BP, Baker run first expandable monobore liner extension system

Bob Coollidge
Bob Baker
BP America Inc.
Houston

Carl E. Smackmeyer
Mark Adam
Bryan Emerson
Baker Oil Tools
Houston

In September 2006, BP and Baker Oil Tools achieved an industry milestone with the successful installation of the world’s first expandable monobore liner extension system, in a commercial well in BP’s Arkansas asset in southeast Oklahoma (Fig. 1).

The successful installation and expansion of 1,514 ft (461 m) of Baker’s 8-in. InnXX solid expandable system below the 9 5/8-in. parent casing proved the feasibility of solid expandable tubulars and enabled operators to plan and drill deeper wells with larger hole sizes at the reservoir.

Earlier in the year, the successful installation of recess shoes in four North Sea wells set the stage for future monobore contingency applications of solid expandable tubulars to isolate trouble zones, such as reactive shale, subsalt environments, and low-fracture-gradient sections, and then drill ahead without having to reduce critical hole size.

The Baker system is currently the only solid expandable monobore liner extension system available on the market. Key enabling features and benefits of the system include:

• A casing shoe with a recessed internal diameter (i.d.) and location profile that enables the liner to be anchored on the bottom of the parent casing and then expanded into the shoe with no ID size restriction below the parent casing. The recess shoe distinguishes the Baker expandable system from others that have an ID size restriction from hanging off in the parent casing.
• An expandable liner hanger/packer that is set into the recess shoe and ties the 8-in. expandable liner to the parent casing strings.
• Cementing is done post-expansion.
• A retrievable guide shoe that guides the expandable liner into the open hole.
• A top-down hydraulic expansion system that prevents losing the hole should a major restriction in the open hole (i.e., collapsed formation) cause expansion cones to become blocked downhole.

Technology development

For years, the exploration and production (E&P) industry has sought an improved alternative to conventional, telescoping casing designs that reduce casing sizes as the well depth increases (Fig. 1).

When expandable metal technology was adapted to oilfield tubular products, efforts began immediately to use the technology to develop a solid expandable monobore well construction method that would allow for much

Prior to expansion, the InnXX assembly hangs in the borehole, as illustrated in this field trial application (Fig. 1).
Casing String Designs

Current design

Optimized design with expandable membrane liner extension system

Deeper or deviated wells to be drilled without any loss in internal diameter.

Further, should an unexpected hole problem be encountered while drilling, a monobore well design allows the operator to set casing across the problem zone and continue wellbore construction without sacrificing hole size.

Ultimately, the reservoir can be enterered with the initial-diameter production casing and thereby maintain the production capability that would have been compromised had a smaller-size casing been used to enter the production zone.

In addition to reducing casing costs, potential benefits of monobore well construction range from downzoned drilling rigs and wellheads and resulting smaller footprint, to decreased mud and cement volumes and increased flow rates.

Baker Oil Tools began developing the In-Bore monobore expandable liner system in 2006. The commercial field installation in 2006 included 4 years of full-scale field testing and modifications as part of the development process.

Critical success factors for the system included expandable material selection, qualification, development, and testing methods; development of an overcasc recess shoe to maintain single-diameter casing without having to create a recess area downhole; and development of an expansion technique that would successfully address a number of operator concerns regarding pressure and wellbore integrity.

Casing Selection

The expandable casing is a quench and tempered, carbon-manganese, low-alloy steel with minimum yield strength of 70 ksi, supplied in accordance with Baker Oil Tools material specifications. Chemical composition, heat treatment, microstructure, and mechanical properties are tightly controlled in order to improve ductility and ensure controlled uniform expansion. Dimensionally, the casing is nominally supplied in accordance with API Specification 5CT, with slightly improved wall thickness tolerances (Fig. 3).

Upon receipt of the casing, Baker specifications require enhanced ultrasonic testing (EUT) on 100% of the pipe volume, over and above the conventionally performed by the mill. The EUT procedure combines highly sensitive compression wave transducers with various obliquely angled shear wave transducers in a single, high-fidelity, ultrasonic testing unit (HUT). The high-fidelity ultrasonic wave shoe is run across the outer surface of each casing length using a water soluble plug. A quasi-pendulum ultrasonic testing system and software generate an accurate and representative picture of individual pipes. The latest version of the software creates a 3D digital picture of the casing by converting and collating the analog compression and shear transducer data.

These data are further enhanced by introducing X-Y coordinates of indications recorded by the shear wave transducers and plugging these coordinates as red circular "potential" defect indicators on a digital representation of the pipe body. The result is a comprehensive, volumetric view of each casing length, which identifies midwall thickness defects as small as 0.0625 in. (1.59 mm) in diameter to within ±0.035 in. (0.86 mm) of the outer surface, traceable back to a unique identification number. Baker Oil Tools now has the technology to expedite casing for successful expansion.

In its preexpanded condition, the casing material complies with NACE MR0175/ISO 15156 hardness limitations for low-alloy steels. Controlled plastic deformation leads to an increase in tensile strength and, subsequently, increased hardness due to cold work hardening.

The casing is normally supplied with a hardness of about 90 Brinell Rockwell "B" scale (HB 91 HB max per Baker material specification [BMS] C 141). This increases to 18 HRC (Hardness Rockwell "C" scale) at the ID and to
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21 HRC at the OD following expansion.

The difference in ID and OD hardness is directly proportional to the degree of plastic strain or expansion. For example, ID expansion of 18% (0.025 in. pre-expansion) vs. an OD expansion of 15.5% (0.006 in. pre-expansion) to 0.010–0.015 in. post-expansion.

Make is conserved during expansion. The inner wall thickness thins only slightly, while the length shrinks about 4%. Burst and collapse ratings are 5,000 psi and 1,200 psi, respectively. Proper handling of the casing and connections during every stage of manufacturing, inspection, and installation is critical to achieving a successful expansion and is therefore tightly controlled by an internal service company specification.

Downhole recess shoe

An overcated casing shoe was developed to be installed with the parent casing string and provide a downhole recess area for the expanded pipe.

The stock's recent ID and location profile enable the liner to be anchored on the bottom of the parent casing and then expanded into the shoe with no ID size restriction below the parent casing. This feature eliminates the ID size restriction that is present in other expandable liner systems that hang off the parent casing.

The recess shoe is available in two versions: one that facilitates fluid and cement circulation of the expanded liner run below the recess shoe, and one that does not. Both versions are rated to 5,000 psi burst and 1,250 psi collapse (Fig. 4).

Top-down expansion

Engineers developed a top-down, hydraulic expansion system that relies on drill pipe pressure to expand the liner. The expansion method addresses operator concerns about not being able to retrieve the expansion cone from expandable products if catastrophic loss of expansion pressure occurs inside the expanded casing.

The expansion assembly consists of an anchor, hydraulic cylinder, and expansion cone. As expanding begins, slips are rotated from the anchor and lock the expansion assembly in place. Continued application of pressure down the workstring extends the hydraulic cylinder and moves the cone downhole in 14-ft (4.3-m) incremental stroke lengths. The design does not rely on drill pipe set-down weight or overpull, or on a direct seating process to assure pressure integrity during expansion.

Additionally, the method does not apply expansion pressure to the expandable casing. The top-down expansion method enables integration of a retrievable collet onto the boom of the expansion assembly, which makes it possible to retrieve the guide shoe and have an open ID through the cavity length of the liner when it is fully expanded. Typical expansion rates are about 100–300 ft (30–90 m)/hr.

With top-down expansion, shrinkage in liner length occurs at the “free” end of the system. In this case, the 9-in. ID shrinkage in expandable liner length will cause a portion of the open hole at target depth (TD) to not be cased by the expandable system. To accommodate the shrinkage, prejob planning addresses drilling cut hole below the target zone.

Recess shoe installations

In 2006, recess shoes were successfully installed on 9⅝-in. casing across four North Sea wells in contingency applications. The wells were located in Statoil Kristin, Kvitbjørn, and Anitra high-pressure, high-temperature (HPHT) depleted-driven fields.

Statoil's conventional method of overcoming low-fracture-gradient-related blowout potential of depleted reservoirs has been to run a 7-in. liner followed by a 4⅝-in. completion. However, field development economics for Kristin and Kvitbjørn dictated 7-in. production liner into the reservoir.

Statoil decided to install 9⅝-in. R9-9 recess shoes in all three fields as contingencies to ensure an aggressive drilling program that could reach target depths of 11,236 ft (3,425 m) and adhere to development objectives. The
successful installation and drill out of the recess shoe set the stage for future contingency applications of monobore expandable liner extension technology.

**Oklahoma world-first**

Up and Baker Oil Tools successfully ran the world's first solid expandable monobore liner extension in Oklahoma in 2006. A 12¾-in. vertical hole was drilled to about 4,108 ft (1,250 m), and then filled with oil-based mud (OBM) prior to running and expanding the tubulars (Fig. 5).

The 9¾-in. parent casing and recess shoe were run to a depth of 2,589 ft (789 m). The casing was then landed and packed off in the surface wellhead. Cement was not pumped at this time to allow for contingency removal of the casing, if required.

Utilizing running and handling procedures similar to those for chrome tubulars, 1¼-in. OD unexpanded liner was run in hole and torque-turn equipment verified a typical makeup torque of about 4,300 ft-lb. The expandable liner hanger-packer was then made up to the expandable liner.

After making up the top-down expansion tool assembly, the 8-in. liner,anger, and expansion tool assembly was run in the hole on drill pipe. The hanger was then positively located in the recess shoe profile and expanded into the shoe, using pressure to "strike" the expansion tool.

The liner was expanded 18% to 8.625 in. nominal ID and 8.44-drill ID in 14.46 (5 in.) increments. The incremental expansion was completed as planned by applying drill pipe pressure to the expansion tool and then decompressing and slacking off to recock the tool until the entire 1,514-ft (461 m) length was expanded. A truck-mounted cement pump supplied the expansion pressure.

After retrieving the expansion assembly, post-expansion drill-out was verified by two independent methods. A drift run "directly to bottom" with a stiff three-point contact drilling assembly provided "mechanical" assurance. Subsequently, a caliper logging tool provided "digital data to support the mechanical method." The combined verification confirmed the ability to deliver a well with 8½-in. drift, to meet EP's needs and expectations.

A cement retainer was run in hole and set near the bottom of the expanded liner. The liner was then cemented in place using the same pump truck that had supplied expansion pressure. Cement volume was selected to ensure that the planned formation integrity test would be achieved without waiting for cement return into the 9¾-in. casing through the recess shoe ports (continuity plan). No changes were required to the cement thickening time since top-down expansion allows the cement to be pumped after expansion.

After successfully pressure testing the expanded liner, the retainer and excess cement were drilled out, and drilling continued with rotary steerable directional tools below the recess shoe. The liner extension system was isolated with the production casing before completing the well.

**Future potential**

The September 2006 installation of the world's first expandable monobore
In order to calibrate an extensive collaborative qualification, testing, and field trial program between BP and Baker Oil Tools, Baker Oil Tools' team will conduct additional field tests and extend applications to the system of other areas.

References


The authors:

Robert Coolidge (Robert_Coolidge@bhp.com) is a project manager for BP Exploration & Production's technology group in Houston. He has served as engineering, management, sales, and technical service project management with extensive development related to drill, bit, solid expandable drilling, wireline logging, and pipeline engineering throughout his career with other companies. Coolidge holds a BS (1977) in mechanical engineering from Purdue University. He is a past board member, chairman of the current management committee, and recipient of the distinguished service award in SPE's Gulf Coast Section, and is currently active in American Association of Drilling Engineers and American Association of Drilling Engineers Committee.

Robert V. Baker (Robertv@bhp.com) is the program manager for the solid expandable and solid expandable production programs in BP America's exploration & production technology group, Houston. He has also served as a drilling engineer and well site supervisor for BHP's Cusona, Condor, and Shell. Baker received a BS (1970) in civil engineering from California State Polytechnic University and is a registered professional engineer in Texas. He is a member of the Society of Petroleum Engineers and the American Association of Drilling Engineers.

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Oil & Gas Journal / Feb. 17, 2007