



Attaining Significant Value with Solid Expandable Tubular Technology

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Abstract

The advent of solid expandable tubulars in the late nineties ushered in a new way to approach wellbore design, to mitigate common drilling problems and to revitalize existing or shut-in wells. With over 490 installations, solid expandable tubulars have established a legacy as an adaptable and enabling technology that provides reliable solutions without sacrificing hole size or the desired completion. As the technology matures, the application realm continues to broaden to include the installation of multiple systems in a single wellbore, expansion through milled windows and use in high-pressure, high-temperature conditions, to name a few. The technology also boasts an adaptable edge that enables it to be used on any of the large offshore rigs as well as the standard land rigs, without the need for any modifications.

Expandable tubulars have saved major and independent operators significant capital whether used as a contingency string or as a primary casing string planned into the base well design. Incorporating these systems into the initial wellbore plan has reduced the overall costs of some wells by up to 30%. These savings have enabled projects to be given the green light that were previously deemed cost prohibitive.

This paper will outline the basic operational process of the technology and explain how solid expandable tubulars have been used in a myriad of environments and conditions to address a variety of drilling challenges and problems. Actual case histories will be used to illustrate how this technology was advantageous to the projects, be it economic, technical or environmental. In addition, this paper explains how the planning and implementation process best ensures that the maximum value of the solid expandable system is attained.

Introduction

The wealth of history that exists regarding solid expandable tubulars is a testament to its enabling and practical capabilities since first field tested in 1999. Actually expanding pipe in situ opened a realm of mitigation possibilities that continue to provide dynamic options to drilling challenges. Solid expandable systems were initially used as last-resort contingencies that enabled operators to:

- Fight fluid losses and other borehole instabilities
- Isolate unwanted perforations of water and gas
- Remediate and strengthen corroded and worn casing while increasing the burst strength of the well
- Increase the probability of reaching the planned total depth (TD) with the desired casing size
- Extend economic field life of mature fields
- Optimize completions for maximum well flow and better reservoir drainage

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The technology quickly became a viable option, seriously considered by operators to address a myriad of drilling challenges and conditions. Installation demands and conditions prompted tool enhancements that made the expandable systems more robust, versatile and applicable.^{3,4} As the technology evolved, operators found that the most advantageous approach is to incorporate the expandable system into the drilling plan as part of the wellbore design.⁵ Solid expandables are able to give drilling engineers another tool to optimize well construction and minimize the loss of hole size while dealing with drilling challenges.⁶ Expandables mitigate difficult drilling conditions and preclude problems associated with challenging formations including the following:

- Sloughing shales
- Loss circulation zones
- Abnormally pressured zones

Fundamental Operational Process

Systems developed from solid expandable tubular technology include the Openhole Liner (OHLTM), Cased-hole Liner (CHLTM), FlexCladTM and Openhole Clad (OHCTM). Expandable casing is nominally sized API L-80 jointed casing manufactured to more exacting specifications. The use of electric resistance weld pipe results in a uniform wall thickness. Additional steps in the manufacturing process provide the material properties necessary to allow successful expansion of the pipe. The underlying concept of solid expandable tubular technology consists of cold-working the steel downhole to the required size.

The installation of solid expandable casing starts with drilling the hole section in which the casing is to be deployed. The launcher assembly, which is the bottom section of the expandable liner containing the expansion cone, is made up and run through the rotary table. Expandable casing is screwed together in approximately 36-ft joints until the required amount of liner is hanging in the slips. A liner hanger with five elastomer sections bonded to the pipe is placed at the top. The drillstring is then run as an inner-string inside the liner, made up to the expansion cone through the use of a safety thread connection and run to bottom.

Once on bottom, the cement is pumped as in an inner-string cement job. The liner can be rotated and/or reciprocated to facilitate an optimum cement job. Immediately after the cement is pumped, a latch-down plug is pumped. When the plug reaches the launcher, it seats and creates a pressure chamber below the expansion cone. Expansion is initiated by applying hydraulic pressure (through the top drive or high-pressure hose) down the drillstring while simultaneously applying sustained pulled (mechanical) force on the drillstring at surface. The liner expands at approximately 20 to 30 feet per minute. As each stand is removed from the hole, the pressure is bled off, and the stand is broken out and racked back. This process is repeated until the entire liner has been expanded and sealed back into the overlap with the base casing. The expansion cone is then recovered to surface, and the float shoe is drilled during the next trip in the hole (**Figure 1**).

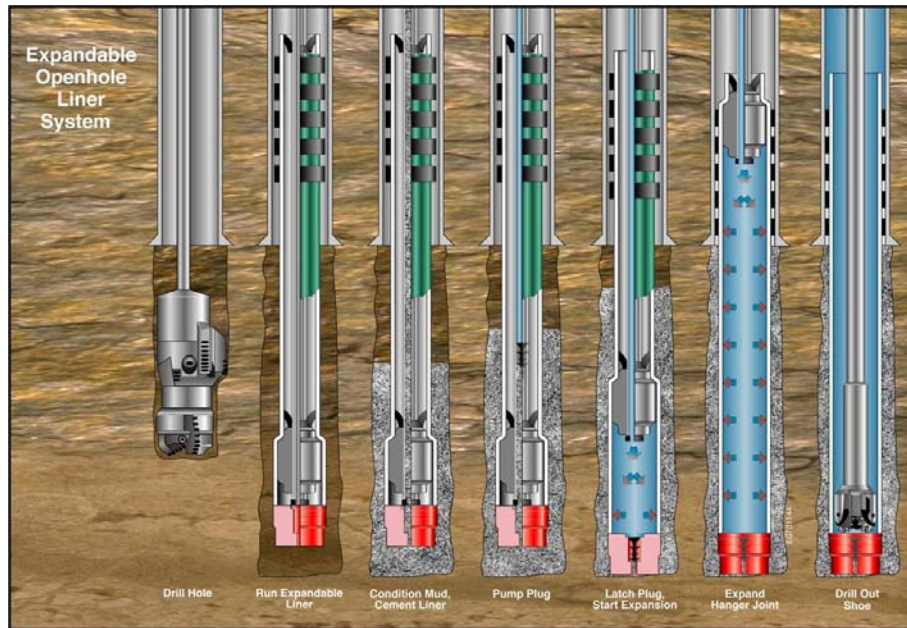


Figure 1 – Expansion sequence of the openhole liner.

Expansion Sequence

1. Drill the hole section to facilitate the expandable liner installation
2. Make a dummy run with a drift tool to ensure passage of the liner assembly
3. Run in the hole with the expandable liner, expansion assembly and launcher
4. Circulate and cement the expandable liner
5. Pump and seat the latch-down plug to facilitate liner expansion
6. Expand the expandable openhole liner
7. Circulate and conduct pressure test of the liner and the seal at the hanger joint
8. Expand the expandable liner's hanger joint
9. Pull out and lay down the expansion assembly
10. Drill out the expandable liner float shoe

Installation Conditions and Challenges

The key advantage of solid expandable tubular technology is that it enables an operator to reach TD with a larger wellbore size than could be achieved using conventional casing. The openhole liner system overcomes operational problems associated with borehole instabilities, pore pressure/fracture gradient issues and the effects of salt or subsalt formations. The expanded openhole liner effectively creates an intermediate size of casing compared to conventional casing sizes. Expandable casing reduces the tapering effect of telescoping casing strings by reclaiming the clearances required between conventional casing strings.

Pressure applied underneath the cone pushes the liner to bottom. The openhole liner system is then expanded from the bottom up. During this process, the length of the liner shrinks from the top. A bottom-up expansion process that pumps through and pulls on the inner-string generates greater forces than by adding weight to it. Because the inner-string is already being pulled out of the hole as a part of the bottom-up expansion operation, additional tensional forces, up to the weight of the liner, can be added as a secondary force to supplement the hydraulic expansion. The size of the tubular and its mechanical properties determine the expansion forces required.

Case History 1

Challenge and Objective

The operator used a semi-submersible rig to drill an exploration well in the Gulf of Mexico (GoM) in approximately 2,000 ft (~600 m) of water to a planned TD of ~20,000 ft (6,100 m). According to the well plan, a conventional 13-5/8 in. casing was set at ~6,500 ft (1,980 m). While drilling the next hole section for the 11-7/8 in. liner, an unexpected high-pressure zone was encountered. Five cement squeeze jobs failed to control fluid entry at the wellbore. The leakoff test at the 13-5/8 in. shoe was lower than the mud weight required to control the high pressure. The operator needed to get back to the planned drilling program and finish the well with an adequate hole size to evaluate potential production zones at TD.

Installation and Results

The operator decided to cut the 13-5/8 in. casing above the cemented section and pull it out of the hole. The well was sidetracked in open hole and drilled to a new formation to run the 13-3/8 x 16 in. expandable openhole liner (**Figure 2**). A drift run with a spiral-bladed stabilizer was made on the last trip in the hole. The expandable liner was made up to ~1,600 ft (490 m) in length, consisting of a launcher with pup joint, 43 full joints, hanger joint and the tapered guide. The well was circulated bottoms-up and the cement job (101 bbl) was performed as per plan. The latch-down dart was displaced and landed on schedule with 109 bbl of mud. The expansion was initiated with 2,000 psi and averaged 1,400 psi during the process. The hanger joint was expanded with 800 psi and by pulling 130 klb over the string weight. The cone exited the top of the liner at the calculated depth. The liner was successfully pressure-tested to 750 psi for 30 minutes. The shoe of the expanded liner was drilled out in five hours with a 13-3/4 in. medium-tooth rock bit.

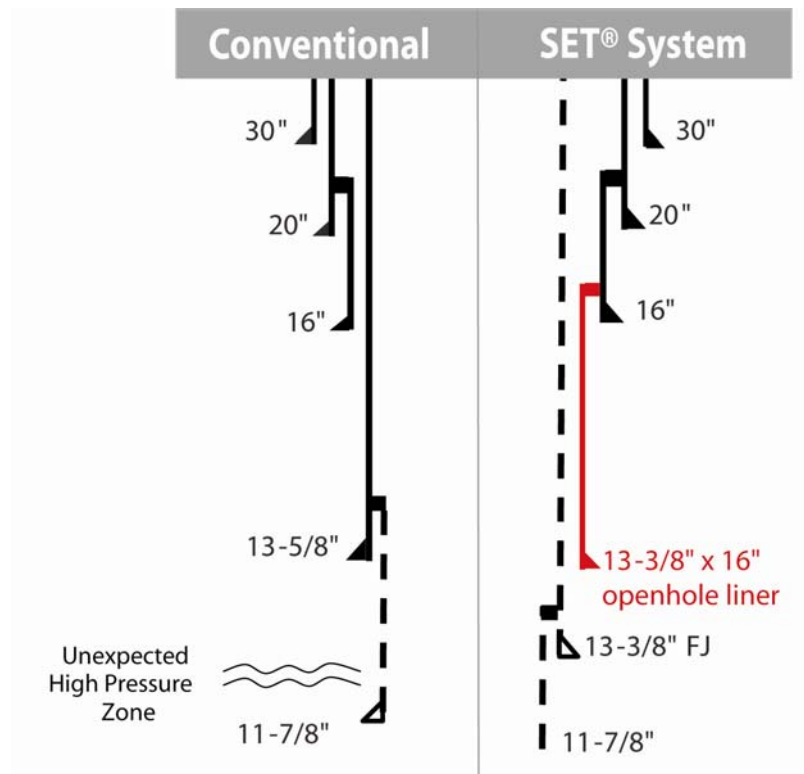


Figure 2 – Wellbore design for Case History #1.

Value Added

The operator could have moved forward with conventional technology by drilling ahead and setting the 13-5/8 in. casing followed by the 11-7/8 in. casing string. Setting the 11-7/8 in. casing higher than planned would have required the operator to drill ahead using slimhole tools, with their inherent problems, including a smaller inside diameter (ID) at TD.

The installed 13-3/8 x 16 in. openhole liner successfully returned the well to its original casing program. The operator ran a 13-3/8 in. conventional casing through the expanded liner. The solid expandable system allowed the operator to manage equivalent circulating densities (ECDs) effectively in preparation to enter the high-pressure zone.

Case History 2

Challenge and Objective

The installation of an openhole liner in a well in western Venezuela shows the versatility of solid expandable tubular technology. The operator had set a 7-5/8 in. conventional liner at ~10,500 ft (3,200 m). While drilling in a new formation, the operator entered a permeable sandstone followed immediately by a high-pressure zone at ~13,200 ft (4,000 m). The well became unstable. Eventually the lower section of the open hole caved in and the permeable zone started to take mud. The well was circulated and the mud weight was lowered. The operator's options to properly address this situation included sidetracking and redrilling a section of the well or applying an expandable openhole liner. In addition to the time and money expended, the sidetracking option also compromised hole size. A 6 x 7-5/8 in. solid expandable tubular system provided a solution that saved time, money and hole size (**Figure 3**).

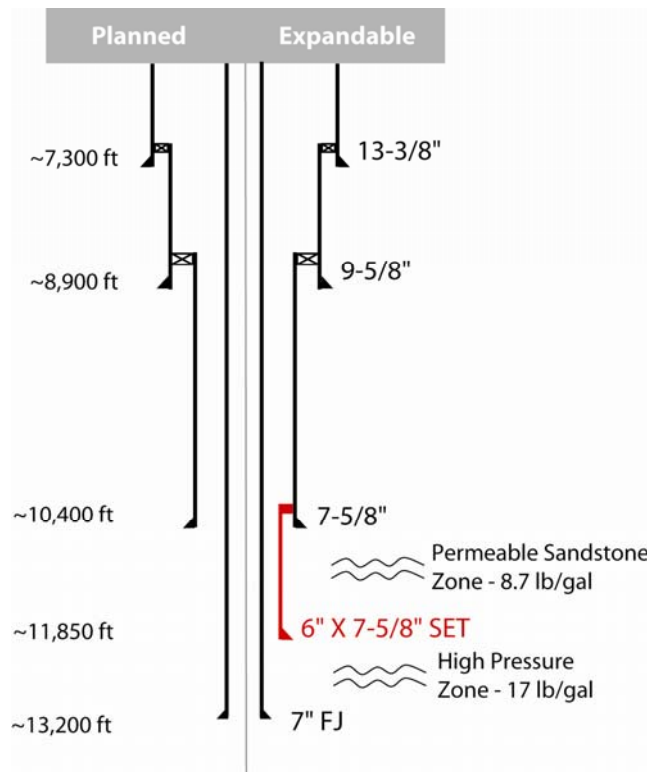


Figure 3 – Wellbore design for Case History #2.

Installation and Results

The purpose of this installation was to isolate high-pressure zones below the 7-5/8 in. liner. The hole was reamed to ~11,900 ft (3,600 m) and a high viscosity pill was pumped prior to pulling out of the hole. The launcher and the shoe joint were lowered in the rotary table. A total of 43 joints of liner and the hanger joint were picked up and run. The pre-expansion liner length run was ~1,650 ft (500 m). The inner-string was made up to the expansion assembly and run in the hole. A tight spot was encountered going in the hole at 11,300 ft and the liner was washed down until no drag was noted. The well was cemented and the expansion process was initiated with ~4,500 psi and 350 klb weight on blocks. The liner was expanded using the rig pump at a pump rate of 1 to 2 bbl/min and an average pressure of 4,400 psi. The pump rate was decreased to 0.5 bbl/min while the hanger joint was being expanded.

Value Added

The installation of this expandable liner enabled the operator to get back on the original wellplan and reach the target zone with adequate wellbore size. By using the solid expandable tubular system, the operator was able to set an unplanned casing string without sacrificing hole size.

Case History 3

Challenge and Objective

An independent operator with a large gas field in Central Texas needed a technical solution to develop the field as economically as possible. With plans to drill 12 to 18 wells in this field over the next few years, the

operator realized that any cost-per-well savings would extrapolate into huge savings for the field. Field development challenges included the determination of the maximum number of wells that could be drilled while reducing the cost per well, despite the rising costs of services. As an example of the rising costs, in the first six months of field development rig rates had increased approximately 40%. To combat rising rig rates, the time spent drilling each well needed to be reduced. The major culprit of time consumption, an intermediate section of 12-1/4 in. hole, had proven to be problematic in the four wells drilled in the field. Eliminating the need for this size of hole section would greatly increase the efficiency of drilling operations. As a challenge, however, the operator required a minimum of 4-1/2 in. production casing to facilitate the high gas flow rates of this field.

Installation and Results

After drilling approximately four wells with a conventional big pipe design, the new slimhole well design was implemented. Incorporating a 6 x 7-5/8 in. solid expandable system into the base well design enabled the operator to drill a 14-3/4 in. surface hole instead of a 17-1/2 in. hole, allowing drillout of surface pipe one day earlier. Below the surface pipe, the operator drilled a 9-7/8 in. hole (drilled at 3.0 days/1,000 ft) versus a 12-1/4 in. hole (drilled at 4.8 days/1,000 ft). The solid expandable liner was then run below this section, allowing for 4-1/2 in. production casing at TD to facilitate planned production rates (**Figure 4**).

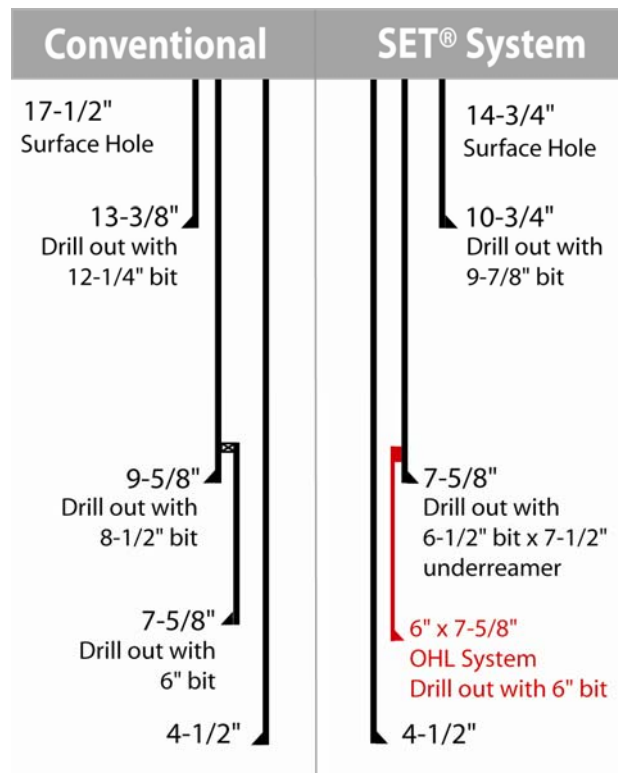


Figure 4 – Wellbore design for Case History #3.

Value Added

Overall results showed that the operator reduced total drilling time to target depth by 19%, from 89 to 72 days. In addition to cost savings from reduced drilling time, the operator could cut costs even further by

using water-based mud, due to the improved hole cleaning dynamics. Using water-based mud saved money in both environmental and disposal costs.

When evaluating total savings per well, the solid expandable system reduced total drilling costs by \$79 per foot, or approximately \$1MM per well. From a field development perspective, these savings translate into every fifth well being drilled at no cost, and four free wells per year.

Planning Process

Engineering support for using expandables can be provided throughout the life of the well. If the well is in the planning stages, the first step is to evaluate the well. It is imperative to know the total depth of the well, the number of casing points required and the production casing required.

Once these questions are answered, potential casing scenarios can be evaluated. Each hole section can be analyzed to determine the best interval for an expandable. When performing this analysis, items to consider include the following:

- Length of hole section
- Burst and collapse requirements
- Hole hydraulics
- Drilling challenges

It is important to note that there are advantages to setting the expandable systems higher in the wellbore. For example, the upper wellbore is more stable because the pore pressure/fracture gradient window is usually wider. Also, in the larger expandable systems, more annular clearance exists between the expandable tubular outside diameter and the ID of the base casing. Due to the larger cross-sectional areas of the big sizes, the expansion pressures are lower. And, running an expandable in the upper section of the wellbore still allows for additional expandables to be run deeper in the wellbore if needed.

By evaluating the placement of the solid expandable liner proactively, the most appropriate section for system installation is decided in the design stage rather than in the operational stage. If the solid expandable tubular is only considered as a last resort to solving drilling problems, then the choice of size, length and depth of the installation are dictated by the situation after a problem occurs. These problems can be difficult to manage and lead to running the expandable system in or around hole sections with the greatest risks.

Following initial placement of the expandable, the design can be validated by calculating the casing design, torque and drag and swab and surge simulations to ensure that the solid expandable system is fit for purpose. At this point, all parameters affecting the expandable can be considered. The ID and weight of the base casing is fundamental information that governs the design because the solid tubular not only expands in the open hole but also expands in the overlap with the base casing. Because ID is crucial to the expansion process, anything that has a restrictive ID should be evaluated. The following components, at a minimum, should be analyzed:

- Openhole conditions
- Inline centralizer ID
- Float equipment
- Landing collar ID
- Casing connection ID
- Shoe joint ID and length
- Dogleg severity in the overlap and openhole section
- Liner hangers
- Overlap casing ID

If the well is already in the operational stages when an expandable is being considered, the well drilled to date is reviewed and the remaining options for placement of the expandable are determined. The installation of the expandable is preceded by a thorough system design, and recommendations on well preparation are provided. Upon installation of the expandable, post-job reports are generated to ensure that

learnings from previous jobs are implemented in the future. Also, timelines are set for each post-job analysis so that information on the installation is available as soon as possible after the job is completed.

Conclusion

The increasing demand for energy has pushed the oil and gas industry to re-examine and re-evaluate processes and equipment. Methodology, procedures and technology evolve to provide the tools for practical and profitable access of production zones. Extreme conditions, troublesome formations and sensitive environments influence drilling programs and projects and can easily turn an already complicated process into a complex ordeal. Static wellbore designs, unreliable cement squeezes and time-consuming lost-circulation materials too often fail to address drilling challenges with longevity and reliability. The problems that ensue require a solution economically feasible, logistically practical and technically proficient. Solid expandable tubular systems provide a dynamic approach to well construction by strategically applying expandables to push the drilling envelope in new territories and to develop mature assets.

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