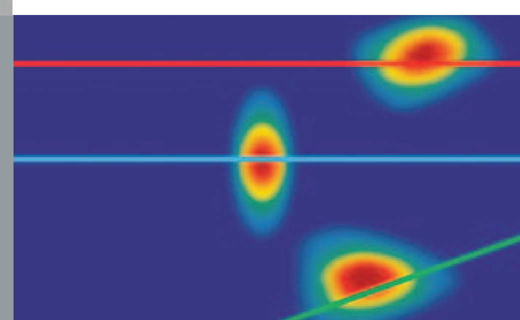
Schlumberger

MR Scanner



Direct reservoir answers

Applications

- Radial profiling of fluid volumes and fluid saturations
- Direct hydrocarbon characterization in fresh, unknown, or varying formation water resistivities, as well as in low-resistivity, low-contrast pay and thin beds
- Formation evaluation in rugose boreholes
- Thin-bed evaluation from high vertical-resolution measurements
- Continuous log of oil viscosity by depth for perforation and completion optimization
- Determination of fluid storage volume based on lithology-independent porosity
- Residual oil saturation in water-base muds and residual water saturation in oil-base muds

Benefits

- Measurements taken beyond damaged zone
- Fluids and environmental effects identified by radial profiling
- Valid interpretations in the presence of borehole rugosity or thick mudcake
- Reduced rig time

Features

- Eccentered, gradient design
- Multiple, simultaneous, well-defined depths of investigation (DOIs) up to 4 in., regardless of hole size or geometry
- Vertical resolution of 7.5 in.
- Logging speeds to 3,600 ft/hr
- Hydrocarbon characterization
- Transverse relaxation time (T_2), longitudinal relaxation time (T_1), and diffusion distributions at multiple DOIs

Formation evaluation simplicity

The MR Scanner* expert magnetic resonance service is provided with the next-generation wireline nuclear magnetic resonance (NMR) logging tool. Using simultaneous multifrequency measurements in a gradient-field design, the MR Scanner tool performs investigations at multiple DOIs in a single pass. Its measurement sequence allows a profiled view of the reservoir fluids.

Deep DOIs enable easy identification of data-quality problems associated with rugose boreholes, mudcake, and fluids invasion; and the measurement depths are maintained regardless of the hole size, deviation, shape, or temperature.

This wireline NMR tool provides numerous user-friendly and direct-depth log outputs for immediate input to petrophysical analysis and log interpretation. They include

- oil and water saturations for identification and quantification of pay zones
- total and effective porosities for determination of pore volume and storage capacity
- bulk volume irreducible water for determination of water-production rate
- crude oil T_2 distributions for determination of oil viscosity and to assist in standard T_2 log interpretation
- brine T_2 distributions corrected for hydrocarbon effects for improved pore size analysis
- hydrocarbon-corrected Timur-Coates permeabilities for determination of producibility
- T_1 for use when T_2 is unavailable; e.g., when logging in vuggy porosities or light hydrocarbons.

These outputs comprise a detailed formation evaluation of the near-wellbore region and are independent of conventional formation evaluation measurements, such as resistivity or density. The answers are independent of Archie analysis and can be derived without having to input water salinity.

The advanced design of the MR Scanner tool and its ready-to-apply computations bring simplicity to formation evaluation. You don’t have to be an NMR data processing and interpretation expert to take advantage of the wealth of information provided by this NMR instrument.

Multiple depths of investigation

An important feature of the MR Scanner tool is its multiple-antenna design.

The main antenna operates at multiple frequencies and is used primarily for fluid characterization applications. It has three different frequencies of operation corresponding to independent measurement volumes (shells) that form concentric arcs in front of the antenna. Because of the eccentered mode of operation and sensor design, the four DOIs, ranging from 1.5 to 4 in., are maintained regardless of hole size, mud type, or temperature.

Because the MR Scanner tool makes simultaneous measurements at multiple DOIs, it can provide a profile of saturation distribution and formation damage in a single pass. Knowledge of the invasion profile lends important insight to the reverse process of production; and along with other formation evaluation measurements, the MR Scanner tool delivers producibility information that governs overall project economics.

The high-resolution antennae operate at a single frequency, which corresponds to a slightly shallower DOI than that of the main antenna. These antennae provide rock-quality and producibility answers, even in thin beds. The MR Scanner tool is capable of downlogging for comparison of main-antenna output with high-resolution-antennae output to identify light hydrocarbons. Downlogging saves time and enables acquisition of data in difficult environments.

A flexible pulse-sequence programmer allows the parameters measured at the multiple frequencies to be acquired in a single pass, thereby eliminating the need for multiple logging passes.

The sensors can be operated either separately or simultaneously at logging speeds to 3,600 ft/hr. Comparison of the responses is used to provide high-resolution identification of fluids with long T_1 values, such as light hydrocarbons.

Fluid saturation depth logging

The MR Scanner tool was run through an oil-bearing sand in a well in Louisiana. The log (Fig. 2) shows continuous oil viscosity of approximately 2 cp and indicates there is no moveable water in the oil zone (A). Filtrate invasion from the water-base mud was determined to be responsible for the lower oil saturation at the 1.5-in. DOI compared with the 2.7 in. DOI (B). The curves for water saturation in the flushed zones (SXO) were computed entirely from the MR Scanner data (C).

Advanced fluids characterization

Diffusion-editing (DE) acquisition methods combined with the multifrequency capability of the MR Scanner tool provide robust fluid saturation and oil viscosity answers using MRF* Magnetic Resonance Fluid characterization (Fig. 3). Analysis of MR Scanner diffusion measurements permits hydrocarbon characterization in environments where traditional log analysis fails, such as low-resistivity pay, laminated sequences, and freshwater formations. Figure 4 shows the interpretation results as they are provided to the end user.

MR Scanner fluid characterization measurements provide initial fluid viscosity information much earlier than a full pressure-volume-temperature (PVT) analysis. MR Scanner fluid characterizations can be used to optimize fluid sampling, saving valuable rig time.

Fig. 2. MR Scanner saturation profile log.

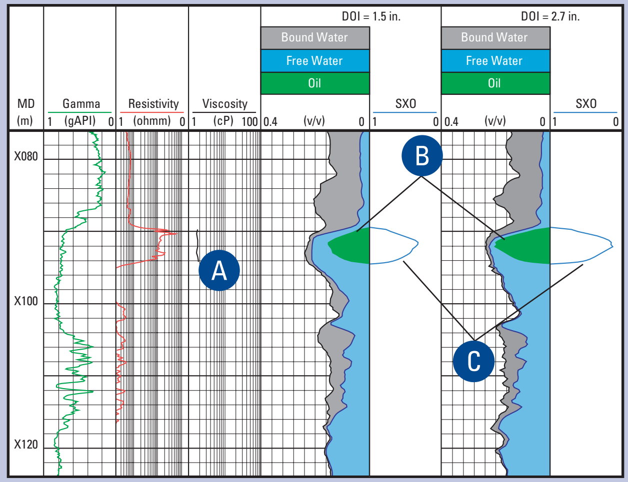


Fig. 3. MRF map of gas, oil, and water diffusion versus transverse relaxation time.

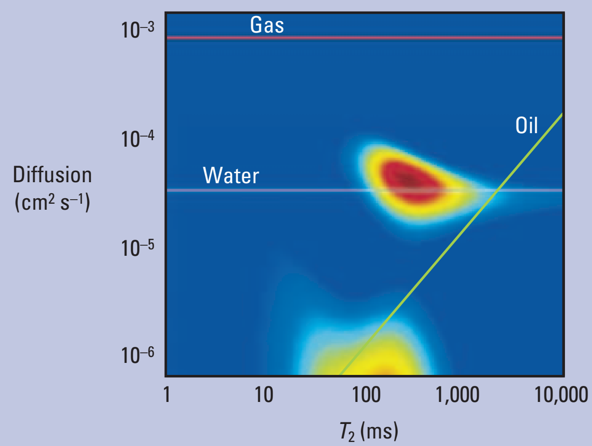
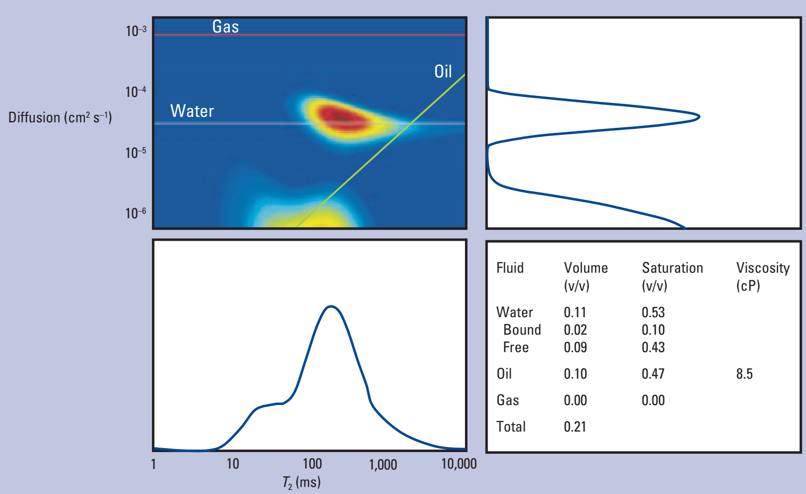


Fig. 4. Interpretation from MRF processing.



Fluid	Volume (v/v)	Saturation (v/v)	Viscosity (cP)
Water	0.11	0.53	
Bound	0.02	0.10	
Free	0.09	0.43	
Oil	0.10	0.47	8.5
Gas	0.00	0.00	
Total	0.21		

Accurate fluids identification in low-resistivity, low-contrast pay

The MR Scanner service was able to identify formation fluids in a low-resistivity, low-contrast pay zone in the deepwater Gulf of Mexico when they could not readily be identified with logging-while-drilling (LWD) logs.

Conventional LWD logs show an obvious gas-bearing interval in the upper zone from X400 to X600 (Fig. 5). However, in the lower zone, low resistivity and the absence of a neutron-density crossover made it difficult to identify fluid type. The MR Scanner tool was run to resolve the ambiguity.

In the upper zone, the exceptional radial profiling capabilities of the MR Scanner tool showed the gas effect of a porosity decrease as DOI increased (Fig. 6).

In the lower zone, the same gas effect was observed, and the interval was determined to be gas bearing (Fig. 7). The neutron-density crossover was being suppressed because of thin laminations in the deepwater turbidite deposit. The MR Scanner log also indicated the zone had good permeability.

Fig. 5. Conventional LWD log.

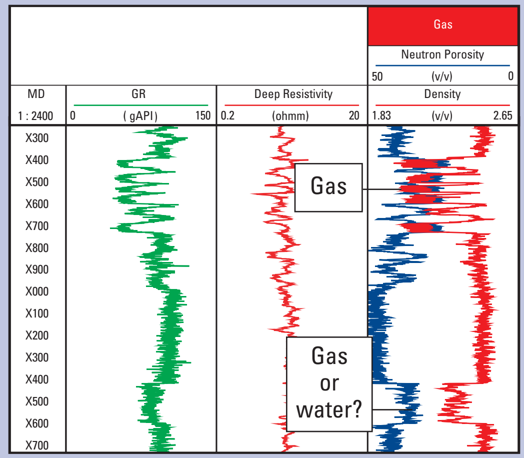


Fig. 6. MR Scanner radial profile of upper sand.

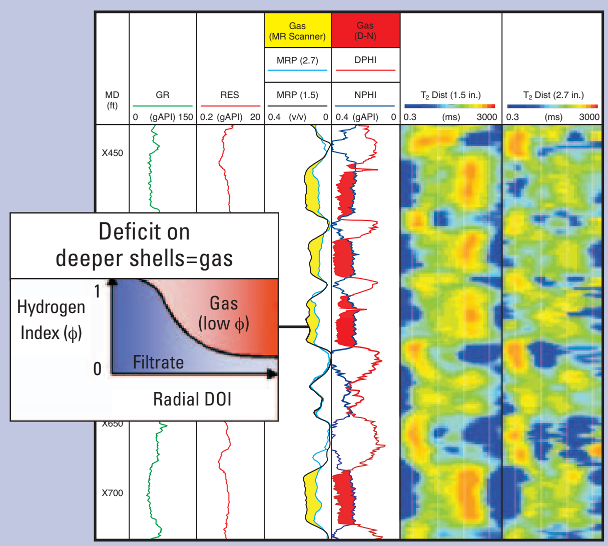


Fig. 7. MR Scanner radial profile of lower sand.

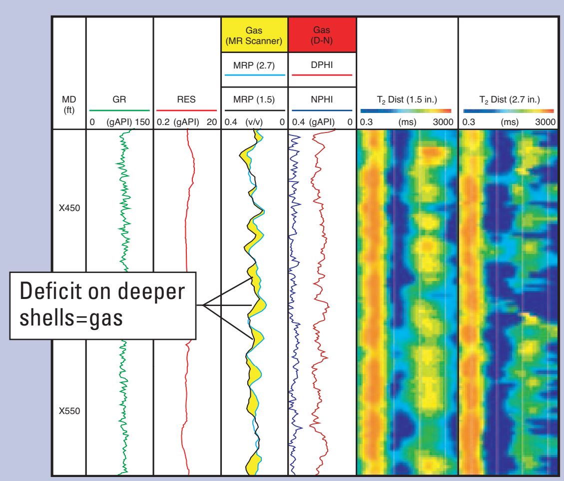
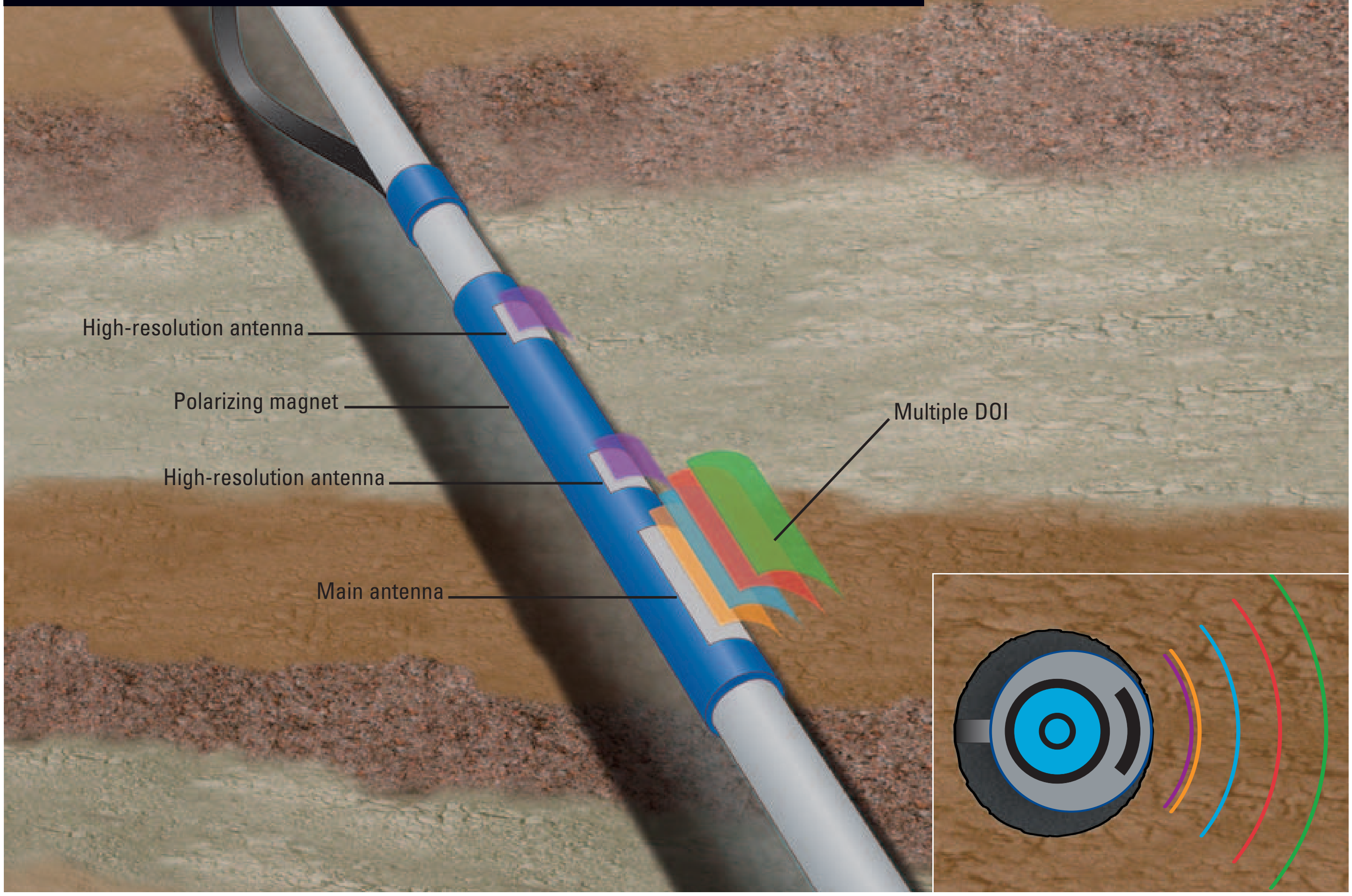


Figure 1. The tool has a multifrequency main antenna designed for fluid characterization applications and two high-resolution antennae that provide rock-quality and producibility answers.



Measurements beyond the zone of formation damage

The MR Scanner tool maintains multiple DOIs regardless of the hole size or shape (Fig 1). Its DOIs are so deep that data-quality problems associated with rugose boreholes, thick mudcake, and mud-fines invasion are easily identified and avoided. Deep measurements provide an excellent opportunity to sense native fluids in shallow-invasion environments.

The deep DOIs allow NMR measurements beyond the zone of formation damage. These measurements include

- total porosity, independent of lithology
- pore size distribution
- permeability
- bound and free fluid volumes
- T_2, T_1, and diffusion distributions.

In addition to improving data quality, deep DOIs maximize the signals from hydrocarbons that are displaced by invasion processes. The MR Scanner tool uses the latest advancements in NMR-based in situ hydrocarbon characterization and analysis methods to provide

- hydrocarbon characterization, including oil viscosity
- hydrocarbon contrasts at multiple DOIs
- near-wellbore oil and water saturations
- wettability indicators and pore-geometry measurements.

Any hole, any size, any shape

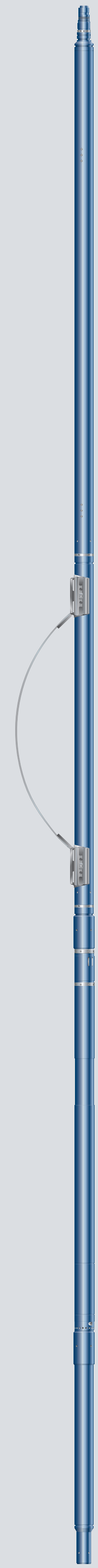
The MR Scanner tool is run eccentered, using bowsprings to press the antennae against the borehole wall. The tool's design enables it to be conveyed on pipe and to be operated in large holes and deviated wells. It also ensures that the measurement volumes and depths of investigation are fixed, consistent, and independent of hole size.

MR Scanner Tool Specifications

Physical specifications	
Length (ft [m])	32.7 [10]
Weight (lbm [kg])	1,200 [544]
Diameter (in. [cm])	5 [12.7] sonde, 4.75 [12.1] cartridge
Measurement point (ft [m])	8.2 [2.5] above the bottom of the tool
Min. hole size (in. [cm])	5.875 [14.9] (in good borehole conditions)
Max. hole size	No limit
Max. tension limit (lbf [N])	50,000 [222,410]
Max. compression limit (lbf [N])	7,900 [35,140]
Operational ratings	
Max. pressure (psi [kPa])	20,000 [137,900]
Max. temperature (°F [°C])	300 [150]
Mud salinity (ohm-m)	(0.05)†
Measurement specifications	
Max. logging speed	
Bound fluid logging (ft/hr [m/h])	3,600 [1,100]
Basic NMR profiling (ft/hr [m/h])	1,800 [550]
T_2 radial profiling (ft/hr [m/h])	900 [275]
High-resolution logging (ft/hr [m/h])	400 [120]
T_1 radial profiling (ft/hr [m/h])	300 [90]
Saturation profiling (ft/hr [m/h])	250 [75]
Min. vertical resolution (in. [cm])	7.5 [19.1], 18 [45.7]
Min. echo spacing	0.45 ms
Frequency (kHz)	1,100 (high-resolution antennae) 1,000–500 (main antenna)
Field gradient (G/cm)	44 (high-resolution antennae) 38–12 (main antenna)
Measurement ranges	
Porosity	0–100 p.u.
T_2 distribution	0.4 ms–3.0 s
T_1 distribution	0.5 ms–9.0 s
Precision	
Total NMR porosity	1-p.u. standard deviation, three-level averaging at 75°F [24°C]
NMR free-fluid porosity	0.5-p.u. standard deviation, three-level averaging at 75°F [24°C]
Depth of investigation (in. [cm])	1.25 [3.2] (high-resolution antennae) 1.5, 2.3, 2.7, and 4.0 [3.8, 5.8, 6.9, and 10.2] (main antenna)

†Main antenna only; stacking may be required. MR Scanner logs have been acquired in 0.02-ohm-m environments with minor loss of precision.

Fig. 8. MR Scanner expert magnetic resonance tool.



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