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Introduction

This information sheet provides guidance on compliance with the relevant regulations for assessing the structural response of installations to fire and explosion events. Expectations for demonstrating risks have been reduced to as low as reasonably practicable (ALARP) should be noted.

Duty holders should be able to demonstrate that, at no time during the life cycle of the installation, a major accident resulting in structural failure from fire and / or explosion events could occur.

This sheet provides guidance on compliance for

- fixed installations
- floating production, storage and offloading installations (FPSOs)
- jack ups
- drilling rigs
- semi-submersible drilling rigs
- flotels, and
- all other vessels which qualify for classification as an installation when working on the United Kingdom Continental Shelf (UKCS)

Duty holders should ensure that relevant current codes and standards are used. Where there are legacy issues using older codes and standards, these must be supplemented with a risk assessment for the ALARP demonstration.

Background

Prior to the Piper Alpha disaster, structural design to limit the consequences of hydrocarbon fire and explosion events was mainly confined to constructing blast walls in the well bay area and around temporary refuges (TRs). These were limited in number and the design pressures used were usually low, of the order of 0.1 - 0.2Barg. Following Piper Alpha, explosion overpressures of several barg were found to be possible due to congestion and confinement resulting from equipment and layouts.

The facilities of all installations must be designed to meet the highest level of protection against fires and explosions defined in codes, standards and guidance, and to demonstrate ALARP as required by the regulations. The regulations promote a goal setting strategy for fire and explosion protection that can be summarised in four basic design features

1. inherently safe design – to ensure designs provide low fire and explosion risks
2. design to reduce the probability of fire and explosion events as far as practicable
3. design to mitigate consequences of fire and explosion with escalation as far as practicable
4. survivability of safety systems exposed to accidental fire and explosion loads

The nature of the threat varies significantly with inventory detail, level of confinement and congestion which is almost always present on UKCS layouts. Even if confinement is reduced, high levels of congestion can create, and enhance, the explosion overpressures experienced by the surrounding plant and structure. This also changes if modifications are made and inventories increase. Ageing installations may also have a higher frequency of releases and leaks due to degradation mechanisms

Legal requirements

The following regulations and associated guidance are relevant to this topic

- The Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015 Regulation 16(1)(d) (e). Relevant Guidance L154 Paragraphs 211, 212 and 213
- The Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996 (DCR) Regulations 4, 5(1)(a) (b), 5 (2) and (e), 7(1) and 8 (1) (a) (b). Relevant Guidance L85 Paragraphs 35 – 41, 46 – 48,49-50, 54, 55– 58, 59-60
- The Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995 Regulations 4 and 5. Relevant Guidance L65 Paragraphs 34, 35, 38, 39, 41 – 45,50 – 55

Standards and guidance

Other relevant guidance and offshore information sheets (OIS) can be found on HSE's website.

A considerable amount of information and guidance for the structural response of fires and explosions is available on the Fire and Blast Information Group (FABIG) website, including Technical Note 13 Design Guidance for Hydrocarbon Fires.

ISO Standards and Eurocodes

FPSOs, drilling rigs and flotels will generally be constructed to Class requirements and the mobile offshore drilling unit (MODU) code. These should be carefully considered when demonstrating compliance with the regulations. In some cases, additional studies will be needed which could require reinforcement of the structure.

Complying with the legal requirements

General

Duty holders must demonstrate that structures have sufficient robustness to ensure a low probability of catastrophic failure when subjected to accidental events from fires and explosions. This can be achieved by satisfying the requirements of relevant standards and guidance, including FABIG Technical Notes 4 Explosion Resistant Design of Offshore Structures, and 13 Design Guidance for Hydrocarbon Fires, BS EN ISO 13702[17] and ISO 19901-3[18]. Special considerations apply to floating structures and jack ups.

Ongoing operational safety should be demonstrated by ensuring design capacity in conjunction with appropriate integrity management systems to ensure degradation is kept within acceptable limits.

The magnitude of design accidental fire and explosion loads for the installation should reflect the residual risks to persons on the installation in line with the ALARP principle. Robustness should be measured against the resilience of the structure to resist these design accidental loads, with appropriate margins to cater for the uncertainties in the load estimation, the modelling scheme chosen, and the properties of the materials used.

The basis of design accidental loads should provide details of all items subject to fire and explosion loading and their performance standards.

Safety and environmental critical elements (SECEs)

Structural elements and systems used in the provision of barriers and control for fires and explosions are often designated safety and environmental critical elements. The performance standard required for these elements and systems should encapsulate the blast wall capacity, the connections to the primary structure, and the response of the primary structure. These should be subject to scrutiny within the verification scheme for the installation.

Temporary refuges (TRs)

The selection of walls and floors as barriers for fire and explosions events must match with the survivability of the profile to afford suitable protection commensurate with the hazard.

Proper assessment of compartment fires should be carried out, and adequate mitigation identified and applied, which should include provisions of ventilation adequacy and emergency response.

Legacy construction issues include the use of ‘A’ rated walls (cellulosic fire tests), and internal ‘B’ rated walls on current installations. Their fire risk design often includes the use of sprinklers as mitigation measures and these should continue to be maintained.

Newer TRs are currently being built without sprinklers and stringent controls of fire-loads, (all fabrics, wall partitions and furniture used in the TR), should be fire retardant and maintain these properties throughout their whole life cycle. Consideration should be given to how doors open, and emergency response. Adequate fire risk design should inform the process.

The future expectation for all new installation TRs, including additional living quarters, is a minimum of external ‘H’ rated walls. Appropriate walls should be used where there is a high probability of jet fires. Internal walls appropriately rated will be required that are suitable for the design fire loads and emergency response.

In recognition of the lessons learned from the explosion, fire and sinking of the mobile offshore drilling unit Deepwater Horizon, which occurred 20 to 22 April 2010, the MODU code Marine Safety Committee have revised the code for construction of keels to be laid after 1 January 2020. ‘H’ class divisions which meet the same requirements as ‘A’ class divisions, as defined in SOLAS, when tested according to the Fire Test Procedures code, with the furnace control temperature curve for hydrocarbon fires defined in international standards. Where bulkheads or decks could be exposed to a radiant heat flux in excess of 100 kW/m2 they should, as a minimum, be constructed to at least ‘H60’ standard. These are the expectations that are required for demonstration of ALARP of MODUs operating on the UKCS.

Fire partitions

All new installations should consider provision of appropriate external ‘H’ rated and jet fire rated walls.

Where there are legacy issues and passive fire protection (PFP) has been used for mitigation this should continue to be maintained. Should there be changes to fire and explosion loads during the life cycle of an installation, then appropriate use and performance standards of the PFP should be demonstrated in the safety case.

The ISO 20902-1 Fire test procedures could also be used to reassess the integrity of partitions.

Explosion and fire rated doors

Doors should remain operable, and retain their specified fire integrity, after being subjected to explosion loading on all escape routes.

There are currently no global standards such as the IMO standard for marine and offshore vessels which include fire-post explosion requirements to date. Some duty holder’s internal standards however attempt to address this gap as good practice in an attempt to demonstrate ALARP.

Designs of doors must consider the condition of the door after an explosion event and should be classed in the categories below

- Category 1: Door should be operable after the loading event. Where post explosion fire resistance is required, acceptance solutions could be by certified single sample testing, split sample testing, or a combination of finite element analysis (FEM) and testing
- Category 2: Door must be operable after the loading event, but significant permanent deformation to the door is permitted. Where post explosion fire resistance is required, acceptance solutions only by certified single sample testing.

Key performance criteria should include the following

- gas tightness

- weather tightness
- missile resistance
- escape route / access control and operability

All main escape route doors must be equipped with a vision panel to check on safety status in the area to be entered in case of an event. A test door equipped with a vision panel must be used for fire or explosion resistant testing. The current industry practice is to use vision panels of 200 x 200 mm.

The peak reflected overpressure, and the duration of the loading in terms of rise and decay time, should be specified in the design accidental loading specifications.

Remedial actions

Retrofit of barriers (usually blast walls) to existing installations plays a major part in reducing the risk and achieving ALARP criteria for accidental explosion events. A key area which requires detailed consideration is the structural details which would perform adequately under static loading but become brittle, and possibly fail, under dynamic loading. Some examples of this include the common practice of snipping secondary beams to minimise weld distortions when attached to webs of plate girders as part of the deck. These have been shown to act as stress raisers and potential failure sources, even at low pressures.

Use of safety gaps

The use of a safety gap between modules for explosion hazards offshore have been deployed as a feature in achieving inherently safe designs. Further information is available in FABIG Newsletter Issue 063[6] February 2014, and paper “Challenges Introduced by the Use of Safety Gaps” Anousone Champassith - Technip. The main purpose was to decelerate flame propagation, particularly on FPSO topsides. some issues to be considered with safety gaps are

- the efficiency of the gap depends on the direction of flame propagation
- gas cloud compositions are important and resulting overpressures experienced could negate the use of the safety gap
- the pressure loads on structures will require to consider the safety gap

Floating structures - special considerations

One of the key differences between FPSOs and fixed platforms is that the option of separation is limited, i.e. having the living quarters on a separate facility or a means of escape onto a separate unit is not an option. Also, the option of minimising congested areas by splitting up the processing into smaller units, and introducing sufficient gaps between the units, is unlikely due to space constraints and economics. This can potentially lead to larger gas cloud sizes as they would not be limited by the volume of the module as on a fixed topside. Previous research has shown that as the gas cloud increases a runaway length can be reached, at which point the overpressure increases significantly. The process design concept should consider limiting a potential gas cloud size as an important issue, as well as keeping the design pressures inherently lower to minimise the effects of an explosion and fire, is a key component on an FPSO facility.

Escape tunnels

There are inherent safety considerations of a double skin versus a single skin tunnel. The design requirements given in the design accidental loading specification should consider the lateral deformations due to explosion loads, and the effect it has on the minimum internal width between rails, and where the rails are fixed to the tunnel, in a single skin design. Designs must consider rupture of the tunnels due to flying shrapnel from the explosion loads.

The tunnel must remain air-tight with a positive pressure. Double skin tunnels consider both these issues and produces a safer option. The outer tunnel is generally sacrificial, and the inner tunnel holds all the outfitting. The combination provides two layers of protection. A double skin tunnel also addresses the issue of sequential and / or simultaneous loads.

Scaffolding and explosion over-pressure vent paths

Installation management activities must consider issues relating to scaffolding which could increase congestion and accelerate flame fronts. The blocking and reduction of vent paths should be considered, and are often undocumented in accepted safety cases, nor mentioned in material change cases. Should the scaffolding be in place for long periods, or become permanent during the installation operations, with a possible increase in explosion over pressures, these should be addressed initially in a risk assessment, and then possibly a material change to the safety case.

Passive fire protection

The majority of topsides on all types of installations have three sided PFP applied to structural members. These SECE structural members global structural integrity performance standards, including collapse, should be demonstrated in the safety case ALARP review, based on an assessment of the response of the entire structure to the design fire loads, which includes the partially protected beams.

Opinions vary based on scenario. For the upper most beams on the perimeter of the envelope the top side may be uncoated because pipes have to rest and slide across. Therefore, fireproofing may not be specified for the top flange of beams where a fire scenario exposure is heat radiation (not flame contact) from a fire below the beam. Note that steel members not completely PFP protected can conduct heat into a fireproofed portion. The interface of fireproofing on an uncoated beam must be rigorously sealed to prevent water incursion under the fireproofing. Only fire engineered solutions should allow for not fireproofing all sides of the beams.

Combined operations (COMOPS)

Each offshore installation will have its own safety case setting out why there is appropriate structural response to fire and explosion events, careful consideration is then required when bringing two, or more, installations together. Each installation will impact on the other and could potentially increase the likelihood of a particular event occurring. This should be addressed within an assessment of the combined operation.

Mobile installations are often designed to classification society standards. The duty holder is required to understand the capabilities of their installation to withstand fire, including jet and pool fires, and explosion events. They must receive sufficient information from the client installation to assess the potential external fire and explosion events their installation could experience.

A duty holder should demonstrate in the COMOPS safety case that their installation will not be operated in any location where the fire and explosion loads it could reasonably and foreseeably experience prejudices the integrity of the installation. For this to be effective, co-operation through sharing information is essential between all the duty holders involved.

References

HSE guidance

1. Fire, Explosion and Risk Assessment topic

Fire and Blast Information Group

2. Technical Note 04 Explosion Resistant Design of Offshore Structures
3. Technical Note 07 Simplified Methods for Analysis of Response to Dynamic Loading
4. Technical Note 10 An Advanced SDOF Model for Steel Members Subject to Explosion Loading: Material Rate Sensitivity
5. Technical Note 13 Design Guidance for Fire Resistance
6. FABIG News, Issue 63 February 2014

- - Anousone Champassith,'Challenges introduced by the use of safety gaps'

7. FABIG News, Issue 71 September 2017

- L Paris, A Dubois: Design Explosion Loads Specification for Safety Critical Systems
- J K Paik, J Czujko, S J Kim, J C Lee: New procedure for the non-linear structural response analysis of offshore installations subjected to explosions
- Prof Y C Wang: Robustness of steel framed structures in Fire-Effects of joints and methods of improvement

8. FABIG News, Issue 72 January 2018

- A.B. Groeneveld: Categorisation of blast and fire rated doors

9. Oil & Gas UK, Fire and Explosion Guidance, Issue 2, March 2018
10. Design Manual for Structural Stainless Steel 4th Edition Steel Construction Institute Publication P413
11. Eurocode - Basis of Structural Design
12. Eurocode 1: Actions on Structures
13. Eurocode 2: Design of Concrete Structures

14. Eurocode 3: Design of Steel Structures
15. Eurocode 9: Design of Aluminium Structures
16. ISO 19900 Petroleum and Natural Gas industries Offshore Structures – General requirements
17. BS EN ISO 13702 Petroleum and Natural Gas Industries – Control and mitigation of fires and explosions on offshore production installations – Requirements and guidelines
18. ISO 19901-3 Petroleum and Natural Gas industries Specific requirements for offshore structures – Part 3: Topside structures
19. BS EN 1363-2: 1999 Fire resistance tests
20. BS 476: Part 7: 1997 Fire tests on building materials and structure, Part 7, Method of test to determine the classification of the surface spread of flame products
21. ISO 9705: 1993 Fire tests – Full scale room test for surface products
22. ISO 20902-1 Fire test procedures for divisional elements that are typically used in oil, gas and chemical industries – Part 1: General requirements

If an ISO standard is not being used, duty holders should consider where the selected standard may not meet the requirements of the relevant ISO standard, and address those areas accordingly.

23. API Recommended Practice 2218 3rd Edition, July 2013
Annex D (informative) Fireproofing Questions and Answers
Section 5 - Installation and Quality Assurance

This guidance is issued by the Offshore Safety Directive Regulator (OSDR). Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.