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Barrier management in the offshore oil and gas industry

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ABSTRACT

Accident investigations indicate that inadequate barrier management has been a main cause of many accidents in the process industry. In 2013, the Norwegian Petroleum Safety Authority issued a barrier management framework for the offshore oil and gas industry. The framework describes principles related to barrier management and may be a valuable guide for the entire process industry. However, the offshore industry faces several challenges when implementing the framework. This paper discusses these challenges and clarifies the central concepts and steps of barrier management. A key message is the need for clarity and integration in a systematic approach to risk and barrier management.

1. Introduction

The importance of (safety) barriers and barrier management in major accident prevention has been demonstrated by investigations after several offshore oil and gas accidents. A recent example is the Macondo blowout in 2010, which involved multiple barrier failures that were attributed to lack of systematic barrier management (NOG, 2012). A rationale for using barriers is given by the *energy-barrier* principle that was introduced by Gibson (1961). This principle says that accidents occur due to loss of control of dangerous energy, and that it is necessary to separate this energy from vulnerable targets. The *Swiss cheese* model of Reason (1997) indicates that all barriers have holes that may line up and allow a hazard to penetrate the system. Barriers degrade over time, and the system may gradually and unnoticeably drift towards a state of high risk if the size of the holes increases. Barriers must therefore be systematically managed to maintain and improve their performance throughout the system's lifetime.

In 2013, the Norwegian Petroleum Safety Authority (PSA, 2013) published a set of principles and a framework for barrier management in the petroleum industry. The industry sees both benefits and challenges of the framework, which has raised a lot of discussions. A common critique is that the principles are vaguely described and that it is difficult to implement the framework in practice (DNV, 2014).

The purpose of this paper is to clarify the concepts and principles of barrier management and provide an overview of requirements and challenges in the offshore oil and gas industry, with special focus on the Norwegian offshore industry. The scope is delimited to the barrier management framework of PSA. Other industries or regulatory regimes are not considered, but the insights are generic. The paper is structured as follows: first, central concepts and principles of barrier management are clarified. Requirements to barrier management in the Norwegian offshore industry are then presented, before a discussion of status and challenges, conclusions, and suggestions for further work.

2. Barrier concepts

This section clarifies central barrier concepts. For some of the concepts, we provide different definitions than the ones provided in PSA (2013), on the grounds that they are considered more clarifying.

2.1. Definitions

A *barrier* can be defined as a physical and/or non-physical means planned to prevent, control, or mitigate undesired events or accidents (Sklet, 2005). This is a collective term that is convenient for speaking about barriers and their purpose in a general sense, but for analytical purposes, it is more precise to refer to barrier functions, systems, or elements. The definition is different from the one provided in PSA (2013), which equates barriers with barrier

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elements and is therefore somewhat circular. In our view, "barrier" is more synonymous to "barrier system", but with a less precise interpretation.

A *barrier function* is the task or role of the barrier (PSA, 2013). It can often be specified by a verb and a noun, such as "stop flow" and "contain fluid." Each barrier function is designed to prevent or mitigate the consequences of a specific hazardous process demand or deviation. A barrier function may sometimes be broken down to several barrier sub-functions, such as to detect, verify, and relieve high pressure. A barrier sub-function cannot perform the barrier function by itself, but is a necessary constituent of the barrier function. In this paper, barrier functions and sub-functions are defined on a lower level than in PSA (2013), where "reduce explosion related risk in area" and "isolate leaking segment" are given as examples of barrier functions and sub-functions. In our view, it is necessary to define the concrete role of a barrier function in the accident scenario, not simply "to reduce risk".

A *barrier system* is a system that has been designed and implemented to perform one or more barrier functions (DNV, 2014), such as a pressure protection system. A barrier system will sometimes have several *barrier elements* that perform one or more barrier sub-functions. *Barrier elements* may be defined as technical, operational, or organizational measures that play a part in realizing a barrier function (PSA, 2013).

Technical barrier elements, such as pressure sensors or shutdown valves, are engineered items that carry out one or more barrier functions. *Operational* barrier elements are tasks performed by an operator, or team of operators, such as to manually open a valve or to operate a manual fire extinguisher. *Organizational* barrier elements are personnel responsible for, and directly involved in, realizing one or more barrier functions, such as the operator of a manual fire extinguisher (DNV, 2014).

Performance influencing factors (PIFs) are conditions which are significant for the ability of barrier functions and elements to perform as intended (PSA, 2013), such as maintenance or training (Sklet, 2005). In contrast to barrier functions, PIFs have only an *indirect* effect on the accident scenario. In some of the risk analysis literature, PIFs are referred to as *risk influencing factors* (RIFs) (Øien, 2001).

2.2. Categorization of barriers

Barriers can be categorized in several ways [see, e.g., Guldenmund et al., 2006; Sklet, 2005]. One is by their function or role in the accident sequence, for example, as preventive, controlling, or mitigating. The *bow-tie* diagram in Fig. 1 illustrates that a hazardous event can be prevented by a set of *proactive* barrier functions and mitigated by a set of *reactive* barriers functions.

Barriers can also be characterized by their nature, such as technical, operational, and organizational; or physical, functional, symbolic, and incorporeal (Hollnagel, 2004). Technical systems can in turn be divided into safety-instrumented systems (SIS),[1] safety systems without integrated logic (e.g., pure mechanical devices), and external risk reduction facilities (e.g., evacuation means) (IEC 61508, 2010; Rausand, 2014). A SIS consists of input items (e.g., detectors), one or more logic solvers, and actuating items (e.g., valves). This is an *active* barrier, and can be contrasted with *passive* barriers that do not require any action to perform their function, such as a fire wall.

[1] IEC 61508 (IEC 61508, 2010) does not use the term SIS, but Electrical/Electronic/Programmable Electronic safety-related system.

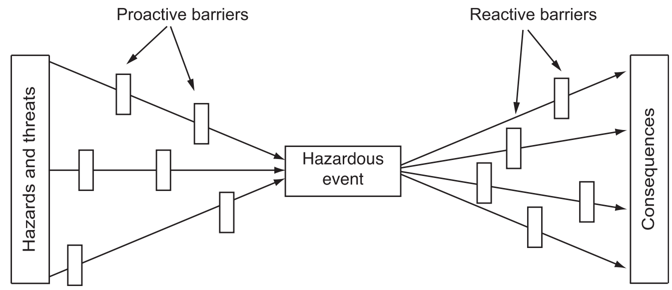

Fig. 1. Proactive and reactive barrier functions in the bow-tie.

2.3. What is (not) a barrier

Many get hung up in discussions of what a barrier is and what it is not. Is, for example, a procedure or test a barrier? First and foremost, this shows the need for being specific and rather refer to barrier functions, systems, and elements. In our opinion, a procedure describes an operational barrier element, for example, a test. A test can be seen to perform a barrier sub-function if it is a necessary basis for an action that has a direct influence on the accident scenario. This furthermore shows the need to distinguish between barrier (elements/functions/systems) and PIFs. For example, a test that is performed to detect the onset of a hazardous event (e.g., inspection to detect leakage as basis for isolation of leaking segment) represents a barrier sub-function, whereas a test that is performed to verify whether the barrier function can be accomplished (e.g., proof test of detection device) is a PIF. The main difference between barrier elements and PIFs is that without the barrier element, the barrier function cannot be realized, whereas without a PIF, the function may still be realized, but its likelihood and/or performance are reduced.

It is furthermore useful to distinguish between barriers and other types of measures to reduce risk, such as inherently safe design or operational restrictions (Kjellén, 2007). Some consider

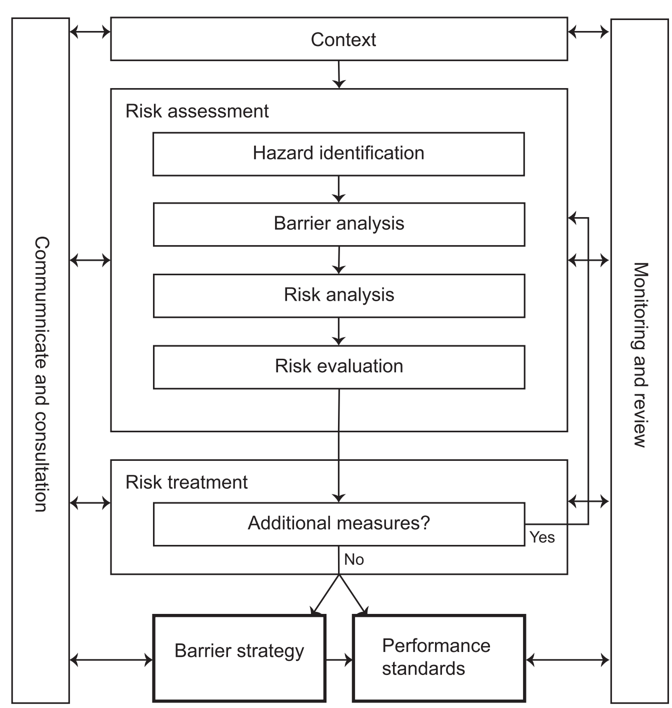

Fig. 2. The PSA barrier management framework (PSA, 2013).