International Association of Oil & Gas Producers

REPORT 544 | APRIL 2016

Standardization of barrier definitions

Supplement to Report 415

Acknowledgements

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Revision history

VERSION	DATE	AMENDMENTS
1.1	April 2016	First release

Contents

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).

Guidance on establishing an Operating Management System (OMS) is now integrated within IOGP Report 510, *Operating Management System Framework for controlling risk and delivering high performance in the oil and gas industry*, published in 2014 [2].

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.

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.

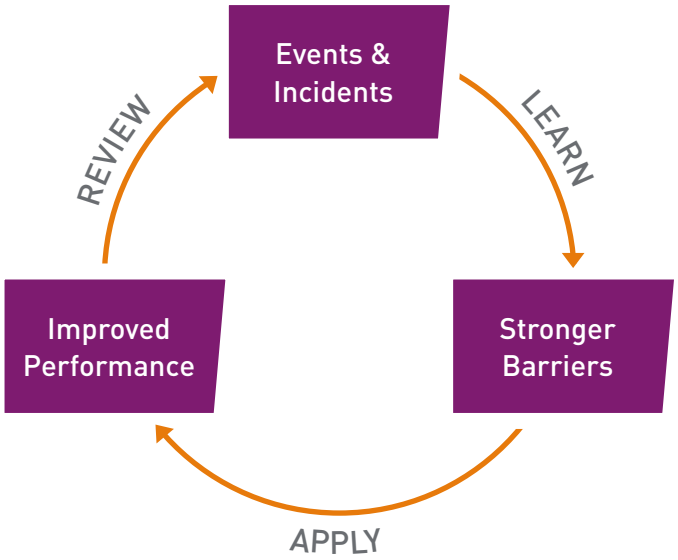

Figure 1: Barrier performance cycle

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].

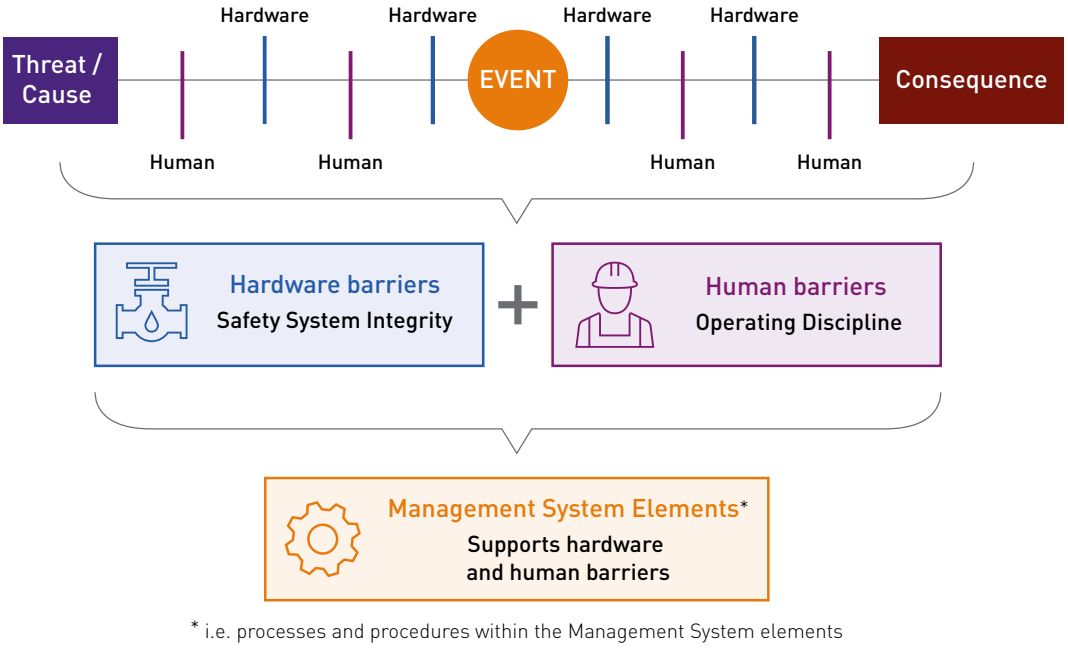

Figure 2: Barrier types

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**

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 Lift 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
Water-in-Condensate/Gas (Dew Point) Measurement.

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 (SSIVs)
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.

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

An Operating Management System (OMS) Framework comprises four fundamentals and ten Management System Elements. See IOGP Report 510 [2].
IOGP Report 511 [5] describes the Elements in detail.

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 functioned 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 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 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.

Threat	Corrosion
Consequence	Release to the Environment
Barrier	Hardware barriers – Process Containment – Pipelines
Barrier	Hardware barriers – Protection Systems – Cathodic protection
OMS Element/Process and Practice	Technical Integrity Preventative Maintenance (Element 7 or Element 8)

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.

Threat	Overfill
Consequence	Release to the Environment
Barrier	Hardware barriers – Process Containment – Other equipment type (road tanker)
Barrier	Hardware barriers – Shutdown Systems – Emergency shutdown systems
Barrier	Hardware barriers – Emergency Response – Drain Systems
Barrier	Human barriers – Response to emergencies
OMS procedure/process	Operating Integrity
OMS procedure/process	Emergency Response

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.

Threat	Corrosion
Consequence	Release to the Environment
Barrier	Hardware barriers – Process Containment – Piping Systems – Threaded connection
Barrier	Human barriers – Surveillance, operator rounds and routine inspection
OMS procedure/process	Technical Integrity – Equipment Inspection
OMS procedure/process	Operating Integrity

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.

Threat	External Damage (e.g. wear, impact)
Consequence	Fire/explosion
Barrier	Hardware barriers – Process Containment – Piping Systems – Flexible Hose
Barrier	Human barriers – Authorization of temporary and mobile equipment
Barrier	Human barriers – Response to emergencies
OMS procedure/process	Management of Change
OMS procedure/process	Emergency Response

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.

Threat	Incorrect Operation
Consequence	Fire/explosion
Barrier	Hardware barriers – Process Containment – Piping Systems – Flange
Barrier	Hardware barriers – Ignition controls
Barrier	Human barriers – Acceptance of handover or restart of facilities or equipment
OMS procedure/process	Technical Integrity – Pipe fitting/flange make up
OMS procedure/process	Operating Integrity (Shift Handover)
OMS procedure/process	Design Integrity

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.

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

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.

Barrier	Hardware barriers – Process Containment – Pipeline
Barrier	Hardware barriers – Protection Systems – Cathodic protection
OMS procedure/process	Technical Integrity Preventative Maintenance

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.

Barrier	Human barrier – Response to process alarm and upset conditions
OMS procedure/process	Operating Integrity – Alarm Management

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.

Barrier	Human barrier – Acceptance of handover or restart of facilities or equipment
OMS procedure/process	Operating Integrity – Shift Handover

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.

Barrier	Human barrier – Operating in accordance with procedures
OMS procedure/process	Permit to Work

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.

Barrier	Human barrier – Surveillance, operator rounds and routine inspection
OMS procedure/process	Technical Integrity

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.

Barrier	Human barrier – Surveillance, operator rounds and routine inspection
OMS procedure/process	Operating Integrity

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.

Barrier	Human barrier – Authorization of temporary and mobile equipment
OMS procedure/process	Technical Integrity – Equipment inspection

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.

Barrier	Human barrier – Authorization of temporary and mobile equipment
OMS procedure/process	Technical integrity – Equipment inspection

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.

Barrier	Human barrier – Response to process alarm and upset conditions
OMS procedure/process	Operating Integrity

Example 9

Automatic sampling equipment for H_2S 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).

Barrier	Hardware barrier – Detection Systems
OMS procedure/process	Management of Change

References

[1] IOGP. Report 415. *Asset integrity – the key to managing major incident risks*. London: December 2008.

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[4]. IOGP. Report 556. *Process Safety – Leading key performance indicators*. Supplement to IOGP Report 456. (In preparation.)

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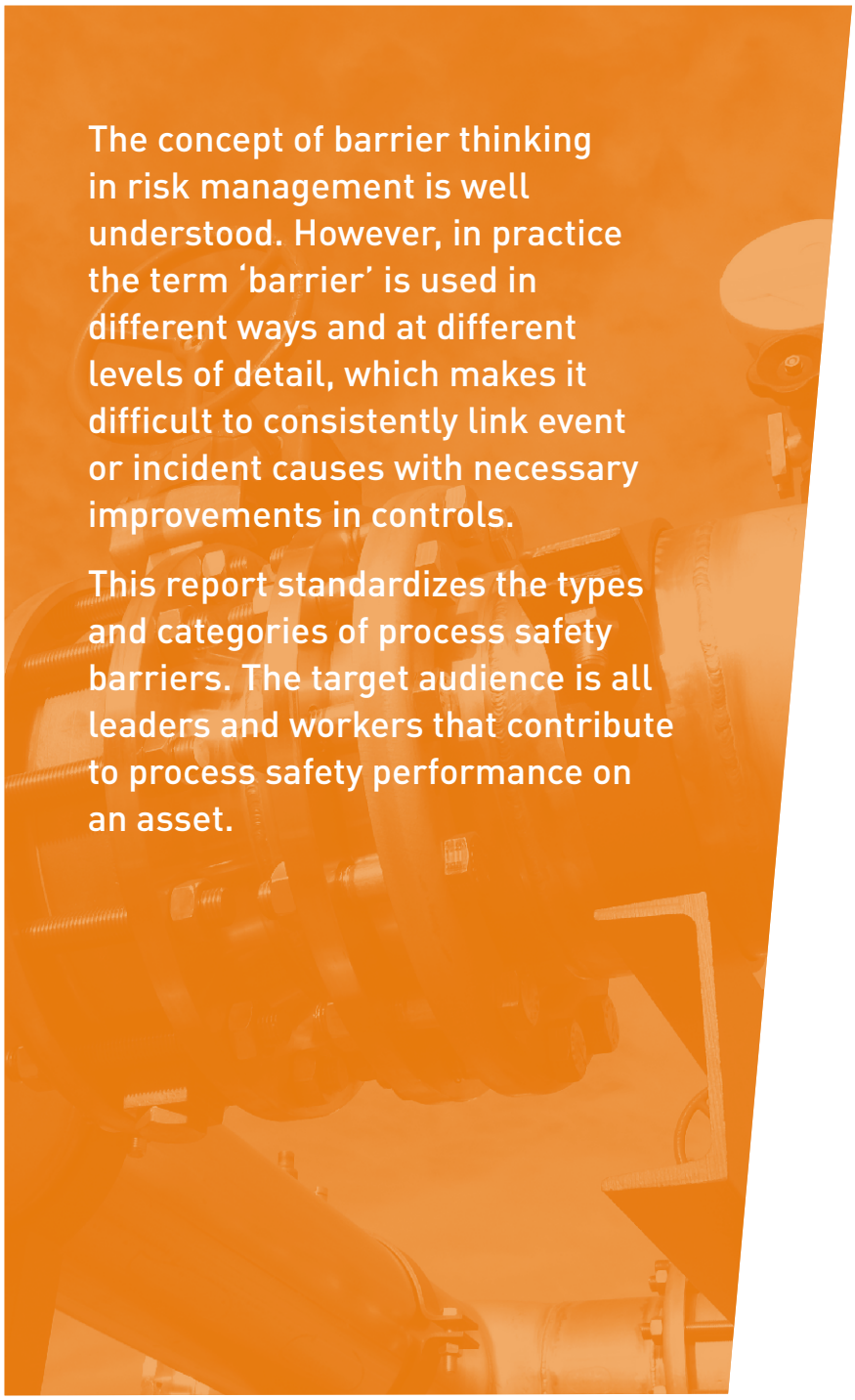

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