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Effective Use of Stabbed-in Inner-string Cementing Technique for Top-hole Temporary Abandonment in Deepwater Gulf Of Mexico

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Abstract

This paper is a case study to provide proof of concept of an alternative method of temporary abandonment of top-hole sections in deepwater Gulf of Mexico “GOM” batch-set wells. This alternative method utilizes a unique technology that enables fully stabbed-in inner-string cementing on large diameter casing sections in subsea environments further enabling a bi-directionally sealing latch-in wiper dart to be landed and locked into the casing shoe. The technology also enables the operator to open a direct channel of communication between the inner-string and the casing ID while still being stabbed and sealed at the shoe. In operations where there is a requirement to Wait on Cement (WOC) hydration before releasing the casing, as an optional benefit the technology allows for a “heat-sweep” of hot water to be introduced into the casing ID significantly improving WOC and transitions times of the slurry in the casing annulus.

While continuously stabbed-in and sealed at the shoe the operator launches a bi-directional latch-in wiper dart rated to 7,500-psi bump and back pressure thereby fully isolating the casing ID from the cement in place adding a robust redundancy to the float valves. In the case study the operator was batch-setting deepwater wells top hole in the Gulf of Mexico (GOM) and wanted a secure base upon which to spot a balanced cement plug of verified length. The operator was able to conduct this operation by pumping the predetermined balanced cement plug in one seamless operation before circulating in the kill weight fluid to temporarily abandon the well.

A further opportunity was recognized using the bi-directional wiper plug once latched and locked as a potential “barrier” which in future operations could avoid the requirement of the balanced cement plug in the shoe track thereby saving additional time when returning to the well with no cement shoetrack to drill.

In deepwater GOM open water operations the operator is challenged with cementing surface casing sections using inner-string cementing that is open ended and suspended 200’ – 300’ above the casing shoe due to the practical inability of effectively spacing out between the casing shoe and the casing running tool. Open-ended cementing presents several challenges regarding cement volumes and contamination and requires a 100’ – 150’ cement shoetrack to be left inside the casing. In the present case study, a technology was deployed enabling cementing through a stabbed-in inner string system, launching and latching a bi-directional wiper dart before spotting a balanced cement plug and abandonment fluid for temporary abandonment. The technology reduces costs and drives efficiency for deepwater drilling operations in addition to enhancing operational safety and reducing the carbon footprint of the top-hole operations with the reduced rig-time. This case study presents the first deployment of a latch-in bi-directionally sealing wiper dart in and open water deepwater application through a novel stabbed-in inner string cementing system.

The successful operation stabbed-in inner-string cementing and of landing and locking the bi-directional plug in the shoe provides proof of concept for future alternative methods of temporary abandonment in batch-set deepwater wells utilizing the latch-in plug as a physical well barrier in place of a cement pug on top of the shoe subject to appropriate regulatory approvals.

Introduction

This paper documents the use of stabbed-in inner-string cementing on a subsea well open water surface casing section and the use of a latch-in bi-directionally sealing wiper dart landed and locked into the casing shoe during temporary abandonment operations and discusses the potential optimization of the technology to eliminate cement shoetracks for future operations.

Background

The operator began a multi-well batch set campaign in the

Gulf of Mexico in Q1 of 2024, with this paper having particular focus on cementing of the 22” surface casing and subsequent temporary abandonment of the well.

Open-ended Riserless Cementing and Temporary Abandonment Method in the Gulf of Mexico.

Open-ended cementing of subsea riserless sections involves running the casing until the Low Pressure WellHead Housing “LPWHH” is in the rotary table, followed by running drill pipe into the casing, spaced back a pre-determined distance from the shoe. The casing can then be made up to the LPWHH running tool and deployed to cementing depth on landing string.

The primary cement job can then be pumped through the drill pipe inner string, before exiting the open-ended cement stinger and free-falling through the casing annular fluid and subsequently through the float equipment into the borehole annulus. The cement is displaced with seawater against the hydraulic seals at the LPWHH running tool and ball valve.

Challenges for the open-ended cementation method include the potential contamination between cement and the displacement fluid, which is often seawater during open water well construction. To help mitigate against this contamination risk a notional volume of additional cement is mixed and pumped over the required volume and left on top of the casing shoe referred to as a “shoetrack.” In the case of open-ended temporary abandonment this volume of cement also serves as a “physical barrier” intended to isolate the wellbore below since the float equipment is not considered as a “physical barrier” under the applicable regulatory scheme.

The open-ended stinger inner string cementing method is shown below in figure 1 below.

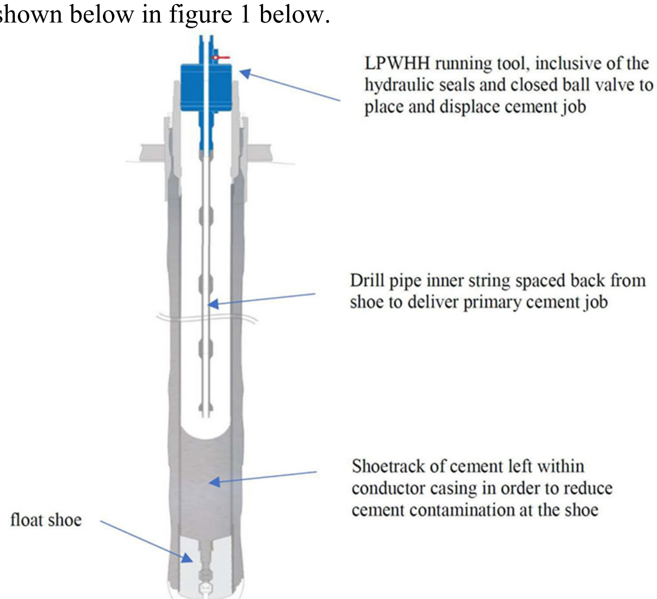


Figure 1—Open ended stinger Inner String Cementing Method

An additional challenge for the operator leaving a cement “shoetrack” in the casing ID is the difficulty in determining the length of the “shoetrack” which can vary considerably. Some operators choose to rely on the calculated volume pumped while others re-enter the well with a dedicated trip to “tag” the top of cement by setting down weight will an inner-string.

Case Study for Alternative Inner-String Cementing and Temporary Abandonment

On an offset well the operator successfully deployed a technology that enables stabbed-in inner-string cementing whereby the inner-string is connected directly to the float shoe through a fully mechanical bottom hole assembly. The method of stabbed in inner-string cementing is recognized in the industry as the optimal method to mitigate against contamination due to the reduction in displacement volume and therefore is common practice in platform or land drilling operations. Previously, this method has not been pragmatic in subsea well construction projects due to the nature of deploying the casing that is to be cemented on a retrievable running tool, with fixed points at the running tool and the float equipment making it impossible to have a stabbed in system that can be made up to the running tool because of the lack of short casing joints to ensure the correct space-out which is otherwise impractical because of the requirement to make up the MRLD to the top of the casing. The stabbed in inner string cementing system addresses these impracticalities through a fully mechanical assembly that comprises of the slip joint tool, weight set centraliser and latch in adaptor.

The configuration of this BHA is shown in figure 2 below.

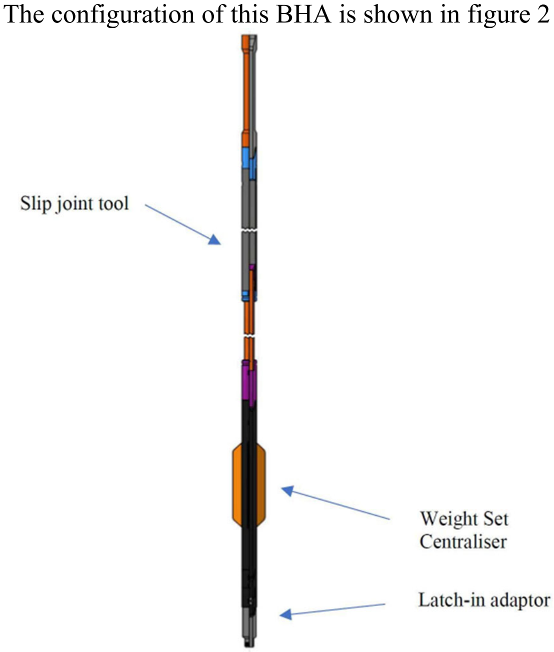


Figure 2—Stabbed in inner string cementing bottom hole assembly “BHA”

The enabler of the system to stab into the shoe and allow for subsequent make-up of the retrievable running tool is the slip joint tool. This tool is a telescopic joint which has ~3m (10ft) of stroking capability and has a clutch-mechanism allowing for free-rotation when partially stroked closed. This allows the inner string tally to be approximated to the casing tally, with the stroking capability accounting for casing space-out and allowing for the inner string to be made up to the running tool, prior to running in hole to cementing depth.

The weight set centraliser provides the set down weight for the latch in/tag in adaptor to stab into the float shoe and provides inner string centralization through 16" OD solid blades.

The circulation sub at the bottom of the BHA is made up to the latch in or tag in adaptor which stabs into the float shoe, moving the hydraulic seal for the placement and displacement of the primary cement job to the seal stack in the adaptor, in comparison to this seal being located at the running tool and ball valve, as it is in open-ended cementing methods. The circulation sub includes a selectable valve in the form of a 1" rupture disc port. When the primary cement job is pumped and displaced through the stabbed in inner string, a volume of cement is left within the inner string, known as an under displacement. This volume of cement mitigates against the risk of a wet shoe and can be circulated out of the casing and vented to seabed once the shoe has been isolated. This post cement job isolation of the shoe is achieved through a 2.500" OD bi-directionally sealing latch-in wiper dart that is from the cement head into the string behind the tail cement and chased with ~10-bbls of tail cement. The dart lands and locks in a dart receptacle within the casing float shoe isolating the wellbore below from the casing. Pressure is applied against the dart to rupture a burst disc in the circulation sub and open a circulation path from the inner string to the casing ID. Due to the hydraulic seal that has been enacted at the float shoe, the running tool ball valve is no longer required as a seal and therefore left open throughout the running in hole and cementing process. The insurance cement behind the dart can therefore be circulated from the inner string and vented to seabed through the open ball valve. It is at this point that the optional rapid cement hydration technology can be introduced to the casing annulus through this circulation path. A temperature gauge on the MRLD allows for real-time temperature to be read by the remote operated vehicle "ROV" and a temperature logger at the shoe retrieves the temperature versus time data once the inner-string is pulled out of hole.

The stabbed in inner string cementing system is shown in Figure 3 below.

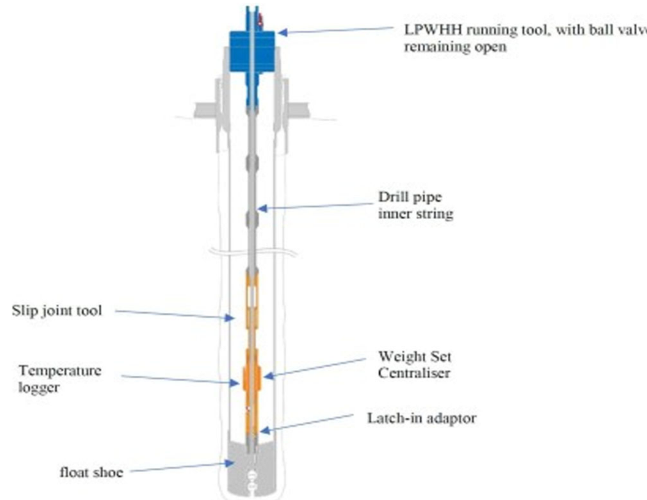
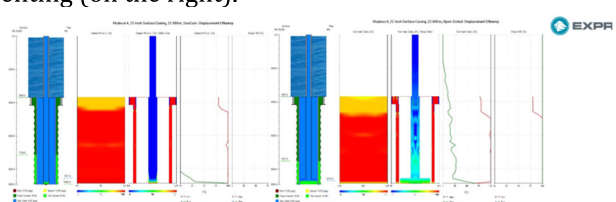


Figure 3—Stabbed in inner string cementing system setup

Pre-Job Preparation and Modeling

Cement Concentration

In preparation for the job the service company provided the operator with cement placement modeling. The predictive modelling confirmed the benefits of stabbed-in inner-string cementing to mitigate against the risk of contaminated cement at the casing shoe. Figure 4 below illustrates the difference in cement concentration at the casing shoe between the stabbed-in inner-string cementing operation (on the left) and open-ended inner-string cementing (on the right).



MD (ft)	Lead cement Conc. – Ann. (%)	Tail cement Conc. – Ann. (%)	Cement Conc. – Ann. (%)
7200.0	21.03	78.95	99.98
7400.0	20.00	80.00	100.00
7600.0	20.00	79.92	99.92
7800.0	20.00	79.96	99.96
8000.0	20.00	79.79	99.79
8200.0	0.00	99.58	99.58
8400.0	33.12	66.35	99.46
8600.0	10.68	89.21	99.89
8800.0	6.81	93.03	99.84
8900.0	0.00	100.00	100.00

MD (ft)	Lead cement Conc. – Ann. (%)	Tail cement Conc. – Ann. (%)	Cement Conc. – Ann. (%)
7200.0	68.91	31.09	100.00
7400.0	55.74	44.26	100.00
7600.0	35.35	64.65	100.00
7800.0	24.32	75.68	100.00
8000.0	34.74	65.26	100.00
8200.0	36.85	63.15	100.00
8400.0	1.92	98.08	100.00
8600.0	13.55	86.45	100.00
8800.0	9.02	90.98	100.00
8900.0	5.79	60.51	66.30

Figure 4 – Cement Concentration at the Shoe

Stabbed-in inner-string cementing provides direct delivery of the cement to the casing shoe and casing/hole annulus with mechanical separation of the cement and displacement fluid providing 100% cement concentration at the casing shoe. In contrast, open-ended inner-string cementing relies on the cement free-falling 200' – 300' from the open-ended stinger through the casing annular fluid to the casing shoe, mixing with that fluid and then being displaced into the casing/hole annulus with either seawater or PAD mud without mechanical separation. The resulting cement concentration is less than 75% which is not optimal for subsequent delivery of casing integrity pressure testing and LOT/PFIT.

On offset wells, monitored by the service companies, open-ended cementing results in a significant number of failed Lot/PFIT operations when coming back to the well. The chart at Figure 5 below demonstrates the difference between the rate of failed LOT/PFIT operations resulting in remedial cement squeeze jobs over the last 50-wells monitored by the service company versus the last 50-wells when using stabbed-in inner-string cementing.

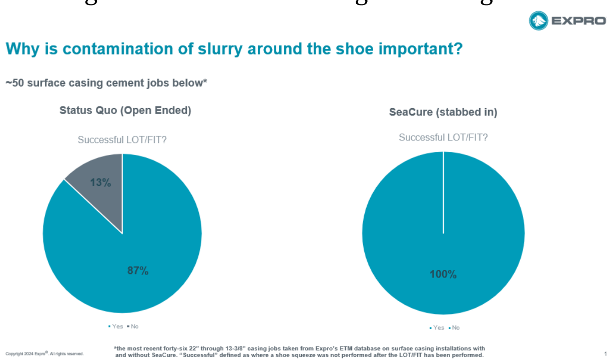


Figure 5 – Stabbed-in Inner-string versus open-ended inner-string

Optional Heat Sweep

The stabbed-in inner-string technology presents an optional capability to pump pre-heated hot water into the casing/inner-string annulus though the port opened in the circulation sub immediately after the cement placement. The heated water allows heat to permeate through the casing wall creating a warmer geothermal environment significantly decreasing the cement hydration time and allowing for reduced wait on cement time prior to releasing the casing. Pre-job modeling using commercially available software indicated a ~10°F increase in the slurry temperature at the shoe which would allow the operator to release the casing 4-hours earlier. The chart at Figure 6 below illustrates the increased temperature through the placement of the pre-heated hot water into the casing/inner-string annulus.

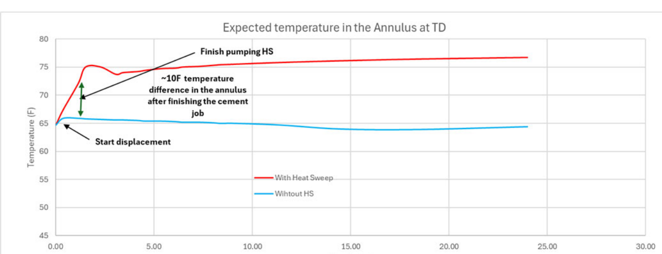


Figure 6 – Downhole Temperature Model

Operational Delivery

Surface Casing Run in Hole and Cementing

Dual derrick operations on the drill ship enabled the 22" surface casing to be run on the auxiliary derrick while the 26" hole was drilled on the main derrick. The 22" casing was top-filled with seawater every three joints and run to 3,606' on auxiliary. On main the 26" drilling BHA was pulled out of hole and the rig was moved to position the auxiliary derrick over the well head enabling the 22" casing to be stabbed into the well. The 22" casing was then run to a depth of 5,126' and while hung off at the rotary table the false rotary table was installed.

The stabbed in inner-string cementing bottom hole assembly consisting of the latch-in adapter, circulation sub, weight set centralizer, temperature probe and telescopic slip-joint was then picked up and run into the 22" casing on drill pipe. The rig then displaced 6-5/8" inner string from seawater to suspension fluid. The rig then slacked-off and stung the latch-in assembly into the 22" shoe with 1,500-lbsdown. A 5,000-lbs overpull was then taken confirming the latch-in adapter was properly latched into the receptacle in the casing shoe. An additional confirmatory step was taken by ensuring that the 22" casing string was top-filled with seawater thus providing a low pressure hydrostatic test. After the casing running tool was made up to the 22" casing top as per procedure, a final definitive confirmation that the latch-in adapter was properly latched and sealed was conducted by breaking circulation down the inner string and up the open-hole annulus with suspension fluid. The ball valves on the casing running tool were left in the open position and the casing was run to depth at 8,845' measured depth.

Cement was then mixed and pumped through the inner-string with full lead cement returns being observed by the ROV at surface. The bi-directional latch-in dart was then launched from the cement head and the cement unit pumped 1-bbl of cement, placing 5-bbls of cement on top of dart for insurance. After switching from the cement unit to the rig's top-drive and pump, the cement was displaced with seawater at 12-bpm and with 10-bbls of calculated volume remaining, the rig slowed the pumps to 2-bpm and continued displacing the remaining 13-bbls at 2 bpm with 1,400 psi and bumped the bi-directional wiper dart with 500-psi over circulating pressure (1,900 psi). The cement unit then bled back 3-bbls to confirm that the floats were holding.

With the dart locked and landed, pressure was then applied to open the circulation sub and the disc was burst at 4800-psi.

Heat Sweep

Though a process of circulating seawater against in a surface pit using the rig pumps and shear guns lines, 1100-bbls of seawater was pre-heated offline prior to the cement job to 140°F. The rig was then able to pump the pre-heated seawater at 21-bbls/m down the inner-string and into the casing/inner-string annulus. The insurance cement behind the dart was vented to seabed through the open ball valves on the MRLD.

Based on the pre-job modelling and the cementing contractor's cement hydration tests the operator was then able to release the casing after WOC for only 4-hours, or approximately 4-hours earlier than otherwise if not heat sweep had been pumped. Data from the downhole temperature logger retrieved after the job confirmed at 10°F increase in the slurry temperature post heat sweep. Figure 7 below is an annotated chart capturing the data from the downhole temperature logger.

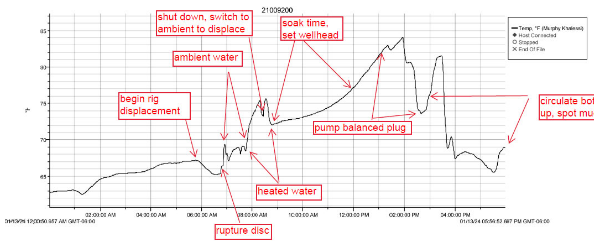


Figure 7 – Downhole Temperature Logger Data

Temporary Abandonment

Post cement placement and with the dart locked and landed, the operator waited on cement hydration for the predetermined 4-hours before performing a slump test and slacking-off the remaining casing assembly weight in increments while monitored the mudline and wellhead for subsidence. No subsidence was observed allowing the MRLD to be released after which an overpull was taken of 45-klbs to shear out the stabbed-in inner-string stinger from the casing shoe. The stinger was then positioned at 8,837-feet or 3-feet above float shoe.

With the bi-directionally sealing latch-down dart locked into the shoe providing a solid base, a cement plug was then pumped from 8,837-feet to 8,710-feet. The operator then displaced wellbore from seawater to 13.7 ppg mud and the inner-string and landing string were pulled out of hole and the well was temporarily abandoned.

Re-Entry and Subsequent Drill-Out and Pressure Testing

Over a month after the well was temporarily abandoned, the operator returned to the well to drill the remaining sections of the well. The top of cement was tagged at 8712' accurately reflecting the length of the cement plug placed during the temporary abandonment operation. A casing integrity pressure test was then performed successfully to 4100-psi. The chart at Figure 8 below shows the pressure versus time from the test.

Test 1

AQUILA Engineering — Test Execution Report 2/17/2024

High Pressure (psi)	Low Pressure (psi)	Pipe Size (in)	Criteria	Comments
4100	--	6-5/8"	Pressure decay less than 10% & test duration 30 min	22" Casing Test

	Result	Evaluation Start	PASS Start	Start Pressure (psi)	PASS End	Final Pressure (psi)	Delta P (psi/min)
Low Pressure							
High Pressure	PASS	02/17/2024 08:00:12	02/17/2024 08:00:15	4132	02/17/2024 08:30:15	4120	1.48

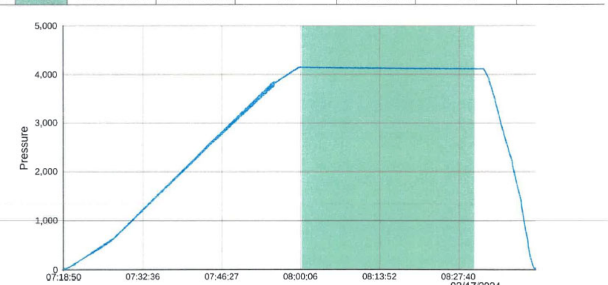


Figure 8 – Casing Integrity Pressure Test

With the successful casing integrity pressure test completed the shoetrack and shoe were drilled out in 5-hours.

A successful pressure formation integrity test (PFIT) was then performed with a target pressure of 414-psi prior to drilling ahead on the next interval. Figure 9 below provides the results of the PFIT over the course of the test.

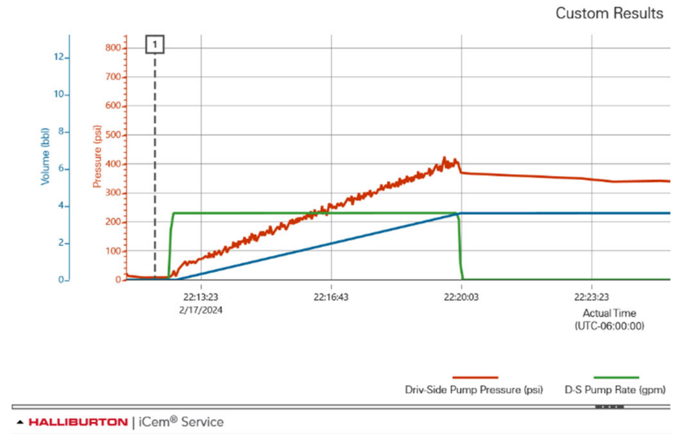


Figure 9 – Pressure Formation Integrity Test

Conclusion and Opportunities for Optimization

The operator was able to recognize several benefits through its ability to deploy a mechanical BHA to connect it cementing inner-string to the casing shoe. Further benefits were recognized relating to the temporary abandonment operations. The recognized benefits to the system can be summarized as follows:

1. By successfully stabbing and sealing the inner-string adapter to the casing shoe, cement was delivered directly to the casing shoe and casing/hole annulus avoiding free-falling from an open-ended stinger system and subsequent cement contamination.
2. With the inner-string cementing adapter sealed in the casing shoe, the cement was displaced with a bi-directionally sealing wiper dart without reliance on the seals on the casing running tool providing mechanical separation between the tail cement and the displacement fluid.
3. With the inner-string stabbed and sealed at the casing shoe the ball valves on the casing running tool could be left open eliminating the need to close the ball valves prior to running the casing.
4. With the inner-string stabbed and sealed in the casing shoe the cement volume was reduced and returns were recognized earlier at surface.
5. The stabbed-in inner-string system enabled a reduced shoe track of 2 ft.
6. The stabbed-in inner-string system enabled a bi-directionally sealing lock-down wiper dart to be latched into the casing shoe, confirmed with 500-psi over circulating pressure and pressure tested to 4,800-psi providing mechanical fluid separation and a 7500-

psi redundancy to the float valves.

7. With the dart in place and pressure tested to 4,800-psi providing a confirmed solid base the operator was able to un-sting from the shoe and place a balanced cement plug on top of the shoe prior to temporary abandonment.
8. Upon re-entry to the well the operator was able to establish successful casing and formation pressure integrity test before drilling ahead.

In addition to the recognized benefits, several potential optimization opportunities for further optimization of the system were recognized for future wells as identified below:

1. With the bi-directionally sealing lock-down wiper dart latched in the casing shoe and confirmed with 500-psi over circulating pressure and 4800-psi pressure to open the valve in the circulation sub, the opportunity was recognized for future batch-set wells to temporarily abandon the well at eh 22” without the requirement of a cement plug. With the plug in place providing a 7500-psi back pressure rating, and the ability to pressure test the casing immediately post-cementing, alternate compliance from BSEE should be attainable.
2. Removing the requirement for a cement plug inside the 22” casing for temporary abandonment will provide considerable rig-time savings upon re-entry to the well without the need to drill-out the cement plug and pressure test the casing and will also de-risk potential issues drilling out the cement shoetrack such as damage to the bit cutting structure or cement sheath issues. The average drill-out for casing shoes using the stabbed-in inner-string system over 100+ wells without a cement shoetrack in place is ~20-minutes versus an average cement shoetrack drill-out of 5+ hours.
3. With the bi-directionally sealing lock-down wiper dart latched in the casing shoe, operator eliminates the 30% FIT deepwater failure rate.

Acknowledgments

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