From: Knox, Tom
Sent: Mon Jul 12 21:12:18 2010
To: Webster, Simon
Subject: Flow regime.doc
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Attachments: Flow regime.doc

Simon,

I have put this together from the data we have at this point, any comments?

Tom

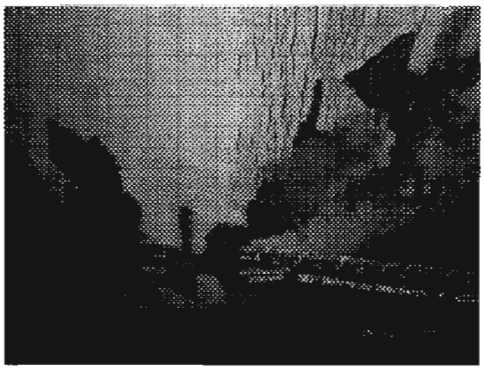
Analysis of Inspection data on Recovered MC-252 Riser section

The MC-252 riser section recovered from the well site by the Olympic Challenger on the 21st June 2010 has been subjected to a range of non-destructive evaluation (NDE) techniques to determine condition of riser and possible damage caused by flow of oil through the riser.

At the point of collapse around the 23rd April 2010 there was no obvious external damage to the riser section at or around the kink region. Within 5 days (23rd April 20101) two holes appeared in the riser, subsequently tagged holes B and C. Approximately 1 month later on the 25th May 2010, two additional holes appeared in the riser, holes E and F. Ultimately there would be 6 holes with Hole D appearing just prior to the mud kill operation and Hole A just after.

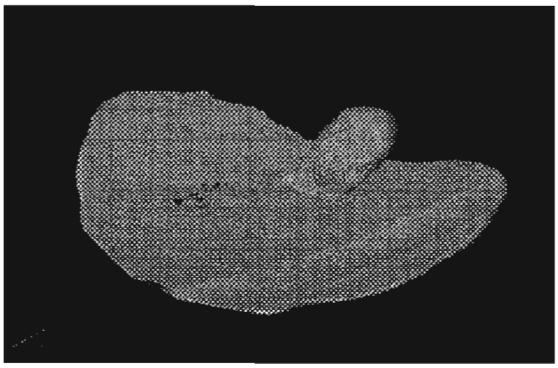
On the 21st June 2010 the riser was recovered from the sea bed to the deck of the Olympic Challenger where non-destructive evaluation (NDE) methods were used to inspect the condition of the riser. The inspection was designed to investigate a number of issues and this note reviews and discusses the information gathered around potential flow patterns through and around the kink and their potential implications for flow through the BOP.

The first and most significant observation when the riser section was cut from the BOP was the presence of two drill string pieces at the BOP end of the riser section while there was only one at the downstream end of the riser section.



Remote visual inspection of the holes in the riser section revealed a number of key pieces of information. Hole B is approximately round with a diameter of 2 cm. Internal inspection of the hole shows that it is at a compound angle of 45° from vertical towards the downstream side and 45° left of vertical when viewing from the upstream end.

An impression of the hole was taken by pressing a dental moulding elastomer into the hole and removing once set. This impression was subsequently laser scanned to produce a number of 3D images of the hole as shown on the right. It can be seen from this image, and confirmed by ultrasonic thickness measurements, the this hole is discrete and that no

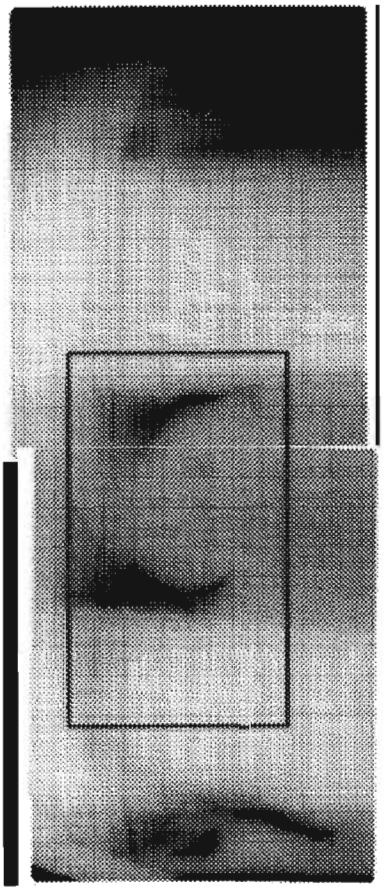


erosional damage can be found in the vicinity of the hole.

The boroscope inspection through hole B identifies the presence of a drill string in close proximity to the wall of the riser. Investigation of the drill string has shown that there is a hole in the drill string opposite the hole in the riser suggesting that the hole in the riser was formed by direct jetting of a high velocity oil stream onto and through the riser section. The nature and morphology of the hole suggest high pressure jetting rather than general erosion and this has consequences for the flow through the system.

Jet cutting of the riser requires high flow velocities from the drill string which in turn requires high flow rates through the string and a high pressure drop across the breach in the wall of the drill string. The high velocity and pressure of this flow provide some indication of the integrity of the drill string through the BOP and possibly into the well.

Hole C also at first glance looks like a jet cut hole in that the walls are steep and it appears that there is no erosion damage in the vicinity. Hole D and E show signs of general wall thinning and are clearly related to each other. When this region is viewed by high energy X-ray imaging (conducted 5th July 2010) it can be seen that though the holes are steep sided there is considerable erosion of the riser wall immediately upstream of the holes as seen in the highlighted area of the x-ray image on the right. For this damage to occur there would need to be high flow rates across the surface of the riser and thus annular flow in the riser cross section



If we consider that both high flow through the left drill string has occurred (hole B formed) and that high riser annulus flow also occurred (holes C, D and E) then we can deduce information about where the drill string could terminate.

We can envision termination in one of three general locations:

The drill string is severed at or around the top of the BOP and flex joint.

If the drill string terminates in this location then pressure in the riser annulus and the inside of the string are the same therefore no flow through the string will occur unless the kink cross section is completely closed and the drill string is the only communication path for fluid across the kink. In this case hole B can occur but holes C, D and E cannot occur. Alternatively, there is a limited path for fluid through the kink, this would allow the erosional holes C, D and E to form but hole B cannot form as a significant differential pressure between the annulus and the string is required.

The drill string is terminated inside the BOP.

As with the case above, hole B requires a significant pressure differential between the riser annulus at the kink and the inside of the drill string. For this to occur with a severed drill string in the BOP region then the BOP annulus must be closed, if it is not then insufficient pressure drop is likely to be generated to induce the flow rates and velocities to create hole B in the riser wall. Further, for the BOP annulus to be sealed then the upper annular seals must be intact and have closed around the drill string. If this was the case then all of the flow would by necessity flow through the drill string and we would expect that the damage seen on the drill string that led to the formation of hole B would then be completely eroded out due to the very high flows through it. This is not the case, once the jetting damage has occurred the general area in the vicinity of hole B is largely intact suggesting that the drill string flow and annular flow are separate.

The drill string terminates inside the well bore.

If the drill string terminates within the well bore below the throat of the well hangers then at the point of termination the pressure inside the annulus and the string are equal. However, the bore of the 5.5" drill string is approximately 4.75" and the annular gap between the drill string and the throat of the well hangers is equivalent to a choke of between 2.5" and 3.5" depending on whether at the throat we have drill string or tool joint. This choke could be sufficient to generate the pressure drop required for Hole B to form and still produce enough annular flow to generate erosion damage across the kink.

Tom Knox 12/07/2010