Operators and their service partners frequently use hole enlargement while drilling (HEWD) in deepwater Gulf of Mexico wells as a way to deploy additional, or larger, casing sizes to increase the diameter of the production string. This well-established practice has proven beneficial compared with non-HEWD operations, which are constrained in the clearance that can be reached between two consecutive casing strings. In wells where HEWD is not deployed, the lower casing size is limited by the hole size that can be drilled with a bit that will pass through the upper casing’s drift internal diameter (ID).

HEWD applications typically use a concentric expandable underreamer housed in a conventional bottomhole assembly (BHA) configuration with a rotary steerable system (RSS). The underreamer sits above the logging-while-drilling and measurements-while-drilling (LWD/MWD) string, which is critical in deepwater operations.

However, this design results in the creation of a long, un-enlarged hole, known as a “rathole,” between the drill bit and the underreamer at target depth. In some cases the rathole can create a situation where the casing shoe is 100 to 200 ft (30 to 61 m) away from the bottom of the hole. This has the potential to complicate cementing and also to compromise the borehole, which can reduce log data quality. Sonic data transmission also can be affected by the distance between the underreamer and the sonic tools.

Greater control for operators
Schlumberger developed the RoD system in response to operators’ need for a technology to give greater flexibility and control of the underreamer in HEWD operations. Conventional HEWD BHA designs consist of a single cutter block and simple expansion mechanism with a hydraulically activated piston that forces the cutter blocks to traverse and expand radially on a spline mechanism. The activation mechanism is deployed by dropping a ball into the drillstring. The ball shears an activation sleeve, triggering deployment of the remaining hydraulic activation mechanism, while a locking device ensures the cutter blocks remain in a predetermined radial position.

This BHA configuration has limitations, particularly related to the placement of the underreamer in relation to the LWD/MWD string. Because the LWD/MWD tools typically have a sonde with electronics set in the ID of the tools, activation balls cannot pass through the LWD/MWD string. The underreamer must be above the LWD/MWD tools to prevent the tools from operating in the enlarged hole, rather than the bit-size or pilot hole, where they are not sufficiently stabilized.

Use of LWD tools in the enlarged hole also increases the clearance between the sensors and the borehole, which can reduce log data quality. Sonic data transmission also can be affected by the distance between the underreamer and the sonic tools.

The dual-reamer drilling system uses the on-demand reamer which can be tested at surface to verify functionality. The system was designed to overcome these challenges and provide greater efficiency in HEWD applications. The RoD tool has a hydraulic mechanism that can activate or deactivate the cutting blocks, and a valve piston that controls fluid flow into the underreamer drive piston. The position of the valve piston is controlled by a cam that is manipulated using mud pump flow rates. Switching between the closed and open modes is done using a pre-determined sequence of indexing flow rates. Operators can monitor flow rates between the modes by observing parameters such as standpipe pressure, surface torque, hookload, and downhole data channels that measure flow rate changes through the MWD tools.

Because the RoD technology also eliminates the need to drop an activation ball into the drillstring, the underreamer can be placed anywhere in the BHA. In addition, two underreamers can be positioned in the...
same drillstring and activated as needed while drilling. This has the effect of stabilizing the LWD/MWD tools, and the wired connections between those tools, while eliminating the rathole.

**An integrated approach**

The location for this dual-reamer system run was Noble Energy’s Big Bend project in the GoM’s Mississippi Canyon, in a water depth of approximately 7,000 ft (2,134 m). The exploration well posed challenges, including pore pressure/fracture gradient profiles that required the casing program with several short drilling intervals. Noble also needed to use a full suite of LWD/MWD tools to characterize the formation. A 12%3/4-in. by 14%3/4-in. BHA was expected to create a rathole of just less than 160 ft (49 m), meaning a significant section of the drilled hole would be unusable.

Schlumberger deployed an integrated BHA design, including all required BHA components along with two underreamers, to perform HEWD, and then reduce the rathole to 26 ft (8 m). The RoD was placed between the MWD and RSS. A conventional, ball-activated underreamer was positioned above the LWD/MWD string in the BHA. This allowed Noble to perform HEWD for the entire interval using the ball-activated reamer and subsequently enlarge the remaining rathole by activating the RoD tool at the top of the rathole and reaming until the bit was back to bottom.

Before the operation was launched, Schlumberger did pre-job planning to minimize potential risks and to customize the BHA components. For example, whereas conventional RSS BHAs typically have a stabilizer above the RSS tool to act as a fulcrum for the deflection assembly, in this case it was determined the RoD could be modified to serve as both a stabilizer in the deactivated mode and as a reamer in the activated state to reduce both the rathole and the spacing between the bit and LWD sensors.

Risk assessment of this scenario indicated that removing the stabilizer might cause a significant change in the directional tendency of the BHA. To evaluate this possibility, Schlumberger used 4D finite element analysis software to model two BHAs, one with a conventional RSS stabilizer and one with the RoD tool in place of the stabilizer. The analysis showed the RoD tool could be used as a stabilizer with no significant change to the directional tendency of the BHA.

The RoD modification plan also included the use of cement removal cutter blocks in place of conventional cutter blocks. The large gauge pad on the blocks would allow the RoD to be used as a stabilizer while PDC cutters in the bottom of the blocks would enlarge the rathole. The internal mechanism of the RoD tool was modified so the cutter blocks would collapse to a 1/8-in. outer diameter under the bit diameter.

A hydraulics analysis verified that all the tools in the BHA could operate within the planned flow rates and mud weights for the drilling interval. This helped define the planned index flow rates so that the indexing procedure for the RoD tool would not interfere with normal drilling. The analysis also defined the nozzle configuration for the bit and the two underreamers to ensure that standpipe pressure changes at surface would clearly signal activation of the RoD tool.

Finally, as a precaution, the service company recommended that additional service personnel be retained to provide 24-hour coverage at the rig site to respond to any unintended activation and/or deactivation of the RoD tool during normal drilling operations.

**Enlarging the rathole**

In preparation of the HEWD operation, the BHA was assembled as normal at the rig site, and the functionality of the RoD tool was tested and verified on surface. After drilling out the casing shoe and obtaining an acceptable formation integrity test, the primary underreamer in the BHA was deployed below the 13%3/4-in. casing with an activation ball released from surface. The ball-activated underreamer and drill bit launched the HEWD operation, reaching target depth without incident. Directional control was maintained at less than 0.1” inclination throughout the interval and had low vibration levels.

During this phase, the hydraulic RoD underreamer remained deactivated, and was monitored from the rig floor by field supervisors and the drilling crew. Average rate of penetration for the interval was 100 ft (30 m) per hour, with a total of 1,221 ft (372 m) of 12¾-in. pilot hole drilled and simultaneously enlarged to 14¾-in.

After reaching target depth, the BHA was pulled back and the hydraulic RoD underreamer’s cutting structure, positioned at the top of the rathole, was activated and confirmed open by both a 225 psi (16 bar) decrease in standpipe pressure and weight testing with 6,000 pounds on top of the rathole ledge. The RoD tool was able to enlarge 153 ft (46.6 m) of the 12¾-in. rathole to 14¾ in. in about three hours.

This first running of this specific BHA configuration in an offshore drilling operation confirmed the RoD tool could be reliable in deepwater wells where the rathole resulting from conventional HEWD BHA applications would otherwise necessitate a dedicated cleanout run. The flexibility of the dual-reamer drilling system, including modifications to the RoD tool made for this specific application, delivered a unique and effective solution that improved the efficiency of the entire well construction process.

The successful integration of the customized RoD system with the RSS and the primary underreamer met the operator’s need to eliminate the long, troublesome rathole without impacting the functionality of the LWD/MWD tools. By eliminating the need for a dedicated rathole cleanout run, Noble Energy saved an estimated 16 hours in non-productive time and reduced operational costs by approximately $625,000. Noble Energy subsequently elected to deploy the Rhino RHE technology to drill an exploration well on the GoM Troubadour prospect, saving approximately 30 hours of drilling operations time and $1.3 million.