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Technology Application Bringing Highly Accurate Answers to Free Pipe Determination, Enabling Operational Certainty and Efficiency, Delivering Optimized Tubular Recovery

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Abstract

For years, the need to quickly and accurately determine where drill pipe is free during a stuck pipe event has been critical – This in turn leading to a pipe backoff or cut that can either result in successful fishing and continuing to planned TD: or an unsuccessful fishing attempt and side-track. Today, accurate free pipe depth determination is equally important when pulling tubulars as part of workover and plug and abandon (P&A) operations. In both scenarios, high accuracy free-pipe determination methodology enables maximum pipe length to be cut and retrieved out of the well at the first attempt.

The clarity and reliability on pinpointing the interface between stuck and free pipe is limited when using conventional tooling, with inherent time inefficiencies due to the requirement for multiple stationary measurements. The electric line deployed technology presented here works on the principle of changes in a magnetic signature brought about by tubular manipulation. With the pipe in a neutral state, a magnetic signature is written and recorded simultaneously along the length of the tubular in the zone where the stuck point is suspected to be located. The pipe is then manipulated, either by tension, compression and or torsion before being returned to neutral. A subsequent logging pass is then completed remeasuring the original signature written. The comparison of the two passes indicates the free or stuck status of the pipe – a change in signature indicating free pipe, no change indicating stuck pipe.

Successful operations have been executed globally with the new pipe recovery technology, both in the drilling and P&A space. The range of application, the efficiency of operation and value of its clear and certain answer has been well recognized by customers. The paper will present two case studies representing a range of operations, each presenting their own unique challenges, be that completion or BHA type, well trajectory or wellbore environment. Each will demonstrate the efficiency of the operation, accuracy, and repeatability of measurement, and ultimately the certainty of the near real time answer. The answer product derived from the acquired data is delivered quickly, providing a clear indication of the free pipe without ambiguity or the need for lengthy interpretation. The new pipe recovery technology simplifies job planning, preparation and execution and has a significantly reduced wellsite footprint and ultimately delivers a reduced carbon footprint.

The technology is compatible with electric line tractor conveyance, primed for high well deviation and extended reach trajectory drilling in mind. The technology is designed for high pressure / high temperature operations as well as multiple sensor combinations for additional data acquisition per trip. The string can also be reconfigured to acquire the required data, logging in different directions to suit the operation, e.g., gravity deployment vs pump down or tractor.

Introduction

This paper discusses a new electric line (e-line) deployed technology development used in pipe recovery operations.

Prevention of drilling related stuck pipe incidents has substantially improved over the years due to general knowledge of the issues coupled with better drilling practices. Drilling technology developments, for example top drives and rotary drilling systems coupled with advancements in drilling fluid design, has also helped avert many a stuck pipe circumstance. There may also be a better understanding of the geology of some hydrocarbon basins which are susceptible to the causes, with prediction modelling now available. That said, drill pipe sticking occurrences continue to happen, the risks remaining in certain formation types, or when executing more ambitious well designs in terms of deep water, well deviation, tortuosity and/or lateral extent. Removal of production tubing or casing from wells as part of P&A and decommissioning operations is a growing activity, one which also confronts stuck pipe during "cut and pull" operations. This can be as expected, due for example to casing or liner cement application design at the time of tubular placement, or unexpected due to formation swelling or tubular collapse which has occurred over the lifetime of the well.

Planning for pipe recovery in both scenarios is an integral part of the well cycle, and when understood and with the correct mix of experience and equipment, the results can be highly valuable. However, with aging assets and fewer experienced personnel to operate, a traditional free point indicator tool (FPIT) run in many locations, has long been associated with an inefficient use of rig time that may not yield reliable results. The most efficient operation involves a "diagnosis" trip to primarily determine the depth which the pipe is deemed free and a "treatment" trip to carry out some form of separation of the bottom hole assembly (BHA). If executed correctly, the rig could continue or be back on the critical path in the time it takes to trip pipe after a successful wireline FPIT followed by separation run. Regardless of the quality of planning, equipment or personnel availability, the diagnosis is the most important run as any subsequent trip to provide treatment will be based on the information ascertained from this run – if the diagnosis is poor then the chance of successful or fully optimized treatment is severely reduced. Segura, 2011 stated that efficient separation of stuck strings with proven results was a must for deep water wells where day rates exceed USD 1,000,000, this is now generally expected across all tubular recovery operations regardless of well depth or rig day rate.

Unlike evolving industry requirements and expectations with regards to pipe cutting technology becoming more precise and controlled (Fanini. O. N., et al 2009), traditional FPIT technology has largely remained the same – a slim tool to fit through most drilling BHA minimum restrictions, installed with either motorized arms, bow-springs or magnets to enable a static survey measurement. Each option had their limitations that ultimately forced a compromise between deployment and data quality. The new pipe recovery technology this paper discusses offers a safer, more efficient, and smarter solution across the various wellbore environments and trajectories and has resulted in a new level of precision and clarity being defined, enabling de-risking both planned tubular recovery and unplanned stuck drill string events.

New free pipe determination technology

The technology presented in this paper utilizes a transmitter that writes an electro-magnetic signature into the downhole tubular, that is then measured via a receiver using uniquely designed sensors and measurement procedures. The result is the delivery of an efficiently acquired, rapidly interpreted and highly accurate free pipe depth determination even in the most complex of pipe or tubular combinations and configurations.

The new pipe recovery technology is a dynamic logging instrument that carries out a "production logging" style survey across the zone of interest. Continuous logging passes are done with the tubular maintained in its neutral state, i.e., without any induced tension, compression, or torque. Between passes however, the tubular is manipulated with tension, torsion or compressional forces applied then released. A comparison of the logged data made pre and post manipulation is then carried out, the difference clearly and accurately pinpointing the free pipe depth. The tool-string consists of a transmitter, a receiver, and a magnet, each with a specific function during the logging passes. These key components and other items of the full tool-string are shown in Fig. 1 below.

Figure 1—New pipe recovery technology. Length; 20 ft, weight; 96 lbs, OD; 1.7 in.

During logging pass 1, the magnet baselines the tubular's inherent electromagnetic field in preparation for logging. The transmitter tool immediately follows and writes a continuous electro-magnetic signature to the tubular, along the length of its inner surface. The receiver then measures and records (logs) the written signature, which will remain in the tubular as is and only altered if the pipe is subjected to a stress. After logging pass 1 is complete, the tools are held stationary while a single event of tubular manipulation is applied from surface – this event inducing a stress across the BHA. When returned to a neutral condition, a second logging pass, post manipulation is made, re-measuring and re-recording the signature for comparison with logging pass 1. Over the interval in which the tubular is stuck, the manipulation applied will have had no effect on the signature as the stresses have not been transferred. Over the interval where the pipe is free however, the electro-magnetic signature along the length of tubular will have been permanently altered by the induced stresses caused by the single event of surface manipulation.

Fig. 2 below shows a typical logging sequence, with a down and up pass undertaken and the tubular manipulation event having been applied in between. The measurements are precise and the change visibly indicated by the unambiguous overlay of the passes, this providing a clear indication of the free pipe depth. The result is almost immediate and finalised at the wellsite with minimal, rapid interpretation.

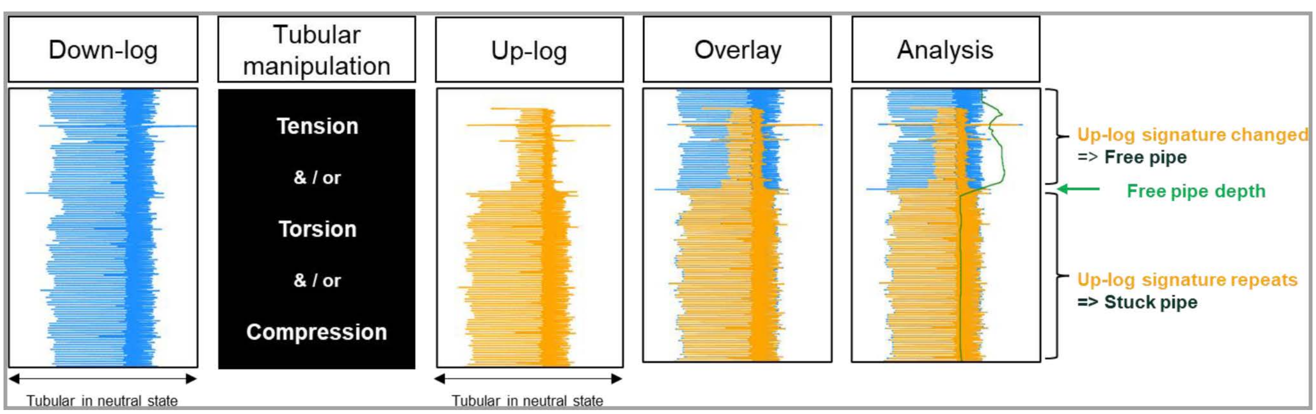

Figure 2—Logging and operational sequence. Interval shown is 600 ft in length

The technology has two main types of sensors inside the receiver module. The primary sensor is immune from tool rotation and decentralization, negating any impact on data quality from wellbore trajectory. It has an enhanced sensitivity level that enables 2 distinct abilities:

- Free pipe detection in pipe with wall thickness >1 in.: In the stuck drill string BHA event, this performance has allowed successful free pipe determination to take place inside heavy weight drill pipes (5 in., 5.5 in. and 6.625 in.) and drill collars (8.25 in.). The sensor response varies for different pipe sizes (ID and wall thickness) and is a key attribute in log quality control.
- Repeatability: the sensor is temperature compensated enabling an almost perfect repeatability between passes where the BHA remains stuck enabling reliable free pipe depth identification.

There are also four secondary sensors inside the receiver that operate independent of the primary and when combined also deliver a valid measurement complementing the primary sensor data. These four sensors are not immune from tool orientation & positioning inside the tubular. The common logging speed of the technology is up to 60 ft/min (20 m/min).

Additional features

Outside the logging data acquisition hardware, the new system has many beneficial features. These include:

- Dedicated reliable telemetry: regardless of the type of e-line technology being deployed, a reliable communications bus is a necessity. The new pipe recovery technology operates on a digital telemetry, negating previous issues associated with analogue FPIT's caused by different wireline types and lengths. This robustness is especially critical in pipe recovery operations as often with the urgency to resolve the situation there isn't time for a system integration test (SIT) with the wireline cable to be used for the operation until the equipment is at the wellsite.
- Low friction roller centralizers: The BHA, pipe ID and minimum restriction are crucial details that need to be known prior to deployment. Fitting through various restrictions but also being able to gain reliable data can often be challenging. Bow springs vs motorized anchors both have limitations regardless of pipe size and type (pipe body ID vs joint ID). The ones used with the new technology have low friction rollers mounted in the hinge and are applicable for 2.875 in. to 9.625 in. OD pipe regardless of inclination.
- Combinability with other sensors: any sensor or hardware that goes downhole serves a purpose to the operational requirement. Common practice is to deploy a production gamma-ray (PGR) as well as casing collar locator (CCL) to tie the free pipe log into the open hole formation as well as pipe tally. The PGR deployment also identifies any radioactive marks installed in the well for additional depth reference. In the stuck drill pipe scenario, deploying a temperature and pressure sensor can provide additional value pertinent to the next part of the operation. During intervention operations, acquiring multiple data sets from a single run is critical – Multi-finger imaging tool (MIT) data and cement bond log (CBL) data can both be acquired in combination providing greater understanding of the downhole environment without requiring additional rig time.
- Separate sensor modules enabling a high degree of configurability for different logging environments: the new pipe recovery technology is made up of separate modules that can be configured in different positions enabling different operational procedures to be used based on the downhole environment and or deployment method e.g. handling pump-down or tractor deployed operations.

Case study 1

Offshore well, stuck cement stinger BHA

An operator in the North Sea had a requirement for an accurate free pipe depth determination due to their cement stinger BHA consisting of both 3.5 in. and 5 in. drill pipe (DP) becoming stuck. The 12.25 in. hole size had been drilled and 9.625 in. casing had been run but during the cement operation, the DP had become stuck due to over displacement of the cement. It was not known if the unplanned top of cement was across the 3.5 in. or in the 5 in. DP. The well was drilled from an offshore platform with 3,006 m measured depth (MD) and 1,851 m true vertical depth (TVD). The well had an inclination above 70° from 2,040 m MD. This trajectory combined with multiple drill pipe sizes gave the operator 2 choices:

1. Cut the drill pipe partially "blind" without diagnosis at a depth based on stretch calculations.
2. Mobilize wireline crew for an e-line deployed pipe recovery survey. This included:
   a. Deployment technology and expertise
   b. "Diagnosis" technology and expertise
   c. "Treatment" technology for use inside casing

From a weekend pre-job with the offshore customer representatives, electric line tractors, electro-mechanical cutters and the new pipe recovery technology performed an SIT and were mobilized to the wellsite within 24 hrs. With 1,000 m of well at 90° inclination, there was significant value to gather a clear free pipe depth. Fig. 3 below shows the tractor section including release subs, combined with the pipe recovery technology and Fig. 4, shows a 3D view of the well created during pre-job tension simulations.

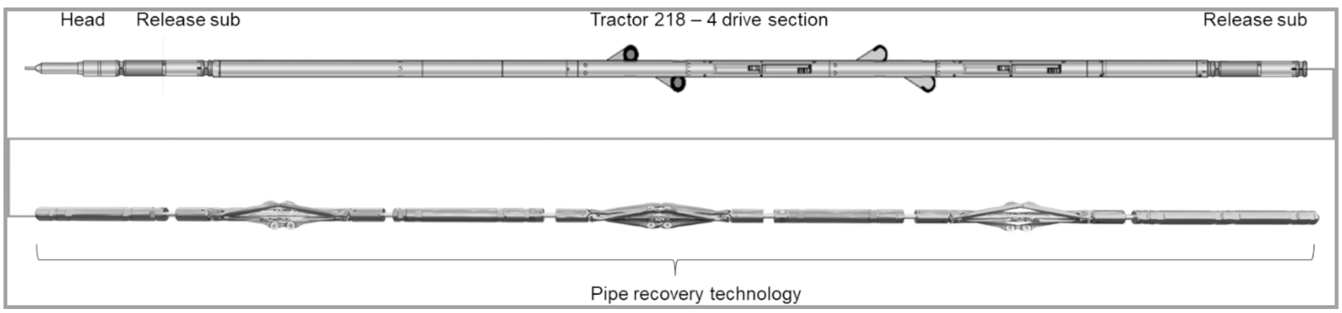

Figure 3—New pipe recovery technology string deployed beneath 2-1/8 in. tractor.

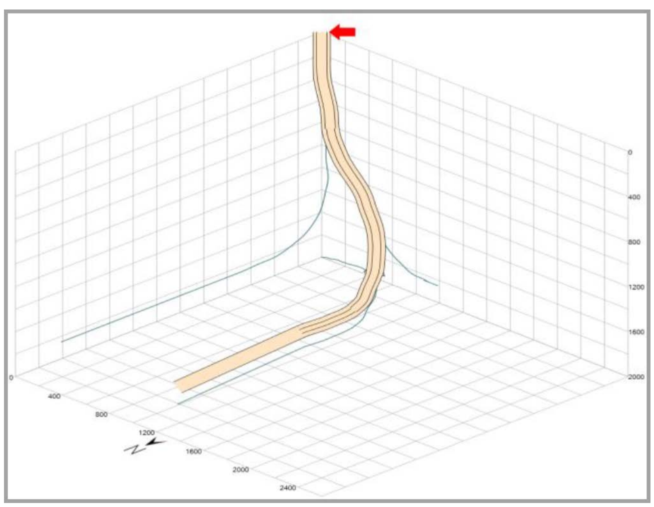

Figure 4—3D view of the well trajectory – survey required across the lateral section.

The electric line tractor was required to deploy the new pipe recovery technology to the hold up depth (HUD) on the first run in hole and two passes of data acquisition were acquired across the 3.5 in. and 5 in. drill pipes either side of a single event of pipe manipulation. Fig. 5 below shows part of the logged interval – indicating the free pipe depth was in the 3.5 in. drill pipe section

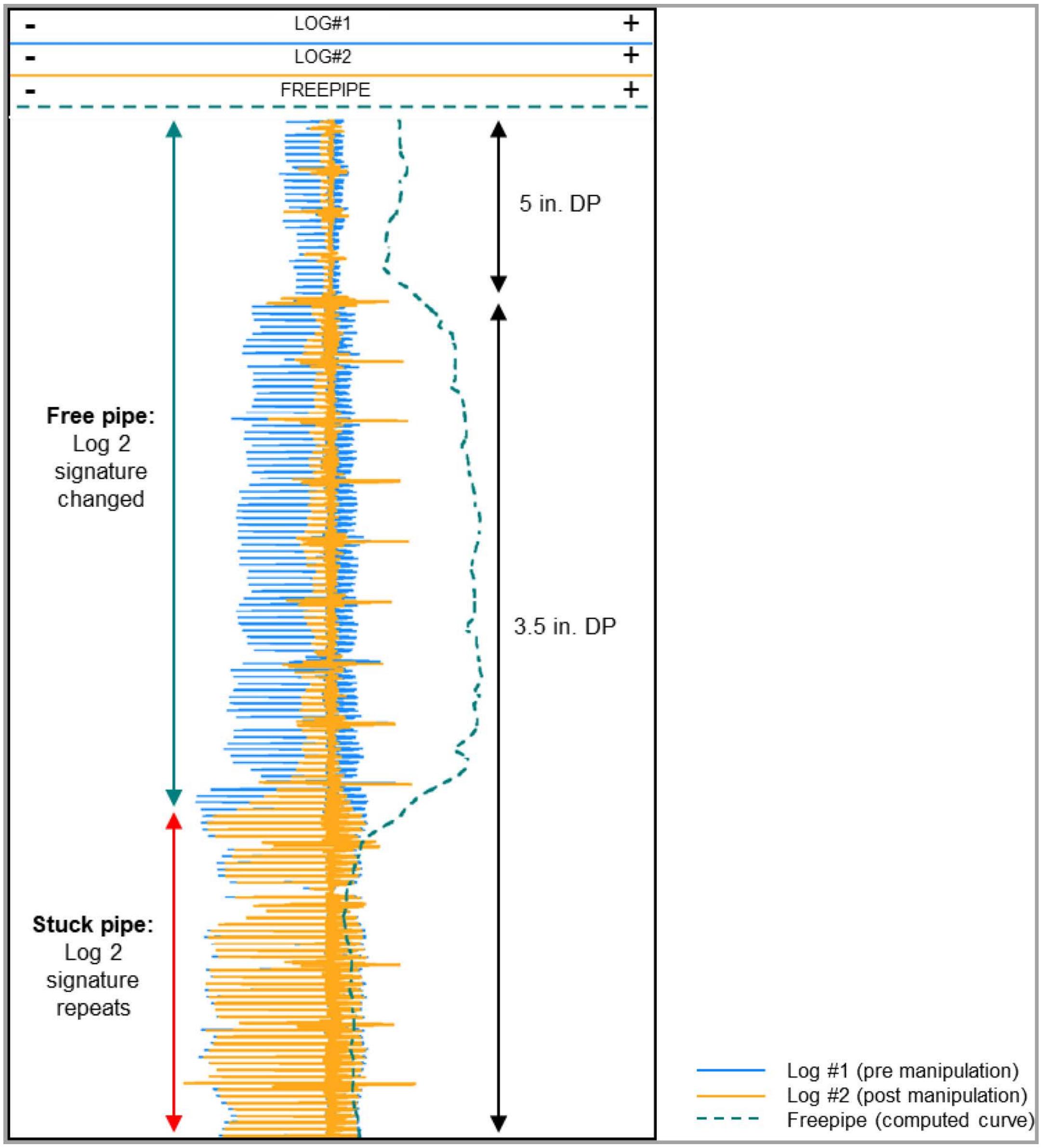

Figure 5—Part of the log acquired over the horizontal zone of interest. Log interval presented 250 m.

The clarity of the data enabled the customer to decide on the optimal course of action with certainty. The total operation was completed as follows:

- 2-1/8 in. Tractor / New pipe recovery technology
- 2-1/8 in. Tractor / Non-explosive setting tool / Plug – plug set in the bottom joint of 5 in. DP
- 2-1/8 in. Tractor / Electro-mechanical cutting tool – pipe cut in the deepest joint of 5 in. DP above the plug

The use of an e-line powered setting tool and electro-mechanical cutter gave the customer a fully explosive free pipe recovery solution. Operational efficiency was enabled by the new pipe recovery technology providing the diagnosis clarity on the depth that the treatment was needed.

Case study 2

Onshore, P&A campaign, 5.5 in. tubing

Efficiency expectation during unplanned operations is always elevated but the same is also the case when volume is introduced. As part of a multi hundred well P&A campaign, it was critical for an operator to cut and retrieve various sizes of tubing in the most efficient way possible. The wells being abandoned were in excess of 50 years old, completed at a time when only the most rudimentary data sets were available. Furthermore, due to the age of the wells, there was significant potential for circumstances downhole to be very different than when the tubing was initially deployed and logs recorded. Fig. 6 below shows the data set acquired from the new pipe recovery log. The free pipe depth was found in the upper part of the zone of interest.

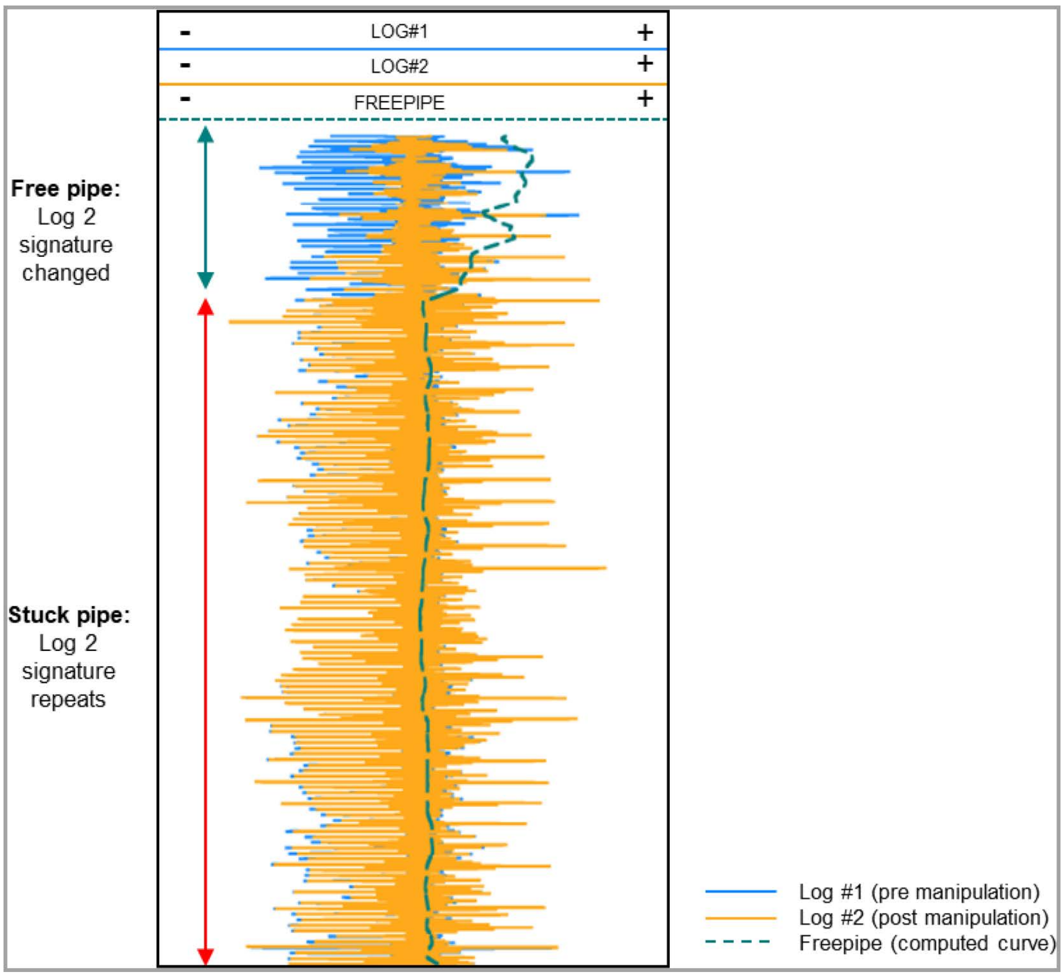

Figure 6—Log acquired over the zone of interest. Log interval presented 850 ft.

On this 1st well, the customer requested a traditional meter point based FPIT be run to validate the new technology log acquired. Two FPIT survey points were carried out – the 1st stationary measurement took place one joint into the stuck zone (where the logs repeat) – FPIT confirmed the tubing was stuck. The 2nd stationary measurement took place in the deepest joint that showed the pre and post logs had changed – the FPIT confirmed the tubing was free at the depth identified previous. As well as carrying out tubular recover determination, the client had a requirement for additional data acquisition for cement bond integrity. Fig. 7 shows a composite plot of the pipe recovery technology log shown in Fig 6, plotted alongside the PGR and CBL data set. The CBL data set consists of variable density log, attenuation and a computed cement map.

Each sensor has a distinct response at the free pipe depth identified by the new pipe recovery technology further enhancing the downhole understanding.

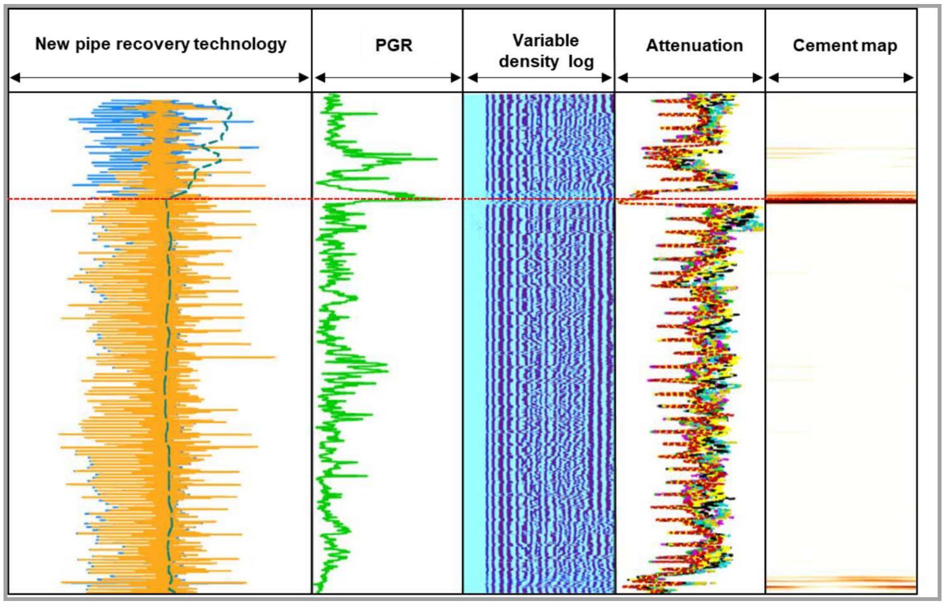

Figure 7—Composite log Log interval presented 850 ft.

Conclusions

Pipe recovery in the oilfield has evolved over the last decade with technology that has focused on the treatment side of the operation, delivering a plethora of advanced cutting and isolation options for the customer. The diagnosis, despite being the most critical part of the operation has largely remained the same. This combination therefore always carried elevated risk into the planned or unplanned cut and retrieval of any BHA. The new pipe recovery technology described in this paper and demonstrated in both case studies presented has overhauled the diagnosis segment and created significant value for each operator by de-risking the "where to cut" question. After case study #1 was performed, the customer was quoted *"We are very pleased with the result from this job – incredibly easy to identify the optimal area for cutting pipe from the data set"*.

The new pipe recovery technology has been commercially proven in excess of 150 operations since January 2022 across many locations and range of circumstances, both drilling and P&A related. Mobilizations have been fast, and certain results have been delivered efficiently at the wellsite. The key factors and value that the new pipe recovery technology brought to the operational success can be summarized as follows:

- Unparalleled data reliability and repeatability providing unprecedented clarity when pinpointing free pipe depth across a wide range of pipe types and wall thicknesses.
- Configurability enabling deployment in many different wellbore shapes and environments – gravity, pumped down and tractor conveyed.
- Combinability with other downhole sensors in the same trip maximizing efficiency & improvement of downhole understanding when presented besides other data sets.

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Acronyms

ID	internal diameter
BHA	bottom hole assembly
DP	drill pipe
HWDP	heavy weight drill pipe
MD	measured depth
TVD	true vertical depth
FPIT	free-point indicator tool
E-line	electric line
SIT	statutory interface test
HUD	hold up depth
CCL	casing collar locator
PGR	production gamma-ray
CBL	cement bond log
P&A	plug and abandon
BHT	bottom hole temperature
QC	quality control

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