

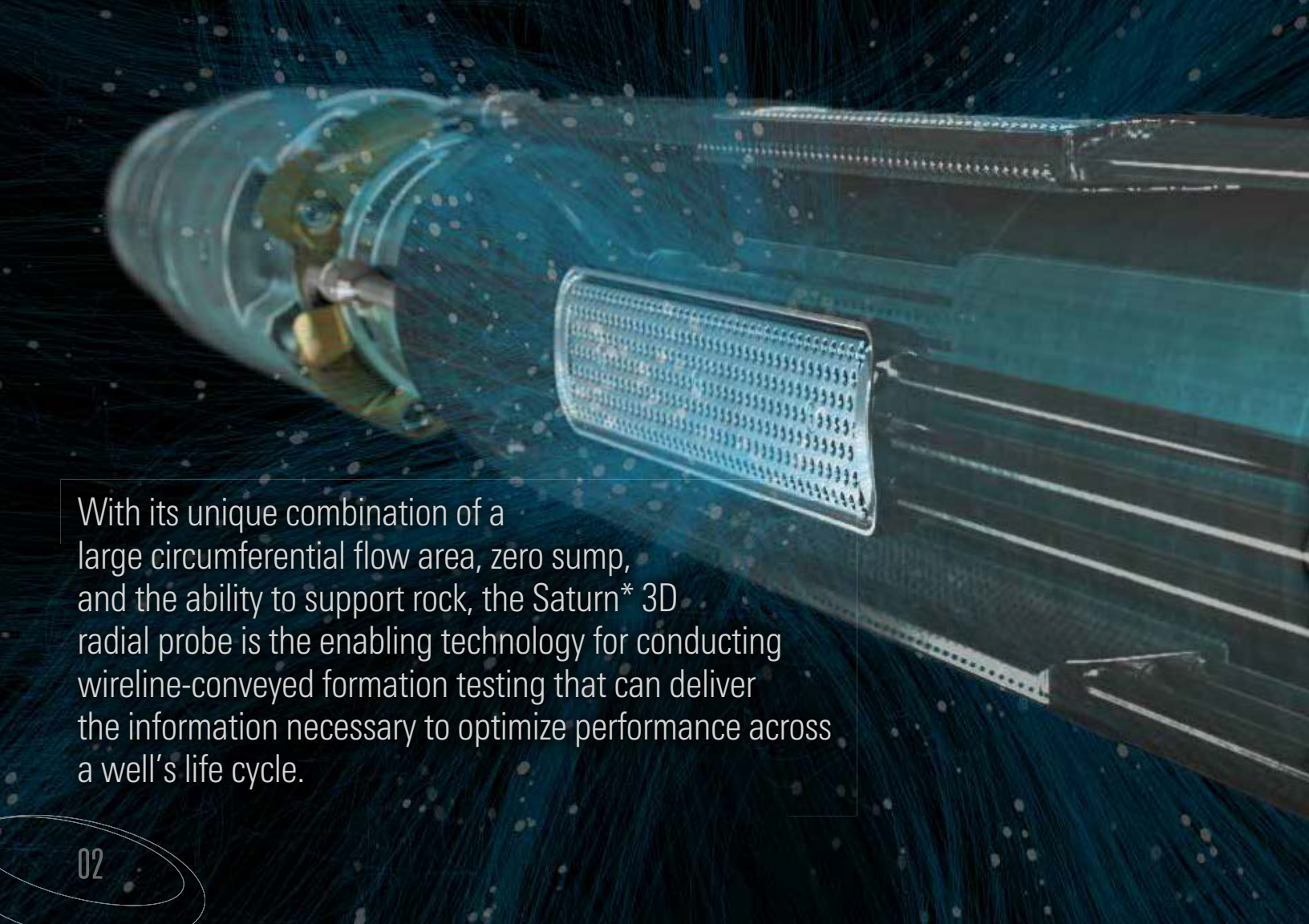
Schlumberger



# Saturn 3D radial probe

Enabling, efficient, derisking, and flexible





With its unique combination of a large circumferential flow area, zero sump, and the ability to support rock, the Saturn\* 3D radial probe is the enabling technology for conducting wireline-conveyed formation testing that can deliver the information necessary to optimize performance across a well's life cycle.



## Applications

- Downhole fluid analysis (DFA)
- Fluid compositional gradient determination
- Formation fluid sampling for laboratory analysis
- Far-field permeability measurement and anisotropy determination
- Pressure transient analysis
- Conventional formation pressure tests

## Benefits

- **Enabling:** pressure measurement, DFA, fluid sampling, and other formation testing objectives in a broad range of challenging environments
  - Wide permeability range, extending down to 0.01 mD
  - Heavy oil
  - Near-critical fluids
  - Unconsolidated formations
  - Thinly laminated formations
  - Rugose and unstable boreholes
- **Efficient:** significant rig-time savings
- **Derisking:** reduced station time and assured retraction
- **Flexible:** deployable across a wide range of hole sizes, temperatures, and pressures on all conveyance options, from wireline to the TLC\* tough logging conditions system to openhole tractors

# Saturn

## 3D radial probe

## Features

- Industry's largest total surface flow area: 79.44 in<sup>2</sup> for 7-in and 9-in versions, 159.49 in<sup>2</sup> for the extralarge 7-in version, and 59.49 in<sup>2</sup> for 5-in version
- Fast setting and retracting time
- Zero sump and low storage effect to eliminate mixing fluids with stationary mud
- Option of vertical interference testing with monitoring probe positioned 4 ft above the probe's radial inlet
- High differential pressure rating
- Self-sealing drain assembly for excellent seal maintenance and wellbore support during sampling in any-quality borehole
- Combinable with the MDT Forte\* rugged modular formation dynamics tester, MDT Forte-HT\* rugged high-temperature modular formation dynamics tester, MDT\* modular formation dynamics tester, and InSitu Fluid Analyzer\* real-time downhole fluid analysis system

# Understanding fluids to drive success across the reservoir life cycle

Over the lifetime of a well, reservoir characterization is key to developing the necessary understanding for optimizing production and recovery. One of the primary data sources for reservoir characterization is the accurate downhole measurement of rock and fluid properties.

Beginning in the exploration and appraisal phases, knowledge of formation pressure and fluid composition is the foundation for developing a formation and fluid model and establishing early understanding of reservoir potential and possible production challenges. In the development and production phases, fluid properties are important for facilities design, production optimization, and salability of the hydrocarbon produced. Concurrently, the downstream phase requires detailed fluid chemistry toward providing quality assurance of the individual petroleum cuts and products.

The accuracy of the decisions resulting from formation pressure and fluid properties data is highly dependent on data integration within the ongoing reservoir characterization process. Instead of the conventional piecemeal approach, Schlumberger employs a digital, integrated strategy. Harnessing the power of data in combination with scientific knowledge and domain expertise within a secure, cloud-based space facilitates collaboration, which in turn drives new insight to reduce uncertainties and risk, from pore to pipeline.





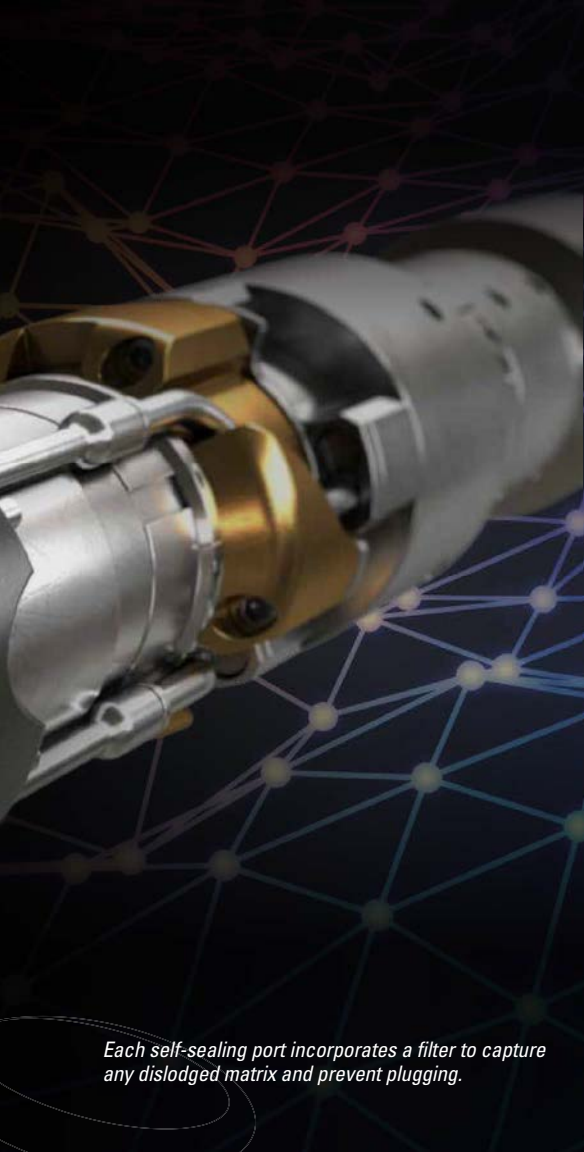
*The self-sealing drain assembly incorporating the four ports circumferentially extracts fluid from the formation instead of localizing flow at a single probe.*

However, as the shift in operations to more complex environments continues, successfully obtaining real-time pressure measurements, DFA, and low-contamination samples as critical components of this digitally integrated approach also becomes a greater challenge.

# Defining the limits of possible

Employing traditional single probes and dual packers for pressure testing and fluid sampling faces numerous challenges, can pose significant operational risk, and limits the addressable range of conditions.



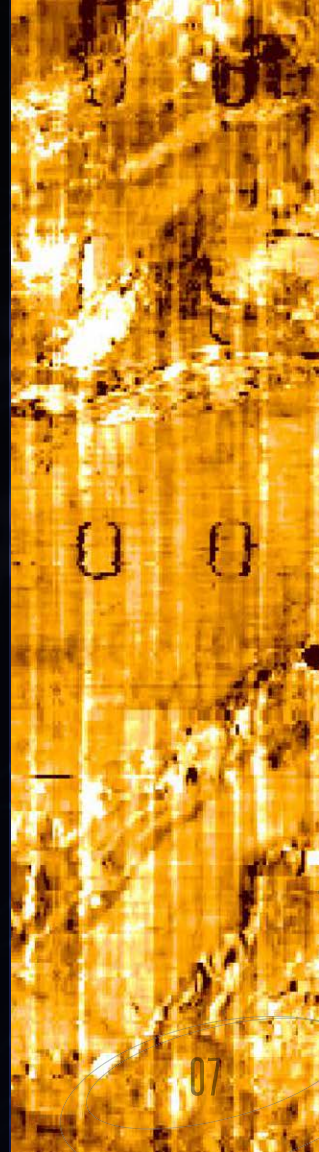


*Each self-sealing port incorporates a filter to capture any dislodged matrix and prevent plugging.*

Pressure testing and fluid sampling require sealing a downhole tool to the wellbore wall and establishing flow from the reservoir that is isolated from the hydrostatic mud column. For sampling and DFA applications, the fluid must be pumped from the reservoir rock into the tool for a sufficient time to decrease the presence of near-wellbore contamination without plugging the tool, collapsing the formation, or allowing a pressure change in the fluid that can cause a phase change to nonrepresentative conditions. For an interval pressure transient test (IPTT) to deliver meaningful drawdown and buildup data, the fluid must similarly be pumped for a sufficient time to create a pressure disturbance far beyond the near-borehole rock damaged by drilling.

The traditional methods for connecting with the reservoir are single probes and the use of dual packers. Single probes can perform efficiently in high-mobility environments, but because fluid flow is directed to a single small inlet, their functionality is greatly limited by low-permeability and low-homogeneity rocks, formations prone to sanding, and high-viscosity fluids. Isolating a wellbore interval with dual packers provides a huge increase in the flow area for withdrawing fluid and a fully radial inlet, but the integrity of the unsupported formation can be damaged, and both cleanup of the large sump area prior to sampling and inflating and deflating the packers at each station greatly add to operational time and risk.

**The Saturn 3D radial probe's integral radial inlet provides the industry's largest flow area to efficiently overcome these conventional challenges and slash operational risk.**



# Setting the standard in downhole formation testing

The Saturn 3D radial probe deploys multiple self-sealing ports around the borehole wall to establish and sustain true 3D circumferential flow in the formation around the borehole. Filtrate is quickly removed to draw in formation fluid, **enabling** highly accurate pressure measurement and high-purity fluid acquisition for sample collection and DFA in what are considered challenging conditions for conventional wireline formation testing:

- rugose or unstable boreholes
- thinly laminated formations
- tight, low-permeability formations
- unconsolidated formations
- heavy oil or near-critical fluid types.

The Saturn probe's fast setting and retracting times, zero sump for a low storage effect and elimination of stationary mud mixing, and largest inlet flow area in the industry—up to 79.44 in<sup>2</sup> for the regular tool sizes and 159.49 in<sup>2</sup> for the extralarge 7-in version—facilitate **efficient** operations across a wide range of reservoir rock, permeability, and fluid types in a single trip in a well.

Reduced stationary time and assured retraction from every seal yield significant **derisking** for operations. **Flexible** deployment is supported by the multiple sizes of the Saturn probe, covering a wide range of borehole diameters while mechanically supporting the borehole. Sandface filters on each port prevent plugging inside the flowline of the MDT tester string if any matrix is disengaged during flow by preventing entry into the Saturn probe.

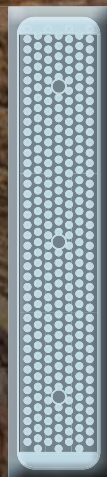
The Saturn 3D radial probe increases the probe surface area by more than 90 times.





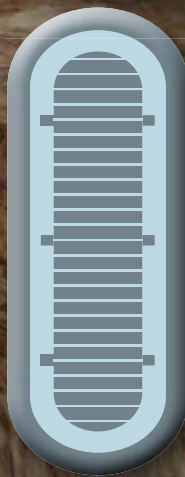
**0.85**

Surface flow area, in<sup>2</sup>  
Standard large-  
diameter probe



**59.49**

Surface flow area, in<sup>2</sup>  
5-in Saturn 3D  
radial probe



**79.44**

Surface flow area, in<sup>2</sup>  
7- and 9-in Saturn  
3D radial probe



**159.49**

Surface flow area, in<sup>2</sup>  
Extralarge 7-in Saturn  
3D radial probe<sup>†</sup>

*Images not to scale*

<sup>†</sup>Available on request

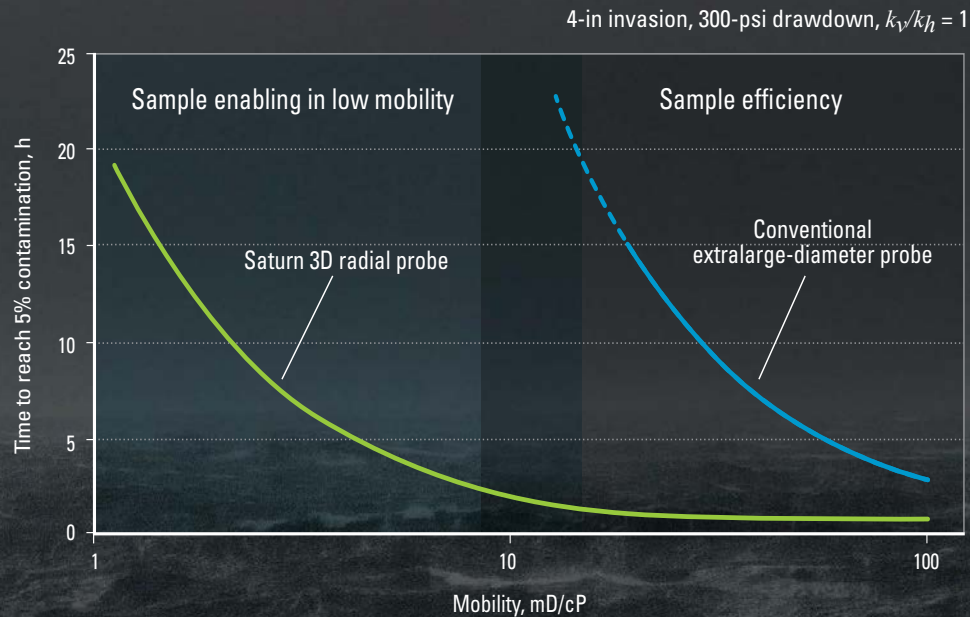
# Enabling formation testing where not previously possible

As the permeability of a formation decreases, the performance improvement of the Saturn 3D radial probe over conventional single and focused probes widens significantly. As shown in comparison with an extralarge-diameter conventional probe for achieving 5% contamination, the Saturn 3D radial probe improves sampling efficiency beginning at formation mobilities of 500 mD/cP, with the performance gap greatly expanding as the mobility decreases. Once mobility decreases below 10 mD/cP, conventional single and focused probes cannot reliably move the formation fluid, whereas the Saturn 3D radial probe is an enabling technology. Dual packers can assist sampling at low mobility but are limited in terms of their capability in unconsolidated rocks and heavy fluids and of efficiency due to their large sump. The Saturn probe addresses both of these issues, enabling targeting new environments with unprecedented efficiency.

## Completing pressure surveys in low-permeability, low-mobility formations

The technology that makes the Saturn 3D radial probe excel at fluid extraction also delivers a step change in formation pressure testing. The highest performing pressure-specific formation testing tools can be applied in mobilities down to 0.1 mD/cP. The Saturn probe can extend this range down by an order of magnitude, to 0.01 mD/cP.





*Modeled cleanup times for the Saturn 3D radial probe and a conventional extralarge-diameter probe show the increase in sampling efficiency possible. The Saturn 3D radial probe is an enabling technology for sampling at mobilities less than 10 mD/cP, at which the conventional probe can no longer perform effectively.*

# Accomplishing goals, whatever the well conditions

Available in 5-in, 7-in, and 9-in -tool diameters and an extralarge 7-in version on request, the Saturn probe brings the efficiency of zero-sump, large inlet area, radial fluid flow to boreholes sizes from 5 $\frac{7}{8}$  to 14 $\frac{1}{2}$  in.

The HPHT rating of the Saturn probe family at up to 30,000 psi and 400 degF extends coverage across practically all downhole environments.

The material used for the probe and its active retraction mechanism minimizes the chance of sticking and optimizes the number of settings possible in a single descent. Qualified for 20 settings at 8,000-psi differential pressure per descent, the Saturn 3D radial probe has achieved up to 60 settings in the field to enable extended deployment. This reliable downhole performance in combination with assured retraction of the self-sealing ports after every station makes it possible to accomplish ambitious formation testing objectives.







*The mechanical retract mechanism of the Saturn 3D radial probe reliably secures the drain assembly when not deployed.*

# Assuring sampling when the going gets heavy

The impact of heavy oil's high viscosity on mobility has traditionally challenged sampling operations.

This challenge is compounded when the oil-bearing formation is poorly consolidated or has a low unconfined compressive strength because the differential pressure required to move the oil across the sandface can cause it to collapse, breaking the necessary seal or plugging the tool's flowline. Dual packers exacerbate the effect, exposing a large area of unsupported formation. In some cases, operators resort to expensive and time-consuming alternatives of setting casing across prospective intervals to enable sample collection or waiting to sample during well completion.

The innovative design of the Saturn probe easily solves the problems posed in sampling heavy oil. The self-sealing drain assembly not only reliably maintains the seal to the borehole wall but also minimizes the differential pressure required to move high-viscosity fluids while simultaneously supporting the formation and preventing its collapse. This approach has enabled acquisition of high-quality heavy oil samples with viscosities up to 1,000 cP.



*The Saturn 3D radial probe reliably enables sampling of highly viscous oils.*



# The global solution

129  
Customers

61  
Countries

2,400  
Samples Acquired

1,183  
Jobs



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## Case Study

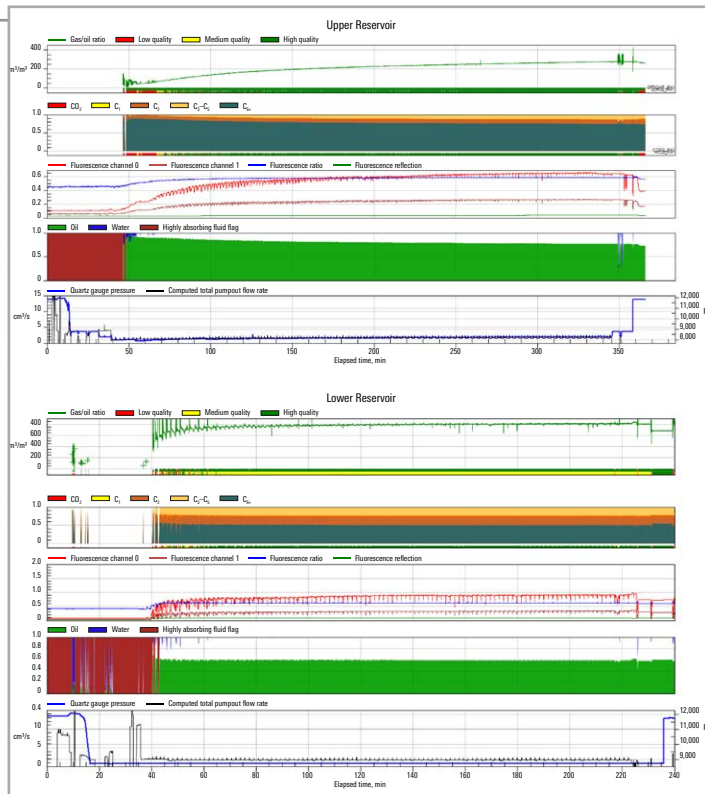
### 5 Reserves Identified and Water Influx Tied to Crossflow by Fluid Sampling and DFA with 5-in Saturn Probe

During drilling of a high-temperature 6.5-in exploration well offshore Mexico, a large water influx occurred that required control with managed pressure drilling. To efficiently resolve whether the water was indicative of well construction problems or a dry hole, the 5-in Saturn probe was deployed with the MDT Forte-HT high-temperature formation tester.

Despite the well's poor prognosis, the formation testing program returned representative pressure and fluid composition data to provide a new perspective on reservoir potential. Water identified at the top of the reservoir section suggested possible crossflow from another zone. A sample collected by the Saturn probe in this zone confirmed that the salinity corresponded to water from the overlying Cretaceous formation, indicating a poor cement job instead of a dry well.

Both oil and near-critical light hydrocarbons were identified in the main reservoir by DFA, proving the well to be hydrocarbon bearing and guiding adjustment of the completion design.

*Real-time DFA conducted at stations in the upper (top) and lower (bottom) sections of the reservoir documents the difference in composition within the hydrocarbon column.*



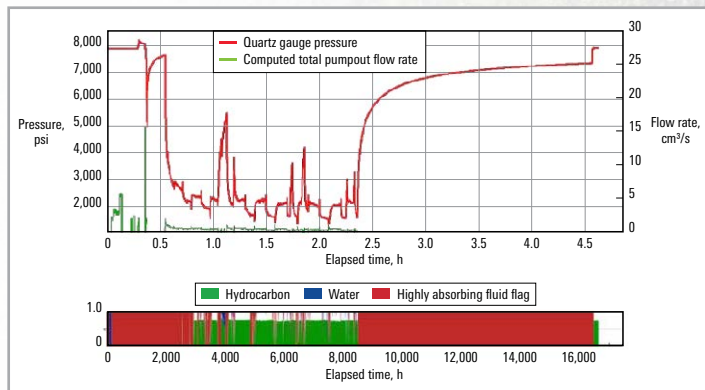


## Case Study

### 5 High-Quality Fluid Samples and Pressure Measurements at 0.05-mD/cP Mobility in Overpressured Subsalt Carbonate

Formation testing was imperative for an operator's first exploration well in the subsalt carbonate reservoir of an offshore field in the Caspian Sea because no prior information about formation permeability and fluid properties was available. However, obtaining pressure data and fluid samples from the overpressured formation would have to be conducted with maximum efficiency in consideration of the high sticking risk and weather conditions.

The 5-in version of the Saturn radial probe was deployed in the 6-in well to successfully collect two oil samples at differential pressures ranging from 5,500 psi to 6,500 psi—well outside of the operating range for a conventional dual-packer configuration. Following sampling, an extended buildup was conducted to calculate accurate formation permeability. The permeability measurement was 0.05 md/cP, which is outside of the operating range for a conventional single probe. The wealth of critical information acquired in only 4.5 h on station minimized rig time and mitigated risk while enabling the operator to confidently continue exploration and appraisal work.



*Pressure measurement and concurrent optical monitoring of the fluid extracted by the 5-in Saturn probe confirmed low sample contamination at a station with 0.05-mD/cP mobility.*

## Case Study

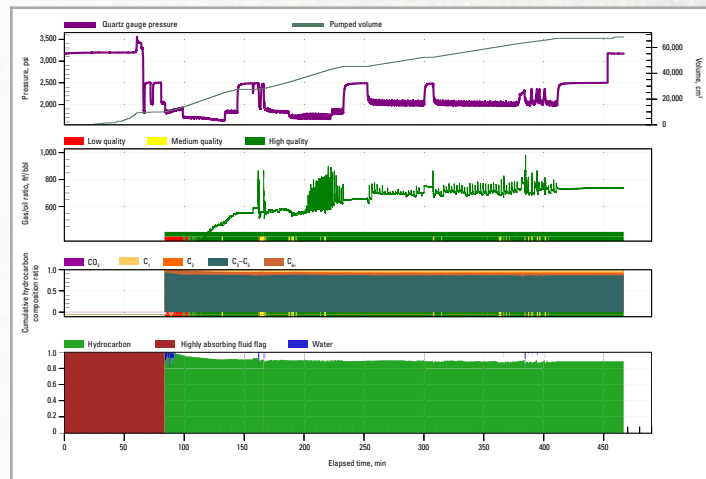
### 7 Mobile Oil Confirmed in a Low-Permeability Sakhalin Reservoir at 85% Water Saturation

An operator sought to assess the productivity potential for low-water-content oil from a low-permeability reservoir with high water saturation. However, conventionally using dual packers to isolate intervals for testing would create a strong wellbore storage effect that would bias pressure measurements and compromise the quality of any fluid samples while the required long pumping times would increase sticking risk.

For these reasons, the 7-in Saturn 3D radial probe was deployed on the TLC system in a sidetrack well with a maximum deviation of 77°. The probe's unique combination of zero sump, large flow area, and fully circumferential flow withdrew a total of 274 L of fluid at four stations with mobilities ranging from 0.1 to 1,000 mD/cP in 136 h of operating time with zero lost time.

DFA conducted on the low-contamination fluid acquired by the Saturn probe confirmed mobile oil at water saturations as high as 85%.

The compositional and pressure information obtained by using the Saturn probe in a single run in an environment where conventional technologies would not be able to function enabled the operator to better align the development approach.



*The C<sub>1</sub> component of the hydrocarbon composition clearly distinguished reservoir oil from oil-based mud filtrate as the Saturn probe efficiently sampled fluids, even in permeability as low as 0.1 mD.*



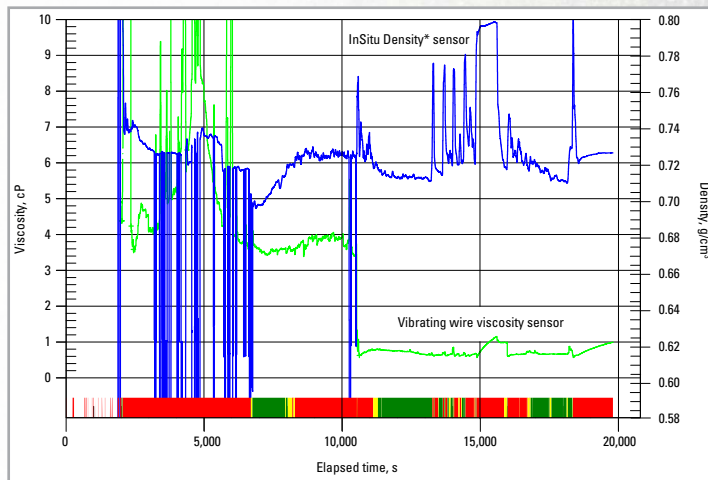
## Case Study

### 7 Successful Permeability Measurement and Fluid Sampling in 0.1-mD/cP Mobility, Deepwater Angola

Pressure measurements and fluid compositional data were needed for a deepwater appraisal well offshore Angola, but a conventional single probe would not be able to effectively perform in the low-permeability consolidated sandstone and a dual-packer inlet would have significantly increased testing time.

The 7-in Saturn probe easily initiated and maintained circumferential flow from the reservoir, even in zones with 0.1-mD/cP mobility, to make multiple valid pressure measurements and retrieve samples with an average pumping time of little more than 4 h per station. At each IPTT station, the Saturn probe pumped twice the volume of fluid that a single probe would have been able to extract and obtained it in half the time.

DFA of the sampled fluid employed a vibrating wire sensor to measure in situ fluid viscosity to complement density measurement. Having these accurate measurements well in advance of laboratory analysis made it possible to derive reservoir permeability and furthered the interpretation of permeability anisotropy from two IPTTs efficiently conducted with the Saturn probe spaced only 1.23 m from a monitoring probe in the toolstring.



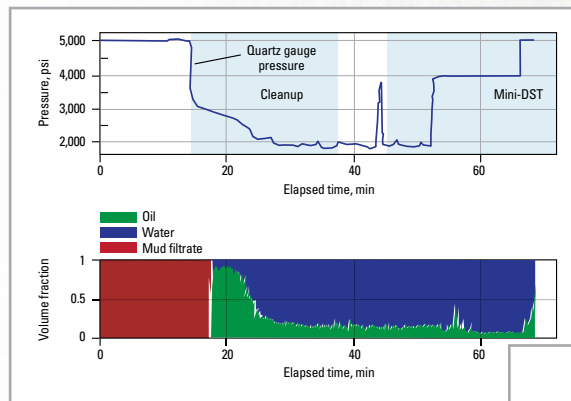
*The high quality of the density and viscosity measurements is flagged green in the bottom track.*

## Case Study

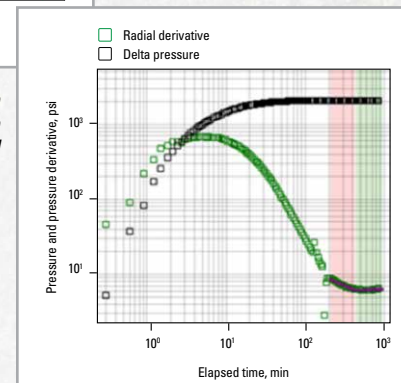
### 7 DFA and Sampling in <1 h from Low-Resistivity, Tight, Laminated Sand Identifies Oil and Water Intervals

Extensive diagenesis, including chloritization, siderite cementation, and quartz overgrowth, of a reservoir's interbedded sand and shale layers had altered the usual clastic porosity-permeability relationship. The resulting abnormally low resistivity response prevented the determination of saturations, necessitating formation testing to obtain this data. However, previous attempts at pressure measurements and sample acquisition with a conventional probe had not been successful because of poor sealing in the typically rugose boreholes and low mobility causing long, unproductive station times.

The Saturn 3D radial probe performed flawlessly, establishing a seal to the rugose sandface in less than 11 min on average, completing DFA in 15–45 min, and collecting samples within 60 min, all in mobilities as low as 0.4 mD/cP. With the oil- and water-bearing intervals now defined, the operator was able to precisely target the completion design.



*At this station in 11-mD/cP mobility, the Saturn probe efficiently initiated and maintained flow from the formation for quick cleanup and collection of a fluid sample after 40 min, followed by a mini-drillstem test.*



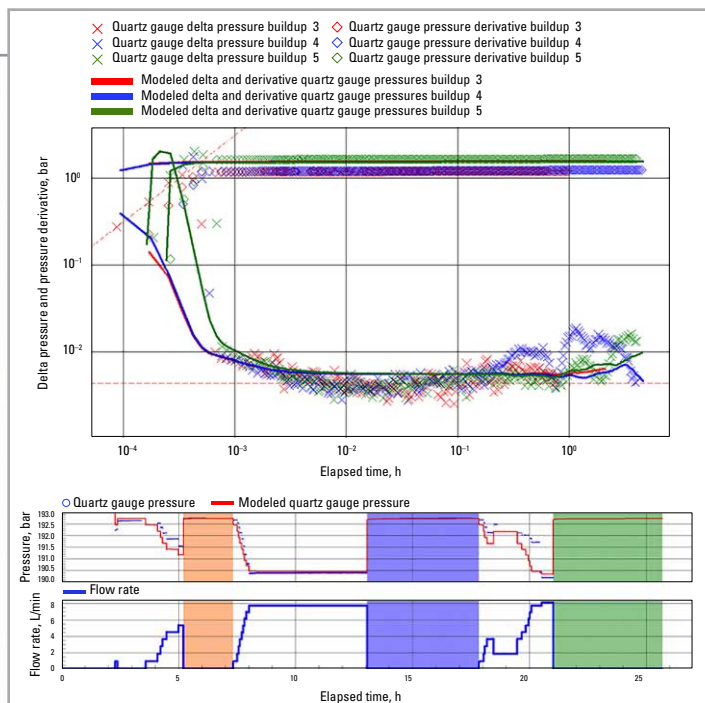


## Case Study

### 9 IPTT in High-Permeability Interval Conducted with Saturn Probe to Formation Test While Tripping

Although IPTTs are a proven method for efficiently determining the permeability and permeability anisotropy of formations, in a high-permeability formation they may not provide sufficient information. Conventional execution on wireline limits the maximum flow rate for pumping formation fluid, which in turn prevents achieving sufficient drawdown in a high-permeability formation to produce a measurable pressure transient laterally and vertically. The radius of investigation is usually only tens of meters, which is often not enough to determine reservoir boundaries and the presence of faults.

To extend testing capabilities, Schlumberger has helped develop formation testing while tripping (FTWT). FTWT was paired with a 9-in Saturn probe for deployment on the Norwegian Continental Shelf to conduct an IPTT in a sandstone with 11-darcy permeability. Total station time was 26 h, with the longest flow period lasting nearly 6 h at a rate of 128 cm<sup>3</sup>/s. For assumed radial flow, this produced a 576-m radius of investigation, the distance where a 0.01-psi pressure drop could be detected. This longer transient enabled efficiently investigating deeper into the reservoir than possible with a conventional IPTT, which would have achieved only a 200-m radius with that sensitivity after 2 h flowing 30 cm<sup>3</sup>/s.



*A radial flow regime was easily determined for the high-permeability reservoir from the extended test and high-quality data delivered by the Saturn probe. Overlay of the derivatives for all three buildup periods increases confidence in the data.*

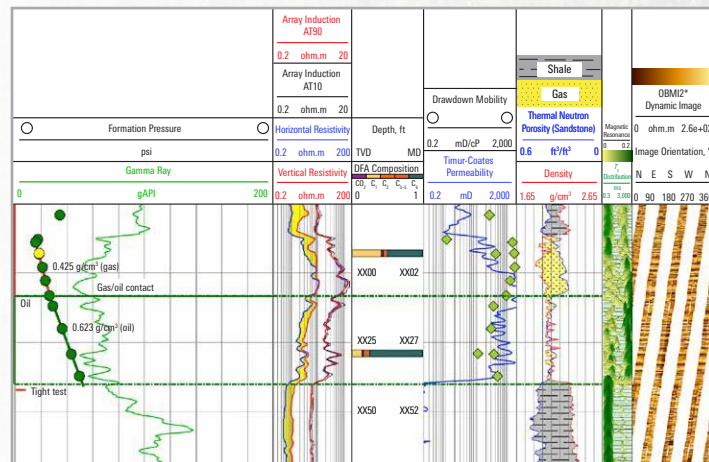
## Case Study

### 9 Acquisition of Ultralow-Contamination Single-Phase Samples from Unconsolidated Reservoir in 80% Less Time

Fluid samples were needed from a 12.25-in wellbore in a high-permeability, highly laminated deepwater reservoir in the Gulf of Mexico. However, a previous sampling attempt in a similar unconsolidated laminated sand in a nearby well by using a conventional single probe had not gone well. Only one of five stations could be sampled, and that operation took more than 12 h because the tool's seal to the wellbore could not be maintained, which also adversely affected sample quality.

Because its elliptical ports self-seal to the borehole wall while the drain assembly helps circumferentially support unconsolidated formations, the 9-in Saturn probe readily overcame the challenges faced by the single probe. In only 2.5 h for cleanup and sampling—one-fifth the time previously required—the Saturn probe collected single-phase samples from a high-mobility (200-mD/cP) layer with only 1.2-wt% contamination measured by DFA, as subsequently confirmed by laboratory analysis.

Connectivity was evaluated by conducting transient testing and vertical interference testing with a probe set at a 4-ft interval above the Saturn probe in the toolstring to quantify vertical communication across the sands.



*The 9-in Saturn probe obtained ultralow-contamination samples (Track 1) to confirm the gas/oil contact indicated by the density-porosity crossover (Track 5) in the high-mobility (Track 4), highly laminated (Track 7) sands.*



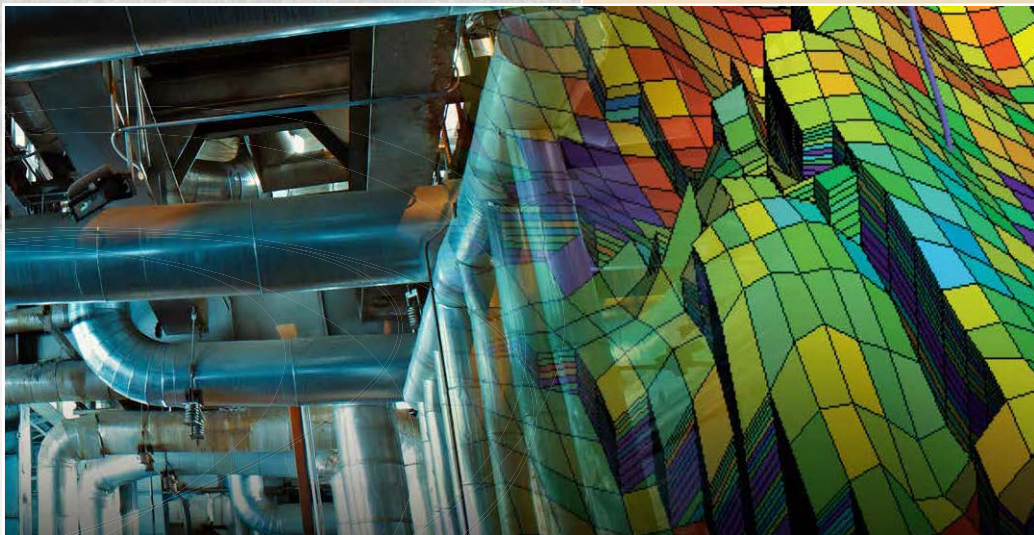


## Saturn 3D Radial Probe

	5 in	7 in	9 in
Inlet flow area, in <sup>2</sup>	59.49	79.44 Extralarge 7 in: 159.49 <sup>†</sup>	79.44
<b>Measurement</b>			
Output	Ultralow-contamination formation fluids, formation pressure, fluid mobility, downhole fluid analysis, permeability anisotropy		
Logging speed	Stationary		
Mud type or weight limitations	None		
Combinability	Fully integrates with all modules of the MDT Forte, MDT Forte-HT, and MDT testers and InSitu Family* sensors		
Special applications	Low-permeability formations, heavy oil, near-critical fluids, unconsolidated formations, rugose boreholes, high temperatures		
<b>Mechanical</b>			
Temperature rating, degF [degC]	400 [204]	350 [177] 400 [204]	350 [177]
Pressure rating, psi [MPa]	20,000 [138]	20,000 [138] 30,000 [207]	20,000 [138] 30,000 [207]
Differential pressure, psi [MPa]	8,000 [55]	8,000 [55]	8,000 [55]
Borehole size—min., in [cm]	5.875 [14.92]	7.875 [20.0]	9.875 [25.08]
Borehole size—max., in [cm]	7 [17.78]	9.5 [24.13]	14.5 [36.83]
Max. hole ovality, %	20	20	20
Length, ft [m]	5.7 [1.74] With Modular Reservoir Sonde and Electronics (MRSE): 12.4 [3.78]	5.7 [1.74] With MRSE: 12.4 [3.78]]	5.7 [1.74] With MRSE: 12.4 [3.78]
Weight in air, lbm [kg]	264 [120]	385 [175]	485 [220]

<sup>†</sup>Available on request

# Saturn



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