STORAGE OF CRYOGENIC AIR GASES AT USERS' PREMISES

AIGA 030/06

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KEYWORDS

- ARGON
- CRYOGENIC
- NITROGEN
- OXYGEN
- PRESSURE VESSEL
- STORAGE

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Table of Contents

1 Introduction

The storage of cryogenic gases in the liquid state under pressure at users' premises not only provides an efficient way of storing gas, but improves safety when used in conjunction with a distribution system by eliminating the need for cylinder handling.

However, the particular properties of cryogenic gases necessitate certain precautions to be taken and certain rules to be followed.

As part of the continuing effort to promote a high standard of safety the former IGC Doc. 16/85 and 17/85 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 cryogenic storage systems.

This AIGA document is intended for the guidance of those persons directly associated with the design, operation and maintenance of bulk liquid storage installations. It does not claim to cover the subject completely but gives advice and should be used with sound engineering judgement.

All new storage installations shall comply with this document.

2 Scope

This AIGA document deals with static vacuum insulated storage systems installed at users premises for liquid Oxygen, liquid Nitrogen and liquid Argon. The principles are also applicable for other cryogenic gases.
This document covers installations of tank with an individual water capacity between 1000 and 125.000 litres.
For installations in excess of 125.000 litres, this document may also be used as a guidance; applicable regulation may impose different safety distance.

3 Definition

The static vacuum insulated storage installation includes:
- the storage tank together with control equipment and safety devices
- the vaporising equipment
- the liquid storage enclosure and liquid transfer area.

4 General

Gaseous oxygen, nitrogen and argon are colourless, odourless and tasteless.
Nitrogen and argon are non-toxic but asphyxiant.
Oxygen is not toxic; it is slightly denser than air. It is not a flammable gas but vigorously supports combustion. Breathing pure oxygen at atmospheric pressure is not dangerous although exposure for several hours may cause temporary functional disorders to the lungs.

The following AIGA documents have to be taken into consideration:
- AIGA 005/04 Fire hazards of oxygen and oxygen enriched atmospheres
- AIGA 008/04 Hazards of inert gases

4.1 Properties of nitrogen, argon and oxygen

The physical properties of nitrogen, argon and oxygen are:

		Nitrogen	Argon	Oxygen
Content in air	Vol %	78.1	0.9	21
Gas density at 1.013 bar, 15 0 c	kg/m^3	1.19	1.69	1.36
Boiling temperature at 1.013 bar	°C	-196	-186	-183
Liquid density at 1.013 bar and boiling temperature	kg/l	0.8	1.39	1,14
Gas volume of the liquid				

at ambient conditions	l_{gas}/l_{liquid}	680	810	840

Cold oxygen, nitrogen and argon vapours are 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:

4.3 Oxygen deficiency or enrichment of the atmosphere

The atmosphere normally contains 21 % by volume of oxygen. Enrichment for example to only 25 % may give rise to a significant increase in the rate of combustion.

Nitrogen and argon will act as asphyxiants by displacing the oxygen from the atmosphere.

Many materials including some common metals which are not flammable in air, may burn in oxygen, when ignited.

The hazards from oxygen enrichment or deficiency are explained in the above mentioned AIGA documents.

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

4.3.1 Cryogenic burns

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

4.3.2 Air condensation

Ambient air will condense on uninsulated pipes and vessels containing liquid nitrogen causing local oxygen enrichment of the atmosphere.

4.3.3 Oil, grease, combustible material and other foreign matter

Most oils, grease and organic materials constitute a fire or explosion hazard in oxygen enriched atmospheres and must on no account be used on 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.

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.

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

Degreasing of an installation or parts of it demands the use of a degreasing agent which satisfies the following requirements

- no or slow reaction with oxygen
- no or low toxicity (low vapour pressure to keep vapour concentration below threshold limit)
- material compatible with oxygen

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 atmospheres or in liquid oxygen.

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

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

4.3.4 Embrittlement of materials

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

4.3.5 Fire protection

A fire hydrant system and/or dry powder extinguisher shall be available near a liquid oxygen storage. They shall be installed outside the installation limit (see appendices A and B).

4.3.6 Smoking/hot work

Smoking, hot work (unless special precautions are taken) and open fire shall be prohibited within the minimum distance specified in appendices A and B.

4.3.7 Insulation materials

The components used in insulating materials shall be such that the finished product is suitable for oxygen service.

4.4 Regulation and codes

Liquid cryogenic storage installations should conform to this document which describes minimum requirements. National or local regulations shall be observed.

5 Layout and design features

5.1 General

The strict adherence to a design and construction code for pressure vessels and their allied equipment is the best guarantee for prevention of dangerous leakage.

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

5.1.1 Safety distances

The given distances are intended to protect the storage installation as well as the environment.
They are considered as protection against risks involved, according to practical experience, in normal operation in cryogenic liquid storage installations.

The distances shown in appendix B correspond to well established practice and are derived from operational experience within Europe and the USA. They relate to over 200 000 tank years of service. Should any evidence become available which indicates that a revision is necessary then such revision will take place.

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

5.1.2 Location of the installation

The installation should be located in the open, in such a place, that there is no risk of damage by passing vehicles.

The installation shall not be erected below ground level unless a documented risk assessment has been carried out and all applicable mitigating measures taken.

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

5.1.2.1 Protection against electrical hazards

The location is to 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.

For oxygen tanks the electrical equipment installed within the distance specified for sources of ignition in appendix B shall be of protection class IP54 or better.

5.1.2.2 Installation level and slope

Where liquid cryogenic storage tanks are required to be installed at an elevated level, they shall be supported by purpose designed structures which should withstand or be protected from damage by cryogenic liquid spillage.

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

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

5.1.2.3 Position of gas vents

Vents, including those of safety relief devices, shall vent to a safe place in the open, so as not to impinge on personnel, occupied buildings and structural steelwork.

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

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

5.1.2.4 Vapour clouds

When sitting an installation, due consideration shall be given to the possibility of the movement of vapour clouds, originating from spillage or venting, which could be a hazard (decreased visibility, oxygen enrichment/deficiency). The prevailing wind direction and the topography shall be taken into account.

5.1.3 Liquid transfer area

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

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

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

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

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

5.1.4 Ventilation of pump enclosure

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 case of oxygen where there will be no accumulation of combustible material liable to form a hazard.

5.1.5 Equipment layout

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

5.1.6 Isolation valves

The protection of isolation valves from external damage shall be considered.

5.1.7 Secondary isolation

Consideration shall be given for the provision of a secondary means of isolation for those lines greater than 9 mm nominal bore

- emanating from below the normal liquid level and
- having only one means of isolation between tank and atmosphere (such as liquid filling lines) to prevent any large spillage of liquid should the primary isolating valve fail.

The secondary means of isolation, where provided, may be achieved for example, by the installation of a second valve, a non-return 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 of any trapped liquid.

5.1.8 Diversion of spillage

Consideration shall be given for provision to divert any spillage towards the safest available area.

Hydrants, hoses and spray nozzles shall be provided. These may be used for dispersing the vapour cloud which could arise from any liquid spillage.

5.1.9 Couplings

Couplings used for the transfer of liquid gas shall be non-interchangeable with those used for other products.

5.1.10 Non-return device

Consideration shall be given to the need to incorporate a non-return device after the cryogenic gas vaporiser to avoid backflow into the storage tank system. This device may be a simple non return valve for a low risk application or a more sophisticated mechanism e.g. double block and bleed in a high risk environment. A risk assessment should be conducted to establish the degree of protection needed

5.1.11 Fencing

Fencing is required to prevent access of unauthorised persons, where other means are not provided.

On controlled sites with sufficient supervision fencing is optional.

Where fencing is provided the minimum clearance between the fence and the installation shall be 0.6 m to allow free access and escape inside the enclosure.

The safety distances given in appendix B will apply regardless of the position of the fence.

The height of the fence shall be approximately 1.8 m.

Timber or other readily combustible materials shall not be used for fencing.

Gates shall be outward opening wide enough to provide for an easy access and exit of personnel, and shall be locked during normal operation.

Consideration shall be given to the provision of an emergency exit.

In case of an oxygen storage installation any firebreak walls or partitions shall be made of brick, concrete or any other suitable non-combustible material.

5.1.12 Liquid vaporisers

Measures shall be taken to prevent the system's temperature from dropping below its minimum permissible operating value (see 4.3.4).

5.1.13 Foundation, construction of floor

The tank foundation shall be designed to safely withstand the weight of the tank, its contents and other possible loads applied by wind, snow etc.

The floor on which the equipment is installed shall be made of concrete or any other suitable material.

In case of oxygen the floor on which the equipment is installed and an area of 1 m radius minimum from the hose filling coupling shall be made of concrete or any other suitable, non flammable, and non porous material.

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

Accumulation of water shall be avoided.

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

5.1.14 Bolting down

Many factors determine whether a tank needs to be bolted down.

The following factors must be considered

- seismic activity
- wind speed
- topography (nature of surrounding terrain)
- ground roughness (open or protection provided)
- tank shape factor (L/D ratio, attachments to tank) (see also appendix C)

5.1.15 Other requirements

The installation site chosen shall be acceptable to the gas supplier and reserved for the storage of cryogenic liquids.

The equipment shall be installed, tested, commissioned and maintained in strict accordance with the liquid supplier's instructions.

Any modifications shall be carried out in accordance with the applicable design code and in consultation with the liquid supplier.

5.2 Indoor installation

Indoor installations are not recommended. If indoor installation is necessary, it shall be within a purpose-designed building, or within an existing building provided the following further conditions are observed.

5.2.1 Construction

The installation should be housed in a separate building constructed of non-combustible material.

For oxygen it should be impervious material.

When enclosed in an existing building, precautions shall be taken to ensure complete isolation of the liquid cryogenic installation from adjacent installations by means of a continuous solid wall or partition. At least two of the walls of the enclosure shall be external walls of the existing building.

Consideration shall be given to the provision of an emergency exit.

5.2.2 Gate(s)

Gate(s) shall be located in an external wall and open outwards.

For widths see paragraph 5.1.11.

Gate(s) shall be locked when the installation is unattended.

5.2.3 Ventilation

Provision shall be made for adequate natural or forced ventilation to the open air.

5.2.4 Trenches, pits, manholes, ducts

Trenches, pits, manholes, open cable or pipe ducts are not allowed in the enclosure.

5.2.5 Crossing of enclosure by electric cable

Above ground electric cables shall not be allowed in the enclosure except for the electrical supply to the installation.

6 Access to the installation

6.1 Personnel

The installation shall be so designed that authorised 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 unauthorised persons. Warning notices shall support this.

6.2 Access to installation controls

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

Filling connections and equipment controls should be located in close proximity to each other and such that they and tanker controls are visible and easily accessible from the operator's position. It shall be kept in mind that the length of the flexible connecting hose is normally 3 m.

Extended filling connections should be limited to 10 m unobstructed walking distance. Greater distances require special provisions.

6.3 Notices and instructions

6.3.1 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:

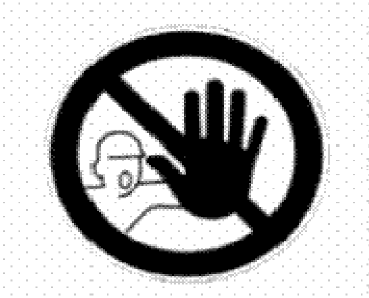
- LIQUID NITROGEN/ARGON/OXYGEN
- NO SMOKING*
- NO HOT WORK*
- NO STORAGE OF COMBUSTIBLE MATERIALS*
- AUTHORISED PERSONS ONLY
- DO NOT ENTER ANY VAPOUR CLOUDS

In addition for oxygen storage installation

- NO NAKED LIGHTS
- NO STORAGE OF OIL; GREASE OR COMBUSTIBLE MATERIALS

Symbols may be used instead of written notices, e.g.





* Although nitrogen and argon are inert gases it is recommended that smoking and open flames are prohibited within the immediate area to avoid the possibility of causing fire.

In order to facilitate control of an emergency, a sign shall be displayed showing:

- gas supplier's name and local address
- gas supplier's local phone number
- phone number of the local emergency service.

This information should also be available at a control point.

6.3.2 Identification of contents

The storage tank should be clearly labelled "LIQUID NITROGEN"; "LIQUID ARGON” or "LIQUID OXYGEN"

The connection fittings of multi-storage installations or long fill lines shall also be clearly marked with gas name or symbol in order to avoid confusion (see also 5.1.9).

6.3.3 Legibility of notices

All displayed notices shall be kept legible, visible and up-to-date at all times.

6.3.4 Operating and emergency instructions

Operating and emergency instructions shall be available before commissioning the installation. These instructions shall be kept legible and up to date.

7 Testing and commissioning

7.1 Testing of the installation

Prior to commissioning the following tests shall be carried out by the supplier or his representative in accordance, with established procedures.

7.1.1 Pressure test

A pressure test shall be carried out in accordance with national and company codes. Means of pressure indication suitable for the test pressure shall be installed before the test. Precautions shall be taken to prevent excessive pressure in the, system during the test. Following any hydraulic test, the system/equipment shall be drained and thoroughly dried out and checked.

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

Pneumatic testing is potentially more hazardous than hydraulic and the operation must be risk assessed to ensure personnel conducting the test and others in the vicinity are not exposed to unacceptable risk

Pressure tests shall be witnessed by a responsible person and a test certificate signed and issued. Such certificates 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).

7.1.2 Pressure relief devices

A check shall be made to ensure that all transport locking devices have been removed from pressure relief devices of inner vessel, outer jacket and piping systems and that the devices are undamaged and in working order.

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.

If a three-way valve is installed to accommodate two pressure relief devices operating either simultaneously or alternatively, 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 three-way valve's actuating device.

*Work's manufactured tanks and pressure vessels of the installation will already have been tested, in compliance with Regulations, in the manufacturer's workshop prior to the first installation. Further tests shall not be carried out in the vessel without reference to the vessel manufacturer. Hydraulic testing should be avoided; refer to EIGA IGC 119/04 Periodic inspection of static cryogenic vessels.

7.2 Adjustment of controlling devices

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

7.3 Posting of notices

Notices (see 5.3) shall be posted before putting the installation into service.

7.4 Commissioning

Commissioning shall only be carried out by authorised personnel and in accordance with a written procedure.
Pre-commissioning checks shall be carried out. Appendix D may be used as a guide for the preparation of a checklist.

8 Operation and maintenance

8.1 Operation of the installation

8.1.1 Operating personnel

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

For the convenience of the operator the supplier may colour code or identify by other means the hand wheels of these valves which are to be shut in an emergency. These valves should normally be:

- feed and return valves to and from the pressure build up vaporiser
- feed valve to the product vaporiser
- user house line isolation valve
- any withdrawal valve.

The number of valves will vary, depending on the type of the installation.

8.1.2 Operating difficulty or emergency

Any operating difficulty or emergency concerning the installation shall be referred to the liquid supplier.
The supplier's equipment shall not be modified by the customer.
Any proposed modification to a customer owned installation or an attached system should be discussed and agreed with the liquid supplier.

8.2 Periodic inspection and maintenance

8.2.1 General

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

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

8.2.2 Tank

Periodic inspection or test of the inner tank is not necessary because of

- dry and clean service conditions
- no corrosion
- 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 immediately prior to re-commissioning.

8.2.3 Installation

Periodic and planned maintenance of the installed equipment shall be carried out.

An annual external visual examination to confirm the satisfactory conditions of the vacuum envelope, exposed pipework and controls is recommended. A check on the vacuum shall be made at least every three years or if an abnormal pressure increase occurs.

8.2.4 Liquid vaporisers

In the winter season, regular checks shall be carried out for snow and ice formation which shall be removed if necessary from the vaporising elements of ambient air vaporisers in order to maintain satisfactory operation.

When a water bath or steam heated liquid vaporiser is used regular visual examination of shell and external tube surfaces together with a pneumatic leak test of the coil are recommended.

8.2.5 Pressure relief devices

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

A regular 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 Doc. 24/02 Cryogenic pressure vessels pressure protection devices, unless National Regulations or unusual conditions of service 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.

9 Training and protection of personnel

9.1 Work permit

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

9.2 Training of personnel

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

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

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

- potential hazards of the gases
- site safety regulations
- emergency procedures
- use of protective clothing/ apparatus including breathing sets where appropriate
- first aid treatment for cryogenic burns
- case of fire fighting equipment

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.

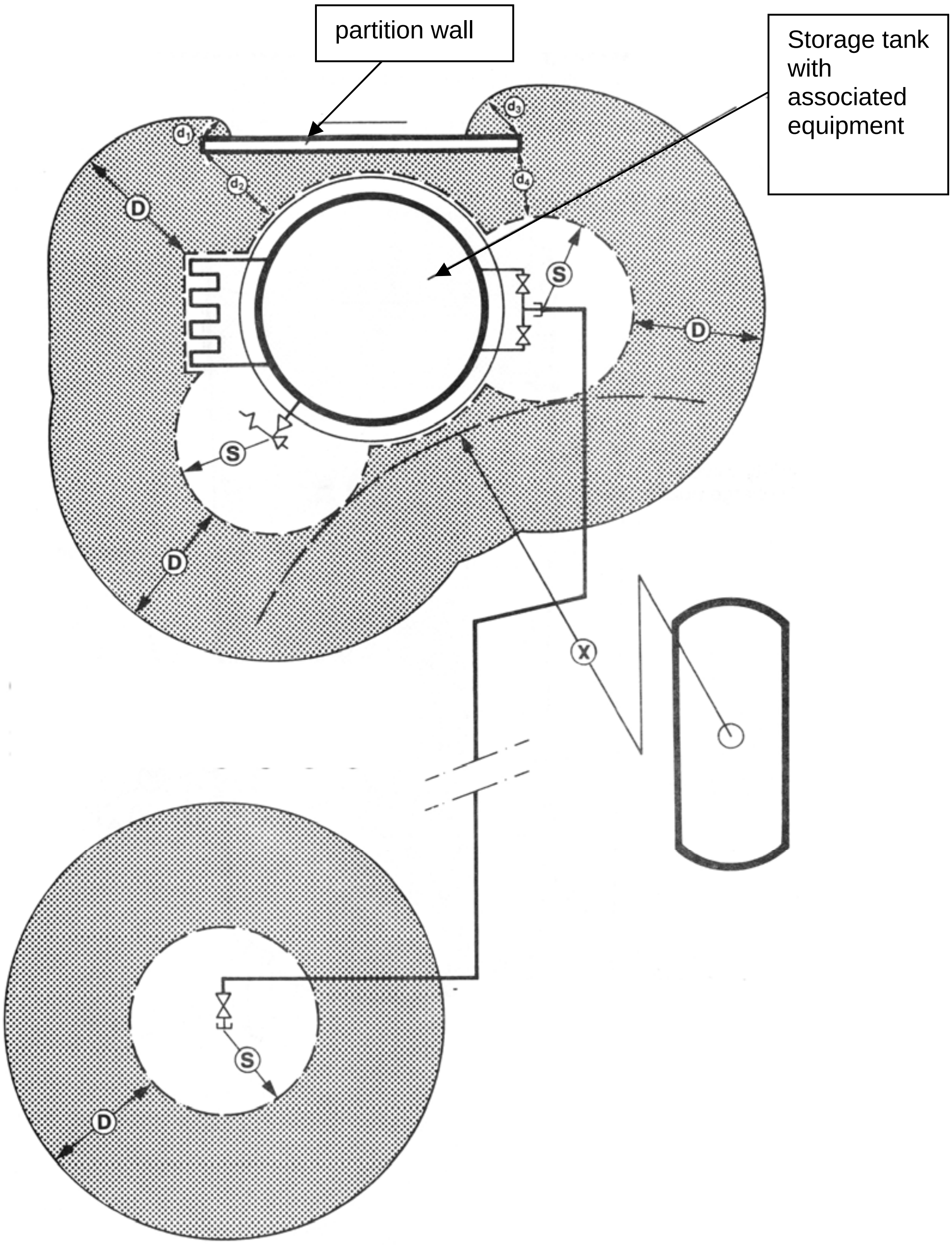
9.3 Emergency procedures

Emergency procedures shall be prepared to cover the event of a spillage of liquid cryogenic gases so that persons likely to be affected shall know the actions required to minimise the adverse effects of such spillage.

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

- raise the alarm
- summon help and emergency services
- isolate the source of gases, if appropriate and where safely possible
- evacuate all persons from the danger area and seal it off
- alert the public to possible dangers from vapour clouds and evacuate when necessary
- notify the gas supplier.

Appendix A: Safety distances definition



$d_1 + d_2 + d_3 + d_4 = D$ (length and location of the partition wall define the distances d_1, d_2, d_3, d_4).

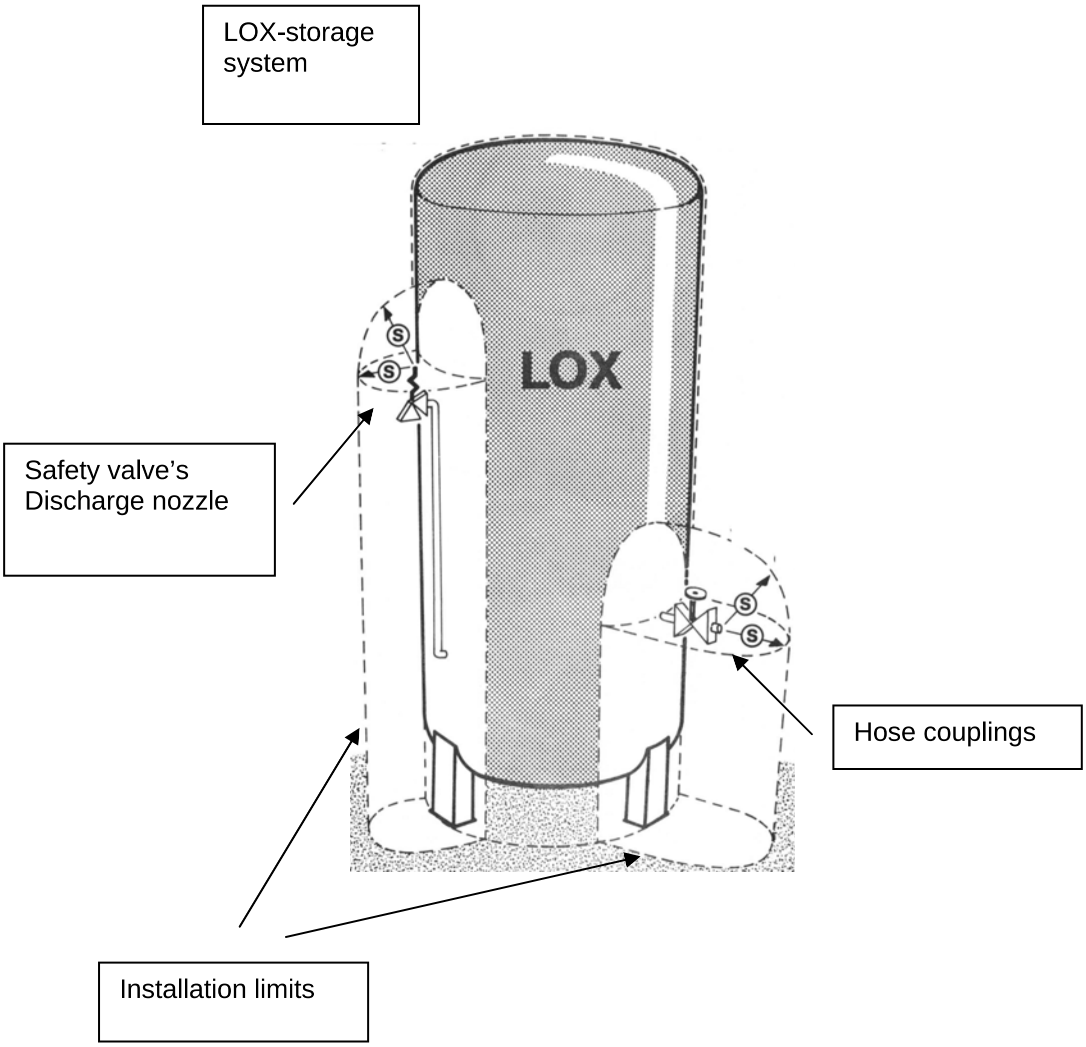
−−−· = installation limit from where the distance "D" is measured

"D" = safety distance according to clause 5.1.1 measured from the installation limit

"S" = according to exposure group 1 of appendix B1 to be measured from all points of the system where in normal operation oxygen leakage s or spillages can occur (for nitrogen and argon S=0)

"X" = Distance for bulk storage of flammable liquids according to appendix B group 4 or local regulations

Illustration of installation limit around system openings, where in normal operation oxygen escape or spillage can occur



Appendix B1: Minimum safety distances for liquid nitrogen and argon

Types of exposure:

Group 1

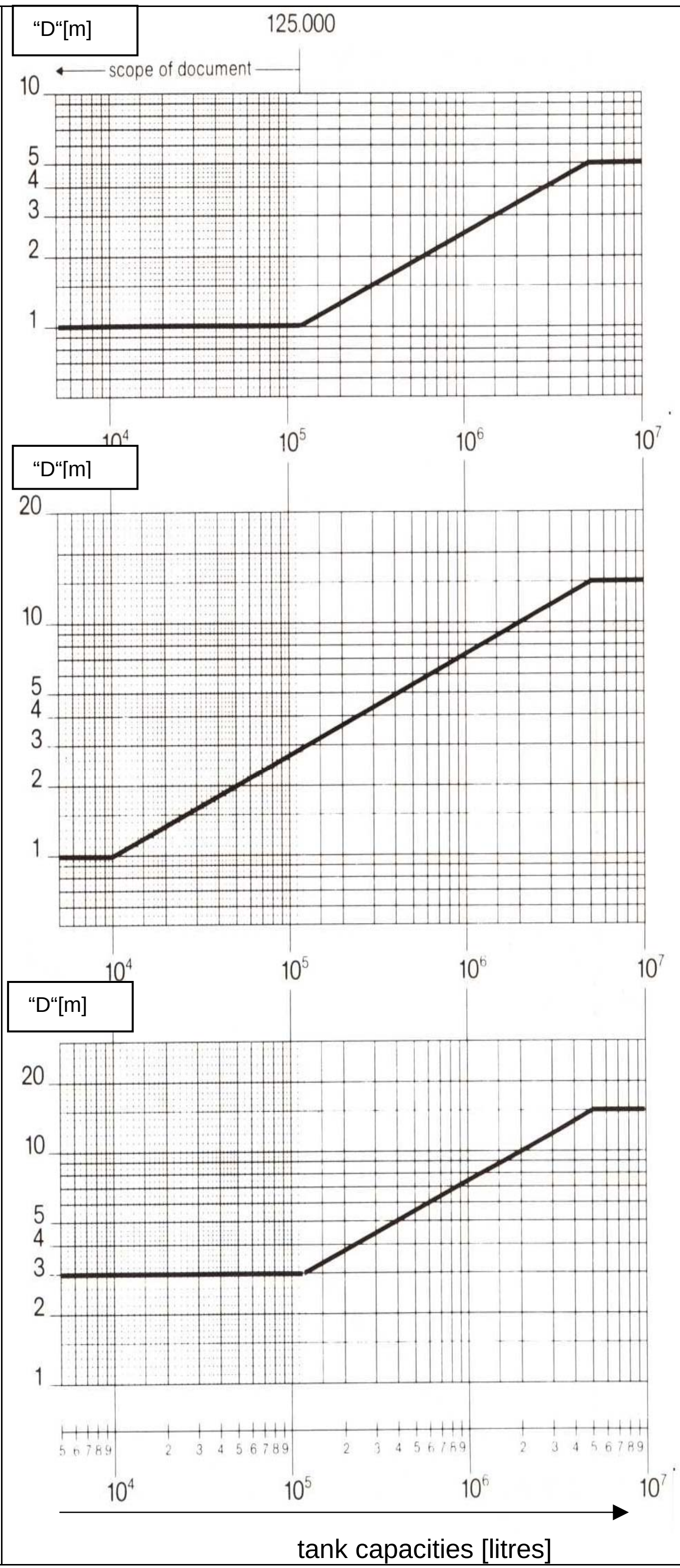
- Continuous sections of pipelines containing flammable gases or liquids, not interrupted by fittings, e.g. valves, unions, flanges

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
- Pits, ducts, surface water drains, openings of systems below ground level

Group 4

- Offices, canteens and areas where employees/visitors are likely to congregate
- Fixed installations of flammable gases
- Fittings e.g. valves, flanges, unions in pipelines containing flammable gases or liquids
- Bulk flammable liquids and LPG-storage in accordance with local codes, where they exists for the particular substances, otherwise according to diagram, measured from LPG tank fittings



Appendix B2: Minimum safety distances for liquid oxygen

Types of exposure:

Group 1

- Distance „S“(see 5.1.1)
- Continuous sections of pipelines containing flammable gases or liquids, not interrupted by fittings, e.g. valves, unions, flanges

Group 2

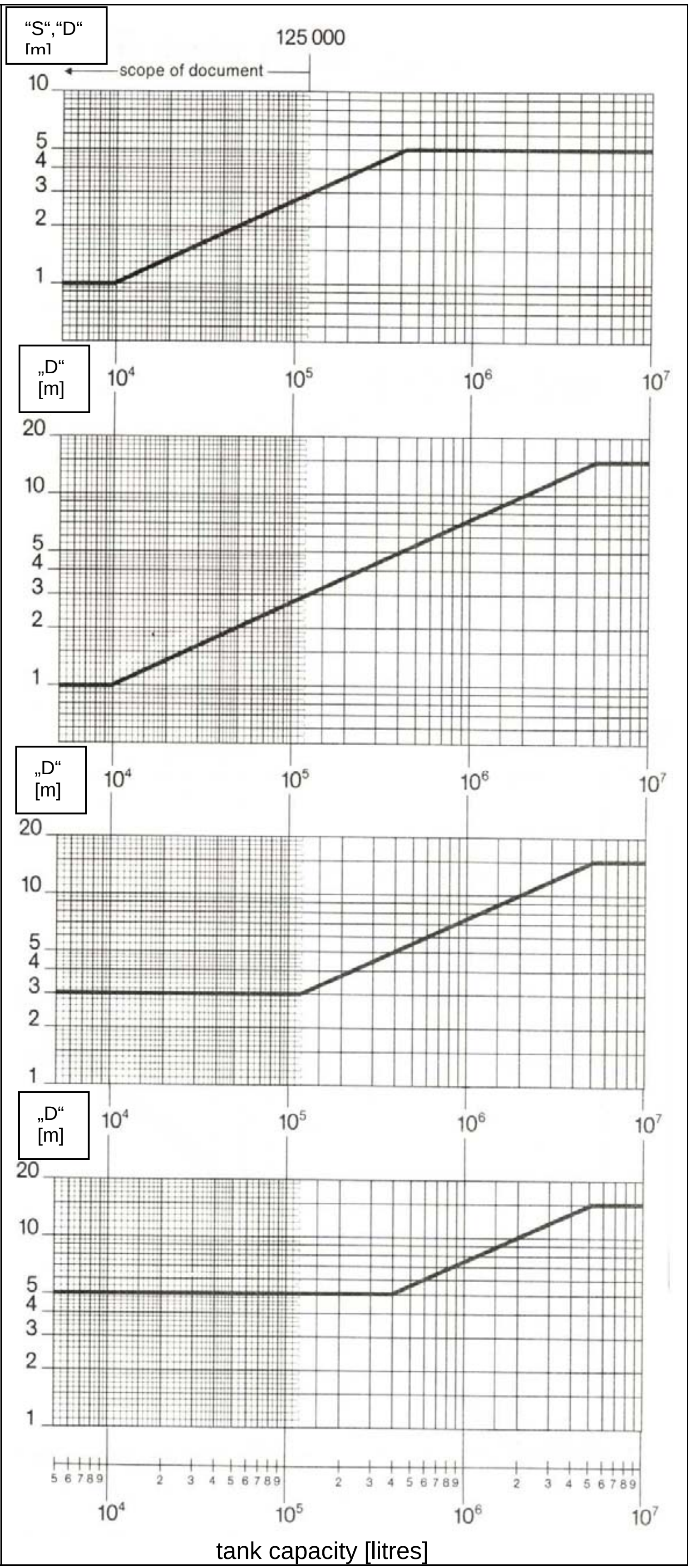
- Site boundary, vehicle parking areas (other than authorized vehicles
- Areas where open flames, smoking or sources of ignition are permitted
- Fixed installations of non flammable HP-gases in cylinders or cylinder bundles

Group 3

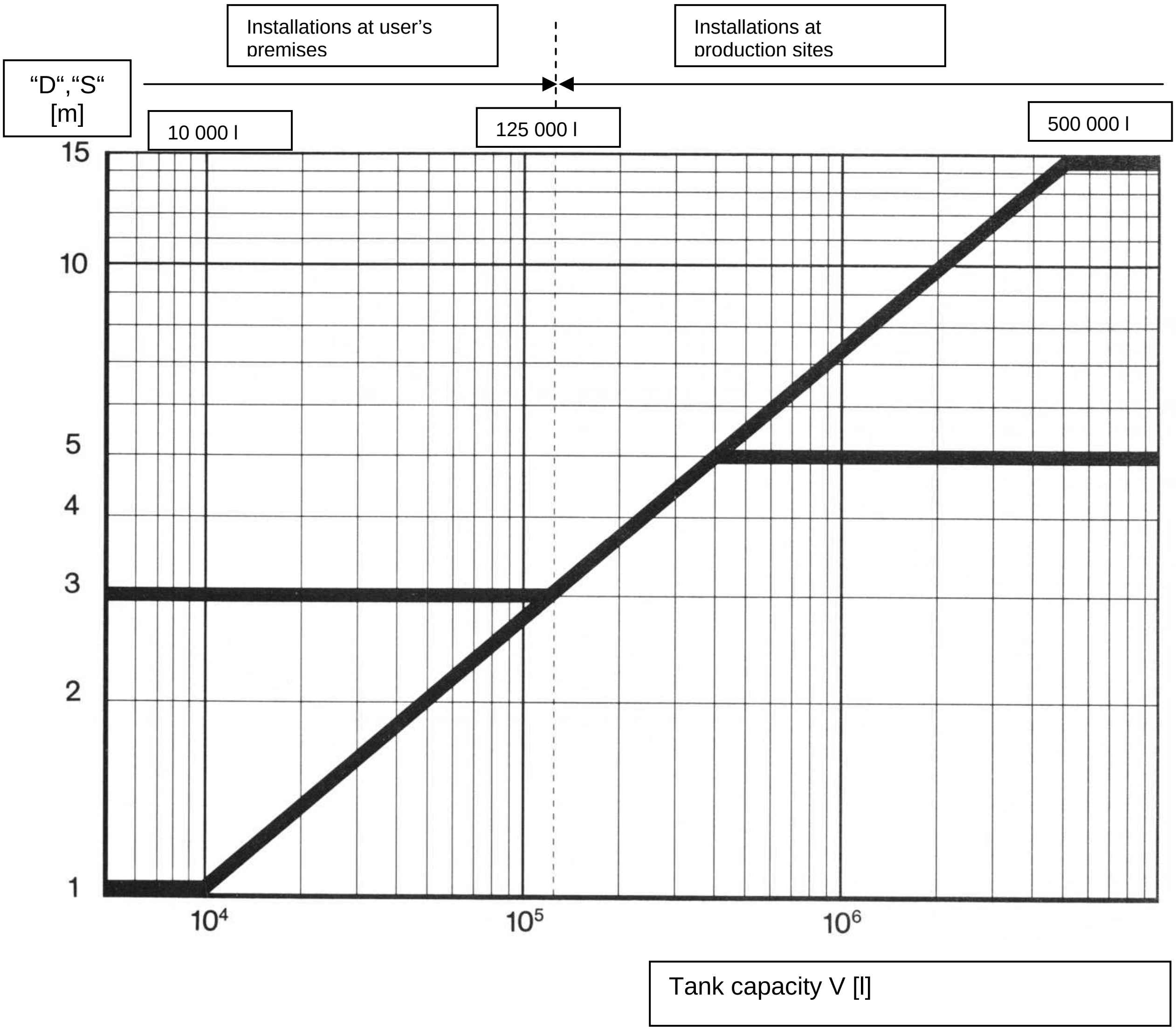
- Medium or high voltage electrical substations/transformers/motor control centres
- Stock of combustible materials e.g. timber including wooden buildings and structures
- Process equipment and machinery which is not part of the storage installation
- Pits, ducts, surface water drains, openings of systems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

Group 4

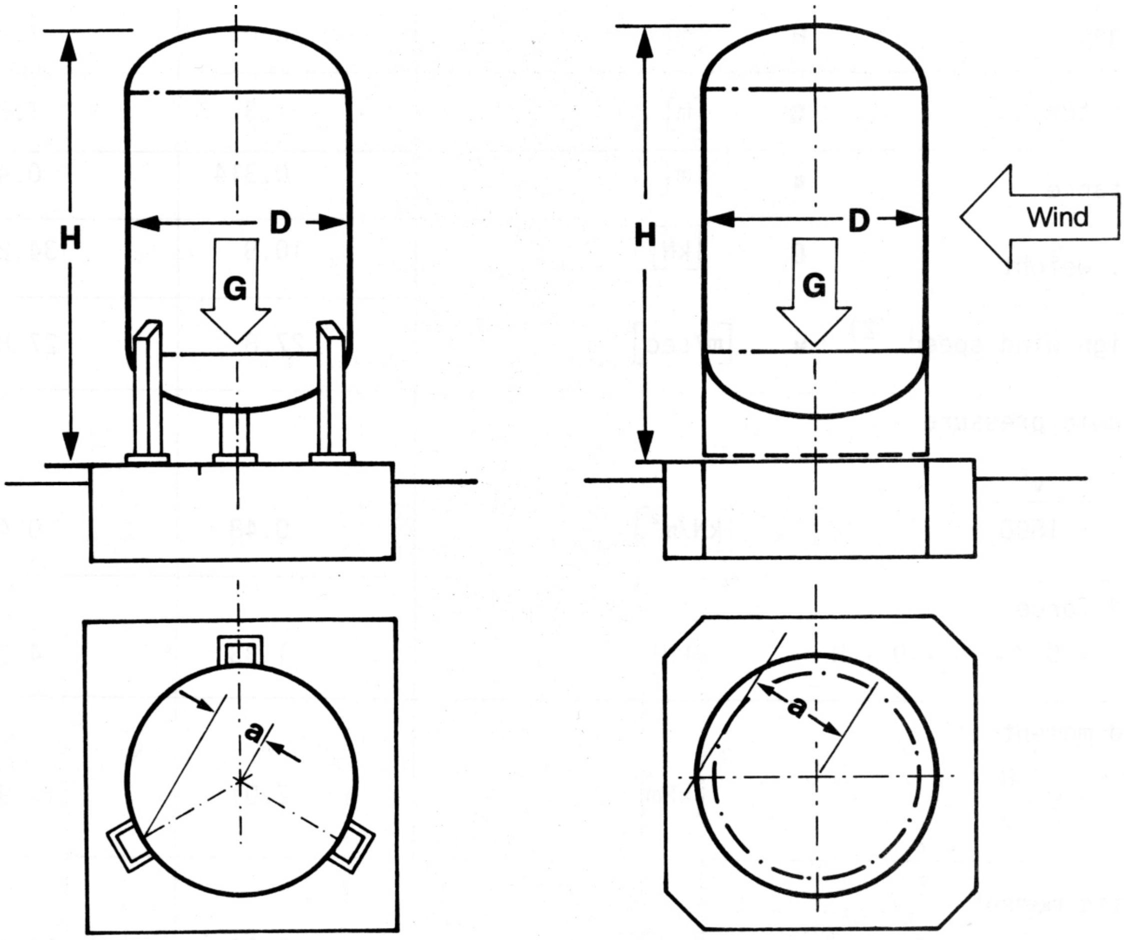
- Offices, canteens and areas where employees/visitors are likely to congregate
- Compressor/ventilator air in takes
- Bulk flammable liquids and LPG-storage in accordance with local codes, where they exists for the particular substances, otherwise according to diagram, measured from LPG tank fittings



Appendix B3: Diagram grid for determination of distances



Appendix C: Simplified tilting stability calculation



Calculation data:

H overall height [m]
D overall diameter [m]
G minimum weight of the empty tank according to technical specification, minus 10% [kN]
a moment length [m]
v design wind speed [m/sec]
c_f aerodynamic factor = 0.7 [-]
q dynamic pressure [1)] [kN/m²]

[1)] q= (1/2)*ρ*v² with a mean air density of 1.25kg/m³, the acceleration due toe the gravity g=9.81*10⁻³ kN, becomes

$q=(1/2)*(1.25/9.81)\ [kg*sec^2/m^3*m]*9.81*10^{-3}\ [kN/kg]*v^2[m^2/sec^2]$

$q= 0.625*10^{-3}\ *v^2[kN/m^2]$

$q= v^2/1600\ [kN/m^2]$

Calculation example:
(all values used are examples only, actual local values must be determined when carrying out calculations)

		Tank 1	Tank 2
Height	H [m]	3.03	7.03
Diameter	D [m]	1.3	1.8
Distance	a [m]	0.314	0.433
Min. weight	G [kN]	10.8	34.20
Design wind speed [2)]	v [m/sec]	27.8	27.8
Dynamic pressure	$q=v^2/1600$ [kN/m²]	0.48	0.48
Wind force	w=0.7*q*D*H [kN]	1.33	4.25
Wind moment	M= w*(H/2) [kNm]	2.01	14.94
Static moment	M_s= G/a [kNm]	3.39	14.81
Tilting factor [3)]	$F_t=M_s/M$	1.69	0.99
Bolting down necessary		no	yes

[2)] f.e. 27.8 m/s = 100 km/h
= max. local wind velocity, adapted according local situation by factors for topography and ground roughness

[3)] If $F_{t < 1.2,}$ the tank has to be bolted down

Appendix D: Pre-commissioning checklist

	Yes	No	Remarks
Easy accessibility for personnel and road tankers			
Safety distances , sufficient			
Foundation suitable			
Tank bolting			
Installation matches flow sheet			
Main isolation valve installed			
Records complete and correct			
Instructions available			
Instructions up-to-date			
Correct fill charts available			
Notices match product			
Local, technically responsible person designated			
Correct installation of safety devices			