Offshore Flare Systems - Identified Issues and Associated Good Practice

Technical Note

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List of Abbreviations

Abbreviations	Definitions
ACOP	Approved Code of Practice
ALARP	As Low as Reasonably Practicable
API	American Petroleum Institute
BDV	Blowdown Valve
BS	British Standard
CCTV	Closed Circuit Television
CFD	Computational Fluid Dynamic
CO_2	Carbon Dioxide
COT	Crude Oil Tank
CRO	Control Room Operator(s)
ED	Energy Division (of the HSE)
ESDV	Emergency Shutdown Valve
FPSO	Floating Production, Storage and Offloading
HAZOP	Hazard and Operability
HAC	Hazardous Area Classification
HSE	United Kingdom Health and Safety Executive
H_2S	Hydrogen Sulphide
IEC	International Electrotechnical Commission
KO	Knock-out [drum]
LEL	Lower Explosive Limit
LOC	Loss of Containment
LOPA	Layers of Protection Analysis [study]
MAH	Major Accident Hazard
MODU	Mobile Offshore Drilling Unit
PFEER	The Offshore installations (Prevention of Fire, Explosion, and Emergency Response) Regulations, 1995 as amended on 2005 and 2015 (SI 1995 no. 743)
SCR 2015	The Offshore Installations (Offshore Safety Directive) (Safety Case, etc) Regulations 2015 (SI 2015 no. 398)
SECE	Safety and Environmentally Critical Element(s)
SIF	Safety Instrumented Function(s)
UK	United Kingdom
UKCS	United Kingdom Continental Shelf

1 Introduction

Pressure relief and blowdown systems along with their associated flare or vent play a key part in the prevention and mitigation of the effects of major accident hazards (MAHs) from hydrocarbon producing facilities. Various international standards exist for the sizing and selection of relief devices and blowdown systems.

In 2019, the United Kingdom (UK) Health and Safety Executive (HSE) identified some concerns associated with offshore vent and flare systems following a series of inspections and investigations. These included:

- Flares being extinguished in normal operation.
- Air ingress to flare/vent stacks during shutdown periods with no/inadequate continuous purge.
- Flammable liquid release from flare and vent stacks.
- Failure to inspect or maintain originally installed flare equipment (including flare purging and ignition facilities).
- Methods and reliability of flare ignition.
- Failures in platform blowdown systems.
- Lack of clarity in the installation's safety case as to the modes of operation of the flare systems and the conditions under which cold venting from a flare system is acceptable.
- Deficient performance standards or written schemes of verification.
- Inadequate consideration of impact of vents on installations under combined operations.

The HSE went on to suggest that:

- API Standard 521 'Pressure-relieving and Depressuring Systems' and API Standard 537 'Flare Details for Petroleum, Petrochemical, and Natural Gas Industries' provisions do not appear to be universally followed across the UK Continental Shelf (UKCS), despite the majority of safety case claims.
- The HSE Energy Division (ED) Inspection Guide Offshore: Inspection of Loss of Containment (LOC) (specifically, Appendix 4 of the guidance) expectations are not being met, based on recent HSE inspection experience.
- There is a variation in approach between different installations and Duty Holders.
- There may be an increase in risk level if the situation is allowed to continue as is.

Whilst there is good practice visible across the UKCS industry, the HSE's challenge was how its application could best be applied to ensure that risk levels were as low as reasonably practicable (ALARP).

An OGUK 'task finish group' was formed to investigate the concerns raised by the HSE. This Technical Note has been produced to highlight good practice within the industry.

The HSE's key issues covers two distinct cases:

1. Flare system: System that is designed to safely dispose of vapours to atmosphere **through the use of combustion. The expectation is that a flare is designed to be lit either during normal operations, or ignited in an emergency, should remain lit in accordance with the performance standards and as stated in the installation safety case**.

2. Cold vent: System that is designed to safely discharge vapours to atmosphere **without combustion**.

This revision of the document addresses the case of flare systems only and is primarily focussed on operations and continued suitability of safety and environmental critical elements (SECE). Cold venting will be addressed as a second phase of work for the task finish group.

This document addresses safe practices in flaring activities only and is not intended to provide information about flare emissions abatement or industry action to meet net-zero commitments.

2 Legislative background

Various items of legislation regulate this area. Flare systems are not explicitly mentioned but could be considered as implied requirements, e.g. via the requirement for suitable measures to be in place. The key pieces are:

- The Offshore Installations (Prevention of Fire, Explosion, and Emergency Response) Regulations 1995 (SI 1995 no. 743) as amended in 2005 and 2015 (PFEER), which is the principal legislation governing offshore hydrocarbon loss of containment prevention and consequence mitigation.
- The Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015 (SI 2015 no. 398) (SCR 2015), which, among other things, requires Duty Holders to manage the risks arising from MAHs.

PFEER Regulation 9 (Prevention of Fire and Explosion) states:

> *"(1) The duty holder shall take appropriate measures with a view to preventing fire and explosion, including such measures to –*
>
> *(a) ensure the safe production, processing, use, storage, handling treatment, movement and other dealings with flammable and explosive substances;*
>
> *(b) prevent the uncontrolled release of flammable or explosive substances;*
>
> *(c) prevent the unwanted or unnecessary accumulation of combustible, flammable or explosive substances and atmospheres; and*
>
> *(d) prevent the ignition of such substances and atmospheres.*
>
> *(2) The measures to prevent ignition referred to in paragraph (1) shall include –*
>
> *(a) identifying and designating areas in which there is a risk of a flammable or explosive atmosphere occurring; …"*

PFEER Regulation 12 (Control of Emergencies) states:

> *"The duty holder shall –*
>
> *(a) take appropriate measures with a view to limiting the extent of an emergency, including such measures to combat fire and explosion; and*
>
> *(b) shall ensure that –*
>
> *(i) where appropriate, those measures include provision for the remote operation of plant; and*
>
> *(ii) so far as is reasonably practicable, any arrangements made and plant provided pursuant to this regulation are capable of remaining effective in an emergency".*

Paragraph 118 of the PFEER Approved Code of Practice (ACOP) and guidance (L65) states (with OGUK emphasis in **bold** relevant to this Technical Note):

> *"Measures to control activities which might lead to a release or ignition hazard should include adequate procedures and arrangements for control of: …*
>
> *(b)* ***maintenance activities****;*

*(c) **modifications, start-up and shutdown of plant and equipment**, storage, handling and use of flammable substances."*

Paragraph 162 of the ACOP states:

"*Equipment used to control the extent of an emergency should, so far as reasonably practicable, be designed on the principle that it **does not fail to danger**. The design of such equipment should take into account human factors – including ergonomic factors – with respect to its operation in an emergency*."

Under SCR 2015, the definition of a major accident is:

*"(a) an event involving a fire, explosion, loss of well control or **the release of a dangerous substance causing, or with a significant potential to cause, death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it**;*

(b) an event involving major damage to the structure of the installation or plant affixed to it or any loss in the stability of the installation causing, or with a significant potential to cause, death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it;

(c) the failure of life support systems for diving operations in connection with the installation, the detachment of a diving bell used for such operations or the trapping of a diver in a diving bell or other subsea chamber used for such operations;

(d) any other event arising from a work activity involving death or serious personal injury to five or more persons on the installation or engaged in an activity on or in connection with it; or

(e) any major environmental incident resulting from any event referred to in paragraph (a), (b) or (d)"

SCR2015 places a duty on duty holders to demonstrate that, among other things, measures, including the selection of SECEs, have been, or will be, taken to control those risks and to ensure that the relevant statutory provisions will be complied with. It should be noted that the decision about what is ALARP is affected by changes in knowledge. If there is evidence showing the hazard presents significantly lesser risks than previously thought, then a potential change in the control measures may be acceptable, provided the new arrangements ensure the risks are ALARP. This approach is not a reverse ALARP argument, but rather re-evaluation of the risk allowing the changes. However, in all cases, claims made in an installation's safety case should be supported by robust and clear rationale.

3 HSE inspection findings and associated good practice

The HSE has identified some concerns associated with offshore flare systems following a series of inspections and investigations. This section summarises, for each concern, the underlying issues identified by the HSE and highlights good practice within the industry to address those concerns. Reference is also made, where relevant, to the ED Inspection Guide Offshore: Loss of Containment.

3.1 Flares unintentionally extinguished in normal operation

3.1.1 Issues identified by the HSE

- Factors such as limited/no gas momentum flow at the flare tip, unfavourable weather and poor flare tip condition resulting in extended periods of cold venting of hydrocarbons without acknowledgement of the full impact on day-to-day operations.
- Subsequent 'slumping' of hydrocarbon gas and accumulation on the deck of the installation. In some flame out situations, 'slumping' of hydrocarbon gas and accumulation has led to activation of fire and gas detection system and topsides blowdown.
- Although dependent on installation configuration, flare design (structure, inclination and length of the stack, flare tip, flare tip location relative to main installation), operating procedures and practice, delays in detection of flame-out and failure to re-ignite extinguished flares may have the potential to expose personnel to additional risk on some installations.
- Results of gas dispersion modelling not being reflective of actual real-life scenarios (particularly under calm weather conditions), leading to inadequate control measures during periods of flame-out, especially when cold venting was assumed to be safe.

The HSE communicated that there have been instances of unignited gas (extinguished flare scenario) from a flare impacting oil and gas installations as a result of one or more of the following factors:

- low wind speeds.
- atmospheric temperature inversions.
- higher than expected/modelled gas molecular weights.
- low gas temperatures.
- mist/droplets being emitted (i.e. 'rainout').

The HSE informed the task finish group that in a limited number of situations, this has led to activation of the installation's flammable gas detectors with subsequent blowdown exacerbating the issue (potentially resulting in the development of hazardous gas clouds, following detection of gas clouds below their lower flammable limit). Whilst a higher flowrate would result in increased velocities at the flare tip, which would tend to increase the turbulence and improve dispersion and hence the likelihood that flammable gases would be directed away from the installation, this may not always be the case.

3.1.2 Good practice

See also Section 4 'Modelling and ignited flares'

Flare systems and their associated components (ignition systems, purge arrangements, etc) may, in accordance with the original design intent of the installation, be identified as SECE and have appropriate performance standards. There may be cases where it can be demonstrated that no MAH events can arise from an unlit or inadequately purged flare and, in these cases, the flare system or parts of it would not require to be identified as SECE.

For installations with an original design of a lit flare, good practice is continuing to operate the installation with the flare remaining lit. Where autoignition systems are no longer present or provided, suitable arrangements should be in place for monitoring of flare condition, e.g., pilot flame detection, closed circuit television (CCTV) and regular monitoring by the operations team (e.g. control room operators (CRO)), and relighting the flare without undue delay.

Where flare extinguishment (flame out) is occurring, records of such events should be reviewed. If records are not kept/retained, then key offshore personnel should be interviewed to obtain information with the aim of identifying any noticeable trends (weather or flow related, any subsequent issues such as gas detection, flare configurations that have/have not experienced this issue, etc.) to provide input to risk reduction measure identification. Each installation should be assessed on its own merit because of the different flare designs, flare configuration and process conditions. Consideration should also be given to where flare ignition systems are installed (pilots, pellet ignition systems, flame front generators, etc.) and how reliable they are.

Where flame-out is occurring, an assessment of the flare tip should be made with regards to the long-term operation or need for replacement. The assessment should be carried out in conjunction with the flare tip provider and consider both normal operational flaring and maximum emergency blowdown requirements. The assessment should be repeated as often as necessary as installation conditions change and new fields change composition and other process parameters.

An assessment should be completed of the potential for unignited hydrocarbons to slump to deck or to impact elevated locations such as the helideck or helicopter flightpaths. There should be an operating procedure to state the wind/weather conditions (directions and minimum velocity, with consideration given to air temperature) under which slumping or other installation impacts could occur. The operating procedure should be linked to the adverse weather policy for the installation and be cross referenced.

Within the operating procedure, there should be restrictions on certain operations (when those potential weather/wind conditions occur), such as:

- Under what circumstances it is safe to continue operating or if a shutdown should be initiated.
- Restricting operations that could more readily initiate an installation blow-down.
- Gas freeing of crude oil tanks (COT) on floating production, storage and offloading (FPSO) vessels.
- Helicopter operations.

Special consideration should be given to those installations where flare recovery systems are installed. Purge and ignition systems for these installations may be more critical and may meet the definition of an (SECE)[1]. Refer to later discussions on flare purge and ignition systems, Section 3.2.2.

All software modelling tools have defined boundary / validity limits. It is recognised that dispersion modelling of unlit flares is subject to uncertainty, with the use of such models, including computational fluid dynamic (CFD) models, limited by the validity range of the model. In particular, a number of models are not suited to low wind speed situations. *See also Section 4: Modelling and Ignited Flares.*

3.2 Air ingress to flare stacks during shutdown periods with no/inadequate continuous flare purge controls

3.2.1 Issues identified by the HSE

- Formation of flammable mixtures in pipework/upstream vessels.
- Risk of internal explosion particularly during re-lighting, but also throughout shutdown period due to lightning or other ignition sources (noting that, generally, there will only be limited electrical equipment in relative proximity to the flare tip).

3.2.2 Good practice

The basis of design for managing purging during platform trips and shutdowns should be established. If the purging system is not operating, it needs to be determined if it can be reinstated or if an alternative equivalent solution is required.

The purging facilities depend on the source of purge gas:

- A nitrogen purge may be limited by the volumes of nitrogen stored or produced: sufficient nitrogen needs to be available during shut down and re-start.
- Purging with process and/or fuel gas depends on the status of the plant and may only be available later in the start-up cycle.

Minimum required purge rates should be determined using a suitable approach such as outlined in API Standard 521 or *Petroleum, petrochemical and natural gas industries. Pressure-relieving and depressuring systems*, BS EN ISO 23251 and the system designed to ensure the minimum purge is always achieved. Sufficient purge should be employed to avoid air ingress or burn-back and purge should be introduced at multiple points to ensure no hazardous conditions in the event of failure of a single purge. Particular attention should be given to those installations operating a flare recovery system (e.g., flash gas recovery systems) where purges are applied downstream of the flare knock-out (KO) drum. For flare gas recovery systems, purge arrangements should be designed to be highly reliable (e.g., backup purge supply employed with automatic switchover on falling pressure - fuel gas/inert gas).

[1] The "such parts of an installation and such of its plant (including computer programmes), or any part of those—
(a) the failure of which could cause or contribute substantially to a major accident; or
(b) a purpose of which is to prevent, or limit the effect of, a major accident"

Where the nitrogen used for a purge is generated from a membrane-type system, care should be taken to ensure the residual oxygen content is low enough such that the purge itself does not introduce a risk. Nitrogen generation systems should ideally be equipped with arrangements for detecting and warning of increased oxygen content with oxygen analysers also considered for new installations / designs.

Purging of flare headers post-shutdown should be assessed separately and be of sufficient flow and duration to promote adequate mixing and displacement of air. The minimum purge rates for both operating modes should be clearly defined. Note that there may be a distinction between short-duration platform trips/outages and longer outages such as turnarounds: the method of managing purging may be different (e.g., a restart after a trip may not require re-purging, but this will be time limited and depend on the controls in place).

It is acknowledged that conducting a comprehensive hazard and operability (HAZOP) study of flare systems is not straightforward, as a result of the wide range of inputs and variables. However, HAZOP reports should be reviewed and it should be determined if adequate consideration has been given to scenarios potentially leading to air ingress. For example, in the case of hot relief to flare, on termination of relief, gases will cool and contract within the flare header, drawing air back through the flare stack, potentially generating a flammable mixture within the flare system. Such additional scenarios may lead to an increased purge rate requirement above those determined using the American Petroleum Institute (API) or British Standard (BS) methodologies. Consideration should be given for flares with purge reduction seals (or the like) that do provide some benefit for drawing air into the flare system.

Arrangements, typically a nitrogen or fuel gas purge, should be in place to ensure that air ingress to the flare headers, leading to the formation of a flammable mixture, cannot occur. This should function under all installation conditions (particularly during start-up and shutdown where a source of fuel gas may not be available).

Following a platform shutdown that results in extinguishing of the flare, operating procedures should provide guidance as to how the flare shall be ignited and must also consider the impacts of venting unignited gas, taking into account atmospheric conditions (wind speed and direction). The procedures should provide guidance on minimum purge rate (fuel gas or nitrogen) and duration of purge to ensure that the flare header (KO drum to tip) is purged of air prior to ignition.

Operating procedures should be in place for the relief and blow-down system, which specify routine checks of purge rates and that header drains (where installed) are clear[2].

Controls that may be used to confirm purge rates are:

- Minimum purge rates to be determined.
- Alarm set at the minimum purge rate to notify CRO.
- Pre-flare ignition oxygen level checks within the flare system (with a robust sampling method so as not to introduce oxygen within the system).

These controls should be added to the flare operations procedure, with the minimum purge rates added to the relevant SECE performance standard where applicable.

[2] Source: ED Inspection Guide Offshore: Inspection of Loss of Containment (LOC)

Whilst older editions of API Standard 521 indicated that flare systems may, depending on the design, be able to withstand an internal deflagration, degradation of flare systems over time means that this relies on the ongoing integrity management of flare system pipework, supports and ancillaries.

3.3 Flammable liquid release from flare stacks

3.3.1 Issues identified by the HSE

- Condensation in lines downstream of KO drums.
- Failure to control liquid level in KO drums (inadequate instrumentation, drainage, design basis) leading to "carryover".

Other potential issues, although not specifically identified by the HSE, are:

- Complex flow patterns within flare KO drums could potentially lead to re-entrainment of liquids. For example, a common design of flare knockout drums is to direct the process inlet against one of the vessel heads – one UK operator's detailed analysis has shown that this can result in the vapour flow sweeping round the dome end and entraining liquid from the bottom of the vessel prior to entering the flare stack.
- Horizontal flares can have low points in the pipework where liquids can accumulate.
- Short swept flares are also more susceptible due to their design.
- KO drums/vessels not sized appropriately for the credible design cases and relying on automatic drains systems that can be overcome quickly causing liquid carry over under certain circumstances or process deviations.

3.3.2 Good practice

HAZOP report(s) and documentation related to the relevant safety instrumented functions (SIF) (e.g., layers of protection analysis (LOPA)) associated with the flare system should be reviewed. This should cover the various operating modes of the installation, including start-up, shutdown and process upset scenarios, as well as changes to the operating conditions over time. It should be confirmed that the flare system HAZOP and other assessments cover the current operating conditions (particularly in terms of the fluid composition). Additionally, it should be confirmed that flare KO drum liquid overfill scenarios were adequately assessed in the HAZOP and that suitable SIF were specified. Potential considerations include:

- Are the level and trip settings adequate such that overfill does not occur?
- Is the instrumentation fit for purpose and does it achieve the required safety integrity level?
- Are design loads of the vessel and supports sufficient for a full liquid head?
- Where liquid boots are present, are they suitably protected from freezing?

The potential for and consequence of condensation in the flare lines downstream of the flare KO drum should be determined. Dependent on the outcome of this review, there may be a requirement to inspect lagging downstream of flare KO drums, and revisit the flare system HAZOP and the SIF assessment (e.g. LOPA) in order to demonstrate that the hazard has been adequately identified and controlled.

The flare KO drum should be capable of performing its relief function when a high liquid level is present and without compromising gas / liquid separation. Where flare KO drum performance is impacted by a high liquid level then a suitable response plan should be in place[3].

The internal design of the flare KO drum should be reviewed to assess if re-entrainment is possible and determine if modifications such as the addition of baffles or changes to inlet/outlet orientation would reduce this potential. Note that re-entrainment can be a consequence of liquid level and vapour velocity, as well as internal design.

3.4 Failure to inspect or maintain originally installed relief equipment

3.4.1 Issues identified by the HSE

- Failure to inspect or maintain originally installed relief equipment including purge systems, flare pilot systems, flame-out detection, ignition systems, flame arrestors, back-up purge gas systems, etc.
- Failure to assess degradation or change versus original design intent (or safety case).
- Attempts to make “reverse ALARP” arguments to not maintain/replace.
- Change may have occurred under different ownership and not been recognised as significant.

3.4.2 Good practice

The current flare design basis should be reviewed (including associated standards), as well as the safety case, performance standards (and associated assurance activities), relevant management of change records, procedures for managing ageing and life extension, etc. and:

- Existing flare system arrangements should be compared to current design intent and any gaps identified.
- An assessment should then be carried out of whether any identified deficiencies fundamentally affect the safety of the flare system or give rise to a potential MAH which then drives SECE requirements.

Evidence exists of lack of original documentation, inadequately sized relief devices or failure to identify credible scenarios e.g., new tiebacks may give rise to packed pipeline scenarios that may be in excess of the ability of the relief system to handle. Operators have retrospectively had to make modifications. Therefore, operators should have an up-to-date and suitably accurate relief and blowdown assessment for the installation.

Examples of changes could also include:

- Significant changes in composition of well fluids – changes in hydrogen sulphide (H_2S)/carbon dioxide (CO_2)/water content.
- Pressure/temperature changes due to new tiebacks.

[3] Source: ED Inspection Guide Offshore: Inspection of Loss of Containment (LOC)

- On ageing plant, where dehydration is no longer a process requirement, dehydration equipment may have been decommissioned, so flare feeds may be “wet”, where once they were “dry”.
- Change in purging arrangements such as the impact of using process gas versus fuel gas.
- Flare throughput may reduce as installation moves into late life.
- Significant changes to topsides plant configuration e.g., decommissioning of process plant, becoming a pumping station etc.

During mid- to late-life operations of an installation, as production profiles drop and maximum blowdown rates decrease, a duty holder may see an opportunity to re-consider the design of a lit flare and examine the opportunity to have an unlit flare, i.e. only lit in an emergency blowdown. If a flare tower sizing was designed based on safe thermal radiation levels at the maximum blowdown rates only (and not assessed on the alternative operation mode of cold venting), a full re-assessment would be required of the flare tower to consider the potential hazard introduced by cold venting. As a new hazard, the risk would need to be managed to ALARP, which should explicitly consider the requirements to ignite the flare and establish a suitable reliability target thereof. However, if the cold venting case was considered in the original design and if the reassessment presents any increase in MAH risk then the design should include suitable provisions to maintain the flare to avoid reverse ALARP.

3.5 Re-ignition of flares

3.5.1 Issues identified by the HSE

- Use of shot gun and inadequate assessment of the risks due to no/delayed ignition.

As communicated by the HSE, the issue is not with the use of shotgun / flare gun for re-ignition, but that this should not be seen as a justification for not reinstating original ignition systems or pilots or providing alternative ignition systems.

3.5.2 Good practice

Historically, creeping change can result in (where installed) automatic systems becoming impaired or out of service due to access issues (flare outage required), integrity issues with pilot pipework or igniters, difficulty in maintaining due to location, etc. The reliance then falls to igniting manually without a thorough management of change being carried out.

An ALARP demonstration should be conducted against the current basis of design and alternative options based on the lifecycle of the installation.

- Review relevant flare ignition procedure and risk assessments.
- Review good practice and lessons learned relevant to this activity (e.g., API Standard 537).

The intent is to perform a cold-eye review of the adequacy of the flare ignition procedure and associated risk assessments, to identify improvement points to strengthen the procedure and, ultimately, to reduce the risk associated with manual ignition of the flare.

When considering the use of an automated system, the reliability of the system needs to be considered as there are examples where the pilot systems extinguish at the same time as the flare. Furthermore, experience suggests that igniters/flame front generators are generally difficult to maintain, especially in an offshore environment.

The following points need to be considered when understanding the reliability of manual ignition of the flare:

- Does the design of the flare (height, orientation, obstacles, etc.) result in it being more difficult to ignite?
- Does the weather materially affect the igniting of the flare?
- How many times was the flare not ignited successfully by this method and, consequently, was the flare left to cold vent for an extended period? Did this coincide with weather conditions that could have resulted in poor dispersion?
- It is only allowed to hold 150 cartridges offshore for a flare gun, which may be a limiting factor.
- Shotgun/flare gun licencing arrangements, e.g. the availability of personnel onboard with the necessary licence.
- What action is taken if the flare cold vents for extended periods, what controls are there in place (procedural, impact on production etc) – see section 3.1.

Where applicable, the alternative means of igniting the flare without undue delay (e.g. flare gun/shotgun) should be reflected within the installation documentation, such as safety case, performance standards or operating procedures.

3.6 Issues in platform blowdown systems

3.6.1 Issues identified by HSE

- Failures to test blowdown system performance.
- Blowdown systems that do not meet performance standards, and with no subsequent assessment of the risk of continued operation.

3.6.2 Good practice

Routine tests should be performed on the operation of blowdown systems to confirm their effectiveness (time to depressurise, excessive vibration, etc) under a controlled (non-emergency) situation. Source: ED Inspection Guide Offshore: Inspection of Loss of Containment

Routine function testing of blowdown valves as part of planned maintenance routines should be performed. There should be a system in place for recording and assessing blowdown events outside of planned testing including identification of any parts of the blowdown system that fail to meet the required performance standard (including issues with emergency shutdown valve (ESDV) or blowdown valve (BDV) functionality) with specific remedial actions to identify failure modes, allow root cause analysis of the issue, and to identify items that require remediation, e.g. problematic valves.

As required by PFEER and SCR 2015, the duty holder shall establish appropriate standards of performance, as well as a verification scheme, for SECE. Duty holders shall confirm that tests are conducted, and remediation or suitable and sufficient risk assessment carried out where tests are failed. Refer also to Sections 3.4 and 3.7. The intent is to identify deficiencies and means to close gaps between required performance and actual performance which should be standard practice for all SECE.

OGUK "Guidance on the Conduct and Management of Operational Risk Assessment for UKCS Offshore Oil and Gas Operations", and "Cumulative Risk Guidelines" present good practice in the conduct of risk assessments.

Duty holders should maintain awareness of the latest standards relevant to their systems and perform and document a review against changes. The HSE inspection experience of relevance here has shown:

- Failure to apply the API Standard 521 revised jet fire guidance resulted in a duty holder attempting to argue that passive fire protection was not required on a vessel that would fail under pressure after four minutes because of a lack of ability to blowdown fast enough.
- Performance standards quoting API Standard 521 guidance on 50% design pressure, with no recognition of the impact of vessel wall thickness on this guidance.
- Reliance on guidance stating that where an inventory is below a certain value then no blowdown is required.
- Failure to meet the 'typical' blowdown criteria (50% design pressure/6.9 barg in 15 minutes) is not necessarily an issue, and instead survivability calculations should be undertaken in accordance with API Standard 521 (or similar), although it should be noted that the system may be a source of jet flame as well as a target.

3.7 Deficient performance standards or written schemes of verification

3.7.1 Issues identified by the HSE

- Critical aspects of systems not checked.

3.7.2 Good practice

Duty holders may wish to alter the conditions in which equipment is operated or alter some or all control measures in response to changed circumstances. Consideration must be given to the effectiveness of the original design (e.g. whether flare ignition facilities were provided or not). This is permissible if it can be shown that the revised control measures continue to ensure that risks are reduced ALARP.

Good practice is to reassess relief stream designs in light of changing process conditions and duties to ensure they remain fit for purpose.

Any changes to the flare system, such as changing from a normally lit flare to an unlit flare, must include development of initial suitability performance standards and be subject to examination by the verifier. The operator shall take due cognisance of any comments/reservations expressed by the verifier (as required by Regulation 9 of SCR 2015). Once the design is completed, a new set of continued suitability performance standards can be implemented, and it is possible that some original SECE (such as components of the ignition system or flame detection system) can be retired.

The SECE, their associated performance standards and associated assurance activities should be periodically reviewed, building on section 3.4, in order to develop a robust set of performance standards and associated assurance activities for the flare system as a whole. This allows the identification of the components of this SECE that have not hitherto been formally defined as safety critical and thus may not have been adequately inspected or maintained.

Clear pass/fail criteria and contingency measures should be included or referenced within the installation's operational (continued suitability) performance standards (and associated assurance routines).

3.8 Inadequate consideration of impact of vents on installations under combined operations

3.8.1 Issues identified by the HSE

- Un-ignited/ignited releases (flammability, toxic impacts, radiation).
- Siting of attendant installation/walk to work vessel in relation to vent location.

3.8.2 Good practice

Siting of attendant installation/walk to work vessels in relation to vent location should be subject to at least the same considerations as normally accessible locations on the host installation, based on relevant assessments of foreseeable un-ignited/ignited releases and their potential flammability, toxic impacts and radiation. However, uncertainty about the robustness of these assessments is one of the concerns identified (refer to section 3.1.2 regarding dispersion modelling uncertainty). The radiation impacts of flares on the attendant installation should be considered, particularly mobile offshore drilling units (MODU) derricks.

Good practice is to:

- Include consideration of routing host installation vents to the attendant vessel vent, provided it does not introduce additional risks, e.g. back pressure.
- Have a schedule of vents and exhausts for both installations when in combined operations.
- There should be consideration of combined operations hazardous area drawings to outline the interactions[4]. Recognise the interactions between the combined operations, record them in the relevant associated documents and on the simultaneous operations matrix. It is conceivable that controls would be required for certain venting scenarios, e.g. such as favourable wind conditions.

Activities that increase the risk should also be minimised, e.g. manual depressurisation.

[4] Note: this may highlight problems such as the differences between Hazardous Area Classification (HAC) such as the use of IEC-60079 Series on Explosive Atmosphere Standards against the Classification Codes (e.g. DNV Class codes OSS-101 and OS-E101).

4 Modelling and ignited flares

See also section 3.1 Good practice

When sizing and evaluating flares, a range of modelling techniques are available for use. For flares intended to be permanently lit or lit in an emergency situation (e.g. plant blowdown), there are multiple considerations, including radiation at areas of the platform that may be occupied, and the predicted concentration of flammable gas at areas where an ignition source may be present.

While CFD is becoming more widespread, use of equation-based models such as DNV Phast, FRED, and various other in-house and commercial modelling tools is common. These models are not applicable across all wind-speed ranges and are generally agreed to apply at wind speeds of 2 m/s or higher. Also, they are based on "averaging" concentrations, and peak instantaneous concentrations may be higher than the averages quoted due to eddy effects, etc. In general, predicted concentrations of 50% Lower Explosive Limit (LEL) or higher from these models are taken to indicate the range of the flammable region. For radiation, vendor-specific models may be required, as the design of the flare tips is optimised to promote maximum efficiency of flame, resulting in lower actual radiation than predicted with conventional equation-based modelling.

Current design approaches to sizing flare systems use equation-based modelling, and the resultant flare designs are in widespread use. There is evidence of extinguished flares resulting in detectable concentrations of hydrocarbon (by fixed detection systems) on facilities in specific wind speed conditions and the HSE has taken enforcement action in a number of these cases. However, there is limited evidence of ignition of such releases, and as far as reported in the incidents reported by the HSE, the measured concentrations remained below 100% LEL. This suggests that the design approach taken is successful in limiting the risk of gas from flare outlets being ignited at areas where personnel are likely to be. Additionally, a number of the incidents were for flare systems that would be unlikely to be in line with modern design approaches.

There has been some mixed experience in the recent past of using CFD to attempt to match actual measured concentrations from incidents. There remains considerable debate on the specifics of some of these cases, as there are alternative approaches available to deal with situations where initial modelling does not match the observed outcomes. This is always complicated by the incomplete knowledge of the specific conditions at the time of any incident, and the limited number of data points available around specific incidents.

Further to this, tests on a mock-up of an FPSO hydrocarbon vent were undertaken by the HSE at their Health and Safety Research Centre in Buxton. In the experiments, flammable gas was ignited upwind of a release where the CFD model predicted there to be no gas present at all (the CFD model instead predicted the gas to be dispersed downwind). At issue is the fact that commonly used CFD models do not take into account the time-varying wind directions produced by turbulence in the atmosphere. Instead, they rely on a mean wind direction. The work at Buxton was in support of an investigation into several incidents on the GP3 FPSO, where gases from the cargo vent below the flare ignited on several occasions. The investigation findings were not conclusive, but they suggested the vent gases could have been ignited from burning droplets falling from the flare or from the vent gases being drawn up into the flare and flashing back to the vent. The work was documented in the papers presented by Pursell et al. (2016) and Gant et al. (2016)[5] at the IChemE Hazards Conference.

Notwithstanding the issues with specific incidents, CFD remains a powerful tool with a range of validation and application across the industries. It is based on the fundamental chemistry and physics of fluid flow and reaction and, with appropriate care taken in the modelling, CFD provides greater power than alternative tools to assess complicated modelling challenges and inform engineering judgement of the balance of risk for operations. It is therefore a key part of the toolkit available to operators and designers in assessing risks of flammable fluids.

[5] Pursell M., Gant S.E., Newton A., Bennett D., O'Sullivan L., Hooker P. and Piper D. (2016) "Investigation of cargo tank vent fires on the GP3 FPSO, Part 1: Identification of ignition mechanisms and analysis of material ejected from the flare", IChemE Hazards 26 Conference, Edinburgh, UK, 24-26 May 2016; Gant S.E., Pursell M., Newton A., Bennett D. and O'Sullivan L. and Piper D. (2016) "Investigation of cargo tank vent fires on the GP3 FPSO, Part 2: Analysis of vapour dispersion", IChemE Hazards 26 Conference, Edinburgh, UK, 24-26 May 2016.

5 References and related documents

5.1 References

1. The Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995 (SI 1995 no. 743).
2. The Offshore Installations (Offshore Safety Directive) (Safety Case, etc) Regulations 2015 (SI 2015/398).
3. ED Inspection Guide Offshore: Inspection of Loss of Containment (LOC).
4. Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995 Approved Code of Practice and guidance, L65 Third Edition.

5.2 Related documents

OGUK Fire and Explosion Guidelines

This sets out guidance and good practice for designing against fire and explosions on offshore installations. It focuses on setting a philosophy for design and assessment in a realistic and accessible manner. In doing this, it provides a rational and pragmatic foundation to support design decisions, allowing the basis of such decisions to be understood and justified.

OGUK Guidance on the Conduct and Management of Operational Risk Assessment for UKCS Offshore Oil and Gas Operations

The objective of the guidance is to help Duty Holders develop, maintain and implement Operational Risk Assessment procedures that achieve a legally compliant, systematic and effective approach to operational risk management processes.

OGUK Cumulative Risk Guidelines

The objective of the guidance is to increase awareness of the need to manage cumulative risk and describe how to do this as a vital part of the MAH management process.

oguk.org.uk/guidelines

OGUK Technical Notes
Member companies dedicate specialist resources and technical expertise in providing technical notes in collaboration with OGUK, demonstrating a commitment to continually improving and enhancing the performance of all offshore operations.

Technical Notes are part of the OGUK suite of Guidelines, free for our members.

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