COMPREHENSIVE RESERVOIR EVALUATION AND MANAGEMENT

The Reservoir Performance Monitor (RPM™) platform is an advanced, slimhole, multifunction, pulsed neutron reservoir monitoring instrument. Its instrumentation combines multiple nuclear measurements in one system with industry-leading accuracy and precision. Carbon/oxygen (C/O) and pulsed neutron capture (PNC) measurements acquired with the RPM tool provide water saturation and three-phase holdup determination, while oxygen activation measurements allow detection of water flow and channels.

RPM services address a broad scope of reservoir evaluation and management applications, including reservoir saturation and produced fluids monitoring, formation evaluation, production profiling, workover and well abandonment evaluation, borehole diagnostics, location of bypassed oil, gas detection and quantification, and identification of water production.

The RPM instrument employs three high-resolution gamma-ray detectors arrayed above an efficient and reliable neutron generator. State-of-the-art detector electronics measure both the arrival time and energy of detected gamma rays. The generator is pulsed at distinct frequencies, and the data acquisition system operates in various timing modes to obtain the different logging measurements. The system hardware is combinable with other production logging instruments; and it is constructed in short, modular sections to facilitate shipping and handling.

ACCURACY IS PARAMOUNT

The accuracy of the RPM service has been ensured by extensive physical characterization in our Houston Technology Center. The tool's measurements have also been enhanced by 3-D and Monte Carlo modeling to provide accurate response in a wide range of borehole, casing, formation, and fluid conditions; and our unique Dynamic Response Generator™ feature delivers accuracy and confidence in any borehole geometry.

Unique downhole conditions can be modeled to ensure that analysis of the reservoir is the most accurate available. And extensive pre-job planning tools are available for design of a data acquisition program that optimizes the final answers delivered by the service.

EFFICIENCY IS DESIGNED IN

Flexibility and operating efficiency make the RPM tool a complete multimode, multisensor, solution-based system. All operating modes are selectable by surface commands.

The RPM instrument can be run in combination with conventional production logging sensors to provide a complete picture of a well's production and reserves in a single trip. It can also be combined with Baker Hughes' unique Multi-Capacitance Flow Meter (MCFM™) instrument in our POLARIS™ system for evaluation of highly deviated wells.

WHY THE RPM TOOL WORKS SO WELL

The RPM instrument uses high-energy neutrons to measure both the inelastic and capture gamma rays.

The inelastic gamma rays, produced by fast neutron collisions during the accelerator pulse, are used for carbon/oxygen measurement to determine the formation water saturation in formations with fresh or unknown connate water salinity.

The capture gamma rays, generated by the absorption of slow or “thermal” neutrons after the pulse, are used to measure formation water saturation in formations with saline connate water. The sensitivity of the capture process to salinity produces a log response similar to a conductivity measurement, where the measured thermal neutron absorption cross section (σ) is used to determine water saturation.
APPLICATIONS AND SOLUTIONS

FORMATION EVALUATION

- Cased hole water and gas saturation measurements
  - Through casing (with through-tubing deployment capability)
  - When openhole logs are unavailable or uneconomical
- Quantification of total hydrocarbons in medium- to high-salinity conditions
- Quantification of liquid hydrocarbons in low- and mixed-salinity conditions
- Identification and quantification of gas, independent of salinity
- Evaluation of porosity
- Identification of mineralogy

RESERVOIR MONITORING AND MANAGEMENT

- Monitoring fluid contacts
  - Time-lapse fluid monitoring
  - Gas/oil/water contact levels
  - Production and reservoir depletion
  - Identification of bypassed hydrocarbons
- Reservoir management base logs

BOREHOLE DIAGNOSTICS

- Identification of water channeling and casing leaks
- Production/injection profiling in multiple-string completions
- Multiphase borehole fluid holdup determination

WORKOVER APPLICATIONS

- Location of bypassed hydrocarbons, independent of water salinities
- Evaluation of stimulation operations
- Log-inject-log surveys for determining irreducible hydrocarbons
- Production/injection profiling

The RPM instrument employs three high-resolution gamma-ray detectors arrayed above an efficient and reliable neutron generator.

PULSED NEUTRON CAPTURE

In the Pulsed Neutron Capture (PNC) logging mode, the detectors record the arrival time of the gamma rays, from which the formation sum is determined. Time spectra from short-spaced and long-spaced detectors can be processed individually to provide traditional sum information. The multiple spectra are processed simultaneously to correct for borehole and diffusion effects, producing a real-time corrected formation sum measurement. Multiple additional measurements are provided to measure formation porosity, shale volume, and borehole fluid changes, as well as to identify formation gas.

Advanced interpretation of PNC data is available through our GEOScience centers using the SEARCH™ analysis program. The identification of gas zones and the measurement of formation gas saturation is performed using the PNC mode. In this application, Baker Hughes combines special instrumentation, response characterization, and an interpretation algorithm to produce a state-of-the-art gas measurement.

Apparent sum measurements from near and far detectors are combined to produce a real-time corrected formation sum.
CARBON/OXYGEN LOGGING

When formation waters are fresh, brackish, or of mixed or unknown salinity, the RPM-C/O acquisition mode is used to detect hydrocarbons. In this mode, direct measurements of the oxygen and carbon content of the reservoir are made, allowing differentiation of hydrocarbon zones from water-bearing zones.

Since chlorine has virtually no inelastic reaction cross section, the C/O measurement can be used to determine formation water saturation independent of salinity.

WATER FLOW LOGGING

The RPM Annular Flow Log (AFL™) and Hydrolog™ measurements use the principle of oxygen activation to measure water flow. In this application, oxygen is made artificially and temporarily radioactive through the neutron exchange reaction, allowing it to be used as a short-lived tracer. Detection of the movement of the activated oxygen can determine water velocity. These measurements provide a powerful diagnostic tool to identify movement inside the casing, outside the casing, or in the tubing-casing annulus. The measurement techniques allow detection of water movement from 2 to 500 feet per minute in simple and complex completions.
**LOG YOUR MOST HOSTILE WELLS**

The RPM-C instrument can provide accurate data in wells in which other pulsed neutron tools cannot even survive. It has industry-best standard environmental specifications of 350°F (177°C) and 20,000 psi (138 MPa). Specially modified hardware enables reliable service at temperatures to 500°F (260°C) and pressures to 30,000 psi (207 MPa).

**HOLDUP IMAGING**

The RPM Pulsed Neutron Holdup Imager (PNHI™) logging mode was designed for measurement of holdups of gas, oil, and water in horizontal boreholes. The PNHI measurement produces a continuous image of the borehole contents, independent of flow regime and unaffected by gravity segregation of the produced fluids.

The PNHI log can determine gas, oil, and water holdups in horizontal boreholes.

**BUILD ON THE DATA YOU ALREADY HAVE**

RPM data can be matched with previous-generation PDK-100™ measurements for easy comparison in mature fields. The RPM service provides real-time emulation of PDK-100 Σ measurements for comparison with historical logs. For remedial work and timelapse monitoring, RPM data can be overlaid with existing log measurements in real time, allowing rapid workover planning.

Although RPM-PNC data acquisition and processing provide analysis results and statistics that are superior to conventional PDK-100 measurements, the RPM-PNC log display and PDK-100 presentation are similar. In time-lapse studies, an emulation of the PDK-100 Σ curve can be provided with RPM-PNC processing for easy comparison of their measurements.

An advanced feature of the RPM service allows real-time computation of “intrinsic” Σ. Innovative data analysis techniques provide a Σ measurement that is corrected for borehole and diffusion effects, without prior knowledge of borehole salinity.
INDUSTRY-BEST STANDARD ENVIRONMENTAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>RPM TOOL SPECIFICATIONS</th>
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<tbody>
<tr>
<td>Temperature (standard)</td>
<td>350°F</td>
<td>177°C</td>
</tr>
<tr>
<td>Temperature (NautilusSM service)</td>
<td>Up to 500°F</td>
<td>260°C</td>
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<tr>
<td>Pressure (standard)</td>
<td>20,000 psi</td>
<td>138 MPa</td>
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<tr>
<td>Pressure (Nautilus service)</td>
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<tr>
<td>Tool OD</td>
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<td>Length (without telemetry)</td>
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<td>Weight</td>
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<tr>
<td>Minimum restriction</td>
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<td>Maximum hole size</td>
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<td>Tool compressive strength</td>
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<tr>
<td>Depth of investigation</td>
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<tr>
<td>Maximum bend rate</td>
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<td>30°/30.5 m</td>
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OUR EXPERIENCE AT YOUR SERVICE

Expert support at the wellsite and from the Baker Hughes GEOScience Center provide the foundation for superior reservoir surveillance solutions.

Since the invention of neutron capture logging by Atlas in 1964, we have led the way in pulsed neutron logging, data handling and processing, advanced interpretation, and reservoir modeling. Our expertise pays off for you whenever we work with you to interpret your wide variety of production environments and complex reservoirs. service provides real-time emulation of PDK-100 $\Sigma$ measurements for comparison with hist...