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Professional paper

THE RADIAL CUTTING TORCH DEVICE APPLICATION DUE TO DRILL STRING STICKING

PRIMENA RADIJALNOG PLAZMA REZAČA PRILIKOM ZAGLAVE BUŠAĆEG ALATA

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Abstract: Stuck pipe is a common problem with tremendous impact on drilling efficiency and costs in the oil industry. Generally, the stuck pipe troubles are solved after their occurrences by using some standard operational procedures such as working the drill string up or down, attempting to rotate the string and pumping mud at higher flow rates through the drill bit to aid pipe release. One may also place different fluids around the stick area and use a drilling jar. However, in cases where common solutions don't work, then the cutoff is the last resort. To have a successful cutoff operation, estimating the location of the free point and choosing the right cutting tool is of vital importance.
This paper presents the Radial Cutting Torch (RCT) as a innovative cutting tool and its oilfield application in stuck pipe events.

Key words: radial cutting torch, stuck pipe, cutoff

Apstrakt: Zaglava alata predstavlja uobičajen problem koji u mnogome utiče na efikasnost bušenja i troškove naftne industrije. U načelu, problemi zaglave alata nakon njihovog uočavanja rešavaju se standardizovanim tehnikama, kao što su: spuštanje i zadizanje, rotiranje alata, upumpavanje isplake većim protokom preko dleta. Takođe, i primenom raznih fluida u području zaglave i upotrebom udarača. Međutim u slučajevima gde uobičajena rešenja ne daju željeni rezultat, kao poslednja opcija uzima se rezanje alata. Za uspešnu operaciju rezanja određivanje mesta zaglave i upotreba odgovarajućeg uređaja za instrumentaciju su od vitalnog značaja.
U ovom radu biće prikazan radijalni plazma rezač i njegova primena na terenu kao specifičnog uređaja za sečenje zaglavljenog alata.

Ključne reči: radijalni plazma rezač, zaglava alata, rezanje

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1. INTRODUCTION

In the petroleum industry drilling is considered of vital importance and in the same time the most expensive and hazardous operation. One of the biggest economic challenges today for a drilling contractor is to reduce non-productive time (NPT) and in that manner the return on investment. Unfortunately, a meaningful share is ascribed to downhole tool problems. These involve loss of material, e.g. drilling equipment and fluids, and loss of productive time. In addition, these losses are made while seeking for and executing improvements to drilling difficulties.

Releasing stuck tubular might be highly priced if not infeasible in some occurrences. It is not unusual for a drill string to get stuck against the uncased borehole wall by lodged in their irregularities, demanding crew experience, ability and rig power to release it. If all of this doesn't help, then the only appropriate solution is to sever and discard the stuck part and again attempt to hit the target zone by sidetracking; which includes fundamental changes in the drilling program. This means the new expenses to the overall well cost grow into millions (Kemp, 1986).

Therefore, the drilling crew usually underestimates the greatness of their contingency approach and planning. A correct approach is to establish the partnership between operators and service companies in order to significantly pare down hazards, operational stagnation and overall expenses. This is made by providing frequent drills for drilling personal which means emboldening the suitable and timely usage of Radial Cutting Torch (RCT) device that have become a new component of contingency plans (Raja and Dodds, 2011).

2. CAUSES OF STUCK PIPE

The static force enables a drill-string motion, but when these values surpass the rig's capacity or the tensile strength of the pipe, the drill-string becomes immobilized. In this situation the drill-string can't be rotated or movable in any direction. Usually pipe sticking occurs while drilling, tripping, testing, making a connection, logging or during any operation in which downhole equipment is in the borehole. Usually mechanical sticking caused near two-thirds of the total stuck pipes and differential sticking was responsible for about one-third, which represent two primary types of pipe sticking mechanisms (Table 1) (Rabia H., 2001).

Table 1 - Pipe sticking mechanisms and their most common causes

PIPE STICKING MECHANISMS AND CAUSES			
Mechanism	**Differential sticking**	**Mechanical sticking**	
Causes		Hole Pack Off	Formation and BHA (Wellbore Geometry)
	Differential Force	Settled Cuttings	Key Seating
		Shale Instability	Mobile Formations
		Fractured Rocks	Under gauge Hole
		Cement Blocks	Micro Doglegs and Ledges
		Junk	Drilling into Magma

It is clearly hard to define which pipe is differentially or mechanically stuck, so many operators tend to treat all stuck pipe cases the same. Research shows that 54% of tubular comes free just with spotting fluid pill. The possibility to free the differentially stuck pipe according to statistics decreases if the mud pill is not used within 10 hours of becoming stuck. However, in directional holes when the spotting fluid is used within 6 hours the possibility of freeing the stuck pipe increases over fifty percent. Generally, if there is no improvement after 72 hours, it is better to stop wasting time and money and to move on searching for another way to free the stuck pipe. Definitely, one of the best ways to solve this problem that includes the stuck pipe severing is to utilize the RCT cutting tool (Shivers and Domangue, 1993).

3. INVOLVING THE RADIAL CUTTING TORCH (RCT)

The Radial Cutting Torch (RCT) tool provides the industry in a safe, efficient and reliable way used as an alternative to explosives and perilous chemicals to cut different types of stuck pipe (casing, tubing, drill pipe and coil tubing). This tool is especially popular for offshore and remote wells, because it is approved for all methods of transport and it's deployable within hours and not days, minimizing downtime and costs. The RCT presents a innovative and sophisticated device which is made of different powdered metals load, torch portion, and a nozzle. The best way to descript the propulsion of the RCT is that it seems alike of an oxyacetylene cutting torch.

The nozzle part is made of carbon and it's placed at the lower end of the torch, this carbon work as a heat obstacle for the diverter, sleeve, the threaded, steel nozzle and the cap. The nozzle section is protected with utilization of a sleeve that skids aside on a ignition point and reveals the nozzle to the well for severing.

The powdered metal components (Iron Oxide, Aluminium, Polytetrafluoroethylene) are pushed into a solid donut and the extended part of the torch body is filled with molded pallets and these are made of solid donuts. An aluminum disc (prior to RCT tool installation does not need to be extract) and snap ring are responsible for holding the pellets in situ. Throughout inflammation process this disk permits the Thermal Generator to break through (MCR, 2002).

3.1. RCT Tool Principle and Operation

After defining the sticking point by using Free Point Tool (FPT), the Radial Cutting Torch equipment is assembled and run into the hole to the point of interest. The RCT is able to be lowered on an electric line, slickline (with downhole power triggers or remote firing mechanism - RFM) and on pipe or coil tubing with a pressure firing system (PFS). As tool reach the target, operator should slowly ramp the current to 1 A and hold for 15 seconds (depending on well conditions it is usually necessary between 10 seconds and 30 seconds) this goes through the wire line string to the resistor in thermal generator accumulating temperature for ignition. Moreover, if there is no ignition after 15 seconds, operator gently ramp the current upward at 0.1 A increments until he spot the initiation. The AC or DC+ current could be used for this purpose. The main pack ignition starts right after the generator produces enough heat, which is powered by the release of oxygen in the blend of powdered metal. The resulting exothermic reaction produces molten plasma on one hand and on the other this heat generated in the torch body induces the boost in internal pressure. As we mentioned earlier just when the pressure in the torch surpasses the wellbore pressure, the sleeve that is covering the nozzle skids aside on the ignition point and reveals the nozzle to the well. Within 25 milliseconds, a stream of ceramic integrated plasma exits the tool diverted 90 degrees through the nozzle severing the target tubular with cutting action of a 3316°C. Once the cut is made, the RCT tool assembly is easily removed from the wellbore and can be cleaned for future use (MCR, 2014).

3.2. Radial Cutting Torch Assembly

The Radial Cutting Torch assembly includes the Thermal Generator, Isolation Sub, Thermal Generator Sub, the Extension Adapter(s) (as needed), the Radial Cutting Torch, and the Pressure Balance Anchor with centralizer.

It is always recommended use of two centralizes for both the upper and lower end of assembly in order of good centralization and overall results (Figure 1).

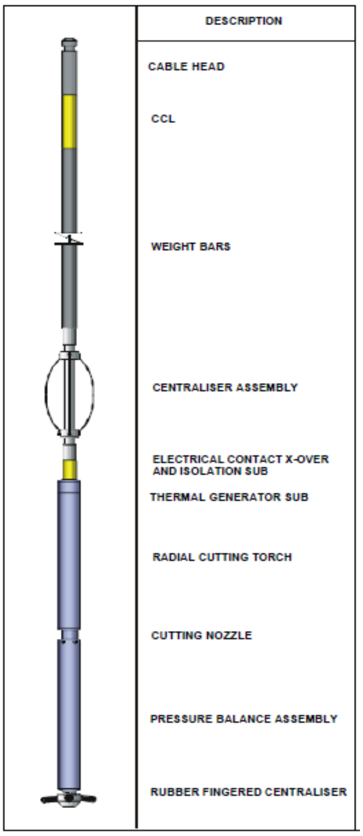

Figure 1 - The most usual RCT run configuration (MCR, 2014)

A typical run configuration presents:

1. the cable head assembly;
2. a centralizer sub with electrical feed through (applied electronics P/N AS5-0023);
3. a CCL assembly;
4. a 5' sinker bar (optional) with electrical feed through;
5. the Isolation Sub;
6. the Thermal Generator sub with the Thermal Generator installed;
7. the Extension Adapter(s) (as needed);
8. the Radial Cutting Torch (RCT);
9. the Pressure Balance Anchor Assembly (PBA);
10. centralizer fingers (rubber) or a bottom centralizer or centralizer sub.

RCT supporting tools:

- Electro-Mechanical Anchor (EMA) / Anchors during cutting operation;
- Generator Safety Sleeve (GSS) / Safety dissipates all Thermal Generator energy in the event of operator activation error on surface;
- Remote Firing Mechanism (RFM) / Data logging tool and firing system; safety enables all MCR systems on coiled tubing, slick line and pipe.

All necessary details about the Radial Cutting Torch mechanical limitation and recommended use are listed below in Table 2 and Table 3.

Table 2 - RCT mechanical specifications for ultra high pressure environments (MCR, 2014)

Description (Outer diameter)	Pressure	Recommended Use
44.45 mm (1.688 in)	103.4 MPa to 137.9 MPa (15 000 psi to 20 000 psi)	73 mm (2.575 in) pipe
50.8 mm (2 in)		88.9 mm (3.5 in) pipe
63.5 mm (2.5 in)		114 mm (4.5 in) pipe
74.6 mm (2.937 in)		127 mm (5 in) pipe
85.7 mm (3.375 in)		140 mm (5.5 in) pipe

Table 3 - RCT mechanical specifications for high pressure environments (MCR, 2014)

Description (Outer diameter)	Pressure	Recommended Use
19.05 mm (0.75 in)	69 MPa to 103 MPa (10 001 psi to 15 000 psi)	Coiled tubing 38.1 mm (1.5 in)
22.23 mm (0.875 in)		Coiled tubing 38.1 mm to 44.4 mm (1.5 in to 1.75 in)
28.58 mm (1.125 in)		Coiled tubing 44.4 mm to 50.8 mm (1.75 in to 2 in)
34.93 mm (1.375 in)		60.5 mm (2.38 in) tubing: 7 kg/m to 8.85 kg/m (4.7 lb/ft to 5.95 lb/ft)
38.1 mm (1.5 in)		60.5 mm (2.38 in) tubing: 7 kg/m to 8.85 kg/m (4.7 lb/ft to 5.95 lb/ft)
44.45 mm (1.688 in)		73 mm (2.875 in) pipe: 12.95 kg/m (8.7 lb/ft)
50.8 mm (2 in)	69 MPa to 82.7 MPa (10 001 psi to 12 000 psi)	88.9 mm (3.5 in) pipe: 13.84kg/m to 19.27 kg/m (9.3 lb/ft to 12.95 lb/ft)
50.8 mm (2 in)	82.7 MPa to 103 MPa (12 001 psi to 15 000 psi)	88.9 mm (3.5 in) pipe: 13.84kg/m to 19.27 kg/m (9.3 lb/ft to 12.95 lb/ft)
63.5 mm (2.5 in)	69 MPa to 82.7 MPa (10 001 psi to 12 000 psi)	102 mm (4 in) pipe, 114 mm (4.5 in) pipe: 23.1 kg/m (15.5 lb/ft)
63.5 mm (2.5 in)		127 mm (5 in) pipe: 26.8 kg/m (18 lb/ft)
63.5 mm (2.5 in)	82.7 MPa to 103 MPa (12 001 psi to 15 000 psi)	102 mm (4 in) pipe: 23.1 kg/m (15.5 lb/ft) 114 mm (4.5 in) pipe: 23.1 kg/m (15.5 lb/ft)
63.5 mm (2.5 in)		127 mm (5 in) pipe: 26.8kg/m (18 lb/ft)
74.6 mm (2.937 in)	69 MPa to 82.7 MPa (10 001 psi to 12 000 psi)	114 mm (4.5 in) pipe: 23.1 kg/m (15.5 lb/ft) 127 mm (5 in) pipe: 26.8 kg/m (18 lb/ft)
85.7 mm (3.375 in)		127 mm (5 in) pipe: 26.8 kg/m (18 lb/ft)
85.7 mm (3.375 in)	82.7 MPa to 103 Mpa (12 001 psi to 15 000 psi)	127 mm (5 in) pipe: 26.8 kg/m (18 lb/ft)
85.7 mm (3.375 in)		140 mm (5.5 in) pipe: 38.7 kg/m (26 lb/ft)
102 mm (4 in)	69 MPa to 82.7 Mpa (10 001 psi to 12 000 psi)	140 mm (5.5 in) pipe: 38.7 kg/m (26 lb/ft)
102 mm (4 in)	82.7 MPa to 103 MPa (12 001 psi to 15 000 psi)	140 mm (5.5 in) pipe: 38.7 kg/m (26 lb/ft)

3.3. Application

When using the RCT tool on wire line it is necessary to bear in mind that any lowering at high speeds or running the assembly through a certain constraint in the wellbore is absolutely irregular and leads to premature ignition and hazards. This behavior can produce huge impact on the RCT's nozzle that could dislodge the o'rings in the nozzle and/or failure of their elements by using massive force. In this situation when the excessive force creates ejection or dislodge of the o'rings they will fail and let formation fluid to enter the RCT. This makes the Radial Cutting Torch unstable and inert by lowering pressure and temperature under 275 bar and 38°C. However, the auto-ignition is possible if the combination of pressure above 275 bar and temperature is above 38°C. Although this auto-ignition can cause critical damage to internal parts of the tool string, such as nozzle and anchor assembly it is important to note that generally casing or tubing damage won't appear. Certainly many field experiences show that a total, partial or no cut could still be expected.

When a stuck string or collapsed tubular occur a minimum quantity of unrestricted flow area below the RCT is necessary for a appropriate cut. And to provide this it is important to perforate string somewhere between the bottom of the torch body and the top of the stuck point. This must be done even if there is no flow restriction. For the sake of RCT stabilization we need to perforate according to the attached perforating table (Table 4).

Table 4 - Minimum required perforating shots for a proper operation (MCR, 2002)

Recommended use	Required perforating shots
Tubing 2⅜ in	minimum 6
Tubing 2⅞ in	minimum 8
Tubing 3½ in	minimum 8
Tubing 3½ in and DP	minimum 12
Tubing 4-4½ in, Casing	minimum 12
Casing 5-5½ in	minimum 12
Casing 6⅝ in, 7 in, 7⅝ in	minimum 12

If the perforation was omitted, the following results can occur: Tool string will be pushed upward resulting stagnation in the torch flow. This will generate and keep all heat and pressure in the torch body ruining the nozzle and body section and balance anchor as well. The stagnated molten plasma under the high pressure and temperature will go upwards through the string by destroying all internal tools of the downhole string. This shows that no cut is possible without first perforating the pipe under the cutter area.

Similar side effects are noticed in low fluid level pipe conditions where shortage of a hydrostatic head will result in concentration declining rate. In some wells with less than 610 m of fluid head above the cutter it is effective to pump out enough fluid so that at least 30 m of dry pipe is below the cutter. Nevertheless, if pumping is not applicable we need to employ different approach with tubing being anchored at surface and RCT attached on tubing. On this way using a CP initiator the RCT will be appropriately ignited. Generally, to overcome the low fluid level pipe / dry pipe we should use the appropriate RCT rated at 275 bar to 650 bar (MCR, 2002).

3.4. Features and benefits of the RCT tool over chemical and jet cutters

Main advantages of the RCT over Jet and Chemical cutters: Contain no explosives or dangerous chemicals; Classified as a Flammable Solid, Organic; No special storage, handling, or disposal problems; Causes no flaring or swelling of the pipe to be cut; Cuts all stainless steel, Hastalloy®, Monel®, Inconel® and plastic coated pipe; Can be run through restrictions to sever piping with large diameter; Can be used in close contact pipe conditions; Can cut in dry pipe conditions; Can operate to temperatures to 260˚C; Can cut in exotic fluids or drilling mud without problems; Cuts heavy wall pipe; New patented Pressure Balance Anchor (PBA) system eliminates movement, slipping, or sticking problems associated with other anchors; PBA also eliminates the problems associated with going thru restrictions and operating in larger diameters below the restriction, because it has no moving parts; The complete system is safe to use in Radio Sensitive areas such as offshore platforms or drill ships without going into Radio Silence resulting in significant savings in rig time; Clean cut for easier fishing operations; Latest design of Radial Cutting Torch tool series for HPHT (High Pressure High Temperature) deployment is capable to withstand pressures up to 206.84 MPa.

Critical Factors are: Nozzle condition, reuse of nozzles is not suggested due to wear; Nozzle to pipe wall clearance is critical to successful application of the tool; Cross flow and flow from outside to inside the cut surface may be detrimental if it disperses the thermite dispersion during the cut (MCR, 2014; MCR Webinar, 2016).

4. CASE HISTORY

This example shows accomplished string recovery using Radial Cutting Torch and Electro-Mechanical Anchor tool (total length: 7.16 m, total weight: 110.78 kg). (Figure 2)

In a deviated well Ve-x drilled with a 215.9 mm (8½ in) bit to measured depth of 775 m a 244.5 mm (9⅝ in x 32.30 lb/ft) casing string was set to a depth of 250 m (TVD). After successful remedy of drilling fluid losses and upcoming kick the stuck pipe event occurred, as indicated on the logs, at approximately 440 m measured depth (MD), what can bee seen in figure 2.

The well was logged by The Free Point tool which measures torque and stretch to accurately locate where any string of pipe is stuck or partially stuck. An additional components that must be run with the Free Point tool assembly is a collar locator (CCL) to determine correct depth (right part of Figure 2).

The drilling personnel approached the problem with standard procedures and tried to free the pipe by: activating jar, flushing with 2 m^3 diesel pill, 120 t overpull, adding 12 t weight on bit, 1400 Nm torque, explosive at 660 m MD and using a cutter (1^{st} at 460 m, 2^{nd} at 453 m, 3^{rd} 444 m MD). Neither of the aforementioned attempts to reciprocate the drill string was successful. Finally, after more than 72 hours downtime a contractor decided to try it with the Radial Cutting Torch tool.

The pipe drift diameter was 78 mm so they used RCT-2937-300 (diameter 74.6 mm; rated 69 MPa to 82.7 MPa) tool. A clean cut was made at 399.7 m MD with 650 l/min circulation flow rate (Figure 3 and Figure 4). Without any over-pull the parted drill-string was successfully removed from the wellbore (Scientific Drilling International, 2014).

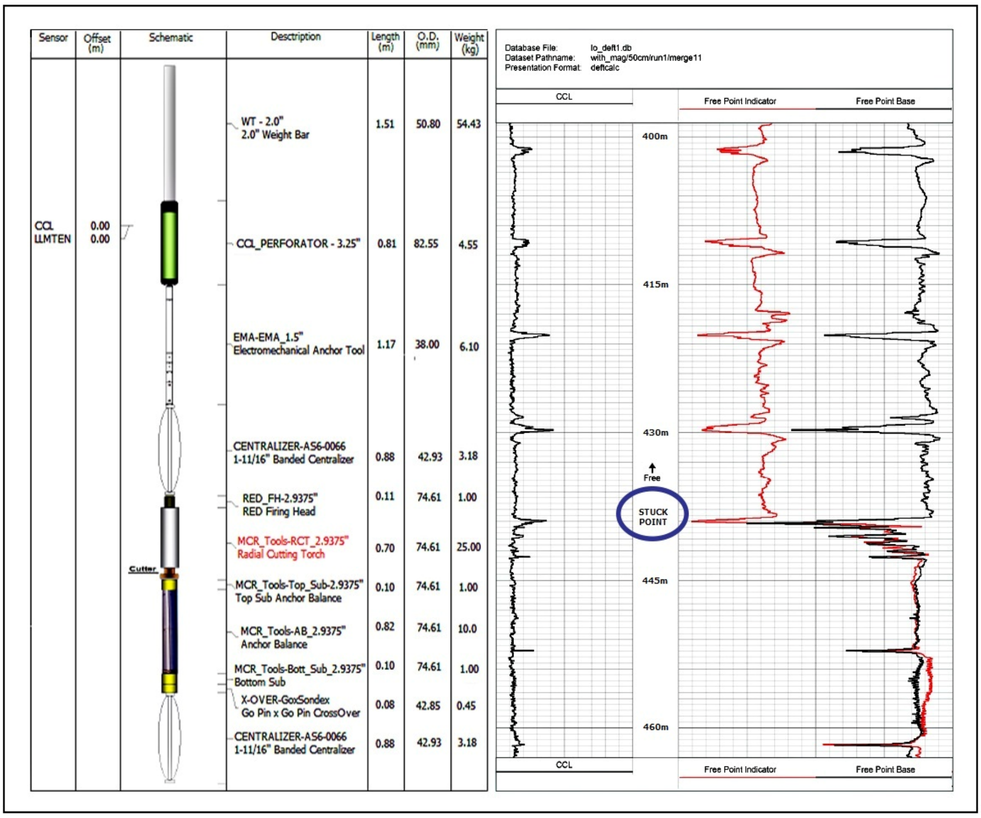

Figure 2 - The RCT + EMA assembly and a Free Point log

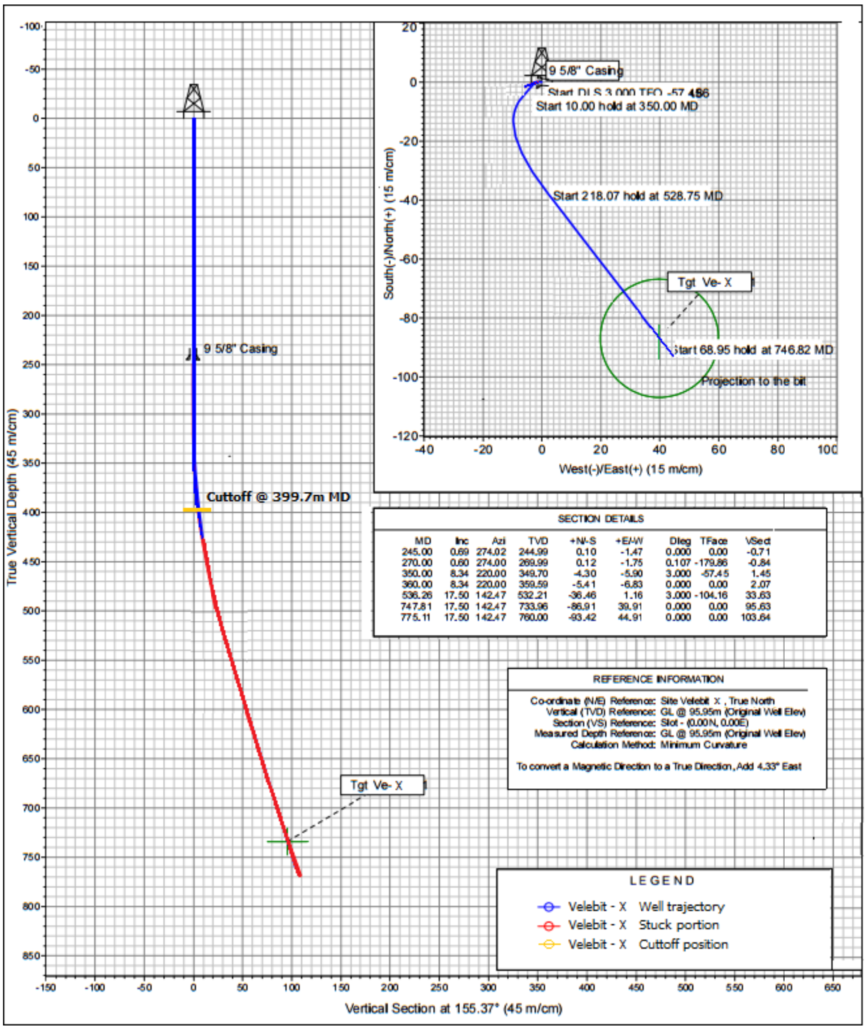

Figure 3 - Trajectory of the well Ve-x (Serbia) and the cutoff position

Figure 4 - Sample of a RCT cut from the well Ve-x

4. CONCLUSION

Every year drilling becomes more challenging because of the well complexity, which directly increases pipe sticking problems. Since 1992 the Radial Cutting Torch has been developed to meet the needs and solve various unpredictable stuck pipe situations. This tool is based on patented MCR's cutting technology without the use of explosives or hazardous materials. For many reasons this device is substantial and shows how truly practical and cost-effective is. It can be used efficiently and promptly in many complex interventions. The tool is radio safe and brings a high percentage of successful operations with remarkable results. Moreover, it proved to be one of the safest pipe cutting tools on the market.

A Radial Cutting Torch was used at a Ve-x development well (Serbia), which resulted in cutting of stuck pipes in one run at the exact depth. Thus non-productive time was reduced, operation was completed immediate safely for personnel and excluding environment pollution.

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