Hazard Installations Directorate
Offshore Division
Fire, Explosion and Risk Assessment Safety Case Assessment Topic Guidance

INTRODUCTION

For each of the topics listed below this guidance provides information to a Safety Case assessor on the relevant:

BACKGROUND,
MINIMUM STANDARDS,
KEY QUESTIONS.

It also provides:

DETAILED GUIDANCE FOR ASSESSORS and;
RELEVANT GOOD PRACTICE with References for OTHER STANDARDS AND GUIDANCE

It should be noted that the guidance, relevant standards and legislation provide here is intended to supplement the references in GASCET and any reference included should be checked for issue status by the user.

This guidance is the updated PMTECH12 assessment manual referenced in GASCET and should be used rather than the link in GACET until the link is updated.

Contents

1 OVERVIEW
2 INTRODUCTION
3 SCOPE AND FORMAT OF GUIDANCE
4 HOW TO USE THIS GUIDANCE
5 HAZARD IDENTIFICATION
6 HARM TRANSMISSION
7 CONSEQUENCE ASSESSMENT
8 QUANTIFIED RISK ASSESSMENT
9 RISK EVALUATION AND REDUCTION
10 RISK MANAGEMENT
11 HIERARCHY OR RISK CONTROL
12 EMERGENCY ARRANGEMENTS
13 HSE PUBLICATIONS
14 OTHER RELEVANT STANDARDS & Guidance
15 ABBREVIATIONS

Appendix A: Interfaces with Other Topic Specialist Teams
Appendix B: Recent Standard & Guidance
1 Overview of Topic Guidance

The principles by which HSE evaluates Safety Cases are set down in APOSC, which in turn complement the interpretative guidance contained in “A guide to the Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015 (SCR)”. As well as the principles of Safety Case assessment, APOSC contains guidance on the information and demonstrations which duty holders must provide to comply with the principles. The guidance expands on APOSC, providing more detail on aspects relevant to fire, explosion and risk assessment, and setting out the minimum standard which should be achieved to comply with the assessment principles. It draws on industry’s own guidance in this area, principally the Guidelines for Fire and Explosion Hazard Management (OGUK) and incorporates the requirements of Offshore Division’s ALARP Guidance (OIS 2/2006 &3/2006), which in turn draws on ‘R2P2’ (HSE, 2001) and the ALARP ‘trilogy’ discussed later. This document provides a supplement to the references in GASCET for the primary standards, codes of practice and design guidance pertinent to the assessment and control of fire and explosion hazards on offshore installations. Specifically, it defines good practice relevant to the offshore industry, as required by the framework document on Assessing Compliance with the Law in Individual Cases and the Use of Good Practice. This guidance also draws on Offshore Division’s Fire and Explosion Strategy.

This topic guidance has been updated to reflect current standards & guidance for Fire, Explosion and QRA Safety case assessment. It also contains details of previous standards and guidance as appropriate.

Relevant Pre-Existing Guidance

APOSC Principles

Principle 1
The factual information should meet the SCR05 requirements and provide sufficient detail to support the arguments made in the case

Safety Management Systems

Principle 2
The safety case should demonstrate that the management system is adequate to ensure compliance with the relevant statutory provisions

Principle 3
The management system should show an appropriate level of control during each phase of the installation life cycle, including design, construction, commissioning, operation, decommissioning and dismantlement

Major accident hazard identification

Principle 4
A systematic process should be used to identify all reasonably foreseeable major accident hazards that apply to the installation, together with potential initiating events or sequences of events

**Major accident risk evaluation**

Principle 5
The methodology and evaluation criteria adopted for major accident risk assessment should be clear

Principle 6
Any criteria for eliminating the less significant risks from detailed consideration in the major accident risk evaluation should be explained

Principle 7
The assessment should take account of people exposed to exceptional risks

Principle 8
The major accident risk evaluation should take account of human factors

Principle 9
Conclusions reached in risk assessment processes should take uncertainty into account

**Risk reduction measures**

Principle 10
The identification of risk reduction measures should be systematic and take into account new knowledge

Principle 11
The reasoning behind the choice of risk reduction measures to be implemented should be described. Decisions on implementation should take reasonable practicability into account

Principle 12
Risk reduction measures identified, as part of the risk assessment, should be implemented if they are reasonably practicable

Principle 13
In deciding what is reasonably practicable, the case should show how relevant good practice and judgement based on sound engineering, management and human factors principles have been taken into account

Principle 14
Where remedial measures are proposed to reduce risk, the timescale for implementing them should take account of the extent of such risks and any practical issues involved
Major accident risk management

Principle 15
Measures taken to manage major accident hazards should be described

Principle 16
The safety case should explain how inherently safer design concepts have been applied in the design decisions taken

Principle 17
The measures for preventing major accident hazards should take account of the various activities undertaken during the installation's current phase of operation

MAH Detection

Principle 18
Appropriate detection measures should be provided for any reasonably foreseeable event requiring an emergency response

MAH Mitigation

Principle 19
Appropriate control and mitigation measures should be provided to protect personnel from the consequences of a major accident

MAH Control

Principle 20
Arrangements for controlling an emergency should take account of likely conditions during emergency scenarios

Principle 21
The measures and arrangements for the management of an emergency should be identified

The Temporary Refuge

Principle 22
The Temporary Refuge (TR) should provide sufficient protection to enable people to muster safely, to permit the emergency to be assessed, and to allow the emergency response plan to be executed

Principle 23
Criteria should exist that describe the Temporary Refuge integrity (TRI) and the time over which TRI needs to be maintained against all hazards identified in the risk assessment. The safety case should demonstrate that these criteria are met i.e. that TRI would be maintained for the necessary time

Evacuation and Escape
Principle 24
Evacuation and escape arrangements should be integrated in a logical and systematic manner, taking account of the environment in which they may need to function

Principle 25
Effective rescue and recovery arrangements should be provided to cope with major accidents

Installation design

Principle 26
A Design Notification should describe how the principles of risk evaluation and risk management are being applied to the design to ensure that major accident risks will be controlled so as to ensure compliance with the relevant statutory provisions

Principle 27
Well engineering aspects, especially those that refer to well operations before the start of facility operations, should be included in the Design Notification

Combined Operations

Principle 28
The management system should address the additional risks associated with combined operations

Principle 29
A systematic approach should be taken to assessing the impact of combined operations on the conclusions of the operational safety case for each installation

Principle 30
A systematic approach should be taken to identifying and assessing any additional major accident hazards arising from combined operations. These can be new hazards or changes to existing hazards

Principle 31
The measures for emergency response should be appropriate to the particular combined operation

Principle 32
Elements that become safety critical elements (SCEs) as a result of combined operations should be identified and made subject to verification. They may be parts of the individual installations, or additional plant or equipment provided for the combined operations

Decommissioning and dismantlement
Principle 33
When the safety case is revised to deal with decommissioning or dismantlement, the sequence of events should be described, from cessation of production to dismantling of the structure.

Principle 34
The case should describe the extent and availability of safety systems during decommissioning or dismantlement.

Principle 35
Any additional major accident hazards arising from decommissioning or dismantlement should be identified.

Principle 36
The management system should demonstrate that effective control will be maintained throughout decommissioning or dismantlement.

Relevant GASCET Chapters:

2.1.2 Risk Assessment including human vulnerability
2.3.3 Loss of Containment – Fire and Explosion
2.4.1 Wells – Risk Evaluation and Management
2.4.5 Helicopter Risks
2.4.6 Non-Process Fire and Explosion
3.2 Design Case
2. Introduction

This document contains the new requirements for duty holders as regards the content of Safety Cases and the criteria, where appropriate by which the acceptability of a Safety Case is judged and an assessment record completed. It provides guidance for assessors of Safety Cases on the topic of fire, explosion and risk assessment. It serves as a supporting reference to the Safety Case Handling and Assessment Manual (SCHAM).

The overall objective of this guidance is to promote greater consistency and effectiveness in the assessment of Safety Cases, and provide greater transparency for duty holders. It provides the rational basis upon which to reach decisions as regards the acceptability of Safety Cases.

Specifically, this document:

- expands on existing guidance, ie Assessment Principles for Offshore Safety Cases (APOS C) (HSE, 2006);
- incorporates the requirements of the Guidance on ALARP for Offshore Inspectors Making an ALARP Demonstration (OIS’s 2/2006 & 3/2006); and
- defines relevant good practice, in accordance with HSE’s framework document on Assessing Compliance with the Law in Individual Cases and the Use of Good Practice.

It is emphasised that this document provides guidance only, not a prescriptive assessment format. This recognises that the goal-setting regulatory regime for the offshore industry, ie Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015 (SCR) and the previously established regulations are now well established and considerable assessment experience and expertise has been built up. This document is therefore intended as a useful checklist for experienced assessors, whilst at the same time providing an essential introduction for new assessors.

This provides an overview of the Topic Guidance and the detailed guidance sub-divided according to the grouping of principles in APOSC with the key supporting references.

The generic term for those standards for controlling risk which have been judged and recognised by HSE as satisfying the law when applied to a particular relevant case in an appropriate manner.

3. Scope and Format of Guidance

The scope and format of this guidance are drawn from the ‘Control of major hazards’ section of APOSC, covering the following aspects:

- hazard identification;
- quantified risk assessment (QRA);
- risk evaluation (ie evaluation of the acceptability of the risk) and risk reduction;
- risk management (concerning the measures in place to eliminate, prevent, detect, control and mitigate major fire and explosion hazards, and their associated performance standards); and
- emergency arrangements.

The Topic Guidance links to APOSC, GASCET, SCR, and the interface with other topic specialist teams. The interface with other topic specialist teams is defined in further detail in Appendix A.

The guidance cover each of the above aspects in further detail. Specifically to:
• Establish the minimum standard which must be met for a Safety Case to be considered acceptable. This draws on the existing provisions of the SCR guidance, GACET and APOSC.

• Identify the key questions for the assessor to consider in determining whether the minimum standard has been met. This draws on: -SCR guidance; -APOSC; -PFEER ACOp (HSE, 2015); -OGUK guidance; and -Offshore Division ALARP Guidance (OIS 2/2006 & 3/2006).

• Provide detailed guidance for assessors, define relevant good practice and make reference to other useful standards and guidance. Particular aspects of APOSC which are expanded on in this document are:

• Examine the appropriateness of the level of risk assessment carried out for the Safety Case in accordance with the principles defined in OIS 3/2006.

• Break down the QRA into its component parts (selection of representative events, frequency estimation etc) to provide further guidance on what constitutes a ‘an adequate’ QRA, in accordance with the requirements of SCR 2015 Schedules 1-7; and


4. How to Use this Guidance

This guidance has been developed to support (not replace) the professional judgement exercised by Energy Division - Offshore inspectors in the assessment of Safety Cases. Although it identifies the key questions for assessors to consider, it is ultimately for assessors themselves to decide, based on the merits of each Safety Case, which issues to raise with the duty holder.

The criteria for non-acceptance of a Safety Case are set down in SCHAM. Those of particular relevance to fire explosion and risk assessment include:

• factual information required by the regulations is not contained in the Safety Case;

• the relevant assessment principles from APOSC are not all addressed in the Safety Case;

• if there are inadequacies in the potential major accident hazard identification and risk assessment process which are likely to render the basis for risk management decisions invalid; and

• further risk reduction measures are reasonably practicable.

The minimum standard set out in this guidance reflects these criteria by drawing directly on the relevant provisions of SCR and APOSC. Therefore assessment against the minimum standard set down here provides the basis for acceptance (or otherwise) of the Safety Case.
5. Hazard Identification (APOS C Principle 4)

- use of a systematic process for hazard identification
- application of appropriate hazard identification methods
- identification of combinations or sequences of events leading to a major accident
- potential initiators of a major accident
- consideration of the various existing (and potential future) activities on an installation

Quantified risk assessment (see APOS C Principles)
- approach to application of QRA
- suitability and sufficiency of QRA
  - selection of representative set of events
  - event frequency estimation
  - hazard assessment
  - consequence assessment
  - escalation analysis
  - risk management

Risk evaluation and Reduction (see APOS C Principles)
- approach to risk evaluation reduction
- criteria for elimination of less significant risks
- consideration of reasonable practicability
- consideration of relevant good practice and application of sound engineering judgement
- consideration of people exposed to exceptional risks
- consideration of uncertainty
- identification and implementation of risk reduction measures

Risk management
- description of measures to manage major accident hazards
- application of principles of inherent safety
- strategy for prevention of major accident hazards
- provision of appropriate detection measures
- provision of appropriate control and mitigation measures
- PFEER summary

Emergency arrangements
- consideration of anticipated conditions during an emergency
- sufficiency of protection of TR
- performance standards and endurance times for access to TR
- ALARP demonstration that frequency of TR impairment is below 1e-3/yr

Hazard identification is a crucial step in QRA, as hazards which have not been identified will not subsequently be assessed and mitigated. SCR requires that a duty holder ‘include in the
safety case sufficient particulars to demonstrate that … all hazards with the potential to cause a major accident have been identified’ [Reg 12 (1) (c)]. APOSC sets out four principles by which the adequacy of the hazard identification may be judged and these are reproduced below as the minimum standard which should be achieved.

Minimum Standard

It should be clear that a systematic process has been used to identify all reasonably foreseeable major accident hazards specific to the installation (APOSC Principle 4 para’s 22-25)

The hazard identification methods applied should be appropriate to the magnitude of the hazards involved and a systematic process should have been used to identify where a combination or sequence of events could lead to a major accident

The sequence of particular activities and their relationship (in time) with other foreseeable future activities in relation to the installation should be considered as potential major accident hazard initiating events

Key Questions

The key questions which the assessor may wish to consider in determining whether the Safety Case complies with the minimum standard are as follows:

Methodology for hazard identification

• Has the appropriateness of the methodology for undertaking the hazard identification process been explained ?

• Has an evaluation been made of the effects of failure of prevention, detection, control and mitigation measures ?

• Has a thorough, structured, systematic and auditable approach been adopted ?

• Has a team of suitable composition been employed ?

Scope of hazard identification

• Have all intended significant operations and activities associated with the installation been considered ?

• Have all reasonably foreseeable causes (initiating events) been considered ?

• For fixed installations, have the anticipated well work-over and well servicing operations and their relationship (in time) to other activities on the installation and any connected activities been considered ?

• Have all foreseeable fires and explosion hazards been addressed ?

Output of hazard identification
• Is there a clear link between the hazard identification, the evaluation of risks and the description of the measures taken and arrangements made to manage risks to ALARP?

• Has the hazard identification process been fully documented?

Detailed Guidance for Assessors

A hazard identification technique appropriate to the complexity of the installation, the stage of the installation in its lifecycle and the scale and nature of the hazards on the installation should be employed, eg:

• Hazard and operability study (HAZOP);
• Failure Modes and Effects Analysis (FMEA);
• Safety reviews;
• Industry standard or bespoke checklists;
• Job safety analysis; and
• Human error identification methods.

Thorough reviews undertaken as part of SCR 13(1) should take account of such factors as:

• plant or process modifications (including the cumulative effect thereof);
• changes in reservoir conditions;
• incidents and near misses; and
• new knowledge.

The hazard identification exercise should be based on suitable reference information, eg:

• Process Flow Diagrams (PFDs);
• Piping and Instrumentation Diagrams (P&IDs);
• Layout plans;
• Equipment lists;
• Process data sheets; and
• Operating and maintenance philosophy.

Appropriate consideration should be given to the various hazardous inventories on an installation, eg:

• Process oil/gas/condensate;
• Process additives or combustible non process chemicals (eg methanol, TEG MEG and so on);
• Fuels (eg, diesel, aviation fuel) and lubricants;
• Bottled gas;
• Explosives and detonators;
• Chemicals; and
• Non-process combustibles.

Appropriate consideration should be given to the potential for release of the down hole annulus gas inventory for wells and the various potential causes (or initiating events) of fire and explosion events should be identified, eg:

• Internal causes
  - Incorrect equipment or material specification;
  - Defective material or equipment;
  - Pressure outside design limits;
  - Temperature outside design limits;
  - Vibration;
  - Corrosion;
  - Erosion;
  - Human error;
  - External loading; and
  - Impact.

• External causes - Helicopter crash; - Ship collision; and - Extreme weather.

The hazard identification team leader should be independent of the project under study.

**Relevant Good Practice**

• HSC/E publications
Other relevant good practice


This standard advises on the tools and techniques which may be used for hazard identification and risk assessment. It covers all types of risk on offshore production installations, including fire and explosion risks. The standard covers hazard and risk assessment concepts, methods for hazard identification and risk assessment, and risk management (including risk reduction). The annexes to ISO 17776 provide more detail on individual hazard identification and risk assessment techniques, including job hazard analysis, fault tree analysis, event tree analysis, HAZOP studies, FMEA, physical effects modelling, QRA, cost-benefit analysis and safety integrity level (SIL) assessment.


The UKOOA GFEHM provide a framework for life-cycle management of fire and explosion hazards on an installation. The management process set down in the guidelines covers various activities from hazard identification, through hazard assessment, to specification of remedial measures, their implementation and verification. Section 4 of these guidelines cover the identification and assessment of fire and explosion hazardous events. This includes hazard identification, selection of events for analysis, initiating event frequency analysis, characterisation of fire and explosion hazardous events, consequence analysis, escalation analysis and risk assessment. The guidance covers the broad objectives and approach applicable to each stage of the analysis but does not cover the details of the assessment methodology. The guidance covers both new design and assessment of existing installations.

Other Standards and Guidance

API 14J, Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities (API, 1993b).

Section 7 of this document covers hazard analysis, which is defined as the systematic procedure for identifying, evaluating and controlling potential hazards in a facility. The standard gives an overview of the application of hazard analysis and then describes the various hazard analysis methods, focusing on hazard identification techniques, ie ‘checklist’, ‘What If?’ analysis, HAZOP studies, FMEA and fault tree analysis.

This guide provides a comprehensive introduction to QRA for the offshore industry, covering all types of major hazard. It includes a selection of data and simple analytical techniques that may be used in performing QRAs, with reference to more sophisticated databases and computational techniques. Sections 6 and 7 of the guide are the main sections covering hazard identification (including failure case selection). This covers the various techniques for hazard identification (eg reviews, checklists, HAZOP studies etc), followed by the selection of failure cases (or initiating events) and accidents scenarios (the various possible outcomes of the initiating event).

*IADC North West European HSE Case Guidelines for MODUs (IADC, 2002).*

These guidelines were developed primarily to support IADC members in preparing HSE cases that would enable MODUs to move between different sectors of the North Sea without necessitating a revision of the HSE case. They cover HSE management, the MODU description, hazard identification and risk assessment, emergency response and the justification for continuous operation. Parts 4.1 and 4.2 cover hazard identification and risk assessment, including the hazard identification process, interrelationship between different hazards, qualitative and quantitative risk assessment techniques and explosion analysis. Attachments list the major hazards associated with MODUs, give a proforma for a ‘compartment study’ and detail good practice in QRA.

### 6. Harm Transmission

**Source terms**

*The models, data and assumptions used to characterise the source of a hydrocarbon leak should be described.*

*The source term models should be fit for purpose and used correctly.*

*Users of source term models should be aware of the limits of applicability and validation of the models and any use outside these limits should be justified.*

*The uncertainties associated with representation of the source term should be recognised and the sensitivity of the conclusions of the QRA to these uncertainties should be considered.*

**Gas Dispersion**

*The models, data and assumptions used to estimate the dispersion of a hydrocarbon leak should be described.*

*The dispersion models should be fit for purpose and used correctly.*

*Users of dispersion models should be aware of the limits of applicability and validation of the models and any use outside these limits should be justified.*
Justification should be provided for the use of any models which pre-date the current version of the model and for the on-going validity of results generated by previous versions of the model.

Advanced models (e.g., CFD) should only be used by suitably competent persons and the results should be subject to appropriate checks by another competent person. The uncertainties associated with modelling the dispersion of hydrocarbon leaks should be recognised and the sensitivity of the conclusions of the QRA to these uncertainties should be considered.

The dispersion analysis should consider a suitable range of wind/ventilation conditions, in particular low wind conditions in naturally-ventilated offshore modules.

Assurance should be provided of the validity of the air flow pattern used as the basis for dispersion modelling in relation to actual conditions within/around the module/structure of interest.

Consideration should be given to the potential for gas/vapour to migrate from one area of an installation to another, e.g., via drains, HVAC systems, process connections etc.

**Fire hazard assessment**

The models, data and assumptions used to quantify fire hazards should be described.

The fire models should be fit for purpose and used correctly.

Users of fire models should be aware of the limits of applicability and validation of the models and any use outside these limits should be justified.

Justification should be provided for the use of any models which pre-date the current version of the model and for the on-going validity of results generated by previous versions of the model.

Advanced models (e.g., CFD) should only be used by suitably competent persons and the results should be subject to appropriate checks by another competent person.

The uncertainties associated with fire modelling should be recognised and the sensitivity of the conclusions of the QRA to these uncertainties should be considered.

Appropriate consideration should be given to the range of types of fire which could occur on offshore installations, i.e.

- jet fires;
- pool fires;
- running liquid fires;
- flash fires;
- fireballs;
- well blowout fires;
• confined and unconfined fires;
• fuel and ventilation-controlled fires;
• fires on the open deck, within a module or on the sea surface; and
• fires involving ordinary combustibles as well as those involving hydrocarbons.

Adequate consideration should be given to the effects of confinement on fires, in particular the increased lateral (or vertical) spread of flames, which may create additional hazards to personnel, equipment and structures.

A suitable assessment should be made of the generation and dispersion of smoke in fire for the purpose of assessing the effect of smoke at key locations on the installation, in particular the Temporary Refuge (TR).

Consideration should be given to the potential for ventilation-controlled fires to occur and the particular hazards of such fires, eg increased concentrations of carbon monoxide, potential for large external flames or release of unburned hydrocarbon vapour.

Explosion hazard assessment

The models, data and assumptions used to estimate explosion overpressures should be described.

The explosion models should be fit for purpose and used correctly.

Users of explosion models should be aware of the limits of applicability and validation of the models and any use outside these limits should be justified.

Justification should be provided for the use of any models which pre-date the current version of the model and for the on-going validity of results generated by previous versions of the model.

Advanced models (eg CFD) should only be used by suitably competent persons and the results should be subject to appropriate checks by another competent person.

The uncertainties associated with explosion modelling should be recognised and the sensitivity of the conclusions of the QRA to these uncertainties should be considered.

Appropriate consideration should be given to the range of types of explosion which could occur on offshore installations, ie

• explosions in unconfined or semi-confined, congested areas (eg on the deck of an FPSO);
• explosions in confined areas (eg within a room or module);
• explosions within equipment or structures (eg an explosion within a flare header);
• external explosions (eg following a confined, vented explosion);
• physical explosions (eg catastrophic failure of a pressure vessel);
• mist explosions; and

• Boiling Liquid Expanding Vapour Explosions (BLEVE) for pressure vessels containing volatile hydrocarbons.

The explosion modelling should consider a suitable range of potential ignition locations/times having regard to the distribution of actual ignition sources within the affected area and the worst case ignition location/time.

The explosion modelling should include an accurate and sufficiently detailed representation of the geometry within the area of interest.

Clear justification should be provided for the assessing explosion hazards for one module or installation on the basis of its ‘similarity’ with another module or installation for which detailed results have been generated.

Consideration should be given to the effects of blast from possible external explosions, including any channelling effects which may act to enhance the blast overpressure.

7. Consequence assessment

The criteria used for harm to people and damage to equipment and structures due to fire should be appropriate and correctly used.

Harm Criteria are provided in the HSE Semi Permanent Circular SPC 30 “Indicative Human Vulnerability Criteria for use in Offshore Risk Assessment” and its associated annex. OGP has also published similar guidelines. Fire exposure on equipment, structures (excluding fire wall performance standards & PFP) is provided in the relevant ISO and international standards and is outside the scope of ED 3.2

In the fire consequence assessment appropriate consideration should be given to:

• the effects of fire on people, equipment and structures.

• the various mechanisms by which fire can harm people, eg:
  • heat (eg thermal radiation, inhalation of hot gases);
  • obscuration of vision;
  • oxygen depletion; and
  • inhalation of toxic gases.
The criteria used for impairment of safety functions (e.g., TR, evacuation and escape routes) due to fire should be appropriate.

Appropriate consideration should be given to the various modes by which smoke from a fire may enter the TR.

This should consider both the TR as it is intended to function and various degraded states.

As well as the TR, consideration should be given to other key locations on the installation, e.g., evacuation and escape routes, outside muster points, control rooms etc.

The assessment should consider the harm which might arise from fire throughout the duration of the incident and the associated response of people on the installation, e.g., initial harm, and harm during mustering, evacuation and escape.

The TR assessment should also include an internal fire risk assessment

The effects of low temperature exposure including, but not limited to, hypothermia should also be addressed as appropriate.

**Explosion consequence assessment**

Adequate consideration should be given to the effects of explosions on people, equipment and structures.

Appropriate consideration should be given to the various mechanisms by which explosions can harm to people, e.g.:

- primary effects of overpressure (e.g., lung or ear damage);
- secondary effects of overpressure (e.g., collapsing structures);
- tertiary effects of overpressure (e.g., whole body translation);
- impact from missiles projected by the explosion; and
- heat.

The criteria used for harm to people (SPC 35) and damage to equipment and structures due to explosion should be appropriate and correctly used.

The criteria used for impairment of safety functions (e.g., TR, evacuation and escape routes) due to explosion should be appropriate.

The output of the explosion modelling should be suitable for the purpose of assessing the response of equipment and structures to blast, i.e.:

- overpressure (peak/average), duration, rise time and impulse;
- local values of the above variables at a point of interest; and
- information to be able to assess drag loadings, as appropriate.
The assessment should consider the harm which might arise from explosion throughout the duration of the incident and the associated response of people on the installation, eg initial harm, and harm during mustering, evacuation and escape.

Appropriate consideration should be given to the combined effects of fire and explosion.

**Toxic gas consequence assessment**

An assessment of the effects of exposure to toxic gases (eg hydrogen sulphide, carbon monoxide) should be performed where this constitutes a major accident hazard. Appropriate criteria for harm to people and impairment of safety functions should be used (SPC 30).

Escalation analysis: A systematic, structured approach to escalation analysis should be adopted to determine if and how an event can escalate to endanger personnel.

The escalation analysis should comprise:

- identification of the mechanisms by which an initial event could escalate to impinge on key systems or facilities (eg TR, evacuation and escape facilities);
- evaluation of the effects on installation safety systems and how this may affect subsequent escalation; and
- evaluation of the probability of each escalation path and the time-duration from the initial event.

Appropriate consideration should be given to the actions of key personnel in responding to an incident, taking into account the effects of smoke, heat and the scale of the incident.

**Relevant Good Practice**

- HSC/E publications
- SCR Guidance
- APOSC Principal 5
- PFEER ACoP Reg.5, Paras 41-59

**Other relevant good practice**

UKOOA Guidelines for Fire and Explosion Hazard Management, UKOOA (1995). The scope of these guidelines is described above.

Interim Guidance Notes for the Design and Protection of Topsides Structures against Fire and Explosion (SCI, 1992). The scope of these guidance notes is detailed in Section 6.5.2 below. In the context of QRA, they provide introductory information on fire and explosion hazards, detail the effects of fire and explosion on personnel and provide methods for the assessment of fire and explosion loads on structures and the associated response of such structures.
ISO/DIS 17776, Petroleum and natural gas industries – offshore production installations –
guidelines on tools and techniques for identification and assessment of hazardous events
(ISO, 1999). The scope of this standard is described above.

Other Standards and Guidance

The scope of this guide is outlined earlier. Sections 8-23 of the guide (supported by Annexes
IV - XVI) are the main sections concerning QRA. They cover frequency estimation,
consequence modelling, assessments for specific hazards (blowout, riser/pipeline leaks and
process leaks) and presentation of the risk results. Detailed in the guide are simple assessment
tools for different types of hydrocarbon event (dispersion, fire, explosion etc), impact criteria
(for personnel and structures) and data sources for assessment of event frequencies and
outcome probabilities.

Z-013 Risk and emergency preparedness assessment (Rev. 3, Oct. 2010). The purpose of this
standard is to establish requirements for the effective planning, execution and use of risk and
emergency preparedness analysis (EPA). The standard covers: establishment and use of risk
acceptance criteria; planning, execution and use of risk and EPA; specific requirements
relating to QRA; and risk and EPA throughout the installation lifecycle. Annexes to the
standard cover various topics, including accident cause and consequence analysis, databases
and computer software, cost-benefit analysis, scenario-based design and probabilistic
explosion simulation.

Health Safety and Environment Case Guidelines for Mobile Offshore Drilling Units Issue 3.6
1 January 2015. The scope of these Guidelines is outlined above.

8. Quantified Risk Assessment

Background
SCR requires that “all major accident risks have been evaluated, their likelihood and
consequences assessed, including any environmental, meteorological and seabed limitations
on safe operations, and that suitable measures, including the selection and deployment of
associated safety and environmental-critical elements have been, or will be, taken to control
those risks to ensure that the relevant statutory provisions will be complied with; and in the
case of a non-production installation, that all the major hazards have been identified for all
operations the installation is capable of performing”. PFEER specifically requires that a duty
holder perform (and record) an assessment of major accidents involving fire or explosion,
including ‘an evaluation of the likelihood and consequences of such events’ [Reg 5(2)(b)].
The UKOOA GFEHM, which contain further details on various aspects of the assessment of
fire and explosion hazardous events (Section 4 of the Guidelines).
The assessment of fire and explosion risks is the essential first step in the effective
management of such risks throughout the life-cycle of an installation. It informs the selection
of risk reduction measures and the establishment of appropriate performance standards for
those measures. The assessment is an on-going process to ensure that, as changes to an
installation occur, fire and explosion risks are maintained ALARP (ensure that the relevant
statutory provisions will be complied with - SCR 2015).
Minimum Standard

The approach adopted for the application of QRA to major accident hazard risk evaluation should be clear (APOS C Principle 5) and the QRA should be suitable to ensure that the relevant statutory provisions will be complied with SCR 2015 Reg 12).

Key Questions
The key questions which the assessor may wish to consider in determining whether the Safety Case complies with the minimum standard are as follows:

General

• Has the approach to the application of QRA been summarised? (APOS C Para 26)

• Is the chosen assessment technique appropriate to the assessment being made?

• Is the scope, quality and rigour of the QRA commensurate with the level of risk on the installation? (SCR Reg 35;OIS 3/2006)

Scope of QRA

• Has a representative selection of events been analysed, ie encompassing the range of foreseeable hazardous events?

• Does the QRA identify the factors which influence the way an event may occur and develop, and which will affect the ability of any of the measures put in place to deal with the hazard?

• Does the QRA identify the causes, characteristics, likelihood and consequences of fire and explosion hazards? (SCR 2015 PFEER Reg 5)

Detailed Guidance for Assessors

Selection of representative set of events

The events selected should be a representative and sufficient set for the purposes of risk assessment. The basis for selection of the representative set of events should be explained. This should include consideration of such factors as:

Initial release: Event: Outcome: and include sufficient details for each MAH scenario including:

  • cause of release

  • leak size (flow rate)

  • ignition characteristics (timing/location)

  • leak duration
• Subsequent hazard formation:
  - Immediate/delayed ignition
  - Pool formation
  - Gas cloud (flammable, toxic or noxious etc.)
  - Fire (pool, jet, flash fireball or BLEVE)
  - Explosion (deflagration/detonation)

• Wind direction and speed
• Composition of hydrocarbon
• Ventilation conditions
• Phase (gas/liquid/two-phase)
• Protective systems (e.g., deluge) operate or fail
• Leak location
• Installation POB
• Leak orientation
• Personnel distribution
• Process conditions
• ESD/blowdown operates or fails
• Installation operating regime

The selection of the representative set of events should have regard to the nature of releases which have occurred on North Sea installations (see Offshore Hydrocarbon Release Statistics, published annually on HSE web site), including any installation-specific data. The basis for selection of representative hole sizes or release rates should be explained and should be appropriate to the characteristics of the installation. Any criteria used for eliminating possible fire and explosion events from further consideration in the QRA should be justified.

Event frequency estimation

Hydrocarbon leak frequencies (or other base event data) used should be justified in the context of the installation-specific circumstances.

The methods used to derive event frequencies (e.g., parts count, fault tree analysis, event tree analysis, human error analysis) should be described and should be fit for purpose and used correctly.
Equipment failure rate data used should be appropriate to the type, standard/design, use and operating conditions of the equipment. The use of any generic failure rates or probabilities should be justified by reference to an analysis of the sensitivity of the conclusions of the QRA to such data.

Estimates of, or assumptions made about, the availability, reliability and response time of protective systems (including any human components thereof) should be realistic and adequately justified.

Estimates of, or assumptions made about, the probability of ignition and detection of a hydrocarbon release should be realistic and adequately justified.

Appropriate consideration should be given to common cause or common mode failures.

Regarding the use of exceedance curves for estimating the probability of exceedance of a given level of explosion overpressure:

- the basis for the derivation of such curves should be explained;
- the means of accounting for uncertainty in the exceedance curves should be explained;
- the derivation of the curves should be statistically sound.

9. Risk Evaluation and Reduction

This section concerns evaluation of the acceptability of risks, and identification and implementation of risk reduction measures. SCR (Reg 12) requires that a duty holder demonstrate that all hazards with the potential to cause a major accident have been identified and all major accident risks have been evaluated and measures have been, or will be, taken to control those risks to ensure that the relevant statutory provisions will be complied with. The basic requirement can be summarised as requiring the safety case to include sufficient particulars to demonstrate that risks have been evaluated and measures have been, or will be, taken to reduce the risks to persons affected by those hazards to the lowest level that is reasonably practicable”.

APOS C sets out various principles concerning risk evaluation and reduction and these are reproduced below as the minimum standard which should be achieved. This section also draws on Offshore Division’s ALARP guidance (OIS’s 2/2006 & 3/2006).

Minimum Standard

**Key Questions**

The key questions which the assessor may wish to consider in assessing whether the Safety Case complies with the minimum standard are as follows:

**Overall approach**
• Does the Safety Case summarise the duty holder’s approach to risk evaluation, including the methods and criteria used to demonstrate that risks from major accident hazards have been reduced to ALARP?

• Does the ALARP demonstration contain elements of the following process: -identification and consideration of a range of potential measures for further risk reduction; -systematic analysis of each of the identified measures and a view formed on the safety benefit associated with each of them; -evaluation of the reasonable practicability of the identified measures; -the implementation (or planned implementation) of the reasonably practicable measures; and -recording of the process?

Identification of risk reduction measures

• Does the duty holder keep risks and risk reduction measures under review to take account of changing circumstances, advances in technology, new knowledge and information?

• Does the Safety Case challenge the adequacy of existing measures and consider any additional identified practicable measures?

• Has a balanced and integrated approach to the choice of risk reduction measures been adopted (i.e., risk reduction measures not viewed in isolation from one another)?

Use of quantitative risk criteria

• Has the duty holder followed common practice in setting the maximum tolerable level of individual risk of fatality at 10-3 per year?

• For risks in the broadly acceptable region, is vigilance maintained to ensure that risks remain broadly acceptable?

• In the intermediate risk region, are risks known, controlled and ALARP?

• For risks close to, or above, the tolerable level, has due account been taken of the potentially large benefits to be gained by taking additional risk reduction measures?

Consideration of relevant good practice

• Does the duty holder have in place suitable controls to address all significant hazards and do these controls, as a minimum, implement authoritative good practice (or achieve similar standards of prevention/protection), irrespective of the specific risk estimates?
• Where relevant good practice is not clearly established (or may not adequately safeguard against the risks under consideration) has the significance of the risks been systematically assessed to determine what actions need to be taken?

• In considering what measures are to be introduced, has account been taken of foreseeable harsh conditions, unusual operating schedules and novel designs of wells or equipment?

Consideration of uncertainty

• Have conclusions reached solely on the basis of the QRA results taken into account the uncertainties associated with these results?

• Have QRA arguments to justify not implementing identified risk reduction measures taken due account of engineering judgement and relevant good practice?

Implementation of risk reduction measures

• Are remedial work programmes risk-based?

• What consideration has been given to the implementation of temporary measures (e.g. additional management controls or restrictions on operations) to reduce risk until remedial measures are in place?

Consideration of people exposed to exceptional risks

• Has attention been paid to any critical groups of people who may be exposed to risks higher than the average for the installation as a whole?

• Has attention been paid to risks which appear low solely by virtue of low occupancy of the affected areas (e.g. a normally unattended installation)?

Detailed Guidance for Assessors

Overall approach

To assist in the ALARP decision-making process, duty holders may refer to useful guidelines developed by OGUK. These guidelines provide a framework for risk-related decision support to assist duty holders in striking the right balance between codes and standards, good practice, risk-based analysis, company values and societal values. A summary of the guidelines is provided below.

Duty holders for Mobile Offshore Drilling Units (MODUs) may also refer to the International Association of Drilling Contractors (IADC) North West European HSE Case Guidelines for MODUs (IADC, 2002). The guidelines set out the process for demonstrating that risks are ALARP and information that should be included in a Safety Case. A summary of the IADC HSE Case Guidelines is provided later in this document.
10. Risk Management

Identification of risk reduction measures
In identifying candidate risk reduction measures, consideration should be given to a range of measures involving inherently safer design, prevention, detection, control and mitigation. The risk reduction measures considered may range from items of equipment and physical systems through to operational procedures, managerial structures and planning examples of previous risk reduction measures which have been implemented on installations include:

<table>
<thead>
<tr>
<th>Type of measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention (reduction of likelihood)</td>
<td>* Removal or strengthening of small bore pipework connections * Isolation of damaged wells at production header as well as Xmas tree and venting of flowlines back to sea * Decommissioning of redundant equipment * Improvements to systems of work * Implementation of competence management and assurance system * Improvements to PTW systems * Improvements in integrity assurance</td>
</tr>
<tr>
<td>Detection (transmission of information to control point)</td>
<td>* Gas detection * Installation of ultrasonic leak detectors * Installation of additional IR beam detectors * Installation of additional fire detectors</td>
</tr>
<tr>
<td>Control (reduction of scale, intensity and duration)</td>
<td>* Emergency shutdown (ESD) systems * Installation of high integrity check valve on gas re-injection header * Blowdown and flare systems * Installation of additional blowdown valves * Explosion control * Initiation of water deluge on detection of gas * Removal of redundant equipment</td>
</tr>
<tr>
<td>Mitigation (reduction from effects)</td>
<td>* Active fire protection * Replacement of deluge system piping * Passive fire protection * Uprising of fire walls * Blast protection * Uprising of blast walls * Temporary Refuge * Re-location of Main Control Room to TR * Re-definition of TR * Enhancement of muster facilities * Protection of external staircase * Provision of airlock doors * Provision of dedicated HVAC system for TR</td>
</tr>
<tr>
<td>Evacuation and escape</td>
<td>* Installation of additional emergency lighting on escape route * Provision and maintenance of proper training in the use of evacuation and escape facilities * Provision of alternative escape routes * Fire-fighting equipment * Installation of new fire monitors * Warning * Reduction of POB</td>
</tr>
</tbody>
</table>

Demonstration that risks are ALARP

*For risks lying below the maximum tolerable, but above the broadly acceptable level, it is expected that:*
• the nature and level of risks are properly assessed and the results used properly to determine control measures;

• the residual risks are not unduly high and kept ALARP; and

• the risks are periodically reviewed to ensure that they still meet the ALARP criteria.

Duty holders should not assume that if risks are below the maximum tolerable level, they are also ALARP. This should be demonstrated through:

• application of relevant good practice and sound engineering judgement; and

• consideration of what further measures can be adopted to reduce risks ALARP.

In essence, the duty holder’s ALARP demonstration should address the question “What more could I do to reduce risks, and why haven’t I done it?”

The degree of rigour of the ALARP demonstration should be proportionate to the level of risk associated with the installation.

In choosing between design options, duty holders should:

• consider risks throughout the whole life-cycle of the project;

• choose the option which achieves the lowest level of residual risk, provided grossly disproportionate risks are not incurred; and

• confirm that the residual level of risk is no greater than that achieved by the best of existing practice for comparable functions.

Consideration of group risk

Duty holders may find it helpful to consider group risk in their demonstration that risks are ALARP. This allows consideration to be given to events which, although low in frequency, may cause multiple injuries or fatalities.

Group risk can be presented in the form of either potential loss of life (PLL), i.e. the number of statistical fatalities per year, or a plot of cumulative frequency versus number of fatalities (FN curve). If individual risk has been calculated, the PLL may be estimated from:

\[ PLL = \text{Average IRPA} \times \text{POB} / (\text{fraction of time an individual spends offshore}) \]

An advantage of the above approach is that consideration can be given to risk aversion, i.e. the aversion society has to large consequence accidents.

Duty holders should justify any criteria they adopt for group risk.

Cost-benefit analysis
Duty holders may find it helpful to apply cost-benefit analysis (CBA) in deciding whether a risk reduction measure is reasonably practicable. CBA is a numerical assessment of the cost of implementing a design change or modification and the likely reduction in fatalities that this would be expected to give. CBA should be applied cautiously in support of (not as a replacement for) sound engineering judgement.

Duty holders should justify any figures they use for the ‘value of preventing a fatality’ (VPF). A suitable factor for ‘gross disproportion’ should be included taking into account the overall level of risk associated with the installation, the potential for multiple fatalities and uncertainty in the analysis.

Duty holders should make an appropriate assessment of the ‘sacrifice’ (ie money, time and trouble) of implementing a particular risk reduction measure. This should take full advantage of the opportunity to reduce shutdown costs (ie by implementing the risk reduction measure during planned shutdown) and exclude consideration of the ability to pay.

### Consideration of uncertainty

Uncertainties in the QRA should be recognised and addressed. There should be a bias towards health and safety if the conclusions drawn from the QRA are to be credible. Where the uncertainties are large, a suitably cautionary approach should be taken, eg by adopting inherently safer designs.

In considering uncertainty, duty holders may refer to guidelines developed by UKOOA. These guidelines seek to promote awareness of the sources of uncertainty in QRA, the means of addressing these uncertainties, and the key benefits and limitations of undertaking an analysis of uncertainty. A summary of the UKOOA guidelines on uncertainty is given below.

### Relevant Good Practice

- HSC/E publications
- SCR Guidance
- APOSC

### Other relevant good practice

Guidance on Risk related Decision Making (UKOOA, 2014). This guidance is designed to facilitate risk related decision making by providing a common understanding of the bases upon which risk related decisions are made. It provides a structured framework that enables business, technical and societal factors to be considered and used to establish a transparent and justifiable basis for decision making.


In addition this document also includes relevant information from the now withdrawn HS005 – Guidelines for Quantitative Risk Assessment Uncertainty - Issue 1 (March 2000).

CMPT Guide to Quantitative Risk Assessment for Offshore Installations (CMPT, 1999). The scope of this guide is outline earlier. Sections 24-26 of this guide cover uncertainties in QRA, risk criteria and risk reduction measures. In Section 24, the guide lists sources of uncertainty, the means by which these can be quantified and the uses of sensitivity analysis. In Section 25, approaches to risk evaluation are described and criteria for individual and group risk are listed. Cost-benefit analysis techniques are also documented. In Section 26 the approach to the
identification and evaluation of risk reduction measures is described and various risk reduction alternatives listed under the categories of concept selection, fire and blast protection, evacuation and collision.

IADC North West European HSE Case Guidelines for MODUs (IADC, 2002). The scope of these guidelines is outlined in Section 3.6 above. Section 4.2.6 of these guidelines (Risk Reduction and ALARP Justification) sets out the process of demonstrating that risks are ALARP and the information which should be included in the Safety Case. This accords with 5-7

the principles contained in APOSC in requiring a systematic identification and assessment of risk reduction measures, including consideration of relevant good practice and application of sound engineering judgement. Specific guidance is provided on ‘tolerability’ and ‘ALARP’ and the distinction between these concepts.

UKOOA Guidelines on Quantitative Risk Assessment Uncertainty (UKOOA, 1999b). In these guidelines, uncertainty in QRA is categorised into three types:

- Type 1: parameter uncertainties;
- Type 2: model uncertainties; and
- Type 3: issues of overall adequacy/quality.

The guidelines note that (as of 1999) only limited analysis of uncertainty had been carried out in QRA studies of offshore installations, mostly of Type 1 uncertainties. The approach suggested in the guidelines is to undertake a conservative assessment of risk together with a limited sensitivity analysis of key parameters. This will provide an initial appraisal of the robustness of the QRA results.

If this approach is unsuccessful, then a more rigorous assessment of uncertainty may be required for which the guidelines describe various approaches.

The guidelines note that uncertainty analysis itself is subject to uncertainties and therefore that a balance must be struck between the efforts to ensure a suitable and sufficient QRA, any uncertainty analysis on the QRA and the overall requirements of the decision-making process.

This Guidance has been recently updated (2013) to enable better use of the principles and is referenced later. However, not all safety cases will have been updated to reflect the new guidance so it remains here for information.

**11. Hierarchy of Risk control**

This section concerns the information provided in the safety case on the measures which have been taken to eliminate, prevent, detect, control and mitigate fire and explosion hazards.

Schedule 2 of SCR require inclusion in the Safety Case of:

Particulars of the plant and arrangements for compliance with the PFEER Regulations including—

- (a) the detection of the presence of toxic or flammable gas
- (b) the detection, prevention and mitigation of fires

A description of the arrangements made or to be made for protecting persons on the installation from hazards of explosion, fire, heat smoke, toxic gas and fumes during any period while they may need to remain on the installation following an incident which is beyond immediate control …’
Schedules 1-6 of SCR also require a demonstration that the above measures will reduce risks ALARP. PFEER requires the selection of appropriate measures as part of the assessment of major accidents involving fire or explosion (Reg 5). It also specifically requires a duty holder to take measures to prevent, detect, control and mitigate fire and explosion (Reg 9, 10, 12 and 13).

APOS contains various principles on the topic of risk management and these are produced below as the minimum standard which should be achieved. Also covered here is the requirement of SCR to include a summary of the PFEER assessment in the Safety Case.

**Minimum Standard**

*Measures taken to manage major accident hazards should be described (APOS C)*

The Safety Case should explain the approach to the application of the principle of inherently safer design to new field or installation design, or to plant on an existing installation undergoing modification (APOS C).

The strategy for the prevention of major accident hazards should be explained (APOS C).

Appropriate detection measures should be provided for any reasonably foreseeable event which would require an emergency response (APOS C).

Appropriate control and mitigation measures should be in place for the protection of everyone from the consequences of a major accident (APOS C).

The PFEER Summary should include sufficient information on the results of the assessment to show that there are appropriate measures and adequate arrangements to secure effective emergency response (APOS C).

**Key Questions**

The key questions which the assessor may wish to consider in determining whether the Safety Case complies with the minimum standard are as follows:

**Description of measures to manage major accident hazards**

- Has a hierarchical approach to managing major accident hazards been taken, including: -elimination and minimisation of hazards by design (inherently safer design); -prevention (reduction of likelihood); -detection (transmission of information to control point); -control (limitation of scale, intensity and duration); and -mitigation of consequences (protection from effects)?

- Has the highest priority been given to inherently safer design and measures to prevent and control major accident hazards?

- In the design process:
  - is due consideration given to inherent safety?
  - are fire and explosion risks addressed?
-are such risks reduced ALARP through sound engineering design (primarily) and management controls?

• For existing installations, does the Safety Case address the scope for improving inherent safety and the measures to prevent and control major hazards? (See earlier 5.4.2 for examples of prevention and control measures which have been implemented on existing installations)

Inherent safety

• Has the hazard management strategy been developed at a suitably early stage in the design process, in order to maximise the opportunity to incorporate inherent safety?

• Have fire and explosion hazards been designed-out, where practicable?

Preventive measures (PFEER) - the measures in place to prevent:

• the uncontrolled release of a flammable substance;
• the hazardous accumulation of the release; and
• ignition of the release,

• Are the preventive measures adopted appropriate to the current stage of the installation’s life cycle?

• Are the arrangements for managing the hazards associated with simultaneous operations described?

• Are appropriate measures in place to prevent the uncontrolled release of a flammable substance;
• prevent the hazardous accumulation of the release; and
• prevent ignition of the release?

• Are the preventive measures derived from the identification and assessment of major accident hazards?

• Do the preventive measures achieve sufficient levels of reliability and availability to meet the demands placed upon them?

• Are adequate procedures and equipment in place for control of:
• hot work;
• use of non-Ex rated electrical equipment;
• maintenance activities;
• modifications;
• start-up and shutdown of plant and equipment; and
• storage, handling and use of flammable substances?

Detection measures
Detection measures are the measures in place to identify hazardous conditions on the installation and transmit this information to the point at which control action is instigated.

- **Is detection provided for reasonably foreseeable events requiring emergency response, including:**
  - potentially hazardous accumulations of flammables, uncontrolled hydrocarbon releases, hydrocarbon fires and fires from other sources; and
  - smoke, toxic gas or fumes entering the TR and accommodation area?
- **Are the detection measures derived from the identification and assessment of major accident hazards?**
- **Do the detection measures achieve sufficient levels of reliability and availability to meet the demands placed upon them?**
- **Is the detection equipment appropriately located, taking account of the type of incident, how it may develop and the capacity of the equipment to respond and to relay the right information for effective control action to take place?**
- **Are the detection measures automatic, where reasonably practicable? If not, are adequate alternative arrangements in place?**
- **Do the detection measures ensure the timely detection of flammable and explosive atmospheres, and toxic gas where appropriate, at locations where their presence presents a risk to people, eg accommodation and work areas; control points; enclosed or partially enclosed escape routes; and evacuation and escape points?**
- **Has the duty holder established effective contingency arrangements for circumstances when all or part of the detection system is unavailable? Do the detection systems remain operational in an emergency to the extent necessary?**
- **Does the selection of the detection systems take into account the conditions and characteristics of the hazardous event and the environmental and operating conditions in the area?**
- **Do the detection systems have adequate coverage, response time and sensitivity?**

**Control measures**

Control measures are the measures in place to limit the scale, intensity and duration of hazardous events on the installation, eg emergency shutdown systems, blowdown and flare systems, bunding and drainage, and explosion control systems.
• Are the control measures derived from the identification and assessment of major hazards?

• Is control equipment of fail-safe design, as far as is reasonably practicable?

• Is plant used to limit the spread of fire, where appropriate, operable from a remote location?

• Are suitably-staffed control points provided which can be used safely, so far as is reasonably practicable, for the period necessary to control the emergency?

• For normally unattended installations have appropriate emergency control arrangements been made?

• Do the control measures provide for the timely and effective shutdown of systems which could exacerbate the emergency? Can emergency shutdown be initiated from the control point?

Mitigation measures

Mitigation measures are the measures in place to protect people from the effects of hazardous events on the installation, eg passive and active fire protection, blast protection, fixed and portable fire-fighting equipment.

• Are the mitigation measures derived from the identification and assessment of major accident hazards?

• Are the measures appropriate for the hazards and do they: -include provision of appropriate fire-fighting media and portable equipment; -provide for automatic systems, or manual operation where this can justified by assessment; and -provide adequate levels of protection for key locations (eg TR, escape routes) and emergency systems?

• Are fire and blast barriers capable of providing the insulation, stability, integrity and overpressure resistance identified as necessary for the period required to protect personnel, structures and plant? Have any conflicts between the provision of fire and blast protection been identified and an appropriate balance been achieved?

• Do active systems deliver the required quantities of fire-fighting media within the required time and to the required locations?

• In determining what portable equipment is provided, has the duty holder taken into account: -the numbers and location of personnel on the installation; -the practicality and effectiveness of its use; and -the hazards and availability of other systems?

• Has the duty holder considered suitable contingency arrangements, eg -operational arrangements -diversity and redundancy in protective systems to ensure that mitigation measures remain effective in an emergency?
PFEER Summary

- Does the summary of the PFEER (Reg 5) assessment include sufficient information on the results of the assessment, in particular covering: -the events and risks; - the measures which have been selected; and - the establishment of performance standards, to show that the arrangements are adequate to ensure that risks from major accident hazards are ALARP?

Detailed Guidance for Assessors

The following sections provide more detailed guidance on the elimination, prevention, control and mitigation systems relevant to the OSD 3.2 fire, explosion and risk assessment team.

Inherent safety

The following principles should be adopted, where possible:

- substitution: use of less hazardous materials
- simplification: use of simpler process systems
- intensification: reduction of inventory of hazardous materials
- attenuation: reduction of temperature and/or pressure of hazardous materials, or use of inert diluents

Examples of the application of inherently safer design principles to offshore installations are as follows:

- concept selection: -multiple (vs single) jackets -subsea (vs topsides) development
- operating philosophy:
  - unattended (vs manned) installations
  - pre-drilling of wells
  - avoidance of simultaneous hazardous operations
- process design: - minimisation of HP/LP interfaces - use of non-flammable or low flammability materials - simplification of processing
- plant design and layout:
  - segregation of hazardous inventories (eg risers, separators etc)
  - reduction of congestion and confinement
  - enhancement of natural ventilation
  - reduction of particular hazards (eg dropped loads)
  - selection of suitable materials of construction (eg corrosion resistant)
  - use of non-intrusive instrumentation
  - design to minimise, or facilitate easier, inspection and maintenance
  - minimisation of piping joints
Preventive measures

Ventilation

The provision of natural ventilation, and the design, construction, installation, operation and maintenance of mechanical ventilation systems on offshore installations should be in accordance with relevant good practice.

Consideration should be given to:
- locating hazardous plant in the open air
- minimising congestion and ‘dead’ areas around likely leak sources
- optimising natural and mechanical ventilation
- reducing the distance from potential leak sources to the open air
- controlling the size of process areas

The adequacy of natural ventilation of complex installations, and mechanical ventilation of large, complex spaces, should be confirmed by CFD modelling or wind tunnel testing, supported by measurements.

Consideration should be given to the provision of ventilation, over and above that required by relevant good practice, as a risk reduction measure.

Measurements of the adequacy of ventilation should ensure that any potential for ‘short-circuiting’ of the flow is identified.

Ignition control

The number of potential ignition sources should be minimised as far as reasonably practicable.

- Areas where leaks of flammable substances could occur should be identified and equipment within these areas should be designed to reduce the likelihood of ignition of such substances.
- Hazardous areas on an installation should be classified in accordance with relevant good practice.
- Consideration should be given to the need to isolate non-essential electrical equipment in the event of a major gas emergency.
- Procedures should be in place to control the use of temporary equipment, which may present an ignition source.
- Direct-fired equipment should be located (or suitably protected) so as to avoid providing an ignition source for flammable releases.
- Permit-to-work (PTW) and isolation procedures should follow relevant good practice.
- Gaseous inerting systems
• The design, construction, installation, operation and maintenance of gaseous inerting systems should be in accordance with relevant good practice (see Section 6.5).

• In selecting gaseous inerting systems, consideration should be given to their effectiveness for prevention of fire and explosion and any potential adverse impacts on health and safety, e.g.
  • noise;
  • turbulence/high velocity;
  • oxygen depletion;
  • low temperature; and
  • hazardous decomposition products. and appropriate measures taken.

Detection measures

General

• Fire and gas systems should be designed, constructed, installed, operated and maintained in accordance with relevant good practice.

• The fire and gas system should have facilities to allow testing of field devices, internal functions and executive outputs.

• Fire and gas detectors should be subject to regular testing and maintenance.

• The information required from the fire and gas system at control points should be considered at the design stage.

• The rationale for selection of the type, location and alarm/action settings of fire and gas detectors should be explained.

• The fire and gas system should be of fail-safe design.

Gas detection

• The provision of gas detection for non-hazardous areas (e.g. in HVAC intakes) should ensure that there is sufficient time available following detection to complete the necessary shutdown actions.

• The calibration of gas detectors should be based on the relevant range of hydrocarbons.

• Information on the level or quantity of gas present should be available at a control station.

• Provision for the detection of toxic gas (if required) should be integrated into the fire and gas system.

• Consideration should be given to provision of a suitable combination of detectors, e.g. acoustic detectors for early leak detection and infra-red detectors (point/beam) for detection of gas accumulation.
• Real time ventilation surveys should be used to confirm the adequacy of the operation and sensitivity of the gas detection system

• Appropriate consideration should be given to the capability of the gas detection system to detect, and respond effectively, to:
  • small leaks;
  • large, rapidly accumulating leaks; and
  • heavier-than-air, slumping releases.

Fire detection

An appropriate range of devices to detect fire should be provided, eg

• point heat detectors;
• optical flame detectors;
• smoke detectors;
• fusible plugs;
• frangible bulbs; and
• CCTV.

Where flame detectors are voted they should be arranged to meet the requirements of PFEER to provide early detection of incidents, incorrectly voted fire detection without supplementary means of detection and alarm activation/automated emergency action, delayed emergency action may result in MAH escalation.

Flammable liquid release

An appropriate range of devices to detect liquid releases should be provided, eg

• low level alarms for process vessels;
• high level alarms for open drains; • oil mist detection; and
• seal leakage alarms.

Control measures

Bunding and drainage

Bunding and drainage should be provided in all areas which have a source of liquid hydrocarbons so as to minimise the fire risk.

• Hazardous and non-hazardous drains should be physically separate.
• **Hazardous closed drains should be separate from open drainage systems**

• The design of the drainage system should limit the maximum spread of a spill and attempt to minimise any escalation arising from the spill.

• The extent of bunding should take account of any liquid trajectory from the point of release

• Drains should be capable of collecting and disposing of all or most of the hydrocarbon release and the applied fire water.

**Explosion control: installation layout**

• The layout of equipment should follow relevant good practice and not impede escape or evacuation routes.

• The layout and location of equipment and pipework should be such as to minimise congestion and confinement, and limit module volumes.

• Specific measures which would limit the achievable blast overpressure are as follows:
  • orientation of vessels parallel to the direction of venting;
  • avoidance of long, narrow modules; and
  • minimisation of obstructions across openings in the module boundary

**Explosion control: venting**

• The design, construction, installation and maintenance of explosion vents should follow relevant good practice.

• The performance of blast relief and ventilation panels should be verified by suitable type testing.

• Particular hazards which should be taken account of in the provision of explosion venting systems are:
  • the risk to personnel from the vent discharge;
  • the potential for obstruction of the vent; and
  • the effects of ignition of the unburnt vent discharge gases.

• The uncertainty as to the precise reduction of blast overpressure achieved by venting should be recognised.

**Explosion control: activation of water deluge**

The activation of water deluge on detection of gas can provide an effective means of reducing the overpressure which would be generated by subsequent ignition of the gas. Deluge will substantially increase low pressure explosions for example an initial overpressure of 0.15barg without deluge can be increased to 0.3 bar with deluge which can have a significant effect on
weak structural support. In adopting this strategy the following should factors be taken into account:

- the dependence of any risk reduction on the effectiveness of gas detection, early detection of gas and rapid activation of the deluge system (seconds);
- the creation of turbulence, hence an increased rate and magnitude of pressure rise (initially and for low pressure explosions (<0.3bar));
- the low benefit of deluge activation in confined situations (low flame speeds);
- the potential for displacement of gas to a more hazardous location;
- the increased probability of ignition (eg due to water entering electrical equipment);
- the capability of the deluge system to provide explosion mitigation in addition to its primary function, ie fire protection; and
- the potential for enhanced corrosion of equipment.

**Mitigation measures** - Active fire protection (AFP).

- Systems should be designed, constructed, installed, operated and maintained in accordance with relevant good practice.
  AFP systems should be suitably located and protected from the effects of fire and explosion.
  - It should be recognised that directed deluge systems designed in accordance with current good practice cannot be relied upon to protect vessels against jet fire attack.
  - The final selection of the type of AFP and quantities/rates of application should be based on fire analysis and evaluations of fire-fighting systems.
  - AFP systems and equipment should be suitable for the intended duty and environment.
  - The ability of the AFP system to perform its intended function should take account of the response time of the system.
  - For automatic AFP systems manual release stations should be provided at suitable locations.
  - In providing AFP systems, the hazard of extinguishment of fires (leading to gas/vapour accumulation and the associated explosion hazard) should be recognised.

**Mitigation measures** - Passive fire protection (PFP)

- PFP of essential systems and equipment (or enclosures containing such systems and equipment) should be provided where failure in a fire is intolerable.
• PFP should be installed correctly by competent installers under proper supervision and the correct environmental conditions as specified by the manufacturer.
Installation records should be recorded in detail and stored for future reference.

• Where PFP is required to provide protection following an explosion, it should be designed and installed such that deformation of the substrate caused by an explosion will not affect its performance.

• Selection of the PFP systems should take into account the duration of protection required, the type of fire which may be experienced and the limiting temperature for the structure or equipment to be protected.

• PFP should be subject to regular inspection and maintenance against defined performance standards.

Mitigation measures - Blast protection

• The detailed design of blast protection is outside the remit of this guidance. However, the specification of explosion loads for the design of blast protection should be in an appropriate format (see GASCET).

• A decision to use a design overpressure less than the predicted maximum should be based on an evaluation of the residual risk to persons on the installations.

• Blast exceedence methodology may be used to specify design loads. In such cases the rigour of the analysis should be sufficiently robust to demonstrate a degree of caution rather than optimism has been applied. It is essential that such an approach is subjected to regular review as assessment methodologies and the hydrocarbon risk profile of an installation changes.

• Where exceedence methodology has been applied a strong challenge is required for non-implemention of risk reduction measures that would suggest a higher design overpressure value could be selected without significant dis-benefit. In such cases justification is typically provided by CBA but the value of absolute cost against the increased level of protection must also be given due consideration particularly during the design phase of an installation or project.

Mitigation measures - Fire-fighting equipment

Portable fire-fighting equipment should be provided in accordance with relevant good practice. The extinguishing media of portable fire-fighting equipment should be appropriate to the anticipated type of fire.

Accommodation/TR fires

A Duty holder should take appropriate measures to adequately define the case for safety for not applying established standards, industry good practice or associated guidance. Established practice on the UKCS has previously been to fit sprinklers to accommodation for permanently manned installations. Where such measures are not applied it is necessary for a duty holder to
provide sufficient detail on how they are providing an alternative and at least equivalent level of safety for persons on board for fire prevention, detection and mitigation systems they require.

This must demonstrated by an appropriate Fire Risk Assessment (FRA).

In this case the demand rate, and response for mitigating the fire, by sprinklers has been reduced to such values that escape and alternative first aid fire-fighting (as appropriate) is deemed equivalent and appropriate measures for these has been taken.

• Fire teams must also be adequately trained to fight fires in such circumstances should such mitigatory response measures be included in the justification.

• Fire fighting equipment and fire fighting strategy, utilising the fire team increases risk to members even if adequately trained it is one thing to go in under the protection of a sprinkler system.

• Search under fire conditions in a building is completely different as each door opened is a potential fatality/serious injury risk for the team.

• Adequate training and practice should also be implemented for all occupants and fire team.

• The FRA should identify and quantify the measures taken to achieve this and establish the means for ensuring they remain effective for the life of the installation.

• This includes the operational requirements of the detection systems particularly where detectors are voted. For example if a single detector requires to be taken out of service in a fire zone (or compartment) where 2oo2 voting exists for alarm, the out of service detector must be “voted” to ensure safety is not degraded.

• Care must be taken to ensure unrevealed failure modes are absent in such systems unless the voting logic and number of detectors in a compartment is designed and operated to address this (i.e. 2oo3 voting)

• As the new accommodation is occupied all materials brought in to it must meet the standards set for combustibility, flame spread, toxic fume generation on fire exposure and ignition source control.

• Firstly the required survivability of the accommodation should be defined and justified with an impairment study SPC 30 provides survivability criteria for occupants. This is not expected to be equivalent in duration of the TR where the accommodation does not function as a TR but must be adequate to provide compliance with the EER requirements of PFEER.

• Prevention includes adequate identification, specification, inspection and maintenance of ALL relevant SCE’s including but not limited to:
  • Construction for flame, fume, smoke & noxious gas spread,
  • fire segregation /compartmentalisation and
There have been some problems with misquoting standards by others to duty holders so definitions need to be clear.

Appropriate certification needs to be referenced and available and control measures to ensure:

- Adequate control of materials used in construct and expected to be used or stored in the accommodation for combustibility, flame spread and products of heat exposure (toxic flame).
- Adequate control of ignition for fixed, permanent and transient sources.
- As combustibles cannot be avoided (?) adequate storage, storage control and fire/smoke/fume detection requirements need to be addressed
- Identification of potential for degradation of the above standards and the means to maintain them for example lint build up in HVAC systems particularly laundry or galley.
- In addition fire as a MAH precursor to the rest of the installation it must also be evaluated particularly as part of the TR impairment study
- Finally there must be a fire strategy that will be different in the absence of sprinklers (BS 13702).

This should all be included in the safety case under Reg 12 the SCE’s and associated details of performance, test, inspection and maintenance should also meet the regulatory requirements of Reg 19 onwards and be reflected in PFEER.

**Relevant Good Practice**

The FIRA international document “fire safety of furniture and furnishings in the contract and non-domestic sectors – A Guide to the UK requirements” gives good guidance on how to develop (and by whom) an adequate fire risk assessment

**Other relevant good practice**

IMO Code for the Construction and Equipment of Mobile Offshore Drilling Units (IMO, 2001). The purpose of the MODU code is to recommend design criteria, construction standards and other measures for MODUs in order to minimise the risks to such units, to the personnel on board and to the environment. The MODU code was first adopted in 1989 and subsequently updated in 1991 and 1994. Chapter 9 covers fire safety. Interim Guidance Notes for the Design and Protection of Topsides Structures against Explosion and Fire (SCI, 1992). The Interim Guidance Notes (IGN’s) were issued in January
1992 and have been supplemented by a series of Technical Notes (TN), of which those relevant here are:

TN1: Fire resistance design of offshore topside structures, 1993

The IGNs provide a reference framework for the design and protection of topsides structures against fire and explosion. They set out the broad design and assessment philosophy, provide detailed design guidance for fire and explosion resistance, then recommend an integrated strategy.

The detailed design guidance covers:
- fire and explosion scenarios;
- the prediction of fire and blast loads;
- information on explosion mitigation systems, and passive and active fire protection; and
- approaches for determining the response of plant and structures to fire, blast and missiles.

The IGNs are periodically updated, under sponsorship from relevant stake holders such as UKOOA and HSE. The objective is to develop guidance for designers and duty holders to use during the design of, and in making operational modifications to, offshore installations. The guidance is intended to achieve international acceptance and foster the creation of a consensus of views between regulators and industry.

ISO 13702, Control and mitigation of fires and explosions on offshore production platforms – requirements and guidelines (ISO, 1998). This standard is presented a series of objectives, functional requirements and guidelines, defined as follows:

- Objectives: the goals to be achieved by the control and mitigation measures
- Functional requirements: the minimum criteria which shall be satisfied to meet the stated objectives
- Guidelines: recognised practices which should be considered to determine that the necessary measures are implemented

The standard covers installation layout, control of ignition, control of spills, emergency power systems, fire and gas systems, active and passive fire protection, explosion mitigation and protection, evacuation, escape and rescue and inspection, testing and maintenance.

ISO 15138, Heating, ventilation and air-conditioning (ISO, 2000). ISO 15138 provides guidance for design, testing and commissioning of HVAC and pressurised systems and equipment on offshore production installations. It includes ventilation of production areas and states that natural ventilation is preferred over mechanical (or artificial) ventilation where practical.

UKOOA Guidelines for Fire and Explosion Hazard Management, UKOOA (1995). The Guidelines cover issues such as inherent safety and prevention as well as the selection, specification of systems for fire and explosion detection, control and mitigation and the various options available for detection, control and mitigation.

Other Standards and Guidance
ANSI/API RP 500 -1998, Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities of Class 1 Division 1 or Division 2 (API, 1998).

API RP 500 is the primary US standard for area classification and also covers ventilation of hazardous areas. The standard defines adequate ventilation as ‘ventilation that is sufficient to prevent the accumulation of significant quantities of vapour-air or gas-air mixtures in concentrations above 25% of their lower flammable (explosive) limit’. API RP500 describes a number of possible strategies for achieving adequate ventilation.

API RP 2A. This standard was first published in 1997 and contains limited guidance for the design of fixed offshore installations for accidental loading, including fire and blast. At the time of preparation of this guidance API were in the process of developing a new standard Design and Assessment of Offshore Structures for Fire and Blast. It is anticipated that the new standard will contain (i) redefined ‘exposure categories’ for fire and blast, to distinguish higher and lower risk installations and (ii) detailed guidance for the protection of offshore structures against fire and blast loading, representing modern best practice which is applicable to all offshore installations. API’s motivation for development of the new standard includes the recent rise in deepwater developments utilising floating installations.

API RP 14G, Recommended Practice for Fire Prevention and Control on Open Type Offshore Production Platforms (API, 1993a). This document presents recommendations for minimising the likelihood of fire and for designing, inspecting and maintaining fire control systems. It is applicable to fixed, open-type offshore production installations. The standard covers fire prevention practices, fire detection and alarms, fire control, portable fire extinguishers, inspection, testing and maintenance, personnel safety and orientation, and passive fire protection.

API RP 14J, Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities (API, 1993b). This document assembles useful procedures and guidelines for planning, designing and arranging offshore production facilities, and performing hazard analysis on open-type production facilities. The standard covers containment and prevention measures, basic facilities design concepts, hazard mitigation and personnel evacuation, platform equipment arrangements and documentation requirements.

BS 5306, Fire Extinguishing Installations and Equipment on Premises (BSI, 1992). BS5306 gives guidance on the selection, installation and maintenance of automatic water sprinkler and spray systems. It also covers carbon dioxide, halon systems, foam and extinguishing powder systems. The standard gives guidance on installed equipment for fire service use and portable extinguishers. More detailed information is given in the specialised parts of this standard. It covers occupational safety, control equipment, halogenated hydrocarbons, dry powder and fire safety.

BS 5925:1991, Ventilation principles and designing for natural ventilation (BSI, 1991). BS5925 gives recommendations on the principles which should be observed when designing for natural ventilation of buildings. The standard is aimed at indoor situations and, whilst useful for background information, its applicability is limited for outdoor areas such as air movement within an ‘open’ module. It is however referenced by many of the other standards.
BS EN 60079-10 is the current standard which deals with the classification of hazardous areas where flammable gas or vapour risks may arise in order to assist selection and installation of apparatus for use in such hazardous areas. The area classification should be carried out by those who have knowledge of the properties of flammable materials, the process and the equipment.

The standard gives guidance on the procedure for classifying areas in which there may be an explosive atmosphere. Recommendations are given on how to depict the various zones on drawings. The standard provides information on:
- safety and area classification (principles and objectives);
- procedure for area classification, based on consideration of sources, zones types and extents;
- effect of ventilation (natural or artificial);
- documentation of the classification process (drawings, data sheets and tables).

IEC 61508 is the major international standard for safety related systems comprised of electrical and/or electronic and/or programmable electronic components. It is intended for use as a stand-alone standard and as a framework for preparation of application sector standards. The standard presents a lifecycle approach including risk assessment, design, integration, testing, modification and maintenance and safety management. It is based on the identification of safety function and all components required to achieve function (including humans) and their associated safety integrity. It adopts a risk based approach for the determination of the required safety integrity. It introduces the concept of safety integrity levels (SIL 1-4) which are associated with target failure rates and configurations of redundant and diverse channels of protection. It covers not only programmable electronics, but also electromechanical and solid state electronic systems.

The complete standard comprises 7 parts:
- Part 1: General requirements;
- Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems;
- Part 3: Software requirements;
- Part 4: Definitions and abbreviations;
- Part 5: Examples of methods for the determination of safety integrity levels;
- Part 6: Guidelines on the application of Parts 2 and 3; and
- Part 7: Overview of techniques and measures.

This handbook arises out of the Gas Explosion Engineering JIP (in part sponsored by HSE) and provides guidance for the design and strength assessment of topsides structures against the effects of accidental gas explosions. Emphasis is given to:
- structural safety and reliability;
- the use of risk analysis methods;
- the use of numerical methods to compute (i) gas explosion loads (with the help of CFD) and (ii) load effects (with the use of non-linear finite element methods); and
• the application of probabilistic methods in the quantification of uncertainties in gas explosion loads and load effects.

Chapter 2 covers the principles of inherent safe design of topside structures against gas explosion loads, and Chapter 4 covers gas explosion loads, including deterministic and probabilistic approaches.

IADC North West European Guidelines for MODUs (IADC, 2002).
The scope of these guidelines is outlined in Section 3.6 above. Section 3 of the guidelines contains advice on what should be included in the Safety case as regards the MODU, its systems and equipment, the activities likely to be carried out and the environmental conditions in which it can operate.

Chapter II-2 of SOLAS covers fire protection, fire detection and fire extinction. In 2002 this part of the Convention was completely revised. The new format focuses on the ‘fire scenario process’ rather than ship type. The regulations cover fire prevention, detection and suppression, following through to escape. Specific system-related technical requirements have been moved to the new International Fire Safety Systems Code (see below).

One of the features of the revision to SOLAS (see above) is the allowance for alternative (or novel) designs and arrangements as opposed to prescriptive fire safety requirements. The purpose of the FSS Code is to provide international standards for fire safety systems required by revised SOLAS Chapter II-2, under which it is made mandatory. The FSS code covers a range of fire prevention, fire-fighting and fire protection systems. It also covers fire and smoke detection, fire pumps and means of escape.


This publication is an update IP Model Code of Safe Practice for the classification of hazardous areas in the petroleum industry. It provides a methodology to comply with the area classification requirements under the new Dangerous Substances and Explosive Atmospheres Regulations, 2002 (DSEAR). The new Code: applies recent understanding in modelling two-phase releases; takes account of high-pressure releases and mist and spray formation; has been broadened to encompass petrochemical as well as petroleum installations; and specifically covers LPG. Subjects covered by the Code include: scope, applicability and definitions; guide to classifying hazardous areas; the technique of hazardous area classification using direct example and point source approaches; how to classify typical facilities such as storage tanks and road tanker loading; the classification of drilling rigs, onshore and offshore; basis and application of point source methodology; the effect of ventilation; the selection of electrical equipment; and ignition risks arising from non-electrical equipment. In IP15 adequate ventilation is referred to as ‘the achievement of uniform ventilate rate of at least 12 air changes per hour, with no stagnant area’.


Rev 4 of this standard is fully aligned with ISO 15138 but includes additional requirements and guidelines specific to the Norwegian petroleum industry. The scope of this standard is as per ISO 15138.

**NORSOK Standard N-003, Actions and Action Effects (NORSOK, 1999).**
This standard specifies general principles and guidelines for the determination of actions and action effects for the structural design and design verification of structures. It applies to all types of offshore structures. Section 8.2 of the standard covers fire and explosion loads, in particular how to quantify such loads and how they should be specified for the purpose of determining structural response. Combined fire and explosion loading is discussed.

**NORSOK Standard S-001, Technical Safety (NORSOK, 2000).**
This standard describes the principles and requirements for the development of the safety design for offshore production installations, fixed platforms, semi-submersibles and vessels. This standard, together with ISO 13702, defines the required standard for implementation of technologies and emergency preparedness to establish and maintain an adequate level of safety for personnel, environment and material assets.

**SI611 - Offshore installations: Guidance on fire fighting equipment, (HMSO, 1980).**
Although this SI611 has now been revoked, this document provides useful guidance on the provision of fire-fighting equipment on offshore installations. It covers fire and gas detection, fire alarms, remote control safety equipment, fire mains, hydrants/hoses/nozzles, water deluge systems/monitors, sprinkler systems, fixed extinguishing systems and portable/non-portable fire-fighting equipment.

**12. Emergency Arrangements**
The descriptive information required under OSD 2015 (Schedules 1-3) includes a description of the provision for

(a) temporary refuge;

(b) routes from locations where persons may be present to temporary refuge and for egress therefrom to points from where the installation may be evacuated;

(c) means of evacuation at those points; and

(d) facilities within temporary refuge for the monitoring and control of the incident and for organising evacuation.

PFEER also requires that the duty holder shall make appropriate provision for –

(a) areas for persons to muster safely;

(b) safe egress from accommodation and work areas, and safe access to muster areas, temporary refuge, and evacuation and escape points; and

(c) safe evacuation and escape points (Reg 14(1)).
This section concerns the aspects of the emergency arrangements relevant to the ED 3.2 fire, explosion and risk assessment team, namely the arrangements for temporary refuge (including access to it and evacuation from it) and the conditions under emergency control arrangements are required to be effective. These are covered by APOSC principles:

**Principle 18**
Appropriate detection measures should be provided for any reasonably foreseeable event requiring an emergency response

**Principle 19**
Appropriate control and mitigation measures should be provided to protect personnel from the consequences of a major accident

**Principle 20**
Arrangements for controlling an emergency should take account of likely conditions during emergency scenarios

**Principle 21**
The measures and arrangements for the management of an emergency should be identified

**Principle 22**
The Temporary Refuge (TR) should provide sufficient protection to enable people to muster safely, to permit the emergency to be assessed, and to allow the emergency response plan to be executed

**Principle 23**
Criteria should exist that describe the Temporary Refuge integrity (TRI) and the time over which TRI needs to be maintained against all hazards identified in the risk assessment. The safety case should demonstrate that these criteria are met i.e. that TRI would be maintained for the necessary time

**Principle 24**
Evacuation and escape arrangements should be integrated in a logical and systematic manner, taking account of the environment in which they may need to function

**Minimum Standards required:**

- Arrangements for controlling an emergency should take account of the anticipated conditions during possible emergency The arrangements for

- TR should provide sufficient protection to enable people to muster safely, to permit the emergency to be assessed, and to allow the appropriate parts of the emergency response plan to be executed

- There should be sufficient evidence to demonstrate that the frequency within which accidental events will result in a loss of TR integrity, within the minimum stated
endurance time, does not exceed the order of 1 in 1000 per year. This frequency should be reduced to a lower level wherever reasonably practicable.

- Where the frequency is close to 1 in 1000 per year, there should be convincing arguments that it is not reasonably practicable to reduce it further

- Performance standards and endurance times should be indicated for access routes and evacuation routes, embarkation points and totally enclosed motor propelled survival craft

**Key Questions**

**Effective Operation of Emergency Arrangements**

- Has appropriate account been taken of the ability of emergency control measures (e.g., ESD, blowdown and flare systems) to function:
  (a) in the presence of potentially flammable mixtures of hydrocarbons,
  (b) during or after a fire and
  (c) following the mechanical shock of an explosion

- Has account been taken of the extent to which an emergency system may be partially or totally ineffective, e.g., due to incident damage, latent defects or components which are out of service at the time at which a major accident occurs?

- Is it clear how emergency systems (e.g., ES D, HVAC systems) are intended to act in controlling emergency situations?

- Have the expected consequences of a shutdown delay or failure of the ventilation systems, and the contribution this would make to the escalation of a major accident scenario, been taken into account?

**Temporary Refuge**

- Is the TR a place where personnel can muster safely in the event of an emergency, monitor and assess the developing situation and take the necessary control action or initiate evacuation from the installation?

- Are there sufficient available safe access routes from all potentially occupied locations to a TR?

- Are appropriate performance standards for the TR in place which take account of, for example, the size and layout of the installation and the numbers and distribution of persons on board (POB). Has allowance been made for the hindering effects of injuries, darkness, smoke and damage to access and exit routes?

- Does the description of the TR include an explanation of how the system will withstand the effects of fire, explosion, smoke and toxic gas, including secondary
effects such as impacts. Will the TR deliver the required functions for as long as is necessary during major accidents?

- Does the assessment of the frequency of loss of TR integrity consider: -loss of structural support; -deterioration of life support functions at TR locations; and -loss of command communication functions?

- In estimating the endurance time for access routes, has account been taken of the time needed for people to travel from their work stations to a TR, possibly helping injured colleagues?

- As exit and evacuation routes may be required some time after the development of a major accident, are they protected accordingly?

- Are muster points usable, and access and egress routes passable, for the time required to safeguard personnel, based on the major accident scenarios which have been identified and assessed?

- Has priority been given to the protection of access and egress routes over providing personal protective equipment (which should be regarded as a last resort)?

**Detailed Guidance for Assessors**

**Escape routes**

Escape routes should, wherever practicable, be designed to remain passable by position rather than protection, ie external escape routes should be physically separated from explosion vent panels, sacrificial walls and open hazardous modules. Where this is not possible alternative routes should be provided which are unlikely to be affected in the same incident. The dimension of escape routes should be adequate for the number of people who may be required to use them and should have adequate vertical clearance.

**Temporary refuge**

- The TR should have sufficient capacity to protect the maximum POB of the installation.

- The TR should maintain the safety of personnel during the period required for completion of the evacuation process, taking into account the time to:
  - complete the full muster at the TR;
  - account for personnel not reporting to their assigned muster stations;
  - evaluate the situation and make decisions;
  - initiate responses to minimise the consequences and control the emergency (if possible);
  - complete the evacuation (if required); and
  - a contingency for unforeseen circumstances.

In assessing loss of TR integrity, the following should be taken into account (as appropriate):
• Loss of structure, eg -collapse of supporting structure -impairment of exterior fabric of an enclosed TR

• Loss of life support, eg due to:
  - ingress of smoke or gas
  - excessive heat stress
  - oxygen deficiency
  - toxic gas accumulation

• Loss of command communication, eg
  - loss of communications within TR, between multiple TRs or with third parties
    - loss of ESD
    - loss of F&G and monitoring
    - loss of emergency power/lighting

• Where it is not possible for a person to reach a TR under certain conditions, consideration should be given to alternative arrangements to allow safe evacuation of these people.

• Where a control station (not within the TR) is required to be occupied in an emergency it should be possible for the personnel at the control station to subsequently reach a TR if the situation makes it necessary.

Other relevant good practice

The scope of the IGN is described in Section 6.5.2 above. Section 2.3 and 2.4 of the IGN cover the basic requirements for temporary refuge, evacuation and escape.

Section 14 of ISO 13702 gives the objectives and functional requirements for evacuation, escape and rescue and Section B12 provides the corresponding guidelines.

IADC North West European HSE Case Guidelines for MODUs (IADC, 2002).
The scope of these guidelines is outlined in Section 3.6 above. Sections 4 and 5 of these guidelines detail the information which should be included in the Safety Case as regards temporary refuge, evacuation and escape. This covers the assessment of TR impairment frequency, demonstration of the adequacy of the design, construction and equipment of the TR, demonstration of the adequacy of TR integrity and demonstration of the suitability and sufficiency of evacuation and escape systems.


13. HSE publications
HSE (1997), Prevention of fire and explosion, and emergency response on offshore installations.


HSE, Assessment principles for offshore safety cases, Health and Safety Executive.

HSE A guide to the Offshore Installations (Safety Case) Regulations.

HSE ALARP Guidance
Energy Division - Offshore ALARP Guidance:

Guidance on ALARP for Offshore Division Inspectors - Making an ALARP demonstration, Semi-Permanent Circular 38, Health and Safety Executive (available on HSE web site).

ALARP Trilogy (available on HSE web site):

Assessing compliance with the law in individual cases and the use of good practice. Policy and Guidance on reducing risks as low as reasonably practicable in Design. Principles and guidelines to assist HSE in its judgements that duty-holders have reduced risks as low as reasonably practicable.


Energy Division - Offshore Fire and Explosion Strategy

Fire and Explosion Strategy, Offshore Division, February 2003.


Reducing risks, protecting people HSE’s decision-making process –


Successful Health & Safety Management. 1997

14. Other relevant good practice & standards


ISO (2000), Petroleum and natural gas industries – offshore production installations – heating, ventilation and air-conditioning,


API (1998), Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities of Class I Division 1 or Division 2, ANSI/API RP 500 – 1998.


NORSOK (2001a), Heating Ventilation and Air-conditioning, Standard H-001, Rev 4, Nov


15. Abbreviations

ACoP
Approved Code of Practice

AFP
Active fire protection
ALARP
as low as reasonably practicable
APOS C
Assessment principles for offshore safety cases (HSE guidance)
CBA
Cost-benefit analysis
COMAH
Control of Major Accident Hazards Regulations, 1999.
EER
Evacuation, Escape and Rescue
EPA
Emergency Preparedness Analysis
ESD
Emergency shutdown
FMEA
Failure Modes and Effects Analysis
FMECA
Failure Modes, Effects and Criticality Analysis
GFEHM
Guidelines for Fire and Explosion Hazard Management (by UKOQA)
HAZOP
Hazard and Operability Study
HSC
Health and Safety Commission
HSE
Health and Safety Executive
HSE case
Health, Safety and Environment case
IADC
International Association of Drilling Contractors
IGN
Interim Guidance Notes
IP
Institute of Petroleum
IRPA
Individual risk per annum
ISO
International Standards Organisation
MODU
Mobile Offshore Drilling Unit
OSD
Offshore Division
OIAC
Offshore Industry Advisory Committee
PFEER
Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations, 1995
9-1
PFP
Passive fire protection
POB
Persons on board
PTW
Permit-to-work
QRA
Quantified Risk Assessment
R2P2
Reducing risks, protecting people (HSE document)
SCHAM
Safety Case Handling and Assessment Manual
SCR
Offshore Installations (Safety Case) Regulations, 1992
SIL
Safety integrity level
SRAM
COMAH Safety Report Assessment Manual
TEMPSC
Totally enclosed motor propelled survival craft
TR
Temporary Refuge
TN
Technical Note
UKCS
United Kingdom Continental Shelf
UKOOA
United Kingdom Offshore Operators Association
VPF
Value of preventing a fatality
Appendix A

Interfaces with Other Topic Specialist Teams
The topic of fire, explosion and risk assessment has various interfaces with other topics which are considered as part of Safety Case assessment. The main interfaces are identified in the Table.

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Interfacing team</th>
<th>Interface issues</th>
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</table>
| Hazard identification   | Control systems, Human factors,       | • Consideration of:  
|                          | Mechanical integrity, Pipelines,      | - control systems failure  
|                          | Process Integrity, Well Operations    | - human error (APOSOC Paras 69-71)  
|                          |                                       | - mechanical failure  
| Quantified risk         | Mechanical integrity, Process integrity, Structural integrity | • Effects of fire and explosion on integrity of plant, equipment and structures  
| assessment               |                                       |                                                                                                                                                  |
| Risk evaluation and     | Control systems, Mechanical integrity, | • Consideration of changing circumstances, advances in  
| reduction                | Pipelines, Structural integrity,      | technology, new knowledge and information in  
|                          | Process integrity, Structural integrity, | identifying risk reduction measures (APOSOC Para 84)  
|                          | Well operations                       | • Selection of reasonably practicable risk reduction measures, taking into account relevant good practice and engineering judgement (APOSOC Paras 53-65, 85-87)  
| Risk management         | Control systems, Mechanical integrity, | • Implementation of reasonably practicable risk reduction measures (APOSOC Paras 88-89)  
|                          | Pipelines, Process integrity,         |                                                                                                                                                  |
|                          | Structural integrity, Well operations |                                                                                                                                                  |
| Emergency arrangements  | EER                                   | • Application of principles of inherently safer design (APOSOC Paras 96-97)  
|                          |                                       | • Provision of appropriate prevention, detection, control and mitigation measures (APOSOC Paras 98-105)  
|                          |                                       | • Establishment of performance standards for above measures (SCR Schedules 1-3)  
|                          |                                       | • Conditions under which emergency control arrangements are required to be effective (APOSOC Paras 106-112)  
|                          |                                       | • Arrangements for temporary refuge (including access to it and evacuation from it) (APOSOC Paras 122-129, 135-137)  
|
APPENDIX B

Recent relevant standards
ISO – International Organization for Standardization ([www.iso.ch](http://www.iso.ch))

<table>
<thead>
<tr>
<th></th>
<th>Standard Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>ISO 13702</td>
<td>Petroleum and natural gas industries - Control and mitigation of fires and explosions on offshore production installations - Requirements and guidelines. 1999.</td>
</tr>
<tr>
<td>3</td>
<td>ISO 14004</td>
<td>Environmental management systems - General guidelines on principles, systems and supporting techniques. 1996.</td>
</tr>
<tr>
<td>4</td>
<td>ISO 15544</td>
<td>Petroleum and natural gas industries - Offshore production installations - Requirements and guidelines for emergency response</td>
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IEC – International Electro-technical Commission

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<th>Standard Code</th>
<th>Description</th>
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</table>
9  IEC 61882  Dependability management - Hazard and Operability (HAZOP) Studies


OGP - International Association of Oil and Gas Producers


Other References


14  DNV  Det Norske Veritas, Rules for Classifying Mobile Offshore Drilling and Support Units

15  DNV/WOAD  World Offshore Accident Databank