Baker Hughes INTEQ

15355 Vantage Parkway West
Houston,Texas 77032
Phone:713-625-4200
FAX: 713-625-5200

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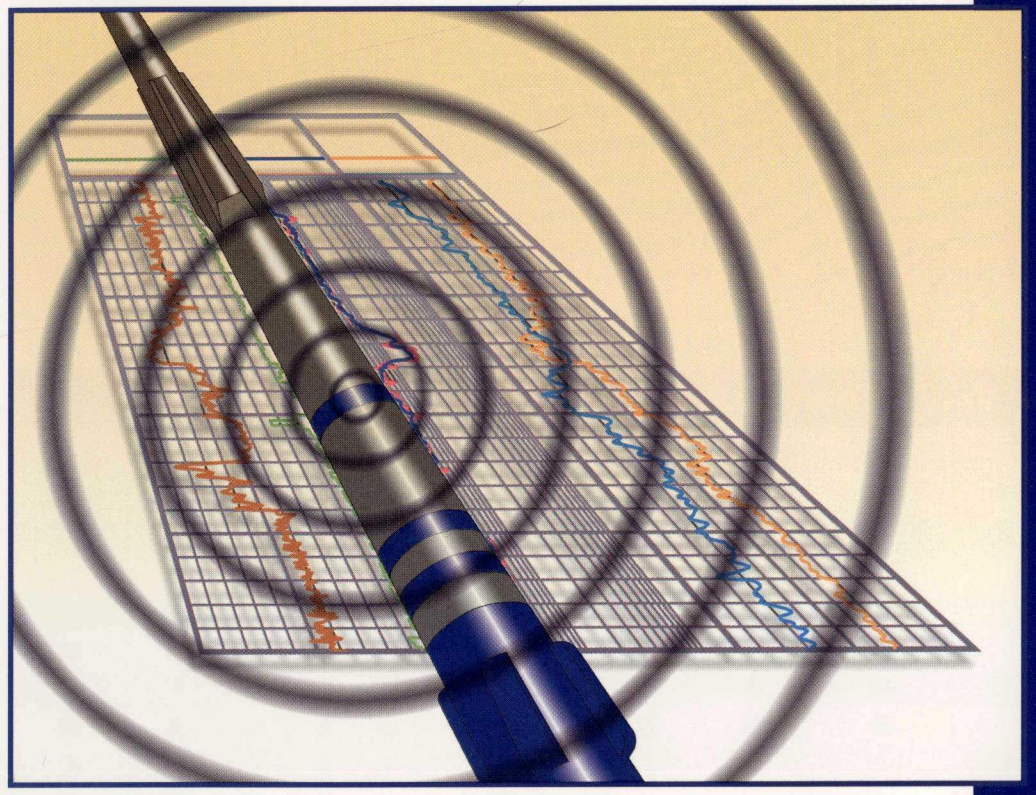
BAKER HUGHES INTEQ

MWD

Measurement-While-Drilling



A New Service Company to Meet Your Objectives.

Baker Hughes INTEQ is a new kind of oilfield services company. We are a company meeting the changing needs of the industry...an organization whose objectives are your objectives. We are dedicated to helping you improve the processes and productivity of drilling, completion and production.

With our company's combination of technologies, Baker Hughes INTEQ can respond to industry needs more efficiently with Integrated Solutions. We also give you single point access to other Baker Hughes technologies, as well as to other contractors' products and services, to match the best solution with your project requirements.

With five global business unit teams providing reinforcement to Baker Hughes INTEQ regional and district personnel, the technical disciplines are championed by two technology units: *Drilling and Evaluation Technology* and *Fluids and Completion Technology*. This publication focuses on Baker Hughes INTEQ's industry-leading MWD technology, an important element in directional and horizontal drilling applications.

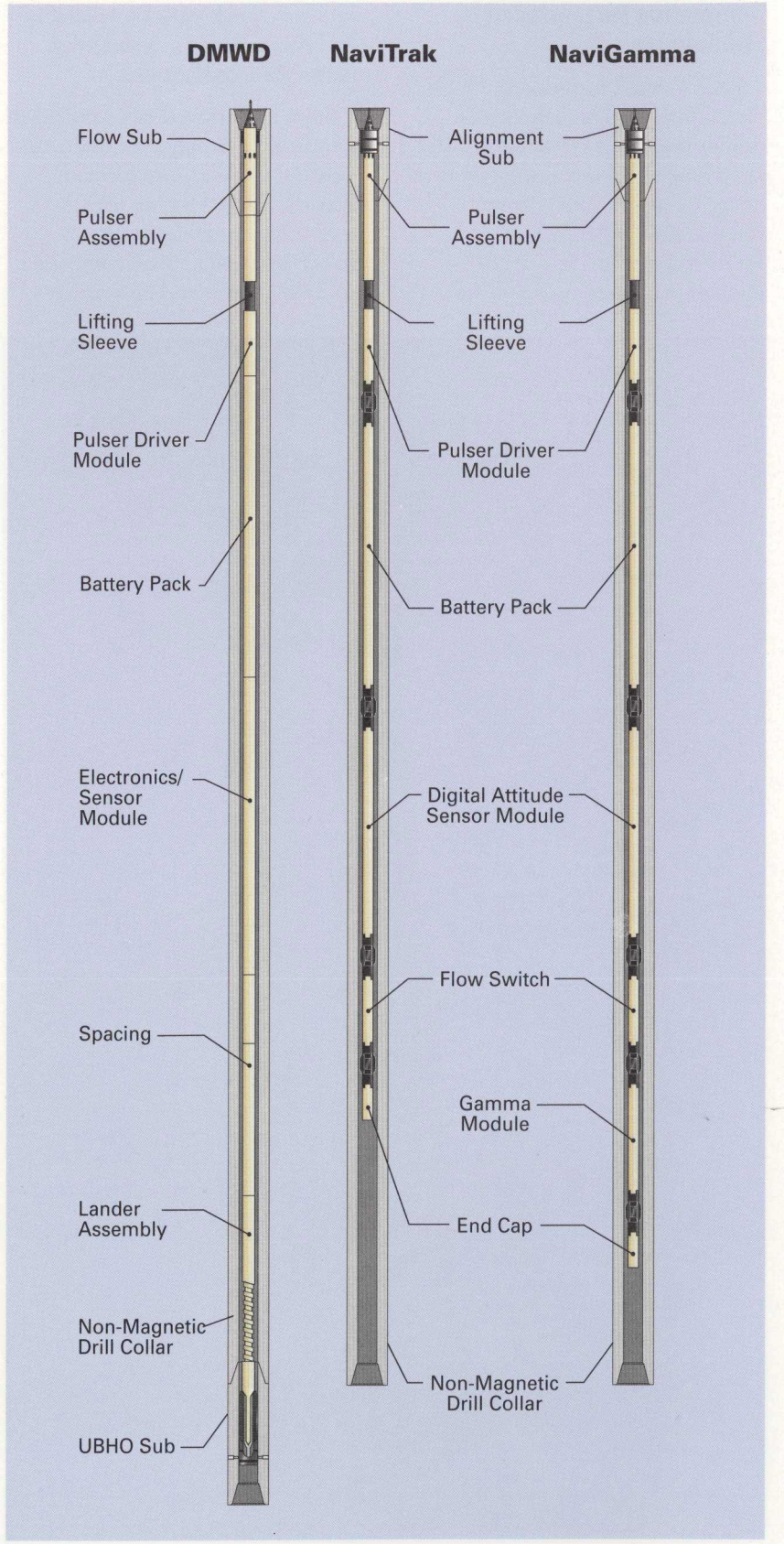
Versatile Systems for All Applications

Applications	Directional	DMWD	NaviTrak	NaviGamma	DG	DDG	RGD	DPR II	Triple Combo
Slimhole Drilling		■	■	■					
Short Radius			■	■					
Horizontal Wells	■	■	■	■	■	■	■	■	■
Borehole Location	■	■	■	■	■	■	■	■	■
Directional Control	■	■	■	■	■	■	■	■	■
Relief Well Drilling	■	■	■	■	■	■	■	■	■
Stratigraphic Positioning				■	■	■	■	■	■
Geosteering in Reservoir				■	■	■	■	■	■
Lithology Identification				■	■	■	■	■	■
Casing Seat				■	■	■	■	■	■
Coring Point Selection				■	■	■	■	■	■
Pore Pressure Analysis							■	■	■
Hydrocarbon Detection							■	■	■
Gas/Oil/Water Contact							■	■	■
Formation Evaluation Analysis							■	■	■
Thin Bed Definition								■	■
Shallow Gas Detection								■	■
Wireline Replacement								■	■
Core Orientation	■	■	■	■	■	■	■	■	■

Depending on the level of MWD service employed, information provided by Baker Hughes INTEQ's measurement systems can be used for a variety of applications.

Reliable Systems for Enhancing Drilling Performance

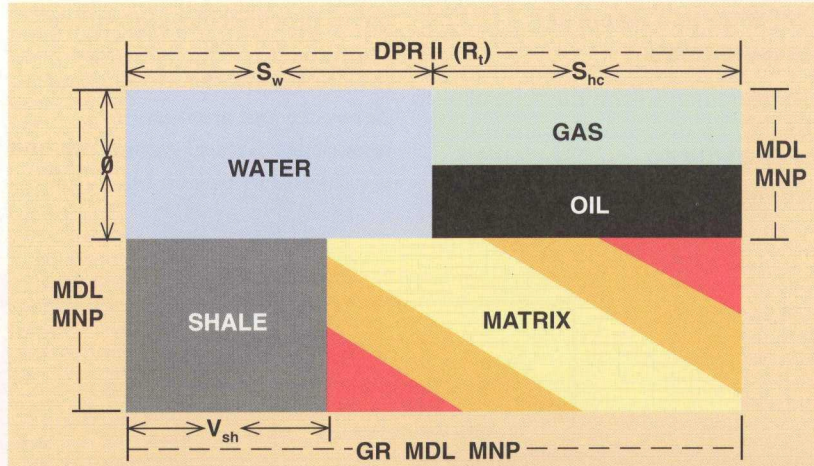
Baker Hughes INTEQ offers Teleco MWD systems for enhancing drilling performance and allowing precise control of the wellbore. In both probe-type or collar-mounted configurations, these tools range from directional systems to more advanced tools which measure downhole drilling parameters and natural-formation gamma ray. These tools deliver reliable, real-time directional information, including hole inclination, azimuth and toolface orientation. Data quality parameters such as sensor temperature, gravitational and magnetic field intensity, and magnetic dip angle are also measured.



Baker Hughes INTEQ's complement of probe-type MWD systems includes the retrievable DMWD directional probe; the NaviTrak directional tool; and the NaviGamma featuring gamma ray detection. Each of these probe-type tools can operate in hole sizes as small as 4'.

Advanced Formation Evaluation with Modular Flexibility

The Baker Hughes INTEQ FEMWD modular system design offers several important advantages. The new system consists of modular sensor subs with simple ring connectors at either end, providing a single wire bus to carry power and data. The new connector allows easier handling in transit and on the rig floor, since tools can be transported in modules rather than as complete units, and the various subs can be combined to provide the exact level of service requested. In addition, the new system allows addition of future downhole sensors as they are developed. Clamp-on stabilizers facilitate optimum BHA design with the full modular Triple Combo suite of tools.



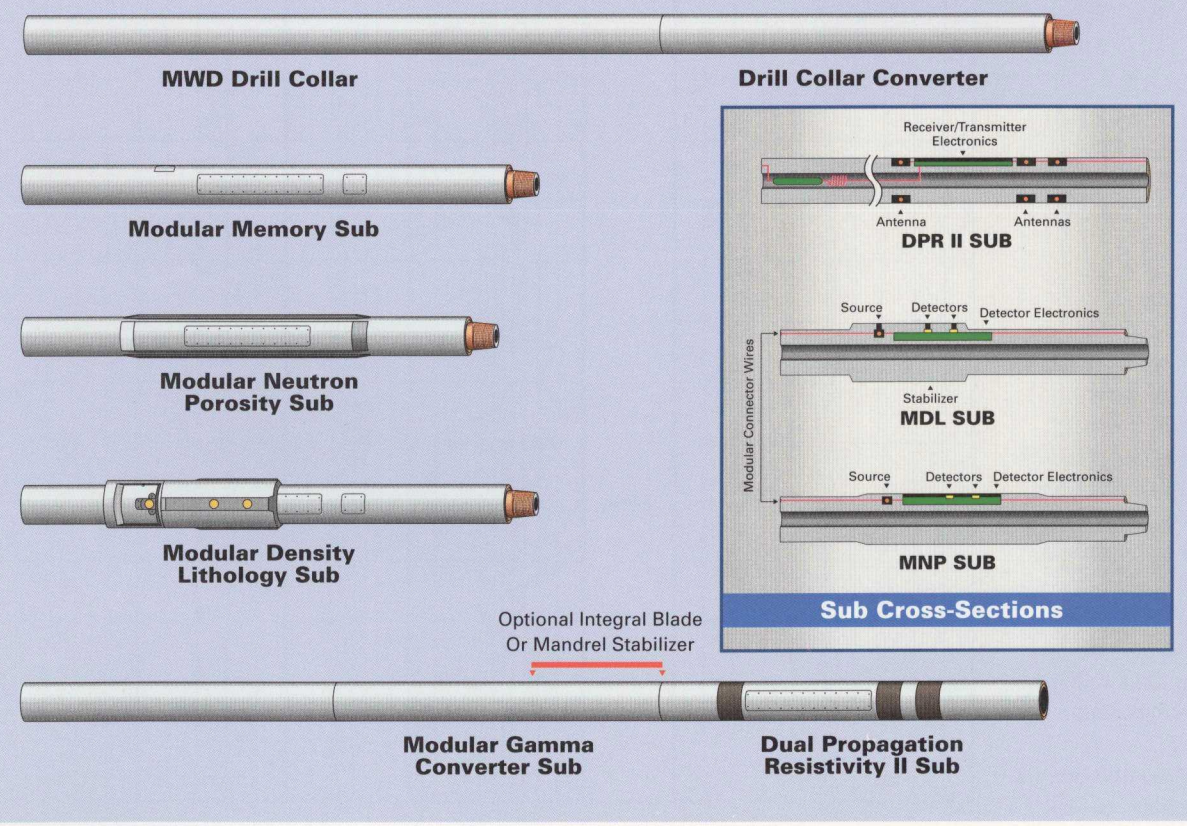
$$S_w = \sqrt{\frac{R_w}{Ø^2 R_t}} \quad \text{or} \quad S_w^n = \frac{a R_w}{Ø^m R_t}$$

$$S_{hc} = 1 - S_w$$

$$V_{sh} = \frac{GR_{shale} - GR}{GR_{shale} - GR_{clean}}$$

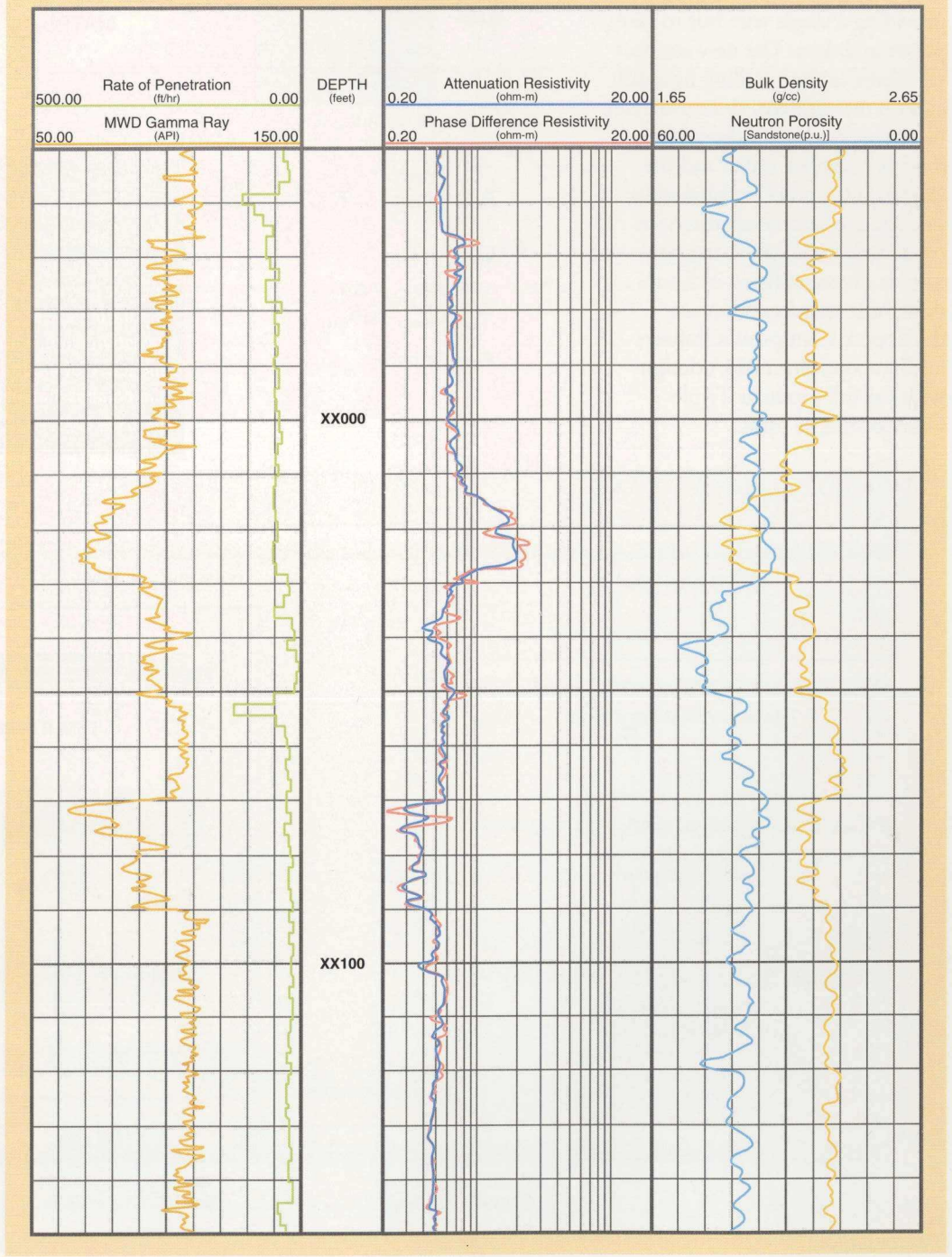
Ø = Porosity

FEMWD data is transmitted in real-time for a variety of applications: Lithology types and shale volume are derived using gamma ray, density and neutron porosity measurements. Water and hydrocarbon saturation are determined using the resistivity tool. Formation porosity and presence of natural gas are measured by the combination of density and neutron porosity logs.



Real-time and Recorded Measurements

Measurements from the suite of FEMWD tools are both transmitted as MWD data, and recorded in memory as RWD data. Measurements provided include toolface, azimuth and inclination; bulk density, neutron porosity; phase difference and attenuation resistivities; natural gamma ray; and weight and torque on bit. While out of the hole, the FEMWD tools can be "mode switched" for different telemetry formats and memory acquisition rates to optimize real-time and memory data collection.



Baker Hughes INTEQ's Recorded-While-Drilling (RWD) logs reflect the highest level of log quality available, containing high density DPR II and gamma ray data in addition to neutron porosity and formation density measurements. Quality Control logs of data density, time-since-drilled and ROP also are generated.

MWD Systems

Information for Improved Efficiencies

Since Teleco® introduced the first directional measurement-while-drilling system in 1978, our MWD technology has been at the forefront of the industry. Today, Baker Hughes INTEQ MWD systems for directional and formation evaluation are recognized as the industry benchmark for reliability and performance in a variety of demanding applications.

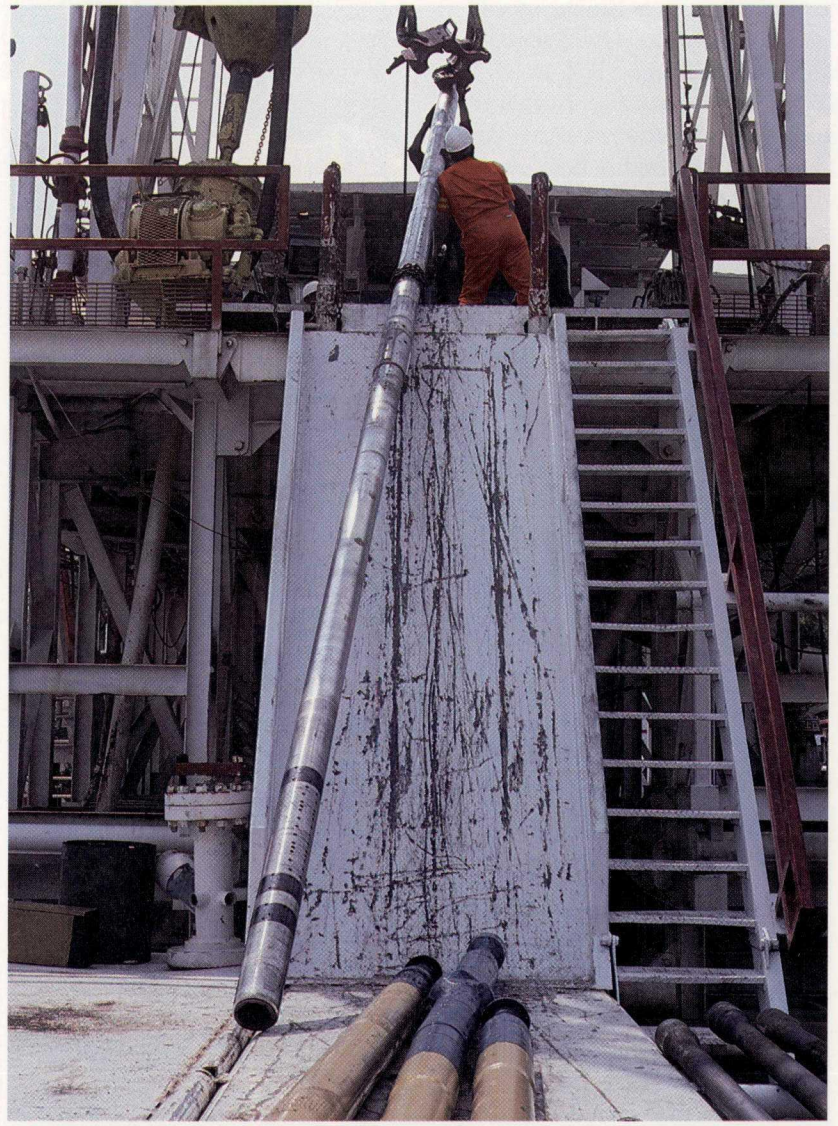
From basic directional readings to advanced resistivity measurements, neutron porosity, and formation density, Baker Hughes INTEQ's technology provides accurate information to help oil companies drill wells faster and more safely.

Baker Hughes INTEQ measurement-while-drilling systems are recognized as the industry benchmark for reliability and performance in a variety of demanding applications.

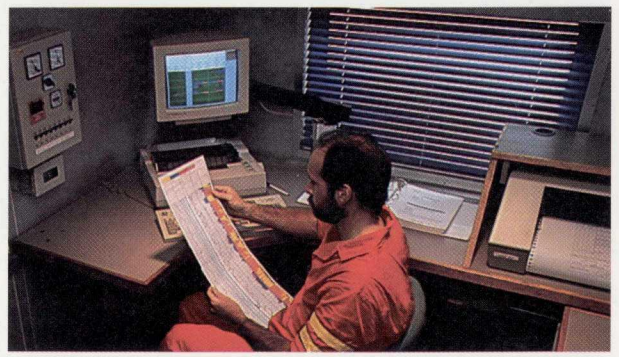
Our advanced systems can replace wireline logs with real-time measurements, enabling you to make key decisions as the wellbore is being drilled.

Because no drilling project confines itself to one technological area, Baker Hughes INTEQ complements its MWD knowledge with expertise in fluid technologies, drilling systems and completion/production technologies. In this way, we provide clients a "total solution" to their drilling questions.

With over 80 locations in 40 countries throughout the world, Baker Hughes INTEQ has an unparalleled network for providing advanced MWD systems to even the most remote locations. Primary Field Maintenance Depots in Lafayette, La., Aberdeen, U.K. and Singapore help ensure all MWD tools meet the most stringent performance standards. As a result, Baker Hughes INTEQ tools have the highest "mean time between failure" (MTBF) in the industry.



Teleco Triple Combo service provides FEMWD measurements before significant hole deterioration or invasion. Continuous transmission of the operational status of each sensor permits early detection of any problems, while the modular design permits quick exchange of any sub for BHA considerations.



The Triple Combo service generates both real-time and high density Recorded-While-Drilling logs, with log quality data plotted at the wellsite.

Teleco Triple Combo℠: Wireline-Quality Logging in Real-time

Baker Hughes INTEQ modular Teleco Triple Combo FEMWD service combines the measurements needed for quantitative formation evaluation. The system incorporates DPR II, MNP and MDL measurements with directional readings and natural gamma ray, all of which are stored in downhole memory and transmitted to surface for real-time MWD. At the surface, the Triple Combo service uses a fully redundant computerized logging system and high speed graphics capabilities to generate both real-time and high density Recorded-While-Drilling® (RWD®) logs. Log quality data such as Time Since Drilled and Data Density also can be plotted at the wellsite.

The Triple Combo service provides accurate, high quality logs in a timely manner, optimizing scheduling of well testing and completion activities, and reducing the possibility of conflicting service overlaps. In high risk wells or difficult drilling conditions, using real-time FEMWD ensures that log data is obtained. In addition, FEMWD provides the most cost-effective means of logging horizontal and high angle wells while maintaining directional control. Re-evaluation of logging requirements while drilling often permits replacement or significant reduction of wireline logs, resulting in substantial cost savings.

Probe-Type Tools:

Teleco DMWD™: Retrievable Directional MWD

Compact enough for use in hole sizes as small as 4½"(11.4 cm), the modular Teleco Directional MWD (DMWD) is wireline retrievable and replaceable in most applications, thus reducing lost-in-hole risk even in deep, high angle and horizontal holes. The slimhole, modular design of the DMWD has a 2"(5.1 cm) OD housing so the system can be run in standard nonmagnetic drill collars as small as 3½"(8.9 cm) OD. Spacer barrels allow for variations in drill collar lengths, and ensure optimum sensor placement. The ability to insert the tool into the collar at the surface or land it downhole by "go-devil" or wireline illustrates the versatility of the DMWD.

Teleco NaviTrak® MWD: A Modular Directional System

The Teleco NaviTrak MWD system provides directional measurements in a compact, modular design, ideal for a variety of applications – including short-radius horizontal wells. Reliable and easy to transport, the NaviTrak system is packaged as either a 1¾"(4.5 cm) or a 2"(5.1cm) OD probe which can be run in nonmagnetic drill collars from 3⅛"(7.9 cm) to 9½"(24.1 cm) OD. Minimum surface equipment results in a flexible MWD system that requires a negligible amount of rigsite space. This modular MWD system also provides accurate, timely surveys and enhanced steering capabilities to increase drilling performance and reduce costs.

Teleco NaviGamma® MWD: Modular Directional plus Gamma System

In addition to providing the benefits of NaviTrak MWD, the Teleco NaviGamma system adds natural formation gamma ray measurement to directional parameters. With a total probe weight of less than 200 lbs (91 kg), the NaviGamma system can be mobilized quickly and made up in the BHA with minimal impact on rig operations. The modular design allows NaviGamma to be assembled in a number of configurations, permitting optimum placement of sensors. The result is a versatile MWD system that supplies accurate, timely surveys and enhanced geosteering capabilities to improve drilling performance and reduce costs.

Modular probe systems are quickly and easily assembled at the rigsite. Compact modules allow for service mobility to make even the most remote locations accessible to MWD.

Collar-Mounted Systems:

Teleco Directional MWD: Reliable, Real-time Information

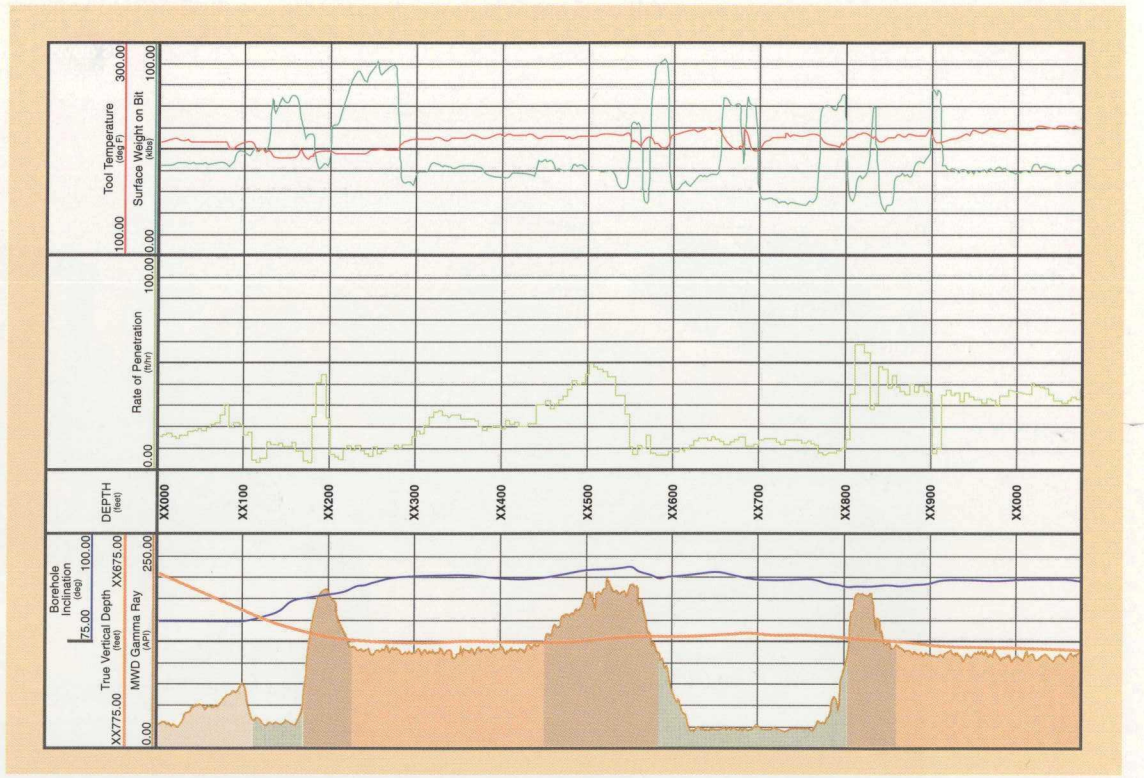
Since its introduction in 1978, the Teleco Directional system has strengthened its industry position by continuous product improvements. The drilling industry regards today's Baker Hughes INTEQ system as the benchmark for MWD reliability. The system provides continuously updated directional data to the driller in real-time using a proven, positive mud-pulse telemetry system. This tool also serves as the foundation for all other Baker Hughes INTEQ collar-mounted MWD tools and is available in 6¾", 7¾", 8¼" and 9½" (17.2 cm, 19.7 cm, 21.0 cm and 24.1 cm respectively) OD sizes.

Teleco Directional-Gamma™: Directional Control and Lithology Identification

Directional gamma tools measure naturally-occurring gamma rays to help distinguish the shale content of sedimentary rocks for real-time lithology identification. The collar-based Teleco Directional-Gamma (DG) tool provides real-time measurements of inclination, azimuth, tool face reference, sensor temperature, and natural formation gamma ray through the use of a scintillation detector. The tool operates in both rotating and steering modes, permitting logging while oriented with a bent-sub or a steerable system.
Gamma ray data is corrected for borehole size, mud density and mud potassium. It is then normalized to API scale and standardized to an 8"(20.3 cm) borehole and 10 ppg(1.2 SG) mud. Extensive computer modeling of the DG tool response confirms the accuracy of API calibrations and borehole corrections.

Drilling Dynamics-Gamma for Drilling Optimization

The Drilling Dynamics-Gamma (DDG®) tool features formation gamma ray, inclination, azimuth, tool face, downhole weight and downhole torque. Using the DDG tool in conjunction with data from surface sensors, it is possible to make accurate, real-time analysis of downhole conditions to optimize drilling parameters and improve



With gamma readings correlated to TVD and borehole inclination, the DG tool is effective for geosteering horizontal wells. Interpretation of the measurement combination helps maintain stratigraphic position. This enables the driller to steer the bit into the proper horizon, while minimizing the number of wellpath adjustments required.

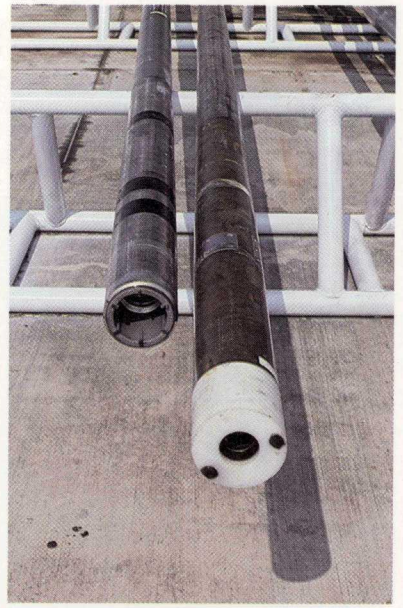
measurements in specially constructed porosity formations and through mathematical modeling. Baker Hughes INTEQ's formation evaluation laboratory has 35 neutron test formations including zero porosity at the three lithologies. Response studies are conducted continuously to provide clients with enhanced characterization charts for an ever-widening set of formation and drilling conditions.

Density Lithology Measurements of Porosity

Baker Hughes INTEQ's MDL uses two sodium iodide (NaI) scintillation detectors to measure formation density and photoelectric factor (Pe), which permits differentiation of the major lithologies: sandstone, limestone, and dolomite. Protected by a stabilizer, the two detectors are mounted in the drill collar wall with beryllium windows. The windows enhance precision and accuracy of both the density and lithology measurements. The tool employs a cesium (Cs_{137}) gamma ray source in a sidewall mounted configuration. Precision downhole circuitry together with seed sources in each detector provide the essential electronic stability for the density measurement.

The MDL's dual detector design provides compensation for rugosity, mud cake, mud density and borehole enlargement using the conventional "spine and ribs" technique. This results in wireline quality density measurements when boreholes are in or near gauge. Because the MWD tool moves through the hole at drilling speeds instead of wireline logging speeds, the precision of the MDL is significantly better than a wireline density log. This allows extremely high resolution in thin beds. As with the MNP, data is transmitted in real time and recorded in downhole memory. Surface data processing techniques provide a compensated accurate density measurement and quality assurance curves.

The MDL primary calibration and tool response characterization comes from Baker Hughes INTEQ's advanced formation evaluation laboratory, with supporting characterization data derived from mathematical modeling.



Teleco Formation Evaluation MWD allows quantitative reservoir evaluation; in many cases, replacing costly wireline logs.

One example of the care taken to ensure accurate and reliable tool development is the Baker Hughes INTEQ calibration facility. The density blocks and porosity formations used are carefully constructed from meticulously-selected materials, screened for purity and grain size, and processed according to the most stringent conditions.

MNP and MDL Formation Density Measurements Determine Porosity

Measuring porosity is essential to quantitative formation evaluation. Baker Hughes INTEQ provides two formation evaluation-while-drilling tools for determining formation porosity: a neutron porosity tool and a gamma-gamma density tool. Log analysts can use the two measurements in a standard open hole analysis to determine porosity, lithology and estimate shale volume. In addition, the density tool also provides an independent lithology curve based on photoelectric effect. Having these reliable density and neutron logs available allows quantitative formation evaluation with the immediacy of MWD information.

Both the neutron and density tools have been characterized using laboratory formations of varying lithologies, porosities and hole sizes. In addition, the tools are technically supported by a team of Baker Hughes INTEQ petrophysicists, engineers, and physicists who are continuously enhancing the performance, reliability, and interpretation of the services. The downhole equipment uses state-of-the-art nuclear detectors and electronics that have been thoroughly tested in the laboratory and in field use.

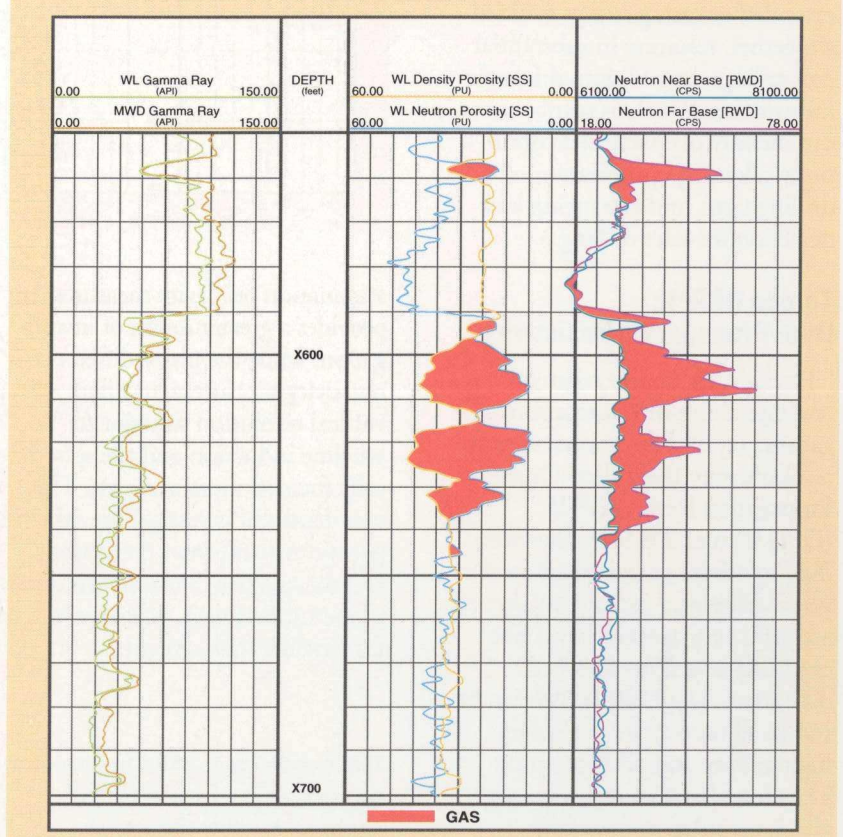
Data from each measurement can be pulsed to the surface in real time for immediate results. A more thorough record of the data is provided in the downhole memory which is reviewed and processed fully with the surface log analysis software. This provides the best porosity estimates and data quality assurance.

Neutron Porosity Measurements

Baker Hughes INTEQ's MNP uses sidewall mounted detectors and a five curie Americium Beryllium neutron source to produce a sensitive measure of formation hydrogen index. The sidewall mounting enhances the measurement of the formation, and minimizes the effects of the borehole and drill collar. The sidewall source port and source mounting mechanism have been extensively analyzed and tested for shock and vibration to ensure durability and reliability.

The tool uses lithium (Li_6) doped glass scintillation neutron detectors that are efficient, rugged and stable at the high temperatures and vibration levels encountered while drilling. These detectors combine the excellent neutron sensitivity of helium (He_3) detectors with the high noise immunity of Geiger tubes; they are an optimum solution for the MWD environment. The downhole electronics, including a spectrum analyzer, keeps the detection system stable against temperature drifts throughout the tool's operating range.

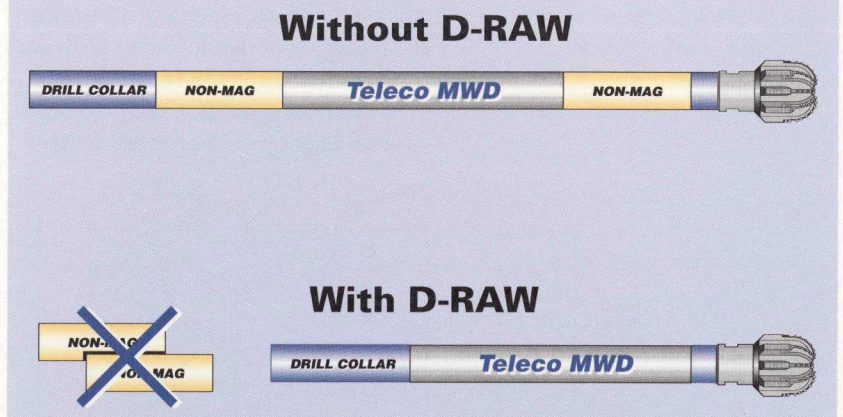
The response of the MNP has been determined by laboratory



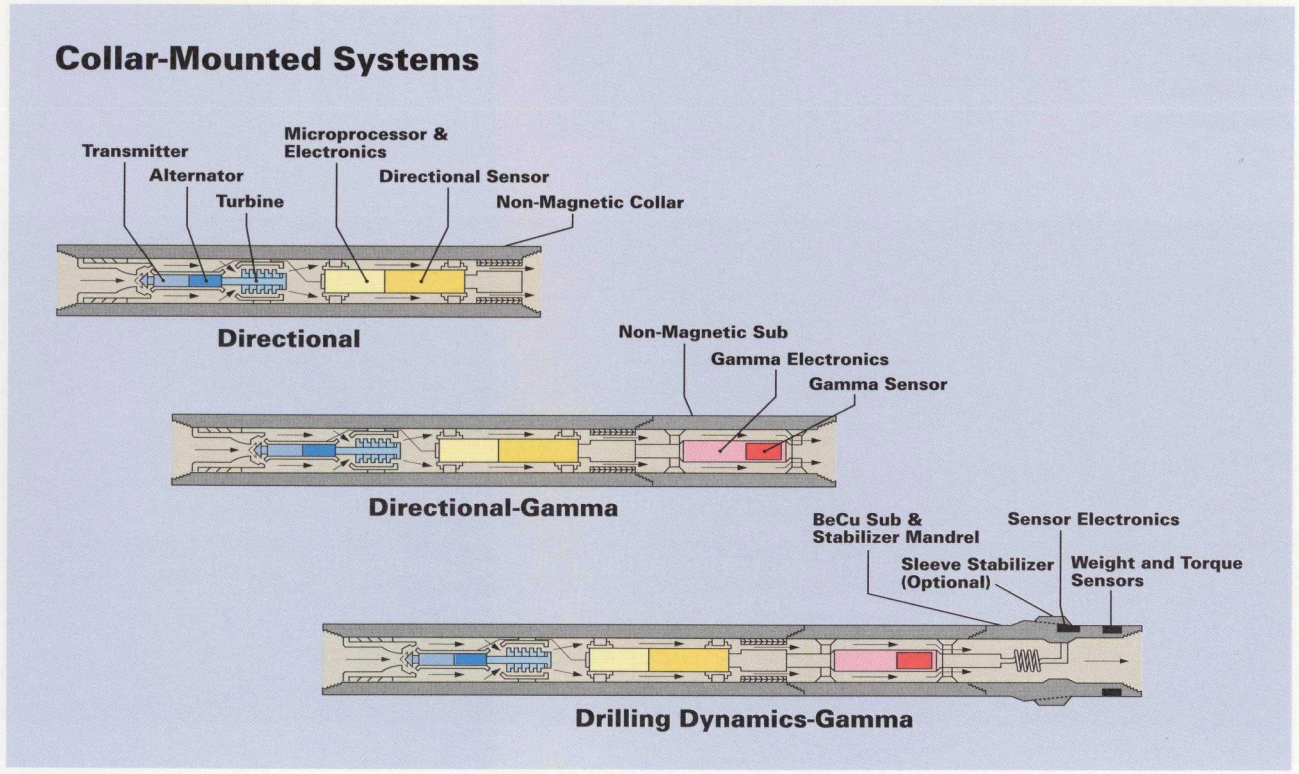
The MNP can be used effectively for identification of gas zones when using normalized near/far neutron count rate overlays. This is demonstrated above by the comparison of MWD normalized neutron near/far count rates (track 3) with the wireline neutron and density porosities (track 2).

performance. In multi-well projects, the DDG tool provides valuable information regarding torque and drag, bit selection and BHA design, which can be applied to improve performance on subsequent wells.

The downhole weight measurement allows precise control of WOB to extend bit life and improve rates of penetration. Comparison of downhole and surface data helps determine potential hole problems, such as undergauge hole or stabilizer hang-up, preventing unnecessary bit trips due to slow ROP. With a steerable system, this information helps optimize assembly performance, and allows gamma measurement to continue during steering operations. In conjunction with gamma ray data, the downhole torque measurement can provide early indication of bit wear, and can be used to identify the effects of formation changes.



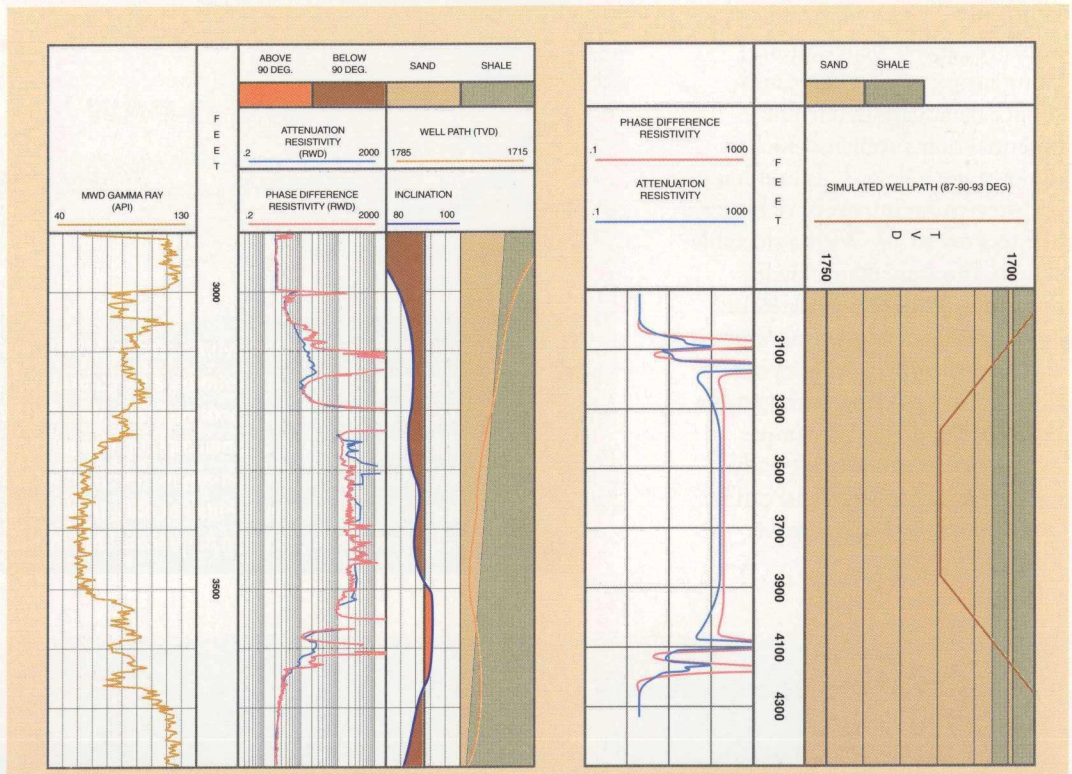
Baker Hughes INTEQ's D-RAW service corrects MWD data for drill string magnetic interference to provide reliable and accurate information on wellbore position. Proven even at extreme latitudes, D-RAW can potentially eliminate the need for excessive nonmagnetic components in the drillstring when MWD systems are run in high-angle or horizontal holes. Using fewer of these expensive monel components not only allows downhole sensors to be located closer to the bit, but also minimizes Lost-In-Hole (LIH) liability.



Formation Evaluation MWD (FEMWD)

Versatile, Cost-Effective Formation Evaluation Services

FEMWD tools and measurements are increasingly replacing wireline logs, especially in medium to high cost development wells and high risk wells where problems with hole geometry, displacement and logging environment make wireline techniques impractical. In rotary and steerable applications, Baker Hughes INTEQ offers Teleco FEMWD tools providing both directional surveys to monitor and guide the well's course, and real-time logs for evaluating the reservoir.



Resistivity data input from an offset well is used in the Dipping Bed Model to create a model which helps identify bed boundaries in a horizontal well. As the model predicted, actual log data from the well featured the characteristic "horns" that indicate an approaching bed boundary at high angle.

Computer modeling

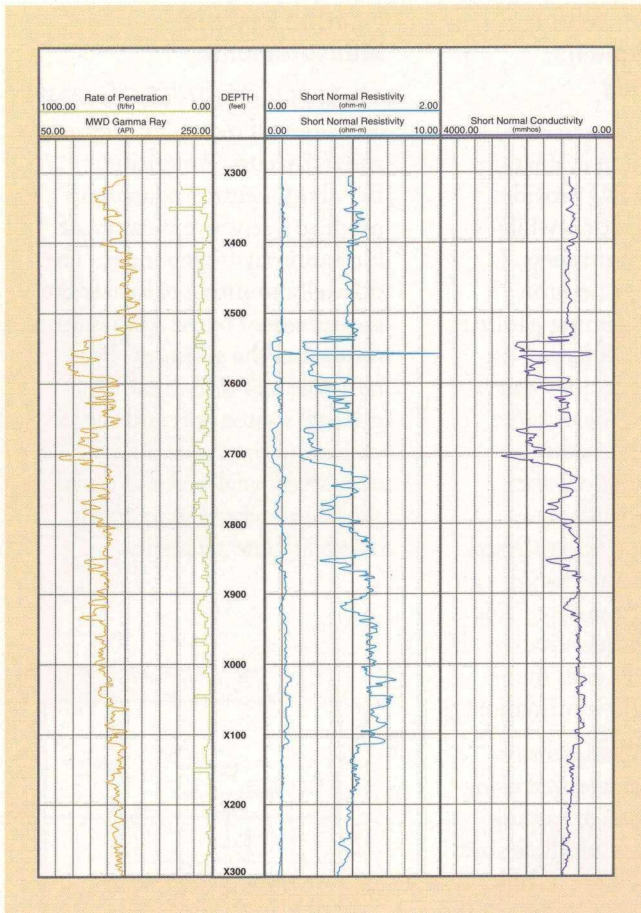
An extensive set of computer models has been developed to predict the response of Baker Hughes INTEQ FEMWD tools under a variety of conditions, allowing efficient design and testing, and accurate interpretation of tool responses. For example, the Mixed Bed Boundary Model calculates DPR II response as the tool crosses mixed geological beds, and allows investigation of the effects of drillstring, borehole and invaded zones on DPR II vertical resolution.

The Dipping Bed Model is used to calculate DPR II response and interpret DPR II logs when the tool crosses geologic boundaries at various angles. In horizontal drilling, where bed resistivities are often known in advance, the Dipping Bed Model can be used to predict what the DPR II log will look like when the well is drilled, allowing the customer to monitor the wellpath and recognize when the bit has entered the pay zone. In addition, post-well computer programs such as inversion enhancements, correct log responses for shoulder bed effects, greatly improving vertical resolution of the DPR II log.

Teleco RGD™: Resistivity-Gamma-Directional™

Combining natural formation gamma ray readings with 16" short normal resistivity measurements, the Teleco RGD tool provides information for real-time hydrocarbon detection. Because this tool logs the formation immediately after it has been drilled, and before appreciable mud filtrate invasion, the RGD tool can provide accurate values of formation resistivity (Rt) for qualitative formation evaluation in wells drilled with fresh water-based mud systems.

Together with pore pressure analysis, RGD measurements may indicate that casing points can be extended or casing strings avoided altogether, resulting in substantial cost savings. In addition, this same measurement/analysis combination can identify overbalanced conditions, allowing optimization of drilling rates, and enhancing kick detection for safer drilling.

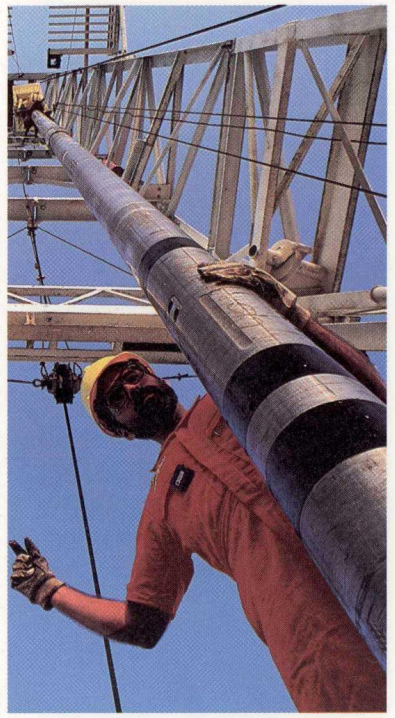


The RGD log measures natural formation gamma ray and short-normal resistivity in real-time for applications such as hydrocarbon detection, offset well correlation, and selection of casing and coring points .

Teleco DPR®II: Dual Propagation Resistivity

Precise quantitative resistivity readings along with formation gamma ray and directional data are available with the Teleco Dual Propagation Resistivity® II (DPR II) tool. DPR II calculates dual resistivity curves based on the phase difference and attenuation of a 2 mHz propagation wave. It is especially useful for thin-bed definition. The DPR II tool can be run in all mud types, including high salinity and oil-base muds. Data is available in real-time, and also is recorded in downhole memory for retrieval during bit trips.

Of the two resistivity values derived with the DPR II tool, the attenuation resistivity measurement provides a greater depth of investigation, while the phase difference resistivity measurement offers vertical resolution superior to wireline induction and the spherically focused measurements. The two depths of investigation, which permit tornado chart corrections, and the excellent vertical resolution of the DPR II tool, make it ideal for wireline replacement.



The versatileTeleco DPR II tool provides accurate, timely measurements of formation resistivity and natural formation gamma ray — plus directional data that lets you monitor wellbore position geologically for real-time decisions - an important factor in geosteering applications.