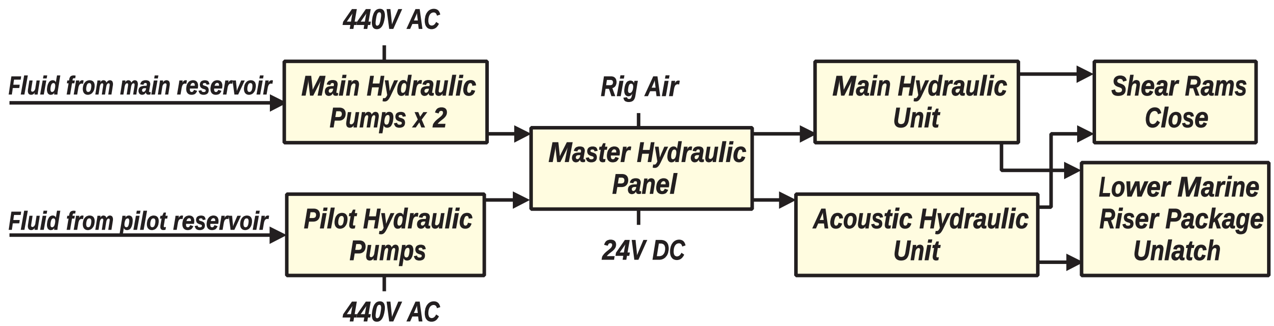
Figure 1: Functional block diagram of the BOP release system



Improving the reliability of emergency disconnect systems for semisubmersibles

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THE MOST RECENT addition to the **Dolphin a.s.** drilling fleet, the Bideford Dolphin, is currently nearing the end of a major upgrade and will shortly commence development drilling operations in the Norwegian North Sea for **Saga Petroleum**. Designed and constructed as a fifth-generation drilling semi-submersible, the Bideford Dolphin is at the forefront of deepwater drilling technology, principally through the rig's new RamRig drilling system and associated drill floor automation. These technological improvements will allow safer, faster and more cost efficient drilling operations to be conducted.

FORMAL SAFETY ASSESSMENT

To operate within Norwegian waters, the Bideford Dolphin has had to comply with the latest **Norwegian Petroleum Directorate** (NPD) and **Norwegian Maritime Directorate** (NMD) health and safety regulations, considered among the most stringent in the world. In order that these requirements could be met, a program of formal safety assessment and hazard management was embarked upon which was progressed alongside the vessel redesign and upgrade. Part of this program was the establishment of risk criteria by Dolphin a.s. and ensuring that this was met through the design and construction of the rig. The criteria covered risk to life and the integrity of critical emergency response provisions.

Although technological development within marine drilling has progressed considerably on a number of fronts over recent years, there are still several issues which continue to challenge the designers and operators of modern drilling rigs. One such issue is the potential for loss of well control and the risk from subsequent blowout leading to fire, explosion or toxic gas release. Between 1980 and 1995, blowout resulted in more than 20 fatalities and caused the total loss of 21 mobile offshore rigs.

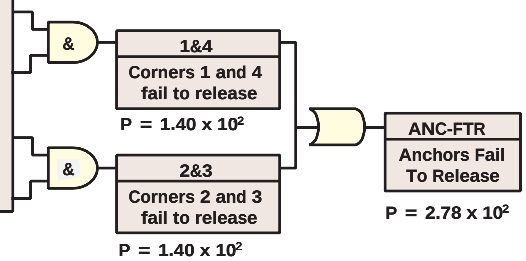
The potential for blowout is inherent in all well operations and the preferred means of managing the hazard is very much through prevention. Indeed, major advances have been made in this respect through improved training and technological developments in the past decade or so. Nonetheless, the ability to reduce blowout risk through prevention alone to a very low level is constrained through human error, equipment reliability and the like. However, it is possible to mitigate against blowout in a number of ways. In the case of semisubmersibles (and drillships), their ability to move off station is a key attribute with regard to minimising blowout risk. The basic principle of this operation involves disconnecting the marine riser (if in use) from the BOP and using the tensile energy stored in the catenary mooring system on the up-wind side of the rig to pull it to a safe distance from the well site. Clearly this also requires that mooring lines on the downwind side are released, preferably in a controlled manner. The effectiveness of this operation has been demonstrated on a number of occasions, particularly in incidents which have involved shallow gas blowout. However, effecting an emergency move off is also achievable whilst connected to the well/subsea BOP through a marine riser.

The practice of drilling shallow hole (where the potential for blowout is comparatively high) without a marine riser, from semisubmersibles is now well established. The principle here is that the potentially vast quantities of gas often associated with shallow gas blowout might be more safely vented at the sea bed (with the semisubmersible moving rapidly off station) than can be handled through a diverter system on the rig itself.

Incidents such as the fatal shallow gas blowout involving the West Vanguard in Norwegian waters in 1985, which also caused extensive damage to the rig, demonstrate the hazard potential of shallow gas blowout and the problems inherent in attempting to divert. In this case, the diverter line failed due to severe erosion and caused the rig to be enveloped in gas which ignited.

Figure 2: Fault tree for anchors failing to release

Event Name	Data Ref	Description	Failure Rate	T_{rep}/T_{test}	Prob	R/U
Corner1	Page 5	Corner 1 fails to release			1.04×10^{-1}	
Corner4	Page 8	Corner 4 fails to release			1.04×10^{-1}	
Corner2	Page 6	Corner 2 fails to release			1.04×10^{-1}	
Corner3	Page 7	Corner 3 fails to release			1.04×10^{-1}	



In evaluating the risk to the Bideford Dolphin and its crew from blowout events, and what this could mean in terms of meeting risk criteria, Dolphin took account of the contribution that the rig's emergency disconnect and move off capability might make. In order that this could be done, a Quantified Risk Assessment (QRA) was carried out. This study took account of the likely frequency of blowouts, their probability of ignition and the severity of any ensuing fire and explosion. A key data point within the assessment of blowout risk was, given a blowout had or was about to occur, the probability that an emergency disconnect and move off would be successfully implemented.

RELIABILITY ANALYSIS

In recognising the potential risk benefits of the emergency disconnect and move-off capability, the Bideford Dolphin project team set about designing the associated systems such that they would have a very high probability of successful operation, should the need ever arise. In order to establish the degree of reliability associated with the rig's emergency disconnect and move off systems, and to identify whether there may be a requirement to make any improvements, Dolphin commissioned WS Atkins to conduct a detailed reliability assessment which would assure them of the systems reliability and functionality. The complex nature of the emergency disconnect system, with many interacting sub-systems, demanded that a properly structured approach be adopted to ensure the analysis was robust. In this case it was identified that a Failure Modes and Effects Analysis (FMEA), with an accompanying Fault Tree Analysis (FTA) was the most appropriate method of conducting the assessment.

In conducting the initial FMEA, the emergency disconnect and move off system was broken down into its component sub-systems, these being:

- Power systems;
- Marine riser disconnect and control systems;
- Anchor winch emergency release system.

Each sub-system was then further broken down into its individual components in the form of a Functional Block Diagram, an example of which is shown in Figure 1. This allowed each sub-system to be assessed in order to identify potential causes of failure, the effect of that failure on the overall functionality of the system and the facilities in place to detect and recover from that failure.

If it was concluded that the facilities in place to detect and recover from the component failure were deficient, or if it was felt that the operability of the system could be improved, then recommendations to enhance the reliability of the system and/or the operability of the system were generated. This opportunity to improve the system resulted in a number of procedural and hardware recommendations being made. An example of one such procedural recommendation made was to monitor the running time of the anchor winch hydraulic servo pumps, as excess running may be masking unrevealed failures. An example of a hardware recommendation made was to soft wire the winch hydraulic accumulator isolation valves to reduce the potential for accumulator isolation due to operator error. It is important to note that consideration was also given in the FMEA (and FTA) to failures which might themselves be caused through blowout events themselves. This, for example, might include fire damage to critical anchor winch emergency release system cabling.

Following the FMEA , those critical failures which prevent successful operation of the emergency disconnect system as a whole were examined further in the FTA.

In conducting the FTA, comprehensive offshore reliability data was referenced to allow accurate frequencies or probabilities of failure to be applied to each identified critical failure. Where a sequence of events led to emergency disconnect system failure, each step was analysed in turn in terms of its frequency or probability of occurrence. The end result was a fault tree which included all identified failure modes and allowed the overall probability of system failure in the event of a blowout incident to be established.

In conducting the FTA, the probability of the emergency disconnect and move off system functioning properly during a blowout was determined to be between 88% and 97%, depending upon whether riserless drilling was being carried out or if operations were being conducted with a subsea BOP and marine riser in place. It should be noted that these reliability results are specific to the Bideford Dolphin. When fed back into the QRA, it was apparent that the system as designed and installed was adequate for enabling risk criteria concerning blowout events to be met. The relatively high level of system reliability can be attributed, principally, to the degree of planning and the high standards employed in the design of the system.

CONCLUSIONS

- Overall, the analysis did not reveal any single critical failures which would cause the emergency disconnect system to fail to operate in the event of a blowout. It was therefore no surprise that the reliability of the system was calculated to be relatively high, between 88 - 97%.
- Although there was found to be a high level of system reliability, there were still a number of areas identified which could have been improved with a view to enhancing system reliability and functionality. As a result, recommendations were made which were considered by the project for implementation.
- Ultimately, the value of conducting such a reliability analysis and combining this with the QRA, was that the Project Team and the regulatory authorities were assured that blowout risk was being properly managed, insofar as the rig and its crew were concerned.
- Rig operators who have identified the emergency disconnect and move-off capability as being critical to their rigs' integrity and to crew safety in the event of blowout should assure themselves that the relevant systems are inherently reliable. ■