

Drilling Management



Last April, I had the opportunity to attend the VI Technical Meeting on Well-Engineering Risk Analysis, at Petrobras University, Rio de Janeiro, Brazil, dedicated entirely to risk management in the area of well engineering. That 3-day meeting gave participants an excellent opportunity to exchange experiences, disseminate know-how and current procedures, and discuss problems and critical developments in the area of risk management for drilling and completion operations.

I was amazed by the number of diversified works as well as the quality of the presentations, panels, and roundtables. Several topics related to drilling management were presented including risk management for well-control operations, risks involved in the implementation of new technologies, risk analysis for prediction of time and costs in deepwater drilling and completion, the effect of drilling costs on the evaluation of new exploration opportunities, and many others.

It is clear to me that drilling management is related closely to risk management. The correct assessment of all risks involved in drilling operations will provide better planning and consequently will improve operational results. Our featured papers bring some examples of better-quality results obtained through superior planning. Project managers, drilling engineers, drilling supervisors, and field engineers will all benefit from careful planning. As most of us should know by now: "If you fail to plan, then you plan to fail" (Saladis and Kerzner 2009).

References

Saladis, F.P. and Kerzner, H. 2009. *Bringing the PMBOK Guide to Life—A companion for the Practicing Project Manager*, 49. Hoboken, NJ: John Wiley and Sons. **JPT**

**Drilling Management additional reading available
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SPE 119287 • "Probabilistic Well-Time Estimation Revisited" by A.J. Adams, SPE, Nexen Petroleum, et al.

SPE 114797 • "Advanced Drilling Simulation Proves Managed-Pressure Drilling (MPD) Economical in Gasfield Developments in Western Canada" by Geir Hareland, SPE, University of Calgary, et al.

SPE 120848 • "Systems Approach and Quantitative Decision Tools for Technology Selection in Environmentally Friendly Drilling" by O.-Y. Yu, SPE, Texas A&M University, et al.

IPTC 12707 • "Automatic Calibration of Real-Time Computer Models in Intelligent Drilling-Control Systems—Results From a North Sea Field Trial" by H.P. Lohne, SPE, International Research Institute of Stavanger, et al.

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Real-Time Drilling-Process Optimization

A new drilling-control system for real-time optimization and automation has been developed in an ongoing research project, which now will enter an industrialization phase. The system, which is based on application of advanced real-time process models for calculation of both hydraulic and mechanical forces, requires an extensive set of input data. Results from the calculation modules are applied directly in the drilling-control system, affecting parameters such as pipe acceleration, velocity and deceleration, and the pump-startup profile.

Introduction

During the last decade, computer-controlled machinery have made it possible to control the drawworks, the topdrive, mud pumps, and the iron roughneck or pipe-handling equipment from a drilling workstation by use of joysticks and keypads. Recent developments enable control of the machinery within safeguard boundaries through application of model simulations, accounting for the effects of fluid and pipe movements in the wellbore. These new extended systems have the potential to reduce the risk of damaging the well and the downhole equipment and, subsequently, to reduce nonproductive time. For such extended systems to function properly, a more precise description of the drilling components is required to calculate pressure losses, mechanical

loads, and heat transfer. Furthermore, complete descriptions of the wellbore architecture, formation prognosis, trajectory, and drilling-fluid properties are needed for configuration of the applied models. Most of this information is not available in standard rig systems, and no standard work process has been established to make this information available before actual operations. For such systems to achieve their full potential, the necessary information must be quality controlled and made available at the right time, because an error in this information could lead to potentially serious incidents.

In January 2008, a field test of a new system for automated control of the drilling process was performed on the Statfjord C platform in the North Sea. Because the system was developed through a research project, the focus up to now has been on robustness. The system now is entering the industrialization phase, with a stronger focus on system application, including the following.

- Sensor quality and reliability.
- Availability of wellbore description including information exchange between different systems.
- Work processes for updating wellbore description and quality control of data.
- User friendliness.
- Personnel training.

These points are regarded as key ingredients to a successful industrialization process.

Management of the drilling process consists of multiple decision cycles of various durations. The shortest cycle constitutes the actions of the driller and his crew, where decisive actions often are made in a matter of seconds. The medium-term decision cycle involves the actions of the drilling supervisor, with the help of the tool pusher, the measurement-while-drilling engineer,

the directional driller, and the operation geologist. The response time for this cycle is between a few minutes and a couple of hours. The outermost decision cycle, where difficult and costly decisions should be made after the occurrence of a critical situation, is controlled by the drilling superintendent, with a decision time in the range of hours. Remedial actions are performed on the basis of advice from drilling engineers or on-call experts. The full-length paper considers a category of model-based systems that apply to the shortest decision cycle in the drilling process. Drilling-automation systems are characterized by a very short reaction time (seconds), with one person being the primary user. Even though one person plays a central role (the driller), many individuals are involved in actual drilling operations.

Drilling-Automation-System Case

The key principle of the new system for drilling presented in the full-length paper is based on experience from the development and testing of the system used on the Statfjord C platform. The key principle of the system is enablement of closed-loop control of the drilling process through integration of dynamic-process models in the drilling-control system. Real-time drilling data are applied for model updating and for continuous automatic diagnostics of the process. The types of model integrated closed-loop control applied are control-parameter optimization and safeguarding of well and hardware. Additionally, simpler robotic functionality is used in the form of automatically run preset test procedures to aid in process diagnostics.

System Integration. The reference system for automatic control is integrated in an existing drilling-control system,

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where setpoints are generated by calculation modules on a separate server and are communicated to the control-system database. The calculation modules consist of dynamic-process models coupled with algorithms for generating setpoints or curves to be applied in the control algorithms, which are integrated in the computerized machine control. Calculation results in the form of limits and trends are displayed to the driller on the control-system graphical user interface (GUI). Several GUIs are used for system configuration.

Integrated Models. The models applied in the reference system are a multiphase transient hydraulics model, a dynamic temperature model, and a soft-string torque-and-drag model (currently being upgraded to stiff string). The models are updated continuously using real-time process data, enabling process prediction, which is used in diagnostics, optimization, and process safeguarding through application of process constraints, including well and material limits.

System Functionality. Three automation functionalities were tested during the system field test. The first module was a pump-startup optimization module, where semiautomatic pump-rate buildup was constrained automatically within the limits with respect to downhole fracture pressure, allowing the driller to activate steps when permissible by the system. The second functionality was automatic velocity and acceleration constraints for tripping and reaming procedures to avoid exceeding downhole-pressure boundaries and to avoid excessive force when reaming. The last functionality was automated preprogrammed friction tests performed to achieve increased accuracy in diagnostics of downhole conditions.

Work Processes and Organization

The introduction of new drilling-automation systems not only put additional constraints on sensors and data-management capabilities, but also on work processes and the organization of people involved with these new support functions. Many of those new technologies have not yet been tested extensively in real operations, and therefore it will take some time to learn how these systems affect the work processes and organization.

Real-Time Sensors. New drilling-automation systems typically are tightly integrated in the drilling-control system. This enables direct access to the sensors connected to the drilling machinery. It is important that critical sensors are of acceptable quality and reliability. In some cases, it may be necessary to implement redundancies of some measurements to be certain of detecting erroneous measurements if their criticality is vital for the safety of the drilling operation. Work processes should regardless be defined to check the quality and reliability of critical sensors before installation of new drilling-automation systems. If there are any changes to the drilling-control system or the drilling machinery, a new system evaluation is required. One example would be if a very accurate, but radioactive, mud-density meter was replaced by a much less accurate Coriolis mass-flow density meter because of health, safety, and environmental reasons. Such a modification might make it impossible to use automated drilling operations relying on real-time measurement of the mud density if the accuracy of the new sensor is low compared to a small pressure window in a depleted reservoir.

Training

Drilling-automation systems have the most influence on the work procedures of the driller. Because manual control may be restricted by application of such technology, the driller needs to have faith in the new technology. It is recommended that, before using a new drilling-automation system, the driller attend courses where all necessary information for detailed understanding of the functioning of the system is presented to build confidence in the new technology.

In normal operations, the driller is in full control of the drilling machinery and therefore his actions do not depend on the work performed by someone else. However, with the new drilling-automation systems, the role of the driller is changed because he will depend on external information managed by other people. Teamwork is raised to new levels, and trust must be established for the whole team to operate the new automation systems. Consequently, it is recommended to increase awareness by training all the team members for their new roles and responsibilities.

The introduction of a new drilling-automation system will result in different drilling practices. Some of the procedures used for managing critical situations may differ from normal practices. The driller's procedures may be altered because of the use of the drilling-automation system. To meet these challenges, the driller should be given training in a drilling-simulator environment to tackle unexpected situations where the drilling-automation system is not capable of controlling the well integrity by itself.

Data Flow

Because of the ever-increasing demand on effective drilling under increasingly difficult conditions, new drilling automated systems are being constructed to assist drilling operations. These new technologies rely on adequate data-flow management, including both real-time data-acquisition systems and accurate descriptions of the wellbore and its constituents. These new drilling systems are changing roles and responsibilities of the drilling staff, and therefore possible errors in the data flow can jeopardize the safety of drilling operations.

Introducing new drilling technologies can be successful only if the working conditions have been prepared beforehand. First of all, the quality and reliability of sensors (both at surface and downhole) need to be assessed with regard to the potential consequences of erroneous measurements to automatic-control or decision-support systems. Second, well-information standards need to be adapted to the additional requirements of those new technologies in terms of parameters necessary for performing real-time hydraulic, thermal, and mechanical calculations. Manually maintained information (wellbore description) needs to be updated and controlled in a timely fashion. This requires changes in standard work procedures. New routines need to be established to ensure that necessary information is entered and that quality is controlled. Existing routines may also need to be modified to comply with additional requirements introduced by the use of these new drilling technologies. Finally, responsibilities of the different participants in the drilling process need to be reassessed in view of the criticality of the new data management necessary for implementing those new drilling technologies. **JPT**

HSE Management in a Drilling Environment

Since the beginning of the Pearl gas-to-liquid (GTL) drilling activities in Qatar's North field in 2004, five drilling rigs have been used and, to date, it has been a 4-year, 3-million-man-hours lost-time-incident (LTI)-free operation. Recognizing the industry challenges of introducing large numbers of inexperienced staff on the drilling rigs, introduction of a program of proactive health, safety, and environment (HSE) management by engaging all levels of the organizations of the operator and contractors has resulted in a top-quartile HSE and operational performance.

Introduction

After drilling and testing an appraisal well in 2004 and a data-acquisition well in 2006, the Pearl GTL development campaign began in earnest with two rigs (one a new build) drilling over two offshore jackets. During 2008, a land rig was taken on contract to drill two water-injection wells to dispose of condensed water from offshore. Also in 2008, an ambitious project matured to perform simultaneous operations in a hydrogen sulfide environment, consisting of drilling and completing wells while simultaneously perforating, acid stimulating, and cleaning up pre-completed wells from temporary decks on the platform jacket.

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Creating an HSE-Enabling Environment

Creating an HSE-enabling environment that is conducive to open, honest, and no-blame relationships generating hazard-reducing ideas is a result of a mix of many elements that require continuous focus and buy-in.

The creation begins at the contract-tender stage where the minimum HSE requirements are set out as an initial qualifying hurdle and where the HSE performance of each contractor is reviewed during the evaluation process. Then, in the period between the award of the contracts and the start of operations, project-kickoff meetings with participation of the operator, drilling contractors, third-party contractors, subcontractors, and office and on-site staff are used as a vehicle to develop the "One Team" approach to HSE. Openness, honesty, mutual trust, and full commitment are the key requirements for all parties involved to accept HSE as a core value and have fully aligned HSE aspirations.

At the commencement of the operational phase, all the enabling elements of the preparation phases, including detailed hazard analysis and the generation of HSE cases, are approached with great enthusiasm. This enthusiastic approach is key and produces clear and effective outcomes.

Challenges. Even with having HSE-enabling-environment elements in place, it was recognized that with our industry stretched to capacity, where rigs are in short supply, and people are even more scarce, working increasingly with people with limited skills in English (our working language) and a lower level of experience than was common in the past, there would be a large challenge to work safely. Compounding this was the fact that

more people were from different cultures with different languages, having different perceptions of the world influenced by their culture, age, sex, values, and background.

The approach taken to creating a One Team with HSE as a core value from this group of people with different views, values, and opinions was one of focusing on implementing a few tools and techniques well, rather than getting lost in the numerous HSE policies and procedures present in our industry.

One Team HSE Inductions

Since the Pearl GTL project inception, the philosophy has been that for each distinct location, (i.e., rigs, yard, and platform) the client and contractors are One Team. Within that team, HSE is a key performance driver. The goal is to ensure that everyone knows how important this is to the project, to themselves, and how they can contribute to a safe work place. The general way the message is delivered is through an HSE induction.

The objective was to create an HSE induction that would leave some key messages deeply embedded in the minds of the participants. The decision was made to use as many media as possible. The HSE induction was designed to do the following.

- Bring the team together—everyone participates, from the upstream and drilling manager to the cabin boys.
- Set the scene for the project, and explain the scope and importance of the project.
- Get across the message that HSE is a core value
- Introduce the concepts of STOP and task/risk identification card (TRIC) for those unfamiliar with the concepts, and have people use these tools in a nonthreatening environment.

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- Demonstrate the commitment of the operator to safety.

A number of group activities were used to convey these HSE messages.

Beat the Drum. When a rig crew walks into a room for yet another client HSE induction, they tend to shuffle, they group together into cliques dependent upon country or origin, status, and discipline. However, the first whole team-building activity was to take the team into an auditorium set up with chairs set in a semicircle, each chair equipped with a bongo drum. There were some bemused faces as each person sat down, not really sure of what they were going to have to do. Some people played with the drums for a while but most were quiet. The facilitator began by getting everyone to follow a basic rhythm, then got different groups to do different rhythms that complemented the other. STOP then was introduced.

STOP is a system used on many rigs. When a safe or unsafe act or situation occurs, anyone can intervene and stop the work, point out the mistake and correct it. The record of this conversation is written on a STOP card.

STOP was used to get people to stop playing. The rhythms would begin then stop, then begin and then stop. The music got more and more complicated as different rhythms cut in and out. Participants were invited to be the person saying STOP to the whole group. They were reluctant at first but soon different people got up and joined in the fun. The message of STOP was left with the group, as was the empowerment of every person to be able to do it. The activity also was a great way for everyone to participate fully, regardless of his or her place in the team.

TRIC Background. Generic job-safety analyses (JSAs) are present on most rigs and for most operations. It was felt that in some cases these were too generic and often failed to capture the

specific hazards on a particular day. For example, changing pump liners in July with a 50°C temperature outside carries a much higher risk of heat stress than if the same changes were made in December. This is one example, but there are other factors that will change each time the job is performed—(e.g., the experience of the crew, the time during the shift that the job is performed, and the ease of access).

To address these deficiencies in the generic JSA, the decision was made to introduce the TRIC system. The TRIC is filled in at the worksite and is an integral part of the Toolbox Talk. It has various prompts that help the team leader to engage his work group and highlight specific hazards when doing a particular job on that particular day, on a particular rig, with the workers available, in the specific weather conditions, and using the actual tools available. It is very much a proactive safety measure. The team discusses what could go wrong, how that could be prevented, and the mitigations should the hazard be realized. The team agrees on specific actions with specific action parties and records these.

The TRIC also has an additional advantage over a generic JSA in that the people doing the work write it. The ownership rests with those individuals.

Operational Phase

The response from the participants of the One Team HSE inductions was very positive because for many, the pieces of the puzzle finally came together. The HSE inductions were timed so they coincided with the start of the operational phase. To succeed in the goal to operate an incident-free workplace, the momentum and enthusiasm that were displayed in the HSE inductions had to be maintained.

STOP-Card Reviews. During the daily morning operations call with all work locations, key STOP observa-

tions are reviewed, cross applications discussed, and learnings efficiently transferred. As a result of the attention given and the follow-up and feedback provided, crews received a continuous confirmation of the One Team approach to HSE.

HSE Technicians. While most rigs now have safety-training supervisors supplied by the drilling contractor, Qatar Shell also provides a dedicated HSE technician to the rig. The HSE technicians play a significant role in maintaining a good HSE culture on the rig. The TRIC system was new to many people, and their first encounter with it was during the induction. Therefore, the HSE technicians provide further on-the-job coaching and training in this vital system, especially in the early stages of the project. In addition, they fulfill a role as an auditor, providing feedback and assistance regarding all safety systems on the rig. Their added value has been proved, and they are now an integral part of the offshore team.

Lessons Learned, Near Misses.

Despite best intentions, luck, on occasion, has played its part in keeping the workplace LTI free. There have been near misses that, had conditions been different, could have resulted in injury. However, reporting of all near misses has been encouraged with the objective of extracting maximum learning from them. For high-potential incidents (currently two during the operating phase), the near miss was investigated as if the incident had reached its full potential. The lessons learned then were shared among other Shell companies and their contractors in the region. In this respect, Qatar Shell not only learns from its own near misses but also from those of other companies in the region. The willingness to learn from these incidents helps significantly in preventing similar incidents. **JPT**

Multiparameter Autodrilling Capabilities Provide Drilling/Economic Benefits

Recent field data have shown significant economic benefits are achievable when using electronic autodrilling technology. An electronic autodrilling system was developed to provide steady-state weight at the drill bit and/or differential pressure across the motors to produce a higher-quality wellbore and faster rate of penetration (ROP). Recent field applications demonstrated conclusively that the electronic autodriller improved control of drilling parameters such as weight on bit (WOB) and ROP.

Introduction

Automatic drillers, or autodrillers, have been used since the early 1970s, although it was not until relatively recently that they could outperform an experienced driller on conventional rigs. The development of the modern autodriller has been supported by the development of more-sophisticated mechanical-braking and electronic-control systems, resulting in systems with substantial capability. Recently, improvements in signal processing and electronic control have allowed modern digital control to be implemented, with early-generation braking systems making a sophisticated level of control available for conventional drilling rigs.

Computerized autodrillers can monitor as many as four drilling parameters simultaneously and continuously, adjusting line payout to optimize over-

all drilling performance. However, it is important to choose hardware and software that are both appropriate and compatible, to provide smooth and accurate brake control. Such a system has been developed and deployed with considerable success on land rigs drilling throughout the US. The full-length paper outlines the historical development of automated-drilling technology, its operational capabilities, and its economic benefits demonstrated in the field.

History

The development of automatic drilling controls began well over a century ago, with the earliest method invented in the early 1860s. They typically were referred to as drilling feed controls, describing the mechanism whereby a device would drill or feed the bit into the formation rock to create a wellbore. Early automatic drillers supplied inconsistent feed and nonuniform progress toward the target well depth. After the turn of the 20th century, better braking mechanisms allowed smoother feed and greater control over the bit feed. Through the 1920s and 1930s, many different automatic drilling methods were used, consisting mainly of purely mechanical devices, from various hydraulic-feed rotary-table designs to torque-based automatic-feed-control machines. By the 1940s, brake performance improved further, leading to the use of band-brake controls for drilling-feed machines. The majority of these feed-control devices were actuated pneumatically, their drilling feed maintained according to the rig's standard weight indicator.

In the 1950s, these pneumatic autodrilling systems were controlled to maintain constant string weight. Although better than those developed previously, these autodrillers still experienced wide bit-weight fluctuations. Consequently, drillers still preferred to control the brake



Fig. 1—Controls for electronic autodriller with proportional disk brakes.

handle themselves, often outperforming these pneumatically controlled machines. Maintaining consistent WOB control over extended time periods required a driller to observe visually a weight indicator and other drilling parameters to manually control the brake continuously and consistently. In the 1980s, disk brakes with hydraulic-actuation systems also were being developed, along with new autodriller electronics, to meet performance drilling needs better.

At this point in automated-drilling development, WOB provided the primary control. Using the deadline-anchor hydraulic-weight-sensor signal to control the proportional controller of the electric brake, WOB was maintained much like the driller had done manually. Subsequent field studies confirmed that rigs equipped with an increased sensitivity, or a high-gain system, exhibited better performance than rigs operated manually. While the early algorithms adjusted well for small changes in formation types and drilling

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conditions, they fell short in situations where larger changes occurred, requiring experience to fill in the gaps with respect to parameter adjustments.

Brake performance continued to improve over time, with disk or plate manufacturers developing new proportional brake technology. Some of the rigs with band brakes were retrofitted with hydraulic caliper disk brakes, although the auxiliary electric brakes still were retained for absorbing energy during lowering operations. New proportional disk brakes gave rise to the first generation of electronic autodrillers (**Fig. 1**). These still involved some complicated tuning procedures that kept the driller busy adjusting control parameters such as brake-handle lift and lowering speeds, deadbands, and other formation-dependent variables.

A new generation of plate-type air-operated brakes with superior friction coefficients spurred the next generation of autodrillers. This pneumatic-brake design required an electrically operated, proportional air-control valve that resulted in a slow system response. In 2002, dynamic system-modeling and -analysis tools were used to develop and test a mathematical model of the complete drilling-rig system, including engines, motors, brakes, and drillstring. With these modeling tools, new drilling-control-system software was developed, which included in its design both WOB and ROP as a steady-state relationship between the drill bit and the rock formation. Rigs that were upgraded with these pneumatic proportional brakes and the new software system exhibited substantially improved performance compared to previously drilled wells. The better air-operated plate-type brakes and higher-resolution sensors enabled autodriller controls to evolve further into sophisticated digital-electronic designs.

Present Situation

The definition of “optimal performance” can vary depending on the objective (e.g., faster ROP, longer bit life, better hole cleaning, or lower tubular loading). Regardless of the objective, the function of a good autodriller is to maintain a consistent set of steady-state conditions at the bit.

The autodriller should use whatever sensors are available to maintain this optimal condition for the bit. Historically, WOB has been the acknowledged best indicator. Thus, the early thinking that

still predominates today is that autodrillers seek to maintain a constant WOB. Greater development of the speed-sensing, pneumatic autodrillers allowed drillers to limit air pressure to the lift motor and hence to implement a crude restraint on ROP. However, this was insufficient when highly deviated drilling was developed. Differential pressure across a downhole motor actually was a better indication of bit/formation interface downhole than was the perceived WOB. This resulted in the development of both pneumatic and electronic autodrillers with multiparameter (WOB, ROP, and differential pressure) control modes, either individually or in combination. Finally, experience gained with these autodrillers contributed to the realization that controlling line payout in response to drillpipe torque could reduce chances of the bit stalling and having to be reset on the bottom, thus increasing overall penetration rates. So, the present state of the art is for four-parameter control to be used at the discretion of the driller.

Multiparameter Control

Any combination of the four control modes can be used. Which control mode is the “primary” and which is the “secondary” is a function of how the driller seeks to use the tool. It would not be uncommon for a WOB target to be set with the ROP at a sufficiently low value to ensure proper hole cleaning. Without a downhole mud motor and at shallow depths, the differential-pressure or torque modes may not be enabled. Thus, the well would be drilled primarily “on WOB,” with ROP limiting drilling breaks in soft formations.

When using a downhole mud motor, the differential-pressure-control mode could be used with a backup setting of WOB to avoid those points where the bottomhole assembly might hang up, increasing the perceived WOB, but not having the mud motor engaged in the formation as it should be. Here, the well would be drilling “on differential pressure” as its primary mode. On the other hand, for some extended-reach wells, hole cleaning becomes the principal concern. Therefore, ROP limits could cause the system to drill primarily “on ROP,” with WOB and differential-pressure set points established to prevent stacking WOB. This multitude of control parameters and their combinations are available to the driller to best suit the particular requirements of the drilling situation.

Field Results

In a north Texas field, the advanced autodriller was used to drill new wells in the Barnett shale. During a 7-month period in 2008, seven offset wells were drilled by the same drilling rig. For the analysis, the drilling performance of all wells was normalized using the depths ranging from 1,500 ft to 8,700 ft. This stipulation removed any inconsistencies with respect to surface hole drilling, comparing only the performance for the specified depth range. The first three wells were drilled with a conventional WOB-controlled autodriller. Four wells then were drilled with the electronic multiparameter autodriller. Their respective performance curves were generated using time-based data obtained from the electronic drilling recorder (EDR). The EDR data were sorted to extract only the time for drilling new hole, removing all connection times and other flat-line activities such as surveys. A set of data for drilling only was created using the following criteria: bit on bottom, 10 rev/min, and standpipe pressure greater than 500 psi. This approach normalized the resulting time and depth data for all wells so that the bit was on the bottom of the hole with rotation (torque) and pump pressure (hole cleaning).

The case study shows increased penetration rates for the wells using the electronic autodriller. The overall ROP for the first three wells drilled with a conventional autodriller was 36 ft/hr, which increased by approximately 11 ft/hr to almost 47 ft/hr for the next four wells drilled with the multiparameter autodriller, resulting in a more-than-30% ROP improvement.

Overall bit usage also improved, with fewer bits used and more per-bit distance drilled. The conventional autodriller used an average of 7.3 bits per well, with each bit drilling on average of 1,605 ft of rock. The new electronic autodriller used an average of 6.5 bits per well, and each bit drilled a 1,648-ft average of rock. Thus, overall, there was a more-than-7% reduction in bits used and an improvement of almost 3% in average distance drilled for each bit.

The rig averaged 26 days at the well-site for the first three wells drilled with the conventional autodriller. For the multiparameter autodriller, the rig was on location for an average of 19.25 days, resulting in a 26% reduction in days on location. **JPT**