

Specialized Tools for Wellbore Debris Recovery

In the late 1700s, Giovanni Battista Venturi, an Italian physicist, described a reduction in pressure when fluid flows through a restriction. Now, engineers are using this principle to design specialized wellbore cleaning systems capable of performing critical debris recovery operations in some of the world's most challenging subsurface environments.

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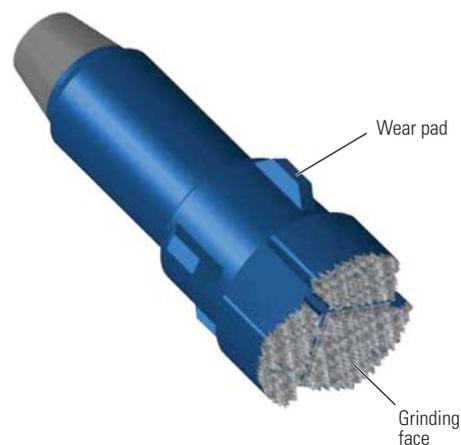
1. Milling is the process of using a downhole tool to cut, grind and remove material from equipment or tools in the wellbore. Successful milling operations require selection of milling tools, fluids and techniques that are compatible with the fish materials and wellbore conditions.
2. Connell P and Haughton DB: "Removal of Debris from Deepwater Wellbores Using Vectorsed Annulus Cleaning Systems Reduces Problems and Saves Rig Time," paper SPE 96440, presented at the SPE Annual Technical Conference and Exhibition, Dallas, October 9–12, 2005.

Debris removal is a vital step in assuring the success of drilling or completion operations. Debris removal involves the extraction of "junk" and unwanted materials from a borehole or completed wellbore. Junk typically consists of small pieces of downhole tools, bit cones, hand tools, wireline, chain, metal cuttings from milling operations and an array of other debris. Although not generally considered junk, sand and other materials used during completion, stimulation and production operations often require removal from the wellbore prior to production.

Because there are many types of debris, engineers have developed a variety of tools and techniques to facilitate debris removal from a wellbore. This article focuses on the postdrilling phase of well construction and issues related to ridding the borehole of relatively small fragments of debris such as metal cuttings, perforating gun debris, small hardware and sand. The article begins with a discussion on the sources of small debris and then reviews various techniques available to remove these materials from the wellbore. Case studies demonstrate how operators are applying these new technologies in a variety of completion environments to reduce risks, minimize downtime and improve well productivity.

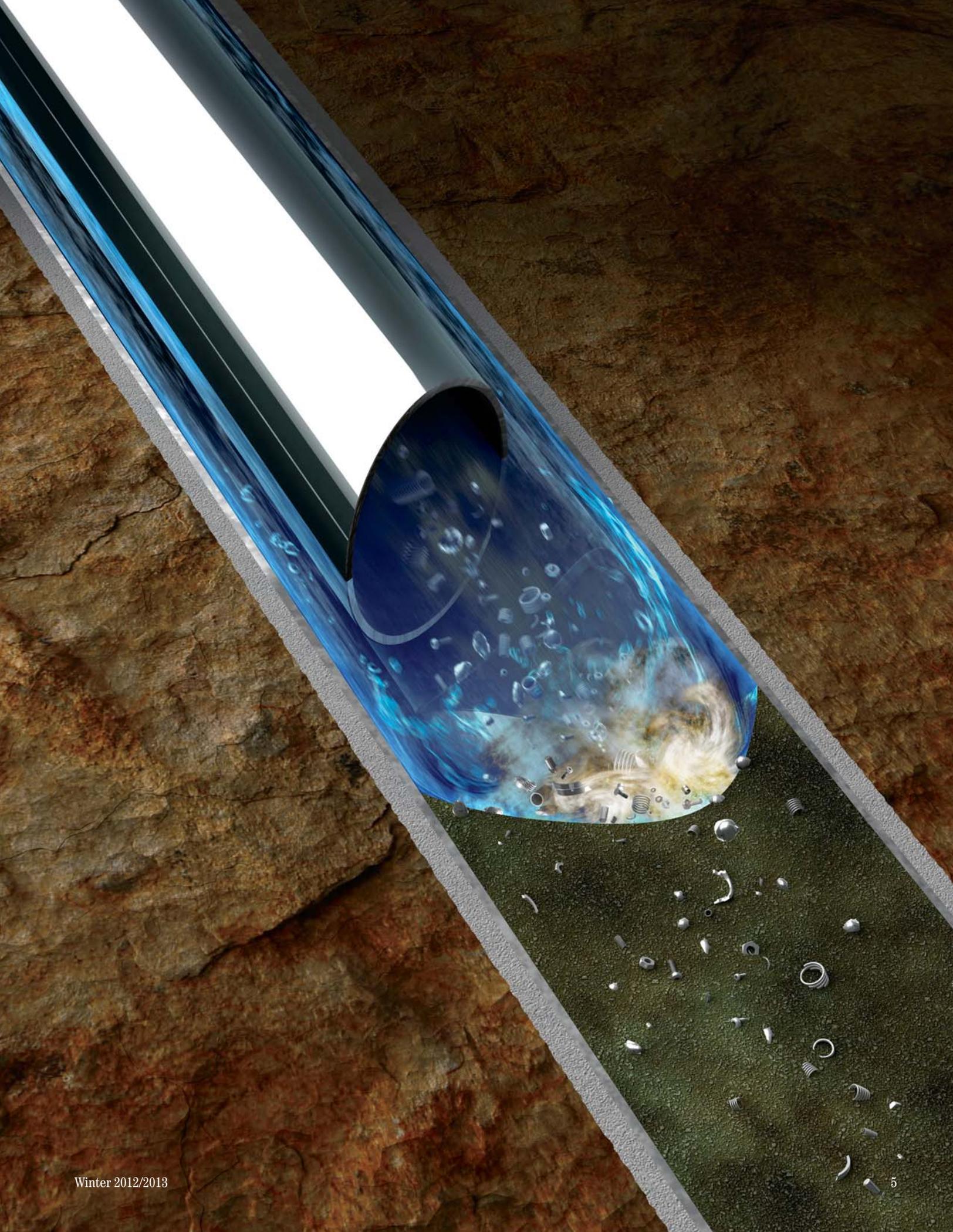
Sources of Small Debris

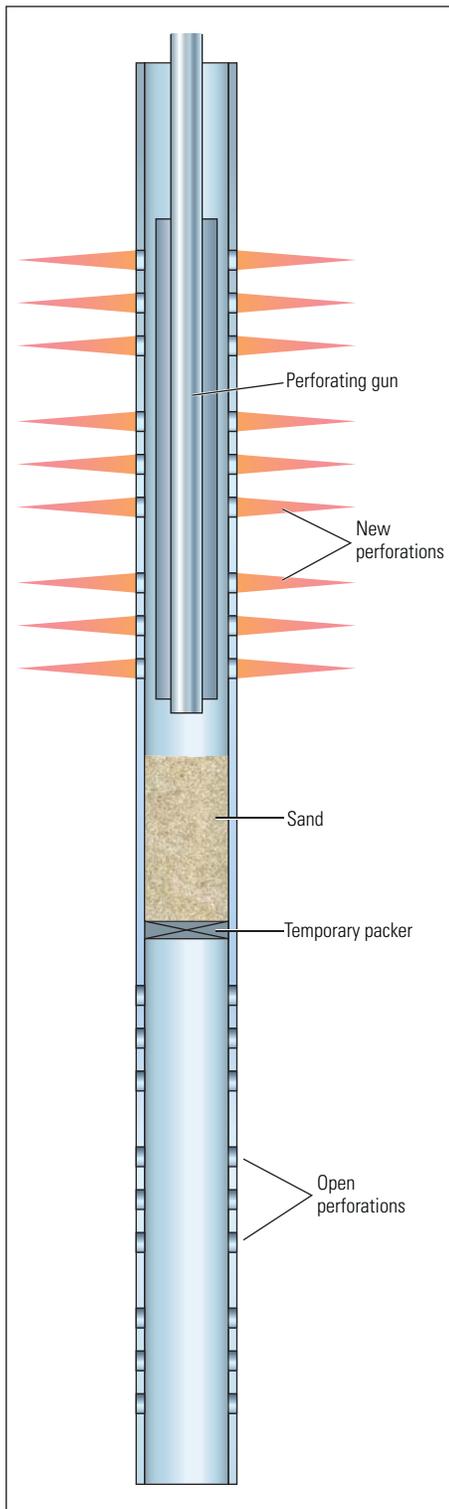
The drill floor is a busy place, providing numerous opportunities for small items to inadvertently fall into an open hole. In deepwater operations, the surface opening at the riser pipe may have a diameter of 1 m [3 ft], creating opportunities for larger items to fall to the depths.



^ Typical junk mill. Junk mills are designed to grind any type of material encountered downhole, including bit cones, drillpipe, bridge plugs or other objects. Wear pads provide stabilization while the mill is grinding. Drillers deploy a variety of grinding faces or tool configurations, depending on the type of material to be milled.

Debris is also generated downhole by various well operations. Often, drillers must mill hardware such as packers, liner tops and equipment within the wellbore (above).¹ Metal cuttings from these operations are among the most common type of debris found downhole. Circulation of drilling, milling or completion fluid transports much of the metal debris to the surface. However, some metal cuttings may still be left in the hole, frequently in locations that cause problems during the completion or production process.²





^ Protecting open perforations. To isolate open perforations, which may be damaged by debris from ongoing well operations in zones above the perforations, drillers place sand on top of a temporary packer. After operations in the upper zone are completed, the sand and debris from uphole are removed from the top of the packer; the packer is then released and retrieved from the wellbore.

During well completion, cased wells may be perforated using an array of specialized explosive charges mounted on perforating guns. When perforating guns are fired, shaped charges pierce the casing, cement sheath and formation. A shot density of 33 shots/m [10 shots/ft] across a producing zone may create hundreds of perforation tunnels; this perforation process generates a considerable amount of metal and formation debris that needs to be cleared from the wellbore.

Historically, fragments from explosive charges, the casing, the cement and the formation were left in perforation tunnels, which may cause a reduction in production efficiency. Postperforation analysis often showed that many perforation tunnels were plugged and nonproductive. Developments in perforating technology, such as the PURE perforating system for clean perforations, in conjunction with shaped charges that generate minimal debris, allow engineers to reduce this type of perforation tunnel damage.³ Although less debris remains in the perforation tunnels using these techniques, more debris may be deposited in the wellbore, potentially fouling latching mechanisms on retrievable bridge plugs or impeding the performance of completion hardware.

Certain materials are sometimes deliberately introduced into the wellbore, only to be removed during subsequent cleanout operations. Stimulation operations typically use sand to cover the top of temporary packers and open perforations to protect them from damage while drillers work in other locations within the wellbore (left). Once these operations are complete, the sand must be removed before production can commence. Other stimulation activities, such as those used in conjunction with the FRAC-N-PAC proppant exclusion system, intentionally place sand and synthetic proppant in the wellbore to aid production.⁴ In all cases, excess sand and proppant must be removed prior to producing a well.

Regardless of precautions taken to keep a wellbore and associated production equipment free of debris, unwanted materials often find their way to problematic locations and increase the risk of damaging completion equipment, reducing production efficiency and jeopardizing the long-term viability of a well.⁵

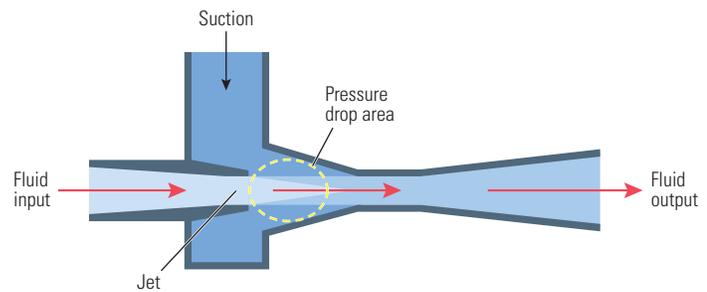
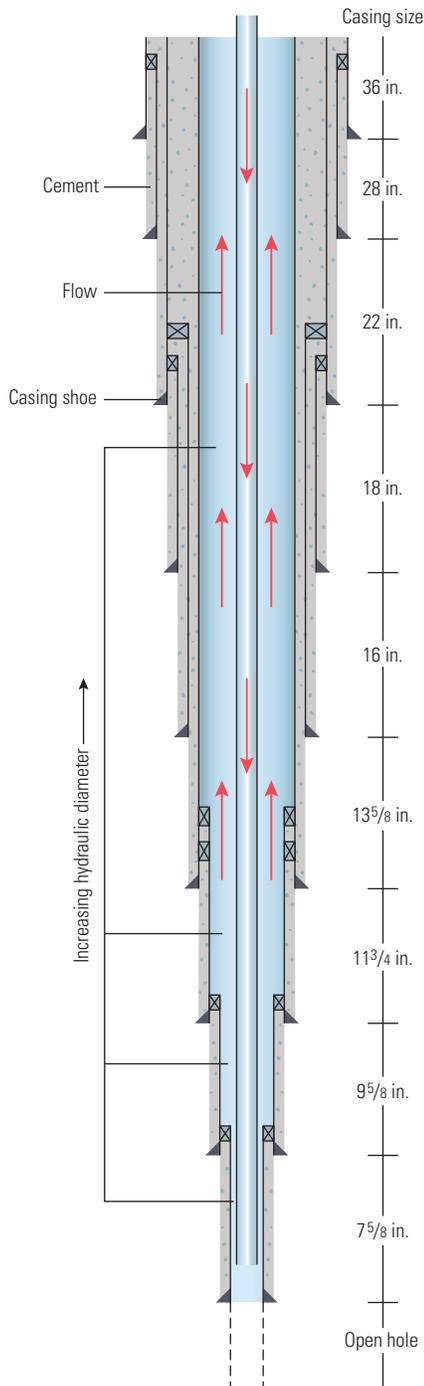
Complexity of Design

Oil and gas wells are becoming more complex and expensive to construct. To drill wells characterized by remote locations, deepwater settings or great drilling depths, operational spread rates often reach US\$ 1 million per day. In the face of such increasing complexities and to hold costs down, operators must make critical drilling and completion decisions. Risk analysis costs, as a result, are now considered on a per minute basis, rather than per day.

With wellbore geometries and completion designs becoming increasingly sophisticated, engineers recognize that risk management, improved efficiency and optimized production may require removal of debris that might have once been considered inconsequential. Even small amounts of debris have the potential to limit production and cause completion failure. Junk and small debris may create difficulties when operators run long and complex completion assemblies in deep and deviated wellbores. In advanced completion designs—such as those with production sleeves that selectively isolate producing intervals—small debris, including metal fragments and sand, may plug or otherwise render production sleeves difficult to access or operate.

Wells with tortuous trajectories are hard to clean using conventional methods. Determining optimal circulation rates is difficult when engineers must consider varying deviation, equivalent circulating density (ECD) limitations, telescoping casing sizes and pump capacity limitations (next page, top left). Even modest circulation rates, in combination with viscous fluids, risk lost circulation from elevated ECDs. These complex well environments demand new approaches.

3. Bersås K, Stenhaug M, Doornbosch F, Langseth B, Fimreite H and Parrott B: "Perforations on Target," *Oilfield Review* 16, no. 1 (Spring 2004): 28–37.
4. Gadiyar B, Meese C, Stimatz G, Morales H, Piedras J, Profinet J and Watson G: "Optimizing Frac Packs," *Oilfield Review* 16, no. 3 (Autumn 2004): 18–29.
5. Haughton DB and Connell P: "Reliable and Effective Downhole Cleaning System for Debris and Junk Removal," paper SPE 101727, presented at the SPE Asia Pacific Oil and Gas Conference and Exhibition, Adelaide, South Australia, Australia, September 11–13, 2006.
6. Visual Physics, School of Physics, University of Sydney, Australia: "Fluid Flow, Ideal Fluid, Bernoulli's Principle," http://www.physics.usyd.edu.au/teach_res/jp/fluids/flow3.pdf (accessed September 16, 2012).



▲ Venturi effect. As fluid passes through a flow constriction at high velocity, it generates a localized pressure drop, thus creating suction, which can be harnessed to vacuum debris.

◀ Annular flow rate and cleaning capacity. Most wells use consecutive strings of casing, with each subsequent string smaller in diameter than the previous one, creating a telescoping effect. In offshore deepwater wells, multiple strings of casing are required to control subsurface pressure and formation stress. The ability to move debris from the bottom of the hole to the top by circulation alone is a function of the fluid's carrying capacity and is directly affected by the fluid's annular velocity and viscoelastic properties. However, as the fluid moves uphole, its velocity slows with each increase in casing size and effective hydraulic diameter. This places greater demand on the viscosity characteristics of the fluid to carry debris. Compensating for loss of carrying capacity by increasing the viscosity or velocity of the carrier fluid may result in increased equivalent circulating density, which places greater hydraulic force on the formation and may promote lost circulation. Achieving satisfactory carrying capacity uphole while keeping the well within ECD limitations downhole is the driller's challenge. Because of this problem, debris removal by conventional methods can be difficult.

The venturi effect can be described as a jet-induced vacuum. The laws of fluid dynamics described by Venturi and Bernoulli dictate that flow velocity increases with a constriction of the flow path diameter, satisfying the principle of continuity, while a corresponding decrease in pressure occurs, satisfying the principle of conservation of mechanical energy. A concurrent drop in localized static pressure creates a vacuum (above).⁶

Venturi vacuum systems have numerous advantages over conventional mechanical pumps. Conventional mechanical vacuum systems typically have moving parts that can be troublesome: Valves may become stuck, intake filters may become clogged and motors are subject to failure. Venturi pumps, by contrast, have few or no moving parts and thus require little maintenance.

Debris from the Deep

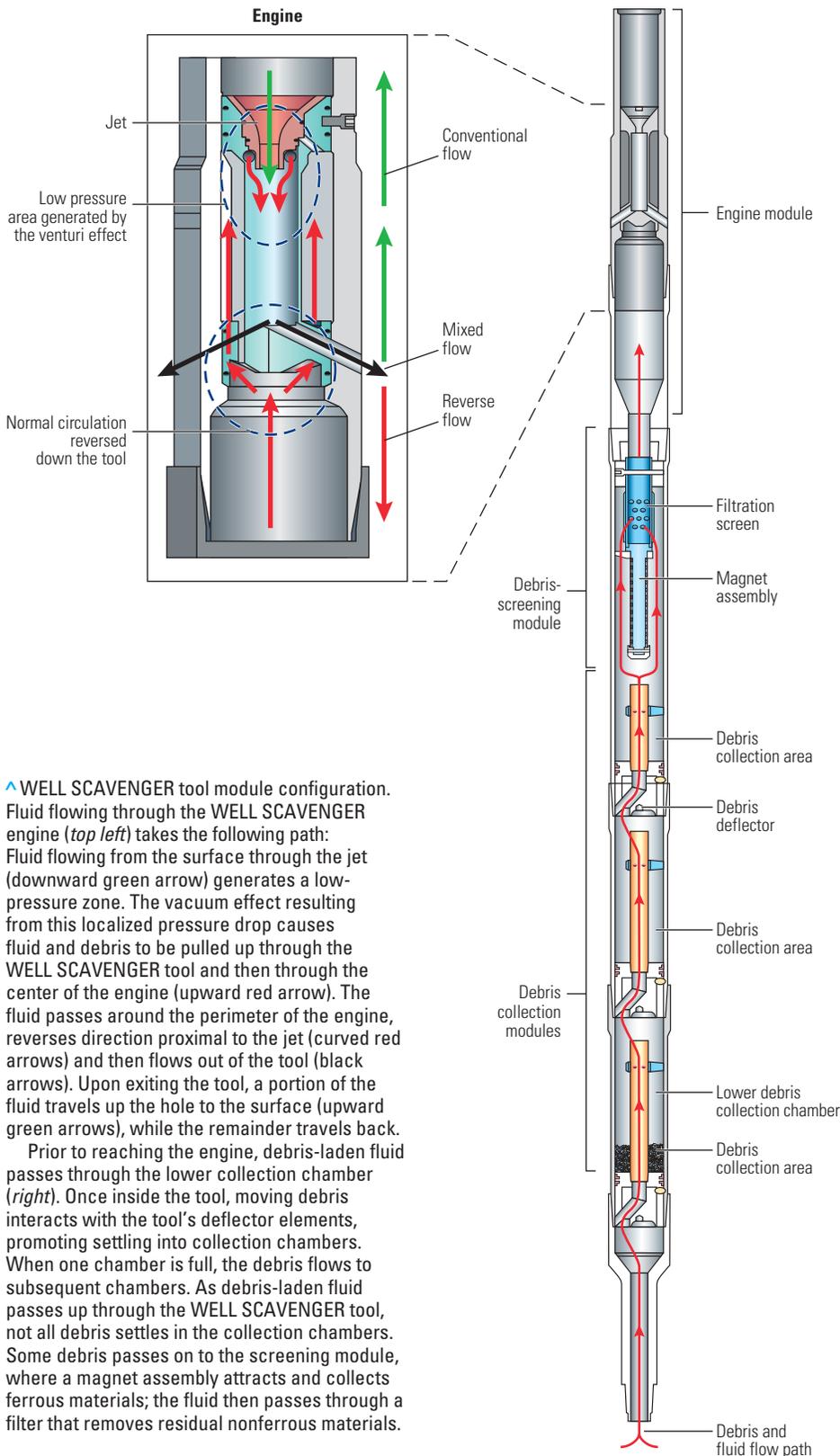
Recently, engineers have used venturi vacuum pumps to remove debris from difficult-to-reach and problematic areas of wellbores. Multiple designs have been developed, each with unique features to meet an array of operational requirements. Several service companies, including M-I SWACO, a Schlumberger company, offer downhole debris recovery tools based on the venturi effect; some are configured to be used on coiled tubing and others to be used on conventional workstrings.

The WELL SCAVENGER tool offers a modular design that provides application flexibility. The upper module contains a single-nozzle fluid-driven engine designed on the venturi principle. Pressure from surface pumps generates an efficient, localized reverse-circulation flow that achieves optimal lifting velocities without high

Old Concept—New Application

One approach to overcoming the risks of high circulation rates—the venturi vacuum—has existed for centuries. In the late 1700s, Giovanni Battista Venturi, an Italian physicist, described the effect that came to be named after him. He and Daniel Bernoulli, a Swiss mathematician who worked in fluid mechanics, are known for discoveries that led to the development of the

venturi vacuum pump. Engineers and developers have used the venturi vacuum pump design in many applications, from fluid mixing systems to health care and home maintenance equipment such as the common garden hose sprayer. Today, engineers are applying this fundamental principle—the venturi effect—to design specialized wellbore cleaning systems capable of performing debris removal operations in difficult subsurface environments.



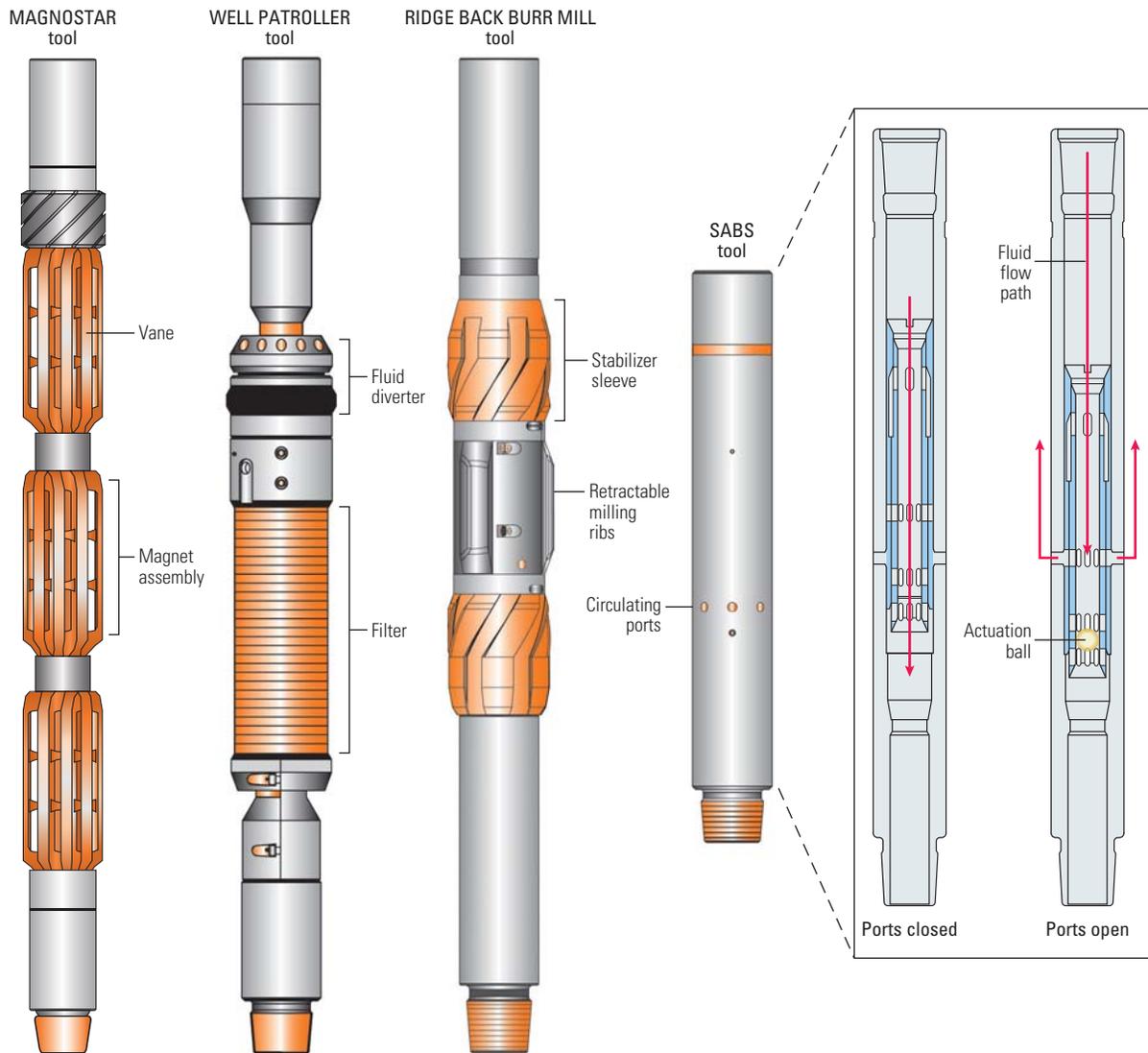
▲ WELL SCAVENGER tool module configuration. Fluid flowing through the WELL SCAVENGER engine (top left) takes the following path: Fluid flowing from the surface through the jet (downward green arrow) generates a low-pressure zone. The vacuum effect resulting from this localized pressure drop causes fluid and debris to be pulled up through the WELL SCAVENGER tool and then through the center of the engine (upward red arrow). The fluid passes around the perimeter of the engine, reverses direction proximal to the jet (curved red arrows) and then flows out of the tool (black arrows). Upon exiting the tool, a portion of the fluid travels up the hole to the surface (upward green arrows), while the remainder travels back. Prior to reaching the engine, debris-laden fluid passes through the lower collection chamber (right). Once inside the tool, moving debris interacts with the tool's deflector elements, promoting settling into collection chambers. When one chamber is full, the debris flows to subsequent chambers. As debris-laden fluid passes up through the WELL SCAVENGER tool, not all debris settles in the collection chambers. Some debris passes on to the screening module, where a magnet assembly attracts and collects ferrous materials; the fluid then passes through a filter that removes residual nonferrous materials.

pump rates. This reverse flow causes debris to flow up the inside the lower tubular and into the collection chambers before it reaches the ferrous collection chamber and then flows through the filtration screen (left). The basic three-module system can be augmented with an array of ancillary tools such as the MAGNOSTAR magnet assembly, WELL PATROLLER downhole filter tool, RIDGE BACK BURR MILL device and single action bypass sub (SABS) to expand the scope of work (next page).

Because debris removal tools are often deployed in brine fluids that inherently have limited solids carrying capacity, conventional techniques typically require high circulation rates or viscous carrier fluids to lift debris into capturing baskets or chambers. These measures are not necessary with the WELL SCAVENGER tool. When perforations are open and subject to lost circulation or damage, when pressure sensitive downhole hardware is in place or when surface equipment limitations make it impossible to achieve high pump rates, the newer generation tools, such as the WELL SCAVENGER device, offer engineers a significant advantage. M-I SWACO engineers use proprietary flow regime software to determine the surface pump rate required to recover the expected debris without affecting downhole hardware or open perforations.

Depending on the volume of debris anticipated, engineers configure one or more debris collection modules at the lower end of the workstring. Each module is designed with a debris collection area, a flow diverter and an inner flow tube equipped with an internal centralizer to provide strength and stability. The inner flow tube provides the path for the reverse flow, and the diverter encourages debris to fall out of the fluid and into the collection area as the fluid flows through each chamber.

The screening unit is fitted above the debris collection modules and below the engine. Fluid flows up through the tool, passes over a magnet assembly and then through a filter before exiting the tool. The screen and magnet assemblies are internally centralized for stability in deviated wells. After cleanup, or when the system becomes filled or plugged, the SABS tool can be opened, allowing higher annular circulation rates, which help clean residual debris located above the tool. The WELL SCAVENGER tool is able to remove a wide variety of debris types from wellbores, including milling debris, bit teeth and cones, sand, small hand tools and debris from perforating guns.



▲ Wellbore cleanup tools. The MAGNOSTAR tool is a magnet assembly that collects ferrous debris as the debris stream passes the tool. The vanes on the magnet assembly housing create a flow area for fluid bypass around the tool while providing standoff from the casing wall. The WELL PATROLLER tool is a downhole filter device that runs in the cleanup string. This device helps clean the wellbore when running in the hole. The tool then filters any remaining debris from the annulus through a wire screen filter as the assembly is pulled from the hole. The RIDGE BACK BURR MILL tool is a casing cleanup tool for perforated casing or liners. The tool removes perforation burrs to ensure unrestricted passage of completion equipment downhole. Users have the ability to turn off the RIDGE BACK BURR MILL after the milling and cleaning operation is complete. The driller circulates an actuation ball down to the tool; the ball shifts an internal support sleeve to remove the expanding force on the milling ribs. The single action bypass sub (SABS) allows drillers to boost the flow velocity in a casing string above a liner or casing crossover. The tool is run in the hole with its circulating ports in the closed position (*second from right*). The driller drops an actuation ball to open the circulating ports (*right*). This action redirects and reverses fluid flow from down the toolstring to bypass the string, thus removing flow restrictions, allowing an increase in pump rate and establishing higher annular velocity. To close the ports, the driller drops a second actuation ball.

At the surface, safe handling of the recovery tools loaded with debris is essential, especially when they have been exposed to zinc bromide and other completion fluids characterized by elevated HSE risks. To address these concerns, the WELL SCAVENGER tool modules are fitted with sealed lifting caps designed to contain recovered materials during tool extraction at the surface.

Sand and Gun Debris Removal

Operators typically set temporary bridge plugs above productive zones while performing operations such as reperfing upper zones. In addition, sand or ceramic proppant is typically placed on top of temporary plugs to provide additional protection to upward facing latching mechanisms that release and retrieve the temporary plugs.

In 2011, Eni SpA used QUANTUM gravel-pack BA packer plugs to carry out multizone gravel-pack completion operations in a series of wells in the Adriatic Sea offshore Italy. After the plugs were set, drillers spotted sand on top of each one to protect the plugs from gun and formation debris generated while perforating the zone above. On completion of perforating operations,

Zone	Depth, top	Depth, base	Zone length	Shots
1	1,782 m [5,846 ft]	1,794 m [5,886 ft]	12 m [39 ft]	472
2	1,640 m [5,381 ft]	1,648 m [5,407 ft]	8 m [26 ft]	315
3	1,522 m [4,993 ft]	1,546 m [5,072 ft]	24 m [79 ft]	964
4	1,471 m [4,826 ft]	1,480 m [4,856 ft]	9 m [30 ft]	354

^ Intervals perforated in an Adriatic Sea well.

the WELL SCAVENGER tool was run in the hole and successfully cleaned the sand and the gun debris from the top of each packer.

M-I SWACO engineers in Aberdeen worked with Schlumberger engineers in Ravenna, Italy, to carefully plan each completion. The operator used 1.3 g/cm³ [10.8 lbm/galUS] of calcium chloride [CaCl₂] completion fluid in the wellbore and spotted 20 liters [5.3 galUS] of 2.7-g/cm³ [22.5-lbm/galUS] ceramic proppant on top of each temporary packer prior to perforating shallower zones. The first well, which was vertical, was perforated with 39 shots/m [12 shots/ft] (above).

After each zone was perforated, the driller ran a WELL SCAVENGER tool and washover shoe in the hole to remove excess ceramic proppant and clear the packer retrieval latching mechanism.

On the first run, the top of the debris was located with the WELL SCAVENGER tool; no circulation was initiated, thus allowing the washover shoe to slide over the debris and land on the

packer plug. The sand and debris were successfully removed and the temporary plug retrieved without incident. However, to reduce the risk of the tool becoming stuck in the sand or damaging the packer, engineers chose to initiate circulation approximately 30 m [100 ft] above the anticipated top of the sand pill on future runs.

In each well, after positioning the washover shoe on the packer plug, the driller circulated one and one-half to three annular volumes to assist in overall debris cleanout. The WELL SCAVENGER tool cleared each sand pill in an average of 25 minutes. Based on total nonferrous debris recovery, 16 kg [35 lbm] wet weight, or approximately 65% of the ceramic sand, was pumped through the filter screen and out of the wellbore. Gun debris and larger sand particles were retained in the collection chambers, and ferrous materials were collected on the filter module magnet assembly (below). The crews handled, cleaned, inspected and prepared

debris chambers for rerun in subsequent bottomhole assemblies (BHAs).

Similar operations were conducted on two subsequent wells; the third well was deviated 24°. Using the WELL SCAVENGER tool, drillers successfully removed the sand and the gun debris in all 12 runs, allowing each packer to be retrieved without incident.

Debris in Pressure Sensitive Areas

Accumulations of sand and other small debris on top of packers can make the packers difficult to retrieve. Similarly, these materials can interfere with the operation of other downhole mechanical hardware such as formation isolation valves (FIVs). Because these valves are pressure activated, debris removal techniques must ensure minimal localized pressure changes. The WELL SCAVENGER single-nozzle venturi engine provides debris removal at low circulation rates, thus minimizing pressure changes near an FIV. In a typical FIV cleanup operation, the BHA comprises WELL SCAVENGER system components and one or more complementary wellbore cleanup tools such as the MAGNOSTAR tool and the WELL PATROLLER tool (next page, left).

In 2012, a major international operator in the UK sector of the North Sea planned a targeted cleanup above an FIV. Conventional tools that require high flow rates may cause problems when they clean the area near the FIV. These conditions increase the risk of accidental valve actuation or damage to components of the completion assembly.

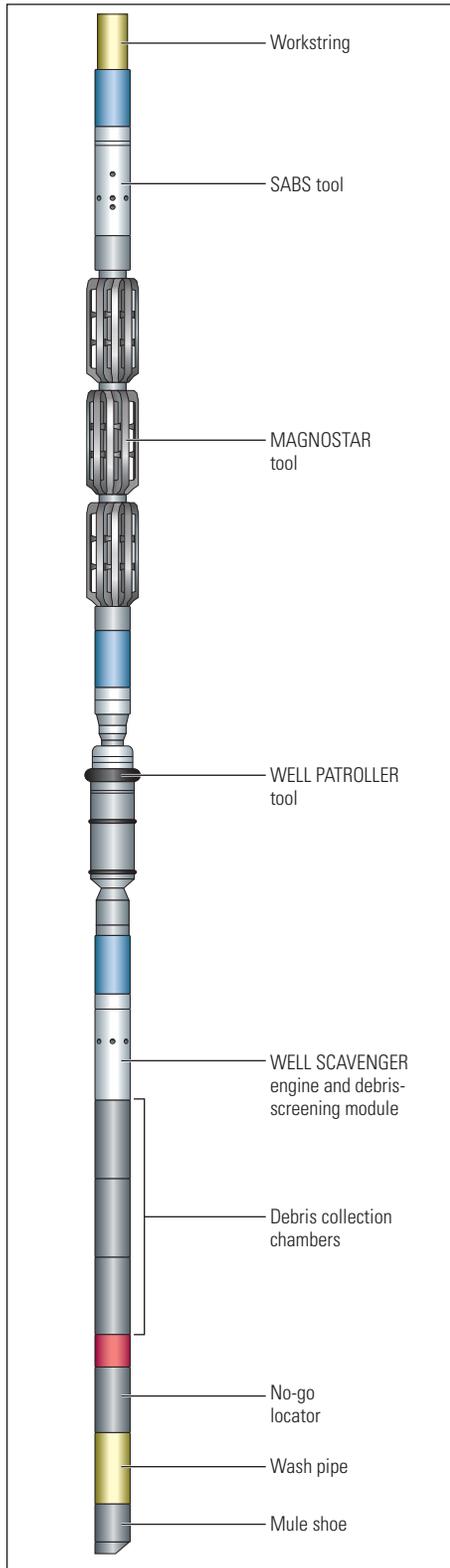
For optimal tool performance, the bullnose on the bottom of the WELL SCAVENGER tool should be placed 0.3 to 1 m [1 to 3 ft] above the FIV actuation ball. In this case, a 7/8-in. landing sub achieved this spacing, thus reducing the risk of damage to the FIV from accidental contact.

In this operation, the WELL SCAVENGER tool was run in the hole until the bullnose was approximately 6 m [20 ft] above the FIV actuation ball. The driller began pumping at a predetermined rate of 4 bbl/min [0.6 m³/min] while slowly running the tool in the hole. When the bullnose was approximately 0.75 m [2.5 ft] above the FIV actuation ball, the engineer increased the pump rates slightly to 6 bbl/min [0.95 m³/min], which ensured optimal cleaning around the FIV ball area without risking damage to the downhole hardware.

After pumping for 30 minutes, the rig crew retrieved the tool to the surface. The debris chambers had collected a total of 11.8 kg [26 lbm] of



^ Collecting wellbore debris in the Adriatic Sea. The WELL SCAVENGER magnet assembly attracts ferrous debris, which has circulated up through the WELL SCAVENGER tool (A). Ceramic debris (B) and perforating gun residue (C) were recovered from the debris collection chambers.



▲ Configuring the WELL SCAVENGER tool for formation isolation valves debris removal. Tools may be configured to clean in sensitive areas near FIVs. In this case, a WELL PATROLLER tool, MAGNOSTAR magnet assembly and SABS tool were run above the WELL SCAVENGER tool to ensure debris removal from the wellbore. A no-go locator limits downward movement of the workstring into the completion assembly.

assorted nonferrous debris consisting mainly of sand and small pieces of rubber. Crews recovered an additional 0.91 kg [2 lbm] of ferrous debris from the internal magnet section of the tool.

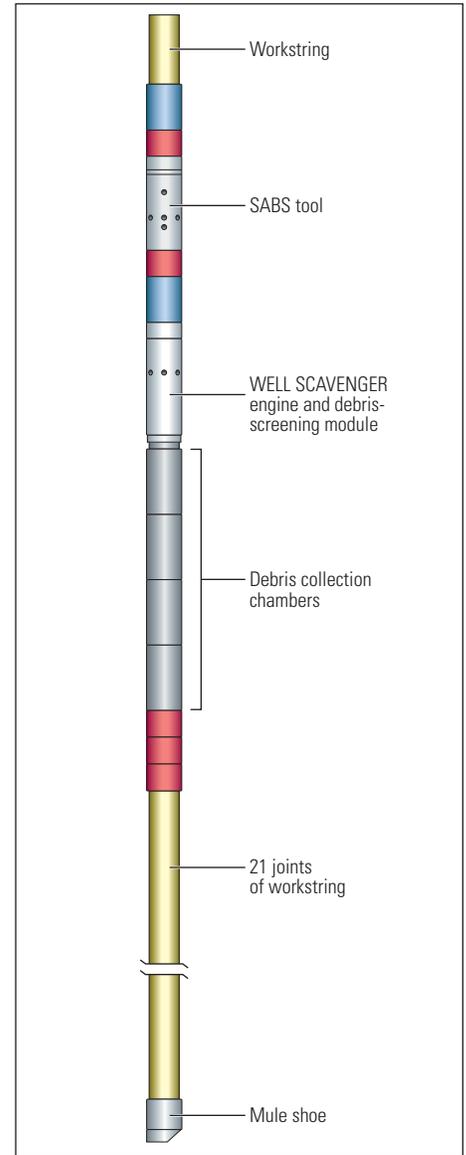
The operator originally intended to operate the FIV within a relatively short period after cleanup. However, the well was temporarily suspended. Although final confirmation of cleanup cannot be verified until the valve is operated, the successful placement of the WELL SCAVENGER tool close to the FIV, combined with the amount of debris recovered, implied a successful operation. The company intends to return to this well in the near future.

Gravel-packed wellbores, particularly those with low reservoir pressure and that are subject to lost circulation, may also be easily damaged by debris removal techniques. Sand and other small debris may accumulate inside the gravel-pack screens and impede production. In recompletion operations, operators often need to remove these materials from the inside of delicate screens to improve production rates.

For completion engineers, the inability to circulate completion brine in low-pressure reservoirs limits debris recovery options. One of the unique features of the WELL SCAVENGER tool is its ability to recover downhole debris at low circulation rates, making it an ideal solution for these difficult applications.

This was precisely the situation in 2012, when an operator working on the North Slope of Alaska, USA, needed to recomplete an openhole gravel-packed well that began experiencing production declines. Engineers theorized that sand building up inside the gravel pack screens was choking off production. But when the well was reentered, low reservoir pressures resulted in loss of returns as workover crews attempted to circulate with 1.02-g/cm³ [8.5-lbm/galUS] filtered water. Engineers at M-I SWACO recommended cleaning the 9½-in. casing to the top of the gravel-pack assembly at around 4,300 ft [1,300 m] and then running the WELL SCAVENGER assembly into the openhole gravel-pack assembly to clean out debris to a total depth of approximately 5,000 ft [1,500 m].

To protect the openhole gravel pack while cleaning and logging the upper 9½-in. casing, a temporary packer was placed just above the lower completion assembly. Next, 1,000 lbm [454 kg] of sand was placed on top of the packer to protect the release mechanism from falling debris during upper casing cleanout. After the casing was cleaned and the well logged, the sand was circulated to the surface and the temporary packer was successfully retrieved.



▲ Cleaning the inside of gravel-pack screens. The WELL SCAVENGER assembly is configured to run inside gravel-pack screen assemblies. Four debris collection chambers and 21 joints of workstring are assembled below the engine; these components are small enough to be inserted inside the gravel-pack screen assembly. In this case, the engine and debris collection chambers sit above the top of the gravel-pack screens during debris removal. After the tool removes the debris, the driller pulls the tool assembly to the liner top and the SABS tool is opened, which allows increased annular circulation rates and ensures that any residual debris in the annular space is removed to the surface.

The M-I SWACO crew ran WELL SCAVENGER tools in the hole at 3 ft/min [1 m/min] while pumping at 4 bbl/min [0.6 m³/min] (above). Surface pump rates were maintained at the low

end of the tool's optimal range, minimizing loss of returns. After the driller circulated down each stand, the pump rates were increased to 7 bbl/min [1.1 m³/min] for five minutes. The tool reached the targeted depth in one run. The workover crew

recovered 14.5 lbm [6.6 kg] of formation sand, rubber and metal debris from the gravel-pack screens (below). Following successful debris recovery from inside the gravel-pack screens, the operator continued well recompletion operations.

Milling Debris Removal

Drillers use milling techniques for various well operations such as cutting windows in casing, smoothing burrs and edges on the top of tools and grinding plugs and packers into small pieces so that they can be circulated out of the wellbore.

In 2010, a major operator working in the Gulf of Mexico planned to remove a cast-iron bridge plug (CIBP) from the wellbore. Before the CIBP could be milled, the operator had to remove 200 ft [60 m] of cement that had been placed on the top of the plug. The driller ran into the hole with an 8½-in. roller cone bit and located the top of the cement at approximately 800 ft [240 m]. During drilling operations, a bit cone was lost in the hole.

The driller pulled the damaged bit from the hole and then ran back in with a mill but was unable to grind up the errant bit cone. To minimize additional lost rig time, the operator sought a solution that could remove the bit cone and mill the CIBP in a single trip. M-I SWACO engineers recommended the WELL SCAVENGER tool with a special BHA to meet the company's objectives in a single trip.

The BHA comprised two pieces: a washover shoe—dressed with a smooth exterior, rough interior and rough leading edge—and a wash pipe extension dressed with two rows of finger baskets. Cable fingers were inserted to help capture the bit cone. The BHA allowed 16.5 ft [5 m] between the bottom of the WELL SCAVENGER tool and the leading edge of the shoe.

The driller tripped into the hole and located the top of the CIBP, broke circulation and began milling the plug. Operating the mill at 80 rpm, the fishing supervisor milled the CIBP in about five hours with 1,000 to 6,000 lbf [4,450 to 26,700 kg] of weight on the tool and 1,000 to 3,000 ft.lbf [1,356 to 4,067 N.m] of torque. When the total interval of 2.0 ft [0.6 m] was milled, the rig crew pulled the BHA to the surface. The tool had collected between 12 and 15 lbm [5.5 and 6.8 N] of metallic debris. Larger items that could not enter the WELL SCAVENGER tool were found inside the cable fingers and below the finger basket. These included the bit cone, cone rings, packer rubber and other CIBP components. Based on the amount of accumulated material, technicians determined that most of the debris had been removed from the wellbore.

Despite the inferior lifting properties of the seawater-base drilling fluid used in the wellbore, the WELL SCAVENGER debris recovery system removed the bit cone and debris associated with milling the CIBP. Drillers successfully tripped into the hole and retrieved the remaining tool elements with no interference from debris or junk, thus avoiding the cost of additional trips.

Recovered Debris



Close-Up View



^ Assorted debris removed from the depths. Drillers sealed the WELL SCAVENGER debris chambers as the tool was removed from a well on the North Slope of Alaska. When opened later at the M-I SWACO facility, the four collection chambers contained various materials, including a mix of formation sand, rubber pieces and ferrous material. A pen, not retrieved from the hole, illustrates relative size.



▲ Recovering ferrous debris. The vanes of the MAGNOSTAR tool are covered with ferrous debris, which has been recovered from the well after milling operations. Debris removed from the tool (*inset*) is laid out for inspection on the drill floor. A ruler, not recovered from the borehole, shows the scale of the debris.

Removing Stuck Packers

Drillers and engineers make every effort to minimize operational risks. Despite these efforts, drillstrings become stuck, completion assemblies fail to reach their objectives and junk winds up in the wellbore. A major operator working on the North Slope of Alaska recently experienced such an event.

While the operator was running a packer in 9 $\frac{1}{2}$ -in. casing, the packer set prematurely at 8,184 ft [2,494 m]. Previously, the operator had set a packer with a stinger assembly attached at approximately 10,100 ft [3,078 m]. Once the stuck packer was drilled out, the wellbore had to be cleaned down to the top of the deeper packer before the driller could resume further recompletion operations.

Debris removal was complicated by the well's 80° deviation from approximately 2,500 ft [762 m] to total depth. After a competitor's boot basket retrieval tool yielded very little debris in two runs, engineers from the M-I SWACO specialized tools group in Alaska and Houston recommended a specially modified BHA combined with the WELL SCAVENGER tool and several high-capacity MAGNOSTAR tools.

The BHA included 90 ft [27 m] of wash pipe, a HEAVY DUTY RAZOR BACK CCT casing scraper, the MAGNOSTAR tools, the WELL SCAVENGER tool and the SABS circulating sub. After the tools reached a depth of 6,200 ft [1,890 m], a large accumulation of debris on the lower side of the wellbore hindered progress. Through continuous circulation and near-constant pipe movement, the driller was able to push the tool assembly to 6,280 ft [1,914 m]. The tools were then pulled from the hole. Once the tools were on the surface, technicians recovered 184 lbm [83 kg] of ferrous debris from the MAGNOSTAR tools (*above*).

While technicians cleaned the MAGNOSTAR tools, the driller ran back into the hole with a competitor's boot basket fishing tool and magnet assembly. When the tool was pulled from the hole, technicians recovered a packer slip and 20 lbm [9 kg] of ferrous debris. A second run of the WELL SCAVENGER assembly included three MAGNOSTAR tools. This run yielded an additional 287 lbm [130 kg] of ferrous debris on the MAGNOSTAR tools and 1,033 lbm [469 kg] of sand and silt along with 168 lbm [76 kg] of ferrous debris recovered from the WELL SCAVENGER tool collection chambers.

A final run made with the three MAGNOSTAR tools yielded an additional 145 lbm [66 kg] of ferrous debris. After clearing most of the debris from the wellbore, the driller was able to run in the hole with a polish mill to clean the lower packer bore. M-I SWACO tools removed a total of 1,817 lbm [824 kg] of ferrous and nonferrous debris from the wellbore.

Rapidly Evolving Tool Development

Complicated completions, complex borehole configurations and high rig-time costs are leading engineers to identify new applications for the WELL SCAVENGER assembly and associated debris removal tools. Because of new debris recovery tools and techniques, drillers are now better able to remove materials intentionally placed downhole or items accidentally lost in the wellbore. Tool combinations are evolving to address a broader array of completion and debris recovery needs. The evolution in debris recovery tool designs is reducing risks, cutting costs and improving well productivity.

Ongoing design work further enhances the range and scope of debris recovery tools used at great depths. Given the increasing cost of rig time, especially in deepwater settings, engineers are focusing on the development of systems that allow debris recovery to be combined with other well operations in a single tool run. For example, field tests have shown that debris recovery and milling tools can be combined with packer retrieval hardware to deburr casing perforations, recover the generated debris and remove a temporary packer all in a single tool run, thus improving operational efficiency and reducing costs. Other developments are underway to help operators recover debris in low-pressure, lost circulation environments, setting the bar for successful completions in increasingly challenging situations. —DW