Testing Oilfield Technologies for Wellsite Operations

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At full-scale test facilities, new drilling, logging and completion technologies can be tested under actual wellsite conditions in a controlled and confidential environment, before they are utilized in the field. The industry is now taking the ultimate step in quality assurance by providing full-scale system integration tests and testing while drilling. The knowledge gained by this rigorous assessment helps create tools that perform as designed, even under the most demanding conditions.

Demand for resources is driving our industry to seek oil and gas in increasingly difficult locations. Operators want new capabilities in downhole tools, but do not want to risk failure of a new tool in a high-cost wellbore. Predeployment testing has become a critical step in the introduction of new tools.

Identification of problems with a new technology is best when done early in the development process, because solutions tend to be more expensive when implemented later. Early testing is therefore crucial and forms an integral part of product development, from conception to design to deployment in the field. Tests should examine general usability, applicability, measurement accuracy and repeatability, product safety, manufacturability, and delivery configuration and logistics.

Service companies are interested in testing a tool under conditions that are as close as possible to those likely to be experienced in the field, but without the logistical and external operational constraints of the field. In a controlled environment, a test can be focused, concise and complete. As a result, unanticipated usage scenarios and measurement issues, as well as hardware reliability, can be thoroughly investigated and worked through on site during the testing phase. Having the ability to address problems when they are first encountered greatly improves the development process.

Oil and gas companies, on the other hand, want to minimize the financial risk resulting from a tool malfunction or failure. In a test facility, they can explore tool functionality or system interface issues in a controlled and well-characterized environment without the constraints of rig-time costs or safety problems. Some of the latest advances in drilling technology, including drilling with casing in high-angle wells, can be evaluated in settings that mimic the actual well conditions.

Equally important for both the operator and the service provider is the need to compare tests on new tools with previously proven technologies performed under similar conditions. The interpretation results of the comparison are more accurate and reliable when test conditions can be controlled and monitored under identical operating conditions, rather than trying to extrapolate between different fields or well conditions.

Various kinds and levels of testing are performed at a number of centers around the world.[1] This article discusses qualification testing, which ranges from components to system integration, and collaborative experiments between oil and gas companies and service providers. Of particular interest are the final tests and performance measurements made just prior to field deployment or before a customized complex product configuration is deployed in a commercial well. The Schlumberger Cameron Texas Facility (CTF) is designed to accommodate such advanced tests.

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[1] Schlumberger test centers include, among others, the Abingdon Technology Center, England; Beijing Geoscience Center, China; Cameron Texas Facility, Texas; Gatwick Technology Center, England; Integrated Productivity & Conveyance Center, Singapore; Oslo Technology Center, Norway; Princeton Technology Center, New Jersey; Schlumberger Conveyance and Delivery Center, Sugar Land, Texas; Schlumberger European Learning Center, Melun, France; Schlumberger Kabushiki Kaisha, Fuchinobe, Sagamihara, Kanagawa, Japan; Schlumberger Reservoir Completions Technology Center, Rosharon, Texas; Schlumberger Reservoir Fluids Center, Edmonton, Canada; Schlumberger Riboud Product Center, Clamart, France; Schlumberger Stonehouse Technology Center, Gloucestershire, England; and Sugar Land Technology Center, Texas. For additional information on other test facilities: Lang K: "Oilfield Testing Centers: Nurseries for New Ideas," *Petroleum Technology Transfer Council Newsletter* 9, no. 4 (2003): 6–9.

From Components to System Integration Testing

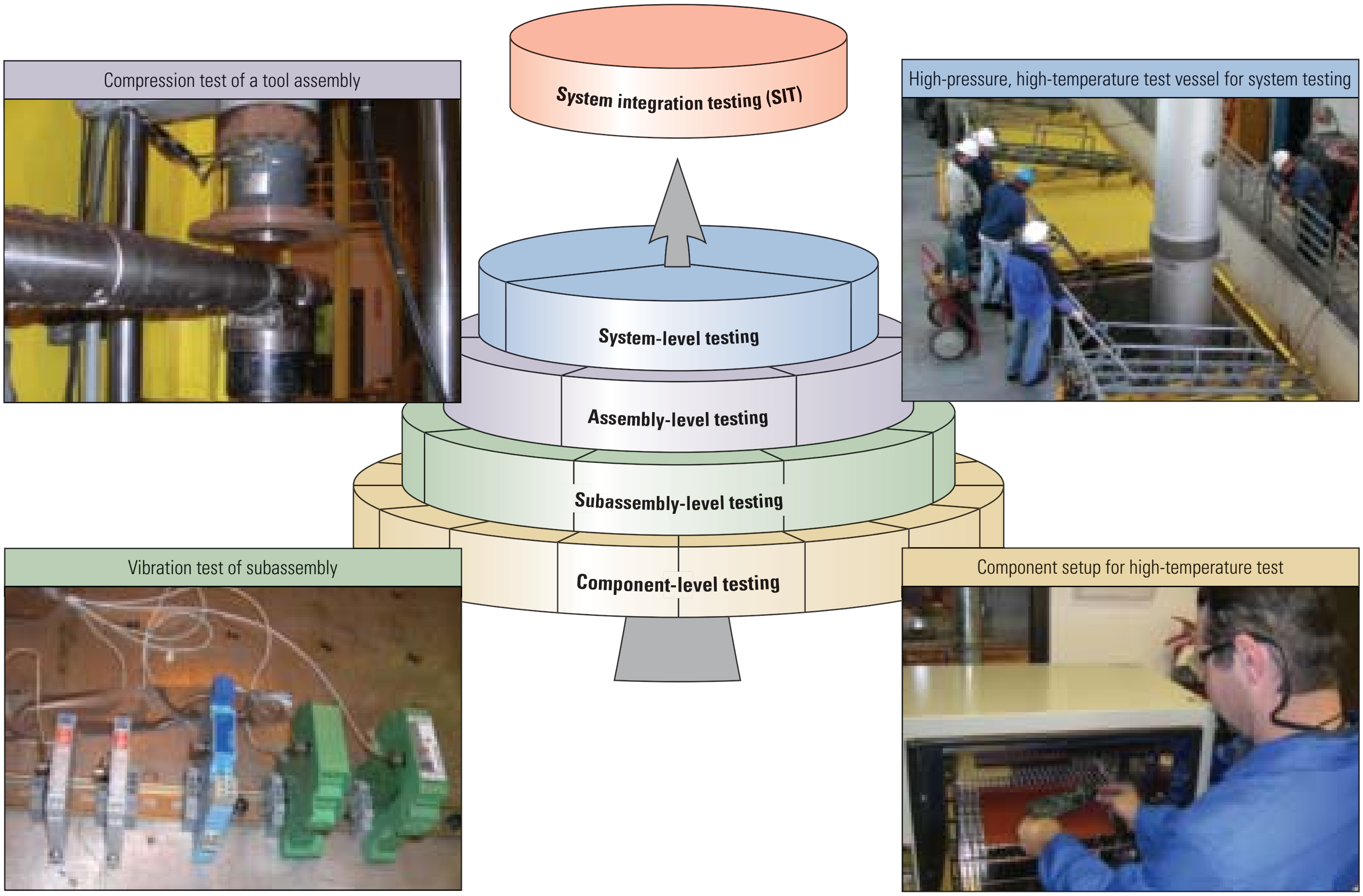
Reliability is a key factor in the success and profitability of any wellsite product. Although any new equipment or tool may be a wonderful innovation, it is destined to fail if it cannot withstand the harsh environment of downhole operations or drilling. Good engineering coupled with rigorous performance and environmental testing is an effective means to success.[2]

For example, each component of a logging tool is tested for a wide variety of factors such as the operating environment, deployment methods and measurement dynamic range. Environmental conditions in the oil field, both uphole and downhole, are quantified for extremes of temperature, pressure, shock, vibration and difficult logging conditions. Deployment and contingency methods tested include wireline, slickline and coiled tubing. Real-time interaction and control through each deployment method are also tested. The absolute and relative accuracy of the measurement dynamic range and its repeatability are tested in different mud types and lithologies.

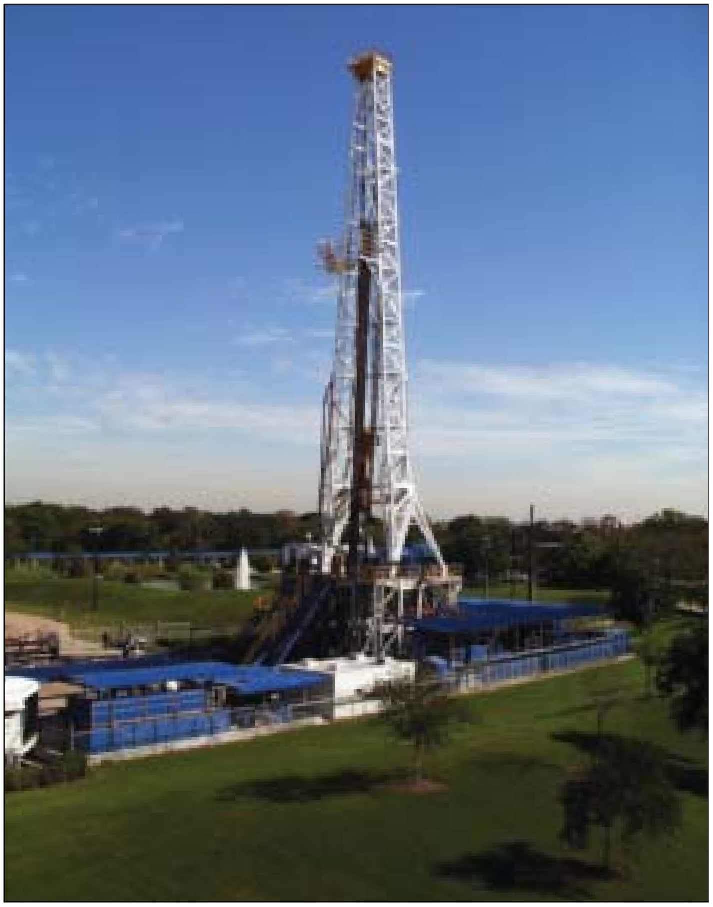
Within Schlumberger, the rigorous product development process begins when the feasibility of a project is first examined. Based on the tool's planned operational environment, a requirement and specification document details the expected use and life of the product and the conditions it will be subjected to over its lifetime. This document provides the basis for a plan that specifies the tests to be performed at the component, subassembly, assembly and system levels to verify that the product's design meets quality and reliability requirements. The final level of tests is system integration testing (SIT), when multiple tools and pieces of equipment from Schlumberger and third-party suppliers are tested in actual wellsite operating conditions.

Also during the project feasibility phase, the physics of the measurements are verified in the laboratory, in external test facilities or downhole. Once the project is shown to be technically feasible and to have sufficient business justification to warrant further investment, the product moves on to the development phase, in which tests are performed every step of the way (below).

During the development phase, component-level testing starts at the earliest possible stage. At this point, test costs are the lowest, yet design improvements at this stage yield the most effective results. During component testing, test machines and laboratory conditions produce stresses on individual components similar to, or in excess of, what can occur in an actual well.



^ Stages of testing—from components to system integration—during the development phase of tools or equipment.



^ Genesis Drilling Test Facility. Genesis is a 142-ft [43.3-m] cantilever-type, skiddable land-drilling rig with 1,250,000-lbf [5,560-kN] derrick capacity. In service at the Sugar Land Technology Center since 1988, Genesis is used to reproduce downhole field conditions for various types of tests. Mud flow, pressure, shock, vibration and rotation of downhole tools can be performed under controlled conditions, either by drilling through cement or by using a shock-inducing device, also known as cam sub.

The test conditions typically range from low temperature during transportation and storage to very high temperature at the bottom of a well and also include shock, vibration, low and high pressure, bending, corrosion and erosion.

Subassembly testing begins when the individual components are qualified and multiple components are assembled and combined. Verifications of performance and reliability are performed. This is accomplished in a manner similar to component-level testing but requires larger test machines. Each engineering center has customized test machines corresponding to the type of subassemblies developed at that center.

The next stage is subsystem or assembly-level testing, when a downhole tool is built to a point where it can stand alone and provide one or more functions at a wellsite. Subsystem testing may be challenging because of equipment size and usually requires special facilities. Surface tests include mud flow through and around the tool, pressure, shock, vibration and rotation of complete downhole tool sections.

In system-level testing or precommercial evaluation, measurements are verified for accuracy and repeatability, especially with respect to variations that occur during the manufacturing process. Many of these test parameters can be examined under controlled conditions, for example, by drilling through hardened well cement (left). Several questions are addressed at this stage of testing. Does the production tool perform according to the specifications of the engineering prototype? Do all the tools perform in a consistent manner? Are there unanticipated tool-to-tool production variations? What is the sensitivity of a specific tool parameter to the overall measurement performance?

Finally, in the SIT phase, multiple tool combinations are tested. For instance, the SIT may involve long well-completion assemblies; these strings may come from different centers and suppliers. Verification of system interoperability and performance is crucial and is virtually impossible to determine without assembling and testing the entire system at a test facility that provides a complete dress rehearsal. In the past, rig qualification was performed on an operator's rig. Today, test facilities equipped with drilling rigs are available to perform the same function without the constraints of costly rig time and safety issues.

About Test Facilities

Schlumberger offers several facilities for system integration testing, each with different capabilities. Beginning with the first test well in 1956, the four test wells at the Schlumberger Reservoir Completions (SRC) Technology Center in Rosharon, Texas, have been used for development and testing of perforating guns, wireline logging tools, tubing-conveyed perforating equipment and, more recently, drillstem test and coiled tubing equipment. The facility also has a small artificial lake that has been used by WesternGeco to conduct tests with marine seismic sources.

The Schlumberger European Learning Center (SELC) in Melun, France, provides cased hole, openhole, downhole and surface well testing primarily for wireline and some well services. Wells at the Sugar Land Technology Center are used for customer acceptance testing of wireline and certain logging- and measurements-while-drilling (LWD and MWD, respectively) tools. The Genesis Drilling Test Facility is a full-size drilling rig that can duplicate many conditions that occur at the wellsite in cased vertical boreholes. The rig not only is an excellent facility for performing drilling tests, but also serves as a training facility.

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2. At Schlumberger, quality and safety assurance are based on industry standards such as the International Organization for Standardization (ISO) 9001certification for engineering and manufacturing, Det Norske Veritas (DNV) certification, International Air Transport Association (IATA) qualification for transportation of explosives and batteries, third-party safety audits, American Petroleum Institute (API) recommended practices for industry standards in hardware tests, NACE International and American Society of Mechanical Engineers standards for completion equipment, and rigorous quality control both on site and off site.

The Schlumberger Cameron Texas Facility (CTF) has a full-capability drilling rig for performing drilling, borehole measurement and system integration tests. The CTF, which encompasses several hundred acres, became operational in 2004 (below left). The CTF drilling rig provides boreholes with more than 6,000 ft [1,829 m] of horizontal reach. The formations penetrated by CTF wells have a wide diversity of porosities, permeabilities and mineralogies. Drilling, LWD, MWD and wireline tools may be run in carbonate and sandstone lithologies. Because the site covers such a large area, many different borehole trajectories can be drilled to penetrate the various formations.

As a Schlumberger facility, CTF serves as a confidential test bed for the latest downhole and uphole technologies. The high-bandwidth connection within the Schlumberger firewall allows for easy, secure movement of confidential data and enables the involvement of remote witnesses in extensive tests while drilling. The facility also provides hands-on experience for Schlumberger employees and clients, including testing of rig-up and transport logistics, and training of rig crews for complex deployment.

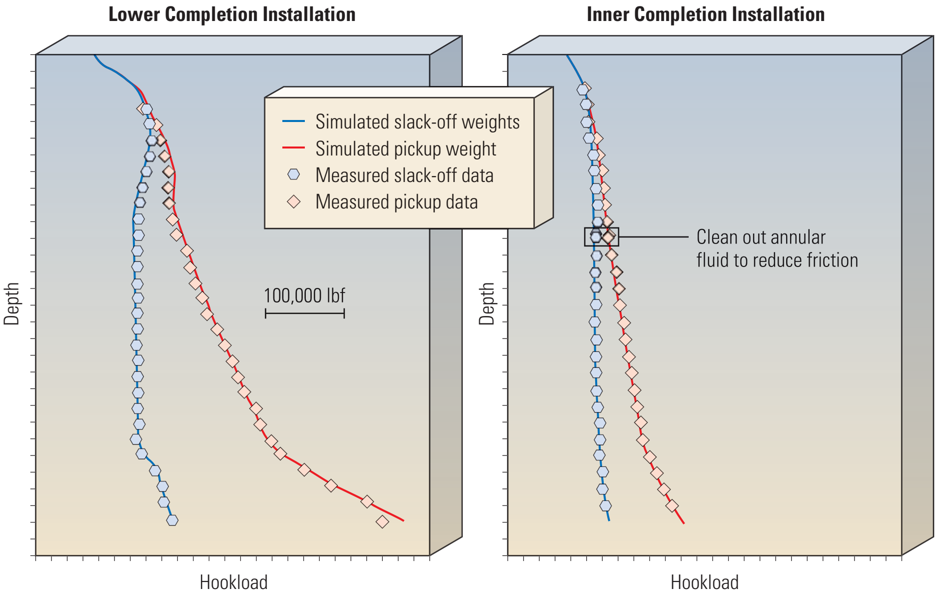
Wide arrays of tests have been run at CTF, ranging from feasibility to precommercialization and system integration. Tests associated with the latest generation LWD tools—TeleScope high-speed telemetry-while-drilling service, EcoScope multifunction logging-while-drilling service and StethoScope formation pressure-while-drilling service—have been run at CTF. The tests run on these tools were compared with results from previous generation LWD tools over the same intervals in the same well and also with wireline logs run over the same intervals. Full-scale qualification tests of the newest while-drilling tools prior to field testing enabled early debugging of the tools and helped to prepare these services for successful introduction on commercial wells.[3] Clearly, this fast-track tool development would not have been feasible without CTF.

Testing Integrated Systems

SIT is especially beneficial for critical development projects that must integrate many types of wells and tools. The increasing number of complex, deep offshore wells has heightened the value of performing SIT, potentially making SIT an integral part of a risk-management plan for high-profile critical projects.

Completion SIT has been performed several times over the past year at CTF and SRC, simulating as closely as possible actual well conditions in different parts of the world. Completion SIT objectives include assembly procedures, interface verification, installation optimization, intervention testing and contingency planning. An important goal is to reduce the learning curve through customized personnel

^ Cameron Texas Facility. This facility is equipped with a drilling rig for performing drilling, borehole-measurement and system integration tests. The rig is capable of handling three-joint stands of drillpipe and is equipped with high-volume mud pumps. The rig is mounted on rails for convenient access to different well slots with a wide variety of directional wells that can be used for both openhole and cased-hole tests.



^ Slack-off and pickup weight data during completion installation. The chart shows the effect of drag on the lower completion installation (*left*). A maximum overpull—the difference between the slack-off and pickup weights—of more than 200,000 lbf observed at TD would have caused tubing stress above the specified rating. Based on the information gained during the SIT and data collected for the lower completion slack-off and pickup weight, the wellbore was cleaned out and the annular fluid was changed to reduce friction. These steps reduced overpull to less than half the lower-completion value (*right*). The measurement of drag encountered during the inner completion installation was used to implement procedural changes both during the test and in the extended-reach offshore well.

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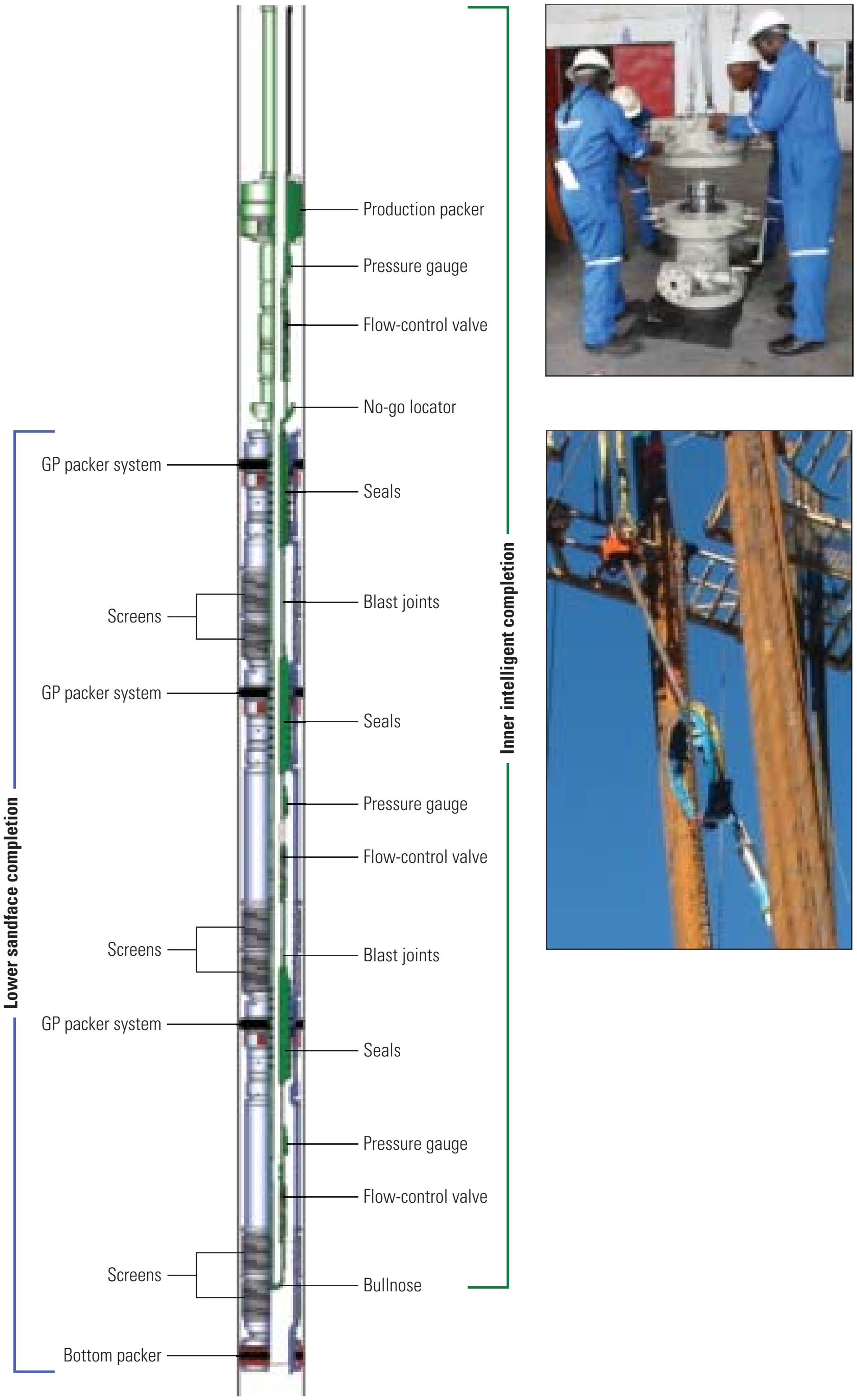
3. Adolph B, Stoller C, Archer M, Codazzi D, El-Halawani T, Perciot P, Weller G, Evans M, Grant BJ, Griffiths R, Hartman D, Sirkin G, Ichikawa M, Scott G, Tribe I and White D: "No More Waiting: Formation Evaluation While Drilling," *Oilfield Review* 17, no. 3 (Autumn 2005): 4–21.
4. Edment B, Elliott F, Gilchrist J, Powers B, Jansen R, McPike T, Onwusiri H, Parlar M, Twynam A and van Kranenburg A: "Improvements in Horizontal Gravel Packing," *Oilfield Review* 17, no. 1 (Spring 2005): 50–60.
5. The customized changes to the completion assembly included a proprietary seal system, allowing bypass of multiple control lines and multiple-choke-position flow-control valves that are set hydraulically. The gravel-packer circulating housing allowed slurry to be pumped into the annulus between the screen and the casing. It has a sleeve designed to close when the gravel-pack pumping operation is completed.
6. The customized gravel-pack system features a single-trip service tool that provides a mechanism for packer setting and testing, fluid circulation and gravel-pack (GP) operation in a highly deviated wellbore. The GP circulating housing is specially modified to accommodate the inner completion string without the risk of opening the port sleeve.

training and experience across service providers, third parties and client operations.

In one SIT example, the first of its kind for an extended-reach well, an intelligent flow-control device was placed within a triple-zone, cased-hole gravel pack in a test well at SRC (right).[4] The completion assembly incorporated a number of newly customized items, including proprietary seal assemblies, reduced outside-diameter flow-control valves and a hydraulically set, single-trip, step-bore gravel-pack system with a dedicated service tool and modified circulating housing.[5] The SIT plan for this well also included a full downhole system test at SRC, followed by verification of the wellhead and control-line interfaces on location prior to equipment mobilization offshore. These tests provided the optimum method for identifying key installation risks and were used to subsequently modify procedures to reduce nonproductive time or failures.

Several specific issues were addressed in this SIT. The issue was interface testing of the lower sandface completion with the intelligent inner completion, particularly the frictional effects of multiple long-seal assemblies, their correct positioning—space out—within the wellbore, equipment eccentricity alignment, and minimization of seal-bore scratching and fatigue prior to landing the completion. Second, drag and wear issues for the inner completion while running through a highly deviated environment were examined. Third was testing of a modified single-trip hydraulically set gravel-pack system utilizing a step-bore and dedicated service tool.[6] Finally, SIT was used to optimize running multiple hydraulic and electric-control lines while minimizing the number of splices to reduce installation time and risk.

SIT proved the feasibility of the completion design, the capability to install the equipment successfully and the device's reliability for zonal isolation. A total of 35 recommendations based on the SIT were incorporated into the preparation and installation procedures as best practices, contingencies or special-attention items during the actual well installation. A subsequent offshore installation was completed with minimal nonproductive time, especially considering the high-drag environment encountered during gravel packing, with a maximum difference of more than 200,000 lbf [890 kN] between slack-off and pickup weight at total depth (TD) (previous page, right). Knowledge gained during the SIT was used to calibrate the installation drag model that ensured successful space out and landing.



^ A three-zone, cased-hole gravel-pack (GP) intelligent completion layout used for system integration testing (SIT) (*left*). Installation of the inner completion string during the SIT was conducted at the Schlumberger Reservoir Completions Technology Center in Rosharon, Texas (*bottom right*). The GP packer system includes the isolation packer and circulating housing. As part of the SIT, additional tests on the wellhead called "stack-up tests" were performed in collaboration with the wellhead supplier on location (*top right*).

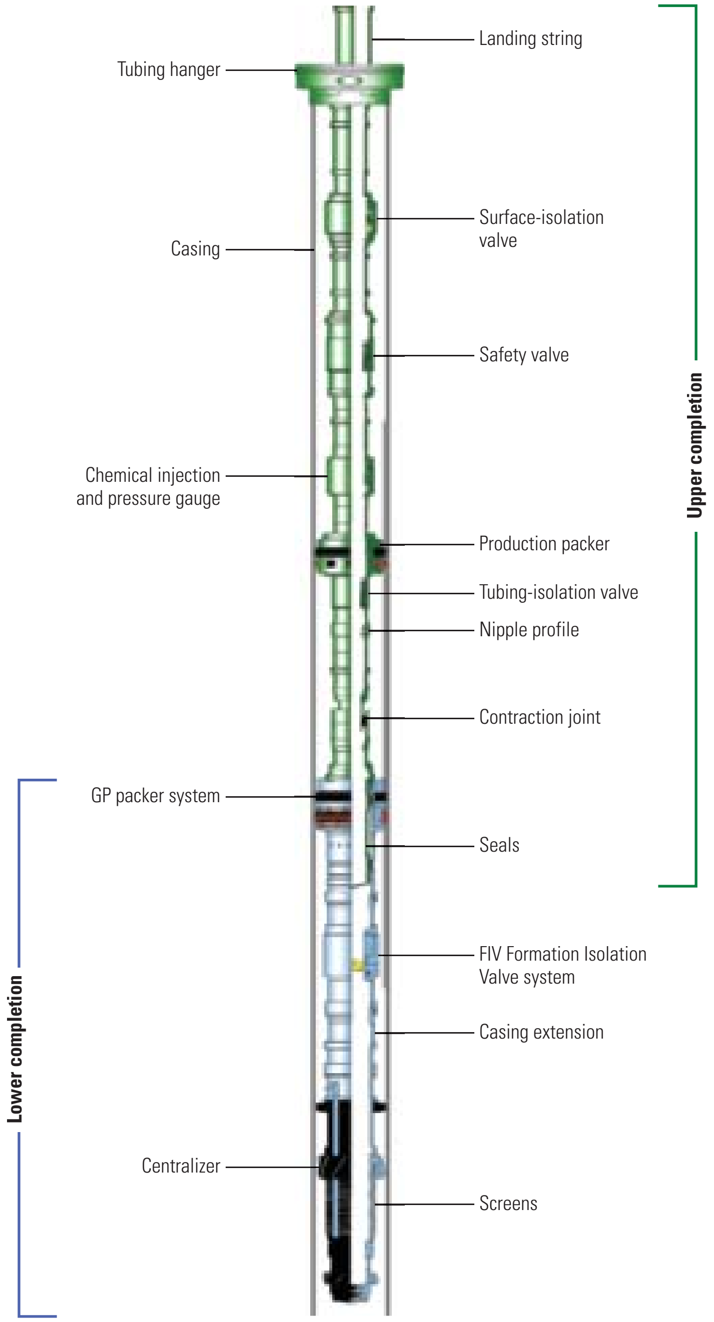
The three zones were individually stimulated and tested using the flow-control valves, proving zonal isolation. Downhole production data, which are used for allocation of production, are currently captured by using InterACT real-time monitoring and data delivery. The project—from inception through planning, testing and execution—was accelerated for completion within a 12-month time frame.

In another example, a month-long SIT of several newly designed completion tools was performed at the CTF in a purpose-built cased well with an extended horizontal leg to simulate as closely as possible the conditions anticipated during an offshore installation (right). The objective of this test was to investigate any interface issues and to verify quality assurance and quality control, assembly procedures, operating procedures and the accuracy of the contingency plans. Additionally, it was important to identify and implement lessons learned, including changes to the design and procedures that would result in increased efficiency, reliability or functionality in the operator's field application.

Knowledge gained during the tests led to improvements in the intervention phase. A new nipple profile used in conjunction with the expandable shifting tool for the tubing-isolation valve was redesigned to overcome an incompatibility with the previously chosen configuration. Additional tests with tractors for conveyance were also explored in conjunction with various intervention methods to avoid the coiled tubing lockup, or helical buckling, anticipated at compressive loads greater than 2,500 lbf [11.1 kN] that were observed during SIT. Additionally, more than 60 different action items related to safety, outlined procedures, equipment modifications and best practices were recorded to increase efficiency, reliability and functionality.

Testing integrated systems has provided proven long-term cost savings, both by solving problems prior to first field installation and by lessons learned to improve efficiency and to reduce installation and nonproductive time. Despite detailed pre-engineering studies that had been performed, SIT clarified the limitations of what could be planned and verified in advance and demonstrated the importance of conducting a field trial in a confidential manner and without rig-time constraints.

The ability to tailor integration tests in a controlled and relatively low-cost environment allows operators and service companies alike to significantly reduce the learning curve and risk. Test facilities, especially those equipped with a



^ A subsea openhole gravel-pack (GP) completion used in a system integration test at CTF. The upper (green) and lower (blue) completion assemblies incorporated a number of newly designed completion tools—a gravel-pack service tool for gravel-pack operation (not shown here), single-assembly integrated products with permanent gauge and chemical injection, and three different types of isolation valves.

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7. Fontenot KR, Lesso B, Strickler RD and Warren TM: "Using Casing to Drill Directional Wells," *Oilfield Review* 17, no. 2 (Summer 2005): 44–61.
8. A retrievable system for drilling with casing is required for directional wells because of the need to recover expensive directional drilling and guidance equipment, to replace failed equipment before reaching casing point, and to quickly and cost-effectively access formations below a casing shoe. A wireline retrievable directional-drilling assembly, positioned in the lower end of the casing, replaces the directional tools used in a conventional bottomhole assembly. For more on retrievable tools for drilling with casing operations: Tessari R, Warren T and Houtchens B: "Retrievable Tools Provide Flexibility for Casing Drilling," presented at the World Oil 2003 Casing Drilling Technical Conference, Houston, March 6–7, 2003.
9. Borland B, Watts R, Warren T and Lesso B: "Drilling High Angle Casing Directionally Drilled Wells with Fit-for-Purpose String Sizes," paper IADC/SPE 99248, presented at the IADC/ SPE Drilling Conference, Miami, Florida, USA, February 21–23, 2006.

full-scale drilling rig, such as the CTF, expand the horizons of what can be achieved in simulating complex well plans and testing new technologies in collaboration with oil and gas companies and other third-party contractors.

A Collaborative Project: Directional Drilling with Casing

In recent years, drilling with casing has steadily gained acceptance because it offers increased well control and safety, enhanced efficiency and demonstrated cost savings.[7] Although the most significant savings can be achieved in offshore environments, drilling with casing in mature assets presents significant challenges. Wells drilled from a platform are typically directional, and drilling deviated wells with casing may require modifications to rig or platform equipment that could affect production at a prohibitive cost in an offshore operational environment. Also, a learning curve typically must be developed with the first few wells drilled in a new application area.

ConocoPhillips, an industry leader in applying retrievable Casing Drilling technology, has multiple offshore assets in which drilling with casing has the potential to help deal with known well-construction problems.[8] In mature fields, such as the Eldfisk field offshore Norway, reservoir depletion leads to well-stability concerns. Drilling with standard drillpipe may require extra casing strings to avoid well-stability problems that are caused by depleted formation pressures. In addition to solving drilling problems, the technology of drilling with casing has the potential to reduce the number of casing strings, which could lead to improved well-construction efficiency and substantial cost savings.

A collaborative project of ConocoPhillips, Tesco and Schlumberger was undertaken to design and test directional drilling with casing for two wells planned for Eldfisk field in 2006. The planned wells were to be drilled from a common wellhead with 10¾-in. and 7¾-in. casing. At the start of the project, drilling with casing tools did not exist in these sizes and operational problems related to directional wells required redesign of the existing hardware.

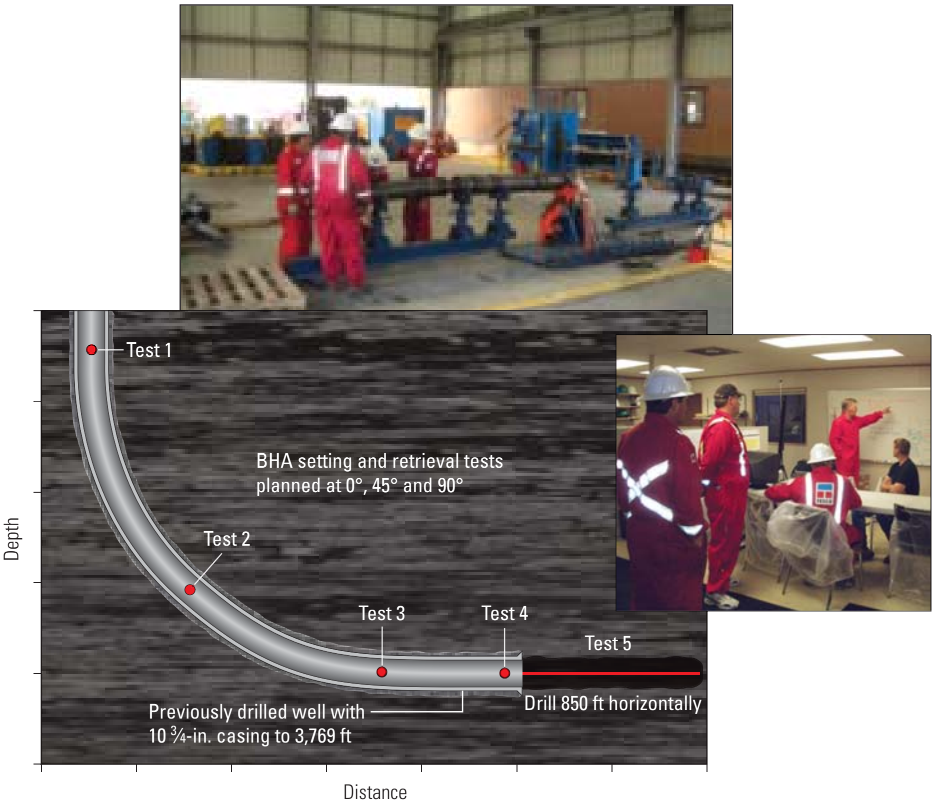
The high risks associated with setting, directionally drilling and retrieving these new tools with modifications in untested borehole sizes warranted testing this technology in directional wells in an onshore field. But there were additional concerns about this approach. First, with multiple partners, it was difficult to conduct a test that would benefit the operator but potentially have little or no benefit to the other partners. Quantifying the costs and risks was complicated.

Second, because pay-zone targets and accompanying directional-well trajectories frequently change as new information is learned about the field, a directional build profile in one casing section may be moved to another section because of a change in a geological model. These changes in the well plan severely constrained the test objectives. Third, commercial wells are drilled to completion. The very nature of testing a drilling process, such as drilling with casing, may lead to problems that are significant enough to abandon the test or well. Once a section of directional drilling with casing is started, it must be finished. If there are problems with the tools, the ability to revert to directional drilling with drillpipe has to be an available option. This fail-safe nature of well construction required extensive planning and budgeting of costs.

These issues, common in well construction, made it difficult to test new technologies for one business unit in the fields of another business unit, even for large multinational operator organizations. Several months were spent in modifying well designs before the decision was made to look for a different approach. The alternative was to utilize CTF.

Two tests were planned. The wells at CTF would mirror the directional sections, build rates and operational parameters such as mud flow rates that are required for Eldfisk wells.[9] The first well would test setting and retrieving the 7⅝-in.-casing bottomhole assembly (BHA) tools in horizontal drilling operations. The second would test the 10¾-in. system with multiple build rates, kicking off a directional well from the vertical section.

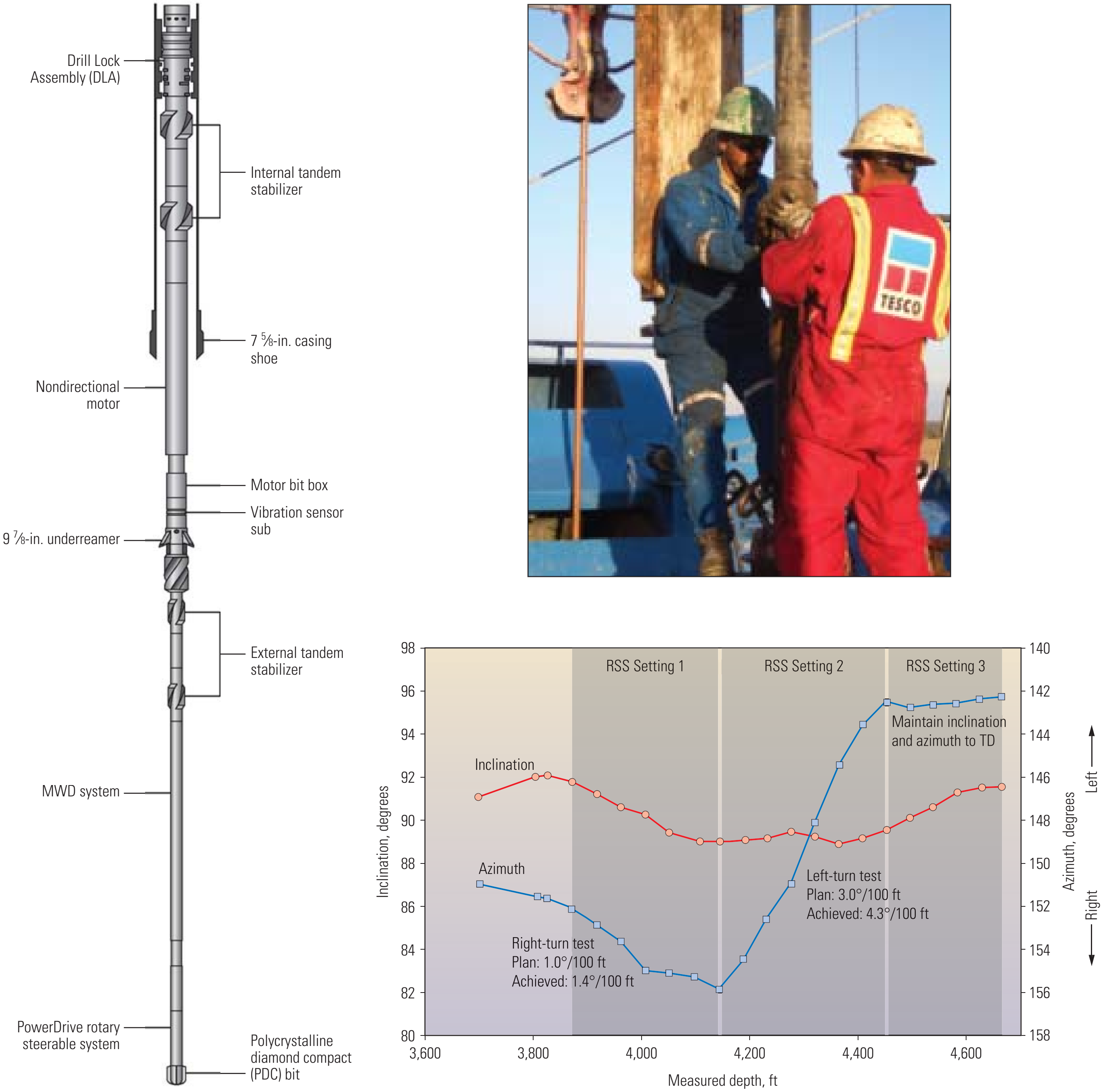
The first test took place in July 2005 in a previously drilled, high-angle borehole at CTF with 13⅜-in. casing, which included about 600 ft [183 m] of horizontal section (below). Tests were conducted for setting and retrieving the BHA in the vertical section and at well deviations of 45° and 90°. A directional drilling with casing BHA incorporating a rotary steerable system (RSS)



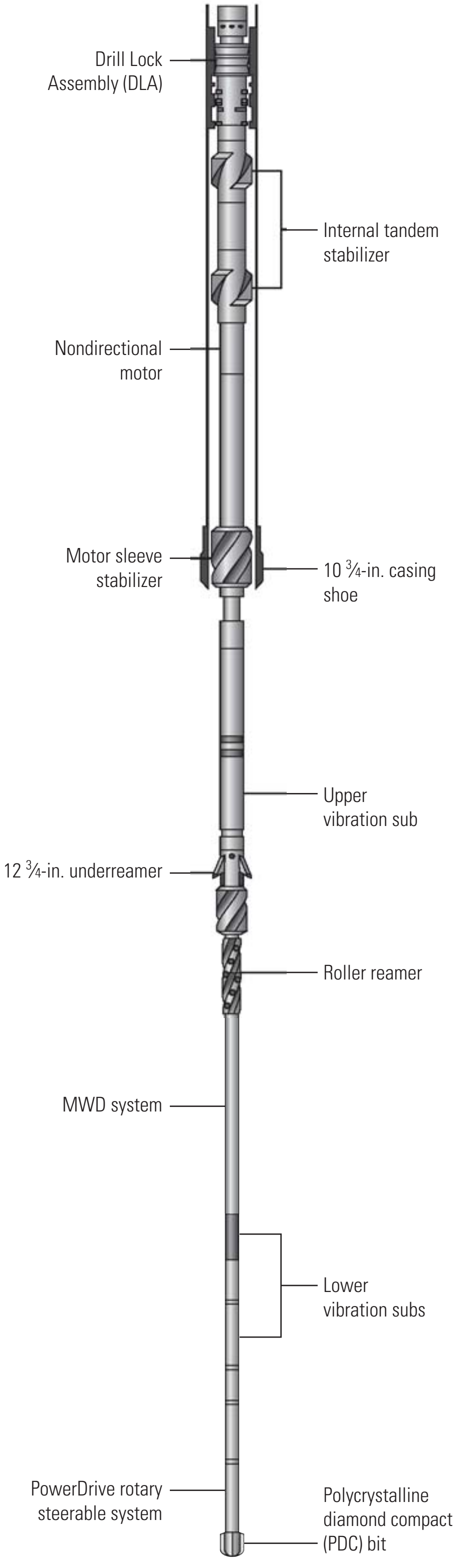
Well profile of the horizontal well at the Cameron Texas Facility for testing directional drilling with casing (*bottom*). Four bottomhole assembly (BHA) setting and retrieval operations at vertical and various inclinations are shown. Test 5 included about 850 ft of horizontal drilling. Rig personnel have the ability to break equipment down and make minor design changes based on the test taking place on the nearby rig, such as the Tesco crew here (*top*). Briefings that include safety guidelines are held each day of the tests to outline procedures for the next 12 hours. During these and other directional drilling with casing tests, two daily briefings included ConocoPhillips, Tesco and Schlumberger personnel (*right*).

was tested (below).[10] The test also included the directional performance of this equipment. A command was sent to the RSS to turn the well path to the right, at 1.0°/100 ft [1.0°/30 m]. After 300 ft [91.4 m], a second command was sent to turn to the left, at 3.0°/100 ft [3.0°/30 m]. Finally, a command was sent to maintain a constant inclination and azimuth until the end of the test. The first turn was accomplished at 1.4°/100 ft [1.4°/30 m], the second turn had a 4.3°/100-ft [4.3°/30-m] rate and the third command resulted in a constant azimuth. About 850 ft [259 m] of new horizontal borehole was drilled.

Setting and retrieving the drilling with casing BHAs were achieved using wireline. However, because of the high well inclination, pumping the tools down the borehole was also tested. The BHA was successfully set and retrieved. It was then reset and then released using a pumpdown



^ Directional drilling with casing BHA used in the 7⅝-in. test (*left*). The PowerDrive rotary steerable assembly included a motor that was run inside the shoe joint of the casing to provide adequate drilling rotational speed while minimizing casing rotation to control wear and fatigue. The directional drilling with casing BHA has a stick-out, or length, below the casing shoe of 85 ft [25.9 m], whereas a typical vertical BHA has a stick-out of only 15 ft [4.6 m]. The directional performance of the rotary steerable system for three PowerDrive settings is shown (*bottom right*). Test results indicate the degree of success of the horizontal drilling test. Tesco and Schlumberger personnel are seen making up the BHA (*top right*).



^ Directional drilling with casing BHA used in the 10¾-in. test. The BHA used in the 10¾-in.-casing test is the heaviest and longest BHA ever used in directional drilling with casing. The BHA has a stick-out of 122 ft [37.2 m], and the BHA weighs three times the weight of a BHA used in the 7⅝-in. test.

releasing tool without a wireline attachment. At a targeted depth, the releasing tool landed in the profile nipple, releasing the drill lock and allowing BHA retrieval, thus completing a full functional test of the hardware.

A downhole vibration sensor sub was run above the underreamer to monitor lateral and torsional accelerations. Shocks during the earlier part of the run were of greater intensity, but tapered off later. These shocks have the potential of causing damage to the RSS. A full inspection of the tools demonstrated that they suffered none of the damage seen previously, probably because of the modifications to the rotary steerable tool to make it more robust. The small-diameter BHA used in drilling with casing is still susceptible to excessive vibrations and shocks and will continue to be monitored. However, modeling to mitigate shocks and improvements in tool robustness have greatly reduced this problem.

The 10¾-in. test took place in November 2005. A previously installed 13⅜-in. casing had been set vertically at about 2,000 ft [609.6 m]. The wireline installation for the 7⅝-in. test used an upper wireline sheave suspended below the rig's conventional traveling block, whereas the 10¾-in. test used a fixed crown sheave and split block to match the equipment on the Eldfisk rig. The directional BHA design was similar to that used in the 7⅝-in. test. An RSS and MWD tool were used for directional control in the pilot section of the BHA (left).

Downhole vibration measurements—shock counts—were transmitted uphole in real time from the MWD tool. Shock counts were also recorded downhole in the RSS. Additionally, three sensor packages were placed in the BHA; one above the underreamer and two below it, between the MWD tool and RSS. Downhole recorded measurements included annular pressure; lateral, axial and torsional shocks; rotational speed; torque; and weight-on-bit. Two BHAs of different lengths were used to test differences in vibration response.

The dataset from this test is the most extensive recording of downhole data ever collected during an operation involving drilling with casing. Data were recorded while kicking off a sidetrack plug, traversing through a maze of other bores drilled from the same parent borehole and drilling to about 850 ft while building angle to about 20°. The well was directionally drilled, first with a low build rate of 0.5°/100 ft [0.5°/30 m] and then a higher rate of 3.0°/100 ft.

The drilling mechanics and dynamics data gathered during these tests have led to recommendations in tactical changes that will improve well designs for the ConocoPhillips Norway operations at Eldfisk.

Expanding Horizons in Quality Assurance

Designing equipment that can withstand the extreme environmental and drilling conditions of global oil fields while making highly sensitive measurements continues to be incredibly challenging. As tools become more complex and hydrocarbons hide in ever more difficult settings, the risk and costs associated with applying new technologies will only increase in the future. Therefore, qualifying oilfield technologies prior to their introduction in the field is essential.

With the need to mitigate exposure to hazardous oilfield environments and keep costs in check, remote testing involving clients and engineering and test facilities personnel has been a growing trend. The high-bandwidth connectivity within the Schlumberger network firewall provides the ability to conduct tests confidentially and involve experts who might be thousands of miles away.[11]

The benefits of maintaining and operating test centers, including full drilling capability, are well-established. Rapid deployment of high-performance enabling technologies in the field and an increasing demand for complex, multidisciplinary, turnkey completion projects are some of the reasons for the necessity of test facilities such as SRC and CTF. In fact, the limits of testing are prescribed only by the creativity boundaries of the technology developers.

The future is likely to see an increased number of collaborative projects between operators, service companies and third-party suppliers to test new limits of technology and provide both quality and safety assurance in tough, geologically complex drilling environments. —RG

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