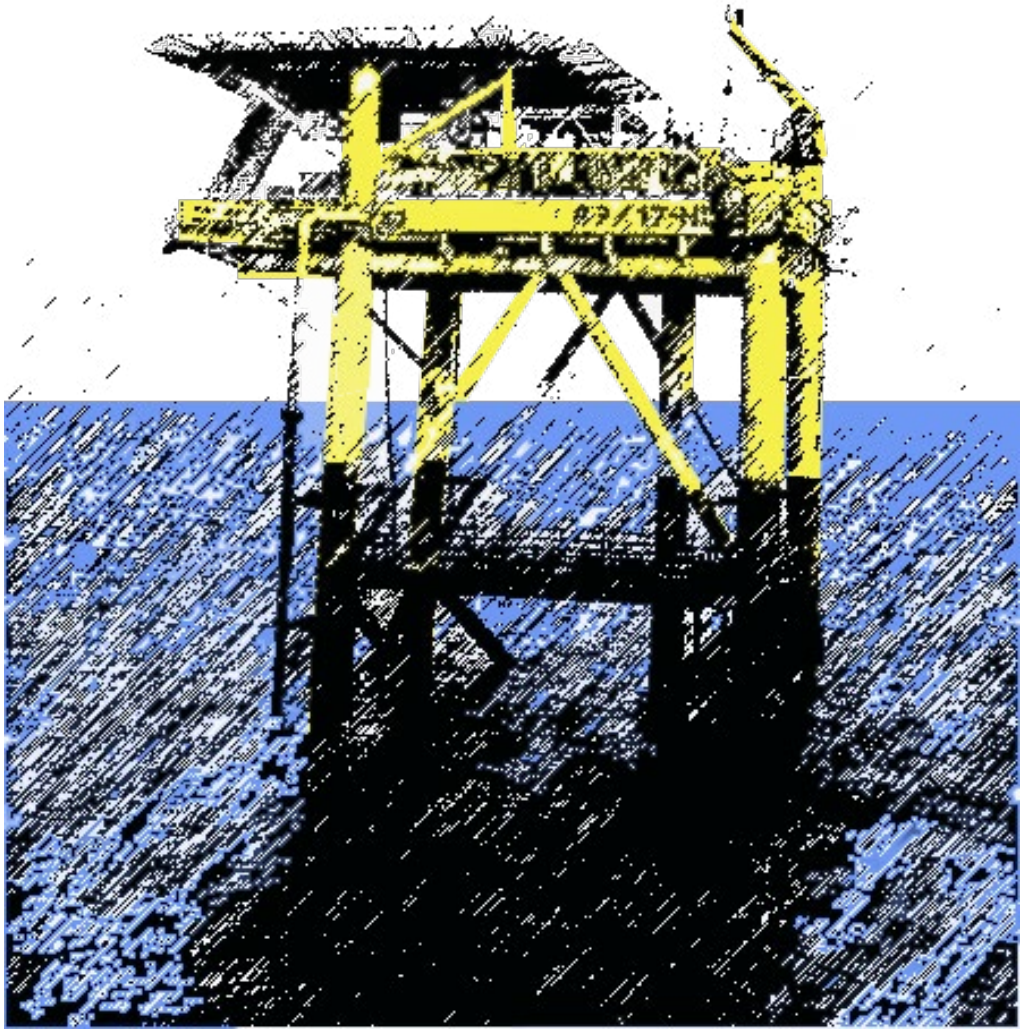
New Technology Concept

Thru-Tubing Multiple Conduit Super Abrasive Filament Cutter



OILFIELD INNOVATIONS

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Abrasive Strand Filament Cutter for Tubular Severance & Rigless Casing Milling

by Clint Smith[a] and Bruce Tunget[b]

Abstract

Oil and gas wells are comprised of multiple concentric conduits that must be cut and removed during drilling rig plug and abandonment (P&A) shown on the left of Figure 1.

While rigless pulling and jacking units may remove casings and conductors on platforms, rigless subsea P&A must perforate through tubing and casing to isolate annuli as shown on the right of Figure 1.

Rigless P&A could greatly benefit from thru-tubing multi-conduit severance and thru-tubing casing milling within both platform and subsea P&A operations.

Conventional downhole cutting technologies generally pertain to precisely severing a single tubular wall and pulling casings one-at-a-time or abrasive fluid jetting severance of multiple conduits simultaneously.

Also, sections of casing can be milled to provide access to larger casings that may be cut using knife blades to allow multiple conduits to be pulled out of the well simultaneously.

Conventionally, cutting through multiple conduits simultaneously uses sand blasting technology that directs a rotated fluid jet of abrasive particles, wherein deployment of the jetting equipment typically requires tubing removal.

Various coiled tubing jetting applications have been used for jetting holes through multiple casings, but non-aqueous thru-tubing rigless tools for severing tubing and casings simultaneously do not exist.

Rigless P&A would benefit from thru-tubing severance of multiple conduits, so Oilfield Innovations have patented an abrasive filament cutter which functions like a garden strimmer that rotates diamond wire filament to sever tubing, control lines and casing simultaneously.

When a diamond wire filament cutter is combined with vertical tubular cutting it can turn tubular walls into confetti-like debris that falls downward to accomplish a scope of work similar to casing milling, as shown in Figure 6.

Tubular severance and casing milling are critical parts of well operations, especially P&A, wherein a diamond wire filament cutter could improve efficiency and lower cost by displacing drilling rigs from P&A where it is necessary to mill or cut through multiple casings to place P&A plugs.

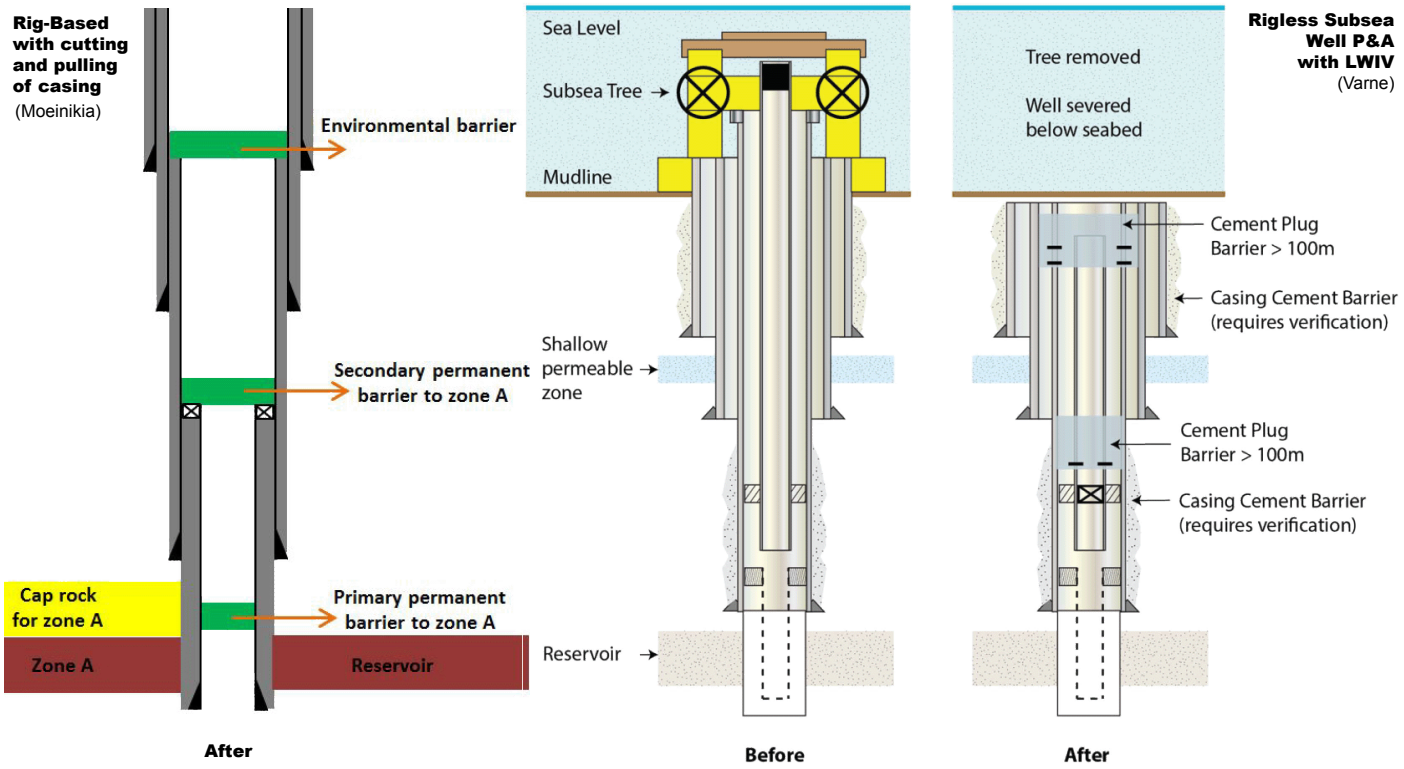

Figure 1 - Simple schematic of abandoned wells (left: Moeinikia[63], 2014; right: Varne[85], 2017)

What is an Abrasive Filament Cutter?

Oilfield Innovations have patented the Figure 2 concept of using a super abrasive or diamond wire filament cutter configured like a conventional horticultural strimmer or weed-wacker.

Super abrasive or diamond wire filaments are proven oil and gas cutting technology used in, for example, conductor cutting, wherein adapting the proven filament technology to be deployed by a strimmer or weed-wacker arranged for downhole cutting could be used to sever through multiple conduits and cables where conventional knife, chemical and explosive cutters cannot.

Some off-the-shelf knife blade cutters can sever tubing and closely adjacent control lines while others cannot.

Cutting a single tubular with knives, chemicals and wheels is relatively common in the oil and gas industry but cutting through more than one concentric tubular is very challenging and generally involves abrasive fluid blasting, large explosives or casing milling to provide access for further knife cutter deployment.

Abrasive particles can be jetted with fluid to cut through multiple conduits and casing but such tooling is not necessarily suited for thru-tubing severance of multiple tubulars and is primarily used in larger diameter casing.

Thru-tubing automatically spooled super abrasive or diamond wire filaments rotated by a fluid or electric motor could sever multiple concentric tubulars and control lines.

Rotated diamond wire filament cutting is not only applicable to P&A. It is also applicable to stuck pipe situations where, for example, drilling or milling strings have become stuck during drilling or workover operations and a means of through tubular severance is needed.

A downhole filament cutter could be run on drill pipe, coiled tubing or electric-line with pipe rotation, fluid motor or electric motor rotation.

Within rigless P&A, where in-situ cement is poor or lacking, the tubing and subsequently the casing could first be vertically shredded as shown in Figures 3 and 4, after which an abrasive filament cutter of Figure 2 could be used to cross cut the vertically shredded tubing or casing walls to create confetti like debris that would fall downward. Accordingly, after vertically cutting, abrasive filament cutting could be used to riglessly remove wall sections to accomplish the same scope of work as casing milling (see Figure 6).

Tubing can be vertically ruptured as shown in Figure 3 using a Gator Perforator® and then cross-cut by the Figure 2 diamond wire filament cutter to, effectively, mill the tubing from the bottom up into confetti pieces that fall into the 80% to 90% liquid space within the surrounding casing to expose the casing walls for subsequent P&A operations. As shown

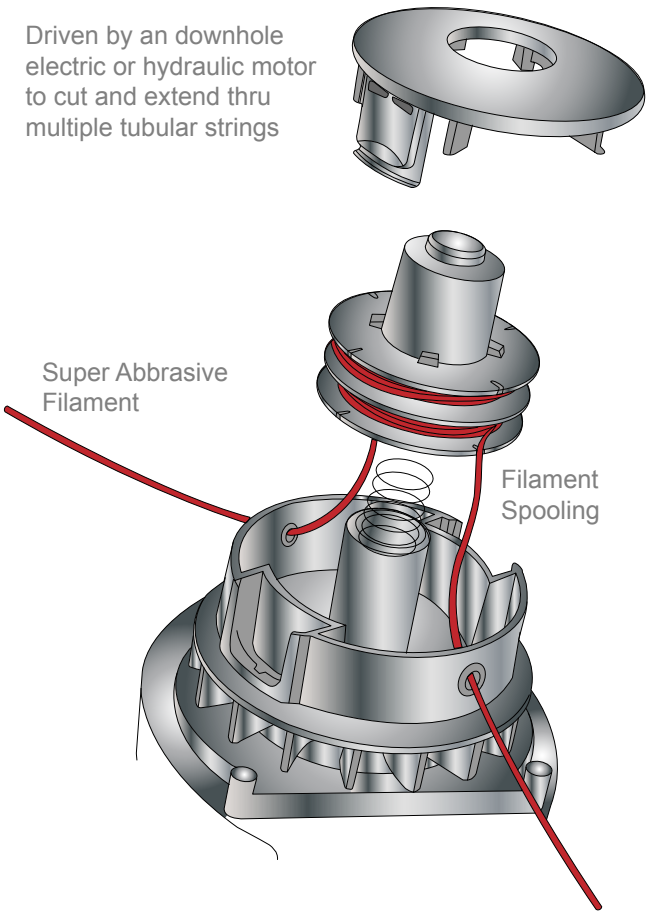

Figure 2 - Abrasive Filament Tubing/Casing Cutter

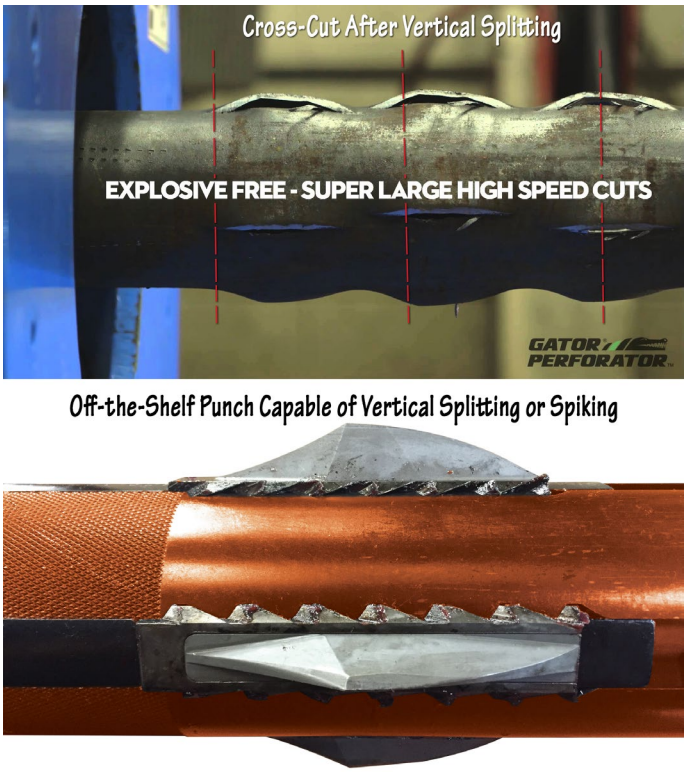

Figure 3 - Gator Perforator® (Source: Website)

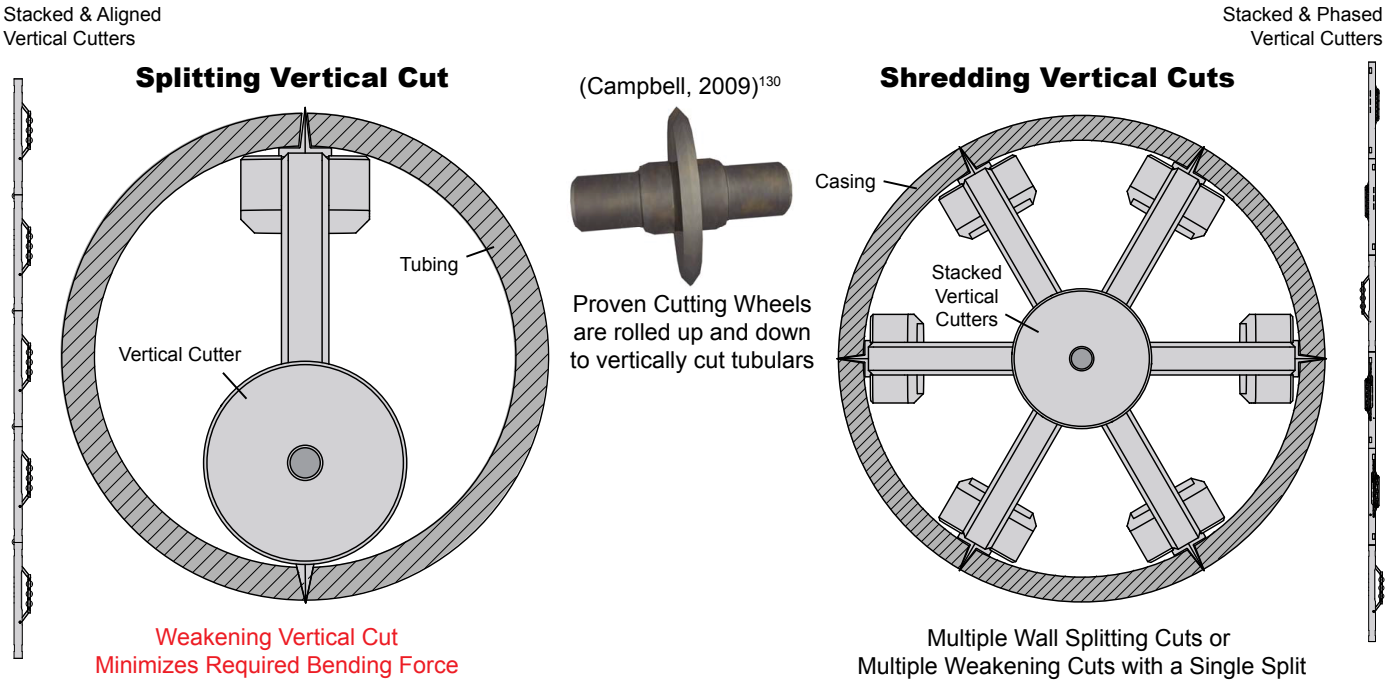

Figure 4 - Splitting and Shredding Tubulars to Facilitate Cross Cutting Compactable Confetti

in Figure 6 a packer can be used to compress the confetti to provide more room for logging and P&A cement plugs.

Oilfield Innovations have also designed tooling to vertically split and shred tubing and casing as shown in Figure 4. When tubulars are vertically split or shredded and then cross cut into confetti, an inflatable packer can be used as a piston to further compress the confetti for P&A logging and cementation space as shown in Figure 6.

Within multiple casing strings, the tubing can be cross cut into confetti or Oilfield Innovations tubing compaction method can be used to expose the production casing. The production casing can then be cross cut to expose the intermediate casing as shown in Figure 6.

Various mode of operation are available to rigless diamond wire filament severance, but confetti cross-cutting milling operations would require coiled tubing or electric motors.

Wireline Fluid Motor Cleaning and Severance

An innovation option for tubing cleaning and severance, within production optimisation or P&A, could comprise using a fluid motor on wireline.

Coiled tubing fluid motors could be run on wireline as shown in Figure 5. Combining non-rotational mechanisms and a seal at the top of a coiled tubing motor can allow a fluid motor to be run on wireline, whereby fluid may be pumped down the tubing when lowering a fluid motor on wire could, for example, clean LSA scale or mill obstructions from the tubing, wherein holding a filament cutter at a specific depth

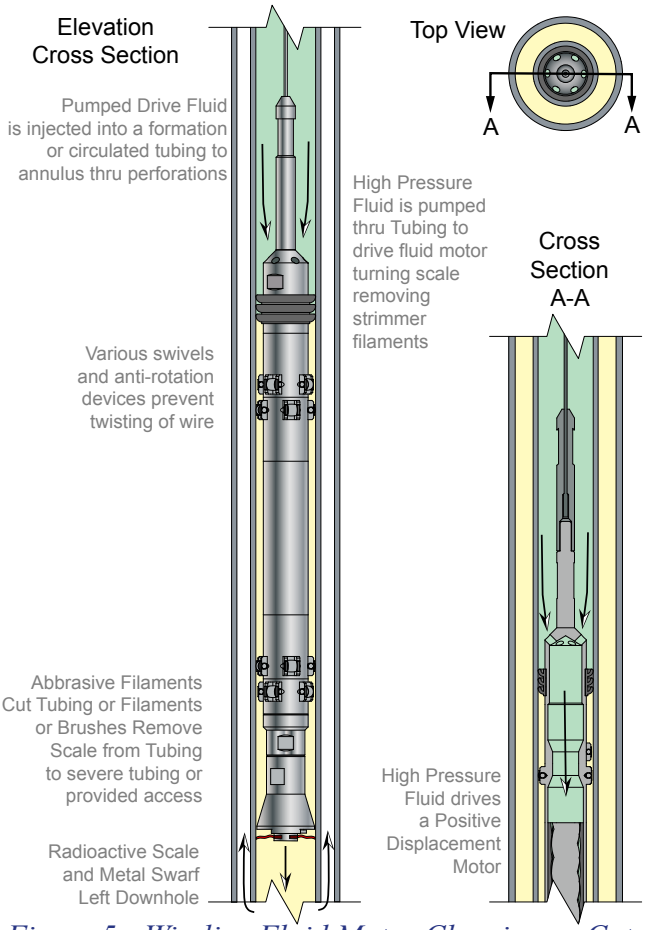

Figure 5 - Wireline Fluid Motor Cleaning or Cut

could be used sever tubing, control lines and clamps.

A primary advantage of using a fluid motor run on wire for P&A is that the pump used for cementing can also be used to run a fluid motor operated brush or filament cutter to, thus, minimise the quantity of equipment and utilities needed.

Also, through tubing P&A operations can be obstructed by LSA scale that can be brushed or cut from the tubing wall and left downhole below a wireline run fluid motor operated by either injection or circulation.

Proven coiled tubing fluid motors, usable on wireline, are available in sizes ranging from 1.68 inches (42.6 mm) to 5 inches (127 mm) in diameter which could be used in 2 $^{3}/_{8}$ inch (60 mm) to 7-inch (178 mm) production tubing.

Cross-cutting P&A compared to Rig P&A

Figure 6 elevation cross-sectional schematic details the differences between rig and rigless P&A with a diamond wire cutter for comparison with Figure 1 rig-based (Moeinikia, 2014)[63] and conventional rigless P&A (Varne, 2017)[85].

Conventional wireline is predominantly used in reservoir P&A. Some companies use wireline to set mechanical plugs to facilitate pulling the tubing with a rig (Shell[6], 2017) while others use wireline crews to set multiple P&A cement plugs to isolate the reservoir (Plumb[16], 2003).

For challenging rig and rigless P&A work scopes, coiled tubing can be used to perform reservoir and intermediate P&A in Phases 1 and 2 (Freeman[12], 2015).

As shown in Figure 6, when isolating the reservoir rig P&A normally leaves the production packer in place. Conventional rig and rigless P&A typically bullheads cement into the reservoir through in situ tubing (Olsen, 2017)[105] to set Plug #1, whereas the tubing can be vertically shredded with cross cutting using the Figure 2 filament cutter to create confetti that will fall to create space for logging in-situ cement and placing primary P&A plug #1 as shown on the right of Figure 6.

Once the well can be opened to atmosphere, rigs remove the tubing and associated production jewelery before logging in situ cement and placing a viscous fluid to support a secondary P&A plug #2 as shown on the left of Figure 6. A rig will then cut and pull uncemented production casing before setting a mechanical plug to support a tertiary P&A plug #3. For reasons of cost, rigs infrequently log in situ cement for a tertiary P&A plug. The intermediate casing will then be cut and pulled before setting an environmental plug #4 and removing above seabed well equipment.

Alternatively, instead of cutting and pulling casing, a rig may use a Perf & Wash method (Ferg[32], 2011; Abshire[69], 2012; Khalifeh68, 2013; Moeinikia[63], 2014; Aas[25], 2016; Delabroy[27], 2017), wherein the method is equally applicable to lower cost rigless P&A, as shown in subsea abandonment on the right side of Figure 1 (Varne, 2017)[85].

Oilfield Innovations' rigless method can vertically shred tubing using the methods of Figure 3 or 4 followed by cross cutting with the Figure 2 filament cutter to create tubing wall confetti that can be further compressed within the production casing using a piston to provide a logging and cement space for plug #2 on the right side of Figure 6.

After compacting the tubing wall confetti and any associated jewelery, control or injection lines, to create a 100-ft (30m) logging window, the 500-ft (152m) cement plug #2 can be placed through the remaining in situ-tubing with 400-ft of tubing embedded in cement as depicted on the right of Figure 6, wherein research (Aas, 2016)[25] for embedding tubing within a P&A plug demonstrates compliance.

The tubing can again be shredded and cross cut to expose the production casing, which can also be shredded and cross cut to expose the intermediate casing. Through the intermediate casing window, a viscous fluid base can be placed and P&A plug #3 can be pumped.

Plugs can be pumped using circulation through the tubing or annuli using various techniques including Reverse Cementing methods (Davies[60], 2004; Marriott[62], 2007; Gubanov[61], 2014; Vrålstad[106],2016; Durmaz[107], 2016; Rogers[108], 2016; Tanoto[109], 2017; Olsen[105], 2017) for placement of P&A plugs #3 and #4 of Figure 6.

Like rig-based milling operations, a surface casing window can be riglessly created by sequentially shredding and cross cutting the tubing, then production casing and then intermediate casing to expose the surface casing before setting a viscous fluid base and cement plug #4.

Once the cement plugs are placed, a filament cutter can sever tubing, casings and conductor for simultaneous jacking and pinning or, alternatively, a rigless pulling and jacking unit can cut and pull the upper most tubing casing and conductor (Canny, 2017)[17] one-at-a-time using a filament cutter to severe each of the strings before it is pulled.

After rigless P&A plugging, the platform or subsea equipment above the mudline is hydrocarbon free and various rigless methods using abrasive cutting, explosives or other means are used to remove the above seabed equipment with jacks and cranes or a boat for subsea wells.

Accordingly, various industry proven methods and equipment can be used to combine rigless P&A with other decommissioning activities to reduce total P&A cost by 30% (Siems, 2016)[21] to 60% (Varne, 2017)[85] when Oilfield Innovations' rigless method of severance and cross cutting is used to provide space for logging and cement within an unobstructed single casing string.

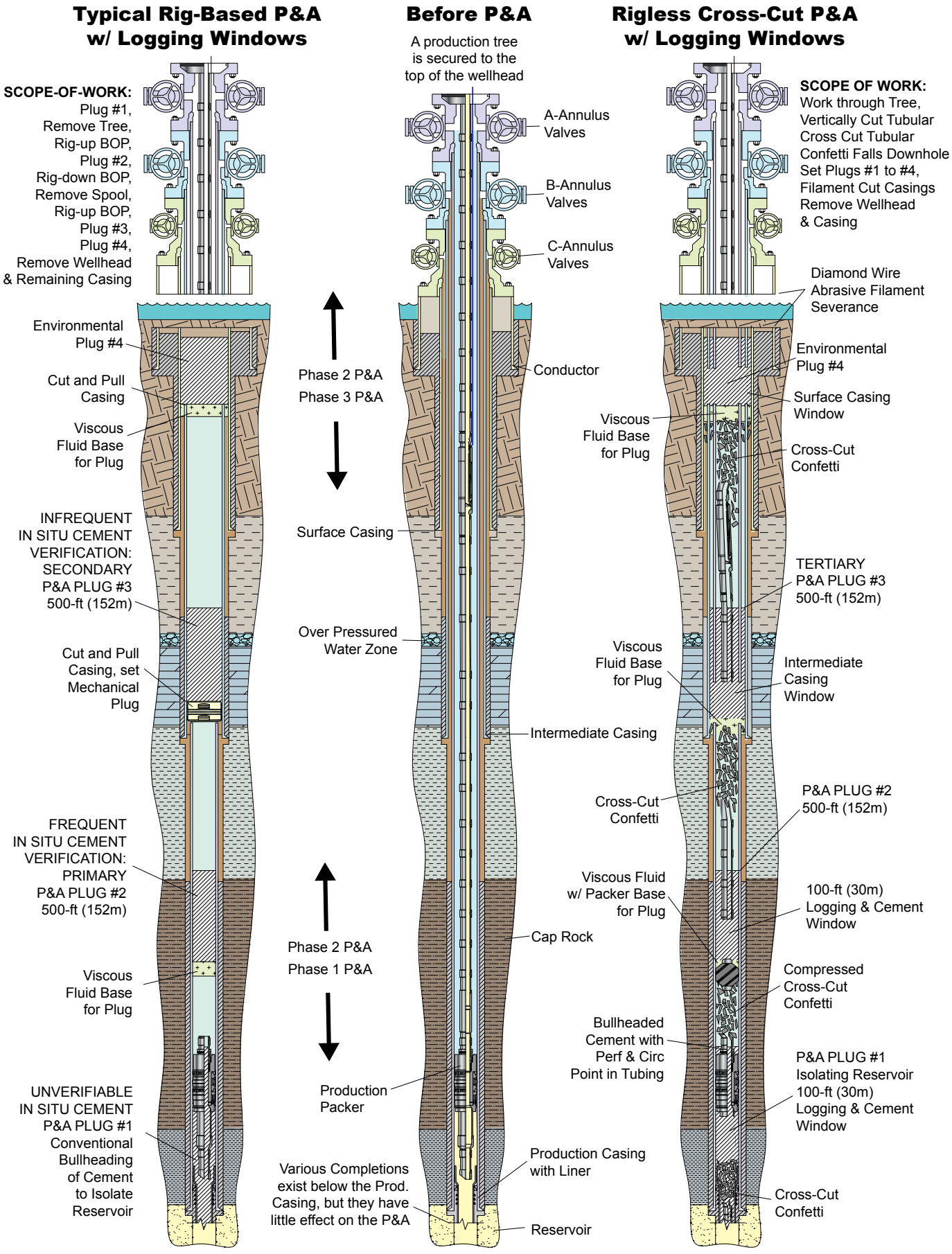

Figure 6 - Comparison of Rig-based to Rigless P&A with Logging Windows

Conclusion

Super abrasive or diamond wire filament cutters have the potential to provide a step change in thru-tubing downhole severance with an ability to effectively cut more than just the tubing.

A filament can extend past the tubing wall to abrade control lines, control line clamps, casing and conductor when the filament is spooled and extended as the abrasive particles attached to the filament dull or are dislodged.

Filament cutters can also be combined with vertical cutting or tubulars to cross shred a tubular wall into confetti that falls and is deposited in the 80% to 90% liquid spaces of a well, wherein the method effectively simulates tubing or casing milling.

If Investors are interested in further discussing the development of a filament cutter deployed from fluid or electric motors or even drill pipe, Oilfield Innovations would be happy to provide additional information.

Further Information

The citations within this prospectus are part of our Universally Compliant P&A Method Prospectus on this website. Please see the citations numbers in that document. For additional information or further queries please contact Clint Smith or Bruce Tunget at the below email addresses.

Notes and references

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† Various photograph have been taken from the following cited references.

‡ Footnotes.