

Fundamentals of Mechanical Debris Management

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Abstract

Debris management is an important consideration when drilling, completing and producing a well. Unwanted debris can be responsible for many problems and unforeseen costs, particularly in highly deviated holes, extreme water depths, and extended reach applications. This debris is generated from a number of sources, including formation cuttings, mud solids, milling, shoe track drill outs, cementing, gun debris and ferrous residuals from casing wear. When debris is left behind in a wellbore, it can ruin a complex multi-million dollar completion and increase the risk that a well will never achieve its full potential.

This paper focuses on the mechanical aspects of debris management that impact various operations performed during drilling and completion. Each operation has its own challenges and specific characteristics that require different wellbore clean out tool configurations and procedures. These range from simple casing scraper/brush combinations to complex assemblies consisting of mills, string magnets, circulating tools and downhole validation filters, in addition to brushes and casing scrapers for multiple casing/liner geometries. While difficult to quantify in terms of cost savings and time efficiency, proper debris management is inarguably an important element of any well program.

Introduction

Wellbore cleanout (WBCO) is a combination of chemical, hydraulic and mechanical processes. However, only the mechanical aspects will be addressed here.

Basic mechanical cleanout tools such as string magnets, baskets and casing scrapers have been in use since the days of wooden derricks. As the cost and complexity of wells increased, our industry recognized the need for a more engineered approach to debris management utilizing a combination of tools to:

- introduce solids to the fluid stream
- reduce particle size
- improve annular velocity
- capture debris
- validate wellbore cleanliness

All WBCO tools fall into one or more of these categories, as shown in the following table.

Table #1: WBCO Tools Listed by Category

Wellbore Cleanout Tool Categories		Casing Scraper	Brush	String Magnet	Ported Sub and Valve	Basket	Hydrostatic Bailer	String Mill	Validation Tool	Venturi Tool
Introduce solids to fluid stream		X	X		X			X		
Reduce particle size		X						X		
Improve annular velocity					X					
Capture debris				X		X	X		X	X
Validate wellbore cleanliness									X	

Selecting the best tools for the job, placing them where they will be most effective and then generating a procedure based on solid “Best Practices” comprise the elements of successful debris management. Listed below are six common operations that require mechanical intervention:

- Milling
- Shoe track drill-out
- Fluid displacement
- Perforating
- Packer plug retrieval
- BOP jetting

Each operation, accompanied by a typical tool schematic, will be discussed.

Tool Categories

Introduce solids to the fluid stream

Casing scrapers and brushes are used to loosen debris from the casing wall while tripping. Casing scrapers typically function only while tripping in, but brushes function equally well while tripping in or out of the hole. Loosening debris in irregular areas such as BOPs, wellheads and open hole sections require the use of ported subs, bypass valves or jetting tools.

Reduce particle size

Properly selected string mills matched with a casing scraper can be used to reduce particle size by employing mills

with progressively shallower fluid courses. Aggressive bits provide good penetration rates, but the trade off can be large chunks of drilled debris. Running these mills behind the bit in cased hole applications can reduce particle size without compromising penetration rate.

Improve annular velocity

Bypass valves, commonly referred to as “circulating subs” are available in a number of different designs for a broad range of applications. From a debris management standpoint, they are opened to boost annular velocities thereby improving the carrying efficiency of the wellbore fluid.

Capture debris

Debris is captured in many different ways depending on the type of debris and specific operation. String magnets are used to collect and extract ferrous debris and should be used in most operations. Junk baskets or finger baskets are beneficial if large debris of any sort is anticipated. Bailers and Venturi tools are used in more specific types of operations. Validation tools can also capture and remove debris. However, that is not their primary function in most instances.

Validate wellbore cleanliness

Filtration or validation tools really tell the story as to how effective the wellbore cleanup operation was performed. Placing validation tools in each section of casing effectively insures that all fluid will be filtered as the drill string is pulled out of the hole. This is accomplished by incorporating a rubber flow diverter that is larger than the casing ID to insure the casing strings are wiped clean and all the fluid is diverted through the integral filters.

Typical Operations

Milling

Milling operations may be performed for a variety of reasons, including:

- washing over a packer
- cutting a casing section or window
- burning over a fish
- milling up junk

These operations require pre planning and coordination between the fishing tool company, the fluid supplier and the WBCO tool provider. (Reference Figure 1)

Properly placed string magnets and a circulating valve are the main WBCO components in a milling operation. In many instances, the predetermined volume of ferrous material can be used to calculate the optimum number of string magnets to run based on total debris capacity. The circulating valve should be placed just above the string magnets to boost annular velocities without pumping the string magnets clean. A ball drop multi-activation circulating valve with a large flow area would be the choice for this application.

Capturing mill debris downhole rather than circulating it out with sweeps is a recent paradigm shift within the industry. The common wisdom now is that circulating

large quantities of milled debris through the BOPs can increase the risk of BOP failure; however, ditch magnets should still be used as well to accurately quantify total recovery. Another location that should be considered for magnet placement is just above a liner top where a decrease in annular velocity could result in an accumulation of debris. While tripping out of the hole, consider locating the circulating valve at the liner top and breaking circulation, rotating and reciprocating at the liner top to loosen any debris that may have accumulated during the operation.

It should be noted that jetting the BOPs is critical after a milling operation. BOP jetting is discussed further in another section of this paper. Recently, there has been more focus on cleaning the ram seal area inside the BOP after a milling operation. Often times jetting can be performed during the same trip as other operations. However, during a packer milling or fishing operation the main goal is retrieval. Therefore, additional circulation while tripping out of the hole should be minimized and a dedicated run to clean the BOP is necessary.

Casing		Description
21.000" Marine Riser I.D. 19.750" 0.00 - 4000.00 ft		5.000", 19.50# Workstring w/ NC-50 (Box up)
Subsurface BOP I.D. 19.750" 4000.00 - 4065.00 ft		Pup Joint NC-50 (Box) X NC-50 (Pin)
9.625" Production Casing 53.50 ppf I.D. 8.532" Drift 8.379" 4065.00 - 15000.00 ft		String Magnet NC-50 (Box) X NC-50 (Pin)
		String Magnet NC-50 (Box) X NC-50 (Pin)
		Pup Joint NC-50 (Box) X NC-50 (Pin)
		String Magnet NC-50 (Box) X NC-50 (Pin)
7.000" Production Casing 29.00 ppf I.D. 5.184" Drift 5.059" 15000.00 - 18000.00 ft		String Magnet NC-50 (Box) X NC-50 (Pin)
		Crossover NC-50 (Box) X NC-38 (Pin)
		Heavy Weight Drill Pipe NC-38 (Box) X NC-38 (Pin)
		Heavy Weight Drill Pipe NC-38 (Box) X NC-38 (Pin)
	Drill Collars (1 stand + single) NC-38 (Box) X NC-38 (Pin)	
	Pony Collar NC-38 (Box) X NC-38 (Pin)	
	Drilling Valve NC-38 (Box) X NC-38 (Pin)	
	Ball Catcher NC-38 (Box) X NC-38 (Pin)	
	String Magnet NC-38 (Box) X NC-38 (Pin)	
	String Magnet NC-38 (Box) X NC-38 (Pin)	
Float Sub NC-38 (Box) X NC-38 (Pin)		
Mill for Packer NC-38 (Box)		

Figure 1

Shoe track drill-out

The shoe track is drilled out for a variety of reasons during drilling and completion operations. Cleaning/smoothing off these areas is very important to ensure that subsequent BHAs can pass through unimpeded. The selection and placement of these tools can significantly reduce the particle sizes of cuttings and can be very effective in managing the debris. In most cases particle size reduction will improve hole cleaning efficiencies and more easily allow them to be circulated out of the hole.

The following tool placement has proven effective in reducing particle size while drilling out the shoe track. Placing a drill collar directly above the bit will provide standoff space for the cement/debris to mix with the drilling mud. A smooth OD tapered spiral string mill is run above the drill collar to reduce the larger drilled debris as it is circulated up the hole. This is followed by a high capacity string magnet and a second string mill with shallower fluid courses. Lastly, a heavy duty casing scraper that incorporates mill rings (upper and lower) with fluid courses equal to or slightly larger than the upper string mill to further reduce particle size. (Reference Figure 2)

Ideally, the WBCO tool array should include a high capacity string magnet designed to remain well centralized in the casing to prevent the debris from being dislodged while drilling and pulling out of the hole. The string magnet should also have a soft steel stabilizer that minimizes casing wear during the drill out. The casing scraper should be non-rotational, meaning that the actual casing scraper element and stabilizers rotate independently of the drill string. This minimizes casing wear during the drill out and reduces torque and drag through deviated sections. Additionally, mill rings with carbide cutting material are integral to the tool in case large pieces of debris are encountered, allowing them to be broken down and circulated past the tool. In some instances, a more aggressive approach has been successfully performed that incorporates a full complement of clean out tools including brushes, filtration tools and circulating valves along with a liner top test packer. This permits conducting both an inflow test on the liner top and the shoe track drill out all in one run. Additionally, field trials are now being performed to allow all of these operations in one run, plus the ability to drill enough new formation to perform a formation integrity test.

Like any operation, pre-planning is essential. Choosing the right combination of bit and tools, along with careful consideration of critical IDs and ODs, RPM, etc., can minimize non productive time and potential train wreck scenarios such as casing back offs and stuck BHAs. With thoughtful planning, it is also often possible to save rig time through the elimination of a trip.



Casing		Description
21.000" Marine Riser I.D. 19.750" 0.00 - 4000.00 ft		5.000", 19.50# Workstring w/ NC-50 (Box up)
Subsurface BOP I.D. 19.750" 4000.00 - 4065.00 ft		
9.625" Production Casing 53.50 ppf I.D. 8.535" Drift 8.379" 4065.00 - 15000.00 ft		Crossover NC-50 (Box) X NC-38 (Pin) 3.500", 13.30# Workstring w/ NC-38 (Box up)
7.000" Production Casing 29.00 ppf I.D. 6.184" Drift 6.059" 15000.00 - 18000.00 ft		Drill Collars (1 Stand) NC-38 (Box) X NC-38 (Pin)
		Drilling Jar NC-38 (Box) X NC-38 (Pin)
		Drill Collars (4 Stands) NC-38 (Box) X NC-38 (Pin)
		Pony Collar NC-38 (Box) X NC-38 (Pin)
		Casing Scraper NC-38 (Box) X NC-38 (Pin)
		Pony Collar NC-38 (Box) X NC-38 (Pin)
		String Mill w/ reduced water course to match scraper tool NC-38 (Box) X NC-38 (Pin)
		String Magnet NC-38 (Box) X NC-38 (Pin)
		String Mill NC-38 (Box) X NC-38 (Pin)
		Drill Collar NC-38 (Box) X NC-38 (Pin)
		Bit Sub NC-38 (Box) X 3 1/2" REG (Box)
		Drill Bit 3 1/2" REG (Pin)

Figure 2

Fluid Displacement

Wellbore displacement is the last step before completion operations commence and can play a big role in the eventual productivity of the well. It is also the only operation that can potentially employ the entire suite of WBCO tools. Casing scrapers and brushes are utilized to clean the casing walls and introduce solids to the fluid stream. Circulating valves are often necessary to boost annular velocities. String magnets and junk baskets are used to capture debris. Validation tools should be placed in each casing section to completely filter the fluid. Particle size reduction utilizing a dual string mill configuration can also be very beneficial in this scenario.

Wellbore geometry is one of many factors that can make the displacement operation challenging. (Reference Figure 3) In this example, a wellbore clean-up string was run into a deviated well that had two liners (7" & 5"), and then 9 5/8" production casing to a subsea stack. The concerns were packer setting areas as well as being unable to circulate debris out of the well. Fluid hydraulics models confirmed inadequate flow without a circulation valve inside the 9 5/8" casing above the 7" liner hanger. By utilizing a casing scraper, filtration tool and string magnet in all three sections, all casing IDs were scraped while RIH (including the critical packer setting areas), and each casing section was filtered and validated while POOH. In many instances brush tools would be located in each casing section to further scour the ID. If a short trip is being performed they would also be spaced out to brush the casing ID repeatedly. The brushes should have a non rotational design similar to the casing scraper and have double crimped steel galvanized bristles engineered to withstand harsh erosive environments. During the displacement, the valve was opened when the brine reached the 9 5/8" annulus, allowing a significant boost in pump rate and annular velocity. The circulating valve used was activated by set down weight rather than a ball drop to avoid the necessity of timing the ball drop to coincide with the spacers and brine displacement. The valve also had a clutch feature that allows drill pipe rotation above the valve but not below while the valve is open. After the main cleanup and displacement trip had been successfully carried out, a short trip into the well was made to clean the BOP and wellhead areas. A filtration tool was spaced out below the wellhead inside of the 9 5/8" casing while the BOPs were jettied in brine and the wear bushing pulled.

The challenges increase significantly when drilling in deep water. The fluid volume in the marine riser alone can be double that of the well casing. A key consideration to effectively manage debris as it enters the riser is hydraulics. While sufficient annular velocities in the lower casing sections may be attainable, when the spacers and brine reach the large ID of the riser, AVs will suffer dramatically and debris will begin to accumulate just above the BOPs. Boosting through the choke and kill lines is a must in this situation, but the AVs still may not be adequate to clean the riser of all debris. Utilizing a brush tool that also incorporates a riser junk bucket just above the BOP will assist in brushing the riser clean as well as capturing any debris that may fall out of suspension during the displacement operation.

Casing		Description
21.000" Marine Riser I.D. 19.750" 0.00 - 131.00 ft		5.000", 19.50# Workstring w/ NC-50 (Box up)
Subsurface BOP I.D. 19.750" 131.00 - 181.00 ft		Pup Joint NC-50 (Box) X NC-50 (Pin)
9.625" Production Casing 53.50 ppf I.D. 9.535" Drift 8.379" 181.00 - 15000.00 ft		String Magnet NC-50 (Box) X NC-50 (Pin)
		Circulating Tool NC-50 (Box) X NC-50 (Pin)
		Pup Joint NC-50 (Box) X NC-50 (Pin)
		Filtration Tool NC-50 (Box) X NC-50 (Pin)
7.000" Production Casing 29.00 ppf I.D. 6.184" Drift 6.059" 15000.00 - 18000.00 ft		Casing Scraper NC-50 (Box) X NC-50 (Pin)
		Crossover NC-50 (Box) X NC-38 (Pin) 3.500", 13.30# Workstring w/ NC-38 (Box up)
		Pup Joint NC-38 (Box) X NC-38 (Pin)
		String Magnet NC-38 (Box) X NC-38 (Pin)
5.000" Production Liner 18.00 ppf I.D. 4.276" Drift 4.151" 18000.00 - 21000.00 ft	Filtration Tool NC-38 (Box) X NC-38 (Pin)	
	Casing Scraper NC-38 (Box) X NC-38 (Pin)	
	Crossover NC-38 (Box) X WT-23 (Pin) 2.875", 10.40# Workstring w/ WT-23 (Box up)	
	Pup Joint WT-23 (Box) X WT-23 (Pin)	
	Crossover WT-23 (Box) X 2 7/8" HT PAC (Pin)	
	String Magnet 2 7/8" HT PAC (Box) X 2 7/8" HT PAC (Pin)	
	Filtration Tool 2 7/8" HT PAC (Box) X 2 7/8" HT PAC (Pin)	
	Casing Scraper 2 7/8" HT PAC (Box) X 2 7/8" HT PAC (Pin)	
	Crossover 2 7/8" HT PAC (Box) X WT-23 (Pin)	
	Pup Joint WT-23 (Box) X WT-23 (Pin)	
	Crossover WT-23 (Box) X 2 3/8" REG (Box) Cement Mill 2 3/8" REG (Pin)	

Figure 3

Perforating

The typical BHA for post-perforation cleanout consists of a bit, burr mill, high capacity string magnets and a validation tool. (Reference Figure 4)

The burr mill is often times a string mill dressed to the casing drift. A better alternative is a spring loaded mill with direct (360°) contact and engineered specifically for the purpose.

The string magnets scavenge ferrous debris generated by the burr mill as well as perforation gun debris. Shot size and the total number of shots dictate the number of string magnets to run. Dog leg severity and rotating hours should also be considered, since both contribute to ferrous debris in cased holes. Besides increasing the likelihood of a successful completion, removing gun debris can actually improve the well’s productivity while reducing the risk of plugging and bridging downstream.

The validation tool serves several functions. If the well takes fluid while milling across the perforations, it may be necessary to reduce the pump rate or stop pumping all together. Even with good AVs, the combination of well geometry and completion fluid rheology can make circulating out high density debris difficult. In addition, polymer sweeps are not usually advised across open perforations. A validation tool with a diverter cup will trap residual gun debris while POOH and filter out any debris larger than 0.025” in the fluid that would otherwise be left behind. A ball drop ported sub is usually run above the validation tool to be utilized as a drain sub and opened just prior to POOH to reduce the risk of swabbing, particularly if the validation tool fills up with debris.

The recommended procedure is to trip in to a depth 30’ above the uppermost perforation. Once on the zone, the pumps are brought up to a rate that calculates to less than 100 ft/minute of annular velocity while rotating at 60 RPM. The drill string is slacked off at 10 ft/minute for 30’, then back reamed and re-reamed downward again. The process is repeated in 30’ increments until the burr mill is below the bottom most perforation. While circulating is preferable, this procedure has been done without circulation and the string magnets still had excellent recovery.

Packer plug retrieval

Managing debris while retrieving a packer plug can be a challenging task as solids may have aggregated on top of plugs for days, months or even years. In other instances, sand may have been spotted on the plug to protect it while perforating operations were performed above, adding gun debris as well. Retrieval of the packer plug requires very specific clean out tools. Depending on the zone, the possibility of fluid losses and the type of fluid in the hole, circulating the conventional way to get down and latch onto the plug may not be desirable. Historically, the tool of choice for debris removal in this operation has been a hydrostatic bailer. However, recent improvements in Venturi pump/chamber combinations have proven them to be a simpler yet successful alternative.

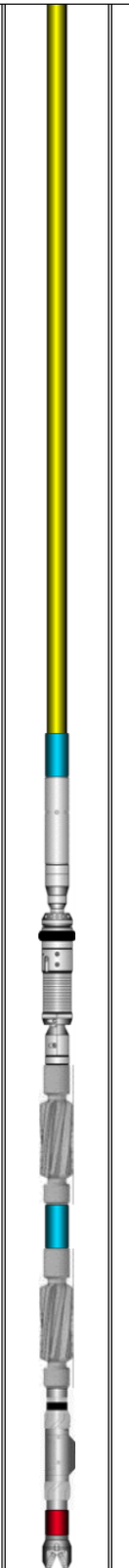
Casing		Description
7.000" Production Casing 29.00 ppf I.D. 6.184" Drift 6.059" 0.00 - 18000.00 ft		3.500", 13.30# Workstring w/ NC-38 (Box up)
		Pup Joint NC-38 (Box) X NC-38 (Pin)
		Drain Sub NC-38 (Box) X NC-38 (Pin)
		Validation Tool NC-38 (Box) X NC-38 (Pin)
		String Magnet NC-38 (Box) X NC-38 (Pin)
		Pup Joint NC-38 (Box) X NC-38 (Pin)
		String Magnet NC-38 (Box) X NC-38 (Pin)
		Burr Mill NC-38 (Box) X NC-38 (Pin)
		Crossover NC-38 (Box) X 3 1/2" REG (Box)
		Drill Bit 3 1/2" REG (Pin)

Figure 4

By utilizing a tool with a Venturi pump that creates a reverse circulation flow downhole, the debris can be circulated up through an internal flow path and captured in tool chambers. The efficiency of the Venturi pump should allow minimal pump rates to create optimum downhole suction. By keeping rates/pressures low, this will alleviate possible fluid loss and/or formation damage. If larger chunks of debris are anticipated, a finger basket is advisable to place in the BHA.

To configure a Venturi tool for a specific application, a good deal of information is required. The type, size, volume and density of debris will yield the amount of capacity needed and whether a basket may be beneficial. The depth of the debris, wellbore geometry, deviation, workstring configuration and fluid properties are all important in specific BHA design.

Clean out and retrieval of the packer plug in one run is the goal here. (Reference Figure 5) A typical BHA above the packer plug retrieval tool would be: the debris capture chambers, a screen module to prevent certain sizes of solids from passing and the Venturi engine module. Placing a circulating valve, filtration tool and string magnet above would be suggested. Features to look for in a Venturi reverse circulation tool include: an efficient engine that generates good reverse flow through the bottom of the tool with minimal pump rates, a large debris capacity, a screen module that filters the fluid and an internal magnet assembly to capture any ferrous debris in an organized manner.

Actually capturing and containing the debris without using high circulation rates in brines or fluids with low carrying capacity is the key. Containment once the tools are pulled out of the hole is also critical depending on the fluid in the well. A chamber system designed to be handled on the deck with 100% fluid and debris containment allows the fluid to be safely drained in a controlled manner and debris emptied to verify content and amount. The circulating valve would be opened after the plug is latched and allow conventional circulation as well as increasing annular velocities to insure any remaining solids are cleaned out of the hole. The filtration tool would provide a generous bypass while RIH, employ a wiping rubber slightly larger than the casing ID to insure all fluid is diverted through the tool while POOH and include a robust filtering screen to capture any larger solids that may have been circulated up the hole. A high capacity string magnet would capture any residual ferrous debris.

Casing		Description
21.000" Marine Riser I.D. 19.750" 0.00 - 4000.00 ft		5.000", 19.50# Workstring w/ NC-50 (Box up)
Subsurface BOP I.D. 19.750" 4000.00 - 4065.00 ft		Pup Joint NC-50 (Box) X NC-50 (Pin)
9.625" Production Casing 53.50 ppf I.D. 8.535" Drift 8.379" 4065.00 - 15000.00 ft		Jetting Tool NC-50 (Box) X NC-50 (Pin)
		5.000", 19.50# Workstring w/ NC-50 (Box up)
		Pup Joint NC-50 (Box) X NC-50 (Pin)
		Filtration Tool NC-50 (Box) X NC-50 (Pin)
		Crossover NC-50 (Box) X NC-38 (Pin)
		3.500", 13.30# Workstring w/ NC-38 (Box up)
		Pup Joint NC-38 (Box) X NC-38 (Pin)
		String Magnet NC-38 (Box) X NC-38 (Pin)
7.000" Production Casing 29.00 ppf I.D. 6.184" Drift 6.059" 15000.00 - 18000.00 ft	Pup Joint NC-38 (Box) X NC-38 (Pin)	
Circulating Valve NC-38 (Box) X NC-38 (Pin)		
Filtration Tool NC-38 (Box) X NC-38 (Pin)		
Pup Joint NC-38 (Box) X NC-38 (Pin)		
Venturi Engine Module NC-38 (Box) X 5" Hydril 521 (Pin)		
Debris Chamber 5" Hydril 521 (Box) X 5" Hydril 521 (Pin)		
Debris Chamber 5" Hydril 521 (Box) X 5" Hydril 521 (Pin)		
Bottom Sub 5" Hydril 521 (Box) X 2.78" HT PAC (Pin)		
Crossover 2.78" HT PAC (Box) X NC-38 (Pin)		
Pup Joint NC-38 (Box) X NC-38 (Pin)		
String Magnet NC-38 (Box) X NC-38 (Pin)		
Plug Retrieval Tool NC-38 (Box)		

Figure 5

BOP Jetting

Keeping the blow out preventer stack free of debris is a maintenance operation fully embraced by companies utilizing sub-sea stacks. (Reference Figure 6)

When it comes to conventional stacks, however, the response is mixed. Many companies still drain their stack and wash through the rotary with a pressure washer or use a “poor boy” jetting sub built from a joint of drill pipe with the pin end capped off and a few holes burned in the tube. Like the previously discussed operations, proper BOP jetting requires an engineered approach. Ported subs, built for purpose, take into account the exit velocity at the ports and the distance between the ports and the BOP cavities. Other factors to consider include reciprocation and rotation speeds and the fluid used for jetting. Another important step is functioning the pipe rams and annular after making three or four passes, followed by three or four more passes. This is a good example of the old saying, “any job worth doing is worth doing right.” Considering the safety aspect of properly functioning BOPs and the potential for considerable NPT if they are not well maintained, proper BOP jetting should be spelled out in every well program in the appropriate places.

If BOP jetting is being done after the well has been displaced to brine, a debris catcher should be positioned below the well head to capture any debris that did not circulate out. The jetting process should start at the well head (with the wear bushing pulled, if possible), and slowly work up to the top of the annular.

A carefully planned BOP cleaning operation can reduce or eliminate the need to pull / inspect the BOP after certain operations saving valuable operational time. A “quickie” cleaning can cause damage to rubber BOP components, resulting in unnecessary NPT as well as possible well control issues.

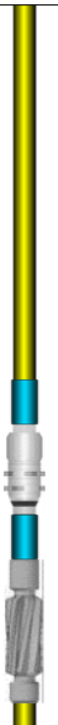



Casing		Description
21.000" Marine Riser I.D. 19.750" 0.00 - 4000.00 ft		5.000", 19.50# Workstring w/ NC-50 (Box up) Pup Joint NC-50 (Box) X NC-50 (Pin) Riser Tool w/ Junk Bucket NC-50 (Box) X NC-50 (Pin) Pup Joint NC-50 (Box) X NC-50 (Pin) String Magnet NC-50 (Box) X NC-50 (Pin) 5.000", 19.50# Workstring w/ NC-50 (Box up)
Subsurface BOP I.D. 19.750" 4000.00 - 4065.00 ft		Pup Joint NC-50 (Box) X NC-50 (Pin) Jetting Tool NC-50 (Box) X NC-50 (Pin)
9.625" Production Casing 53.50 ppf I.D. 8.535" Drift 8.379" 4065.00 - 15000.00 ft		5.000", 19.50# Workstring w/ NC-50 (Box up) Pup Joint NC-50 (Box) X NC-50 (Pin) String Magnet NC-50 (Box) X NC-50 (Pin) Debris Catcher NC-50 (Box)
7.000" Production Casing 29.00 ppf I.D. 6.184" Drift 6.059" 15000.00 - 18000.00 ft		Debris Catcher NC-50 (Box)

Figure 6

Conclusions

By analyzing specific operations requiring mechanical debris management, it is clear that certain elements are required to optimize a well engineered solution. The following points describe key features for efficient WBCO tools:

- Casing scrapers should be non-rotational (i.e., the actual scraper element and stabilizers should rotate independently of the drill string). This minimizes casing wear and reduces torque and drag, particularly through deviated sections. In some instances, casing scrapers should also employ mill rings dressed with carbide cutting material to more effectively break up and circulate debris past the tool.
- Brushes should have double crimped steel galvanized bristles engineered to withstand harsh corrosive environments. Using the same non-rotational design as a casing scraper minimizes brush wear and maximizes the effectiveness of the tool.
- String magnets should be equipped with strong magnetic inserts specifically designed for the tool and encased in stainless steel. The magnetic inserts should be fixed into precisely engineered ribs to greatly increase the string magnet's surface area and allow the debris to bridge, thereby enhancing recovery. The tool should also be designed to remain well centralized in the casing to prevent the debris from being dislodged downhole, and it should also have a soft steel stabilizer that minimizes casing wear while rotating. In short, a string magnet should remove ferrous debris, not add to it.
- Circulating valves should be selected to create optimum performance based on the operation. In a displacement, for example, it is best to have a valve activated by set down weight to avoid the necessity of timing a ball drop to coincide with the spacers and brine displacement. A valve chosen for spotting LCM pills should permit multiple open/close cycles, wireline and ball drop accessibility, generous TFA, and the ability to isolate the lower BHA. A valve specifically designed for jetting should be utilized to clean BOPs.
- The validation tool should provide a generous bypass while RIH, employ a wiping rubber slightly larger than the casing ID to insure all fluid is diverted through the tool while POOH and include a high strength filtering screen to capture any larger solids that may have been circulated up the hole. Validation is confirmed when the tool is pulled from the hole with little or no debris. If significant debris

is present in the tool, the procedure should be examined before the next operation.

- Features to look for in a Venturi tool include: an efficient engine that generates good flow through the tool with minimal pump rates, a large debris capacity, a screen module that filters the fluid and an internal magnet assembly to capture any ferrous debris in an organized manner. Actually capturing and containing the debris without using high circulation rates in brines or other fluids with low carrying capacity is the key. Containment once the tool is pulled out of the hole is also critical depending on the fluid in the well. A chamber system designed to be handled on the deck with 100% fluid and debris containment allows the fluid to be safely drained in a controlled manner and debris emptied to verify content and amount.

By combining mechanical wellbore clean out tools employing the key features outlined above with proper placement and procedures based on "Best Practices," optimum results should be obtained. The completion and production of the well will more likely be done on time and without incident. Formation damage due to debris will be minimized and production goals more likely attained.

Acknowledgments

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Nomenclature

AV = Annular Velocity
BHA = Bottomhole Assembly
BOP = Blow Out Preventer
DLS = Dog Leg Severity
FIT = Formation Integrity Test
ID = Inside Diameter
LCM = Lost Circulation Material
NPT = Non Productive Time
OD = Outside Diameter
POOH = Pulling Out Of Hole
RIH = Running In Hole
RPM = Revolutions per Minute
TFA = Total Flow Area
WBCO = Wellbore Clean Out