TECHNICAL SPECIFICATION

# ISO/TS 16901

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

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



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# Contents

Page

# Foreword

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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).

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This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 9, *Production, transport and storage facilities for cryogenic liquefied gases*.



This second edition cancels and replaces the first edition (ISO/TS 16901:2015), which has been technically revised.

The main changes are as follows:

— reference to IGF code added to the scope;

— references updated in Clause 2 and the bibliography;

— definitions added for HSE critical activity and HSE critical element.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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

## 1 Scope

This document 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 document.

This document is applicable both to export and import terminals but can be applicable to other facilities such as satellite and peak shaving plants.

This document is applicable to all facilities inside the perimeter of the terminal and all hazardous materials including LNG and associated products: LPG, pressurized 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 document. 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 that LNG fuelled vessels receiving bunker fuel are designed according to IGF code.

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

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

See IEC 31010 and ISO 17776 with regard to general risk assessment methods, while this document focuses on the specific needs scenarios and practices within the LNG industry.



## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO Guide 73, *Risk management — Vocabulary*

## 3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

 

**3.1**
**as low as reasonably practicable**
**ALARP**
reducing a *risk* (3.28) 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 pressurized flammable liquid followed by a fireball

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

[SOURCE: ISO/TS 18683, 3.1.2, modified — Note to entry added.]

**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* (3.20) by the reduction in *potential loss* (3.22) 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* (3.28) 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 is able to withstand during a required period of time, in order to meet the defined *risk* (3.28) acceptance criteria

 

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

EXAMPLE A wall.

**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* (3.39) 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: It consists of four steps: definition, preparation, documentation/follow up and examination to manage a hazard completely.

**3.17**
**health, safety and environmental critical activity**
**HSE critical activity**
activity or task that provides or maintains barriers

**3.18**
**health, safety and environmental critical element**
**HSE critical element**
component or system whose failure could cause or substantially contribute to the loss of integrity and safety of a system and whose purpose is to prevent or mitigate from the effects of hazards

**3.19**
**impact assessment**
assessment of how *consequences* (3.6) (fires, explosions, etc.) do affect people, structures the environment, etc.

**3.20**
**mitigation**
limitation of any negative *consequence* (3.6) of a particular event

**3.21**
**Monte Carlo simulation**
simulation having many repeats, each time with a different starting value, to obtain distribution function

**3.22**
**potential loss**
product of frequency and *harm* (3.13) summed over all the outcomes of a number of top events

**3.23**
**probability**
extent to which an event is likely to occur

**3.24**
**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.

**3.25**
**protective measure**
means used to reduce risk



**3.26**
**quantitative risk assessment**
**QRA**
techniques that allow the *risk* (3.28) 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. See ISO 17776:2016, B.12.

**3.27**
**residual risk**
*risk* (3.28) remaining after *protective measures* (3.25) have been taken

**3.28**
**risk**
combination of the *probability* (3.23) of occurrence of *harm* (3.13) and the severity of that harm

**3.29**
**risk analysis**
systematic use of information to identify sources and to estimate the *risk* (3.28)

**3.30**
**risk assessment**
overall process of *risk analysis* (3.29) and *risk evaluation* (3.33)

**3.31**
**risk contour**
**RC**
two-dimensional representation of *risk* (3.28) on a map

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

**3.32**
**risk criteria**
terms of reference by which the significance of *risk* (3.28) is assessed

**3.33**
**risk evaluation**
procedure based on the *risk analysis* (3.29) to determine whether the *tolerable risk* (3.47) has been achieved

**3.34**
**risk management**
coordinated activities to direct and control an organization with regard to *risk* (3.28)

**3.35**
**risk management system**
set of elements of an organization's management system concerned with managing *risk* (3.28)

**3.36**
**risk matrix**
matrix portraying *risk* (3.28) as the product of *probability* (3.23) 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, environment, assets, and reputation. Plotting the intersection of the two considerations on the matrix provides an estimate of the risk.



**3.37**
**risk perception**
way in which a *stakeholder* (3.46) views a *risk* (3.28) based on a set of values or concerns

**3.38**
**risk ranking**
outcome of a qualitative *risk analysis* (3.29) with a numerical annotation of *risk* (3.28)

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.

**3.39**
**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

**3.40**
**risk transect**
**RT**
representation of *risk* (3.28) as a function of distance from the hazard

**3.41**
**rollover**
sudden mixing of two layers in a tank resulting to a massive vapour generation

**3.42**
**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).

**3.43**
**safety**
freedom from unacceptable *risk* (3.28)

**3.44**
**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* (3.28) than normal.

**3.45**
**showstopper**
event or *consequence* (3.6) that produces an unacceptable level of *risk* (3.28) such that the project cannot proceed and where the level of risk cannot be mitigated to an acceptable level



**3.46**
**stakeholder**
individual, group, or organization that can affect, be affected by, or perceive itself to be affected by a *risk* (3.28)



**3.47**
**tolerable risk**
*risk* (3.28) that is accepted in a given context based on the current values of society

**3.48**
**individual risk**
probability of being killed (or harmed at certain level) on an annual basis from all *hazards* (3.13)

**3.49**
**potential loss of life**
expected value of the number of fatalities per year (or over the life time of a project)

## 4 Abbreviated terms

| | |
|---|---|
| ALARP | as low as reasonably practicable |
| 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 |
| HSE | health, safety and environmental |
| 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 conformity with 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.

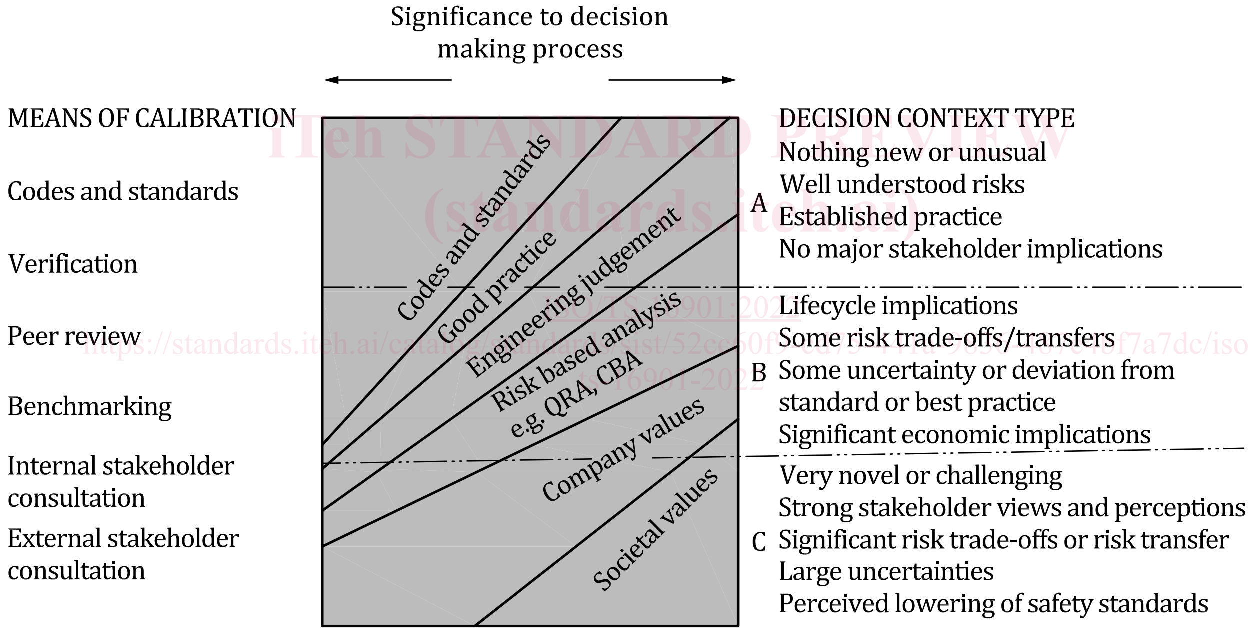




**Figure 1 — Decision support framework for risk management**

## 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 stimulates 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 owner’s requirements. National and international regulations can apply.

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.



 