Standardization of barrier definitions

Supplement to Report 415
Acknowledgements

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Standardization of barrier definitions

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1. Background

Barriers represent a grouping of risk controls

IOGP Report 415, *Asset Integrity – the key to managing major incident risks* [1], published in 2008, explicitly addressed asset integrity and process safety risks as part of a company’s overall health, safety and environment management system (HSE-MS).


Reports 415 and 510 both provide guidance on how apply risk management as a fundamental process that puts planned measures in place to eliminate or reduce release of hazards by applying risk controls.

Report 415 introduced the concept of establishing a set of barriers, each of which represents a grouping of risk controls.

A barrier is designed to either prevent an event caused by release of a hazard or to mitigate an event’s potential consequences, including major incidents. Multiple barriers are deployed in combination to address each type of threat or cause of an event and its consequences.

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**Barrier**

*A risk control that seeks to prevent unintended events from occurring, or prevent escalation of events into incidents with harmful consequences.*

From IOGP 510 [2].

Implementation of the barrier concept is described in Report 415 using

- the bow tie model (an analysis of all potential threats), and
- the Swiss Cheese model (an analysis of a single threat within the bow tie).

The concept of barrier thinking in risk management is well understood. However, in practice the term ‘barrier’ is used in different ways and at different levels of detail, which makes it difficult to consistently link event or incident causes with necessary improvements in controls.
Key Performance Indicators applied using the barrier concept

The barrier concept was further developed in IOGP Report 456, *Process Safety – Recommended Practice on Key Performance Indicators* in 2011 [3]. The application of leading process safety KPIs benefits from application of the barrier concept.

Report 456 established four Tiers of Key Performance Indicators to collect data on significant loss of primary containment (LOPC) events (Tiers 1 and 2) and to establish leading indicators to assess barriers (Tiers 3 and 4).

Report 556, *Process Safety – Leading key performance indicators* is a new supplement to Report 456 in preparation [4]. It will align the hardware and human barrier categories defined here with the development of leading KPIs at the Tier 3 and 4 levels.
2. Scope

This report standardizes the **types** and **categories** of process safety barriers. The target audience is all leaders and workers that contribute to process safety performance on an asset.

The terminology provides a basis of common understanding which companies can use to further refine or develop more detail as appropriate to their activities.

The use of consistent and simple terminology is aimed at personnel at all levels and will assist in communication. The standardization and common understanding will assist the review of bow ties and related tools to ensure clarity and completeness.

Barrier standardization also provides the means to identify areas of shortfall in a consistent way, gathering data from more operations (and operators) enabling trending and focus on the specific causes of failure on certain barriers and facilitate improvements.

Figure 1 illustrates how consistently defined information drawn from events and incidents can provide learning to strengthen barriers, reduce risk and improve operating performance.

Using consistent barrier definitions through this cycle enables the identification of trends in similar barrier failures and the opportunity to learn and improve.

![Figure 1: Barrier performance cycle](image-url)
3. Defining barrier types

Figure 2 illustrates two primary types of barrier: hardware barriers and human barriers.

Hardware and human barriers are put in place to prevent a specific threat or cause of a hazard release event, or to reduce the potential consequences if barriers have failed and an event has occurred.

Both hardware and human barriers are supported by the processes and procedures contained within the Management System Elements, such as those in the Operating Management System in Report 510 [2].

* i.e. processes and procedures within the Management System elements

Figure 2: Barrier types
Hardware barriers
Primary containment, process equipment and engineered systems designed and managed to prevent LOPC and other types of asset integrity or process safety events and mitigate any potential consequences of such events. These are checked and maintained by people (in critical activity/tasks).

Human barriers
Barriers that rely on the actions of people capable of carrying out activities designed to prevent LOPC and other types of asset integrity or process safety events and mitigate any potential consequences of such events.

Management System Elements
Management System Elements that group processes and practices designed to prevent LOPC and other types of asset integrity or process safety events and mitigate any potential consequences of such events. Management System Elements support hardware and human barriers.
4. Hardware barrier categories

Hardware barriers implemented by the oil and gas industry for process safety can be broadly categorized under eight hardware barrier categories:

Category 1: **Structural Integrity**
Category 2: **Process Containment**
Category 3: **Ignition Control**
Category 4: **Detection Systems**
Category 5: **Protection Systems** – including deluge and firewater systems
Category 6: **Shutdown Systems** – including operational well isolation and drilling well control equipment
Category 7: **Emergency Response**
Category 8: **Life-saving Equipment** – including evacuation systems

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Examples of hardware barrier subcategories for an operating facility

Operators may define subcategories slightly differently but the objective is alignment under the eight categories.

Subcategories of Category 1, **Structural Integrity**

Subsea/Vessel Hull/GBS/Foundation Structures
Topsides/Surface Structures
Heavy Life Cranes & Mechanical Handling Equipment
Ballast and Cargo Management Systems
Road Vehicles
Mooring Systems
Drilling Systems.
Subcategories of Category 2, **Process Containment**

Pressure Vessels  
Heat Exchangers  
Rotating Equipment  
Tanks  
Piping Systems  
Pipelines  
Relief Systems  
Operational Well Containment  
Fired Heaters  
Gas Tight Floor/Wells  
Tanker Loading Systems  
Helicopter Refuelling Equipment.

Subcategories of Category 3, **Ignition Control**

Hazardous Area Ventilation  
Non-Hazardous Area Ventilation  
Certified Electrical Equipment  
Cargo Tanks Insert Gas System  
Earth Bonding  
Fuel Gas Purge System  
Chemical Tanks Inert Gas Blanket System  
Miscellaneous Ignition Control Components  
Flare Tip Ignition System.

Subcategories of Category 4, **Detection Systems**

Fire and Gas Detection  
Security Systems  
Subcategories of Category 5, **Protection Systems** – including deluge and firewater systems

- Deluge System
- Fire and Explosion Protection
- Firewater Pumps
- Firewater Ring Main
- Passive Fire Protection
- Gaseous Fire Protection System
- Fine Water Spray System
- Sprinkler System
- Power Management System
- Fixed Foam System
- Sand Filters
- Chemical Injection Systems
- Navigation Aids
- Collision Avoidance Systems
- Metocean Data Gathering Systems
- Cathodic Protection,

Subcategories of Category 6, **Shutdown Systems** – including operational well isolation and drilling well control equipment

- Emergency Shutdown System
- Depressurization System
- High Integrity Protection Systems (HIPPS)
- Operational Well Isolation
- Pipeline Isolation Valves
- Process Emergency Shutdown Valves (ESDVs)
- Subsea Isolation Valves (SIVs)
- Drilling and Well Intervention Well Control Equipment.
Subcategories of Category 7, **Emergency Response**

Temporary Refuge/Primary Muster Areas
Escape and Evacuation Routes
Emergency/Escape Lighting
Communication Systems
Uninterruptible Power Supply (UPS)
Helicopter Facilities
Emergency Power
Open Hazardous Drains Systems
Miscellaneous Ignition Control Components
Flare Tip Ignition Systems.

Subcategories of Category 8, **Life-saving Equipment – including evacuation systems**

Personal Survival Equipment (PSE)
Rescue Facilities
Lifeboats/TEMPSCs
Tertiary Means of Escape.

Operator-specific systems can further break down the subcategories into specific components or equipment lists as appropriate.
5. Human barrier categories

Human barriers implemented by the oil and gas industry for process safety can be broadly categorized under six human barrier categories:

Category 1: **Operating in accordance with procedures**, e.g.
- Permit To Work
- Isolation of equipment
- Overrides and inhibits of safety systems
- Shift handover

Category 2: **Surveillance, operator rounds and routine inspection**

Category 3: **Authorization of temporary and mobile equipment**

Category 4: **Acceptance of handover or restart of facilities or equipment**

Category 5: **Response to process alarm and upset conditions** (e.g. outside safe envelope)

Category 6: **Response to emergencies**

Operators may define subcategories slightly differently but the objective is alignment under these six categories.

A human barrier model requires a desired set of individual and collective behaviours that ensure the barriers remain effective (e.g. not short-cutting procedures, honouring the full Management of Change process, and staying within the safe operating envelopes). Sometimes these behaviours are referred to as ‘operating discipline’.

Without these desired behaviours, resilience of human barriers will be very low. Strong, energetic and consistent leadership will always be required to maintain acceptable human barrier health.

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*Human barriers do not include critical activity/tasks required to check and maintain hardware barriers. This is typically defined in the process supporting the hardware barrier e.g. Maintenance and Inspection (M&I) or Technical Integrity Management described within the Management System.*
6. Management System Elements

The processes and practices (plans, procedures, instruction, etc.) within the ten Management System Elements directly support hardware and human barriers that are designed to prevent LOPC and other types of asset integrity or process safety events, and mitigate any potential consequences of such events.

Some examples are:

- Permit to work (Element 8)
- Management of Change (Element 5)
- Emergency Response Procedure (Element 7)
- Competency Management (Element 3)
- Contractor Management (Element 3)
- Technical Integrity (Element 6)
- Corrosion Management (Element 6)
- Equipment Isolation (Element 8).
7. Categorizing LOPC events and improving barrier effectiveness

The most severe LOPC events are categorized as Tier 1 and 2, and indicate the failure of multiple barriers. Barrier definitions used for Tier 1 and Tier 2 can also be used in the reporting of events where no loss of containment or incident has occurred but where one or more barriers, or supporting systems, failed or did not function as expected, i.e. Tier 3 process safety events.

(Tier 3 process safety events are also sometimes called ‘single barrier (failure) events’, ‘barrier events’ or ‘controls non-compliance’. Standardization of this terminology will assist consistent communication by leadership, learning/sharing of lessons and the development of performance metrics.)

An impaired hardware or human barrier can contribute to a Tier 1, 2 or 3 process safety event [PSE] [3]. An ineffective Management System Element can contribute to the failure of a hardware or human barrier, resulting in a Tier 1, 2 or 3 PSE.

Tier 4 KPIs are used to monitor activities that maintain or strengthen the Management System Elements, which in turn support the effectiveness of the barriers. This is further developed in [4].

Together, the four Tiers support continuous improvement of barrier effectiveness, particularly in response to any failures or weaknesses identified through Tier 1–3 events.

It can be hard to precisely attribute a barrier category when learning from a process safety event but precise attribution should not be an issue if an actionable improvement can be applied to prevent a recurrence.

Take for example an event [not necessary a process safety event] that has resulted from a failure of an individual to recognize a hazard/risk [e.g. entering an area which should be treated as a confined space]. This can be attributed to a human barrier failure [failure to operate in a in accordance with procedures]. However, the cause may be attributable to one or more Management System Elements, e.g. Communication or Competence management.
Appendix A

Examples of hypothetical events with a loss of primary containment, where malfunctioning or failed barriers and critical processes are identified

These are hypothetical examples for illustrative purposes only and are not intended to represent actual events.

Example 1: **Offshore pipeline cathodic protection**

A crude submarine pipeline has a sudden failure in near shore area due to degradation of the cathodic protection system affording protection against external corrosion. This degradation resulted from a lack of maintenance. The spill response was effective.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Corrosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequence</td>
<td>Release to the Environment</td>
</tr>
<tr>
<td>Barrier</td>
<td>Hardware barriers – Process Containment – Pipelines</td>
</tr>
<tr>
<td>OMS Element/Process and Practice</td>
<td>Technical Integrity Preventative Maintenance [Element 7 or Element 8]</td>
</tr>
</tbody>
</table>

Example 2: **Tank overfill**

An LOPC occurs due to overfill from a truck loading produced water. The flow totalizer failed to shut the inlet flow (because it was bypassed) and the operator response was delayed to the overflow. The overflow drained off the pad due to plugged drains that were not identified during regular site tours.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Overfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequence</td>
<td>Release to the Environment</td>
</tr>
<tr>
<td>Barrier</td>
<td>Hardware barriers – Process Containment – Other equipment type (road tanker)</td>
</tr>
<tr>
<td>Barrier</td>
<td>Hardware barriers – Shutdown Systems – Emergency shutdown systems</td>
</tr>
<tr>
<td>Barrier</td>
<td>Hardware barriers – Emergency Response – Drain Systems</td>
</tr>
<tr>
<td>Barrier</td>
<td>Human barriers – Response to emergencies</td>
</tr>
<tr>
<td>OMS procedure/process</td>
<td>Operating Integrity</td>
</tr>
<tr>
<td>OMS procedure/process</td>
<td>Emergency Response</td>
</tr>
</tbody>
</table>
Example 3: **Valve bullplug**

An LOPC occurs from a threaded bullplug connection on the bottom of a valve at a gas gathering site. The bullplug had blown out due to corrosion and rust marks indicating corrosion on the underside of the valve had not been detected on rounds. The release is unignited and the system is quickly isolated and depressurized to flare.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Corrosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequence</td>
<td>Release to the Environment</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Hardware barriers – Process Containment – Piping Systems – Threaded connection</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Human barriers – Surveillance, operator rounds and routine inspection</td>
</tr>
<tr>
<td><strong>OMS procedure/process</strong></td>
<td>Technical Integrity – Equipment Inspection</td>
</tr>
<tr>
<td><strong>OMS procedure/process</strong></td>
<td>Operating Integrity</td>
</tr>
</tbody>
</table>

Example 4: **Hose rupture**

A temporary flexible hose is employed on a site to transfer oil from a waste separator and, due to heavy use, has sustained chaffing and abrasion damage. The hoses are not included in the monthly revalidation check. The hose ruptures and there is a hydrocarbon spill and a fire. Emergency response is effective although there are learnings to improve the speed of response.

<table>
<thead>
<tr>
<th>Threat</th>
<th>External Damage (e.g. wear, impact)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequence</td>
<td>Fire/explosion</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Hardware barriers – Process Containment – Piping Systems – Flexible Hose</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Human barriers – Authorization of temporary and mobile equipment</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Human barriers – Response to emergencies</td>
</tr>
<tr>
<td><strong>OMS procedure/process</strong></td>
<td>Management of Change</td>
</tr>
<tr>
<td><strong>OMS procedure/process</strong></td>
<td>Emergency Response</td>
</tr>
</tbody>
</table>
Example 5: Piping handover

A mechanical supervisor and production supervisor check that all pipe work and fittings are satisfactorily closed up and checked after process containment system reinstated. One coupling remains to be completed once tensioning equipment becomes available later. The handover documentation is signed off [e.g. Statement of Fitness/Handshake] with the exception noted. The incomplete work is not captured in the handover to night shift and on start up, a significant leak occurs. The leak ignites because of an electrical equipment with an incorrect classification and is quickly extinguished and the asset isolated and depressured.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Incorrect Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequence</td>
<td>Fire/explosion</td>
</tr>
<tr>
<td>Barrier</td>
<td>Hardware barriers – Process Containment – Piping Systems – Flange</td>
</tr>
<tr>
<td>Barrier</td>
<td>Hardware barriers – Ignition controls</td>
</tr>
<tr>
<td>Barrier</td>
<td>Human barriers – Acceptance of handover or restart of facilities or equipment</td>
</tr>
<tr>
<td>OMS procedure/process</td>
<td>Technical Integrity – Pipe fitting/flange make up</td>
</tr>
<tr>
<td>OMS procedure/process</td>
<td>Operating Integrity [Shift Handover]</td>
</tr>
<tr>
<td>OMS procedure/process</td>
<td>Design Integrity</td>
</tr>
</tbody>
</table>
Example 6: **Pump seal in offshore module**

There is a significant undetected loss of containment with a condensate mist filling an offshore module. The fire and gas detection system fails to detect the leak due to improper positioning. The situation is not recognized by the control room operators through video and/or process alarms. Eventually the leak is detected in adjacent modules and an automatic ESD occurs. The release is unignited and is reduced and isolated. It is identified that the leak originated from a transfer pump seal that failed prematurely due to improper alignment done by crew missing training on this type of equipment. Quantity of condensate lost would have been significantly reduced by more timely recognition and response to the upset.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Fatigue (Mechanical)/Vibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequence</td>
<td>Release to the Environment</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Hardware barriers – Process Containment – Rotating Equipment – Seal</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Hardware barriers – Detection – Fire and Gas Detection</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Human barriers – Surveillance, operator rounds and routine inspection</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Human barriers – Response to emergencies</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Human barriers – Response to process alarm and upset conditions</td>
</tr>
<tr>
<td>OMS procedure/process</td>
<td>Competence management</td>
</tr>
<tr>
<td>OMS procedure/process</td>
<td>Operating Integrity</td>
</tr>
<tr>
<td>OMS procedure/process</td>
<td>Design Integrity</td>
</tr>
<tr>
<td>OMS procedure/process</td>
<td>Emergency Response</td>
</tr>
</tbody>
</table>
Appendix B

Examples of hypothetical events where a barrier has malfunctioned or failed but there has been no incident or loss of primary containment

These events can also be referred to as 'single barrier failure events' or 'barrier events' and correspond to API Tier 3 and 4 Process Safety Events PSE.

Reporting against these can use the same defined barriers and will form part of a later implementation programme (Phase 2).

Hardware barrier

Example

A survey of the cathodic protection levels of a submarine pipeline carrying crude in the near shore area shows a drop in protection to unacceptable levels due to deterioration of the grounding connections. Immediate action is taken to restore protection levels to an adequate level.

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Hardware barriers – Process Containment – Pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hardware barriers – Protection Systems – Cathodic protection</td>
</tr>
<tr>
<td><strong>OMS procedure/process</strong></td>
<td>Technical Integrity Preventative Maintenance</td>
</tr>
</tbody>
</table>

Human barriers

Example 1

In a flaring event, a flare high level Knockout drum reaches high level. A procedure is in place to shutdown the contributing streams. However, the high level is noticed after the Level Alarm High High (LAHH) just prior to overflow. No LOPC occurs.

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Human barrier – Response to process alarm and upset conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OMS procedure/process</strong></td>
<td>Operating Integrity – Alarm Management</td>
</tr>
</tbody>
</table>
Example 2

Maintenance work on a pump had been suspended until next day shift; adjacent pipe work isolated and gas detection in module overridden. During shift handover, this was not effectively communicated and hot work was approved in the same module without recognizing that gas detection system was disabled.

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Human barrier – Acceptance of handover or restart of facilities or equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMS procedure/process</td>
<td>Operating Integrity – Shift Handover</td>
</tr>
</tbody>
</table>

Example 3

Following gas tests and permit issued where hot work is to be performed, one of the construction supervisors notices that there is a drain nearby where there is a strong smell of hydrocarbon yet this has not been discussed in the permit or the pre job toolbox talk. The supervisor fails to highlight this and commences the welding work and does not inform the PTW signatory. The job is stopped by the operations permit issuer on a follow-up walk through.

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Human barrier – Operating in accordance with procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMS procedure/process</td>
<td>Permit to Work</td>
</tr>
</tbody>
</table>

Example 4

A pump on routine Preventative Maintenance (PM) is noticed to have a damaged seal and a check indicates high vibration had occurred. No LOPC involved. Routine monitoring had not detected the vibration.

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Human barrier – Surveillance, operator rounds and routine inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMS procedure/process</td>
<td>Technical Integrity</td>
</tr>
</tbody>
</table>

Example 5

A field supervisor notes unusual and excessive vibration from pipe work near compression modules but does not advise the control room immediately to take appropriate measures. The excessive vibration increases and later causes a shutdown and equipment replacement, but not an LOPC.

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Human barrier – Surveillance, operator rounds and routine inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMS procedure/process</td>
<td>Operating Integrity</td>
</tr>
</tbody>
</table>
Example 6
A site supervisor notes that, despite having a current ‘approved for use on site’ certificate, an electric access scissor lift platform in use in the field has damage to the insulation of the power cables to the hydraulic pump and personally ensures that it is removed from the facility.

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Human barrier – Authorization of temporary and mobile equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMS procedure/process</td>
<td>Technical Integrity – Equipment inspection</td>
</tr>
</tbody>
</table>

Example 7
Supervisor suspends vacuum truck operations until truck is returned to maintenance to have earthing cables and clamps satisfactorily repaired, re-inspected and tested. A check had not been completed during the authorization of the vacuum truck to ensure earthing equipment was in good order.

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Human barrier – Authorization of temporary and mobile equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMS procedure/process</td>
<td>Technical integrity – Equipment inspection</td>
</tr>
</tbody>
</table>

Example 8
During the loading of crude offshore from a Floating Production Storage Offloading (FPSO) vessel to a tanker, a buildup of pressure in the system was not recognized in the control room as it was difficult to hear or see the problem. An off-shift maintenance foreman heard an unusual noise from the loading pumps and raised the alarm with the control room that something was wrong. They immediately ceased loading and depressurized the loading line thus averting a potential significant spillage.

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Human barrier – Response to process alarm and upset conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMS procedure/process</td>
<td>Operating Integrity</td>
</tr>
</tbody>
</table>

Example 9
Automatic sampling equipment for H₂S levels in a process stream offshore has failed and manual sampling undertaken instead. The change has not been recognized and, as a result, the necessary steps to manage the new risks have not been taken or approved (e.g. assessment, training, PPE and recovery measures).

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Hardware barrier – Detection Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMS procedure/process</td>
<td>Management of Change</td>
</tr>
</tbody>
</table>
References


The concept of barrier thinking in risk management is well understood. However, in practice the term ‘barrier’ is used in different ways and at different levels of detail, which makes it difficult to consistently link event or incident causes with necessary improvements in controls.

This report standardizes the types and categories of process safety barriers. The target audience is all leaders and workers that contribute to process safety performance on an asset.