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Enhancing Safety Barriers for the Next Generation of GOM Drilling MODUs

Yaneira Saud CSP
Kumar (Chris) Israni P. Eng
ERM Americas Risk Practice
Houston, Texas

Introduction

It has been three years since a major accident took place at a mobile offshore drilling unit (MODU) – rig – in the Gulf of Mexico (GOM). As offshore exploration and development activities recaptures momentum, Operators and Drilling Contractors (DC) are compelled to incorporate lessons learned from the incident. At least one of the investigation reports questioned the rig's barriers for fire, explosion and emergency evacuation; the United States Coast Guard (USCG) marine casualty investigation of the event [1]. However, the main regulations for the design and construction of mobile offshore drilling units (MODU) are dictated by the International Maritime Organization (IMO) and marine Class requirements (e.g. American Bureau of Shipping [ABS] and Det Norske Veritas [DNV]), have not been updated to reflect the USCG proposed amendments.

This case study is presented from the perspective of a new development field Operator to approach assurance of adequate barriers in the design and construction of MODUs – ship shaped or drillships that will be leased in the near future for GOM development. The focus was to capitalize learning to improve MODU newbuild designs tackling the most effective controls in the risk hierarchy– Eliminate, Substitute, Isolate, and Engineer – (Refer to Figure 1); mechanisms related to process safety design. Personnel safety belongs to the Organizations, Procedures, and Personnel Protection Equipment risk controls, and is not within the scope of this case study.

The Incident

The incident referred herein is the extensively investigated Macondo well MC-252 blowout occurred the evening of 20 April 2010, and the subsequent explosion, fire sinking and loss of crew members aboard the Deepwater Horizon MODU [1].

The accident initiating event, a well control failure that led to the uncontrolled flow of the reservoir –aka blowout– is not the main theme of this paper; but the mitigation barriers to minimize the effects of a catastrophic outcome, as illustrated to the right side of the Top Event in the bow-tie in Figure 2.

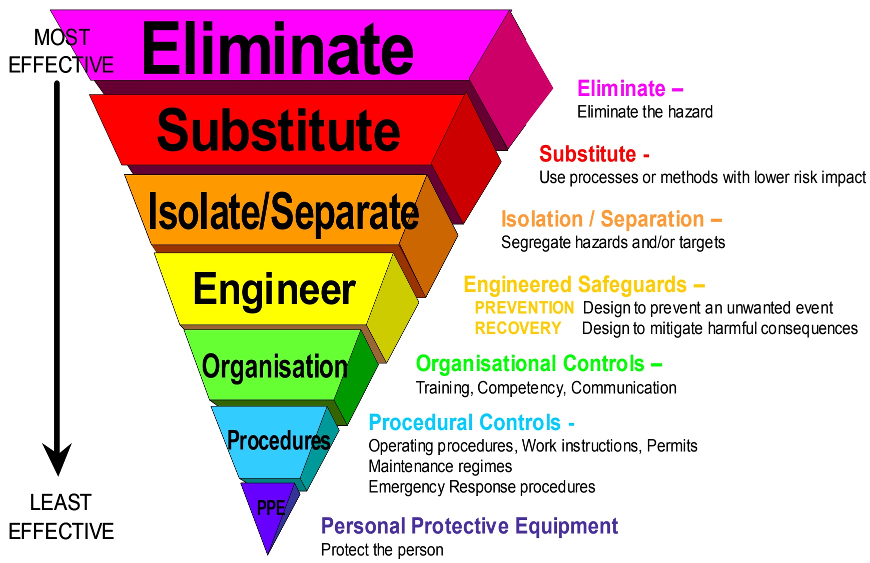

Figure 1. Risk Hierarchy of Control

The Challenge

Gaps in Current Marine Codes

According to the USCG investigation, the current 2009 IMO regulations have gaps and any newbuild MODU would have insufficient barriers for a catastrophic event such as a loss of well control resulting in loss of containment. Once control of the well has been lost, the potentially enormous volume of flammable gas often makes ignition inevitable, even if all electrical equipment is properly located and maintained. Moreover, for the blowout in the studied incident, the first explosion occurred even before the rig' alarms were triggered [2]. Nonetheless, the main gaps identified by the USCG were: absence of clear requirements for explosion, fire and evacuation for the mitigation of a sudden influx of hydrocarbons in the MODU drillfloor. These requirements are listed below:

Explosion

- Labeling and control of electrical equipment in hazardous areas and to require continued inspection, repair, and maintenance of such electrical equipment
- Design and arrangement of gas detection and alarm systems and to identify recommended automatic and manual emergency shutdown actions to be performed following gas detection in vital areas
- Ventilation inlets for machinery spaces containing power sources be located as far as possible from hazardous locations
- Explosion risk analysis to determine whether the barriers around a MODU's accommodation areas, escape paths and embarkation stations provide adequate protection

Fire

- Availability of a non-electrically powered fire pump to provide fire main pressure during a loss of electrical power
- Fixed water deluge system to fight fires on or near the Drill Floor, which may automatically activate upon gas detection
- Hydrocarbon fire-resistant bulkheads between the drilling area, adjacent accommodation spaces, and spaces housing vital safety equipment

Evacuation

- Type, frequency, extent, randomness and evaluation criteria for all emergency contingency drills
- Adequacy of design and performance standards for lifeboats and liferafts in the Lifesaving Appliances (LSA) Code
- Maximum allowable heat exposure for personnel at the muster stations and lifeboat/liferaft lowering stations
- Fast rescue boat/craft onboard MODUs

Safety and Environmental Management System Compliance

- Efficient management systems are known to improve the safety performance for the process industries. In the marine realm, per IMO International Safety Management (ISM) Code [3], offshore oil and gas vessels are required to have a system to ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular to the marine environment and to property. The USCG investigation also pointed to safety system deficiencies not only on the part of the DC, but the “maritime safety net” comprised of the DC, ABS and DNV as well; included the United States regulatory scheme and oversight.

SEMS Rule

In the United States Outer Continental Shelf, Safety and Environmental Management Plans (SEMPs) were introduced in 1991 to address the finding of the National Research Council’s Marine Board about the prescriptive approach of the Minerals Management Service (MMS) to regulating offshore operations. The Marine Board recommended a systematic approach to managing offshore operations; therefore, API, in cooperation with MMS, developed API Recommended Practice (RP) 75, [4]. Since API RP 75 was published, MMS promoted voluntary implementation of SEMPs. However, is was not until months after the MC-252 accident, when the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE) published in October 2010 the Final Rule 30 CFR Part 250 Subpart S, Safety and Environmental Management Systems (SEMS) that incorporates by reference API RP 75. Compliance with SEMS is now mandatory to ensure that safety and environmental hazards are properly identified, assessed, documented and communicated and the appropriate preventive and mitigation barriers are included in the design and administration measures for a MODU.

The same API-industry recommended principles that led to the evolution of the Process Safety Management Rule [5] for onshore facilities take part in SEMS to provide guidelines for prevention and mitigation elements, with particular interest in the review of a representative (1991- 2006) set of offshore incident investigations, showing as key preventive elements: hazard analysis, operating procedures, mechanical integrity, and management of change. Also, the deliberate inclusion of requirements to adequately address human factors also resulted from the persistent human error causes observed the review.

<u>Shaping a Pre-design</u>
For SEMS to be effective it can't just be an administrative system put together in the fashion of compliance manual right before the rig's commissioning. Unless SEMS requirements are incorporated early in the drillship design and construction, three will not be effective, inherent preventive and mitigation provisions and the evidence of operational safety culture in the MODU.

For our case study, it is important to acknowledge that the newbuild drillships which the Operator intends to lease in a couple of years, are the repetition of an existing design of "sister rigs" being delivered for a different Operator. This is not uncommon in the marine world; that a proven ship design only needs to be replicated to produce the next order. Design changes impact schedule and budget, and are typically avoided if not strongly justified or enforced. The Operator will not own the ships, but lease them for only a fraction of the unit's lifecycle. Yet, per SEMS requirements, while the rigs are working on behalf of the Operator, the later has the ultimate responsible for the safety and environmental performance of the drilling campaign.

Problem at Hand

To timely and effectively verify and shape the existing typical drillship pre-design, by ensuring that fire, explosion, and evacuation barriers are sufficient, appropriate, and as low as reasonably practicable (ALARP); towards the safe and clean commissioning and operation of the ship-shaped MODU during the field development stage.

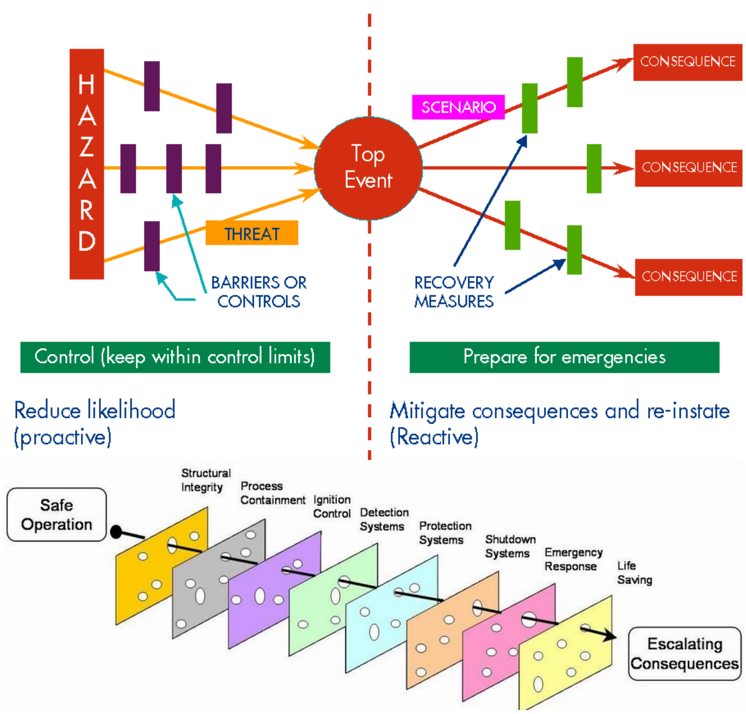

Figure 2. New Drillship Case Study Barriers

Selected Approach

Doing the Right Thing

Given the challenge and problem at hand, the Operator examined its HSE control framework applicable to drilling units and had to ponder an applicable approach. The natural way was to dismiss the internal framework applicability based upon contract mode, conform to the current IMO Code, and let the course of the drillship continue as planned and managed by the DC. On the other hand, the conservative proposal called to adhere to the internal framework and request the DC to comply with the same design engineering standards and derogation processes used of an Operator-owned oil and gas facility. The big differentiator was ownership, for the drilling unit will be leased only for a limited period of time and the DC is responsible for its design, integrity and performance per the Operator's specifications. This more stringent way would not be economically feasible for the DC and would hinder timely delivery of the MODUs for the field development.

Then, the Operator had to establish the right level of process safety intervention, and opted for a middle ground plan – an "accompanying approach"- between what was considered either an "unacceptable" or "unfeasible" option, as illustrated in Table 1.

Do Nothing	Accompanying Approach: Early engagement, mutual agreement	Do It All
• No influence and control • Settle to current IMO 2009 Code • Drilling contractor standards and processes **UNACCEPTABLE**	• Drilling rig specifications, including blast rating and safety studies • Key engineering standards - Dynamic Positioning - Well Control Manual - Dropped Objects Prevention Manual - Lifting & Hoisting Standards - Temporary Buildings Standard - Temporary Piping Standard - Human Factors Engineering • Screening of Process Safety Basic Requirements (PSBR) • Override of Process Safeguarding Systems • USCG Recommendations Design Verification - Deluge systems - ESD of engines on confirmed F&G - Emergency disconnect on confirmed F&G - USCG Recommendations • Statement of Fitness	• Full Influence and control • Full application of Asset Integrity-Process Safety Management Manual **UNFEASIBLE**

Table 1. Operator Level of Intervention on the Newbuild Rig Design

The middle ground "Accompanying Approach" with early engagement and mutual agreement to incorporate learning establish our case study and the components are individually elaborated in the sections below:

Drilling Rig Specifications and Key Decisions

The classic Operator rig specifications to the Drilling Contractor include rig type/design, variable deck load, operating conditions, station keeping, and storage and material handling. However in a proactive step as part of the specifications, the Operator proactively set up the living quarters (that would be the temporary refuge in the case of a physical effects phenomenon) blast rate to 2.0 bar overpressure over 100ms and J60 fire rating on all six faces. This is a stringent requirement that would need additional modeling and assessment to examine the survivability of the living quarter's blast per the existing design.

In addition, a specific list of all required formal safety studies was included, to shed more light into specific USCG recommendations and assist the decision process:

- Hazard identification
- Fire and explosion risk assessment
- Evacuation, temporary refuge, and escape risk analysis
- Dropped objects
- Hazard and Operability Study (HAZOP) -Layer of protection analysis (to verify emergency shutdown functions in case of loss of containment scenarios)
- Fire and gas detection mapping
- Operations safety case demonstrating as low as reasonably practicable (ALARP)
- Failure mode and effects analysis: dynamic positioning , blow-out preventer, drill control systems

Key Operator Engineering Standards

Key Operator design standards were specified, their importance highlighted in historical record of drilling-related accidents:

- Dynamic Positioning: loss of position can result in a well control event with loss of containment. Human error has been identified as a cause of 80% of loss of positioning events
- Well Control Manual: the most devastating major accident event is a blowout, well control needs to account for pressure management, pockets of shallow gas as the drillbit advances to the reservoir
- Dropped Objects Prevention Manual: accident statistics point to dropped objects as a frequent event that can cause major consequences, especially if heavy loads are traversed over people or live equipment
- Lifting & Hoisting Standards: on top of the dropped objects, lifting and hoisting can be a significant occupational hazard
- Temporary Buildings Standard: the temporary building offers shelter to the operators en the case of an emergency protecting them from damaging radiation, overpressure or toxic gases, as such they need to survive a credible worst case event
- Temporary Piping Standard: rigs have numerous systems operated by 3rd parties and are connected and disconnected as needed, for example well testing and chemical treatment
- Human Factors Engineering (HFE): SEMS is the first mandatory requirement for HFE in GOM and its application tends to be overlooked, frequently because of lack of practical guidance to incorporate HFE reviews throughout the design and construction phases

Screening of Process Safety Basic Requirements (PSBR)

The Operator has incorporated a learning system to complement the design engineering manuals with lessons from past process safety accidents. Basically, a specific lesson to optimize design has been extracted in the form of an additional design obligation to avoid the recurrence of the same event, as applicable to the operator assets and operations (Figure 3). Note that PSBR 11 was added after the Macondo blowout to address deepwater well design, construction and control. A screening workshop was competed to review the applicability of the PSBR to the drill rig. The PSBR screening results indicated the need to:

- PSBR 1: Assess occupied portable buildings against fire and explosion risk assessment results
- PSBR 3: Confirm survivability of living quarters/temporary refuge
- PSBR 4,5,10: Produce a robust bridging document for the Operator and DC safety and environmental management system during the drilling campaign
- PSBR 6: Verify the diverter philosophy and HAZOP scenarios, to be able to send the flow over the side of the MODU and avoid the formation of flammable gas cloud in the drillfloor and MODU electrically classified areas. Also, ensure a HAZOP is performed and recommendations implemented for the 3rd party Well testing Equipment
- PSBR 7: Review MODU storage of fluids with reid vapour pressure > 2.5 psi with overfill potential
- PSBR 8: Ensure well material selection, testing and qualification for the production and completion fluids
- PSBR 9: Review and assess the alarm management and DC's override philosophy of process safeguarding systems, e.g. DP, driller and marine controls

PSBR 11 deserves special attention, because well control and barrier management is the foremost responsibility of the Operator, but robust communications and shared decision channels need to me continuously maintained with the DC. Some of the key issues are:

- At least two barriers preventing loss of containment at all well modes: drilling, completions, intervention, abandonment
- Casing and hanger design, completions architecture, accessories compatible with design load, worst case discharge and fluids chemistry
- Cementing work integrity verification
- "A" annulus and trapped annular pressure management
- Effective well isolation, Surface Controlled Subsurface Safety Valve (SCSSV) placement
- BOP shear ability suitable for the well size and configuration
- Emergency capping stack and contingency plans

PSBR	Requirement	Major Incidents in Industry
PSBR 1	Safe siting of occupied portable buildings	BP Texas City Isomerisation Unit Explosion, Texas, USA, 2005
PSBR 2	ESD valves on platform risers	Piper Alpha Platform, UK, North Sea, 1988
PSBR 3	Temporary refuges	Piper Alpha Platform, UK, North Sea, 1988
PSBR 4	Permit To Work	Piper Alpha Platform, UK, North Sea, 1988 BP Grangemouth Flare Line Fire, Scotland, UK, 1987
PSBR 5	Management Of Change	Chernobyl, USSR, 1986
PSBR 6	Avoid liquid release relief to atmosphere	BP Texas City Isomerisation Unit Explosion, Texas, USA, 2005
PSBR 7	Avoid tank overfill followed by vapour cloud release	Buncefield storage terminal explosion, UK, 2005
PSBR 8	Avoid brittle fracture of metallic materials	Esso Longford Gas Plant Explosion, Australia, 1998
PSBR 9	Alarm management	Three Mile Island Nuclear Reactor Core Meltdown, Pennsylvania, 1979 Esso Longford Gas Plant Explosion, Australia, 1998
PSBR 10	Sour Gas (H2S)	Chuandongbei gas well blow-out, Gao Qiao, China, 2003
PSBR 11	Deepwater Well Design & Construction	Macondo, Gulf of Mexico, 2011

Figure 3. Lessons from past process safety accidents - Operator PSBRs

USCG Recommendation Design Verification

Each one of the USCG recommendations was presented to the DC and proof of compliance was requested. The majority of recommendations were already included in the design; however for ones not easily implemented because of drilling operations constraints, additional engagements and ALARP demonstration were documented.

Statement of Fitness

The Operator has a "Statement of Fitness" system that includes and goes beyond the MODU's pre-start up review to be completed previous to the drillship commissioning. Preceding the MODU deployment for production field development using the newbuilds, the Operator will formally verify with the DC that:

- Process safety risks have been identified and documented and are managed to ALARP
- Employees or contractors executing health safety and environment (HSE) critical activities are competent and fit to work
- HSE critical equipment meets its technical integrity requirements, and justified modifications are completed and have been authorized as specified by management of change
- The design and construction Class and engineering requirements are verified
- PSBRs are met, as applicable
- Procedures are in place to operate HSE critical equipment within its operating limits

Conclusions

The authors have been involved in a challenging case study to incorporate lessons learned in the newbuild design of ship-shaped MODUs. Given the Operator contractual mode, the problem at hand is being addressed through a Process Safety Design Accompanying Approach. This has entailed setting, communicating, following-up, and demonstrating compliance to specific feasible requirements into the rig general specifications, using the available window of opportunity in the design and delivery schedule. Intensive communication and engagement is taking place in a good faith environment to enhance the barriers of the next generation of drillships. The most compelling reason is the memory of 11 lives lost in an avoidable accident, and working the way through the design barricades that will obstruct its recurrence.

Endnotes

[1] United States Coast Guard. Report of Investigation into the Circumstances Surrounding the Explosion, Fire, Sinking and Loss of Eleven Crew Members Aboard the MOBILE OFFSHORE DRILLING UNIT DEEPWATER HORIZON In the GULF OF MEXICO, April 2011

[2] Sutherland Asbill & Brennan LLP, Response to Coast Guard Graft Report by Transocean Offshore Deepwater Drilling Inc and Transocean Holdings LLC in the Matter of the Fire & Explosion on the Deepwater Horizon, 8 Jun 2011

[3] International Safety Management (ISM) Code 2002 http://www.imo.org/blast/mainframe.asp?topic_id=287

[4] American Petroleum Institute, API Recommended Practice 75, Recommended Practice for Development of a Safety and Environment Management Program for Offshore Operations and Facilities, 3rd edition, Washington, DC: API, May 2004

[5] 29 CFR 1910.119 Process Safety Management of Highly Hazardous Chemicals, 1992