Multi-service system achieves new level of pressure control in Myanmar shallow gas well

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PETRONAS CARIGALI'S DECISION to explore the Nagar prospect offshore Myanmar's southern coast hinged on finding a solution to reduce the risks of drilling shallow gas targets from a moored drillship in intermediate water depth. In their search for a solution to drill the Nagar #1 well, Petronas focused on pressure data accuracy, real-time pressure management, well flow modeling and well control techniques at very shallow depths. Three separate yet complementary technologies were combined on this project to form the first jointly operated, automated pressure control system. It provided the solution Petronas sought and offers the industry a proven approach to pressure management and well control in other difficult-to-drill areas.

The Nagar prospect, located in block M16 in the Andaman Sea beneath approximately 400 m of water, contains several gas-bearing sands within 400 m of the sea floor. Petronas planned to drill the Nagar #1 exploration well from a moored drillship to evaluate the prospect. But drilling safety was a challenge in the shallow, high-pressure gas. They had to contend with a number of potentially high risk scenarios arising from a combination of situations: a weaker than expected surface casing shoe, a narrow pressure margin, inability to circulate out gas, and short response time.

One of the most important situations in the Nagar #1 well was related to the strength of the 20-in. casing shoe and its shallow depth (about 250 m below the sea floor). A weak shoe would be unable to contain the shut-in pressure of a high-volume gas kick. In the worst case scenario, the shoe breaks down and large volumes of gas escape, possibly up to the sea floor and into the water surrounding the drill ship, endangering people, environment, rig and well.

The OnTrak tool is used in Nagar #1 to provide continuous downhole annular pressure measurements to the DAPC system via drill string telemetry.

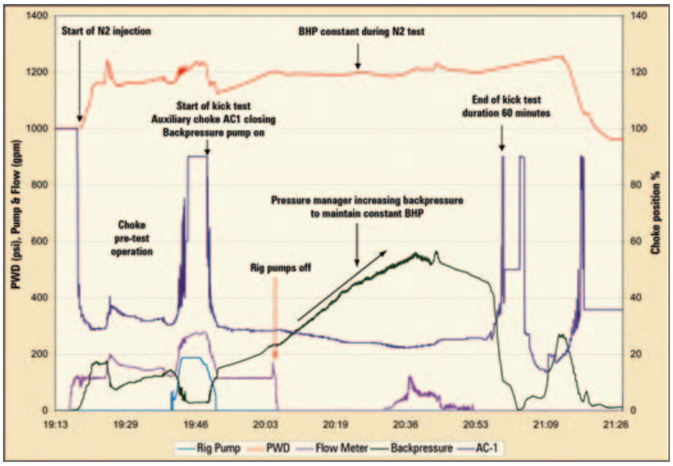
Another possible scenario involved adverse circumstances surrounding the narrow pressure margin in the Nagar well, which left little room to safely circulate out gas with a conventional well control system. In the conventional system, there was too high a pressure loss in the choke line and too much imprecision with manual choke manipulation. It was estimated that the pressure would fluctuate between 150-200 psi and cause the bottomhole pressure (BHP) to exceed the margin. Safety dictated that the pressure could not fluctuate more than +/- 30 psi during a well control scenario, which was not achievable with the conventional system.

The very shallow depth of the Nagar prospect created the conditions for yet another high-risk scenario. Potentially overpressured gas sands lie between 260 m and 400 m below the sea floor. At that depth, drilling personnel would have very little time to detect, respond to and contain a gas kick. Within minutes of a kick, gas would travel the short distance to the mud line, fill the riser, unload its pressure, force the rig to shut-in the well and again, possibly break down the shoe.

Petronas concluded that the Nagar prospect could safely be drilled only with a closed circulation and pressure management system that would monitor and maintain constant BHP while drilling, and during connections and well control. The system would have to detect kicks as early as possible, respond immediately to downhole pressure changes, and simultaneously circulate out gas from a kick. In their search, Petronas learned that no one system can provide all those capabilities. But, they also learned that by combining specific technologies, they could make one that did.

THE SOLUTION

Petronas elected to develop a new solution from three technology providers. Once interconnected, the three formed a new system that could control the BHP and the well, with the accuracy and speed they needed.



Pressure plot during one of several simulated kicks with N2. BHP was controlled by the DAPC pressure manager using downhole PWD data transmitted via drill string telemetry. The test proved the system's ability to circulate out the gas while maintaining constant BHP at a specified setpoint.

The system had three parts — one to control surface annular backpressure, one to measure downhole annular pressure, and one to provide high-speed, drill string telemetry between the surface and downhole systems. Advanced transient flow modeling and rig-based tests involving simulated nitrogen gas kick proved to Petronas the system's ability to control pressure continuously and respond instantly to downhole fluctuations.

At Balance provided surface annular pressure control with the Dynamic Annular Pressure Control (DAPC) system. **Baker Hughes INTEQ** provided downhole annular pressure while drilling (PWD) data with the OnTrak MWD system. And **IntelliServ** provided the IntelliServ Network that connected the two. Modifications were made to the surface and downhole systems so that they could work with one another via the drill string network.

ANNULAR PRESSURE CONTROL

Surface pressure control was provided by the DAPC system, an automated managed pressure drilling system for constant BHP. The system controls pressure with a choke manifold, a backpressure pump, a real-time hydraulics model, and an integrated pressure manager (IPM). The system also monitors flow-in and flow-out data for early kick detection and is capable of being operated from a remote data center.

Designed for contingencies, the system includes two redundant chokes, a redundant auxiliary manifold leg, remote manual controls and emergency shutdown.

Additional contingency backup capabilities were installed when the system was connected to the drilling rig's circulation system. The rig manifold was connected in parallel for backup manual choke control, and the cement pump was connected as a standby backpressure pump.

Overall control of the system is provided by the integrated pressure manager. It controls the equipment, coordinates data acquisition and communication, and manages backpressure based on calculated or actual BHP and the setpoint.

Maintaining the BHP at the setpoint at all times is the pressure manager's most important task. The setpoint is the pressure control point at a specific depth in the well; it guides the pressure manager's every action. In the Nagar #1 well, the setpoint was located at the casing shoe. If the BHP deviates from the setpoint, the pressure manager automatically corrects the backpressure by adjusting the choke position.

In normal drilling mode, the DAPC hydraulics model provides frequent updates to the pressure manager so that it can respond to pressure changes in a timely manner and maintain a constant BHP. It calculates the BHP once a second and calibrates itself every time it receives updated downhole pressure data. As the update rate from the downhole tool increases, so does model accuracy.

A modification was made to the system that enabled it to receive and use real-time PWD data via the drill string for continuous model calibration. The drill string network provided PWD updates every 2 seconds compared with the normal update rate of 40 seconds or more.

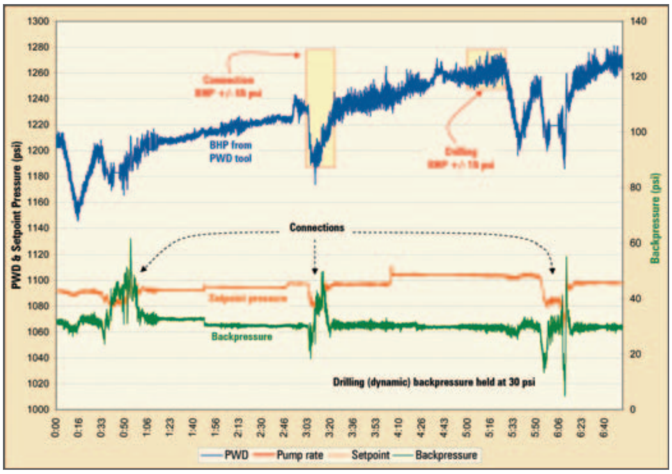
The model is very accurate in low compressibility, single-phase fluids, which made it ideal for steady state drilling with water-based mud in Nagar #1. But with a high-volume influx of gas, the mud becomes a compressible, dual-phase fluid, and the model would lose some of its accuracy. Any loss of accuracy was unacceptable because it would affect the pressure manager's ability to maintain constant BHP during well control.

To preserve the DAPC system's accuracy and ability to maintain constant BHP during a well control scenario, the pressure manager was modified to switch from using the model calculated BHP to the real-time PWD data. The system's accuracy and ability to maintain constant BHP with PWD data was proved during well control simulations on the drilling rig using nitrogen gas.

DRILL STRING TELEMETRY

Drill string telemetry from the IntelliServ Network comprised of conventional drilling tubulars modified to incorporate a high-speed, low-loss data cable that runs the length of the drill pipe joint encapsulated within a pressure sealed, stainless steel conduit.

Each drill pipe contains two inductive coils connected by the cable. One coil is installed in the pin nose and another in the

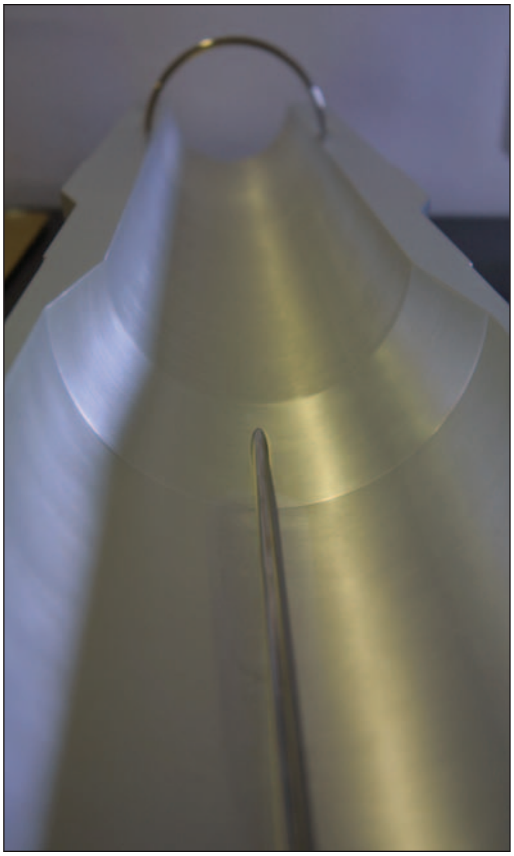


Detail pressure plot from Nagar #1. While drilling, the BHP was maintained within +/- 15 psi and during connections within +/- 45 psi. The BHP log from the PWD tool is in psi units and increases with depth. In terms of EMW, the BHP is constant at 10 ppg.

box shoulder of every connection. When two connections are threaded together, the pin end coil in one joint is brought into close proximity with the box end coil of another. Data is passed from one coil to another by the electromagnetic (EM) field associated with the alternating current (AC) signal transmitted along the cable. As the alternating EM field from one coil induces an AC signal in the nearby coil, it passes data from one joint to the next.

The high bandwidth of the network, 57.6 kbps, enables it to transmit large volumes of data to the surface from downhole tools and virtually eliminate the lag time inherent in mud pulse telemetry. Speed was essential in Nagar #1 due to the shallow depth of the gas. Minutes meant the difference between gaining and losing control in the event of a gas kick.

The telemetry drill string is designed for simultaneous bi-directional communication, which at one point early in the well enabled the MWD tool to be reprogrammed for faster pressure updates.



Cutaway photograph of a wired drill pipe shows where the data channel exits the upset and the inductive coil in the back.

No special handling or make-up procedures are required, and any thread compound can be used. Other than a higher make-up torque, the telemetry tubulars have the same mechanical and hydraulic properties and are handled in the same as standard, double-shouldered drilling tubulars.

PRESSURE WHILE DRILLING

In addition to directional surveys, gamma ray and resistivity measurements, INTEQ's OnTrak MWD tool provided the downhole pressure while drilling (PWD) data used to manage the BHP.

Continuous BHP control was a critical operational requirement in Nagar #1, which required a continuous stream of accurate downhole annulus pressure data. In support of that requirement, modifications were made to the tool that enabled it to measure and transmit downhole pressure data with or without mud circulation. Normally, the tool operates off of power generated by a turbine energized by the mud flowing through it. For Nagar #1, a battery sub was included in the bottomhole assembly (BHA) to provide backup power. Modifications made to the tool's programming enabled it to switch from turbine to battery-supplied power whenever mud circulation stopped, ensuring an uninterrupted flow of pressure data during well control.

It was important to ensure that power would be available when it would be needed most, during well control. The bi-directional capability of the drill string network supported interactive communications between the MWD surface system and downhole tool, making it possible to conserve the batteries by turning them on only when they were needed — during well control test scenarios and before entering critical pressure zones.

A downhole interface sub specifically developed to condition data from the OnTrak tool and connect it to the drill string telemetry network was placed at the top of the BHA.

Programming modifications were made to transmit annular pressure data every 2 seconds, which was significantly faster than the standard 40-second update rate with mud pulse telemetry. On the surface, a WITS feed delivered the downhole pressure data directly to the DAPC system.

THE RESULTS

During steady state drilling operations, the jointly operated system maintained the dynamic BHP within +/- 15 psi of the static BHP and, during connections, it maintained the BHP within +/- 45 psi, both of which were well within the Petronas specified criteria.

Advanced well flow modeling showed that the system would act as an early kick detection system, resulting in kick volumes more than 10 times smaller than a conventional system. The smaller volume was attributed to the system's capability to control the influx rate with an automated choke, instantly monitor BHP, accurately measure flow out with a coriolis meter, and enable well shut-in within seconds with the DAPC system, compared with minutes with the BOPs.

A volumetric kill and lubricate method proved to work well during the nitrogen kick simulations on the rig. During the simulations, while the gas migrated to the surface, the mud was diverted through the choke line and bled off through the automated choke manifold. The integrated pressure manager proved capable of managing the backpressure at the levels required to maintain a constant BHP (within the +/- 15 psi window) while allowing the gas to expand. Pressure buildup levels were monitored continuously to determine when the nitrogen gas was no longer migrating to the surface. At that point, the well was isolated by closing the BOP fail safe valves, effectively trapping the remaining gas in the choke line. From there the remaining gas was bled off to the atmosphere and replaced with mud using the system's backpressure pump. The process was repeated if evidence indicated the presence of additional gas below the BOPs.

Petronas could not have drilled Nagar #1 without this jointly operated pressure management system, made possible by the application of new automated pressure control and telemetry drill string technologies, in combination with existing PWD technology. The system enabled Petronas to drill the well to TD safely and cost-efficiently, compared with the conventional alternatives.

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