

Risk and emergency preparedness assessment

This NORSOK standard is developed with broad petroleum industry participation by interested parties in the Norwegian petroleum industry and is owned by the Norwegian petroleum industry represented by The Norwegian Oil Industry Association (OLF) and The Federation of Norwegian Industry. Please note that whilst every effort has been made to ensure the accuracy of this NORSOK standard, neither OLF nor The Federation of Norwegian Industry or any of their members will assume liability for any use thereof. Standards Norway is responsible for the administration and publication of this NORSOK standard.

Standards Norway
Strandveien 18, P.O. Box 242
N-1326 Lysaker
NORWAY

Telephone: + 47 67 83 86 00
Fax: + 47 67 83 86 01
Email: petroleum@standard.no
Website: www.standard.no/petroleum

Copyrights reserved

Foreword	5
Introduction	5
1 Scope	7
2 Normative and informative references	7
2.1 Normative references	7
2.2 Informative references	7
3 Terms, definitions and abbreviations	8
3.1 Terms and definitions	8
3.2 Abbreviations	15
4 The role and use of assessments in risk management	16
4.1 Risk assessment: A key element in risk management	16
4.2 The process of performing a risk and emergency preparedness assessment	17
5 General requirements for a risk assessment process	18
5.1 General	18
5.2 Establishing the context for a risk assessment process	19
5.3 Hazard identification (HAZID)	22
5.4 Analysis of initiating events	23
5.5 Analysis of potential consequences	24
5.6 Establishing the risk picture	25
5.7 Risk evaluation	28
5.8 Communication and consultation	28
5.9 Monitoring, review and updating the risk assessment	29
6 Additional requirements to quantitative risk analysis (QRA) in concept selection phase	30
6.1 General	30
6.2 Establishing the context	30
6.3 Hazard identification (HAZID)	31
6.4 Analysis of initiating events	31
6.5 Analysis of consequences	31
6.6 Establishing the risk picture	32
6.7 Risk evaluation	32
6.8 Communication and consultation	32
6.9 Monitoring, review and updating the risk assessment	32
7 Additional requirements to quantitative risk analysis (QRA) in concept definition, optimization and detailed engineering phases	33
7.1 General	33
7.2 Establishing the context	33
7.3 Hazard identification	33
7.4 Analysis of initiating events	34
7.5 Analysis of consequences	37
7.6 Establishing the risk picture	44
7.7 Risk evaluation	44
7.8 Communication and consultation	44
7.9 Monitoring, review and updating the risk assessment	44
8 Additional requirements to quantitative risk analysis (QRA) in operational phase	44
8.1 General	44
8.2 Establishing the context	45
8.3 Hazard identification	46
8.4 Analysis of initiating events	46
8.5 Analysis of consequences	46
8.6 Establishing the risk picture	47
8.7 Risk evaluation	47
8.8 Communication and consultation	47
8.9 Monitoring, review and updating the risk assessment	47
9 General requirements for emergency preparedness assessment	47
9.1 General	47

9.2	Establish the context of the assessment	49
9.3	Hazard identification (HAZID)	51
9.4	Identify defined situations of hazards and accident	51
9.5	Governing performance requirements	51
9.6	Identify and evaluate	52
9.7	Documentation of assessment	53
9.8	Communication and consultation	53
9.9	Monitoring, review and updating of the emergency preparedness assessment	53
10	Evaluation of emergency preparedness in concept selection phase	54
10.1	Establish the context of the assessment	54
10.2	Hazard identification (HAZID)	55
10.3	Identify defined situations of hazards and accident	55
10.4	Governing performance requirements	55
10.5	Identify and evaluate	55
10.6	Documentation of assessment	56
11	Emergency preparedness analysis (EPA) in concept definition, optimisation and detailed engineering phases	56
11.1	Establish the context of the assessment	56
11.2	Hazard identification (HAZID)	57
11.3	Defined situations of hazards and accident (DSHA)	58
11.4	Governing performance requirements	58
11.5	Identify and evaluate	58
11.6	Documentation of assessment	59
12	Emergency preparedness analysis (EPA) in operational phase	59
12.1	Establish the context of the assessment	59
12.2	Hazard identification (HAZID)	60
12.3	Defined situations of hazards and accident (DSHA)	60
12.4	Governing performance requirements	61
12.5	Identify and evaluate	61
12.6	Documentation of assessment	62
	Annex A (informative) Risk metrics, criteria and ALARP evaluations	63
	Annex B (informative) Assessment of loss of main safety functions (offshore only)	71
	Annex C (informative) Hazard identification (HAZID) check lists	79
	Annex D (informative) Recognised data sources	83
	Annex E (informative) Probabilistic fire analysis (HOLD)	91
	Annex F (informative) Procedure for probabilistic explosion simulation	92
	Annex G (informative) Environmental risk and environmental preparedness and response analysis	102

Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are, as far as possible, intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable for most standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by The Norwegian Oil Industry Association (OLF), The Federation of Norwegian Industry, Norwegian Shipowners' Association and The Petroleum Safety Authority Norway.

NORSOK standards are administered and published by Standards Norway.

All annexes are informative.

Introduction

The purpose of this NORSOK standard is to establish requirements for effective planning and executive of risk and/or emergency preparedness assessment. This NORSOK standard has emphasis on requirements related to ensuring that the process of conducting such assessments are suitable for their intended purposes, rather than detailed requirements related to how the assessment and the various hazards typically included in such assessment should be analyzed.

This NORSOK standard is structured around the following main elements:

- use of risk and emergency preparedness assessment as a basis for decision-making. General requirements for planning and execution of risk and emergency preparedness assessments regardless of activity and life cycle phase;
- specific requirements for planning and execution of risk and emergency preparedness assessments for different activities and life cycle phases;
- the relation between the risk and emergency preparedness assessments, especially the integration of the two types of assessments into one overall assessment process.

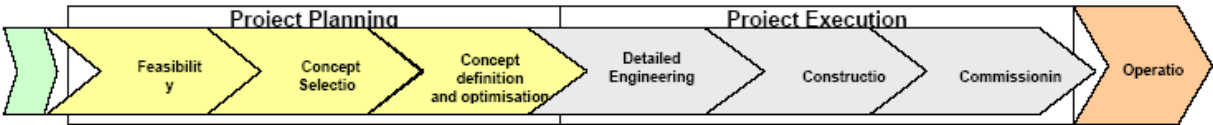
Clause 5 and Clause 9 describe the general requirements for risk assessments and emergency preparedness assessments, respectively.

Requirements for risk and emergency preparedness assessments for some defined life cycle phases are described in separate clauses. The phases included and the sections in which they are covered are:

	Risk assessment	EPA
Project planning:		
• Concept selection	(Clause 6)	(Clause 10)
• Concept definition and optimization	(Clause 7)	(Clause 11)
Project execution:	(Clause 7)	(Clause 11)
• Detailed engineering		
Operation (including small modifications)	(Clause 8)	(Clause 12)

For assessments in feasibility, construction and commissioning, cessation phases, as well as assessments of specific activities during the operational phases, the general requirements in Clause 5 and Clause 9 apply.

Project life cycle phases are illustrated in the figure below.



1 Scope

This NORSOK standard describes risk and emergency preparedness assessments for offshore and onshore facilities for production of oil and gas. Where applicable, this NORSOK standard may also be used for mobile offshore drilling units.

This NORSOK standard covers the process of planning and execution of risk and emergency preparedness assessments, including how to establish the risk picture and the assessment of potential risk reducing measures. Risk treatment, i.e. the process and decisions related to how to deal with identified risks (e.g. acceptance, the need for modifications and/or implementation of risk reducing measures) are, however, not covered by this standard. Nor is the establishment of risk acceptance criteria covered by this NORSOK standard.

This NORSOK standard covers risk for major accidents. Analysis of occupational fatalities and injuries are not covered in this NORSOK standard although this risk contribution from occupational fatalities often is included in risk calculations. Nor does the standard cover occupational health risk aspects, including physical and psychological working environment, working environment mapping and analysis.

This NORSOK standard covers requirements related to the risk assessment processes which include a quantitative risk analysis.

NOTE Requirements related to qualitative risk analysis are only briefly addressed.

This NORSOK standard does not cover security aspects, except from some implications for the emergency preparedness analyses.

2 Normative and informative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet the requirements of the referenced standards.

2.1 Normative references

IEC 61508,	Functional safety of electrical/electronic/programmable electronic safety related systems – (all parts)
IEC 61511,	Functional safety instrumented systems for the process industry sector – (all parts)
ISO 17776,	Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for identification and assessment of hazards
ISO/IEC 31000,	Risk management, principles and guidelines on implementation
NORSOK N-001,	Structural design
NORSOK N-004,	Design of steel structures
NORSOK S-001,	Technical safety
OLF GL 070,	Guidelines for the application of IEC 61508 and IEC 61511 in the petroleum activities on the Norwegian continental shelf

2.2 Informative references

DNV report 2005-1221 rev 4 September 2006,	Anbefalte feildata for rørledninger
DNV report 2009-1115: rev HOLD, November 2010,	
ISO 13702,	Petroleum and natural gas industries - Offshore production installations - Control and Mitigation of Fires and Explosions - Requirements and guidelines
FABIG Technical note 8, 2005,	Protection of piping systems subject to fires and explosions

3 Terms, definitions and abbreviations

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

3.1.1

accidental event

AE

event or a chain of events that may cause loss of life or damage to health, assets or the environment

NOTE The accidental events that are considered in risk and emergency preparedness analyses are acute, unwanted and unplanned. For instance; planned operational exposure that may be hazardous to health or to the environment, is usually not considered as an accidental event.

3.1.2

area exposed by the accidental event

AEAE

area(s) on the facility (or its surroundings) exposed by the accidental event

NOTE 1 An area (fire area or main area) shall be considered included as a part of the AEAE if the AE may cause loss of life or damage to health and/or assets in the area. The AEAE may be limited to a single fire area, or it may include several fire areas or several main areas.

NOTE 2 For some AE the AEAE may expand after a period of time due to the evolvement of the accidental event (e.g. due to impairment of a fire wall after a period of time).

3.1.3

area risk

risk personnel located in an area is exposed to during a defined period of time

3.1.4

as low as reasonably practicable

ALARP

ALARP expresses that the risk shall be reduced to a level that is as low as reasonably practicable

NOTE 1 ALARP expresses that the risk is reduced (through a documented and systematic process) so far that it is not justifiable to implement any additional risk reducing measures.

NOTE 2 The term reasonably practicable implies that risk reducing measures shall be implemented until the cost (in a wide sense, including time, capital costs or other resources/assets) of further risk reduction is grossly disproportional to the potential risk reducing effect achieved by implementing any additional measure.

3.1.5

average individual risk

AIR

risk an average individual is exposed to during a defined period of time

NOTE 1 The average individual risk may be established for defined groups of personnel and/or for all personnel on a facility.

NOTE 2 The average individual risk may be established by combining the fraction of time an individual, representing an average member of the relevant group of personnel, is located in various areas and the area risk in each of the areas.

3.1.6

barrier element

physical, technical or operational component in a barrier system

3.1.7

barrier function

function planned to prevent, control, or mitigate undesired or accidental events

3.1.8

barrier system

system designed and implemented to perform one or more barrier function

3.1.9**can**

verbal form used for statements of possibility and capability, whether material, physical or casual

3.1.10**defined situations of hazard and accident****DSHA**

selection of hazardous and accidental events that will be used for the dimensioning of the emergency preparedness for the activity

NOTE 1 The selection will be representative for possible hazards and accidental events for the facilities and activities, and includes DAEs, hazardous and accidental situations associated with a temporary increase of risk and less extensive accidental events, e.g. man overboard situations, limited oil spills exceeding the stipulated discharge limits, occupational accidents, etc.

NOTE 2 Situations associated with a temporary increase of risk, may involve drifting objects, work over open sea, unstable well in connection with well intervention, 'hot' work, jacking up and down of jack-up installations, special operations and environmental conditions, etc.

3.1.11**design accidental load**

chosen accidental load that is to be used as the basis for design

NOTE 1 The applied/chosen design accidental load may sometimes be the same as the dimensioning accidental load (DAL), but it may also be more conservative based on other input and considerations such as ALARP. Hence, the design accidental load may be more severe than the DAL.

NOTE 2 The design accidental load should as a minimum be capable of resist the dimensioning accidental load (DAL).

3.1.12**dimensioning accidental event****DAE**

accidental events that serve as the basis for layout, dimensioning and use of installations and the activity at large

3.1.13**dimensioning 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 acceptance criteria

NOTE 1 DAL is normally defined based on DAE.

NOTE 2 The dimensioning accidental load (DAL) are typically generated as a part of a risk assessment, while the design accidental load may be based on additional assessments and considerations.

NOTE 3 The dimensioning accidental load (DAL) are typically established as the load that occurs with an annual probability of 1×10^{-4} .

3.1.14**emergency preparedness**

technical, operational and organisational measures, including necessary equipment that are planned to be used under the management of the emergency organisation in case hazardous or accidental situations occur, in order to protect human and environmental resources and assets

3.1.15**emergency preparedness analysis****EPA**

analysis which includes establishment of DSHA, including major DAEs, establishment of emergency response strategies and performance requirements for emergency preparedness and identification of emergency preparedness measures, including environmental emergency and response measures

3.1.16**emergency preparedness assessment**

overall process of performing a emergency preparedness assessment including: establishment of the context, performance of the EPA, identification and evaluation of measures and solutions and to recommend strategies and final performance requirements, and to assure that the communication and consultations and monitoring and review activities, performed prior to, during and after the analysis has been executed, are suitable and appropriate with respect to achieving the goals for the assessment

NOTE Emergency preparedness assessment does not include establishment of emergency preparedness.

3.1.17

emergency preparedness philosophy

overall guidelines and principles for establishment of emergency response based on the operator vision, goals, values and principles

3.1.18

emergency response

action taken by personnel, on or off the installation, to control or mitigate a hazardous event or initiate and execute abandonment

3.1.19

emergency response strategy

specific description of emergency response actions for each DSHA

NOTE 1 Emergency response strategies shall be the basis for the establishment of the emergency response plan

NOTE 2 To illustrate the variability of each DSHA, more than one scenario description may be developed for each DSHA. The specific strategies may therefore be defined for each of the scenarios.

3.1.20

environment

surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans and their interrelation

3.1.21

environmental impact

any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services

3.1.22

escalation

escalation has occurred when the area exposed by the accidental event (AEAE) covers more than one fire area or more than one main area

NOTE 1 The definition of escalation covers both a) immediate escalation: Escalation due to the initial accidental event (e.g. an initial explosion causing impairment of a fire and/or explosion wall separation two neighbouring areas) and b) Delayed escalation: Escalation occurring at any time after the initial accidental event has occurred (e.g. a fire causing the impairment of a fire wall separation two neighbouring areas after a period of time).

NOTE 2 An escalation is either internal or external, see 3.1.29 and 3.1.40.

3.1.23

escape route

route from an intermittently manned or permanently manned area of a facility leading to safe area(s)

3.1.24

establishment of emergency preparedness

systematic process which involves selection and planning of suitable emergency preparedness measures on the basis of risk and emergency preparedness analysis

3.1.25

emergency preparedness organisation

organisation which is planned, established and trained in order to handle occurrences of hazardous or accidental situations

NOTE The emergency preparedness organisation includes personnel on the installation as well as onshore, and includes all personnel resources that will be activated during any occurred situation of hazard or accident.

3.1.26

essential safety system

system which has a major role in the control and mitigation of accidents and in any subsequent EER activities

3.1.27

evacuation

planned method of leaving the facility in an emergency

NOTE 1 For offshore facilities the methods are normally by bridge to neighbour facility not exposed to the accidental event or by helicopter, lifeboat etc.

NOTE 2 For onshore facilities the methods are normally by getting out of the plant area.

3.1.28

explosion load

time dependent pressure or drag forces generated by violent combustion of a flammable atmosphere

3.1.29

external escalation

when the area exposed by the accidental event (AEAE) covers more than one main area, external escalation has occurred

3.1.30

facility

offshore or onshore petroleum installation, facility or plant for production of oil and gas

3.1.31

fire area

area separated from other areas on the facility, either by physical barriers (fire/blast partition) or distance, which will prevent a dimensioning fire to escalate

3.1.32

group individual risk

GIR

average IR for a defined group

3.1.33

hazard

potential source of harm

NOTE In the context of this Standard, the potential harm may relate to loss of life, or damage to health, the environment or assets or a combination of these.

3.1.34

hazardous event

incident which occurs when a hazard is realized

3.1.35

immediate vicinity of the scene of accident

main area(s) where an accidental event (AE) has its origin

NOTE 1 In case of an AE occurring in one main area personnel located in other main areas are considered to be outside the immediate vicinity of the scene of accident.

NOTE 2 The main safety function: "preventing escalation of accident situations so that personnel outside the immediate vicinity of the scene of accident are not injured" shall be considered as impaired if and when external escalation has occurred in the period before.

3.1.36

individual risk

IR

risk an individual is exposed to during a defined period of time.

NOTE The individual risk may be established by combining the fraction of time an individual is located in various areas and the area risk in each of the areas.

3.1.37

informative reference

reference used informative in the application of NORSOK Standards.

3.1.38

inherently safer design

In inherently safer design, the following concepts are used to reduce risk:

- reduction, e.g. reducing the hazardous inventories or the frequency or duration of exposure;
- substitution, e.g. substituting hazardous materials with less hazardous ones (but recognizing that there could be some trade-offs here between plant safety and the wider product and lifecycle issues);
- attenuation, e.g. using the hazardous materials or processes in a way that limits their hazard potential, such as segregating the process plant into smaller sections using ESD valves, processing at lower temperature or pressure;
- simplifications, e.g. making the plant and process simpler to design, build and operate, hence less prone to equipment, control and human failure.

3.1.39

intermittently manned

work area or work place where inspection, maintenance or other work is planned to last between 2 h and 8 h a day for at least 50 % of the installation's operation time

3.1.40

internal escalation

when the area exposed by the accidental event (AEAE) covers more than one fire area within the same main area, internal escalation has occurred

3.1.41

main area

defined part of the facility with a specific functionality and/or level of risk

NOTE 1 A main area may consist of one or several fire areas.

NOTE 2 The defined main areas shall be separated by distance, by use of physical barriers as fire and blast divisions or by a combination of these to prevent external escalation.

NOTE 3 For an offshore installation the following main areas shall as a minimum be defined when relevant: a) accommodation (living quarter), b) utility, c) drilling d) wellhead, e) process and f) hydrocarbon storage.

NOTE 4 For a land-based facility the following main areas shall as a minimum be defined when relevant: a) administration building, b) central control room, c) process area, d) utility area, e) storage area, f) loading/unloading area and g) landfall.

3.1.42

main load bearing structures

structure, which when it loses its main load carrying capacity, may result in a collapse or loss of either the main structure of the installation or the main support frames for the deck

3.1.43

main safety function

most important safety functions that need to be intact in order to ensure the safety for personnel and/or to limit pollution

3.1.44

major accident

acute occurrence of an event such as a major emission, fire, or explosion, which immediately or delayed, leads to serious consequences to human health and/or fatalities and/or environmental damage and/or larger economical losses

NOTE This definition is not completely in accordance with the SEVESO2-directive:

'major accident' shall mean an occurrence such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any establishment covered by this Directive, and leading to serious danger to human health and/or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances'.

3.1.45

may

verbal form used to indicate a course of action permissible within the limits of this NORSOK standard

3.1.46

normally unmanned

work area or workplace that is not permanently or intermittently manned

3.1.47

normalisation

the normalisation phase starts when the development of a situation of hazard or accident has stopped.

NOTE Measures related to personnel safety in the normalization phase includes

- organizing transportation of injured or sick personnel,
- transportation of rescued personnel from safe area to the land-based health service,
- transportation of evacuated personnel from safe area to a land-based reception facility when needed,
- re-establish the normal operation of the facility.

3.1.48

performance requirements for safety and emergency preparedness

requirements to the performance of safety and emergency preparedness measures which ensure that safety objectives, RAC, authority minimum requirements and established norms are satisfied during design and operation

NOTE - The term 'performance' is to be interpreted in a wide sense regarding personnel, environment and assets and include availability, reliability, capacity, mobilisation time, functionality, vulnerability, personnel competence, expressed as far as possible in a verifiable manner.

3.1.49

permanently manned

work area or workplace manned at least 8 h a day for at least 50 % of the installation's operation time

3.1.50

recovery time

time from an accidental event causing environmental damage occurs until the biological features have recovered to a pre-spill state or to a new stable state taking into consideration natural ecological variations, and are providing ecosystem services comparable to the pre-spill services

NOTE Populations are considered to be recovered when the population is 99% of the pre-spill population.

3.1.51

risk

combination of the probability of occurrence of harm and the severity of that harm

NOTE - Risk may be expressed qualitatively as well as quantitatively. Probability may be expressed as a probability value (0-1, dimensionless) or as a frequency, with the inverse of time as dimension.

3.1.52

risk acceptance criteria

RAC

criteria that are used to express a risk level that is considered as the upper limit for the activity in question to be tolerable

NOTE RAC are used in relation to risk analysis and express the level of risk tolerable for the activity, and is the starting point for further risk reduction according to the ALARP-principle, see also 3.1.2. Risk acceptance criteria may be qualitative or quantitative.

3.1.53

risk analysis

structured use of available information to identify hazards and to describe risk

NOTE 1 The risk analysis term covers several types of analyses that will all assess causes for and consequences of accidental events, with respect to risk to personnel, environment and assets. Examples of the simpler analyses are SJA, FMEA, preliminary hazard analysis, HAZOP, etc.

NOTE 2 Quantitative analysis may be the most relevant in many cases, involving a quantification of the probability and the consequences of accidental events, in a manner which allows comparison with quantitative RAC.

3.1.54

risk assessment

overall process of performing a risk assessment including: Establishment of the context, performance of the risk analysis, risk evaluation, and to assure that the communication and consultations, monitoring and review activities, performed prior to, during and after the analysis has been executed, are suitable and appropriate with respect to achieving the goals for the assessment

NOTE See Figure 3.

3.1.55

risk evaluation

judgement, on the basis of risk analysis and RAC, of whether a risk is tolerable or not

3.1.56

risk picture

synthesis of the risk assessment, with the intention to provide useful and understandable information to relevant decision makers

NOTE Establishing the risk picture includes reporting of the risk assessment process.

3.1.57

rooms of significance to combating accidental events

CCR and other equivalent room(s) that are essential for safe shutdown, blowdown and emergency response

NOTE E.g. the room/area where the BOP control panel is located if and when drilling or well operations are performed (offshore), or the part of substations incorporating ESD and F&G nodes and essential power supply (onshore).

3.1.58

safe area(s)

area(s) which, depending on each specific defined situation of hazard and accident (DSHA), are defined as safe until the personnel are evacuated or the situation is normalized.

NOTE E.g. mustering area(s), life boat stations, helicopter deck or bridge connected neighboring installation. As the safe area(s) are specific to each DSHA the area(s) may differ depending on the DSHA.

3.1.59

safety barrier

physical or non-physical means planned to prevent, control, or mitigate undesired events or accidents

3.1.60

safety function

measures which reduce the probability of a situation of hazard and accident occurring, or which limit the consequences of an accident

3.1.61

safety objective

objective for the safety of personnel, environment and assets towards which the management of the activity will be aimed

NOTE Safety objectives will imply short or long term objectives that have been established for the activity, while the RAC express the level of risk (in relation to the risk analysis) that is currently acceptable.

3.1.62

shall

verbal form used to indicate requirements strictly to be followed in order to conform to this NORSOK standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.63**should**

verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required

3.1.64**system**

common expression for installation(s), plant(s), system(s), activity/activities, operation(s) and/or phase(s) subjected to the risk and/or emergency preparedness assessment

3.1.65**system basis**

inputs (regarding the system subjected to assessment) used as basis for the assessment

3.1.66**system boundaries**

system boundaries defines what shall and what shall not be subjected to the assessment

3.2 Abbreviations

AE	accidental event
AEAE	area exposed by the accidental event
AIR	average individual risk
ALARP	as low as reasonably practicable
ALS	accidental collapse limit state
BLEVE	boiling liquid expanding vapour explosion
BOP	blowout preventer
CAD	computer aided design
CCR	central control room
CFD	computational fluid dynamics
CODAM	Corrosion DAMage
DSHA	defined situations of hazard and accident
DAE	dimensioning accidental event
DAL	dimensioning accidental load
DNV	Det Norske Veritas
DP	dynamic positioning
EER	escape, evacuation and rescue
EnvRA	environmental risk analysis
EPA	emergency preparedness analysis
ER	emergency response
ERS	emergency response strategy
ESD	emergency shutdown
ESV	emergency shutdown valve
F&G	fire and gas
FAR	fatal accident rate
FMEA	failure mode and effect analysis
GIR	group individual risk
HAZID	hazard identification
HAZOP	hazard and operability study
HC	hydrocarbons
HSE	health and safety executive
IEC	International Electrotechnical Commission
IR	individual risk
IRPA	individual risk per annum
ISO	International Organization for Standardization
LEL	lower explosive limit
MSF	main safety function
NCS	Norwegian Continental Shelf
NOFO	Norwegian Clean Seas Association for Operating Companies
OGP	International Association of Oil & Gas Producers

OLF	The Norwegian Oil Industry Association
P&ID	piping and instrument diagram
PARLOC	Offshore North Sea Pipeline and Riser Loss of Containment Study
PFD	process flow diagram
PLL	potential loss of life
PSA	Petroleum Safety Authority
QRA	quantitative risk analysis
RAC	risk acceptance criteria
SIL	safety integrity level
SJA	safe job analysis
UEL	upper explosive limit
UKCS	United Kingdom Continental Shelf
UKOOA	United Kingdom Offshore Operators Association

4 The role and use of assessments in risk management

4.1 Risk assessment: A key element in risk management

The elements of a risk management process according to ISO/IEC 31000 are illustrated in Figure 1. Risk assessment, which include: risk identification, risk analysis and risk evaluation, is a key element in a risk management process.

ISO/IEC 31000 emphasises the importance of establishing the context prior to starting or executing any of the elements included in the process, and the importance of updating the context throughout the process. It also emphasises the importance of communication, consultation, monitoring and review throughout the entire process.

Although risk management in general is a subject beyond the scope of this NORSOK standard, the same structure, principles and model as the one used in ISO/IEC 31000 have been applied for the processes of performing a risk and emergency preparedness assessment covered by this NORSOK standard. The main difference is that the element “risk treatment” is not covered. The establishment of the context, communication and consultation, as well as monitoring and review, are included as a part of the assessment. Establishment of emergency preparedness is part of risk treatment and not part of an emergency preparedness assessment. Thus, the establishment of emergency preparedness is not covered by this NORSOK standard.

A complete risk reduction process (often referred to as ALARP process or evaluation) is part of risk treatment, and as such not part of this NORSOK standard, in accordance with the previous paragraph. However, in an ALARP demonstration process the risk analysis process may be used for the identification of potential risk reducing measures and evaluation of risk reducing measures.

An illustration of how the ISO/IEC 31000 principle has been used and modified in this NORSOK standard is illustrated in Figure 1.

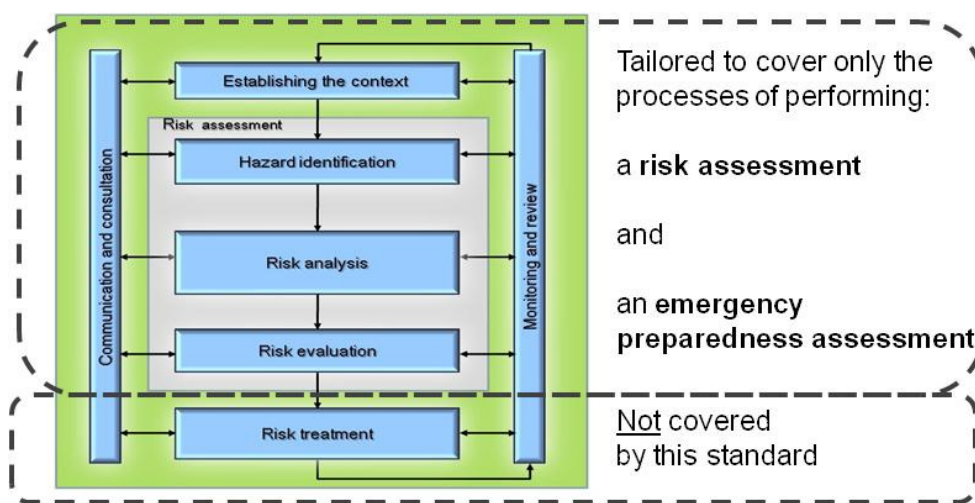


Figure 1 Use of ISO/IEC 31000 in this NORSOK standard

4.2 The process of performing a risk and emergency preparedness assessment

This NORSOK standard covers both a) the process of performing a risk assessment and b) the process of performing an emergency preparedness assessment. The standard is structured in a way that makes it easy to identify the requirements applicable for the two processes separately. Hence, the standard may be used when only one of the two processes is to be performed. However, if/when both processes are to be performed “simultaneously”, or during the same phase of a project, the two processes should as far as possible be integrated and/or coordinated. Input data used and results generated from one process will in many cases be used as input to the other process and vice versa. Thus, to some extent the two processes become one.

An illustration of the “common” or joint process of performing a risk assessment and an emergency preparedness analysis is presented in Figure 2. The figure illustrates the process of performing both processes “simultaneously” and thus illustrates what is common for the two processes and how they interact.

This common process and the elements included found the basis for the way the requirements related to risk and emergency preparedness assessments are structured in this NORSOK standard. The same process and the same elements are therefore used in each main section covering risk assessments or emergency preparedness assessments in general and/or for a specific phase (i.e. the concept selection phase), the concept definition and optimization phase, detailed engineering phase or the operational phase. The elements included in the processes are illustrated by the boxes in Figure 2.

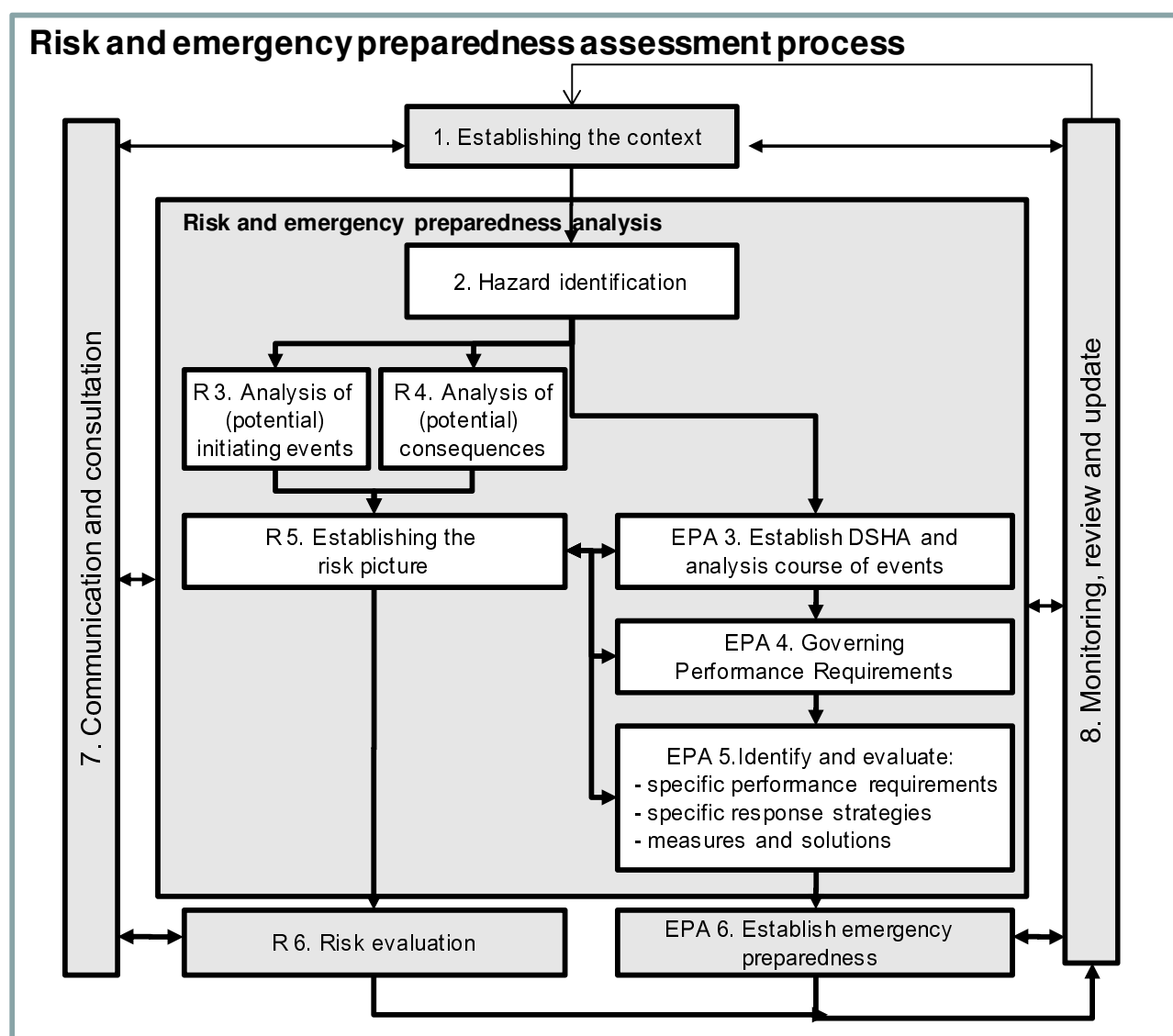


Figure 2 The process of performing a risk and emergency preparedness assessment

A description of the risk assessment process and the various elements included in the process is given in Clause 5. A description of the emergency preparedness assessment process and the various elements included in the process is given in Clause 9.

GENERAL REQUIREMENTS, i.e. requirements applicable for risk assessments and emergency preparedness assessments in all phases covered by this NORSOK standard, are also given in Clause 5 and Clause 9.

PHASE SPECIFIC REQUIREMENTS, i.e. requirements applicable for risk assessments and/or emergency preparedness assessments in one of the phases covered by this NORSOK standard (i.e. the concept selection phase, the concept definition and optimization phase, detailed engineering phase or the operational phase) are given in separate clauses. These requirements are to be considered as supplementary requirements to the general requirements.

Thus, in order to be in compliance with this Standard when conducting a risk assessment and/or an emergency preparedness assessment for a specific phase both the general requirements and the phase specific requirements for the specific phase shall be complied with.

5 General requirements for a risk assessment process

5.1 General

For the system subjected to the assessment, the risk assessment process shall always

- a) identify hazardous situations and potential accidental events,
- b) identify initiating events and describe their potential causes,
- c) analyse accidental sequences and their possible consequences,
- d) identify and assess risk reducing measures,
- e) provide a nuanced and overall picture of the risk, presented in a way suitable for the various target groups/users and their specific needs and use.

Figure 3 shows the main elements and the steps included in a risk assessment process. The general requirements to element 1 to element 8 as defined in Figure 3 are described in 5.2 to 5.9. Overall requirements to the entire risk assessment process are included in 5.2.

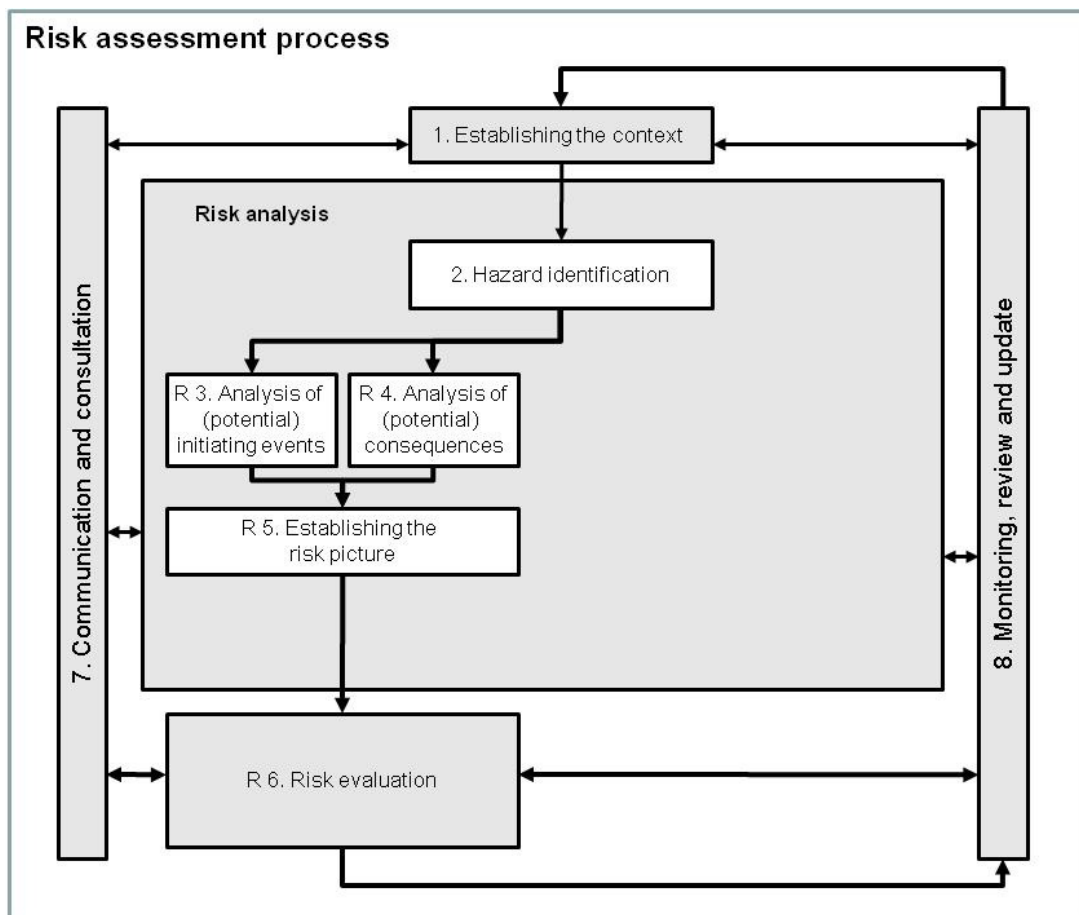


Figure 3 The process of performing a risk assessment

5.2 Establishing the context for a risk assessment process

5.2.1 Objective

The objective is to define the basic parameters for the risk assessment process, and to set the scope and criteria for the rest of the process. The context may include both parameters related to the internal context (anything within the organization that may influence the process) and the external context (anything outside the organization that may influence the process).

Establishing the context covers all activities carried out and all measures implemented prior to or as a part of the initiating phase of a risk assessment process, with the intention of ensuring that the risk assessment process to be performed is

- a) suitable with respect to its intended objectives and purpose,
- b) executed with a suitable scope and level of quality,
- c) tailored to the facility, system(s), operations, etc. of interest,
- d) tailored to the required and available level of detail.

5.2.2 Requirements

5.2.2.1 General

The establishment of the context for the risk assessment process shall involve, but not be limited to, the following:

- a) defining the objectives (for the process and for each of the elements 2 to 6 in Figure 3);
- b) defining the scope (of the process and for elements 2 to 6);
- c) defining responsibilities (for the process and for elements 2 to 6);
- d) defining the methods, models and tools to be used (in elements 2 to 6);

- e) defining the system boundaries and the system basis (for the system(s) that are to be analyzed and assessed);
- f) defining the risk acceptance criteria to be used;
- g) defining deliveries throughout, and at the end of the process;
- h) defining the execution plan (for the process and for elements 2 to 6).

The general requirements related to each of the above listed subjects are given in the following subclauses.

5.2.2.2 Defining the objectives

The following shall be considered, defining the objectives:

- a) for the system subjected to the assessment, the risk assessment process shall always be suitable for its purpose(s), particularly with respect to providing sufficient and appropriate input to the decision-basis at the right time, i.e. prior to decisions affecting/concerning the risk being assessed are made;
- b) the established objectives for each specific risk assessment process (and its included elements) shall be documented.

5.2.2.3 Defining the scope

The following shall be considered, defining the scope:

- a) depending on the system subjected to the assessment, the risk acceptance criteria and the objectives of the process, the risk assessment will normally include assessment of
 - 1) risk to people,
 - 2) risk to the environment,
 - 3) risk to assets,
 - 4) frequency of loosing (main) safety functions and impairment of barrier functions, systems and/or – elements.
- b) the scope may also include identification, assessment and/or the establishment of
 - 1) dimensioning accidental loads,
 - 2) requirements for barrier functions, systems and/or –elements,
 - 3) operational constraints and limitations,
 - 4) defined situations of hazards and accidents (DSHA),
 - 5) area, system and equipment classification.
- c) if the risk assessment is to include analyses of new concepts, solutions or technologies, or when analysing new approaches or solutions for performing specific operations or activities, emphasis shall be put on identifying and analysing hazards and risk specific for the new solution(s);
- d) the scope of the risk assessment process shall be documented.

5.2.2.4 Defining responsibilities

Responsibilities related to planning and execution of the risk analysis process, the elements and the various tasks/activities included shall be defined. This is typically related to approval of assumptions, definition of objectives, providing of study basis, time schedule for required information and definition of acceptance criteria.

5.2.2.5 Defining the methods, models and tools to be used in the process

The following shall be considered, defining the methods, models and tools to be used in the process:

- a) methods, models and tools to be used in the process shall be suitable with respect to the decisions to be made and the defined objective(s) and scope for the assessment. The choice might need to be reconsidered based on results of the HAZID;
- b) the availability of relevant and/or required input data and models shall be considered when selecting the methods, models and tools to be used;
- c) it shall be documented which methods, models and tools that have been chosen in each specific risk assessment;
- d) in general only recognized and validated methods, models and tools shall be used. If new and/or none recognized and validated methods, models and tools have been used this shall be clearly stated. A description of the method, model or tool used, including a justification of its use in the analysis, shall be documented;

- e) an evaluation of the effect of human and organisational factors shall be performed. This may range from a qualitative discussion to a detailed analysis of human and organisational errors, depending on the criticality of such aspects for the risk picture;
- f) the use of alternative approaches (e.g. expert judgements, non-representative data, etc.) to compensate for lack of relevant and/or required input data and models, shall be clearly stated. The composition of the expert group should be documented;
- g) limitations in the validity of results due to lack of availability of relevant data and models, shall also be documented.

5.2.2.6 Defining the system boundaries and the system basis

The system that is to be subjected to the risk assessed shall be defined and described in a suitable manner.

The following apply:

- a) the system boundaries, i.e. what shall and what shall not be subjected to the assessment, shall as a minimum be defined for the following main aspects:
 - 1) the technical system(s): structures, buildings, layout, process system(s), utility system(s), safety systems(s), emergency preparedness system(s), pipelines, wells, storage, etc.;
 - 2) the organisation and the operational system;
 - 3) the period, phase(s) and/or activities.
- b) the inputs used as system basis in the risk assessment process, given the system boundaries, shall be documented. As a minimum the document/report/drawing name, revision number and date of issue shall be listed. This includes (if used)
 - 1) layout drawings, P&IDs, PFDs, etc.,
 - 2) descriptions of technical systems (fluid data reservoir, process, utility systems),
 - 3) descriptions of operational aspects (manning distributions, lifting activities, traffic, hot work etc),
 - 4) descriptions and/or data related to environmental loading,
 - 5) studies/analysis performed outside the scope of, or prior to, the risk assessment process,
 - 6) input data, e.g. equipment/system failure data, leak frequencies,
 - 7) description of neighbouring activities, environment and population, including vulnerable areas and objects,
 - 8) safety design basis, e.g. fire water strategies, gas detection strategies, blowdown strategies,
 - 9) SIL analysis according to IEC 61508/61511/OLF GL 070. This states specific requirements to safety barriers. The QRA assumptions and SIL analysis data basis/results should be harmonized as far as possible to ensure consistency and transparency between the two analyses.

5.2.2.7 Defining the risk acceptance criteria to be used

The following apply:

- a) RAC shall be established prior to the assessment as they constitute a reference for the evaluation of the results from the risk assessment;
- b) the process of establishing RAC is beyond the scope of this Standard. However, the need for establishing new RAC in order to fulfil the below mentioned requirements may be one of the outcomes of this activity. The RAC shall as far as possible reflect the safety and environmental objectives and
 - 1) be suitable for evaluation of the activity/activities and/or system(s) in question,
 - 2) be suitable for comparison with the results of the analysis to be performed,
 - 3) be suitable for decisions regarding risk reducing measures,
 - 4) be suitable for communication,
 - 5) be unambiguous in their formulation (such that they do not require extensive interpretation or adaptation for a specific application),
 - 6) not favour any particular concept solution explicitly nor implicitly through the way in which risk is expressed.

NOTE But the application of RAC in risk evaluation will usually imply that one concept (or concepts) is (are) preferred over others, due to lowest risk.

- c) the main safety functions, including their required functionality, is to be defined for each facility individually;

- d) the established RAC to be used in each specific risk assessment process shall be documented.

Measures/quantities that may be considered for the evaluation of the risk, together with interpretation of authority requirements related to acceptance criteria for main safety functions are presented in Annex A and Annex B.

5.2.2.8 Defining deliveries

As a risk assessment process may be conducted over a period of time, several deliveries from the assessment may be required during or throughout the process in order to provide decision support at the right time. Example of such deliveries may be input to decisions regarding the overall layout of the facility or input to the dimensioning accidental loads to be used. As the need for deliveries throughout a process will vary for each specific phase, the requirements related to such deliveries are given in Clause 6 to Clause 8. See also 5.2.2.9.

Required deliveries at the end of the process are also mainly phase specific. These requirements are therefore also given in Clause 6 to Clause 8. Deliveries at the end of the process include all deliveries not included as a part of the presentation of the risk picture and the risk evaluation covered in 5.6 and 5.7.

5.2.2.9 Defining the execution plan for the process

As the main purpose of performing a risk assessment is to provide decision relevant information, the risk analysis shall be carried out prior to decisions affecting/concerning the risk being analysed are made.

However, during the feasibility, concept and/or engineering phase of a project (e.g. a new facility), or during the planning of an operation, several decisions, which could have a minor or major effect on the risk, are typically made throughout the project. It is therefore important that the risk assessment contribute with decision-support throughout the development of the project, at the right time and with the appropriate level of detail, and not only at the end of the assessment process.

Typical decisions that are taken throughout the various phases in a project, which the risk assessment should provide decision-support to, are described for the recommended risk assessment process for each of the phases covered in Clause 6 to Clause 8.

A plan for the execution of the risk assessment process, which ensures that the objectives are met and that the deliveries are available at the right time, shall be established and documented.

5.3 Hazard identification (HAZID)

5.3.1 General

A comprehensive and thorough identification and recording of hazards is critical, as a hazard that is not identified at this stage will be excluded from further assessment. Well planned and comprehensive hazard identification (HAZID) is therefore a critical and important basis for the other elements of the risk assessment process.

5.3.2 Objectives

The objectives of the hazard identification are as follows:

- a) to identify hazards associated with the defined system(s), and to assess the sources of the hazards, events or sets of circumstances which may cause the hazards and their potential consequences;
- b) to generate a comprehensive list of hazards based on those events and circumstances that might lead to possible unwanted consequences within the scope for the risk and emergency preparedness assessment process;
- c) identification of possible risk reducing measures.

5.3.3 Requirements

The requirements to the hazard identification are as follows:

- a) identification of hazards should include hazards whether or not they are considered to be under control of the organization;

- b) tools and techniques which are suited to identify all relevant hazards associated with the system, and suitable with respect to the established context for the risk assessment process, shall be used. Possible basis for a HAZID may be
 - 1) use of check lists (typically ISO 17776) and accident statistics,
 - 2) experience from previous similar analyses/assessments, safety inspections and audits,
 - 3) internal/external incident reports,
 - 4) step-by-step methodologies such as HAZOP/FMEA.
- c) the system basis for the hazard identification (HAZID) shall be established upfront. Activities ensuring that the involved personnel know and understand the basis shall be performed;
- d) establish requirements related to which disciplines that shall participate in the HAZID, in order to assure that all relevant hazards are identified;
- e) the HAZID shall include
 - 1) a broad review of possible hazards and sources of accidents, with particular emphasis on ensuring that relevant hazards are not overlooked,
 - 2) a rough classification into critical hazards as opposed to non-critical,
 - 3) identification of measures to control hazards, e.g. by inherent safer design, possible design improvements, further evaluations or analysis etc.,
 - 4) classification of hazards relevant for the emergency preparedness analysis process if this is part of scope.
- f) the documentation of the HAZID shall as a minimum include
 - 1) personnel attending,
 - 2) method/guide words applied,
 - 3) statement of the criteria used in the screening of the hazards,
 - 4) documentation of the evaluations made for the classification of the non-critical hazards, i.e. hazards that are excluded from further assessment, and the basis for this evaluation,
 - 5) hazards identified with description of causes and consequences,
 - 6) description of implemented safety barriers,
 - 7) hazards that are to be subjected for further evaluation,
 - 8) a description of the system basis used in the HAZID, according to 5.2.2.6 b).

A list of potential hazards relevant for some facilities and operations is given in Annex C.

5.4 Analysis of initiating events

5.4.1 Objective

To analyze and identify potential causes of initiating events, and to assess the probability/frequency of initiating events occurring.

5.4.2 Requirements to qualitative analysis

The initiating events to be analysed shall be determined by the hazard identification as specified in 5.3. The following requirements apply:

- a) the level of detail for analysis of causes of the initial event shall be suitable in relation to the context of the risk assessment;
- b) the analysis of causes shall reflect a broad experience basis, with respect to design, operation and maintenance;
- c) if coarse and subjective analysis is performed, it shall be ensured that the experience basis is adequate.

5.4.3 Requirements to quantitative analysis

The following requirements apply:

- a) the initiating events to be analysed shall be determined by the hazard identification as specified in 5.3.

Analysis of the following shall as a minimum be included if the hazard is relevant according to the objective:

- 1) process accidents;
- 2) risers/landfall and pipeline accidents;
- 3) storage accidents (liquid and gas);
- 4) loading/offloading accidents;
- 5) blowouts and well releases;

- 6) accidents in utility systems, e.g. leaks of chemicals, fires, explosion of transformers etc.;
- 7) accidents caused by external impact and environmental loads, e.g. collision, falling/ swinging loads, helicopter crash, earthquake, waves;
- 8) structural failure (including gross errors);
- 9) loss of stability and/or buoyancy (including failure of marine systems).

The frequency of the above listed initiating events shall be established. The following requirements apply (in addition to the requirements given in 5.2.2.5 concerning the methods, models and tools used):

- a) if failure data are used, the failure and accident data applied shall be suitable in relation to the context of the study and the method, model(s) and tool(s) used. Consideration shall be made with respect to how representative and suitable the available failure data (considered) used are. Factors for consideration may be (see also Annex C and ISO 14224)
 - 1) type of facility and the equipment used,
 - 2) process parameters, including substances involved,
 - 3) weather conditions on location at time,
 - 4) available safety barriers,
 - 5) working procedures, organisation and possible changes,
 - 6) reservoir conditions,
 - 7) design standards, margins,
 - 8) the quality and relevance of available historical data,
 - 9) technology development,
 - 10) maintenance programs,
 - 11) operational standards.
- b) explicit analysis of possible causes of initiating events should complement the assessment in lack of representative and suitable data;
- c) if trends in data are used, they shall be substantiated;
- d) the data applied shall be documented as well as a discussion of their relevance, see 5.2.2.5.

5.5 Analysis of potential consequences

5.5.1 General

The term "analysis of potential consequences" is here used in a wide sense, covering the entire accidental sequence or sequences that may be the outcome if an initiating event should occur, see 5.3 and 5.4.

As the objective and scope of a risk assessment may vary, the way to perform the analysis of potential consequences may range from detailed modelling (using extensive event-trees including a comprehensive assessment of the various branches) to coarse judgemental assessment (by e.g. extrapolation from experimental studies or from available data). Analysis of the potential consequences may therefore be qualitative, semi-quantitative or quantitative, depending on the context.

5.5.2 Objective

The following are the objectives of consequence analysis:

- a) to assess possible outcomes of identified and relevant initiating events that may contribute to the overall risk picture;
- b) to analyze potential event sequences that may develop following the occurrence of an initiating event, determine the influence of the performance of barriers, the magnitude of the physical effects and the extent of damage to personnel, environment and assets, according to what is relevant given the context of the assessment.

5.5.3 Requirements to qualitative analysis

The initiating events to be analysed shall be determined by the hazard identification as specified in 5.3. The following requirements apply:

- a) the level of detail for analysis of consequences shall be suitable in relation to the purpose and context of the analysis;
- b) the analysis of consequences shall reflect a broad experience basis, with respect to design, operation and maintenance;

- c) if coarse and subjective analysis of consequences is performed, it shall be ensured that the experience basis is adequate and extensive.

5.5.4 Requirements to quantitative analysis

The following requirements apply:

- a) the level of detail for analysis of consequences shall be suitable in relation to the purpose and context of the analysis;
- b) the initiating events to be analysed shall be determined by the hazard identification as specified in 5.3. The following separate event types shall as a minimum be included if the hazard is relevant:
 - 1) process accidents;
 - 2) risers/landfall and pipeline accidents;
 - 3) storage accidents (liquid and gas);
 - 4) loading/offloading accidents;
 - 5) blowouts and well releases;
 - 6) accidents in utility systems (leaks of chemicals, fires, explosion of transformers etc);
 - 7) accidents caused by external impact and environmental loads, e.g. collision, falling/ swinging loads, helicopter crash, earthquake, waves;
 - 8) structural failure (including gross errors);
 - 9) loss of stability and/or buoyancy (including failure of marine systems).

5.6 Establishing the risk picture

5.6.1 Objectives

To establish a useful and understandable synthesis of the risk assessment, with the intention to provide useful and understandable information to the relevant decision makers and users about the risk and the risk assessment performed. Establishing the risk picture includes reporting of the risk assessment process.

5.6.2 General requirements

The following requirements apply:

- a) the risk picture shall include
 - 1) a clear and balanced description of the objective and scope of the assessment, and of the system boundaries and system basis used,
 - 2) a clear description of the methodology, models and/or tools used, including a justification of their use,
 - 3) a presentation of the risk acceptance criteria and/or other decision criteria used, and the results compared with these criteria,
 - 4) a clear and balanced picture of the risk exposure and the main risk contributing factors,
 - 5) a discussion of uncertainty, including the following aspects:
 - i. the perspective on risk used in the assessment, e.g. classical, statistical, probability of frequency, combined classical and Bayesian, Bayesian, Predictive approach;
 - ii. the effect and level of uncertainty given the adopted perspective and the context for the assessment (including the 'system boundaries' and 'system basis') compared to the 'actual' or 'real' systems and/or activities of interest;
 - iii. possible implications for the main results;
 - iv. occurrence of unexpected outcomes, as a result of invalid assumptions and premises, or insufficient knowledge.
 - 6) if used, define and/or discuss the meaning of terms and quantities like: probability, frequency, mean value, expected values, conservative side, conservative approach, etc.,
 - 7) factors such as divergence of opinion amongst experts or limitations of the modelling should be stated and may need to be highlighted.
- b) the risk picture shall
 - 1) be suited for decision-making,
 - 2) be understandable to all relevant personnel, decision makers as well as engineering and/or operating personnel. This may be solved by the use of tailored documentation and presentations to different groups of internal and external stakeholders.
- c) the analysis itself should aim at presenting expected consequences. The expected level should be approached from the "slightly conservative side";
- d) within the limitations provided by the scope and methodology, the presentation and documentation of the risk picture shall be a comprehensive, balanced, many-faceted and holistic picture of the risk associated

with facilities and operations, including main contributions to risk from various areas, locations, phases, hazards, systems and operations. Focus areas for best possible risk reducing effect shall be part of the documentation;

- e) assumptions and presuppositions shall be clearly and explicitly documented and categorised in the following groups:
 - 1) analytical;
 - 2) technical;
 - 3) organisational/operational.
- f) assumptions and presuppositions which imply restrictions to the operation of the facility, the activities assessed or to modifications/changes in the system basis shall be described in a manner which is understandable and easy to use for the various users of the risk analysis. This includes a description of the implication of deviations from these assumptions and presuppositions. The need for sensitivity analysis in order to identify and to assess the implications of changes in the study basis shall be considered and performed when necessary. For quantitative risk analysis see also 5.6.3.4;
- g) results, premises and assumptions shall be documented in a manner which enables easy use as input to planning of operational activities, maintenance and modifications;
- h) an evaluation of the robustness of the conclusions given in the assessment with respect to changes in study basis shall be presented;
- i) background for the choice of assumptions/presumptions shall be given;
- j) for modification projects: a comparison of all risk metric before and after the proposed modifications shall be included.

5.6.3 Requirements to quantitative risk analysis

5.6.3.1 General

The requirements in this regard fall in two categories; concerned with the process of establishing the risk picture and the presentation of it.

5.6.3.2 Calculations needed to establish the risk picture

For the calculations needed to establish the risk picture, the following requirements apply (if included in scope):

- a) the following fatality risk contributions shall be considered and, when applicable, calculated and presented separately:
 - 1) immediate fatalities;
 - 2) offshore transportation fatalities including shuttling;
 - 3) escape fatalities;
 - 4) evacuation and rescue fatalities;
 - 5) off-site risk.
- b) the fatality risk contributions shall be split into areas or exposed employee groups and, if relevant, between 1st and 3rd party;
- c) when required, the probability of loss of main safety functions is established in accordance with guidelines given in Annex B;
- d) the environmental risk shall as a minimum be calculated for the environment in general, but it is recommended to calculate risk for identified environmental risk indicators or specific sensitive resource.

5.6.3.3 Presentation of the risk picture

For the presentation of the risk picture, the following requirements apply (if included in scope):

- a) the main results and conclusions of any risk analysis shall be presented as risk for the activity in question, in accordance with the structure of the RAC and for the relevant risk elements. The risk picture shall include
 - 1) ranking of risk contributors,
 - 2) identification of potential risk reducing measures,
 - 3) important operational assumptions/measures in order to control risk.
- b) if required, the presentation of risk picture shall include dimensioning accidental loads;
- c) presentation of possible measures that may be used for reduction of risk and their risk reducing effect;
- d) the analysis shall present and describe accident scenarios relevant for the assessment of the emergency preparedness, see 9.4;

- e) presentation of the sensitivity in the results with respect to variations in input data and crucial premises. The basis for the chosen sensitivity analyses shall be presented;
- f) the results of the QRA shall be traceable through the analysis report. It shall be possible to identify any mechanism/equipment that causes large risk contribution;
- g) intermediate results shall be presented such that risk contributors can be traced through the report;
- h) assumptions and premises of importance to the risk assessment results, to decisions related to future project development or with implications to operations/maintenance shall be documented;
- i) assumptions, premises and results shall be presented in a way suitable as input for defining performance requirements for safety and emergency preparedness measures in later life cycle phases;
- j) assumptions, premises and results for environmental risk shall be presented in a way suitable as input for the environmental preparedness and response analysis;
- k) all recommendations made in the analysis shall be listed separately with references to calculations.

5.6.3.4 Sensitivity analysis

The following requirements apply:

- a) sensitivity analyses shall be carried out to include
 - 1) identification of the most important aspects and assumptions/parameters in the analysis,
 - 2) evaluation of effects of changes in the assumptions/parameters, including the effect of any excessively conservative assumptions,
 - 3) evaluation of effects of potential risk reducing measures.
- b) the input parameters to be considered for sensitivity analyses should, if relevant, include
 - 1) total manning and personnel distribution,
 - 2) leak frequencies,
 - 3) probability of ignition,
 - 4) performance (reliability, availability, functionality, etc.) of important barrier functions, systems and/or elements (technical, human and organisational) for personnel, environment and asset risk,
 - 5) operational parameters, such as the activity levels,
 - 6) environmental resources and their vulnerability,
 - 7) spreading of contaminant.

5.6.3.5 Establish input to design accidental loads

DALs are initially established in early project phases, based on quantitative risk analysis. The modelling may at that time be somewhat coarse and details concerning, layout, systems, equipment, etc., may not be available.

The following apply:

- a) the establishment of dimensioning accidental loads shall start with the completion of a risk analysis and the comparison of calculated risk with RAC;
- b) the risk analysis shall establish sets of accidental events and associated accidental loads, and possibly also associated probabilities. The dimensioning accidental loads are chosen from these sets, such that the RAC are complied with;
- c) it may be difficult to define the accidental load in relation to some types of accidental events, for instance in relation to filling of buoyancy compartments that may lead to instability of topside equipment, impact of escape routes, personnel panic, capsizing or loss of buoyancy. In these cases, the basis of dimensioning is given by the DAEs;
- d) the selection of dimensioning accidental loads shall take considerations described in c) into account, and provide sufficient margins in order to avoid inadequate dimensioning accidental loads at a later stage;
- e) tolerable damage or required functionality shall be defined in such a way that the criteria for dimensioning are unambiguous. The term 'withstand' in the definition may be explained as the ability to function as required during and after the influence of an accidental load, and may involve aspects such as
 - 1) the equipment has to be in place, i.e. it may be tolerable that some equipment is damaged and does not function and that minor pipes and cables may be ruptured. This may be relevant for electrical motors and mechanical equipment,
 - 2) the equipment has to be functional, i.e. minor damage may be acceptable provided that the planned function is maintained. This may be relevant for ESVs, deluge systems, escape routes, main structural support system, etc.,
 - 3) the equipment has to be gas tight. This may be relevant for hydrocarbon containing equipment.

The final establishment of the design accidental loads will be decided based on a consideration of the DALs but also a consideration of other factors, e.g. risk reducing measures, design safety factor etc.

5.7 Risk evaluation

5.7.1 General

Assessments and decisions concerning whether or not risk is acceptable, whether or not additional risk reducing measures may be required, or if a measures should be implemented or not, is beyond the scope of this NORSOK standard. Hence, this subclause does only cover the part of the decision basis that may be used for such assessments and decisions which the risk assessment process can and should provide.

5.7.2 Objective

The objective is to establish a basis for decision-making, given the context of the analysis.

5.7.3 Requirements

If the consequences are expressed in categories in the quantitative analysis, the risk shall also be expressed as the cumulative frequency for all consequences.

Identification of possible risk reducing measures shall be performed throughout and as a part of any risk assessment process as follows:

- a) separate assessments with the purpose of identifying possible risk reducing measures and evaluating their effect shall be performed as a part of the risk assessment process;
- b) the assessment shall seek to identify measures with the following priority:
 - 1) measures that provide inherently safer design;
 - 2) measures that reduce the possibility of accidental events occurring;
 - 3) measures that reduce the consequences if accidental events should occur.
- c) evaluation of possible risk reducing measures should be based on
 - 1) qualitative assessments, i.e. reflecting inherent safety principles, best available technology, cautionary principles,
 - 2) quantitative or qualitative analysis of cost, benefit, and other effects of the relevant measures, i.e. reputation, robustness, effectiveness, maintenance and operational effects.
- d) the identification and evaluation of risk reducing measures shall be documented. It shall include a description of the risk reduction process that has been followed (see item e), as well as the results of the risk reduction process;
- e) documentation of the risk reduction assessment shall include
 - 1) overview of the elements in the risk reduction assessment,
 - 2) overview of the involved parties in the assessment,
 - 3) documentation of the identified measures and their effect on the risk, supporting analyses and evaluations.

5.8 Communication and consultation

5.8.1 Objective

The objective is to involve relevant internal and external stakeholders (relative to operator), at the right time and with the appropriate level of involvement throughout the entire process, as a measure to improve the quality of the risk assessment process and its ability to be tailored and suitable for its intended purpose(s).

Experience transfer from personnel with operational knowledge from practical utilisation of critical equipment and systems is of importance to establish high level of safety and predictability of risk assessment outcome.

Effective internal and external communication and consultation shall be done to ensure that those affected by the hazards and those accountable for managing the risk understand the established context on which the results are calculated and evaluations are made, the risk picture, and the reason why particular priorities may be needed in the risk treatment.

5.8.2 Requirements

The following requirements apply:

- a) a plan to communicate and consult with internal and external stakeholders shall be developed at an early stage of the process;
- b) the plan shall address communication and consultation related to (but not limited to)
 - 1) the establishment of the context for the risk assessment,
 - 2) the execution of the assessment,
 - 3) how the assessment and its results shall be communicated to various stake holders,
 - 4) involvement of personnel with operational knowledge.
- c) the plan shall include a brief description of how and when the communication shall be performed (written and/or oral communication) in general, and for subjects that requires a specific form of communication, including feed-back from the receiver to the sender. Assumptions and presuppositions that are to be used in the assessment are examples of information that requires communication between those performing the assessment and those responsible for the technical and operational solutions to be used;
- d) those responsible for the communication and consultation needed shall be identified and included in the plan.

5.9 Monitoring, review and updating the risk assessment

5.9.1 General

In several of the phases covered by this NORSOK standard (e.g. the concept selection phase and the engineering phase), several changes may be implemented (or decided implemented) to the plant, installation or operation(s) subjected to the assessment as the project evolves. The level of details will also in many cases increase throughout the process as a project develop.

5.9.2 Objective

The objectives of monitoring, review and updating the risk assessment are

- to monitor the established context, with respect to its validity due to decisions made, new knowledge (including the level of details available about the system or operation to be analyzed) or other factors which may jeopardize the validity of the context. Results from scoping or framing studies, performed after the context was updated, or results from studies or assessments performed as a part of the risk assessment process may also require the context to be updated,
- to update the context throughout the process, if and when required,
- to assure that the risk assessment process and its various elements is executed based on an updated context, if and when the context has been modified.

5.9.3 Monitoring and review of risk assessment process

Monitoring and review is related to

- analyzing and learning lessons from events, changes and trends,
- detecting deviations from assumptions and premises of the risk assessment,
- detecting changes in the external and internal context, including changes to the risk itself, that may required revision of risk assessment and evaluation.

The monitoring and review in all phases will be a mixture of qualitative and quantitative analyses. It will be essential to have a system to follow up results and recommendations from all types of studies.

Requirements to monitoring and review:

- a) monitoring and review can involve regular checking or surveillance of what is already present or can be periodic or ad hoc. Both aspects shall be planned. It is not sufficient to rely only on occasional reviews and audits;
- b) the results of monitoring and review shall be recorded and internally or externally reported as appropriate;
- c) responsibilities for monitoring and review shall be clearly defined;
- d) a plan for follow-up of the analysis shall be prepared, containing an assessment of the conclusions and recommendations as well as plans for implementation of risk reducing measures, including emergency preparedness measures.

5.9.4 Updating of risk analysis

A risk analysis is in general only valid as a basis for decision-making as long as the basis for the analysis (e.g. its methods, models, input data, assumptions, limitations, etc.) is assessed to be valid. Any deviation from the basis for analysis should therefore initiate an assessment of the deviation with respects to its effect on the risk and/or the validity of the analysis and its results, provided that the analysis is intended to be used as a basis for future decisions. When updating an analysis (or using an analysis as basis for sensitivity studies) all basis for the analysis should be reviewed. The review of the basis for QRA shall be documented.

Update of a risk analysis or performance of a new analysis shall be based on consideration of

- a) the current phase in a project (changing from feasibility to the concept and/or engineering phase of a project, or from the detailed engineering phase to the operational phase),
- b) the period for future use of the current risk analysis (short-term or long-term use (operational phase),
- c) the types of decisions that the analysis is intended to support in the future,
- d) the extent of work and the time required to perform a new analysis versus the need for decision support at a given time.

6 Additional requirements to quantitative risk analysis (QRA) in concept selection phase

6.1 General

The requirements stated in this subclause are in addition to the general requirements given in Clause 5, and reflect an assessment performed in the concept selection phase.

The main purpose of the assessment is to compare different concepts and to identify any potential showstoppers for each concept. The available level of details related to the various concepts is assumed to be limited.

The risk assessment in this phase can be qualitative or quantitative or a combination of these. This would be dependant of the following aspects related to the various concepts listed below:

- complexity;
- applicable hazards;
- exposed systems;
- availability of information.

For combination of qualitative and quantitative analysis, the relevant parts of Clause 5 apply accordingly.

6.2 Establishing the context

6.2.1 Objective

The general objective of a QRA in the concept selection phase is to identify risk challenges for each concept, and to compare the concepts with respect to risk level and possibility of risk reduction. The more specific objectives are to

- a) identify potential showstoppers for concepts and risk challenges for any of the concepts under evaluation i.e. evaluate if it is likely that the authority and acceptance criteria for any of the concepts cannot be met,
- b) describe and characterise all risks that are significant for the facility, in order to assist the concept selection and optimisation process,
- c) identify possible significant risk reducing measures, so that safer, more environment friendly, more cost-effective design and/or inherently safe options can be adopted,
- d) provide a risk ranking of the proposed concepts. The risk may be expressed as risk to people, environment, assets and impairment of safety functions,
- e) evaluate the robustness and uncertainties of the proposed concepts with respect to possible changes during design development,
- f) identify need for any further risk assessments or detailed studies that should be performed,
- g) identify need and scope for further risk assessments during the next phase,
- h) establish preliminary DSHAs,

- i) evaluate the layout of main areas,
- j) establish preliminary dimensioning accidental loads and/or safety zones/separation requirements.

Other objectives shall be considered, see 5.2.2.2.

6.2.2 Requirements

No additional requirements, see 5.2.2.

6.3 Hazard identification (HAZID)

6.3.1 Objectives

Identify contributors to the major accident risk that will be dimensioning for separation between systems, systems safety zones or environmental risk level, main dimensioning loads etc, or which will be the most critical hazards for the concepts.

The HAZID approach shall also be used to identify construction and installation risks. The objective of this activity is to identify any such risks that may be of importance for development of the design solutions, costs, schedule or that might otherwise be of importance for concept selection. This is of particular importance for modifications on a facility in the operational phase. Construction related activities or significant increase in manning in construction period can be a significant risk for some of the concepts under evaluation and shall thus be identified.

6.3.2 Requirements

No additional requirements, see 5.3.3.

6.4 Analysis of initiating events

6.4.1 Objective

No additional objectives, see 5.4.1.

6.4.2 Requirements

The following requirements apply:

- a) hazards that represent a significant difference between concepts or represent a high risk shall be quantified. Normally limited information and time is available for a detailed analysis of initiating events. In a QRA in this phase it is therefore recommended to use data for comparable systems, or to use data from similar facilities;
- b) extra focus shall be on new unconventional concepts or concepts with limited operational experience;
- c) personnel transport risk, with respect to possible differences between the concepts or specific challenges, is an element that shall be considered in this phase;
- d) when ship collision risk is deemed to be significant, a detailed collision analysis shall be performed in this phase. This is in particular the case when collision risk will be dimensioning for the facility structure or determining for the location of the facility;
- e) possible concept challenges and differences regarding effects from and impact on neighbouring activities, environment and population (3rd party) shall be considered.

If the hazard identification process identifies hazards not critical for the decision making, either due to low risk potential, negligible difference in risk level between concepts or a combination of these, a qualitative analysis of these hazards may be appropriate.

6.5 Analysis of consequences

6.5.1 Objective

No additional objectives, see 5.5.2.

6.5.2 Requirements

The following requirements apply:

- a) all hazards that may contribute significantly to the overall risk picture for the facility shall be included in the consequence modelling in the concept selection phase. Analysis of consequences may often be performed by simplified (analytical/empirical) models. However, in situations where the results of such analyses are critical for concept selection or optimisation, more accurate modelling may be required;
- b) the valuation of robustness of the proposed concepts shall focus on impairment of main safety functions;
- c) the level of detail of the documentation of intermediate results shall be in line with the consequence modelling accuracy. For simplified modelling, the simplifications shall be documented. For more accurate modelling, the documentation of intermediate results shall be in accordance with needs for decision support.

6.6 Establishing the risk picture

6.6.1 Objective

No additional objectives, see 5.6.1.

6.6.2 Requirements

6.6.2.1 Presentation of the risk picture

The result shall be presented in such a way that

- a) it is clear if any of the concepts under evaluation cannot or will have difficulties to meet authority or company acceptance criteria,
- b) it is possible to rank between the concepts in a risk perspective,
- c) opportunities for inherently safe design, robustness and risk reducing measures are identified and the benefits from these can be clearly communicated,
- d) focus items for the next phase can be identified.

6.6.2.2 Estimation of dimensioning accidental load

In this phase a coarse evaluation of the dimensioning accidental loads should be performed. Aspects that should be evaluated are as follows:

- For land based facilities:
 - safety zones around the facility;
 - separation distances between main process functions such as administration building, tank farms, process areas, flare, utility area, landfall, burners etc.;
 - need for explosion protection on buildings, fire protection on major process equipment, or structures etc.;
 - earthquake, flooding and meteorological loads.
- For offshore facilities:
 - structural load actions due to ship collisions, earthquakes, anchor failures, ice and meteorological loads etc.;
 - fire and explosion loads for main barrier elements;
 - fire loads for risers and structure;
 - dropped object impact load, particularly for risers and structure.

For modification of existing facilities it is important to identify possible new dimensioning accidental loads. Equipment and structures shall be designed in accordance with the relevant DALs specification for the existing facility.

6.7 Risk evaluation

No additional objectives or requirements, see 5.7.

6.8 Communication and consultation

No additional objectives or requirements, see 5.8.

6.9 Monitoring, review and updating the risk assessment

No additional objectives or requirements, see 5.9.

7 Additional requirements to quantitative risk analysis (QRA) in concept definition, optimization and detailed engineering phases

7.1 General

The requirements stated in this clause are in addition to the general requirements given in Clause 5, and reflect an assessment performed late in the concept definition and optimisation phases.

Detailing of the analysis and the objective will typically differ during the various stages of these phases. It is assumed that the design is mature but it can still be modified. It is further assumed that layout drawings and P&IDs for process and essential safety systems are available at the time of the assessment.

Risk analysis of construction work and installation activities are not covered in this clause.

7.2 Establishing the context

7.2.1 Objective

The objective of the QRA in the concept definition and optimisation and detailed engineering phases is to provide input to decisions relating to

- a) compliance with acceptance criteria,
- b) ALARP evaluations,
- c) establishment of DSHAs,
- d) layout of main areas and equipment,
- e) site layout, including location of traffic routes and ignition sources (e.g. furnaces, flares, transformers etc),
- f) design of systems and equipment,
- g) DALs and/or safety zones,
- h) requirements to barriers,
- i) operational restrictions and conditions including restrictions applicable to simultaneous operations.

7.2.2 Requirements

The overall requirements to the QRA studies in the concept definition, and optimisation phases are as follows:

- a) the analysis shall consider the operational phase;
- b) different activity levels during the lifetime of the facility shall be considered;
- c) the need for revisions of the analysis during the concept definition and optimisation phases shall be considered;
- d) the risk assessment shall include evaluation of risk at the same format as given in the company and authority RAC;
- e) if risk to people is to be calculated, the risk in a quantitative study should be expressed in terms of: area risk for defined areas on the facility, group individual risk for defined groups of personnel and average Individual risk. Risk to 3rd parties shall be expressed, if relevant. Other additional measures of risk to personnel may be used in order to fulfil the objectives of the risk assessment process;
- f) a guidance for assessment of the main safety functions is given in Annex B;
- g) if risk to the environment is to be calculated, the risk shall be expressed in the same format as given in the company RAC. Further requirements and guidelines for the analysis methodology are given in 7.5.12 and Annex G respectively. Acceptance criteria for environmental risk are treated in Annex A.

7.3 Hazard identification

7.3.1 Objective

The objectives of the activity during these phases are

- a) to review and update the HAZID performed in the concept selection phase, given the available information (level of details) at the time of the assessment,
- b) to assess hazards related to systems and activities not covered in the concept selection phase, including hazards related to various utility systems,

- c) to identify hazards which may cause requirements to emergency preparedness (e.g. man over board, acute illness, acute pollution),
- d) to identify critical health, safety and environmental issues and provide essential input to project decisions so that safer, more environmental friendly and more cost-effective design options are being adopted,
- e) identification of possible risk reducing measures.

7.3.2 Requirements

No additional requirements, see 5.3.3.

7.4 Analysis of initiating events

7.4.1 General

In this phase the focus is on establishing a comprehensive understanding of initiating events. This will normally require a detailed modelling and assessment of causes and probabilities of initiating events. The listed initiated events as given in 5.4.3 shall be evaluated, if relevant.

7.4.2 Objective

No additional objectives, see 5.4.1.

7.4.3 General requirements

The following requirements apply:

- a) the analysis shall be based on best available site specific information as well as generic data;
- b) Initiating events resulting in harmful releases to the environment (air, water, sediments or ground) shall be analysed with the purpose of reflecting the variation in the release rates, duration and frequency of the events for each environmental compartment, e.g. air, water, sediments or ground. If relevant, at least four different release rates shall be applied for each initiating event;
- c) the significant failure modes for the incidents shall be identified and categorised. The relevance of the failure modes for the facility shall be considered and adjustments to failure frequencies substantiated. Typical categories of the immediate failure cause are
 - 1) operational failures (e.g. overpressure),
 - 2) technical failures (e.g. fatigue, material failure, corrosion, vibration),
 - 3) external impact (e.g. trawling, dropped objects, anchors, excavator, mines),
 - 4) common cause failures.

7.4.4 Process accidents

The following requirements apply:

- a) the initial event for risk related to process accidents shall be loss of containment (leakage) or other events as identified in the hazard identification;
- b) the analysis shall consider leakage sources from the main process;
- c) the analysis shall include leakage from other sources as identified in the HAZID;
- d) in case of insufficient and/or lack of representative data necessary conservatism shall be included and sensitivity analysis shall be carried out;
- e) recommended data sources for use in the analysis are given in Annex D;
- f) the leak frequencies shall distinguish between contribution from different: types of equipment (e.g. valves, flanges, piping, vessels, pumps, compressors, heat exchangers, instruments etc), ESD segments and types of release (substance and phase). The frequencies shall also be established in a way that makes it possible to identify location/area where the different leaks may occur;
- g) the leak frequencies shall distinguish between different leak sizes, either by hole sizes and/or leak rates. At least four different leak categories shall be applied;
- h) the leak frequencies shall be established in a way that enables the assessment of loss of main safety functions (see Annex B), and for the assessment of risk to personnel, asset and the environment;
- i) leak frequencies as specified in item g) and h) above shall be documented as intermediate results.

7.4.5 Riser/landfall and pipeline accidents

The following requirements apply:

- a) the initial event for risk related to riser and pipeline accidents shall be loss of containment (leakage) or other events as identified in the hazard identification;
- b) the analysis shall consider leakage sources from hydrocarbon containing risers and pipelines such as
 - 1) production lines,
 - 2) export and import lines for gas, condensate and oil,
 - 3) transport pipelines,
 - 4) gas lift pipelines,
 - 5) landfall stations.
- c) the analysis shall also include leakage from other sources as identified in the HAZID;
- d) the effect from pipeline specific conditions such as free span, geological conditions, 3rd party activities or ship or road/rail traffic shall be considered;
- e) the historical data sources that should be considered for use in the analysis is given in Annex D;
- f) the leak frequencies shall distinguish between each pipeline/riser and contribution from type of equipment (e.g. valves, flanges) and location/area. Typical segregation between areas are
 - 1) offshore inside safety zone (topside, splash zone and subsea),
 - 2) offshore outside safety zone,
 - 3) landfall,
 - 4) onshore onsite,
 - 5) onshore offsite.
- g) the leak frequencies shall distinguish between different leak sizes, either hole sizes or leak rates. At least four different leak categories shall be applied;
- h) leak frequencies as specified in item f) and g) shall be documented as intermediate results.

7.4.6 Accidents in utility systems

The following requirements apply:

- a) the analysis shall assess all accidents in utility systems (e.g. transformers and boilers) that might cause a major accident in itself, or which might develop into a major accident;
- b) the potential effect on critical utility systems caused by other accidents shall also be evaluated;
- c) for accidents in a utility system which are found to contribute to the major accident risk (including the environmental risk), frequencies shall be established.

7.4.7 Storage accidents

The following requirements apply:

- a) the analysis shall include identification of causes for accidents in storages and calculate frequencies for accidents;
- b) operational aspect with respect to loading and unloading shall be reflected.

7.4.8 Blowouts and well releases

The following requirements apply:

- a) a blowout and/or well release can occur during various work operations and in various locations, and these shall be identified. Examples are
 - 1) work operations: drilling (exploration, development), completion, production, injection, workover, stimulation,
 - 2) blowout location: drill pipe/tubing, BOP, X-mas tree, wellhead, outside the casing.
- b) blowout frequencies shall be established for the various operations, blowout locations, phases and flow rates. The frequencies shall be established with respect to scenarios that may cause damages and releases to both the facility and to the environment;
- c) the frequencies shall be based on generic data when considered representative. The historical data sources that should be considered for use in the analysis is given in Annex D;
- d) the blowout frequencies as specified in item b) and c) above shall be documented as intermediate results.

7.4.9 External impact (collision, falling/swinging loads)

7.4.9.1 Ship collisions

The following requirements apply:

- a) for offshore installations the analysis shall include a site specific evaluation of the ship traffic;
- b) the data basis for the evaluation shall be specified. Recognised data sources are given in Annex D;
- c) the evaluation shall include, when relevant:
 - 1) vessels to and from the facility;
 - 2) vessels and other floating facilities in close proximity;
 - 3) floating units located nearby (e.g. mobile drilling units, flotels, crane vessels etc);
 - 4) fishing vessels;
 - 5) passing vessels (e.g. merchant vessels, tankers, ferries, passing offshore vessels, submarines etc.).
- d) the analysis shall include calculation of probability of collisions and the associated impact loads. The following shall be reflected, if relevant:
 - 1) powered and drifting collisions;
 - 2) anchor line break or dragging;
 - 3) faults in DP systems/thrusters;
 - 4) effect of navigational errors;
 - 5) unsuccessfully correction using own propulsion machinery;
 - 6) unsuccessful warning and/or assistance;
 - 7) procedures for emergency preparedness;
 - 8) wind and wave conditions.
- e) ship impact for onshore facilities shall be included if relevant, including ship approach to pier;
- f) the probability of collisions with different impact loads shall be presented as intermediate results.

7.4.9.2 Falling and swinging loads

The following requirements apply:

- a) falling or swinging loads causing damage to hazardous systems (leak) or significant structural damage shall be studied. The risk shall focus on the impact on major accidents. Personnel risk related to no escalating falling and /swinging loads is covered as occupational accidents;
- b) the following accidental events shall be analysed:
 - 1) Fall of crane, boom or load into sea, including impact of pipelines, risers, anchor lines, etc.
 - 2) Fall of crane, boom or load on the facility.
 - 3) Swinging loads that may cause loss of containment or damage to essential safety systems.
 - 4) Trawl or anchor impact on subsea installations.
 - 5) Falling and swinging loads towards drillers cabin.
- c) the data basis for the evaluation shall be specified. Recognised data sources are given in Annex D;
- d) the systems/areas exposed to risk shall be identified;
- e) a differentiation shall be made between various types of loads, such as containers and various types of piping;
- f) the probability of damage shall be assessed for the relevant systems by taking into account
 - 1) the probability of the object's impact on the system,
 - 2) the object's impact load on the system.
- g) the analysis shall be based on operational lifting patterns and load distribution;
- h) the probability for dropped objects different impact loads shall be presented as intermediate results.

7.4.9.3 External impact, other

The following requirements apply:

- a) the analysis shall include a site specific evaluation of natural hazards (e.g. earth quake, avalanche, flooding etc.) Assessment of environmental hazards shall be based on available geological and meteorological information and accident statistics;
- b) for land-based facilities, the analysis shall include a site specific evaluation of hazards represented by neighbouring facilities and internal/external traffic. Assessment of risk represented by neighbouring facilities shall be based on information from risk analyses. Possibility of domino effects between facilities shall be analysed. Assessment of risk represented by traffic (e.g. rail, road or ship) shall be based on appropriate statistics, including type and size of vehicles.

7.4.10 Helicopter accidents

The following requirements apply:

- a) the risk related to a helicopter crash or other helicopter accidents on the helideck or the facility outside the helideck and during flight to/from shore, shall be analysed;

- b) shuttling between facilities as well as all intermediate stops during transit flights to/from shore shall be included;
- c) the data basis for the evaluation shall be specified. Recognised data sources are given in Annex D;
- d) the analysis should consider facility specific elements, e.g. type of helicopter, facility geometry incl. height of helideck, obstructions close to helideck, climate reference points for the pilot etc.

7.4.11 Marine hazards

Hazards related to marine systems (e.g. ballast, anchor, positioning) and marine operations shall include the following:

- a) the cause analysis for marine hazards shall be sufficiently detailed in order to allow identification of potential for risk reducing measures;
- b) the analysis of causes for marine hazards shall include analysis of technical faults as well as operational faults through suitable analysis techniques such as failure mode, effects, and criticality analysis (FMECA) and task analysis;
- c) analysis of combination of technical and/or operational faults shall be carried out through suitable analysis techniques such as fault tree analysis and/or event tree analysis;
- d) the analysis shall include and assessment of common mode and common cause failures;
- e) the analyses shall reflect accident and incident statistics from relevant operational areas;
- f) the data basis for the evaluation shall be specified. Recognised data sources are given in Annex D.

7.5 Analysis of consequences

7.5.1 Objective

No additional objectives, see 5.5.2.

7.5.2 General requirements

The following requirements apply:

- a) the initiating events to be analysed shall be determined by the hazard identification as specified in 7.3. and the listed initiated events as given in 5.4.3;
- b) event sequences shall be explicitly modelled using suitable tools such as event tree or similar. If event tree is used, the nodes shall reflect important barriers and premises that determine the outcomes. Not all barriers need to be modelled as nodes, but the most important barriers shall be explicitly modelled. The tool should facilitate sensitivity analysis with respect to barrier functionality and/or reliability;
- c) node probabilities shall be based on the following as far as possible:
 - 1) barrier systems: specifications, SIL requirements, actual experience data;
 - 2) physical effects: calculation of physical effects and responses;
 - 3) physical outcomes: modelling of outcomes according to detailed system modelling.
- d) physical effects that determine sequences and/or consequences shall be modelled using recognised models, either empirically based, analytical or simulation based models. Choice of models will be dependent on the lifecycle phase and the level of details available as input;
- e) escalation and secondary accidental effects shall be based on calculation of physical effects and responses;
- f) consequences to people, environment and assets shall when relevant be determined based on calculation of physical effects and responses, as detailed further below;
- g) a separate study shall either be performed as part of the QRA or included in the EPA to consider escape and evacuation aspects. The following should be reflected:
 - 1) the escape, evacuation and rescue strategy;
 - 2) the potential for personnel to be trapped by the accident both within the same main area as the accident and in neighbouring areas;
 - 3) necessary time for escape, rescue and evacuation;
 - 4) availability and capacity of evacuations means;
 - 5) risk of fatalities during escape and evacuation.
- i) as far as possible, the effect of human and organizational factors shall be explicitly analysed. This should include the effect on
 - 1) appearance at the accident scene,
 - 2) effect on risk reducing barriers including reliability and required time for actions to be performed.
- j) the fatality calculations shall include response of people to accidental loads:
 - 1) heat radiation;

- 2) toxic (including narcotic effect) gas, suffocating gas, smoke, etc.;
- 3) primary and secondary (usually most important) effects of blast/impulse loads.
- k) human tolerability limits applied in the study shall be stated. Functions based on the dose (exposure and duration) shall normally be applied. Recognised data sources are given in Annex D;
- l) if relevant, environmental consequences shall be calculated as described in 7.5.12;
- m) if relevant, impact on asset shall be carried out reflecting
 - 1) distribution for duration of accidental events (often an extension beyond the period of exposure of personnel),
 - 2) responses for equipment and structures,
 - 3) required man hours and duration of restoration work,
 - 4) cost of restoration and duration of operations shut down including possible temporary solutions, e.g. by-pass, temporary equipment, substitution, etc.

7.5.3 Process accidents

The following requirements apply:

- a) the analysis shall consider separately leakage from each ESD segment in the main process;
- b) the analysis shall include calculation of the transient behaviour of releases, e.g. amounts, rates, duration;
- c) the transient leak duration shall have a cut off $\leq 0,1$ kg/s. The following should be reflected in the calculations:
 - 1) hydrocarbon amount, temperature, pressure, composition and volatility of hazardous substances for each ESD segment;
 - 2) effect and reliability of ESD sectionalisation and blowdown;
 - 3) effect of possible leak sizes distributed into at least four different leakage size categories.
- d) the analysis shall include calculation of dispersion of the releases. The following should as a minimum be reflected:
 - 1) effect of bunds and drain;
 - 2) evaporation;
 - 3) layout and equipment location including obstacles;
 - 4) momentum in the release;
 - 5) effect of wind and ventilation;
 - 6) ambient conditions.
- e) the analysis shall include calculation of ignition potential. The potential ignition sources which may be exposed to flammable gas concentrations shall be identified and described. The applicability of the ignition model shall be documented;
- f) the analysis shall include fire load calculations. Fire intensities according to NORSOK S-001, shall be applied. Fire durations shall consider duration of releases as well as credible escalation;
- g) escalation and/or damages to load bearing structures, firewalls separating main areas, vessels and piping, safety critical equipment, control room and safe area shall be considered, see NORSOK S-001, Edition 4, Clause 19, for reference. Extent and severity of escalation shall reflect the design requirements implemented. If design studies are performed on these matters they shall be referred to;
- h) the analysis shall include an explosion risk assessment. In case of probabilistic assessment, calculations shall be performed according to Annex F;
- i) the analysis shall include dispersion evaluations for smoke and toxic gas to consider availability of escape routes, safe areas and evacuation means;
- j) releases to the environment shall be included in the environmental consequence analysis, see 7.5.12;
- k) the analysis shall include modelling of accident sequences reflecting capacity, reliability and integrity of important safety barriers. As a minimum the following barriers should be considered (see ISO 13702):
 - 1) detection;
 - 2) emergency shutdown system and blowdown;
 - 3) control of ignition;
 - 4) control of spills;
 - 5) emergency power system;
 - 6) fire and gas system;
 - 7) active fire protection;
 - 8) passive fire protection;
 - 9) explosion mitigation and protection systems;
 - 10) evacuation, escape and rescue;
 - 11) segregation of main areas;
 - 12) structural integrity and stability.
- l) the analysis should quantify the probability of distinct different consequences such as

- 1) unignited leakage,
 - 2) ignited leakage without escalation,
 - 3) ignited leakage with significant spread to other ESD segments,
 - 4) ignited leakage with significant escalation to, exposure of or effect on other main areas.
- m) intermediate results from the consequence analysis shall be presented in order to increase the traceability of the assessment and enable comparison of results. The format of the results shall be adjusted to fit the purpose of the analysis, but the following aspects shall be included:
- 1) ignition probabilities;
 - 2) fire frequencies;
 - 3) leak rate as function of time;
 - 4) explosion frequencies;
 - 5) escalation frequencies;
 - 6) Failure probabilities of main barriers as applied in the event tree analysis.
- n) the analysis shall be based on the latest available engineering data for the facility. This should include
- 1) P&IDs,
 - 2) PFDs,
 - 3) volumes, pressures, temperatures and compositions for the ESD segments,
 - 4) ESD shut down logic,
 - 5) layout drawings,
 - 6) 3D models of sufficient accuracy,
 - 7) escape route drawings,
 - 8) fire and gas detectors layout,
 - 9) design requirements incl. design basis and design specifications for safety systems,
 - 10) safety strategies,
 - 11) dimensioning accidental load specification,
 - 12) safety studies,
 - 13) emergency preparedness plans (if established).

7.5.4 Riser and pipeline accidents

The following requirements apply:

- a) the analysis shall consider separately leakage from each riser / pipeline at different locations. The release locations shall reflect both the release potential and possible critical exposure from the release. Possible locations can be
- 1) offshore inside safety zone (topside, splash zone and subsea),
 - 2) offshore outside safety zone,
 - 3) landfall,
 - 4) onshore.

NOTE If there exist subsea isolation valves, leakages from both sides should be reflected.

- b) the analysis shall include calculation of the transient behaviour of releases (amounts, rates, duration). The following should be reflected in the calculations:
- 1) hydrocarbon amount, temperature, pressure, composition and volatility for each riser or pipeline;
 - 2) effect of friction;
 - 3) effect and reliability of ESD sectionalisation and blowdown if installed;
 - 4) effect of all possible leak sizes distributed into at least four different leakage size categories.
- c) the analysis shall include calculation of dispersion of releases. The following should be reflected:
- 1) evaporation,
 - 2) momentum in the release. It should be distinguished between
 - i. releases in free air,
 - ii. releases from buried pipelines (erosion effects),
 - iii. subsea releases.
 - 3) dispersion. It should be distinguished between
 - i. subsea dispersion,
 - ii. dispersion on sea surface,
 - iii. dispersion on land,
 - iv. dispersion within confined areas.
 - 4) effect of wind,
 - 5) ambient conditions.
- d) the analysis shall include evaluation of potential water hammer effects due to pressure build-up inside guide tubes;

- e) the analysis shall include calculation of ignition potential. The potential ignition sources which may be exposed to flammable gas concentrations shall be identified and described. The applicability of the ignition model shall be documented;
- f) the analysis shall include fire load calculations. Fire intensities according to NORSOK S-001, shall be applied. Fire durations shall consider duration of releases as well as credible escalation;
- g) fire escalation affecting main safety functions shall be considered. Extent and severity of escalation shall reflect the design requirements implemented. If design studies are performed on these matters they shall be referred to;
- h) if leaks from risers and pipelines represent a significant potential explosion risk in confined areas, the analysis shall include explosion risk calculations according to Annex F. For other explosion scenarios methods such as Multi-energy methods should be used;
- i) for riser accidents, the analysis shall include smoke dispersion evaluations to consider availability of escape routes, safe area and evacuation means;
- j) releases to the environment shall be included in the environmental consequence analysis, see 7.5.12;
- k) the analysis shall include modelling of accident sequences reflecting capacity, reliability and integrity of important safety barriers. As a minimum the following barriers should be considered:
 - 1) detection;
 - 2) emergency shutdown system and blowdown;
 - 3) control of ignition;
 - 4) fire and gas detection system;
 - 5) fire protection;
 - 6) evacuation, escape and rescue;
 - 7) structural integrity and stability;
 - 8) the analysis should quantify the probability of distinct different consequences:
 - i. unignited leakage;
 - ii. ignited leakage without escalation;
 - iii. ignited leakage with significant escalation.
- l) the analysis shall be based on the latest available data for the riser/pipeline;
- m) intermediate results from the consequence analysis shall be presented in order to increase the traceability of the assessment and enable comparison of results. The format of the results must be adjusted to fit the purpose of the analysis, but the following aspects shall be included:
 - 1) ignition probabilities;
 - 2) fire frequencies;
 - 3) leak rate as function of time;
 - 4) explosion frequencies;
 - 5) escalation frequencies;
 - 6) failure probabilities of main barriers as applied in the event tree analysis.
- n) for onshore pipelines the effect of escape and shelter should be taken into account.

7.5.5 Accidents in utility systems

The following requirements in the section on process accidents generally apply, whenever applicable:

- a) modelling of ignition probabilities and thermal/pressure loads shall reflect the chemical and physical properties of the relevant substances;
- b) for exposure to toxic and suffocating gases, both time and concentration shall be included in analysis of consequences;
- c) for analysis of consequences on personnel, the real exposure, considering protection from clothing, walls etc., shall be evaluated, giving sufficient consideration to individual variations;
- d) for accidents in a utility system, which are found to contribute to the major accident risk (including the environmental risk), consequences shall be established.

7.5.6 Storage accidents

The following requirements apply:

- a) for analysis of leaks from a storage tank, the principles as given in 7.5.3 shall apply;
- b) in addition tank explosions and escalation of accidents to the storage tank including external impact shall be evaluated;
- c) accidents related to loading and unloading of the tanks shall be included;
- d) releases to the environment shall be included in the environmental consequence analysis, see 7.5.12;
- e) for pressurised storage vessels, BLEVE shall be evaluated;
- f) the BLEVE analysis shall evaluate thermal radiation, pressure loads and fragments/projectiles;

- g) the analysis shall reflect all relevant safety systems such as
 - 1) bunds,
 - 2) passive and active fire protection,
 - 3) pressure relief systems,
 - 4) purge gas,
 - 5) water curtains etc.

7.5.7 Blowouts and well releases

The following requirements apply:

- a) the analysis shall consider separately leakage from all identified leak locations;
- b) the analysis shall reflect a transient behaviour of releases, e.g. amounts, flowrates, duration. The following should be considered:
 - 1) hydro carbon amount, temperature, pressure, composition and fluid phase;
 - 2) effect and reliability of diverter system;
 - 3) effect and probability of blowout/well release control techniques: mud, cement, relief well, bridging, etc.
- c) the analysis shall include effects of pressure drop in the reservoir with respect to
 - 1) permeability of the reservoir,
 - 2) pressure drop in reservoir as a function well lifetime.
- d) the analysis shall include calculation of dispersion of releases;
- e) the analysis shall establish ignition potential. The potential ignition sources which may be exposed to flammable hydrocarbon concentrations shall be identified and described. The applicability of the ignition model shall be documented. Recognised data source is given in Annex D;
- f) the analysis shall include smoke dispersion, fire load calculations escalation and explosion risk assessment similar to what is specified in 7.5.3;
- g) the analysis shall include evaluation of toxic effects to personnel as a result of the releases. For exposure to toxic and suffocating gases, both time and concentration shall be included in analysis of consequences;
- h) the analysis shall include modelling of accident sequences reflecting capacity, reliability and integrity of important safety barriers. The following barriers should be considered:
 - 1) riser margin;
 - 2) mud balance system;
 - 3) pressure balance system;
 - 4) diverter system;
 - 5) control of ignition;
 - 6) control of spills;
 - 7) emergency systems related to well operations and drilling;
 - 8) annulus safety valves;
 - 9) BOP;
 - 10) X-mas tree;
 - 11) down hole safety valve;
 - 12) barrier functions as for process accidents.
- i) the analysis shall reflect different flow potentials according to restrictions in the flowpath;
- j) the analysis shall quantify and present frequency of distinctly different consequences such as
 - 1) unignited blowout/well release,
 - 2) ignited blowout/well release without escalation,
 - 3) ignited blowout/well release with escalation to, exposure of, or effect on other main areas.
- k) releases to the environment shall be included in the environmental consequence analysis, see 7.5.12;
- l) intermediate results from the consequence analysis as specified in item j) and k) shall be presented in order to increase the traceability of the assessment and enable comparison of results. The format of the results shall be adjusted to fit the purpose of the analysis, but the following aspects shall be included:
 - 1) ignition probabilities;
 - 2) fire frequencies;
 - 3) leak durations;
 - 4) explosion frequencies;
 - 5) escalation frequencies;
 - 6) failure probabilities of main barriers as applied in the event tree analysis.

7.5.8 External impact

7.5.8.1 External impact – Ship collisions

The following requirements apply:

- a) the ability of the facility structure to withstand the collision impact loads shall be reflected considering both local and global structural overloading. The methods described in NORSOK N-004, Annex A, may be used. If simpler methods are applied the required need for conservatism shall be considered;
- b) damage related to superstructure or bulbous bow of the vessel to hit critical parts of the facility shall be considered;
- c) the analysis shall include evaluation of damage related to risers, ballast and storage tanks;
- d) potential of the ship to sink and cause damage to pipelines, well templates and other subsea installations;
- e) the analysis shall include damage related to effects of emergency anchoring;
- f) the analysis shall include possibility to evacuate prior to collision;
- g) the analysis shall be based on location specific aspects;
- h) the consequence evaluation shall include assessment of impact from different energy levels according to size speed and hit geometry;
- i) releases to the environment shall be included in the environmental consequence analysis, see 7.5.12;
- j) the analysis shall reflect relevant safety barriers. As a minimum this shall include
 - 1) planned operational restrictions for vessels,
 - 2) collision resistance of the facility (including risers),
 - 3) planned traffic surveillance,
 - 4) planned emergency preparedness measures.

7.5.8.2 External impact – Falling and swinging loads

The following requirements apply:

- a) the following consequences shall be analysed separately or as input to other parts of the QRA:
 - 1) releases of hazardous materials;
 - 2) structural damage or progressive collapse;
 - 3) direct Impact on personnel is covered by occupational risk.
- b) releases to the environment shall be included in the environmental consequence analysis, see 7.5.12.

7.5.8.3 External impact – Other

The following requirements apply:

- a) the ability of the facility structure to withstand the impact loads shall be reflected considering both local and global structural overloading;
- b) possible escalation through loss of containment may need to be analysed according to process or riser leak scenarios;
- c) the analysis shall include possibility to evacuate prior to the accident;
- d) the analysis shall be based on location specific aspects;
- e) the consequence evaluation shall include assessment of impact from different accident loads;
- f) the analysis shall reflect relevant safety barriers;
- g) the analysis shall reflect planned emergency preparedness measures;
- h) releases to the environment shall be included in the environmental consequence analysis, see 7.5.12.

7.5.9 Helicopter accidents

The following elements should be reflected:

- a) type of helicopter (elements that are different for different types are: survivability, escape routes, crashworthiness, fuel tank crash protection, etc.);
- b) helicopter accident/crash (related to relevant flight stage, e.g. landing, take-off or transit);
- c) design of helicopter deck such as size and layout;
- d) personnel on the facility being hit by the helicopter or fragments;
- e) leak, fire of fuel;
- f) mechanical damage to process equipment with subsequent hydrocarbon leak;
- g) damage to jet fuel tanks, leak and ignition;
- h) ineffective fire fighting, escalation of fire to surroundings such as living quarters;

- i) number of persons inside the helicopter;
- j) survivability of the passengers if landing on water.

7.5.10 Marine hazards

The following requirements apply:

- a) the analysis of floating offshore installations shall include an installation specific analysis of the consequence of marine hazards;
- b) the analysis shall, when relevant, include
 - 1) calculation of residual buoyancy and stability in damaged condition,
 - 2) calculation of load distribution in damaged condition,
 - 3) dynamic response to accidental loads.
- c) the analysis shall include effect on main safety functions. The following shall be reflected:
 - 1) both local and global structural overloading;
 - 2) loss of buoyancy and/or stability;
 - 3) heeling angles and effect on escape routes and evacuation means;
 - 4) potential to evacuate prior to loss of control.
- d) the analysis shall include possible escalation effects;
- e) releases to the environment shall be included in the environmental consequence analysis, see 7.5.12;
- f) the analyses should reflect the performance of the main safety barriers.

7.5.11 Human tolerability limits, escape and evacuation

The following requirements apply:

- a) human tolerability limits applied in the study shall be stated;
- b) for evaluation of risk related to escape and evacuation, the following shall be reflected:
 - 1) the escape, evacuation and rescue strategy;
 - 2) the potential for personnel to be trapped by the accident both within the same main area as the accident and in neighbouring areas;
 - 3) necessary time for escape, rescue and evacuation;
 - 4) availability and capacity of evacuations means;
 - 5) risk of fatalities during escape and evacuation;
 - 6) loss of escape routes due to visibility problems.

7.5.12 Environmental consequences

The following requirements apply:

- a) the analysis shall include all relevant scenarios as identified in the HAZID. Relevant scenarios are those that can contribute to the risk level of the system, see 7.4.3;
- b) for the identified release scenarios, discharge rate and duration distributions shall be established. The analysis shall reflect the variation in release rates and release durations;
- c) the analysis shall include modelling of drift and dispersion of the relevant harmful substance(s) on the sea surface and in the water column, and exposure of coastline, if relevant;
- d) the analysis shall consider the effect of relevant barriers such as detection, drain systems etc.;
- e) the analysis shall include modelling of the exposure of sensitive environmental resources, at least for the period for the planned activity and subsequent month;
- f) the analysis shall include calculation of environmental consequences. The consequences shall be a function of the relationship between amount of harmful substance and environmental sensitivity. Consequences shall be calculated for the identified risk indicators, e.g populations or habitats;
- g) if calculations of environmental effects are performed, these results shall be documented;
- h) it shall be possible to compare the environmental risk contributions from different facilities in an unambiguous way, i.e. the calculation of environmental consequences must be comparable;
- i) the analysis shall also reflect planned emergency preparedness measures.

See Annex G for informative description of environmental risk analysis methods and principles.

7.6 Establishing the risk picture

7.6.1 Objective

The objective of the risk documentation in the concept definition, optimization and detailed engineering phase is to establish and describe a risk picture in order to

- a) evaluate the risk level and the main risk contributors,
- b) compare the risk level with the risk acceptance criteria,
- c) confirm/revise dimensioning accidental loads,
- d) establish a basis for decision-making i.e. choice of systems, locations, redundancies, operational restrictions and limitations, safety strategies etc.,
- e) identify risk reducing measures,
- f) give input to the emergency preparedness analysis.

7.6.2 Requirements

The number of personnel injured shall be given as input to emergency preparedness analysis, if required. This will imply that the consequence assessment for personnel is extended to include injuries. The analysis may also be used for dimensioning of evacuation and rescue capacity.

Otherwise, see 5.6.2 and 6.6.2.

7.7 Risk evaluation

Identification and assessment of risk reducing measures as input to ALARP evaluations shall be performed.

7.8 Communication and consultation

No additional objectives or requirements, see 5.8.

7.9 Monitoring, review and updating the risk assessment

For analysis update close to operations phase, the following apply:

- a) results shall be presented in a way that facilitates use by operating personnel in planning and performing operational and maintenance work and small modifications;
- b) intermediate results from dynamic development of selected scenarios are examples of information that may be requested as input to the operational phase.

Otherwise, see 5.9.

8 Additional requirements to quantitative risk analysis (QRA) in operational phase

8.1 General

The requirements given in this clause are in addition to the general requirements given in clause 5, and reflect an assessment of a facility during the operational phase. The requirements are given for the assessment of a facility that has been in operation for a period of time, and thus some operational experience with the facility is assumed gained.

The basis for the requirements given in this clause is that an assessment performed during the detailed engineering phase, an as built assessment or an earlier performed assessment of the operational phase exists. An assessment similar to the one described in clause 7 is thus assumed available.

The emphasis in this section is placed on how to update the assessment described in clause 7 after a period of operational experience, and to tailor the assessment to provide decision support in the operational phase.

Assessment related to commissioning and start-up of a facility, and/or assessments related to lifetime extension for facilities planned to operate longer than the design period, are not covered in this clause, nor are assessments of major modifications. For such and other assessments not covered specifically by this clause the general requirements in clause 5 apply. The relevance and appropriateness of the requirements

given in clause 7 should be considered in each case for assessments not specifically covered by this NORSOK standard.

8.2 Establishing the context

8.2.1 Objective

The information provided by a risk assessment of the operational phase would mainly be used by operational personnel and the emergency preparedness organisation. The analysis should therefore be tailored to provide the information needed by these users, e.g. risk area maps, scenario descriptions etc. This includes input to minor modifications as well as input to decisions about required follow-up of faults and abnormal conditions, including interventions.

When a facility is in the operational phase the layout and design of the facility are to a large extent fixed. Assessments providing input to dimensioning accidental load etc. are therefore not as relevant as in engineering phases, given that no major modifications has been performed/is planned to be performed.

Also other contexts of QRA in the operational phase are indicated, but the requirements in 8.2 through 8.6 apply to the update of the analysis described in clause 7.

Objectives for operational risk assessment are as follows:

- a) assess overall risk level in the operational phase, reflecting modifications and operational status, e.g. activity level and manning;
- b) provide input to operational decisions may affect the risk on the facility;
- c) identify how operational tasks and special operations may be safely carried out;
- d) identify important improvement areas for operation;
- e) identify adequate maintenance strategies;
- f) assess barrier performance and demonstrate effects on the risk level of barrier deterioration;
- g) review status of assumptions and effect of changes during operations and modifications;
- h) communicate risk results and important factors to the workforce.

The general objectives for the risk assessment during operational phase is to verify previous risk results, update the risk picture according to changes and to provide input to decisions concerning further risk reduction through technical modifications and operational and administrative measures. The QRA shall provide input to

- a) compliance with acceptance criteria,
- b) ALARP evaluations,
- c) verification/update of DSHAs,
- d) verification/update of requirements to barriers,
- e) operational restrictions and conditions including restrictions applicable to simultaneous operations,
- f) minor modifications,
- g) assessment of operational barriers.

8.2.2 Requirements

The overall requirements to the QRA studies in the operational phase are as follows:

- a) the establishing of an updated study basis (given the defined objectives and scope for the assessment, etc.) The validity of all technical, operational and analytical assumptions that were made for the latest revision of the QRA shall be verified and the need for changes assessed. Technical assumptions shall as far as possible be verified and eliminated as assumptions, i.e. be reflected in system description;
- b) operational experience with respect to technical conditions, experienced failure rates and incidents that have occurred on the facility shall be reflected as appropriate in the study basis, taking statistical significance of the data into account;
- c) assumed or planned different levels of activity, such as simultaneous operations or periods with a high level of activity, shall be described as a part of the study basis, if relevant, given the objectives and scope for the assessment;
- d) description of the current technical condition (in relation to possible degradation) for essential technical systems and safety functions;

- e) description of current organisational/operational condition (in relation to possible positive or negative effects on the risk or the basis for the risk assessment).

8.3 Hazard identification

8.3.1 Objectives

The main objective in the operational phase should be to update the previously performed HAZID given the gained experience from operation of the facility, new knowledge and possible technical, organisational or administrative changes on the facility.

8.3.2 Requirements

The requirements to hazard identification in the operation phase are as follows:

- a) in addition to reviewing and updating the HAZID performed in earlier phases (in optimisation phase or previously during operations) the following shall be evaluated and the possible risk influence considered:
 - 1) new knowledge about accidents or near accidents (on the facility and/or relevant knowledge gained from accidents or near accident occurring on other facilities, industries, etc.);
 - 2) modifications/technical changes (minor and major) implemented since the previous assessment was performed;
 - 3) planned modifications in the future;
 - 4) operation/organisational changes (minor and major) implemented since the previous assessment was performed;
 - 5) the technical and operational conditions on the facility.
- b) the HAZID group shall include personnel with operational and emergency preparedness experience from this facility;
- c) high activity periods shall be identified and evaluated explicitly.

8.4 Analysis of initiating events

8.4.1 Objective

In this phase it is important to focus on the experience obtained at the facility and knowledge of experience from similar facilities. Otherwise, see 5.4.1.

8.4.2 Requirements

The following requirements apply:

- a) when a QRA is performed for a facility that has been in operation for several years, the frequency calculations shall include actual statistics for the facility. However, such adjustment should only be performed for data that can be considered statistically significant;
- b) the technical condition of equipment and barriers at the facility shall be evaluated, and the possibility of adjusting failure frequencies considered;
- c) in case of adjusted frequencies, the background data, the judgements made and possible statistical treatment shall be documented.

8.5 Analysis of consequences

8.5.1 Objective

No additional objectives, see 5.5.2.

8.5.2 Requirements

The following requirements apply:

- a) the focus of the analysis in the operational phase or late engineering phases shall be related to operational and emergency preparedness issues, this implies changes in the need of consequence analysis both with respect to detailing of the analysis and the result presentation;
- b) the consequence analysis shall, when relevant, reflect the need for information by e.g. personnel involved in operations and emergency preparedness, e.g. scenario descriptions.

8.6 Establishing the risk picture

8.6.1 Objective

The presentation of the risk picture shall reflect the objective of the risk analysis for this phase, see 8.1.

8.6.2 Requirements

The following requirements apply:

- a) the requirements in 5.6 apply, with exception of requirements related to design criteria and facility layout;
- b) example of information that may be requested as input to the operational phase is intermediate results from dynamic development of selected scenarios;
- c) results shall be presented in a way that facilitates use by operating personnel in planning and performing operational and maintenance work and small modifications;
- d) all operational and technical assumptions and presuppositions (used as a basis for the assessment) that represents restrictions or conditions for the operation of the facility, or restrictions related to modifications on the facility shall be listed and described separately;
- e) the effect of deviation from an assumption or presupposition shall, if assessed (by the use of sensitivity analysis), be described in a manner that provides understandable information to the users;
- f) it shall be documented how deviations from assumptions and presuppositions that have not been subjected to sensitivity analysis are to be treated, e.g. 'deviation from this assumption requires a new assessment of...';
- g) all analytical assumptions and presuppositions shall be listed.

8.7 Risk evaluation

No additional requirements, see 5.7.

8.8 Communication and consultation

No additional requirements, see 5.8.

8.9 Monitoring, review and updating the risk assessment

No additional requirements, see 5.9.

9 General requirements for emergency preparedness assessment

9.1 General

Figure 4 presents the steps of emergency preparedness assessment process in relation to input from the QRA. The emergency preparedness assessment will consist of the following main steps:

1. Establish context of assessment (Step 1).
2. HAZID (Step 2).
3. Establish defined situations of hazards and accident (DSHA) and analyse course of events (Step EPA 3).
4. Identify governing performance requirements for emergency preparedness (Step EPA 4).
5. Identify and evaluate (Step EPA 5).
 - Specific performance requirements.
 - Specific emergency response strategies.
 - Measures and solutions.
6. Documentation of process and results.

Step 7 and step 8, illustrated in Figure 4, are described in 9.8 and 9.9, respectively.

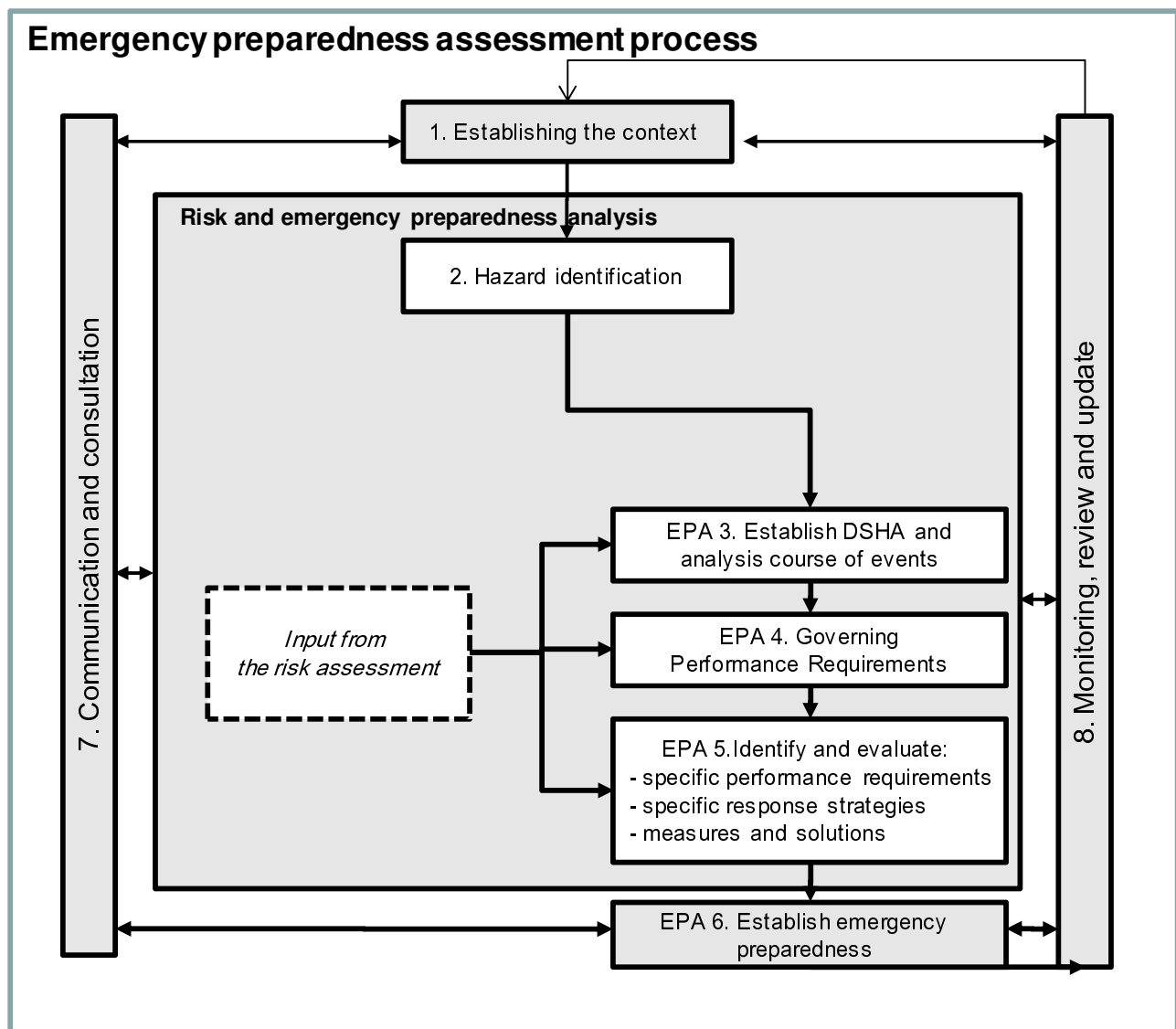


Figure 4 The process of performing an emergency preparedness assessment

The different steps of the assessment will have different focus in different life cycle phases. The following chapters describe the different steps for three main categories of project phases:

- the concept selection phase, see clause 10;
- the concept definition, optimization and detailed engineering phases, see clause 11;
- the operational phase, see clause 12.

The objective and content of each step of an EPA in each phase will vary.

The emergency preparedness assessment shall be carried out in every life cycle phases of a facility in close interaction with the QRA.

When an emergency preparedness assessment is carried out, the following aspects shall be carried forward from the risk analyses:

- DAEs (as part of the DSHAs) shall be identified and described. Relevant information about the major accidents from the QRA shall be identified and described. This is typical information about potential consequences of an initial event, variation in consequences and course of events etc.;
- assumptions and premises shall be identified and documented as a basis for establishing performance requirements for emergency preparedness and limitations for operation;

- c) recommendations from the QRA shall be considered when establishing performance requirements for emergency preparedness.

9.2 Establish the context of the assessment

9.2.1 Objective

The objective of step 1 in Figure 4 is to define the basic parameters for the emergency preparedness assessment and to set the scope.

9.2.2 Requirements

9.2.2.1 General

The establishment of the context for the emergency preparedness assessment shall as a minimum include, but not be limited to, the following:

- define the objectives;
- define the scope;
- describe premises;
- define responsibilities;
- describe required competence and participation in the emergency preparedness assessment;
- select suitable process/method – plans/activities;
- define the system¹ (analysis object);
- define the execution plan.

The general requirements related to each of the above listed subjects are given in 9.2.2.2 to 9.2.2.9.

9.2.2.2 Define the objectives

The objectives for the emergency preparedness assessment relevant for the project phase for the system(s) shall be defined. The objectives shall be suitable for the purpose of the assessment, particularly with respect to providing sufficient and appropriate input to the decision-basis at the right time.

The defined objectives for the emergency preparedness assessment (and its included elements) shall be documented.

9.2.2.3 Define the scope

The scope of the emergency preparedness assessment shall be defined and as a minimum include

- a) defined analysis objects,
- b) description of activities to be carried out.

Depending on the system(s) subjected to the assessment and the objectives of the process, the emergency preparedness assessment may include establishment of EER strategies.

9.2.2.4 Describe premises

The premises for the emergency preparedness assessment shall be identified and described. The premises shall as minimum

- a) define the purpose of the assessment in accordance with the needs of the activity,
- b) identify and describe the target groups for the results of the assessment,
- c) identify relevant regulations, possible classification society rules and applicable requirements and specifications,
- d) identify overall emergency preparedness philosophy,
- e) identify other internal company requirements,
- f) identify relevant QRA premises and assumptions that may influence the EPA,
- g) identify relevant operational premises for the EPA.

¹ 'System' is used in this NORSOK standard as a common expression for installation(s), plant(s), system(s), activity/activities, operation(s) and/or phase(s)

9.2.2.5 Define responsibilities

Responsibilities related to planning and executing of the entire process, the elements and the various tasks/activities included shall be defined between the involved parties.

9.2.2.6 Describe required competence and participation in emergency preparedness assessment

During the process of the emergency preparedness assessment the following personnel/competence shall be involved in all life cycle phases:

- a) operational experience;
- b) emergency preparedness assessment (regulatory requirements, methods);
- c) QRA knowledge;
- d) health personnel;
- e) safety representative/work-force;
- f) external emergency resource representatives, if applicable and required.

In addition personnel with engineering/design competence shall be involved during project phases.

Personnel from the emergency preparedness organisation shall be involved for assessments in operational and modification phases.

9.2.2.7 Define the methods, models and tools to be used in the process

All methods, models and tools that are used shall be tailored to the needs of the decision support, the objectives and scope of the individual analysis.

9.2.2.8 Define the system(s)

The boundaries for the emergency preparedness assessment shall be defined and described in a suitable manner.

The description shall as a minimum include the following main aspects:

- a) the technical system (process, structure, utility, safety, emergency preparedness systems);
- b) the period of time and types of operations and activities to which the analysis relates;
- c) available resources on the facility;
- d) interaction with relevant resources:
 - 1) company, field, area and external emergency resources for offshore facilities;
 - 2) company and external emergency resources for onshore facilities.
- e) definition of risk exposed groups including possible 3rd party groups.

The boundaries set in the emergency preparedness assessment process shall be documented.

9.2.2.9 Define the execution plan for the process

A plan for the execution of the emergency preparedness assessment shall be established. The plan shall include the following aspects:

- a) deliveries throughout and at the end of the process;
- b) time schedule;
- c) decision milestones;
- d) involvement of target groups for the assessment;
- e) establishment of the basis for the assessment;
- f) quality assurance process.

Responsibilities for executing, follow-up, and management of deviations from the plan shall be established in accordance with the requirements given in 5.9.

The plan and the follow-up of the plan shall be documented.

9.3 Hazard identification (HAZID)

9.3.1 Objective

The objective of step 2 in Figure 4 is to select hazards relevant for the emergency preparedness analysis process.

9.3.2 Requirements

The following elements shall be included in the emergency preparedness assessment process:

- a) participation in the risk assessment HAZID; or
- b) screening of risk assessment HAZID.

The HAZID is described in 5.2.

9.4 Identify defined situations of hazards and accident

9.4.1 Objective

The objective of step EPA 3 in Figure 4 is to select and describe the DSHAs that reflect the analysis object(s) and operation/activity in question.

9.4.2 Requirements

The following requirements apply:

- a) the selection of DSHAs shall include
 - 1) major accidents including the dimensioning accidental events identified in the QRA,
 - 2) accidental events that appear in QRA without being identified as major accidents, as long as they represent separate challenges to the emergency preparedness, including accidental events with an annual probability lower than 1×10^{-4} ,
 - 3) events that have been experienced in comparable activities,
 - 4) acute pollution,
 - 5) events for which emergency preparedness exists according to normal practice,
 - 6) temporary risk increase e.g. drifting objects, man over board, unstable well in connection with well intervention, and environmental conditions, etc.
- b) description of each DSHA;
- c) the selection of the DSHAs shall be documented including description of the criteria for the selection.

9.5 Governing performance requirements

9.5.1 Objective

The objective of step EPA 4 in Figure 4 is to establish a list of governing performance requirements as basis for the emergency preparedness analysis.

9.5.2 Requirements

For the analysis a set of performance requirements for the facility and the DSHA shall be established. Company performance requirements for emergency preparedness should be a starting point for the analysis.

The list of governing performance requirements for emergency preparedness shall

- a) be in accordance with relevant requirements from authority regulations, possible classification society rules and applicable standards and specifications,
- b) be in accordance with the operator overall emergency preparedness philosophy or principles,
- c) be in accordance with any company and/or operator requirements to emergency preparedness.

9.6 Identify and evaluate

9.6.1 Objective

The objective of step EPA 5 in Figure 4 is to identify and evaluate the need for specific performance requirements and emergency preparedness measures and solutions required to supplement the governing performance requirements and to establish emergency response strategies.

9.6.2 Requirement

The analysis shall give input to emergency preparedness solution such as

- a) escape routes,
- b) safe area including main muster and evacuation area,
- c) means of evacuation (type, location and capacity),
- d) equipment for rescue of personnel,
- e) use of and interaction with external resources and possible interface with 3rd party,
- f) standby vessels,
- g) equipment and means for mitigating environmental impact from acute pollution,
- h) dimensioning of the emergency preparedness organisation and necessary equipment.

The different solutions shall be evaluated against the performance requirements for emergency preparedness. The need for specific performance requirements as well as specific strategies for emergency response shall be evaluated, see 9.6.3 and 9.6.4.

9.6.3 Specific performance requirements

Possible need for specific performance requirements shall be evaluated. The specific performance requirements for emergency preparedness shall

- a) be based on the governing performance requirements,
- b) be concept/facility specific when required,
- c) be based on the DSHA descriptions,
- d) be established as an integrated part of the analysis,
- e) include/reflect relevant assumptions and premises in the risk analysis,
- f) be
 - 1) expressed as functionality,
 - 2) easy to understand,
 - 3) explicit and measurable,
 - 4) realistic.
- g) be established in relation to the following typical emergency response phases:
 - 1) detection and alert;
 - 2) danger limitation;
 - 3) rescue;
 - 4) escape and evacuation;
 - 5) normalisation.
- h) include a description of the background for the performance requirements.

9.6.4 Specific emergency response strategies

Specific emergency response strategies against the DSHAs shall be prepared. The strategies shall include a description of emergency response actions.

The following apply:

- a) the strategies shall be based on an assessment of the DSHAs and the overall emergency preparedness philosophy or principles;
- b) the strategies shall be based on an evaluation of the performance requirements for emergency preparedness and the identified measures and solution;
- c) the strategies shall be established as an integrated part of the analysis.

9.7 Documentation of assessment

9.7.1 Objective

Suitable information shall be provided in a way understandable to all relevant personnel, decision-makers as well as operating personnel to make sure that it is sufficiently adapted for operational use.

9.7.2 Requirements

The documentation and results of the emergency preparedness assessment shall include

- a) stating of the objectives, scope and limitations,
- b) description of the facility in question, inclusive all phases,
- c) identification of assumptions and premises, in particular those derived from the QRA,
- d) description of the methodology used,
- e) identification of the analysis team,
- f) description of all relevant DSHA,
- g) description of the defined performance requirements for emergency preparedness,
- h) description of the emergency response strategies,
- i) description of the required resources and solutions,
- j) recommendations.

9.8 Communication and consultation

9.8.1 Objective

Relevant internal and external stakeholders (relative to operator) shall be involved to improve the quality of the emergency preparedness assessment process and its ability to be tailored and suitable for its intended purpose(s). Involvement should be at the right time and with the appropriate level of involvement throughout the entire process.

9.8.2 Requirements

The following requirements apply:

- a) a plan for communication and consultation with internal and external stakeholders shall be developed at an early stage of the process;
- b) the plan shall address communication and consultation related to (but not limited to)
 - 1) the establishment of the context for the risk assessment,
 - 2) the execution of the assessment,
 - 3) how the assessment and its results shall be communicated to various stake holders.
- c) the plan shall include a brief description of how and when the communication shall be performed (written and/or oral communication) in general, and for subjects that requires a specific form of communication, including feed-back from the receiver of the information. Assumptions and presuppositions that are to be used in the assessment are examples of information that requires communication between those performing the assessment and those responsible for the technical and operational solutions to be used;
- d) those responsible for the communication and consultation needed shall be identified and included in the plan.

9.9 Monitoring, review and updating of the emergency preparedness assessment

9.9.1 General

In several of the phases covered by this NORSOK standard (e.g. the concept selection phase and the engineering phase), changes (or decided implemented) to the facility or operation(s) subjected to the assessment may be implemented as the project evolves. The level of details may also increase throughout the process as the project develops.

9.9.2 Objective

To monitor the established context, with respect to its validity due to decisions made, new knowledge (including the level of details available about the system or operation to be analysed) or other factors which may jeopardise the validity of the context. Results from scoping or framing studies, performed after the

context was updated, or results from studies or assessments performed as a part of the emergency preparedness assessment process may also require the context to be updated.

To update the context throughout the process if and when required.

To assure that the emergency preparedness assessment process and its various elements is executed based on an updated context, if and when, the context has been modified.

9.9.3 Monitoring and review of emergency preparedness assessment process

Monitoring and review is related to

- analyzing and learning lessons from events, changes and trends,
- detecting deviations from assumptions and premises of the emergency preparedness assessment,
- detecting changes in the external and internal context, including changes to the risk itself, that may required revision of emergency preparedness assessment and evaluation.

The monitoring and review in all phases will be a mixture of qualitative and quantitative analyses. It will be essential to have a system to follow up results and recommendations from all types of studies.

Requirements to monitoring and review are as follows:

- a) monitoring and review can involve regular checking or surveillance of what is already present or can be periodic or ad hoc. Both aspects shall be planned. It is not sufficient to rely only on occasional reviews and audits;
- b) the results of monitoring and review shall be recorded and internally or externally reported as appropriate;
- c) responsibilities for monitoring and review shall be clearly defined;
- d) a plan for follow-up of the analysis shall be prepared, containing an assessment of the conclusions and recommendations as well as plans for implementation of risk reducing measures, including emergency preparedness measures.

10 Evaluation of emergency preparedness in concept selection phase

10.1 Establish the context of the assessment

10.1.1 Define the objective of the emergency preparedness assessment

The objective for the EPA in the concept selection phase is to form basis for input to comparison and ranking of field development concepts, to identify any emergency preparedness aspects that may require extra costs in order to achieve an acceptable solution, and to identify any conditions that may expel a concept.

The following requirements apply:

- a) the EPA shall integrate premises and results from the facility risk assessment, through each project phase;
- b) the EPA shall be carried out by a integrated analyse team that holds
 - 1) risk Analysis expertise,
 - 2) EPA expertise,
 - 3) technical/design engineering expertise,
 - 4) general operational expertise for similar operations and activities.
- c) the EPA shall include planned/expected activities relevant for the operation of the facility, e.g.:
 - 1) normal operation;
 - 2) well intervention and drilling activities;
 - 3) intermediate phases with temporary increase of risk, e.g.:
 - i. commissioning;
 - ii. marine activities (flotel, heavy lifting, subsea installation);
 - iii. installation activities;
 - iv. turnarounds.
- d) the effectiveness of the available field- and/or area resources that are part of the emergency preparedness for the facility shall be addressed in the EPA, in addition to dedicated facility specific resources.

10.1.2 Define the scope

No additional requirements to 9.2.2.3.

10.1.3 Describe premises**10.1.3.1 Objective**

The objective is to identify and describe the premises for the emergency preparedness assessment.

10.1.3.2 Requirements

No additional requirements to 9.2.2.3.

10.1.4 Define the system**10.1.4.1 Objective**

The objective is to define, describe and set boundaries for the emergency preparedness assessment for each concept.

10.1.4.2 Requirements

No additional requirements than listed in 9.2.2.8.

10.2 Hazard identification (HAZID)

No additional requirements than those given in 9.3.

10.3 Identify defined situations of hazards and accident**10.3.1 Objective**

The objective is to select and make an overall description of the DSHA that reflects each concept and operation/activity in question.

10.3.2 Requirements

In addition to the general requirements in 9.4.2, the following requirements apply:

- a) a list of DSHA for each concept shall as a minimum be established for each concept;
- b) the description of each DSHA shall as minimum include
 - 1) relevant information that illustrates the variability of each DSHA,
 - 2) a coarse estimate of the number of persons that may be threatened or injured, as well as environmental resources and assets that may be threatened or damaged.

10.4 Governing performance requirements**10.4.1 Objective**

The objective is to establish a list of governing performance requirements for emergency preparedness for the concepts.

10.4.2 Requirements

No additional requirements to those given in 9.5.2.

10.5 Identify and evaluate**10.5.1 Objective**

The objective is to identify and describe the overall emergency preparedness measures and solutions required to meet the overall philosophies and governing performance requirements for emergency preparedness and to establish overall emergency response strategies for each concept.

10.5.2 Requirements

No additional requirements to those given in 9.6.2.

10.5.3 Specific performance requirements

No additional requirements to those given in 9.6.3.

10.5.4 Specific emergency response strategies

The emergency response philosophy/strategy shall set the premises for each concept to achieve a successful emergency response. A concept specific philosophy/strategy for emergency preparedness against situations of hazard and accident shall be prepared for all concepts.

EER philosophies/strategies shall be described for each concept. The philosophy and EER philosophies/strategy shall be based on an assessment of the DSHAs and the overall emergency preparedness philosophy.

10.6 Documentation of assessment**10.6.1 Objective**

Suitable information shall be provided in an understandable way for all relevant personnel, decision-makers.

10.6.2 Requirements

The documentation and results of the emergency preparedness assessment shall include

- a) stating of the objectives, scope and limitations,
- b) description of the concepts in question, inclusive all phases,
- c) identification of assumptions and premises, in particular those derived from the risk analysis,
- d) description of methodology,
- e) identification of the analysis team,
- f) description/list of all relevant DSHA for each concept,
- g) description of the emergency response philosophies for each concept,
- h) descriptions of the overall performance requirements for emergency preparedness,
- i) description of the required measures and solutions for each concept,
- j) minimum requirements for facility, field and area measures and resources,
- k) description of emergency preparedness measures and resources which is required for each concept,
- l) recommendations (input to selection of concept).

11 Emergency preparedness analysis (EPA) in concept definition, optimisation and detailed engineering phases**11.1 Establish the context of the assessment****11.1.1 Define the objective of the emergency preparedness assessment**

The objective for emergency preparedness assessment in the concept definition, optimization and detailed engineering phases is to form basis for

- optimization of the chosen concept,
- EER solutions.

In the late optimisation and detailed engineering phases the emergency preparedness assessment objective shall also be to

- establish and structure response strategies, performance requirements for emergency preparedness, the emergency response organisation and measures,
- specify minimum requirements for emergency response by the organization,
- provide basis for the emergency preparedness plans,
- provide basis for facility specific training and exercise plans.

The following requirements apply:

- a) the emergency preparedness assessment shall integrate premises and results from the facility QRA, through each project phase;
- b) the emergency preparedness assessment shall be carried out by a integrated analyse team that holds
 - 1) QRA expertise,
 - 2) EPA expertise,
 - 3) technical/design engineering expertise,
 - 4) general operational expertise,
 - 5) safety delegate.
- c) the emergency preparedness assessment shall include known/planned activities relevant for the operation of the facility, e.g.:
 - 1) normal operation;
 - 2) well intervention and drilling activities;
 - 3) intermediate phases with temporary increase of risk, e.g.:
 - I. commissioning;
 - II. marine activities (flotel, heavy lifting, subsea installations);
 - III. installation activities;
 - IV. turnarounds;
 - V. combined construction and operational phases.
- d) the effectiveness of the available field- and/or area resources that are part of the emergency preparedness for the facility shall be addressed in the emergency preparedness assessment, in addition to dedicated facility specific resources;
- e) final version of assessment shall be based on as-built documentation.

11.1.2 Define the scope

The scope of the emergency preparedness assessment process shall, in addition to the requirements in 9.2.2.3, as a minimum include the following:

- a) define analysis object, i.e. facility, operations, activities and organisation;
- b) describe premises for the emergency preparedness assessment such as emergency preparedness and EER philosophies and company requirements;
- c) select and describe the defined situations of hazards- and accident;
- d) establish specific performance requirements for emergency preparedness;
- e) identify and evaluate the emergency preparedness measures and solutions;
- f) establish and detail the facility specific emergency response strategies;
- g) prepare documentation, sufficient adapted for operational use.

11.1.3 Describe premises

11.1.3.1 Objective

The objective is to define and describe the premises for the emergency preparedness assessment.

11.1.3.2 Requirements

No additional requirements than those given in 9.2.2.4.

11.1.4 Define the system

11.1.4.1 Objective

The objective is to define and describe and set boundaries for the emergency preparedness assessment.

11.1.4.2 Requirements

No additional requirements than those given in 9.2.2.8.

11.2 Hazard identification (HAZID)

No additional requirements than those given in 9.3.

11.3 Defined situations of hazards and accident (DSHA)

11.3.1 Objective

The objective is to select and describe the DSHAs that reflect the analysis object and operation/activity in question.

11.3.2 Requirements

The general requirements in 9.4.2 apply. In addition the the description of each DSHA shall as minimum include:

- a) relevant scenarios to illustrate the variability of each DSHA;
- b) situations in terms of duration and extent;
- c) the number of persons that may be threatened or injured, as well as environmental resources and assets that may be threatened or damaged;
- d) operational and environmental conditions that may be present when the DSHAs occur;
- e) description of the development of each scenario, including the escalation potential;
- f) relevant barriers.

11.4 Governing performance requirements

No additional requirements to those given in 9.5.

11.5 Identify and evaluate

11.5.1 Objective

The objective is to identify and evaluate emergency preparedness measures and solutions required to meet the governing and specific performance requirements for emergency preparedness and to establish emergency response strategies.

11.5.2 Requirements

The assessment shall

- a) give recommendations to design of the facility, such as
 - 1) escape routes,
 - 2) safe area including main muster and evacuation area,
 - 3) evacuation means (type, location and capacity),
 - 4) availability and location of emergency response equipment.
- b) give input to emergency preparedness solution (Facility Regulations, Chapter III-IV) such as
 - 1) interface with 3rd party,
 - 2) equipment for rescue of personnel,
 - 3) material for action against acute pollution,
 - 4) use of and interaction with external resources,
 - 5) standby vessels,
 - 6) means of escape and evacuation,
 - 7) manual fire-fighting and fireman's equipment,
 - 8) survival suits and life jackets etc.
- c) form basis for dimensioning of the emergency preparedness organisation including their plans and procedures:
 - 1) identify necessary organisational functions and organisation;
 - 2) skills and competence;
 - 3) robustness and flexibility.

NOTE The ER organisation should be flexible, taking into account human behaviour under stress and that key personnel may be unavailable or injured in the emergency. Flexibility in the ER organisation should therefore be considered.

- d) evaluate the emergency preparedness organisation to ensure that all each position in the organisation only is assigned to tasks which are compatible.

11.5.3 Specific performance requirements

No additional requirements to those given in 9.6.3.

11.5.4 Specific emergency response strategies

In addition to the requirements given in 9.6.4, the following requirement shall as a minimum be included:

- a) a facility specific strategy for emergency preparedness against situations of hazard and accident shall be prepared;
- b) an ERS shall be based on an assessment of the DSHAs and the emergency preparedness philosophy.

11.6 Documentation of assessment

11.6.1 Objective

Suitable information shall be provided in an understandable way for all relevant personnel, decision-makers as well as operating personnel.

11.6.2 Requirements

The requirements in 9.7.2 apply.

12 Emergency preparedness analysis (EPA) in operational phase

12.1 Establish the context of the assessment

12.1.1 Define the objectives of the emergency preparedness assessment

The objective with the emergency preparedness assessment in operational phase is to provide an up to date basis for

- establishment and structuring of response strategies, performance requirements for emergency preparedness, the emergency response organisation and measures,
- minimum requirements for organisational response resources,
- emergency preparedness plans,
- facility specific training- and exercise plans.

Additional requirements:

- a) the emergency preparedness assessment in operational phase shall reflect the facility's QRA, both premises and results;
- b) the analyses documentation shall be adapted for operational usage;
- c) the emergency preparedness assessment in operational phase shall be carried out by a integrated analyse team that holds
 - 1) QRA expertise,
 - 2) detailed knowledge of the QRA in question, from the operator,
 - 3) EPA expertise,
 - 4) operational expertise (from the actual facility if possible),
 - 5) safety delegate.
- d) the emergency preparedness assessment in the operational phase shall include activities relevant for the operation of the facility. Following activities shall be included, when relevant:
 - 1) normal operation, including well intervention and drilling activities,
 - 2) intermediate phases with temporary increase of risk, e.g. commissioning,
 - 3) minor modifications (those not requiring QRA update):
 - i. marine activities (e.g. flotel, heavy lifting, subsea installations);
 - ii. maintenance shutdown periods;
 - iii. simultaneous construction and operational phases.
- e) bridge linked installations shall be included in the emergency preparedness assessment as a totality;
- f) the effectiveness of the available field- and/or area resources that are part of the emergency preparedness for the facility shall be addressed in the emergency preparedness assessment, in addition to dedicated facility specific resources.

12.1.2 Define the scope

No additional requirements to 9.2.2.3.

12.1.3 Describe premises

12.1.3.1 Objective

The objective is to define and describe the premises for the emergency preparedness assessment, alternatively verify and update the premises for emergency preparedness assessments carried out in earlier phases.

12.1.3.2 Requirements

The following requirements apply:

- a) define the purpose of the assessment in accordance with the needs of the activity;
- b) identify and describe the target groups for the results of the assessment;
- c) verify and update emergency preparedness philosophies;
- d) verify and update EER philosophies/strategies;
- e) identify relevant regulations, possible classification society rules and applicable standards and specifications;
- f) identify other internal company requirement;
- g) identify relevant QRA premises that may influence the emergency preparedness assessment;
- h) identify and verify relevant operational premises for the emergency preparedness assessment:
 - 1) operational constraints;
 - 2) technical status of safety system and barriers.

12.1.4 Define the system

12.1.4.1 Objective

The objective is to define and describe and set boundaries for the emergency preparedness assessment.

12.1.4.2 Requirements

To define the object of the assessment the following apply:

- a) describe the technical system (process, structure, utility, safety, emergency preparedness systems);
- b) define the period of time and types of operations and activities to which the assessment relates;
- c) available resources on the facility;
- d) describe interaction with relevant resources:
 - 1) company, field, area and external emergency resources for offshore facilities;
 - 2) external emergency resources for onshore facilities.
- e) identify assumptions and premises in the QRA relevant for the emergency preparedness assessment;
- f) describe design and operational premises.

12.2 Hazard identification (HAZID)

No additional requirements than those given in 9.3.

12.3 Defined situations of hazards and accident (DSHA)

12.3.1 Objective

The objective is to select and describe the DSHA that reflects the analysis object and operation/activity in question, alternatively review and update the DSHA scenario descriptions for emergency preparedness assessments carried out in earlier phases. In addition the objective is to assess of the need for additional DHSAs.

12.3.2 Requirements

The following requirements apply:

- a) the selection of DHSAs shall include:
 - 1) major accidents identified in the QRA;
 - 2) accidental events that appear in HAZID without being identified as major accidents, as long as they represent separate challenges to the emergency preparedness. Examples are
 - i. man overboard situations,

- ii. limited oil spills and other spills,
 - iii. occupational accidents.
- 3) events that have been experienced in comparable activities;
- 4) acute pollution not part of the QRA;
- 5) events for which emergency preparedness exists according to normal practice;
- 6) situations/activities with temporary risk increase. Examples are
 - i. commissioning activities,
 - ii. drifting objects,
 - iii. unstable well in connection with well intervention,
 - iv. maintenance shutdown periods,
 - v. simultaneous construction and operational phases,
 - vi. safety system temporarily out of operation.
- b) the selection of the DSHAs shall be documented, and include description of the criteria for the selection.
- c) the description of each DSHA shall as minimum include
 - 1) relevant scenarios to illustrate the variability of each DSHA, such as:
 - i. different process leak scenarios in the QRA;
 - ii. possible development of the scenario in both duration, extent, escalation potential and possible impairment of main safety functions.
 - 2) the number of persons that may be threatened or injured, as well as environmental resources and assets that may be threatened or damaged;
 - 3) operational and environmental conditions that may be present when the DSHAs occur;
 - 4) description of the development of each scenario, including the escalation potential;
 - 5) relevant barriers performance that may influence on the response strategy.
- d) relevant barriers performance may be, but are not limited to
 - 1) permanent barrier degradation, i.e deviations to regulatory requirements,
 - 2) insufficient, or lack of barriers, that influences duration and extent of the DSHA scenarios.

12.4 Governing performance requirements

12.4.1 Objective

The objective is to verify the relevance of the governing performance requirements for emergency preparedness used in earlier phases.

12.4.2 Requirements

No additional requirements to those given in 9.5.2.

12.5 Identify and evaluate

12.5.1 Objective

The objective is to identify and evaluate emergency preparedness measures and solutions to meet the governing and specific performance requirements for emergency preparedness and to establish emergency response strategies.

This includes evaluation of effectiveness and review of the basis and results of the emergency response dimensioning.

12.5.2 Requirements

The analysis shall

- a) give input to need for additional emergency preparedness solution such as
 - 1) interface with 3rd party,
 - 2) use of and interaction with external resources,
 - 3) equipment for rescue of personnel,
 - 4) measures for action against acute pollution,
 - 5) standby vessels,
 - 6) means of escape and evacuation,
 - 7) manual fire-fighting and fireman's equipment,
 - 8) survival suits and life jackets etc.,
- b) dimension and verify the emergency preparedness organisation including their plans and procedures:
 - 1) identify necessary organisational functions and organisation;

- 2) describe skills and competence;
- 3) evaluate robustness and flexibility.

NOTE [The emergency response organisation should be flexible, taking into account human behaviour under stress and that key personnel may be unavailable or injured in the emergency. Flexibility in the ER organisation should therefore be considered).

- c) describe which functions in the emergency preparedness organisation that are not compatible.

12.5.3 Specific performance requirements

No additional requirements to 9.6.3.

12.5.4 Specific emergency response strategies

Additional requirements to 9.6.4:

- a) a facility specific strategy for emergency preparedness against situations of hazard and accident shall be updated for all facilities;
- b) an ERS shall be based on an assessment of the DSHAs and the emergency preparedness philosophy;
- c) performance requirements for emergency preparedness shall be set at appropriate levels, as part of the ERS, against which the adequacy of the measures can be judged;
- d) the strategy shall be based on the results from the QRA, the possible chain of events and the performance of the barrier systems.

12.6 Documentation of assessment

12.6.1 Objective

Suitable information shall be provided in an understandable way for all relevant personnel, decision-makers as well as operating personnel to make sure that it is sufficient adapted for operational use.

12.6.2 Requirements

The documentation and results of the emergency preparedness assessment shall include

- a) statement of the objectives, scope and limitations,
- b) description of the object/facility in question, inclusive all phases,
- c) identifying assumptions and premises, including those derived from the QRA,
- d) detailed description of all relevant DSHA,
- e) description of the emergency response strategies,
- f) descriptions of the defined performance requirements for emergency preparedness and the barriers,
- g) description of the required emergency response organisation,
- h) description of the required equipment,
- i) description of the required and available resources.

Annex A

(informative)

Risk metrics, criteria and ALARP evaluations

A.1 Introduction

The decision context (in relation to phase, activity or system) and the need for decision support are aspects that need to be considered when choosing the RAC. In addition, the criteria have to reflect the approach to risk analysis. There are different types of RAC suitable for different purposes and the levels of detail of the analysis:

- quantitative RAC for quantitative studies, typically covering
 - facility integrity,
 - personnel (first party),
 - personnel third party,
 - environment.
- risk matrixes for qualitative/semi-quantitative studies;
- risk comparison criteria.

The ALARP principle is valid for all categories, see A.5.

Requirements stipulated in standards, specifications, procedures, etc. which are necessary to achieve acceptable safety, should not be viewed as RAC. However, such requirements will be important premises in relation to the risk analysis in order to achieve an acceptable level of risk.

A.2 Risk acceptance criteria for quantitative analyses

A.2.1 General

Quantitative safety risk acceptance criteria should as a minimum cover risk related to people (loss of lives), environment and impairment criteria for dimensioning of vital buildings/equipment (in project/modification phases). Risk criteria related to other types of risk (e.g. health effect, financial etc.) are also needed, but are not included in the scope of this annex. The basis for defining environmental risk acceptance criteria is discussed in A.2.4.

The basis for the formulation of RAC should include

- a) the regulations that control safety and environmental aspects of the activities,
- b) the ALARP principle,
- c) recognized norms for the activity,
- d) the criteria and risk level of similar industry.

The RAC should be at a level where there is a reasonable balance between ambitions as to continuous improvement, defined safety objectives and technology improvements on one hand and what is realistic to achieve on the other.

A.2.2 Risk acceptance criteria related to main safety functions

This is presented in Annex B.

A.2.3 Risk acceptance criteria related to loss of life

A.2.3.1 General

Risk to people normally only considers risk of loss of life.

“People” are in this context divided into the following groups:

- 1st party: people working for the company, both employees and contractors (= personnel).

- 3rd party: bystanders, e.g. people passing by or living close to a facility.

In order to produce a full picture of the risk, one single criterion for each of these will normally not be sufficient. For example, criteria reflecting the average risk of all personnel might need to be complemented by a criterion on risk exposed groups.

In some cases, there are groups exposed to the risk that do not fall into the traditional definitions of groups as defined above, and where special considerations are needed. Examples of this are

- visitors,
- personnel involved in transport to and from facility,
- personnel at neighbouring facilities.

It should be considered whether it is necessary to establish risk acceptance criteria for these groups in order to have reference basis for all exposed personnel groups.

The criteria shall generally specify whether or not the exposure with respect to time spent at the location and the possible sheltering effect of buildings shall be taken into account. Alternatively, it is possible to express criteria in the form of probability of exceeding certain exposure limits in residential areas, etc.

As risk parameters for loss of lives, it should separate between parameters for individual risk, and parameters for societal risk. The first type is the risk seen from the individual's point of view; the latter is the risk as seen from the facility or society, i.e. the risk of causing fatal accidents, not related to specific individuals.

A.2.3.2 Risk metrics for individual risk

Some risk parameters are

- FAR is the number of fatalities per 100 million exposed hours. Used as a measure for overall risk, either for all personnel at a facility or for defined groups,
- IR is the annual probability of fatality for the individual person,
- GIR or AIR or, equals average IR for defined groups,
- IRPA.

GIR and FAR are both measures of the mean (average) risk of the members in a specific group.

It is essential when applying IR (or AIR or GIR) that the exposure time per year is specified. Both exposure for an individual person (typically $8760/3 = 2920$ h/year) and exposure for a position (typically 8760 h/year) are used. Time should be considered for different shift schedules (night vs. day) in operations phase and in the different project phases in quantitative construction risk analyses to reflect difference in risk exposure for an individual/group over a year/project.

GIR is used to express the probability that a randomly selected person from the group shall be killed (due to an accident) in a period of one year. AIR is used to express the average probability that a person (in a group) shall be killed (due to an accident) in a period of one year, GIR and AIR values are equal with these premises.

IRPA is used to express the probability that a specific person in a group, reflecting the average exposure time per annum for the individual of that group, typically 2920 h for an offshore installation employee, and the number of working hours per year for an onshore facility employee.

These metrics are often used for 1st party, and can also be used for 3rd party.

A.2.3.3 Risk metrics for group and societal risk

Some risk parameters are

- PLL is the expected number of fatalities per year,
- f-N curve – curve representing the frequency (f) of accidents causing $\geq N$ fatalities. The curve specifies a tolerable and a non-tolerable area within the diagram. Axes are normally logarithmic.

For manned facilities, PLL is normally used only as an intermediate result and not as a tolerance criterion, as it will mainly serve as a restriction on number of people. However, PLL does give a picture of the risk of fatalities that the facility or workforce is exposed to, and might thus make the risk picture more complete, even though not used as a risk criterion. PLL could be used as criterion for normally unmanned installations or for groups with an irregular risk exposure.

An f-N curve is often used for 3rd party, and can also be used for 1st party.

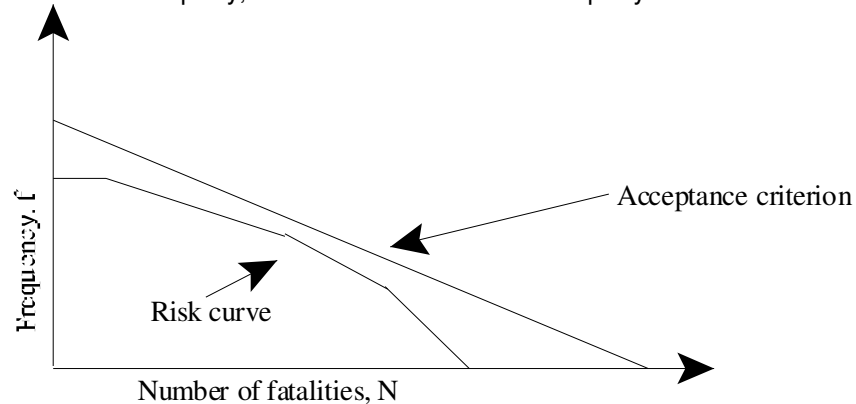


Figure A.1 – Example of f-N curve

A.2.4 Environmental risk acceptance criteria

Quantitative and/or qualitative environmental RAC for acute pollution should according to the Management Regulations be established for offshore activities to evaluate the risk level of the systems. Qualitative RACs are further discussed in A.3.

Quantitative environmental RAC can be defined for various operations, e.g. drilling operation, operation of installations and/or fields. More than one type of RAC, per operation, can be established to be able to cover several analytical endpoints.

Environmental RAC should include frequencies of discharges to the environment that results in defined environmental consequences. As a simplification of this, frequencies of discharges to the environment of pollutants and their volume and consequence potential may be used.

Environmental consequences can be defined as recovery time of sensitive habitats or populations. It may also be defined as e.g. effect on individuals, populations or habitats, or exposure of areas/volumes of a certain environmental sensitivity, for instance length of polluted shoreline or areas with specifically sensitive resources.

An environmental RAC commonly applied for offshore activity at the NCS is based on recovery time for sensitive environmental resources. The RAC is divided into five consequence categories:

1. Insignificant damage: recovery time less than 1 month
2. Minor damage: recovery time 1 month to 1 year
3. Moderate damage: recovery time 1 year to 3 years
4. Considerable damage: recovery time 3 years to 10 years
5. Serious damage: recovery time more than 10 years

The above mentioned environmental RAC based on recovery time, is specified as the upper limit for acceptable frequency for each of the consequence categories.

A.3 Qualitative and semi-quantitative criteria

A.3.1 Risk matrixes

The arrangement of accident probability and corresponding consequence in a matrix (see Figure B.2) may be a suitable expression of risk for early project phases where limited information is available, and for assessment of single operations, tasks or scenarios. The consequences may be defined in relation to

personnel, environment or assets, or to a combination of these. The matrix is separated into three regions as follows:

- high risk (red): risk reduction, high management attention or more detailed assessment is necessary;
- medium risk (yellow): risk reduction based on ALARP principle;
- Low risk (green): broadly acceptable risk.

The limit of acceptability is set by defining the regions in the matrix which represent high, medium and low risk. The risk matrix may be used for qualitative as well as semi-quantitative studies, depending on the definitions of categories. An example of a risk matrix is shown in Figure B.2. The categories would need to be further defined.

Impact category	E					
	D					
	C					
	B					
	A					
	Likelihood	1	2	3	4	5

Figure A.2 – Example of risk matrix

The following are examples of situations where the use of risk matrix is relevant:

- evaluation of risk in early project phases;
- evaluation of risk in relation to operations such as exploration drilling;
- evaluation of risk in relation to a particular system such as mechanical pipe handling;
- evaluation of risk related to single activities or tasks.

A.3.2 Comparison criteria

This type of criteria is suitable in more limited studies which aim at comparing certain concepts or solutions for a particular purpose with established or accepted practice. Often our risk studies for such purposes are relatively limited, implying that this type of RAC will be the most suitable. The criteria are suitable in relation to operations which are often repeated such as drilling and well interventions, heavy lift operations, diving, etc. The use of the comparison criteria requires that the basis of the comparison is expressed relatively precisely.

The formulation of the acceptance criterion in this context may be that the new solution should not represent any increase in risk in relation to current practice.

Examples of comparison criteria are as follows:

- alternative design (or use of new technology) for fire water system should be at least as safe as conventional technology;
- the risk level for the environment should not be higher compared to existing solution;
- alternative solution should be at least as cost effective as the established practice.

This type of RAC is also suitable for risk to personnel, environment and assets.

A.4 Risk acceptance criteria (RAC) for specific purposes

A.4.1 Time limited risk increase

There are operations that are not covered by the base case risk analysis as they are usually carried out during limited periods. Such operations may be construction, special lifting operations, drilling or other well activities, manned underwater operations, shut down periods for maintenance purposes, modification work, etc. Risk acceptance criteria for such conditions will have to reflect

- the duration of the period with increased risk,
- the peak level of risk during this operation,
- whether the risk increase is local or global for the installation,
- whether the risk increase affects the different personnel groups in the same way or differently.

A.4.2 Modifications

For significant modifications on existing facilities, the existing criteria for the facility apply. In addition, it might be useful to define criteria regarding the possible additional risk that the modification (after implementation) could cause.

A.4.3 Normally unmanned offshore facilities

Normally unmanned offshore installations are defined as offshore installations with a limited number of working hours, FAR or IR criteria considering only the time present at the facility will be misleading. Other criteria may be necessary.

A.4.4 Onshore pipelines

The paragraph below applies to the onshore pipelines that are connected to an onshore petroleum facility, for which PSA has the regulatory responsibility.

The individual and societal risk criterion for third party should be stipulated for any 10 km section of the pipeline route. This means that the risk is calculated for the “worst” 10 km section. If it is not evident which section is the “worst”, the risk may have to be presented for several sections. If the pipeline is shorter than 10 km the criterion remains the same, i.e. the criterion for individual risk or the f-N curve should not be shifted (scaled) according to the actual length.

A.5 As low as reasonably practicable (ALARP) evaluations

A.5.1 Objectives of risk reduction/ALARP process

Authority requirements, corporate requirements and international standards and recommended practices together define an upper level of risk above which the risk is considered to be intolerable. This represents the horizontal line in Figure A.3.

The region above the intolerable level is called the intolerable region, and risk cannot be justified except in extraordinary circumstances. The region below the intolerable level is called the ALARP or tolerable region. In this case, no lower level is defined which means that the risk shall be demonstrated to be ALARP regardless of the risk level.

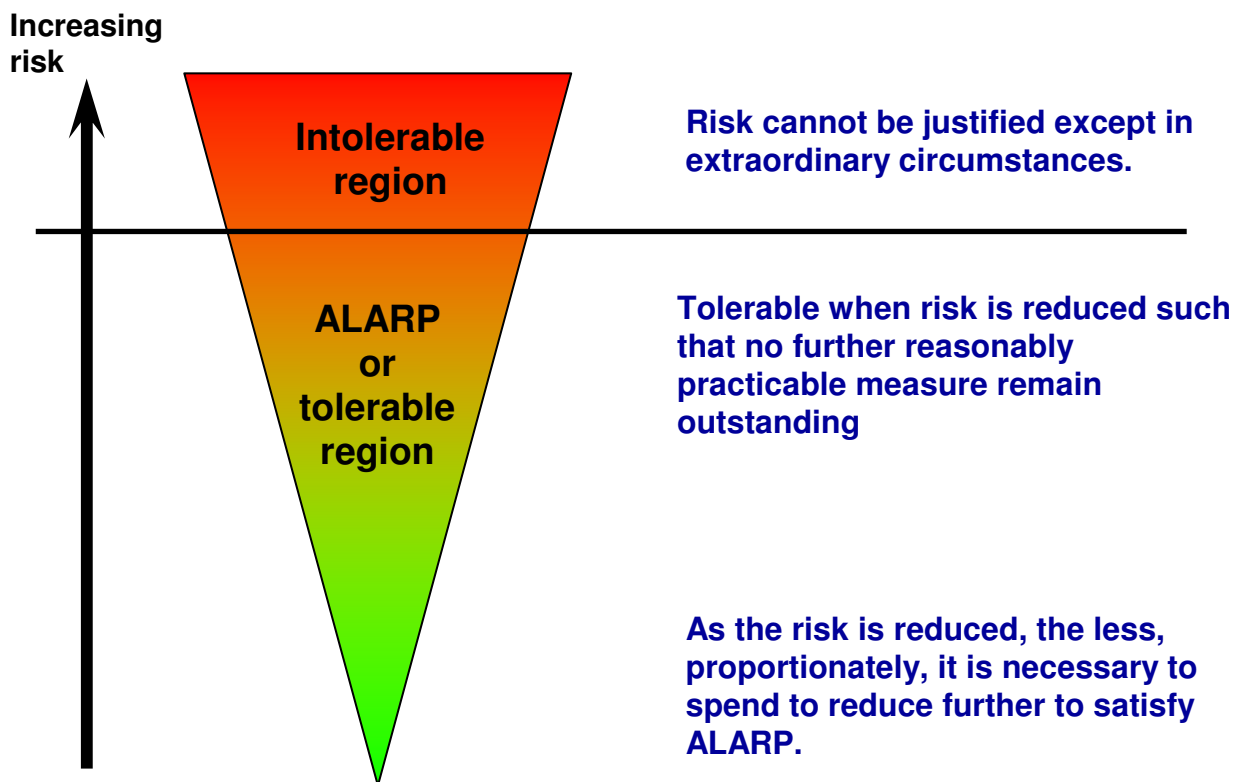


Figure A.3 – ALARP principle according to Norwegian legislation

Risk can be reduced by avoidance, adopting an alternative approach, or increasing the number and effectiveness of controls.

Identification of options/risk reduction measures is the fundamental stage in the risk management process and involves defining the various courses of actions, or alternatives, available and identifying possible risk reduction measures.

The generation of alternatives and measures will to a large degree be dependant of the scope of the ALARP process.

A.5.2 ALARP demonstration process

An ALARP demonstration process consists of the following steps:

1. Identification of potential risk reducing measures
2. Evaluation of risk reducing measures
3. Decision-making
4. Documentation of accepted risk reduction measures and rejected measures

Step 1 and step 2 have strong connections to risk analysis, and should have input from risk analysis studies. Step 3 and step 4 belong to risk treatment, and these steps are not discussed in this NORSOK standard.

A.5.3 ALARP evaluation principles

ALARP evaluations should be carried out with a 'reversed onus of proof' mindset, thus emphasising that it is not required for a proposed risk reduction measure to 'prove' its merit, but rather to 'prove' why it is justifiable not to implement a proposed measure.

The following should as a minimum be evaluated during the risk and ALARP evaluation:

- a) are authority requirements satisfied?
- b) are all corporate and local requirements, guidelines and philosophies as well as national and international standards and recommended practices satisfied?
- c) is the quantified risk level at least on par with risk levels of similar concepts?

- d) if there are solutions that do not meet the conditions of item b) or item c) above, can it be satisfactory demonstrated that no significant increase in risk level will result as a consequence of these deviations?
- e) where quantitative requirements have been defined, is there a sufficient margin, which may allow some increases later in the design process to be absorbed without massive need for improvement?
- f) is best available technology (BAT) being utilised?
- g) have inherent safe solutions been chosen whenever possible?
- h) are precautionary and cautionary principles considered?
- i) are there unsolved aspects relating to risk to personnel and/or working environment, or possibly areas where there is a conflict between these two aspects?
- j) are there unsolved aspects relating to risk of major oil spill?
- k) is the concept chosen robust with respect to safety?
- l) are the latest research and development results and new technology aspects reflected in the solutions that are adopted?
- m) are societal concerns met, if required to consider?
- n) are the associated costs significantly disproportionate to the risk reduction achieved?

NOTE 1 Item a) is actually a precondition of ALARP evaluation, but is included here for the sake of completeness.

NOTE 2 Item d) can be applied in relation to item b) and item c), but in general not in relation to item a), according to Norwegian regulations (deviations could be accepted for e.g. normally unmanned installations).

A.5.4 Scope of ALARP evaluation in concept phase

The main object for the ALARP evaluation in this phase will be to demonstrate that the chosen option for further development has the lowest risk, or justification if not. ALARP during concept development should focus on the following:

- make sure that necessary number of options is considered to be able to meet main objective;
- additional concept improvements beyond minimum requirements, standard practice and risk acceptance criteria;
- identification of high level options and solutions;
 - with increased safety for personnel, environment and/or assets.
- possibilities to chose inherently safer concepts/solutions;
- making high-level broad evaluations;
 - with focus on risk reduction, robustness and other positive aspects in addition to cost and plan.
- allowing for a decision-making process;
 - considering options and solutions that give improved safety for personnel, environment or assets in a 'reversed-onus-of-proof' context.
- documentation of options considered and decision-making.

A.5.5 Scope of ALARP evaluation in engineering phases

The main objective for the ALARP evaluation in the engineering phases (including front end engineering design and detailed engineering) is to demonstrate that the chosen layout and system options for detailed design has the lowest risk, or justification, if not.

ALARP during engineering work should focus on

- consideration of layout alternatives in order to meet the main objective,
- consideration of system options and alternatives in order to meet the main objective,
- consideration of equipment options and location options in order to meet the main objective,
- additional concept, system and equipment improvements beyond minimum requirements, standard practice and risk acceptance criteria,
- possibilities to chose inherently safer concepts/solutions/systems,
- allowing for a decision-making process,
 - considering options and solutions that give improved safety for personnel, environment or assets in a 'reversed-onus-of-proof' context.
- documentation of options considered and decision-making.

A.5.6 Scope of ALARP evaluation in operational phases

The main objective in operational phases is to demonstrate that the risk level during operations is the lowest, or justification, if not. In the operational phase (without major modifications), relevant sources of identifying risk reducing measures include

- quantitative risk analyses updates,
- external and internal audits,
- reviews of the installation's technical condition,
- reported incidents and dangerous conditions,
- limited risk assessments in operations, e.g. SJAs,
- general proposals for risk improvement actions.

All identified risk reducing measures, where the conclusion to implement or reject is not obvious, should be registered and treated in a systematic way in order to ensure that the risk is ALARP. An ALARP register can be established to keep track of identification, evaluation and decisions regarding risk reducing measures that are subject to an ALARP process.

Documentation of risk reduction should be documented as part of the planning of major

- re-buildings or modifications of the facility,
- changes to the operation or organisation of the facility.

Risk reduction should be summarised as part of the risk analysis of the major change and the ALARP register should be updated to reflect the process.

ALARP during operational phase should focus on

- consideration of risk reduction proposals of an operational nature,
- consideration of equipment replacements that may improve risk, for aspects that are found to represent the highest risk potential,
- consideration of risk reduction proposals in relation to modification projects,
- allowing for a decision-making process,
 - considering options and solutions that give improved safety for personnel, environment or assets in a 'reversed-onus-of-proof' context.
- documentation of options considered and decision-making.

Annex B

(informative)

Assessment of loss of main safety functions (offshore only)

B.1 General

This annex includes

- an interpretation of the Norwegian regulatory requirements for offshore petroleum facilities concerning main safety functions, and
- a description of how the assessment of loss of main safety functions should be performed.

As the term "main area" (and the definition of main areas) and the term "accidental and environmental loads" constitute a central part of both the interpretation of the regulatory requirements and the assessment of loss of several main safety functions, this annex starts with two sections defining and discussing these terms before moving on to the main parts referenced above.

NOTE It should be noted that this NORSOK standard distinguishes between the terms "escape" and "evacuation", while the term "evacuation" as used in the regulations covers both escape and evacuation. Hence, only quotes (*written in italic*) from the regulations, which contain the term evacuation and which are included in this annex, should be assigned the regulatory interpretation of the term evacuation.

B.2 Main areas

Each offshore petroleum facility shall be divided into main areas to distinguish between areas with different functionality and level of risk. The defined main areas shall be separated either by distance, by use of physical barriers as fire and blast divisions or by a combination of these to prevent external escalation of an accident from one main area to another.

The main areas are to be defined for each facility individually in an unambiguous way. For an offshore facility the following main areas shall as a minimum be defined, when relevant:

- a) accommodation (living quarter);
- b) utility;
- c) drilling and wellhead;
- d) process;
- e) hydrocarbon storage.

Some of the above listed areas may for some facilities be divided into two or several main areas due to other requirements. This may typically be relevant for large process areas, turret areas or areas where risers/pipelines are located.

A main area may consist of several fire areas. Hence, additional fire and blast divisions within one main area (horizontal and/or vertical) do not require that each fire area shall be defined as a main area.

The immediate vicinity of the scene of accident shall for the assessment of loss of main safety functions be considered as the main area where the accident event has its origin.

B.3 Accidental and environmental load categories

The following accidental and environmental load categories shall be used when distinguishing between different types of hazards and loads that shall be assessed and compared separately against the defined risk acceptance criteria for loss of main safety functions:

- a) heat loads (e.g. due to HC processing leaks, riser/pipeline leaks, blowouts or fires in combustible materials);
- b) smoke and toxic loads (e.g. due to HC processing leaks, riser/pipeline leaks, blowouts or fires in combustible materials);
- c) explosion loads (any kind of explosion). This includes overpressure and drag loads etc.;

- d) impact loads (e.g. collision loads from vessels, helicopters, drifting icebergs, dropped object loads from lifting operations, falling ice etc.);
- e) extreme environmental loads (design load principles according to NORSOK N-001) such as
 - 1) from wind, wave, current,
 - 2) earthquake.

Other accidental and environmental load categories (e.g. to cover loads from nuclear accidents, gross error, ballasting failure etc) shall be considered, when relevant.

B.4 Regulatory requirements

The Norwegian regulatory requirements for offshore petroleum facilities concerning main safety functions are quoted in this clause (*written in italic*), followed by a description of its area of application and/or an interpretation of each requirement. The Facility Regulations requirements applies to offshore petroleum facilities build in accordance with the 2001 regulations regardless of whether a facility is permanently manned or not. Offshore petroleum facilities build in accordance with regulations issued prior to the 2001 regulations or in accordance with maritime regulations may use other risk measures and acceptance criteria related to loss of main safety functions.

- a) **Facility Regulations (3rd September 2001), Section 6: Main safety functions, paragraph 1:** *The main safety functions shall be defined unambiguously in respect of each individual facility in order to ensure the safety for personnel and to limit pollution.*

Area of application/interpretation:

- This requirement applies to all phases of the offshore petroleum activities and to all offshore facilities regardless of when the facility was built/used the first time, and regardless of whether they are permanently manned or not.

- b) **Facility Regulations (3rd September 2001), Section 6: Main safety functions, paragraph 2:** *With regard to permanently manned facilities the following main safety functions shall be maintained in the event of an accident situation:*

- a) **preventing escalation** of accident situations so that personnel outside the immediate vicinity of the scene of accident, are not injured,
- b) maintaining the **main load carrying capacity** in load bearing structures until the facility has been evacuated,
- c) protecting **rooms of significance** to combating accidental events, so that they are operative until the facility has been evacuated,
- d) protecting the facility's **safe areas** so that they remain intact until the facility has been evacuated,
- e) maintaining at least one **escape route** from every area where personnel may be staying until evacuation to the facility's safe areas and rescue of personnel has been completed.

Area of application/interpretation:

- This requirement applies to all phases of the offshore petroleum activities and to all offshore facilities regardless of when a facility was built/used the first time, but only to permanently manned offshore facilities. Hence, facilities not permanently manned may define other main safety functions.
- The requirement related to maintaining the main safety function '**preventing escalation**' applies to the prevention of escalation from one defined main area to another (external escalation). Hence, a development which only leads to a worsening of the accidental event within the same area (e.g. for a small to a medium or large fire) or internal escalation (escalation between fire areas within the same main area as the initiating accidental event had its origin) shall not be accounted for when establishing the probability of loss of this main safety function.
- The requirement related to maintaining the main safety function '**preventing escalation**' applies to each division (which is established to fulfil this function) between each main area. Thus, separate assessments shall be performed for each division when assessing the loss of this main safety function due to each of the defined accidental and environmental load categories.

- The requirement related to maintaining the main safety function '**main load carrying capacity**' applies to the prevention of losses which may cause significant deformation or collapse of the entire or any major part of the facility. An example may be the loss of an entire module which may cause the entire facility to collapse or capsize. Minor and local losses of the load carrying capacity and/or loss of the capacity to structure which are not critical, shall not be accounted for. The assessment of loss of this main safety function due to each of the defined accidental and environmental load categories shall be assessed globally for the entire facility.
- The requirement related to maintaining the main safety function '**rooms of significance**' applies to each such room. The assessment of loss of this main safety function due to each of the defined accidental and environmental load categories shall therefore be assessed individually/separately for each such room (i.e. not the sum of losses of all 'rooms of significance' on the facility).
- The requirement related to maintaining the main safety function '**safe areas**' applies to each defined safe area. The assessment of loss of this main safety function due to each of the defined accidental and environmental load categories shall therefore be assessed individually/separately for each defined safe area (i.e. not the sum of losses of all 'safe areas' on the facility). For facilities using different safe areas for different accidental events, the requirement applies to maintaining the safe area(s) for the accidental events they are intended to be used for.
- The requirement related to maintaining main safety function '**escape route**' applies to the escape possibilities from manned parts of each main area, except the main area where the accident was initiated, to the defined safe area(s) (i.e. at least one escape route from central locations in the main area to the defined safe area(s) shall be available). The assessment of loss of this main safety function due to each of the defined accidental and environmental load categories shall therefore be assessed individually/separately (i.e. not the sum of losses of escape possibilities from all main areas on the facility).
- Each of the five defined main safety functions shall as a minimum be intact/maintained for the following durations:
 - For main safety function a) '**preventing escalation**' and e) '**escape routes**': The time required to escape to the defined safe area(s) and the time required to perform search and rescue of personnel. This applies to personnel located in other areas than the main area where the accident was initiated.
 - For main safety function b) '**main load carrying capacity**', c) '**rooms of significance**' and d) '**safe areas**': The time required includes the time to escape and evacuate the whole facility in a safe manner, including the time required to perform search and rescue of personnel.

c) **Management Regulations (3rd September 2001), Section 6: Acceptance criteria for major accident risk and environmental risk:** *The operator shall set acceptance criteria for major accident risk and environmental risk. Acceptance criteria shall be set for:*

b) the loss of main safety functions as mentioned in the Facility Regulation Section 6 on Main safety functions

Area of application/interpretation:

- This requirement applies to all phases of the offshore petroleum activities and to all facilities regardless of when a facility was built/used the first time, and regardless of whether a facility is permanently manned or not.

d) **Facility Regulations (3rd September 2001), Section 10: Loads, load effects and resistance:** *... Accidental loads and environmental loads with an annual probability greater than or equal to 1×10^{-4} shall not cause the loss of a main safety function cf. Facility Regulation Section 6 on main safety functions....*

Area of application/interpretation:

- The ' 1×10^{-4} ' criterion applies to offshore petroleum facilities built in accordance with the 2001 regulations regardless of whether a facility is permanently manned or not. Offshore petroleum

facilities built in accordance with regulations issued prior to the 2001 regulations or in accordance with maritime regulations may use another annual probability than 1×10^{-4} as their risk acceptance criteria related to loss of main safety functions.

- The risk acceptance criterion related to loss of main safety functions (regardless of whether the criterion is 1×10^{-4} or another annual probability) applies to the loss of each main safety function, due to each accidental or environmental load category.
- The risk acceptance criterion related to loss of main safety function '**preventing escalation**' (regardless of whether the criterion is 1×10^{-4} or another annual probability) applies to the loss of each side of each division (established to fulfil the function prevent escalation) separating one main area from another main area (e.g. when assessing the loss of one side of one specific division separating one main area from another due to fire loads, all fires that may cause loss of the specific division shall be included. A similar assessment shall thereafter be performed for the other side of the division and for all other divisions between the main areas on the facility).
- The risk acceptance criterion related to loss of the main safety function '**main load carrying capacity**' (regardless of whether the criterion is 1×10^{-4} or another annual probability) applies to the global sum of losses on the facility due to each accidental or environmental load category (e.g. the sum of all fires that causes loss of the main load carrying capacity on any part of the facility).
- The risk acceptance criterion related to loss of the main safety function '**rooms of significance**' (regardless of whether the criterion is 1×10^{-4} or another annual probability) applies to the loss of each room.
- The risk acceptance criterion related to loss of the main safety function '**safe areas**' (regardless of whether the criterion is 1×10^{-4} or another annual probability) applies to the loss of each safe area. The probability of loss of each safe area shall however only be considered for the events or scenarios which they are intended to be used for (relevant for large facility complexes consisting of several facilities using different safe areas for different scenarios/events).
- The risk acceptance criterion related to loss of the main safety function '**escape routes**' (regardless of whether the criterion is 1×10^{-4} or another annual probability) applies to the loss of the escape possibility from each main area not immediately exposed to the accident.

B.5 Assessment of loss of main safety functions

B.5.1 Introduction

Although additional main safety functions and/or other acceptance criteria than the ' 1×10^{-4} criterion' may be defined (as discussed in B.4 above), the below presented interpretation is in accordance with the requirements given in the Facilities Regulations, Section 6 and Section 10, and in the Management Regulations, Section 6, for a permanently manned facility built in accordance with the 2001 regulations. The approach assessing loss of main safety functions (as described below in this annex) is however valid for all facilities that have defined the five safety functions given in the Facilities Regulations, Section 6, (due to mandatory requirements or due to other considerations).

Figure B.1 and Figure B.2 clarify and exemplify how to assess loss of main safety functions. The figures illustrate a fictional facility consisting of four main areas: main area A (MA-A), main area B (MA-B), main area C (MA-C) and main area D (MA-D). The four main areas are separated by fire and explosion walls (dotted blue lines). Both sides of each wall are labelled with two letters, e.g. A – B. The first letter identifies which main area is located in "front" of the wall, the second letter identifies the area at the "back" of the wall. Hence, the wall separating main area A and main area B is labelled A-B on the side of the wall facing towards main area A, and B – A on the side of the wall facing towards main area B.

The safe area on the facility is located in MA-A. The green arrows in Figure C.1 illustrate the escape routes from one main area to main area MA-A. E.g. the label EW D – A (1) and (2) illustrates the two escape routes from MA-D to the safe area in MA-A.

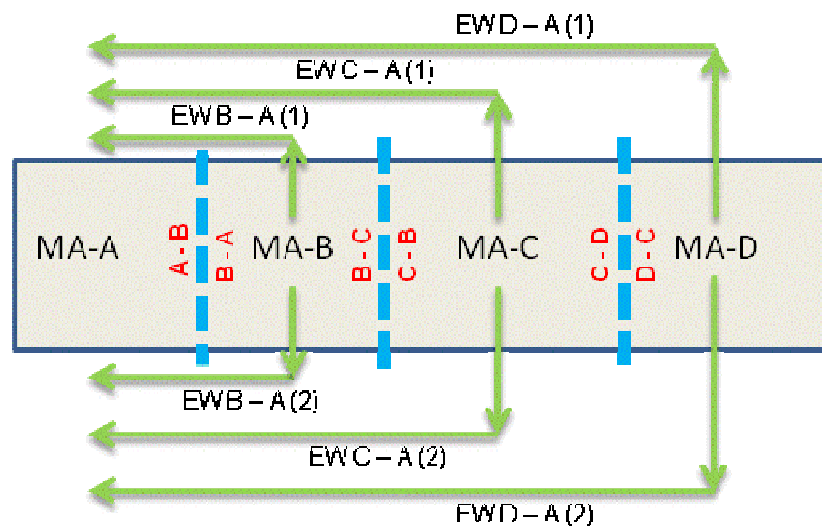


Figure B.1 - Simplified facility layout including labelling and direction of escape routes

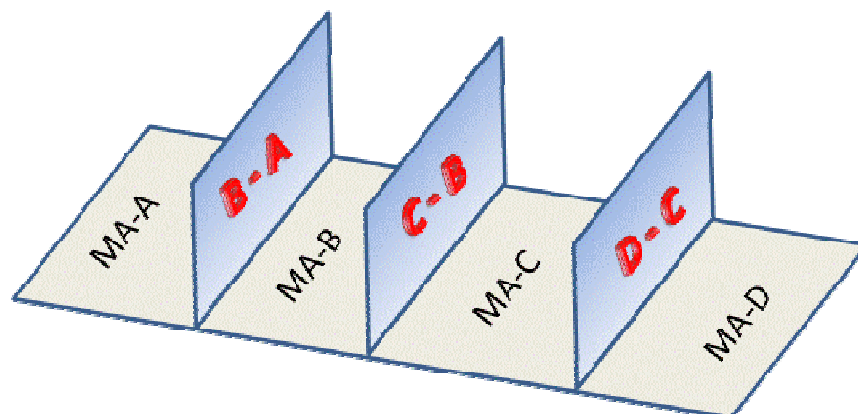


Figure B.2 - Side view of a simplified facility layout

B.5.2 Assessment of loss of main safety functions: General approach

The general approach for assessment of main safety functions is as follows:

- identify all accidental events which may expose/threaten the main safety function of interest, including their potential evolvement during the period of time for which the main safety function (as a minimum) shall be intact or maintained;
- identify the relevant environmental and accidental loads;
- compare the environmental and accidental loads with the design specifications (or current design),
- identify scenarios/accidental events which may impair the main safety function;
- based on the above, identify the probability of impairing the main safety function for each of the defined accidental and environmental load categories;
- compare the results from point 5 for each of the defined accidental and environmental load categories with the established risk acceptance criteria (1×10^{-4} per year);
- for the safety functions preventing escalation, protecting rooms of significance, and maintaining at least one escape route repeat point 1 to point 6 for each subset of the main safety function (e.g. each side of each fire and/or explosion wall separating main areas on the facility).

MSF causing or contributing to the loss of another MSF shall not be accounted for in the loss assessment of the second MSF. E.g. an accident causing loss of the main load carrying capacity (resulting in partial or full collapse of the installation) shall not be accounted for when assessing the probability of loss of escape routes (or any other main safety function) due to the collapse of the installation. This does not mean that accidents causing loss of several main safety functions shall only be 'counted' once. E.g. a large fire causing the loss of both a safe area and the loss of the escape possibility from a main area, shall (naturally) be considered and accounted for when establishing the frequency of loss of both these main safety functions.

When assessing the loss of main safety functions considerations shall be made with respect to

- established safety strategies (e.g. manual or automatic intervention in case of an emergency),
- the location, availability and efficiency of critical equipment/systems that must be operable during an accident category (e.g. firewater systems, ESD systems and evacuation means).

Depending on the timing of the assessment, comparison of accidental and environmental loads with the current design may be difficult or impossible as the level of detail on the design may be limited, or not even available. The described assessment may then be used the other way around, i.e. as input to the design. The need to update the assessment throughout the design phase will vary depending on changes in the design and the level of detail available as the design of a facility evolves.

B.5.3 Assessment of loss of main safety function: Preventing escalation

An accident or environmental load category which originates in one main area on the facility shall not cause external escalation (escalate into another main area on the facility) before escape and rescue in/from the other main area has been completed. External escalation in this respect means that the area exposed by the accidental event (AEAE) covers more than one main area.

Assessment of the failure of this main safety function shall include the probability of external escalation due to failure of a physical barrier between the main areas, and external escalation into a neighbouring main area due to insufficient extent of barriers between the areas. All requirements related to the fulfilment of the safety function (e.g. integrity, functionality, capacity, etc) should be considered. A comparison of e.g. the radiation load from a fire with the fire resistance of applied passive fire protection on a wall alone is therefore not necessarily sufficient.

A requirement for the availability of this safety function needs to be determined in each case.

As an example, assume that fire and explosion loads act on wall B – A on the facility illustrated in Figure B.1 and Figure B.2. For the assessment of loss of this main safety function the following steps should be performed:

1. Identify all accidental events which may expose fire / explosion wall B – A, including the potential development of the various events during the (minimum) period of time for which the wall shall maintain its integrity.
2. Identify the relevant environmental and accidental loads.
3. Compare each environmental and accidental loads with the design specifications (or current design) for fire/explosion wall B - A.
4. Identify scenarios or accidental events which may cause impairment of fire/explosion wall B - A.
5. Based on the above, identify the probability of having an external escalation due to each of the defined environmental and accidental load categories.
6. For each defined accidental and environmental load category exposing fire/explosion wall B – A, compare the results from step 5 with the established risk acceptance criterion (e.g. frequency of exceeding a load leading to escalation, shall be less than 1×10^{-4}). If the current design satisfies this criterion, the design is in compliance with the criterion given the established context of the assessment. If the design is not decided, use the results as input to design.

Repeat step 1 to step 6 for all other divisions (A – B, B – C, C – B, C – D, D – C) on the facility, as the same requirement applies to all divisions between the main areas on the facility.

B.5.4 Assessment of loss of main safety function: Main load carrying capacity

A defined accidental and environmental load category shall not cause impairment of the installation's main load bearing structure or stability (relevant for floaters) before the facility has been evacuated, including the time required to perform search and rescue of personnel. The criterion is valid for the whole facility. Accidental loads that lead to collapse of cause box girder or chassis shall be accounted for. Loss of support structure for equipment etc. shall not normally be accounted for.

For the assessment of loss of this main safety function the following steps should be performed:

1. Identify all accidental events which may threaten the installation's main load bearing structure, including the potential development of the various events during the (minimum) period of time for which the installation's main load bearing structure shall be intact/maintained.
2. Identify the relevant environmental and accidental loads.
3. Compare the environmental and accidental loads exposing the different parts of the facility with the design specifications (or current design).
4. Identify scenarios/accidental events which may cause impairment of the installation's main load bearing structure.
5. Based on the above, identify the probability of losing the installation's main load bearing structure due to each of the defined environmental and accidental load categories.
6. Compare the results from step 5 with the established risk acceptance criteria (1×10^{-4}).

B.5.5 Assessment of loss of main safety function: Rooms of significance to combating the accidental events

An accidental load category shall not cause impairment of a room which is of significance to the ability to combat the accident before the facility has been evacuated, including the time required to perform search and rescue of personnel. The CCR is an example of a room that typically will be defined as significant to the ability to combat the accident. But other rooms (e.g. fire pump rooms, electrical rooms, emergency generator rooms, etc.) could also be of importance to combat an accident as such rooms could have functions that are critical in order to combat the accident.

When assessing the loss of this main safety function, the function and role of each room in maintaining one or several functions should be considered. If the loss of one particular room (in the event of an accidental event) may reduce or remove the facility's ability to maintain safety critical functions, measures shall be implemented to reduce the likelihood of or eliminate such situations. However, considerations related to the design of each room (that may have an effect on the facility's ability to maintain safety critical functions) is not to be considered as a part of the assessment of this main safety function, as it is assumed that normal design in accordance with the regulations will provide the appropriate level of protection of such rooms.

The assessment of loss of this main safety function shall therefore only include the assessment of loss of CCR and other rooms manned when combating of the accident. Rooms where the BOP operation panel is located may be such rooms (given that the panel is to be operated during the combating of the accident). Although it is expected that rooms not manned when combating of an accident are assessed and designed in an suitable manner, such rooms (not manned during the combating of an accident) shall, as stated above, not be accounted for when assessing the loss of this main safety function.

For the assessment of loss of this main safety function the following steps should be performed:

1. Identify all rooms that are manned during the combat of an accident and evaluate their significance to the ability to combat the accident.
2. Identify all accidental events which may threaten each of the identified rooms, including the potential development of the events during the (minimum) period of time for which each room shall be intact or maintain its integrity.
3. Identify the relevant environmental and accidental loads.
4. Compare the environmental and accidental loads with the design specifications (or current design).
5. Identify scenarios/accidental events which may cause the impairment of each room.
6. Based on the above, identify the probability of impairing each room due to each of the defined environmental and accidental load categories.
7. For each room, compare the results from step 6 with the established risk acceptance criteria (1×10^{-4}).

B.5.6 Assessment of loss of main safety function: Safe area(s)

An accident load category shall not cause impairment of the defined safe area(s) before the facility has been evacuated, including the time required to perform search and rescue of personnel. The criterion is valid for each safe area defined, given the set of situations/accidental events that each area is to be used.

Some facilities, typically minor stand-alone offshore facilities, may only have one defined safe area to be used for all possible accidental events that may occur. Other facilities, typically large onshore plants or bridge connected installations, may define and use different safe areas depending on the situation. A typical approach is to use a bridge to a neighbouring installation for all situations that require mustering of personnel and that do not impair or threaten the bridge, and to define a safe area on the neighbouring installation(s) for

those situations. For events which impair or could impair the bridge, other safe areas on the facility may be defined.

For the assessment of loss of this main safety function the following steps should be performed:

1. Identify all safe areas defined to be used for the various accidental events that may occur.
2. For each specific safe area: Identify all accidental events (for which the safe area is defined to be used) that may threaten the area. Take into account the potential development of the events during the (minimum) period of time for which the safe area shall be intact or maintain its integrity..
3. Identify the relevant environmental and accidental loads.
4. Compare the environmental and accidental loads with the design specifications (or current design).
5. Identify scenarios/accidental events which may cause the impairment of each safe area.
6. Based on the above, identify the probability for impairing each safe area due to each of the defined environmental and accidental load categories.
7. For each safe area, compare the results from step 6 with the established risk acceptance criteria (1×10^{-4}).

For the example in Figures B.1 and Figure B.2 only one common safe area is defined. Hence, all accidental events which may impair the safe area located in main area MA-A, shall be considered.

B.5.7 Assessment of loss of main safety function: Escape routes

The availability of at least one escape route from central locations in all main areas shall not be impaired due to any accident or environmental load category which originates in another main area. This requirement does not apply to the main area where the accident was initiated, and it is applicable until any main area (not initially exposed) has been evacuated and rescue of personnel has been completed. This requirement applies to all main areas permanently or intermittently manned.

Loss of escape possibilities from the main area that is initially exposed to the accidental event (i.e. in the period before the event escalates) shall not be included in the assessment of loss of this main safety function. Nor shall the assessment include loss of escape possibilities from intermittently or not permanently manned areas.

The requirement applies to the entire escape route, from the central position in the main area to the safe area.

For the example in Figure B.1 this requirement applies to the entire escape route from main area MA-D to MA-A, i.e. the escape route on one side of the facility (either EW D – A (1) or EW D – A (2)) shall not be impaired by accidents occurring in MA-B or MA-C, in the event that an accident not initially exposing main area MA-D occurs.

For the assessment of loss of this main safety function for the escape routes from main area MA-D illustrated in Figure B.1 the following steps should be performed:

1. Identify all accidental events that do not initially occur in or expose main area MA-D, and which may expose both escape routes (EW D – A (1) and EW D – A (2)) from MA-D to the safe area in MA-A. This should include the potential development of the events during the (minimum) period of time for which at least one of the escape routes shall be intact or available.
2. Identify the relevant environmental and accidental loads.
3. Compare the environmental and accidental loads with the design specifications (or current design) of the escape routes.
4. Identify scenarios/accidental events which may cause the impairment of both escape routes (EW D – A (1) and EW D – A (2)).
5. Based on the above, identify the probability for impairing both escape routes due to each of the defined environmental and accidental load categories.
6. Compare the results from step 5 for each defined environmental and accidental load with the established risk acceptance criteria (1×10^{-4}). If the results of the assessment show that the current design is capable of withstanding each load with an annual probability of exceedance lower than 1×10^{-4} , the design is in compliance with the criterion given the established context for the assessment.

Repeat step 1 to step 6 for the escape routes from all other main areas (MA-B and MA-C).

Annex C

(informative)

Hazard identification (HAZID) check lists

Hazards

Reference is made to ISO 17776, Annex C.

Accident categories

- Blowouts and well leaks, including shallow gas and reservoir zones, unignited and ignited.
- Leakages from the main process, unignited and ignited (fire and explosion).
- Riser and pipeline leakages, including landfall, unignited and ignited (fire and explosion).
- Leakage of/exposure to toxic or suffocating gases/fluid/solids.
- Utility area and utility system accidents (fires and explosions).
- Fire in accommodation areas and office/administration buildings.
- Transportation accidents:
 - transport of personnel between installations,
 - transport of personnel from shore to the offshore facility,
 - helicopter crash on the installation,
 - transport to/from onshore facilities,
 - vehicles/traffic on onshore facilities.
- Loading/unloading accidents.
- Ship/vessel collisions, including fields related traffic, and external traffic, drifting and under power:
 - passing vessel traffic,
 - offshore vessel traffic,
 - attendant vessels,
 - other offshore installations.
- Falling and swinging loads from
 - cranes,
 - derrick and drilling area lifts,
 - temporary/mobile lifting equipment.
- Accidents during escape, evacuation and rescue, i.e. until a so-called 'safe place' has been reached.
- Accidents causing acute pollution to sea or air.
- Fatal occupational accidents.
- Risk exposure of neighbours.
- Exposure from neighbour activities.
- Third party interference.
- Structural collapse.
- Foundation failure.
- Extreme environmental loads from
 - wind,
 - waves,
 - flooding,
 - current,
 - ice,
 - temperature,
 - earthquake.
- Loss of stability/position caused by
 - ballast systems,
 - anchor line failures,
 - DP failures,
 - excess or displaced weight.
- Marine hazards.
- Electrical hazards.

- Hazards related to storage of HC or other flammable substances.
- Hazards related to storage of ammonia, CO₂, nitrogen or other toxic/suffocating gases.

Inherently safe design

- Potential hazardous material or methods are avoided.
- Dangerous substances or processes are modified or replaced with less dangerous ones.
- Implementing high safety margins to critical operational parameters, e.g. pressure, temperature.
- Simple and robust design.
- Process safety.
- Segregation between people and processes/materials.
- Layout/distances.

Utility systems

- Hydraulic systems, lube oil systems.
- Power supply incl. transformers, diesel engines, fuel gas.
- Gas lift.
- Drilling mud system.
- Methanol and glycol systems.
- Diesel and jet fuel systems.
- Drain system.
- Acid stimulation system.
- Chemical handling and storage system.
- Heating, ventilation and air conditioning (HVAC)
- Living quarter functionality systems.
- Temporary storage.
- Radioactive sources.
- Explosives
- Rotating equipment (leakage, breakdown - projectiles).
- Exhaust systems.
- Shafts
- Flare system.
- Purge system.
- CO₂ treatment and storage system.
- H₂S treatment and storage system.
- H₂ treatment and storage system.
- Cooling and heating systems.
- Water, air and steam systems.
- Water treatment.

Marine hazards

- Generic marine hazards for floating installations:
 - technical fault or operational fault in ballast system, including pumps, valves, control system;
 - filling of buoyancy compartments from 'internal' sources, such as fire water, from external impact, such as collision, due to structural failure or due to fire/explosion;
 - filling of pump room;
 - mooring system failure, including anchor lines, anchors, anchor system winches, anchor system brakes;
 - DP system failure, including reference systems, thrusters, control systems, computer systems, human intervention.
- Specific marine hazards for semi-submersible installations:
 - excess or displaced weight;
 - loss of weight due to anchor line failure or loss of line holding power.
- Specific marine hazards for jack-up installations:
 - technical fault in ballast system, including pumps, valves, control system during transfer;
 - operational fault of ballast system during transfer;
 - displaced weight during transfer;
 - jacking system failure.

- Specific marine hazards for floating production, storage and off-loading installations. The evaluation shall include generic marine hazards as well as concept specific hazard:
 - failure of loading/off-loading system resulting in unacceptable weight distribution;
 - operational fault of loading/off-loading system resulting in unacceptable weight distribution;
 - turret turning system failure.

Safety systems (barriers)

- Layout
- Structural integrity and stability.
- Segregation of main areas.
- Containment
- Control of spills.
- Process safety.
- Emergency shutdown system and blowdown.
- Fire and gas detection system.
- Control of ignition.
- Human-machine interface.
- Natural ventilation and heating, ventilation and air conditioning.
- Public address, alarm and communication.
- Emergency power system and lighting.
- Passive fire protection.
- Active fire protection.
- Explosion mitigation and protection systems.
- Evacuation, escape and rescue.
- Rescue and safety equipment.
- Marine systems and position keeping.
- Ship collision barriers.

Activities and phases

- Construction
- Start up.
- Operation:
 - high activity;
 - low activity.
- Simultaneous operations.
- Maintenance , degradation, reliability.
- Modifications
- Removal

Human and organisational failures

- Selection and training of personnel.
- Experience and education.
- Work permit system.
- Procedures
- Safe job analysis.
- Safety culture.
- Ergonomics
- Psycho social work conditions.

Occupational hazards

- Slips, trips and falls.
- Rotating machinery.
- Electrical shock.
- Chemicals
- Noise and vibration.
- Dust
- Ergonomics and access.

- Stress

Environmental risk

- Acute pollution to sea, ground or air.
- Type of release and release properties.
- Size of release.
- Sensitive environmental resources:
 - distribution;
 - time of year;
 - sensitivity;
 - tolerability limits.
- Drifting time and exposure probability.
- Emergency preparedness resources:
 - availability;
 - effectiveness.
- Inherent safety check list, see [27], table 32.19.

Annex D (informative) Recognised data sources

The following data sources should normally be used:

Hazard	Data source
1. Process leak	HSE Leak and ignition data base, offshore hydrocarbon releases The hydrocarbon releases database system contains supplementary information, dating from 1 October 1992, on all offshore releases of hydrocarbons reported to the HSE Offshore Division under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995, and prior offshore legislation. Authorised users in the UK Offshore Oil & Gas industry and in HSE can log on to the hydrocarbon release system to enable search and other reporting facilities. Bona-fide applicants from offshore consultancies, academia, etc. may be given read only access to the hydrocarbon release system, given sufficient details of their occupational role. https://www.hse.gov.uk/hcr3/ DNV Standardized leak frequencies have been developed for offshore topside equipment based on the hydrocarbon release database from the British offshore sector. The leak frequencies are presented as continuous leak frequency functions and described in report: “Offshore QRA –Standardised Hydrocarbon Leak frequencies” DNV report 2008-1768 rev 0 2009 01-06 PSA Risk Level in Norwegian Petroleum Activity Offshore data for the NCS: Risk level in the petroleum industry. Annual Environmental Reports, The Norwegian Oil Industry Association (OLF) The objective of the annual Environmental Report from the Norwegian Oil Industry Association (OLF) is, in addition to communicating discharge and emission data, to contribute to increasing knowledge of the environmental aspects of the petroleum industry. The Environmental Report provides an updated overview of discharges to sea and emissions to air, as well as waste creation from industry on the Norwegian Continental Shelf. The report also discusses what environmental aspects the combined petroleum industry has focused on. The Annual Environmental Reports are available in both English and Norwegian. Field specific discharge reports are available in Norwegian.

2. Riser/pipeline leak

<http://www.olf.no/publikasjoner/miljorapporter/>

PARLOC

The update of loss of containment data for offshore pipelines, Advanced Mechanics and Engineering Ltd.

The main objective of this continuing study is to update and improve confidence in the statistical information available to assess the generic frequency of loss of containment associated with operation of North Sea pipelines. Presented in the report are summarised contents of the comprehensive pipelines and incidents databases and analyses of incidents reported with respect to frequency, loss of containment and operating experience. PARLOC 2001 is the latest edition.

NOTE It should be noted that PARLOC 2001 contains some errors in the frequency estimates.

The 96 edition is available from:

<http://www.hse.gov.uk/RESEARCH/othpdf/500-599/oth551.pdf>

Office of Pipeline Safety (OPS)

OPS is the primary federal regulatory agency responsible for ensuring the safe, reliable, and environmentally sound operation of America's energy pipelines.

Natural Gas Distribution Incident Data from 1984 to present and Natural Gas Transmission Incident Data from 1984 to present.

<http://ops.dot.gov/stats/IA98.htm>

PSA

Petroleum Safety Authority Norway

Pipelines – Incidents and damages from the CODAM database. Data from 1975 to present. Available from:

http://www.ptil.no/NR/rdonlyres/2906DCE5-3EAA-42FB-8819-78D0FD8AE7A8/14448/Roerledningsskader_juni.pdf

Riser – Incidents and damages from the CODAM database. Data from 1975 to present. Available from:

http://www.ptil.no/NR/rdonlyres/2906DCE5-3EAA-42FB-8819-78D0FD8AE7A8/14449/Stigeroersskader_juni.pdf

DNV

Recommended failure data for risers and onshore and offshore pipelines. The data has been based on PARLOC, Concawe in addition to other sources.

DNV report 2005-1221 rev 4, September 2006

DNV report 2009-1115: rev HOLD, November 2010

EGIG

European Gas Pipeline Incident data Group

3. Blowout

The EGIG database offers a global overview of the safety level of the European onshore gas transmission pipelines system. It gives information on the distribution of incidents per pipeline design parameter (e.g. diameter, pressure wall thickness) but does in general no offer the possibility of making correlation analyses. Contains data from 1970 to present. Reports available from:

<http://www.egig.nl/>

CONCAWE

Conservation of clean air and water in Europe

CONCAWE has collected 35 years of performance data on Western European cross-country oil pipelines, which currently comprise 34 800 km transporting 789 million m³ per year of crude oil and oil products. Incidents are analysed by cause and the effectiveness, cost and time for clean-up are recorded. Reports available from:

<http://www.concawe.org/Content/Default.asp?PageID=31>

United Kingdom Onshore Pipeline Operators

The database is available for use by all interested parties. Three reports on pipeline product loss incidents have previously been published, in 1998, 2000 and 2002. The report listed below is an updated report which presents the collaborative pipeline and fault data taken from operating records of the contributing companies from 1962 up to the end of 2004 for major accident hazard accident pipelines within their onshore steel pipeline systems. This data represents the UK major accident hazard pipeline population.

<http://www.ukopa.co.uk/publications/pdf/UKOPA-05-0095.pdf>

SINTEF

Blowout database, Report SFT38 F00431

The SINTEF Blowout database is confidential and only accessible for the project sponsors. Some statistics from the database are presented in the following references

Holand, Per:

"Offshore Blowouts Causes and Trends" Doctoral Dissertation, Norwegian Institute of Technology, Department of Production and Quality Engineering, Trondheim, Norway, March 1996

Holand, Per:

"Experienced Offshore Blowout Risk" presented at the IADC 1996 Well Control Conference of the Americas, Rio de Janeiro 31. July - 2. August 1996.

Holand, Per:

"Offshore Blowouts Causes and Control", Gulf Publishing Company, Houston Texas, 1997

Information about the database is available through the SINTEF webpage:

http://www.sintef.no/content/page1_4649.aspx

SCANDPOWER:

BlowFAM report

4. Offshore collision	The Scandpower BlowFAM report is confidential and accessible to the sponsors of the SINTEF blowout database and the BlowFAM sponsors. Recommended blowout and wellrelease frequencies including ignition probabilities in the report "Blowout and well release frequencies – based on SINTEF offshore Blowout Database". More information available on www.scandpower.com SAFETEC Computer assisted shipping traffic (COAST) The COAST database was first developed by Safetec in 1996 under the funding of the HSE, UKOOA and Department for Transport, Local Government and the Regions (DTRL). Later it was increased to include the entire Norwegian continental shelf, under funding from OLF. Using COAST it is possible to identify all regular shipping traffic within a defined area both on the British and Norwegian continental shelves. More information available from: http://www.safetec.no/article.php?id=105
5. Dropped objects	HSE Ship/platform collision incident database Data has been collected from a number of collision incident record sources to confirm or complete previous records and to expand the database up to October 2001. The database of operating experience has been recompiled and extended to encompass all mobile and fixed installations operating on the UKCS. Report is available at: http://www.hse.gov.uk/research/rrpdf/rr053.pdf CODAM Dropped objects Dropped objects are registered in the CODAM database under construction damages. The data dates from 1974 to present. Available at: http://www.ptil.no/NR/rdonlyres/92CE62F9-DF55-44FF-B270-2C738B7B1C19/12887/Konstruksjonsskader.pdf
6. Helicopter transport	Helicopter Safety Advisory Conference Statistics from the Gulf of Mexico offshore helicopter operations dating from 1999 to 2005 and the E & P Forum world-wide oil industry helicopter operations and safety reviews dating from 1998 to. Available from: http://www.hsac.org/ HSE UK Offshore Public Transport Helicopter Safety Record UKCS offshore helicopter operations data covering 27 years (1976

7. Occupational accidents	to 2002) are available for analysis and comparison, and have been grouped into three 9-year inclusive periods as follows: 1976 to 1984, 1985 to 1993, and 1994 to 2002. Available at: http://www.hse.gov.uk/research/misc/helicoptersafety.pdf PSA Facts and statistics from the Petroleum Safety Authority Norway The 2006 annual report contains information on personal injuries, work related illnesses, leaks, fires and damage to structures and pipelines. Additional statistics on personal injuries dating from 1997 to 2006 are also available. http://www.ptil.no/English/Helse+miljo+og+sikkerhet/Fakta_statistik_k/coverpage_faktakanal.htm http://www.ptil.no/English/Helse+miljo+og+sikkerhet/Sikkerhet+og+arbeidsmiljo/7_personskadestatistikk_2006.htm HSE Statistics from the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 database distributed by occupation. http://www.hse.gov.uk/statistics/occupation.htm
8. Human tolerability levels	Scandpower/DNV Scandpower/DNV report for Statoil, "Human resistance against thermal effects, explosion effects, toxic effects and obscuration of vision", dated 14.9.1993² The main objective of the study was to carry out a state of the art study on human impact loads and provide a consistent set of human impact load criteria for use in the fatality assessment in offshore and onshore risk analyses. Available at: http://www.preventor.no/tol_lim.pdf in "SPC/Tech/OSD/30, Health and Safety Executive – Indicative Human vulnerability to the hazardous agents present offshore for application in risk assessment of major accidents, January 2006", Gidelines for Chemical Process Quantitative Risk Analysis, second edition, issued by Center for Chemical Process Safety"
9. Safety and production systems	DNV Offshore Reliability Data (OREDA) OREDA's main purpose is to collect and exchange reliability data among the participating companies and act as the forum for co-ordination and management of reliability data collection within the oil and gas industry. OREDA has established a comprehensive databank with reliability and maintenance data for exploration and

² Other sources should also be consulted, such as flare load limits, etc.

10. Environmental resources	production equipment from a wide variety of geographic areas, installations, equipment types and operating conditions. Only participating companies have access to the database. Non-OREDA members may get access to this database when doing contract work for any of these member companies. Additionally, data have been issued in generic form in reliability handbooks. More info available at: http://www.sintef.no/static/tl/projects/oreda/ Marine Resource Data Base (MRDB®) MRDB® is at database that contains publicly available information on the distribution of vulnerable resources within Norwegian territorial waters including Svalbard. The vulnerable resources are typically seabirds, marine mammals, fish, zooplankton, seaweeds, seashore localities, protected areas and aquaculture localities. MRDB® is financed by Operators on the NCS represented by the Norwegian Clean Seas Association for Operating Companies (NOFO), the Norwegian Climate and Pollution Agency, the Norwegian Coastal Administration (Kystverket) and Headquarters Defence Command Norway. The objective of MRDB® is to gather publicly available information on coastal and marine resources vulnerable to oil pollution, and make them easily accessible through simple search- and display functions, for use in environmental impact analysis, environmental risk analyses, oil-spill response planning and emergency response operations. MRDB® is available on DVD and at the internet; http://www.mrdb.no The latest version of MRDB is distributed to the partner at revisions of the database, at least once a year. MRDB secretariat can be contacted to obtain MRDB on DVD. For general information on MRDB, see http://www.mrdb.no.
11. General	DNV WOAD, Worldwide Offshore Accident Data Det Norske Veritas (DNV) has collected accident data and provided the offshore industry with statistical material since 1975. The data sources included, go back to 1970 and the 30-year experience of world wide offshore accident history is today systemised and stored in DNV's Worldwide Offshore Accident Databank (Woad). Woad data may be accessed through purchase of data search consultancy or a database subscription. More info available at: http://www.dnv.com/services/software/products/safeti/safetiqlra/woad.asp HSE Accident statistics for fixed offshore units on the UK Continental Shelf 1980 – 2005 Report and spreadsheet available at: http://www.hse.gov.uk/research/rrhtm/rr566.htm

Accident Statistics for Floating Offshore Units on the UK Continental Shelf 1980-2005

Report and spreadsheet available at:

<http://www.hse.gov.uk/research/rrhtm/rr567.htm>

Accident/incident data

Report available at:

<http://www.hse.gov.uk/foi/internalops/hid/spc/spctosd24.pdf>

International Association of Oil & Gas Producers (OGP)

Safety performance indicators.

Safety performance of helicopter operations in the oil and gas industry.

Environmental performance in the exploration and production industry.

QRA datasheets:

- 1 Process release frequencies
- 2 Blowout frequencies
- 3 Storage incident frequencies
- 4 Riser and pipeline release frequencies
- 5 Human factors
- 6 Ignition probabilities
- 7 Consequence modelling
- 8 Mechanical lifting failures
- 9 Land transport risks
- 10 Water transport risks
- 11 Air transport risks
- 12 Occupational risks
- 13 Structural risks for offshore installations
- 14 Human vulnerability
- 15 Structural vulnerability
- 16 Ship collision risks
- 17 Major accidents
- 18 Construction accidents
- 19 Escape, evacuation and rescue
- 20 Emergency systems: reliability data and methods

Reports available at:

<http://www.ogp.org.uk/>

For an updated version of this annex, see the following internet address:
<HOLD>

Annex E
(informative)
Probabilistic fire analysis (HOLD)

To be completed in 2010.

Annex F

(informative)

Procedure for probabilistic explosion simulation

F.1 Introduction and basic requirements

F.1.1 General

In the following a procedure for the complete calculation of explosion risk is described, see Figure F.1. The outcome of the procedure is a relation between frequency and explosion load exceedance (or structural capacity exceedance, if required).

The procedure described here is meant to be used for detailed analyses of process areas at facilities in operations or in the project phases where the necessary information on all design elements influencing the risk picture is available. In early project phases, the procedure shall be simplified according to the design information available. The amount of equipment shall in such cases be calculated based on equivalent areas in previous studies.

F.1.2 Conservatism

Uncertainties and conservatism shall be discussed. As part of this, it may be necessary to perform sensitivity analyses of design input and modelling assumptions.

In some cases (e.g. where low loads are expected or where the structure has high strength) this procedure may be simplified providing that the conservatism is under control. Simplifications and deviations from the procedure shall be agreed upon by the operator in advance and be stated in the report. If using a simplified approach with a higher conservatism, conclusions regarding the effect of mitigation measures or design modifications may not be valid.

Analyses shall strive for realistic modelling to isolate and emphasize the effect of both risk reducing and contributing measures. The solution shall be approximated from the conservative side.

Undesirable consequences shall be evaluated, unacceptable responses shall be defined, the necessary resolution and accuracy of the loads shall be determined and the rest of the methodology shall be established accordingly.

The modelling of explosion risk should be as realistic as possible. If conservative approaches are used, a summary of such should be presented together with a discussion of possible effect on the importance of safety systems with respect to risk reduction.

Conservatism should be evaluated in relation with analysis lifetime as follows:

- design of new installations should focus on conservatism in safety systems, layout, etc, to ensure dimensioning accidental loads that are realistic throughout project lifetime;
- analyses in later project stages such as detailed design and operation phase, should strive for as realistic modelling as possible to isolate and emphasize the effect of both risk reducing and contributing measures/characteristics.

The purpose of the procedure is to standardise the analyses so that the risk of explosions can be compared between different areas, installations and concepts, even if the analyses are performed in different circumstances and by different personnel. At the same time the procedure shall not stop the development towards improved explosion risk modelling.

F.2 Explosion modelling overview and basic requirements

F.2.1 Reporting of results

Steps in explosion modelling and intermediate results shall be described. The following list is a guide and illustration of the level of reporting:

- a) all assumptions that influence the final results shall be presented;
- b) present the geometry model and the process that has been undertaken in order to verify the congestion and confinement;
- c) present leak frequencies and durations. Cumulative frequency distributions (frequency for leak with initial rate > x) should be included;
- d) document the gas dispersion model (e.g. numerical grid, jet modelling, etc.);
- e) present results of the gas dispersion analysis. Tables with at least the following data shall be presented: leak location, leak direction and leak rates, wind direction and wind speed, flammable gas cloud size, volume > UEL, equivalent stoichiometric gas cloud size and mass of gas in the region monitored;
- f) document the gas dispersion assessment of scenarios not simulated with CFD, including gas cloud formation for 2-phase and liquid releases;
- g) document the transient ignition modelling including ignition source isolation;
- h) present delayed ignition probabilities, including frequency distribution for delayed (not immediate) ignition and corresponding leak rates as
 - 1) cumulative distribution of time of ignition,
 - 2) cumulative distribution of leak rate and frequency of ignited scenarios.
- i) present frequency distribution for ignited gas cloud sizes;
- j) document the explosion simulation model; monitor points and panels, gas cloud and ignition point locations, explosion panels, calculation grid, boundary conditions;
- k) present raw explosion simulations results (cloud sizes, locations, ignition points and resulting pressures and durations) and established relations between cloud sizes and explosion loads, if relevant;
- l) present frequency distribution for explosion loads;
- m) dimensioning accidental scenarios should be identified and presented to form basis for evaluation of risk reducing measures and EPA.

All frequency distributions should be cumulative to facilitate comparison between studies and to visualise the effect of each of the calculation steps. The minimum required documentation of the explosion modelling includes the steps presented in Figure F.1.

Figure 1: Schematics of Procedure for calculation of explosion risk

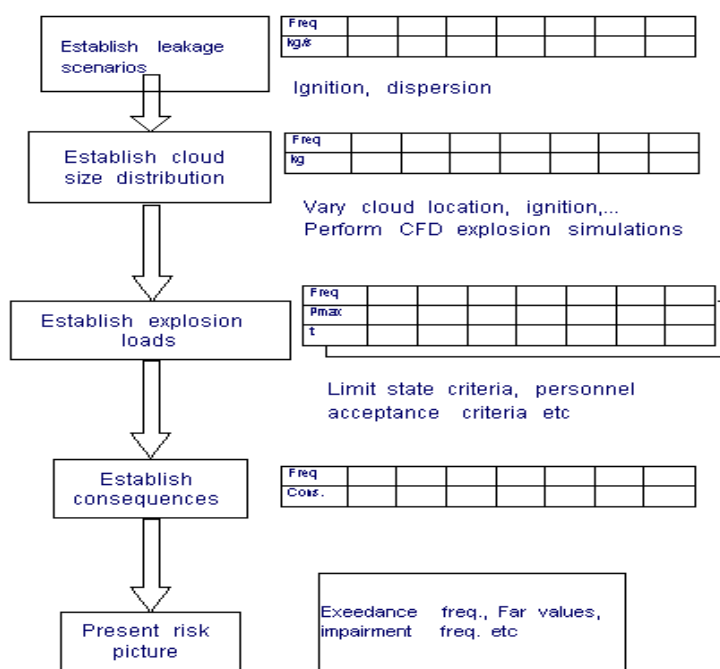


Figure F.1 – Schematics of procedure for calculation of explosion risk

F.2.2 General simplifications in modelling

For the purpose of gas explosion simulations, non-homogeneous clouds should be modelled as rectangular cuboid stoichiometric clouds. This idealised cloud is established in order to give explosion loads similar to the non-homogeneous gas cloud.

Several scenarios for gas cloud formation shall be evaluated based on the leak segment, leak points, directions and the time of ignition. These may be represented by a set of 'standard' scenarios, i.e. clouds and locations. Symmetry considerations, reasoning and simplifications based on understanding of the physics may be used to reduce the number of scenarios for consideration.

Simplified relations between input parameters and the results from the CFD calculations can be established both for gas dispersion and explosion. The validity and limitations of such relations shall be documented.

Simplified modelling as compared to what is outlined in this procedure can be applied. If so, it is required that the analysis results are conservative, and that this conservatism is documented. This involves presenting intermediate results as required.

Non-homogeneous clouds may be modelled as non stoichiometric clouds if this is considered to be the most realistic representation of the scenarios. Discussion of effects and comparison with stoichiometric gas clouds shall be included.

F.2.3 Geometry model

The geometry model needs to be modelled as realistic as possible. All objects should be modelled, independent of size and shape. If details of the geometry model are not available, it is essential that all anticipated equipment is identified and modelled based on experience and engineering considerations. The following should be carried out to verify the geometry model:

- equipment count of the explosion geometry model;
- equipment count of the CAD model, including an evaluation of the effect of e.g. pipes inside pipes on the count result;
- comparison of equipment count from explosion model and CAD model, globally and locally, e.g. part of module, where relevant;
- comparison of equipment count compared to other similar modules;
- visual comparison of explosion model and CAD model, in order to identify any discrepancies between representation of confinement and larger objects;
- review with designers (including review of decks and walls).

For early phase analyses it may be required to carry out sensitivity studies on the effect of changing the congestion level inside the module (especially small equipment that has been anticipated).

F.2.4 Selection of area

A CFD-based explosion analysis requires the definition of calculation domains for the different analysis phases.

For ventilation simulations of a naturally ventilated installation, the calculation domain shall extend far enough outside the installation that the wind field is not (or only marginally) influenced by the presence of the installation.

Dispersion simulations shall be performed in a calculation domain which is large enough that any gas-air cloud which forms from leak(s) inside the domain and which may contribute to explosion loads upon burning, is included in the domain.

Explosion simulations shall be performed in a volume which includes the relevant exploding gas-air clouds and targets of interest. For targets too far away from the gas clouds, such that CFD simulations are too time consuming or expensive, other methods for calculating far field blasts can be applied. In this case, the accuracy and/or conservatism of the results shall be addressed.

F.3 Leakage

F.3.1 Frequency and rate

The starting point is a distribution of hole sizes. Based upon the pressure in the system, initial leak rates shall be calculated and classified according to a distribution with narrow categories. The categories shall match possibly wider categories used in the fire risk analyses. The following categories should be used (all values in kg/s):

0,1-0,5; 0,5-1; 1-2; 2-4; 4-8; 8-16; 16-32; 32-64; 64-128; 128-256; 256-512; 512-1024; 1024-2048.

The nine smallest rates are standard rates expected to be used. However, the smallest leak rate categories listed above can be omitted if it is documented that the contribution to explosion risk is negligible. The upper cut-off should reflect the maximum credible initial leak rates. Normally this would reflect a piping rupture scenario. Note that these scenarios are in most cases of a very transient nature.

A continuous distribution of leak sizes may be used. If used, the frequencies for the defined categories shall be stated.

F.3.2 Transient gas leak modelling

Credible transient leak profiles shall be reflected. This includes modelling of segment inventories, time till isolation and pressure drop due to blowdown and leak.

It is important that the variation in inventory and pressure is reflected, if a limited number of scenarios are selected as representative.

The effect of buoyancy and any transient behaviour of the leak on gas cloud size and location can be significant, and should therefore be accounted for.

The effect of possible isolation and blowdown failure shall be addressed, and modelled, where required.

F.3.3 Shape of equivalent stoichiometric gas cloud

The gas cloud will have an irregular shape and be longer and larger than the representative stoichiometric gas cloud. It can nevertheless be modelled by a rectangular cuboid cloud, extending from floor to ceiling (except in cases with small clouds).

This normally means (due to the computational cost) that a stratified (non-homogenous 'pancake-like') cloud in an enclosed area is not considered. It should be commented upon where CFD indicates stratification.

F.3.4 Location and direction of leak

In order to obtain a representative distribution at least three leak points in each area should be used, all of them with 4 to 6 jet directions. Area and selection of area are defined in F.2.4.

Leaks oriented into or towards areas of locally high congestion and/or confinement, where one might presume that the momentum of the leak is significantly reduced by the interaction with the geometry, have on occasion been represented as (very) low momentum releases.

This practise does not necessarily constitute a physically sound approach. Therefore, in situations where this practise is considered used, one should evaluate whether it is representative for the case studied.

There shall be at least one scenario with leak orientation against prevailing ventilation direction, i.e. wind at leak location.

Symmetry considerations and evaluations based on the understanding of physics as well as geometry and ventilation direction effect may be used in order to limit the number of scenarios that need to be explicitly simulated. Simplifications made shall be documented and justified.

Both mass, energy and momentum should be conserved in the jet leak from a high pressure system. If this is deviated from, the accuracy of the simplification shall be commented, and preferably documented.

G.3.5 Liquid release

The fraction of the mass that flashes or evaporates from a liquid release shall be modelled as a corresponding gas release. For a low-pressure liquid release, this can be modelled as a low momentum gas leak. The possibility of aerosol (mist) formation for a high pressure liquid release, shall be assessed when relevant. In this case the use of a representative high-momentum gas release shall be considered. The equivalent gas composition shall be chosen to reflect the assumed reactivity of the part of the leaking medium that will form the explosive cloud. This selection process shall be documented.

F.4 Gas cloud formation

F.4.1 Wind direction and strength

In principle, at least eight wind-directions shall be considered with a frequency and speed distribution determined from the wind rose of the area. Often these can be grouped into a few (2 to 4) different ventilation regimes. CFD ventilation simulations may be used to establish these. It is acceptable to assume that the ventilation rate for a wind direction is proportional to the wind speed, but it is important also to consider that the proportionality constant may be different for the different wind directions. This shall be taken into account when the contributions from the different wind directions to the ventilation regimes are established. In practice, this means that at least two wind velocities shall be simulated.

The above proportionality considerations are not valid for low wind speeds as the buoyancy from hot equipment will influence the ventilation. It shall be documented how this is handled. For weather vaning installations the number of different wind directions may be reduced.

The validity range for the relationship shall be indicated. The relationship may subsequently be used for extrapolation to other leak rates and ventilation velocities.

F.4.2 Calculation of equivalent stoichiometric gas cloud

Gas-air clouds from dispersion simulations are normally irregular in shape and varying in concentration. As a minimum approach, for the purpose of performing explosion simulations, these clouds can be represented by equivalent stoichiometric clouds.

The purpose of this equivalent approximation is to reduce the number of simulations required and at the same time provide a representative (for explosions in the dispersed clouds) distribution of explosion loads for all defined targets.

Representative in this context should mean either accurate or conservative.

The equivalent stoichiometric gas clouds should be based on the volume of flammable gas mixture in the explosive region, weighted by the concentration dependency of the flame speed and the expansion ratio for the actual gas mixture. If this approximation method is used, the following considerations shall be taken into account:

- the amount of gas above UEL will in such an approach not be represented. Gas-air clouds at concentrations partly or entirely above UEL might in an explosion mix with gas at lower concentrations (or even with air) such that the volumes of flammable gas-air and/or gas-air near stoichiometric concentration (i.e. with high reactivity) will increase. The effect of these phenomena shall be investigated and documented. Explosion simulation with non-homogeneous gas clouds should be used as documentation;
- this approach may for some cases be non-conservative for highly enclosed modules. Hence, the model should be validated if this minimum approach is used;
- in situations with high degree of confinement, the equivalent stoichiometric cloud volume dependence on burning velocity is likely to be less realistic. In this case the expansion ratio of the gas is more important in determining overpressure. It is furthermore possible that rich, but still flammable, clouds are not well represented by the equivalent stoichiometric cloud volume since the maximum burning velocity and thereby the highest overpressure often occurs for a slightly rich mixture. The applied methodology for use of representative stoichiometric gas clouds shall therefore be justified and documented for each specific area analysed;
- more conservative equivalent stoichiometric cloud representations than what is described above, could be used, if deemed necessary.

F.4.3 Initial turbulence

A jet leak will generate a turbulent flow field in the gas cloud. In most leak scenarios studied in risk analyses the jet will be flowing at the time of ignition. Hence, the jet-induced turbulence should be included as initial turbulence in the explosion simulation.

The effect of initial jet turbulence will necessarily be dependent on the explosion scenario. The stronger the combustion generated turbulence level becomes the less the effect of initial turbulence will be. Scenarios with low to moderate congestion and high degree of openness will, for the same gas cloud, produce lower levels of combustion generated turbulence. Hence, the effect of initial turbulence should be specifically addressed in such cases.

F.4.4 Dispersion, selection of models

CFD models shall be used for dispersion calculations. In order to include the large number of parameter variations that the procedure implies, it may be necessary to use correlations based on these dispersion calculations. The validity of these correlations shall be documented by independent calculations.

If meandering wind boundary condition during dispersion calculations is considered relevant for the mixing of gas and air, this should be implemented in the explosion analysis.

F.5 Ignition

F.5.1 Location of gas cloud and point of ignition

The frequency distribution of gas cloud locations shall take into account the location of leak sources and ventilation conditions, e.g. wind rose, etc.

Ignition can in principle take place anywhere in the gas cloud. Explosion simulations shall include at least three different ignitions: central, edge and other.

The layout as well as the selected method for calculation of equivalent stoichiometric gas clouds (size and location) shall be taken into account when evaluating credible locations for the ignition points.

F.5.2 Ignition modelling

The purpose of ignition modelling is to determine frequencies for gas cloud size and locations at ignition time.

Conditional ignition probabilities upon gas exposure should be based on the JIP ignition modelling report as referred to in the main report.

A time dependent ignition probability model should be used and the frequency distribution of cloud sizes shall be calculated at the time of ignition.

Transient modelling of the gas cloud is required as input to the ignition model. Simplification of the cloud development using continuous relations is acceptable. This means that steady state gas dispersion results can be used as basis for the transient gas cloud model. It is important to take into account that for rich gas clouds (significant volume with concentration > UEL), the gas cloud is generally more explosive during gas cloud build-up than at steady state. To base the analysis on the volume with concentration > LEL, possibly with a reduction factor for equivalent stoichiometric cloud size, is considered a conservative approach.

The time to reach the maximum stoichiometric equivalent cloud as well as the time from the maximum to the stationary solution shall be evaluated and modelled accordingly.

Gas detection and actions thereof that might influence the probability of ignition and the formation of a cloud (isolation of ignition sources, shut-down and blow-down), should be taken into account such that the time dependencies are reflected.

Immediate spontaneous ignition (auto-ignition) occurs so quickly that the scenario should result in a fire. It should be documented that ignition within a few seconds will not result in significant explosion loads.

F.6 Explosion

F.6.1 Definition of load

In order to determine the structural response of safety critical structural elements of an installation, a time dependent gas explosion overpressure and, if relevant, drag force shall be applied. Design loads for structural design shall reflect peak explosion pressure with corresponding durations or alternatively impulse for relevant areas exposed. The loads shall be presented as exceedance curves for pressure and impulse or duration when relevant as required by the subsequent structural response analysis, see also F.7.3.

The loads for different structural elements as well as which elements are potentially simultaneously exposed, have to be described. In general, local loads (average over a small surface) are significantly higher than global loads (typically average load over a larger surface).

For objects with a cross-sectional dimension smaller than 0,3 m (e.g. piping, etc.) drag loads apply. For larger objects (e.g. vessels), simulations may result in both drag loads and differential overpressures being generated. It may be overly conservative to add both loads to obtain the actual load. A sensible approach may therefore be to compare drag and overpressure loads and select the highest value.

Drag loads can be described individually for different directions. Dimensioning drag loads should be derived from dimensioning explosion scenarios for explosion barriers. Alternatively, dimensioning drag loads can be based on a relation between drag loads and overpressures from dimensioning explosion scenarios for explosion barriers.

The frequency of explosions exceeding the dimensioning drag load shall be quantified.

Detailed information about drag loads and the protection of piping systems subject to explosions are found in FABIG Technical note 8, 2005.

If blast induced vibration load is considered relevant, vibration loads should be included.

F.6.2 Geometry modelling

The standard for modelling shall be selected according to requirements from the software supplier. This should be sufficient to the extent that effects observed in the Blast & Fire Project may be modelled.

Experience shows that it is vital to use a sufficiently detailed representation of the module geometry in the explosion simulations. Studies shall be performed on selected scenarios to show the sensitivity of the load to variations in congestion.

Where detailed module geometries are not available, the input geometry shall reflect the congestion experienced in relevant geometry models. An alternative is to apply explosion simulation results (typically relations between cloud size and explosion loads) from similar geometries. In such cases, a margin should be included in the explosion loads to reflect the uncertainty. It is likely that the reference case and the case studied will differ in e.g. leak frequencies, ignition frequencies, confinement, congestion ventilation rate etc. The effects of these differences on the analysis results shall be addressed, see also F.1.2.

The equipment densities used in the simulations shall always be documented (equipment counts). Comparison with similar modules from other projects is recommended.

F.6.3 Explosion load outside the area

Explosions inside modules may cause a considerable explosion load on surfaces and structure outside the module/process area. In case flame acceleration simulator (FLACS) is used, one should follow most recent recommendations from developer regarding far field blast pressures.

It is recommended that worst-case scenarios and some scenarios around the dimensioning scenarios are calculated, more scenarios, if required.

If the dimensioning explosion scenarios are derived from stoichiometric gas clouds with a smaller gas quantity than the non-homogeneous gas cloud, the explosion load outside the area could be unrealistic. In addition, the extent of the combustion zone might be underestimated. This shall be considered in deriving dimensioning far field explosion loads and/or far field explosion consequences.

Dedicated explosion simulations may be performed taking into account gas clouds outside area. Alternatively, the explosion load outside the area from gas clouds within area should be investigated. Explosion simulation outside area shall take the following into consideration if using the method of calculation of equivalent stoichiometric gas cloud as described in F.4.2:

- amount of flammable gas in fuel rich gas clouds might be underestimated. Explosion simulations with non-homogeneous gas clouds (and a larger number of ignition locations) should be used as documentation of possible effects;
- the effect of concentration of flammable gas shall be investigated with respect to cloud size and leak rate variations.

F.6.4 Effect of deluge

It is acceptable to assume that deluge can reduce high overpressure in unconfined explosions.

As it is necessary to establish deluge before ignition in order to have an effect on overpressure generation, deluge will only be effective with late ignition (typically 20 s or later). Ignition probability is generally not assumed to increase due to use of deluge at unignited gas leaks.

Gas dispersion and cloud formation is affected by deluge. Small gas clouds might be diluted and thus reduce the potential explosion load. Larger gas clouds might be diluted as well with the result of increasing expected explosion load.

The effect on gas dispersion and cloud formation of implementing deluge in explosion analysis shall be addressed and preferably taken into account. If accounted for, the effect shall be documented and the degree of conservatism presented in F.1.2 shall be adhered to.

F.7 Calculations of response

F.7.1 Relation of response analysis to RAC

Risk acceptance criteria are in general related to the implications for the explosion. An explosion response analysis is required to establish a relation between explosion loads and their consequences on structures and equipment.

F.7.2 Limit state

Structural response shall be classified according to ALS, as defined in F.6.1.

The following scenarios shall be amongst those considered related to strength and functionality requirements:

- global structural collapse;
- rupture or unacceptable deflection of an explosion barrier including unacceptable damage of the passive fire protection of the barrier;
- damage to equipment and piping resulting in unacceptable escalation of events (applies also for pipe and cable penetrations through barriers). This includes damage due to deflection/damage of supporting structure;
- unacceptable damage to safety critical equipment which need to function after the explosion.

F.7.3 Structural response interface

Calculation of structural response to explosion load is described in NORSOK N-004, A.6.

The response of structural components can conveniently be classified into three categories according to the duration of the explosion pressure pulse, t_d , relative to the fundamental period of vibration of the component, T :

- impulsive domain (where t_d is small compared to T);
- dynamic domain (where t_d and T are of similar duration);
- quasi-static domain (where t_d is long compared to T).

There are two different uses of a probabilistic explosion analysis with respect to the structural response (A and B) as follows:

A. To provide a dimensioning explosion load as input to a structural design process based on an acceptance criteria either for the load or for the corresponding response. In the general case load will have to be described as an exceedance curve both for pressure and impulse or duration. In cooperation with the structural discipline this can be simplified to pressure exceedance curves or impulse/time exceedance curves alone for those cases where the structural response is within the quasi-static domain or the impulsive domain.

B. Assessment of the response of a known structure to ensure that the response is within the given acceptance criteria. In such cases there are two different approaches:

B1. Assessment of the structural response based on the load - frequency relation. As the structure response characteristics are known, the iso-damage curves in terms of pressure and impulse/time for the dimensioning response can be calculated. Then the frequency of exceeding that response, i.e. for pressures and impulses/times above the iso-damage curves, can be calculated and checked against the acceptance criteria.

B2. Direct response calculation on the pressure-time history from each explosion simulation. The response is then evaluated as acceptable or unacceptable according to the damage criterion in the acceptance criteria. The frequency of unacceptable response is then checked against the acceptance criteria.

More details on probabilistic pressure-impulse analyses can be found in [26].

Typical blast walls and decks are relatively large and the load from an explosion is unevenly distributed over the wall or deck. Therefore, the explosion analysis should describe the size and shape of the areas for which the given loads are applicable. These areas correspond to monitoring panels in the simulator, and it is highly recommended that these are defined in close cooperation with structural engineers. The relation between the size of the exposed area and the explosion load should be described.

F.8 Uncertainty

Uncertainty in the explosion modelling shall be addressed.

The uncertainty of the response is mainly governed by the uncertainty in the load and the accuracy of the structural analysis models. Thus it is not necessary to take into account the uncertainty of material quality, fluctuations in materials dimensions, etc. However, if the installation analysed is old, it may well be relevant to consider uncertainties in material characteristics.

As the problems related to non-homogeneous clouds are solved through establishment of equivalent stoichiometric clouds, the calculated loads may have a too short duration. The effect of increasing the load duration should be discussed in the response analysis, and reflected in the analysis results

Grid and congestion sensitivities of explosion simulations should be included as part of the uncertainty.

Annex G

(informative)

Environmental risk and environmental preparedness and response analysis

G.1 Requirements

The Norwegian Management Regulations states the requirements for EnvRA and environmental preparedness and response analysis. Further the Framework Regulations states requirements to risk reduction, including environmental risk reduction, for all phases of petroleum activities.

This informative annex provides guidance in how to perform EnvRA and environmental preparedness and response analysis in different life cycle phases of an activity.

G.2 Objectives

The objectives of an EnvRA can vary as follows:

- present environmental risk picture resulting from activities and operations, for short and long term effects;
- input to risk assessment with respect to comparison with operator's acceptance criteria and environmental goals;
- input to decision-making related to different development concepts and design/decommissioning options;
- input to decision-making with focus on consideration of environmental risk reducing measures for activities and operations, including environmental preparedness and response.

The EnvRA will often be part of an overall risk assessment process for personnel, environment and assets. The approach should be the same irrespective of the context.

Calculations should be detailed towards geographical areas, time of year, resources at risk and which events are causing the risk. The analysis should also be suitable for calculation of changes in risk following from risk reducing measures, e.g. environmental preparedness and response.

The environmental preparedness and response analysis will also often be a part of the overall risk assessment process. The analysis should be suitable for analysing different response options, in terms of response time, response capacity and response method.

G.3 Main principles of environmental risk and environmental preparedness and response analysis

G.3.1 Offshore facilities and operations

The following should be performed for offshore facilities in relation to environmental risk and environmental preparedness and response analysis:

- a) the operator should perform risk and emergency preparedness analyses for acute pollution from its own installations and activities. The risk contributions from different installations shall be considered together. Unmanned installations shall be considered together with the manned installations to which they are connected. It shall be possible to compare the environmental risk contributions from different installations in an unambiguous way;
- b) the operator should establish goals for protection of prioritized, vulnerable resources. Alternative equipment solutions and their availabilities should be identified at an early stage, and their effect should be analysed. The analyses shall include the categories sea surface, water column, coast and shoreline when relevant, and should ensure that different vulnerabilities in different geographical areas are considered;
- c) the characteristics of oil and chemicals and actual effectiveness values for preparedness equipment should be included in the basis for analyses;
- d) the analyses should use the event sequences that may result in acute pollution. The initiating events should be ranked, preferably based on analyses of transport and spreading. In addition, the event

sequences should be supplemented with other types of incidents and conditions that also can result in acute pollution;

- e) for the identified release scenarios, discharge rate and duration distributions shall be established. Selected scenarios shall be subject to transport and spreading analyses, based on discharge rate and duration distributions. The transport and spreading calculations shall include the periods for the planned activity and the subsequent month;
- f) with respect to risk reduction, it is required that all risk contributions are considered together. This implies that the analyses shall have the possibility to classify results into applicable and comparable categories;
- g) consideration of vulnerable environmental resources shall be made visible in the environmental risk and environmental preparedness and response analyses. The environmental preparedness and response analysis shall, where relevant, consider fields and areas as well as regions in the same context.

G.3.2 Onshore facilities

The following should be performed for onshore facilities in relation to environmental risk and environmental preparedness and response analysis:

- a) the responsible should establish goals for protection of prioritized, vulnerable resources. Alternative equipment solutions and their availabilities should be identified at an early stage, and their effect should be analysed in the analysis. The analyses shall include the categories sea surface, water column, coast and shoreline, when relevant, and should ensure that different vulnerabilities in different geographical areas are considered;
- b) the analyses should use the event sequences that may result in acute pollution. The initiating events should be ranked, preferably based on analyses of transport and spreading. In addition, the event sequences should be supplemented with other types of incidents and conditions that also can result in acute pollution;
- c) for the identified release scenarios, discharge rate and duration distributions shall be established. Selected scenarios shall be subject to transport and spreading analyses, based on discharge rate and duration distributions. The transport and spreading calculations shall be carried out in a manner which includes the periods for the planned activity and the subsequent month;
- d) with respect to risk reduction, it is required that all risk contributions are considered together. This implies that the analyses shall have the possibility to classify results into applicable and comparable categories;
- e) consideration of vulnerable environmental resources shall be made visible in the environmental risk and environmental preparedness and response analyses.

G.3.3 Input data requirements for EnvRA

The following are important input data for execution of environmental risk analyses for offshore facilities:

- a) release potential of the reservoir and the installation;
- b) probability for release from different installations and operations that involves risk;
- c) the physical, chemical and ecotoxicological properties of the pollution;
- d) meteorological and oceanographic data relating to wind, temperature and currents;
- e) transport and spread of the pollutants;
- f) weathering and decomposition of the pollutants;
- g) vulnerability of eco systems;
- h) environmental data including information on vulnerable resources and their distribution in time and space.

The following are important input data for execution of environmental risk analyses for onshore facilities:

- a) release potential of the onshore facilities;
- b) probability for release from different facility systems and operations that involves risk;
- c) the physical, chemical and ecotoxicological properties of the pollution;
- d) local meteorological and oceanographic data relating to wind, temperature and currents;
- e) transport and spread of the pollutants;
- f) weathering and decomposition of the pollutants;
- g) vulnerability of ecosystems;
- h) environmental data and including information on vulnerable resources and their distribution in time and space.

G.2.4 EnvRA methodology

The following steps may form part of an environmental risk analysis:

1. Identify release scenarios to the environment, based on an environmental HAZID as well as the scenarios from quantitative risk analyses.
2. Analyse barriers on the installations that may prevent spills or reduce amount of spilled volume to the environment, including reduction of discharge rates and duration of spills.
3. Establish release scenarios (e.g. leak location (geographical, topside and subsea), contaminant characteristics, discharge rates and durations.
4. Simulation of the drift and dispersion of the contaminant (e.g. oil) for relevant scenarios. This includes spread on the sea surface, contamination of water column, drift time, evaporation, emulsification and eventually stranding of oil on shore.
5. Establish the occurrence of environmental resources within the influence area and their vulnerability/sensitivity towards the contaminant.

NOTE Indicators for sensitivity can be vulnerability of the resources (individual and/or population/habitat level) to the contaminant and/or the scientific value or administrative protection value of the resources.

6. Calculate drift time to and the exposure of these environmental resources to the contaminant (overlap between the contaminant and scenarios for distribution of the biological resources).
7. Assess (qualitatively or quantitatively) the short and long term effects on these environmental resources, e.g. on individuals and populations (establish relevant, reliable and valid consequence categories).
8. Assessments shall be based on updated science and monitoring and mapping of biological resources.
9. Calculate the risk as a combination of the probability of a certain event causing environmental damage and the degree of seriousness of this damage.
10. Compare the risk with the environmental acceptance criteria.
11. ALARP evaluations, see Annex A.

The environmental risk analysis should address all acute release scenarios which may affect the environment, including large spills as well as limited releases.

Information about vulnerable populations and sensitive areas should as a minimum be based upon Norwegian official White papers and environmental impact assessments for the area.

G.2.5 Environmental preparedness and response

The environmental preparedness and response philosophy applicable for the Norwegian shelf, is primarily to use mechanical recovery of the acute pollution near the source of the spill, and application of chemical dispersants as a supplement where and when applicable and when causing less environmental damage.

An environmental preparedness and response analysis shall identify the required time for detection and monitoring of releases and extent of the different barriers with regards to capacity, response time, types of equipment, and other specific aspects related to the activity of interest.

The environmental preparedness and response analysis shall preferably be integrated with the EnvRA and shall include

- dimensioning of oil spill response measures,
- recommended oil spill response measures.

Required capacity and oil spill response measures to combat the acute pollution, shall be analysed based on the EnvRA. In the environmental preparedness and response analysis several response alternatives should be analyzed in order to assess different response solutions and their performance. The different combat alternatives can be measured against several parameters, e.g. residual amount of oil on the sea surface, response time, amount of emulsion stranded and environmental risk in open sea and near-coastal areas.

The recommended oil spill response options shall be analysed in terms of effect on the environmental risk level. This shall be done for the analysed period, as well as for the scenarios associated with highest environmental risk, near shore/coastal and offshore.

Finally the analysis shall conclude on a recommended solution which will be an input to further planning of the environmental preparedness and response.

Bibliography

- [1] ISO 15544, Petroleum and natural gas industries - Offshore production installations – Requirements and guidelines for emergency response
- [2] ISO 20815, Petroleum, petrochemical and natural gas industries - Production assurance and reliability management
- [3] ISO Guide 73, Risk management - Vocabulary - Guidelines for use in standards
- [4] NORSOK S-002, Working environment
- [5] NORSOK S-003, Environmental care
- [6] NORSOK Z-008, Criticality classification method
- [7] NS 5814:2008, Requirements for risk assessment
- [8] OLF 064, Guidelines for Area-based Emergency Preparedness, 30.6.2000
- [9] Temporary regulations relating to safety and working environment for certain petroleum facilities on land and associated pipeline systems
- [10] The Activities Regulations
- [11] The Information Duty Regulations
- [12] Sjøfartsdirektoratet; "Forskrift av 22. desember 1993 om risikoanalyse for flyttbare innretninger" (Regulations of 22. December 1993 covering risk analyses for mobile offshore units), NMD.
- [13] Health and Safety Executive: Tolerability of Risk from Nuclear Power Stations, HMSO, 1992
- [14] Assessment Principles for Offshore Safety Cases (APOSC), HSE March 2006, www.hse.gov.uk/offshore/aposc190306.pdf
- [15] Lord Cullen; The Public Inquiry into the Piper Alpha Disaster. UK Department of Energy 1990. ISBN 0 10 113102.
- [16] A guide to the Offshore Installations (Safety Case) Regulations, 2005, Statutory Instrument 2005 No. 3117, UK HSE
- [17] Prevention of fire and explosion and emergency response on offshore installations Regulations 1995, (SI 1995 743) UK HSE
- [18] UKOOA: HSE Management guidelines
- [19] Guidelines for the Development and Application of Health, Safety and Environmental Management Systems, OGP, July 1994
- [20] NS-EN ISO 14121-1 "Maskinsikkerhet – Risikovurdering – Del 1: Prinsipper" (Safety of machinery – Risk assessment – Part 1: Principles)
- [21] Occupational health and safety management systems – Guidelines for the implementation of OHSAS 18001, BSI-OHSAS 18002:2000
- [22] NORSOK standard N-001, Structural design, Rev. 4, February 2004
- [23] NORSOK standard N-003, "Actions and Action Effects", Ed. 2, September 2007
- [24] NS 5814 - Krav til risikoanalyse (NS5814:2008, ICS 03.120.01, Juli 1998)
- [25] IEC 60300-3-9 (1995) Dependability management - Part 3: Application guide - Section 9: Risk analysis of technological systems
- [26] Design of Offshore Facilities to Resist Gas Explosion Hazard Engineering Handbook, J. Czujko, ed., Corrocean, 2001
- [27] Lees, Loss Prevention in the Process Industries, 3rd edition. Edited by Sam Mannan. Elsevier 2005.
- [28] Metode for Miljørettet Risiko Analyse (MIRA)" Revisjon 2007 ([OLF Recommended method for environmental risk analysis, MIRA](#), Norwegian only,) April 2007
- [29] OLF/NOFO Veileder for miljørettet beredskapsanalyser, Rapport nr. 2007-0934, rev. 16.06.2007
- [30] OLF, Retningslinjer for beregning av utblåsningsrater og -varighet til bruk ved analyse av miljørisiko, rev. 02, 15.01.2007
- [31] International Association of Drilling Contractors,(IADC), Health, Safety and Environment Case Guideline for Mobile Offshore Drilling Units, Issue 3.2, 03.10.2006
- [32] Vinnem: Offshore Risk Assessment, Kluwer, 2. edition, Springer, 2007.
- [33] Aven, Vinnem: Risk management, with applications from the offshore petroleum industry, Springer 2007.
- [34] Scandpower/DNV report (2001): Human Resistance Against Thermal Effects, Explosion Effects, Toxic Effects and Obscuration of Vision. Rev00, Date: 20.03.2001
- [35] Rausand and Utne, Risikoanalyse. Teori og metoder (in Norwegian), Tapir Akademisk Forlag, Trondheim, 2009

- [36] Justis- og politidepartementet, Forskrift om tiltak for å forebygge og begrense konsekvensene av storulykker i virksomheter der farlige kjemikalier forekommer (storulykkesforskriften), FOR-2005-06-17-672
- [37] TNO, Guidelines for quantitative risk assessment (Purple book)
- [38] TNO, Methods for the calculation of physical effects (Yellow book)
- [39] TNO, Methods for determining and processing probabilities (Red book)
- [40] TNO, Methods for determining the potential damage to humans and the surrounding area resulting from the release of hazardous substances (Green book)
- [41] Nilsen, H. et al. (2005) Development of the Environmental Impact Factor model for risk assessment of acute oil spills (EIF Acute), Proceedings from the 8th International Marine Environmental Modelling Seminar, IMEMS 2005, Helsinki, Finland, 23-25 August, 2005
- [42] Selby, C., Burgan, B. "Blast and fire engineering for topside structures, Phase 2, Final summary report", Steel Construction Institute, UK, Publication number 253, 1998

