



PETROLEUM SAFETY AUTHORITY  
NORWAY

Principles for barrier management in the petroleum industry

# BARRIER MEMORANDUM 2017

**DETECT**  
**REDUCE**  
**LIMIT**



**DETECT  
REDUCE  
LIMIT**

## PREFACE

Risk shall be managed by means of safe and robust solutions. These may be technical, organisational and operational solutions aimed at preventing failure, hazard and accident situations arising. However, experience and accidents show that, despite having established safe and robust solutions, such situations will still arise from time to time. In such situations, it is important to have barriers as an additional protection in order to maintain the necessary level of safety.

History has shown that petroleum activities cause major accidents and incidents with major accident potential. Examples of these include:

- the structural accident on the Alexander L. Kielland floatel in 1980 in which 123 people died
- the uncontrolled hydrocarbon leak escalating to a fire on Piper Alpha in 1988 which caused 169 fatalities
- the uncontrolled blowout at Snorre A in 2004
- the fire and explosion at the Texas City refinery in 2005 in which 15 people lost their lives
- the Deepwater Horizon well control accident in 2010 in which 11 people died and a large leak of hydrocarbons caused major environmental damage
- an HC leak at Gudrun in 2015 which, under marginally different circumstances, could have turned into a major accident with loss of life
- a structural incident on COSLInnovator in 2015 in which caused one fatality, with the potential for more

These are accidents and incidents where the safe and robust solution proved inadequate. In addition, barriers failed, or were inadequate or missing.

**“Barrier management involves systematically ensuring that necessary barriers are identified and in place, in order to provide protection in failure, hazard and accident situations”**

Barriers are measures intended to detect failure, hazard and accident situations at an early stage, reduce their potential for propagating and limit harm and disruption. The functions that barrier elements provide may be technical, operational and organisational. Barrier management comprises the coordinated activities undertaken to establish and maintain barriers so that they retain their functions at all times.

Since 2002, the Management Regulations have stipulated a general requirement for barriers, but the implementation of this requirement has taken time. We have seen that some companies have included the human role in the barrier functions to a limited extent. On the basis of these experiences, we have decided to update the memorandum.

The memorandum has been reworked since the previous version in 2013. The distinction between “safe and robust solutions” and “barriers” has been made in order to clarify what barriers are and what they are not. The interaction between technical, organisational and operational elements is expounded on. Chapters about barrier management in the concept and design phases, as well as the operational phase, have been incorporated. An appendix has also been added, containing examples from various specialist fields, including security.

The purpose of this memorandum is to provide information about the basis for Section 5 of the Management Regulations about barriers and related regulatory requirements. We do this by setting the requirements in the regulations in a clearer context in order to make their intention more explicit. This memorandum introduces no new requirements. Audits we perform will be based on the requirements as defined in the regulations. The memorandum does not form part of the petroleum regulations.

*Anne Myhrvold, Director General,  
Petroleum Safety Authority Norway*

## Summary

### WHY BARRIER MANAGEMENT?

The object of barrier management is to establish and maintain barriers in order to handle the risks faced at any time. This is achieved by implementing barriers that contribute to risk reduction in failure, hazard and accident situations.

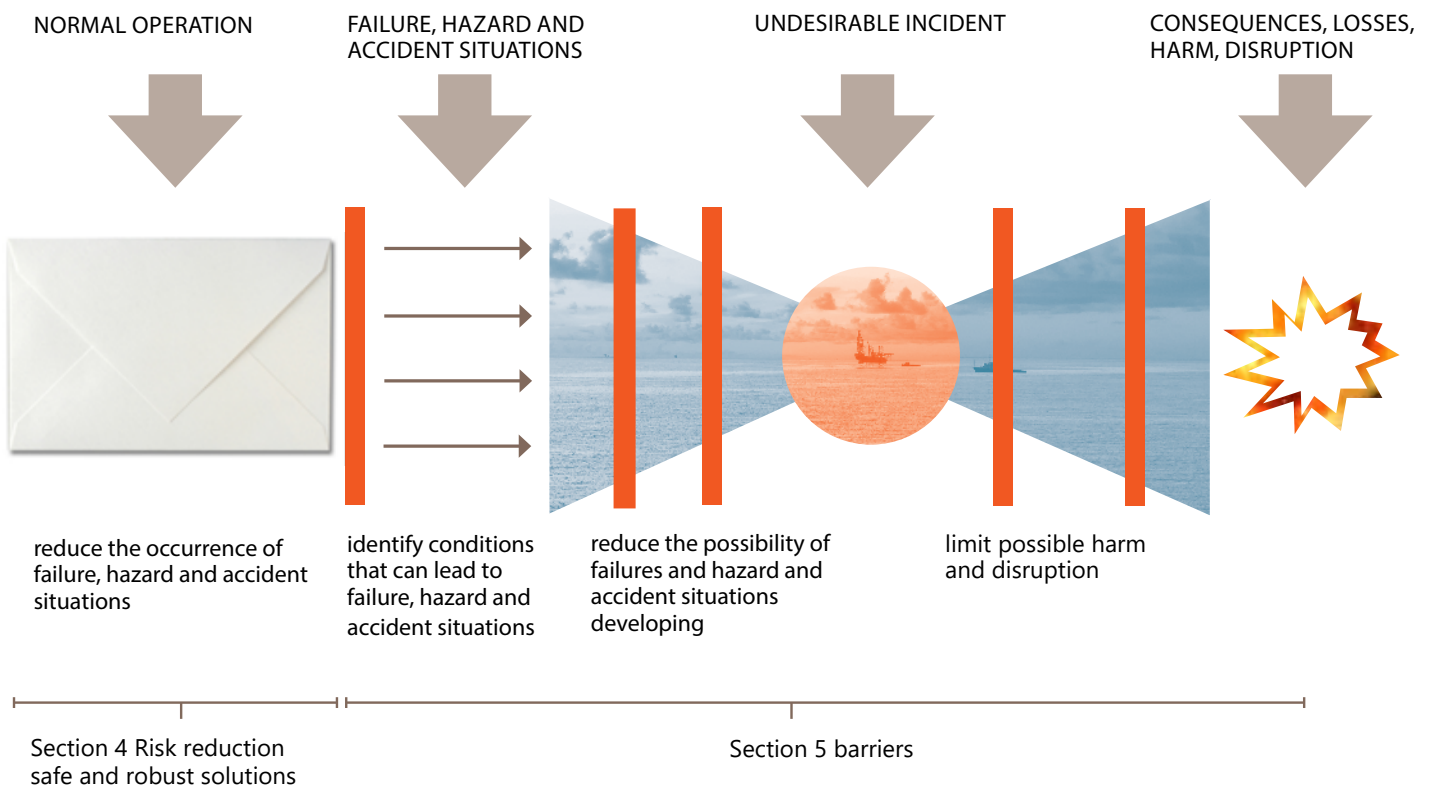
**“No matter how safely and robustly we design and operate petroleum activities, failure, hazard and accident situations may still arise. This is when we need barriers to help protect against accidents.”**

### WHAT ARE BARRIERS?

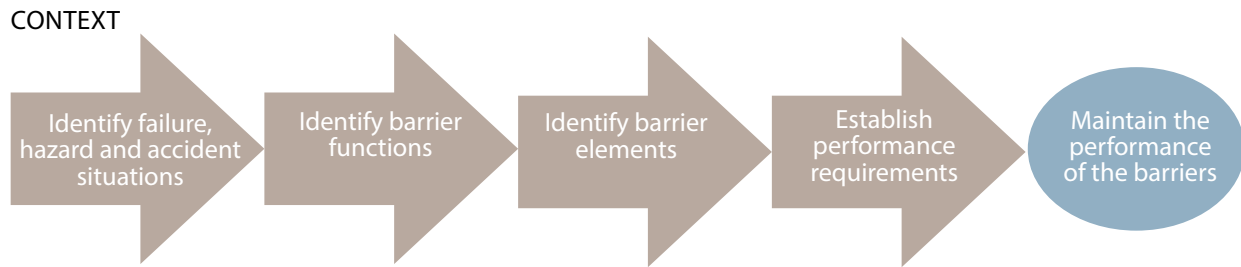
Barriers are measures whose function is to offer protection in failure, hazard and accident situations. Their function is provided by barrier elements which may be technical, organisational or operational. Technical elements might be, for example, sensors that measure the pressure in a well, while organisational and operational elements might be mudloggers and drillers who monitor, detect and implement measures in the event of loss of well control.

### WHAT IS BARRIER MANAGEMENT?

Barrier management involves ensuring, through a systematic and continuous process, that necessary barriers are identified and in place, in order to provide protection in failure, hazard and accident situations. These situations may be linked to the risk picture on or in a specific facility or plant, or in a specific area of the facility or plant. In accordance with Section 5 of the Management Regulations, barriers must detect incipient incidents, prevent the propagation of a chain of events and limit damage.



**Figure 1:** Traditional barrier diagram showing functions (in red) to handle failure, hazard and accident situations outside of normal operations (based on Ersdal 2014)



**Figure 2:** Key points in barrier management

Barrier management also involves ensuring that the different barrier elements in combination have the properties required for fulfilling their intended function.

Barrier elements should have

- **functionality:** this can be understood as the influence they have on the chain of events (assuming their presence)
- **integrity:** this can be understood as their ability and potential to be in place and intact at all times
- **robustness:** this can be understood as their ability to withstand situations that are somewhat different from the intended circumstances and that they “survive” a failure, hazard and accident situation

Barrier management should begin with an understanding of the context the barriers are intended to function in. For example, there will be large differences in their design depending on whether a facility is unmanned or manned, or whether it produces oil or gas. The context may influence how one conceptualises potential failure, hazard and accident situations. It also affects which requirements for protection may arise.

It is important to identify which failure, hazard and accident situations need to be handled. Facility- and area-specific risk analyses may also be a useful source for helping to identify these. In order to protect against and combat these situations, the necessary barrier functions must be established (Section 5 of the Management Regulations). A function often comprises several barrier elements.

Requirements must be defined for the performance of the barrier elements in order to ensure that the barrier fulfils its function. This may include requirements for functionality, integrity and robustness. Performance requirements must be defined for the technical elements, as well as the organisational

and operational ones. For organisational elements, this may include requirements related to specific competence, training and safety drills of the persons involved. For operational elements, this may include requirements for response times and for how the operations are to be performed.

Many factors will affect the performance of the barrier elements, such as weather and visibility. It is important to have an overview of which performance-influencing factors are significant, and in which situations the barrier or barrier element cannot be expected to function. One example here might be weather preventing the launch of a man overboard boat (MOB). It is important for barriers to be robust. It is impossible ensure that all potential future incidents have been identified, or that failure, hazard and accident situations will develop as predicted. It is therefore necessary to take uncertainty into account.

Barrier management is a continuous process. It does not only concern the choice of technical, organisational and operational solutions during the concept and design phases. It is also about ensuring that the solutions retain their intended properties over time. For example, this might mean people who directly or indirectly affect the risk picture or the barriers’ properties having an understanding of the consequences of their decisions and actions. Even if good barriers have been planned, situations that have not been planned for may arise. The risk picture, manning, personnel, production, assumptions, and condition of technical elements will change, engendering a need for new or altered risk-reducing measures. Deficient follow-up of the condition of the barrier elements may result in a failure of necessary performance when the need arises.

The activities and solutions comprised by the barrier management should be appropriate for achieving a real risk reduction.

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## 1 Introduction

### 1.1 OBJECTIVE

This memorandum describes principles for barrier management in petroleum activities in Norway. It was first issued in 2011 and updated in 2013, as part of our main prioritisation of barriers. The aim of this memorandum is to provide information about the basis of Section 5 of the Management Regulations concerning barriers, as well as related regulatory requirements.

**“The aim is to provide information about the basis of barrier management”**

Over a number of years, a focus on barrier management has contributed to an increase in competence and understanding of the importance of barriers in preventing and limiting the propagation of accidents. It has also led to the enhancement of the companies' systems for barrier management.

**“The memorandum aims to clarify the interaction between technical, operational and organisational barrier elements”**

However, through audits and inspections, we have found that the companies have identified the human contributions to providing barrier functionality only to a limited extent. The focus has mainly been directed at the technical barrier elements, whereas operational

and organisational elements have been identified and emphasised to a lesser degree. Based on these experiences, we have perceived a need to update the memorandum, in order to clarify the interaction between technical, operational and organisational barrier elements. The updated memorandum is intended to help show how the interaction between technical, operational and organisational elements included in barrier functions can be planned for and monitored over time. “Who does what with which equipment in failure, hazard and accident situations” has been developed as an instructional phrase for clarifying the interaction between organisational, operational and technical elements. Operational and organisational elements are tasks that personnel must perform in order for a barrier to function as intended. However, the fundamental meaning is unchanged from previous versions of this memorandum.

### 1.2 TARGET GROUP

The target groups for this memorandum comprise everyone who has special responsibility for deciding on, designing, implementing and following up barrier management systems.



## 2 Definitions

<b>Barrier:</b>	A measure intended to identify conditions that may lead to failure, hazard and accident situations, prevent an actual sequence of events occurring or developing, influence a sequence of events in a deliberate way, or limit damage and/or loss.
<b>Barrier function:</b>	The task or role of a barrier.
<b>Barrier element:</b>	Technical, operational and organisational measures or solutions involved in the realisation of a barrier function.
<b>Technical barrier element:</b>	Equipment and systems involved in the realisation of a barrier function.
<b>Organisational barrier element:</b>	Personnel with defined roles or functions and specific competence involved in the realisation of a barrier function.
<b>Operational barrier element:</b>	The actions or activities which personnel must perform in order to realise a barrier function.
<b>Barrier strategy:</b>	Plan for how barrier functions, on the basis of the risk picture, are implemented in order to reduce risk.
<b>Barrier management:</b>	Coordinated activities for establishing and maintaining barriers so that they fulfil their functions at all times.
<b>Performance requirement:</b>	Verifiable requirement for the properties of the barrier elements in order to ensure that the barrier is effective.
<b>Robust barriers:</b>	The concept that barriers should incorporate margins in respect of changed assumptions and uncertainties, and function as intended in failure, hazard and accident situations.
<b>Performance-influencing factors:</b>	Factors identified as having significance for barrier functions and the ability of barrier elements to function as intended.
<b>Context:</b>	Factors in the surroundings that are relevant for assessing safety and the need for barriers.
<b>Major accident:</b>	An acute incident, such as a major discharge/emission or a fire/explosion, which immediately or subsequently causes several serious injuries and/or loss of human life, serious harm to the environment and/or loss of substantial material assets.
<b>Risk:</b>	The consequences of the activity and its associated uncertainty.
<b>Risk picture:</b>	The risk picture is an understanding and overview of potential failure, hazard and accident situations and how to protect against them.
<b>Risk management:</b>	Coordinated activities to direct and control an organisation with regard to risk.

*The term “barrier” is defined differently in different literature and within different specialist domains. Detailed discussion of our definition compared to others is provided in Lauridsen et al. (2016).*

### 3 What are barriers and barrier management?

#### 3.1 BARRIER MANAGEMENT IS AN INTEGRAL PART OF RISK MANAGEMENT

**“The function of barriers is to help handle failure, hazard and accident situations”**

Barrier management represents an integral part of the companies' risk management which in turn forms an integrated part of their corporate governance, as illustrated in Figure 3. As a result, management standards such as ISO:9000 and ISO:31000 can also form a basis for barrier management.

Barrier management is important in order to have a clear process for handling failure, hazard and accident situations. Barriers must be established when the risk management process detects failure, hazard and accident situations in which there is a need for extra protection.



**Figure 3:** Barrier management – an integral part of risk management and corporate governance.

#### 3.2 BARRIER MANAGEMENT AND RISK REDUCTION

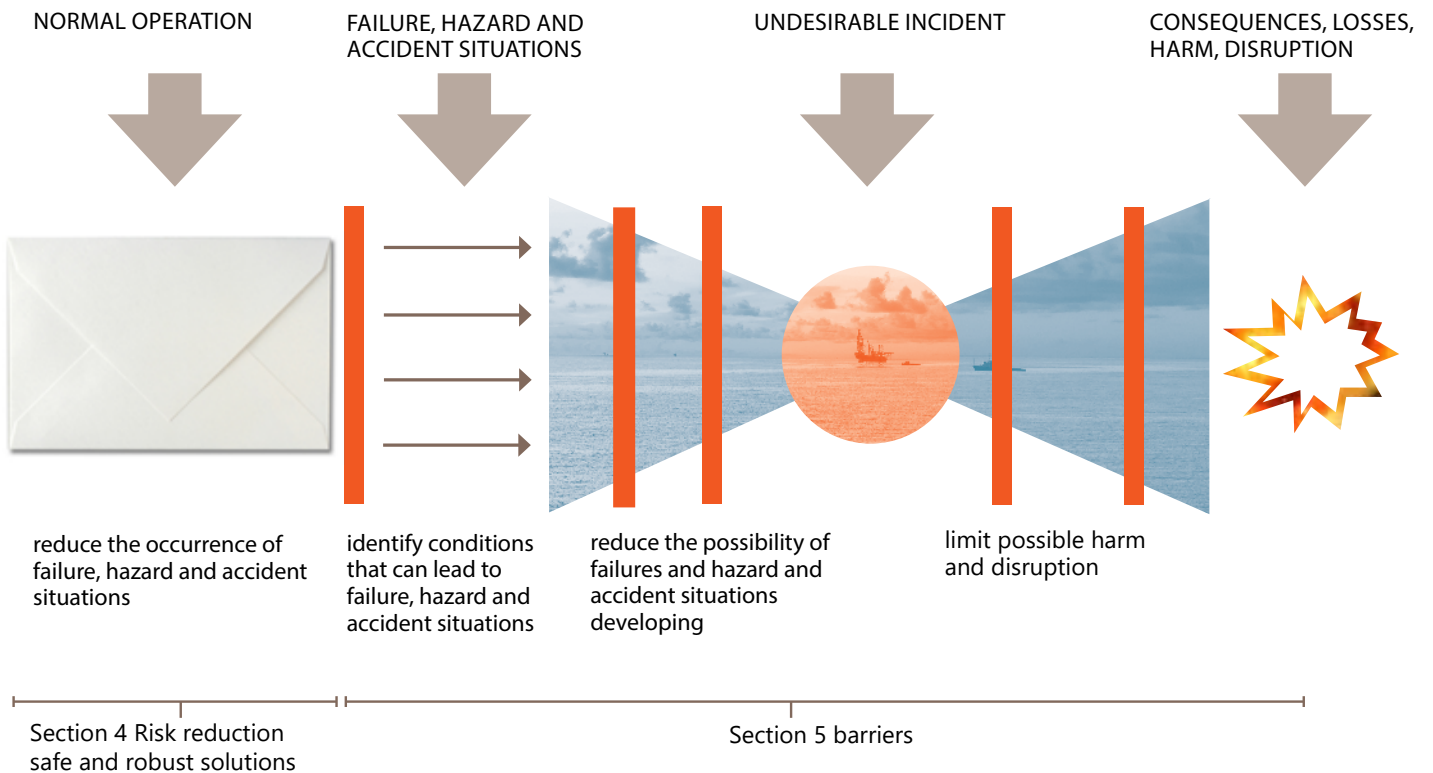
**“The aim of barrier management is risk reduction”**

The primary purpose of barrier management is to establish and maintain barriers so as to be able to handle the risk faced at any given time. This is done by having barriers whose function is to help prevent failure, hazard and accident situations occurring or which restrict the consequences if they do occur. Barrier management involves coordinated activities for establishing and maintaining barriers so that they fulfil their functions at all times.

Barriers supplement a safe and robust solution

**“Barriers supplement a safe and robust solution”**

The regulations differentiate between establishing a solution that is optimal for avoiding getting into failure, hazard and accident situations (Section 4 of the Management Regulations concerning risk reduction), and barriers intended to prevent failure and hazard situations developing into incidents and damage, loss and disruption (Section 5 of the Management Regulations concerning barriers). Regardless of the efforts made to secure a safe and robust solution, failure, hazard and accident situations will occur. Barriers must then fulfil their functions in order to help handle such situations. This is illustrated in Figure 4.



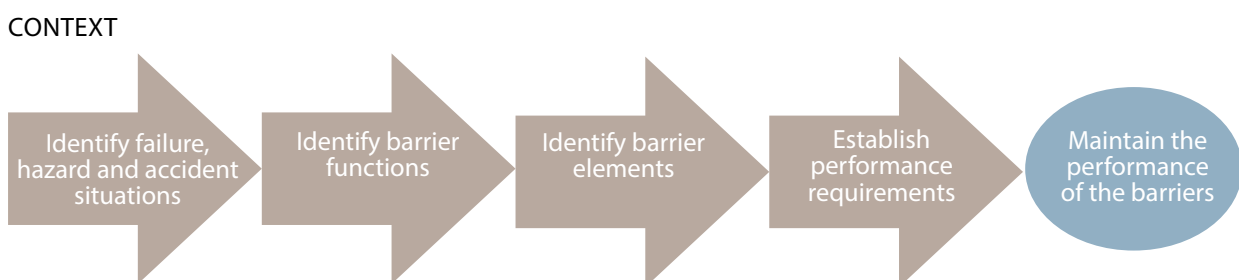
**Figure 4:** Model to illustrate the relationship between a safe and robust solution and the place of barriers in risk management (based on Ersdal 2014)

### 3.3 BARRIER MANAGEMENT AND BARRIER STRATEGY

The barrier strategy is a plan for how barriers should be established on/in the individual facility or plant. The barrier strategy includes establishing which barrier functions are necessary. It also determines which technical, operational and organisational barrier elements must be included in order to fulfil the function. Performance requirements for these elements must also be part of the strategy. Barriers must be established based on the specific risk picture for the individual areas of the facility or plant and for different activities or operations.

The main features of barrier management are illustrated in Figure 5.

**“How, given the risk picture, should the barriers help handle failure, hazard and accident situations? What should the barriers do?”**



**Figure 5:** Main features of barrier management.

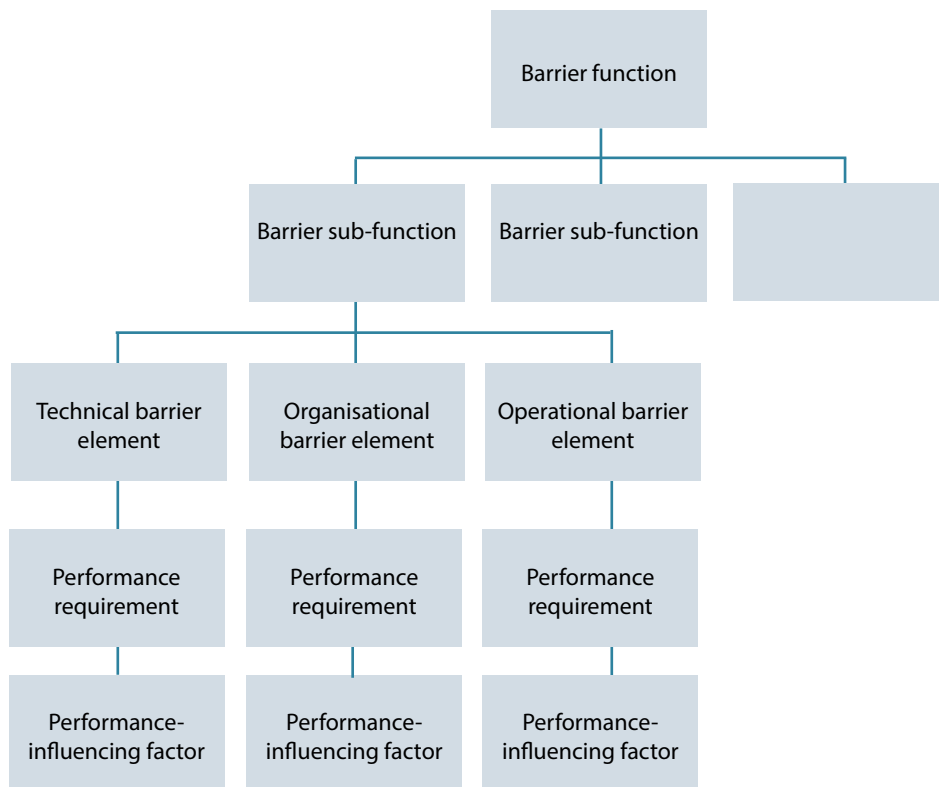
### 3.4 BARRIER HIERARCHY

The realisation of a barrier function can be illustrated using a hierarchy consisting of

- the function at the highest level (what should the barrier do?) and sub-functions below this if necessary
- elements (specific equipment, personnel and operations designed to take care of the function)
- performance requirements (verifiable requirements for the elements' properties)
- performance-influencing factors (factors identified as having significance for barrier functions and the ability of barrier elements to function as intended)

*An example of a barrier function might be to "Reduce explosion risk". Sub-functions linked to this might be "Reduce duration and size of leaks", "Limit opportunities for build-up of gas cloud", "Reduce explosion loads" and "Design the area to withstand explosion loads". The sub-function "Reduce duration and size of leaks" can in turn be split into "Detect the leak", "Reduce pressure in leaking segment" and "Isolate leaking segment". For the sub-function "Reduce pressure in leaking segment", for example, push buttons, Fire & Gas logic and valves will represent technical barrier elements. If a control room operator must initiate manual actions in order to realise the "Reduce pressure in leaking segment" function, that person will be incorporated as an organisational barrier element. Actions carried out will be an example of an operational barrier element.*

Figure 6 shows a generic example of such a hierarchy.



**Figure 6:** Barrier hierarchy

## 4 General principles for barrier management

### 4.1 SPECIFIC ASSESSMENT

#### “Barrier management must be based on a specific risk picture for the plant, facility, area or operation”

The risk picture will be different for different facilities and plants, areas and operations. An overall assessment of failure, hazard and accident situations and barriers at facility and plant level will be important for platform and onshore management. For personnel working in a specific area or on a specific task, assessments are required for the specific areas of the facility and for the specific operations in order to obtain a good risk picture. This means that failure, hazard and accident situations must also be assessed in sufficient detail so as to identify the situations where the individual barrier element has a function.

### 4.2 PRIORITISATION OF BARRIER FUNCTIONS AND ELEMENTS

As a fundamental principle, priority should be given to likelihood-reducing measures over consequence-reducing measures, but there is often a need for both types of measures (Sections 4 and 5 of the Management Regulations).

Barriers are normally categorised as passive or active. Passive barriers are present without needing activation or intervention, such as a firewall. Active barriers require activation or intervention. Normally, passive barriers should be preferred over active ones. Active barriers that are activated automatically are normally preferable to active barriers that require intervention and actions in order to be implemented. As a result, technical barrier elements are often preferred to elements that require human intervention. An assessment should be made of the reliability, strengths and weaknesses of the technical elements in relation to the organisational and operational elements in handling the specific failure, hazard and accident situation.

The strengths of technical systems are that they are “always” in place and ready to perform their tasks. Their strength is also evident when many signals have to be processed quickly and fixed actions performed

in sequence or simultaneously. They are also designed to be reliable and robust and maintain their function and performance during necessary maintenance. Technical systems may, however, have weaknesses in terms of flexibility and their ability to handle unforeseen situations or combinations of situations. Increased complexity in the maintenance of the technical barrier elements may also introduce an increased risk of system failures occurring. Technical systems may also fail if non-predefined situations arise.

The strength of humans resides in greater flexibility, the ability to see new patterns, and assess complex and unforeseen situations (“black swan events”). However, humans have their weakness in that they may misunderstand complex situations, make errors, not be situationally aware and act slowly.

Therefore, it is often beneficial to distribute tasks between technical systems and people, where each have their own strengths and weaknesses. The boundaries between which functions are allocated to the technical systems and which to humans have changed over the years and will also change going forward.

### 4.3 THE INTERACTION BETWEEN TECHNICAL, ORGANISATIONAL AND OPERATIONAL BARRIER ELEMENTS

#### “Who does what with which equipment in failure, hazard and accident situations?”

Barrier functions are provided for in differing degrees through the interaction between technical, organisational and operational barrier elements. In some cases, it is purely technical elements that provide a barrier function.

*For example, gas detection in an area will cause automatic decoupling of ignition sources and shutdown of production. For the further handling of the leak, the control room operator can initiate manual pressure relief. This barrier function includes technical, organisational and operational barrier elements. The technical elements are the pressure relief system (from the panel in the control room, pressure relief valves, the flare drum to the flare stack). The organisational elements are the control room operator, and the operational elements are the actions which the control room operator performs in order to initiate pressure relief.*

The operational and organisational barrier elements are tasks performed by dedicated personnel and which directly affect a barrier's function.

*General alarms can be triggered automatically or set off by the control room operator, and the emergency response organisation will be established in accordance with the defined hazard and accident situation in question. The technical elements here are, for example, the PA system and other communications equipment, such as radios and phones, and the emergency response vessel. The organisational elements are the control room operator, emergency preparedness management, the crew of the emergency response vessel and other external resources. The operational elements are decisions made, communication between the parties involved, the mustering of personnel and the positioning of the emergency response vessel.*

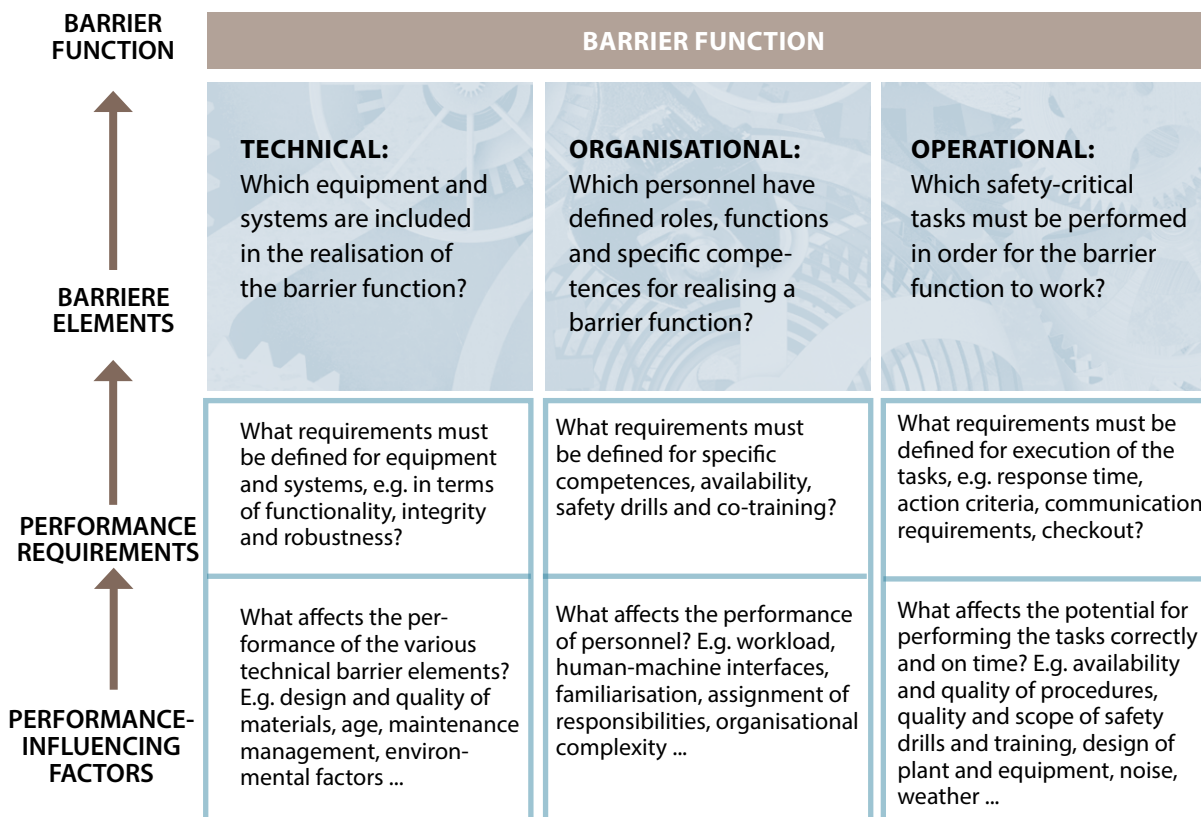
A ballast system's function is to detect and prevent heeling and capsizing. It consists of technical barrier elements such as a control system, valves, pumps and tanks. Operating this system requires competent personnel in the control room/on the bridge.

In the vast majority of barrier functions, technical

elements will be included to one degree or another. However, there are certain barrier functions where personnel must perform various actions in order for the function to be provided for. As shown in the examples above, organisational and operational elements interact to differing degrees with the technical elements. The age of facilities and equipment and the type of operation will also influence the degree to which different elements are involved.

Figure 7 illustrates the interaction between the technical, organisational and operational barrier elements involved in realising a barrier function. Furthermore, examples are provided of performance requirements and performance-influencing factors for the different barrier elements. The question "Who does what with which equipment in failure, hazard and accident situations?" encapsulates the interaction between the technical, organisational and operational barrier elements. This formulation also clarifies what is necessary for realising a barrier function.

The appendix to this memorandum provides examples of barrier functions, barrier elements, performance requirements and performance-influencing factors within different specialist areas.



**Figure 7:** Illustration of how a barrier function can be ensured through the interaction between technical, organisational and operational barrier elements, performance requirements of the elements and performance-influencing factors

#### 4.4 PERFORMANCE REQUIREMENTS

### “Performance requirements are specific and verifiable requirements for the barrier elements’ properties”

It is important to define specific and verifiable requirements for the performance of barrier elements to ensure that the barrier function works as intended in the specific risk picture.

Performance requirements can also be defined for the barrier function, where appropriate.

### “Barriers must have functionality, integrity and robustness”

Performance requirements may include requirements for functionality, integrity and robustness. Functionality is the effect that the barrier has on the sequence of events. Integrity is their ability and potential to be in place and intact at all times. Robustness covers their ability to withstand situations that are somewhat different from the intended circumstances and to “survive” a failure, hazard and accident situation.

For organisational and operational barrier elements, examples of functionality might be specific competences and participation in training and safety drills (Section 23 of the Activities Regulations and Section 52 of the Technical and Operational Regulations). Examples of integrity might be availability and mobilisation time. Examples of robustness might be capacity and redundancy in the organisation, such as deputies in key roles with the necessary competence and capability.

Examples of performance requirements for the “safe evacuation” barrier function are shown in Table 1.

Performance requirements are normally dimensioned relative to the most serious incident. Which means in the situation, for example, where the largest capacity or shortest mobilisation time is required.

Performance requirements will depend on site-specific factors, the incidents and their seriousness. Performance requirements may not necessarily be limited to numerical values, but may also be qualitative assessments. This is perhaps especially relevant when defining performance requirements for personnel and the actions they are to perform. For example, participation in a course is not always sufficient; actual competence achieved must also be assessed.

BARRIER	PERFORMANCE REQUIREMENT (EXAMPLES)
Barrier function	Time to safely evacuate the personnel
Technical barrier element	Capacity of means of evacuation, audibility of alarms, etc.
Organisational barrier element	Specific competence requirements for personnel – e.g. frequency of participation in safety drills, etc.
Operational barrier element	Criteria for warning/informing (time requirement, responders in relation to sequence of events), etc.

**Table 1:** Examples of performance requirements for barrier functions and for technical, operational and organisational barrier elements for the “safe evacuation” barrier function.

**“Barrier elements have a concrete and specific role with regards to the barrier function. It must also be possible to define performance requirements for the barrier element.”**

#### **4.5 WHAT ARE BARRIER ELEMENTS?**

Barriers must detect incipient incidents, prevent the development of a chain of events and limit harm and disruption. The elements of a barrier in combination must be able to realise this function.

The regulations require that performance requirements are defined for barrier elements. Further, it must be possible to verify this performance in order to be aware which barrier elements are not functioning or are impaired (Section 5 of the Management Regulations). There is a widespread perception that anything that may help prevent an incident occurring or limit damage is a barrier, which then makes it difficult to define verifiable performance requirements.

Barrier elements should be restricted to those elements that have a specific role in ensuring the barrier function. For example, a procedure may be a useful aid to describe what is needed to safeguard a barrier function. However, in itself the procedure cannot be considered to be a barrier element. The same is true of safe job analyses, which are useful tools for identifying risk in operations and establishing temporary barriers which must be in place before performing an operation. A safe job analysis is not in itself a barrier element.

#### **4.6 PERFORMANCE-INFLUENCING FACTORS**

Performance-influencing factors are factors that affect the ability of barrier functions and barrier elements to work as intended. This term is not directly used in the regulations, but is reflected in various regulatory requirements, standards and methods (for example, requirements for maintenance procedures and organisational capacity).

**“Many factors influence the performance of a barrier. Performance-influencing factors are those which have a significant impact”**

Not all performance-influencing factors are equally important. In barrier management, it may be appropriate to restrict oneself to performance-influencing factors that have a significant effect on the barrier elements' ability to function.

*Examples of factors that may impact peoples' ability to perform specific tasks might be the design of the workplace, visibility, lighting and fatigue. The design of the workplace may, for example, include the availability of and access to technical equipment used by people.*

In order to identify key performance-influencing factors, it's useful to review what may affect specific barrier elements and functions. Interviews with maintenance personnel and operators may be useful for obtaining important information. This may concern the physical surroundings of equipment and personnel, operator logs for alarm systems, communication and interaction during safety drills. Reviews of incidents may also be a good source of information.

To a large extent, performance-influencing factors comprise the interaction between people, technology and organisation. People must be enabled to utilise their abilities to identify, prevent or handle failure, hazard and accident situations. Workplaces and systems must be designed with regard to man-machine interfaces, information presentation on screens and alarm management. Furthermore, it is important to ensure sufficient capacity and competence in the organisation to avoid excessive time pressure and stress. Personnel must be familiar with checklists and procedures, which must be useful for the actual work tasks and incident situations. Checklists and procedures must also be easily accessible and comprehensible. Good management, workplace cooperation and physical working environment factors will also be important.



#### 4.7 MAINTENANCE MANAGEMENT AND BARRIER MANAGEMENT

**“Maintenance consists of verifying, maintaining and restoring the performance of barriers”**

Maintenance consists of verifying, maintaining and restoring the performance of barriers. Maintenance makes three core contributions to safety and barrier management:

- Maintenance helps maintain and, where appropriate, restore the technical aspect of the safe and robust solution so that failure, hazard and accident situations do not arise.
- Maintenance also contributes to maintaining and, where appropriate, restoring the performance of the technical barrier elements.
- Maintenance also contributes to verifying the performance of the technical aspects of a safe and robust solution and the technical barrier elements.

A further description of the place of maintenance in barrier management is provided in the appendix and in a report from SINTEF (SINTEF 2014).

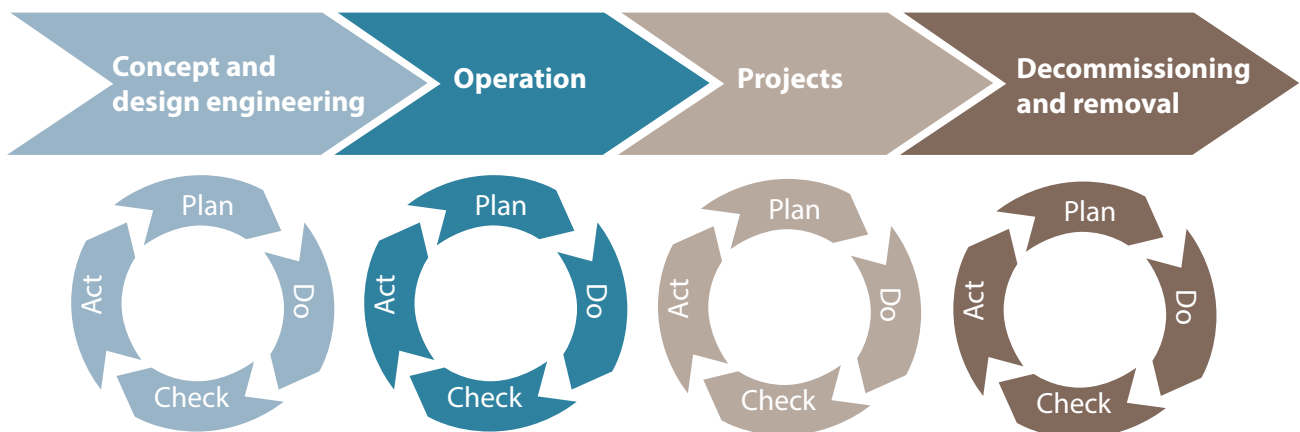
#### 4.8 BARRIER MANAGEMENT IN ALL PHASES

Barrier management is a persistent process and it is important that the management loop (plan-do-check-act) is continuously used in all phases of a facility's life, from design to removal, as illustrated in Figure 8 (Sections 6 and 23 of the Management Regulations).

The foundation and primary emphasis in preparing the barrier strategy will take place in the concept and design phases. It is in these phases that one is best able to influence the design of the facility and the technical barrier elements, and facilitate sound operational and organisational elements. During the design phase, there will be changes to the planned facility and in respect of the planned organisation and manning of the facility, and the barrier strategy will therefore need to be constantly corrected.

Similarly, there will be changes to the facility in subsequent phases, including in terms of organisation and manning. Here too, the barrier strategy must be updated on the basis of changes and the outcome of monitoring and improvement activities.

In the operational phase, the barriers' function and performance must be safeguarded by means of monitoring, maintenance, training and safety drills (Sections 23, 31 and 45 of the Activities Regulations).



**Figure 8:** Barrier management in all phases



## 5 The barrier management process

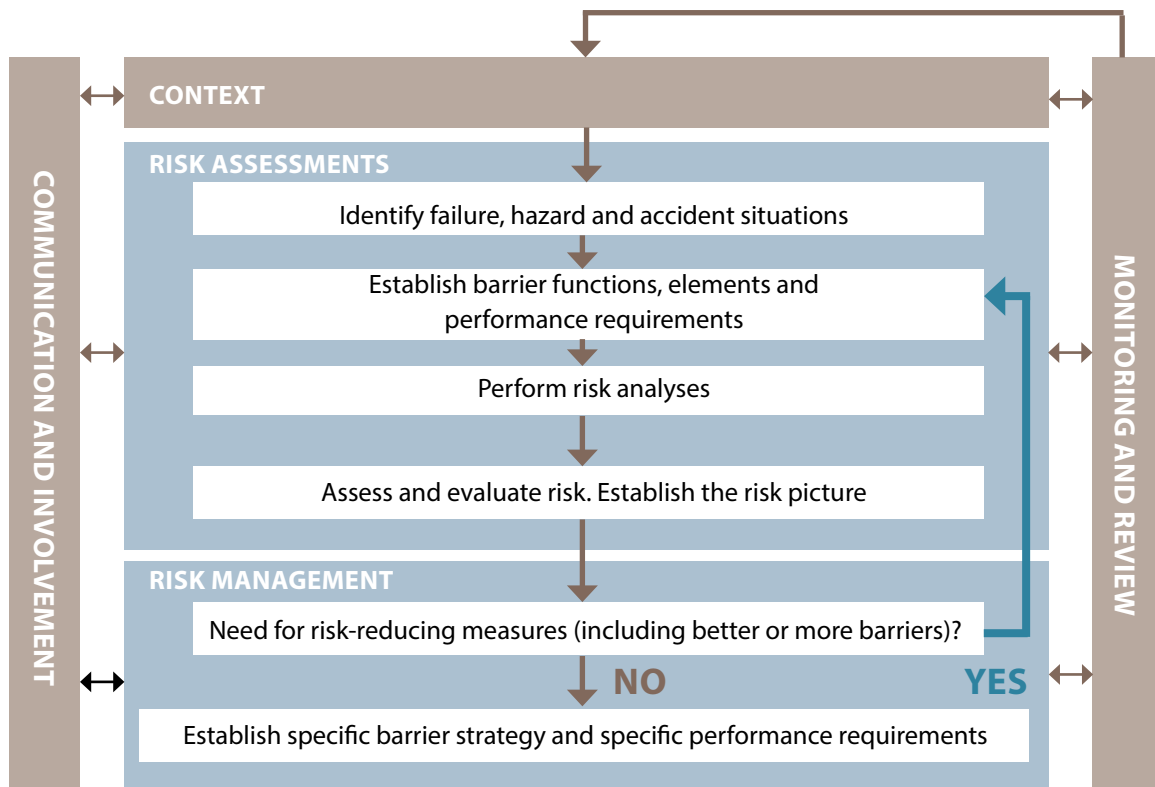
### 5.1 INTRODUCTION

Barrier management is a process for

- establishing a context for barrier management
- establishing the risk picture and barriers, including facility- and plant-specific barrier strategies and performance requirements
- adhering to and maintaining the barrier strategy in further activities, including
  - operating in compliance with assumptions and requirements
  - keeping the barriers intact and handling changes in the risk picture and barrier status when necessary

- monitoring and reviewing compliance of the barrier strategy and maintenance of barriers (with Section 10 of the Management Regulations), including
  - collecting measurement data, results from safety drills and verifications in order to create the necessary foundation for this
- establishing a basis for decisions on improvements where necessary, based on results from monitoring and reviews

On the basis of regulatory requirements and ISO 31000 (Risk management - principles and guidelines), this document describes a process and the foundation for barrier management. This process is shown in Figure 9.



**Figure 9:** Process for planning as a part of barrier management

## 5.2 ESTABLISH THE CONTEXT

**“Context is the surroundings that are relevant for assessing safety and the need for barriers.”**

The context is the interrelationships, operating parameters and guidelines (external, internal and project/activity-specific) which are relevant for performing the other steps in the barrier management process. In other words, it encompasses everything which directly or indirectly is or could be important for implementing and for shaping the strategy that is ultimately adopted. Factors of importance might include:

- Requirements and guidelines in regulations, standards and company-specific policies.
- Company-specific strategies, goals and principles for risk and barrier management.
- Actual design, condition and location.

To achieve continuous improvement which contributes to good and robust solutions, the requirement for risk reduction must also form part of the context. See Section 11 of the Framework HSE regulations. Furthermore, steps must be taken to ensure that this is taken care of throughout the entire process.

## 5.3 RISK ASSESSMENT

Risk assessment must contribute to identifying failure, hazard and accident situations, and the need for and functions of barriers. Furthermore, the properties of the individual barrier elements must be specified. The collective term “risk assessment” includes the following steps:

- Identify failure, hazard and accident situations,
  - their possible causes,
  - the damage they cause and their consequences
- Establish barrier functions, barrier elements, and associated performance requirements and performance-influencing factors.
- Carry out risk analyses and necessary safety studies/analyses.
- Assess and evaluate risk, including sensitivity and uncertainty – establish the risk picture.

### 5.3.1 Identify potential failure, hazard and accident situations

**“Which failure, hazard and accident situations should we be able to handle?”**

Identification of potential failure, hazard and accident situations must be performed in sufficient detail and specifically for the facility, plant, area and operation, so as to identify the situations that the individual barrier element has a role in handling. Realistic combinations of failure, hazard and accident situations must be assessed, since such combinations may determine the dimensions of barriers.

**5.3.2 Establish barrier functions, barrier elements, and associated performance requirements**

**“How must we handle these situations?”**

Once potential failure, hazard and accident situations have been identified and assessed, the necessary barrier functions and barrier elements must be identified and the process of establishing associated performance requirements and mapping performance-influencing factors should start.

**5.3.3 Carry out risk analyses and necessary safety studies and analyses**

Risk analyses conducted as part of decision support for barrier management must be planned and performed in such a way that they are sufficiently detailed and appropriate for their use.

Assumptions on which a decision is based must be expressed so that they can be followed up (Sections 11 and 16 of the Management Regulations). The specific barrier strategy should indicate which assumptions are significant for the individual barrier function and the individual barrier element. This does not necessarily mean that all assumptions have to be described in one place, but it must be easy to obtain such information by referring to the barrier strategy.

**5.3.4 Assess and evaluate risk – establish the risk picture**

**“The risk picture is an overview of failure, hazard and accident situations and how to protect against them”**

The risk picture is an understanding and overview of potential failure, hazard and accident situations and how to protect against them. This means relevant, usable and appropriate information for the individual in the specific situation, including the significance of his/her own choices, decisions and actions.

As specified in Section 17 of the Management Regulations, sensitivity and uncertainty assessments must be performed as part of a risk analysis. The primary purpose of this is to give users of the analysis the best possible basis for understanding its strengths, weakness and limitations, as well as which suppositions, assumptions or assessments are of importance for the results of the analysis. It is also important to understand the uncertainty underlying the input parameters and assessments on which the analysis is based. Sensitivity and uncertainty must be assessed and used in the work of risk handling, whether that involves communicating the need for risk-reducing measures in barrier strategies or detailing specific performance requirements.

In most cases, it is not sufficient to exclusively use quantitative risk analyses for deciding if the individual barriers are needed. Nor is it sufficient to establish specific performance requirements for the individual barrier element.

## 5.4 RISK MANAGEMENT

### “Risk must be reduced as far as possible ”

Section 11 of the Framework HSE Regulations requires that efforts must always be made to reduce risk as far as practicable. There is a much greater chance of achieving good solutions by working in a structured and targeted way to reduce risk in the concept and design phases. As a rule, this will also yield the best solutions in terms of execution, cost and operation.

### “Common sense must also be used in addition to risk analyses ”

The requirement to reduce risk is not confined to measures which can be quantified in the results of a risk analysis. For example: “preventing hot surfaces on equipment which could be exposed to diesel oil leaks” will be a sensible measure in most cases, even if its effect cannot be quantified in a QRA, TRA or the like. Common sense should therefore be the guiding principle when assessing the effect of measures, rather than relying exclusively on the results of risk and/or cost-benefit analyses. On the other hand, risk analyses will in many cases represent a necessary and important supplement when assessing the effect of various measures. In other words, it is a case of finding the tools, analyses and so forth which provide relevant decision support for the various issues.

#### 5.4.1 Establish a specific barrier strategy and specific performance standards

The process for establishing, updating and maintaining a sufficient set of barriers has two key end products:

- Specific barrier strategy.
- Specified performance requirements in specific performance standards.

A brief description of the principles related to establishing these is provided below.

### *Specific barrier strategy*

### “What is the risk picture in this area? Which barriers and barrier elements contribute to protection?”

A specific barrier strategy is a plan for how barrier functions, on the basis of the risk picture, are to be implemented in order to reduce risk.

The following principles should form the basis of a barrier strategy. It should

- be designed so that it helps the parties involved gain a common understanding of the basis of the requirements for the different barriers, including
  - which phases, operations and activities the strategy has been established for
  - which failure, hazard and accident situations may occur in the phases, operations and activities the strategy has been established for
  - which barrier functions are required to handle these situations
  - where additional information is to be found for about the performance requirements for which specifically apply for the individual for barrier
- sufficiently fine-grained for the individual plant (e.g. area, system, equipment) and phases, operations and activities
- be kept updated at all times
- identify which roles/tasks the different barrier functions have
- identify important assumptions which are significant for the individual barrier function and the individual barrier element
- identify the relationship between strategy and performance requirements established for the individual barrier. The strategy should provide information about where the different performance requirements for the individual barrier element and the individual barrier function are described

Barrier strategies do not necessarily need to be described in special documents, but should be described where it is natural, appropriate and easy to find them.

### **Performance requirements**

Performance requirements are verifiable requirements of the barrier elements' properties to ensure that the barrier is effective.

## **“What condition must the barriers have? What requirements must they meet?”**

Establishing and using (a) specific barrier strategy(ies) and associated performance requirements will be crucial for the ability to establish effective barrier management. Good usage requires that this documentation is sufficiently well-known to relevant personnel on/in the individual facility.

It might be appropriate to group the established performance requirements in performance standards at the system/function level, as some companies have done. NORSOK S-001 is built around this thinking. In addition to specifying performance requirements for barrier elements, a performance standard should clarify interfaces with other barriers (systems and functions).

Specific barrier strategies and associated performance requirements could be used, for example, to:

- clarify the relationship between specific risk assessments and the role of barrier functions overall and in different areas of the facility or plant
- provide an overview of specific performance requirements tailored to a specific risk picture and strategy
- describe solutions other than those specified in referenced standards/codes
- identify and classify systems/equipment in terms of the consequences of potential functional failures
- plan and/or execute maintenance to safeguard the performance of barrier functions and elements in every phase of the life cycle
- provide input for procedures
- provide input for performance requirements for technical, operational and organisational

barrier elements required to handle failure, hazard and accident situations in a prudent and robust manner

- manage competence
- manage change
- verify activities
- establish barrier-related measurement parameters
- maintain an overview of non-conformities and exemptions
- identify compensatory measures
- provide input for studies and analyses
- communicate and consult
- monitor and assess

### **5.4.2 Communication and involvement**

It must be ensured that the risk picture and barrier strategy and associated performance requirements are communicated to and anchored with both internal and external stakeholders, and are appropriate throughout the entire barrier management process. This is intended in part to ensure:

- good quality – by drawing on relevant expertise and experience throughout the process, including when establishing the context, when conducting risk assessments and management, and for supervising and monitoring at all times
- participation by, and a sense of ownership among, stakeholders who will be affected by decisions in every phase
- understanding of the background to decisions
- that risk analyses are communicated in such a way that target groups obtain a nuanced and coherent presentation of the analysis and its results
- that the barrier strategy is actively used to provide those involved with a common understanding of the risk picture and the basis for the requirements specified for the various barriers

Communication and anchoring of the risk picture and barrier strategy are not to be regarded as an independent activity, but as one which will pervade the whole barrier management process in every phase.

## 5.5 BARRIER MANAGEMENT IN THE DESIGN PHASE

### 5.5.1 Introduction

Barrier management in the design phase of a new facility follows in principle the planning element in the barrier management loop; see chapter 5.2-5.4.

### “Establishment of a barrier strategy is an iterative process”

One key challenge in designing a new facility or a new plant onshore is having the necessary information in place when decisions have to be made. It would, of course, be beneficial to have all the results of risk analyses, barrier strategies and performance requirements on hand when the facility is designed. Similarly, such information will be necessary in order to ensure that the facility is designed so that it allows for good organisational and operational barrier elements. At the same time, the results of risk analyses and barrier analyses derive in turn from how the facility is designed. This makes it an iterative process in which one must make sure to have good results in place as early as possible in order to ensure good decision support. The risk and barrier management process in a design phase must contribute to the sufficiently safe design and use of the plant. To achieve this, it is essential to have systematic means of identifying and defining relevant failure, hazard and accident situations. Failing this, the basis for subsequent assessments, measures and actions will be lacking.

The focus must be directed at identifying barriers that provide adequate risk reduction. Furthermore, it is important to identify at the earliest possible stage the necessary operational and organisational elements in addition to the technical ones.

### “Barriers must be maintainable, performance must be verifiable and operations must be achievable within the defined limitations”

The process for barrier management in the design phase results in relevant and specific barrier strategies with associated performance requirements and performance standards. Right from the concept and design phases, it is important to start thinking about how statuses and performance are to be measured, verified and followed up in the operational phase. It is also necessary to assess how strategies and performance requirements and standards are to be included in the operations and maintenance systems. Additionally, it is important to ensure that it is actually possible to operate within the assumptions and limitations in place (for example, the size of supply vessel that can be used), and these are properly communicated to the operations side. This means that the involvement of the operational organisation is important for achieving good barrier management.

### “Sufficient manning for safeguarding barrier functions and operational tasks”

Once barrier function tasks that have to be performed by humans have been identified, an assessment should be made of necessary manning in the organisation. Manning depends on which technical equipment is to be used and which tasks are to be performed. Manning should be assessed on the basis of tasks to be covered both in normal operation and in a failure, hazard and accident situation.

Another precondition for achieving good barrier management in a project is to put in place at an early stage the division of responsibilities between project, operations, EPC contractor, consultants and suppliers. Barrier management is an interdisciplinary activity.

It is important to ensure interdisciplinary involvement in the work of risk and barrier management in the design phase. One condition for effective risk and barrier management is to think both holistically and sequentially. A traditional approach with responsibilities delimited by specialism will not necessarily provide the holistic perspective. It will be necessary to establish work methods that ensure interdisciplinary and timely involvement in the risk and barrier management process.

### “Barrier management is an interdisciplinary activity”



### 5.5.2 Some useful questions about barrier management in the design phase

Some useful questions for those responsible for barrier management processes in the design phase to ask:

- Are the elements in the model in place?
- Is there good familiarity with the model?  
And has the model been adhered to?
- Has the timely establishment of barrier management been emphasised, along with coordination and communication related to contexts and dependencies in the model?
- When and to what extent are operational personnel and safety delegates involved?
- Do the barrier management systems established in the design phase meet the operational organisation's needs, objectives and expectations?  
Barrier strategies and performance standards (purposes and who are the users?)
- Have the suppositions, assumptions and results from risk analyses and studies been implemented and identified for the operational organisation?
- To what extent does this affect contractors, suppliers and other key stakeholders?
- How do the barrier strategy and performance requirements affect the test and maintenance programme?
- Is the equipment hierarchy in the maintenance system sufficiently fine-grained to allow requirements and historical logging to be linked to the individual barrier element?
- Are special requirements defined for performance-influencing factors of significance in the design of the maintenance programme?
- Are special requirements defined for, for instance, manning, competence, training, procedures etc. in order to meet the performance requirements?

## 5.6 BARRIER MANAGEMENT DURING OPERATION

### 5.6.1 Introduction

In order to meet the requirements relating to barriers, follow-up and improvement, the performance of the barriers must be monitored, followed up and, where necessary, improved throughout the facility's life cycle. In addition, the role responsible must follow up and enhance management systems (Section 17 of the Framework Regulations) in order to ensure compliance with the regulations and to further reduce risk as far as is practicable (Section 11 of the Framework Regulations). This means that barrier strategies must be employed and followed up during operation, and improvements must be implemented in order to reduce risk as the need arises.

The following factors are key to operations:

- Operate and use the facility in accordance with assumptions, requirements and technical condition.
- Ensure and maintain necessary barrier performance.
- Measurement and verification of the barriers' performance.
- Maintain control over contributors to risk and performance-influencing factors.
- Follow up and enhance the barrier management system.

Establishment of the foundation for safeguarding these conditions will play a key role in the importance of barrier management for preparations for operation. Securing effective communication and involvement in

the planning stage will be important for establishing and following up this foundation.

Examples of these factors are shown in Figure 11.

The foundation for safe operation of the plant is laid during the design phase. At the same time, we know from experience that the assumptions made in this phase can be difficult to implement in the operational phase, which can lead to new measures being taken in the operational phase. For example:

- Vessel operations in the safety zone (number and size of vessel, routines on arriving at the installation).
- Materials handling (crane and lifting operations).
- Operation, maintenance and testing of equipment.
- Manned/unmanned areas.

We also know that assumptions and parameters can change during the operational phase.

Examples of this might be:

- Changes in organisation, manning and responsibilities, restructuring of operating routines.
- Altered operating conditions.
- Change in management system.
- Modifications.

Through ongoing operational experience, factors will be revealed that mean that initial assumptions are no longer valid, due, for example, to

- results from the operation and maintenance programme.
- temporary or permanent non-conformities
- changes, etc.

## BARRIERS DURING OPERATION

### Operate the facility in compliance with preconditions, requirements and technical condition

- Operational procedures and routines
- Preconditions for startup and use
- Routines when barriers are non-functional and establishment of compensatory measures
- Non-conformity handling

### Ensure and maintain necessary barrier performance

- Maintenance, testing and inspection programmes and routines, including verification that performance requirements are met
- Continuous condition monitoring
- Instruction, drills and training
- Improvement measures in respect of changes
- Learning from incidents

### Measurement and verification of the barriers' performance

- Management's monitoring activities
  - Condition of barriers and use – altered properties and nonconformities
  - Compliance with preconditions and context
- Use of indicators
- Verify drills and training

### Maintaining control of performance-influencing factors

Changes in performance-influencing factors  
Maintenance  
Competence Management  
Risk perception  
Compliance

## FOLLOW UP AND ENHANCE THE BARRIER MANAGEMENT SYSTEM

Figure 10: Barrier management during operations – maintaining and monitoring barrier elements and functions

## “A structured approach and a continuous process are important”

Furthermore, certain ageing facilities in operation have not had the most systematic basis for sound barrier management in place from their concept and design phases. This makes it necessary to establish the requisite basis after the event.

These examples show the importance of structured barrier management and continuous improvement throughout the entire operational phase.

Good barrier management requires systems and tools to be established in order to

- measure and verify performance
- ensure that the barriers are available
- maintain the performance throughout the entire operational phase, if necessary, incorporating modifications and changes

In other words, barrier management in the operational phase is not an activity that can be finished off and “parked” in a barrier strategy and in performance standards. It is important that these barrier strategies and barrier requirements are easy to update and that they are used in day-to-day work in order to provide good safety. Barrier management is a continuous process.

### 5.6.2 Operate in compliance with assumptions, requirements and technical condition

The regulations require having in place the necessary systems and processes in order to verify that one is operating in compliance with the preconditions defined for the activity (Section 19 of the Framework Regulations). It is also a requirement that systems and processes have been established to identify and handle non-conformities in a prudent manner (Section 22 of the Management Regulations).

Operations must be based on the risk picture, the barriers established in the barrier strategy, technical condition, assumptions and requirements. These must be monitored in order to provide for any changes, so that the barrier functions and elements perform as they must. Such changes may occur in relation to preconditions, requirements, condition, personnel and other performance-influencing factors.

## “Compensatory measures must be implemented in the event of impaired barriers”

Necessary measures must be implemented to rectify or compensate for missing or impaired barriers. In some circumstances, necessary compensatory measures will need to be clarified in advance. In other cases, situations which have arisen will have to be dealt with there and then. In any event, it is crucial that compensatory measures provide a genuine risk reduction relative to the barrier functions and areas affected by missing or impaired barriers.

## “What is the condition of the barriers? Do they meet the requirements? Do they fulfil their role?”

### 5.6.3 Ensure and maintain necessary barrier performance

## “Technical barrier elements must be tested, inspected and maintained”

For technical barrier elements, in many cases testing, inspection and maintenance will be a good solution for verifying their condition and compliance with established performance requirements.

## “Organisational and operational barrier elements must be trained and drilled”

For operational and organisational elements on the other hand, other systems and processes will be required to verify performance. For verification of the performance of operational and organisational barrier elements, examples of verification activities might be table top simulations and safety drills for the emergency response organisation. In addition to safety drills, there is considerable value in learning from actual incidents and alarms in the plant. Such incidents and alarms can be used to verify whether the performance requirements are actually fulfilled, and they should therefore be registered, documented and included in an evaluation.

There may be certain situations where barrier elements are not able to perform their intended tasks and functions. There may, for example, be automated systems that fail, or personnel who are unable to perform a task or are absent. In such situations, alternative ways will often be sought to perform the same

task and secure the barrier. For especially vulnerable barrier elements and tasks, it may be useful to review alternative ways of performing the task.

Interdisciplinary involvement in different barrier reviews may be important, for example in respect of failures and impairments of barriers and handling changes and non-conformities. From experience, it is often in the boundary layer between different specialisms and units that difficulties may arise. Here, there will often be a lack of a holistic overview of the barriers. It is easy to imagine that slippage may occur in handling a barrier system if, for example, a safety critical valve is “owned” and assessed by one discipline, the instrumentation by another and the hydrocarbon-carrying pipeline by a third. In order to ensure a holistic perspective of the barrier status at the plant at all times, it is important to implement processes that guarantee the integrity of the barrier function and the interaction and any dependencies between different barrier functions.

### **“Performance requirements must be reviewed and updated in the operational phase”**

The performance requirements must be monitored, reviewed and, where necessary, updated in the operational phase in order to help ensure robust barriers throughout the whole life cycle.

### **“The effect of modifications and changes must be assessed. Organisational changes are also considered changes”**

During a facility’s life, there will be technical modifications, replacement of equipment and changes of personnel. Systematic management and risk assessments of the consequences of changes must relate to normal operation of the facility, but also to their significance for the performance of the barrier elements and barrier functions. Changes require a process for change management that identifies and assesses as a whole the influence of barrier strategies. Changes will trigger a need to systematically check whether they have consequences for the safeguarding of barrier functions or for the relationship between technical, operational and organisational barrier elements. Personnel changes should be risk-assessed and evaluated against the performance requirements.

The need to investigate the consequences of changes also applies to changes in working practices and the division of responsibilities. Changes to the division of responsibilities between the onshore and offshore organisations might be an example of this. Similarly, it might apply to changes in respect of determining manning under new, or renegotiated, contracts with subcontractors.

#### **5.6.4 Measure and verify the performance of the barriers**

### **“Results of measurements and verifications must be communicated to those who have tasks in a barrier function”**

A number of assumptions and prerequisites will underlie barrier management. These could include prerequisites about the way a facility is to be operated, or assumptions which influence testing and maintenance of equipment. These prerequisites will be determinative for subsequent operations. Failure to conform with one or more of these prerequisites would accordingly invalidate the basis of the subsequent steps in the process. The most important job in ensuring good barrier management is accordingly to monitor, test and verify that operations accord with the prerequisites which apply at any given time.

### **“Safety drills can be used to measure and verify the performance of barriers”**

Measurements and verifications of performance can be usefully based on existing systems within the company. This type of follow-up can provide information about the condition of barrier functions and elements. It may also provide support for decisions about necessary measures and improvements, and provide explanations and motivation for anyone with responsibilities for taking care of barrier functions. This makes it important for measurements and verifications to be appropriately communicated, so as to be seen as useful by those involved in a barrier function.

Evaluation of training and safety drills is one way of verifying and improving performance. This is a recognised method after training and safety drills within emergency preparedness, but is also a way of improving other barrier functions involving personnel.

Non-conformities may affect both the risk picture and the barriers' ability to perform their intended tasks. A non-conformity in this sense might be reduced performance of the barrier elements, but could also include disparities in context, assumptions and prerequisites. The combination of several non-conformities might be critically important, even if the individual non-conformities in themselves are small. Non-conformities that affect the risk picture and barriers must therefore be assessed and dealt with together.

Good barrier management provides access to a lot of useful information that helps produce a holistic risk picture prior to operational decision-making. The difficulty is often not a lack of information. Rather, it is the opportunity and ability to sort and utilise relevant information in a timely manner, and to understand and contextualise the totality of the information. Various tools for barrier management are in development, with the object of assisting with and supporting different decision-making situations. These can be used in overall planning processes and risk assessments, but also in risk assessments performed during operations. These might include work permit processes, safe job analyses and in the case of jobs undertaken directly in the plant. This type of tool can be useful as one of a number of decision-support aids, but no tool provides a full, coherent overview.

## “Decisions must be based on good understanding of risk”

Decision-makers and risk owners must recognise the associated uncertainty and understand potential consequences of their choices and decisions, and make decisions on the basis of good risk understanding.

### 5.6.5 Maintain control of performance-influencing factors

Performance-influencing factors are factors that affect the ability of barrier functions and barrier elements to work as intended. In operational phases, it will be important to maintain control of how these change, since this may be significant for the barrier's function. Such changes may be short-term (e.g. weather, visibility and manning) or long-term (e.g. modifications, degradation of materials, and organisational changes). Maintenance and retaining competence are import-

ant performance-influencing factors for managing change. In addition, good decisions based on sound risk assessments through cooperation between management, operational personnel and safety delegates will represent a key performance-influencing factor for managing change.

Management is a performance-influencing factor that is able to ensure that systems and resources are in place, so that barriers are established and their integrity is assured.

Risk understanding is one prerequisite for understanding what can go wrong, and also how to protect against this. Good risk understanding in all phases is therefore key to achieving the compliance of procedures, working practices and follow-up.

### 5.6.6 Follow up and enhance the barrier management system

For monitoring, testing and verification to have a value, systems and processes must be established to assess the results of these activities, so as to be able to identify, assess and deal with changes and non-conformities in respect of established contexts, assumptions and preconditions. Follow-up must identify needs for improvement in the barrier management process and implement necessary improvement measures.

### 5.6.7 Manning, competence, roles and responsibilities

It is important to ensure that the individual is able to understand the relationship between

- the facility- and area-specific risk pictures
- the need for and role of the established barriers
- the individual's role in handling risk prudently and well

This can help ensure that the different tools for barrier management and the associated information and results are used appropriately. This in turn will help provide a holistic perspective of barrier statuses and understand the risk picture for the area and plant at all times. Everyone responsible for tasks or roles that affect the risk picture and/or the barriers' ability to handle failure, hazard and accident situations requires such competence.

Recognised methods and analyses for determining manning and competence may be used, such as task analyses, function allocation analyses, manning analyses, CRIOP, compatibility analyses etc. A definition of competence is an individual's or a group's ability to apply skills and knowledge to performing a job or task in an effective, correct and safe manner.

### **“Sufficient manning must be in place to perform the tasks”**

Once tasks that have to be performed by humans have been identified, an assessment should be made of who in the organisation is to perform them. Manning levels should be assessed against the actual equipment to be operated, the scope of tasks to be performed, the sequences of tasks in a chain of events and the time available. Manning should also be sufficient to cater both for safe operation and for handling failure, hazard and accident situations (Section 14 of the Management Regulations).

### **“Personnel must know which tasks they have been assigned and be ready to perform them”**

Personnel must be familiar with the requirements defined for the safety-critical tasks they have to perform. Each individual and group must be able to perform their tasks. The amount of training and safety drills associated with various specific incident scenarios can constitute appropriate performance requirements for the personnel to be able to perform their tasks. Evaluation of the completion of training and safety drills can constitute verification of the performance.

### **“Practice is the key”**

Competence abates over time and therefore requires repetition and quality in training. Familiarity with the equipment and systems involved in the barriers is important for ensuring barrier function. Training must be facility-, area- and system-specific.

Training and drilling are key activities for ensuring that personnel are capable of handling the tasks required to protect barrier functions. Scenario-based safety drills can usefully be undertaken as table top exer-

cises, or as simulator-based training. This will allow key elements such as affirmative communication to be practiced, and facilitate an increase in the understanding of the risk potential of incidents and the significance of the individual's own role and responsibilities in safety-critical tasks that are necessary for achieving barrier functions.

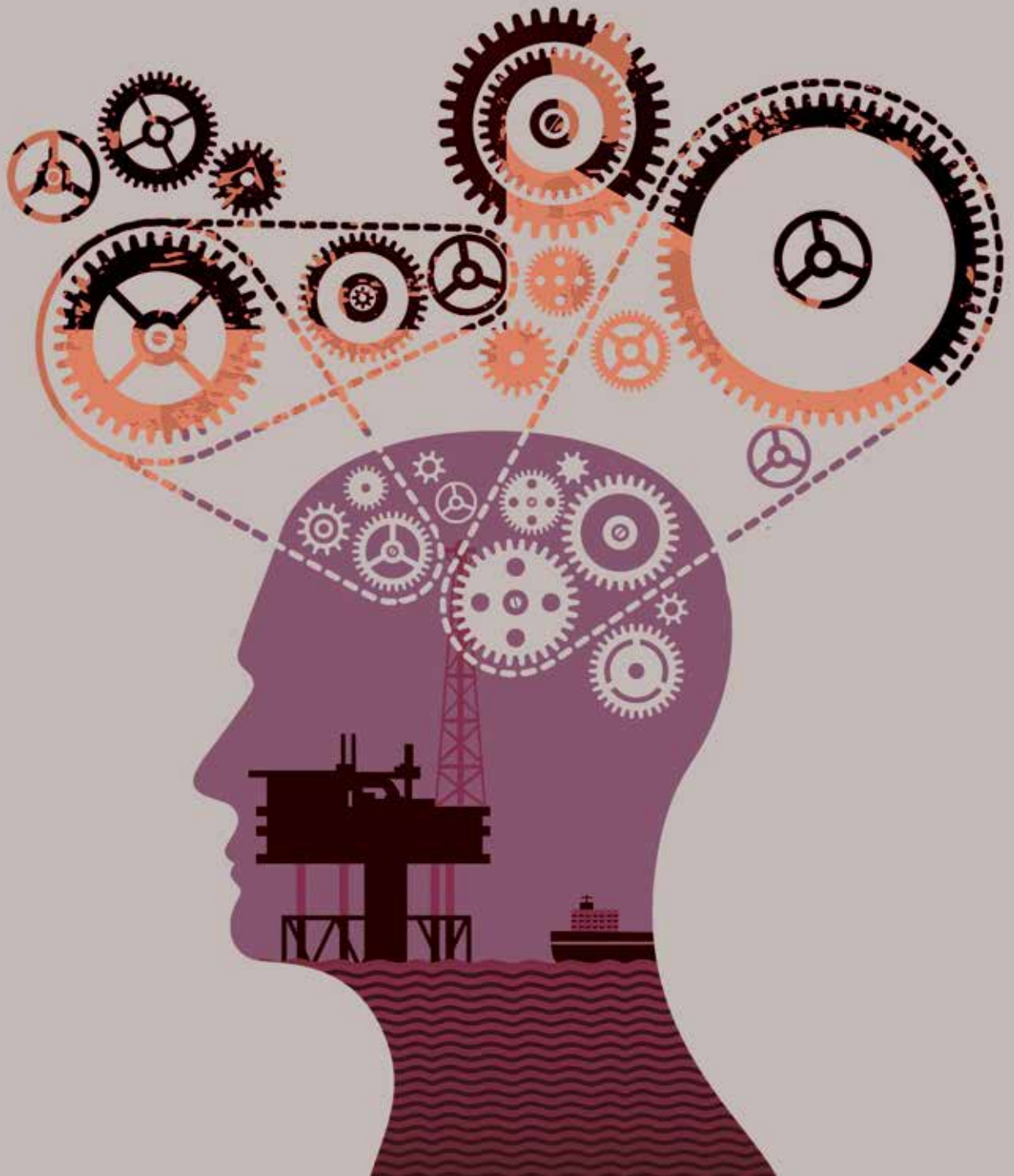
It is not necessarily possible to drill all major accident scenarios, but, on the basis of investigations following actual incidents, it is possible to provide training on who must do what with which equipment or systems during a sequence of events.

#### **5.6.8 Some useful questions about barrier management in the operational phase**

Some useful questions for those responsible for barrier management processes in the operational phase to ask:

- How are the barrier strategies and associated requirements applied/brought into use, and how are they made available to those who need them, when they need them?
- How are performance requirements identified and followed up in different operational and maintenance procedures?
- How is it monitored that the individual barrier elements and overall barrier function retain their necessary properties over time?
- Are the barrier functions adequately tested and how are the test results followed up in practice?
- How are changes that affect the assumptions from the design phase handled?
- How are barrier statuses incorporated in the basis for decision-support and activity planning?
- How is it ensured that the individual (see above for what “the individual” means) has knowledge of relevant hazards and is able to understand the relationship between the specific risk picture, the need for and role of barriers, and the individual's role in handling the risk?

Management's involvement and commitment are crucial for achieving sound and systematic processes for barrier management in the operational phase. Without good management and the management's commitment, barrier management will rapidly become simply documentation of “how good we are”, with an aggregated and static display of KPIs that apparently demonstrate oversight and control.



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## 7 Appendix – Complementary examples

### 7.1 SECURITY

#### 7.1.1 Is barrier management relevant for security?

Security incidents are themselves incidents outside of normal operating situations. In a world where everyone was law-abiding, security measures would not be necessary. However, because security incidents do occur, it is necessary to establish barriers (security measures) in order to reduce the opportunity for such situations to occur and develop. The use of barrier management principles for security incidents contributes to a more systematic approach to the identification, establishment and maintenance of the barriers.

#### 7.1.2 The relationship between the security plan and the emergency preparedness plan

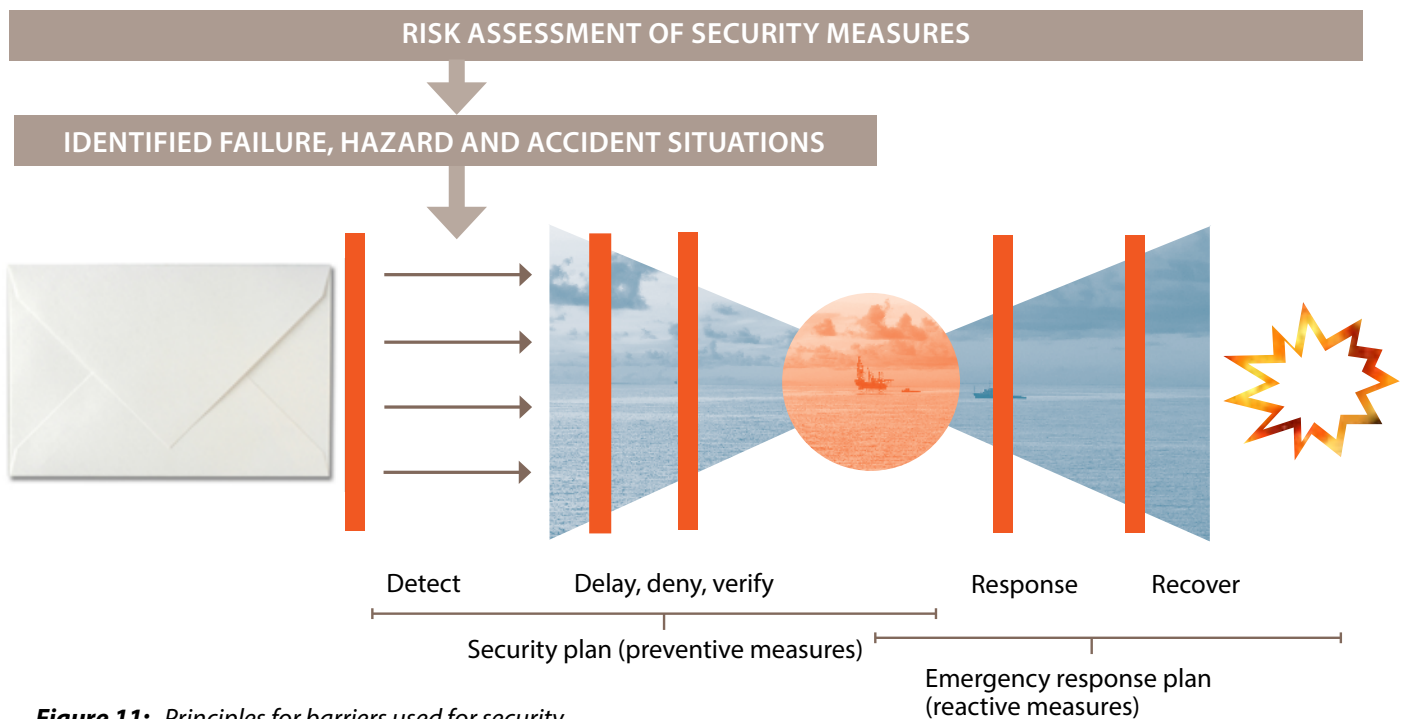
The barrier process is based on existing documentation and information. Therefore, there is no requirement for new documentation, but a more systematic and conscious approach towards the work on security is needed.

Figure 11 shows the principles for barriers used

for security purposes. Examples of barrier functions within security are to deter, detect, delay, deny and verify the existence of an attack, respond to the threat and restore functionality. The security plan primarily covers preventive and protective measures, or likelihood-reducing measures (such as reducing vulnerability), while the emergency preparedness plan covers the reactive and consequence-reducing measures. There will however be a degree of overlap between these two plans as well as measures taking place concurrently.

*Example: Having performed a security risk analysis, a scenario has been identified in which three people (with limited knowledge but high motivation) will attempt to break into the base in order to place explosives into an open basket that is going out to a facility. Based on this scenario, various barriers/measures have also been identified to reduce the risk, both a robust baseline security and measures that can be implemented in the event of a raised threat level. This is catered for, notably, by a security plan. Once an incident has occurred, the emergency preparedness plan will be set in motion. The design of the facility can help make it better at dealing with security incidents.*

**“The design of the facility can help make it better at dealing with security incidents.”**



**Figure 11:** Principles for barriers used for security

When designing a facility, it is also possible to reduce the risk of security incidents. For example, “vulnerable” rooms (server rooms, water, food, etc.) can be situated to make them inaccessible to unauthorised parties. Similarly, the facility can be designed so that unauthorised personnel are unable to climb up from sea level without being detected. Furthermore, physical obstacles can be established to make it more difficult to climb up (delay). Principles that can be set out in the concept and design phases might be balanced security<sup>1</sup> and security in depth<sup>2</sup>.

**7.1.3 The interaction between technical, organisational and operational barrier elements**

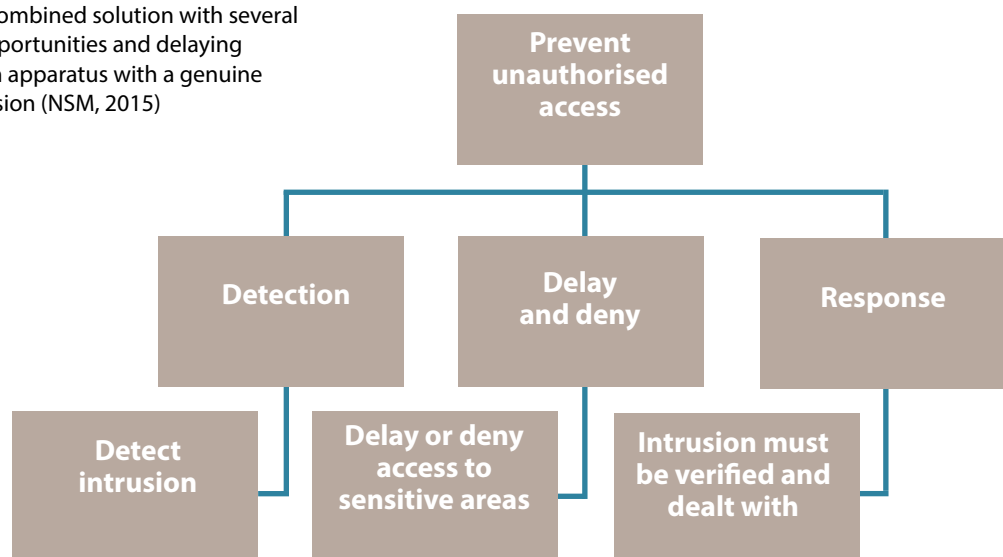
A physical protection system (PPS) may be intended to prevent unauthorised access to a facility or plant. It can be seen as a barrier function, which in turn may comprise various barrier sub-functions. Examples of barrier sub-functions in the security domain are deterrence, detection, prevention and response. Intelligence and monitoring (CCTV and guards) can be sub-functions of detection.

*Example: A physical security concept may comprise technical, operational and organisational elements. For example, there may be surveillance cameras monitoring different zones. Images from the cameras are displayed in a monitoring centre manned by guards. These have instructions and routines describing how the cameras are to be monitored, what they should surveil and how they should react to different observations. Performance/operational requirements are defined for both cameras and guards. Cameras must be able to identify a person moving at a given speed in a defined zone under certain performance-influencing conditions (for example, night time, fog, rain). Guards must have verified alarms and, where relevant, notified the police within two minutes. In other words, “Who does what with which equipment in a security incident”.*

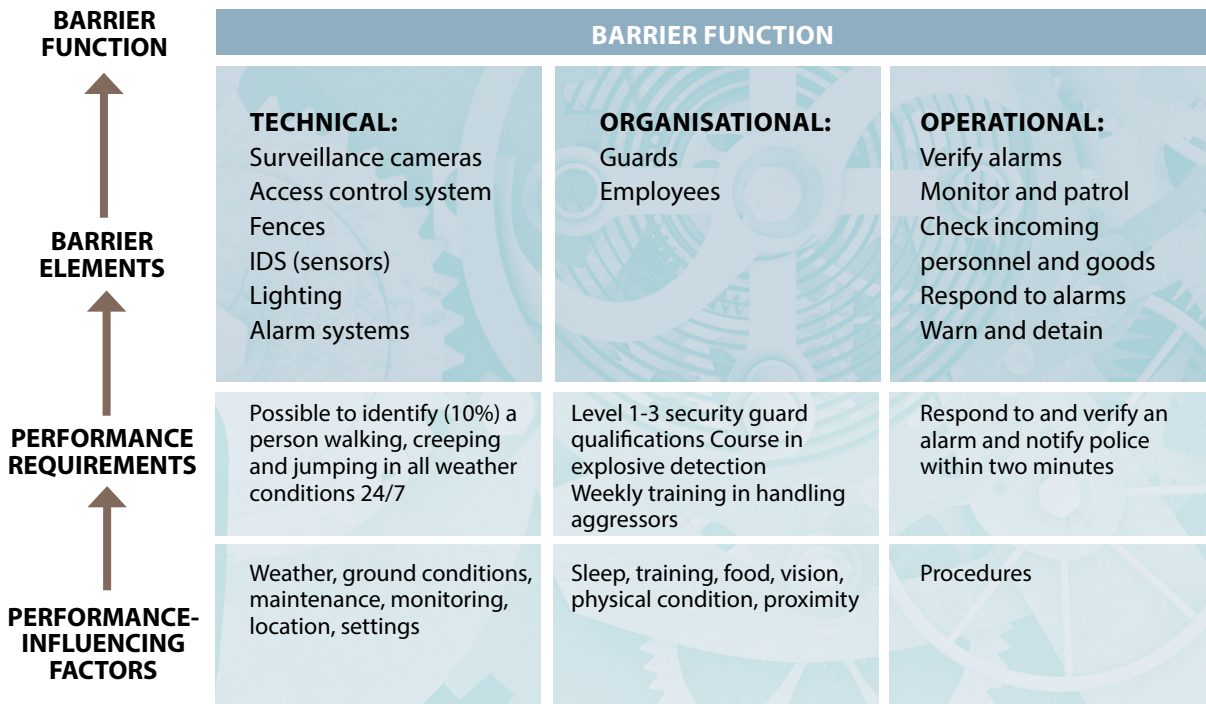
In this example, we have used physical security, but the principles are equally relevant for cyber security.

<sup>1</sup> Balanced security: this means that the total delay provided by the security measures is greater than the response time. Balance in the security measures refers to coherent security against a threat and, for example, that doors, walls and windows have the same resistance to intrusion. (Sikringshåndboka, 2016)

<sup>2</sup> Security in depth: a combined solution with several stages of detection opportunities and delaying barriers, and a reaction apparatus with a genuine ability to stop an intrusion (NSM, 2015)



**Figure 12:** Barrier functions and sub-functions for security incidents



**Figure 13:** Example of technical, organisational and operational barrier elements involved in providing the “Prevent unauthorised access” barrier function. The figure also shows examples of performance requirements and performance-influencing factors.

## 7.2 MAINTENANCE MANAGEMENT

By virtue of its purpose, to sustain and restore the performance of barrier elements among others, maintenance is a key aspect of barrier management. In addition, maintenance will be directed at equipment that is not defined as barriers, including processing and auxiliary systems.

The relationship between maintenance management and barrier management is described in “Vedlikeholdets plass i barrierestyringen” (SINTEF 2013). Reduced performance and failure of HSE-critical equipment (such as barriers) may affect risk, which means that its maintenance must be continuously improved as far as is practicable.

Risk analyses performed as part of the decision support for barrier management must be planned and executed so that they are sufficiently detailed and appropriate, including being capable of communication to different user groups – including maintenance

personnel. For example, the risk analysis may assume that equipment is tested and maintained, meaning that delayed maintenance may affect the risk picture negatively, and must therefore be monitored. It is worth noting that RNNP (Trends in risk level in the petroleum activity) shows that year-on-year certain facilities fail to meet industry standards in respect of the performance of selected barrier elements. This may be indicative of a deficient capability for continuous improvement.

A comparison of results from risk analysis with established decision-making criteria and acceptance criteria may lead to more (or less) stringent criteria for testing of the barriers, with associated adjustments to the maintenance programme. It must also be assessed whether the defined requirements for frequency of maintenance and testing are realistic in respect of operational limitations and resources.

### 7.2.1 Regulations

The HSE regulations require that facilities (including all their systems and equipment, including barriers) be maintained so as to be capable of performing their intended functions in all phases of their lifetime (Section 45 of the Activities Regulations). Maintenance should help prevent the occurrence of faults with negative consequences for personnel, the external environment, operational regularity and material assets.

This clearly shows the importance of maintenance management, not least in terms in HSE-critical equipment and barriers. The participants therefore need appropriate usable and cost-efficient maintenance methods based on the equipment's failure patterns. In situations where a given design has already been deployed, it is through the maintenance function that the problem of recurrent faults must be identified and resolved, whether this entails redesign/modification or better-adapted maintenance.

### 7.2.2 Major accident potential

One aim of maintenance management is to identify critical functions and ensure that barriers function when required.

Maintenance is a necessary prerequisite for upholding the performance of a barrier element and to improve its condition and performance over time. This is done through

- verification of the performance of the barrier elements (functional testing and condition monitoring)
- preventive maintenance (PM) to prevent the occurrence of safety-critical failures
- corrective maintenance (CM) to restore functionality once a fault has occurred or is developing

In respect of corrective maintenance, it is also important to detect causes of the failures to avoid recurrences.

### 7.2.3 Safety-critical failures

Reviews of safety-critical failures in the operational phase show that a considerable proportion of the faults may be ascribed, directly or indirectly, to

deficient or defective maintenance. Certain findings from RNNP show that there is large variation between companies and between facilities in respect of the performance of key barrier elements. More systematic improvement work, through, for example, experience transfer between facilities in the same company and between companies, can help reduce the differences. A failure to observe deadlines or a lack of follow-up of degradation has been observed to be a challenge in barrier maintenance.

## 7.3 WELLBORE DRILLING AND WELLS

One example of a barrier function within drilling is the detection of influx or kick during a drilling operation<sup>3</sup>.

Figure 14 illustrates how the different technical, organisation and operational barrier elements are incorporated in order to provide this barrier function. Mudloggers and drillers have volume control for the mud during drilling in order to detect influx from the well. The mudlogger warns the driller and the driller decides on the measures to implement. Subsequent barrier functions might include the driller closing the BOP and the drilling supervisor and toolpusher managing ensuing killing of the well in order to restore well control.

The figure also shows some examples of performance requirements defined for the technical, organisational and operational barrier elements and performance-influencing factors.

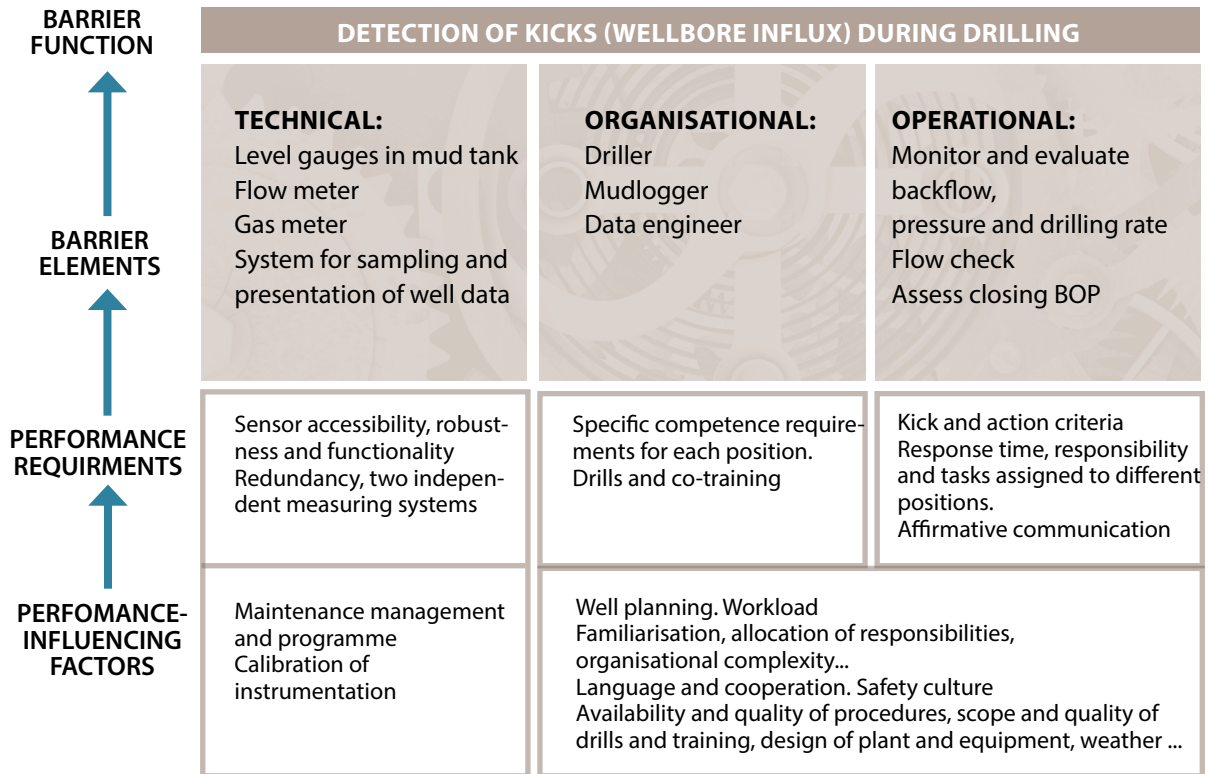
## 7.4 STRUCTURES AND MARINE SYSTEMS

Structures are primarily components of a safe and robust solution. Without them, none of the activities on a petroleum facility could take place. At the same time, structures and marine systems are barrier elements in failure, hazard and accident situations.

Examples of these include:

- The structure must be able to withstand a collision from a vessel up to a certain size and at a certain speed. In the hazard situation of a collision from a vessel, many barrier functions will normally be in place and should normally prevent the collision, but the structure needs to provide functionality to contribute to preventing a

<sup>3</sup> Within the drilling and wells domain, the term "barrier" refers to technical barriers in the well (the Facilities Regulations, Chap. VIII and the Activities Regulations, Chap. XV). The barrier memorandum does not seek to change the definitions linked to well barriers.



**Figure 14:** Example of technical, organisational and operational barrier elements involved in providing the “Detection of kick during a drilling operation” barrier function. The figure also shows examples of performance requirements and performance-influencing factors.

- collapse of the facility if none of the preceding barriers have worked as intended.
- Structures must have the necessary load capacity following incidents such as fire, explosion, partial structural failures, water ingress or collision from vessels of sufficient duration to allow evacuation of the facility.

Similarly, marine systems for stability and positioning are primarily aspects of a safe and robust solution. Marine systems have a number of barrier functions for providing stability and positioning. Examples of these include:

- Withstand unintended filling (flooding).
- Two on the bridge – one monitoring and one acting – barrier function to identify failure, hazard and accident situations.
- Redundant systems for ballasting.

Like structures, marine systems have functions in other failure, hazard and accident situations:

- Floating structures and their marine systems must have the necessary stability and position following incidents such as fire, explosion, structural failures, water ingress or collision from vessels of sufficient duration to allow evacuation of the facility.

The functions of structures and marine systems as barrier elements are essentially covered by the existing standards for structures (NORSOK N-series of standards and the Norwegian Maritime Directorate’s rules). A review of failure, hazard and accident situations for the specific facility and where the structure and marine systems contribute to barrier functions is equally important in order to define the correct performance requirements for the design and implementation of structures and marine systems. This is especially important for new concepts and systems used in contexts that are atypical.



**DOCUMENT HISTORY**

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**Which failure, hazard and accident situations do we need to be able to handle?**

**“Failure, hazard and accident situations may arise.**

**How should we handle these situations?**

**The function of barriers is to detect these at an early stage, reduce their potential for propagating and limit harm and disruption.**

**Barriers supplement a safe and robust solution.”**

**“Sufficient manning must be in place to perform the tasks.**

**Who does what with which equipment in a failure, hazard and accident situation?**

**Personnel must know which tasks they have been assigned and be able to perform them.**

**Technical barrier elements must be tested, inspected and maintained.**

**What is the condition of the barriers?  
Do they meet the requirements?  
Do they fulfil their role?**

**Personnel must be trained and drilled in performing their barrier function.”**

**“The object of barrier management is to reduce risk”**



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