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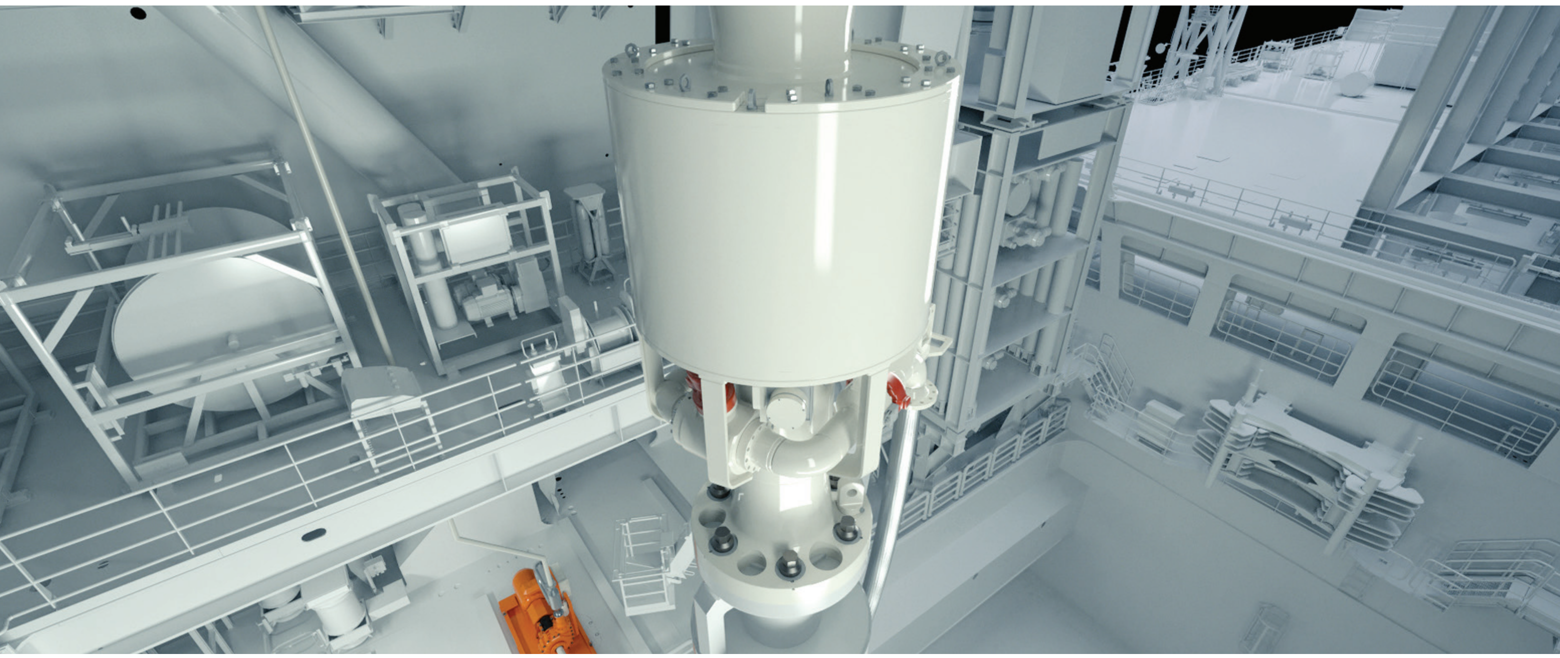
SPECIAL FOCUS: OFFSHORE DEVELOPMENT

Dynamic kick & loss detection for improved well integrity



A next-generation enhanced kick/loss detection technology offers economic and safety benefits, and improved well integrity, based on more precise, real-time wellbore fluid monitoring.

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Significant effort during the past decade has gone into developing more advanced kick detection systems, using various algorithms and measuring equipment. These advancements have improved wellbore fluid volume control accuracy.

When drilling a well from a floating vessel, rig motion impacts the ability to accurately monitor wellbore fluid flow and volume. Pitch and roll do have effects, but the most significant impact is the telescopic joint motion that, in effect, constantly changes the fluid volume of the riser. This newest technology, EC-Monitor, eliminates this effect, resulting in more precise volume measurements. This provides a significant improvement in volume control fidelity and offers economic and safety benefits, due to real-time monitoring and more precise measurements.

A rendering of the EC-Monitor system on a Transocean Ultra-Deepwater Drillship. Image: Transocean.

SETTING UP THE JOINT PROJECT

Developing the EC-Monitor system was sanctioned by Transocean in January 2019. The joint development between Transocean and Enhanced Drilling combines core expertise and decades of operational experience in drilling operations and controlled mud level managed pressure drilling technology, to solve an old problem in an innovative way. Why did Transocean choose to develop through its collaboration with Enhanced Drilling rather than buy? Existing kick detection systems do a decent job of alerting the driller to a discrepancy in flowback to surface, but accuracy is often impeded by various factors, such as:

- Surge through the flowline caused by contraction and extension of the telescopic joint due to vessel heave and fluid movement in the pits from pitch and roll, or fluid transfer;
- The dead band to eliminate nuisance alarms has to be set wide, resulting in higher-than- desired kick or fluid loss detection volumes;
- Very low influx rates can go undetected for some time, resulting in lengthy critical path remediation time;
- A discrepancy in fluid flowback currently necessitates work stoppage and a static flow check, increasing well construction duration.

By focusing on only the fluid system contained within the wellbore and the riser, rather than the entire rig circulating system, these external factors can be eliminated. If flow is measured at the riser outlet, and the effect of the telescopic joint motion is eliminated from the volume measurements, improved detection accuracy can be achieved. To achieve true barrel in, barrel out monitoring of wellbore fluids, the foundation was provided by Enhanced Drilling's Controlled Mud Level technologies, and techniques to accurately maintain and monitor mud levels below the telescopic joint in order to, in essence, achieve continuous and dynamic wellbore fluid return flow monitoring.

With EC-Monitor, the team recognized that faster kick or wellbore fluid loss detection, and smaller influx volume, has a reasonable correlation to faster recovery, and therefore lower non-productive time (NPT). However, quantifying the business case from this intangible is difficult. More tangible is the opportunity that this system provides to reduce well construction critical path by significantly reducing the time spent stopping operations to do static flow checks. The EC-Monitor system provides real-time kick or loss confirmation, now only available through static flow checks. A return on investment is anticipated in less than a year and supports lower emissions per well through the drilling efficiencies achieved.

SYSTEM DESIGN

The system design focused on three main elements:

1. Remove topside fluid system effects;
2. Eliminate the telescopic-joint effect; and
3. Minimize the effect of sensor noise and measurement uncertainty.

The team moved through concept development, detailed design and computer simulations into manufacturing and pilot testing during a stage-gate development. In late 2020, five weeks of flow loop pilot testing were conducted in Norway, to compile results from extreme environmental and operational conditions to de-risk field deployment.

The system's design is quite basic, but the control algorithms provide the intelligence.

The flow spool pictured (**Fig. 1**) replaces a spacer spool between the telescopic joint and the diverter, and functions as an in-riser trip tank. Fluid height is measured accurately by a set of sensors mounted in the flow spool. Telescoping joint stroke position is monitored.

The actual level within the flow spool is continuously compared to the virtual "telescopic-joint displacement volume," calculated from the measured telescopic joint position. The level in the flow spool (**Fig. 2**) is maintained at this virtual level, and return flow is accurately measured before the mud is discharged into the flow line, upstream of the existing flow/show equipment, to return into the active mud system. The return flow is then compared to the flow-in measurements. The flow spool is sized to absorb volume changes caused by telescopic joint motion in harsh environments and adverse weather.

Computer-based simulations were conducted in the first quarter of 2020 to verify the system design and control logic algorithms against the system performance requirements (**Fig. 3**), prior to entering the manufacturing phase. A simulator was developed to represent the well, the rig and the EC-Monitor control system. The simulator was used to perform each of the system use cases and test the potential of the system to meet the performance requirements. Sensibility analysis was carried out to identify the contribution of the sensor package to system accuracy. Effects, such as wave scatter with varying periods, were part of the simulations. Various methods were tested to identify and smooth sensor and process noise.

In the end, filters were used and the noise and offset in the signal were removed from the calculation. A fingerprint value was then established for each operational condition, such as drilling, tripping or connections. During the design process, a computational fluid dynamics

Fig. 1. This image shows the flow spool above the telescopic joint. Image: Transocean.

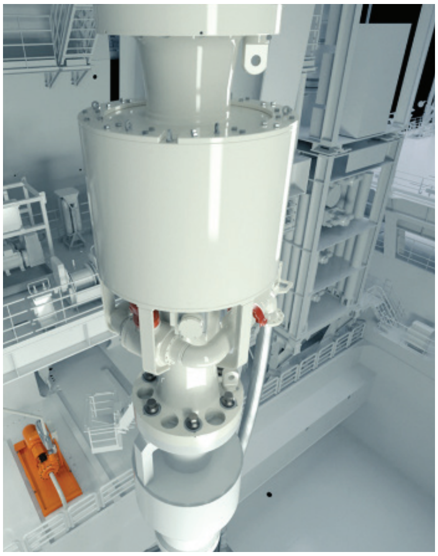

Fig. 2. This image shows the fluid level in flow spool. Image: Enhanced Drilling.

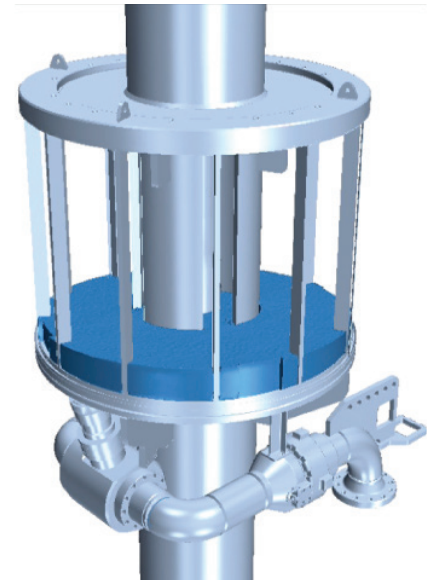

Fig. 3. An extract from the System Performance Requirements. Image: Transocean.

ID	Description
B1	The EKD system aggregate instrument and algorithmic error shall be no greater than ±3 GPM
B2	The EKD system algorithms shall consider a trend duration no longer than 5 minutes to determine loss or gain
B3	The EKD system shall recognize gain or loss of 1 GPM while static
B4	The EKD system shall recognize gain or loss of 5 GPM while Drilling
B5	The EKD system shall recognize gain or loss of 2 GPM while tripping without pumping
B6	The EKD system/Inline trip tank shall recognize gain or loss of 5 GPM when tripping without pumping

(CFD) study was carried out. The CFD provided insight into the pressure profiles and flow patterns inside the flow spool. This insight resulted in the re-design of the flow spool internals. This CFD model was compared with the heave modeling from the simulator. It was noted that the CFD yielded more weather noise than anticipated, and this was corrected in the model. Through further simulations, the new noise level was then reduced by altering the filtering algorithm.

In order not to distract the Driller with unnecessary information, the EC-Monitor value and alarm setpoints are the only values displayed graphically. An output of the control algorithms represents a delta volume to the Driller.

The value, which is the black line on the screen (**Fig. 4**), is allowed to rise and fall within the kick or loss alarm limits. If the value trends upward, crossing the yellow alarm, a gain warning is issued to the Driller. If the value continues upward, and crosses the red line, a kick alarm is sounded, alerting the Driller to stop operations and shut-in. The same is true for a wellbore fluid loss. The alarm thresholds in the example are set at eight gallons total influx volume for yellow and 12 gallons for red, which were found effective through flow loop tests with no nuisance alarms seen. As a result, the well can now be dynamically flow-checked in real time, resulting in significantly quicker gain or loss detection, and far fewer critical path static flow checks.

The EC-Monitor system was pilot-tested at its functional limits, including 16-ft heave, which may not have been possible in an offshore pilot test. All gain and loss operational scenarios were simulated at varying flowrates and vessel motions, with the notable exception of tripping, which will be tested during the first deployment.

SIMULATED EVENT

A simulated well control scenario was assembled, where a rig experienced a 3.7-gpm gain. As part of the simulated scenario in benign environmental conditions, the gain went undetected for 48 hrs, resulting in a 243-bbl kick. To further challenge the system, 13 ft of vessel heave was introduced to the simulated scenario and tested the EC-Monitor system's response to detect this kick.

The top right camera (**Fig. 5**) is looking into the flow spool, and the bottom right is looking into the heave tank. This was used to simulate the volume changes from the telescopic joint. More than 180 gal are moving into and out of the flow spool for each heave period. As the wellbore fluid influx begins, the EC-Monitor value trends upward until the warning and alarm thresholds are crossed, alerting the Driller to shut-in. This 243-bbl kick could have been detected in less than 2 min., with less than a quarter-barrel wellbore fluid influx, and would have saved days of critical path remediation time.

De-risking field deployment and validating simulations was the goal of the pilot tests. The EC-Monitor system completed 125 drilling connections and 170 gain/loss scenarios throughout the operational design range. By validating and exceeding performance expectations, the team's confidence was solidified in the operational readiness of the system. As an extra step, a third party verified and validated the system design and functionality.

The first EC-Monitor system has been delivered to the Gulf of Mexico region, where it awaits its initial deployment. Installation is engineered to take place completely offline to the critical path of well construction, and deployment of the flow spool is not expected to impact critical path of riser running operations. The EC-Monitor system is an industry step change that will save customers well time while reducing operational integrity risks. WO

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Fig. 4. Enhanced Drilling: A screenshot of User Interface Main Page. Image: Enhanced Drilling.

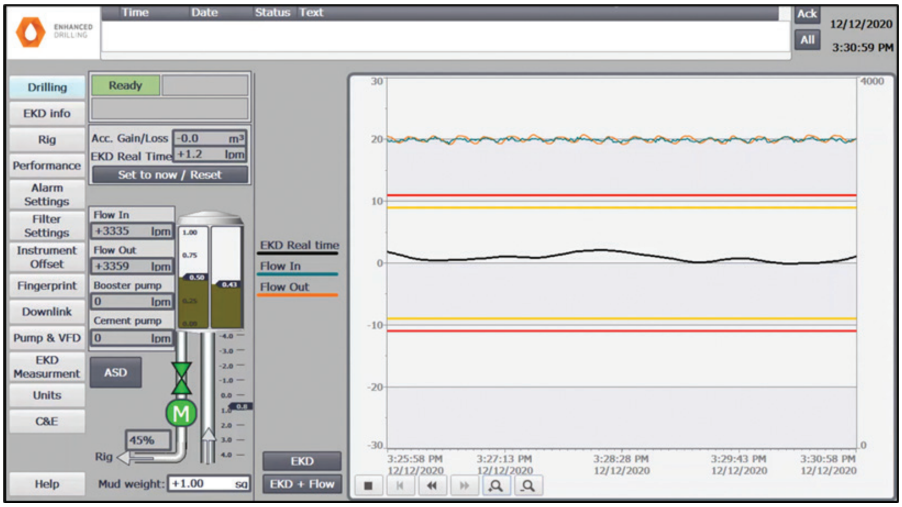

Fig. 5. A screenshot of flow loop testing simulated well control scenario. Image: Enhanced Drilling.