The Evolution and Potential of Networked Pipe

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The need for "next-generation" technology for improved data transmission up the hole in drilling operations has been acknowledged for more than 2 decades. The term "next generation" typically implied a quantum leap in transmission speed from that available, by means of current state-of-art telemetry. That need is now filled by networked drillpipe **(Figs. 1 and 2).** Development of the technology began in 1997. Initial R&D addressed two problems, the growing need for a high-rate data-communications system that would allow high-resolution downhole drilling information to facilitate informed drilling decisions in real time and the attendant need to bring data-transmission rates to up to five orders of magnitude from mud-pulse telemetry's approximate high of 10 bits per second.

Evolution of Networked Pipe

Networked pipe had its genesis in a program undertaken by Novatek in 1997 to develop a mud-actuated hammer and a unique hammer bit. The company proposed to develop a set of complementary technologies integrated into the mud hammer that would enable various functionalities of the bit, including: 1) downhole bit rotation, 2) sensing and control, 3) data transmission, and 4) directional-drilling capability.

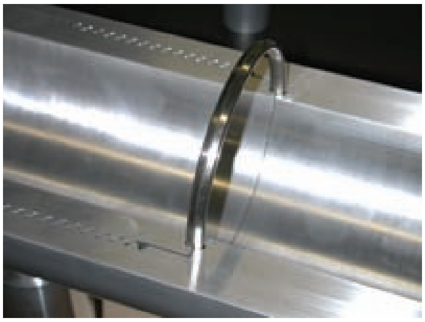

Fig. 1—The inductive coils come together when the pipe is made up, providing communication from joint to joint.

In the case of data transmission, the company concluded that a much higher data bandwidth was needed by the oil and gas industry than could be delivered by either existing mud-pulse telemetry or a new hammer acoustic-telemetry system. This was particularly true when considering the need for real-time data to support seismic while drilling (SWD), another possible offshoot of the hammer development. With this conclusion in mind, other acoustic sources with higher frequency ranges than the hammer were investigated. Substantial project focus was directed to this area of R&D, as it was deemed to be a critical enabling technology for the rest of the drilling system under development.

Initial development focused on the use of acoustic transmissions to carry high-frequency data through a single length of standard drillpipe. Data-rate limitations led to the abandonment of the concept and to the investigation of wired pipe that transmitted data across the tool joints using high-frequency acoustic transducers. However, the need for electric power and electronic support for each transducer, and the need for timing of the threaded connections when made up, led to the abandonment of that approach also. The company then directed its focus to fundamental work performed with a high-efficiency inductive-coupling system that looked promising. That technology resulted in networked drillpipe.

The National Energy Technology Laboratory's (NETL's) substantial interest in the latter, inductive-coupling approach led to the spinoff of the data-transmission project from the hammer-bit project in 2001 and a separately funded partnership between NETL and Novatek to develop the telemetry system. The partnership covered three phases of R&D, ending in 2004. That partnership, notes David Pixton, vice president, Mechanical Engineering at National Oilwell Varco (NOV) IntelliServ, was key. "In my view, NETL's involvement in the development of networked drillpipe was absolutely essential. Novatek had limited resources and NETL provided critical funding that kept the project going. When dealing with a revolutionary technology like the IntelliServ broadband network, funding is very difficult to find in the early stages of development where, at the same time, the new technology is unproven and it poses a threat to existing products that represent a substantial investment on the part of potential funding organizations."

Toward the end of NETL's involvement in the networked drillpipe development, Grant Prideco bought IntelliServ to further develop and market the technology. Grant Prideco was purchased by NOV in 2008, and in September 2009, the NOV IntelliServ joint venture was formed with a 55% NOV, 45% Schlumberger ownership.

Current Progress of Networked Pipe

Networked drillpipe has been in commercial application for 3 years. While many broad applications have yet to be thoroughly developed, the technology has demonstrated a number of potential improvements in well construction—including the ability to transmit unprecedented amounts of data in real time for better control of well steering and enhanced, real-time reservoir analysis. Additional applications will improve drilling efficiency and economics further in a number of areas.

Fig. 2—The communication cable is connected to the coil inside the tool joint and stretched along the inside diameter of the pipe without modifying its characteristics.

• Networked pipe can enable the interrogation of downhole tools and their control. This, in turn, enables understanding of tool performance and condition. Where a tool might be pulled because of suspected wear or damage, interrogation of the tool would allow assessment of the tool's condition, the amount of functionality remaining in the tool, and whether it should be pulled. It would also allow operators to alter the working parameters of the tool to extend run life.

• The network can also continuously monitor rotary-steerable rotation and pump modulation and send commands to alter rotary-steering configurations in real time, resulting in a less-tortuous hole and potentially deeper casing points.

• Distributed sensing along the entirety of the drillpipe is now possible through placement of sensors in the signal-booster packages located every 1,500 ft along the drillstring. Additional sensors can be added in closer proximity, if desired. Currently, sensors measure and transmit temperature and pressure data, allowing drillers to detect kicks, lost circulation, and cuttings blockage, as well as calculate equivalent circulating densities. Work is ongoing to add drilling-dynamics sensors to measure acceleration, tension, compression, and torque, thus allowing continuous monitoring of drillstring operational parameters. Having the real-time data will allow, for example, calculation of helical buckling conditions before the pipe reaches "lockup" conditions that would slow drilling progress.

Case Studies

On a drilling campaign for Occidental in California, the network enabled real-time downlinking, enhancing wellbore quality, saving an average of 10% in drilling time, and reducing overall costs. This was achieved by the network's ability to downlink and transmit two additional resistivity curves, an eight-sector gamma image, and all the drilling-dynamics and pressure-management information at update periods as short as every 5 seconds. (For more details, please refer to IADC/SPE paper 119570.)

On a well in the Visund field for Statoil, the bottomhole assembly (BHA) did not respond as expected while building angle to land a well horizontally in the Statfjord formation using a rotary-steerable system (RSS). The BHA was designed to build angle at a rate of 3°/98.4 ft, but less than 1° of build was observed after the first stand had been drilled. Drillers were concerned that the well would land too deep at the lower build rate, raising the possibility that the first geological target might be missed. The asset team was faced with two possible reasons for the lower rate: 1) a drilling-equipment malfunction requiring a trip out of the hole to replace failed/damaged BHA components, or 2) a formation change or other effect causing the unexpected directional tendency, in which a trip would not likely change the outcome.

Measurement tools—including additional status indicators for the measurements-while-drilling (MWD), logging-while-drilling, and RSS tools in the BHA—were used to investigate these possibilities. The indicators were available, real time, on bottom and drilling hole. Transmission of full-borehole caliper data, real time, enabled the drillers to confirm that reamer performance was acceptable, avoiding the need for an unnecessary trip to change the RSS and troubleshoot the underreamer.

Potential Applications

Development continues on networked pipe. The system now operates at 57,000 bits per second. A second, prototype version operating at 2 megabits per second, with 1 megabit per second available for transmitting data, has been developed. The higher transmission speed will enable a number of new applications, including:

• SWD. The current, 57,000-bit-per-second data-transmission speed does not allow full-wave-form transmission. The prototype, 1-megabit speed will facilitate full-wave-form transmission, enabling SWD. The use of SWD, when done in a vertical-seismic-profiling configuration (the receiver in the drillstring with the source/sources at the surface), provides a number of important advantages, including accurate geosteering, accurate pore-pressure estimates ahead of the bit, accurate seismic depths, and reservoir-modeling verification. SWD might be done at a cost no more than that of placing an additional MWD tool on the string.

• Along-string measurements. A second application arising from the improved data-transmission speed is drillstring monitoring and control. Sensors, together with network boards required to feed data into the system, may be deployed at chosen intervals along the drillstring. These sensors will monitor drillstring vibration, torque, energy loss, compression, tension, strain, and stress, allowing drillers to continually monitor drillstring operation parameters and tailor those parameters for optimum drillstring performance and run life. Additional sensors may be added to monitor temperature and pressure, allowing drillers to identify kicks and lost-circulation incidents at an early point.

• Downhole tool control. A third application enabled by higher data-transmission rates is evaluation of, and automatic adjustment and/or configuration of, downhole tools to remediate problems and optimize tool performance. These functions can be conducted automatically, in a closed-loop system, without intervention from rig personnel. A caliper with sensors, for instance, can identify an undergauge hole and immediately send a signal to reconfigure the reamer to eliminate the problem.

Given the importance of these new applications, it is clear that further development of networked pipe will inspire additional, creative applications that will lower costs and increase efficiencies. **JPT**

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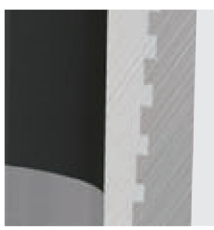

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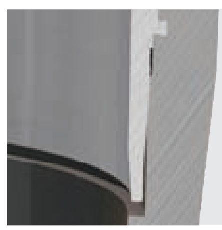

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