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The joining and splicing of internal cable CT strings to enable deeper Coiled Tubing Deployed ESP completion.

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Abstract

Coiled Tubing conveyed Electrical Submersible Pump completions (CT-ESP) have now been established as a cost-effective means of improving production in pressure depleted reservoirs, with low installation and work over costs. However, due to max lift limitations, and crane down grading practices associated with offshore platforms, the use of CT-ESP's in many cases cannot be considered, because it is simply impossible to lift a CT-ESP reel of the required length on board the platform. This paper describes a worked solution (1) for a conventional CT reel that exceeded the platform crane lift capacity. A worked solution (2) for a CT-ESP re-completion, followed by a proposal (3) for a complete CT-ESP solution, with a focus on overcoming the max crane lift issue, thereby allowing deeper CT deployed ESP completions in the future.

Introduction

The reservoir parameters that normally trigger the need for CT-ESP completions are low flowing bottom hole pressures (FBHP), gas lift no longer effective, water injection causing unacceptable water production, and a need for increased drawdown capability. These parameters typically exist in wells that have produced over a long period of time. Here is where the conflict of interest exists for the CT-ESP solution. If a well has been producing for twenty years then the offshore platform has been operational for even longer. This means that the platform crane will either have had a low max lift capacity to begin with (as is the case in marginal fields with small platforms) or will have gone through a down grade program as the platform has aged. The scenario is simple, how do you get a CT-ESP reel in excess of 30 Tons onto a platform with a max crane lift of 20 Tons? For example a 10,000ft CT-ESP string, outside diameter (OD) 2 3/8", with 0.204" wall thickness, including lifting arrangement and transport base weights 34.5 Tons. The present solutions of boat spooling or crane barge are prohibitively expensive. The solution described here is to transport the required length of CT on two separate reels and use a split reel spooler system. The challenge then is to join the CT sections together on the platform. This will be achieved using a specially designed tube / tube connector. This not only enables the pipe to be joined together, but also allows access to enable the splicing of the electrical cables and hydraulic control lines inside. From an engineering perspective, the joining of two conventional CT strings offshore presents a number of challenges if field welding is not an option. However, existing methods, tools and equipment can be used in innovative ways to overcome these challenges. The added complexities associated with joining electrical cables and hydraulic flow lines will involve new design concepts for the connector and some inventive methods being applied to ensure a successful connection offshore. It is clear that the problem with crane lift capacities must be overcome, as it is safe to say that the CT-ESP completion solution will always be faced with platform crane lift limitations.

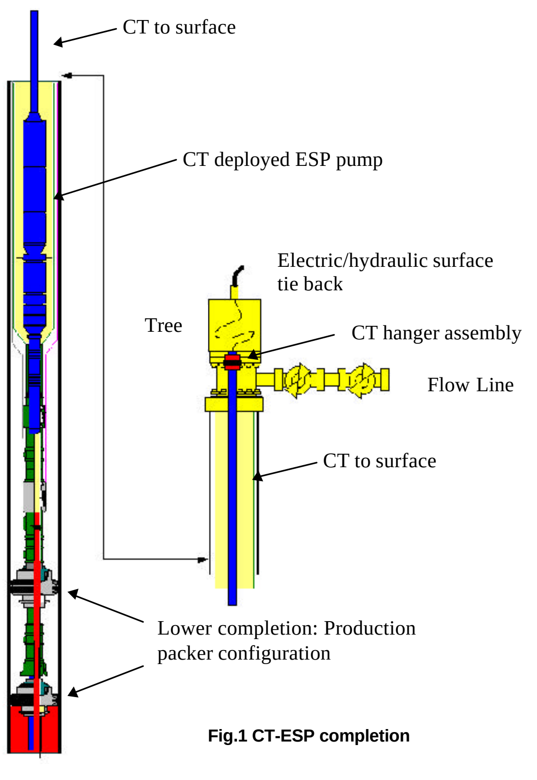


Fig.1 CT-ESP completion

Worked Solution 1: Joining Conventional CT Offshore

A newly completed gas producer in the Norwegian sector of the North Sea required a cleanout operation prior to perforating. The cleanout was necessary due to mud settlement caused by delays between the completion phase and the perforating phase. The mud solids had settled to a depth above key perforation zones. The rig crew and drill pipe had been demobilized immediately after the completion phase. The cheapest option available was to mobilize CT to do the cleanout. The completion was a 7” monobore with a total measured depth of 19,686 ft. Following some extensive simulation work to ensure sufficient flow rates to achieve solids transport during the cleanout, the only suitable coil size was 2 7/8”. The string length required would need to be around 20,000ft. The calculated CT reel weight was 42 Tons, including lifting equipment and transport base. With a platform crane limit of 40 Tons the use of a single length of CT was not an option.

It was decided to mobilize the CT as two separate strings (A & B) and join them together on the platform using a tube to tube Dimple On Connector (DOC). String A was 16,400ft long, and 35.8 Tons. String B was 6000ft, and 18.0 Tons. Using a split reel spooler system, together with a hydraulic work window positioned in the riser arrangement below the injector, the option of joining strings A&B together in the actual riser was possible.

Job Execution. Firstly string B was run into the well to a depth of 4,920ft with the motor and milling bottom hole assembly (BHA) installed on the end. In order to facilitate the make up of the connection a pipe straightener was used to ensure that the CT was as straight as possible across the window. The CT pipe ram, slip ram, and annular BOP were closed, allowing the work window to be opened, exposing the straightened pipe section. A backup clamp was fitted to the pipe. The coil was then cut using a hydraulic cutting tool. (Fig.2). The remainder of string B was un-stabbed from the CT injector head and spooled back to the CT reel.

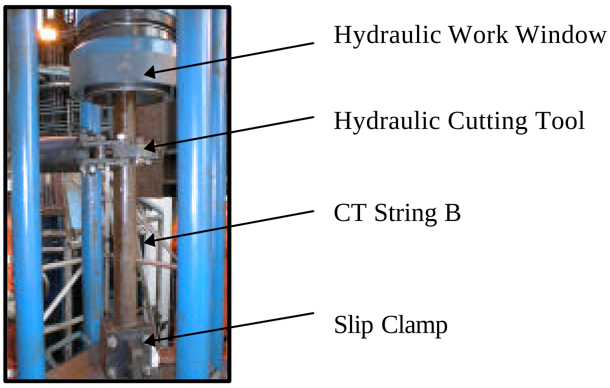


Fig.2 Cut CT String B

The exposed end of string B was dressed using reaming tools designed to remove the internal weld seam, and to prepare a tapered leading edge on the pipe, allowing smooth installation of the connector. The DOC was then installed onto string B without dimpling on at this stage. (Fig.3&4)

Fig.3 Dressed Pipe

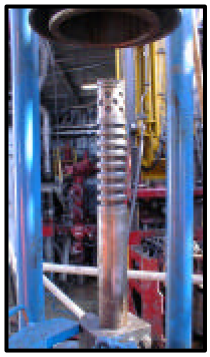


Fig.4 Connector String B

The CT reels were then changed out. With CT string A installed in the spooler, the pipe was stabbed into the injector head and run in hole (RIH) to the work window. The pipe straightener was again used to ensure that the pipe was as straight as possible through the window. The exposed end of string A was dressed with the reaming tools. Using the injector slow speed control, string A was then RIH and the upper end of the DOC was guided into the pipe and shouldered out. (Fig.5)

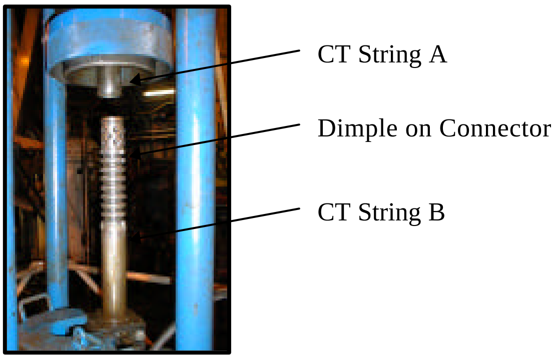


Fig.5 RIH CT string A

The connection was then secured using the jig and hydraulic dimple tool. (Fig.6 & 7). The connection was pull tested, pressure tested, clamp removed and the work window closed, prior to opening the annular BOP, slip ram, and pipe ram. The CT was then RIH to 17,550ft where the mud solids were tagged. The cleanout was achieved, with a final cleanout depth of 19,545ft. The connection was secure throughout the job with no leaks or mechanical wear and tear.

Fig.6 Dimpling Process

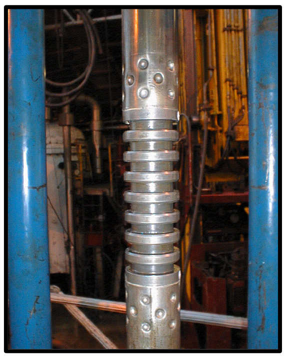


Fig.7 Dimpled Connection

Worked Solution 2 CT ESP Re-completion: North Sea

The Tor platform was an integrated drilling and production platform installed in the Ekofisk area in 1976 and has produced oil and gas since 1978. With the drilling program complete the drilling derrick was removed from the platform. A gas lift system was installed to enhance production from the mature reservoir.

With a view to increasing production and efficiency even further all wells on the Tor platform were analyzed as potential candidates for CT ESP completion. After a thorough reservoir modeling study and detailed design analysis of the existing completions, two candidate wells were selected. The two wells (E-06 & E-12) are now flowing by means of CT ESP completions. E12 is a slightly more complex completion in that it was run into an existing 7"casing and consequently the down hole safety valve (DHSV) is part of the ESP assembly.

After running for only a short time the original installation in E-12 developed a fault. It was decided to retrieve the ESP from the well, correct the problem, and re-run the same completion.

Once the CT hanger has been pulled, in order to retrieve the pump from the well, it is necessary to join a pulling string (String A) to the ESP string in the well (string B), much as in the previous case. However, in this case the added complexity of the electrical cables and hydraulic flow lines is present. To re-run the same CT ESP completion it was necessary to hook up all three hydraulic control lines inside the CT. This allows pressure and integrity checks to be carried out during the assembly of the ESP pump BHA at surface. It also enables control of the DHSV during the re-run of the completion. Without these facilities a new CT ESP string would be required. This option would be very costly, and there was a high chance that bad weather conditions would not allow the new CT reel to be lifted on to the platform.

From the previous worked solution the joining of two CT strings was already field proven. The joining of hydraulic control lines had not been attempted before using the DOC. Following technical evaluation and some trials, it was decided to attempt to join the control lines inside the DOC. As with the previous case a hydraulic work window was used to allow access to the coil and provide a safe environment for preparing the pipe and control lines for joining.

The bundle inside the coil for this completion consists of an armored ESP electric cable and three ¼" hydraulic control lines and a ¼" instrument cable, armored together as a flat pack. These cables and pipes control and operate the, power for the ESP, pressure transducers, DHSV, chemical injection, and the emergency release mechanism on the ESP pump.

The bundle is an unsupported column inside the CT string. The pulling and re-running of the completion results in independent movement of the bundle relative to the pipe. To allow for this differential a slack and expansion capability had to be built into the hydraulic control lines at the joint location, within the DOC.

Job Execution. The connector used to join strings A&B was a specially modified version of a DOC. It had a larger internal diameter to accommodate the hydraulic fittings used to join the lines together, and other features to ease the make up in the window. The hydraulic fittings used were a special slim-line design manufactured from high tensile material. The reamers for preparing the pipe were also specially developed to accommodate the cables and control lines.

Once the ESP completion string had been secured in the hydraulic work window using the BOP slip ram and back up clamp, the pipe was cut away exposing the bundle. (Fig.8)

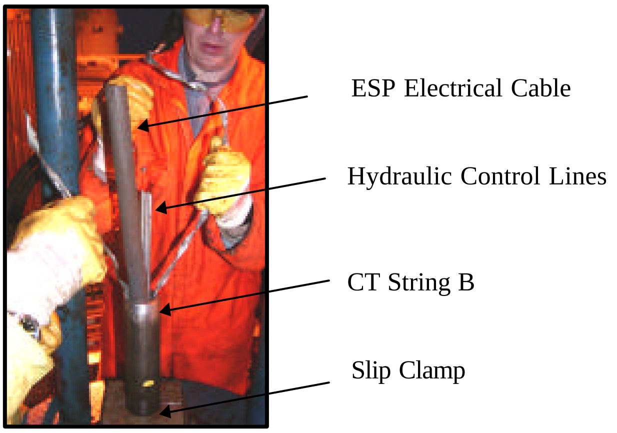


Fig.8 Exposed Bundle

CT strings A&B were dressed using the reaming tools to remove the internal weld seam and to prepare a tapered leading edge on the pipe to allow smooth installation of the DOC, and to minimize the potential for damaging the seals during installation. (Fig.9&10)

Fig.9 Special Reaming Tools

Fig.10 Pipe Dressing

The DOC was trial fitted into the CT string ends to confirm smooth installation before proceeding to the next phase. The ESP electric cable was terminated by insulating and sealing each of the three cores in turn. The ability to compensate for any movement of the bundle during retrieval and re-run of the CT ESP completion was achieved by manufacturing a splice section for each flow line. The splice section was made from three lengths of 1/8" hydraulic control line spiraled into a shape similar to a coil spring. The helical spring design allows each splice to stretch depending on the movement of the bundle relative to the CT.

Each 1/8” line was attached to the original ¼” lines using the slim line cross over fittings. (Fig.11)

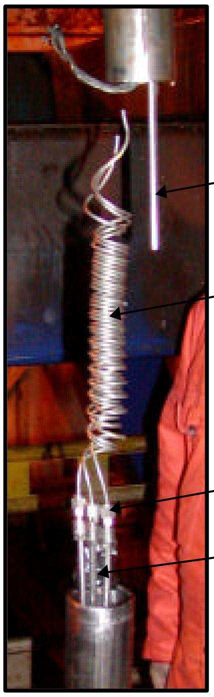


Fig.11 Splicing Procedure

The DOC was then placed over the splices and the upper string run down to make the final connections. With the strings A&B landed on the DOC, the hydraulic dimple tool was applied and the connection was secured. (Fig.12)

Fig.12 DOC Secured

After pull testing the connection to 80,000lbs, the 10,000ft CT ESP string was pulled out of the well and spooled onto the CT drum. The necessary repairs were carried out to the pump and after adding one joint to BHA length, the ESP assembly was re-deployed into the well, hung off, and the CT ESP string was then connected. A full hydraulic control line integrity test, enabled by the splice, was carried out prior to running in hole with the CT ESP. The completion was run in and landed off, the CT hanger locked down, and the Tree electrical/hydraulic tie back completed at surface. The re-completion process was successful and the pump in Tor E-12 is now producing once again.

The tube / tube connection and splice was only required during the re-run operation. The DOC (or “coil saver”) was inspected externally and internally once the CT equipment had been rigged down. It was found that the expansion facility (the helical spring) had been fully utilized in tension mode during the re-completion process. The helix had been stretched to the point that the 1/8” hydraulic control lines were completely straight. The splice had therefore compensated for the maximum bundle movement experienced during the re-run, thereby maintaining hydraulic integrity throughout to the BHA.

To summarize the worked solutions presented before moving on to the proposal for the complete CT ESP solution. It has now been field proven that CT and hydraulic control lines can be joined together by means of a connector offshore without compromising the function or performance of the CT or control lines. To enable CT ESP strings to be joined together as a means of overcoming crane lift limitation, and allow deeper CT ESP completions in the future, the connector concept must be taken one step further. The next step will be to join together the electrical cables, as well as the hydraulic control lines when connecting the CT.

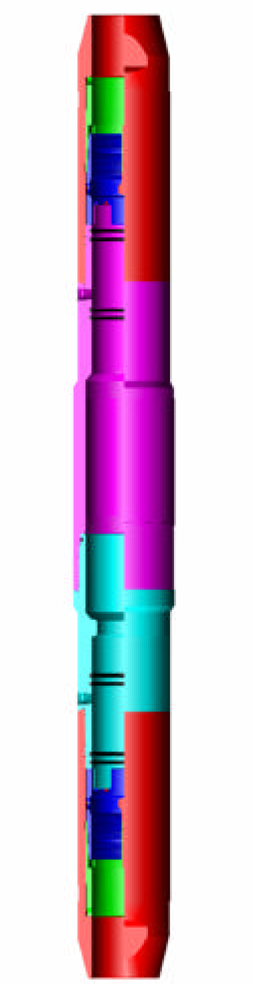
Proposal 3: A Coil Tubing solution to overcome crane lift Limitations, allowing deeper completions

The connector proposed for this application is based on an existing outline slip type coil connector, as used on typical CT BHA`s. The challenge is to engineer a tube – tube connector from this proven technology, with the key design criteria being, efficient assembly and installation, and total reliability. The method of application is much the same as in the first worked example (1). The CT string will be mobilized on two separate reels (A&B). String A being the longest, and String B as short as possible. Once again a split reel spooler system would be used, together with a hydraulic work window positioned in the riser arrangement below the injector head.

Job Execution. String B is run into the well as deep as possible with the ESP BHA installed on the end. Then close the CT pipe ram, slip ram, and annular BOP, before opening the work window to allow access to fit the back up clamp to the CT. The coil is then cut with the hydraulic cutting tool. Ref. (Fig.2). The remainder of string B is then spooled back to the CT reel.

The exposed end of string B is dressed using the reaming tools and the hydraulic control lines and electrical cables prepared for splicing.

Install string A into the spooler and feed the CT through the injector head down into the hydraulic work window. Dress up the exposed end of string A. Splice the hydraulic control lines and the electrical cables together before securing the tube-tube connector. (Fig.13&14). Pull test the connection, and pressure test the seals via the test ports. Confirm line integrity through each hydraulic and electrical connection, before running in with the full CT ESP completion to setting depth.



The coil extender Tube-Tube Connector

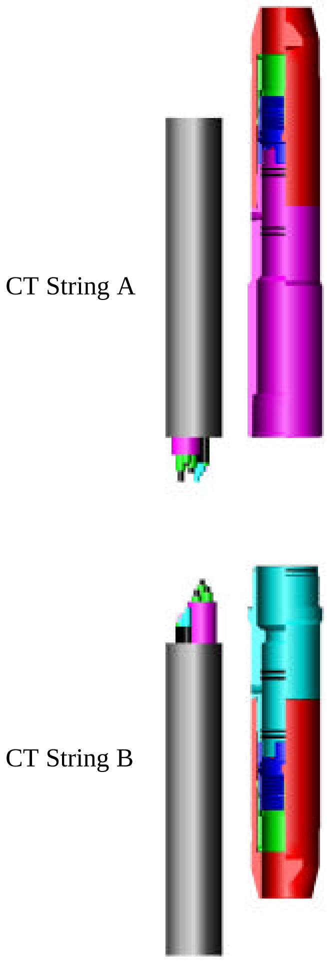


Fig.13 String A&B Illustration

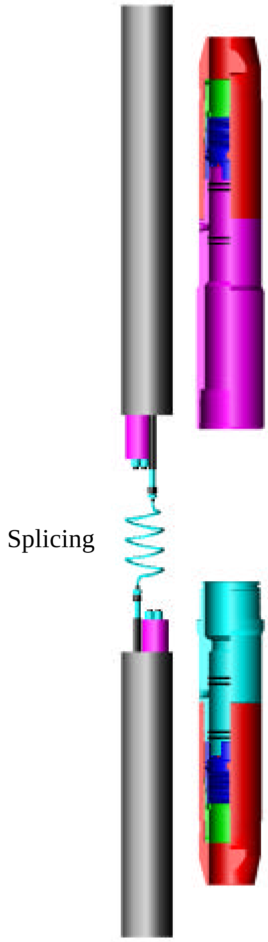


Fig.14 Splicing Illustration

Conclusions

The proposal presented has evolved from proven CT equipment and techniques. The connector is based on existing technology and off the shelf components tested by leading CT tool manufacturers. The exact specification of the connector can be engineered to suit the type and size of CT ESP completion to be run.

The simple design, efficient and reliable installation, combined with the application of specialized ESP cable splicing knowledge, provides a powerful solution to the problem of deep CT ESP completions with offshore crane limitations.

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