Extended Reach: New-Generation Frontier Drilling Rigs

Common features of frontier development are fragile environment and high operating costs, which require unique operating methods. Planned well trajectories have departures and complexity such that feasibility risk is a critical part of the evaluation before investing in these projects. Primarily, this risk is determined on the basis of rig design and capacity to drill these extreme-reach well designs. Aspects of land-rig design, procedures, and operations that enable continued drilling of more-complex well trajectories with longer departures are discussed.

Fig. 1—Yastreb Rig 262 pipe barn during assembly.

Early Experience

The original Prudhoe Bay multiwell development-drilling programs from small pad-based surface locations required directionally drilled well trajectories to reach the bottomhole targets. Bottomhole-assembly (BHA) technology and rig-hydraulic capacities enabled extended-reach drilling (ERD) with horizontal displacement at least twice that of vertical depth. The technique increased well productivity, limited environmental effects, and helped to avoid surface obstacles. Improved directional-drilling technology and departure limits enabled progressively smaller pad sizes. New rig designs were required to fit the rig on the site while allowing transportation access and simultaneous drilling and production activities. Elimination of pits and new cantilever designs were implemented to fit the rig between more-tightly spaced wellheads.

Approximately 10 years ago in China, reserves from the Xijiang 24-3 offshore field in the South China Sea were upgraded after a revised seismic interpretation provided several new locations. However, the bottomhole locations required departures beyond technical limits at the time. By 2006, 13 ERD multilateral wells were drilled from Platform 24-3.

This article, written by Technology Editor Dennis Denney, contains highlights of paper OTC 19067, "Extended Reach: New-Generation Frontier Drilling Rigs," by ***F.J. Husband,*** *SPE,* ***George Bitar,*** *SPE, and* ***Mark Quinlan,*** *SPE, Parker Drilling Company, prepared for the 2007 Offshore Technology Conference, Houston, 30 April–3 May.*

One-of-a-Kind Projects

The designing, fabricating, and operating of special-purpose drilling rigs for remote environments is unique, but all such projects have common features.

- Challenging well design
- Extreme environment
- Difficult delivery conditions
- Constrained exit conditions

Sunkar Rig 257. This purpose-built rig was constructed on a unique shallow-draft arctic hull designed for drilling in extreme ice and wave conditions of the north Caspian Sea. It required year-round self-sufficient operations while drilling subsalt high-pressure/high-temperature sour-gas fractured formations by use of closed-circulation drilling techniques. Because of logistics, drilling environment, and operating regulations, these wells are among the most expensive in the industry, including deepwater wells. The unique design delivered significant benefits in executing the planned scope of work. However, it also restricts use of the vessel to regional programs without significant capital investment.

Yastreb Rig 262—Arctic, Seismic, and Extended-Reach Land Rig. The Yastreb arctic- and seismic-class ERD land rig was designed and fabricated with an extreme delivery schedule and challenging logistics of the Russian Far

East. The project in northeast Sakhalin Island targets the northern flank of the Chayvo offshore oil and gas field with wells drilled from an onshore location. The rig achieves well displacements of 8 to 10 km at vertical depths of 2600 m. The basis of design for this purpose-built drilling rig combined structural features and automation to drill offshore targets from a land location underneath Pacific gray whale migratory routes in an area of high seismic activity. A collaborative industry ERD network leverages lessons learned from previous projects to improve reliability, drilling performance, safety, and efficiency, all of which reduce the risk profile of ERD projects in remote regions.

Rig Engineering and Design

Exploration frontiers have unique geographical and geological features that affect rig design or existing rig deployment in those areas. The recommended approach for deploying the correct rig includes balancing new features with industry standards, cost-effective equipment standardization, and engineering process. Combining modular design with equipment standardization optimizes rig use for a longer period of time and in a wider theater of operations.

In general, rig designs to extend well departures and depths require more power and more fluid capacity, and must occupy a smaller footprint, than previous generations of drilling units. Large wellbores and associated casing programs require the appropriate setback and hookload capacity to handle, store, and run extreme lengths of tubulars. These capacities must take into account the rig footprint on the site, fabrication options, and on-site rig-up limitations. In ERD wells with relatively low true-vertical-depth targets, much of the directional work is performed in large hole sections. At such angles and section lengths, the rig's capacity for handling a high volume of drilling fluid and cuttings plays a significant role in maintaining high penetration rates and avoiding trouble time caused by hole conditions.

The basis of design for ERD rigs includes reliability, well-to-well mobility, drillpipe capacity and torque, pick-up weights, flow rate, and working mud-pressure requirements. Other design factors are surface location, production requirements, mobilization routes, and demobilization plan. Underlying these technical requirements, successful designs integrate personnel considerations and site protection with a balanced mix of automation and mechanization.

Pipe Handling and Rig Footprint

Because of the length of ERD-well tubulars and structural limitations of conventional rigs, there is a design relationship between pipe storage and handling, as well as the rig layout required to manage both. The reduction of vertical setback capacity on Rig 262 in Sakhalin was to increase seismic stability of the rig. An independent pipe-barn module was necessary to make up stands horizontally to supply enough drillpipe and casing for ERD trajectories. During startup, the pipe-barn assembly took place away from the drilling unit so that initial drilling activities could go on without interference, as shown in **Fig. 1.** It was fully assembled and powered by electrical umbilicals to enable commissioning before its ultimate installation alongside the drilling unit.

The 30-m stands of drillpipe and casing are made up and racked horizontally in the pipe barn. The make-up operation uses two horizontal bucking machines that can handle drillpipe and casing up to 20 in. in diameter. The storage capacity of the barn is 11 000 m of $5^{7}/8$-in. drillpipe and 8000 m of $9^{5}/8$-in. casing. Because torque applied to all connections is controlled within a tight range, bucking machines are outfitted with electronic instrumentation to enable accurate and recordable makeup torques. For future ERD wells, the pipe-barn design weight can exceed 4,000 tons with extreme lengths of pipe.

To test the effectiveness of pipe-handling systems on ERD wells, timed data were gathered on the Yastreb to evaluate the efficiencies associated with horizontal-pipe-racking facilities. The objective was to identify key handling equipment in the critical path for tripping and whether each was operating to specification.

The evaluated equipment included a tubular shuttle, floor monkey, drawworks, and iron roughneck. The bucking units and pipe tables were omitted because stands are assembled beforehand and inspected before being racked. These tasks are performed in an enclosed, environmentally monitored area.

The time trials showed that pipe handling is mechanized, but not fully automated. Therefore, crew training, interaction, and experience have a direct effect on performance. Equipment must function to design specifications for accurate evaluation of times and effective action planning for improvement. Simultaneous operations are required to optimize performance. An example is the pipe-barn handling operation. The operation of gantry cranes and tubular shuttle occur while rig-floor equipment is functioning. The driller does not have to wait on the shuttle to present a stand of drillpipe to the rig floor.

Well-to-Well Mobility

The configuration of wellhead surface locations on a permanent development pad can vary. However, most are arranged linearly to optimize surface area, facilitate well-to-well moves, and permit-batch drilling operations. Because of wellhead proximity, well-to-well pad moves can be accomplished with hydraulic rig-skidding systems consisting of large-bore cyclinders and skid rails.

To allow batch drilling of a series of hole sections and further minimize space, modifications can be made to reorient the rig to a "side-saddle" configuration. Rig 236 was modified in this way to perform batch workovers on Kharyaga Pad 108 in Russia. As wellhead spacing shrank with pad size, skidding from well to well was constrained between wellheads. Cantilever designs were implemented to fit the rig between more-tightly spaced wellheads. To move into drilling position, the rig floor and mast are skidded over the well by rails and hydraulic control, at a right angle to the skid rails of the substructure, drilling modules, and pipe house.

Current moving systems allow the entire rig to move, fully loaded and operational, from well to well at a speed of 0.6 m/min. Each package is self-contained to ensure zero discharge of any liquids, and holding tanks are adequately sized to reduce the frequency of waste transportation. A lift-and-roll "walking" system adds transverse moving capabilities to all modules, not available with conventional skid-rail designs. This method allows minor adjustments when aligning the rig over existing wellheads. A second advantage is cost and timesavings for pad-to-pad moves. With a skidding system, civil site work is required at each new location, in addition to welding skid rails to pilings. With a walking system, the matting boards and base structure are set up on the new site, precluding major earthwork because loads are distributed over a large area of the matting-board layout.

High-Capacity Hydraulics Design

Drilling highly deviated wells safely, successfully, and economically depends on a thorough understanding of the drilling hydraulics. The mud properties and flow rate are optimized to provide adequate hole cleaning and fulfill hydraulic requirements of downhole equipment while remaining within safe operating limits of the equipment and pore-pressure and fracture gradient. How increased penetration rates, cuttings volume, and cuttings size affect solids handling and mud cleaning is important in rig design and equipment selection, especially for ERD wells.

Cuttings-transport modeling takes into account empirical data for deviated and horizontal wellbores and computes a critical flow rate by well section and inclination. Transport is sensitive to rate of penetration, pipe eccentricity, and rotation. The flow rate must be high enough to transport cuttings, but low enough to avoid hole erosion, equipment wear, and excessive standpipe pressure. Therefore, 51.7-MPa high-pressure fluid ends vs. conventional 34.5-MPa systems facilitate efficient hole cleaning in a highly deviated long section of the well.

Solids-control equipment on ERD rigs is designed on the basis of flow rate. For typical ERD top-hole hydraulics, maximum rates of 6.8 m^3/min are used to determine the number of shakers required and to size auxiliary equipment. With an average flow-rate capacity of 1.9 m^3/min for each shaker, four shakers typically are required to process mud volumes effectively.

Torque Requirements

While drilling extended-reach wells, topdrive units provide reaming capabilities, full rotation and circulation while tripping out, controlling stand connections, efficient drilling through bridges and tight spots, and instant stabbing and well shut-in at any derrick position when tripping. ERD-well aspects that affect torque requirements for the topdrive include high friction factors, large BHA pressure drops, and vibration and shock while drilling. Therefore, driving drillpipe with high rotary speeds to lift cuttings places demands on the topdrive and associated equipment. The result is a topdrive specification that pushes the boundaries of those currently available.

Rig Electrical-Power Design

Engineered rig-power supply, distribution, and control enables simultaneous operation of large mud pumps, topdrive, and drawworks for long drilling sections. Drilling with bicenter bits, underreamers, and hole openers to optimize casing programs also requires higher-capacity hydraulics and torque delivery from the rig. Operating high-capacity mud pumps simultaneously to achieve high flow rates while efficiently removing cuttings requires optimized rig power.

An integrated rig-control system is used for managing, controlling, and monitoring rig-floor equipment in independent and activity-based operations. The system is designed to allow drillers to focus on drilling, tripping, and stand-building processes with a rig-floor command center. Commercial control systems are interactive with the use of color-graphic data and control screens viewed on multiple touchscreens integrated into operator workstations. Touchscreens allow the driller, assistant driller, or pipehandler to supervise and control all drilling-related functions.

Information on current activities and drilling progress is sensed electronically, and data are presented to the driller on the floor, sent to rig offices, and transmitted to international offices. Drilling engineers, both on- and offsite, can view the data and analyze drilling performance in real time. Real-time decision making while drilling ERD wells is important for steering and navigation, troubleshooting, and risk reduction. In addition to receiving information on drilling performance, tools such as the topdrive and diesel engines have the ability to transmit real-time performance data to remote locations so maintenance issues can be evaluated and recommendations for correction made by technicians working remotely. **JPT**