Solid expandable tubulars are enabling technology

THREE LONG-STANDING ISSUES that affect virtually every well have continued to become more important: conservation of hole size, hydraulic isolation of selected zones and maximization of well life.

All of these issues involve one of the industry's most fundamental technologies—wellbore tubulars.

Until recently, resolving these issues with conventional tubular technology was difficult, especially in deep-drilling and extended-reach applications, in wells utilizing liner hangers, and in aging wells containing deteriorating casing.

A new technology—solid expandable tubulars—is successfully addressing these issues in commercial applications.

Over the past year, Solid Expandable Tubular (SET) technology has made the leap from conception to an enabling technology.

TECHNOLOGY OVERVIEW

The underlying concept of expandable casing is cold-working steel tubulars to the required size downhole.

The process is very unstable mechanically. Thus, there are many technical and operational hurdles to overcome when using cold-drawing processes in a downhole environment.

An expansion cone is used to permanently mechanically deform the pipe. The cone is moved through the tubular by hydraulic pressure across the cone itself and/or by a direct mechanical pull or push force.

The differential pressure is provided through an inner string connected to the cone, and the mechanical force is applied by either raising or lowering the inner string.

The progress of the cone through the tubular deforms the steel beyond its elastic limit into the plastic region, while keeping stresses below ultimate yield.

Expansions greater than 20% based on the inside diameter of the pipe have been accomplished. However, most applications using 4¼-in. to 13⅜-in. tubulars have required expansions of less than 20%. At the bottom of the solid expandable tubular (SET) system is a canister, commonly known as the "launcher," that contains the expansion cone.

The launcher is constructed of thin-wall, high-strength steel that has a thinner wall thickness than the expandable casing.

Because the launcher has a thinner wall and its outside diameter (OD) is the same as the drift of the previous string of casing, it can be tripped into the hole through the previous casing string.

The difference in the wall thickness of the launcher and the elastomer-coated hanger joint(s) allow the expanding pipe to be sealed, or "clad", to the previous casing string.

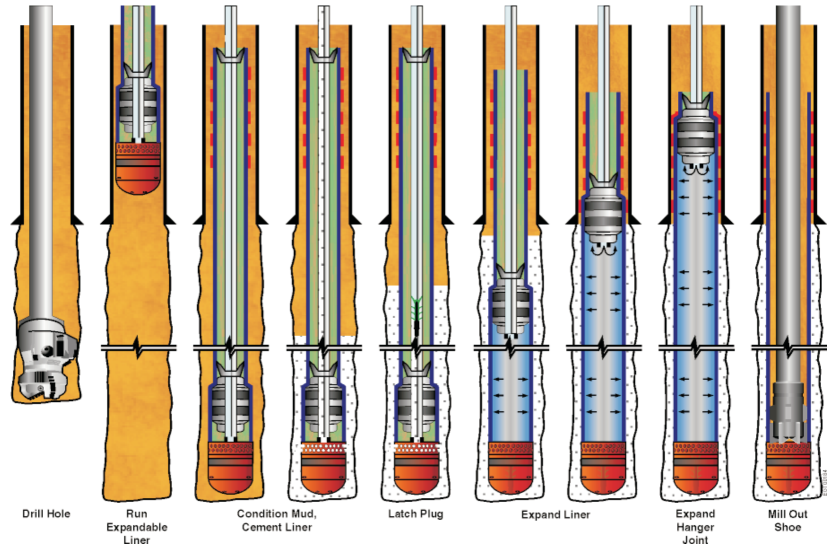
The expanded pipe ends up with an outer diameter, after expansion, that is greater than the outer diameter of the launcher, while the inner diameter of the pipe expands to the same inner diameter of the launcher and the expanded pipe.

The expandable casing itself is run pin up. A proprietary thread design was developed in cooperation with **Grant Prideco** so that the connection would maintain a seal throughout the four-point bending process the connection would experience during expansion.

Because the expansion cone moves from the bottom to the top of the string, expansion forces must be applied to the inside component of the connection (the pin) first, so there is no risk of the connection "unzipping" during the expansion process.

Applying expansion forces to the box first might cause the box threads to move away from the pin threads.

At the top of the liner string is a special liner-hanger joint that includes an external elastomeric coating and external steel rings.



Installation of the Expandable Openhole Liner System involves, from left: Drill hole; run expandable liner; condition mud, cement liner; latch plug; expand liner; expand hanger joint; and mill out shoe.

When the expansion cone runs through this joint, it produces metal-to-metal and elastomeric seals with the previous casing string.

Serving as the liner's top seal, this joint replaces any liner-top packer as well as the liner hanger.

INSTALLING A SET SYSTEM

To install an expandable system, it is necessary to drill an over-gauge hole. The extra space allows a good cement job around the expanded casing.

Once the open hole is drilled, the string is run with a launcher sub-assembly made up on the bottom of the expandable casing string.

An inner string cement job is run through the assembly to avoid contamination of the cement by other fluids while cementing.

Once the casing is cemented through the inner string, cone and shoe, the displacement dart lands in the shoe, sealing off the end of the work string and creating a pressure chamber.

The assembly is then pressured up to 1,500-3,000 psi (depending on system size). The pressure blows out burst disks in the sub-assembly, transmitting pressure to the base of the expansion cone.

The pressure drives the cone up the casing string causing the casing to expand. The work string rises with the cone out of the hole. Each stand of the work string is broken out and racked back before the next section of casing is expanded.

CURRENT PRODUCTS

Initially, three expandable tubular products have been identified and developed by **Enventure Global Technology** for commercialization.

The first, an Expandable Openhole Liner System (OHL), solves lost circulation problems and seals off trouble zones, such as those encountered in subsalt rubble zones, or in zones where the pore pressure/fracture gradient relationship is of concern.

It is the Expandable Openhole Liner that will be discussed in this article.

The second SET product is the Expandable Cased-Hole Liner (CHL) System, used for remediation work.

This system can be installed in older or damaged wells to repair casing over several thousands of feet, resulting in a liner that can be drilled through and that causes minimal hole reduction

The third product, the Expandable Liner Hanger (ELH) System, uses expandable tubulars to create a liner hanger.

Data indicates 45% to 60% of conventional liners exhibit hydraulic leakage after installation.

To fix the problem may require cement squeeze jobs or liner hanger packers, or both, to create the necessary hydraulic integrity.

The Expandable Liner Hanger can minimize the occurrence of this type of hydraulic leakage.

SET APPLICATIONS

Probably the most significant benefit of expandable technology is its "enabling" capacity.

Currently, certain critical wells cannot be drilled to their objectives without solid expandable tubular technology.

One example is ultra-deepwater wells (over 5,000-ft water depth) where the operator uses every casing string available in the well design, yet the drilling environment requires more casing points than there are casing sizes.

Expandable casing technology can provide value in deepwater engineering operations in two areas: First as an enabling technology for low drilling margin conditions and secondly as a cost-effective solution to smaller rig requirements.

As operations move into deep water, drilling margins (the difference between pore pressure and frac pressure gradients) become narrower.

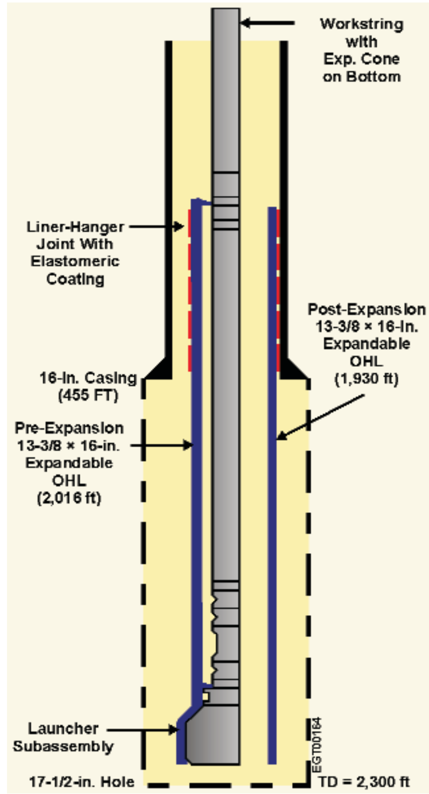
This results in more casing strings required to drill to an equivalent depth below the mudline compared to wells drilled in shallower water.

Also, as water depth increases, the size of the drilling vessel and equipment capacities increase.

The well objectives and casing program determine the minimum BOP stack and riser size, whereas the size of the riser affects many other systems on a drilling rig.

If the riser size can be reduced, the overall deck load and deck space requirements also can be reduced, allowing the selection of smaller (lower cost) rigs.

And next-generation SET systems may allow the equivalent of a "monodiameter" well to be drilled, in which the same hole size is drilled from surface to total depth (TD). A "monodiameter" well opens up further cost-saving opportunities for an operator by allowing a narrower wellbore to be drilled with a smaller vessel.



A record length OHL system was installed as an extension of 16-in. conductor casing in S Texas.

OFFSHORE SET INSTALLATION

Severe depletion in an abnormally-pressured subsea environment has been a historical problem on the "shelf" in Gulf of Mexico wells.

Attempts to drill through depleted intervals, without first achieving zonal isolation, had been unsuccessful, even with special drilling fluids and lost circulation materials.

Isolating these depleted intervals with casing allows the mud weight to be reduced to successfully drill through the interval.

In November 1999, **Halliburton Energy Services**' Integrated Solutions group, working as lead contractor for **Chevron USA Production Company**, installed the first expandable tubular system offshore in the West Cameron 17 field just outside Louisiana state waters.

The Expandable Openhole Liner was the most economical solution to reduce the casing and hole sizes required in the upper portions of the hole while providing for the specified size of casing at the producing interval. The resulting casing program called for 13⅜-in. surface casing, $9\frac{5}{8}$-in. protective casing set in the pressure transition zone and a $7\frac{5}{8}$-in. X $9\frac{5}{8}$-in. OHL system set just above the depleted intervals.

The casing program also called for a 7-in. production liner set below the depleted intervals, and 5-in. production liner set at total depth (TD).

The next best alternative casing program utilizing conventional tubulars would require 16 in. or $13\frac{5}{8}$-in. surface casing, $11\frac{3}{4}$-in. intermediate casing or drilling liner, $9\frac{5}{8}$-in. production casing, 7-in. production liner, and 5-in. production liner at TD.

The West Cameron 17 well illustrates a common problem that expandable casing can resolve.

There are a variety of situations where an expandable contingency string of casing would allow the operator to downsize the diameter of the tubulars used in the upper portions of the well.

That will improve well economics by providing properly-sized production casing without jeopardizing success.

The estimated maximum savings using an SET installation in this well compared to conventional technology was about $400,000.

Actual savings were about $85,000 due to the learning curve associated with the new technology.

Future installations would include best practices developed during the operation that when effectively applied, could improve the cost savings to approximately $290,000.

FIELD VALIDATION

Preparing to implement cutting-edge technology in 7,900 ft of water demanded extensive validation to ensure operational risk was minimized and contingency plans were in place.

In preparation for installation of SETs in an ultra-deepwater environment, **Shell Exploration and Production Company** (SEPCo) had the expandable tubular technology tested in a lower risk environment prior to implementing it in a higher cost area.

To that purpose, in September of last year, commercial application of a $13\frac{3}{8}$-in. X 16-in. openhole liner was executed to prove the technology for deepwater applications.

The record length expandable OHL system was installed as an extension of 16-in. conductor casing in SEPCo's Thomas Rife 13 well in South Texas.

The 2,016-ft (pre-expanded length) installation was set from a 2,300-ft well depth, using an expandable $13\frac{3}{8}$-in. 54.5 ppf casing expanded into 16-in. 84.0 ppf base casing.

This represented a 12.8% expansion in diameter. Total job time was 48 hours.

Then SEPCo was ready to use the expandable technology in deepwater and ultra-deep water.

The objective for the ultra-deepwater Gulf of Mexico well, Alaminos Canyon 557, was to overcome low drilling margins without sacrificing the benefits of a larger hole size.

The solution was to install an expandable tubing string below the 16-in. casing, and once it was expanded to a little over 14-in. ID, run the 13⅜-in. flush joint string below it.

The world's first ultra-deepwater SET openhole system was successfully installed in the Alaminos Canyon 557 well from **R&B Falcon**'s Deepwater Nautilus semisubmersible in 7,790-ft water depths in October 2000.

After a casing string of 16-in. 84.0 ppf was set, the next hole section was drilled with a bi-center bit creating a 17½-in. diameter hole in which to install the 13⅜-in. X 16-in. SET openhole system.

The 1,186-ft (pre-expansion length) liner was expanded in 8 hours, utilizing propagation pressures of 1,500 to 1,800 psi.

Post-expansion ID of the 13⅜-in. expandable liner was 14.170 in. (compared to a pre-expansion diameter of 12.615 in.), while post-expansion yield and collapse were estimated at 3,420 psi and 570 psi, respectively (based on prior surface tests).

The 13⅜-in. 54.5 ppf liner, expanded 12.3% into 16-in. base casing and open hole, exhibited a 4% reduction in overall length.

After the expandable OHL had been successfully installed, the shoe was drilled out into the next hole section being drilled to run a string of 13⅜-in. flush joint casing inside the expanded string.

Two additional expandable contingency strings (9⅝-in. X 11¾-in. and 7⅝-in. X 9⅝ -in. systems) were available, if well conditions dictated a need.

MULTIPLE SET INSTALLATIONS

And indeed, the decision was made to install a second solid expandable tubular system in the Alaminos Canyon 557 well in January of this year.

That made the Alaminos Canyon well the first well to have multiple openhole SET installations.

The 9⅝-in. expandable liner system was set inside 11¾-in. casing, further increasing overall length-of-hole with negligible reduction in casing diameter.

It was the first expandable openhole system of its size (9⅝ in. X 11¾ in.).

The well was the world's deepest SET installation (measured depth of more than 16,000 ft) ever installed.

The 1,521-ft (pre-expansion length) liner was expanded in approximately 5 hours, using propagation pressures of 2,000 psi.

Post-expansion ID of the 9⅝-in. expandable liner was 9.978 in. compared to a pre-expansion diameter of 8.921 in.

The post-expansion yield and collapse were estimated at 4,430 psi and 1,270 psi, respectively (based on prior surface tests).

The 9⅝-in. 36.0 ppf liner, expanded 11.8% into 11¾-in. base casing and open hole and exhibited a 4% reduction in overall length.

This allowed another string of 9⅝-in. flush joint casing to be run inside the expandable 9⅝-in. liner.

CONCLUSION

Over the past year, Solid Expandable Tubular technology has made the leap from conception to an enabling technology in the drilling environment.

November of 1999 saw the first drilling application of Solid Expandable Openhole Liners to solve a pore pressure/fracture gradient drilling challenge in the Gulf of Mexico. Since then, the use of SETs has provided operators with a cost-effective solution to solve a variety of drilling challenges.

The correct application of this tool in the drilling "tool box" will prove successful for myriad drilling challenges, while increasing operators' return on investment.

Enventure Global Technology has performed 20 commercial solid expandable tubular installations (6 openhole and 14 cased-hole systems), and expanded over 16,000 tubular ft with more than 525 connections.