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Solid Expandable Tubulars Offset Extreme Drilling Conditions

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Abstract

Regardless of locales and geological environments, hotter and deeper conditions reflect the current global hydrocarbon and geotechnical drilling environment. Facilitating technologies and processes that enable extreme drilling operations have had to sustain a level of evolutionary change that considers and addresses the resulting challenges. Solid expandable tubulars have not only maintained their relevance as an enabling technology but have proven to be a viable solution to challenging conditions that include high pressure/high temperature (HPHT) wellbores, sub-salt formations, flows, losses, hole instability and narrow-margin drilling environments.

The solid expandable tubular operating envelope enables this robust technology to be used by operators world-wide who need a responsive system that address conditions proven to hinder drilling objectives, particularly in hostile and frontier environments. A more recent emphasis on expandable applications has focused on opportunity rather than need. Incorporating and planning the systems into wellbore construction as a design element rather than a contingency plan has averted numerous problems identified from offset data or real-time challenges during the drilling process. In this capacity, the expandable systems have become the enabling technology for previously undrillable wells. These systems have proven their relevance in wells without offset data and in hot exploratory profile wells where the operator has been able to drill deeper than previously thought possible. Also, when unknown conditions necessitate setting casing higher than planned, expandable technology has successfully minimized wellbore size reduction and enabled the operator to get back to the casing program with an optimized hole size.

Solid expandable tubulars continue to grow in acceptance and use, especially in wells that require atypical solutions, due in part to innovative technical development and equipment enhancements. This paper will explain how solid expandable tubulars are applicable in extreme drilling projects. Case histories will be used to illustrate how the current operating parameters facilitate a robust technology that can address difficult conditions and yet is adaptable enough to be tailored to help meet the growing worldwide energy demand.

Introduction

Previously published material discusses in detail the concepts of solid expandable tubular technology[1], application of the technology to address well challenges[2], and the effect of the expansion process on the system's tubulars[3, 4] and connectors[5]. Extreme drilling conditions add an extra element of difficulty when addressing the usual drilling problems – lost circulation, whether from a weak formation or from equivalent circulating density (ECD) related events, and borehole instabilities caused by complex lithologies or geological uncertainties. Although these problems might be due to extreme conditions, they may not necessarily require an extreme solution. The preemptive approach to incorporate solid expandable tubulars into the well plan has enabled operators to counteract the negative influence a problem may have on the drilling design be it in wellbore design or drilling methodologies. Taking the approach to focus on opportunity for the application of solid expandable technologies rather than only a need-based strategy has helped mitigate many challenges once considered to be hard boundaries that defined drilling limits. The proven installation history of expandable applications in extreme conditions illustrates the sound application of this technology and engineering processes. A design aspect of the system itself was developing an enabling technology robust enough to handle worst-case scenarios in uncharted drilling environments.

To isolate lost circulation, solid expandable openhole liners allow for effective isolation by preserving hole size due to the zero-clearance casing design effected by the use of solid expandable tubulars. Isolation is ensured by the liner being positioned accurately due to its bottom-up expansion process. This design element allows the liner to be "pulled" into the well-bore. During the installation process, a bottom-up expansion procedure pushes the liner to bottom during a pressure-regulated expansion, thus keeping the expandable liner at its lowest depth. The subsequent shortening experienced during the expansion process occurs in the overlap.

Borehole instabilities can be alleviated by running a solid expandable openhole liner without prematurely downsizing the wellbore. Instabilities can include sloughing or swelling shales due to incompetent formations or differential sticking due to low-pressure/high-differential pressures zones. Mud losses can occur due to the convergence of pore pressure and frac gradient. To overcome those issues, an unplanned solid expandable openhole liner can be set to compensate for low mud-weight drilling margins without sacrificing hole size.

In addition, solid expandable tubular systems reduce the well-tapering effect and help maximize wellbore internal diameter (ID) at TD. Conserving hole size, or diametric efficiency (DE), allows additional casing strings to be deployed to drill deeper and evaluate the resulting wellbore with sufficient hole size since the larger tools are more

- Reliable and efficient
- Readily available
- Durable and rugged
- Reasonably priced

In the case of extended-reach drilling (ERD), additional casing strings can be deployed with less penalty in regard to preserving hole diameter. This approach allows the operator to produce target zones through larger diameter production tubulars resulting in high efficiency completions.

Case Histories

Troublesome drilling zones expose a challenge to be dealt with whether in the guise of sub-salt rubble zones, known HPHT areas or low margin drilling environments. Knowing the most practical method of addressing these probable adverse conditions and when to act delineates need from opportunity. The case histories used to illustrate how expandables address problems in extreme conditions reflect the current state of the system, not the limits of the technology.

Case History 1

An operator drilling in HPHT conditions exceeding 380 degrees F and in excess of 20,000 psi in the Gulf of Mexico (GoM) experienced a major pressure regression and losses due to a geologically unpredictable zone. The deep shelf well required a means by which to isolate this unstable zone below the 11-3/4 in. base-casing shoe. The well was located in only 20 ft of water, considered shallow in this area, but the problem zone surfaced at a depth of ~17,000 to 19,000 ft. The needed expandable liner solution consisted of installing a 9-5/8 x 11-3/4 in. openhole liner ~2,150 ft in length (**Figure 1**). This liner-size selection optimized the well design and provided a system that covered the problematic zone and allowed for the installation of a 9-3/8 in. outside diameter conventional liner with an 8-1/2 in. ID. The application essentially enabled the operator to make-up, run and cement two strings of 9-5/8 in. series casing.

The liner, installed for isolation purposes, was also used to assist in controlling the unexpected pore pressure while drilling the next section. In spite of the elevated temperature and ~17,400 psi bottomhole pressure (BHP), the solid expandable system enabled the operator to drill and evaluate virgin rock in previously un-drilled formations with sufficient hole size.

Case History 2

To contrast the shallow water as depicted in the previous case history, a multi-national operator in the GoM drilled an ultra-deep, high-pressure well in ~3,400 ft of water and encountered a narrow pore pressure/fracture gradient zone. Encountering the problem zone dictated running and setting casing to cover up a weaker zone in a narrow-margin environment. Exacerbating the problem was the fact that the geologically unpredictable interval was at a measured depth of ~25,500 to ~28,700 ft, which resulted in an estimated BHP of ~23,320 psi in a 15.6 pound per gallon (PPG) mud weight environment.

The application of ~3,340 ft of 7-5/8 x 9-3/8 in. solid expandable casing installed at 28,750 ft is currently the deepest expandable casing system installed worldwide (**Figure 2**) to date. The expandable openhole liner preserved hole size to TD and enabled the operator to successfully drill and evaluate the intended ultra-deep target formation in a demanding frontier environment.

Case History 3

Encountering a challenging interval exhibiting lost circulation in a +6,600 ft deepwater environment can result in prohibitive costs to mitigate the situation. Deployment in 2002 of an expandable openhole liner system in an ultra-deepwater well to isolate a lost circulation zone illustrates how solid expandable tubular systems provide viable solutions to extreme engineering challenges.

A major operator was faced with a lost circulation zone from ~20,300 to 20,635 ft and was unable to drill ahead due to pore-pressure regression below a salt body.[6] The total amount of drilling mud lost to the formation exceeded 3,545 bbls.

The operator opted to run the next liner at 21,470 ft which was short of the planned depth of 23,000 ft. This 11-7/8 in., 71.8 lb liner would put the operator behind on the planned casing design by ~1,500 ft. While running in the hole, the 11-7/8 in. liner became stuck at ~20,190 ft, which then put the casing depths ~2,800 ft short of the original plan. All attempts to free the liner failed, so the liner hanger was set and the 11-7/8 in. conventional liner cemented at that depth.

The operator then drilled out the 11-7/8 in. shoe and cleaned out the already underreamed original hole section to prepare it for the solid expandable installation by spotting zonal isolation material in the hole section destined for the liner. The 9-5/8 x 11-7/8 in. solid expandable tubular system was run to TD at 21,442, which regained the original hole section and effectively extended the shoe depth of the 11-7/8 in. liner without sacrificing the previously drilled hole section. An inner-string cementing job was performed prior to expanding the liner. After the drill out of the 9-5/8 x 11-7/8 in. expandable liner shoe, an acceptable leak-off test was achieved for drill-ahead operations. This application and the subsequent solid expandable application, due to a sidetrack of the original wellbore, enabled the operator to drill to 29,452 ft with a 9-7/8 x 11-3/4 in. final hole section (**Figure 3**).

Case History 4

For a GoM well drilled from a tension leg platform in ~4,700 ft of water, the operator was drilling a geological sidetrack and needed an additional casing string to reach the objective. This deepwater directional well, angled at 41 degrees with a terminal sail angle of 71 degrees from vertical, was essentially a high angle, ERD challenge. The initial scope of the application consisted of running ~6,500 ft of 8-5/8 x 10-3/4 in. expandable tubulars to extend the intermediate string set at 15,766 ft. This application was followed by the installation of a "nested" 7-5/8 x (expanded) 8-5/8 in. openhole expandable system (**Figure 4**). The second system extended the shoe of the previously expanded system. Both systems added up to nearly 10,000 ft of solid expandable tubulars in one well. These two systems, one "nested" in the other, extended the definition and operating envelope of what could be expected with the application of solid expandable tubulars.

Case History 5

For the deepest well in the GoM, a major operator planned and executed an exploratory drilling operation with a TD of over 34,100 ft in ~3,570 ft of water. While drilling an intermediate wellbore section, losses were sustained due to a narrow margin drilling environment and the 11-3/4 in. casing had to be set higher than planned. To preserve hole size, the operator installed ~1,450 ft of a 9-5/8 x 11-3/4 in. system at a depth in excess of 28,550 ft, which effectively cured the drilling mud losses to the formation. After expansion, the operator was able to drill the next hole section and set 9-3/8 in. casing. This solid expandable tubular application helped the operator adhere to the well plan and reach the objective target that ultimately resulted in the deepest well drilled, logged and evaluated in the GoM.[7]

Operating Envelope for Expandable Liners

Although expandable liners and the expansion process have progressed greatly since the inaugural commercial installation in late 1999, wellbore conditions, drilling circumstances and current technology define the application limit. The current operating envelope is as follows:

- Inclination: 100° from vertical
- Temperature: 400° F
- Mud weight: 19.8 PPG
- Depth: 28,750 ft
- Hydrostatic pressure: 23,300 psi
- Length: 6,750 ft

Regardless of the operating conditions or any technology that may restrict application of these systems, solid expandable tubulars provide an enabling solution with the following benefits:

- Effectively creates an intermediate size of casing compared to conventional casing sizes
- Enables an operator to increase final hole size for a given number of casing strings
- Allows use of smaller marine riser, such as 13-3/8 in. casing, thereby enabling the operator to reach TD with adequate hole size while reducing the capital expenditure of the drilling phase.

Conclusions

Each solid expandable tubular application reinforces the versatility and reliability of this technology. The installation of expandable tubulars under the previous circumstances proves that these systems provide a viable solution to drilling and completion challenges in extreme conditions. Solid expandable systems have provided technically reliable solutions in the following conditions:

- HPHT environments
- Sub-salt sections
- Rubble zones
- Unconsolidated formations
- Shallow gas hazards
- Flows and losses
- Unstable hole sections
- Narrow margin environments

Many of these applications have optimized the technology by seizing installation opportunity rather than waiting on trouble-oriented need. As an enabling technology, previously "undrillable" wells are a possibility with the resulting improved hydraulics and reduced cuttings loading as well as minimizing the well tapering effect while adding strings for needed depth and reach.

Equipment and production records frequently mark milestones in the petroleum industry. Solid expandable tubular technology is making history not only as a viable contingency for drilling challenges but as planned-in solutions in the initial well design. These systems enable operators to explore for petroleum reserves in the most technologically challenging areas of the planet. Current and future environmental concerns and economic challenges for operators are forcing the industry to re-examine the drivers for exploring and producing hydrocarbons. With this goal in mind, the industry continues to look for ways to conduct a more environmentally friendly process that reduces the carbon footprint during drilling and production operations.

This revolutionary technology can be used as a cost-effective alternative, a feasible contingency or as a substantial element in the well design. The wells used in this paper to illustrate these versatile systems are generally below 20,000 ft in the most challenging frontier environments, such as ultra-deepwater, ERD projects and high-consequence areas. Even though geological targets are getting deeper and have been identified from 30,000 to 40,000 ft, solid expandable tubulars continue to be one of the few enabling technologies that help reach reserves that were previously labeled as inaccessible.

References

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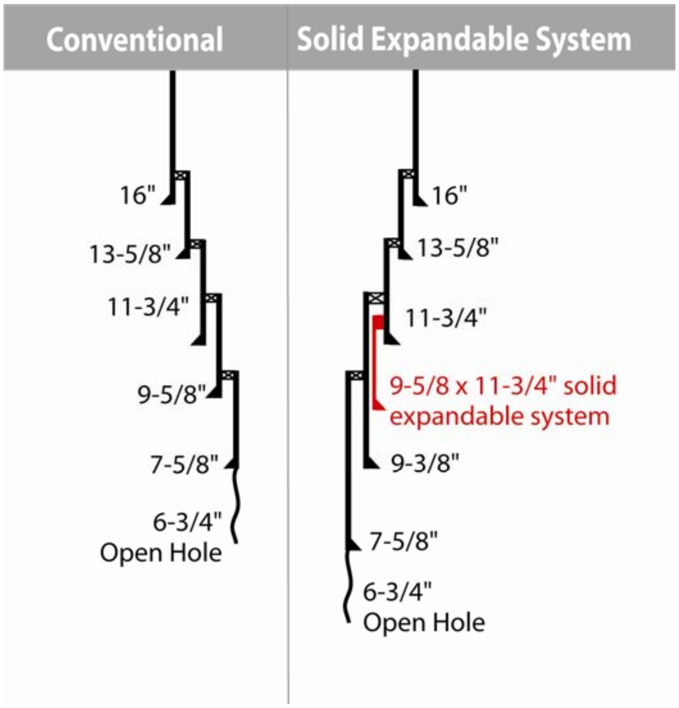

Figure 1 – Wellbore diagram for solid expandable system use in HPHT conditions.

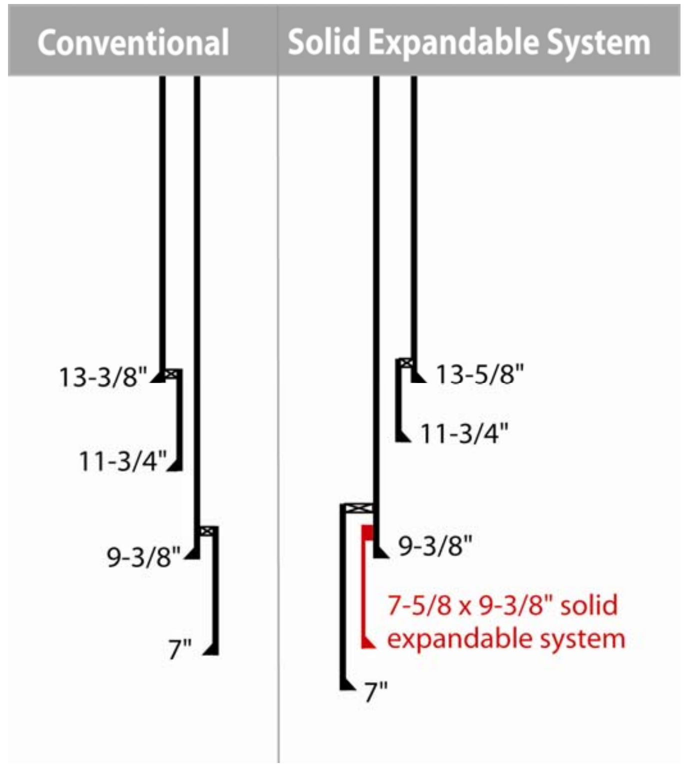

Figure 2 – Wellbore diagram to mitigate narrow pore pressure/frac gradient zone.

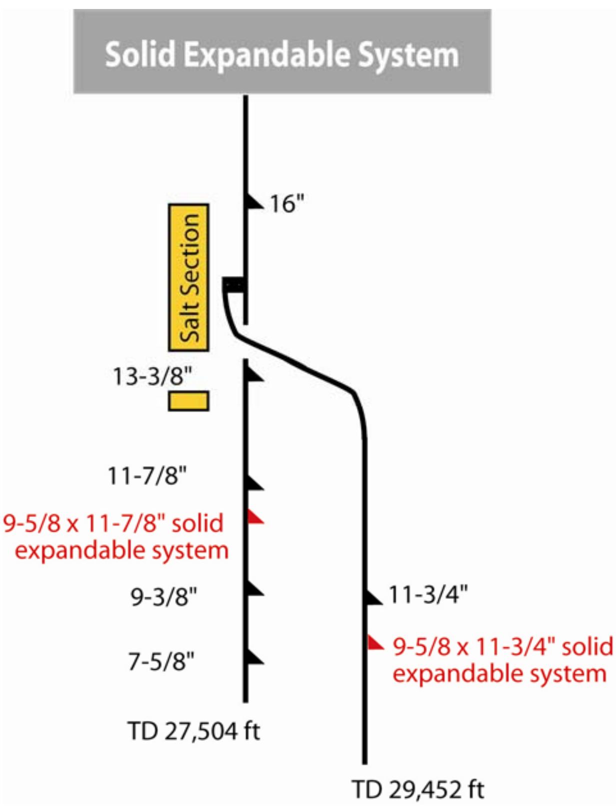

Figure 3 – Wellbore diagram of solid expandable system to extend shoe depth.

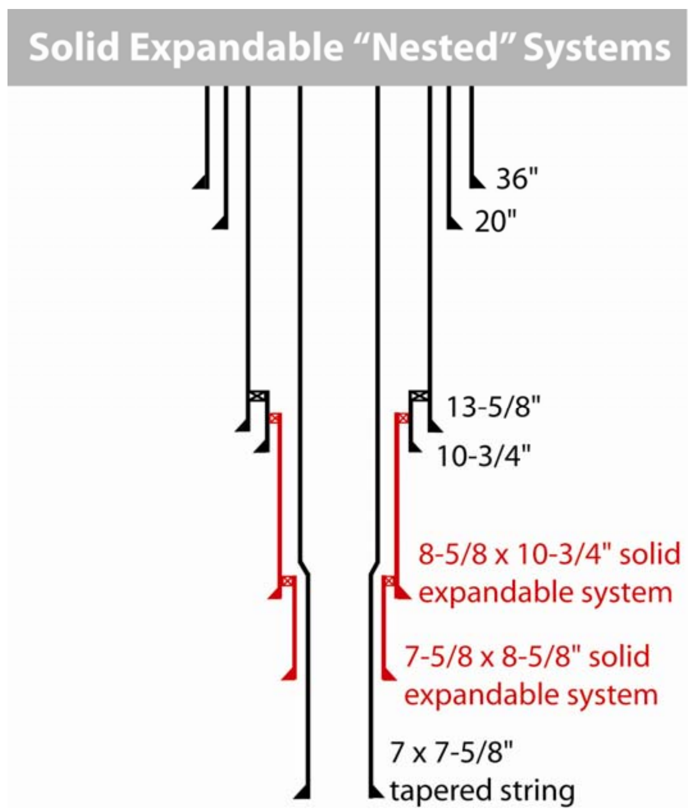

Figure 4 – Wellbore diagram of "nested" solid expandable systems.