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Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface

Guide pour l'évaluation des risques dans la conception d'installations terrestres pour le GNL en incluant l'interface terre/navire

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*.

Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface

1 Scope

This Technical Specification provides a common approach and guidance to those undertaking assessment of the major safety hazards as part of the planning, design, and operation of LNG facilities onshore and at shoreline using risk-based methods and standards, to enable a safe design and operation of LNG facilities. The environmental risks associated with an LNG release are not addressed in this Technical Specification.

This Technical Specification is aimed to be applied both to export and import terminals, but can be applicable to other facilities such as satellite and peak shaving plants.

It applies to all facilities inside the perimeter of the terminal and all hazardous materials including LNG and associated products: LPG, pressurised natural gas, odorizers, and other flammable or hazardous products handled within the terminal.

The navigation risks and LNG tanker intrinsic operation risks are recognised, but they are not in the scope of this Technical Specification. Hazards arising from interfaces between port and facility and ship are addressed and requirements are normally given by port authorities. It is assumed that LNG carriers are designed according to the IGC code, and LNG fuelled vessels receiving bunker is designed according to IMO's regulations.

Border between port operation and LNG facility is when the ship/shore link (SSL) is established.

It is not intended to specify acceptable levels of risk; however, examples of tolerable levels of risk are referenced.

This Technical Specification is not intended to be used retrospectively.

It is recognised that national and/or local laws, regulations, and guidelines take precedence where they are in conflict with this Technical Specification.

Reference is made to ISO 31010 and ISO 17776 with regard to general risk assessment methods, while this Technical Specification focuses on the specific needs scenarios and practices within the LNG industry.

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

ISO/IEC Guide 73:2009, *Risk management — Vocabulary*

ISO 17776:2000, *Petroleum and natural gas industries — Offshore production installations — Guidelines on tools and techniques for hazard identification and risk assessment*.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 73 and the following apply.

3.1
as low as reasonably practical
ALARP
reducing a *risk* (3.26) to a level that represents the point, objectively assessed, at which the time, trouble, difficulty, and cost of further reduction measures become unreasonably disproportionate to the additional risk reduction obtained

3.2
boiling liquid expanding vapour explosion
BLEVE
sudden release of the content of a vessel containing a pressurised liquid and for flammables often followed by a fireball

Note 1 to entry: This hazard is not applicable to atmospheric LNG tanks, but to pressurized forms of hydrocarbon storage.

3.3
bow-tie
pictorial representation of how a hazard can be hypothetically released and further developed into a number of *consequences* (3.6)

Note 1 to entry: The left-hand side of the diagram is constructed from the fault tree (causal) analysis and involves those threats associated with the hazard, the controls associated with each threat, and any factors that escalate likelihood. The right-hand side of the diagram is constructed from the hazard event tree (consequence) analysis and involves escalation factors and recovery preparedness measures. The centre of the bow-tie is commonly referred to as the “top event”.

3.4
cost to avert a fatality
CAF
value calculated by dividing the costs to install and operate the protection/*mitigation* (3.18) by the reduction in *potential loss* (3.20) of life (PLL)

Note 1 to entry: It is a measure of effectiveness of the protection/mitigation.

3.5
computational fluid dynamics
CFD
numerical methods and algorithms to solve and analyse problems that involve fluid flows

3.6
consequence
outcome of an event

3.7
cost benefit analysis
CBA
means used to assess the relative cost and benefit of a number of *risk* (3.26) reduction alternatives

Note 1 to entry: The ranking of the risk reduction alternatives evaluated is usually shown graphically.

3.8
design accidental load
DAL
most severe accidental load that the function or system shall be able to withstand during a required period of time, in order to meet the defined *risk* (3.26) acceptance criteria

3.9
explosion barrier
structural barrier installed to prevent explosion damage in adjacent areas

Note 1 to entry: A wall is an example of an explosion barrier.

3.10
F/N curve
FN
plot of cumulative frequency versus N or more persons that sustain a given level of harm from defined sources of hazards

3.11
failure mode and effect analysis
FMEA
analytically derived identification of the conceivable equipment failure modes and the potential adverse effects of those modes on the system and mission

Note 1 to entry: It is primarily used as a design tool for review of critical components.

3.12
fatal accident rate
FAR
number of fatalities per 100 million hours exposure for a certain activity

3.13
harm
physical injury or damage to the health of people or damage to property or the environment

3.14
hazard
potential source of *harm* (3.13)

3.15
hazard identification
HAZID
brainstorming exercise using checklists the hazards in a project are identified and gathered in a *risk register* (3.37) for follow up in the project

3.16
hazard and operability study
HAZOP
systematic approach by an interdisciplinary team to identify hazards and operability problems occurring as a result of deviations from the intended range of process conditions

Note 1 to entry: All four steps are in place and recorded to manage a hazard completely.

3.17
impact assessment
assessment of how *consequences* (3.6) (fires, explosions, etc.) do affect people, structures the environment, etc.

3.18
mitigation
limitation of any negative *consequence* (3.6) of a particular event

3.19
Monte Carlo simulation
simulation having many repeats, each time with a different starting value, to obtain distribution function

3.20
potential loss
product of frequency and *harm* (3.13) summed over all the outcomes of a number of top events

3.21
probability
extent to which an event is likely to occur

3.22
probit
inverse cumulative distribution function associated with the standard normal distribution

Note 1 to entry: Probit is used in QRA to describe the relation between exposure, e.g. to radiation or toxics, and fraction fatalities.

3.23
protective measure
means used to reduce risk

3.24
quantitative risk assessment
QRA
techniques which allow the *risk* (3.26) associated with a particular activity to be estimated in absolute quantitative terms rather than in relative terms such as high or low

Note 1 to entry: QRA may be used to determine all risk dimensions, including risk to personnel, risk to the environment, risk to the installation, and/or the assets and financial interests of the company. Reference is made to ISO 17776:2000, B.12.

3.25
residual risk
risk (3.26) remaining after *protective measures* (3.23) have been taken

3.26
risk
combination of the *probability* (3.21) of occurrence of *harm* (3.13) and the severity of that harm

3.27
risk analysis
systematic use of information to identify sources and to estimate the *risk* (3.26)

3.28
risk assessment
overall process of *risk analysis* (3.27) and *risk evaluation* (3.31)

3.29
risk contour
RC
two dimensional representation of *risk* (3.26) on a map

Note 1 to entry: Also called individual risk contours (IRC) or location-specific risk (LSR).

3.30
risk criteria
terms of reference by which the significance of *risk* (3.26) is assessed

3.31
risk evaluation
procedure based on the *risk analysis* (3.27) to determine whether the *tolerable risk* (3.45) has been achieved

3.32
risk management
coordinated activities to direct and control an organization with regard to *risk* (3.26)

3.33
risk management system
set of elements of an organization's management system concerned with managing *risk* (3.26)

3.34
risk matrix
matrix portraying *risk* (3.26) as the product of *probability* (3.21) and *consequence* (3.6), used as the basis for risk determination

Note 1 to entry: Considerations for the assessment of probability are shown on the horizontal axis. Considerations for the assessment of consequence are shown on the vertical axis. Multiple consequence categories are included: impact on people, assets, environment and reputation. Plotting the intersection of the two considerations on the matrix provides an estimate of the risk.

3.35
risk perception
way in which a *stakeholder* (3.44) views a *risk* (3.26) based on a set of values or concerns

3.36
risk ranking
outcome of a qualitative *risk analysis* (3.27) with a numerical annotation of *risk* (3.26)

Note 1 to entry: It allows accident scenarios and their risk to be ranked numerically so that the most severe risks are evident and can be addressed.

3.37
risk register
hazard management communication document that demonstrates that hazards have been identified, assessed, are being properly controlled, and that recovery preparedness measures are in place in the event control is ever lost

3.38
risk transect
RT
representation of *risk* (3.26) as a function of distance from the hazard

3.39
rollover
sudden mixing of two layers in a tank resulting to a massive vapour generation

3.40
rapid phase transition
RPT
explosive change from liquid into vapour phase

Note 1 to entry: When two liquids at two different temperatures come into contact, explosive forces can occur, given certain circumstances. This phenomenon, called rapid phase transition (RPT), can occur when LNG and water come into contact. Although no combustion occurs, this phenomenon has all the other characteristics of an explosion. RPTs resulting from an LNG spill on water have been both rare and with relatively limited *consequences* (3.6).

3.41
safety
freedom from unacceptable *risk* (3.26)

3.42
SIMOPS
concatenation of simultaneous operations

Note 1 to entry: SIMOPS often refers to events such as maintenance or construction work in an existing plant when there are more personnel near a live operating plant and who are exposed to a higher level of *risk* (3.26) than normal.

3.43
showstopper
event or *consequence* (3.6) that produces an unacceptable level of *risk* (3.26) such that the project cannot proceed and where the level of risk cannot be mitigated to an acceptable level

3.44
stakeholder
any individual, group, or organization that can affect, be affected by, or perceive itself to be affected by a *risk* (3.26)

3.45
tolerable risk
risk (3.26) which is accepted in a given context based on the current values of society

4 Abbreviations

For the purposes of this Technical Specification, the following abbreviations apply:

ALARP	as low as reasonably practical;
BLEVE	boiling liquid expanding vapour explosion;
CAF	cost to avert a fatality;
CFD	computational fluid dynamics;
CBA	cost benefit analysis;
DAL	design accidental load;
EDP	emergency depressuring;
ERC	emergency release coupling;
ESD	emergency shutdown;
ETA	event tree analysis;
FAR	fatal accident rate;
FEED	front-end engineering design;
FEM	finite element method;
FN	frequency vs number (of affected individuals);
FMEA	failure mode and effect analysis;
FMECA	failure, modes, effects, and criticality analysis;
HAZID	hazard identification;
HAZOP	hazard and operability study;
HEMP	hazards and effects management process;
IR	individual risk contour;
LSR	location-specific risk;
LOPA	layers of protection analysis;
MTTF	mean time to failure;
MTTR	mean time to repair;

OBE operating basis earthquake;

PERC power emergency release coupler;

P&IDs process and instrument diagrams;

PIMS pipeline integrity management system;

PLL potential loss of life;

QRA quantitative risk assessment;

RC risk contour;

RPT rapid phase transition;

RT risk transect;

SIL safety integrity level;

SMS safety management system;

SSE safe shutdown earthquake;

SSL ship/shore link.

5 Safety Risk Management

5.1 Decision support framework for risk management

Safety risk management is integrated in the project development and decision making processes and need as consistent support for decisions in all phases of an LNG development but does not include the full operational lifecycle.

The approach to risk management should address the project-specific requirements as agreed between the different parties and stakeholders and also establish an agreed format to communicate risk and ensure that decisions are made in a consistent and agreed format through the life of the project.

The acceptance criteria including the format should be defined in compliance with regulations and company standards. The format of the acceptance criteria prescribes thereby the approach as discussed below.

There is a wide range of tools and approaches that can be used to support decisions related to risk management. UK Offshore Operators Association (UKOOA) presented a framework for decision support reflecting the significance of the decision as well decision context. The framework as shown for information in Figure 1 illustrates the balancing between use of codes and standards, QRA, and decision processes reflecting company and societal values.

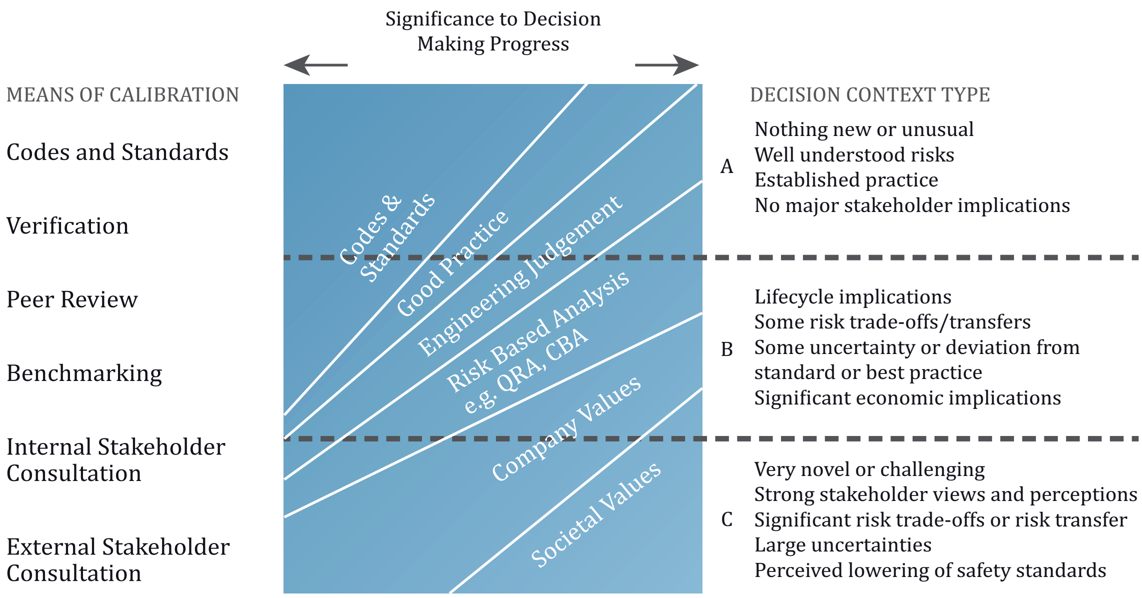

Figure 1 — Decision support framework for major accident risk management

5.2 Prescriptive safety or risk performance

Both prescriptive and risk-based approaches are used in the planning, design, and operation of LNG facilities.

Prescriptive approaches represent industry experience and practices.

The main advantages with prescriptive approaches are predictability and effective decision processes in the design.

The main objections to the use of prescriptive approaches are that they do not accommodate new solutions and thereby can limit novel development and improvement. Further, when the requirements are met, the prescriptive approaches do not encourage a continued effort for further improvements.

Risk-based approaches have developed in the nuclear and offshore industries. Risk-based approaches are used in many parts of the world and are gaining a wider usage.

In essence, risk-based approaches start from first principles aiming at demonstration that the risk acceptance criteria are met with a proper selection of design and operational measures. In principle, no “prescribed solutions” should be given as a starting point (but in reality, good industry experience, practices, and standards are adopted as the starting point).

The main advantage of a risk-based approach is that it does stimulate new and improved solutions; it encourages continuous focus on improved safety, and it focuses efforts on the key areas as formulated in the risk acceptance criteria.

Normally, a risk-based approach starts early and focuses the attention on the key issues that should be addressed in the different project phases. In most cases, a risk-based approach ensures that the correct decisions are made at the right time and thereby avoids costly revisions and adjustments. Further, the site specific conditions and particular stakeholder views are better reflected.

The main criticism to risk-based approaches focuses on the complexity of the process, and the line of responsibility can become unclear. It is essential that risk acceptance criteria are established and derived from national and international regulations and owner’s requirements.

It is often found that a risk-based design does not enable all engineering design disciplines to proceed on a firm design basis until the results from the risk analysis is available. This can have a schedule impact.

Further, the uncertainty involved due to e.g. lack of relevant failure data, model assumptions can make it difficult to relate to the results. A situation where detailed results from sophisticated computational models can generate false confidence in the results can lead to the wrong conclusion. The uncertainty is a particular concern when a risk-based approach is used to demonstrate that sensible safety measures are not needed.

Risk analyses shall not be used to deviate from good engineering practice.

Finally, it is often claimed that the lack of predictability leads to increased cost. But the savings earned by adopting novel solutions can be significant but difficult to quantify.

Successful use of a risk-based approach normally requires an iterative process where the first layouts and decision are based on experience and industry practice (i.e. prescriptive guidelines, standards for process design, etc.) and that this first estimate is qualified and improved using risk-based techniques.

Risk analyses also enable areas and causes of higher risk to be identified so that mitigation measures can be applied in a cost effective manner.

5.3 Risk assessment in relation to project development

Risk assessment is used for decision support.

The decisions being made in the different phases of a project development vary, and the need for decision support accordingly.

The available information and level of detail as input to any risk assessment increase as the planning progresses. As a result, the requirements to risk assessment techniques and results vary over the project phases, and this can represent a challenge in the communication of the results.

In the early phase of the planning where the key issue is to select business model and technical concept, the main risk activities are to establish risk criteria and safety targets, as well as to demonstrate absence of showstoppers. This requires qualitative approaches.

At this stage of project development, quantitative risk analyses have limited value as no detailed information to describe the facilities are available as input.

In the next phase, the risk assessment should provide quantitative risk information related to the land planning in support of the permitting process.

In later project phases where key issues are the design of mitigation measures, more detailed analyses are appropriate to provide a proper basis for project decisions.

In some jurisdictions, the planning process makes it difficult to modify proposals once they have been submitted to the planning authorities. This makes it difficult to modify the design to reduce risk as detailed engineering develops. This aspect should be considered in project planning.

The requirements, recommendations, and advice given in this Technical Specification reflect this need. Risk assessment and risk results shall always reflect the following:

a) the type of decision that shall be made;

b) effective utilization of available information.

Actions arising from reviews such as HAZID, risk matrix, HAZOP, etc., which are not closed out after the review, should be recorded in a tracking system (for example, a risk register). This should answer that items requiring action at later project stages (i.e. items for operating manuals, etc.) should not be overlooked or forgotten.

This varying level of details in the risk assessment process is illustrated in Table 1 which also is relevant to a wide range of different types of industrial risk assessment