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OH – Hot Stuff!!! HPHT Wellbore design with a Solid Expandable!

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Abstract

Solid expandable technology will enable flexibility in your next wellbore casing design when dealing with High Pressure High Temperature (HPHT) trouble zones. Even with our most skilled engineering and diverse technologies available today, wellbores often do not reach planned Total Depth (TD), or TD is reached with a less-than-optimum wellbore size, having a devastating effect on the project and often asset economics.

This paper will review the extensive utilization of solid expandables in HPHT applications, and take a close look at case histories which feature comprehensive well design planning and preparation, utilizing solid expandable liners.

Final HPHT wellbores often require supplemental casing seats (over the original well plan), to reach planned TD due to an exceptionally narrow, unanticipated, pore pressure / frac gradient window. These extra casing seats can be achieved with solid expandable liners. Ultimately, expandable liner installations enable operators to successfully reach TD and evaluate challenging HPHT wellbores.

Additionally, to accommodate "Ultra HPHT" wellbore environments, solid expandable systems with a 450˚F (232˚C) temperature rating are now available. This increase in rating (fifty degrees Fahrenheit greater than standard solid expandable systems) will enable operators to add that one critical casing string deep in the most challenging HPHT wellbores.

Introduction

In the sixteen years that solid expandable technology has been available, more than 1,660 systems have been installed globally. This equates to enough solid expanded pipe to reach from earth to the International Space Station (ISS) and beyond – over 264 miles (Fig. 1). A significant portion of this pipe was designed for HPHT applications.

Over 60 miles of expandable pipe has been installed in HPHT wellbores. Each application added significant value to the wellbore construction process by resolving unique drilling challenges.

Bottomhole temperatures in extremely deep wellbores may exceed the 400°F (204°C) rating of standard solid expandable systems. To address these extremes, several High Temperature (HT) solid expandable systems have been developed. This improvement increases temperature rating by 50°F (~28°C) to 450°F (232°C).

In the challenging operational and economic conditions presented by HPHT wellbore construction, using expandable system allows an operator to add additional casing strings that may be critical in reaching the planned depth with the optimal wellbore diameter.

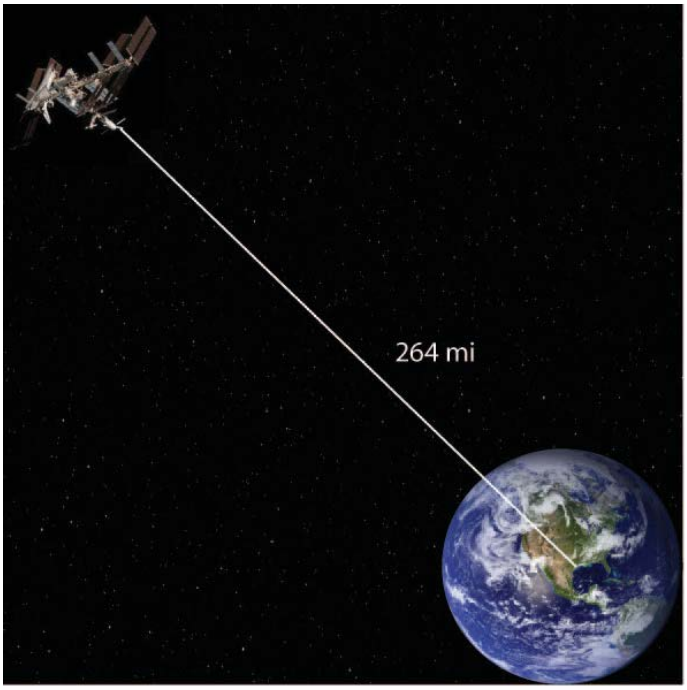

Fig. 1 - Expanded pipe installations reach from Earth to beyond the International Space Station

Critical ECD Management

In drilling HPHT wells, there is often a very narrow window between Pore Pressure (PP) and Fracture Gradient (FG) which requires close management of Equivalent Circulating Densities (ECDs). Since fluid properties are typically dictated

by pore pressure and formation sensitivity, one variable to work with is the annular flow area.

The post-expansion properties of an expandable tubular provide greater Internal Diameter (ID) than alternative conventional pipe. This allows running optimized drilling assemblies and installation of larger conventional pipes through an expanded liner, resulting in improved ECDs below the expandable liner. These valuable benefits, if narrow pore pressure window is experienced, enable drilling or cementing with reduced losses while minimizing Non Productive Time (NPT).

By appropriate application of an expandable liner in a deep HPHT well the effective flow area of the annular sections below the expanded liner can potentially be increased up to four times compared to alternative conventional liner options.

One example is illustrated below (Fig.2), which presents two different well design options, one with conventional 11-7/8 inch liner, and the other one with 11-3/4 inch expandable liner both below 14 inch intermediate casing string.

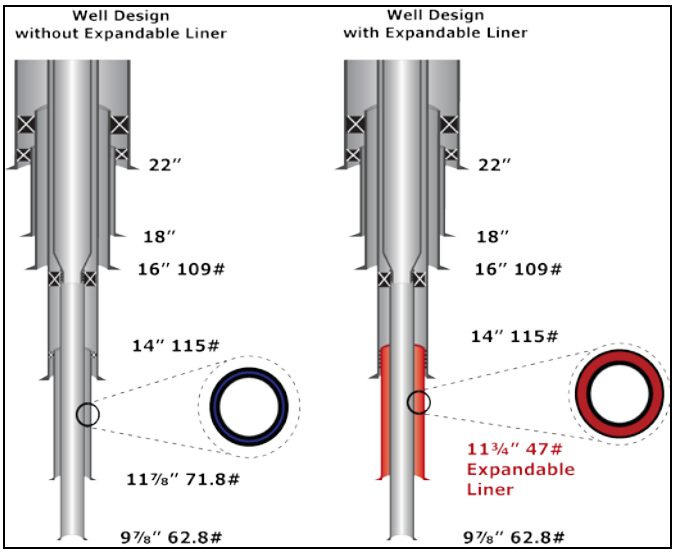

Fig. 2 - Well design defines annular flow area

Figure 3 compares annular flow areas between a 9-7/8 inch production liner and previously installed liner for two well design scenarios shown in figure 2. The blue area represents the annulus had the expandable liner not been installed, and the red area represents the annulus obtained after expansion of an 11-3/4 x 14 inch solid expandable system**.**

The comparison of annular areas is shown below:

Blue = 27.26 in^2
Red = 13.50 in^2

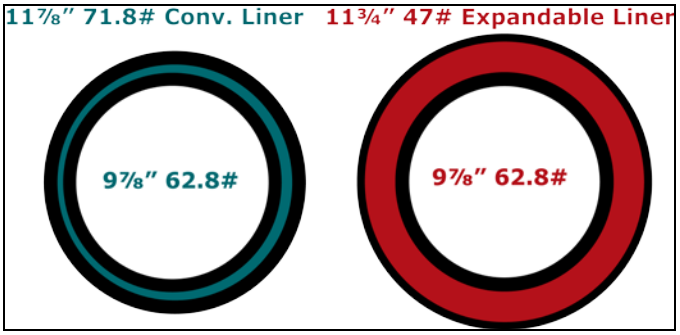

Fig. 3 - Comparison of annular areas

Annular area after expansion of 11-3/4 inch expandable liner is two times larger (over 100% increase) than annulus if the alternative option without an expandable liner had been selected.

The well design configuration with 11-3/4 inch expandable liner creates improved hydraulic conditions for drilling and cementing the 9-7/8 inch production liner compared to design option with 11-7/8 inch conventional pipe.

Solid Expandable Technology Envelope and Applications in HPHT Environments

Since 1999 over 190 solid expandable liners were successfully installed in HPHT environments. Most of these applications were drilling liners installed either in GOM Shelf or GOM Deepwater. Ten expandable liner applications for each of these GOM areas are listed in tables 1 and 2.

Table 1: HPHT Installations – GOM Shelf

No.	Year	System Size	Length	Shoe Depth	T at the SET Shoe	HP at the SET Shoe
		in. x in.	ft	ft	°F	psi
1	2011	5-1/2 x 7	1,958	22,817	374	21K+
2	2009	7-5/8 x 9-5/8	6,638	23,500	369	22K+
3	2006	9-5/8 x 11-7/8	1,877	17,544	355	16K+
4	2006	7-5/8 x 9-5/8	1,134	16,800	338	16K+
5	2011	9-5/8 x 11-7/8	1,538	24,101	332	22K+
6	2011	7-5/8 x 9-3/8	3,056	17,493	330	16K+
7	2012	9-5/8 x 11-7/8	2,914	20,080	320	18K+
8	2008	5-1/2 x 7	1,204	16,800	319	15K+
9	2010	9-5/8 x 11-3/4	2,485	20,983	310	18K+
10	2006	7-5/8 x 9-5/8	1,795	13,858	300	10K+

Table 2: HPHT Installations – GOM Deepwater

No.	Year	System Size	Length	Shoe Depth	T at the SET Shoe	HP at the SET Shoe
		in. x in.	ft	ft	°F	psi
1	2005	7-5/8 x 9-5/8	3,348	28,742	279	23K+
2	2003	7-5/8 x 9-5/8	2,608	23,866	255	20K+
3	2009	9-5/8 x 11-3/4	968	21,005	250	12K+
4	2006	9-5/8 x 11-7/8	1,552	25,213	245	19K+
5	2001	7-5/8 x 9-5/8	1,498	21,623	230	17K+
6	2006	9-5/8 x 11-3/4	3,656	27,568	225	22K+
7	2007	9-5/8 x 11-7/8	3,794	26,344	220	20K+
8	2005	9-5/8 x 11-3/4	1,429	28,554	220	20K+
9	2012	7-5/8 x 9-7/8	1,936	24,641	175	20K+
10	2009	7-5/8 x 9-5/8	1,971	28,281	170	22K+

Examples of solid expandable HPHT installations from Tables 1 and 2 were charted into the HPHT Classification Chart to define an "HPHT envelope" for solid expandable technology (Fig. 4).

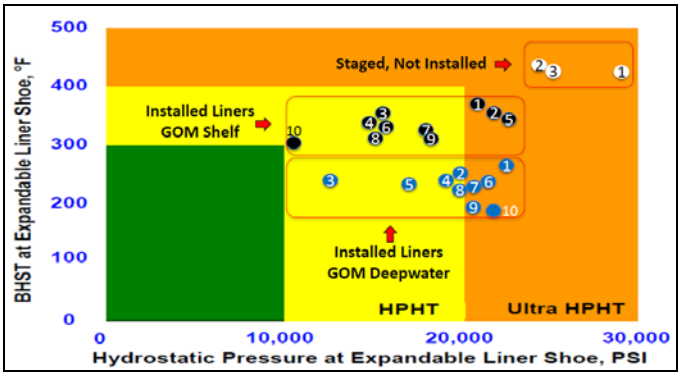

Fig. 4 - HPHT Classification Chart

Pressure and temperature data plotted in the HPHT Classification Chart are shown for expandable liner shoes; not the well's TD. The chart exhibits utilization of solid expandables in "Ultra HPHT" environments exceeding 20,000 psi and approaching 400°F. Furthermore, some of the planned applications were prepared and staged for installations in environments with hydrostatic pressures and temperatures approaching 30,000 psi and 450˚F, respectively.

Case Histories

Case History 1 (Fig. 5) illustrates two solid expandable liners isolating two deep pressure regression zones. These zones, with their low fracture gradients, resulted in non-productive time due to lost circulation and hole stability problems in offset wells. Solid expandable liners were planned into the well design, which resulted in a larger hole size and completion at TD. (See left side of well schematic which shows previous conventional well design with 4-1/2 inch production liner at TD vs. enhanced well design with 7 inch production liner at TD, on the right side.) This is an example of a project where savings of $24MM was achieved by not only optimizing well design but also improving drilling efficiency with solid expandable technology. The well was brought to production approximately two months faster than the previous well drilled in the same field.

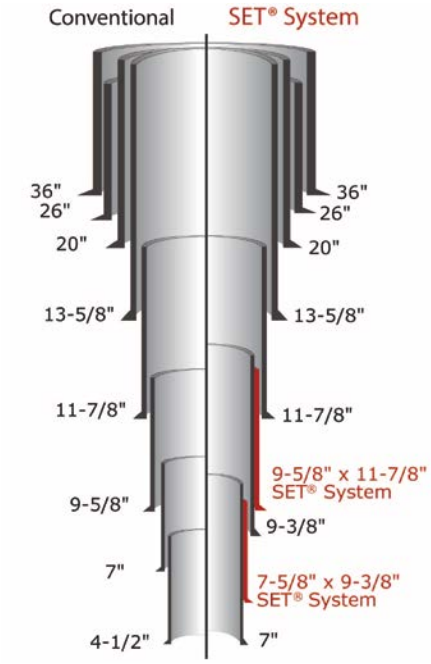

Fig. 5 - Solid Expandable Liners Isolate Depleted Zones

Case History 2 (Fig. 6) shows an HPHT application of solid expandable technology to deepen the well. An operator reduced drilling expenditures by sidetracking out of an older, previously abandoned well by applying an expandable liner to maintain the hole size while drilling an ultra-deep target. Utilizing expandable technology, the operator preserved hole size allowing use of optimized Bottom Hole Assemblies (BHAs) for managing ECDs and more efficient drilling to TD. Additionally, swellable elastomers were used with expandables to enhance zonal isolation at the casing shoe.

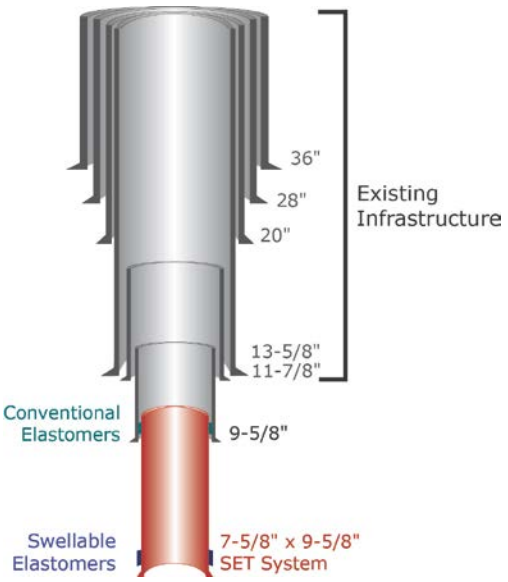

Fig. 6 - Solid Expandable Shoe Extension Enables Discovery of New Reservoir

High Temperature Solid Expandables

As wells are drilled deeper, bottomhole temperatures are likely to increase. In recent years, operators around the world have requested solid expandable systems that can handle temperatures up to 450°F (232°C). To accommodate this requirement, a testing/qualification program was commissioned to elevate the temperature rating of the 7-5/8, 8-5/8 and 9-5/8 inch solid expandable systems to 450°F.

The 7-5/8, 8-5/8 and 9-5/8 inch solid expandable systems are now qualified and available for installations in Ultra HPHT downhole environments up to 450°F.

Conclusion

Past applications of solid expandable liners have played a major role in successful completion of over 190 HPHT drilling projects. Many of these most challenging wells were completed in Ultra HPHT downhole environments with BHSTs at TD approaching 500˚F and hydrostatic pressures exceeding 30,000 psi. By implementation of solid expandable liners, operators were able to complete their project objectives by reaching planned targets with reduced NPT and maximized hole size at TD.

Important benefits of solid expandables, such as improved ECDs or ability to optimize drilling BHAs in the well sections below expanded liner are better understood and more frequently utilized today. Improved ECDs while cementing enhance zonal isolation in deep wells, thus improving overall well design and safety. To address operator needs for Ultra HPHT drilling applications, solid expandable tubulars rated to 450˚F are now available.

As wellbore construction continues to become more intricate, operators will continue to look for enhanced technical solutions needed to achieve their wellbore and economic objectives. It is reasonable to expect that, as has been the case in the preceding sixteen years, solid expandable tubulars will continue to play a significant role in HPHT wellbore construction.

References

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