

BS EN 1473:2016



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Installation and equipment for liquefied natural gas — Design of onshore installations

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee GSE/38, Installation and equipment for LNG.

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

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ISBN 978 0 580 85804 8

ICS 75.200

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2016.

Amendments issued since publication

Date	Text affected
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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1473

May 2016

ICS 75.200

Supersedes EN 1473:2007

English Version

**Installation and equipment for liquefied natural gas -
Design of onshore installations**

Installations et équipements de gaz naturel liquéfié -
Conception des installations terrestres

Anlagen und Ausrüstung für Flüssigerdgas - Auslegung
von landseitigen Anlagen

This European Standard was approved by CEN on 4 March 2016.

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Ref. No. EN 1473:2016 E

Contents

Page

European foreword.....	7
Introduction	8
1 Scope	9
2 Normative references	9
3 Terms and definitions	13
4 Safety and environment.....	18
4.1 General.....	18
4.2 Environmental impact.....	19
4.3 Safety general	20
4.4 Hazard assessment.....	24
4.5 Safety engineering during design and construction.....	30
4.6 Safety during operation	33
5 Jetties and marine facilities.....	34
5.1 General.....	34
5.2 Siting	34
5.3 Engineering design	34
5.4 Safety	35
6 Storage and retention systems.....	35
6.1 General.....	35
6.2 Types of tank.....	35
6.3 Types of containment	36
6.4 Design principles.....	37
6.5 General design rules	39
6.6 Foundations	40
6.7 Operating instruments.....	40
6.8 Pressure and vacuum protection	42
6.9 Bund walls and impounding area for single and double containment.....	43
6.10 Safety equipment.....	45
6.11 Tank piping	46
6.12 Distance between tanks.....	46
6.13 Commissioning and decommissioning.....	47
6.14 Testing.....	47
7 LNG pumps.....	47
7.1 General.....	47
7.2 Materials.....	48
7.3 Specific requirements.....	48
7.4 Inspection and testing	48
8 Vaporization of LNG	48
8.1 General requirements	48
8.2 Design conditions.....	50
8.3 Vaporiser requirements	50
9 Pipe-work.....	50
9.1 General.....	50
9.2 Piping systems.....	50

9.3	Rules for design.....	52
9.4	Pressure tests.....	53
9.5	Piping components.....	53
9.6	Valves.....	56
9.7	Relief valves.....	56
9.8	Thermal insulation.....	57
9.9	Pipe rack/pipe way.....	61
9.10	Corrosion.....	61
10	Reception/send out of natural gas.....	61
10.1	Metering.....	61
10.2	Gas quality.....	62
10.3	Odourizing.....	62
11	Boil off recovery and treatment plants.....	62
11.1	General.....	62
11.2	Boil off collection system.....	63
11.3	System of gas return to tanker(s) or to export terminal.....	63
11.4	Boil off gas recovery.....	64
11.5	Gas compressor.....	64
11.6	Flare/vent.....	64
12	Auxiliary circuits and buildings.....	66
12.1	Electrical equipment.....	66
12.2	Lightning and earthing.....	67
12.3	Cathodic protection.....	68
12.4	Warning lights.....	68
12.5	Sea water supply.....	68
12.6	Gas contaminant removal plant.....	68
12.7	Instrument air.....	68
12.8	Fuel (utility) gas.....	69
12.9	Nitrogen system.....	69
12.10	Buildings.....	70
13	Hazard management.....	70
13.1	Inherent safety.....	70
13.2	Passive protection.....	72
13.3	Security.....	73
13.4	Incident detection and signalling.....	74
13.5	Emergency Shutdown System.....	75
13.6	Active protection.....	76
13.7	Other requirements.....	80
14	Control and monitoring systems.....	81
14.1	General description.....	81
14.2	Process control system.....	81
14.3	Safety control system.....	82
14.4	Access control system.....	84
14.5	Anti-intrusion system.....	84
14.6	CCTV.....	84
14.7	Jetty and marine monitoring and control.....	84
14.8	Communications.....	85
14.9	Environmental monitoring and control.....	85
15	Construction, commissioning and turnaround.....	85
15.1	Quality assurance and quality control.....	85

15.2	Acceptance tests	85
15.3	Preparation at start-up and shutdown.....	85
16	Preservation and corrosion protection	86
16.1	Painting.....	86
16.2	Cathodic protection	87
17	Training for operations	87
18	Pre-operational marine training.....	87
Annex A (normative) Thermal radiation threshold values.....		88
A.1	Heat radiation from LNG fires.....	88
A.2	Heat radiation from flare or ignited vent stack	89
Annex B (normative) Definitions of reference flow rates.....		91
B.1	General.....	91
B.2	V_T (heat input)	91
B.3	V_L (fluid input).....	91
B.4	V_O (over filling).....	91
B.5	V_F (flash at filling).....	91
B.6	V_R (LNG recirculation by a submersible pump).....	92
B.7	V_A (variation in atmospheric pressure)	92
B.8	V_V (control valve failure)	93
B.9	V_I (heat input in the course of a fire).....	93
B.10	V_D (fluid suction)	93
B.11	V_C (compressors suction)	93
B.12	V_B (roll-over).....	94
Annex C (informative) Seismic classification		95
C.1	Introduction	95
C.2	Some basic principles	95
C.3	Example of safety approach after SSE.....	95
C.4	Example of classification for SSE	96
Annex D (normative) Specific requirements for LNG pumps.....		97
D.1	Introduction	97
D.2	Design	97
D.3	Inspection	97
D.4	Testing.....	98
D.5	Declared values.....	100
D.6	Marking.....	100
D.7	Particular requirements for submerged pumps and related cables.....	101
D.8	Vertical external motor pumps.....	102

Annex E (normative) Specific requirements for LNG vaporizers	103
E.1 Operating parameters/declared performance.....	103
E.2 Water stream vaporizers: Open rack type (ORV)	103
E.3 Water stream vaporizers : Closed type (STV).....	105
E.4 Intermediate fluid vaporizers (IFV).....	106
E.5 Submerged combustion type vaporizers (SCV)	106
E.6 Ambient air vaporizers (AAV).....	108
Annex F (normative) Criteria for the design of pipes	109
Annex G (informative) Description of the different types of onshore LNG installations.....	111
G.1 LNG liquefaction plant	111
G.2 LNG receiving terminals.....	111
G.3 LNG peak shaving plants	112
G.4 LNG satellite plants	112
G.5 LNG bunkering stations	112
Annex H (informative) Definition of different types of LNG tanks.....	113
H.1 General	113
H.2 Spherical storage tank	113
H.3 Cryogenic concrete tank.....	113
Annex I (informative) Frequency ranges	116
Annex J (informative) Classes of consequence.....	117
Annex K (informative) Levels of risk	118
K.1 General	118
K.2 Acceptability criteria.....	118
Annex L (informative) Typical process steps of liquefaction	120
L.1 Introduction.....	120
L.2 Treatment of natural gas/extraction of acid gases	120
L.3 Natural gas treatment/dehydration	122
L.4 Treatment of natural gas/removal of mercury	123
L.5 Natural gas liquefaction unit	124
Annex M (informative) Odourant systems	129
M.1 Odourants in general.....	129
M.2 Odourant systems requirements.....	129
M.3 Odourant handling.....	130
M.4 Odourant injection	130
M.5 Odourant leakage	131
M.6 Safety of personnel.....	131

Bibliography	132
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European foreword

This document (EN 1473:2016) 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 November 2016, and conflicting national standards shall be withdrawn at the latest by November 2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1473:2007.

In comparison with EN 1473:2007, the following changes have been made:

- the scope definition has been modified to cover interfaces and limits with floating solutions, plants refurbishing, renovation and expansion, and to better complement EN 14620;
- some requirements were revisited, such as tank containment types, new air vaporizer and sections that were subject to questions from the 2007 version;
- terms and definitions were adjusted to cope with new market development;
- the normative references were updated.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

The objective of this European Standard is to give functional guidelines for on-shore LNG installations. It recommends procedures and practices that will result in safe and environmentally acceptable design, construction and operation of LNG plants.

It need not be applied retrospectively, but application is recommended when major modifications of existing installations are being considered.

This standard is also recommended for debottlenecking, revamping and plant life extension in the limits that will be defined by the local Authorities. The appliance of the European Directives to the existing facilities is part of the limits to be defined together with the local Authorities.

In case of plant expansion, this European Standard is applicable for the new facilities. The application of these recommendations for the tie-ins and connections to the existing facilities will be defined by the local Authorities. The limits of such application should consider the practicality of such appliance. In the same way the limits of the European Directives appliance will be accurately defined with the local Authorities.

1 Scope

This European Standard gives guidelines for the design, construction and operation of all onshore liquefied natural gas (LNG) installations for the liquefaction, storage, vaporization, transfer and handling of LNG.

This European Standard is valid for plants with LNG storage at pressure lower than 0,5 barg and capacity above 200 t and for the following plant types:

- LNG liquefaction installations (plant), between the designated gas inlet boundary limit, and the outlet boundary limit which is usually the ship manifold and/or truck delivery station when applicable; feed gas can be from gas field, associated gas from oil field, piped gas from transportation grid or from renewables;
- LNG regasification installations (plant), between the ship manifold and the designated gas outlet boundary limit;
- peak-shaving plants, between designated gas inlet and outlet boundary limits;
- the fixed part of LNG bunkering station.

A short description of each of these installations is given in Annex G.

Floating solutions (FPSO, FSRU, SRV), whether off-shore or nearby shore, are not covered by this European Standard even if some concepts, principles or recommendations could be applied. However, in case of berthed FSRU with LNG transfer across the jetty, the following recommendations apply for the jetty and topside facilities if the jetty is located within 3 000 m from the shore line.

In case of FSU type solution, the on-shore part is covered by these standard recommendations.

This standard is not applicable for installations specifically referred or covered by other standards, e.g. LNG fuelling stations, LNG road or rail tankers and LNG bunkering vessels.

The plants with a storage inventory from 50 t up to 200 t with tanks at a pressure higher than 0,5 barg are covered by EN 13645.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 809, *Pumps and pump units for liquids — Common safety requirements*

EN 1092-1, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, PN-designated — Part 1: Steel flanges*

EN 1127-1, *Explosive atmospheres — Explosion prevention and protection — Part 1: Basic concepts and methodology*

EN 1474 (all parts) *Installation and equipment for liquefied natural gas — Design and testing of loading/unloading arms*

EN 1514-1, *Flanges and their joints — Dimensions of gaskets for PN-designated flanges — Part 1: Non-metallic flat gaskets with or without inserts*

EN 1591 (all parts), *Flanges and their joints — Design rules for gasketed circular flange connections*

- EN 1776, *Gas infrastructure — Gas measuring systems — Functional requirements*
- EN 1991-1-2, *Eurocode 1: Actions on structures — Part 1-2: General actions — Actions on structures exposed to fire*
- EN 1992-1-1, *Eurocode 2: Design of concrete structures — Part 1-1: General rules and rules for buildings*
- EN 1992-1-2, *Eurocode 2: Design of concrete structures — Part 1-2: General rules — Structural fire design*
- EN 1993-1-1, *Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings*
- EN 1993-1-2, *Eurocode 3: Design of steel structures — Part 1-2: General rules — Structural fire design*
- EN 1994-1-1, *Eurocode 4: Design of composite steel and concrete structures — Part 1-1: General rules and rules for buildings*
- EN 1994-1-2, *Eurocode 4 — Design of composite steel and concrete structures — Part 1-2: General rules - Structural fire design*
- EN 1997 (all parts), *Eurocode 7: Geotechnical design*
- EN 1998-1, *Eurocode 8: Design of structures for earthquake resistance — Part 1: General rules, seismic actions and rules for buildings*
- EN 1998-5, *Eurocode 8: Design of structures for earthquake resistance — Part 5: Foundations, retaining structures and geotechnical aspects*
- EN 10204, *Metallic products — Types of inspection documents*
- EN 12065, *Installations and equipment for liquefied natural gas — Testing of foam concentrates designed for generation of medium and high expansion foam and of extinguishing powders used on liquefied natural gas fires*
- EN 12066, *Installations and equipment for liquefied natural gas — Testing of insulating linings for liquefied natural gas impounding areas*
- EN 12162, *Liquid pumps - Safety requirements — Procedure for hydrostatic testing*
- EN 12308, *Installations and equipment for LNG — Suitability testing of gaskets designed for flanged joints used on LNG piping*
- EN 12434, *Cryogenic vessels — Cryogenic flexible hoses*
- EN 12567, *Industrial valves — Isolating valves for LNG — Specification for suitability and appropriate verification tests*
- EN 13445 (all parts), *Unfired pressure vessels*
- EN 13480 (all parts), *Metallic industrial piping*
- EN 14620-1:2006, *Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0 °C and -165 °C — Part 1: General*

EN 14620 (all parts), *Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0 °C and - 165 °C*

EN 60079-0, *Explosive atmospheres — Part 0: Equipment — General requirements (IEC 60079-0)*

EN 60079-1, *Explosive atmospheres — Part 1: Equipment protection by flameproof enclosures "d" (IEC 60079-1)*

EN 60079-2, *Explosive atmospheres — Part 2: Equipment protection by pressurized enclosure "p" (IEC 60079-2)*

EN 60079-5, *Explosive atmospheres — Part 5: Equipment protection by powder filling "q" (IEC 60079-5)*

EN 60079-6, *Explosive atmospheres — Part 6: Equipment protection by liquid immersion "o" (IEC 60079-6)*

EN 60079-7, *Explosive atmospheres — Part 7: Equipment protection by increased safety "e" (IEC 60079-7)*

EN 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres (IEC 60079-10-1)*

EN 60079-10-2, *Explosive atmospheres — Part 10-2: Classification of areas — Explosive dust atmospheres (IEC 60079-10-2)*

EN 60079-11, *Explosive atmospheres — Part 11: Equipment protection by intrinsic safety "i" (IEC 60079-11)*

EN 60079-13, *Explosive atmospheres — Part 13: Equipment protection by pressurized room "p" (IEC 60079-13)*

EN 60079-14, *Explosive atmospheres — Part 14: Electrical installations design, selection and erection (IEC 60079-14)*

EN 60079-15, *Explosive atmospheres — Part 15: Equipment protection by type of protection "n" (IEC 60079-15)*

EN 60079-17, *Explosive atmospheres — Part 17: Electrical installations inspection and maintenance (IEC 60079-17)*

EN 60079-18, *Explosive atmospheres — Part 18: Equipment protection by encapsulation "m" (IEC 60079-18)*

EN 60079-19, *Explosive atmospheres — Part 19: Equipment repair, overhaul and reclamation (IEC 60079-19)*

EN 60079-20-1, *Explosive atmospheres — Part 20-1: Material characteristics for gas and vapour classification - Test methods and data (IEC 60079-20-1)*

EN 60079-25, *Explosive atmospheres — Part 25: Intrinsically safe electrical systems (IEC 60079-25)*

EN 60079-26, *Explosive atmospheres — Part 26: Equipment with Equipment Protection Level (EPL) Ga (IEC 60079-26)*

EN 60079-27, *Explosive atmospheres — Part 27: Fieldbus intrinsically safe concept (FISCO) (IEC 60079-27)*

EN 61508-1, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 1: General requirements (IEC 61508-1)*

EN 62305 (all parts), *Protection against lightning (IEC 62305)*

EN ISO 1460, *Metallic coatings — Hot dip galvanized coatings on ferrous materials — Gravimetric determination of the mass per unit area (ISO 1460)*

EN ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods (ISO 1461)*

EN ISO 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles (ISO 3452-1)*

EN ISO 9606-1, *Qualification testing of welders — Fusion welding — Part 1: Steels (ISO 9606-1)*

EN ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel (ISO 9712)*

EN ISO 10456, *Building materials and products — Hygrothermal properties — Tabulated design values and procedures for determining declared and design thermal values (ISO 10456)*

EN ISO 10497, *Testing of valves — Fire type-testing requirements (ISO 10497)*

EN ISO 12944 (all parts), *Paints and varnishes — Corrosion protection of steel structures by protective paint systems (ISO 12944)*

EN ISO 13709, *Centrifugal pumps for petroleum, petrochemical and natural gas industries (ISO 13709)*

EN ISO 15607, *Specification and qualification of welding procedures for metallic materials — General rules (ISO 15607)*

EN ISO 15609-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 1: Arc welding (ISO 15609-1)*

EN ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1)*

EN ISO 16903, *Petroleum and natural gas industries — Characteristics of LNG, influencing the design, and material selection (ISO 16903)*

EN ISO 17636-1, *Non-destructive testing of welds — Radiographic testing — Part 1: X- and gamma-ray techniques with film (ISO 17636-1)*

EN ISO 17636-2, *Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors (ISO 17636-2)*

EN ISO 17637, *Non-destructive testing of welds — Visual testing of fusion-welded joints (ISO 17637)*

EN ISO 17640, *Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels, and assessment (ISO 17640)*

EN ISO 28460, *Petroleum and natural gas industries — Installation and equipment for liquefied natural gas — Ship-to-shore interface and port operations (ISO 28460)*

HD 60364-5-54, *Low-voltage electrical installations — Part 5-54: Selection and erection of electrical equipment — Earthing arrangements and protective conductors (IEC 60364-5-54)*

IEC/TR 60079-16, *Electrical apparatus for explosive gas atmospheres — Part 16: Artificial ventilation for the protection of analyser(s) houses*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

abnormal operation

operating conditions such as plant trip, the production and disposal of off-spec products and also operation with production equipment failed or on maintenance are modes of abnormal operation and are not accidental events

3.2

accidental event

event that arises from an uncontrolled or unplanned situation with safety and/or environmental consequences

3.3

boundary

property line on land or water inside which the operator/owner has full control and authority, or exclusive use

3.4

bund or bund wall

raised impermeable structure, able to withstand the static pressure and temperature of the spilled liquid, around the perimeter of an impounding area for the confinement of hydrocarbon spills, usually associated with storage areas

3.5

condensate

hydrocarbon liquids (liquid state at standard conditions) produced from primary separation of natural gas from a reservoir

Note 1 to entry: Natural gas condensates consist primarily of pentanes and heavier components, although quantities of propane and butane may be dissolved within the mixture.

3.6

primary container

container in continuous contact with LNG, i.e.:

- the cryogenic container of the single containment tank;
- the cryogenic container of the spherical tank;
- the cryogenic container of the double containment tank;
- the 9% Ni-steel self-supporting container;

- the concrete self-supporting container;
- the cryogenic membrane of the membrane tanks

3.7 secondary container

container in contact with LNG only in the event of a failure of the primary container i.e.:

- the bund walls for single and double containment tanks and spherical tanks;
- the outer container of full containment 9 % Ni-steel tanks, or membrane tanks or cryogenic concrete tanks

3.8 conventional onshore LNG terminal

LNG export or receiving terminal that is located on-shore and has a marine transfer facility for the loading or unloading of LNG carriers

Note 1 to entry: The transfer facility is located in a harbour or other coastal location and consists of a fixed structure, or wharf, capable of withstanding the berthing loads of a fully laden LNG carrier of a given specification and mooring the vessel safely alongside. The structure is connected to the shore by a trestle, tunnel or other means, facilitating the LNG transfer and ancillary services and providing safe access and egress for personnel performing maintenance or operational duties.

3.9 Operating Basis Earthquake OBE

maximum earthquake for which no damage is sustained and restart and safe operation can continue

Note 1 to entry: This higher probability event would result in no commercial loss to the installation and public safety is assured.

3.10 Safe Shutdown Earthquake SSE

maximum earthquake event for which the essential fail-safe functions and mechanisms are designed to be preserved

Note 1 to entry: Permanent damage can be expected of this lower probability event, but without the loss of overall integrity and containment. The installation would not remain in continuous service without a detailed examination and structural assessment at the ultimate limit state.

3.11 Emergency Shut Down (ESD) system

system that safely and effectively stops the whole plant or individual units to minimize incident escalation

3.12 fire area

an area of the plant delimited by physical boundaries or separations from other fire areas by boundaries such as site roads

Note 1 to entry: Multiple trains in a large plant are each a fire area. Different processing units each separated by plant roads are individual fire areas. A fire area is often self-defining in that it may be a single plant unit, a storage or utility area or a separate operating area such as a road tanker loading bay.

Note 2 to entry: The typical firewater ring main routeing often encloses each fire area.

Note 3 to entry: Pipe racks joining plant areas are not considered to affect fire area considerations.

3.13

fire zone

an area of the plant or process system within a fire area that requires to be isolated by ESDVs in the event of a fire to control and minimize the fire event, or in the event of a process upset or malfunction to minimize the extent of the process upset

3.14

flammable gases

gas or vapour which, when mixed with air in certain proportions, will form a combustible gas mixture

3.15

FLNG

floating liquefaction unit producing LNG, which will treat gas, process it to make LNG as a main production, store and unload LNG to a LNG carrier

3.16

FPSO

in LNG business, alternate word for FLNG

3.17

frequency

number of occurrences per unit of time

3.18

FSRU

floating storage regasification unit

3.19

FSU

floating storage unit

3.20

golden weld

weld that cannot be pressure tested due to its nature or location and that consequently will be subjected to a high level of non-destructive examination to prove that it is safe

3.21

hazard

property of a dangerous substance or physical situation with a potential for creating damage to human health and/or to environment¹⁾

3.22

impounding area

area where spills from liquid hydrocarbon storage containers may be confined or controlled, close to the source of leakage

¹⁾ Refer to European Directive [Council Directive 2012/18/EC on the control of major-accident hazards involving dangerous substances].

3.23

impounding basin

container within or connected to an impounding area or spill collection area where liquid hydrocarbon spills can be collected and safely confined and controlled

3.24.1

SLS

serviceability limit state (SLS), which is determined on the basis of criteria applicable to functional capability or to durability properties under normal actions

3.24.2

ULS

ultimate limit state (ULS), which is determined on the basis of the risk of failure, large plastic displacements or strains comparable to failure under augmented actions

3.25

Liquefied Natural Gas

LNG

LNG (Liquefied Natural Gas) is defined in EN ISO 16903

3.26

LNG bunkering station

LNG station where LNG is brought by road, rail, sea, cryogenic pipe from a neighbouring terminal, and delivering LNG to ships using LNG as a marine fuel

Note 1 to entry: Delivery of the LNG can be done by road, sea or by fixed dispenser along the jetty.

3.27

LNG liquefaction plant

site at which natural gas coming by pipe from one or several gas producing fields or other sources is liquefied then stored for subsequent transport, normally by sea, to other destinations

Note 1 to entry: It has marine facilities for the transfer of LNG and can have loading stations for road, rail, barge or small LNG carriers.

3.28

LNG peak-shaving plant

plants connected to a gas network and that is used to balance the gas demands

Note 1 to entry: During the period of the year when gas demand is low, natural gas is liquefied and stored. LNG may be vaporized for short periods, when gas demand is high.

3.29

LNG receiving terminal

site where LNG carriers (ships) are unloaded, and where LNG is stored in tanks, vaporized and sent to the gas networks or gas consumers

Note 1 to entry: It has marine facilities for the transfer of LNG and can have loading stations for road, rail, barge or small LNG carriers.

3.30

LNG satellite plant

small LNG plants where LNG is supplied by road tankers, rail, barge or small LNG carriers

Note 1 to entry: LNG is stored in insulated pressure vessels, vaporized and sent to the network.

3.31

Natural Gas Liquid

NGL

liquid composed of light hydrocarbons (typically ethane through hexane plus) condensed from the natural gas prior to its liquefaction

3.32

normal operation

operation including intermittent operation such as ship loading or unloading, start-up, maintenance, planned shutdown and commissioning

3.33

operator/occupier

company responsible for the operation of the installation

3.34

owner

company responsible for the safe design and construction of the installation

3.35

PASQUILL atmospheric stability factors

factors that are determined as a function of the wind speed and solar radiation (see [1])

Note 1 to entry: The six factors are:

- A: extremely unstable;
- B: moderately unstable;
- C: lightly unstable;
- D: neutral;
- E: lightly stable;
- F: moderately stable.

3.36

probability

number in a scale from 0 to 1 which expresses the likelihood of an event occurrence

3.37

PSD (Process Shut Down) system

system that safely and effectively stops individual units within the plant for process reasons

3.38

risk

combination of the consequence and the frequency of a specific hazard occurring within a specified period under specified circumstances

3.39

Safety Management System

management process which defines and monitors the organizational structure, responsibilities, procedures, processes and resources for determining and implementing the major accident prevention policy²⁾

3.40

SIL

Safety Integrity Level required of a safety related system in terms of EN 61508

3.41

spill collection area

area at LNG production or transfer areas where leakages can be confined or controlled, often by the use of kerbing and/or controlled sloping of paved areas

3.42

SRV

shuttle regasification vessel

3.43

tank

equipment item in its entirety for the storage of LNG

Note 1 to entry: The different types of tank with pressure < 0,5 bar are described EN 14620 or are shown in Annex H.

3.44

transfer area

area containing a piping system where flammable liquids or gases are introduced into or removed from the plant or where piping connections are connected or disconnected routinely

3.45

validated model

mathematical model, the scientific basis of which is accepted to be sound and is proven to provide mathematical outputs to the relevant mathematical problem, and is shown to cover the full range of usage of the model and which has been calibrated or checked using realistic test data or results

3.46

vent stack

elevated vapour disposal system for the safe dispersion of vapour releases from the plant

Note 1 to entry: Reference [3] requires that the vent be designed with the assumption that it could become ignited and cause damage or injury due to thermal radiation.

4 Safety and environment

4.1 General

The design, procurement, construction and operation phases should all be implemented in accordance with the requirements of the Quality, Health, Safety and Environment management systems.

²⁾ Refer to European Directive [Council Directive 2012/18/EC on the control of major-accident hazards involving dangerous substances].

Furthermore, each phase shall be controlled by an acceptable Safety Management System.

In case of plant expansion or debottlenecking, the environmental and safety impacts shall be appraised in accordance with the following recommendations. The potential consequences shall be analysed with regard to the current local regulations.

In case of revamping for life extension, the environmental and safety impacts shall be appraised in accordance with the following recommendations. The appliance of the current local regulations, and the extent of such appliance, shall be agreed upon with the local authorities.

In case of revamping without life extension and without debottlenecking, the principle of non-retroactivity shall prevail.

4.2 Environmental impact

4.2.1 Environmental Impact Assessment

During the feasibility study phase of the project, a preliminary Environmental Impact Assessment (EIA) shall be carried out for the proposed location in accordance with local regulations. Consideration should be given to formally recording the base line site environmental characteristics.

When the site has been selected, a detailed EIA shall be carried out.

All emissions from the plant, that is, solid, liquid (including water), and gaseous (including noxious odours) shall be identified and measures taken to ensure they will not be harmful to persons, property, animals or vegetation. This applies not only to normal, but also to accidental emissions.

During or prior to operation an effluent management procedure shall be established. The precautions for handling toxic materials shall be identified and be regularly updated by the operator/occupier.

The environmental impact due to construction and operation shall also be assessed and undesirable levels of activities shall be eliminated or minimized and restricted. The following checklist covers the main items:

- increased population, permanent and temporary;
- increased road, rail and ship traffic;
- increased noise levels, sudden and intermittent noise;
- increased vibration levels, sudden and intermittent;
- increased night working, effect of lights and their intermittent use;
- flaring, intermittent and/or continuous;
- warming or cooling of water.

4.2.2 Plant emissions

During the design, plans shall be developed to eliminate, minimize or render harmless emissions resulting from commissioning tests, operations and maintenance activities, and shall set targets for quantities and concentrations of pollutants in emissions.

4.2.3 Emission control

The following shall be safely controlled:

- combustion products;

- normal or accidental venting of gas;
- normal or accidental flaring of gas;
- disposal of acid gas removal solvent;
- disposal of spent mercury removal reactant (as the demercurization process is not regenerative, it is necessary to store and then treat the used absorbent mass or have it removed by a licensed waste disposal contractor);
- oily water condensed during dryer regeneration or from machines;
- in the case of water cooled equipment, hydrocarbon contamination of cooling water from leaking exchanger tubes;
- disposal of waste products (including waste oil and chlorinated organic compounds);
- vaporizer water;
- odourant chemicals.

4.2.4 Flare/venting philosophy

Plants are to be designed around the principle of no continuous flaring or venting. Provisions should be taken during design and operation to ensure that potential gas waste streams, wherever practically possible, are recovered and not routed to flare or vent during the normal operation of the plant.

4.2.5 Noise Control

The design of the plant shall consider the effects of noise on people within the plant exposed to noise and the effect of noise on any community surrounding the plant.

It is recommended that the noise design procedure of the plant should comply with ISO 15664.

4.2.6 External traffic routes

External traffic routes near to the LNG plant shall be listed in EIA, stating the volume and nature of present traffic and also any foreseeable development caused by the plant. In particular, the following shall be examined:

- overland routes (roads, railways);
- navigable routes (sea or river routes, canals);
- air routes and the proximity of airports and aerodromes.

4.2.7 Water discharge

The impact of water discharges shall be studied (temperature, currents, winds, etc).

4.3 Safety general

4.3.1 Safety philosophy approach

LNG installations shall be designed to provide generally accepted levels of risk (see Annex K) for life and property outside and inside the plant boundaries. In order to ensure this high level of safety in the LNG facilities and its surroundings, safety shall be considered throughout all the project development phases: engineering, construction, start-up, operation and decommissioning. In particular, hazard

assessments, see 4.4, shall be carried out and the required safety measure implemented to ensure acceptable risk levels.

ISO/TS 16901 gives items to be covered by the QRA (in complement to here after subclause 4.3 items) and an approach to address the potential scenarios, their probability of occurrence and the consequence analysis.

4.3.2 Installation and its surrounding

4.3.2.1 Description of the installation

A functional description of the installation shall be written by plant area and/or by process function, for use in the safety assessment.

4.3.2.2 Site study

The site study shall include, where appropriate:

- a soil survey;
- a study of terrain to enable the dispersion of liquid and gas clouds to be assessed;
- a study of vegetation to enable, in particular, vegetation fire risks to be identified;
- a study of ground water tables;
- a study to identify sources of stray electrical currents (e.g. those emanating from high voltage power lines, railways);
- a study of the marine aquatic environment and marine access;
- a study of sea water quality and temperature;
- a study of tidal conditions;
- a study of shock waves and flooding (tsunami, failure of dams, etc.);
- a survey of the surrounding infrastructure (e.g. industrial sites, built up areas, communications);
- manoeuvring areas, safety distances whilst a LNG carrier is in transit within the port and at berth (see Clause 5 and EN ISO 28460).

The soil survey shall include:

- the geotechnical survey that will enable the geo-mechanical characteristics of the subsoil to be defined;
- the geological and tectonic investigation.

The geological characteristics of the region shall be investigated in sufficient detail to provide a clear understanding of the physical processes that formed the area, as well as the potential for the future seismic activity.

A more specific survey shall be done on the site and its vicinity to detect the presence of karst, gypsum, swelling clays, soluble salt deposits, soil liquefaction, mass movement etc. and their relative impact shall be evaluated.

Such phenomena are not allowed under the tank and/or equipment foundations unless it can be proved that appropriate measures have been undertaken to overcome the potential problems.

4.3.2.3 Climatology

The climatic study shall include the following points:

- wind strength and direction including frequency and strength of severe storms;
- temperatures;
- atmospheric stability;
- range and rate of change of barometric pressure;
- rainfall, snow, icing;
- corrosive characteristic of the air;
- risks of flooding;
- frequency of lightning strikes;
- relative humidity.

Climate change will be analysed as part of other investigations that may be required by the local conditions.

4.3.2.4 Seismology

An earthquake is defined by the horizontal and vertical accelerations of the ground. These accelerations are described in accordance with EN 1997 (all parts) and EN 1998 by:

- their frequency spectrum;
- their amplitude.

A site-specific earthquake analysis shall be performed. This shall include assessments of the risks of earthquake, tsunamis, landslides and volcanic activities. This analysis shall be presented in a Seismic Report where geological and seismic characteristics of the location of the facility and the surrounding region as well as geo-tectonic information shall be taken into account. As a conclusion, this report shall define all seismic parameters required for the design.

The size of the region to be investigated depends on the nature of the area around the site and the geological and tectonic conditions resulting from the soil survey, see 4.3.2.2. Generally, it is limited to a distance less than 320 km from the site, but in some instances it can include an entire tectonic province, larger than the above (see [22] for the principle). In this context, the investigations shall be extended down to a depth equal to at least twice the diameter of the structure or a coextensive circular foundation surrounding the same area as the structure.

A second level of analysis shall be made on the region within the 80 km from the site (regional seismo-tectonic investigation) with the aim of detecting the presence of any active geological faults (see [23]).

These investigations involve thorough research, review and evaluation of all historically reported earthquakes that have affected, or that could reasonably be expected to have affected the site.

In case of seismic faults in the immediate vicinity of the site, further investigations shall be conducted to estimate their possible activity. Faults for which inactivity cannot be confirmed are not allowed inside the site or within a distance to be determined from the soil morphology.

For details of the seismic investigations, surveys, analysis and format of response spectrum, reference is made to EN 1997 (all parts), EN 1998-1 and EN 1998-5.

The geological, tectonic and seismological studies help to establish:

- the safe shutdown earthquake (SSE);
- the operating basis earthquake (OBE).

These shall be established:

- probabilistically, as those that produce ground motions with the mean recurrence as a minimum interval of 5 000 years for the SSE and 475 years for the OBE, and/or,
- deterministically, assuming that earthquakes which are analogous to maximum historically known earthquakes are liable to occur in the future with an epicentre position which is the most severe with regard to its effects in terms of intensity on the site, while remaining compatible with geological and seismic data.

NOTE Both OBE and SSE define specific performance limits for seismic events of increasing severity for systems as defined in 4.5.2.2.

4.3.2.5 Location

During the feasibility study phase of the project site location assessments shall be carried out to ensure the suitability of the location options with regards to adjacent development. The assessment shall as a minimum consider the following:

- residential development;
- retail and leisure developments;
- sensitive developments (schools, hospitals, retirement homes, sports stadium, etc.);
- industrial development;
- transportation infrastructure.

When the site has been selected, a detailed site location assessment shall be carried out. The location assessment methodology and scope shall have regard for the proposed inventory of hazardous material contained on the plant and the presence and scale of adjacent existing and identified future developments, whilst being in conformance with local and national regulatory requirements.

It is recommended that:

- the assessment is updated on a regular basis and when major modifications or changes take place;
- the development around the plant is controlled to minimize the subsequent incompatible development.

Guidance for the probabilistic assessment acceptance criteria of site location are presented in Table K.2. These minimum acceptance criteria can be adopted in the event that no such criteria exist in the country where the plant is to be built.

4.4 Hazard assessment

4.4.1 General

A hazard assessment shall be carried out during the design of the plant and it is also recommended if a major modification or change takes place.

The following methodology and requirements see annexes that show examples of frequency ranges, classes of consequences and levels of risks. However, there is a variation in national and company acceptance criteria and the examples given in the informative Annexes I, J and K should be considered as minimum requirements. If more stringent local or national requirements exist they shall supersede these minimum requirements.

4.4.2 Assessment

4.4.2.1 Methodology

The methodology of the hazard assessment can be deterministic and/or probabilistic.

The deterministic approach consists of:

- list of potential hazards of external and internal origin;
- establishment of credible hazards;
- determination of the consequences;
- justification of the necessary safety improvement measures to limit the consequences.

The probabilistic approach consists of:

- list of potential hazards of external and internal origin;
- determination of the consequences of each hazard and their allocation into classes of consequence (an example is given in Annex J);
- collection/input of failure rate data;
- determination of the probability or frequency of each hazard;
- summation of frequency for all hazards within any one allotted consequence class and classify the frequency range for that consequence class (an example is given in Annex I);
- classification of hazards in accordance with their consequences class and frequency range, in order to determine the level of risk (an example is given in Annex K).

In the event that the risk determination indicates "Unacceptable Risk" levels (for example, risk level 3 of Annex K) the plant design or operating practices shall be altered and the assessment repeated until such time that no such "Unacceptable Risk" levels exist. In the event that the risk determination indicates normal, acceptable, risk levels (for example, risk level 1 of Annex K) no further action is considered necessary. For risk levels determined as requiring further reduction (for example risk level 2 of Annex K) additional safety measures should be considered to limit the risk to as low as reasonably practicable.

The hazard assessment can be based on conventional methods such as:

- hazard and operability study (HAZOP);

- failure mode effect analysis (FMEA);
- event tree method (ETM);
- fault tree method (FTM).

The hazard assessment procedure should be carried out during all stages of the design process. Implementation during the early stages of a project or design modification is recommended, this allows unacceptable designs to be improved in the most cost effective manner.

The probabilistic assessment minimum acceptance criteria given in Table K.1 are based on risk to personnel inside the plant boundary. Comparable categories for mass of hydrocarbon released are also given for guidance in Annex J. Alternative risk assessment methods can be used to assess the suitability of the plant design, typically business and hazardous incident escalation risk assessments. However, as a minimum personnel risk should be assessed and verified as acceptable during the plant design and following major modifications.

Risk analysis and its conclusions should not compromise good engineering practices.

4.4.2.2 Identification of hazards of external origin

Studies should be undertaken to identify hazards arising from outside the plant. Such hazards can be caused by:

- LNG carriers approaching the berth at excessive speed or angle;
- the possibility of collision with the jetty and/or LNG carrier at berth by heavy displacement vessels passing the berth (see [23]);
- the impact of projectiles and consequences of collision (ship, truck, plane, etc.);
- natural events (lightning, flooding, earthquakes, tidal bores, icebergs, tsunamis, etc.);
- ignition by high energy radio waves (see [25]);
- proximity of airport and/or flight-paths;
- a “domino effect” resulting from fires and/or explosions at adjacent premises;
- flammable, toxic or asphyxiant drifting gas clouds;
- permanent sources of ignition, such as high voltage power lines (corona effect);
- the proximity of the site to any external uncontrolled sources of ignition.

4.4.2.3 Identification of hazards of internal origin

4.4.2.3.1 Hazard arising from LNG

Loss of containment of LNG and of natural gas shall be considered for all items of equipment including the loading or unloading of road tankers or LNG carriers. To simplify the study, scenarios may be established.

These scenarios shall be defined in terms of:

- the probability or frequency of the hazard;
- the location of the leak;

- the nature of the fluid (LNG or gas, specifying the temperature);
- the rate and the duration of the leakage;
- the weather conditions (wind speed and direction, atmospheric stability, ambient temperature, relative humidity);
- the thermal properties and the topography of the ground (including any impounding area);
- the proximity of structural steelwork that may be susceptible to brittle failure due to low or cryogenic temperatures. Under certain circumstances when quantities of LNG have been introduced into water, over-pressurization without combustion has been known to occur; this phenomena is referred to as a Rapid Phase Transition (RPT). Refer to EN ISO 16903 and see [33] and [34].

In particular, the scenarios to be considered for various types of LNG tanks are listed in Table 1.

Table 1 — Scenario to be considered in the hazard assessment as function of tank types

Type of tank containment ^d	All metallic or only with metallic roof	Prestressed concrete (including reinforced concrete roof)
Single containment	a	
Double containment	b	
Full containment	b	c
In-ground	b	c
Scenarios to be considered: a In case of collapse of the tank primary container, fire pool size corresponds to the impounding area. b In case of collapse of the tank roof, the fire pool size corresponds to the secondary container. c Roof collapse is not considered for these tank types except if it is specified in risk analysis. d For definition, see 6.3.		

4.4.2.3.2 Hazards which are not specific to LNG

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

- LPG and heavier hydrocarbon storage;
- simultaneous loadings on multi-product jetty;
- poor communication between ship and shore;
- traffic within the plant both during construction and operation;
- leakage of other hazardous substances, in particular flammable refrigerant;
- missiles originating from explosion;
- pressurised and steam raising equipment;
- fired heaters and boilers;

- rotating machinery;
- utilities, catalysts and chemicals (fuel oil, lubricating oils, methanol, etc.);
- pollutants found in the feed gas of liquefaction plants;
- electrical installations;
- harbour installations associated with the LNG plant;
- security issues (e.g. intrusion, sabotage);
- accidents during construction and maintenance;
- escalation of accidents.

4.4.2.4 Estimation of probabilities

The estimation of the probability associated with a given hazard, where utilised, shall be based on reliable data bases available in public domain and which are suitable for the LNG industry or on recognized methods as in 4.4.2.1 which will determine the frequency range for this hazard (see Annex I). The human factor shall be taken into account.

4.4.2.5 Estimation of consequences

4.4.2.5.1 General

The consequences of each scenario as defined above will depend on the characteristics of LNG and other phenomena described EN ISO 16903. For the hazardous characteristics of fluids other than LNG reference shall be made to their Material Safety Data Sheets.

4.4.2.5.2 Evaporation of spilled LNG

The phenomenon of instantaneous vaporization (flash, including possible aerosol formation) shall be taken into account.

Calculation of evaporation due to heat transfer shall be carried out using appropriate validated models.

The model shall take the following into account:

- LNG flow rate and duration;
- LNG composition;
- nature of the ground (thermal conductivity, specific heat, density, etc.);
- temperature of the ground or of the water;
- atmospheric conditions (ambient temperature, humidity, wind velocity);
- atmospheric stability or temperature gradient.

The model shall enable the following to be determined:

- pool propagation speed;
- wetted area in terms of time, and, in particular, the maximum wetted area;

- rate of evaporation in terms of time and, in particular, the maximum evaporation rate.

4.4.2.5.3 Atmospheric dispersion of LNG vapours

Calculation of the atmospheric dispersion of the cloud resulting from evaporation of LNG due to flashing and evaporation when in contact with the ground or water shall be carried out using appropriate validated models.

The determination of dispersion shall, as a minimum, take into account:

- the diameter of the evaporating pool;
- the evaporation rate;
- properties of the vapour;
- the nature of the ground (thermal conductivity, specific heat, density, etc.);
- the temperature of the ground or water;
- the atmospheric conditions (ambient temperature, humidity, wind speed);
- atmospheric stability or temperature gradient;
- site topography (surface roughness, etc.).

The atmospheric dispersion simulation shall be based on the combination of wind speed and atmospheric stability that can occur simultaneously and result in the longest predictable downwind dispersion distance that is exceeded less than 10 % of the time.

If no other information is available, the following atmospheric condition shall be considered: F (PASQUILL) atmospheric stability or equivalent temperature gradient, for a wind of 2 m/s and a relative humidity of 50 %.

The model shall enable the determination of:

- concentration contours;
- the distance to the lower flammability limit.

4.4.2.5.4 Jet release of natural gas or LNG

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

Sources of jet releases should include releases from atmospheric safety valves, un-ignited flare and vents. Where appropriate it shall consider possible aerosol formation.

4.4.2.5.5 Over-pressure

The ignition of natural gas can create in certain circumstances (e.g. congested areas) an explosion generating an over-pressure wave. The flammability range of mixtures of gas and air is given in EN ISO 16903.

Recognized methods and models, for example the multi energy method (see [5]) and/or deflagration at constant speed method (see [6]) which have been validated can be used to calculate the over-pressure. This over-pressure should be specified where applicable for equipment, buildings and structures.

Where over-pressure on a tank, equipment item, building or structure is specified, it shall always be the incoming wave characteristics. In this case it may be assumed that a deflagrating explosion near the tank gives rise to an over-pressure that is applied, as a worst case assumption, to a half perimeter of the tank. The stresses in the tank caused by over pressure shall be determined by dynamic calculation. For the other structures, the stresses may be determined by static calculation.

The effect of potential over-pressure under elevated tank basis due to the ignition of a flammable mixture under the tank shall be considered.

The effects of wave reflection on the objects shall be the responsibility of the supplier.

4.4.2.5.6 Radiation

Calculation of the radiation caused by ignition of the vapour from a pool or jet of LNG or release of natural gas shall be carried out using appropriate validated models.

The model shall take the following into account:

- area of the pool fire or the dimensions of the flame;
- surface emissive power of the pool fire or of the flame (see EN ISO 16903);
- ambient temperature, wind speed and relative humidity.

The radiation calculation shall be based on the combination of wind speed and atmospheric conditions that can occur simultaneously and result in the highest predictable radiation that is exceeded less than 10 % percent of the time.

If no other information is available the following atmospheric condition shall be considered: a wind of 10 m/s and a relative humidity of 50 %.

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

4.4.3 Safety improvement

Where the hazard assessment demonstrates that threshold values defined in Annex A are exceeded or shows that the level of risk requires improvement (see Annex K), measures shall be taken, as for example:

- setting up a safety system which allows early detection of a leak and limitation of the consequences of ignitions (see 4.5 and Clause 13);
- increasing the dilution of the flammable cloud;
- elimination of potential sources of ignition inside a flammable cloud;
- reducing evaporation rates through minimization of heat transfer;
- reducing heat radiation by water curtains, deluge systems, foam or insulation;
- reducing vapour dispersion distance by warming the cloud by the use of foam or spraying;
- increasing spacing between equipment;
- protection of the installation against blast;
- alarm systems such as break-glass units, telephones, paging systems, closed circuit television and sirens.

4.5 Safety engineering during design and construction

4.5.1 Introduction

During engineering and construction, the safety shall be continuously scrutinized to guarantee the appropriate safety level with regard to the hazard assessment.

The safety management during design and construction shall include design considerations and continuous reviews as outlined respectively in 4.5.2 and 4.5.3.

4.5.2 Design

4.5.2.1 Common safety design features

4.5.2.1.1 Equipment and piping design for low temperature

Design pressures and temperatures of piping and equipment shall be selected to cover all anticipated operation and upset conditions. Suitable materials are listed in EN ISO 16903.

The stresses in pipe-work and equipment are affected by contraction/expansion phenomena due to temperature changes, the possibility of thermal shock and the method of insulation. Physical phenomena such as: liquid hammer, cavitation, flashing and two-phase flow shall be taken into consideration. The recommendations of Clause 9 are applicable. It is recommended that the main pipes are maintained in a cold condition, e.g. by circulating of LNG, line weathering.

4.5.2.1.2 Hazardous area classifications

All installations shall be subjected to a hazardous area analysis (see [12] and [13]). The terms of reference for such an analysis shall be laid down in accordance with EN 1127-1 and EN 60079-10-1 and EN 60079-10-2.

The form and the extent of each zone may differ slightly depending on the national or professional code used but shall be in line with the methodology set forward in EN 60079-10-1 and EN 60079-10-2. Consideration shall be given to EN ISO 28460 for the jetty, particularly for the hazardous zones generated when the LNG ship is alongside.

The selection of equipment for use in particular locations shall be determined from the hazardous zone classification of these locations in accordance with EN 1127-1 and EN/IEC series (parts 0 to 25).

4.5.2.1.3 Internal over-pressure protection

Safety devices shall be provided to cover all internal over-pressure risks including those due to fire.

It is recommended that the discharges from conventional safety devices (safety valves, relief valves) are routed to the flare/vent system or the storage tank. Tank and vaporiser safety valve releases, if not routed to the flare/vent systems, should be routed to a safe location as defined by hazard assessment.

If low and high pressure releases are routed to the same system, the risk of excessive back pressure shall be avoided. If excessive back-pressure could occur in low pressure release system due to high pressure release, then separate flare/vent systems may be considered for high and low pressure releases.

4.5.2.1.4 Emergency depressurizing

It is recommended that a depressurizing system is provided.

The intention of this measure is to:

- reduce the internal pressure;
- reduce the effect of leakage;

- avoid the risk of failure of LNG, hydrocarbon refrigerant or gas filled pressure vessels and piping from external radiation.

Devices for depressurizing high pressure equipment shall allow the pressure of one or more item of equipment to be reduced quickly (see [3]). These gases shall be sent to the flare system which shall be capable of handling the low temperatures generated during depressurizing.

Isolation valves, activated from a control room or other remote location or automatically, shall be provided so that the unit can be isolated into several sub-systems and where it is required to isolate sensitive equipment. This will make it possible to depressurize only one part of the plant, while limiting the entry of hydrocarbons into a fire containing zone.

4.5.2.1.5 Safety control system

A safety control system (see Clause 14) shall be provided to identify, inform and react appropriately to hazardous events. The safety control system shall be independent of the process control system and identify the hazard and, where appropriate, automatically bring the plant to safe conditions.

4.5.2.1.6 Inherent safety

The inherent safety protection shall be provided to:

- contain LNG spills within the fence, and minimize the credible scenarios where there could be the risk that vapour clouds spread beyond the plant periphery fence;
- minimize the possibility of a fire in any one area of the plant spreading to another area;
- minimize damage in the immediate area of a fire by the use of separation distances, minimizing the hydrocarbon inventory feeding a possible fire (by segregating the plant in different fire-zones, by isolation valves).

The inherent safety is to be encouraged over the use of complex systems.

Inherent safety protection measures are detailed in 13.1.

4.5.2.1.7 Passive fire and embrittlement protection

The passive fire and embrittlement protection shall be provided to:

- protect equipment and main structural supports from localized fire incident minimizing escalation and endangerment of emergency response personnel;
- protect the main structural members from cold-splash brittle failure and resulting overall collapse.

Passive protection measures are detailed in 13.2.

4.5.2.1.8 Active fire protection

Equipment and or systems shall be provided to control and fight the emergency situations.

These equipment items/packages and systems are described in 13.6.

4.5.2.1.9 Additional LNG plant safety measures

Leaks of LNG and hydrocarbon liquids such as Natural Gas Liquid (NGL) and refrigerants produce flammable vapour clouds denser than air. The plant shall therefore be designed to eliminate or minimize the quantity and probability of accidental and planned emissions of these fluids.

This shall be achieved by using a Safety Management System during design, procurement, fabrication, construction and operation of the plant to ensure that the best available rules of technology are implemented. Particular consideration shall be given to the following:

- wherever possible plant and equipment containing flammable fluid shall be located in the open; however, maintenance and climatic conditions will affect this decision;
- plant layout shall be designed to minimize congestion;
- appropriate piping flexibility to suit all operating conditions;
- the number of flanges in pipe runs shall be minimized by using welded inline valves with due consideration for commissioning, isolation and maintenance. Where flanges are used qualified gaskets as specified in EN 12308, suitable for the joint and service, shall be selected and, wherever possible, flanges should be oriented so that if a leak occurs the jet stream shall not impinge on nearby equipment;
- the location of relief valve tail pipes shall be such as to minimize hazard;
- design pressures shall leave a sufficiently wide margin above operating pressures so as to minimize the frequency of the lifting of relief valves;
- pumps with high integrity seals or submerged pumps and motors shall be used for LNG and LPG;
- it is recommended that galvanized surfaces are located so as to avoid the possibility of molten zinc contaminating austenitic stainless steel piping and equipment in the event of a fire possibly leading to brittle fracture or rapid failure;
- attention should be paid to the installation of zinc and aluminium above unprotected steel and copper systems. If aluminium or zinc is heated for a long time with a steel or copper object, that object could develop pits or holes from alloying during future operation. This phenomenon will not be instantaneous, but would affect the integrity of the plant in future operation (see [14]);
- isolation valves shall be fitted as close as possible to the nozzle, but outside the skirt, of process liquid outlets of pressure vessels containing flammable liquids. These isolation valves shall be capable of remote operation by push button in safe location or automatically by ESD (see Clause 14).

4.5.2.1.10 Impounding basin

The extent of the impounding basins and spillage collection channel for LNG and hydrocarbon pipe-systems and equipment shall be evaluated as a part of the hazard assessment (see 4.4). In general, it has been found that the collection of spill from interconnecting LNG and hydrocarbons piping, without branch, flanges or instrument connections, is not justified by hazard assessment.

If required, it shall be designed to accommodate potential leaks that will be identified in the hazard assessment.

Possible LNG and hydrocarbon spills should be drained into impounding basins, with foam generators or other measures for improved evaporation control.

Provisions for water recovery as given in 6.8.4 shall be applied.

4.5.2.2 Site specific: Seismic protection

The plant shall be designed to allow easy operational resumption after an OBE level earthquake (see OBE definition in Clause 3).

The following systems shall withstand actions resulting from higher earthquake (from OBE through to SSE levels):

- systems for which rupture can create a hazard for the plant;
- protection systems for which operation is required to keep a minimum safety level.

For this purpose, the plant systems and their components shall be classified on the basis of their importance (see Annex C). Such classification shall be analysed during the hazard assessment:

- **Class A:** systems which are vital for plant safety or protection systems for which operation is required to keep a minimum safety level. They shall remain operational for both OBE and SSE. The ESD system and LNG storage secondary container shall be in Class A.
- **Class B:** systems performing vital functions for the plant operation or systems for which rupture can create a hazard for the plant for which collapse could cause a major impact on the environment or could lead to additional hazard. These systems shall remain operational after OBE and shall keep their integrity in case of SSE. The primary container of all LNG tanks shall be in Class B.
- **Class C:** other systems. These systems shall remain operational after OBE and shall not fall on or impact other systems classes and components after SSE.

The systems include the related equipment, piping, valves, instrumentation, power supply and their supports. Structures shall be designed as for the class of the most stringent system component they are supporting.

The buildings that have a safety function, or which are normally manned, shall be designed to keep their integrity in case of SSE. Heating, ventilating and air conditioning shall be designed in order to fulfil the criteria of the classified systems which are located in the buildings.

4.5.3 Reviews

The reviews shall be organized through a strict application of an all-encompassing QA system (see Clause 15).

These reviews shall include as a minimum:

- Preliminary Hazard Analysis;
- layout review;
- HAZOP;
- maintenance and accessibility review;
- SIL review;
- pre-start-up review.

4.6 Safety during operation

4.6.1 General

The local regulations prevail but their appliance shall ensure that the items as listed in 4.6.2 and 4.6.3 are covered.

4.6.2 Preparation for plant operation

The preparation for plant operation shall include:

- personnel training, as outlined in Clause 17;
- development of plant operations, maintenance and inspection procedures;
- development of safety and security procedures, which integrate with the overall port emergency procedures and International Ship and Port facilities Security (ISPS) code, where relevant.

4.6.3 Safety during plant operation

Safety during the operational phase shall be achieved by the following features and measures:

- operation control, monitoring and safeguarding systems including work permits;
- reduction of uncontrolled sources of ignition;
- local and remote control of the firefighting system.

5 Jetties and marine facilities

5.1 General

This clause deals with the siting, engineering design, pre-operational training and safety requirements of the jetty and marine facilities.

5.2 Siting

The positioning of a jetty at a LNG marine terminal is a prime factor in determining the overall risk of the ship/shore transfer operation and a detailed study to determine the most acceptable position shall be undertaken at the conceptual stage of the project. Determination of what is acceptable in specific circumstances shall follow from an assessment of the actual risks posed by the operation of adjacent sites and harbour traffic.

Provisions described in EN ISO 28460 should be incorporated into jetty design and ship shore interface. See also other internationally recognized publications for additional requirements which may be relevant (such as [23] and [16]).

5.3 Engineering design

An appropriate standard for marine structures shall be used (see [22]) to determine the selection of relevant design parameters and methods of calculation to derive the resulting forces on the jetty structure. This should allow for soil conditions, plus the loads imposed on a LNG terminal jetty due to natural phenomena, such as winds, tides, waves currents, temperature variation, ice and earthquakes and those imposed by operational activities, such as berthing and mooring, cargo handling and vehicles used during construction, operation and maintenance.

A compatibility study should be undertaken to ensure the range of vessels that it is anticipated will berth at the terminal can safely do so (see EN ISO 28460).

Consideration within the design should be given to the possibility of LNG spills, particularly in the area adjacent to the transfer arms. This may be by provisions for containment of LNG spill and brittleness protection of carbon steel structural members, or by other appropriate measures.

A jetty operator room should be provided, having communications with both ship and terminal control rooms. It should contain controls for emergency shut down and release equipment for the LNG transfer

system and jetty remote operated firefighting and vapour control equipment. Equipment should also be provided for monitoring sea and weather conditions and the ship's position and tension in the mooring lines.

A detection system shall be provided to give warning of any leakage of LNG or natural gas and also to give warning in the event of fire. Activation of this system shall automatically initiate an ESD of the ship-shore transfer system and give alarms in the jetty operator room, terminal control rooms and also be communicated to the ship by the means as recommended by EN ISO 28460. Marine transfer arms shall be used for the transfer of LNG between ship and shore. These shall be equipped with powered emergency release couplings according to EN 1474 (all parts).

Quick release mooring hooks shall be provided and the design of the release system shall be such that the operation of one switch, or failure of a single component, cannot release all moorings simultaneously.

5.4 Safety

Provision shall be made for rapid access and egress to the berth by emergency vehicles or vessels involved in firefighting, medical evacuation or pollution control.

On jetties relying on vehicular access it may be necessary to provide passing places.

Provision shall also be made for emergency escape routes from fire or liquid spill. From any point on the berth it should be possible to escape to a place of safety. This is most easily achieved by providing two independent routes to safety from the berth. These may include:

- additional walkways;
- provision of a manned standby boat(s).

Escape route shall be protected by water spray if found necessary by the hazard assessment.

Access to ship from jetty shall comply with requirements of EN ISO 28460.

It should not be possible for unauthorized persons to gain access to the jetty area, without being challenged, at any time (see [30]). Where security fences are used to achieve this consideration should be given to the general fire precautions and means of emergency egress. (See [24].)

6 Storage and retention systems

6.1 General

The design and construction of vertical, cylindrical, flat bottom LNG tanks are covered by EN 14620.

6.2 Types of tank

The types of tanks are characterized by their technologies, their secondary container (containment) and their foundations.

The main technologies are:

- the self-supporting 9 Ni-steel tank;
- the membrane tanks;
- the concrete tanks.

The types of containment are described in 6.3.

Other types could be accepted provided that their concept and safety could be proven appropriate for the functions as defined in 6.4.2 and the requirements in 6.4.1.

The tanks can be placed on the ground, or semi buried, or in ground or in pit. The raft of the tank can be supported by raised piles. The type of foundation depends on the result of the soil report and seismic study.

The different types of tanks are described in EN 14620 or shown in Annex H.

6.3 Types of containment

SINGLE CONTAINMENT

A single containment shall be designed to achieve the following functions:

- The primary container, or inner tank, shall contain the cryogenic liquid.
- This inner container could contain the product vapour or breathing nitrogen or could be duplicated by an outer shell that will contain the product vapour or breathing nitrogen.

In case of a leakage of the inner tank, the following scenarios shall be considered:

- release of cryogenic product;
- release of product vapours (also in case of leakage of the outer shell).

In case of single containments, the inner tank shall be surrounded by a bund wall to contain the possible product spillage.

DOUBLE CONTAINMENT

A double containment shall be designed to achieve the following functions:

- The primary container, or inner tank, shall contain the cryogenic liquid.
- The outer shell shall contain the product vapour or breathing nitrogen.
- The secondary container, or bund wall, shall contain the spilled LNG in case of leakage of the primary container.

In case of a leakage of the inner tank, the release of cryogenic product shall be considered.

In case of the outer shell leakage, the uncontrolled release of product vapour shall be considered.

FULL CONTAINMENT

A full containment shall be designed to achieve the following functions:

- The primary container, or inner tank, shall contain the cryogenic liquid.
- The secondary container, or outer tank, shall contain the product vapour and shall be able to contain the spilled LNG in case of leakage of the primary container.

The boil-off gas generated during the primary container leakage shall be contained within the secondary container with possibility of controlled venting through the pressure relief system. It is, however, acceptable that some gas leaks could occur through the secondary container in case of such accidental event.

6.4 Design principles

6.4.1 General requirements

The EN 14620 standard does not apply for storage tanks for which the design pressure is more than 500 mbarg. Higher pressure tanks shall meet the requirements of applicable standards or codes used for the design of the related type of pressure vessels³⁾.

Vertical, cylindrical, flat-bottomed steel LNG tanks shall meet the requirements of EN 14620.

The cylindrical cryogenic concrete tanks and spherical tanks for LNG shall be designed in accordance with the requirements from applicable standards or codes³⁾ and all requirements relating to LNG storage contained in this European Standard.

The LNG tanks shall be designed to:

- safely contain the liquid at cryogenic temperature;
- ensure gas tightness;
- permit the safe filling and removal of LNG;
- permit the boil off gas to be safely removed;
- prevent the ingress of air and moisture except as a last resort to prevent unacceptable vacuum conditions in the vapour space;
- minimize the rate of heat in leak, consistent with operational requirements and prevent frost heave;
- withstand the damage leading to loss of containment due to credible internal and external factors as defined in Clause 4;
- operate safely between the design maximum and minimum (vacuum) pressures;
- withstand the number of filling and emptying cycles and the number of cool down and warming operations which are planned during its design life.

6.4.2 Fluid tightness

The tank shall be gas and liquid tight in normal operation.

The degree of resistance to leakage required in the event of external overloads such as impact damage, thermal radiation and blasts shall be defined in the hazard assessment (see Clause 4).

LNG tightness of the primary container shall be ensured by a continuously welded plate, membrane or cryogenic concrete pre-stressed with cryogenic reinforcement.

LNG tightness of the secondary container shall be ensured by:

- continuously welded plate;
- concrete;
- compacted earth or sand provided LNG tightness can be ensured;
- other proven suitable material.

³⁾ E.g. EN 13445.

The outer envelope of the tank which is exposed to the atmosphere (metallic or concrete) shall be designed in such a way as to minimize water penetration, whether this is surface water, firewater, rainwater or atmospheric humidity. Moisture can introduce corrosion problems, deterioration of the insulation and of the concrete.

To contain liquid in case of LNG leakage in case of double or full containment (as defined by their functions in 6.3), the following requirements shall be applied for the secondary container.

- if made of metal, it shall be of cryogenic grade;
- if made of pre-stressed concrete, the temperature of the pre-stressed cables shall remain compatible with the strength of the maximum hydrostatic head. It is to be assumed for calculation that the temperature of the LNG is applied directly onto the internal face, including the insulation, if any;
- it shall withstand all operational and accidental loading conditions, as per EN 14620, and all hazardous conditions that are identified during the QRA (refer to 4.4). In case of damages to the secondary container, they shall be limited in size to prevent domino effect and loss of integrity of the primary container.

For a secondary concrete container where a rigid base/wall connection exists, a thermal protection system shall be foreseen to prevent uncontrolled cracking in this connection area. This thermal protection system shall be designed in accordance with EN 14620-1:2006, 7.1.11.

6.4.3 Tank connections

External connections shall be designed to accept loads imposed from the external piping and internal piping, if any.

The fluid and gas transfer pipes which penetrate the container shall satisfy the following requirements:

- penetrations shall not give rise to excessive heat input;
- where penetrations may be subject to rapid thermal contraction and expansion; if necessary the internal connections shall be strengthened and the external connections shall be designed to transmit external piping loads to a thermal expansion compensating system;
- there shall be no penetrations of the primary and secondary container base or walls;
- if needed, connections shall be provided for nitrogen into the annular space between the inner tank and the outer containment to enable air to be purged out before commissioning and LNG to be purged out after emptying for maintenance.

The absence of wall or base penetrations requires the use of submerged pumps. A platform and suitable lifting equipment on the roof shall be provided to allow pumps to be removed for maintenance.

The design shall prevent any siphoning effects.

6.4.4 Thermal insulation

Materials used for thermal insulation should be chosen from those defined in EN ISO 16903.

The installed insulation systems shall be free from contaminants which can corrode or otherwise damage the pressure-containing components with which they come into contact.⁴⁾

⁴⁾ However, insulation used in the annular space or above a suspended deck (refer to definition in EN 14620) of self-supporting and concrete tanks, will be exposed to the boil-off gas.

Base insulation is installed beneath the primary container base to reduce heat transfer from the foundation and so that heating of the ground if required, to prevent frost heave, can be minimized.

Base insulation shall be designed and specified to be able to withstand any kind of action combinations as defined in EN 14620.

The thermal expansion of components shall be taken into account; therefore insulation installed outside the primary container, when it is made up of expanded perlite, can be protected from settling, for example, by glass wool padding which absorbs variations in the diameter of the primary container.

The thermal insulation of a membrane tank shall withstand the hydrostatic load.

Insulation of spherical tanks shall be at the outside the sphere and shall not be not exposed to any internal hydraulic or mechanical actions.

External insulation shall be protected from moisture by cladding and the installation of vapour barrier.

Exposed insulation shall be non-combustible.

The quality of insulation shall be such that no single point of the external envelope (excluding penetrating components) of the tank will remain at a temperature below 0 °C by an air temperature above or equal to 5 °C. The relevant conditions (atmospheric, soil, design, etc.) have to be taken into account for the thickness calculations.

In case of above ground storage tanks the minimum wind speed to be considered is 1,5 m/s.

6.4.5 Operating actions

LNG Tanks shall be capable of withstanding the combinations of actions as defined in EN 14620 and those resulting from changes in temperature and pressure during:

- initial cool down and warm up to ambient temperature;
- filling and emptying cycles.

The manufacturer shall indicate the maximum rate of temperature change that the tank can withstand during cool down and warm up operations.

For self-supporting steel tanks, the primary container shall be designed to withstand the maximum differential pressure which could occur during all operating phases. A system shall be provided to prevent lifting of the floor, if required.

6.5 General design rules

The structures of the tank shall be designed to withstand at least the combination of actions defined in EN 14620.

In addition, structures and structural elements shall:

- maintain their characteristics during normal conditions, with regard to degradation, displacement, settling and vibration;
- have adequate safety margin with regard to resisting fatigue failure;
- have adequate ductile and crack arresting properties and little sensitivity to local damage;
- provide simple stress paths with small stress concentrations;
- be suitable for condition monitoring, maintenance and repair.

The design shall minimize any degradation of the rebar or concrete to prevent reduction of the structural integrity of the tank during its design life.

6.6 Foundations

Foundations are designed to prevent differential settling higher than the permissible limit for the raft.

The design of the foundation shall be such that frost heave is avoided either by position of the base slab or by heating systems. If a heating system is used it shall be capable of in service repair or replacement and have 100 % redundancy.

Seismological analysis and the geotechnical analysis of the nature of the ground shall define the criteria for foundation design. Seismic insulators may be required in order to reduce the consequences of an earthquake. They shall be replaceable without decommissioning of the tank.

The raft can be raised, laid on the ground, semi-buried or in-ground.

When the raft is raised, the clearance left shall be sufficiently large to permit natural circulation of air which will maintain the lower face of the raft at a temperature not more than 5 °C cooler than atmospheric temperature. Gas detectors shall be installed in this bottom space to monitor the presence or accumulation of gas in case of leak. The effect of over-pressurization due to ignition of flammable mixtures shall be evaluated and mitigated.

Spherical tanks founded on solid rock do not need any heating device when the ground is properly drained and the space between the insulation jacket and the rock is properly ventilated or purged.

6.7 Operating instruments

6.7.1 General

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

- liquid level indicators and/or switches;
- pressure indicators and/or switches;
- temperature indicators and/or switches;
- density indicator, (except at peak shaving plants if provisions as defined in EN ISO 16903 are taken to prevent roll-over).

In general, the reliability of such measurements is to be ensured by the following minimum arrangements:

- instrumentation should be able to be maintained in normal operation of the tank;
- instrumentation related to safety and operation for which maintenance requires dismantling shall have sufficient redundancy;
- threshold detectors which have a safety function (pressure, LNG level, etc.) are to be independent of the measurement sequence;
- measurements and alarms shall be transmitted to appropriate control room(s);
- in earthquake areas, critical alarms, e.g. pressure and level, shall be transmitted by duplicated, diverse routes to the central control room.