BULK LIQUID OXYGEN, NITROGEN AND ARGON STORAGE SYSTEMS AT PRODUCTION SITES

AIGA 031/06

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1 Introduction

This publication is issued by the Asia Industrial Gases Association to satisfy the demand for information related to the storage of liquid oxygen (LOX), liquid nitrogen (LIN) and liquid argon (LAR) at production sites.

The increase in recent years in the size and production capacity of air separation plants has led to a corresponding increase in the capacity of cryogenic liquid storage installations at production sites. It has therefore become more important to consider at the design stage the potential hazards associated with liquid products, the consequences and effects on the local environment of a major release of liquid and the preventive measures required.

As part of the continuing effort to promote a high standard of safety the former EIGA documents IGC 21/85 (Bulk liquid oxygen storage at production sites) and IGC 25/85 (Bulk liquid nitrogen/argon storage at production sites) have been reviewed and this new document incorporates the results of that review plus recent information and experience in connection with the safety and reliability of liquid product storage systems. The Compressed Gas Association (of America) document CGA P-25 (Guide for flat bottomed LOX/LIN/LAR storage tank systems) and the British Compressed Gas Association documents BCGA CP-20 (Bulk liquid oxygen storage at production sites) and CP-22 (Bulk liquid argon or nitrogen storage at production sites) were also examined and pertinent information from these included in the present document.

This AIGA document is intended for the guidance of those persons directly associated with the design, installation, operation and maintenance of bulk cryogenic liquid storage systems. It does not claim to cover the subject completely but gives advice and should be used with sound engineering judgement. The intent of this guide is to ensure that a minimum, uniform level of safety is provided throughout the industrial gas industry for the protection of the public and industry employees. The information presented does not supplant, but is intended to complement national and local regulations.

This document provide a reference code of practice to reduce the possibility of large releases of stored cryogenic fluids from a storage system through installation of protective equipment and instrumentation, equipment inspection and testing, and storage system design criteria.

It is the intent of this guide to emphasize prevention of releases rather than the mitigation of consequences following a release.

All new storage installations shall comply with this document. Application of this guide to existing installations is an individual company or storage system owner’s decision.

2 Scope

A bulk liquid storage installation is defined, for the purpose of this document, as the total fixed assembly of liquid storage tank(s) and other equipment, such as pumps, filling equipment, pressure build-up vaporizers, controls and other related ancillary equipment which are connected to it, required to discharge the product from the storage into pipelines or to transfer liquid to or from road vehicles and includes the liquid transfer area for road vehicles. A typical installation is showed in Fig.1. The facilities for filling rail vehicles are not specifically covered in this document, although its provisions can generally be applied to the liquid storage part of the rail fill installation.

This code of practice specifically covers storage installations on production sites where the storage installation is connected to the production process plant and the individual tank capacity exceeds 125.000 litres. For tanks having a capacity less than 125.000 litres it is an individual company or storage system owner’s decision to use the present document or to use as a reference the AIGA document 030/06 “Storage of cryogenic air gases at users’ premises”.

Other storage installations usually found in production plants (for example a nitrogen tank for instrument air and seal gas back-up system) as well as the process systems of the production plant (such as compressors, heat exchangers, distillation columns, etc.) are specifically excluded from the scope of this document.

Fig.1

3 Definitions

Although AIGA documents have no mandatory character, a clear distinction must be made between "shall" and "should".

"Shall" indicates a very strong concern or instruction.

"Should" indicates a recommendation.

"May" and "need not" are used when the application is optional.

"Will" is used to indicate the future only, not a degree of requirement.

4 General

Gaseous oxygen is colourless, odourless and tasteless; it is non toxic; it is slightly denser than air. It is not flammable but vigorously supports combustion.

Breathing pure oxygen at atmospheric pressure is not dangerous although exposure for several hours may cause temporary functional disorder to the lungs.

Nitrogen and argon gases are colourless, odourless and tasteless. Nitrogen and argon are non-toxic but do not support life or combustion (inert gases classified as simple asphyxiants).

4.1 Properties of oxygen, nitrogen and argon

		Oxygen	Nitrogen	Argon
Content in air	Vol%	21	78,1	0,9
Gas density at 1,013 bar and 15°C	kg/m3	1,36	1,19	1,69
Boiling temperature at 1,013 bar	°C	-183	-196	-186
Liquid density at 1,013 bar and boiling temp	kg/l	1,14	0,8	1,39

At ambient conditions one litre of liquid oxygen gives approximately 850 litres of gas, one litre of liquid nitrogen gives approx. 690 litres of gas and one litre of liquid argon gives approximately 830 litres of gas.

Cold gaseous oxygen, nitrogen or argon is heavier than air and may accumulate in pits and trenches.

4.2 Precautions

The properties of oxygen, nitrogen and argon justify the following special precautions:

4.2.1 Oxygen enrichment or deficiency of the atmosphere

The hazards from oxygen enrichment or deficiency are explained in the AIGA document 005/04 "Fire hazards of oxygen and oxygen enriched atmospheres" and in the document AIGA 008/04 "Hazards of inert gases".

The atmosphere normally contains 21% by volume of oxygen. Many materials, including some common metals, which are not flammable in air may burn in oxygen enriched atmosphere when ignited. In oxygen system design, the possible mechanisms for developing enough energy to ignite system components in oxygen service shall be considered.

Both nitrogen and argon act as asphyxiants by displacing the oxygen from the atmosphere. Any potential for depletion of oxygen below 21% shall be treated as hazardous, and relevant precautions taken.

Attempts to rescue affected persons from confined spaces or where oxygen-deficient atmosphere may be present should be made only by persons who are wearing and trained in the use of breathing apparatus and who are familiar with confined space entry procedures.

The victim may well not be aware of the asphyxia. If any of the following symptoms appear in situations where asphyxia is possible and breathing apparatus is not in use, move the affected person immediately to the open air, if necessary following up with artificial respiration: rapid and gasping breath, rapid fatigue, nausea, vomiting, collapse or incapacity to move, unusual behaviour.

Good ventilation shall always be provided in places where liquid oxygen, nitrogen or argon are stored and/or transferred.

4.2.2 Air condensation

Ambient air may condense on un-insulated pipes and vessels containing liquid nitrogen or argon causing oxygen enrichment of the atmosphere.

4.2.3 Oil, grease, combustible materials, cleaning and other foreign matter

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

All equipment for oxygen service shall be specifically designed and prepared. Designers and manufacturers of oxygen storage systems should be knowledgeable of industry tests and experiences with aluminium/oxygen systems and the safety issues involved before specifying aluminium for this application.

Before putting equipment into service with oxygen, either for the first time or following maintenance, it is essential that all surfaces which may 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. For practical guidance on how to prepare equipment for oxygen service see the AIGA document 012/04 "Cleaning of equipment for oxygen service".

The maintenance and assembly of equipment for oxygen shall be carried out in 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 that satisfies the following requirements:

- good degreasing properties;
- easily removable;
- non corrosive;
- compatible with commonly used metallic and non-metallic materials;
- non flammable or low flammability;
- non toxic;
- non ozone depleting;
- environmentally safe;
- disposable.

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, may be non-flammable in air, but can explode in oxygen enriched atmosphere or in liquid oxygen.

Although neither liquid nitrogen nor argon reacts with oil or grease, it is good practice to apply a reasonable standard of cleanliness, although not as stringent as that required for an oxygen installation. Particular consideration should be given to cleaning nitrogen or argon systems as for oxygen service if they may be put into oxygen service in the future.

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

4.2.4 Embrittlement of materials

Many materials such as some carbon steels and plastics are brittle at very low temperatures and the use of appropriate materials for the service conditions prevailing is essential.

Metals suitable for cryogenic liquids are 18/8 stainless steel and other austenitic steels, 9% nickel steel, copper and its alloys. For its larger margin between tensile stress and yield stress and the consequent better resistance to fatigue, austenitic stainless steels shall be preferred to aluminium alloys and 9% nickel steel. Particular attention shall be paid to site erected vessel made with aluminium alloys and 9% nickel steel owing to the difficulties of welding such materials.

PTFE (polytetrafluoroethylene) is the most widely used plastic material for sealing purposes in cryogenic liquids service but other reinforced plastics and copper are also used in certain cases.

4.2.5 Cryogenic burns

Severe damage to the skin may be caused by contact with cryogenic liquids, cold gases or with non-insulated pipes or receptacles containing liquids. For this reason, gloves and eye protection shall be worn when handling equipment in service with liquid or cold gaseous cryogenic fluids. Liquid or cold gas piping in personnel accessible area should be protected whenever it is possible (but it is not practical for flexible hoses).

4.2.6 Fire fighting

The type and quantity of the fire fighting equipment, depend on the size of the installation and the cryogenic liquid stored. Advice can be obtained from the fire authorities.

Oxygen storage installations are vulnerable to oxygen enriched fires spreading out of control. A fire fighting system shall be capable of reaching the whole of the area between the tanker loading area and the bulk storage installation and any other potentially vulnerable equipment (e.g. pumps).

4.2.7 Smoking/hot work

Smoking, hot work and open fires shall be prohibited for oxygen installations within the distance specified in appendix 2a unless special precautions are taken.

4.2.8 Insulation materials

If the installation is for oxygen service or may be put into this service in the future, the components used in insulating materials shall be such that the finished product is suitable for oxygen service.

For nitrogen or argon service, insulating materials should be chosen bearing in mind that local oxygen enrichment of the atmosphere may occur near un insulated pipes and vessels containing these liquids.

5 Design of installation

5.1 General requirements

Installations shall be designed, manufactured and installed in accordance with recognized pressure vessel, storage tank, piping and building codes and where appropriate in accordance with statutory requirements (including the computation of wind loads and seismic loads if required) and shall comply with the equipment manufacturer's and the production site operator's specifications.

5.1.1 Pressure relief devices

Pressure relief devices shall be provided to prevent overpressure especially as pressure extremes can cause structural failure of the tank and release of contents. To define the capacity of pressure relief devices all operational and upset conditions in the worst foreseeable combination must be considered. The devices shall be suitable for the prevailing environmental conditions.

The design relieving flow capacity Qs for each inner tank relief device shall consider the following formula:

$$Qs \geq \Sigma Qv + Qa$$

where:

Qv = the sum of all the flows in normal operating conditions Qv that are expected to be simultaneous, and

Qa = the highest flow generated by upset conditions

Normal Operating Conditions Qv to be considered are, for example:

- normal boil-off rate from ambient heat leak;
- liquid flash and gas displacement from plant production;
- liquid evaporation during cool down or recycling of pump systems for loading road trailers and rail tank cars (if performed for the particular tank installation);
- liquid flash and gas displacement from unloading road trailers or rail tank cars into the tank (if performed for the particular tank installation);
- vapour return from loading tank trucks;
- cool down of lines and connected equipment.

Upset Conditions Qa should include the largest of the following independent upset conditions :

- malfunction of control valves in the pressure control circuits or filling line causing excess vapour generation in the tank;
- substantial decrease in barometric pressure;
- liquid production subcooling defects;
- excessive rate of cool-down of discharge lines;
- other circumstances resulting from equipment failures that may be unique to the particular installation;
- external fire (for example as stipulated in standard API 2000).

In any case it is the responsibility of the designer to evaluate the maximum flow capacity taking into consideration all the normal operating conditions and the maximum upset condition that could occur for the specific installation.

Experience has shown that during the lifetime of a plant the operating conditions of storage can change in relation to those at the beginning that had been the basis of sizing the overpressure relief devices. In a few exceptional cases, the result was that the design pressure of the inner vessel/tank or the design capacity of vent valve and relief valve was exceeded. A strict management of change protocol is therefore required as specified at 9.3. Particular care shall be paid when road trailers are used to transfer product into the tank as such operations are usually done by on-board pumps that could have increased performances with respect to the ones that were considered at the design stage.

The devices used such as spring loaded safety valves, pilot operated safety valves and bursting disc are described in the EIGA document IGC 24/02 “Vacuum insulated cryogenic storage tank systems pressure protection devices”. The same or similar devices can also be used on other types of bulk storage such as flat bottom or cluster tanks as specified at 5.2.7. Moreover, consideration should be given to the requirements of the EN 13648 “Cryogenic vessel: Safety devices for protection against excessive pressure” (Part.1 “Safety valves for cryogenic service”, Part.2 “Bursting disc safety devices for cryogenic service” and Part.3 “Determination of required discharge capacity and sizing") in specifying the devices.

Consideration shall be given to the provision of a secondary pressure relief device, depending on the degree of risk associated with the installation. Assessment of this risk has to take into account proximity of buildings, areas of public access, other vulnerable site equipment (particularly other storage tanks), and prevailing climatic conditions (high humidity, atmospheric corrosion).

Consideration shall also be given in the design of the installation for the need to facilitate the periodic testing or replacement of the pressure relief devices to ensure that the system is fully protected at all times.

The pipes and valves connecting to pressure relief devices and the vent piping shall be adequately sized for the flow conditions in accordance with a relevant code such as API 521. Excess pressure drop in the piping system can lead to tanks exceeding their design pressure, and to relief valve chattering. The vent pipes shall be correctly supported, and designed to prevent blockage by ice and other foreign matter.

If a three-way valve is installed to accommodate two pressure relief devices, operating either simultaneously or alternately, then the design shall be such that at least one relief device is exposed to tank pressure with full bore at all times regardless of the position of the actuating devices on the three-way valve.

5.1.2 Under-pressure prevention devices

Where necessary the installation should be equipped with under-pressure (vacuum) prevention devices. These devices shall be used for inner vessel if there is the danger of collapse due to the development of partial vacuum conditions that can arise due to excessive liquid withdrawal rates, by introducing sub-cooled product into a partially filled inner vessel or, under certain conditions, sudden increases in atmospheric pressure outside the tank.

5.1.3 Isolation valves

Each liquid line into or out of the inner vessel of a storage tank shall be provided with an isolation valve. This isolation valve shall be located as close as practical to the outer tank wall penetration in an easily accessible location. The protection of isolation valves from external damage shall be considered.

The isolation valve of all liquid lines of 50 mm bore or greater that connect to the inner tank below the maximum liquid level shall be capable of being remotely operated in emergency situations to isolate spills from failed piping. Such emergency isolation valve is additional to any normal isolating valve required for process operation (for example to isolate a transfer pump).

Check valves designed with the capability for testing (Fig.2) can be used in place of external remote operated emergency isolation valves on inlet piping entering below maximum liquid levels.

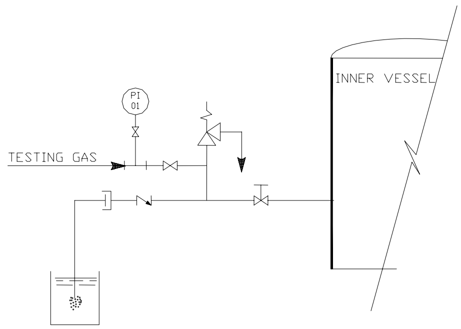


Fig.2

The remote operated emergency isolation valves may be located externally or internally in the inner vessel or in the annular space between outer and inner vessels.

The emergency isolation valves shall restrict the flow of liquid from the tank in the event of a line failure downstream. Each emergency valve shall be reliable and quick acting and be capable of operation under conditions of heavy liquid spillage. The valve shall fail safe in a closed position on failure of operating power or operating fluid supply. The tank pressure or the liquid head shall act to assist the closing of the valve.

The location and design of external, remote-operable shut-off valves should provide adequate protection against damage from external sources. Where it is judged that the presence of an oxygen liquid pump or other equipment constitutes a hazard, action shall be taken to protect the emergency valves and their actuators from the consequences of fire including projectiles or molten metal.

Liquid spills from storage tank inlet line failures can be eliminated by designing the liquid inlet nozzle to be in the vapour space of the tank with a siphon break provided in the design. Inlet line failures using this design will result in a release of cold gas rather than a cryogenic liquid. Releases of cold gas from a failed inlet line will allow operators to safely initiate closure of manual valves to limit the amount of release. The line should be provided with a manual valve located in an easily accessible location as close to the outer tank wall penetration as the line routing permits.

Provision shall be made for operation of the emergency isolation valves at ground level from a safe point remote from the potential area of flow of leaking liquid. To improve personnel capabilities to actuate closure in emergencies, consideration should be given to provide multiple locations for emergency shut-off valves actuation. This decision should be based on plant staffing and the possibility of locating one actuation station in an area with a low probability of being influenced by a vapour cloud such as a normally manned control room. The locations of the operating points, their purpose and mode of operation shall be clearly indicated by suitable notices.

The selection, design and arrangement of the emergency isolation system shall be based on an assessment of the risk and consequences of exposure to operating personnel and the general public as a result of a spillage due to failures of equipment or piping.

To prevent any large spillage of liquid should the primary isolation valve fail, a secondary means of isolation shall be provided for those lines greater than 9 mm nominal bore emanating from below the maximum liquid level and having only one means of isolation between the tank and the atmosphere (such as liquid filling lines from trailers). The secondary means of isolation may be achieved for example by the installation of a second valve, an excess flow valve, or a fixed or removable cap on the open end of the pipe. Suitable means shall be provided for preventing the build up of pressure due to trapped liquid or cold vapour between any two isolation valves or between the valve and the cap.

5.1.4 Piping and nozzles

Failure of a liquid nozzle or piping connected to the inner tank can lead to hazardous off-site effects.

The risk of liquid nozzle failures is minimised by proper inspection of the installation after construction has been completed. All connections and joints in liquid outlet nozzles and piping systems, other than instrument and sample lines, up to the inlet side of the external, remote-operable, emergency valve shall be of all-welded construction. The design of these piping segments should not include use of flanged joints, bellows, or flexible metal hoses. The piping design shall consider thermal expansion and stresses that may result in this segment of piping. All butt welds in these sections of piping should be 100% radiographed.

Piping and nozzles connected to the inner vessel shall comply with the material requirements adopted for inner tank. If aluminium is used for the inner tank, piping should also be aluminium.

5.1.5 Foundations

The tank foundation shall be designed to safely withstand the weight of the tank and insulation, tank contents, internal pressure, and other possible loads resulting from wind, snow, ice, earthquake, and/or water content during testing. Subsidence conditions should be considered where appropriate.

5.1.6 Underground pits, cable ducts, trenches, drains

Underground pits, cable ducts, trenches, drains should be avoided where possible at design stage to prevent both confined spaces where oxygen enrichment / depletion could occur and pathways for leakage from the tank to travel to other areas

Equipment requiring regular attention or maintenance should not be installed in pits. Flanged joints and similar sources of potential leakage should also be avoided in pits. Where the installation of equipment and/or the inclusion of potential sources of leakage in pits cannot be avoided notices shall be positioned, warning of the hazards of oxygen enrichment or deficiency and that entry to the pit is forbidden unless specific precautions are observed, including as a minimum, analysis of the pit atmosphere and the issue of a written entry permit.

5.1.7 Electrical equipment

Electrical equipment installed for oxygen systems do not need to be flameproof, explosion proof or other forms of classified type since oxygen is not classified as a flammable gas. The installation shall comply with the separation distance specified for sources of ignition in appendix 2 and shall be of protection class IP54 or better. For more severe environmental conditions IP 55 (designed to protect against jets of water) or IP 65 (designed to protect against dust and water jets) should be used. See also 6.3.2.

Electrical equipment installed for nitrogen and argon systems should be of protection class IP54 or better, with similar considerations as oxygen in more severe environmental conditions.

5.1.8 Tank grounding

Storage tanks shall be grounded in at least one location. The inner vessel is grounded to the outer vessel by various piping connections. Grounding clips should be austenitic stainless steel or sufficiently painted to prevent corrosion.

5.1.9 Couplings

Couplings used for the transfer of liquid oxygen, nitrogen or argon into trailers shall be non-interchangeable with those used for other products. AIGA standards for couplings are described in the AIGA document 024/05 'Connections for transportable and static bulk storage tanks.

5.1.10 Lighting

Lighting shall be provided of adequate intensity for all working areas so that at all times operations can be carried out safely. The need for emergency lighting shall be considered.

5.2 Specific requirements for flat bottom storage tanks

5.2.1 General

The typical tank configuration for the storage of LOX, LIN and LAR in flat-bottomed tanks is a double wall, single containment type, where the liquid is contained in an inner tank and an outer tank serves mainly to contain the insulation (Fig.3).

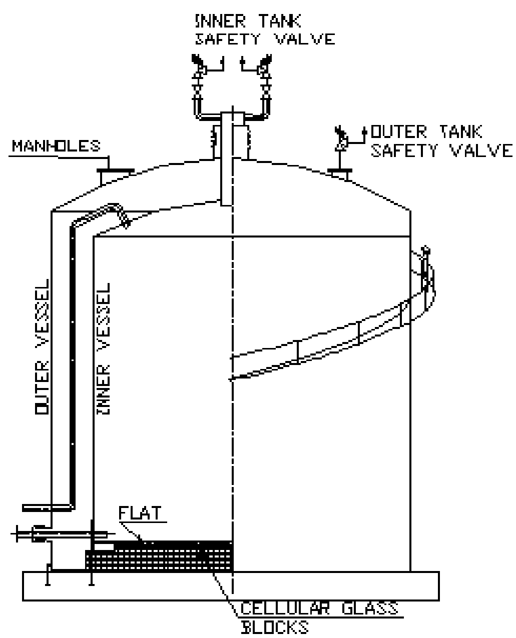


Fig.3

Single containment is the type of containment comprising an inner tank and an outer tank which is designed so that only the inner tank is required to meet the low temperature ductility requirements for storage of the product. The interspace, that is the annular space between the inner and outer tanks, is purged/pressurised with a dry, non flammable gas (usually nitrogen). It is not designed to contain the cryogenic liquid in the event of leakage from the inner tank. Inner and outer tanks should be of all-welded construction.

The design, fabrication, and testing of flat-bottom storage tanks shall conform to all applicable national and local regulations.

Design, fabrication and testing of flat-bottom storage tanks can be guided by the requirements of the latest edition of API 620 Code, including Appendix Q. Although the scope of Appendix Q is limited to a design temperature of –270 °F (-167,8 °C), flat-bottomed storage tank systems can be designed for operating temperatures as low as –320°F (-195,6 °C) by following the practices and procedures stated in the Code and Appendix. Alternative codes that can be directly used include BS 7777, Part 4 “Flat bottomed, vertical cylindrical storage tanks for low temperature service” or DIN 4119 in its latest edition. None of these three codes include any reference for the verification of inner vessel to external pressure but a design method can be found in AD-Merkblatt AD-B6 or DIN 18800.

Seismic loads and method of analysis for the storage tank system can be in accordance with API 620 including Appendix L.

5.2.2 Inner tank

The inner tank shall be fabricated of materials capable of withstanding the cryogenic temperature (see also 4.2.4), the internal pressure of the stored fluid and compatible with oxygen when in LOX service.

Thermal stresses due to cool down, and external pressure due to compaction of the insulation and gas purge maximum pressure should be considered in the design of the inner tank for the worst case where the vessel is empty and at minimum design pressure.

Cryogenic spillage due to the major failure of a flat-bottomed storage tank is one of the worst case scenarios of Air Separation Plant risks. In case of extreme overpressure it should be ensured that the weakest point of the structure is not at the bottom cylindrical seam.

The need to prevent a rupture by overpressure at the bottom of the inner tank is identified in the various available codes. API 650 talks of a frangible joint between the roof and the shell and gives it as a possible purchaser requirement. API 620 establishes a link between the sizing of the anchorage straps and the design of the roof-to-shell junction. BS 7777 explicitly states that the weakest point of the structure shall not be at the bottom and present it as a further increase in safety. None of the three codes describe how to design and manufacture a frangible joint so that it will break as intended.

If the design code allows, an alternative to having a frangible roof could be the installation of a limited size frangible piece such as a rupture disc that permits a predictable protection and a large flow capacity.

5.2.3 Outer tank

The outer tank shall be designed to support the annular space insulation material and the gas purge pressure but it is not required to be fabricated with materials capable of withstanding the cryogenic temperatures of the stored fluid.

As a minimum the outer tank shall be designed to resist the minimum wind loads required by national codes for the installation site. External loads such as snow and ice and mechanical loads such as stairs, platforms, and ladder shall be considered in the design of the system.

5.2.4 Annular space purge/pressurising gas

Annular spaces of flat-bottomed storage tanks should be initially purged and then continuously pressurised with a dry, non-flammable gas that will not condense or freeze at the operating conditions of the inner tank. Sufficient pressurising gas should be supplied to ensure a positive pressure is maintained throughout the annular space. Sufficient annular space pressurising gas will maintain the insulation in a dry state, which provides the best insulation qualities. Wet or frozen insulation conducts heat better and will increase the boil-off rates of the stored material.

Past incidents have shown that an annular space pressure which is higher than the inner tank pressure can damage the roof and the bottom of the inner storage. The relative movement between inner tank and pipe can lead to rupture of pipe. This can occur:

- after the hydraulic test, if the vessel is emptied without a vent valve opened;
- if the pressure building system is out of order, and liquid is withdrawn;
- as a result of gas (vapour) condensation when filling tank through top fill nozzles;
- before cool down, if the annular space is pressurized with the empty vessel at atmospheric pressure.

There are the following safety concerns about inadequate purging of the annular space:

- If air is present in the annular space of LIN or LAR storage tanks, components of the air with a dew-point temperature above that of the stored contents can condense;
- Accumulation of condensed fluids in the annular space can lead to cooling of the outer tank to a point where the outer tank could fail;
- The condensed fluid can become oxygen enriched and can include atmospheric contaminants such as hydrocarbons. A rapid reaction between the accumulated hydrocarbon contaminants and the condensed oxygen-enriched fluid can occur and result in an energy release within the annular space. A rapid reaction can also occur with the insulation or other materials in the annular space that may not be compatible with the oxygen-enriched fluid;
- If there is some cryogenic liquid trapped in the annular space, a pressure increase can occur due to rapidly expanding liquid to gas by vaporisation during warming of the tank;
- A failure of the annular space piping components and insulation system may occur if a proper annular space purge or pressurising gas is not maintained because atmospheric moisture and carbon dioxide in the air could freeze on cold surfaces causing for example a restriction in free movement of piping.

A purge/pressurising gas distribution system should be provided around the complete circumference of the base of the tank in the annular space. This purge/pressurising system should be designed to prevent insulation from plugging the purge system piping and ensure uniform distribution of gas throughout the annular space. Operation of the system should ensure that there is positive pressure throughout the annular space.

An appropriate pressure or flow-indicating device should be provided to indicate the presence of pressurising gas in the annular space. An alarm should be provided on the pressurising gas supply to alert the operator in case the purge gas supply is inadequate or too high. As an alternative to the alarm, periodic verification of the presence of the pressurising gas in the annular space can be performed.

5.2.5 Overpressure and vacuum control and protection

A high pressure or vacuum condition in the inner tank or in the annular space could result in storage tank failure and the possibility of a release of the stored cryogenic fluid to the atmosphere. Overpressure in the inner vessel affects mainly the shell anchorage system and the junction between roof and shell or between bottom and shell depending upon the inner tank design.

The pressure in the inner tank shall be monitored with high and low pressure alarms to provide warnings to operating personnel. The pressure in the inner tank shall be measured on a local and/or remotely located pressure indicator.

Consideration should be given to safety interlocks of the pressure monitoring system of the inner tank to automatically isolate on high pressure all liquid filling sources into the storage tank, including stopping any pumps transferring liquid into the tank, and closing storage tank isolation valves on the inlet line(s) to the tank and, on high vacuum, closing all withdrawal lines.

5.2.5.1 Inner tank pressure control

The primary pressure control system should include the following:

- an automatic positive pressure control venting system to maintain the pressure at or below the design pressure of the inner tank. For determining the design capacity for this positive pressure control system, refer to the normal operating condition cases Qv listed at 5.1.1;

- if required, an automatic minimum pressure control system should be provided by a pressure build-up coil to maintain a minimum positive pressure in the inner tank where there is a possibility of pulling a vacuum. For determining the design capacity for this minimum pressure control system, refer to the cases listed at 5.2.5.3.

5.2.5.2 Inner tank overpressure protection

Overpressure relief devices for the inner tank shall include a minimum of two independent pressure relief devices with both pressure relief device set no higher than inner tank design pressure.

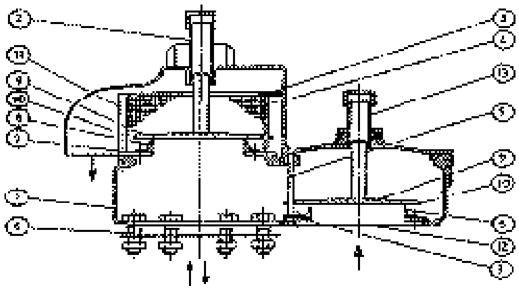
The capacity of each device shall be such that if one malfunctions or is removed for maintenance, the tank is still protected from all overpressure cases considered in the design of the pressure relief devices.

This requirement to have a minimum of two independent pressure relief devices can be achieved by any combination of safety valves and bursting discs with two separate nozzles connected to the inner tank for the relief devices. This will lessen the potential risk for plugging of a single nozzle with ice rendering all of the relief devices inoperable.

As an alternative to separate nozzles a single large nozzle connecting to both safety valves can be used. This large connection to the inner tank shall have a diameter larger than the branch connections to the safety valves. A large connection is unlikely to plug. In addition to risk of plugging of a single nozzle, the inlet line pressure drop has to be calculated considering that both safety valves are normally in simultaneous service. Chattering of the safety valves can make the safety valves leak with resulting ice formation and consequent plugging of the safety valves. The above requirement is especially important if combined pressure-vacuum valves are used, due to the higher risk of moisture entering the inlet nozzle from the ambient air.

The design of the system should facilitate periodic testing, maintenance, and replacement of the relief devices. The time period with only one operable relief device for inner tank protection should be kept to a minimum.

For flat-bottomed tanks plate relief valves are commonly used as an alternative to the equipment described at 5.1.1.. These valves feature a dead weight plate that covers the venting or relief port; they have a high capacity together with simplicity in construction, which makes them reliable. A typical plate relief valve is illustrated in Figure 4.



1	BODY	8	PRESSURE AND VACUUM SEATS
2	STEM GUIDE (PRESSURE)	9	DIAPHRAGM BACK UP DISC
3	VACUUM COVER & PRESSURE HOOD	10	DIAPHRAGM
4	PRESSURE PALLET GUIDE	11	PRESSURE SCREEN
5	VACUUM PALLET GUIDE	12	VACUUM SCREEN
6	FLANGE BOLT	13	STEM GUIDE (VACUUM)
7	SEAT PLATE		

Fig.4

The pressure and vacuum relief ports are separate on the valve. The plate relief valve is secured to a nozzle on an extension pipe from the vessel. The seat sealing diaphragm material recommended is P.T.F.E., or similar, in applications where cold conditions may apply. It is important, however, to locate the valve so that it is not subject to excessively low temperatures. The valves shall be regularly examined to ensure that continuous venting of cold vapour has not caused icing that could affect the operation of the valve. The plates shall be self-aligning or otherwise correctly positioned to the seat. Ensure that the friction forces between plate and seat are minimal and have minimum contact area. The valve shall re-seat reliably. The seat shall be lappable for refurbishment or have a removable insert.

Plate guides shall be suitably designed to ensure freedom of movement for plate reseating. They shall be of compatible materials and of sufficient hardness to avoid galling. Seats shall be of harder material than the plate and have a lappable surface for refurbishment. The seat position relative to the plate and body shall be lockable or secured.

5.2.5.3 Inner tank under pressure control and vacuum protection

If required, the tank should have a pressure raising system which is capable of maintaining a minimum operating pressure under all circumstances described below (e.g. by a pressure raising coil). Repeated operation of the vacuum valves results in ice formation blocking the tank nozzle. At least one vacuum relief device should be installed to protect the inner tank from vacuum.

A combination overpressure/vacuum relief device can be used for this application and substituted for one of the pressure relief devices mentioned at 5.2.5.2.

The design vacuum relieving capacity for the inner tank should consider the worst foreseeable combination of operational and upset conditions such as:

- withdrawal of liquid at the maximum rate;
- withdrawal of vapour at the maximum compressor suction rate;
- increase in barometric pressure;
- sudden cooling of tank vapour when filling or recirculating liquid through a top fill nozzle;
- other circumstances resulting from equipment failures and operating errors that may be unique to the particular installation.

5.2.5.4 Outer tank overpressure protection

Overpressure of the annular space could lead to failure of the inner tank. The annular space can be over pressurised from a number of sources including a leak from the internal tank or annular space piping, failure of the annular space pressurising system, sudden changes in atmospheric pressure, or exposure to thermal radiation such as would occur during a nearby fire.

The annular space shall be protected against over pressurisation by a single pressure relief device such as a vent valve, a breather valve, a pressure relief device, or spring-loaded or weighted cover. When necessary, a separate relief device should be provided for emergency venting purposes. The relief device shall be sized to evacuate the maximum potential flow of the source in case of failure of the pressure control system.

If a filter is placed upstream of the relief device to avoid perlite escaping from the annular space, consideration shall be given to avoiding plugging and excess pressure drop in the system.

An additional safety relief device or a bursting disc should preferably be placed immediately downstream of the pressure reducer supply valve of the annular space pressurising system. Manual bypassing of the pressure reducer valve should be avoided.

5.2.5.5 Outer tank vacuum protection

A vacuum condition can be created in the annular space by rapid cool down of the inner tank or certain changes in atmospheric conditions.

Vacuum protection of the outer tank should be accomplished by installing at least one vacuum relief device on the outer tank.

A combination overpressure/vacuum relief device can be substituted for this application while meeting the requirements in point 5.2.5.4.

Installation and sizing criteria for the pressure and vacuum relief devices for flat-bottomed storage tanks can be referenced in the applicable portions of currently recognized standards such as API 620 and API 2000.

5.2.6 Overfill protection

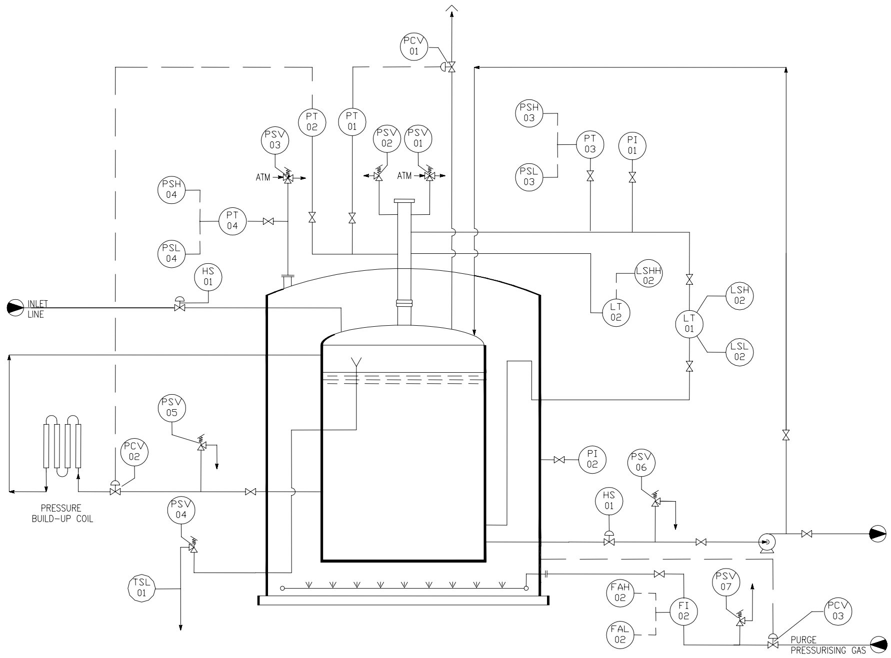
If overfilled, flat-bottomed tanks are subject to serious damage that may result in failure of the inner tank and a release of the tank’s contents from the overpressure induced by the high liquid level or the consequential spillage of the overflowing liquid.

Filling a flat-bottomed tank to levels above the maximum design level can result in an uplifting, hydrostatic force on the inner tank dome that may cause the failure of a number of components including the inner tank anchor/hold down straps, the inner tank shell to floor joint, or the inner tank shell to roof joint. Therefore, the relief valves do not protect the tank against the overfilling hazard.

On high tank level the overfilling protection device shall be either a high level trip to close the tank filling valves or an overflow line capable of passing the maximum liquid filling rate.

Liquid level measurement not only provides normal operating inventory status, but also input to safety systems to prevent overfilling. Therefore two independent liquid level measurement devices shall be installed on flat-bottomed cryogenic storage tanks. Liquid level measurement and indication can be provided by a number of means such as differential pressure indication, liquid float devices, temperature detection in an overflow line, sonic measurement, radar or conductivity.

Typical diagram for flat bottom storage tank system



Legend and references to the paragraphs:

PSV01-02: Inner tank overpressure-vacuum protection devices (5.2.5.2 and 5.2.5.3)

PSV03: Outer tank overpressure-under pressure protection device (5.2.5.4 and 5.2.5.5)

PSV04: Overfilling protection (5.2.6)

PSV05-06: Thermal relief valve

PSV07: Annular space pressurising gas safety valve

PCV01-02: Inner tank pressure control valve (5.2.5.1)

PCV03: Outer tank pressure control valve (5.2.4)

HS01: Remote operated emergency isolation valve (5.1.3)

LT01-02: Inner tank level measurement devices (5.2.6)

PI: Pressure indicator

PT: Pressure transmitter

Fig.5

The primary liquid level measurement instrument should be used for normal operating indication. The read out should be accessible to the operator and provide a continuous indication of the tank inventory. This device should alarm on both low and high levels indicating possible abnormal tank operation. Typical set points could be 5% of full tank contents and falling and 95% of full tank contents and rising. Operator response to the high alarm should be to terminate liquid flow to the storage tank.

The secondary measurement device independent of the primary device should be installed to detect a full liquid level (100%) and initiate immediate action to isolate the tank to prevent further filling. This device can be of similar construction as the primary liquid level instrument as long as its input signals are not common to the primary device. The secondary device should not be used for normal operating indication but could function as a backup device to the primary indication if desired. This secondary device should be used to automatically isolate all liquid filling sources into the storage tank, including de-energizing any pumps transferring liquid into the tank and closing storage tank isolation valves on the inlet line(s) to the tank. If only one isolating device is provided, the possibility of failure has to be considered.

The secondary measurement device shall have an alarm to inform the operator that isolation has occurred. The operator shall be instructed to verify if liquid flows into the tank have terminated.

The previous intent can be met with other system designs such as an overflow device directed into a cryogenic vaporizer directed to a safe location with appropriate shutdown instrumentation or by the use of a liquid pressure relief valve with a low temperature sensor to alarm and isolate the filling process. The vaporizer should be installed in such a manner to prevent the possibility of a cryogenic liquid release in the event of an overfill.

5.2.7 Piping in the annular space between inner and outer tanks

Within the annular space all joints made in piping connected to the inner tank shall be welded. No aluminium to stainless steel transition joints, flanged or threaded joints, bellows, or flexible metal hoses shall be used in the annular space piping connected to the inner tank. No piping branch connections shall be located within the annular space of the tank, upstream of the tank's isolation valve.

5.2.8 Foundations

In addition to what specified at 5.1.5, flat bottom of inner tank shall be insulated from the foundation by an adequate number of layers of cellular glass blocks (foam glass). Each layer should be laid at 90° to the previous one. A layer of sand or cement may be laid above the top layer of foam glass (Fig.6) and in case of seismic installation be reinforced at periphery. The laying of base insulation should be carried out under dry weather condition.

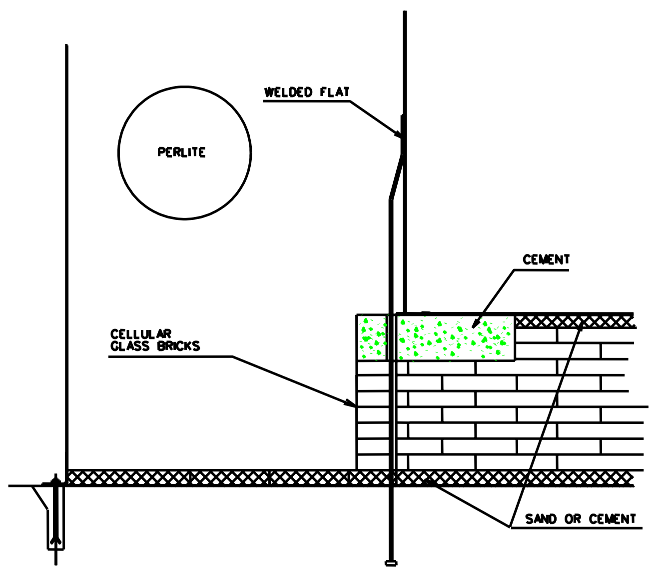


Fig.6

For tank bottoms and foundations in contact with the soil, foundation heating should be provided to prevent ground freezing and frost heave. For tanks supported above ground on a pile-cap, a minimum air gap of 1 m is required for adequate air circulation under the pile-cap.

Anchor/hold down straps of inner vessel and their embedding in the concrete foundation shall be designed with adequate safety margin for the following two cases:

- inner vessel maximum overpressure caused by inner vessel overfilling
- maximum overpressure with minimum liquid content in the tank to avoid lifting failure of the tank and release of contents

As part of a quality assurance program, consideration may be given to the sample testing of anchorage straps before fixing them to the shell.

5.3 Specific requirements for cluster storage tanks

A cluster storage tank is a system of multiple inner pressure vessels in a single outer jacket. Usually the inner vessels are workshop manufactured and installed inside the site erected outer jacket.

The inner vessels are piped together without intermediate liquid line manual or automatic isolation valves irrespective of pipe size since their location within an outer jacket provides protection against mechanical damage. The vapour spaces are manifolded together without valves and the inner tank over/under pressure protection devices are provided for the common system.

The inner vessels may be designed for full vacuum in which case the cluster does not require under pressure control and protection.

The following paragraphs for flat bottom storage tank are also applicable to cluster tanks:

- 5.2.2 Inner tank
- 5.2.3 Outer tank
- 5.2.4 Annular space purge/pressurising gas
- 5.2.5 Overpressure and vacuum control and protection
- 5.2.6 Overfill protection. It is good practice to install the two level devices on separate vessels.

5.4 Specific requirements for vacuum insulated storage tanks

Large capacity vacuum insulated storage vessels are often used for bulk storage at production sites. They will usually be works manufactured to the same standards as for customer installation tanks as described in the AIGA document -030/06 “Storage of cryogenic air gases at users’ premises”

Fundamental requirements of European Standard EN 13458 Cryogenic vessels: Static vacuum insulated vessels” (Part.1 “Fundamental Requirements”; Part.2 “Design, fabrication, inspection and testing”; Part.3 “Operational requirements”) should be also considered.

The provisions of EIGA document IGC 24/02 “Vacuum insulated cryogenic storage tank systems pressure protection devices” apply to these tanks particularly Section 6 (Generally used pressure protection systems).

Inner tank pressure control systems as specified at 5.2.5.1 for flat bottom tanks shall be also installed. If the inner vessel is designed for full vacuum conditions, the under pressure control and protection are not required.

Care has to be taken with vapour nozzle sizes for the pressure protection devices where standard tank designs are used as these often have inadequate vapour vent line sizes for production plant flow conditions.

6 Layout of installation

6.1 General

The strict adherence to nationally accepted design and construction codes for pressure vessels, storage tanks and associated equipment, and to the specific operating instructions is the best guarantee for safe operation, and the prevention of accidental releases.

The installation shall be sited to minimise risk to personnel, local population and property. Consideration shall be given to the location of any potentially hazardous processes in the vicinity, which could jeopardize the integrity of the storage installation.

An installation may, because of its size or strategic location, come within the scope of specific legislation for planning control. If so, the siting of any such proposed installation shall be discussed and agreed with the local authority.

6.2 Safety distances

The given distances are intended to protect the storage installation as well as personnel and the environment. They are intended to protect personnel from exposure to an oxygen enriched or deficient atmosphere or from cryogenic burns in the event of a release of liquid, to prevent fire enhancement due to a release of liquid oxygen, and to protect the installation from the effect of thermal radiation or jet flame impingement from fire hazards.

The safety distances given as protection are based on practical experience for the risk involved in the normal operation in cryogenic liquid storage installations. They are not intended to protect against catastrophic failure of the liquid storage vessel.

The distances shown in the appendixes 1 and 2 correspond to well established practice and are derived from operational experience within Europe and the USA. They relate to 200.000 tank years of service. Should any evidence become available which indicate that a revision is necessary then such a revision will take place.

The minimum safety distances “D” are specified in appendix 2a for oxygen systems and in appendix 2b for nitrogen and argon systems.

The distances shall be measured from the installation limit, which is an imaginary frame close round the tank itself and with a distance “S” for oxygen systems around all points of the system where during normal operation spillages or leakages can occur (hose couplings, relief valve vents, etc). The distance “S” is defined in appendix 1a. The illustration in appendix 1a and 1c demonstrates the application. For minimum lengths of “S” see appendix 2a group 1.

The installation limit defines the origin of measurement of the safety distances for the specific conditions of a LOX storage installation recognising that from time to time increased oxygen concentrations in certain zones of the storage area may occur.

The minimum recommended safety distances for nitrogen and argon systems are given in appendix 2b. They are measured in plan view from either the outer shell of the liquid nitrogen/argon 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, as shown in appendix 1b.

These distances are the minimum required and shall be observed, but it is recognised that it is not reasonably practicable to define safety distances which alone give adequate protection in the event of a continuous release of liquid from storage installations. They have to be adopted in conjunction with a package of precautions to control spillage and minimize risk, such as:

- taking into account topography, containment or diversion of spillage;

- careful siting of storage to allow for likely movement of vapour clouds;
- provision of emergency isolation valves; implementation of emergency procedures;
- adequate personnel training.

To minimize the off-site risk to the general public and the environment it is necessary for each of the likely risks and exposures to be considered individually. In particular large bulk oxygen storage tanks with capacity greater than 200 tons are subject to the Seveso Directive which depending on the local detail will probably require significantly greater distances to be considered in the safety case. Under this legislation nitrogen and argon are not considered dangerous substances. See EIGA document IGC 60/98 "Prevention of Major Accidents: Guidance on compliance with the Seveso II Directive".

The assessment of the risks should take into account the package of precautions provided within the site boundary, but shall recognise that on-site emergency procedures and personnel training cannot normally be applied outside the site. Methods for the calculation of safety distances are described in the EIGA document IGC 75/01 "Determination of Safety Distances for Codes of Practice".

6.3 Location of the installation

6.3.1 Outdoor Installation

All cryogenic liquid storage installations at production sites shall be situated in the open air in a well ventilated position. The installations shall not be located inside buildings.

6.3.2 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 properly earthed and protected against lightning according to local regulations.

6.3.3 Installation level and slope

Where liquid storage tanks are required to be installed at an elevated level, they shall be supported by purpose-designed structures. Consideration should be given to protect such structures from damage by cryogenic liquid spillage.

The slope of the ground shall be such as to provide normal surface water drainage, but shall also take into consideration the prevention of directing hazardous materials, such as oil or flammable liquids, towards oxygen installations and the prevention of directing liquid spillage towards hazardous or vulnerable materials, or locations where people could be at risk.

6.3.4 Diversion of spillage

Consideration shall be given to provisions to contain spillage or diverting it towards the safest available area.

The maximum liquid spillage which may occur due to failures of associated equipment, other than the main storage tanks, shall be determined, and provisions made to contain or divert it towards the safest available area. Hydrants, hoses and spray nozzles shall be provided. These may be used for diverting from vulnerable areas, the vapour clouds or liquid flows which could arise from any liquid spillage.

In all cases, liquid spillage must be prevented from reaching sensitive areas like control room, electrical equipment, machines, natural gas fire heaters, gutters, neighbours, public areas, etc. This consideration must be taken into account during the development of the overall plot plan.

6.3.5 Protection of other areas

The site layout shall provide protection from liquid spillage for vulnerable areas, such as steel structures, other tank foundations and places where people may congregate. This protection may be achieved by the slope of the ground, provision of kerbs, gulleys or barriers of adequate size.

Drainage systems within the distance specified in Appendices 2a and 2b shall be provided with traps to prevent the ingress of liquid or gaseous products. Untrapped drainage systems shall be at least the distance from the installation specified in the Appendices 2a and 2b.

6.3.6 Position of gas vents

Vents, including those from safety relief devices, shall vent to a safe place in the open, so as to avoid the risk of impingement on personnel, buildings or structural steelwork and, in the case of venting oxygen, on combustible materials.

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

Vent discharge pipes should also be routed to a location and elevation that minimises fogging and provides for atmospheric dispersion to avoid localized oxygen enrichment or deficiency in areas frequented by operating personnel. Dispersion modelling can be a useful tool in locating vent discharge points.

Vent pipes from relief and vent devices should be directed away from the outer tank or sufficiently elevated to avoid contact from the cold venting fluids, which could cause the carbon steel roof of the outer tank to crack.

When local environmental conditions or outlet piping orientation cause atmospheric moisture to condense and freeze or corrode valve internals, which interferes with normal operations, a dry gas purge installed on the relief and vent device discharge piping has been proven to be effective prevention. Purging may be avoided by locating the relief or vent device inlet at a sufficient distance from the roof of the storage tank so that condensation from the cold gas in the inner tank does not result in icing in the discharge piping.

6.3.6.1 Pressure relief devices

Pressure relief valve operation does not typically provide a constant source of either cold gas or icing. On flat-bottom tanks and on cluster tanks, the pressure relief devices are typically located on the top of the outer tank shell, which minimises fogging at grade.

Provision should be made to orient relief device outlet lines to reduce the possibility of rain water accumulation or to provide a drain opening in the low point of the outlet piping. This drain opening should be inspected periodically to ensure that it is not plugged. The inspection period should be set by the tank owner/operator based on local environmental conditions.

Design of relief device outlets should consider methods such as installation of screens, flappers, or blow-off caps to prevent birds or debris from entering the outlets and causing a possible restriction or total blockage of relief device flow. Screen designs should not restrict device flow. Periodical inspection of the vent piping may be performed as an alternative to screen installation to ensure that the discharge is not blocked.

6.3.6.2 Automatic vent valves

The automatic vent valve discharge should be located sufficiently above grade to provide adequate atmospheric dispersion to dilute the gas to a safe concentration and to warm the gas to prevent fogging before it settles to operating personnel levels.

Since the exiting vent gas will cool the discharge vent piping tip to near vent gas temperature, the tip should be insulated or heated to prevent ice build-up. The ice could result in blockage of the tank nozzles or malfunction of the control valves or creation of a large ice-ball that could fall off and injure operating personnel, and therefore may need periodic thawing. Cyclic thawing of the vent valve ice build-up may cause a safety concern for personnel or equipment damage from falling ice. The heating device shall be suitable for cryogenic service and for the vented gas. An alternative to heating the tip may be to place a catch grating below the vent exit or to limit access to the area beneath the vent.

6.3.7 Vapour clouds

When siting the installation, due consideration shall be given to the possibility and the likely direction and velocity of the movement of vapour clouds, originating from spillage or venting, which could be a hazard (decreased visibility, oxygen enrichment or deficiency). The vapour fog, capable of limiting visibility on roads or inside plant boundaries, is composed of atmospheric water condensed by the cooling effect of the liquid being vaporized. Dispersion modelling may be useful as a tool in assisting in the optimal location of storage tank systems.

Installation of vapour barriers to control the spread of vapour clouds off site may be considered. Vapour barriers can provide additional time for implementation of site emergency response procedures before the vapour cloud travels off site. Vapour barriers are not required for every facility.

Site topography, prevailing wind direction, proximity of off-site structures, and location of public roads in relation to the storage tank installation need to be considered in determining the need for installation of site perimeter vapour barriers.

6.4 Liquid transfer area

6.4.1 Location of area

A road or rail tanker, when in position for filling from or discharging to the installation, shall be in the open air 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.

Kerbs or barriers shall be provided to prevent damage to any part of the installation by the tanker or other vehicles.

6.4.2 Control of tanker operation

Operating personnel shall have unobstructed freedom of movement between the tanker and the controls on the installation.

All tankers shall be provided with a positive means of preventing tow-away accidents. Such devices shall be ‘fail-safe’ in operation and regular checks on the operation of such devices shall be included in maintenance procedures. Operating procedures shall be written to take account of such means. Detailed systems and procedures to avoid such accidents are described in EIGA document IGC 63/99 “Prevention of tow-away accidents”.

6.4.3 Construction of floor

The access area (2.5 m in plan view from all points where liquid can escape during filling) for oxygen filling shall be of an inorganic non-combustible material acceptable for use with liquid oxygen. Asphalt, tar or other hydrocarbon based substances constitute a hazard and shall not be used; if saturated with liquid oxygen an explosion could be caused e.g. by falling objects or tyre friction. Similar considerations should be given to nitrogen filling points as liquid air (oxygen enriched) could condense on the outside of the filling hoses.

Expansion joint materials shall be acceptable for use with liquid oxygen.

Since no joint material is totally compatible with oxygen, the design should avoid joints within 1 m in plan view of the hose coupling points.

The area shall be constructed either to direct any cryogenic liquid spillage to a spillage pond away from vulnerable areas or to include a trench filled with non-porous gravel to allow for evaporation.

6.4.4 Pump systems

Centrifugal pumps for oxygen service shall be installed so as to comply with the EIGA document IGC 11/82 “Code of Practice for the design and operation of Centrifugal Liquid Oxygen Pumps” or similar code.

Reciprocating liquid oxygen pumps shall be installed in accordance with the accepted principles of good practice for oxygen service.

Pumps for liquid nitrogen/argon are not required to comply with EIGA document 11/82 because of varying safety reasons, however it is recommended that the application of this standard, to achieve complete inter-changeability with liquid oxygen pumps after appropriate preparation, should be considered.

Where pumps and/or vaporising equipment are located in enclosures, these shall be properly 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 oxygen installations case, where there will be no accumulation of combustible material liable to form a hazard.

6.4.5 Equipment layout

The equipment shall be installed so as to provide for easy access and maintenance.

7 Access to installation

7.1 Personnel

The installation shall be so designed that authorized persons shall have easy access to and exit from the operating area of the installation at all times.

Access to the installation shall be forbidden to all unauthorized persons. Warning notices shall support this.

7.2 Access to installation controls

Filling connections and equipment controls shall be located in such a way that easy access is provided

Filling connections and equipment controls should be located in close proximity to each other and such that tank and tanker controls are visible and easily accessible from the operator's position.

7.3 Notices

7.3.1 General precautions

Notices shall be clearly displayed to be visible at all times on or near the tank, particularly at access points, to indicate the following:

- LIQUID OXYGEN (or NITROGEN or ARGON)
- NO SMOKING
- NO HOT WORK
- NO NAKED LIGHTS
- NO STORAGE OF OIL, GREASE OR COMBUSTIBLE MATERIALS
- AUTHORIZED PERSONS ONLY

Symbols may be used instead of written notices, for example:

7.3.2 Identification of contents

The storage tank should be clearly labelled "LIQUID OXYGEN", "LIQUID NITROGEN" or "LIQUID ARGON".

The connection fittings of multi-storage installation or long fill lines shall be clearly marked with the contents or the chemical symbol in order to avoid confusion (see also 5.1.9)

7.3.3 Legibility of notice

All displayed warning signs and labels shall be legible, visible and up-to-date at all times.

7.3.4 Operating and emergency instructions

Operating and emergency instructions shall be available and understood before commissioning the installation (see also 10.4).

These instructions shall be kept legible and up-to-date.

8 Testing and commissioning

8.1 Testing of installations

Prior to testing and commissioning, measures shall be taken to ensure that the subject systems have been designed and constructed in accordance with recognised pressure vessel, tanks and piping system codes and that all statutory requirements have been met.

These measures will normally take the form of review of drawings of pressure vessel and tanks and of piping systems, manufacturing certificates and constructions specifications.

Prior to its first use, a competent person shall validate the installation, as suitable for the duty within defined operating limits for a defined operating period. A competent person means a person that should have such practical and theoretical knowledge and actual experience of the type of plant which he has to examine as will enable him to detect defects or weakness, which it is the purpose of the examination to discover, and to assess their importance in relation to the integrity and function of the plant.

Check shall also be made to ensure that the cleanliness requirements of 4.2.3 have been met.

In addition the following tests shall be carried out by the supplier or his representative in accordance with approved procedures.

8.1.1 Pressure test

Works manufactured storage tanks and pressure vessels of the installation will normally already have been tested and inspected in compliance with National Regulations in the manufacturer's workshop prior to the first installation. Further tests shall not be carried out on the vessel without reference to the vessel design documents of the manufacturer.

On site erected tanks and systems, a pressure test shall be carried out in accordance with design codes and appropriate standards.

Means of pressure indication suitable for the test pressure shall be installed before the test and precautions shall be taken to prevent excessive pressure in the system during the test.

Water to be used for an hydro-pneumatic test shall be analysed during the filling of the tanks and appropriate additives shall be used. To prevent the risk of heavy corrosion of stainless steel tanks, the Cl- contents (chlorine ion) shall be lower than 25 mg/l with a pH between 7 and 8,5 and in any case according to the prescription of the tank manufacturer. Water shall be filtered to avoid matter in suspension. Water in the tank shall be kept only for the time required to perform the test and the time the water is in contact with the vessel shall be minimised. Vents to atmosphere shall be checked to avoid over-pressurization or excess vacuum of the tank during the filling and the emptying of the tank. Immediately after the test, the system/equipment shall be drained, the bottom surface shall be rinsed with clean water and thoroughly dried out and checked.

Where a pneumatic test or a hydro-pneumatic test is specified, dry oil-free air/nitrogen is the preferred test medium. The pressure in the system shall be increase gradually up to the test pressure. Any defects found during the test shall be rectified in an approved manner and the system retested.

The pressure test shall be witnessed by a responsible person and a test certificate signed and issued. Such certificate shall be kept for future reference.

Plant instruments, gauges, etc. are not normally fitted during any pressure test but shall be fitted prior to pressurising for leak testing (leak testing consists of checking for leaks at joints and is normally carried out at pressure below that of design pressure).

8.1.2 Pressure relief devices

A check shall be made to ensure that all transport locking devices have been removed from pressure relief devices for the inner vessel, outer jacket and piping systems and that the devices are undamaged and in working order. Several models of safety valves are provided with a locking screw to the stem to allow pneumatic testing at a higher pressure than the set pressure. Usually this locking screw is identified with a self-adhesive plate: be careful that the locking screw has been removed before commissioning of the equipment.

The relief device set pressure (stamped on or attached to each device) shall be checked to see it is in accordance with the maximum permissible operating pressure of the system. Relief valves must be subjected to a successful functional test.

8.1.3 Under-pressure prevention devices

A check shall be made to ensure that all transport locking devices have been removed and that the under-pressure prevention device is undamaged and is in working order.

8.1.4 Supports

A check shall be made to ensure that all relief valves or bursting disc vent lines are positioned such that any discharge cannot impact on personnel or equipment and that the valves and vents are properly supported to take into account reaction forces.

8.2 Adjustment of controlling devices

Controlling devices shall be adjusted to the required operating conditions of the system and be subjected to a successful functional test.

8.3 Posting of notices

Notices (see 7.3) shall be posted before putting the installation into service.

8.4 Commissioning

Commissioning shall be carried out only by authorized personnel and in accordance with a written procedure.

Whenever initial cooling down of the tank is performed (either from road tankers or from the production air separation unit) at no time shall the positive pressure or the negative pressure in the inner vessel and in the annular space exceed the maximum operating values indicated in the manufacturer documents. In addition for flat-bottom tanks, the pressure in the annular space shall never exceed the actual pressure in the inner tank to avoid lifting of the tank flat bottom.

First liquid fill shall be performed carefully by limiting the liquid flow to avoid thermal stresses and excessive pressure in the inner vessel by violent liquid flashing in the warm tank.

9 Operation and maintenance

9.1 Operation of the installation

Only authorized persons shall be allowed to operate the installation. Operating instructions shall be supplied to operating personnel.

The instructions shall define the safe operating limits of the system and any special procedures, which may be required to operate the system in an emergency situation. In general such instructions should be written and presented in a clear concise format.

If during the operation of the installation an excursion occurs outside the design or safe operating limits of the system (for example: overpressure, rapid temperature change, mechanical damage, etc) a program of inspection shall be drawn up by a qualified person and implemented.

9.2 Periodic inspection and maintenance

9.2.1 General

Periodic inspection and maintenance are required to ensure that the installation remains in a safe condition. The responsibility for the inspection, maintenance and repair shall be established between the manufacturer, the user and the local authorities. Maintenance of the installation shall comply with the current approval documentation.

Routine inspection and maintenance of equipment should be carried out on a planned basis and be adequately recorded.

The site should be inspected regularly to ensure that it is maintained in a proper condition and that safety distances are respected.

A comprehensive installation dossier shall be held on site; this dossier shall include:

- process and instrumentation diagrams;
- vessel or tank dossier;
- operating instructions.

Maintenance will generally include:

- checking the condition of the tank, piping and accessories;
- checking the operability of the valves;
- minor repairs, e.g. changing of seals;
- cleaning.

Inspection, maintenance and repairs shall only be carried out by personnel trained for the tasks.

Equipment shall not be taken out of service for repair until all pressure has been released. Any leakage shall be rectified promptly and in a safe manner. Only original spare parts should be used. If this is not possible the suitability of the spare part shall be approved by a competent person.

9.2.2 Tank

Periodic inspection or test of the inner tank should not be necessary because of:

- dry and clean service conditions
- product are non corrosive
- enhanced material properties at low temperatures
- special insulation

When a tank is taken out of service for modification or maintenance, the accessible areas of the tank should be examined by a competent person (as defined at 8.1) immediately prior to re-commissioning.

An annual external visual examination should also be carried out to confirm the satisfactory condition of the outer containment tank, exposed pipe-work, valves and controls.

Periodic monitoring to identify the existence of inner tank leaks should be carried out on either the insulation space vacuum or the composition of the purge gas in the insulation space. The supply of purge gas to non-vacuum insulated tanks should be checked periodically to ensure an effective purge is being maintained.

When soil or other conditions demand, a regular monitoring of the stability of the tank foundation should be carried out.

9.2.3 Pressure relief devices

Regular visual inspections of the devices shall be carried out during normal operation.

A periodic test of each relief valve shall be carried out to demonstrate its fitness for a further period of service. Pressure relief valves shall be tested in accordance with EIGA document IGC 24/02 “Vacuum insulated cryogenic storage tank systems pressure protection devices” unless national regulations dictate more stringent requirements.

Bursting disc elements may deteriorate with time resulting in their relief pressure rating being reduced. It may, therefore, be necessary to replace disc elements from time to time.

Where block valves are installed upstream of pressure relief devices to allow their inspection with the tank in operation, specific locking systems and operational procedures shall exist to assure that the safety devices are not isolated after the testing. At least one safety device shall be kept in operation during the testing of the second one.

9.2.4 Level indication and overfill protection

The liquid level measurement system and the overfilling protection system should be tested every 2 years, or more frequently if desired. This test must confirm operability of the entire system including actuation of the shutdown device at the appropriate set point and closure of the isolation valves in each tank liquid inlet line.

9.2.5 Emergency isolation valve(s)

Periodic checks shall be made to ensure that any emergency isolation valves are operating and any flow from the closed emergency isolation valve is acceptably small. The emergency shut-off valves and/or check valves installed to reduce the possibility of continuous liquid releases from the storage system should be tested every 2 years or more frequently if desired by the tank owner. The test for remotely operated emergency shut-off valves should confirm valve closure from all actuation points. For check valves the test should confirm the valve's capability to prevent significant liquid back flow through a failed line.

9.2.6 Ancillary equipment

Ancillary equipment other than previously detailed (e.g. level gauges and level transmitter, pressure and temperature gauges and transmitters, pressure reducers, pressure build-up vaporizers, etc) shall be maintained in accordance with either manufacturers' recommendations or national codes, whichever is the more stringent.

9.3 Modifications and changes

No modification shall be made to a plant, equipment, control systems, process conditions and operating procedures without authorization from a responsible manager or his delegate.

Any modification shall be carried out in accordance with the applicable design code; some modification may require consultation with the supplier.

Proposed modifications must be evaluated for safety, health and environmental impact and a signed document should be available before the change can be implemented. The document should be signed for a second time before the equipment is released to become operational. The AIGA document 010/04 "Management of change" should be referred to implement such procedure.

10 Training and protection of personnel

10.1 Work permit

Recommendations and prescriptions about work permits are described in AIGA document 011/04 "Work Permit Systems"

Before maintenance is carried out on the installation a written work permit for the particular type of work (cold work, hot work, entry of vessel, electrical work etc.) shall be issued by an authorized person to the individual(s) carrying out the work.

10.2 Entry into vessels

The following precautions, which are not necessarily all those required, shall be observed before entering any tank, vessel or annular space between inner and outer tanks:

- complete emptying and purging of the tank contents
- ensure inner tank is approximately at ambient temperature before entry is permitted
- complete isolation of the annular space purge lines and process lines from other equipment which may still be in service, by blanking discs or physical disconnection
- analysis of the atmosphere in the vessel and/or annular space at several selected points with a suitable gas detector (probes may be necessary) to ensure that the oxygen content is 21 %. It may be necessary to measure this regularly or continuously and to install forced ventilation while work is in progress
- presence of standby person (s) outside or adjacent to the access manhole

- use of appropriate safety equipment such as harnesses, protective clothing, fire extinguishers, etc….

- availability of rescue equipment (harnesses, self contained breathing apparatus, winches, radio links, etc...)

10.3 Training of personnel

Recommendations and prescriptions about training of personnel are described in AIGA document 009/04 "Safety training of employees"

All personnel directly involved in the commissioning, operation and maintenance of storage systems shall be fully informed regarding the hazards associated with oxygen, nitrogen and argon and properly trained as applicable to operate or maintain the equipment.

Training shall be arranged to cover those and other potential hazards that the particular operator is likely to encounter.

Training shall cover, but not necessarily be confined to the following subjects for all personnel:

- potential hazards of the cryogenic fluids

- site safety regulations

- emergency procedures

- use of fire fighting equipment

- use of protective clothing/apparatus including sets where appropriate

- first aid treatment for cryogenic burns.

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

It is recommended that the training be carried out under a formalised system and that records be kept of the training given and where possible, some indication of the results obtained, in order to show where further training is required.

The training programme should make provision for refresher courses on a periodic basis.

10.4 Emergency procedures

Emergency procedures shall be prepared to include the event of spillage of the cryogenic fluids. It is advisable that emergency procedures are prepared in conjunction with the emergency services or fire brigade and that local conditions are considered.

The procedures shall be readily available to all personnel involved, regularly practised and checked periodically that they are up to date. Employees likely to be affected shall know the actions required to minimise the adverse effects of such spillage.

The procedure should consider:

- the properties of the cryogenic fluids;

- the quantities involved;

- the local topography;

- the design and equipment of the storage system.

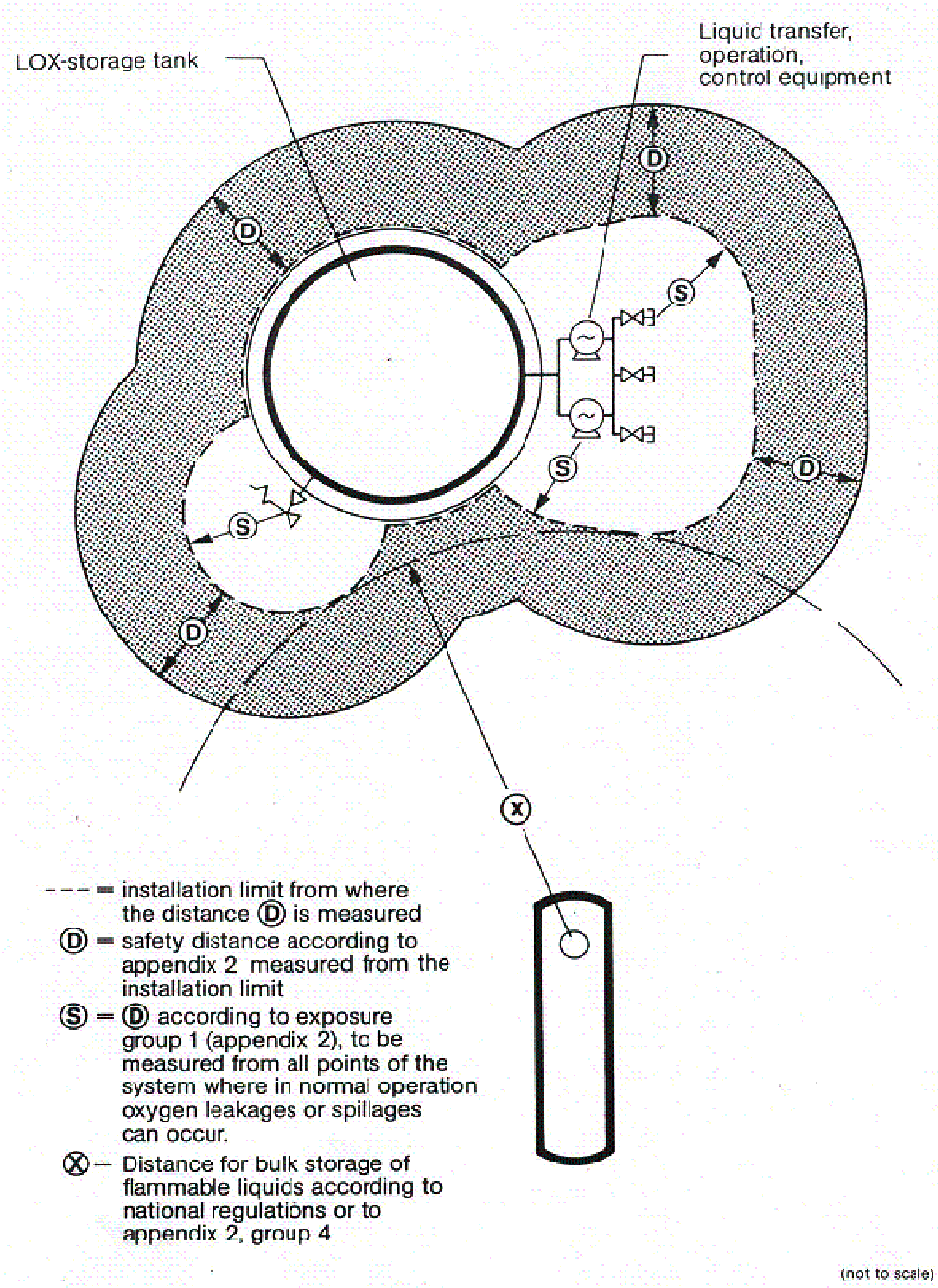
The following are guidelines which should be used for formulating emergency procedures:

- raise the alarm
- summon help and emergency services
- notify fire brigade immediately (if necessary)
- evacuate all persons from the immediate danger area and seal it off
- in case of leakage/spillage:
    - o tighten up leaks if this can be done without risk;
    - o allow liquid to evaporate
    - o prevent liquid entering sewers, pits, trenches
- in case of fire:
    - o keep vessel cool by spraying it with water
    - o do not spray water directly on valves or safety equipments
- alert public to possible dangers from vapour clouds and evacuate when necessary

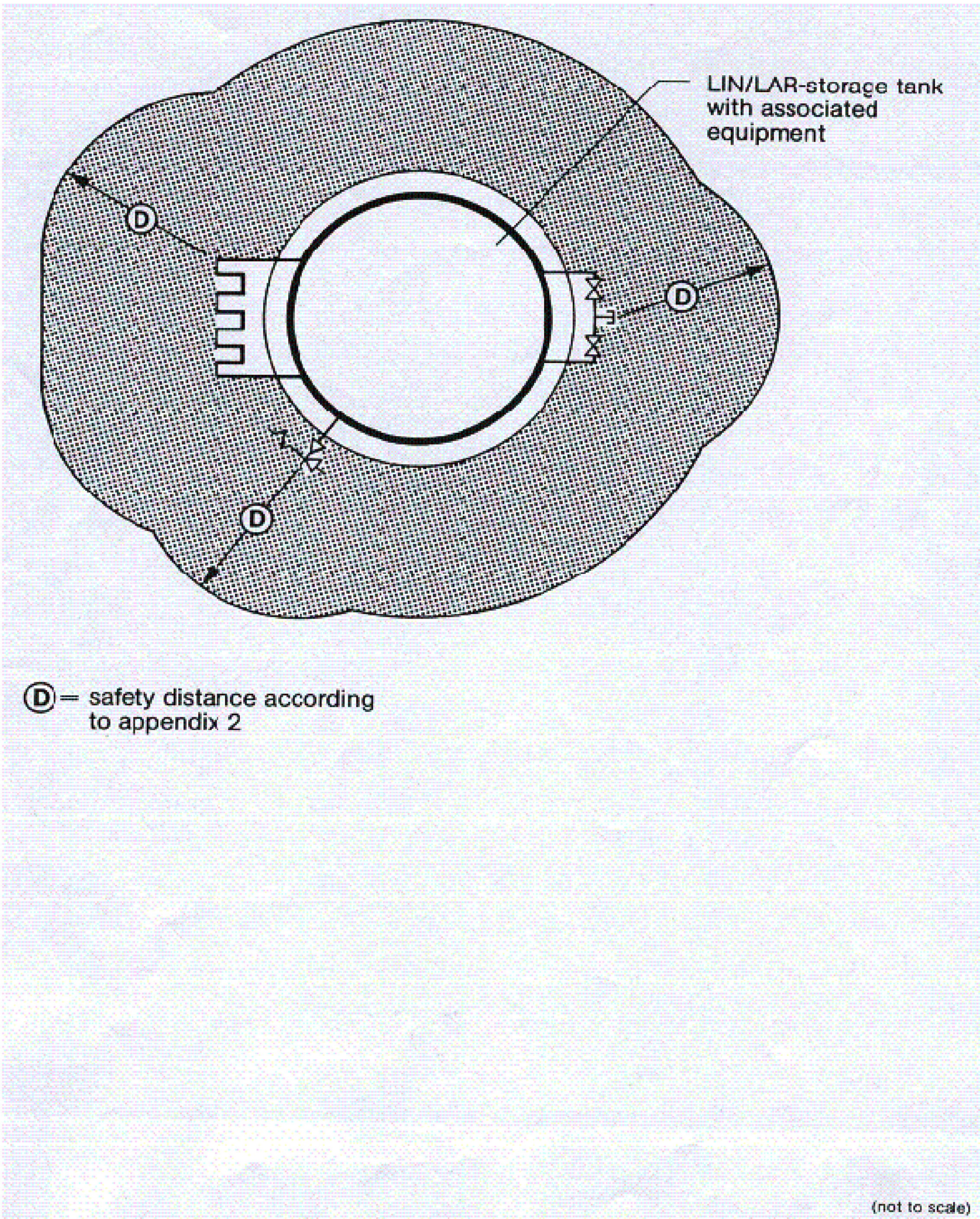
The procedure shall include:

- listing of emergency equipment required
- nomination of back-up personnel/organization for managing emergencies and procedures for contacting them both during and outside working hours
- identification of contents

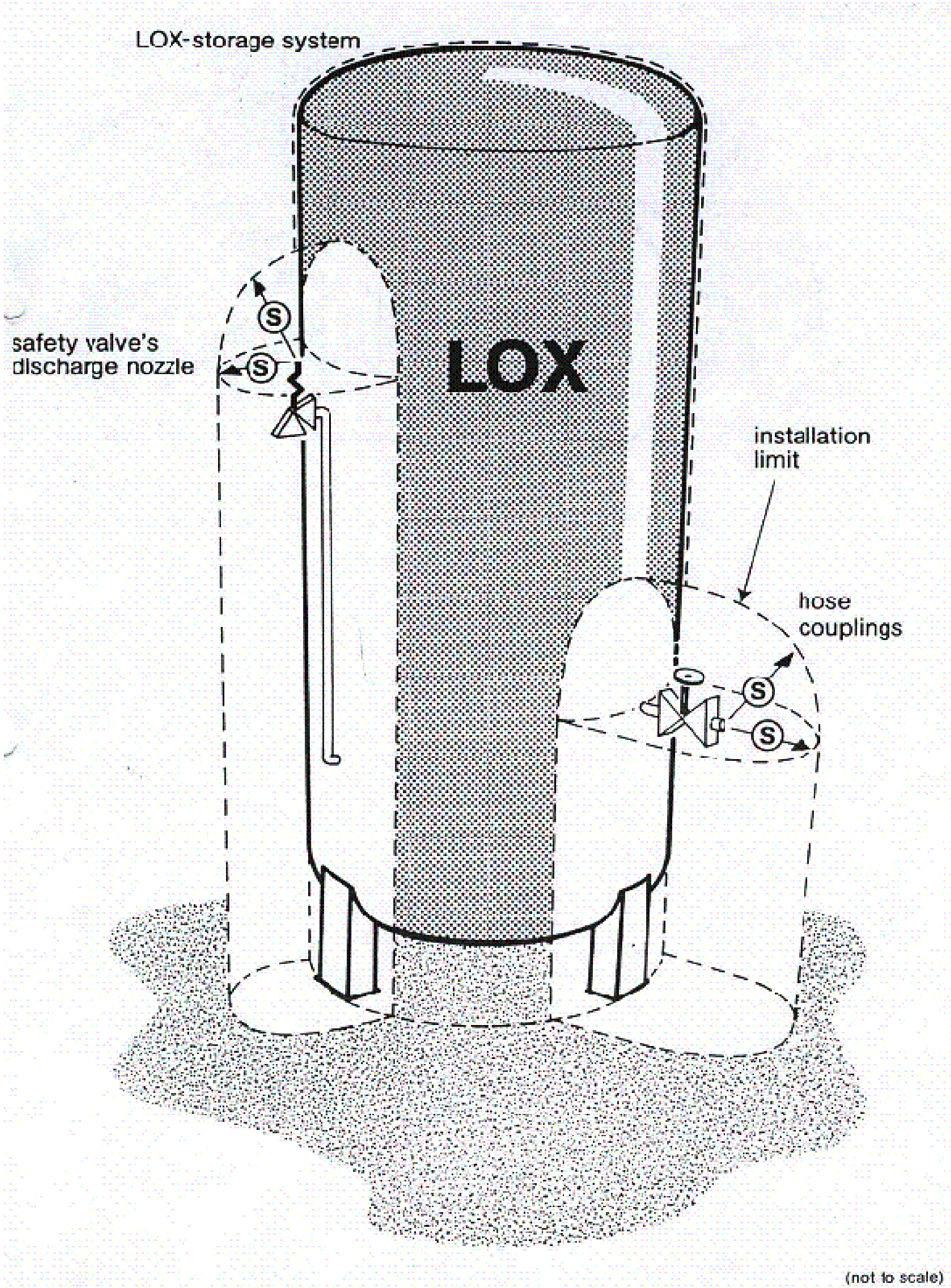
Appendix 1a: LOX Safety distances definition



Appendix 1b: LIN and LAR Safety distances definition



Appendix 1c: Safety distances definition



Appendix 2a: LOX Minimum Safety distances definition "S" and "D"

Types of exposure:

Group 1

- Distance (S) (see 2.2)
- Continuous sections of pipelines containing flammable gases or liquids, not interrupted by fittings, e.g. valves, unions, flanges

Group 2

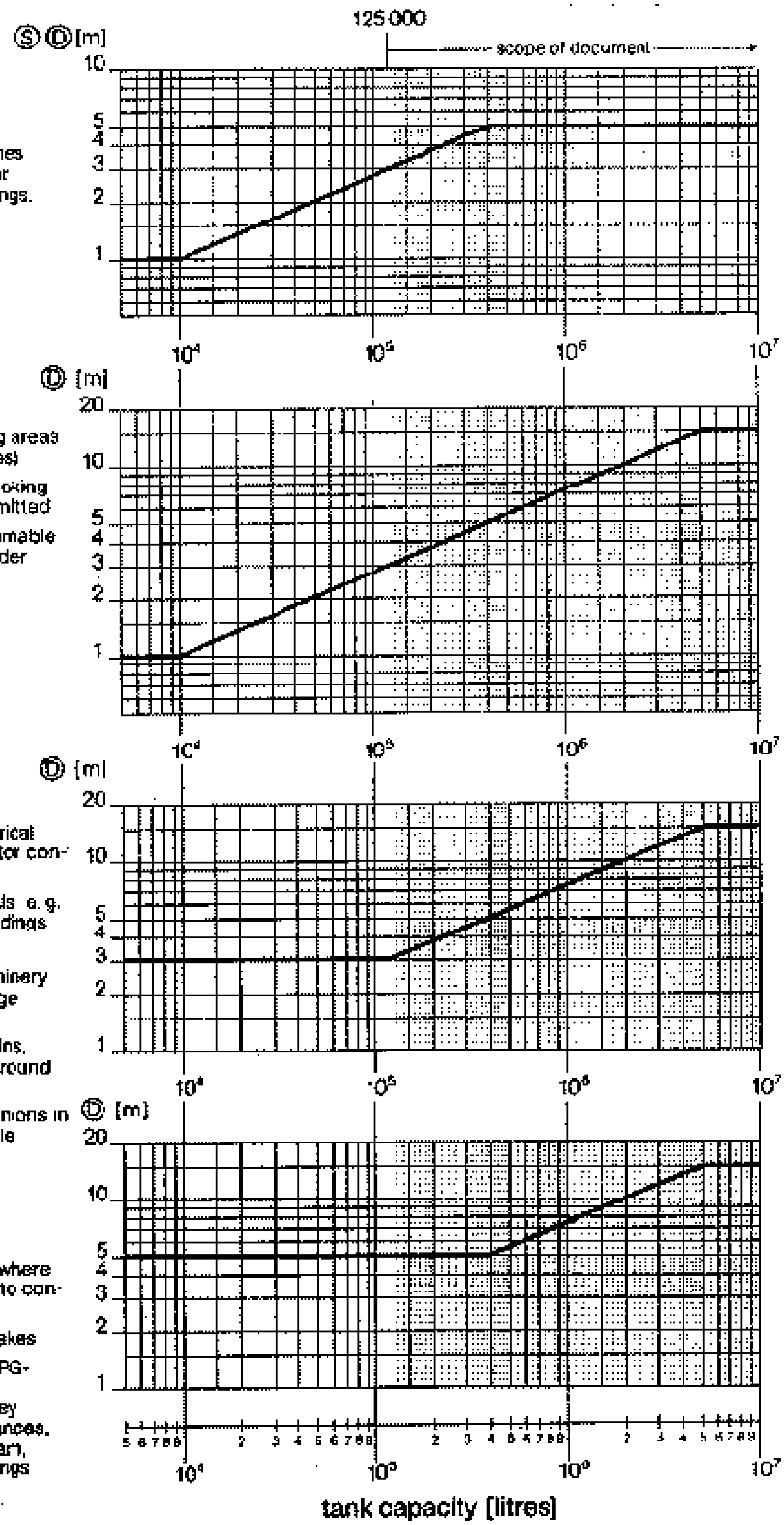
- Site boundary, vehicle parking areas (other than authorized vehicles)
- Areas where open flames, smoking or sources of ignition are permitted
- Fixed installations of non flammable HP-gases in cylinders or cylinder bundles

Group 3

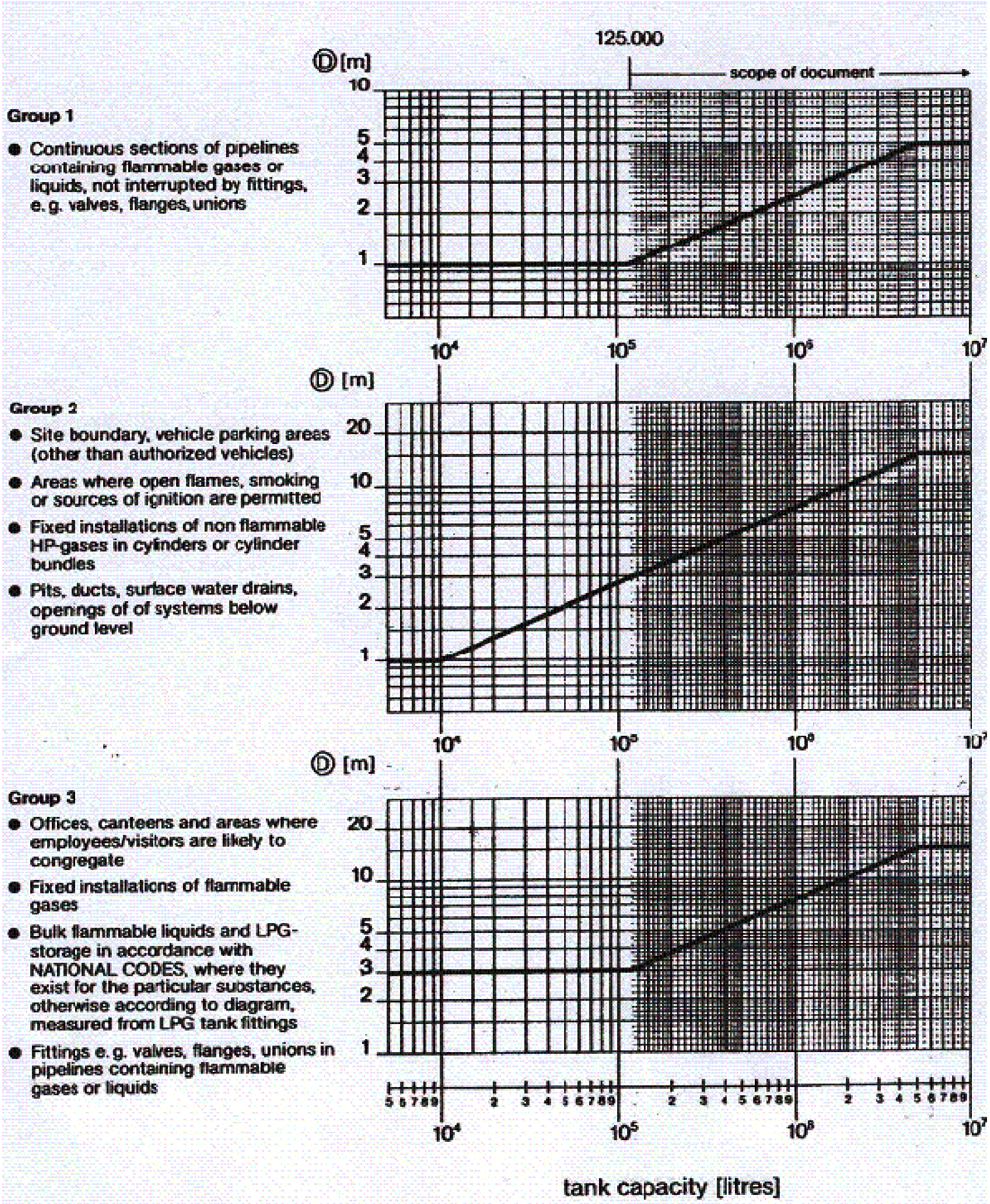
- Medium or high voltage electrical substations/transformers/motor control centers
- Stock of combustible materials e.g. timber, including wooden buildings and structures
- Process equipment and machinery which is not part of the storage installation
- Pits, ducts, surface water drains, openings of systems below ground level
- Fittings e.g. valves, flanges, unions in pipelines containing flammable gases or liquids

Group 4

- Offices, canteens and areas where employees/visitors are likely to congregate
- Compressor/ventilator air intakes
- Bulk flammable liquids and LPG-storage in accordance with NATIONAL CODES, where they exist for the particular substances, otherwise according to diagram, measured from LPG tank fittings



Appendix 2b: LIN and LAR Minimum Safety distances "D"



Appendix 2c: Diagram grid for determination of distances "S" and "D"

For calculation: The diagonal line of the diagram grid is described by the equation:

$$\text{Ⓓ,Ⓢ [m]} = \left(\frac{V\,[l]}{10^4}\right)^{0.4358}$$