

The Value of Solid Expandable Tubulars in Openhole and Cased-hole Environments

Author: Eduardo Pérez-Roca

Company: Enventure Global Technology

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Abstract

Since its inception in the late nineties, solid expandable tubular technology has saved major and independent operators significant capital whether used in drilling operations or in workover projects. In drilling operations, these systems have been used as a contingency string and as a primary casing string planned into the well design. Incorporating these systems into the initial wellbore plan has helped reduce the overall costs of some wells by up to 30%. For workover projects, solid expandable tubulars repair and/or reinforce existing casing while minimizing loss of hole size that enables use of the same 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. In addition, these systems have provided the impetus for operations that result in compelling returns on production-enhancement projects for old and new wells and fields.

This paper will explain how solid expandable tubulars have been used in a myriad of environments and conditions to address a variety of drilling and workover challenges and problems. Actual openhole and cased-hole case histories will be used to illustrate how this technology was advantageous to the projects, albeit economic or technical.

Introduction

Solid expandable tubular technology has not only lived up to its promised potential but surpassed it with a proven record of over 700 applications (as of July 2007) in varied locales, circumstances and environments. This broad installation history illustrates how adaptable and enabling expandable technology and engineering processes have become. Previously published material discusses in detail the technical and evolutionary concepts of solid expandable tubular technology. To briefly recap the basic concepts of the expandable technology, tubulars are re-sized in-situ through a cold-drawing process that deforms the steel past its elastic yield limit into its plastic deformation region but stops short of its ultimate yield strength. The main components of an expandable liner run in the openhole, from bottom to top, include a launcher assembly that houses the expansion cone, the solid expandable liner and an anchor hanger. The launcher is constructed of a thin wall, high-strength steel with an outside diameter (OD) compatible with the drift of the base casing. These same components are part of the cased-hole expandable liner with a simple variation—an anchor-hanger joint with a series of elastomer bands outside the body immediately above the launcher serves as a seal and anchors the bottom of the system to the base casing.

Solid expandable tubulars are made of electric resistance weld (ERW) pipe manufactured to specifications considerably more stringent than those specified by API for oilfield use but with pre-expansion properties similar to those of L-80 material. The metallurgical composition of this pipe yields greater ductility while still retaining its strength properties. The use of ERW pipe provides greater uniformity of wall thickness—a constant value of the inside diameter (ID) that facilitates a smooth expansion. The effectiveness of the expandable connections is of utmost importance, which enables extensive lengths, to date up to 2,093.60m (6,867 ft), to be expanded in a single run. The upper section of the system, the hanger joint, has elastomer bands on the outside of the tubular body that allows the expanded liner to be “clad” to the base casing.

The Solid Expandable Solution

Installing solid expandable liners starts with drilling the hole section followed by making up the launcher assembly and running it through the rotary table. Expandable casing is screwed together in approximately 36-ft joints until the required amount of liner is hanging in the rotary table with the liner hanger placed at the top. The drillstring is run inside the liner, latched into 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 dropped. 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 base casing. The expansion cone is then recovered to surface and the float shoe is drilled out during the next trip in the hole (**Figure 1**).

Expandable technology can be applied throughout well construction and remedial work across field operations at different phases. These enabling systems address well challenges from the usual to the extreme—including openhole expandable liners used for control of lost circulation zones, casing shoe extensions and isolation of unstable formations. Water-bearing fractures have been successfully isolated and controlled with openhole expandable systems installed across the problem area only, rather than the entire open hole. Cased-hole applications have been used to isolate old perforated intervals or protect weak casing in areas where a conventional squeeze would not have been effective enough to adequately seal off the open intervals. Developing a field rejuvenation plan with solid expandable systems incorporated as a key strategic element has enabled operators to counteract the negative effects of corrosion, thereby extending the life of the wells. Operators have been able to recomplete into other reservoirs using the existing wellbore reinforced with a solid expandable system to recover reserves that otherwise might have required drilling new wells. Many challenges once considered severe enough that wells were identified as plug and abandon (P&A) candidates have been mitigated with solid expandable liners, turning costly liabilities into productive assets.

When conducting exploratory drilling operations, the unknown can be potentially hazardous. Unpredicted hole conditions are difficult to plan for and lead to running the expandables in or around hole sections with the greatest risks. Initially, operators focused on using a solid expandable solution primarily to cure wellbore problems and minimize any loss of hole size incurred by setting the string high and losing a casing point. However, for wells in development and remedial phases, solid expandable tubulars have provided flexibility in design and well construction. Taking full advantage of system potential requires incorporating it into the original well design. Instead of being used as just a remedial solution to unexpected problems during drilling or production operations, solid expandable tubulars have been deployed as an efficient construction element able to significantly “enhance” wells. Wellbores constructed to maximize productivity provide a conduit to recuperate the economical investment in a shorter period of time.

Building on Success

With over 250,000m (820,000 ft) of pipe expanded, solid expandable tubulars have successfully been used to:

- drill in high pressure zones
- drill in deepwater environments
- drill in troublesome sub-salt plays
- repair and mechanically enhance existing casing strings
- revitalize existing wells

This extensive application legacy reinforces the systems’ reputation as a practical solution to access reserves that cannot be reached with vintage methods, processes and tools. The increased ID attained with solid expandable tubulars enables the use of larger drillpipe for greater weight-on-bit as well as improved hydraulics and hole cleaning results in extended-reach drilling (ERD). Another advantageous application for solid expandable tubulars is in conjunction with sidetracking operations. Expanding solid tubulars through windows and off whipstocks preserves hole size that results in increased openhole lateral length and better directional control in the openhole. The larger ID enables the operator to consider more options such as implementing “smart-well” systems and multilateral technology. The evolutionary direction of solid expandable technology is not only to enhance systems that reduce wellbore tapering but to commercialize systems that eliminate loss of hole size altogether. A recent field appraisal well included the successful expansion achieving a uniform 10.4 in. ID across three consecutive liners in real-life conditions. Being able to redefine use and expand the application realm have been primary drivers behind the continuous development and evolution of the technology.

Case History 1: Ultra-Deepwater Application

Traditionally, as water depth increases, the size of the drilling vessel and equipment capacity increases. Water depth, ocean conditions, BOP and riser size affect the size of the rig. Drilling margins, such as the difference between pore pressure and fracture gradient, narrow as operations move into deeper water. Narrower margins require more casing strings to drill to an equivalent depth below the mudline compared to a well drilled in shallower water or drilled on land. To address these issues while still in the project planning process, an operator incorporated solid expandable tubular systems into the wellbore design to reduce the chance of

unstable hole conditions during installation. The well in which these two planned systems were installed was in water depth ~2,440m (~8,000 ft) (**Figure 2**). The initial solid expandable openhole liner was installed below the 16 in., 84.0 lb/ft casing string set at ~3,600m (~11,800 ft). A 13-3/8 x 16 in. expandable openhole liner was set at ~3,870m (~12,700 ft). The second application in the well consisted of ~460m (1,500 ft), 9-5/8 x 11-3/4 in. openhole expandable liner installed below the 11-3/4 in. drilling liner. These two successful applications enabled the operator to explore deeper objectives and ultimately reach TD with 8-5/8 in. casing. The up-front planning made it possible for the operator to reach TD with adequate hole size and to mitigate downhole risk. Optimum hole size enabled the operator to log the well with larger, more reliable tools. Planning solid expandable tubular system high in the wellbore contributed to a significant reduction in flat time when compared with offset wells drilled in the area.

Case History 2: Slimhole System Installation

Another operator took up-front planning a step further by incorporating solid expandable systems into a multi-well development project. Offset data and prior experience enabled this operator to mitigate known challenges before they became problems; the most critical being designing and implementing an effective BHA that resulted in fine-tuning the use of built-for-purpose bi-center bits and underreaming technology. The defined project objective was to reach TD in a high pressure, high temperature (HPHT) environment and provide a 4-1/2 in. minimum production casing to facilitate the potential high-flow rate in the field.

The optimized well design drilled a 13-1/2 in. surface hole instead of a 17-1/2 in. hole and ran a 10-3/4 in. surface casing instead of the 13-3/8 in. A slimmer well profile at the surface resulted in one less day of drilling operations for this section. Drillout of the surface pipe with a 9-7/8 in. bit replaced an earlier design of the 12-1/4 in. hole section. A corresponding 7-5/8 in. intermediate string replaced the customary 9-5/8 in. casing. The operator continued to see significant decreases in drilling and underreaming times in these upper sections. To achieve the desired 4-1/2 in. production casing at TD to facilitate planned production rates, the operator followed up with a 6 x 7-5/8 in. solid expandable tubular system in lieu of an 8-1/2 in. hole with a 7-5/8 in. drilling liner. This 6 x 7-5/8 in. system has a 6.640 in. launcher OD with a 6.009 in. drift ID post expansion that enables drilling a 6 in. hole to TD. The production casing consisted of a 5 x 4-1/2 in. tapered string to surface (**Figure 3**). Without the solid expandable liner, conventional tubulars would have necessitated setting 5-1/2 in. flush-joint liners, limiting the available hole to 4-3/4 in., and resulting in a 3-1/2 or 4 in. liner at TD.

A smaller hole impacts operations with a slower rate of penetration and a higher equivalent circulating density that would detrimentally affect drillability of overpressured lower zones and compromise overall completion strategy and productivity. Improvements in drilling performance by slimming the wellbore ultimately reduced drilling time to TD from 94 days to ~54 days, nearly 43%.

Case History 3: Field Restoration

As oil fields mature, producing wells occasionally experience co-production of oil and water because of aquifer encroachment. Controlling water production is a major challenge in reservoir management. In many cases, economic analysis reveals that handling producing water may be as expensive, if not more, as recovering the oil. An initial remedy has been to simply shut in the wells because of the high water cut. This drastic measure would occasionally cause the wells to corrode and expose the formation water to the fresh water level up the hole. An operator in the Far East considered labeling a large quantity of wells as P&A candidates because of high water cut even though significant oil reserves were present. Previous alternate solutions such as cement squeezes and casing patches did not provide adequate results and proved to be inconsistent from one job to another. Taking into account the favorable oil price in the current international market, the operator decided to use solid expandable technology. For this multi-well, multi-field project, bull-nosed 4-1/4 x 5-1/2 in. 23 lb/ft cased-hole liner systems were installed. Liner lengths for this extensive project have ranged from ~25 to 80m (~75 to 260 ft) with setting depths ranging from ~500 to 3,150m (~1,650 to 10,400 ft). Usual initiation pressure has been ~32 MPa (~4,700 psi) with the average expansion pressure ~20 MPa (2,900 psi) (**Figure 4**). Compared to other technologies and solutions for restoring old wells, these systems simplified the workover process and reduced total cost. These application have had a success rate of 99% and increased the average daily output about 22 bbl/day per well. At this rate of return, the installation is paid for in 30 days. Additionally, individual wells have shown improvement from five to over 400 BOPD and from shut-in to 128 BOPD.

Case History 4 – Sidetrack and Smart Well Integration

A major operator in the Middle East implemented a plan to maximize oil recovery from a large field producing from a limestone reservoir. Although significant production increases were initially attained, recovery efforts were hampered by the inability to re-enter openhole sidetracks for remedial purposes. The operator also encountered water-production problems with no real way to identify the source of the water or to remediate it if the source was found. By introducing solid expandable liner systems into the plan in combination with intelligent well technology, a reliable and feasible solution was implemented. Due to the presence of a large gas cap and a relatively weak aquifer, the use of horizontal completions to minimize the chances of early water breakthrough were required to achieve economically desirable production rates. The original main wellbore was underreamed from 6-1/8 to 7-1/2 in. from the 7 in. shoe. A 5-1/2 x 7 in. expandable liner was then made up and run in the hole. Once on depth, the hole was circulated with water to ensure adequate hole cleaning while batch mixing spacer and slurry. After displacing the spacer and cement, the assembly was expanded (**Figure 5**).

A cement retainer was run and set after which a 5-1/4 in. OD whipstock was run inside the expandable liner. A window was milled in the casing followed by a 5-1/2 in. directional drilling assembly to drill the lateral off the whipstock to a TD of ~1,410m (~4,625 ft). The whipstock was retrieved to prepare for drilling the second lateral. A retrievable plug was run and set at ~1,760m (~6,430 ft) and a whipstock was run on top of the plug. Again, a 5-1/2 in. assembly was used to drill the second lateral that achieved total footage of ~2,235m (~7,340 ft). The whipstock and plug were retrieved and a concave mill drilled out the float shoe in the expandable liner.

The final step in the workover operation involved installing the intelligent completion system (**Figure 6**). Integrating sidetracking operations, solid expandable tubulars and intelligent well technology has allowed for re-entry into the lateral for remedial work and real-time pressure, temperature and flow data without the need for well intervention. Intelligent well components have enabled the operator to quickly identify any water-producing zones and have provided a means for shutting off the water production, again without the need for well intervention.

Conclusion

As illustrated with the previous case histories, new uses for solid expandable technology are being identified regularly. This enabling technology is no longer just an interesting theory but provides viable solutions to drilling and recompletion challenges in both conventional and extreme well environments. Solid expandable systems have provided operators with solutions and options that bring an attractive value proposition for field development and revitalization. Accessing previously out-of-reach reserves and recompletion of lost or shut-in wells are less cost prohibitive with solid expandable technology. The savings in time, money and resources realized have given operators the impetus to use the systems in more innovative applications. The evolution of the technology is due in part to the documented success of how expandable tubulars have been able to save wells in danger of not reaching their planned objectives. The increasing demand for oil and gas has pushed the energy industry to re-examine and re-evaluate processes and equipment to tap potential zones and probable resources. Methodology, procedures and technology, such as the solid expandable solution, have evolved to supply the necessary tools to practically and profitably access valuable reserves.

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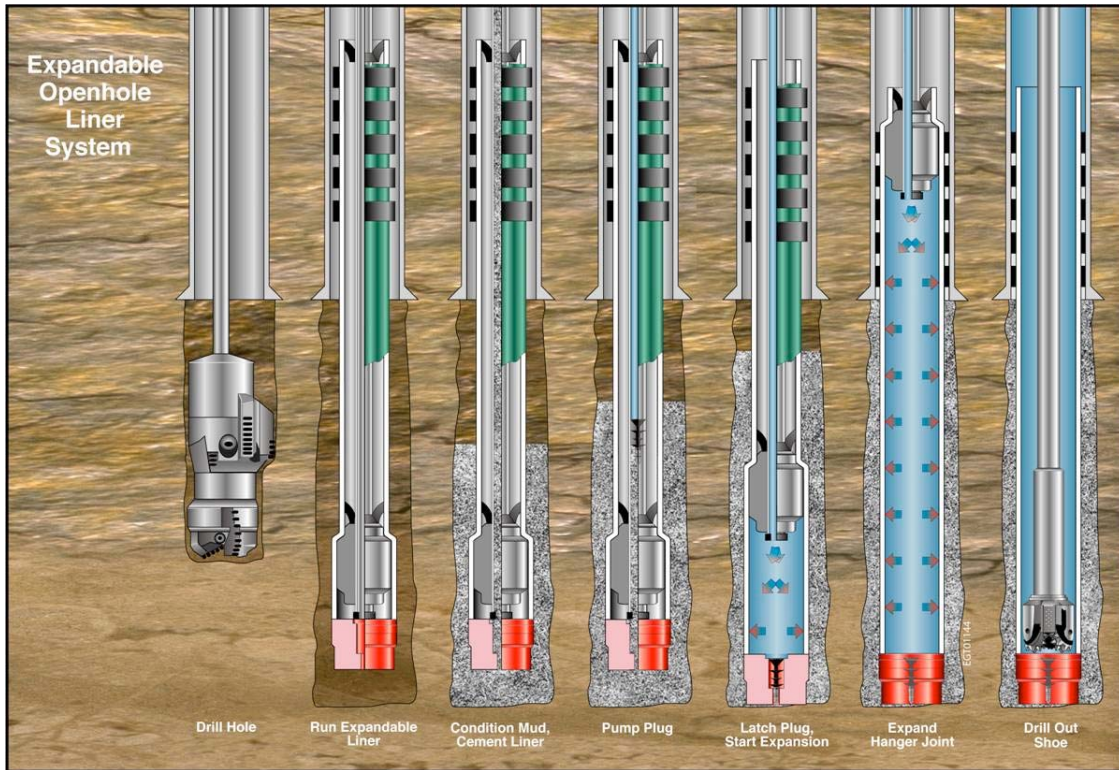


Figure 1 - Installation sequence for a solid expandable openhole liner system.

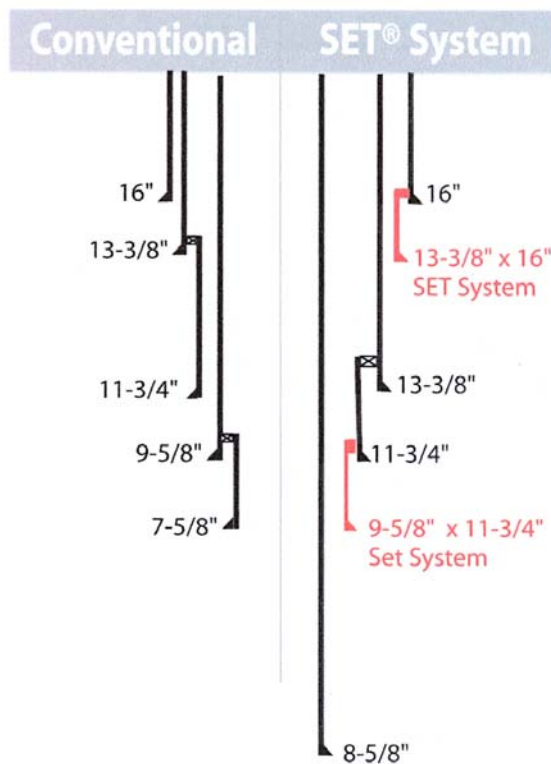


Figure 2 – Conventional vs. expandable solid expandable tubular installation for an ultra-deepwater well.

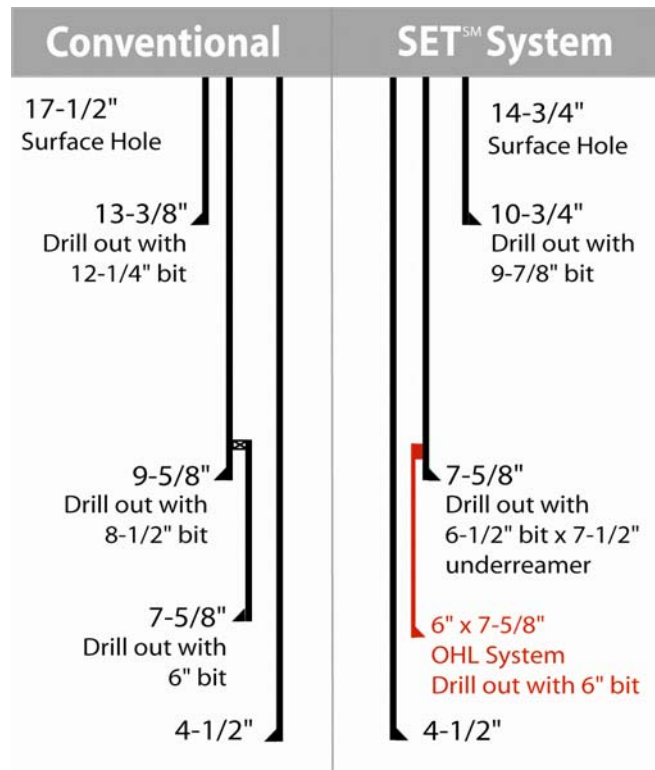


Figure 3 – Solid expandable system provides a slimming wellbore profile while maintaining adequate hole size at TD.

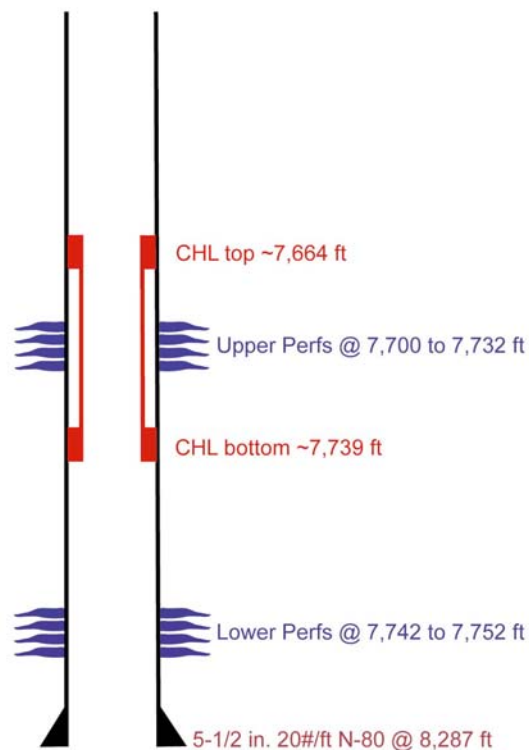


Figure 4 – Wellbore schematic example of solid expandable systems that simplify the workover process and reduce total cost in a field-restoration project.

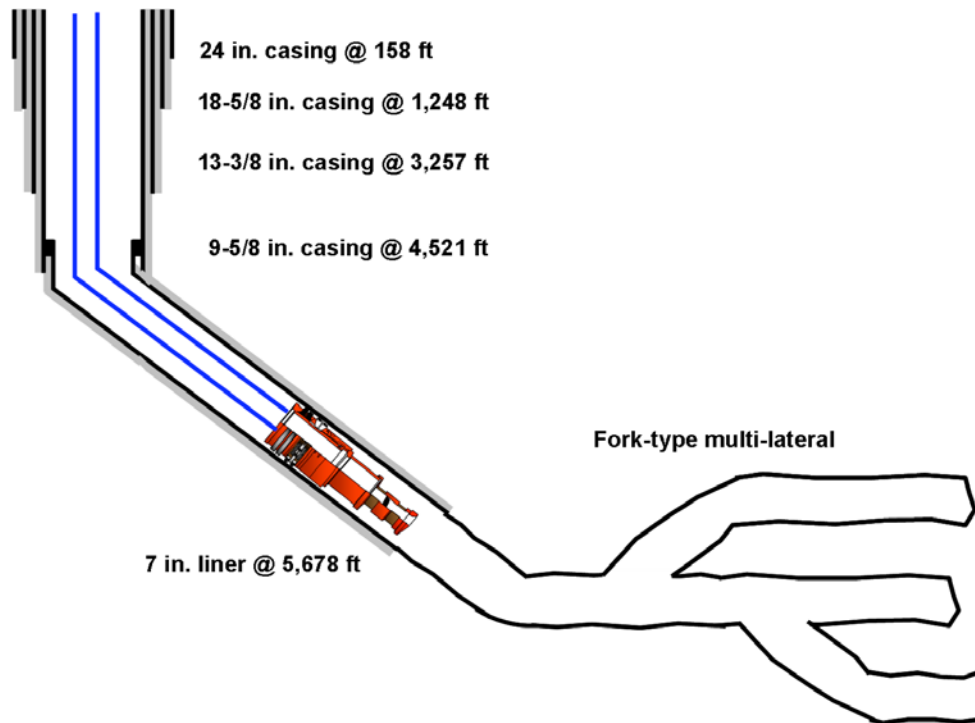


Figure 5 – Hole diagram of upper casing and horizontal completion construction.

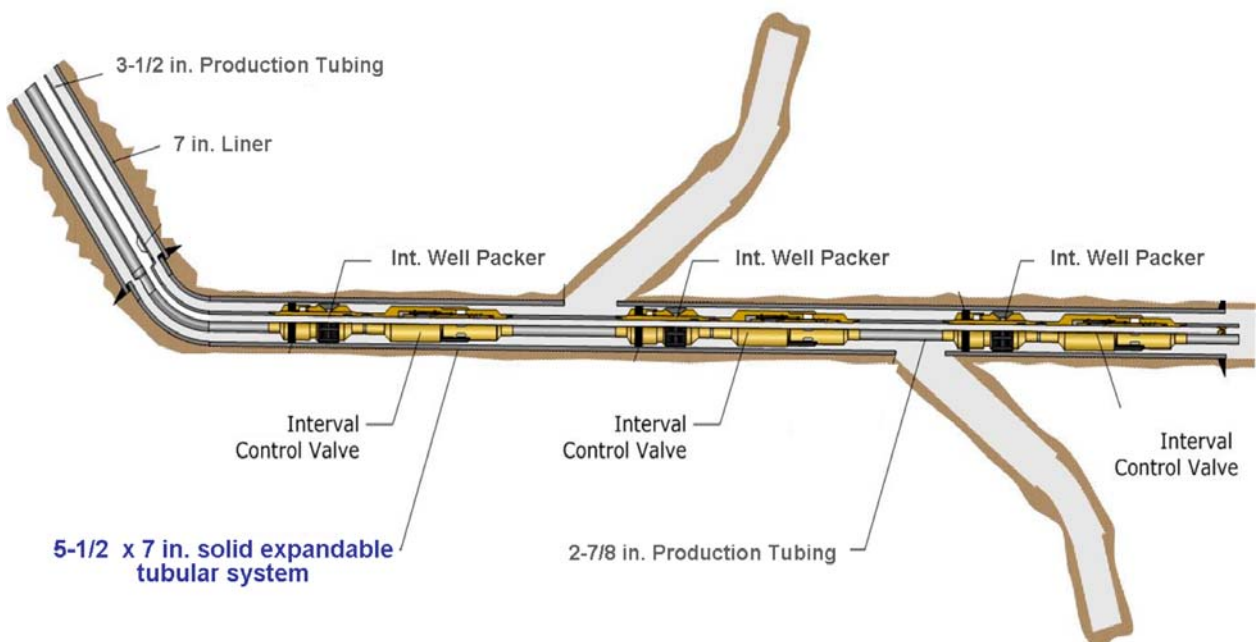


Figure 6 – Combination of solid expandable tubulars and intelligent well completion system.