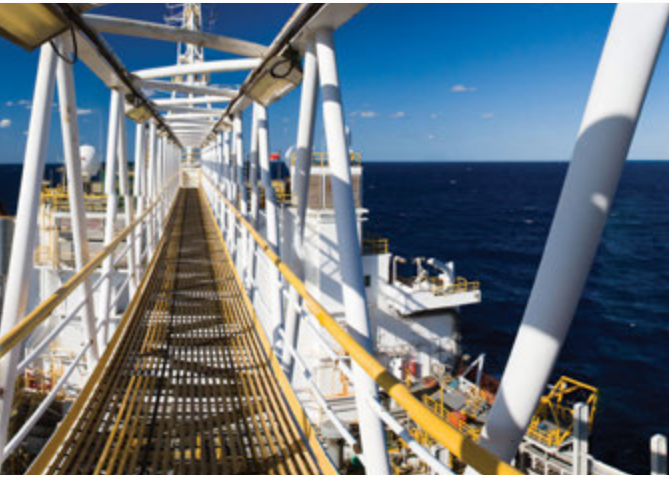


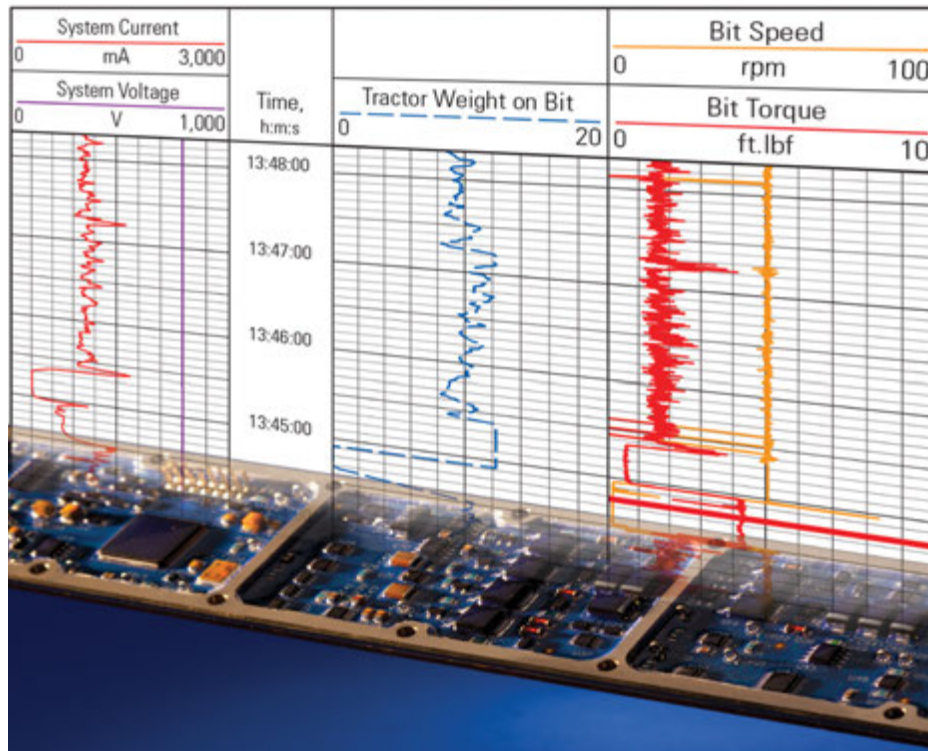
ReSOLVE

Instrumented wireline intervention service

ReSOLVE

A measured response

ReSOLVE instrumented wireline intervention service brings precision to well intervention operations, eliminating the reliance on estimates and assumptions that is usually associated with conventional intervention methods. The bidirectional, high-speed digital telemetry system provides precise control from the surface, resulting in a dynamically controlled modular tool that provides maximum flexibility during intervention operations. Sensors incorporated in the tools of the ReSOLVE service enable the engineer to monitor tool response and the progress of downhole operations while responsively controlling the tool for optimal performance. By combining monitoring and control, ReSOLVE service delivers an intelligent wireline workover solution that greatly increases the success rate of intervention operations.



Sophisticated electronics and sensors in the ReSOLVE service's family of tools enable real-time monitoring, dynamic tool control, and verified downhole actuation to set new standards for success in intervention operations.



ReSOLVE instrumented wireline intervention service integrates real-time monitoring, dynamic tool control, and verified downhole actuation to set new standards for success in intervention operations.

Applications

- Nonexplosive setting of bridge and tubing plugs, packers, casing patches, and cement retainers
- High-force axial shifting
 - opening and closing of isolation valves
 - shifting sliding sleeves
 - pulling retrievable plugs
 - fishing operations
 - replacing gas lift valves
 - safety valve lockout
- Selective shifting with a universal shifting tool (UST)
 - sliding sleeves in multizone completions
 - mechanically opening isolation valves
 - single-run multiple shifting
 - shifting components below restrictions
- Milling
 - removing scale accumulation in well tubulars
 - milling plugs
 - removing tubing restrictions

Features and Benefits

- Dynamic, precisely measured control of all tool functions
- Direct confirmation of operations through real-time downhole measurements
- Automated milling operations using TuffTRAC* cased hole services tractor
- Safer setting operations without explosives
- Deployment by regular wireline crew using standard cables and surface systems
- Lower cost, small-footprint conveyance on wireline or tractor instead of coiled tubing or drillpipe
- Independent control of all actuators for greater flexibility, more intervention options, and increased functionality in fewer runs
- Highly efficient electromechanical design delivering high downhole force, torque, and speed with minimal surface power
- Fully compatible with other Schlumberger cased hole services



The TuffTRAC wireline tractor integrates seamlessly with the tools of the ReSOLVE service to provide unprecedented control of intervention operations.

The engineer has direct control of the intervention, in real time, independently controlling the application of radial and linear forces and rotary torque supplied by the ReSOLVE service tools.

Conveyance

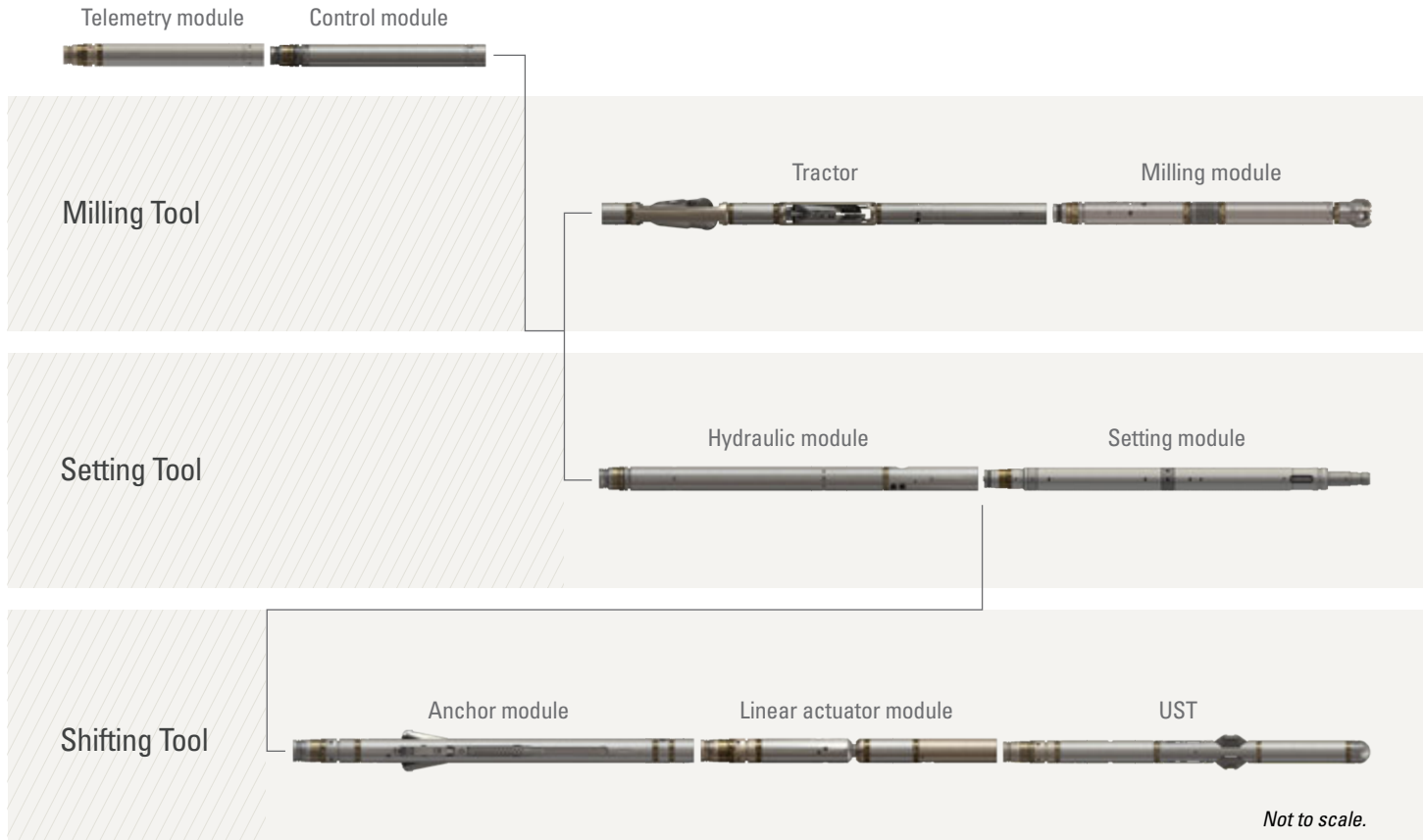
Instrumented ReSOLVE service is conveyed on wireline by gravity or optionally with the TuffTRAC cased hole services tractor or MaxTRAC* downhole wireline tractor system in highly deviated and horizontal wells. The power-efficient design delivers high-level performance on even the slimmest cables that Schlumberger offers, increasing operational flexibility. Reliability of the power system is maximized, and the cable and other components are always operated within their rated limits.

Modular system

Modular ReSOLVE service is readily configured for maximum operational flexibility by adding tools to the basic configuration, which consists of the telemetry and control modules. Four tools are currently available for ReSOLVE service:

- high-force linear actuator tool
- universal shifting tool (UST)
- nonexplosive setting tool
- milling tool.

Modular ReSOLVE Service



Tool sketch showing how the modules of the ReSOLVE service are configured for milling, setting, and shifting operations with optional UST.

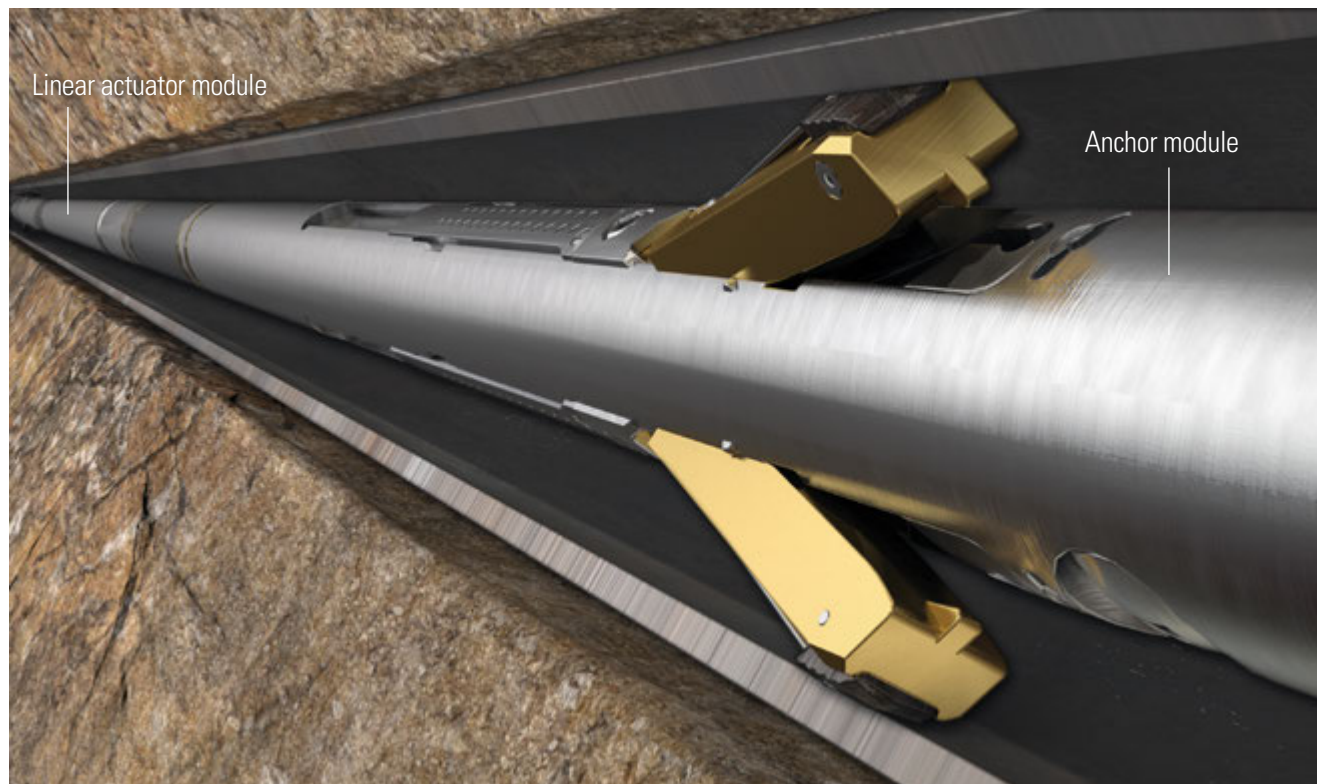
High-force linear actuator tool

The ReSOLVE service's linear actuator tool incorporates anchor and linear actuator modules to apply controlled axial force to a well component. First, the anchor module opens with the industry's largest reach of nearly 2 in [5 cm] diametrically to anchor the tool in the well. A precisely controlled anchoring force of up to 150,000 lbf is applied to maximize traction while minimizing tubing damage thorough the innovatively designed anchors. Once the ReSOLVE service confirms anchoring to the surface, the linear actuator can be extended and retracted multiple times to apply a large, controlled force of up to 45,000 lbf to the specific well component. The linear actuator can extend up to 20 in [51 cm] and delivers continuous measurements of displacement along with the force applied to validate the operation.

The speed, force, and displacement of the anchor and linear actuator are controlled automatically downhole according to parameters set by the operator at the surface, providing unparalleled remote control of the tool. Precise, detailed measurements are reported as movements occur to deliver confirmation that an operation has been successfully completed. This level of monitoring and control stands in stark contrast to conventional methods of performing shifting operations, including slickline jars, coiled tubing, and wireline systems lacking downhole measurement capability, none of which provides precise control or definitive verification of the operation's completion. The linear actuator can be used with either the ReSOLVE service's UST or third-party shifting, pulling, or other interface tools.

In addition to the common measurements of wellbore pressure and temperature and correlation measurements (gamma ray and casing collar locator [CCL]), the following downhole measurements made by the instrumented tools of the ReSOLVE service are relayed on wireline to the surface in real time to constantly monitor the progress of linear actuator operations:

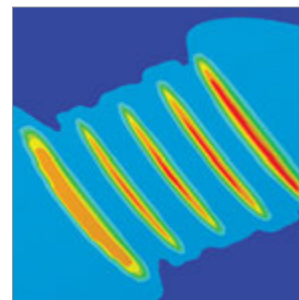
- anchor force
- anchor diameter
- linear actuator force
- linear actuator position.



The linear actuator tool adds a hydraulically powered anchor and linear actuator to the basic ReSOLVE service configuration to deliver measured and controlled axial force (pushing and pulling) for intervention operations.

Low-stress anchor grips

The low-stress anchor grips employed by ReSOLVE service produce very high traction but minimize impact to the tubing when anchoring. The grip design was optimized through the application of extensive computer simulation, with the models validated by extended testing on various grades of tubing alloys. The grips are a key component of the shifting tool's state-of-the-art anchor, which enables the ReSOLVE service to achieve linear forces far higher than previously possible on wireline.



The patented, innovative low-stress anchor grips (left) used by the ReSOLVE service are designed with rounded, shallow, and wide grooves that minimize the imprint effects on tubing (top) while also providing very high traction capability. The effects on tubing were evaluated through finite-element analysis of stress (bottom) to optimize the grip design.



Selective universal shifting tool

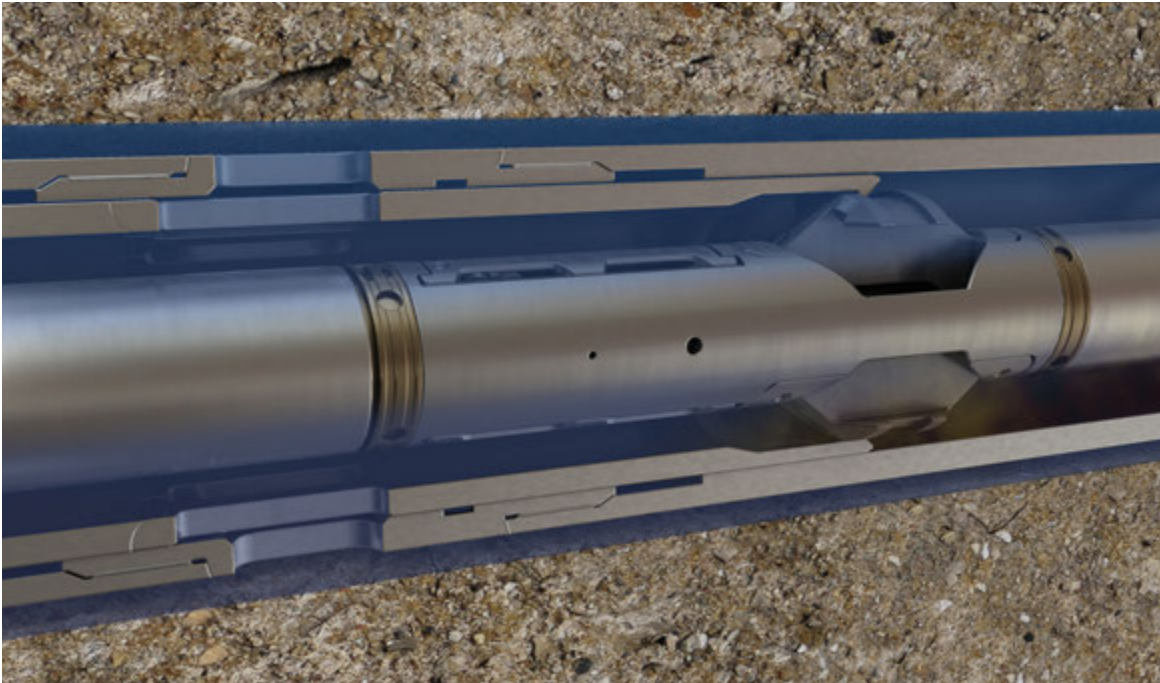
The ReSOLVE service's UST can make multiple shifts in any direction in a single run, whether to a single component or multiple components in multizone completions. The UST is paired with the anchor and linear actuator so that throughout the operation, the forces and displacements are measured to confirm that the expected force and distance were achieved.

To open or close a well component, such as a sliding sleeve, the UST radially extends profile keys to engage the completion component. The keys are extended with a specified preload force but remain compliant to navigate well geometry. The preload force can be precisely controlled for different well conditions and conveyance methods. Once the UST is latched into the profile of the component, the anchor secures the tool in the well, and the linear actuator extends or retracts to shift the component. The keys can fully retract into the UST to enable the tool to pass by ledges and other restrictions in the well.

Running the ReSOLVE service's UST in combination with production logging tools makes it possible to obtain true single-descent diagnosis and resolution of production problems in wells with advanced multizone completions.



The high-expansion UST is shown closed (left) and fully expanded (right). The profile keys are opened by applying a controlled force and remain compliant for the ReSOLVE service to navigate well geometry.



In addition to the measurements made by the linear actuator tool, the UST also measures

- profile key radial force
- profile key extension.

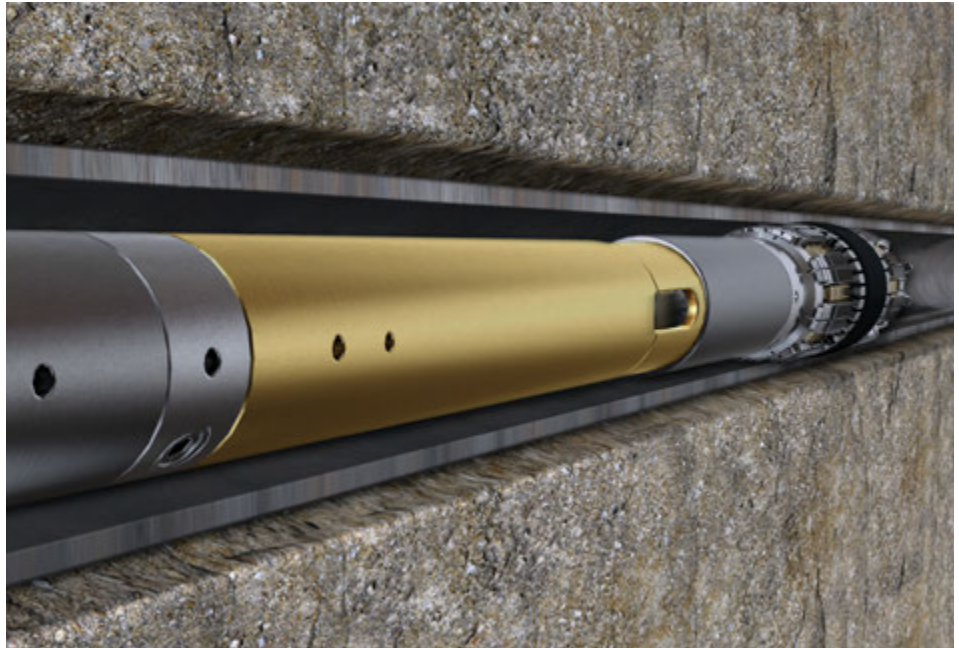
These measurements provide real-time positive confirmation that a device has been shifted.

The UST used with the linear actuator provides multiple shifting capabilities for installed casing hardware in a single run of the ReSOLVE service.

Nonexplosive setting tool

The ReSOLVE service's setting tool is hydraulically powered, providing a large force of up to 78,000 lbf for setting plugs and packers. With real-time reporting of the setting force applied and a variable setting speed, the setting tool is a reliable, low-risk alternative to the conventional use of explosives to set plugs and packers. This capability is a significant advantage for operations in locations where security and safety concerns over the use of explosives can complicate logistics and cause delays.

Unlike conventional explosives-actuated plug-setting tools, the setting tool can be performance tested at the surface before deployment in the well. Radio silence is not necessary during operations. Successful completion of the setting operation is verified by the accurate force record measured by the ReSOLVE service.



The setting tool of the ReSOLVE service is pulling off from a plug that was set in casing for zonal isolation.



These broken 55,000-lbf tension studs are from reliability testing of ReSOLVE service during which a single setting tool performed hundreds of simulated plug sets.

Milling tool

The ReSOLVE service's milling tool mills through debris and scale buildups, tubing restrictions, and plugs. The TuffTRAC tractor is seamlessly integrated to automatically drive the milling tool forward and resist rotation while the milling tool's rotating bit engages the obstruction. Operational efficiency is further improved through immediate stall detection, enabling faster recovery.

Unlike conventional uninstrumented milling tools, which do not report measurements and are not controllable from the surface, the ReSOLVE service's milling tool features real-time monitoring and control. The engineer is fully informed of the tool's performance status and dynamically controls the bit speed and weight on bit (WOB) to optimize removing obstructions. The MillOptimizer* automatic milling system can also be used to automatically adjust the WOB to achieve a particular torque. The engineer monitors and adjusts parameters as needed while the MillOptimizer system automatically controls

the operation of the tractor and milling tool to maximize milling efficiency and prevent stalling. The real-time measurements available when operating the milling tool include

- bit speed
- torque on bit (TOB)
- WOB
- tool orientation for detecting tool spin
- tool temperature.



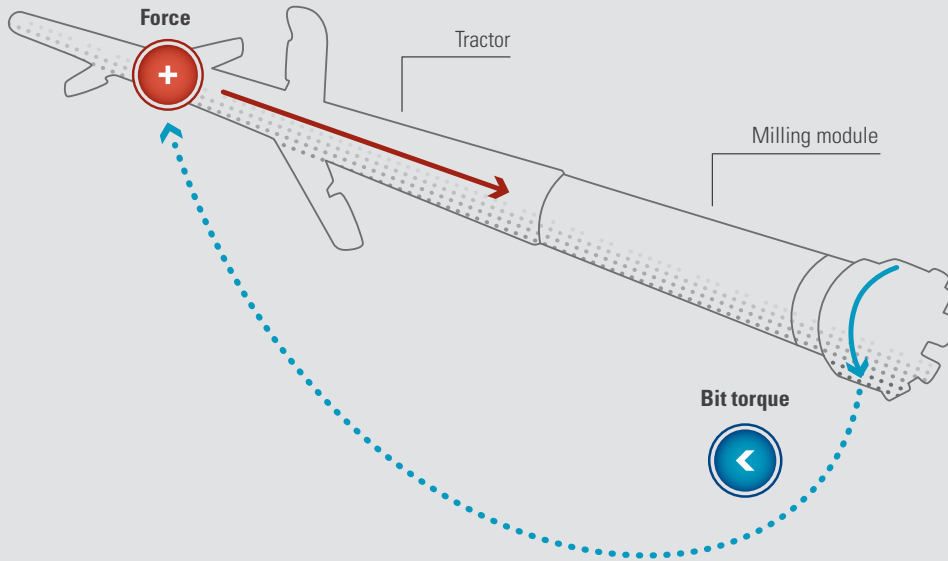
Lyng Drilling has designed a PDC bit optimized for scale milling with the ReSOLVE service's milling tool.

Optimized scale-milling PDC bit designed by Lyng Drilling, a Schlumberger Company

Conventional bits used on drillpipe or coiled tubing require an order of magnitude more power than available on wireline so they are not the best choice for lightweight intervention applications. Lyng Drilling, in cooperation with the Schlumberger Gould Research Center, developed a novel PDC bit for the ReSOLVE service's milling tool that is optimized for a maximum rate of penetration (ROP) when milling hard scale buildup in tubulars. Now in its fifth generation, this groundbreaking mill bit design achieves the maximum rate of scale volume milled within the power limits of electric wireline systems.

How it Works

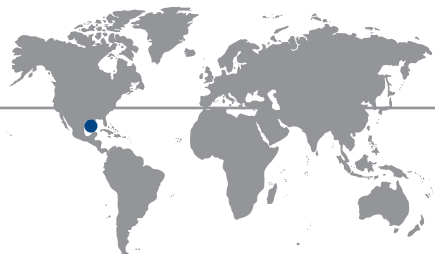
MillOptimizer system for truly autonomous control



The MillOptimizer system for the ReSOLVE service's milling tool delivers the world's first truly robotic intervention system.

MillOptimizer automatic milling system

The ReSOLVE service's milling tool incorporates the innovative MillOptimizer system that automatically coordinates the operation of the TuffTRAC tractor and the milling tool to optimize the milling process. The MillOptimizer system leverages the instrumentation built into the two separate tools and the downhole communication between them so they operate as a single intelligent system. In operation, the engineer sets the bit speed and the desired bit torque. While operating, the milling tool communicates the bit torque to the tractor in real time, and the tractor continuously adjusts the applied WOB to keep the system milling at the desired torque. MillOptimizer system control enables the milling tool to automatically respond to variations in the amounts of scale by pushing with less or more force as necessary to keep operating without stalling. If bit stalling does occur, it is immediately detected by the MillOptimizer system, which automatically stops the tool, disengages the scale by reversing the bit and the tractor, and then resumes milling.



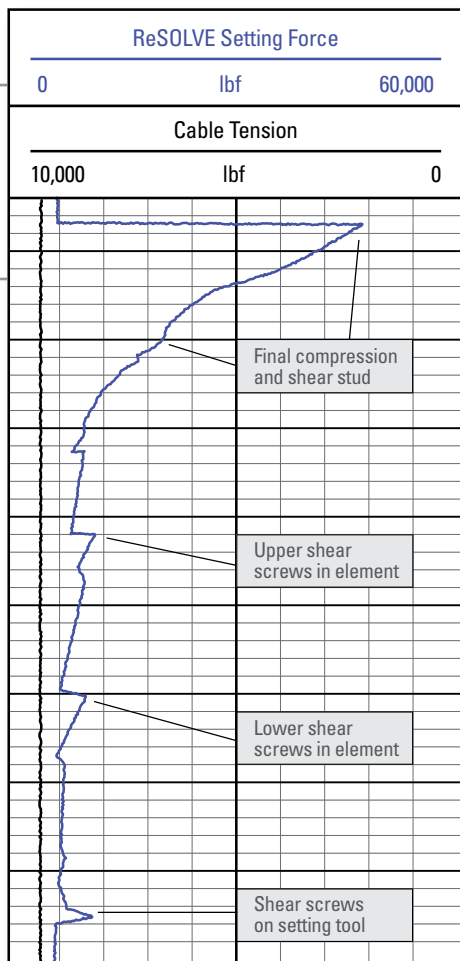
World record on Chevron Tahiti: ReSOLVE service's setting tool installs deepest plugs

Pressure limitations and force requirements for setting the large plugs needed in deepwater environments have often precluded their deployment via conventional wireline. Introduction of ReSOLVE instrumented wireline intervention service in the Gulf of Mexico brings a total solution for deployment and confirmation of plug setting for the challenging operating conditions.

The ReSOLVE service's setting tool was deployed for the first time for Chevron to set bridge plugs in the primary Tahiti field injector wells. Real-time reporting of the force measurements eliminated the need for deck testing, which had been previously required to confirm a tool's capability to shear the plug's stud. Coordination with the

Schlumberger product center had determined the optimal surface-controlled setting speed to ensure the quality of the plug setting. A full downhole function test was performed prior to initiating the set to confirm the operation of the tool.

The real-time downhole measurements during the setting operations gave a positive confirmation on the quality of the set. The deepest and second deepest plugs to date were set worldwide with ReSOLVE service in Tahiti IS001 and IS002, at 28,239 ft MD and 28,133 ft MD, respectively, breaking the previous record by over 5,000 ft.

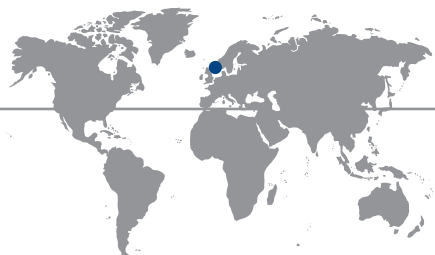


The real-time response measured for plug setting in the Tahiti 15002 well confirms the success of the ReSOLVE service operation in setting a world record for plug depth of installation.



ReSOLVE well intervention services were deployed on the Discoverer Clear Leader drillship in the Gulf of Mexico.

Case Study

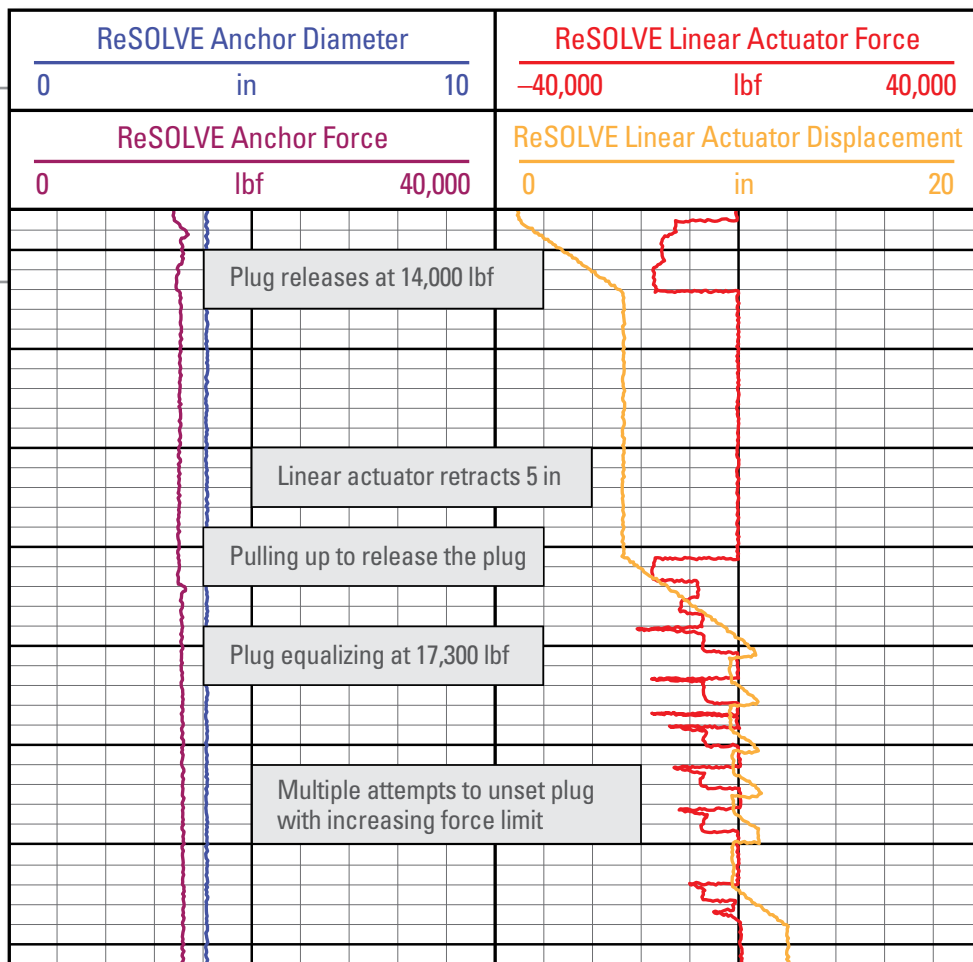


ReSOLVE intervention service unsets stuck retrievable plug, overcoming differential pressure and monitoring pressure equalization forces

An operator needed to remove a stuck deep-set HPHT bridge plug in the North Sea. The plug was designed to equalize differential pressure at 7,800 lbf and release at 10,400 lbf. However, the initial attempt to equalize and release the plug with a mechanical jar proved unsuccessful when the plug failed to equalize pressure. A steady force large enough to overcome the differential pressure was needed to remove the plug.

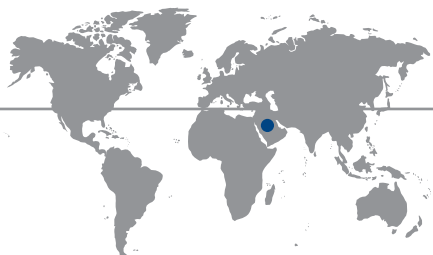
The ReSOLVE service's linear actuator tool is ideally suited to this application. In addition to its maximum pulling force of 45,000 lbf—the industry's highest for this tool size—ReSOLVE instrumented intervention service incorporates numerous downhole sensors that directly measure progress, enabling precise control of the operation in real time.

The linear actuator tool latched onto the plug, anchored, and began pulling to unset it. The built-in borehole pressure sensor indicated that the plug began to equalize at a pulling force of 17,300 lbf as it was unsetting, indicating that the plug had collapsed enough to allow equalization around its seal element. As the pressure was equalizing, the linear actuator force measurement was used to monitor the force on the plug. Once the pressure was fully equalized, the anchor module was retracted, and the tool began to be pulled out of the well with the attached plug. While being pulled out of hole, the plug hung up on several restrictions. The ReSOLVE service's anchor and linear actuator were used to pull the plug through with a controlled force higher than could be applied with the cable alone.



The ReSOLVE service log documents the real-time anchor and linear actuator measurements of force and displacement, respectively, while unsetting the plug and equalizing to clearly show precise control of the operation and confirmation of the tasks performed.

Case Study

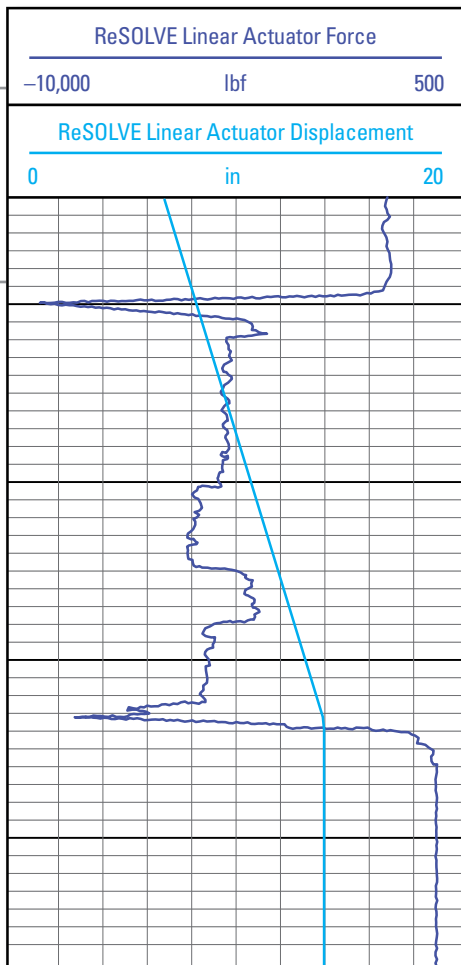


ReSOLVE service's universal shifting tool intervention delivers precise control and real-time confirmation while shifting 10 sliding sleeves in two runs

An operator in the Middle East needed to open the sliding sleeves in multiple inflow control devices (ICDs) in a new horizontal multizone ResFlow* completion. The completion, designed to allow selective shutoff of multiple zones in the reservoir, had been installed with all of the sleeves closed, but now they needed to be opened to begin production. ReSOLVE instrumented wireline intervention service was chosen by the operator because of its ability to confirm and document the shifting of each valve through real-time downhole measurements of the applied force and displacement.

The ReSOLVE service's UST would be used to selectively engage the profiles in each ICD, and the anchor and linear actuator would secure the system and pull to shift open the ICDs. The MaxTRAC downhole wireline tractor system would be used to convey the ReSOLVE service's tools in this horizontal well.

Before the operation, a surface test was performed in a mockup of a part of the completion to produce the reference log for positively confirming ICD shifting. Over the course of two runs in the well, the ReSOLVE service was used to shift open 10 ICDs. Force versus displacement signatures were captured for each shifting operation and compared with the reference log to confirm that each ICD had been fully opened. Conventional shifting tools would not have provided any assurance that the ICDs were fully open, necessitating additional production logging runs to confirm ICD status.

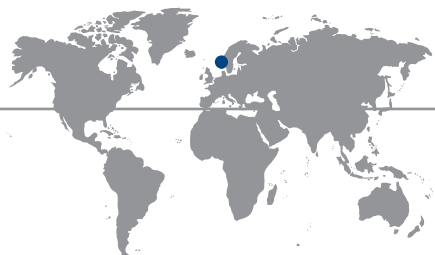


Successful shifting to open each of the 10 ICDs in the horizontal well is showing the expected displacement and force signature that matches the reference log made at the surface.



The key profiles are extended from the ReSOLVE service's UST to engage the ICDs.

Case Study

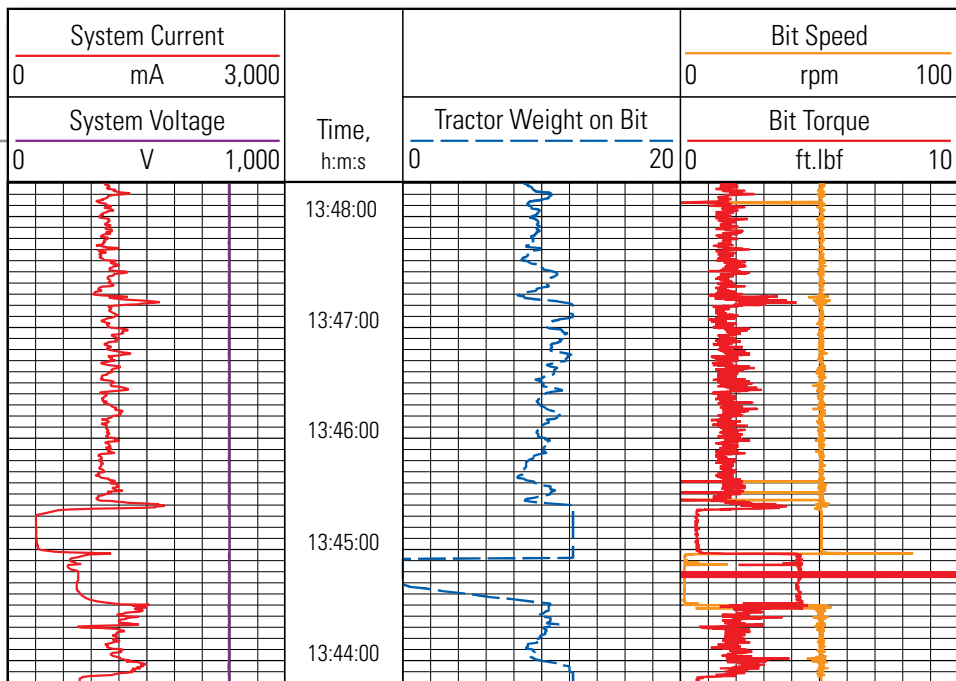


ReSOLVE service's milling tool's first commercial job mills 4,650 ft of barium sulfate scale in 81 operating hours offshore Norway

The ReSOLVE service's milling tool completed its first job in June 2012. The operator of a well offshore Norway wanted to install an isolation sleeve in the production tubing to repair a leak, but scale accumulation along several thousand feet of tubing above the leak prevented conveying the sleeve into position.

The milling tool was paired with the UltraTRAC* all-terrain wireline tractor system, which provides greater WOB and better traction as the milling tool moves through the scale. Operation of the milling tool and the tractor was coordinated by the MillOptimizer automatic milling system to enable the two separate tools to perform as a single intelligent system. A custom PDC bit was used, designed by Lyng Drilling specifically for scale-milling operations with the ReSOLVE intervention service.

A total of 4,650 ft of barium sulfate scale was milled at an average of 57 ft/h in the first job worldwide for the ReSOLVE service's milling tool. The MillOptimizer system was used extensively to automatically adjust the force provided by the tractor and automatically recover from any bit stalls. This integration made operations much more efficient and protected the tool and bit from damage in areas where variable scale accumulation caused frequent sudden increases in torque. MillOptimizer system control enabled much higher average milling speeds, resulting in faster job completion with fewer trips out of the well.



The ReSOLVE service log documents the precision of MillOptimizer automatic system control for a milling operation.

Specifications				
	Shifting	Setting	Milling	UST
Measurement				
Output	ReSOLVE service basic configuration: wellbore pressure, wellbore temperature, head tension, CCL, head voltage, DC current, optional gamma ray			
	Anchor force, linear force, anchor displacement, linear displacement	Setting force	Bit torque, WOB, bit speed (rpm), relative bearing (tool orientation)	Key radial force, key radial position
Resolution	ReSOLVE service basic configuration Wellbore pressure: 17 psi [117 kPa] Wellbore temperature: 0.36 degF [0.2 degC] Digital CCL: 0.02 V Head tension: 8 lbf [36 N]			
	Linear force: 43 lbf [191 N] Linear displacement: 0.005 in [0.127 mm] Anchoring diameter: 0.004 in [0.10 mm] Anchoring force: 60 lbf [267 N]	Setting force: 50 lbf [222 N]	Bit torque: 0.2 ft.lbf [0.27 N.m] Bit speed: 0.5 rpm	Key radial range: 5 lbf [22 N] Key radial position: 0.050 in [1.27 mm]
Mud type or weight limitations	None	None	None	None
Special applications			Complete range of standard brushes, hones, and other accessories and a full set of bits, with custom bits made on request	

Specifications				
	Shifting	Setting	Milling	UST
Mechanical				
Temperature rating	302 degF [150 degC]	302 degF [150 degC]	302 degF [150 degC]	302 degF [150 degC]
Pressure rating	20,000 psi [138 MPa] High-pressure version: 30,000 psi [207 MPa]	20,000 psi [138 MPa] High-pressure version: 30,000 psi [207 MPa]		20,000 psi [138 MPa] High-pressure version: 30,000 psi [207 MPa]
Performance limits	Anchoring range: 3.13–5.10 in [7.95–12.95 cm] Anchoring range, large-pipe version: 4.63–6.60 in [11.76–16.74 cm] Linear range: 20 in [50.8 cm] Linear force: 45,000 lbf [200,170 N]	Setting range: 11.4 in [28.96 cm] Setting force: 78,000 lbf [346,960 N]	Max. milling torque: 250 ft.lbf [339 N.m] Max. bit speed: 130 rpm	Key opening range: 3.13–5.10 in [7.95–12.95 cm] Key radial force: 700 lbf [3,100 N] Linear force: 30,000 lbf [133,450 N]
Borehole size—min.	3.2 in [8.13 cm]	4 in [10.16 cm]	3.2 in [8.13 cm] [†]	3.2 in [8.13 cm]
Borehole size—max.	6.7 in [17.02 cm]	— [‡]	— [‡]	— [‡]
Outside diameter	3.125 in [7.94 cm] High-pressure version: 3.625 in [9.21 cm] Large-pipe version: 4.624 in [11.75 cm]	3.625 in [9.21 cm]	3.125 in [7.94 cm] (without bit)	3.125 in [7.94 cm]
Length	25.0 ft [7.62 m] [§]	18.9 ft [5.76 m] [§]	8.7 ft [2.65 m] [§]	5.5 ft [1.79 m]
Weight	489 lbm [223 kg]	423 lbm [192 kg]	441 lbm [200 kg] ^{††}	141 lbm [64 kg]
Tension	60,000 lbf [266,890 N]	60,000 lbf [266,890 N]	60,000 lbf [266,890 N]	60,000 lbf [266,890 N]
Compression	20,000 lbf [88,960 N]	20,000 lbf [88,960 N]	20,000 lbf [88,960 N]	20,000 lbf [88,960 N]

[†] Based on current minimum bit size

[‡] Configuration dependent

[§] Complete toolstring, without a tractor or logging head

^{††} Minimum with two drives

ReSOLVE



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