Enhancing offshore safety and environmental performance

KEY LEVERS TO FURTHER REDUCE THE RISK OF MAJOR OFFSHORE ACCIDENTS
Global Services to the Maritime, Oil & Gas and Energy Industries

- Asset risk management
- Enterprise risk management
- Offshore classification
- Safety, health and environmental risk management
- Ship classification
- Technology qualification
- Verification

Introduction

Offshore oil and gas exploration and production activities are, by their nature, not inherently safe. These are complex activities that require the handling of large amounts of pressurised hydrocarbons and other produced fluids and gases, some sour and extremely poisonous, in a dynamic maritime environment. History shows that major offshore accidents have occurred on all of the world’s continental shelves, resulting in loss of lives, damage to the environment and destruction of assets.

Since the start-up of offshore oil and gas exploration more than 65 years ago, tremendous developments have taken place. The drive has been to find, develop and produce large amounts of hydrocarbons in a safe, efficient and responsible manner. Throughout these years, the industry has gained extensive operational experience and, from this, learned valuable lessons about how to enhance safety and environmental performance. New and improved technical solutions have been developed and, operational systems and regulations were developed to support a wide variety of oil and gas developments. Operating practices have been tested and refined to unlock a wide variety of oil and gas resources within increasingly advanced regulatory frameworks. Despite these achieve-

1) The first offshore drilling was reportedly in 1869, with patents granted to T.F. Roland for an offshore drilling rig design. The first offshore well out of sight of land dates back to 1947 and was owned by Kerr McGee and located in the Gulf of Mexico.
merts, major accidents and near-miss incidents continue to occur. The world’s energy demand is increasing and hydrocarbons are foreseen to continue to be the most important energy source for decades to come. A substantial amount of the world’s remaining oil and gas reserves is believed to yet to be developed offshore. As the more easily accessible resources have to a large degree already been developed, there is now a drive to explore for oil and gas in more challenging environments. We are heading into deeper waters (see Figure 1), more remote locations, increasingly challenging reservoirs, harsher environments and more environmentally sensitive areas. These trends introduce new risks that need to be understood and managed.

This document suggests ways to improve offshore safety and environmental performance above current levels and, in particular, suggests ways to prevent and mitigate major accidents. In the following pages, we address some key principles which, in DNV’s opinion, need a special focus.
Over the last 20 years, the offshore and onshore process industries have attained a step change improvement in occupational safety.

However, what works to improve occupational safety does not necessarily improve the prevention of major accident hazards.

In dealing with offshore safety, we differentiate between occupational safety and technical safety to prevent major accident hazards. Occupational safety is about preventing workplace-related accidents that might affect individuals. Examples are falling from heights, the impact from dropped objects, confined space entry accidents, pinch injuries and so on. Major accident hazards are accidents that could put the whole offshore facility at risk and have a potentially large number of casualties, and/or which result in a large uncontrolled hydrocarbon spill into the sea and releases to air. This differentiation is important, as the measures needed to prevent and mitigate occupational accidents are very different from the technical safety measures to prevent and mitigate major accident hazards.²

The offshore oil & gas industry has achieved an outstanding improvement in occupational safety over the past 20-30 years. This has been through a combination of good regulations, senior management commitment, enhanced safety management systems, hazard and risk assessments and safety culture and behaviour programmes. An improvement of a factor 10 has been achieved in most occupational accident metrics, see Figure 2 (ref. DNV internal study [2]).

Regarding the trend relating to major hazard accident risk over the same timeframe, there have also been improvements, but not all regions share the same level of success. Too many major accidents continue to occur in the global offshore oil & gas industry.

² The term “Technical Safety” is introduced as complementing the area of “Occupational Safety”
Increased Focus
On Major Accident
Risk Needed

It is difficult to obtain clear statistical records for major accident hazards in the same way as for occupational safety, but some data is available, such as the EU MARS (Major Accident Reporting System) database and the EPA-Star database. Analysis of this data shows a steady number of events and level of severity per year with essentially no improvement (Pitblado and Bjerager 2013 [3], Kleindorfer et al 2007 [4]).

Since there are no good globally accepted metrics for major accident hazards, the Marsh 100 Largest Losses trends are used as a proxy, averaged over five-year periods (see Figure 3). Other analysis, such as by Wharton, of EPA RMP-star data also shows no statistically significant improvement, but OSHA reports fewer fatalities.

Against these disappointing global trends for major accident hazards, there are regions where we are seeing an improving performance trend. One of these is the North Sea, spanning both the UK and Norwegian legislative sectors. Both the UK and Norway have implemented stringent reporting requirements for all offshore leaks, both liquid and vapour. The UK HSE data set has recorded over 3,500 leak events at close to 300 installations since 1992. The occurrence of a major leak event is a key cause that has the potential to lead to a major hazard accident. It is therefore revealing that, in the UK, major leak events have shown a steady decline from 19 per year to two per year over the past 15 years. Similar data exists for the Norwegian sector. The combination of the absence of major disasters in the past 24 years and the reduction in major leaks supports the view that the North Sea has achieved an order-of-magnitude reduction in major accident hazards. This observation was confirmed by the Oil Spill Commission, which assessed the BP Deepwater Horizon. In its report on the disaster [5], the Commission observed that “From 2004 to 2009, fatalities in the offshore oil and gas industry were more than four times higher per person-hours worked in US waters than in European waters, even though many of the same companies work in both areas. This striking statistical dis-
crepancy reinforces the view that the problem is not an inherent trait of the business itself, but rather depends on the differing cultures and regulatory systems under which members of the industry operate.” [6] It is important however that we do not become complacent. The Elgin platform gas leak in March 2012 and the Gannet Alpha pipeline leak in August 2011 both remind us of the potential for a major accident and the need for effective barriers to be in place.

The Norwegian and UK sectors implemented different legislative regimes after the catastrophic Alexander Kielland event in 1980 and Piper Alpha disaster in 1988. The offshore safety regime in Norway is based on detailed risk assessments by the operators, with the regulator reviewing and accepting - rather than approving - these before implementation. Following the Cullen Inquiry, the UK implemented the Offshore Safety Case regulations. A Safety Case is a documented, facility-specific, safety and environmental programme that identifies all hazards, estimates risks and demonstrates how these are prevented or mitigated to a stringent target level of safety. This merges both prescriptive and facility-specific requirements. In a Safety Case, all safeguards are documented, their required performance is defined, owners are assigned and the means to keep safeguards functional at all times are specified (eg, maintenance, competence, etc) and it provides a transparent means to verify the conditions. An independent verification scheme then checks the conformance of the installation to the performance standards laid down in the safety case production process. Once accepted by the UK regulator, operations not in conformance with the Safety Case are an offence.

The common denominator of the offshore safety legislation in the UK and Norway is that both regimes are performance-based (also referred to as functional-based or goal-based). In these regimes, performance requirements and risk acceptance criteria are specified and companies must document that their specific solutions meet such requirements, for example in terms of acceptable risk levels. The advantage of performance-based regulation is that solutions for the problem at hand can be developed free of specific prescriptions (Pitblado 2010 [7]). In performance-based regimes, significant emphasis is placed on risk assessment and there is a focus on critical barriers (also referred to as Safety Critical Elements) and the responsibility of the operator to demonstrate how risk will be managed.

Many other offshore safety regimes around the world are based on prescriptive (or rule-based) regulations. Although these regimes have the advantage of being relatively easy to implement and monitor, they are not as effective at preventing new types of accidents which may appear in the future and are not anticipated by the existing rules. The rules are often updated after the occurrence of a major accident, but these expanded rules then often prevent further innovation due to their specific and prescriptive nature. A prescriptive regime may also limit the operators’ understanding of responsibility as well as proactive initiatives to increase the safety level beyond compliance. A performance-based approach is particularly important in the deepwater offshore arena, where new technologies and techniques to improve production and safety, and also reduce costs, are constantly being developed. These, by their nature, may also introduce potential new risks.

DNV believes that an offshore safety regime using performance-based regulation that requires safety cases, including risk assessments and independent verification, supplemented by required or recommended specific prescriptive regulation for selected areas, is the most effective regime model. The view has recently been supported by the new European Union Offshore Safety Directive (Directive2013/30/EU [8]). Areas that may be

3) Performance-based regulatory regimes encourage the risk-based introduction of new technologies, in particular those technologies that promote technical safety, without potentially conflicting with compliance issues that are required in the more prescriptive regulatory regimes.
addressed by prescriptive regulation are typically facilities, components and situations where sufficient maturity in experience exists. The prescriptive regulation may include specific requirements, supplemented for example by API or ISO standards as well as independent standards and recommended practices, such as DNV Offshore Codes.

Looking at global performance, we see that serious accidents and near miss incidents continue to occur; the Montara blowout offshore Australia, the fire and explosion on the Endeavour rig offshore Nigeria, the loss of the Kolskaya rig on the east coast of Russia, the well kick on Gullfaks C and, of course, the Deepwater Horizon are recent examples of this (see Figure 5).

In addition to enhancing offshore legislation towards a more performance-based regime, further efforts are required by operators, regulators and contractors alike to incorporate risk-based approaches in the planning and execution of offshore activities and across the development lifecycle.

Figure 5: Examples of major accident hazards in the offshore industry in the last few years.
TOWARDS A SAFER OFFSHORE INDUSTRY

Given the empirical data demonstrating the global trends over the past twenty years, DNV has studied the key factors necessary for improved offshore safety and the management of the associated risks, especially when entering more demanding areas.

The resultant model that has emerged from the study is one of six interconnecting performance levers and dependencies which, if achieved, should improve risks and therefore lessen the probability of a major accident. The model should form the basis for all planning and execution of offshore oil and gas operations.

As illustrated by the inner part of the model, the operator must achieve performance excellence in all these important elements or dimensions. Poor performance in one or more will weaken the overall safety level.

In order to achieve this framework, the following levers must be in place:

1. PERFORMANCE-BASED REGULATIONS
   Offshore oil and gas operations are complex and often tailor-made for site-specific conditions. Performance-based regulation requires a risk-based health, safety and environmental (HSE) management system and is deemed fundamental to ensure continuous improvement, innovation and adaptations to relevant conditions and new risks. It should, however, be supplemented by prescriptive regulations and standards for well-proven solutions and conditions. An independent verification scheme is needed to validate that the required performance is met.

2. CLEAR ROLES AND RESPONSIBILITIES
   Generally, many parties are involved in oil and gas operations under a variety of contracts and sub-contracts. It is therefore of the utmost importance that all the parties involved clearly understand their roles and responsibilities with regard to safety, and have common goals. The overall accountability for all operations should rest with the operator or licensee. The operator may subcontract an activity, but the risk remains with the operator.

When considering the “barrier” approach to the management of major accident potential, it is also important that each part of the organisation, from the boardroom to the offshore installation, is aware of its role in barrier management.

The Montara accident4 is a key example that highlights the importance of setting clear roles and responsibilities for maintaining and communicating safety conditions. After the blowout

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4) The Montara rig, located in the Timor Sea off Australia, suffered a blowout in August 2009. The rig caught fire and a well leaked tens of thousands of barrels of oil over two and a half months before it was shut down. The government report into the accident found that the leak occurred because the cement seal failed.
Similarly, the decision-making process for Transocean’s Deepwater Horizon rig was excessively compartmentalised whilst drilling the Macondo well, with individuals on the rig frequently making critical decisions without fully appreciating just how essential those decisions were to well safety.

3. HOLISTIC RISK APPROACH

It is crucial to identify and understand the risks related to any offshore oil and gas operation. These risks will be site, operation and time specific. It is a challenge to maintain a holistic risk overview in a total field lifecycle perspective, from early field development through engineering, construction and many years of operations and modifications and on to decommissioning. This is no less challenging when the numbers of involved parties at the different field life stages are taken into account. To ensure such a holistic approach to risk management, all parties involved in the activities need to have access to a tool that records up-to-date risk identification and provides a complete view of the risk exposures for an asset, asset cluster, project or company. This tool must include consideration of major hazards that might result in loss of life or large hydrocarbon spills, and also address the risk of rare events that would have major consequences.

4. SHARED PERFORMANCE MONITORING

Many parties are generally involved in the planning and execution of an offshore operation. To ensure effective risk management, they must share the same safety performance targets, monitor the same safety conditions and have a common understanding of the status and effect of nonconformities/deviations.

Again, the Deepwater Horizon accident offers key insight into the importance of a shared performance-monitoring process. BP and Transocean had a communication plan in place to alleviate some of the confusion about who should make decisions concerning rig operations and when such decisions should be made. According to the communication plan, BP was responsible for all of the drilling-related decisions made on the Deepwater Horizon. The communication plan depicted direct lines between the well site leaders and onshore personnel. There were multiple daily meetings between BP personnel in Houston and personnel on the Deepwater Horizon.

accident, the Australian government inquiry concluded that “Halliburton was not required or expected to ‘value add’ by doing more than complying with [the operator’s] instructions.” [9] The report further said it would not be appropriate to criticise Halliburton, because the operator “exercised overall control over and responsibility for cementing operations.” This incident “offers yet another example of a lack of communication between operators and service providers and of the gaps between the silos of expertise that exist in the deepwater oil and gas industry.” [5]
Nonetheless, the Investigation Panel found evidence that BP personnel in Houston did not transfer critical information to rig personnel. This communication failure, which resulted in the rig crew being unaware of increasing operational risks, may have created a false sense of security among those on the rig [10].

5. ADVANCED BARRIER MANAGEMENT
Investigations into major accidents conclude in most cases that the events which occurred were known risks for which a number of safety measures had been planned and implemented. However, the accidents occurred as a result of multiple barrier failures, often in combination with a lack of or inadequate barriers in certain areas. Effective risk management requires a thorough understanding of the relevant risks and that applicable and reliable safety barriers are at all times in place to prevent and mitigate the different risks. The safety barriers’ performances must be defined and their status must be continuously monitored, and action must be taken if they deviate from the set targets. Although preventive barriers are preferred, mitigating barriers are also important. In this respect, improved emergency response solutions are part of the portfolio of instruments to limit harm to people, assets and the environment.

6. PEOPLE, PROCESS & PLANT
Safety and environmental performance cannot be assured through technical systems alone. Safe operations are the product of safe and reliable technology, an effective organisation and a competent strong management, and motivated people who at all times know the relevant risks, understand their role in managing those risks and then effectively manage them. Therefore, the interaction between people, technology and the organisation must be taken into account when managing the risk relating to our operations. Requirements regarding this interaction must be clear in all parts of the safety and environmental management system. However, this experience within the industry may be decreasing as people, processes and plant age, and capturing this knowledge becomes an increasing concern.

FURTHER TECHNOLOGICAL STEP-OUTS IN OFFSHORE DEVELOPMENTS AND INTENSE PUBLIC SCRUTINY WILL DRIVE IMPROVEMENTS IN RISK MANAGEMENT PERFORMANCE

Now that shallow-water development areas are more mature, operators are looking towards new offshore and onshore areas to further develop their oil and gas portfolios. Although target areas can vary (ultra-deep waters, remote oil and gas provinces, Arctic, harsher waters, unconventionals), what these developments have in common is a large degree of technical innovation in combination with new risks.

New geographical areas for oil & gas developments may not have the benefit of well developed regulatory regimes (such as in the UK and Norway) to guide a risk-based approach. There is therefore an increased reliance on companies’ standards and policies to incorporate the performance levers to enhance risk management as described in the previous section.

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\text{RISK} = \text{PROBABILITY} \times \text{IMPACT}
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As the offshore industry is increasingly adopting a risk-based approach in developments and operations, efforts are being directed at reducing the probability of major accident hazards occurring (preventive barriers) as well as at mitigating the negative impact of these accidents. An example of implementing mitigation barriers is the Marine Well Containment Company initiative (ref [11],[12]).
In addition, increased global communication and intense public scrutiny are driving a zero tolerance for major accident hazards, regardless of where these occur. Where, in the past, hydrocarbon spills were mainly a matter between the operator and regulator, in today’s world a networked public of engaged citizens will scrutinise and judge operators’ and contractors’ performances globally. The pressures exerted by the media and networked public on the offshore industry have given rise to the new term “a social licence to operate”.

Companies in the offshore industry have yet to develop adequate responses to the appearance of these perceived risks that present new business risks at a global level. Increased openness through independent risk assessment and independent verification of safety critical elements is a key step in adjusting public perceptions and aligning perceived risk and risk management.

The combination of technical step-outs as companies seek to further develop their portfolios in new offshore areas and high public expectations that the social licence to operate will be maintained requires companies to put particular emphasis on advanced barrier management in offshore operations.

DNV believes that the frequency of major accidents can be significantly reduced by identifying the risks and the factors influencing these risks through quantified risk assessment (QRA). QRA allows the effect of prevention and mitigation measures to be directly evaluated and compared. This methodology has been introduced in other industries, such as nuclear and aerospace, and has proven to be successful in reducing major accidents.

Most major accident hazards (such as Bhopal and Texas City) were not caused by an unforeseen threat, but instead by a known threat which was actually adequately addressed by regulations and company requirements. These accidents occurred when technical, human and/or organisational safeguards were allowed to degrade over time. Therefore, risk management in offshore operations requires an up-to-date and clear understanding of the performance standards and current status of all barriers and how they affect risks. It must be specified how barrier degradation can be detected, and what must be done to return the system to a safe state when barriers have degraded or conditions have changed. Examples of a change in barriers are modifications to the offshore installation, changes in external loading conditions on a structure, changes in the fluid composition, pressures, temperatures or process system, ageing/obsolescence factors or a change of operator and crew experience. All company staff, contractors and regulators need to be aware of the barrier’s status at all times in daily operations. Each change of condition must be monitored and documented via an effective Management of Change process in order to ensure safe operations.

The barrier approach is based on the bow-tie risk model. This sets out in a simple figure the hazard, the top event (ie, the undesired loss of control or leak event), the threats that may cause this and the consequences that might arise. In between the threats and the top event are the prevention barriers which stop a threat from...
propagating through to the top event. Similarly, between the top event and the consequences are the mitigation barriers which reduce the magnitude of the potential consequences. The scheme is further extended by depicting the barrier decay mechanisms, which also show what specific controls are put in place to prevent degradation (e.g., training, competence, inspection, preventive maintenance), see Figure 8. The process includes assigning responsibility for all barriers to the appropriate parties in the operations. The term barriers is in this instance used interchangeably with controls or safeguards, which are any technical, human or organisational feature interrupting an accident sequence – either stopping it or reducing its likelihood or consequence or both.

When the root causes of major accidents are identified, it generally turns out to be a combination of several factors that have lead to the accident – and often a combination of technical, human and organisational failures. This concept is sometimes known as the “Swiss cheese model” (Prof James Reason [13]), with major accident hazards shown to occur when threats exist continuously across deficient barriers. When the deficiencies (i.e., the holes in the cheese) line up, a top event is triggered. The more operational barriers that exist, the smaller and fewer the holes, and the safer the operation (see Figure 9).

It is critical that an offshore safety regime properly accounts for technological, organisational and human factor defences – or barriers – in the prevention and mitigation of accidents throughout the lifetime of the offshore installation. Ideally, companies should have near real-time status on each barrier to manage their activities safely. It is sometimes a problem to know what barriers have been degraded, i.e., what holes in the barriers have occurred over time, which is why active workforce involvement in major hazard management is essential to promote vigilance. Inspections, preventive maintenance and audits are good techniques to assess the status of barriers, but these typically occur at a low frequency (once a year).

DNV has developed the BSCAT (Pitblado 2011 [14]) methodology that provides much more frequent updates on the barrier status. BSCAT is the barrier-based extension to DNV’s SCAT (Systematic Cause Analysis Technique) method. Every incident or near miss means that some barriers have failed, and since many facilities experience a high frequency (for example over 100 a year) of actual or near-miss events, analysing these for barrier failures can provide the most frequent and up-to-date barrier status. The status of barriers is identified as amongst the most useful leading indicators for major hazard accident risks. The combined BSCAT approach and bow-
Throughout the years, the offshore industry has gained extensive operational experience and, from this, learned valuable lessons about how to enhance safety and environmental performance. Occupational safety has improved by a factor of 10 during the last 20 years. The risk of major accidents has also decreased in some operating areas, but not to the same degree globally. What has worked to improve occupational safety has not improved the prevention of major accident hazards to the same degree.

Historical evidence shows that most major accident hazards were caused by a known threat, when technical, human and/or organisational safeguards were allowed to degrade over time. Therefore, risk management in offshore operations requires an up-to-date and clear understanding of the current status of all barriers and how they affect risks. The model to improve major accident safety addresses six levers identified by DNV and, if followed, should lessen the probability of major accidents. This must be coupled with workforce understanding of major hazards to ensure constant vigilance of barrier “health” amongst the offshore workforce.

The bow-tie risk model presented in combination with the BSCAT model allows frequent updates on the barrier status. This process reinforces the role of supervisors and staff in reporting every incident and near miss. The status of barriers is identified as among the most useful leading indicators of major hazard accident risks. The continuous feed of data allows statistical inferences to be made about the quality of the barriers and provides a continuous assessment of the overall risk of the facility in operation.

These risk-based approaches in regulations and operations, in combination with the deployment of the practical tools presented, will allow the offshore industry to achieve similar levels of improvement in the prevention of major accident hazards as the industry has achieved in occupational safety.
REFERENCES

[2] DNV internal study on Occupational HSE performance data based on the annual reports and sustainability reports of key companies.
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- Safety, health and environmental risk management
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