Barrier Management in the Design of Unattended Offshore Oil and Gas Installations

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It is the Norwegian regulator requirement that operators of offshore oil and gas installations stipulate the strategies and principles on which the design, use and maintenance of safety barriers shall be based, so that barrier function is ensured throughout the life time of the facility. It is a requirement of most operators that a safety strategy be developed for each, installation. Such requirements can therefore be applied to other offshore sectors in order to demonstrate that the risks are ALARP. This paper will explain the main purpose of barrier management, the processes, systems, solutions and measures which must be in place to ensure the necessary risk reduction through the implementation and follow-up of barriers and specific examples of typical non-physical and physical barriers will be provided. The purpose will therefore be to define the role of each barrier and the basis for development of that barrier through design phases of the project, to ensure that it will fulfil that role in operation. A typical overall safety strategy will be developed, on which the strategy for each barrier will be summarized. The strategy will recognize that once hazards have been eliminated as far as practicable, the most effective means of protecting personnel is to avoid exposing them to the hazard. It also recognizes that the basis for responding to incidents occurring is to escape from the immediate area and allow installed safety protection systems to isolate hydrocarbon inventories and in the worst case evacuate, rather than attempt to manage a major incident with the personnel on the platform.

Keywords: Normally Unmanned Installation, barrier management, inherently safe design, ESD

Introduction

For most offshore oil and gas projects, a Hazard Register is developed based on the outcome of various hazard studies, notably the Hazard Identification (HAZID) study and the Hazard and Operability (HAZOP) study. The Hazard Register includes a summary of identified Major Accident Hazards (MAH), their possible causes, consequences and the safety barriers (including Inherently Safer Design (ISD) measures and Safety Critical Equipment (SCE)) implemented to reduce risk. It is a 'live' document to be updated with design development.

It is a requirement of the Norwegian regulator that the operator of a facility shall stipulate the strategies and principles on which the design, use and maintenance of safety barriers shall be based, so that the barrier function is ensured throughout the lifetime of the facility. It is also a requirement of most operators that a safety strategy be developed for each installation. The purpose of this paper is to define the role of each barrier typically identified in the Hazard Register and the basis for development of that barrier through the design phases of a project, to ensure that it will fulfil that role in operation. This is in particular context of a Normally Unmanned Installation (NUI).

Overall Safety Strategy

The overall safety strategy for an offshore oil and gas installation may be summarised in the following hierarchy:

- Eliminate as far as practicable by applying ISD principles to all aspects of design
- Minimise exposure of personnel to the remaining hazards by minimising manning requirements for typical installations
- Provide barriers to prevent hazards occurring, whilst ensuring that such barriers do not lead to excessive manning requirements for testing, inspection and maintenance
- Provide clear means of escape and evacuation, so that should an incident occur personnel are able to reach a safe shelter and if necessary evacuate the platform as quickly as possible
- Provide barriers to control and mitigate the effects of hazards, again ensuring that manning requirements are not increased

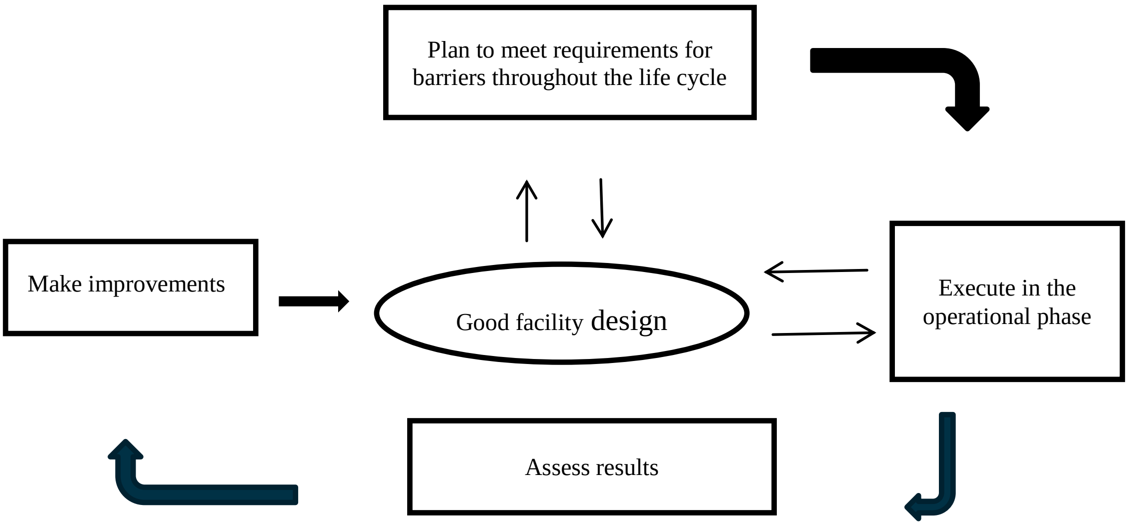
This strategy recognises that once hazards have been eliminated as far as practicable, the most effective means of protecting personnel is to avoid exposing them to the remaining hazards. This is particularly applicable to a small facility where the basis for responding to incidents occurring is to escape from the immediate area and allow the installed safety protection systems to isolate hydrocarbon inventories and in the worst case evacuate, rather attempt to manage a major incident with the few personnel on the platform.

Barrier Management

Barrier Management Model

The management of barriers is best illustrated in Figure 1.

Figure 1 Model for Barrier Management



This model is based on a process for establishing the risk picture and barriers in planning, designing and constructing offshore oil and gas platforms. This basis is then monitored, reviewed and updated as required as the platform is operated.

List of Barriers

The model for barrier management described in the previous section focuses on physical barriers that are implemented during the design and operational phases. However, there are also non-physical barriers established that have a significant impact on safety of such platforms.

- **Inherent Safety Strategy**: The design of such installations must maximise the use of Inherently Safer Design, focussing on elimination and prevention of hazards rather than implementing mitigation and control measures. This strategy is adopted in all design engineering aspects and is implemented through design review including model reviews through all design phases. It is evident in the strategy adopted for several physical barriers described in this paper, including optimisation of layout and selection of equipment for reducing maintenance and removal of equipment where possible.
- **Unattended Operation**: Normally unmanned facilities are designed with remote operation as far as practicable. The most effective means of reducing risk to personnel operating an offshore facility is to minimise exposure to hazards. On an unattended facility the duration and number of routine tasks must be managed to ensure that they can be done in daylight hours. All equipment installed on the platform requires periodic inspection, testing and maintenance, which in turn increases the manning requirements for the platform and the overall risk to personnel, therefore a strategy of minimising equipment count where possible is essential.
- **Minimising Maintenance and Inspection**: As noted above, safety on the platform will be maximised by minimising requirements for personnel to visit the platform. This is achieved through minimising requirements for routine maintenance and inspection tasks, by eliminating equipment where practicable, selecting high reliability, low maintenance equipment and by ensuring that procedures minimise the time required to complete such tasks.
- **Trained Personnel for Working on an Unmanned Facility**: Teams should be highly experienced in operating and maintaining a normally unmanned facility.

Physical Barriers

Some typical physical barriers that maybe identified in the HAZID review and the Hazard Register are listed in Table 1.

Table 1 Physical Barriers

Ref.	Barrier
1	Layout and Arrangement*
2	Structural Integrity
3	Fire and Gas Detection*
4	Emergency Shutdown (ESD)*
5	Ignition Source Control
6	Heating, Ventilation and Air Conditioning (HVAC) and Natural Ventilation
7	Control of Spills*
8	Active Fire Protection (AFP)*
9	Passive Fire Protection (PFP)*
10	Emergency Power and Lighting
11	Public Address (PA), Alarm and Emergency Communication
12	Escape and Evacuation*
13	Blowdown and Flare/Vent System
14	Process Safety*
15	Barriers to Prevent Loss of Containment*
16	Barriers to Prevent Ship Collisions*
17	Well Gas and Fluid Containment
18	Rescue and Safety Equipment

These barriers (marked *) are discussed in more detail below. For each barrier, the following are presented:

- **Barrier Function**: The job or role of the barrier. Examples include preventing leaks, preventing ignition, reducing fire loads and ensuring acceptable evacuation.
- **Interfaces and Dependencies**: In general barriers should function independently of others. However, in many cases the performance of a barrier may affect another barrier, particularly since some barriers have preventative functions and others mitigate or control hazards. An example is fire and gas detection, which initiates both ESD and AFP systems.
- **Strategy**: This presents the ways in which the barrier will be designed to meet the stated barrier function for the platform.

Layout and Arrangement

Barrier Function

The layout of an installation will reduce the probability and the consequences of accidents through location, separation and orientation of areas, equipment and functions. The layout can:

- Minimise the possibility of hazardous accumulations and spread of both flammable liquids and gaseous hydrocarbon
- Provide clear arrangements for escape and evacuation
- Minimise the probability of ignition
- Separate non-hazardous areas from those designated as being hazardous
- Minimise the consequences of fire and explosions and thereby reduce escalation risk;
- Facilitate ease of maintenance to limit time on the platform; &
- Facilitate effective emergency response.

Dependencies and Interfaces

Layout and arrangement have interfaces with all the technical safety barriers.

Layout Strategy

The layout of the platform incorporates the following features:

- Segregation of hazardous areas of the platform from non-hazardous areas and sources of ignition by a fire and blast-rated division;
- Free ventilation for dispersion of any flammable gas by positioning equipment to provide an open layout, avoiding stagnant air pockets;
- Provision for containment and safe disposal of hydrocarbon liquid spillage by kerbed or bunded areas where appropriate;
- Atmospheric vents designed so that dispersion of flammable gas cannot reach the platform or any adjacent jack-up rig.
- Enclosed areas located in non-hazardous areas so that 'safe by ventilation' areas are eliminated;
- The crane, lifting beams and laydown areas located to minimise lifting, swing load and impact damage;
- HVAC air intake points located so as to avoid potential gas or smoke ingress and be located as far as possible from HVAC exhaust ducts;
- Access to mechanically ventilated rooms is located well away from hazardous areas (a minimum of 3 metres from any hazardous area);
- Provisions for maintenance for all equipment has been considered;
- Escape and mechanical handling routes have reserved volumes within the 3D model;
- Risers and conductors are located within the jacket and positioned such that the likelihood of damage from ship impact and dropped objects is minimised;
- Riser ESDVs are located above the 100 year wave elevation and designed to withstand the 10,000 year wave condition;
- Pig launchers and receivers are located in open, naturally ventilated areas, at the periphery of the platform, and with hatches directed away from equipment and structures (including any located on the jack up rig); &
- Topsides riser ESD valves are located as low down the riser as practicable, so as to minimise the exposure to damage below the ESDV and release of non-isolatable pipeline inventories.

Fire and Gas Detection Systems

Barrier Function

The function of the gas detection system is to monitor continuously for the presence of flammable gas, to alert personnel and allow control actions to be initiated manually or automatically to minimise the probability of explosion and/or fire by segregating and minimising the size of hydrocarbon releases.

The function of the fire detection system is to monitor continuously for the presence of a fire, to alert personnel and allow control actions to be initiated manually or automatically to minimise the likelihood of fire and associated risks to personnel, by isolating inventory.

Dependency and Interfaces

The fire and gas detection system has the following interfaces:

- ESD
- Ignition source control (executed by ESD)
- HVAC (shutdown of ventilation and dampers)
- Blowdown (enabled by ESD where appropriate)
- Active Fire Protection
- Alarm system (activation of alarm is an automatic action by fire or gas detection)
- UPS system (provides battery power supply independent of main power to support safety functions to shut down and isolate hydrocarbon inventory)

Strategy

The common function of the detection systems is to protect personnel on the platform. However it must be noted that personnel are only at risk when they are on the platform, and that detection systems themselves require maintenance and testing, with associated exposure of personnel to hazards, in order to ensure that the barrier function can be met. The strategy for this barrier is therefore to avoid over-complexity and excessive testing requirements, while protecting personnel from hydrocarbon releases and their consequences.

A fire and gas detection system is used to alert personnel on the platform of hazardous incidents and to initiate appropriate executive action. The fire and gas detection system is an independent system separate from the process control system, and will be active both when the platform is manned and unmanned.

Emergency Shutdown (ESD)

Barrier Function

The function of the ESD system is to prevent escalation of abnormal conditions into a major hazardous event and to limit the extent and duration of any such evens that do occur. This function in general is achieved by:

- Stop and isolate hydrocarbon flow on the platform
- Shutdown process equipment
- Isolate non-essential power
- Sectionalise hydrocarbon inventories
- Enable blowdown
- Reduce ignition probability

Dependency and Interfaces

The ESD system has interfaces with the following barriers:

- F&G system (F&G system gives input signals to ESD system)
- Ignitions source isolation (ignition source isolation is an automatic action by ESD)
- PSD (ESD activation will cause PSD trips)
- Alarm system (activation of alarm is an automatic action by ESD)
- UPS system (provides battery power supply independent of main power)
- Process control system (interfaces only)

Strategy

In order to meet the barrier function described above, the ESD system should be developed as follows:
The ESD system will:

- Via the alarm system, provide visual and audible indication on the platform of an ESD event
- Provide indication of an ESD event on the ESD panel in the emergency shelter or LER and/or the control room
- Be designed to be fail safe, i.e. activates on de-energisation of output

Control of Spills

Barrier Function

Control of spills is fulfilled through the open drains system. The purpose of the open drain is to provide measures for containment and proper disposal of liquids.

Dependency and Interfaces

This barrier has interfaces with the following barriers:

- AFP (the drainage system for each area should be capable of receiving the maximum amount of firewater that may be expected in the area)
- ESD system

Strategy

Drip trays should be provided under equipment liable to leak chemicals or liquid hydrocarbons in normal operation or during maintenance. They should be routed to the open hazardous drains.

Open drains headers from areas classified as non-hazardous should be segregated from any open drains headers in areas classified as hazardous. Backflow from the hazardous open drain to the non-hazardous open drain should be prevented by collection in separate headers.

Drip trays should be provided as necessary on plated areas below the weather deck in order to control the spread of accidental liquid hydrocarbon spills or chemical spills. Drip trays should be located where there is potential for a significant liquid spill and generally be located to segregate process areas from utilities or refuge areas. Drainage from drip trays should be provided.

The helideck should have a dedicated drainage system for removing liquid to the sea. The drainage should be adequate to remove spills of fuel and to prevent standing rainwater on the surface and to cater for the maximum anticipated discharge from the helideck foam system.

Active Fire Protection

Barrier Function

The design of the AFP systems should reflect the fire hazards identified in the HAZID review. For small, unattended installations, topsides inventories should, by design, be low and minimised. As such, durations of releases and fires will be short once inventories are isolated by the ESD system. Taking this into account, a deluge system will be ineffective in fighting process fires. AFP will however be effective in fighting fires on the helideck.

A further role of AFP is to prevent escalation to other hydrocarbon inventories, where escalation would significantly increase the consequences of the incident and the risk to personnel. On such facilities under consideration, escalation can be limited by:

- Low process inventories resulting in short fire durations.
- High mechanical design pressure relative to operating pressures: the time required to heat pipework and vessels to yield exceeds calculated the fire durations.
- Segregation (as far as practicable on a small platform) of bulk diesel storage from other equipment, and the use of deck trays and kerbing to limit the spread of diesel spills.
- Methanol storage can be drained directly to sea if required. Drip tray limits the spread of methanol.
- Diesel storage volume is minimised

Dependency and Interfaces

An AFP system has interface/interactions with the following barriers:

- Fire detection system (activation of firefighting functions is an automatic action by fire detection
- Ignition source control (equipment affecting firewater system can be subject to shut down or special requirements).
- ESD

Passive Fire Protection

Passive fire protection is the preferred method for preventing escalation of fire; it is by design, inherently better as it is a low maintenance method of protection.

The function of PFP is to:

- Prevent a fire escalating within an area and/or to other areas as a result of structural failure or loss of containment;
- Ensure survival of the emergency shelter and associated evacuation routes for sufficient time for the platform to survive a major accident or until all personnel can be safely evacuated; and
- Protect safety critical items such as the riser ESD valves.

Dependency and Interfaces

PFP and fire divisions protect barriers intended to function during a fire. PFP has interface/interactions with the following barriers:

- AFP
- Escape and evacuation
- Structural integrity (load bearing capacity/structural capability)

Strategy

PFP for structures and equipment is assessed based on Design Accidental Loads (DALs) from fire events and specified based on the duration of such events. Fire and blast walls should be provided to ensure protection of the Emergency Shelter and means of evacuation including the lifeboat. The blast wall should provide sufficient resistance against jet fires and have a minimum rating for a jet fire of 15 minutes.

PFP should be applied to load bearing structures (including vessel supports and pipe supports) where failure of the structure could lead to escalation of the fire, affect the function of emergency equipment or hinder safe evacuation of personnel. ESD valves should also be protected.

Escape and Evacuation

Barrier Function

The purpose of the escape routes is to ensure that personnel may leave areas in case of a hazardous incident by at least one safe route and to enable personnel to reach the muster area within the Emergency Shelter from any area of the platform.

The purpose of the evacuation system is to ensure clear, rapid and secure means of abandonment of the installation for the maximum PoB, following a hazardous incident and a decision to abandon the platform.

On small facilities, the ability to escape and evacuate quickly and safely is the primary protective barrier for personnel in the event of a major accident.

Dependency and Interfaces

Escape and Evacuation has interfaces with the following barriers:

- Emergency power and lighting (lighting for escape and rescue)
- Alarm / PA system (warning and directions for escape and evacuation)

- ESD (pushbuttons located alongside escape routes and on mustering areas)
- Structural integrity (critical structures supporting the escape and evacuation facilities must withstand DAL in the required period of time).

Strategy

To meet the defined barrier function, escape and evacuation facilities are provided as follows:

Escape routes provide clear and direct access to the muster area. Surfaces are no slip and fully marked with photo luminescent paint. At least two escape routes are provided from any external area and no dead end corridor or platform exceeding 5m.

Sliding doors are preferred for external boundaries. All hinged exit doors open in the direction of escape without blocking escape routes. For the Emergency Shelter, the direction of escape is into the shelter.

The primary muster area is the Emergency Shelter. Sufficient free room of at least $0.4m^2$ per person should be allowed to enable the donning of life jackets and survival suits. It should be designed for a minimum duration of 30 minutes from the effects of smoke and heat, while maintaining suitable internal conditions for personnel in terms of air quality, humidity and air temperature.

The preferred means of evacuation is by helicopter. However in the event of emergency evacuation being required a helicopter may not be available, so the primary means of emergency evacuation will be a freefall lifeboat with a minimum capacity of 2x100% of normal PoB plus a helicopter crew. The lifeboat should be readily accessible from the Emergency Shelter.

Secondary means of emergency evacuation will be via an escape chute system to life rafts, sized for the maximum PoB. The chute should be deployable from the platform and personnel will descend the chute to life rafts which will inflate automatically.

Grab bags should be located within the emergency shelter, each containing a survival suit, 10 minute smoke hood, torch and fire resistant gloves. Lifejackets should be located in a cabinet adjacent to the access route to the lifeboat, and additional lifejackets should be adjacent to the escape chute.

Process Safety

Barrier Function

The function of process safety as a barrier is to ensure that process conditions do not exceed specified process safety limits and to control abnormal operating conditions to prevent possible hydrocarbon release. This is typically done by:

- Stopping hydrocarbon flow
- Shutdown of process and utility equipment
- Pressure relief

Dependency and Interfaces

The process safety system is designed to operate independently of other systems. However, functionally there are interfaces with the following barriers:

- ESD
- Emergency power

Strategy

Process safety systems typically include PSD, PSV and local instrumented functions (including HIPPS). However, an inherently safer design approach should be applied; where practicable, a design pressure should be selected which equals or exceeds the wellhead shut-in pressure, which is the maximum possible system pressure.

Barriers to Prevent Loss of Containment

Barrier Function

The function of this barrier is to ensure that the potential for leaks to occur is minimised.

Dependency and Interfaces

Preventing loss of containment has interfaces with the following barriers:

- AFP (protection to prevent escalation from a possible fire)
- PFP (protection to prevent escalation from a possible fire)
- Process safety (barrier to prevent critical process conditions and thereby leaks)
- Explosion barriers (protection to prevent escalation from possible explosion)
- Structural integrity (loss of structural integrity may result in loss of containment)
- Blowdown (protection against high pressures from blocked outlets and fires)

Strategy

The general strategy for preventing loss of containment is to maximise the integrity of pipework and vessels through design, and minimising reliance on inspection, maintenance and testing programs during operation. The key measures adopted for leak minimisation are described below:

- Hydrocarbon pipework should be fully welded where practicable
- Corrosion resistant alloys should be employed
- Insulation of flange joints should be avoided
- Use of flexible hoses should be minimised
- An assessment of the likelihood of failure of pipework due to vibration induced fatigue should be carried out

Barriers to Prevent Ship Collisions

Barrier Function

To reduce the risk of a passing ship or supply vessel colliding with the platform.

Dependency and Interfaces

This barrier has interfaces with the following barriers:

- Structural integrity (failure of this barrier will place a demand on structural integrity of the platform)
- Escape and evacuation
- PA, alarm and emergency communication

Strategy

The strategy for prevention of ship collisions is that the platform should have a collision monitoring system able to detect a vessel on collision course at least 50 minutes before collision. Navigational aids should be provided to ensure that passing vessels are aware of the location of the platform.

Conclusions

The overall safety strategy for an offshore oil and gas installation has been presented, along with a model for the management of safety barriers. Both non-physical and physical barriers have been described along with barrier function, interfaces and dependencies and safety strategy for a selected number of barriers. This has been set out with the design of a NUI in mind.