New generation of solid expandable liners help give operators a jump on trouble zones

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SINCE SOLID EXPANDABLE technology has gained credibility as an effective contingency option, end users now realize that by including them as an enabling tool in the basis of design (BOD), significant well construction dollars can be saved in mitigating drilling hazards. By using solid expandables uphole prior to encountering problematic formations, operators can get a jump on trouble zones.

TROUBLE ZONES IN COMPLEX WELLS

Complex wells come in many forms – from the 30,000-ft well in deepwater that requires 10 strings of casing to reach TD to the 10-km extreme-reach horizontal well that extends from one field to another. To successfully meet drilling challenges, each complex well requires a unique set of drilling technologies combined with good drilling practices “honed” through familiarity with the local drilling environment.

Whether through good drilling practices or the application of drilling technologies – such as implementing managed pressure drilling techniques, drilling with casing/liner technology, using solid expandable technology, or a combination of technologies – complex-well construction requires dissecting mounds of information.

Another layer to making quality decisions requires “listening to the well,” which consists of understanding all drilling dynamics (weight on bit, ROP, pore pressure and applied mud weight) and their dependencies on one another. Reconciling collective real-time drilling data with fluids and solid returns is imperative to accurately interpreting what is taking place downhole and making quality drilling decisions.

Analysis has shown that 25% of the well’s cost can be budgeted to cover accepted nonproductive time (NPT). Excessive drilling-associated NPT can generally be categorized as drilling trouble zones within overpressured, underpressured or unstable zones. No one process or technology can be used to mitigate all drilling challenges, but choosing wisely from the drilling supervisor’s tool box and exercising good drilling practices can significantly reduce these large NPT costs.

Good drilling practices include well construction skills, processes and conventional equipment and services, such as effectively using a quality mud program. Although the mud program is a standard operating procedure, its misuse can result in the loss of a hole section or well – for example, accurately deciphering whether encountered gas is connection gas or the first indication of a kick. Employing the correct practice to effectively deal with this situation is a critical drilling skill. Connection gas can be misinterpreted as a kick and mistakenly dealt with through a series of reactions that include increasing the mud weight repeatedly. This misdiagnosis can then be exacerbated by not listening to the well as it begins ballooning and eventually fractures a weak zone uphole.

Good drilling practices coupled with effective and appropriate drilling tools can mitigate most drilling challenges. The combinations vary, but generally employing good drilling practices can address...
about 50% of the drilling hazards encountered. The remaining 50% can usually be addressed with drilling technologies.

Solid expandables are only part of the answer to dealing with drilling hazards. Application and installation experience, combined with zero hole loss or monobore solid expandables, are giving the engineer more effective tools to combat drilling hazards.

In the past, solid expandable technology has been a last resort used for drilling problems when every other practice and technology had failed. Remarkably, solid expandable liners have been largely successful when applied out of desperation; however, the many dollars used in fighting the drilling hazard before the decision to use expandable technology become a sunk cost that cannot be recovered. Analysis has shown that if an identified hazard has been unsuccessfully fought for two days, a different path is most prudent.

NEW GENERATION OF SOLID EXPANDABLES

Solid expandable liners have a long history, with one of the first patents issued in 1865 to J.A. Patterson (Figure 1). Since then, the technology has evolved to include a suite of expandable tools for both open hole and cased hole that not only minimize hole reduction but eliminate it. One of the more significant advancements in expandable technology has been the development of the monobore liner system.

Monobore solid expandables installed in critical sections of wells are being used to prepare for, rather than react to, trouble zones. A significant application
Drilling Technology

Figure 4a: A solid expandable liner was used to try to get back to the original well design. Figure 4b: Completion option using monobore open-hole expandable liner.

Figure 5a: In North Africa, solid expandable systems were planned as a way to combat pore pressure/fracture gradient challenges. Figure 5b: Expandable options were identified to mitigate tight tolerance drilling conditions.

drilling consists of using a monobore open-hole liner to extend the critical 13 3/8-in./13-5/8-in. casing string. It has been determined that if a casing string could be added below the conventional 13-3/8-in. string without sacrificing any hole size, many drilling challenges encountered further downhole can be addressed while maintaining an optimum-sized hole for completion or evaluation.

One challenge with using large-diameter solid expandable products has been the lack of external-pressure performance. Collapse is especially critical as it decreases as much as 50% when expanded. The most effective means of increasing the post-expanded collapse properties of cone-expanded tubulars is to increase the product’s wall thickness.

An 11 3/4-in. x 13 3/8-in. monobore open-hole liner has been developed with a seamless casing whose wall thickness is 0.682, almost twice as thick as any expandable currently available.

This monobore liner system uses a flush-joint shoe, which has a slightly larger ID (~13.625 in.) than the 13-3/8-in. casing and is run on the bottom of the conventional 13-3/8-in. casing string. This tieback shoe provides a receptacle for the 11 3/4-in., 71-lb-ft expandable casing to be expanded into and still result in an expanded drift diameter of 12 3/4 in., the same as the previously run conventional 13-3/8-in. casing string. Once the 13-3/8-in. casing is run and the next hole section is drilled, the running sequence is similar to most conventional expandable open-hole liners (Figure 2).

Preparing for Trouble

The following examples illustrate how operators use solid expandables to maintain hole size when faced with or in preparation for drilling through trouble zones. By planning additional monobore liners or conventional expandable liners deeper in the well, drilling hazards can be effectively addressed and NPT can be minimized.

Example 1 - subsalt rubble zones in deepwater Gulf of Mexico wells

A Gulf of Mexico (GOM) deepwater well encountered a rubble zone upon drilling out of a salt formation that resulted in the unexpected need to set a casing string. An 11-3/8-in. high-collapse conventional liner (Figure 3a) had to be set higher than planned to cover the approximately 1,000-ft rubble zone.

This lost casing point would put the 9 5/8-in. casing being set where the 11-3/8-in. was originally planned. Consequently, after encountering another trouble zone, the hole to reach TD would be 4 3/4 in. and result in the well’s potential completion size reduced by as much as 3 3/4 in. from originally planned (Figure 3b).

To reach TD with a 7-1/2-in. hole, a 3,000-ft 9 5/8-in. x 11-3/4-in. conventional expandable liner was run below the conventional 12-7/8-in. liner. Because the expanded ID of the conventional expandable was not large enough to accommodate running conventional 9 5/8-in. 53.5-lb-ft casing and set across the subsequent hole section, a non-API 9 5/8-in. OD conventional liner was run.

To get as close as possible back to the original well design, a 7 3/4-in. x 9 5/8-in. expandable liner was subsequently run that allowed a 7-in. flush joint liner to be run at TD (Figure 4a). Hole size conservation (2 3/4 in.) assisted in the management of the ECD and increased the chance to properly evaluate a critical section of the well.

These three liners covered this approximately 5,000-ft interval that had a 0.4-0.6 lb/gal pore pressure/fracture gradient window. Using a combination of conventional solid expandable liners and non-API casing preserved approximately 60% more hole size compared with using only conventional tubulars.
Alternately, when the rubble zone was encountered under the salt, an approximately 1,000-ft 11 ¾-in. x 13 5/8-in. high-collapse monobore open-hole expandable liner could have been run. The installation of this single monobore expandable liner has the ability to bring the well construction back to the original design and allow running the 11 7/8-in. conventional high-collapse liner at its originally planned depth. The subsequent well construction (Figure 4b) could have been continued to reach the well’s TD with a 7-in. flush joint liner.

The shorter monobore expandable liner (approximately 1,000 ft versus approximately 3,000 ft) doesn’t require the subsequent use of the non-conventional sized well construction equipment. Because the casing used in the 11 ¾-in. x 13 5/8-in. monobore system has a 0.682 wall, its collapse resistance is higher than conventional thin-wall solid expandable liners.

**Example 2 - shallow flow & tight-margin zones in North Africa offshore wells**

In North Africa, solid expandables were planned as contingencies because of pore pressure/fracture gradient challenges (Figure 5a). The use of conventional casing designs would require the upper strings in the well to grow in size, driving up the cost significantly. Solid expandable liner systems planned as contingencies could downsize the upper well plans while maintaining completion size.

Due to the risks associated with tight tolerance drilling, several solid expandable liners were identified as contingency options (Figure 5b) to maintain hole size and achieve optimum completion sizing within the reservoir. Various drilling hazards and the need to reach the target at approximately 16,500 ft (5,000 m) measured depth (MD) with long step-outs and eventually TD the well with a 7-in. production casing, necessitated solid expandable liners.

Figure 6: An ERD well with unstable formation was remediated with a monobore open-hole liner in its upper section and with coal hazard remediated with a monobore clad liner near TD of an 8 1/2-in. hole section.
A shallow flow hazard at about 5,870 ft (1,790 m) is sometimes encountered that requires premature setting of the 16-in. casing.

This short landing in turn requires the 13 ¾-in. casing string to be set in the hole section originally planned where the 16-in. liner was to be set. To mitigate setting the 16-in. liner early due to the shallow trouble zone, an expandable monobore liner could be considered. Approximately 2,260 ft (688 m) – 2,001 ft (610 m) in open hole – of an 11 ¾ in. x 13 ¾-in. monobore open-hole liner would extend the 13 ¾-in. casing shoe to its planned TD.

In anticipation of this application, an oversized shoe is run on the bottom of the 13 ¾-in. liner, which is set and followed by normal drill-out to the next hole section. This configuration allows the monobore system to be run through the tieback shoe into the 2,001 ft (610 m) of the open wellbore, cemented (if required), and expanded back into the tieback shoe. Effectively, this liner extends the conventional 13 ¾-in. casing shoe, maintains hole diameter, and eliminates the need to alter the casing plan of the well.

The design requirement for the solid expandable liner is to provide larger drift IDs, thus rendering more contingency options and improving the chance of reaching TD. Monobore expandable liners used in shallower hole sections and lower pressure and temperature environments reduce the operational risks and add contingency options for later in the drilling process if required.

The monobore system allows conventional drilling products and casing strings to be used above and below this particular solid expandable liner system while offering the benefit of an “additional” casing string. Following the installation of the 11 ¾-in. x 13 ¾-in. monobore open-hole liner, drilling ahead can continue with a standard 12 ¾-in. drill bit. Conventional 11 ¾-in. or 9 5/8-in. casing or liners can be installed through the expanded liner. Only with up-front planning of these contingency options can the proposed field development be economically feasible.

In the same field development project, a sand formation at approximately 15,100 ft (3,690 m) TVD, a 2,000-psi pressure change occurs that typically results in the short landing of the 11 ¾-in. casing string. To minimize telescoping of the well, a 9 5/8-in. x 11 ¾-in. conventional solid expandable liner can be run followed by a 9 5/8-in. x 9 5/8-in. liner. This combination of liners returns the well profile to a size closer to the original well plan and facilitates the eventual completion of the well with a 7-in. casing.

**Example 3 – multiple unstable zones in ERD well - Norwegian North Sea**

Shallow-set casing and unstable sections: Extended-reach wells are typically used to “reach” out from a common point to the outer edges of a field development to maximize reservoir drainage. These wells are capable of reaching targets in excess of 10 km and can eliminate the need for permanent drilling facilities/platforms. ERD wells contain long sections of wellbore that transverse several geological horizons and are exposed for a relatively long time before they are cased off.

As illustrated in the following example, unstable or sloughing formations up hole and again near the reservoir can jeopardize the well’s economic success if an optimum-sized completion cannot be facilitated.

Mitigating shallow setting of 13 ¾-in. casing

In an ERD well in the Norwegian North Sea, setting the 13 ¾-in. casing string to cover a set of unstable shale formations is problematic and can jeopardize the well’s primary target with the optimum-size completion. Unstable shale formations must be isolated before the long horizontal well section can be drilled successfully.

Setting a conventional casing string is unacceptable if the well is to be TD’ed with a 7-in. production liner. If the conventional 13 ¾-in. casing is set higher than planned, a monobore open-hole liner can extend the 13 ¾-in. casing shoe and isolate the trouble zones without the loss of any hole size (Figure 6).

Mitigating unstable coal section above primary target

In the casing program for lower in the ERD well, the long 9 5/8-in. x 12 ¾-in. hole section has been cased off with a 9 5/8-in. liner, and an 8 1/2-in. bit has been used to drill to TD. An unstable coal section near TD tends to slough, jeopardizing setting the production string at its planned depth.

### Additional drilling solution

The coal hazard can be mitigated using an 8 1/2-in. monobore open-hole clad liner. This liner is not tied back, and its length is sized to cover just the drilling hazard. The monobore clad liner is installed in a slightly underreamed (approximately 1 in. on diameter) hole section and expanded directly against the unstable formation. Effectively isolating the hazard while maintaining an 8-7-in. ID allows drilling the remainder of the section and then casing off the entire 8 1/2-in. hole section with the 7-in. production liner.

### Conclusion

Many complex wells are not drilled simply because multiple trouble zones within the projected well plan and tight budget constraints rule out their economic justification using conventional drilling technologies. Applying innovative engineering and enabling technologies, such as drilling with casing/liners, managed pressure drilling techniques or solid expandable liners, these complex wells can be drilled successfully and economically.

The development of expandable tubular technologies was initiated by the business need to reduce drilling costs, to increase production of tubing constrained wells, and to enable operators to access reservoirs that could otherwise not be reached economically.

Whether a solid expandable system is used as part of the initial wellbore design or for contingency purposes, the technology saves hole size, compensates for unplanned events, and allows for flexibility in the well-planning process.

The introduction of monobore liners and clads can be used to maintain the complex well’s BOD when trouble zones are encountered.

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