BRITISH STANDARD

BS EN 13645:2002

Installations and equipment for liquefied natural gas — Design of onshore installations with a storage capacity between 5 t and 200 t

The European Standard EN 13645:2001 has the status of a British Standard

ICS 75.180.99

National foreword

This British Standard is the official English language version of EN 13645:2001.

The UK participation in its preparation was entrusted to Technical Committee GSE/38, Installation and equipment for liquefied natural gas, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

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Installations and equipment for liquefied natural gas - Design of onshore installations with a storage capacity between 5 t and 200 t

Installations et équipements de gaz naturel liquéfié - Conception des installations terrestres d'une capacité de stockage comprise entre 5 t et 200 t

Anlagen und Ausrüstung für Flüssigerdgas - Auslegung von landseitigen Anlagen mit einer Lagerkapazität zwischen 5 t und 200 t

This European Standard was approved by CEN on 15 November 2001.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 282 "Installation and equipment for LNG", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2002, and conflicting national standards shall be withdrawn at the latest by June 2002.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Annexes A, B and C are informative.

Introduction

The objective of this standard is to give functional guidelines for LNG facilities with a total storage capacity between 5 t and 200 t. It recommends procedures and practices which will result in safe and environmentally acceptable design, construction and operation of LNG plants.

This standard is not applicable to existing installations, but its application is recommended when major modifications are considered.

1 Scope

This European Standard specifies requirements for the design and construction of onshore stationary liquefied natural gas (LNG) installations with a total storage capacity between 5 t and 200 t. This standard is not applicable to liquefaction process facilities based on hydrocarbon refrigerants. Larger installations are treated according to EN 1473:1997.

If other dangerous substances are present in the facility, the aforementioned storage capacity thresholds may be reduced.

NOTE It is essential that the designer refer to local regulation to determine the new values.

The installations to which this standard is applicable include the following:

— LNG satellite plants. The LNG may be supplied by road tankers, barge or rail carriers. After storage, LNG is vaporized and sent out to consumers;

— LNG gas fuelling stations for vehicles.

The installation is limited from the gas inlet or the loading LNG area to the gas outlet or the unloading LNG area. Filling systems are not covered here.

For the purposes of clause 4 «Environment Impact» and clause 5 «Safety Plan», this standard applies where LNG storage capacity exceeds the threshold specified in the local regulation. If this value is not available, a threshold of 50 t is recommended.

It is recalled that, in any case, local regulations prevail.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1127-1, *Explosive atmospheres- Explosion prevention and protection- Basic concepts and methodology.*

EN 1160:1996, *Installation and equipment for liquefied natural gas - General characteristics of liquified natural gas.*

EN 1473:1997, *Installation and equipment for liquefied natural gas - Design of onshore installations.*

EN 12066, *Installation and equipment for liquefied natural gas - Testing of insulation linings for liquefied natural gas retention bunds.*

EN 60079-10, *Electrical apparatus for explosive gas atmospheres- Part 10: Classification of hazardous areas (IEC 60079-10:1995).*

ENV 1991-2-2, EUROCODE 1 *Basis of design and actions on structures - Part 2-2: Actions on structures - Actions on structures exposed to fire.*

ENV 1992-1-1, EUROCODE 2 *Design of concrete structures - Part 1-1: General rules and rules for buildings.*

ENV 1992-1-2, EUROCODE 2 *Design of concrete structures - Part 1-2: General rules - Structural fire design.*

ENV 1993-1-1, EUROCODE 3 *Design of steel structures - Part 1-1: General rules and rules for buildings.*

ENV 1993-1-2, EUROCODE 3 *Design of steel structures - Part 1-2: General rules - Structural fire design.*

ENV 1994-1-1, EUROCODE 4 *Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings.*

ENV 1994-1-2, EUROCODE 4 *Design of composite steel and concrete structures - Part 1-2: General rules - Structural fire design (including Technical Corrigendum 1:1995).*

3 Terms and definitions

For the purposes of this European Standard, the definitions given in EN 1160:1996 and EN 1473:1997, and the following terms and definitions apply.

3.1
above ground vessel
vessel of which all or part is exposed above ground level

3.2
boil-off gas
gas resulting from evaporation of LNG near its equilibrium state

3.3
emergency shutdown
a system that safely and effectively stops the whole plant or individual units when an incident occurs

3.4
flash gas
gas resulting from sudden evaporation of LNG out of equilibrium condition

3.5
impounding area
an area defined through the use of dykes or topography at the site for the purpose of containing any accidental spill of LNG

3.6
LNG gas fuelling station
installation including an LNG storage which supplies vehicles with LNG or gas from vaporized LNG

3.7
loading area
area where LNG is loaded from storage vessels to transport vessels when the plant supplies LNG

3.8
local regulation
set of rules, laws, national agreements, international conventions which apply to a site

3.9
operating personnel
any person who is authorised to act on the control of the plant, remotely or locally

NOTE It can include the drivers of LNG carriers who supply the plant with LNG. In the case of fuelling stations for vehicles, drivers of these vehicles are not included unless it is specified in the management plan of the installation.

3.10
plant or site
area inside of which public access is unauthorised

3.11
underground vessel
vessel which is completely buried below the general ground level of the facility

3.12
unloading area
area where LNG is unloaded from transport vessels to storage vessels when the plant is supplied with LNG

3.13
validated model
model whose effectiveness has been demonstrated by LNG industrial tests through clearly identified procedures

4 Environmental impact

4.1 General

An environmental impact study shall be carried out when the LNG storage capacity exceeds the threshold specified in the local regulation. If this value is not available, a threshold of 50 t is recommended.

The impact study shall take into account any restrictions on the transportation of LNG.

All emissions from the plant, that is, solid, liquid (including water), and gaseous (including noxious odours) shall be identified. Measures shall be implemented to ensure that normal and accidental emissions are harmless to persons, property, animals or vegetation.

An effluent management policy shall be established if relevant. The requirements in the handling of any toxic materials shall be identified.

Any increase in activity caused by operation shall also be assessed and undesirable levels of activities shall be eliminated if possible or minimized and restricted. The following items should be considered:

- noise levels;
- vibration levels;
- night working, effect of lights;
- gas flaring or venting;
- warming or cooling of water.

NOTE Fog may be created locally by atmospheric vaporizers.

4.2 Emission control

The following shall be safely controlled:

- combustion products from compressor drivers, submerged vaporizers, fired heaters for regeneration;
- normal or accidental venting of gases;
- normal or accidental flaring of gases;
- oily water condensed during dryer regeneration or from machines;
- in the case of water-cooled equipment, hydrocarbon contamination of this water from leaking exchanger tubes;
- disposal of waste products (chemicals, waste oil and chlorinated organic compounds);
- vaporizer water;
- odorant chemicals.

The standard of emissions control shall follow as a minimum specifications set by local regulation.

4.3 Boil-off / flash gas management

Continuous flaring or venting shall be avoided.

Boil-off gas can be recycled in a liquefaction process or included in the send-out gas to avoid waste gas during normal operation.

4.4 External communication networks

Traffic rates of external roads, railways and waterway networks near the LNG plant shall be identified.

5 Safety plan

5.1 Purpose

LNG installations shall be designed to minimize the risks to property and life outside and inside the plant. A safety plan shall be defined during the design of the plant or during a major modification when the LNG storage capacity exceeds the threshold specified in the local regulation. If this value is not available, a threshold of 50 t is recommended.

The safety plan shall include an identification of risks and an appropriate appraisal of the consequences. It shall also include the safety measures and principles of the actions performed by the operator for controlling risks for accidents.

Implementation of the safety plan shall be initiated as early as possible and be reviewed when unacceptable risks are identified during the design.

A hazards and operability study (HAZOP or equivalent) shall be conducted to identify and eliminate or minimise hazards.

Annex A illustrates the schematic description of the process related to an LNG satellite and fuelling plant. This description is simplified and it is not considered to be directly applicable for an actual project.

5.2 Collection of data and information

Initially all available data and information shall be assembled. It should be related to:

- natural conditions:
  - soil characteristics;
  - meteorological conditions, to include at least atmospheric temperature and wind statistics, occurrence of lightning strikes, relative humidity, atmospheric stability;
  - flooding risks;
  - seismic activity;
  - topography;
  - vegetation for identification of fire risks;
- surrounding integration:
  - surrounding infrastructure (e. g. industrial sites, built-up areas);
  - access for possible LNG trucks;
  - location of nearest fire services.

When the available information is not sufficient enough to identify the possible risks or to define relevant measures, an additional survey of data may be performed.

5.3 Threshold values

5.3.1 Heat radiation from fires

a) inside the plant:

1) in the safety plan, it shall be determined if fire can damage pieces of equipment. The maximum thermal radiation flux until which a damage to the components may be acceptable shall be specified. Table 1 gives informative maximum values excluding the solar flux, in case they are not already given in the local regulations.

Table 1 — Thermal radiation fluxes excluding solar radiation inside the boundaries

Equipment inside the plant	**Maximum thermal radiation flux** kW/m^2
Concrete surface storage vessels	32
Outer surfaces of pressure storage steel vessels and process facilities	15
Control room, maintenance workshops, laboratories, warehouses, etc.	8
Administrative buildings	5

The radiation fluxes of Table 1 may be increased according to the duration of the fire. In any case, the maximum radiation flux levels acceptable for each main structure or equipment inside boundaries shall be confirmed by the manufacturer or using validated methods or curves defined in ENV 1991-2-2, ENV 1992-1-1, ENV 1992-1-2, ENV 1993-1-1, ENV 1993-1-2 and ENV 1994-1-1 and ENV 1994-1-2.

The time during which the radiation is experienced is a major factor in determining the consequences on people. The observed effects of thermal radiation are in summary:

— 1,5 kW/m^2 will cause no discomfort for long exposure;

— 5 kW/m^2 is sufficient to cause pain to people if unable to reach cover within 15 s; otherwise, blistering of the skin (second degree burns) is likely.

The pieces of equipment can be either unprotected, or protected by means of water sprays, fireproofing screens or similar systems.

For storage vessels, the permissible radiation flux shall be determined taking into consideration at least the following factors:

— loss of mechanical strength of vessel;

— pressure build up within the vessel;

— the relief capacity of the safety valves;

— the temperature of the safety valve. It shall not reach the auto-ignition temperature of the flammable substance in the vessel.

Specific attention shall be given to aluminium-based vaporizers and piping which could be subjected to fire:

b) outside the plant:

   1) Table 2 gives the recommended values for the maximum incident radiation flux excluding solar radiation beyond a boundary in case it is not already defined in the local regulations.

Table 2 — Thermal radiation fluxes excluding solar radiation beyond a boundary

Area adjacent to the concerned boundary	Maximum thermal radiation flux kW/m^2
Isolated area: area only occasionally occupied by a reduced number of persons, e.g. farmland	13
Intermediate area: area which is neither isolated nor critical. This is the general case	5
Critical area: place difficult or dangerous to evacuate quickly (e.g. sports stadium, play ground, ...) or area where public circulation cannot be prohibited during emergencies.	1.5

5.3.2 Heat radiation from flare or lightning of vent

Inside the plant boundaries, the designer shall make sure that the radiation flux excluding solar radiation cannot exceed 1,5 kW/m^2 at buildings, vessels and other equipment for normal conditions and 5 kW/m^2 for accidental conditions.

Outside the plant boundaries and for accidental conditions, the thermal radiation flux shall not exceed 5 kW/m^2 in isolated areas, 3 kW/m^2 in intermediate areas or 1,5 kW/m^2 in critical areas. For normal condition, it shall be less than 3 kW/m^2 in isolated areas and less than 1,5 kW/m^2 in intermediate or critical areas.

5.3.3 Ignition limit of natural gas

The flammable mixture range of natural gas in air is the value given in EN 1160:1996.

5.4 Identification of risks

5.4.1 Identification of risks of external origin

Risks arising from outside the plant can be listed on the basis of the aforementioned data. They may be caused by:

— LNG supply vehicles;

— heat radiation (fire);

— clouds of flammable, toxic or asphyxiating gas;

— impact of projectile;

— natural events (lightning, flooding, earthquakes ...).

5.4.2 Identification of risks of internal origin

Possible losses of containment of both liquid and gaseous natural gas shall be listed for all facilities including systems for loading or unloading vehicles. Leakage or spillage of natural gas may be defined by location, duration and flow rate.

The following causes of hazards which are not specific to LNG shall also be considered:

- LPG and heavier hydrocarbon storage;
- traffic within the plant;
- leakage of other hazardous substances, in particular flammable refrigerant;
- pressurised equipment (boilers...);
- rotating machinery;
- utilities, catalysts and chemicals (fuel oil, lubricating oils, methanol ...);
- electrical equipment.

5.5 Estimation of the consequences of a gas or LNG release

5.5.1 General

The consequences depend on the physical properties of LNG and other phenomena described in clause 5 of EN 1160:1996. The informative annex B gives examples of consequences estimated for normal and accidental conditions.

5.5.2 Evaporation of LNG

The phenomena of instantaneous vaporisation (flash) due to depressurisation and heat transfer with the ground or water for instance, shall be determined. Calculation may be carried out using appropriate validated models taking account of composition and flow rate of LNG, nature and temperature of ground and atmospheric conditions. The model may enable the determination of the time-dependent wetted area and the rate of evaporation.

5.5.3 Atmospheric dispersion of LNG vapour

Calculation of the atmospheric dispersion of the cloud resulting from evaporation of LNG may be carried out using appropriate validated models. The model output are concentration contours and distance to the lower flammability limit.

5.5.4 Jet release of liquid natural gas or gaseous natural gas

Calculation of atmospheric dispersion resulting from jet release shall be carried out using appropriate validated models to determine at least the height or the distance reached by the jet and the concentration of gas at a given point.

5.5.5 Over pressure wave

The ignition of gas may create a deflagration generating an over pressure wave. Validated models shall be used to calculate the over pressure field.

This result shall then be used to appraise stresses on structures.

5.5.6 Radiation

Calculation of the radiation caused by ignition of the vapour from a pool or jet of LNG or release of gaseous natural gas may be carried out using appropriate validated models. A vehicle fire may also be considered.

The model enables the determination of the incident radiation at various distances and elevations.

6 General safety measures

6.1 Leaks and spillage protection

6.1.1 Detection system

Correct design, fabrication, construction and operation will minimize the quantity and frequency of leaks of flammable fluids. However, where leaks can occur and can escalate to a more serious incident, consideration shall be given to the installation of fixed leak detection systems with executive action to stop the leak source, to isolate relevant sections of plant and to shutdown sources of ignition in the vicinity.

6.1.2 Piping and equipment

Contraction/expansion phenomena due to temperature variations can induce material fatigue and create significant stresses in pipework and equipment leading to ruptures. To avoid this risk or to reduce the consequences, the following arrangements should be taken:

— the number of flanges in pipe runs should be minimized. When it is possible, valves should be welded in line;

— the orientation of relief valve outlets shall be such as to minimize hazards. When a jet stream occurs, it shall not reach nearby equipment or people;

— piping design shall take account of all operating conditions;

— systems shall be designed to avoid excessive operation of relief valves;

— pumps with high integrity seals or submerged motors shall be used for LNG;

— above ground vessels shall be located in the open;

— equipment containing flammable fluid should be located in the open, but this recommendation can be affected by maintenance requirements or climatic conditions. In some circumstances, equipment may be installed in confined areas, for instance, to ensure an early detection of small gas releases or to contain high pressure jets. If installed in a confined area, this area should be ventilated. The air renewal rate shall be determined by an appropriate study;

— routing of pipework through concrete walls shall allow free expansion of the pipework.

Non-visible parts of pipework endangered to corrosion shall be subject to special protection.

When under pressure, leaking valves or connections shall only be tightened using suitable tools and procedures.

6.1.3 Impounding areas

If leaks of flammable liquids are considered to be a possible scenario, then the leaks should be confined by dykes. Flammable liquid flowing from a leak may be directed in open channels towards an impounding basin.

The design of an impounding basin shall be such that flammable fluids do not enter the surface water drainage system.

Consideration shall be given to the installation of leak detection devices and means to control the evaporation rate in the impounding basin. The basin may be partitioned to reduce vaporization of LNG and therefore gas emission into the atmosphere.

When pipework is routed through the wall of an impounding basin, a suitable seal shall be provided.

6.1.4 Protection against low temperature

In the event of a leak, low temperature fluid can come into contact with metallic components which can fail due to embrittlement. Measures can be taken to prevent serious damage by suitable selection of materials of construction or by embrittlement protection such as insulation.

6.1.5 Isolation valves

Isolation valves shall be fitted as close as possible to the nozzles of process liquid outlets of pressure vessels containing flammable liquids such as hydrocarbon refrigerants and LNG. These isolation valves shall be remotely closed either by automatic emergency shutdown or by manual action.

6.2 Overpressure protection

Safety devices shall be designed to prevent overpressure inclusive of fire engulfment. The gas discharged from relief valves of vessels and vaporizers should be safely discharged directly to the atmosphere or in cases where discharge directly to atmosphere is considered unsafe a vent stack or a flare shall be employed.

For other equipment, discharged gas shall be transferred to the flare/vent system or to the storage vessel. If the safety and environment assessment shows that the consequences of the discharge directly to the atmosphere are acceptable, then connection to the flare/vent system is not compulsory.

Automatic or semi-automatic emergency depressurization systems are recommended if fire insulation or a water deluge system is not installed. Isolation valves, activated from the control room or other remote location, shall be provided to isolate sensitive equipment.

6.3 Fire protection

The fire protection system shall include powder extinguishers in all cases. It shall be designed taking into account the reaction time and the fire fighting equipment of the local fire service.

Alert systems such as break-glass units, telephones, paging systems, closed circuit television and sirens may be used.

Measures to prevent the freezing of fire water circuits shall be provided.

If LNG storage exceeds 50 t, the fire protection system shall include foam generators for the impounding basin of the vessel, if any, or a validated system composed of material floating on the LNG surface (such as foamglass) which reduces its evaporation in order to keep the radiation fluxes of the LNG fire under the maximum values given in 5.3.

6.4 Confinement

Apart from intended situations (see 6.1.2, piping and equipment), confined or partially confined zones shall be avoided as far as possible, in particular:

— gas and LNG pipework should not be situated in closed ducts;

— if there is a space under an aboveground vessel, it shall be large enough to allow air circulation;

— ducts for cables, cable trays, etc. shall be filled with compacted sand and covered with flat slabs with ventilation holes.

6.5 Emergency shutdown

An emergency shutdown system independent from the process control system shall be provided.

When personnel are not permanently present on the site, an automatic system is required.

A shutdown system shall be provided to prevent embrittlement of the piping material due to low temperature downstream of the vaporizers.

6.6 Commissioning and decommissioning

Before the start of operation the commissioning tests shall be performed by an approved test engineer or expert.

All pressure loaded equipment shall be pressured and leak tested in accordance with the local regulation and the manufacturer's requirements.

The procedures for commissioning and decommissioning operations shall be defined at the design stage. Drain circuits shall enable inerting and complete drying of main components and insulation spaces also.

All pipework circuits shall be inerted at the initial stage.

6.7 Inspection

Testing shall follow the relevant standards and codes.

The installation should allow external inspection of above ground vessels on all sides. The suitable space for maintenance and cleaning should be at least 1,5 m around the vessels.

The inspection intervals shall not exceed 3 years for auxiliary equipment of vessels containing LNG.

The periodic inspection of equipment covers at least:

— safety devices against overpressure;

— safety shut-off devices;

— safety fittings;

— gauges;

— controlling devices.

6.8 Personnel

Personnel operating the installation shall have required competency. In particular they shall be familiar with the handling of liquefied and gaseous natural gas.

The required competency is defined in the safety plan.

Training shall be conducted upon employment and periodically thereafter.

Non-operating personnel shall have an appropriate training induction.

7 Design of vessels

7.1 General

Cryogenic vessels for LNG shall be designed in accordance with relevant standards or codes.

Annex C provides some examples of the design concepts of storage pressure vessels. Other concepts such as atmospheric vessels are not illustrated in this annex because they are not used generally for small LNG capacity storage for economical reasons. However, they are not excluded from this standard.

7.2 Insulation

Materials used for thermal insulation defined in EN 1160:1996 shall be used.

The outer envelope of the vessel which is exposed to the atmosphere (metallic or concrete) shall be designed to prevent penetration of surface water or atmospheric humidity. Humidity could introduce some corrosion problems, deterioration of the insulation and of the concrete.

7.3 Foundations

Foundations shall be designed in accordance with recognized civil engineering practice including provisions for seismic loading if recommended. Foundation design shall take into account LNG spillage, fire and the associated possible duration of the spillage and fire.

Freezing due to LNG of the soil supporting the vessel shall be avoided in normal conditions. For underground vessels, soil temperature measuring devices and underground heaters may be recommended.

7.4 Instrumentation

Sufficient instrumentation is required to enable the vessel to be commissioned, operated and decommissioned in a safe manner. Instrumentation shall include at least the following measurements:

— liquid level. The vessel shall be equipped with two independent systems, one with a continuous indication;

— pressure. A pressure gauge connected above the maximum liquid level shall give a continuous indication.

The insulating space of the vessel may be equipped with temperature gauges, for instance in the case of double wall flat bottom vessels.

The following arrangements shall be ensured:

— in general, maintenance of instruments shall be possible during normal operation of the vessel;

— the designer shall avoid the need to decommission the vessel for maintenance of instruments. However when decommissioning is required, instruments shall have sufficient redundancy;

— threshold detectors which have a safety function (pressure, LNG level, ...) shall be independent of the measurement devices;

— measurements shall be transmitted to the control unit;

— alarms shall be transmitted directly to the operator who can be on the site or at a remote place.

7.5 Overpressure protection

The vapour space of the vessel shall be connected to a flare or a vent system, to safety valves and possibly rupture disc for ultimate situation, to evacuate gas discharge due to the following events:

— evaporation due to heat input;

— displacement due to filling;

— flash at filling;

— variations in atmospheric pressure;

— pump spill back from a submerged pump.

The vessel shall be equipped with at least one relief valve and a rupture disc or two relief valves. They can relieve directly to the atmosphere except when a vapour emission in an emergency case leads to an unwanted situation. In this case, the valves shall be linked to the flare or vent system. The two relief devices shall be designed taking into account a failure of one of these devices.

If a rupture disc or equivalent is installed, it shall be designed in such a way that:

— it can be replaced in operation;

— fragments can not fall into the vessel;

— fragments can not damage any other part of the vessel.

Boil-off gas compressors shall stop automatically when the rupture occurs.

7.6 Impounding basin

Normally a vessel and its equipment are designed to avoid the complete loss of liquid in accidental situations. For instance stop valves can be welded on liquid pipes connected to a pressurized vessel as close as possible to the vessel. So the capacity of the impounding basin of a vessel, if deemed necessary, may be restricted to a small part of the vessel capacity. Otherwise, when the total loss of liquid cannot be excluded, the basin capacity shall be at least equal to the related vessel capacity if not specified in the local regulation.

The basins of two vessels may be adjacent. An excavation in the ground could act as an impounding basin provided that its properties are suitable.

The bottom can be covered with an insulation layer or built with special materials to minimize evaporation. It shall not be covered with gravel or vegetation (refer to EN 12066). Any means for limiting evaporation and reducing the radiation rate of ignited spills may be considered.

Rain or fire water which could accumulate in the basin shall be removed by relevant means without transferring spilled LNG.

The top level of surrounding dykes shall not be so high as to prevent fire brigade intervention and excessive vapour confinement.

7.7 LNG transfer

LNG can be transferred out of the vessel by a pump or by increasing the pressure in the gaseous space to transfer the liquid. The increase in pressure can be obtained by vaporizing LNG through an atmospheric vaporizer.

7.8 Overflow

Overflow during the filling of a vessel shall be avoided by an automatic system. Otherwise, if it is authorized by local authorities, a vessel overflow system shall be installed and sized for the maximum flow rate of the filling pumps without causing any damage to the vessel structure.

If an overflow pipe is installed, it shall cross the vessel shell at a level at least equal to the highest level alarm. An alarm shall detect the presence of liquid in the pipe.

7.9 Distance between vessels

The minimum distance between vessels shall be determined in accordance with the safety plan if any (see clause 5).

8 Installation design

8.1 Hazardous areas and restricted access area

If not given in the local regulation, a classification of hazardous areas shall be performed in accordance with EN 60079-10 and the equipment in these zones shall be selected in accordance with EN 1127-1.

The fencing of areas or plant, if necessary, shall be permeable to avoid gas confinement.

Warning signs shall be installed to inform people of risks or provide instructions.

8.2 Unloading and loading areas

When a loading/unloading process is complete, hoses shall be drained and depressurized prior to disconnection.

The unloading or loading area when a temporary hose is connected shall be considered in the classification of hazardous areas.

An operational instruction shall define the required safety procedures for the unloading or loading area.

8.3 Circulation and parking

The plant layout shall be designed to avoid vehicle congestion. It shall provide safe access for operation, maintenance and for fire fighting.

The circulation and parking of vehicles within the site shall be defined in accordance with the safety plan. The design and operating procedures shall be designed to reduce or cancel the risk of a vehicle impact with a loading or unloading vehicle.

Measures and protection shall be taken to avoid vehicle impacts of storage vessels.

The lighting of the systems for loading and unloading shall be sufficient to ensure the safety of these operations.

8.4 Location of facilities

Separation distances shall take into account as a minimum:

— radiation flux levels;

— lower flammability limit contours;

— noise;

— blast effects.

A place for safety control shall be located outside the hazardous area. The occupants shall be protected to allow sufficient time to operate emergency procedures and to leave.

The air intake of possible diesel-driven fire water-pumps and electric generators shall be located outside the flammable cloud envelope.

8.5 Lightning and earthing

Facilities shall be protected against lightning.

For potential equilibrium, all metal structures, including vessel product delivery/collection vehicles, shall be electrically bonded to a common earth.

Major items of equipment such as vessels and vent stacks shall be bonded directly to the earth point and not rely upon the piping conductivity.

Annex A
(informative)

Schematic description of a process for a satellite and fuelling plant

Figure A.1 shows a schematic diagram of the process of a satellite and fuelling plant.

In this example, the plant is supplied by LNG trucks. After storage, LNG is used to supply the gas grid or vehicles. The different annotated circuits have the following purposes:

1) LNG is pumped from the offloading tanker to the storage vessel;

2) in order to balance the volume of the pumped liquid removed from the vehicle tank, a small amount of LNG is vaporized through an atmospheric vaporizer and the resulting gas flows into the vehicle tank. The gas flow rate in this circuit is controlled by the vehicle tank pressure;

3) during periods when the storage vessel is not being filled and its pressure is high enough, gas may be sent to the gas grid. This gas is warmed up through an atmospheric heat exchanger before being delivered to the gas grid;

4) liquid is vaporized through a heat exchanger and delivered to the gas grid;

5) liquid is pumped at high pressure, vaporized through a heat exchanger and fed to high pressure tanks of vehicles;

6) LNG is supplied to tanks of vehicles in a subcooled liquid state. Liquid nitrogen can be used to subcool the LNG;

7) liquid nitrogen may be used to cool the gas phase of the storage vessel;

8) liquid nitrogen may be used to subcool LNG for vehicle tanks and for precooling the transfer system;

9) LNG is vaporized through a heat exchanger to pressurize the LNG storage vessel.

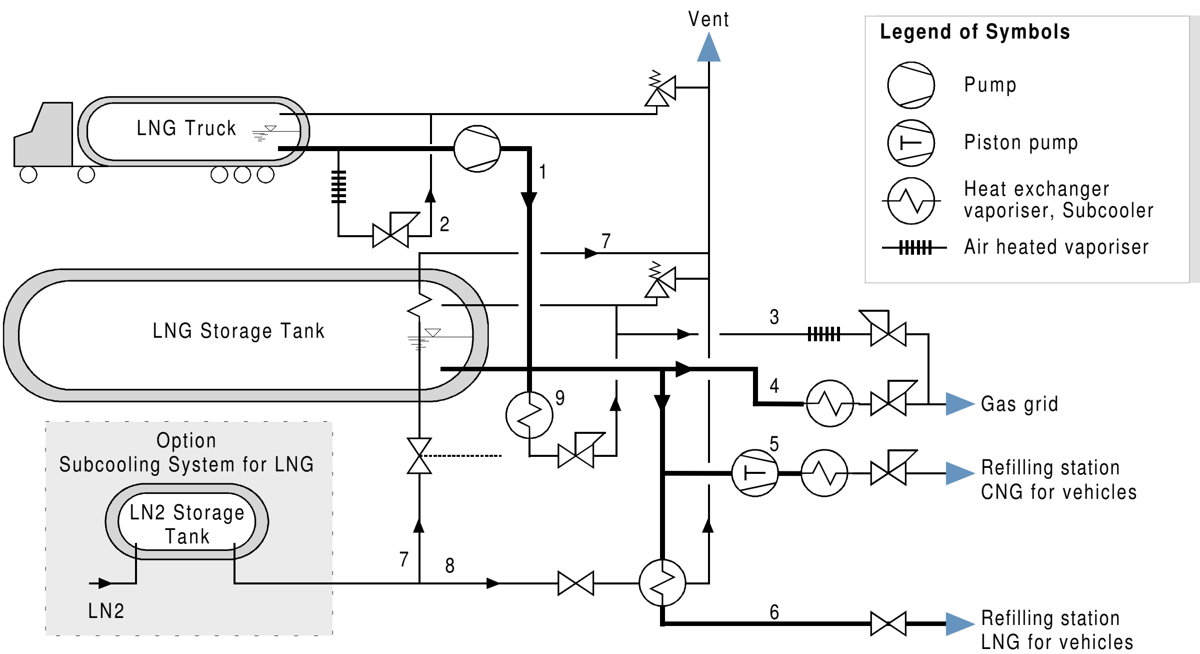

Figure A.1 — Example of a LNG satellite and fuelling plant

Annex B
(informative)

Examples of safety scenarios and calculations

B.1 Introduction

This annex gives examples of safety calculations applied to typical installations with a storage capacity between 50 t and 200 t. The calculations include the description of pool spreading, dispersion and radiation phenomena, and give safety distances in terms of release scenarios. These distances shall not be considered as general references for the sizing and installation of equipment.

B.2 Calculation methods and models

B.2.1 Mass flowrate and flash

For two-phase releases, the fluid at exit of a hole will be shared between flashed vapour (natural gas), liquid droplets that are entrained in the jet (aerosols), and the liquid that deposits on the ground (rainout). Aerosols only include airborne droplets that will not deposit on the ground, and will therefore transform into vapour within the cloud. Rainout includes the liquid that deposits just after the hole section and further away as droplets fall down.

The mass flowrate through a hole section is calculated using simple methods based on fluid mechanics. The flash is calculated by thermodynamic software. The occurrence of rainout is estimated from a simple method based on a criterion for droplets to fall down. The following criterion is considered (Figure B.1):

— if rainout does not occur, all the liquid released is entrained in the two-phase release as an aerosol. The vapour and aerosol proportions are given by the flash calculation;

— if rainout does occur, the proportion of aerosol and rainout is unknown. The rule of «twice the flash" is used to calculate the quantity of aerosol: the mass flowrate of aerosol is equal to the mass flowrate of flashed vapour.

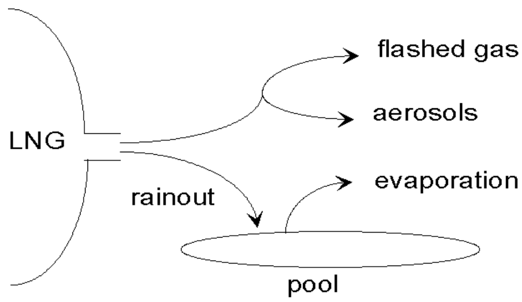

Figure B.1 — Description of phenomena

B.2.2 Pool spreading and vaporisation

The pool spreading of the rainout and the vaporisation of LNG on the ground are calculated using a box type model. The model enables the determination of the time evolution of the wetted area and the rate of evaporation. It has been validated with small scale LNG vaporization experiments on different surfaces, and LNG spreading experiments on concrete.

B.2.3 Dispersion

The dispersion of a pressurized jet of natural gas is calculated by an integral type model in this example. This model has been validated with 18 natural gas releases, either horizontal or vertical from vents, the latter leading to a plume.

The main output is the downwind distance to the LFL (lower flammable limit).

B.2.4 Radiation

The model shall take into account:

— the flame dimension;

— the surface emissive power of the flame;

— the ambient temperature and relative humidity;

— the wind speed and atmospheric stability.

It enables the determination of the incident radiation at various distances and elevations.

The radiation from a pressurized jet of natural gas is calculated by a simple model, based on semi-empirical correlations for natural gas. The model has been validated with 39 real scale tests including ignited vent releases, pipe ruptures or perforations.

The radiation from an LNG pool fire is calculated by an integral type model, which has been validated with both small and large-scale tests.

B.3 Characteristics of the scenarios

B.3.1 General data

B.3.1.1 Installation

Storage vessel	Liquid density Mass of LNG Internal pressure	450 kg/m^3 50 t 3 barg
Impounding basin	Surface material Area	concrete partitioned 50 m^2, 20 m^2,10 m^2 or 5 m^2
LNG pipework	Maximum diameter	40 mm
Vent	Diameter Height	80 mm 5 m

B.3.1.2 Weather conditions

	Weather 1	Weather 2
Ambient temperature (air, ground)	15 °C	15 °C
Humidity	50 %	70 %
Wind speed	2 m/s	5 m/s
Stability class (Pasquill)	F	C

The weather 1 refers to advocated conditions for dispersion calculations in EN 1473:1997. These conditions should be applied if no other information is available.

B.3.2 Accident scenarios and releases

Table B.1 gives some examples of scenarios, with either suggested protective measures or calculation of consequences.

Table B.1

N°	Description	Example of measures or consequences	Calculation in the annex
1	Rupture of the unloading flexible hose from the LNG tanker	Possible equipment: an automatic valve which shuts if the vehicle moves, a manual valve, a check valve and an optional excess flow valve device.	-
2	Failure of the LNG vessel	the vessel insulation, the isolation and relief valves protect the vessel against failure due to corrosion or an external fire.	-
3	Rupture of a pipe: liquid release upstream of the stop valve	protection around the liquid lines to avoid any impact welded stop valves as close as possible to the storage vessel.	-
4	Rupture of the maximum diameter pipe: liquid release	Radiation of a resulting pool fire is estimated in this annex.	Spreading (B.5) Radiation (B.6.2)
5	Opening of valves and vent release	Normal conditions: the release of the boil-off gas from the evaporation rate of the vessel. The radiation fluxes of the vent accidentally ignited are estimated in this annex. Accidental conditions: the release of excessive boil-off gas from the vessel due to damaged insulation added to the maximum flowrate of the pressurizing system. The dispersion of the gas cloud and the radiation of the vent accidentally ignited are estimated in this annex.	Radiation (B.4) Dispersion (B.6.3) Radiation (B.4)

B.4 Heat radiation from an ignited vent (scenario 5)

The flowrate calculation at the vent has been performed both for normal and accidental conditions defined as follow (scenario 5):

- normal conditions with release of the boil-off gas that corresponds to the evaporation rate of the tank;
- accidental conditions with release resulting from a damaged insulation (loss of vacuum) combined with the maximum flowrate of the pressurization system.

The flowrate calculated previously is the input of a radiation code. The wind speed is 5 m/s.

Figure B.2 gives the radiation flux versus distance on a downwind line at a given height from a vent accidentally ignited, for two different values:

- 2 m (maximum height for a person);
- 5 m (vent height).

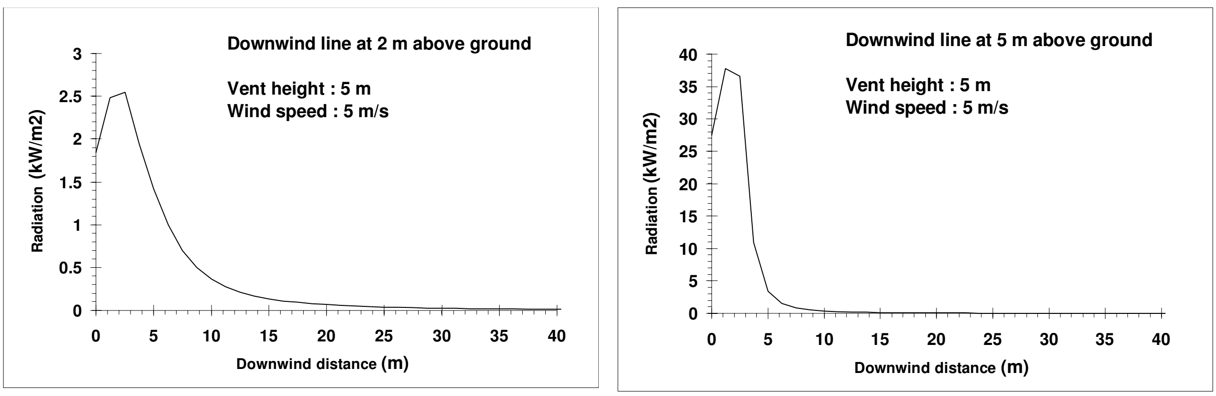

Figure B.2 — Radiation fluxes vs. distance on a downwind line from a vent accidentally ignited

For accidental conditions (refer to Figure B.2), the thermal radiation flux outside the plant boundary will not exceed 3 kW/m^2, if the boundary is at least 5 m away from the vent, and 1,5 kW/m^2 at 6,5 m. The thermal radiation flux inside the plant boundary will not exceed 5 kW/m^2 at the buildings, vessels and other equipment, provided they are at least 5 m away from the vent.

For normal conditions, the radiation flux from the ignited vent will not exceed 1,5 kW/m^2 anywhere inside the plant boundary (the maximum calculated radiation flux is 10 % of this value).

B.5 LNG pool spreading within an impounding basin and evaporation (scenario 4)

A liquid release of short duration due to the rupture of the maximum diameter pipe leads to the formation of a pool.

The scenario 4 is the rupture of a 40 mm pipe connected to a storage vessel (Figure B.3). The mass flowrate is 12,4 kg/s (refer to B.2.1), the flash or mass vapour fraction is 13 % (thermodynamic software, refer to B.2.1). The quantity of aerosol entrained in the release is assumed to be equal to that of flashed gas: both aerosol and flashed gas result in a gas flowrate of 3,2 kg/s. The flowrate of the liquid that deposits on the ground (rainout) is 9,2 kg/s. Assuming that the detection and emergency shutdown systems will not make the release last more than 30 s leads to a spillage of a maximum of 276 kg of LNG, that is approximately 610 l.

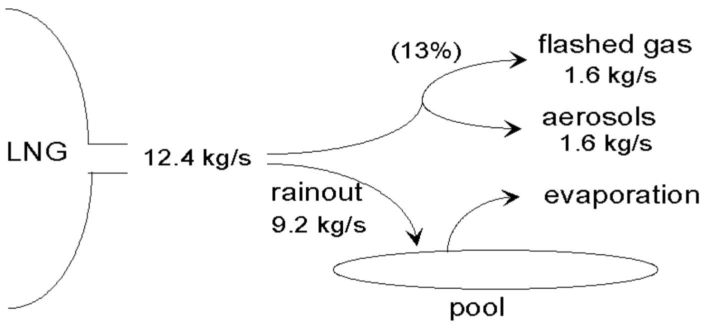

Figure B.3 — Distribution of LNG release

A liquid release on the ground can be divided into two distinct stages: the first stage corresponding to the spreading of the pool, and the second stage corresponding to the pool thickness increasing once the pool has reached the dyke of an impounding basin, or decreasing if the release stops before the pool has reached the dyke. The spreading of the pool depends on the release flowrate and the ground surface. The evaporation rate varies, it increases in the first stage and decreases in the second stage (Figure B.4). It is dependant on the type of surface, area of wetted surface (Figure B.4) and the duration of the release.

Table B.2 shows for four different concrete impounding areas, the maximum wetted area, the time of the maximum evaporation rate and the corresponding maximum flowrate. The maximum extension of the pool is 43 m^2 after a 30 seconds release.

Table B.2

Impounding area m^2	Maximum wetted area m^2	Time of maximum evaporation rate s	Maximum evaporation rate kg/s
50	43	30	3,5
20	20	12,6	2,5
10	10	6,2	1,7
5	5	3,3	1,1

Figure B.4 shows the relationship of evaporation rate and wetted surface area versus time for the impounding area of 5 m^2.

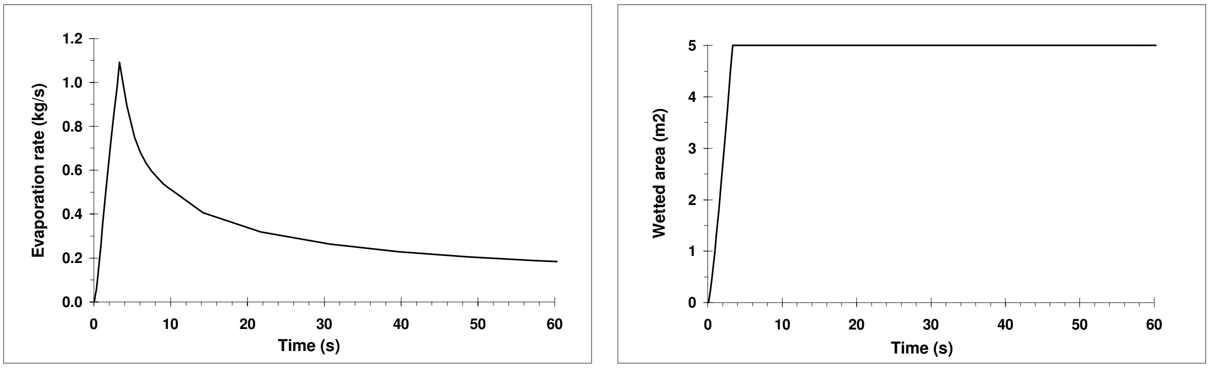

Figure B.4 — Time evolution of the evaporation rate and of the wetted area (Scenario 4 - 5 m^2 concrete impounding basin)

The impounding area is generally the basin area, but can be a part of it if the basin is divided into compartments. A smaller impounding area (partitioned basin) is a practical way to reduce the maximum wetted area, and therefore the evaporation rate, leading to a reduction of the LFL distances.

Radiation from the fire of an LNG pool is estimated as given in B.6. A 5 m^2 LNG pool in a partitioned basin is assumed.

B.6 Gas dispersion and radiation

B.6.1 Selected scenarios

The following scenarios include a natural gas jet release at the vent and a liquid release from a pipe. Radiation calculations give the downwind distances to given radiation levels. Dispersion calculations give consequences in terms of distances to the LFL (lower flammable limit), that is the maximum distance reached by the flammable cloud.

B.6.2 Radiation

Scenario 4: rupture of a 40 mm diameter LNG pipe.

The LNG pours into a 5 m^2 impounding area, with a flowrate of 9,2 kg/s. Table B.3 shows the downwind distances from the centre of the ignited LNG pool, to the radiation levels as defined in 5.3, excluding solar radiation.

Table B.3

Radiation flux	32 kW/m^2	15 kW/m^2	13 kW/m^2	8 kW/m^2	5 kW/m^2	1,5 kW/m^2
Distance	< 5 m	6 m	7 m	9 m	11 m	18 m

The radiation levels are almost the same with the two different weather scenarios. According to 5.3, the safe distance from the centre of the pool is 11 m inside the plant boundaries; outside the plant boundaries the safe distance is 11 m for intermediate areas and 18 m for critical areas.

B.6.3 Dispersion

Scenario 5: natural gas discharge from the vent for accidental conditions on the storage vessel.

Accidental conditions include:

— the evaporation rate resulting from a damaged insulation (loss of vacuum);

— the maximum flowrate of the tank pressure raising system.

The release of natural gas at the vent leads to a flammable cloud, with an horizontal extension less than 4 m (Figure B.5).

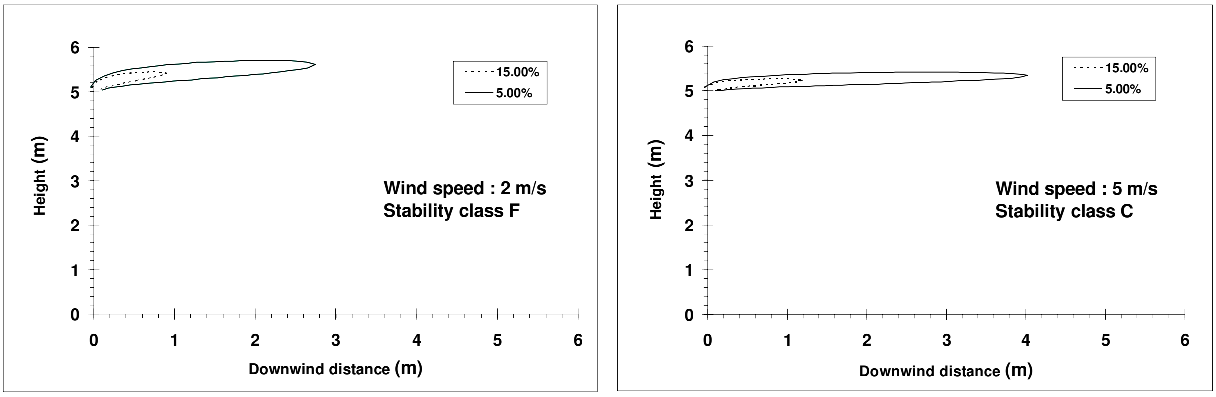

Figure B.5 — Concentration contours of the flammable plume of a natural gas release from a vent (Scenario 5, weather 1 and 2)

Annex C
(informative)

Examples of LNG storage vessels - Design concepts

The following figure presents some examples of steel pressure vessels. Other types of design such as atmospheric tanks are not illustratred in this annex because they are not generally used for small LNG capacity storage for economical reasons. However they are not excluded from this standard.

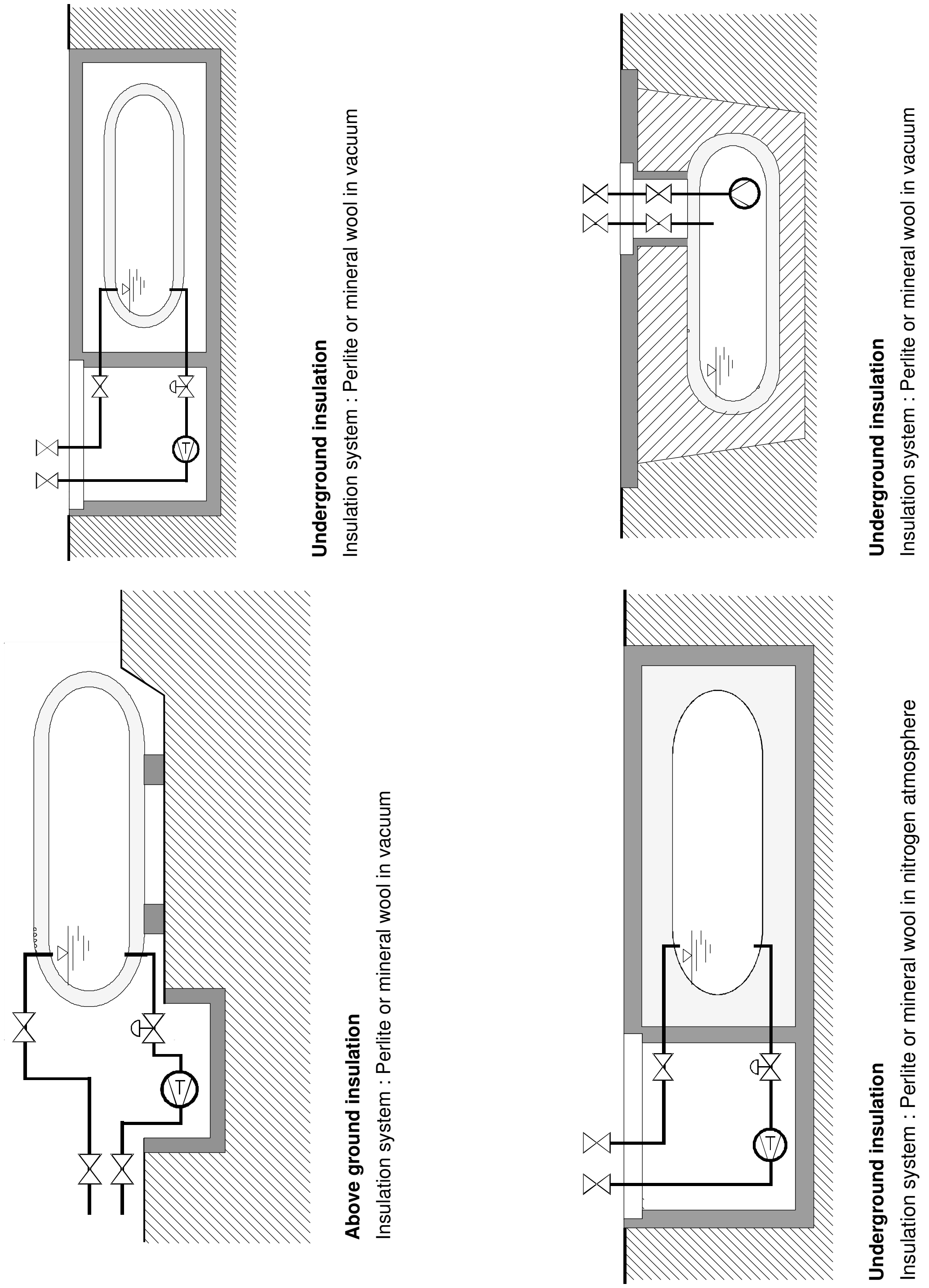

Figure C.1

Listed below are some typical design characteristics of steel storage vessels:

Table C.1

Installation	**Position**	**Volume** m^3	**Insulation concept**	**Boil-off-rate** %/day
Above ground	vertical	3-50	vacuum-perlite	0,2 – 0,5
Above ground	horizontal	20-250	vacuum-perlite	0,1 – 0,2
Under ground	horizontal	20-250	vacuum-perlite	0,1 – 0,2
Under ground	horizontal	100-500	perlite-nitrogen	0,3 – 0,6

If the daily throughput of LNG is large enough a perlite-nitrogen insulation can be sufficient.

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