An innovative automated method for drilling directional wells remotely was successfully deployed in southern Mexico during 2008. Remote automated directional drilling combines two enabling technologies—rotary steerable drilling and remote control of the rig’s mud pumps—to allow the directional drillers to steer the drillbit to its geological target remotely from an offsite office.

All steering commands are executed by using the mud pump controls to create coded pressure pulses in the mud column that are detected and interpreted by the Rotary Steerable System (RSS). The RSS, in turn, makes the necessary toolface adjustments to execute the command.

This technique, called downlinking, was previously performed manually at the rig by the directional driller. As with many manual functions, different rig consoles, different hands on the pump control valve and slightly different timing sometimes result in missed commands because pulse sequences could not be interpreted by the downhole tools. Part of the new remote actuation system is automated pulse generation, so all downlink commands are uniform and of maximum quality. For the two-well trial described here, implementation of remote automated directional drilling with automatic pulse-code generation resulted in a 90% downlink success rate, up from an average of around 70%, resulting in better quality holes and smoother trajectories, Fig. 1.

ENABLING TECHNOLOGIES

Since, by definition, a rotary steerable system is constantly rotating, there is no need to stop the drillstring rotation in order to shift to sliding mode while making inclination or direction changes, as is necessary when drilling with mud motors and bent subs. This means that the driller and his crew on the rig floor only need to keep turning to the right, stopping occasionally to make a connection.

On one of the first RSS-drilled wells, located in southern Mexico, the change in Rate Of Penetration (ROP) was quite dramatic—from 295 ft/day to 558 ft/day (90 m/d to 170 m/d)—just from eliminating slide drilling with motors. On the remote directional drilling field trial for Pemex, RSS technology improvements helped improve ROP and borehole trajectory quality. One such improvement was automatic hold on inclination and azimuth through the use of a closed-loop control system. This feature allowed directional drillers to program their tools to drill a pre-set well profile, intervening only if the bit began to move off track. Directional driller productivity was positively impacted.

**Downlinking improvements.** Remote directional drilling is largely made possible by recent improvements in the range and efficiency of downlink commands, due to improved transmission capabilities with much better signal-to-noise ratios. Nowadays, downlinking can be effectively carried out at a surface-to-tool distance of more than 40,000 ft (12,200 m), and steering changes can be implemented without interruption of drilling. Signal clarity is improved by automatic pulse generation techniques, which are also a key enabler of remote direction drilling.

**Control and monitoring of steering commands.** For the field trial, a new mud pump control system was introduced to automate the pulse generation process. The system eliminated human error by removing the risk that an incorrect series of pulses could be sent downhole in manual operation. It also allowed steering commands to be sent to the RSS without disturbing the driller. System redundancy allows steering commands to be sent from the rig logging unit or remotely, from the drilling center. This provides a backup system in case of an interruption in office-to-rig communication. The directional driller can contact the LWD engineer, who can issue the steering commands from the field unit.

A unique quality control system allows the directional driller to monitor the actual command sent downhole and compare it with an idealized sequence. It also indicates whether the steering command has been received and properly acted upon.

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**Directional wells drilled remotely using rotary steerable systems**

A two-well field trial for Pemex demonstrated the hybrid technology incorporating RSS and remote control of mud pumps.

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Fig. 1. The real-time downlink monitor allows the directional driller to observe downlink effectiveness and quality by comparison with an ideal signal.
Onsite override. Before Pemex’s rig crews would accept the idea of remotely controlling the mud pumps, they had to be convinced that the driller on the rig floor had ultimate control of the pumps. To answer this concern, the service company included a positive override capability for the driller. No matter what the remote directional driller is doing or trying to do from the office, the driller onsite can override it if local control of the mud pumps is required for any reason.

FIELD TRIAL

Two wells in southern Mexico were selected to test the ability to reliably and safely steer a directional well from the office. The first well was located 94 mi (150 km) from the nearest town and had its vertical section drilled and cased to 7,872 ft (2,400 m). The initial directional section would encounter extremely hard sandstone with bulk compressibility peaking to 23,700 psi, which had caused very low ROP of 4.20 ft/hr (1.27 m/hr). In addition, the section consisted of alternating hard and soft streaks, which cause destructive bit vibration and abnormal bit wear. In a nearby offset well, four bits were needed for Pemex (red indicates remotely drilled section).

Fig. 2. Trajectory of the first remotely drilled directional well for Pemex (red indicates remotely drilled section).

Fig. 3. Trajectory of the second remotely drilled directional well for Pemex (red indicates remotely drilled section).

As the wellbore quality issues did not add to the problems. The drilling team concluded that most of its focus must be on managing wellbore stability and geopressed risks, while maximizing ROP to minimize openhole exposure time.

Managed-pressure drilling was considered to maintain effective circulation density within the narrow limits of pore pressure and fracture pressure gradients. MWD parameters were as important as LWD data to ensure maximum drilling efficiency along with precise well placement. The team developed efficient workflows that coordinated the efforts of all stakeholders with those of the directional driller.

Real-time data from downhole was streamed into the remote office (a Schlumberger Operation Support Center, or OSC) manned by a multi-
disciplined team of experts from both Pemex and Schlumberger. In addition, a specialized drilling optimization crew from Houston was networked in to monitor real-time drilling data on a round-the-clock basis with the objective of helping in the early detection and rapid prevention or mitigation of incidents related to wellbore stability or risky drilling practices.

Close coordination between the directional driller and the rig driller added to the effective operational control of the well construction. While executing steering commands remotely, as in the first test, the directional driller was able to assist the rig driller with timely advice on optimum rotation speed, mud weight and weight-on-bit as indicated by real-time downhole data. The team identified the top of salt in time to adjust mud weight and drilling parameters to avoid saltwater influx and stuck pipe incidents. It also accomplished the timely identification and mitigation of wellbore stability issues and destructive vibration.

As with the first test, the second well was drilled vertically to a casing point at about 3,243 ft (989 m). From that point it was directionally drilled by remote to the next casing point, located at 9,169 ft (2,795 m), by first steering the azimuth about 17° to the left and then building borehole inclination to 33°, Fig. 3. After setting pipe, the remote control system was used to drop inclination back to vertical. The average drilling rate was 349 ft/day (106.5 m/d). Drilling was completed 39% more quickly than the previous best well in the field and 18 days faster than an offset well drilled from the same pad. While offset wells encountered considerable saltwater flow that made it very difficult and time-consuming to run casing, the test well experienced no such problems.

**OPERATIONAL BENEFITS**

It was discovered that effective decision-making was facilitated by having the directional driller physically present with the decision team in the OSC. This especially benefited drilling efficiency, by allowing great confidence in steering decisions and in decisions to optimize penetration rates.

Remote directional drilling with RSS also allowed a major improvement in utilization of experienced personnel. Pemex officials were able to reduce the numbers of specialists at the wellsites, and concentrate the company’s geoscience and well construction expertise at the real-time drilling center, eliminating significant nonproductive time associated with transport to and from the rig.

Another quality benefit was experienced when directional drillers found they could use the automatic pulse generator to execute several small, sequential steering changes instead of one big change, thus allowing them to drill smoother trajectories and thereby managing wellbore stability.

Though the onsite override allowed the driller on the rig, if necessary, to override commands from the office, minimal coordination during the field trial allowed the onsite driller and the remote directional driller to perform their functions without interfering with each other. Rig crews reported that they found the remote pump control so unobtrusive that they were hardly aware that downlinking was going on at all.

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