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Application of Modern Technology to a Multi-position Down hole Drilling Electronic Circulating Valve and Integral Disconnect Mechanism

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Abstract

There are several areas where modern technologies can be applied to improve hole conditions reducing the chances of tight hole and stuck pipe. Hole cleaning has always been a key issue in inclined and horizontal wells where cuttings bed form and can lead to time consuming, difficult hole conditions and sometimes stuck pipe when attempting to trip out the hole. Annular velocity is one of the critical parameters that can improve cuttings bed removal but power hungry BHA's and bit hydraulics can sometimes compromise the ability to provide sufficient flow rate to clean the hole. A circulating sub is often installed above the BHA that can be opened to bypass the BHA and provide maximum flow rate to clean the hole. It can also be used to dump high concentrations of LCM in a lost circulation situation that would otherwise block the BHA and bit nozzles. Almost all circulating subs are of a drop ball/dart type that has a limited number of cycles, usually 6 to 9. Balls have to be dropped to open and separate balls dropped to close. These subs have limitations when it comes to hole angle, as the balls require gravity to reach their seats. They are unreliable in inclinations above 65 deg, require surface intervention and are usually only two positions i.e. open or closed. In a packed off situation where the annulus is sealed around the BHA and circulation is prevented, the balls or dart sometimes do not reach their seat and the sub cannot be opened to try and relieve the pack off.

This paper discusses the development of a multi-position electronic circulating valve that can be set to multiple positions by surface down linking. The circulating valve can be configured as a standalone tool or combined with a unique motorized disconnect clutch mechanism that is activated by sensing its environment, working through internal logic modes before being in a position to receive a surface signal to disconnect. This has application in a stuck pipe situation where the tool can be commanded to disconnect and the drillstring recovered avoiding the need for surface intervention and any form of wireline and explosives. This tool has application in any well but particularly high angle wells where the circulating valve can be down linked to the first position for partial BHA bypass increasing annular flow and the final, maximum bypass, position can be used for dumping LCM or fast wellbore clean up at section TD or at any point in the well. Deepwater operations with spread rates in excess of \$1M per day can benefit from the time savings in wellbore clean up, response to lost circulation and flexibility and control in a stuck pipe situation without waiting for wireline crews or explosives to perform a disconnect.

Introduction

Inadequate hole cleaning can lead to costly drilling problems such as pipe sticking, high ECD's, high torque and drag, pack offs resulting in fractured formations and losses (Brown et al, 1989; Ozbayoglu et al, 2007). From an engineering perspective, cuttings transport is dependent on wellbore inclination, cuttings slip velocity, flow regime, rotary speed of the drillpipe, fluid rheology, annular velocity, rate of penetration, cuttings size and shape and many other parameters. In fact, annular velocity is the dominant drilling variable affecting hole cleaning due to its direct relationship with the shear stress acting on the cuttings bed (Kamp and Rivero, 1999). Maintaining an adequate annular velocity (AV) can be challenging in deep, high inclination wells and often compromised due to BHA and Bit requirements.

At best, this can lead to additional time required to clean up the well, wiper trips to remove cuttings bed and stressing the wellbore with potential pack offs and high ECD's. This can result in lost circulation or stuck pipe.

Global statistics for stuck pipe are not readily accessible but regional data collated from collaborative operators gives an indication of the scale of the issue. One major Middle East Operator calculated it accounted for 25% of their NPT with a

cost of 2 rig years per annum (Muqeem, 2012). In the Gulf of Mexico, statistics gathered estimated a total \$7.6 billion USD would be spent on stuck pipe issues (Tollefson et al, 2008). In addition, data collected by the James K Dodson Company for Gulf of Mexico deepwater operations between 2004-2009 (York, 2009), calculated that 5.6% of total well time of Pre Salt wells would be spent on wellbore stability issues and 12.6% on Sub Salt wells. Extrapolating this to today's potential \$100M deepwater well cost, this could be anything between \$6M and \$12M spent on wellbore stability issues including stuck pipe related issues per well. Analysis of data gathered from a database of 27,000 bit runs in US Land operations (Robson, 2012) showed an increasing trend in stuck pipe incidents since 2010, correlating with an increase in well complexity. It also concluded that the increasing activity and lack of skilled personnel may be an influence.

Lost circulation and stuck pipe are governed by numerous factors that make finding analytical solutions with acceptable accuracy very difficult or impossible (Moazzeni, 2011). There is no doubt that stuck pipe and the issues that lead to stuck pipe, for example, inadequate hole cleaning are still major causes for concern in any drilling operation. The drive to drill deeper, in more hazardous environments with the inherent huge costs associated with NPT (Chatar, 2010) drives the necessity to develop technology that can reduce risk and uncertainty. The technology and ingenuity that drove the development of drilling tools like Rotary Steerables and modern LWD tools can be applied to the more fundamental drilling operations like optimizing wellbore circulation through electronic variable circulating subs and effecting a surface controlled, non invasive, disconnect using intelligent electro/mechanical BHA tools.

Economics of Stuck Pipe

The cost of a stuck pipe incident in its entirety is a function of operations spread rate (rig plus services), Lost in Hole (LIH) cost of the stuck BHA and duration of recovery attempts. The final cost will depend on the outcome of the recovery i.e. was the BHA recovered and drilling continued (best outcome) or was the hole plugged back and sidetracked with the BHA lost. The final outcome will depend on many factors, which are specific to each operation and situation. The course of action will also depend on an assessment of the chances of success to recover the stuck BHA. The initial assessment will take into account the following conditions:

1. Sticking mechanism – hole geometry (ledging, Key seats etc.), hole cleaning (cuttings bed), unstable wellbore (geo-mechanics)
2. Hole inclination – vertical, high inclination > 60 degs, horizontal.
3. Hole depth and size – small hole at greater depth is less likely to yield recovery success.
4. Drilling Rig capability – expertise of rig crew and quality of drilling equipment.

When taking all those factors into account a decision can be made whether or not the BHA stands a good chance of being recovered. A chance of recovery factor could be assigned i.e. 50/50, 60/40, 70/30 etc. There are more in depth mathematical relationships that could be explored but at the end of the day, it is a judgment decision.

The move into deep water and higher risk wells demanding high tech solutions and top class equipment has resulted in higher spread costs. A 5th / 6th generation deepwater operation may have a spread cost in excess of \$1M per day and a modern 400ft water depth Jack up may have a spread cost of up to \$350K per day. This has a fundamental effect on the economics of attempting to fish a BHA. Clearly if a basic rotary drilling BHA with an LIH of less than \$1M gets stuck on a deepwater operation with a spread rate of \$1M per day, then depending on the results of the recovery assessment, the most economic way forward may be to get off the BHA and sidetrack immediately. Conversely, the same BHA stuck on a land rig operation with a spread cost of \$125k per day, it may be worthwhile, depending on the recovery assessment, to attempt a recovery.

In addition to the economics of the spread rate/LIH cost/chances of recovery factors, there is a consequential value that must be assessed. This could concern the loss of Radio Active sources and regional legislation where it must be seen that every attempt to recover the sources has been made. Economics is not a factor in this case. There is also the consequence of a sidetrack. There are certain scenarios where a sidetrack is not the best economical solution e.g. a long horizontal section that may have to be redrilled in its entirety because the DP can only be disconnected in a lower inclination section, higher up the hole.

Every recovery from a terminal stuck pipe situation DEPENDS upon the successful separation of the drillstring from the stuck BHA. What is not always taken into consideration is the time spent working the BHA when initially stuck, acceptance that it is not going to come free and the time taken to back off the drillstring so that the recovery process can begin.

Drillstring Separation Current Methods

Before any recovery can commence, the BHA must be separated from the drillstring. This is normally achieved using explosives or chemicals. Most Operators will have an Explosives Box onboard or on site with a collection of explosives designed to perform various functions. This is usually tubing punchers to perforate the drillpipe to enable circulation,

detonating cord which can be used as a “string shot” to “hammer” a drillpipe connection loose or Colliding charges which are shaped explosives which when correctly deployed will sever either the drillpipe or drill collars. To enable their deployment an electric wireline unit and specialist technicians are required. This may require specific mobilization of personnel which depending on the location could be anything from 6hrs to several days.

The Operator will normally run a Free Point Indicator tool inside the drillpipe to indicate where the stuck point is. An attempt to back off the drillpipe will be made just above the stuck point usually by applying left hand torque to the DP and placing a String shot via electric line opposite the connection to be backed off. The hope is that the hammer like explosive blow will undo the connection. Several attempts may be required. In high inclination holes the left hand torque may not get transmitted down to the stuck point and a severing charge is used to “cut” the drillpipe. Sometimes it does not go according to plan and results are obtained as depicted in Figure 1.



Figure 1 – examples of severed Drillpipe.

Results as in Figure 1 more or less write off any chance of being able to reconnect with the fish and a sidetrack is inevitable. There have been significant advances in the technology of cutting and severing stuck tubulars (Segura, 2011), however, explosive jet cutters and chemical cutters which can produce a cleaner cut usually have to be specifically mobilized and engineered for each application. Depending on rig location this could take several days. In the case of chemical cutters, these are rarely air transportable.

The disadvantages in wireline-deployed explosives to separate drillpipe are as follows:

1. Specialist technicians required to deploy the explosives.
2. Several attempts may be required.
3. Damage to top of fish left downhole.
4. Unable to access horizontal or greater than 65deg inclination hole sections.
5. Remote logistics may delay the start of the process.

With the advent of highly sophisticated downhole technology in the form of Rotary Steerable systems and LWD technology in combination with the huge daily cost of some of the high technology rigs, there is an opportunity to deploy intelligent non-invasive technology to reduce uncertainty and risk when performing this operation.

The Cost of Poor Hole Cleaning

If poor hole cleaning does not result in stuck pipe or losses, it will definitely result in additional rig time to enable the next stage of operations. At TD of an inclined hole section, circulating bottoms up three or four times may be required before attempting to pull out the hole. If a cuttings bed has been allowed to form, only mechanical action i.e. back reaming will enable it to be removed. It may take several trips to ensure the hole is clean and clear to allow logs or casing to be run. The additional cost to resolve this situation is a function of the Spread rate of the Operation. A Deepwater operation may have a \$1.2m daily spread cost. Additional time circulating and back reaming out the hole may add a day or more to the operation. Very quickly, one can be spending \$millions to be able to progress to the next stage of operations. In lower spread rates such as jack up or Land Rig it can be anything between \$100k and \$400k but the principles are the same and several \$100,000 can be lost due to poor hole cleaning.

Application of Intelligent Technologies to Mitigate Stuck Pipe

There are several areas where modern technologies can be applied to improve drilling conditions that will reduce the chances of stuck pipe. Hole cleaning has always been a major issue in inclined wells where cuttings bed form and can lead to stuck pipe when attempting to trip out the hole. Annular velocity is one of the critical parameters that can improve cuttings bed removal but power hungry BHA's and bit hydraulics can sometimes compromise the ability to provide

sufficient flow rate to clean the hole. A circulating sub is often installed above the BHA that can be opened to bypass the BHA and provide maximum flow rate to clean the hole. It can also be used to dump high concentrations of LCM in a lost circulation situation, which would otherwise block the BHA and bit nozzles. Almost all circulating subs are of a drop ball/dart type that has a limited number of cycles, usually 6. Balls have to be dropped to open and separate balls dropped to close. These subs have limitations when it comes to hole angle, as the balls require gravity to reach their seats. Also, in a packed off situation where the annulus is sealed around the BHA, the balls or dart sometimes do not reach their seat and the sub cannot be opened to try and relieve the pack off. They are also not through bore which is a major disadvantage if there is a requirement to place a circulation point higher in the drillstring e.g. in a long tangent section.

The limitations of these devices and methods appeared out of sync with technology advancements in other areas. Development of an electronic, multi position, through bore circulating valve with intelligent disconnect began in 2008 and is currently in pre-production testing using a purpose built flow loop testing facility at Sheffield, UK.

Electronic Multi Position Circulating Valve and Disconnect Device

The multiple position circulating valve can be configured to provide optimal annular velocity while drilling utilizing all the available hydraulic power. The valve has 3 positions, Closed, Intermediate and Full Open, which can be selected to allow partial fluid bypass of the BHA while drilling, maximizing the use of surface pressure limitations and optimizing AV. At section TD, the valve can be put into the Full Open position and the well cleaned up at maximum flowrate bypassing the BHA. A second device can be positioned in the string at the end of the buildup section when the bit is at TD. Once cuttings have been moved from the high inclination section into the build up section, the primary device can be closed and the secondary device opened to allow efficient cuttings transportation through the Build up section and lower overall ECD's. In addition, there is the assurance that the device is not limited by hole inclination, as there are no darts or balls to be dropped. The disconnect feature is particularly useful in high inclination and horizontal drilling which would be beyond the normal operating limits of wireline if an explosive back off were to be considered.

Therefore, the device provides the Operator with the ability to utilize a multi position circulating valve at any time during the drilling process without surface intervention i.e. No drop balls or darts.

The tool can be configured with an integral Disconnect feature that allows the Operator to activate the mechanism and separate the lower half from the upper half in a stuck pipe situation. The combined circulating valve and disconnect feature is distinct from the stand alone circulating valve. The device has the ability to sense its downhole environment through electronic sensors, process that information and move through various pre-defined modes and respond to surface Downlinks.

The concept behind these devices is to provide controlled functions at the Operators discretion without the intervention of surface tools or mobilization of 3rd parties and 3rd party equipment. The combined circ v/v and disconnect has three distinct sections; the Disconnect section; the Electronic Service Module (ESM) and the Circulating valve. The stand alone circ v/v is very similar but consists of the ESM and Circulating valve section only. Each section is discussed below.

Electronic Service Module (ESM)

The ESM contains the triple axis accelerometers, pressure sensors, proximity sensors, electric drive motors, processors and battery pack to service the Disconnect and Circulate sections (Figure 2.). The sensor outputs are processed according to a Sensor Map (see Figure 4), which will define the required action. An example of a sensor map can be found later in this section and is fully customizable to the operator's needs and environment. At each end of the ESM there is an electric motor to drive the respective system, either disconnect or circulate.

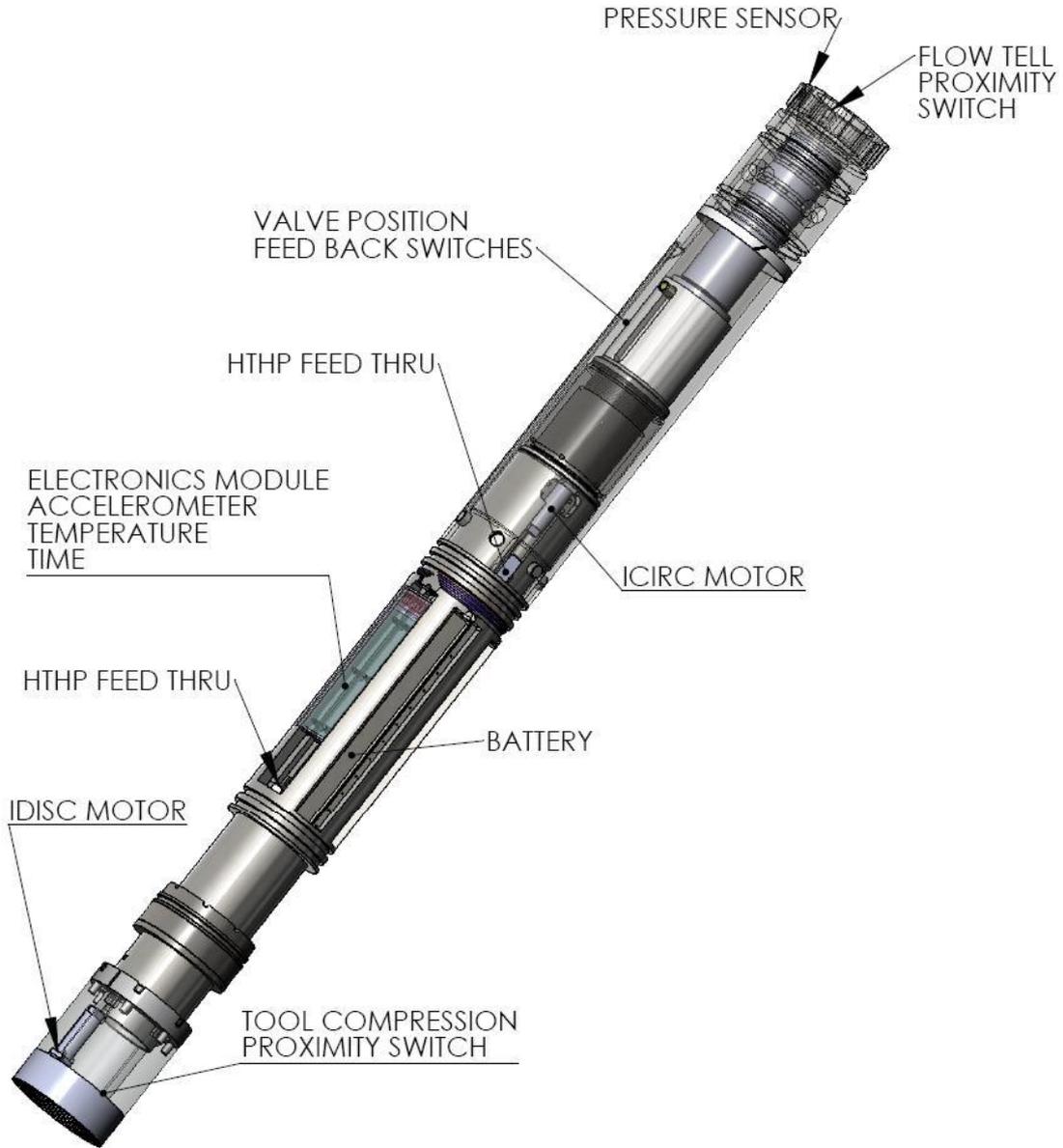


Figure 2 – Electronic Service Module (ESM)

The system is battery driven i.e. no turbines, therefore, the sensors, processor and motor current draw is being designed to be very low. The entire tool is through bore.

Disconnect Section

The Disconnect system is designed to recognize various “modes” and progress through them in sequence before entering the Disconnect mode where a confirmation signal from surface will activate the Disconnect motor. This system is to ensure that there is no accidental release. The sequence is explained below.

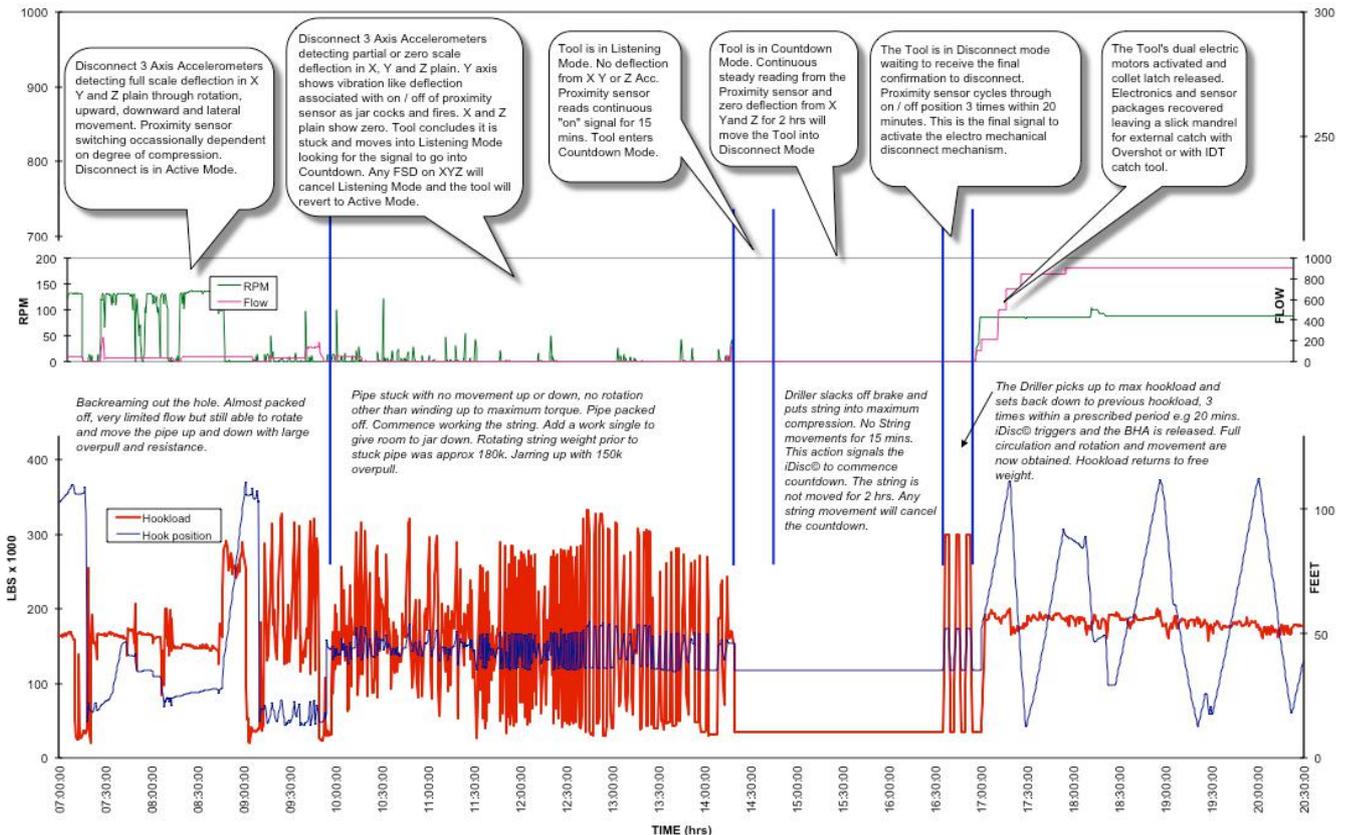


Figure 3 – Disconnect Process Chart

Please refer to the chart in Figure 3. The values on this chart are taken from an actual stuck pipe incident with the device modes inserted. The purpose of having a sequence of Modes that the tool must progress through prior to Disconnect as opposed to a simple command to Disconnect, are to ensure that the tool does not misinterpret signals and disconnect prematurely. The Modes are explained in the table below and are as follows:

Active Mode

In this mode the tool is below the rotary table and the hydrostatic pressure switch has switched the tool on when the tool is approximately 50ft below RT. All sensors are active and feeding data to the processor. In this mode, the tool recognizes normal drilling activity such as drilling, reaming, pumping, tripping, backreaming etc.

Listening Mode

If the BHA becomes stuck, the sensors note the lack of movement and switching of the proximity sensor indicating jarring. After a period, the tool moves into a Listening mode where it is standing by for the signal to move into Countdown Mode. If any sensor detects movement then the tool reverts to Active Mode.

Countdown Mode

Once the tool is in Listening Mode, the next step in the sequence to disconnect is for the tool to enter into a Countdown. This is initiated by compressing the string to ensure the proximity sensor is closed or “on” for 15 minutes continuously. The tool will then go into a countdown to the next mode, Disconnect Mode. The countdown is fully customizable to the Operators spec but is suggested to be 2 hours. The string must be kept stationary. Any movement detected by the sensors will abort the Countdown. At the end of the Countdown, the tool will move into Disconnect Mode.

Disconnect Mode

The tool is now ready to receive the final signal to disconnect which it must receive in a pre-determined period of time suggested at 20 mins. The string is lifted into tension and then lowered into compression 3 times within the time period. Ultimately hall affect switches pick up on the linear movement to provide a final confirmation prior to activating the disconnect motors. Power is sent to the disconnect motor and the release mechanism activated.

Circulating Valve

This is controlled by the same sensors in the ESM but according to a different mapping. The valve has three positions, which can be customised to operators needs in terms of hydraulics and flow area (see figure 6). The valve is not sequential therefore it can go from fully closed to fully open with one command. The circulating valve installed in the combined disconnect tool has a ball valve that closes the through bore when the valve moves to full open position. This is to ensure that if high concentrations of LCM are pumped, it does not block the BHA or bit.

Downlink

The tool can recognize a “downlink” through a timed sequence of specific rotations and prepare itself to function through three different positions according to the Operators needs. There are two phases of Operation; “Drilling” and “Stuck”. In the Drilling phase, the tool responds to downlinks as defined in the ESM Sensor Maps table below, however, if the tool becomes stuck, it cannot respond to downlinks as rotation will not be possible. In “Stuck” phase, the circulating valve can be opened to the full position as part of the Disconnect sequence. When the device enters the Countdown Mode, a sequence of signals is sent via the proximity sensor that tells the circulating valve to go to the full open position. This will automatically cancel the Countdown and the string attempted to circulate to move any pack off.

ESM Sensor Maps

iDisc		Accl Radial	Accl Lateral	Accl Rotn	Compression	Flow (differential pressure)	Pressure Switch	Comments
MODE	ACTIVITY	x	y	z				
Active	BHA Racked back	0	0	0	0	0	0	tool switched off
	BHA running in hole	1	1	1	0	0	1	tool switches on when pressure switch reads in excess of 10psi
	Reaming	1	1	1	0	1	1	pumps on, rotating, working in the hole
	Drilling	1	1	1	1/0	1	1	pumping, rotating, WOB
	Circulating	1/0	1	1/0	1/0	1	1	pumping, on/off rotn, moving string up and down
	Wiping	1	1	0	1/0	0	1	moving string through resistance to clean hole
Listening	BHA static at casing shoe	0	0	0	0	0	1	string stationary
	BHA pulling out of hole	1	1	1	0	0	1	
Countdown	BHA stuck & jarring	0	0	0	1/0	1/0	1	comp sensor cycling with jar action. Possible slight pressure surges due to jarring
	String put in compression to trigger the countdown	0	0	0	1	0	1	string put in compression and held stationary for X mins to trigger countdown
	Abort countdown (within countdown time period)	0	0	0	0	0	1	String lifted into tension aborting countdown
	Re-instate countdown after abort	0	0	0	1	0	1	string put in compression and held stationary for X mins to trigger countdown
Disconnect	Trigger disconnect	0	0	0	0,1,0,1,0,1	0	1	countdown period expired. Lift string into tension and back to compression 3 times within X mins
Circ v/v - Drilling								
Downlink	Prepare for Downlink	0	0	1 (30&60 rpm)	0	1 (300gpm)	1	constant pump rate, 30rpm for 1min followed by 60rpm for 1min, back to 30rpm
	listening for command sequence	0	0	1 (30rpm)	0	1 (300gpm)	1	tool waiting for pumps on/off sequence. Must be received within 5 mins from end of downlink signal
Command	Open 33%	0	0	1 (30rpm)	0	0,1	1	pumps off for 30 secs, pumps back on. After 30 secs v/v should open and pressure drop observed at surface.
	End Downlink	0	1	1 (+rpm)	0	1	1	increase RPM and move string up or down
Command	Open 66%	0	0	1 (30rpm)	0	0,1,0,1	1	pumps off, on, off, on. 30 sec intervals.
	End Downlink	0	1	1 (+rpm)	0	1	1	increase RPM and move string up or down
Command	Open 100%	0	0	1 (30rpm)	0	0,1,0,1,0,1	1	pumps off, on, off, on, off, on. 30 sec intervals.
	End Downlink	0	1	1 (+rpm)	0	1	1	increase RPM and move string up or down
Command	Close 0%	0	0	1 (30, 60rpm)	0	0,1	1	increase rpm to 60. Pumps off for 1min, then back on.
	End Downlink	0	1	1 (+rpm)	0	1	1	increase RPM and move string up or down
Circ v/v - Stuck								
Listening	BHA stuck & jarring	0	0	0	1/0	1/0	1	comp sensor cycling with jar action. Possible slight pressure surges due to jarring
	String put in compression to trigger the countdown	0	0	0	1	0	1	string put in compression and held stationary for X mins to trigger countdown
Command	100% open	0	0	0	1 (...-...)	0	1	once tool is in countdown mode (15mins static compression), the string is lifted and lowered to give a 3 short, 3 long, 3 short compressions (SOS), v/v will open 100%

Figure 4 – Sensor Map

Fully Programmable and Customisable

Both the circ v/v and combined circ v/v and disconnect tool are fully programmable through the ESM. They can be individually set up to receive separate downlinks that only they will respond to. Downlink commands and Disconnect Modes are fully customisable. They can also be setup to work together or in TANDEM.

Optimum Hole Cleaning and Reduction in ECD through TANDEM Application

Maximising annular velocity, while drilling, is instrumental in preventing or minimizing the formation of a cuttings bed. The higher the flowrate and drillstring RPM, the better the conditions for effective cuttings transportation. This is especially true for high inclination or ERD wells. MWD/LWD tools, Motors, Rotary Steerables and Bit hydraulics can often consume hydraulic power to the detriment of optimized flowrate. It is possible to optimize the split between BHA/Bit power requirements and divert some flow from the BHA, utilizing a circulation sub above the major components, thereby using the available hydraulic horsepower much more efficiently. The combined circ v/v disconnect tool would normally be run below the jar. The circulating valve can be opened to its intermediate position providing partial BHA bypass to increase the annular velocity without losing BHA/bit efficiency. The intermediate circulating position can be nozzled accordingly.

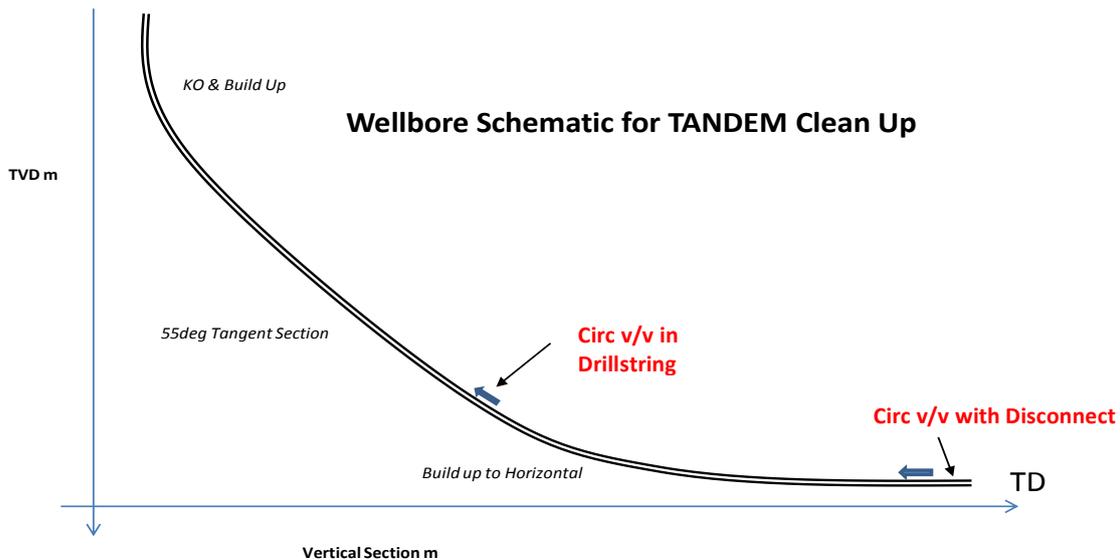


Figure 5

Because of the programmable nature of the tools, circ v/v and combined circ v/v disconnect can be setup to work together under a single downlink command. Figure 5, above, depicts a deviated horizontal well. The drillstring has been configured to have an circ v/v tool at the base of the long tangent section. The combined tool is part of the BHA and at section TD. A specific programme called TANDEM has been entered into each tools memory at surface before running in the hole. This programme contains calculations concerning the theoretical hole volume separating each tool from each other and the hole volume from the top circ v/v to surface when the bit is at section TD. When the TANDEM downlink command is sent, both tools recognize this and the combined tool opens fully to allow maximum flowrate and AV along the horizontal hole section until the pre-programmed volume has been pumped. The circ v/v moves to full open position and the combined tool moves to the intermediate position. Max flowrate is maintained from the circ v/v along the tangent section to surface. ECD is minimized as there is little circulation back pressure along the horizontal section.

This programming allows the wellbore to be effectively cleaned with the maximum flowrate at the lowest ECD.

Lost Circulation

The combined tool circulating valve assembly is configured with a full closure that closes off the bore when the valve is moved to the full open position. If high concentrations of LCM are pumped, the full closure ensures that LCM does not make its way to MWD components or block the bit nozzles.

Mechanical Design Circulating Valve

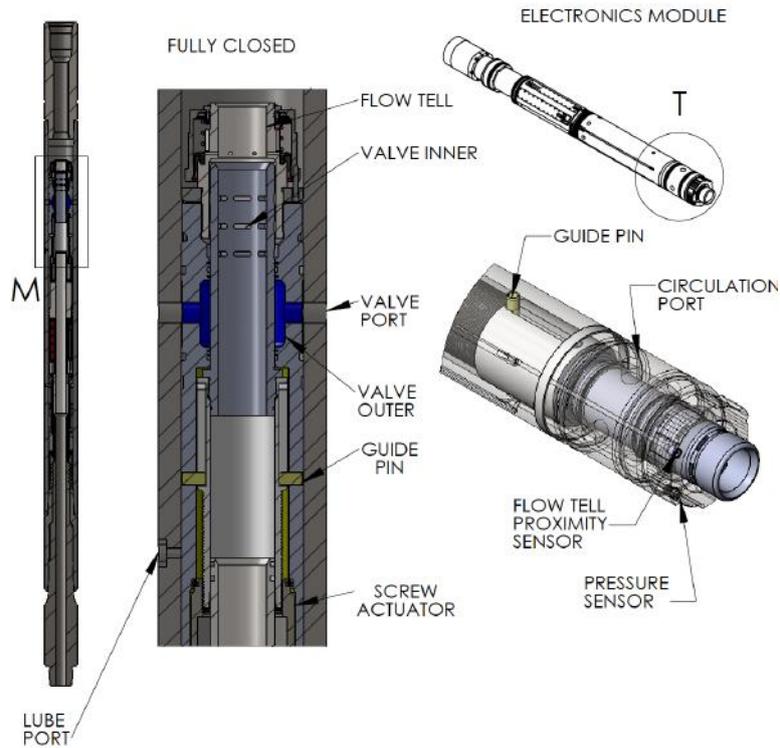


Figure 5 – Circulating Valve layout

The three position circulating valve is positioned at the top of the assembly (see Figure 5). Circulation can be routed to the annulus via the Valve Inner tube which can move down under command from the ESM, to expose the array of circulation ports to the external valve ports. Port sizing can be customised by the operator to suit a particular well design. When circulation commences, the Flow Tell switch activates to tell the ESM that there is flow. The tool is instructed to move to its various port positions by a series of downlinks transmitted by sequences of RPM and pumps on/off. The sequences are outlined in the ESM Sensor Maps. Sensors confirm to the ESM the exact position of the Valve Inner tube. The tube is driven up and down by a screw actuator, which is driven by an electric motor under the control of the ESM. The three circulating positions are shown below.

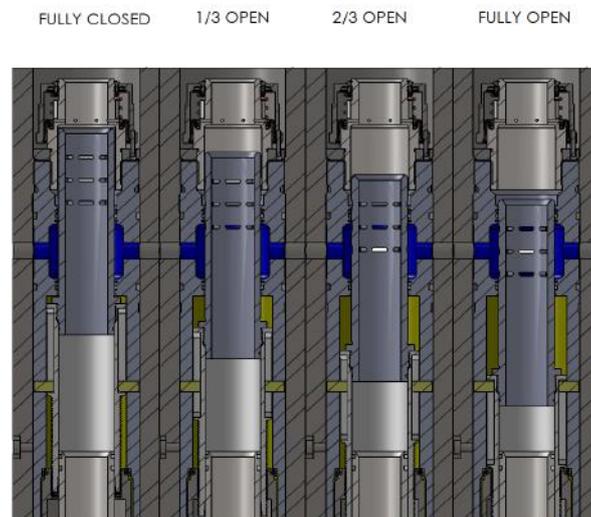


Figure 6 – Circulating Valve positions

Intelligent Disconnect

The Disconnect mechanism is at the lower end of the assembly below the ESM. When disconnected the ESM and Circulating valve mechanism are recovered. This leaves the “Stinger” looking up, for which a matching Fishing overshoot can be supplied which will mate with the Stinger.

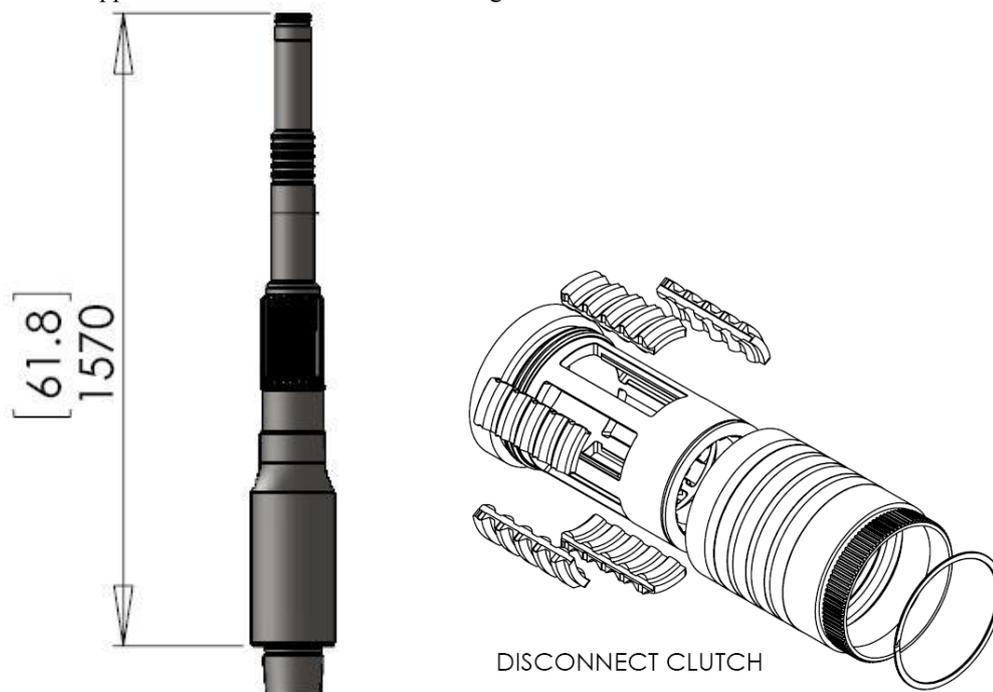


Figure 7 – Clutch

Mechanism

The Stinger and the upper half of the assembly are connected by the segmented “Disconnect Clutch” as depicted in Figure 7. This has six segments, which sit, in a basket and the engineered waveform profile engages with a matching profile on the stinger. The segments are held in place by a retaining cylinder which has a matching waveform profile with the back of the clutch segments. The clutch is engaged when the retaining cylinder waveform profile is “crest to crest” with the clutch segments rear waveform profile (see Figure 8). This keeps the clutch and stinger waveforms fully meshed. The specially engineered waveform profile ensures uniform and equal distribution of tension and compression forces minimising stress concentrations. Torque and torsional forces are transmitted by a drive spline arrangement. The clutch is disengaged when the retaining cylinder is caused to move up and the waveform profile moves from “crest to crest” to “crest to trough”. The clutch segments then have enough room to move back from the stinger and fully disengage their waveforms. See drawings below:

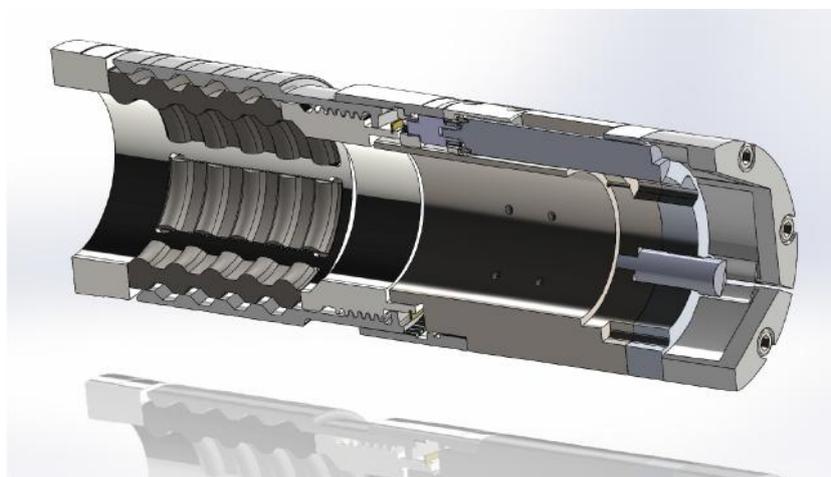


Figure 8 – Section through Clutch

With the clutch disengaged, the upper assembly consisting of the clutch, ESM and circulating v/v (connected to the drillstring) can be withdrawn from the stinger and lower BHA. The movement of the clutch segment retention collar is

by a screw actuator driven by an electric motor.

Electronics and Design Integrity

The design intent of the disconnect tool was to ensure that any component failure would not create a situation in which the tool would perform an unplanned disconnect, and also that when a disconnect action is required the mechanism would perform in a reliable manner. Due to the high vibration environment that can be encountered care has been taken to ensure the components are robust. One example is that the torque transmitted through the tool does not introduce stress near where disconnect collets are positioned. This region is further protected from adverse bending moments and compressive stresses, leaving the collets only taking tensile loads.

The tool body components Mandrel, Spline housing Main Body and Top sub are manufactured with alloy steels namely AISI4145H or AISI 4330V, in accordance to Fearnley Proctors NS-1 standard which exceeds the material testing requirements of DS-1 and API spec 7-2 standards. The connections on the 8" prototype joining these components with exception to the disconnect collets are standard API 6 5/8 API Reg or 6 5/8 Full Hole. The Disconnect collets have been designed to the strength limits expressed in typical Drilling Jar catalogues. Manufactured from tool steel for optimum durability. Presently the tool is limited to operations up to 150 deg c.

The motors operating both the circulation valve and the disconnect function are geared up to provide a mechanical advantage of approximately 20,000 to 1. The EC22HD+GP22HD Maxon motors are 22mm diameter and specifically designed for high temperatures. i.e. 2000 hours at 180c and operation in a fluid oil fluid environment. Although vibration test results on the motors are presently available to 17G the motors are securely housed (to remove strain on the mountings). Further testing at higher levels is being scheduled. Photos 1 and 2 show the motor testing. The motor supplier provides motors to the Aerospace industry as well as for Drilling applications. Figure 9 shows endurance reliability testing charts of the motors at 180 DegC and vibration levels up to 17G.

The present 8" tool is designed with an unobstructed through bore of 60mm to ensure ball drop or wire line tools can be deployed below it. All mechanisms are lubricated in a pressure compensated oil reservoir to reduce friction and ensure reliability. Electronics circuitry and batteries are housed in a sealed enclosure behind high temperature, high pressure bulkheads. The electronic monitoring sensors are recorded on the onboard memory microprocessor. On retrieval of the tool separated or whole this information can be extracted though a port on the side of the tool.

Surface Testing

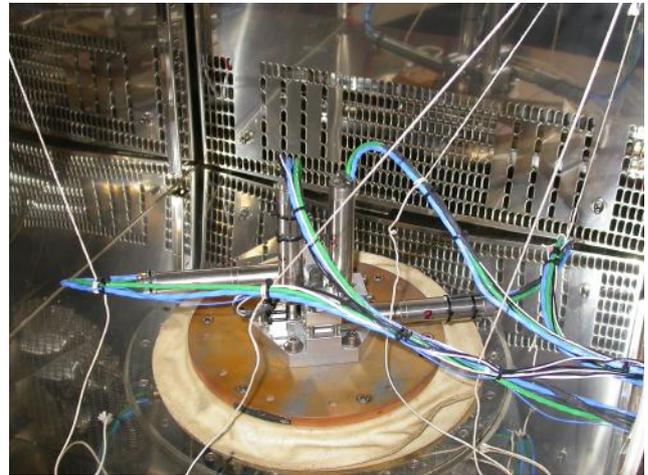
Surface testing and functionality is done on a full flow loop facility consisting of high pressure mud pumps, 500bbl water tanks and associated pipework and a mobile water well rig to enable horizontal and vertical actuation of the tools. Photograph 1 shows the full circ v/v disconnect tool inserted into the test scabbard and hooked up to the top drive of the rig. The tool has a test port and is electrically connected to the surface logging cabin. All sensors are monitored as the Downlink procedure is followed to ensure they are fully received.



Photograph 1 – Flow Loop and Test Rig



Photograph 2 – Monitoring Sensor output during Downlinks



Photograph 3 and 4 showing electric Motor testing rigs.

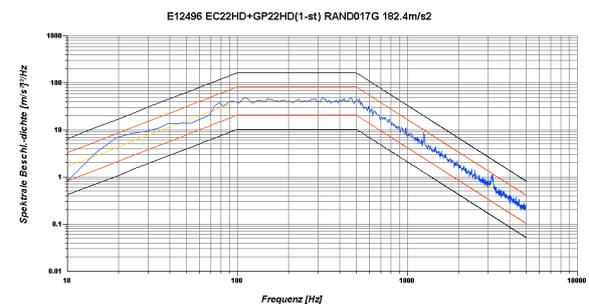
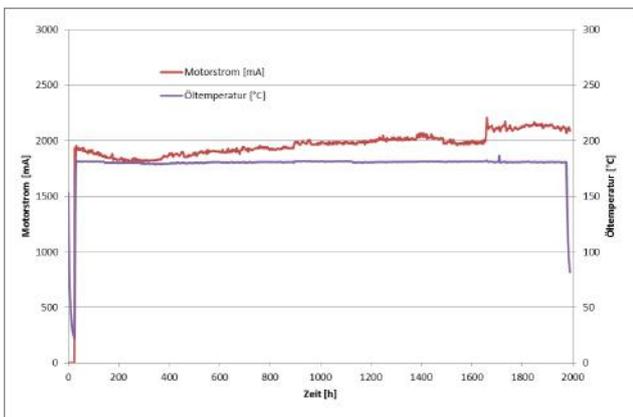


Figure 9 – Graphs of Motor reliability testing, 2000hrs operating at 180 degC at up to 17G vibration levels

Conclusion

It is clear that lost circulation and stuck pipe will continue to be major causes for concern and account for large NPT events. This is something that is becoming more influential as wells become more complex and difficult. The lack of a skilled workforce is also something that is recognized by the industry. It has already been shown that the use of high technology in complex wells can reduce the incidence of stuck pipe (Tollefson et al, 2008). The application of technology to improve wellbore clean up, mitigate lost circulation and reliably disconnect from the BHA, must be an area of focus to provide better performance in these areas. Having a reliable solution for these events already built into the BHA, allows the Operator to accurately build in to their contingency planning, the recovery timeline.

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