Topic #6: Need/Process for Risk Assessment of Critical Operations and Activities

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Topic #6: Need/Process for Risk Assessment of Critical Operations and Activities

General Purpose

This white paper will be used as baseline starting point for discussions in the Topic #6 breakout session at the Nov 2-3, 2011 BSEE/ANL/Industry workshop on the *Effects of Water Depth on Offshore Equipment and Operations*. This paper is meant to provide a brief background of Topic #6 and identify current trends and challenges. This paper is intended to address:

- Current technologies and challenges with implementing those technologies.
- Trends and/or notable technologies envisioned for the near and long-term
- Coordination and communication to help align the efforts of industry and regulatory agencies
- Human Factors in safety (eg., training, procedures)

Background

Prior to the Macondo accident in 2010, the MMS performed an analysis of the commonalities among accidents occurring between 2000 and 2007 on the Outer Continental Shelf (OCS). This analysis considered 33 accident panel investigation reports and an additional 1,443 incidents. It determined that the root cause of most safety and environmental accidents and incidents on the OCS over that period was due to a failure in 4 key offshore operator management system elements[1]

- Hazard Analysis
- Management of Change (MOC)
- Operating Procedures
- Mechanical Integrity

After Macondo, the regulator's preliminary investigations of that accident, along with their previous analysis, prompted them to publish a new regulation, 30 CFR Part 250 subpart S (SEMS), in October 2010.[2] This new regulation mandates (among other requirements) that the 4 elements as well as all other elements of a safety and environmental management system per API RP 75 (totaling 13 elements), be implemented by OCS operators.

The successor to the operational aspects of the MMS, the BSEE (as of October 2011), still believes that improvement in the implementation of these elements is a priority for the offshore oil and gas industry.[3] Yet the new regulation does not provide guidelines as to how, for example, to integrate hazard analysis, MOC, mechanical integrity, and operational procedures into a process risk management methodology that can minimize the likelihood and/or the consequences (i.e. reduce the risk) of another accident on the OCS that leads to loss of life or significant damage to environment.

Such an aggregated approach toward process risk management is needed not only for the industry itself, but also to help form the basis of an ongoing dialogue between the industry regulators and the industry – a dialogue based on data, facts, and demonstrable best practices.

[1] U.S. Federal Register, Vol. 74, No. 115,Wednesday, June 17, 2009, page.28639
[2] U.S. Federal Register, Vol. 75, No. 199, Friday, October 15, 2010, page 63610
[3] Remarks by BOEMRE official, David Dykes at June 28, 2011, OOC meeting, Robert, LA.

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Scope:

The focus of this paper is to engage a group of Subject Matter Experts for the November 2-3 Workshop discussion on how risk based strategies are being and may be used in the near future to improve risk methodology for managing offshore operations. For purposes of this discussion, “risk” is defined as the product of the probability of an undesirable event and the consequences of the event. The focus of the discussion is on critical operations and activities, defined as those with large-scale consequences. The goal is not just to prevent “Macondo” type events, but also consequential events that may arise from altogether different circumstances.

Risk categories in this industry include safety (preventing people from getting hurt), environmental (maintaining well integrity to prevent uncontrolled releases), economic (determining whether it is a good investment to drill a well), and political. Risks can be managed through identification, assessment, controls, response, mitigation and remediation. The scope of this paper includes approaches to managing environmental and major process safety risks. While also important, personal safety (eg.,, slips, trips, and falls), economic, and political risks are not addressed in this paper.

This paper focuses on risk assessment (and management) related to the following offshore processes:

- Well design
- Well drilling and construction
- Well completion
- Critical topside and subsea operations

(Intervention activities need to be included in an overall risk management program although these are covered separately in White Paper number 5, and will not be discussed as part of this workshop session.)

Listed below are three definitions used in this paper:

- Industrial risk – focuses on the individual to avoid injury to him/herself and for others to avoid injury to co-workers or other parties. May also be called "operational safety," "personnel safety" or similar.
- Process risk – focuses on multiple and/or intertwined (though perhaps not communicated or understood) decisions, operations, and actions that may affect the overall safety of a facility.
- Structural risk – focuses on inherent design and function of structural components and mechanical equipment that may affect the integrity of all or part of an individual barrier or multiple barriers designed to minimize risk to a process or facility.

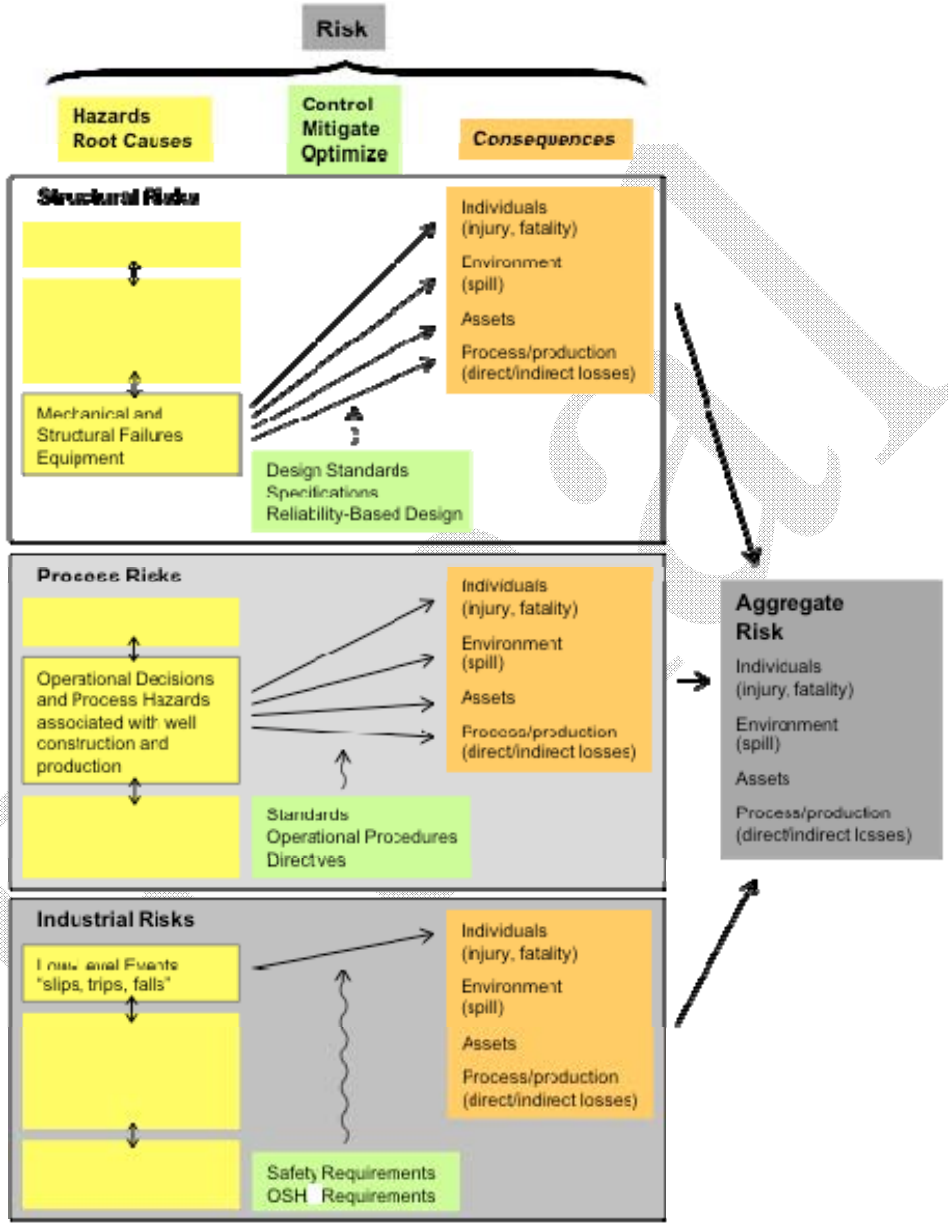

Figure 1. Integration and Aggregation of Three Types of Drilling Risks

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The integration and aggregated effect of these three types of drilling risk are illustrated in Figure 1. The tools, techniques, programs etc. required to manage different forms of risk such as Process and Industrial safety can sometimes be the same (for example a Work Permit system) and in other cases may have very different approaches. Quantified Risk Assessments, for example focus on Process Safety whereas PPE (Personnel Protective Equipment) is very much an Industrial Risk issue.

The focus of this paper is tipped toward Process Risk although all the risks mentioned above are coupled.

It is expected that not all of the methodologies and techniques for the future will come from inside the oil and gas industry as multiple industries (including: refining, aviation, aerospace, chemical industries, and nuclear power operations) each have strategies for managing risk that may be informative for the oil and gas industry.

Also it is not within the scope of this paper to exhaustively cover risk management, rather it is to identify areas that are seen as highly important to discuss with key stakeholders at this juncture in the ongoing evolution of the industry.

Introduction:

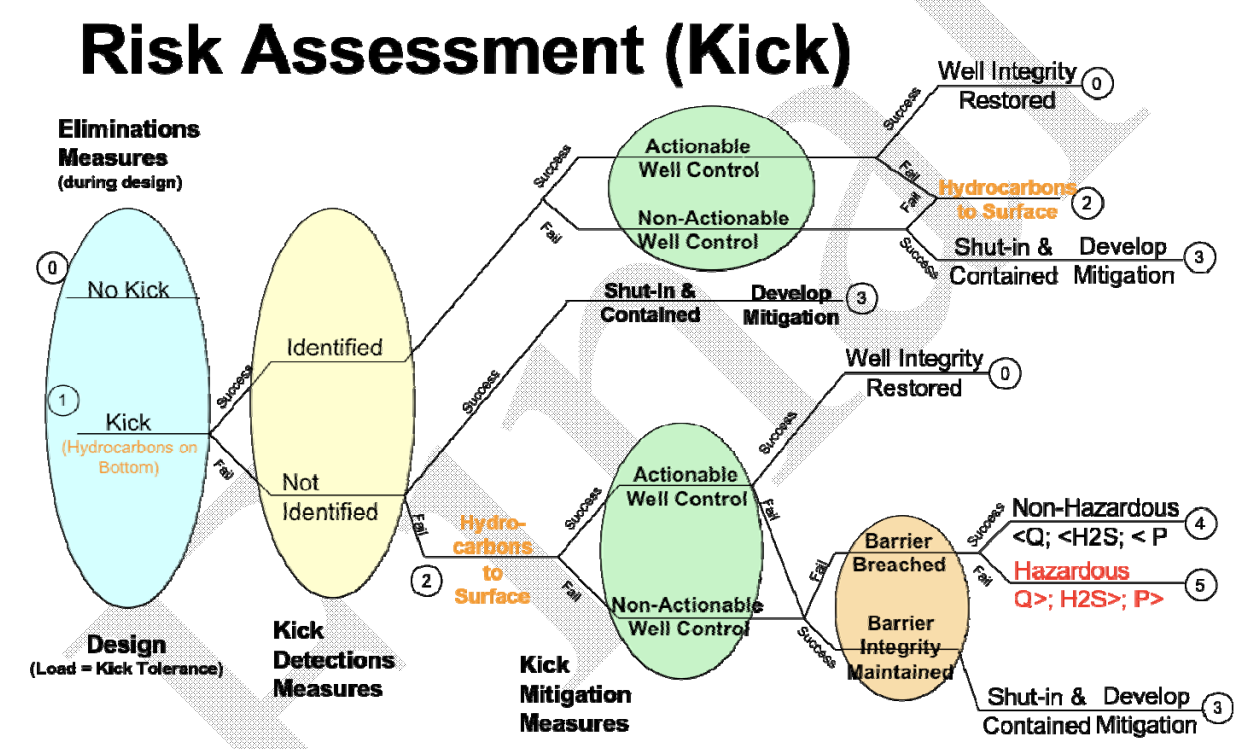
It must be accepted that no endeavor is totally risk-free. The well construction process involves a continuous series of decisions that are continuously increasing or reducing risk – the challenge is measuring, modeling, weighing the risks of available options, making sure this information is communicated to the rig and operational managers, and effectively utilizing this information while the rig is operating. Since the focus is on preventing high consequence safety/environmental events it should be understood that risk assessment may be long-term in the design phase, medium term during the process of optimizing the drilling program, or short-term when involving dynamic activities in progress on the rig floor. Consideration should be given to the factors that influence decision-making and adopting practices that can manage the risks inherent in the various phases of well design and construction.

Risk assessment is familiar to the oil and gas industry, and there have been a variety of efforts to describe, classify, and even to create standards. A brief history is provided in Appendix 1. Also, there is a noteworthy effort currently underway on a joint industry project (JIP) being led by the OOC to help standardize a methodology for risk assessment in the oil and gas industry. Creating an accepted methodology for such risk assessment is an important first step. On other fronts, some in the industry are pursuing the strategic use of mathematical approaches and modeling. Such approaches enable users of the model to obtain useful numerical information such as how the risk is changed by differing environmental dynamics. One strategy being proposed by the industry is to adapt the principles utilized in ISO TR 10400:2007 (Petroleum and natural gas industries -- Equations and calculations for the properties of casing, tubing, drill pipe and line pipe used as casing or tubing) to process risk management in an operational setting. This approach is discussed in Appendix 2.

Discussion:

Process risk management

Process risk management occurs during drilling and completion service delivery, both of which rely heavily on the design and structural integrity of the well. In a real-time sense risk parameters are dynamically changing as the well is being constructed. It is important to translate these changes into to effectively communicate these changes into information that can be used to inform process management on the rig. Risk-informed decision making implies that decision makers at all levels have the necessary information as well as the understanding of how to use that information to inform their operational decisions. See figure 2 as one example.



	Design		Detection			Control		Barrier	
Reliability	No Kick	Kick	Pore Pressure Prediction	Pressure Monitor	Flow Controls	Actionable	Non-Actionable	Breached	Integrity Maintained
High									
Medium									
Low									

Figure 2. High Level Event Tree for a Kick -- This diagram shows some of the risk management stages for process decisions in managing an event such as a kick.

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Risk management systems serve as a foundation for process decisions. With the risk management process, the possible outcomes of each activity are determined and contingency plans for addressing undesirable scenarios are developed. With lists of risks associated with drilling well offshore, there can be two types of risk control mechanisms.

- Proactive control
- Reactive recovery

Proactive control addresses threats through effective risk management. These activities include audits, safety case, equipment inspection, well integrity review, and safety management system design. Reactive recovery aims at consequence mitigation. It also mitigates the risks associated with a poorly controlled incident. (There is currently an IADC standard for adopting a safety case as expressed in HSE Case Guidelines for MODUs version 3.3; but there is currently no industry consensus on whether a safety case strategy should be implemented or not.)

Generally, process excellence requires four attributes:

1. Equipment that is fit for the purpose;
2. Material fit for the purpose (eg., barite, cement, …);
3. Personnel who are competent and fit for purpose; and
4. An effective management system

Regardless of how management is approached, human behavior and decision making are some of the most critical safety components. It is necessary to achieve a balance between levels of risk that are deemed acceptable (both by industry and regulators) and what is physically possible. When this is accomplished, process excellence can be achieved.

The following false premises must be addressed:

- Policy and Procedure alone are not sufficient management capabilities. Paper does not protect people. Human behavior that is in compliance with sound policy and procedure is what is needed.
- A set of documents does not constitute a management system. The system must drive a process that becomes self-sustaining.
- Safe Work Practices enhance <u>personal</u> safety of rig-based workers, but they are not enough. The management system must be extended to the larger realm of operations.

Draft

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Some Important Aspects of Process Risk Management

Tools and Processes

There are numerous methods available for conducting hazards analysis on operating facilities or new projects. Both API RP 14J (Recommended practice for design and hazards analysis for offshore production facilities), and the IADC HSE Case Guidelines for MODUs provide guidance on some of the common techniques and selection of the appropriate methodology. A key philosophy is selecting the techniques that are commensurate with the inherent risk and complexity of the facility and related processes. Examples of factors that influence the risk include size and complexity of the facility, types of hazards, personnel exposure and proximity to environmentally sensitive areas. Some of the techniques that have been applied in offshore well construction operations include:

- HAZOP (Hazard and Operability Study)
- HAZID (Hazard Identification Study)
- HEMP (Hazard and Effects Management Process)
- SHIDAC (Structural Hazard Identification and Control Process)
- FMECA (Failure Modes, Effects, and Criticality Analysis)
- LOPA (Layer of Protection Analysis)
- QRA (Quantitative Risk Assessment)
- PRA (Probabilistic Risk Assessment)

Many of the methodologies used on shallow water facilities, such as HAZID, HAZOP, and LOPA are equally applicable to deepwater facilities. However, when considering fire and blast hazards, approaches and assumptions used for shallow water facilities may not be sufficient for deepwater facilities. Use of advanced modeling programs such as computational fluid dynamics software are typically used to more fully assess these hazards.

Compared to shallow water operations, deepwater operations have a number of challenges that affect the associated hazards and risks. While deepwater does not necessarily imply higher reservoir pressures, there will be high pressures at the wellhead due to water pressure. These have a direct impact on the mechanical design of well components and drilling and well control equipment. Operating in deep water can also significantly change the characteristics of the risk and in some instances introduces novel risks to operating in shallow water. Differences result from deep water facilities having larger topside facilities, export oil and gas systems operating at higher export pressures, larger inventories of hazardous material, topsides production modules with more congestion and/or confinement, and generally a larger number of personnel on board. These differences can consequently result in higher blast overpressures and more severe fire and smoke scenarios, potentially resulting in significantly higher risks to personnel and the environment then when compared to the typical shallow water facility. Additionally, the subsea components and production and export risers are often at the limits of current technology and may require the application of new technology such as subsea High Integrity Pressure Protection Systems.

Additionally, the general hazard identification and risk assessment process addressed for well design and well execution activities should be equally applicable to topside and subsea systems. The differences would be the details such as initiating causes and detailed barriers. (The Barrier Philosophy incorporated in API RP 96 (Deepwater Well Design and Construction) and API/IADC Bul 97 (Well Construction Interface Document Guidelines) has been recognized as a valuable principle that crosses multiple risk areas.)

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Risk Communication to onsite decision makers including contract personnel

Some risks in the well construction process are inherent in the large scale of the equipment and the isolated operating location of the rig. These risks do not change much from day to day. Examples include hurricane exposure and dropped objects (risk may be seasonal or affected slightly by weather, but are present each day). However, some risks associated with maintaining the integrity of the wellbore and the rig do depend strongly on the particular operation during the well construction process and on the particular details of a well's location. Examples include drilling into a subsurface formation with unknown pore pressure and cementing a high-pressure gas zone. These risks may be understood and anticipated better by the operator who has knowledge of the anticipated subsurface conditions and the particulars of the wellbore design than by the rig contractor and other contractor personnel on the rig. Risk assessments are often performed by office-based personnel and the relevance and findings must be communicated to rig-based personnel. This enables rig-based supervisors and other operations and engineering personnel to be prepared to make decisions (possibly under pressure) that weigh risks and benefits against pre-defined acceptance criteria. Key outcomes from risk assessments must also be communicated across organizational boundaries, and across the various phases of the project life cycle.

It is important to:

- establish clear expectations in commercial agreements regarding risk;
- make risk assessment a priority in the same way HSE is prioritized; and
- have core competencies in both operator and contractor organizations to understand risk.

There has been some recent important progress in this area through development of API RP96 and Bull 97 (both still in draft form) by the IADC and API. RP96 emphasizes barrier design and management as key contributors to total well system reliability with respect to well design, construction, and operation control. Bull 97 links the operator's and drilling contractor's safety and environmental management systems, and describes a formal mechanism for the operator to communicate well-specific information such as the basis of design, well execution plan and risk assessment to the drilling contractor.

A remaining step is to ensure processes are in place to translate the risk assessment results for the individual well's unique conditions into hourly highlights for the rig-based personnel, enabling them to make risk-informed decisions in response to any event. One tool that has been applied successfully to facilitate communication between office-based and rig-based personnel is the "Drill Well on Paper" exercise (DWOP). This exercise brings together the office-based and rig-based perspectives on the well and can be an effective tool for risk and hazard communication in addition to its alternative role to identify optimization opportunities.

❋ How does the rig crew member know about the particular well integrity risks for that tour's planned activities? Does he understand the consequences of various possible responses to things he may observe during his tour (shift)?

❋ Do rig-based personnel understand the types of events that have the potential to escalate to major consequences like the loss of the rig or loss of well integrity or loss of the reservoir asset? Do they understand the key mitigation steps that are intended to prevent the escalation? Can they identify these situations developing and shift their focus to mitigation?

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Managing Downhole Uncertainties

The management of downhole uncertainties is an important part of process risk management. In many cases drillers do not know with a high degree of certainty what is downhole until they begin drilling. This is especially true in new fields, but there can also be uncertainties in mature fields as well. There is also uncertainty in defining abnormal or upset conditions associated with events such as kicks.

- ✱ What are some of the strategies currently being used to manage downhole uncertainties?
- ✱ To what degree have Predictive Pressure Tools been adopted by the industry?
- ✱ Where do new technologies such as dual gradient drilling fit in to the overall risk picture?

Limitations of Current Process risk management Practices

Limited standard definitions and sharing of tools and processes

Notwithstanding the existence of several ISO standards, there is limited acceptance of standard definitions and sharing of tools and processes. Part of the reason for this is that risk management is perceived to be an internal affair to each company to the extent that taxonomies are sometimes identifiable and specific to an individual company or business unit within a company. (There is currently a JIP being assembled by the OOC to perform a comparative risk assessment. Part of this effort will make an attempt at standardizing some of the terminology and processes.)

Need for agreed upon Methodologies for Risk Assessment

Currently there is no commonly agreed upon methodology for risk assessment. Below is an outline that could be used for working toward a consensus on a methodology for risk assessment:

- Standardize the taxonomy
- Identify the key features of a process for managing risk
- Identify requirements to have a basis for likelihood values (leveraging references in Appendix 2)
- Establish consistent methods to estimate consequences
- Create a set of pre-defined scenarios, along the lines of those developed for the Environmental Protection Agency's Risk Management Program
- Within the 'process' gradually move toward the endorsement of the risks in the framework of the organizations' risk 'criteria'. However it is acknowledged that there is a considerable amount of engineering judgment required here. Rules cannot replace this.
- This would also require a statement about the adequacy of emergency response capabilities.
- Establish criteria to accommodate how to manage changes to the estimations as the industry evolves

Limited Common Risk Understanding for Discussion Between Industry and Regulators

As methodologies are defined, the next step is for the industry to work with regulators on an agreement for what constitutes acceptable levels of risk. As can be seen from figure 1, methodologies used in well design and construction are relevant.

Without an agreed upon common understanding for discussing systematic risk both the industry and the regulators must resort to either focusing on specific risks or inexact specifications that can have unintended side effects. These side effects, while perhaps limiting certain specific risks, can sometimes

increase the overall systematic risks in non-obvious ways. Adding to the complexity of the risk acceptance process is the division of regulatory authority over OCS operations where regulatory authority doesn't align with equipment and processes necessary to control risk.

✱ Manufacturer recommended inspections and maintenance of equipment is mandated by the new regulation. Is this the best approach or should operators and contractors be allowed and/or encouraged to implement risk based inspection (RBI) and reliability centered maintenance (RCM) techniques and thereby focus on their limited efforts on "critical" systems?

✱ In the wake of the large spill resulting from the Deepwater Horizon disaster, the BSEE revised and increased the requirements for Worst Case Discharge (WCD) Scenario calculations to support Offshore Oil Spill Response Plans required for new offshore Exploration Plans (EPs), Development and Production Plans (DPPs) and Development Operations Coordination Documents (DOCDs).[4] Some in the industry feel that the requirement in the new regulation for consideration of an "uncontrolled flow" event does not give credit to specific operator controls that would dramatically reduce either the likelihood or the size of a spill from a blowout, thus making the WCD volumes unrealistic. The risk contribution from a WCD (risk contribution = probability X consequence) can be much smaller than other higher probability but lower consequence events in the risk assessment chain (see figure 1). Also, increasing casing thicknesses to support the worst case discharge adds significantly more stress on the overall casing structure and can contribute to other types of failures.

Would it make sense to work toward regulations that limit the overall aggregated risk (both probability as well as consequence) as opposed to isolating lowest probability risk contributors?

In those cases where the volumes are unrealistic, what alternate approaches to calculating discharge volumes could be used to achieve the level of assurance against large spills that regulators and the general public expect?

Numerical Models for Process Risk Assessment

Numerical models as an aid toward building consensus on industry best practices

There is often diversity and disagreement surrounding technologies and processes where there is not enough data to establish consensus. In these cases, numerical models could be created that can be used as a tool for "experimenting" with new technology and capabilities. These models could be used to provide insights and statistics to help guide in the industry determination of best practices. Models like this are widely available in the automotive, aviation, astronautics, and nuclear industries and could be developed for offshore oil & gas usage.

Real time models to support dynamic Risk Informed Decision Making

Continuously running models with real time data feeds are currently in use on many oil and gas rigs. These models could be enhanced to better inform rig operators of the current risk status of their operations and thereby provide necessary information for dynamic risk informed decision making (as in other industries).

Models for training new managers

There is currently a considerable amount of change occurring within the operators and contractors as many of the experienced (baby boomers) have started to retire and new managers need to be trained. Risk models can be an invaluable tool for use in simulators for training up a new crop of rig operators and drillers.

[4] NTL No.2010-06, June 18, 2010

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Findings and Recommendations

Findings and Recommendations will be noted after the workshop discussion

Reference Documentation:

Regulatory documents include:

- SEMS Rule – *BOEMRE Safety and Environmental Management Systems* 30 CFR 250, subpart S.

Industry documents include:

- API/IADC Bulletin 97 (Draft) -- *Well Construction Interface Document & Guidelines*
- API RP 96 (Draft) – *Deepwater Well Design Considerations*
- API RP 75 – *Recommended Practice for Development of a Safety & Environmental Management Program for Offshore Operations & Facilities*
- API Std 65-Part 2 -- *Isolating Potential Flow Zones in Well Drilling and Cementing Operations*
- IADC HSE Case Guidelines for Mobile Offshore Drilling Units version 3.3
- ISO 31000:2009 – *Risk management: principles and guidelines*
    - http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=43170
- ISO 17776:2000 -- *Guidelines on tools and techniques for hazard identification and risk assessment*
- ISO Guide 73:2009 -- *Risk management – Vocabulary*
    - http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_detail_ics.htm?csnumber=44651.
- ISO 10400:2007 -- *Petroleum and natural gas industries - Equations and calculations for the properties of casing, tubing, drill pipe and line pipe used as casing or tubing*

Appendix 1: Brief History of Risk Assessment

An important milestone in the history of risk assessment in the oil & gas industry was the publication of the ISO Guidelines on Tools and Techniques for Hazard Management and Risk Assessment in 2000. This document describes hazard identification as well as risk assessment tools and techniques and is widely followed in the industry particularly for HSE initiatives in process risk assessment. The IADC used this to build additional documents targeted at specific operational capabilities such as the *IADC HSE Case Guidelines for Mobile Offshore Drilling Units*. Widespread use of documents like these in the industry has led to measurable and dramatic improvements in reducing the number of industrial injuries. (One of the important techniques is the bow-tie diagram, a graphical approach for understanding the barriers that prevent and mitigate catastrophic events.)

Moving beyond HSE however, there have been different attempts to assess risks involved in offshore drilling and production, and each of the major oil companies has implemented its own risk management program. One important document that attempts to provide generic guidelines for the design, implementation and maintenance of risk management processes throughout an organization (although not specifically the oil and gas industry) is ISO 31000:2009 *Risk Management: Principles and Guidelines*.

This document has been used in some cases to develop a broader enterprise risk management approach, and has made some important contributions specifically by extending the scope of risk management to support the wide variety of strategic, management, and operational tasks of an organization through projects, functions, and processes aligned to risk management objectives.

The generality of ISO 31000:2009 means that there can be a variety of different strategies and methodologies for both risk assessment and the implementation of risk programs. Safety cases, while not mandated until the SEMS rule are an important capability being considered that requires the focused attention of the operator on risk assessment. If the future direction of the industry evolves toward safety cases, a lengthy period of time should be allowed to help develop industry and regulator consensus on the definitions and applications of safety cases.

Appendix 2: Toward a Common Methodology of Well Design, Construction and Operations Risk Assessment

In order to meet the objective of assessing the overall risk of wells for the purposes of risk comparison and risk acceptance, it is convenient to use the Barrier Philosophy incorporated in API RP 96 and API/IADC Bul 97.

The overall risk analysis can be viewed as consisting of four areas of barrier analysis, each conditional on the outcomes of the previous one:

(1) risk controlled using physical well barriers such as casing, cementing, equipment,

(2) risk controlled by operational barriers

(3) risk controlled by a cultural/organizational infrastructure

(4) risk mitigated by subsequent containment.

In order to link these together in a risk-consistent way, a common methodology is needed.

Risk accumulates as the sum of all possible outcomes and consequences C_i weighted by their aggregated probabilities:

$$R = \sum_i C_i p(C_i)$$

In addition, the consequences C_i can be ranked and plotted versus the cumulative probabilities $\sum_k^i p(C_k)$ in a probability – consequence graph or in a Whitman plot.

The probabilities $p(C_i)$ can be found by conditional aggregation along all possible sequential paths that lead to the outcome C_i, as shown in Figure 1. Each path crosses of a (large) number of barriers b_j that operate either successfully or unsuccessfully (with probability p_{F_j}). Each bifurcation point or chance fork in the event tree shown in Figure 1, represents either a physical barrier or an operational barrier. At each barrier node, a probability needs to be determined which depends on:

- the capacity of the barrier to resist the demand or to meet its objective:
  - for physical barriers j, this is the failure probability p_{F_j}; it is controlled by design, testing, and quality control, and it is therefore a function of specified design criteria, design scenarios, testing and QA protocols.
  - for operational barriers, p_F represents the inability to function as intended, and it is dependent on standards, regulations, procedures, training, human factors, etc.
- the "path" followed previous to the point that the barrier is crossed or becomes active: therefore p_{F_j} is **conditional** on the outcome of previous barriers.

In order to link all bits and pieces of the risk analysis together, the above principles should therefore be respected: represent all systems/operations in terms of barriers, consider the operation of each barrier as conditional on the outcome of all (previously encountered) barriers along a given path, aggregate consequences over all paths leading to a given outcome.

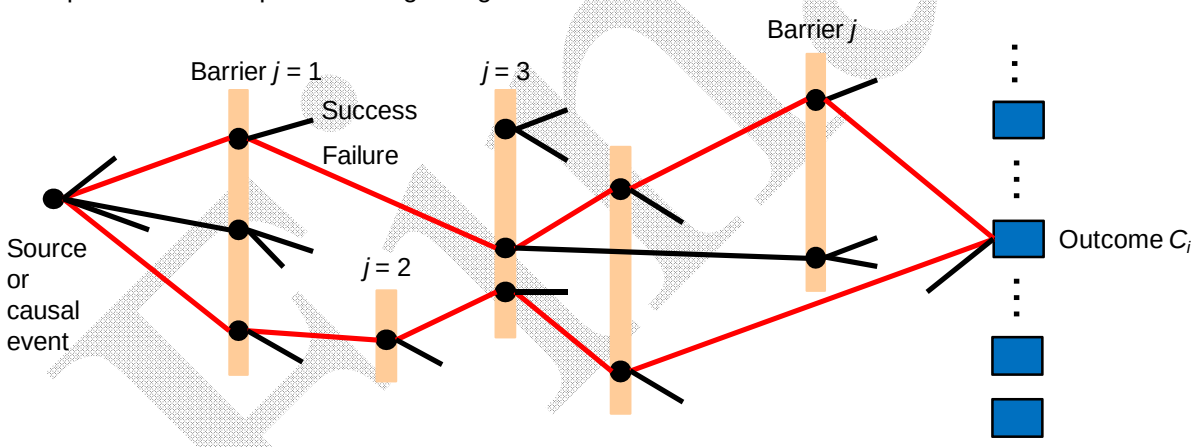

Figure 1: Well risk analysis spanning over all possible physical and operational barriers: illustration of a number of paths leading to a number of outcomes or consequences.

In order to link all bits and pieces of the risk analysis together, the above principles should therefore be respected: represent all systems/operations in terms of barriers, consider the operation of each barrier as conditional on the outcome of all (previously encountered) barriers along a given path, aggregate consequences over all paths leading to a given outcome.

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Using the Barrier Philosophy on API RP 96, API/IADC Bul 97, and NTL-10 Well Containment Analysis (L1L2 Rev 1.18), the plan is to outline a methodology for a analysis of the BOD (Basis of Design).

Proposed Methodology:

1. Identify the barriers between reservoir energy and the environment for the section of well or activity to be performed.
2. Rank the failure mechanisms of the in place barriers across all flow paths using a FMEA or other process.
3. Qualify the probability of failure (***'p'***) (i.e. the probability that the loss will occur) and the consequences of failure (i.e. the magnitude of the potential loss) (***'L'***).
4. Work the risk treatments/trade-off's: avoid, control and transfer until the acceptable risk meets set criteria.

The plan is to use this methodology to design a system consisting of many components (barriers) and procedures (operational barriers).

For the system to be reliable we need the individual barriers to be reliable plus we need redundancy and robustness. The risk analysis would involve establishing the modes of barrier failure, probability of barrier failure, the consequences of barrier failure, and the system effect caused by barrier failure. Then we should also include the updating of barrier reliability based on various barrier testing methods (similar to proof loading of infrastructure) and risk treatment (avoid, control, mitigate, transfer). The last important aspect is risk acceptance -- what should the criteria be at the end of the analysis and how should this be established?

The approach is consistent with risk assessment methods used in say, aerospace, nuclear, pipeline and infrastructure risk assessment.

Final

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Appendix 3: The management and assessment of risk within the context of a UK offshore drilling operation. (Don Smith, Eni UK)

1. Introduction

This appendix presents an overview of the types of risk assessments undertaken prior to and during the drilling of an offshore exploration well[5]. It assumes that the drilling operation is being undertaken in the UK sector, with the licence holder being an E&P company which has contracted a MODU and supporting services to carry out the operation. Many of the processes outlined below are applied in other types of drilling activity, for example the drilling of a well from an operator's own production installation.

The appendix aims to illustrate that there are many forms of risk assessment required during a typical drilling operation. They vary from those that rely on the application of state-of-the-art computation models (eg., fire and blast analysis) to those carried out within the context of a job specific risk assessment or toolbox talk.

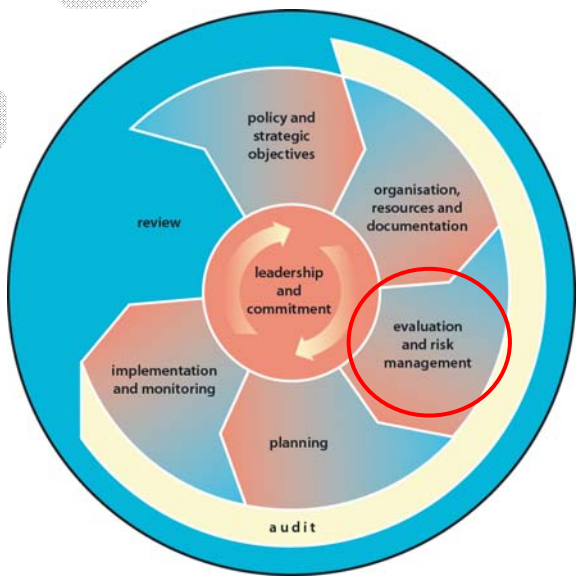
Risk assessment activities within the UK sector are, to an extent, influenced by the requirements of the regulatory regime. The regulatory process dictates that certain rig and site specific risk assessments be undertaken and documented in the form of a Safety Case, Environmental Impact Assessment and Oil Spill Response Plans. Section 9 provides an overview of the relevant aspects of the regulatory regime and the requirements it imposes on drilling operations.

2. Overview of the Risk Management Process

Risk assessment is an integral part of the risk management process, which is in itself an integral part of an organisation's HSE-Management System.

Risk assessment encompasses the identification of the hazards that may arise during an activity, and the assessment of the probability that certain consequences may result.

There are many different types of risk assessment undertaken during a typical E&P operation. Some require the input from technical specialists using highly sophisticated computational models or industry recognized failure rate data, other will rely on the competence of the individual(s) performing a specific activity. A key requirement within any HSE-MS is that an appropriate form of risk assessment is undertaken which is commensurate with the nature of the risk being managed.



[5] An exploration well is chosen as it incorporates a wider spectrum of risk assessment activities than many other types of well.

2.1 Risk Matrix

The risk assessment process results in the identification of a large variety of risks, each having its own mix of probabilities and consequences. A tool frequently adopted by E&P companies to determine the action required with respects to each risk, is the Risk Matrix (Ref: Figure 1).

The Risk Matrix can be applied to different risk types including:

- Injury to personnel (safety)
- Damage to the environment
- Damage to the asset
- Company reputation

Each risk when plotted on the matrix falls into one of three categories:

- Red Zone: the risk level is such that the operation is deemed to be too risky and additional risk reduction measures need to be applied.
- Yellow Zone: Within this zone the risk needs to be managed to a level that is as low as reasonably practicable (in line with the UK regulatory requirement).
- Green Zone: risks within this zone are viewed as being sufficiently low as not to warrant a major effort to identify risk reduction measures. Continuous improvement in risk management is, where practicable, delivered within this zone.

In practice, the uncertainties inherent in the risk assessment process results in the risks being shown on the matrix as areas rather than individual points. In addition, the recognition that a given hazard can result in a range of consequences and associated probabilities, further complicates the use of the matrix.

CONSEQUENCE					**PROBABILITY**			
Severity	**People**	**Assets**	**Environ**	**Reputation**	**A** Rare	**B** Unlikely	**C** Probable	**D** Likely
0	Zero Injury	Zero Damage	Zero Effect	Zero Impact	**CONTINOUS IMPROVEMENT**			
1	Slight Injury	Slight Damage	Slight Effect	Slight Impact				
2	Minor Injury	Minor Damage	Minor Effect	Limited Impact				
3	Major Injury	Local Damage	Local Effect	Considerable Impact		**ALARP ZONE**		
4	Single Fatality	Major Damage	Major Effect	Major National Impact			**INTOLERABLE**	
5	Multiple Fatalities	Extensive Damage	Extensive Effect	Major International Impact				

Figure 1: Typical (simplified) Risk Assessment Matrix

Implicit within the use of the matrix is the concept of *risk acceptance*. While there are differences within E&P companies with respects to the range of consequences and probabilities addressed within the matrix, and the boundaries at which changes in the risk profile occur, their matrices are broadly similar. For example, all organizations view the risk that an activity will result in an individual having a probability of greater that 10^{-3} per annum of becoming a fatality as intolerable (unacceptable).

3. Drilling Risk Assessment

An exploration drilling activity can be broken into a series of stages during which different types of risk assessments are undertaken:

- Pre-operational risk assessments and permitting activities
- Well design
- Selection of rig, equipment and services
- Pre-mobilisation
- Operation

The following sections provide a (non-exhaustive) list of types of risk assessment undertaken within each stage.

4. Pre-Process Risk Management

Prior to commencing a drilling operation, and as part of the regulatory permitting requirements, a range of activities are undertaken aimed at demonstrating to the E&P company and the regulators that the well can, in principle, be drilled in a manner that should not result in harm to individuals or damage to the environment.

Many of the activities carried out during this stage will not rely on detailed knowledge of the MODU or associated support systems (which, at this early stage, may not have been contracted).

Activities that rely on the outcome of some form of risk assessment include the development of:

- Environmental Impact Assessment and Environmental Statement
- Oil spill response, blowout and relief well plans
- High level risk register (and associated risk management plan)

4.1 Environmental Impact Assessment

Many E&P companies will, as part of their own corporate requirements, undertake some level of environmental risk assessment (Environmental Impact Assessment, EIA) for any project with the potential to have an environmental impact.

For UK offshore drilling operations, the regulator (DECC) requires an Environmental Statement (an output from the EIA process) to be produced in advance of commencing the drilling operation[6]. The ES is reviewed by the regulator and a number of government agencies prior to the E&P company being given the approval to drill the well.

[6] For 'low risk' wells being drilled in 'non sensitive' areas, an ES may not be required.

The level of detail contained within the EIA, and the site specific information that needs to be collected to support its production, is related to the environmental sensitivity in the region of the well to be drilled.

A typical EIA will include an assessment of the risks associated with:

- Accidental spills (hydrocarbon and chemicals) including blowout potential
- Disposal of drill cutting
- Damage to sensitive environments (eg., due to mooring lines and anchors)
- Disturbance to marine life and birds
- Sound being introduced into the water column and its effects on marine life
- Impact on fishing

These different types of risk assessments will draw on information from site specific investigations, modelling, similar, past operations and failure rate data in order to determine appropriate probability and consequence values to apply within the context of the Risk Matrix.

4.2 Oil Spill Risk Assessment Activities

Irrespective of the likelihood of a blowout occurring, UK regulations require E&P companies to model a range of potential blowout scenarios and assess the risk of hydrocarbons impacting (for example) sensitive areas. This type of risk assessment requires the use of sophisticated computational models, capable of modelling the propagation and fate of hydrocarbon products over prolonged durations and in a range of (statistically realizable) metocean conditions. An output from this type of modelling will be 'risk contours' which indicate the likelihood of a certain concentration of hydrocarbons arriving at a particular location. This information will (for example) allow the operator to determine what type of oil spill response equipment may be required to respond to different levels of spill.

4.3 High Level Risk Register

As part of its own internal assurance processes, an E&P company will normally produce a high level risk register which documents the main HSE specific risks associated with the planned drilling activity. This information will be used in developing the project specific HSE management plan and may influence the selection of the MODU, equipment and supporting services.

5. Well Design

An exploration well is designed to manage the uncertainty in the true nature of the well to be drilled. The possibility of shallow gas, uncertainty in pore-pressure and temperature, porous and permeable intervals, weak formations etc all need to be assessed, and the well design and drilling programmed developed to cater for 'worse-case' scenarios.

Offset well data, computation modelling and site specific survey data allow the geoscientists to provide the drilling engineers with information on the likely range (probabilistic) and maximum values of key design parameters. The drilling engineer designs the well (and the associated drilling programmed) on the basis of maximum anticipated values.

Explicit risk assessment, in terms of assigning quantitative probabilities of failure to all parts of the well design, does not feature in the design of a typical exploration well. However risk assessment is implicit within the design process, specifically through the adoption of E&P company manuals and procedures and industry recognized design approaches.

Independent review (both within the E&P company and by the Independent Well Examiner) provides further assurance that the key risks have been identified and are being appropriately managed.

Fundamental to the control of drilling related (down-hole) risks is the ability to detect, risk assess and respond to deviations out with the expected drilling parameters.

6. Selection of Equipment, Systems and People

6.1 Assessing the Ability of the MODU to Perform the Required Operation

The water depth, environmental conditions, reservoir and geophysical properties will dictate the type of rig and equipment required to perform the drilling operation.

Highly technical risk assessments will be undertaken both to demonstrate that the rig is capable of providing an acceptable working environment, and to determine the limits to which certain operations will be undertaken.

During this phase, the ability of the equipment and systems on the rig to provide a suitable barrier(s) to well control incidents will be reviewed (eg., pressure rating and functionality of the BOP).

The ability of a MODU to operate at the specific location will be assessed, usually through the application of an industry recognized site assessment practice (eg., SNAME 5-5A Guidelines for the Site Specific Assessment of Mobile Jack-Up Units). The objective being to ensure that the risk of (for example) a structural or mooring failure does not exceed the company's and regulator's (risk acceptance) requirements.

The risk assessment process is, to an extent, embodied within the relevant design and assessment standards applicable to the particular type of MODU. However, detailed, site-specific risk assessments support the application of these standards, for example the analysis of borehole data to establish the risk of a punch-through.

Where a MODU is deemed to be operating close to the limits of its operating envelope, more detailed risk assessments may be undertaken. These may require the use of appropriate metocean criteria and structural response models.

6.2 Major Incident Risk Assessment

How major incident risks are managed by the drilling contractor on the MODU is of interest to both the E&P company contracting the rig and the UK regulator. UK regulations require the drilling rig operator (Duty Holder) to produce a Safety Case for the rig that (amongst other things) demonstrates that all major incident risks have been assessed and suitable controls put in place to reduce the risks to as low as reasonably practicable (ALARP).

The Safety Case is used to demonstrate that the risk to an individual worker is as low as reasonably practicable. Typically this is demonstrated through the analysis and summation of all the individual risks and how they impact different classes of offshore personnel.

Final

The major incident risks for which some level of risk assessment is undertaken normally include:

- Hydrocarbon releases resulting in fires, explosions or asphyxiation
- Structural failure (environmental overload, foundation failure, seismic etc)
- Mooring failure (loss of station keeping and secondary impacts)
- Ship Collision
- Helicopter operations
- Lifting operations and dropped objects (with major incident potential)

The nature of the risk assessment exercise undertaken for each of the risk types varies from analysis of past incident data, to the detailed assessment of blast overpressure resulting from hydrocarbon releases of varying sizes and from different locations.

6.3 Selection of Support Services

All drilling operations require some level of 3rd party support which typically includes: helicopter operations, standby and supply vessels, 3rd party services and equipment on the rig, onshore supply base and so on. Associated with each of these activities some level of risk assessment will be undertaken (normally by the E&P company). These risk assessments will, for example, drive the need to develop 'bridging arrangements' between the contractors that contribute to the management of a particular activity and the risks that arise from it.

7. Pre-mobilisation activities

7.1 HAZID/ENVID Meetings

HAZID/ENVID meetings form part of a structured approach to identifying safety and environmental hazards and the risks they pose. HAZIDs focuses on safety related risks, while ENVIDs on environmental risks.

Where possible they involve all the key parties that may have a role to play in identifying, assessing, accepting and managing the risks identified. A drilling HAZID/ENVID meeting will typically include the involvement of the E&P company, drilling contractor and drilling service companies, and it is often facilitated by an expert in the use of HAZID/ENVID processes.

Risk assessment within the HAZID/ENVID process takes many forms, ranging from the experience of the individuals present to determine an appropriate risk level (and any additional risk controls required) to passing the a 'risk' on to a specialist contractor to assess in detail.

Perhaps the most important aspect of this process is the identification of hazards through the experience and knowledge of all the parties engaged, and the identification of those areas where further effort is required to manage the risk to an acceptable level.

7.2 Drill a Well on Paper (DWOP) and Related Activities

A DWOP meeting takes place shortly before the drilling operation commences. It engages key individuals involved in the planning and delivery of the well. Its focus is on analyzing the proposed drilling operation in detail with those individuals who will be carrying it out (or are indirectly involved).

By this stage of the process it is expected that the more technical risk assessments activities will have been undertaken, however the DWOP represents the opportunity for the parties involved in each operation to ensure that they have fully appreciated the operation and their role in it, are able to deliver the required performance and where necessary are able to identify further risk reduction measures.

Similar process are used to address the completion and testing phases of a drilling operation.

7.3 Well Specific Operating Guidelines (WSOG)

WSOGs are the output from risk assessments exercises which may be rig specific or specific to the operation being undertaken.

The WSOG will, for example, require certain operations to be suspended when a semi-submersible's motions (heave in particular) exceeds a pre-determined value. That value is based on a detailed analysis of how the semi-submersible will respond in varying environmental conditions, what effect those responses will have on, for example, the drilling riser loads, and what is an acceptable probability (given the seastate during which drilling continues) that a particular seastate will be experienced which overloads the riser.

While the WSOG may be little more that a single sheet indicating the limits at which certain actions are taken, it is supported by a considerable volume of detailed technical risk assessment.

Considerable expertise and access to fit-for-purpose structural and response models are required to carrying out these types of risk assessment.

8. Process risk management

During the drilling operation itself, a range of risk assessment and management activities are undertaken on a daily basis.

As each section of the well is drilled, the programmer is reviewed and a confirmed to be appropriate given the conditions experienced to date.

Many activities are undertaken within the bounds of a risk assessment activity carried out some time earlier (eg., through the development of WSOG).

Many maintenance activities, whether directly or indirectly related to the drilling programmer, will require some form of risk assessment to be undertaken, commensurate with the type of risks the activities presents. Certain types of activity (eg., work on electrical systems or entry into confined spaces) will be controlled through the Permit to Work System, embedded within which is the requirement for some form of risk assessment to be undertaken and signed off by an appropriate level of management.

8.1 Management of Change

A Management of Change process is a key process with any HSE-Management System. It will include a requirement to consider whether the change (proposed or actual) will affect the risk profile, and what, if any, additional risk control measures need to be put in place. For the majority of changes (specifically where an urgent decision is not required) an appropriate level of risk assessment can be undertaken to support the decision to proceed with the change.

The extent to which personnel on the rig will be authorized to deviate from the drilling programmer without consulting the shore will vary depending on the nature of the deviation and the desire of the E&P company (and rig owner) to be involved in the decision making process. Normally the E&P company's expectations in this area are communicated through pre-agreed 'bridging arrangements' and operationally through the drilling supervisor.

8.2 Working Beyond the Limits of Existing Risk Assessments

The nature of exploration drilling is such that, on occasion, urgent decisions will need to be taken concerning whether to proceed on a particular course of action. The WSOG and other documents will have assessed a range of potential scenarios and identified the procedure required to manage the risk should one of those scenarios arise. However, there will arise situations where a risk management decision will need to be taken for which an existing risk assessment is unavailable.

In such situations reliance is placed on the competence and skills of the rig based personnel to carry out some level of risk assessment to determine an appropriate course of action. Where time allows, land based expertise can be accessed to support the decision making process.

Ultimately the decision rests with the OIM, who needs to be comfortable that the proposed course of action does not compromise the safety of personnel on the rig (as a priority) or lead to some level of damage to the environment.

9. The UK Regulatory Framework

Different UK government departments are responsible for the management of safety and environmental risks. The UK Health and Safety Executive (UK HSE) through its Safety Case and supporting regulations, leads on the management of risks that can result in death or injury, while the Department of Energy and Climate Change (DECC) takes the lead on environmental risk management.

UK Safety Case Regulations (SCR) requires the Duty Holder to identify, assess and manage all major incident risks, including:

- A fire, explosion or release of a dangerous substance involving death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it.
- An event involving major damage to the structure of the installation or plant affixed thereto or any loss on the stability of the installation.
- Any other event arising from a work activity involving death or serious personal injury to five or more persons on the installation or engaged in an activity in connection with it.

The Duty Holder is defined as either the operator of a production operation, or the owner of a non-production operation. In the case of a MODU, the rig owner is normally the Duty Holder.

9.1 Independent Verification and Well Examination

UK offshore regulations[7] establishes two processes through which independent and competent bodies become part of the risk management process. One process relates to safety critical elements associated with the MODU itself, the other relates to the well. There is an area of overlap between the two processes (not discussed further here).

[7] The Offshore Installations (Safety Case) Regulations 2005 and the Offshore Installations and Wells (Design and Construction, etc) Regulations 1996.

9.2 Independent Verification of Safety Critical Element

The Safety Case Regulations require the Duty Holder to identify any parts of the MODU (including computer software) the failure of which may cause or contribute substantially to a major accident, or the purpose of which is to prevent or limit the effect of a major accident. These items are termed Safety Critical Elements (SCEs).

The regulations require the Duty Holder to put in place a scheme for the verification of the choice and ongoing effectiveness of the SCEs. Hence, for example, the ability of a semi-submersible to withstand extreme metocean conditions would need to be verified by an independent and competent body or person (ICB or ICP).

9.3 Well Verification Scheme

The Design and Construction Regulations requires the well-operator (normally the E&P company) to ensure that a well is so designed, modified, commissioned, constructed, equipped, operated, maintained, suspended and abandoned such that:

- So far as is reasonably practicable, there can be no unplanned escape of fluids from the wells;
- Risks to the health and safety of persons from it or anything in it, or strata to which it is connected, are as low as is reasonably practicable.

The regulations go on to require the well-operator to document and put in place a system for the examination by an independent and competent person (the well examiner) of the design, operation and maintenance of a well. The expectation of the regulations is that the well examiner becomes an integral part of the process through which the above objectives are met.

9.4 Verification, Examination and Risk Assessment

The verification and examination processes draw on what should be the broad experience of the independent and competent bodies to identify areas where the Duty Holder's or Well Operator's own processes may have failed to deliver fit-for-purpose solutions. Some level of secondary risk assessment is implied within this process. It may be that the ICB does little more than confirm that the analysis carried out by the Duty Holder is acceptable (eg., by acknowledging that the application of a particular design standard is appropriate), or the ICB may carryout its own risk assessment (eg., where it may wish to confirm that the hydrocarbon release frequencies, used in deriving individual risk levels, are appropriate).

The verification and examination processes required through UK legislation do not replace the need for the Duty Holder or Well Operator to have in place its own quality assurance and control processes.