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Intelligent Coiled Tubing Operation Practices to Install Expandable Casing Patch

Khalid Rahimov, Haleyna Arstianti, and Agus Cahyono, Baker Hughes

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Abstract

A customer in Asia Pacific had challenges with high gas oil ratios on several wells that limited production as not to exceed a gas handling facilities capacity. One of the most effective and challenging options proposed to isolate the intervals of high gas production was the installation of expandable metal patches. While historically the preferred deployment method of a patch has been wireline, due to the accuracy required to set the patch, with coiled tubing enhanced in providing real-time data transfer, the advantages of utilizing it for installing mechanical isolation become superior.

The Intelligent coiled tubing system consists of a customized bottom hole assembly that transmits differential pressure, temperature, casing collar locator and tension-compression-torque data instantaneously to the surface via a nonintrusive wire installed inside the coiled tubing string. All of these parameters are crucial for an appropriate deployment of a patch, the information is required to accurately understand the scenario of what is happening downhole at each given moment and what effect a control input could possibly have on the work scope

The right solution to a problematic well is only as good as the accuracy it can be applied with. The Intelligent Coiled Tubing System was a defining factor for the success of the production solutions. The setting process of the patch is composed of several duplicated cycles; these cycles must be performed simultaneously and be harmoniously integrated with a very small margin for error. On an intervention where 99% accuracy is not enough, the proper performance of each patch installed, is also attributed to the precision of the data received from the sensors in the BHA, this made possible for the patch to be set at the right depth and in the due diligence required for the scope.

The efficient system performance confirmed the advantage of using intelligent coiled tubing for patch installation, providing immediate production benefits to the operator and direct positive financial impact. This paper will detail the process followed, to successfully set the multiple patches in the several wells. It will also highlight the accuracy from the coiled tubing performance simulation vs the execution.

Introduction

The carbonate Field with High GOR wells is located onshore Asia Pacific. Monitoring and survey of the field indicated that GOR increasing in many wells. With increase gas output, oil production curtailment and well shut-in were becoming unavoidable as surface facility is not setup to handle the increased volume of gas production. Production logging survey was conducted and concluded that source of excessive gas was from top perforation interval, which is estimated to flow to wellbore from the existing reservoir gas cap. It has been projected that isolating the top perforation interval would delay gas invasion thus stabilize GOR. The proposed solution estimated to be efficient measurement to maximize oil production.

Extensive study of the wells in the field by the operator identified seven immediate candidate wells for the top perforations shut off. Along with studying the wells, operator was also investigating the market to find fit for purpose technology to isolate the interval. Aggressive wellbore conditions as well as sensitive formation requiring minimum intervention with chemical treatment eliminated most of the conventional remediations methods. Well kill operations were discounted as well since it has been estimated to be costly and highly damaging to the reservoir. Requirements on performing well work activities under live well condition with limited to no chemical solution available, lead the operator toward selecting the hydroformed expandable mechanical casing patches solution that would be run and installed on Coiled Tubing. Special attention was given to the material selection that would withstand the downhole condition with increased volume of the aggressive gasses, salinity, and pH. Expandable patches also fulfilled the requirement of running through the restriction and being deformed to fully isolate ID of the completion at intended zone. Critical parameters such as accurate depth control, downhole setting pressure, downhole forces monitoring when expanding a metal patches were requiring accurate real time data transfer technology. Real time intelligent coiled tubing telemetry (ICTT)solutions capable of providing measurement of above mentioned parameters ea. CCL, pressure and force measurements was selected as most fit for purpose technology. ICTT system transferred downhole data to surface at the real time mode allowing operator to make precise decisions on forward steps.

Selected mechanical patch isolation methods involved running and expanding the metal patch against the completion ID. Role of the coiled tubing in the process was to deliver the patch to required depth and use it as a fluid conduit to carry the fluid into hydraulically expandable setting tool. Once installation process initiated, force measurement downhole becomes a critical parameter to keep an eye on. With anchored patch, coiled tubing get fixed at two point in the wellbore one being downhole and second at surface. Due to the continuously applied pressure into setting tool excessive force start acting on the tool. Primary source of the "force" is hydraulic pressure applied into CT that in terms forces fixed length of the pipe in the wellbore to either stretch or elongate (depending on direction of pressure). Downhole stress measurement and its elimination was critical to success of the operations. Further in this paper these forces and their effect on installation of the patch as well as methods on compensating of unwanted stresses on the setting tool are detailed out.

Essentials of the technology solutions

Real time intelligent coiled tubing telemetry

Figure 1—Telemetry wire vs standard Wireline Hepta-cable

consists of the 1/8-in. non-intrusive electrical conductor wire (fig 1) inside the carrying CT, surface hardware and software, and the bottom hole assemblies.

Telemetry downhole tools (fig. 2) designed in separate setup that allows to deploy

- Fully electrically activated tools that would normally be deployed on electrical wire line
- Hydraulically activated downhole applications
- Downhole real time camera technologies

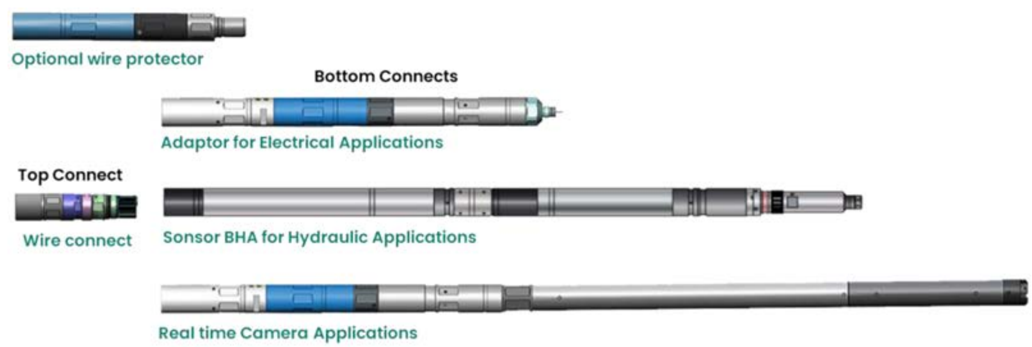


Figure 2—Intelligent Coiled Tubing Telemetry BHA

The telemetry tools consists of the top connect (head-up) and the bottom assemblies (Fig. 2). While the top part is interchangeable for all the applications, the bottom part (sensor BHA, an electrical application, or a camera adapter) is assembled specifically to the job requirements. The sensor assembly combines a conventional motorhead assembly features with sensor package that allow detecting casing collars (CCL), measures tool-to-completions annulus and tool-internal pressure, and external and internal temperature, tension, torsion, and compression forces. This sensor BHA is specifically designed to measure the downhole job parameters while performing the wide variety of the hydraulic/mechanical operations. The adapter for electrical applications also combines the standard bottom hole safety features(DFCV, tool disconnect, circulation ports) with capabilities to create electrical conduit to operate the larger array of an electrical tools. The camera adapter is intended to connects one or two cameras with front or lateral views. The camera applications can transmit real time data about the well deviation, tool topside, and internal temperature. Note that the cameras have front and back flushing sleeves that allow fresh fluid washing the camera lenses for better downhole imaging (Garner et al. 2016).

As it was mentioned above one of the purposes of the sensor BHA is to transmit the downhole data to surface while operating the hydraulic or mechanical tools at the depth. The critical real time data reading while engaging with patch setting was established to be the force behavior acting on setting tool.

Tension, Compression and Torsion (TCT) reader (that is part of the tool) enabled the required data transfer as per requirements.

The TCT assembly contains foil strain gages that are permanently glued with heat-cured epoxy resin on the inside wall of its pressure housing. Mounting requires a specialized tool and a highly skilled technician. The five TCT printed circuit boards (PCBs), shown in Fig. 3, are mounted on the outside of the annular ring of the atmospheric chamber (Fig. 4). There are three boards for signal conditioning, one board for power gage excitation, and one board for signal processing. The atmospheric chamber has a central flow passage, such that the electronics components must fit on the annular ring that is mounted inside the module housing (Fig. 4). (Diego Blanco et al 2016)

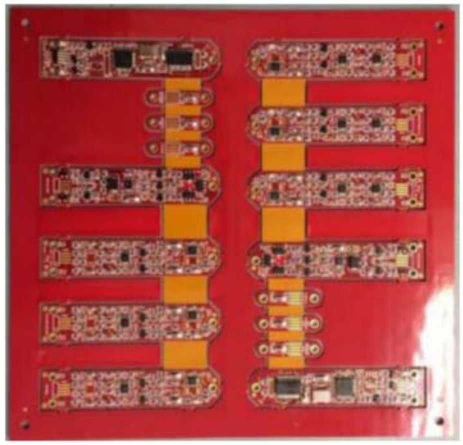


Figure 3—TCT electronic boards(from Garner et.al. 2016)

Figure 4—TCT annular ring(left) and module housing(right)(from Garner et.al.2016)

The TCT electronics module, shown in Fig. 5, uses pressure transducers for pressure compensation. It is rated for tension and compression forces and torques as great as 30,000 lb and 1,500 lb-ft, respectively.

Figure 5—TCT Electronic Module

Expandable Steel Patch

selected for the remediation purposes utilized the hydraulically expandable packer type setting tool to enlarge metal patch. Patch itself consist of metal that is uses the ductile steel as a base material and isolation elements to seal off the patch-to-completion annular from leaking. The metal tubes are expanded by forcing the walls of the tubular via pumping up the setting tool that in term pushes metal from the elastic region until it reaches the permanent plastic region.

Once the problem zone reached and depth correlation confirmed the hydraulic surface pressure is applied into setting tool installed into the patch at surface. The pressure applied will then act against the metal pushing it against completion inside diameter (ID). The high expansion ratio of the metal sleeves enables the packer to cover a larger completion ID. Capabilities of passing through the restrictions and having the high expansion ratio was one of the enablers for the technology at the given project.

Setting tool equipped with required mechanisms to be installed into patch at surface and hold it firm while delivering it to destination downhole. Gauge ring on top if the setting mechanism allows to identify any flaw in case expansion process would not yield required results. Down hole expansion tool(DHET) also equipped with check valve to prevent the fluid from entering the CT and emergency disconnect capabilities.

Operation Design and Project Delivery

Challenges and preventative measurement

Severe sour-corrosive environment. with high H2S and CO2 concentrations was main concern at start of the operation. Patch material selected for the project was C276 nickel alloy which is known for its robustness in sour environment and tolerance to wide range of H2S partial pressure. Downhole tool selection as well commenced with aggressive environment in mind. All the element of the tool string, including packing elastomers has been carefully selected. Lower grade H2S Resistance CT pipe material was consideration point as well and extra precaution of using high temperature H2S inhibitor was projected into operations.

Preventing gas leak. via patch-to-completion micro-annular (or the gas tight annular) was considered another priority and the Tetrafluoroethylene Propylene (FEPM) elastomer was selected as external to path isolation material. This polymer packing has high resistance to H2S and high temperature. Similar material had already existed in well completion and proven to be highly effective at the well conditions.

Pressure induced excessive force acting on setting tool. during patch installation had to be addressed at planning stage. Previous practice of similar operation established the fact that when CT tied at 2 point one being downhole the other at surface – any pressure applied into pipe would affect the dimensional change on length rather than resulting in diametral changes - ballooning. Elongation or stretch of CT that would take place depending on the flow/pressure direction creates the push or pull forces at the setting tool. Defeating this forces was critical for the success of the operations. Primary reason of the deployed telemetry system was to understand the occasions real time and take an action that would eliminate mentioned challenge.

High bottom hole temperature. marked as challenge next in line. Similarly, to the aggressive environment all the elastomeric elements has been carefully assessed against the temperature and those with low temperature limits has been replaced with alternative materials capable of withstanding expected downhole conditions. Most critical assessment against the temperature conducted on steel patch expansion tool (down hole expansion tool- DHET). It was identified that high temperature at aggressive environment would significantly reduce the operation time of the inflatable element thus manufacturer had to adjust the tool design. Laboratory testing on optimized design yielded expected results and it further proved itself on actual operations.

Total length of the patch. along with the setting BHA which was in an excess of 70 ft required appropriate deployment length to safely assemble and lubricate the technology at surface. Approximately 90 ft (fig.6) tall tower were mobilized to enable the safe operations. Tower provided the capacity to erect designed pressure control stack and offered the stable platform for the safe and efficient operations.

Rapid gas decompression. damage to the DHET was projected based on past experience. it was expected that pressure release from lubricator section when BHA at surface may cause the inflatable element swelling due the the gas existence in the bore. Changed dimension of the setting tool would result it being stuck inside of the 4 1/16" riser section. To avoid an occurrence, controlled pressure bleed off procedure was developed. On top of that larger size of the riser section (5 1/8") erected instead of originally intended 4 1/16" risers that would leave extra space even if tool gets oversized.

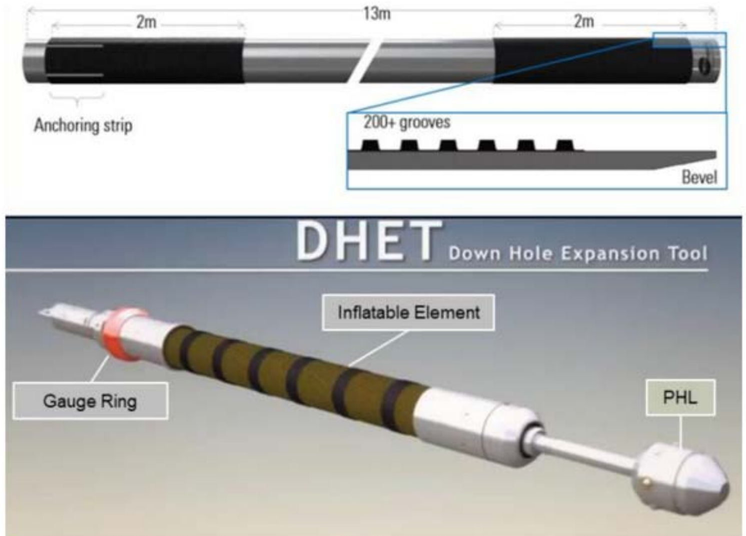


Figure 6—Patch and Down hole expansion tool illustration

Challenges with reverse flow. was anther instance requiring the accurate risk assessment and mitigation measurement implementation. Patch inflation process consist of multiple and continues pressure up and bleed cycles that would inflate and deflate the setting tool. Pressure bleed supposed to be taken place at surface. That in turn would require removal of the conventional dual flapper check valves from inside of the MotorHeadAssembly as inflation chamber is under the check valves. While patch setting mechanism incorporated the back pressure valve that would play a role of the barrier to prevent fluid migration via CT to surface, nevertheless in an emergency when BHA would needed to be disconnected, barrier would be left downhole as disconnect point located above it. To mitigate the challenge secondary, mechanically activated flapper check valve was incorporated into BHA design. Proposed tool would have mechanism in place to hold the check valve inactive thus allow the fluid bleed off from inside of the DHET. In case of an emergency disconnect dropped ball activates the check valves and provide the required downhole barrier.

High pressure cycles fatiguing the BHA. also projected to be an issue that would deteriorate the BHA integrity. Potential weak points were identified to be the O-rings and emergency rupture discs. Repeated pressure cycles acting on o-rings would results of them moving in their grooves and rubbing against the edges thus creating fatigue point over the time. Emergency rupture disc also were projected to be affected by pressure induced fatigue. To prevent the O-ring failure all the primary and backup rings exposed to the pressure were assessed and equipped with backup Teflon rings reducing the movement of the primary o-ring in the groove. To avoid burst disk failure, rating of the disks were selected higher than usual for the downhole conditions. Extensive pressure cycle testing performed in the workshop to confirm the efficiency of proposed solution

Operation sequence plan

To ensure safe and efficient isolation of the faulty zones following steps has been designed for all the well candidates:

- Clean out activities utilizing the high impact rotational washing tool (fig. 7)- intended to jet through the identified isolation zone thus remove potential impurities, scales, sand that would ensure smooth expansion of the patch at the zone.
- Deploy wireline style CCL/ Gamma ray depth correlation and caliper logging BHA(fig.8) to confirm depth accuracy for the subsequent runs and caliper check the ID of the completion to ensure uniformity and no restriction that could affect the quality of patch expansion.

– Downhole Expansion Tool (DHET) test run (fig.9) with no patch deployment performed to practice on actual patch setting and ensure personnel gets required confidence.
– Casing patch setting is to be performed that would deliver and expand the patch in place
– Continue casing patch setting until entire intended zone are isolated.
– When deemed necessary repeat the caliper log to confirm set patch uniformity
– Finally, in case natural flow could not be established then nitrogen unloading was proposed as contingency step.

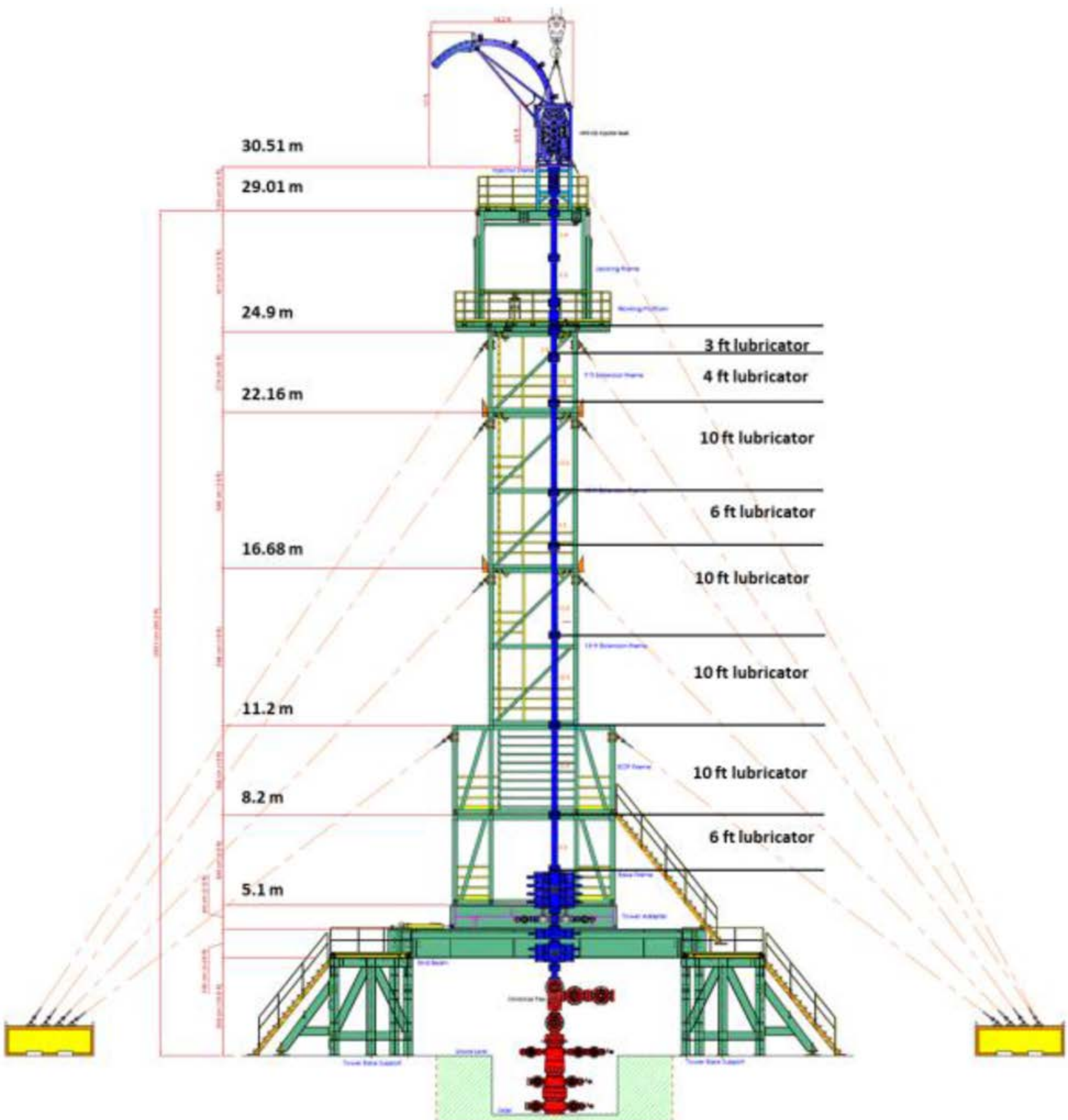


Figure 7—Coiled Tubing Tower Setup

High impact Jetting BHA

Item	Tool Description	Tool Connections	Tool O/D (in)	Tool I/D (in)	T-Length (ft)
1	CT External Connector for 2" CT	2.0" CT - 2 1/8" 8 SA Pin	2.75	1.25	0.34
2	X-over	2 1/8" 8 SA Box - Spline Box	2.875	1.275	0.58
3	Upper intelligent Coiled tubing telemtry tool	Spline Pin - Spline Pin	2.875	1	0.51
4	Lower Sensor Adapter MHA with incorporated Tension and Compression sub, Pressure, Temeperature, and CCL - Double Flapper Check Valve Installed, & Circulation Shuttle L677862 installed, 7/8" Wire Release Ball (1 x shear pin, 2500 psi), 3/4" BHA Disconnect Ball (3 x shear pins, 3000 psi), 5/8" Circ Sub Ball (3 x shear pins, 3000 psi), 5000 Psi Burst Disc	Spline Box - 2 3/8" Pac DSI Pin	2.875	0.563	5.17
5	X-over	2 3/8" Pac DSI Box- 2 1/8" 8 SA Pin	2.875	1.375	0.66
6	2-7/8" Rotojet with 3.5 inch guide 45 Deg Nozzle A Turbin Stages 8 Magnet 6 Diverter Bypass port 4	2 1/8" 8 SA Box - n/a	3.5	0.75	8.84
		Maxiumum Tool-String OD:	3.5		
		Minimum Tool-String ID:		0.563	
		Total Length of BHA in ft:			16.08

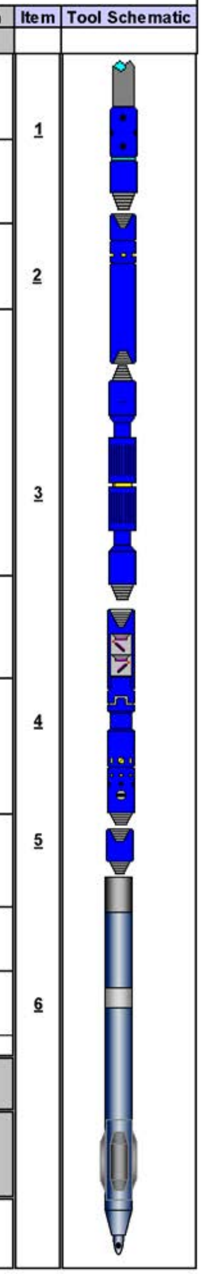


Figure 8—High Impact rotational washing tool

Depth Correlation & Logging BHA

Item	Tool Description	Tool Connections	Tool O/D (in)	Tool I/D (in)	T-Length (ft)	Weight (Lbs)
1	CT External Connector for 2" CT	2.0" CT - 2 1/8" 8 SA Pin	2.75	1.25	0.34	8
2	X-over	2 1/8" 8 SA Box - Spline Box	2.875	1.275	0.58	7.7
3	Upper intelligent Coiled tubing telemtry tool	Spline Pin - Spline Pin	2.875	1	0.51	13
4	Lower Logging Adaptor - Double Flapper Check Vavles, 7/8" Wire Release Ball (1 x shear pin, 2500 psi), 5/8" BHA Disconnect Ball (3 x shear pins, 3000 psi), with Circulating Port open, BPV Installed	Spline Box - 1.188"-12 UN GO Pin	2.875	0.563	3.90	69
5	Adapter GO to Baker A3	Go Box - A3 Pin	1.69	N/A	0.26	2
6	High Strength Swivel	A3 Pin - A3 Box	1.69	N/A	1.00	5
7	Adaptor Baker A3 to GO	A3 Box - GO Pin	1.69	N/A	0.41	2
8	XTU (Crossover Ultra Wire Tool Bus)	Sondex Box - Sondex Pin	1.69	N/A	1.58	6.5
9	HTU (Head Tension Unit)	Sondex Box - Sondex Pin	1.69	N/A	1.93	11.6
10	CCL (Casing Collar Locator)	Sondex Box - Sondex Pin	1.69	N/A	1.54	9
11	PGR (Production Gamma Ray)	Sondex Box - Sondex Pin	1.69	N/A	1.93	9.4
12	PKJ (Production Knuckle Joint)	Sondex Box - Sondex Pin	1.69	N/A	0.55	3.5
13	PRC (Production Roller Centralizer)	Sondex Box - Sondex Pin	1.69	N/A	2.75	13
14	PRC (Production Roller Centralizer)	Sondex Box - Sondex Pin	1.69	N/A	2.75	13
15	Multifinger Imaging Tool with electrical centralizer	Sondex Box - Sondex Pin	2.75	N/A	4.53	61.1
16	PRC (Production Roller Centralizer)	Sondex Box - Sondex Pin	1.69	N/A	2.75	13
17	QPS (Quartz Pressure Sensor)	Sondex Box - Sondex Pin	1.69	N/A	1.58	9
18	CTF (Capacitance Temperature Flow)	Sondex Box - Sondex Pin	1.69	N/A	1.54	5.4
19	Bull Nose	Sondex Box - Sondex Pin	1.69	N/A	0.23	1.2
		Maxiumum Tool-String OD:	2.875			
		Minimum Tool-String ID:		0.563	Maximum Tool weight:	269.4
		Total Length of BHA in ft:			30.65	9342

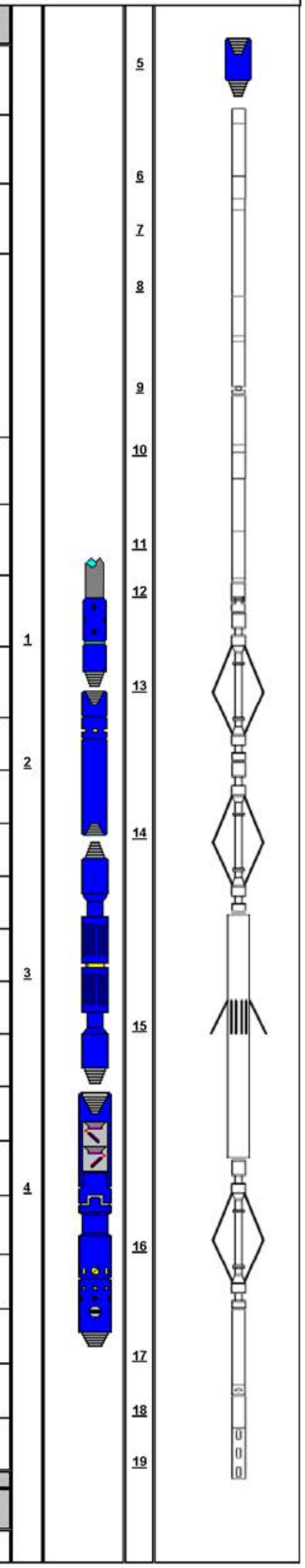


Figure 9—Caliper Logging BHA

Execution were conducted in following sequence

- Start RIH CT with 2-7/8" Jetting BHA (fig.8) and perform washing with friction reduced water at intended interval pumping at mostly 2.5 BPM. Reciprocate along the zone at least 1 time before pulling to surface. Once required depth reached stopped pumping and continue running in hole to tag the bottom and confirm the depth. At the end of the tag CT pulled back to surface and BHA swapped with Caliper tool(fig.9).
- Run in hole with the same(fig9). Upon reaching the required depth perform correlation at patch installation zone. Continue RIH CT to confirm the depth measurement. Stop CT at the next predefined depth and pulled to surface to replace the toolstring.
- When at surface swapped the tool string to Casing Patch Dummy BHA(fig.10) and performed RIH at potential patch setting depth. Start pressuring up the tool to imitate the setting patch expansion process. Once Dummy DHET practice completed successfully pulled the tools to surface.
- At surface actual patch and setting BHA(fig.11) assembled into lubricator and depth corrected to zero reference depth. While RIH depth has been correlated tying to the casing collar at several occasion and comparing the depth to previous run with CCL/ gamma ray references. Once at depth, pressured up to 3500 psi to test the internal burst disc (not to be confused with emergency rupture disk). Pressured up the setting tool to 6,000-6,500 psi depending on wells to start casing patch cycle 1 - disc burst at around 5,300-5,500 psi. Bled pressure after 2 min with holding slack and tension. Performed cycle 2 - 3 at 5,600-5,800 psi(depending on well), to anchor the patch and bled off pressure at the end. Once pressure bled CT RIH to tag below the unexpanded zone and drift the expanded section. Tag down performed with 3.59"-gauge ring and then tag up completed with patch holder installed below the patch body. To continue the process RIH to unexpanded section and performed cycle 4 - 6 at 5,600 psi, once expansion confirmed bleed the pressure and run into next section to perform cycle 7 - 18 at 5,300-5600 psi. At this point another controlled tag up and down performed to ensure smooth ID of the expanded patch. Process continued with cycle 19 at 5,500-5,700 psi, At the final stage pressure pumped up to complete the last section and firmly expand the section of the patch where the isolation element located.
- Once setting up the first patch successfully completed CT pulled out of surface and second section of the patch prepared to be installed. Subsequent patches located in the well the way that bottom part of them overlapped with top of previous section installed thus leave no voids between them.

Patch setting step in details

As it was mentioned above overall it took around 18-20 steps to go through the entire length of the patch and complete its setting. It was highlighted in multiple occasion throughout the paper that during pressure cycles CT tends to elongate and shrink depending on the pressure/flow direction. It was also mentioned that any deformation of the CT length would exert the excessive force to the setting tool thus challenging the efficient performance of the DHET. To overcome the complications Tension, compression and torsion tool readout would be interpreted and appropriate action to compensate the forces would take place. Fig. 12 is data from actual single patch setting where CT movement can clearly be identified. Fig.13 is the one particular step that clearly demonstrate the sequence of the single pressure cycle. As its seen from the graph with pressure increase compression forces start acting on tool indicating pipe elongation push. When compression increase reaches to certain level operator pull CT to neutralize the elongation force. Once expansion completed expected next stage is pressure release. Since it was well projected that CT would immediately tend to go into initial shape, CT run in slightly to prevent potential tensioning on the DHET at the moment of pressure release. CT movement eventually compensated excessive forces during expansion process and deflation of the tool after patch expansion complete.

BHA 3 - 2 7/8" IS-TCT with Saltel Test Packer BHA

Item	Tool Description	Tool Connections	Tool O/D (in)	Tool I/D (in)	T-Length (ft)
1	CT External Connector for 2" CT	2.0" CT - 2 1/8" 8 SA Pin	2.75	1.25	0.34
2	X-over	2 1/8" 8 SA Box - Spline Box	2.875	1.275	0.58
3	Upper intelligent Coiled tubing Telemtry tool	Spline Pin - Spline Pin	2.875	1	0.51
4	Lower Sensor Adapter MHA with incorporated Tension and Compression sub, Pressure, Temeperature, and CCL - Double Flapper Check Valve removed & Flapper sleeve installed, Circulation sealing installed, 7/8" Wire Release Ball (2500 psi), 3/4" BHA Disconnect Ball (3 x shear pins, 3000 psi), Burst Disc blanked off	Spline Box - 2 3/8" Pac DSI Pin	2.875	0.688	5.17
5	2.7/8" OD Reverse Circulating MHA with c/w QIKTech(carsac) .5/8" Check valve activation ball (2x Screw 3100 Psi release Preesure), 1/2" Disconnect ball (4xScrew 2800 Psi release Pressure), 10mm Circulation sub activation Ball (2 x Screw 2500 Psi release pressure) Burst disk 9000 psi, Carsac Type bottom sub with 2 3/8" EUE pin, Burst disk 9000 psi	2 3/8" Pac Box - 2 3/8" Pac DSI PIN	2.875	0.359	3.37
6	X-over	2 3/8" Pac DSI Box - 2 3/8" EUE Pin	2.875	1.370	0.66
7	Module 1 Mechanical weak point = 27 klbs / 12 tons Fishing profile 3.5in GS internal	2 3/8" EUE box - 3"-8TPI SA Pin	3.3	3.5in GS profile IDs	2.10
8	Module 2 Mechanical bleed off = 9.9 klbs / 4.5 tons	3"-8TPI SA Box- 3"-8TPI SA Box	3.3	0.79	5.28
9	Top of M3 (XO, IEC, gauge ring)	3"-8TPI SA Pin - packer box	3.5	0.79	0.85
10	3in M3 extension (rod + new M3 + new IEC)	Packer pin - Packer box	3	0.79	6.53
11	Top of Packer (incl. 2cm of cables)	Packer pin	3.19	0.79	0.75
12	TOP OF PATCH 3in Expansion Packer PDRT Connecting pipes		3	0.79	42.65
13	Patch Holder Mechanical weak point: 7.7 klbs / 3.5 tons Keys collapse 2.2-4.5 klbs / 1-2 kdaN Fishing profile 2.5in GS internal		3.54 (3.05 collapsed)	N/A	0.69
		Maxiumum Tool-String OD:	3.5		
		Minimum Tool-String ID:		0.359	Maximum Tool weight:
		Total Length of BHA in ft:			69.47

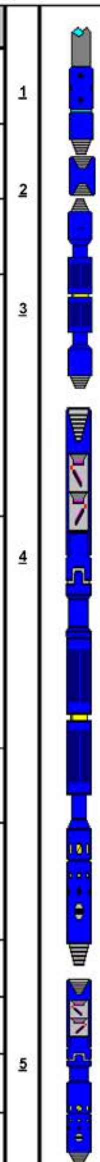
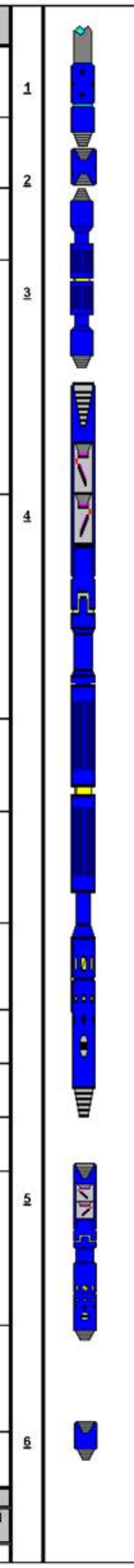


Figure 10—Patch Dummy Setting BHA

BHA 4 - 2 7/8" IS-TCT with Saltel Patches

Item	Tool Description	Tool Connections	Tool O/D (in)	Tool I/D (in)	T-Length (ft)
1	CT External Connector for 2" CT	2.0" CT - 2 1/8" 8 SA Pin	2.75	1.25	0.34
2	X-over	2 1/8" 8 SA Box - Spline Box	2.875	1.275	0.58
3	Upper intelligent Coiled tubing Telemtry tool	Spline Pin - Spline Pin	2.875	1	0.51
4	Lower Sensor Adapter MHA with incorporated Tension and Compression sub, Pressure, Temeperature, and CCL - Double Flapper Check Valve removed & Flapper sleeve installed, Circulation sealing installed, 7/8" Wire Release Ball (2500 psi), 3/4" BHA Disconnect Ball (3 x shear pins, 3000 psi), Burst Disc blanked off	Spline Box - 2 3/8" Pac DSI Pin	2.875	0.688	5.17
5	2.7/8" OD Reverse Circulating MHA with c/w QIKTech(carsac) . 5/8" Check valve activation ball (2x Screw 3100Psi release Presure), 1/2" Disconnect ball (4xScrew 2800 Psi release Pressure), 10mm Circulation sub activation Ball (2 x Screw 2500 Psi release pressure), Carsac Type bottom sub with 2 3/8" EUE pin, Burst Disc 9000 psi	2 3/8" Pac DSI Box - 2 3/8" Pac DSI PIN	2.875	0.359	3.37
6	X-over	2 3/8" Pac DSI Box - 2 3/8" EUE Pin	2.875	1.370	0.66
7	Module 1 Mechanical weak point = 27 klbs / 12 tons Fishing profile 3.5in GS internal	2 3/8" EUE box - 3"-8TPI SA Pin	3.3	3.5in GS profile IDs	2.10
8	Module 2 Mechanical bleed off = 9.9 klbs / 4.5 tons	3"-8TPI SA Box- 3"-8TPI SA Box	3.3	0.79	5.28
9	Top of M3 (XO, IEC, gauge ring)	3"-8TPI SA Pin - packer box	3.5	0.79	0.85
10	3in M3 extension (rod + newM3 + newIEC)	Packer pin - Packer box	3	0.79	6.53
11	Top of Packer (incl. 2cm of cables)	Packer pin	3.19	0.79	0.75
12	TOP OF PATCH 3in Expansion Packer PDRT Connecting pipes		3	0.79	42.65
13	Patch Holder Mechanical weak point: 7.7 klbs / 3.5 tons Keys collapse 2.2-4.5 klbs / 1-2 kdaN Fishing profile 2.5in GS internal		3.54 (3.05 collapsed)	N/A	0.69
		Maxiumum Tool-String OD:	3.5		
		Minimum Tool-String ID:		0.359	Maximum Tool weight:
		Total Length of BHA in ft:			69.47



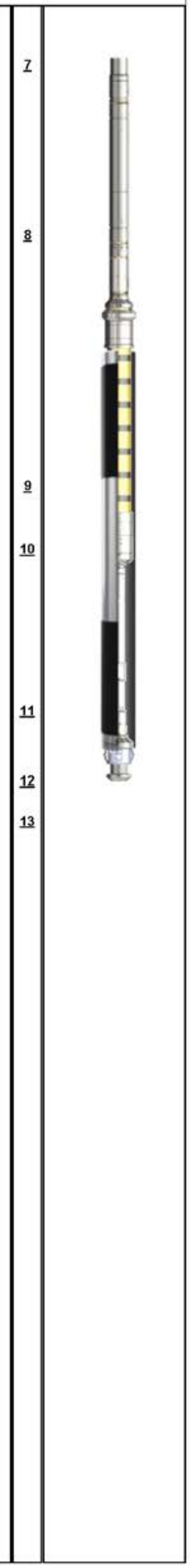


Figure 11—Expandable Patch Setting BHA

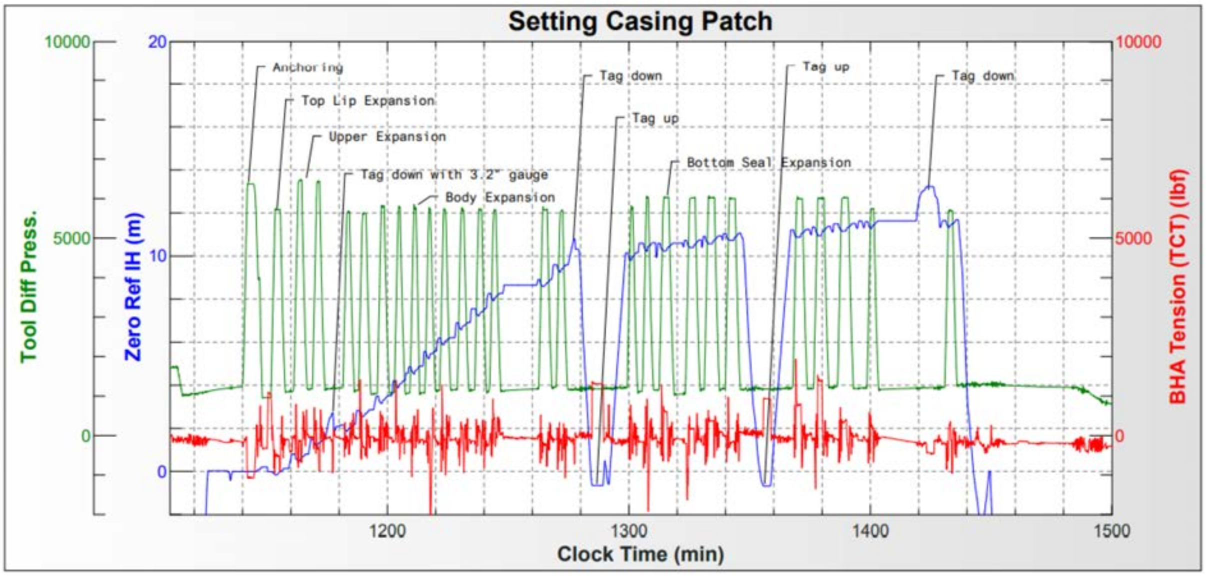


Figure 12—Setting sequence of the entire patch

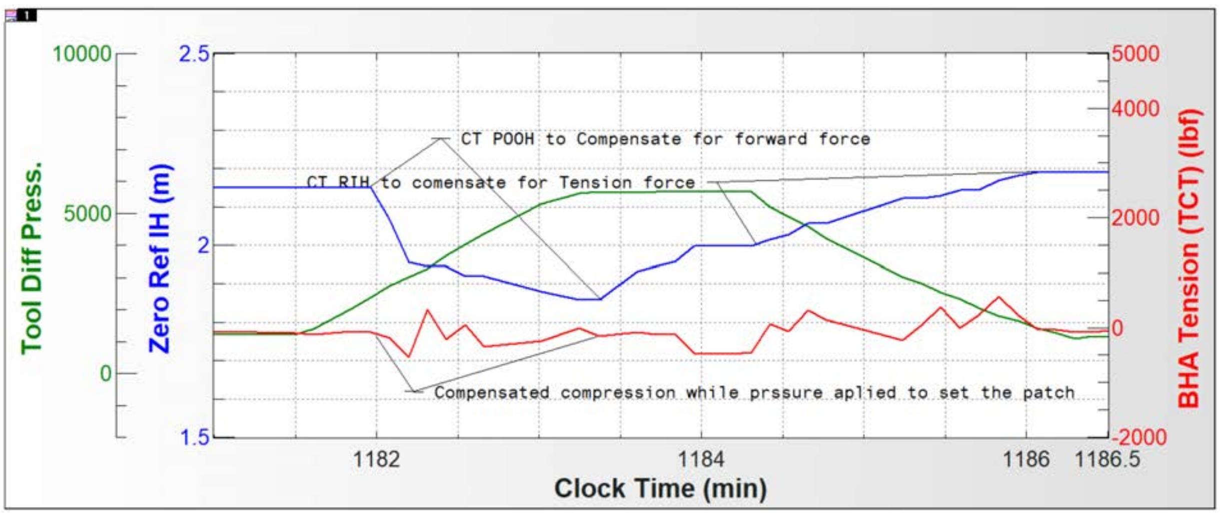


Figure 13—Single Pressure Steps to set the section of the patch

Conclusion

All the projected wells were successfully completed as per plan. Top section of the perforation zones was isolated and ultimate goal of reducing the amount of the excessive gas successfully achieved. The average time to perform the operation per well was 369 hours. This included 255 hours for the CT equipment rig-up (CT unit; Rig up CT Tower, BHA preparation, make up and laydown; and pressure test of surface lines, BHA and stack), 18 hours for the rig-down, and 96 hours for the CT running time. The test packer run was 11.08 hours, including the run in hole and pull out of hole times. Each of the four expandable steel patch runs lasted with average times 18.14 hours, including the run in hole and pull out of hole times. The total time necessary for one patch setting was between 2 to 4 hours.

Overall, 27 patches were successfully installed utilizing Intelligent coiled tubing technology. The successful intervention campaign resulted in the reduction of the gas production by 26%, which allowed significant incremental delivery of Oil production within the field.

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