Reeves

Oilfield Services Catalogue

Introduction

Reeves Wireline Services provides open and cased hole logging and formation evaluation services to hydrocarbon and mineral resource companies around the world.

The **Oilfield Services Catalogue** describes the tools, surface systems and analysis software used in the exploration, appraisal and development of oil and gas resources. This edition has a new section devoted to **Compact** Services, and includes revised charge performance data from an expanded range of perforating services.

For interpretation charts, borehole environmental corrections and more information on response characteristics, see the **Oilfield Services Chart Book.** For a detailed account of the acquisition and processing of Reeves logs, see the **Calibration and Signal Processing Guide.**

The **Minerals Services Chart Book, Slim Tool Calibration Guide** and **Minerals Services Catalogue** contain additional information, related principally to non-oilfield tools and services.

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Conveyance Methods

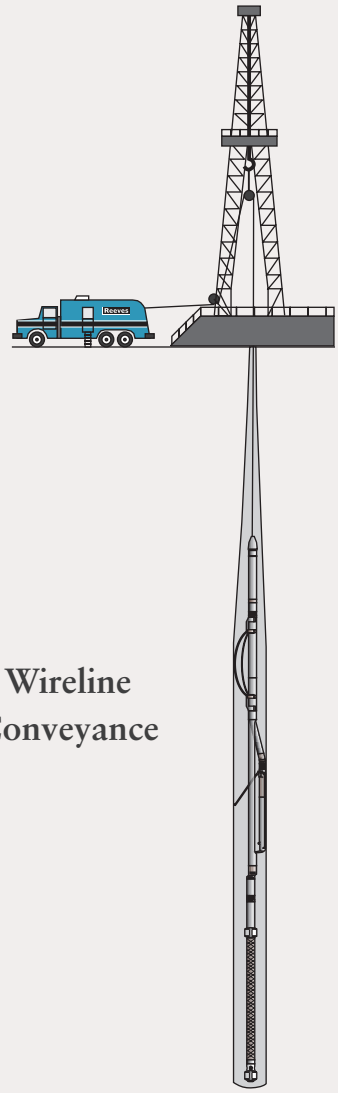
Wireline Conveyance

This is the normal conveyance method for wells up to about 60 degrees deviation.

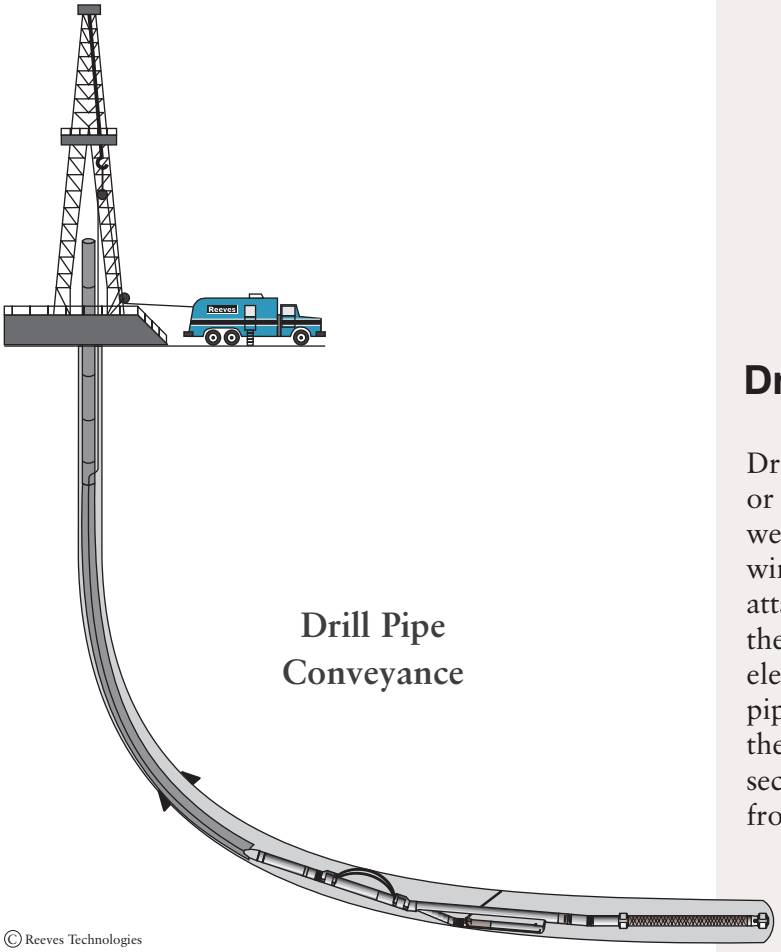
Stand Alone Logging Service (SALS)

SALS records and processes data from our conventionally-sized tools when run on third party cables, without the need to mobilize a full size logging unit.

It is a PC based acquisition system that interfaces to any monocore or multicore cable; it works with all production logging tools (including TDS), all Compact tools, and some conventionally-sized tools. It is used for logging on coiled tubing (when the acquisition equipment is installed inside the coiled tubing unit), and is a highly cost effective production logging solution. It can also be run with its own wireline in a lightweight logging unit appropriate for remote or environmentally sensitive locations, or for sites with restricted access.



Wireline Conveyance



Drill Pipe Conveyance

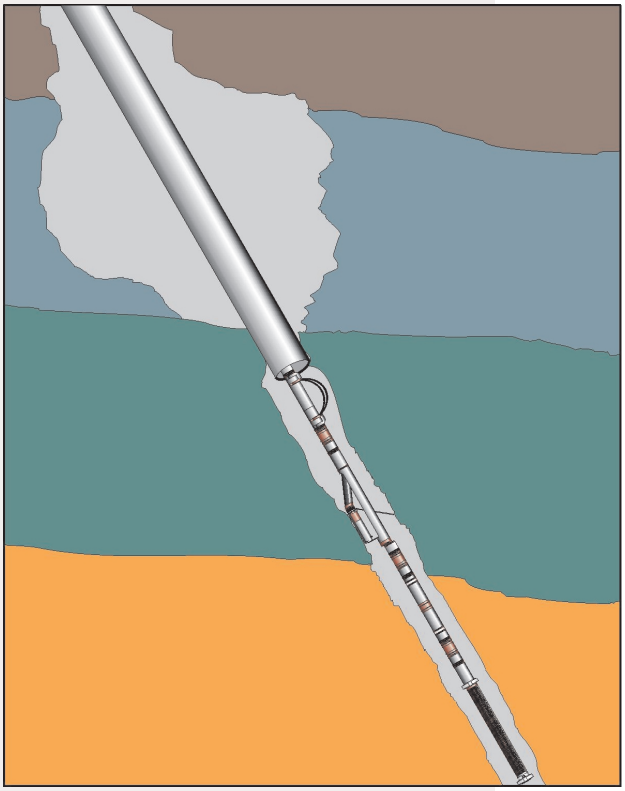
Drill Pipe Conveyance

Drill pipe conveyance is used in high angle or horizontal wells, and in washed-out wells where ledges prevent the passage of wireline conveyed tools. The tool string is attached to drill pipe placed at the end of the zone of interest. The wireline and electrical connector are pumped down the pipe and mated to a connector at the top of the tool string. Data are acquired in sections as each stand of pipe is removed from the well.

Conveyance Methods

Coiled Tubing Conveyance

This is a fast alternative to drill pipe conveyance in highly deviated and horizontal wells, being particularly appropriate in wells drilled on coiled tubing, or where a CT unit is already providing other well services. CT units with integral wireline allow surface recording of data; logs can be run on standard CT units without wireline with the **Compact Memory Logging (CML)** service.



Slimline Express Conveyance

Normal methods can fail in wells with extreme caving. The Slimline Express service places drill pipe past the obstructed interval before winching or pumping Compact format tools through the pipe into open hole. This method retrieves quality data in circumstances which have previously resulted in no data recovery.

Conveyance Methods - Compact Memory Logging

Compact Memory Logging (CML) needs no wireline, winch or logging unit, and is the starting point for a new generation of conveyance methods. It uses **Compact** tool strings powered by downhole battery packs, with data recorded to high capacity memory chips in a downhole memory sub. A single 2.4 m (7.8 ft) long battery sub powers the **Compact** triple combo for 18 hours. The new conveyance methods offer significant time savings.

Drill Pipe Conveyed CML

Drill pipe conveyed CML is an alternative to conventional drill pipe conveyance in many difficult hole or high angle well scenarios.

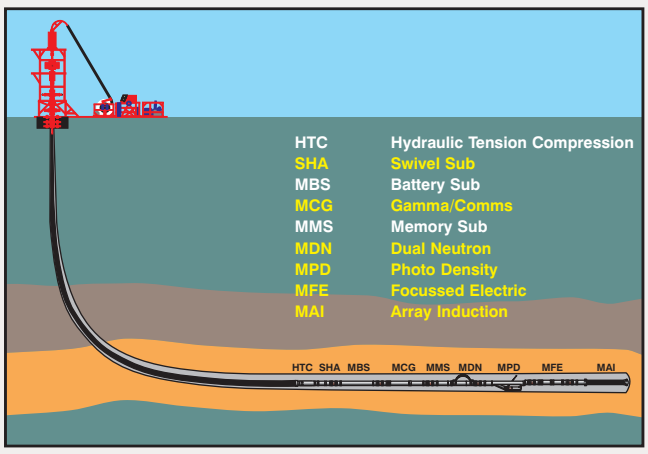
It benefits from operational simplicity and speed, and completely eliminates the risks associated with cable damage and failed wet connections. It augments and/or provides an attractive alternative to LWD in wells where data quality is critical.

The speed advantage is significant. With no side entry sub or wireline to consider, the drill pipe and CML tool string are run more rapidly into and out of the well, and no time is spent pumping a wet connect. Surface indication of downhole tension and compression is provided by the **Hydraulic Tension Compression (HTC)** sub which communicates via changes in mud pressure, and contains a damper to cushion the tools.

Coiled Tubing Without Wireline

Because CML tools need no wireline, they can be used with any coiled tubing unit, dramatically reducing the cost of acquiring data in many horizontal and re-entry style wells. And because the tools have a low coefficient of friction, they are more likely to reach bottom hole.

The mud pressure operated Hydraulic Tension Compression (HTC) device replaces the conventional TCS in these operations. Cement Bond Logs can be run in tandem with other CT services to eliminate the time associated with conventional CBL logging jobs.



Land Service Unit - LSU

Land Service Units are fully self-contained wireline logging units with integral generator, **Computer Graphics Unit (CGU)**, winch and sonde compartments. Dual or triple air conditioning systems allow operation in diverse environments.

The LSU's prime mover provides electrical power, and power for the hydraulic logging winch. A typical drum holds 5800 m (19000 ft) of $^{3}/_{8}$ in (9.53 mm) 3 core cable or $^{7}/_{16}$ in (10.82 mm) 7 core cable.

Sonde power and communications, up-hole data handling and log preparation are handled by the CGU's triple computer system. Fast thermal plotters provide hard copy logs to supplement the digital logs.

Physical Dimensions (typical)

Length	10.67 m (35.0 ft)
Width	2.44 m (8.0 ft)
Height	3.35 m (11.0 ft)
Weight	18.4 tonnes (18.1 tons)

Compact Logging Unit - CLU

The **Compact Logging Unit** is a small footprint vehicle developed for operations with **Compact** logging equipment. Reduced tool dimensions, lower cable weights, and a PC based acquisition system make for a smaller, lighter vehicle, with consequential logistical and environmental benefits, most notably for congested and environmentally sensitive locations.

The acquisition and processing software handles all aspects of calibration, data capture, presentation, analysis and transmission. Each tool has an unique digital code cross referenced to a properties database that simplifies tool string configuration, and helps verify performance.

The multi-tasking 32-bit operating system has a familiar graphical interface which is easy to use, and which improves operational efficiency - for example, by performing simultaneous satellite data transmission or evaluation on data from one run, whilst data are acquired from another.

Wellsite results are produced by the **PetroSolve** analysis product from environmentally corrected data.

Offshore Tool House - OTH

The **Offshore Tool House (OTH)** is a fully equipped heavy duty workshop and ancillary equipment storage facility. It is designed for use in hazardous areas and has full Zone 2 and A60 ratings.

The tool house provides all the facilities and can store all the spares necessary for field crews to carry out all routine operations, maintenance, gun loading and repairs whilst off-shore or remote from the local operating base. It accepts 440 volt, 3 phase AC electric power and 110/150 psi (760/1030 kPa) compressed air services.

- *Built to Zone 2 (BS 5345 Pt. 1) and other offshore standards*
- *Constructed to A60 fire ratings*

Physical Dimensions

Length	7.30 m (24.0 ft)
Width	2.44 m (8.0 ft)
Height	2.69 m (8.8 ft)
Weight (tare)	8.0 tonnes (7.9 tons)
(max. gross)	13.0 tonnes (12.8 tons)

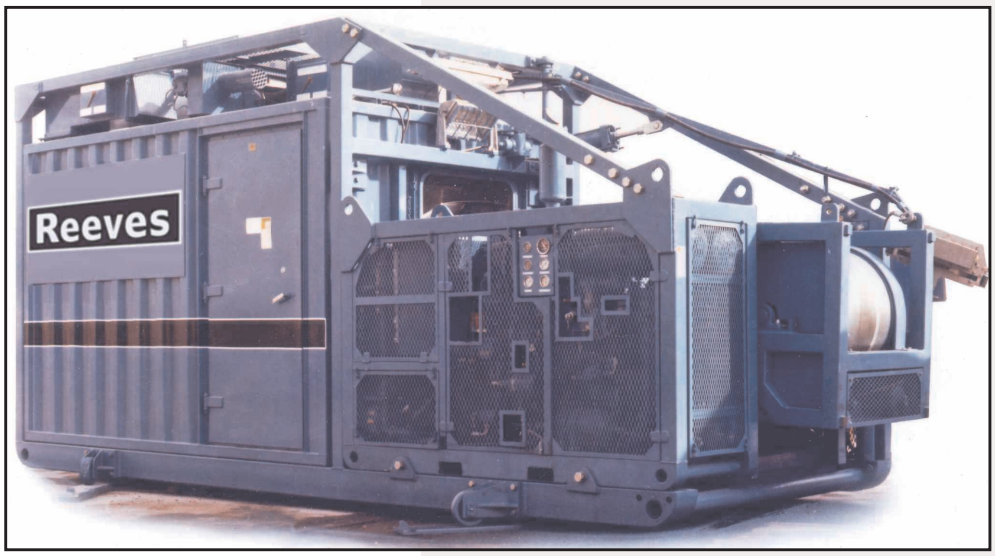
Offshore Service Unit - OSU

Offshore Service Units (OSU) are built to operate in the most challenging offshore environments. They are extremely robust and conform to stringent health and safety requirements.

The Zone 2 rated diesel unit provides power for the hydraulic generator and logging winches. Up to 7620 m (25000 ft) of $^{7}/_{16}$ in (10.82 mm) 7 core cable is carried on the primary winch whilst the secondary production logging winch accommodates 7300 m (24000 ft) of $^{7}/_{32}$ in (5.66 mm) mono-core cable. The generator also powers all OSU electrical equipment.

Data acquisition and analysis are performed by two independent Computer Graphics Units (CGU). This dual processing capability allows simultaneous logging and data transmission, and provides complete redundancy of computer systems.

- *Built to Zone 2 (BS 5345 Pt. 1) and other offshore standards*
- *Logging cabin rated to A60 fire requirements*
- *Certification from Lloyds and DNV*



- Full oilfield capability
- Comprehensive wellsite processing, analysis and presentation
- Log data transmission to any destination
- Dual air conditioning units
- Zone 2 rated diesel providing hydraulic power for the winches and generator
- Secondary production winch
- Duplication of CGU systems for complete redundancy
- Double encoder depth system

Physical Dimensions

Length	6.25 m (20.5 ft) 7.37 m (24.2 ft) (with production winch)
Width	2.44 m (8.0 ft)
Height	3.00 m (9.8 ft)
Weight (tare)	8.0 tonnes (7.9 tons)
(max. gross)	17.0 tonnes (16.7 tons)

Tool Combinability

All conventional and new generation **Compact** (M-Series) tools offer high levels of combinability and short string lengths. This means fewer runs in the hole, more operational flexibility, and reduced rathole drilling, which in turn means lower cost.

For example, the **Compact** triple combo of **Array Induction / PhotoDensity / Compensated Neutron** is just 8.81 m (28.9 ft) long. Even the conventional triple combo measures just 11.46 m (37.6 ft) including SFE, Hole Finder and Gamma Ray from the AIS. The super stack of **Array Induction-SFE / PhotoDensity / Compensated Neutron / Spectral Gamma Ray / Compensated Sonic / Microlaterolog** measures just 24.9 m (81.7 ft) from Hole Finder to top measure point.

Stack lengths are short. The table shows some common combinations. Many other options are possible.

The table shows bottom of tool to top measure point lengths for some other popular combinations. They include Hole Finder, and the ancillary equipment needed to ensure optimum performance from tools with differing eccentralisation requirements. All include Gamma Ray and can be run with a **Tension Compression Sub (TCS).**

Combination	Length (with ancillaries)	
	m	ft
AIS / CSS	10.36	34.0
AIS / PDS / CNS / TAC	15.99	52.5
MAI-MFE /MPD / MDN /MTC	13.62	44.7
AIS / PDS / CNS / CSS	17.81	58.4
AIS / PDS / CNS / LCS / TAC	23.86	78.3
DLS / MLS / LCS	12.66	41.5
DLS / MLS / PDS / CNS	13.39	43.9
DLS / MLS / PDS / CNS / LCS	18.95	62.2

Repeat Formation Samplers and some conventional high data rate tools (Dipmeters, Acoustic Scanning Tools and Sonic tools operating in waveform mode) do not normally acquire data in combination, but can be combined in a stack which collects data in two passes without tripping out of the well.

Oilfield Services Catalogue

Compact *Services*

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Compact Array Induction/Resistivity - MAI/MFE

The **Compact Array Induction** is an advanced version of our conventionally sized tool in a package just 3.3 m (10.8 ft) long and 57 mm (2.25 inches) diameter. It combines unique operational versatility with superior measurement technology that covers a broad range of mud salinities and well diameters.

Raw data from multiple sub-arrays are combined vertically and radially with environment-dependent processing to produce 8 depths of investigation, from the shallow penetration Apparent Rxo to the very deep Apparent Rt. These can be visualised as invasion profile or radial saturation images, the latter using an additional independent porosity log.

Traditional Deep and Medium curves are available for backwards compatibility. Apparent Rxo substitutes for guard log resistivity in non-conductive muds or when there is no MFE tool. VECTAR© processing enhances resolution by matching all vertical responses to that of the shortest sub-array.

The **High Resolution Shallow Focussed Electric (MFE)** tool is an Rxo-sensitive mandrel device that combines excellent vertical resolution with high immunity to borehole wall rugosity. The output (FE) curve has an ultimate resolution of 100 mm (4 inches) with 25 mm (1 inch) sampling, and can be resolution matched to the induction. Generally run with the MAI, but also combinable with other Compact tools.

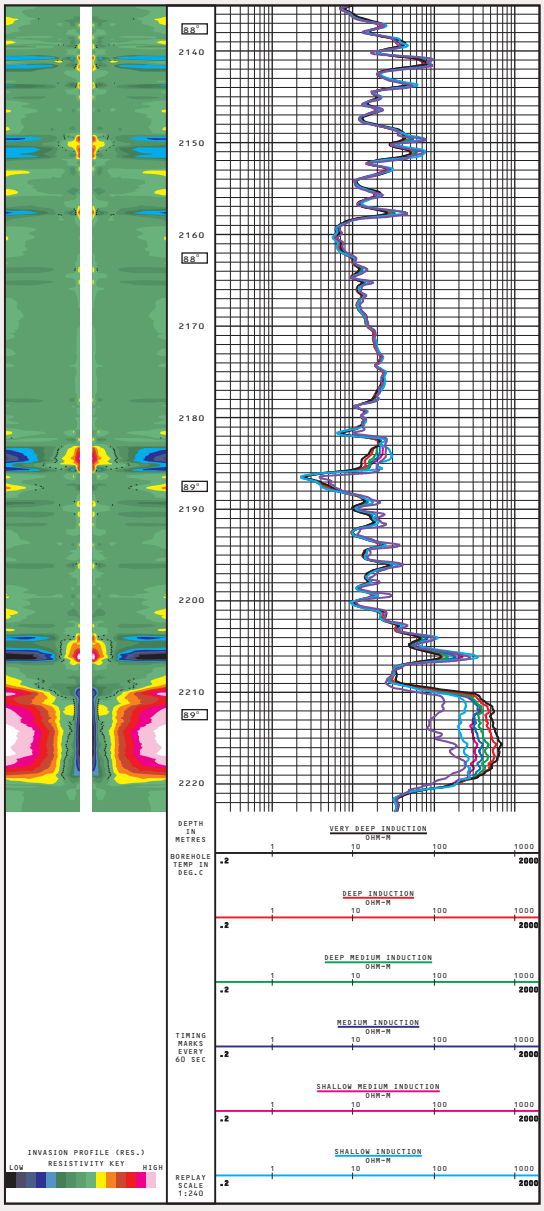
- *Multi-penetration conductivity for invasion profiling and moveable oil detection*
- *High resolution Rxo with immunity to rugosity-induced noise*
- *Operates with all conveyance methods*

Measurements

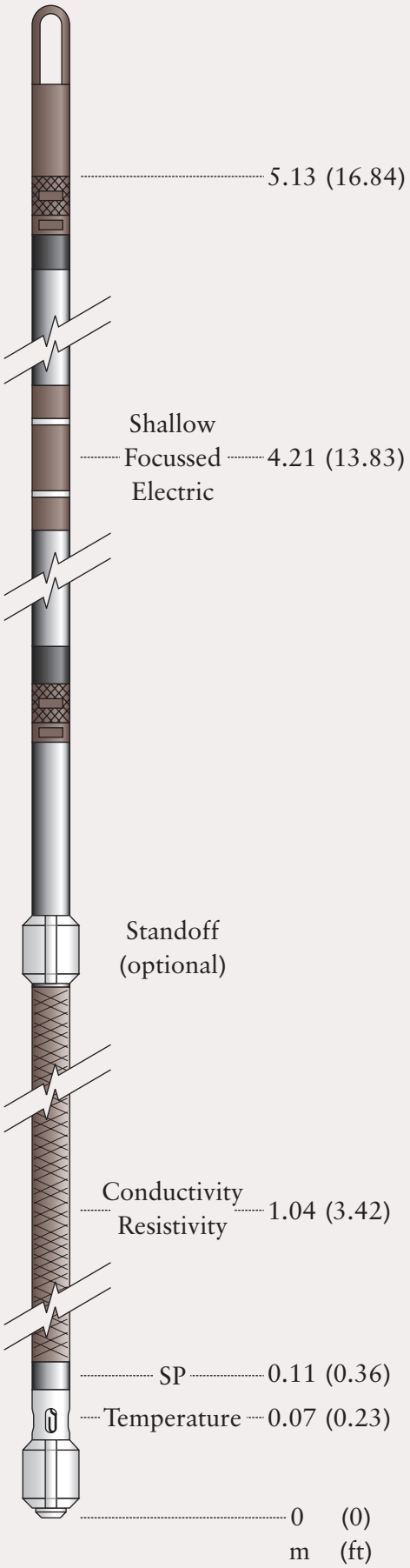
- Multi-penetration conductivity
- Shallow Resistivity (from MFE)
- SP and Temperature

Applications

- Saturation and porosity
- Invasion profiling
- Thin bed processing
- Out-of-pipe logging
- Logging high dogleg severity wells



Compact Array Induction/Resistivity - MAI/MFE



Physical Dimensions

Length	MFE/MAI	5.13 m (16.84 ft)
	MFE	1.84 m (6.04 ft)
	MAI	3.29 m (10.80 ft)
Diameter	57 mm (2.25 in)	
Weight (in air)	MFE/MAI	43.5 Kg (96 lb)
	MFE	22 Kg (49 lb)
	MAI	21.5 Kg (47 lb)

Ratings

Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter	70 to 400 mm (2.75 to 15.75 in)

Curve Parameters

Range	MFE	0.2 to 2000 Ωm
	MAI	0 to 10 S/m (∞ to 0.1 Ωm)
Resolution	MFE	better than 0.05 %
	MAI	0.00025 S/m
Vertical Resolution	MFE	0.1 m (0.3 ft)
	MAI	1.0 m (3.3 ft) in VECTAR© mode and Rt > 200 Ωm

Depth of Investigation (median radial)

For Rxo = Rt and Rt > 100 Ωm :

MFE	0.38 m (15 in)
MAI	0.3 to 1.2 m (12 to 47 in)

Compact Dual Laterolog Sonde - MDL

The **Compact Dual Laterolog** is the resistivity tool of choice in wells drilled with saline muds.

Its unique design provides individually optimised Deep and Shallow penetration curves that share a common 2 ft (0.6 m) vertical resolution (resolution sharing helps avoid anomalous bed boundary effects on interpreted logs). Optimized electrode geometry and digital measurement sequence control give the tool excellent environmental performance over a wide range of mud resistivities and hole sizes, and virtually eliminate electrode polarisation effects. The addition of a continuous Rm measurement further increases the accuracy of the logs.

The voltage reference and simultaneous SP electrodes are incorporated into a stiff bridle at the top of the tool string. Stiff bridles give optimum reliability, and the Cableless Logging variant allows the MDL to be run without a wireline.

The Groningen curve is used with the Deep measurement to detect anomalous responses as the tool approaches non-conductive formations such as salt caps.

MDL tools are normally run with the Rxo sensitive **Compact Microlog (MML)** or **Microlaterolog (MMR)** tools, allowing determination of the uninvaded zone resistivity Rt.

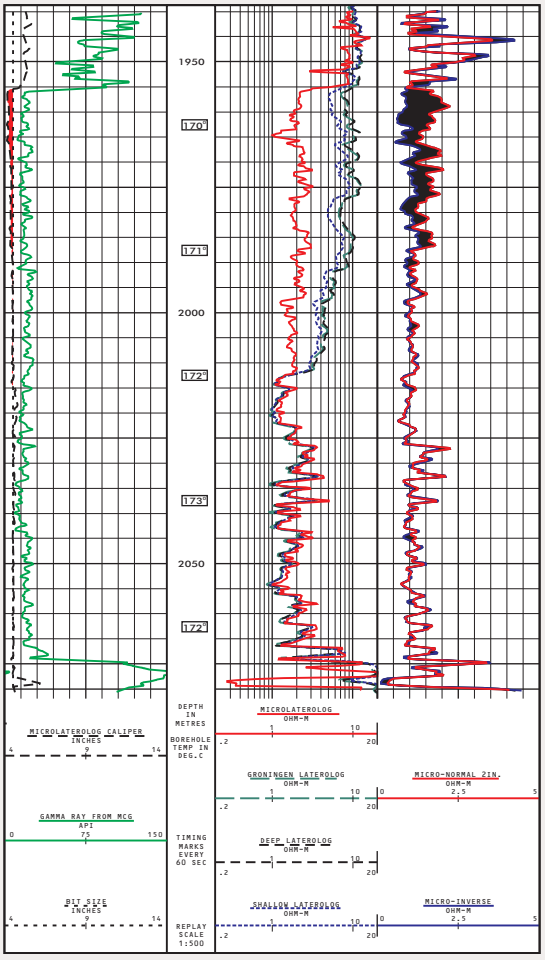
Measurements

- Deep and Shallow resistivities
- Groningen resistivity
- Rm
- SP

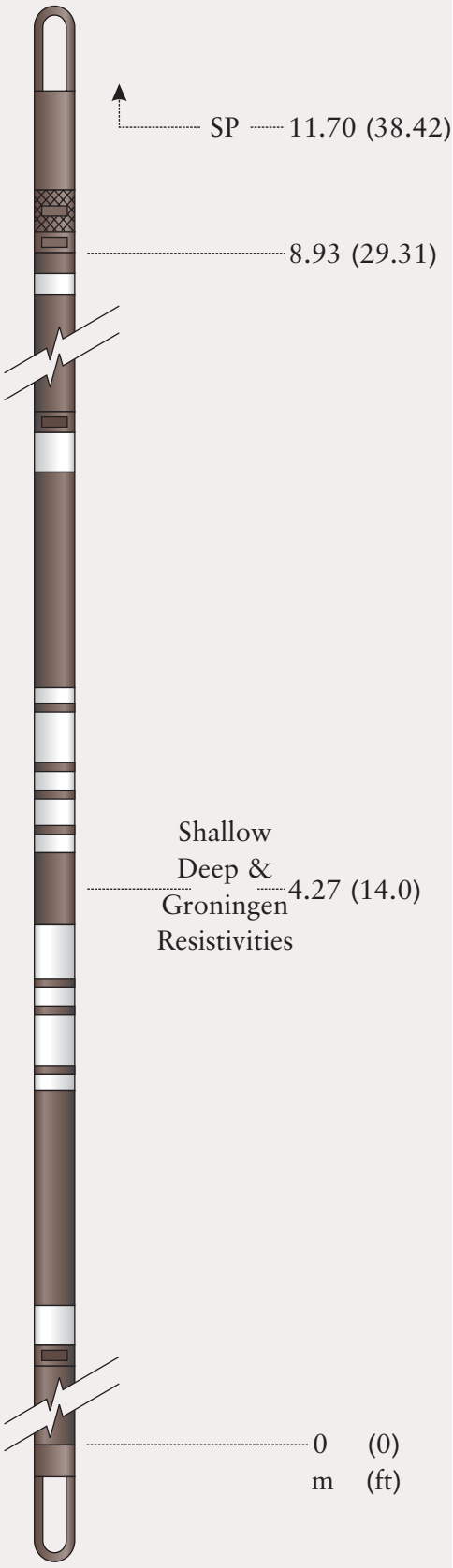
Applications

- Saturation determination
- Porosity
- Permeability

- *Deep and Shallow penetration with common 2 ft (0.6 m) resolution*
- *Continuous Rm curve helps optimise hole corrections*
- *Ultra-wide Rm and hole size operating envelope*



Compact Dual Laterolog Sonde - MDL



Physical Dimensions

Length	8.93 m (29.31 ft)
Diameter	57 mm (2.25 in)
Weight (in air)	95 Kg (109 lb)

Ratings

Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter	70 to 400 mm (2.75 to 15.75 in)

Curve Parameters

Range	0.1 to 40,000 Ωm
Resolution	1 % of measured value
Vertical Resolution	0.6 m (2 ft)
Depth of Investigation (median radial)	
	For Rxo=Rt and Rt > 100 Ωm :
	Deep Laterolog 1.27 m (50 in)
	Groningen 1.27 m (50 in)
	Shallow 0.41 m (16 in)

Compact MicroLog & Microlaterolog - MML & MMR

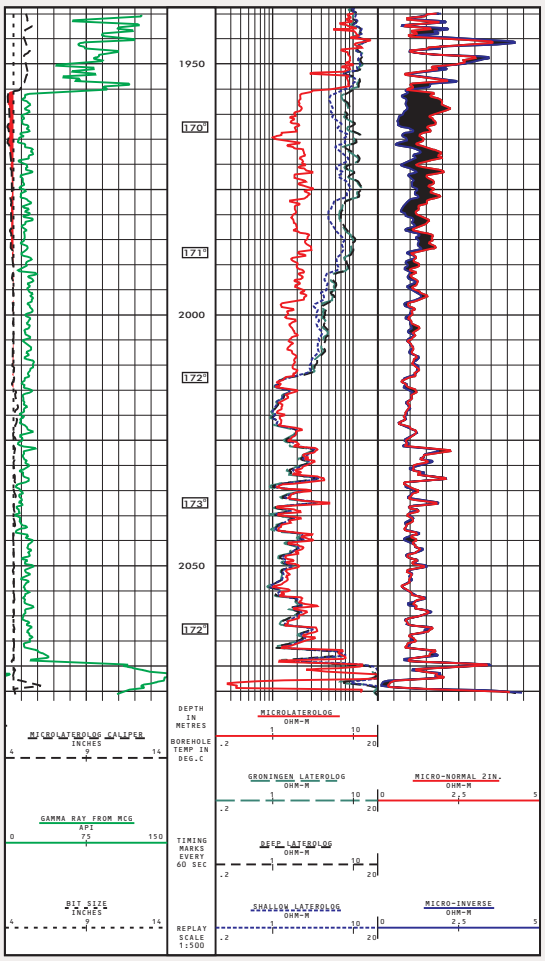
The **Compact MicroLog (MML) and Compact Microlaterolog (MMR)** make high resolution shallow penetration resistivity measurements, each from a single conformable pad held against the borehole wall by a sturdy caliper mechanism. The tools differ only in the type of pad used - they are interchangeable, and the tools may be stacked if both sets of measurements are required.

The MML provides **Micro Normal** and **Micro Inverse** curves; the combination is highly sensitive to mudcake thickness, making it an important permeability indicator.

The MMR **Microlaterolog** measurement is made with a focussed current beam that penetrates mud cake, making it sensitive to Rxo. This is used to correct the Deep penetration curve from the **Compact Dual Laterolog (MDL)**, and in the detection of moveable hydrocarbons via computation of the flushed zone saturation Sxo.

The electrode configuration within each pad matches that used in conventionally-sized tools, giving almost identical response characteristics. However, the smaller diameter of the tool body extends the operating envelope into smaller diameter wells.

- *High resolution Rxo, and permeability indication*
- *Self-combinable, or with Dual Laterolog and Array Induction tools*
- *2.5 cm (1 inch) depth sampling option*



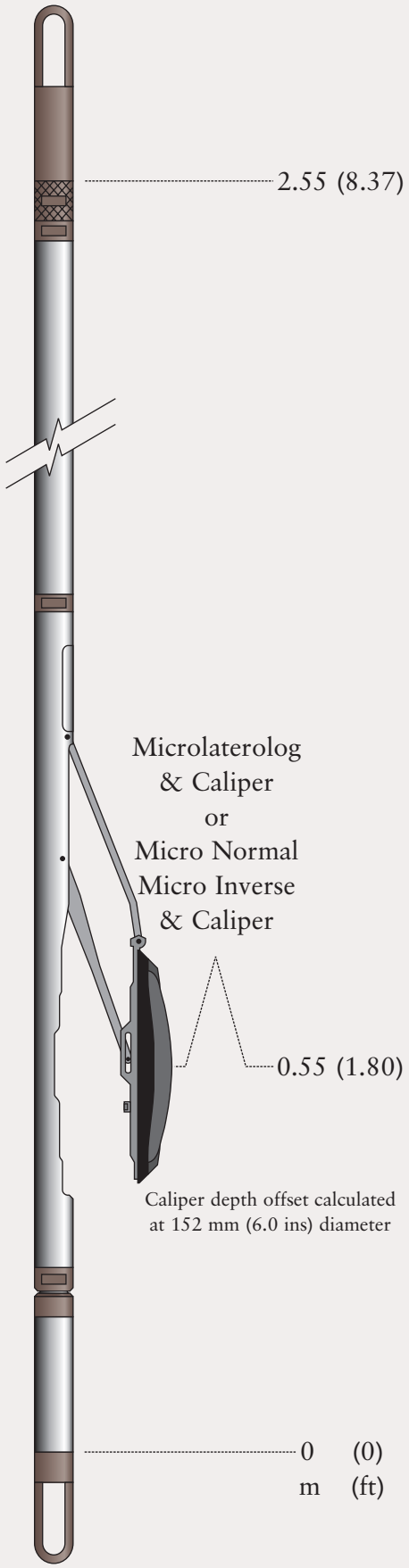
Measurements

- Micro Normal (from MML)
- Micro Inverse (from MML)
- Microlaterolog (from MMR)
- Caliper

Applications

- Invaded zone resistivity, Rxo
- Invasion correction for Rt
- Permeability indication
- Moveable hydrocarbons
- High resolution logging

Compact MicroLog & Microlaterolog - MML & MMR



Physical Dimensions

Length	2.55 m (8.37 ft)
	2.40 m (7.86 ft) for MML.A only
Diameter	125 mm (4.9 in)
Weight (in air)	32 Kg (71 lb)

Ratings

Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter	140 to 340 mm (5.5 to 13.5 in)

Curve Parameters

Range	Microlaterolog	0.2 to 2000 Ωm
	Microlog	0.2 to 200 Ωm
Resolution	1 % of measured value	
Vertical Resolution	50 mm (2.0 in) at 40 samples / metre	
Depth of Investigation (median radial)		
	Microlaterolog	80 mm (3.1 in)
	Micro Normal	12 mm (0.5 in)
	Micro Inverse	25 mm (1.0 in)

Compact PhotoDensity Sonde - MPD

The **Compact PhotoDensity** is an advanced Density, Caliper and Photoelectric (Pe) tool for lithology and density determinations in conventional and ultra-slim wells. Small diameter and short length give unrivalled dogleg capability and reduce rathole drilling.

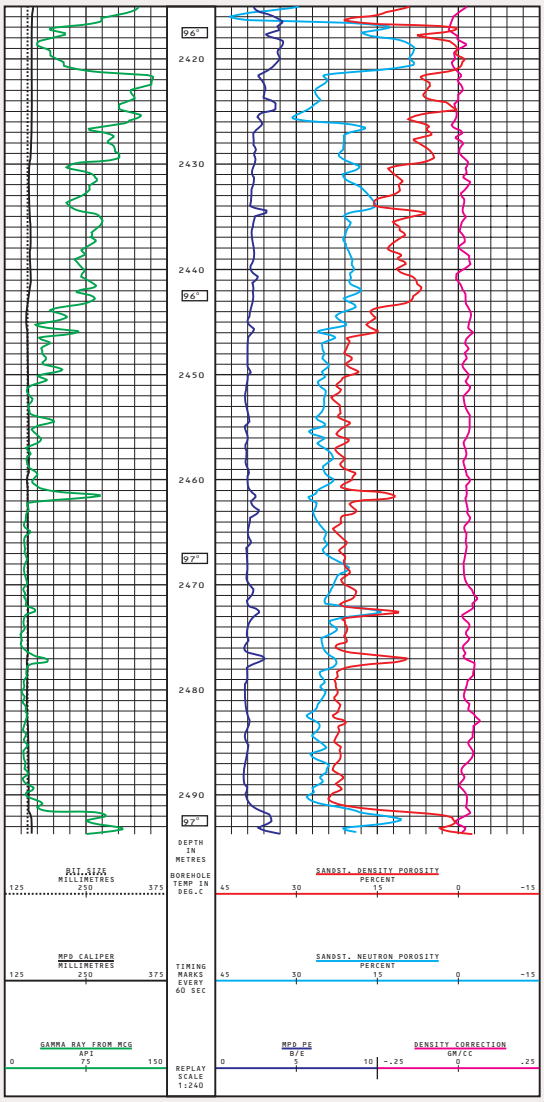
At the heart of an innovative design is the articulated shoe containing the entire Density and Pe detection and processing system. Unique in a tool of this diameter, it allows the shoe to maintain contact with formations over caved intervals, and eliminates gross errors typical of mandrel tools in these conditions.

The short spaced Pe has excellent statistical precision, and because low energy radiation originates close to the detector, it has superior vertical resolution.

The highly optimised shoe has smaller borehole size corrections than many conventional tools. Unlike larger tools, however, the MPD will pass through restrictions as small as 63 mm (2.5 in), allowing conveyance into open hole inside thick-walled drill pipe positioned below severe hole conditions. This out-of-pipe logging is extremely cost-effective where severe conditions are encountered.

A connector at the bottom of the tool can be rotated 180^0 to provide 13 mm (0.5 in) of standoff to tools below. It is normally used to ecccentralise an induction, and eliminates an inter-tool crank.

- *Compensated Density and high precision Pe*
- *Highly optimised for reduced borehole effect*
- *Articulated shoe maintains log quality in caved intervals*
- *Out-of-Pipe logging past bad hole conditions*



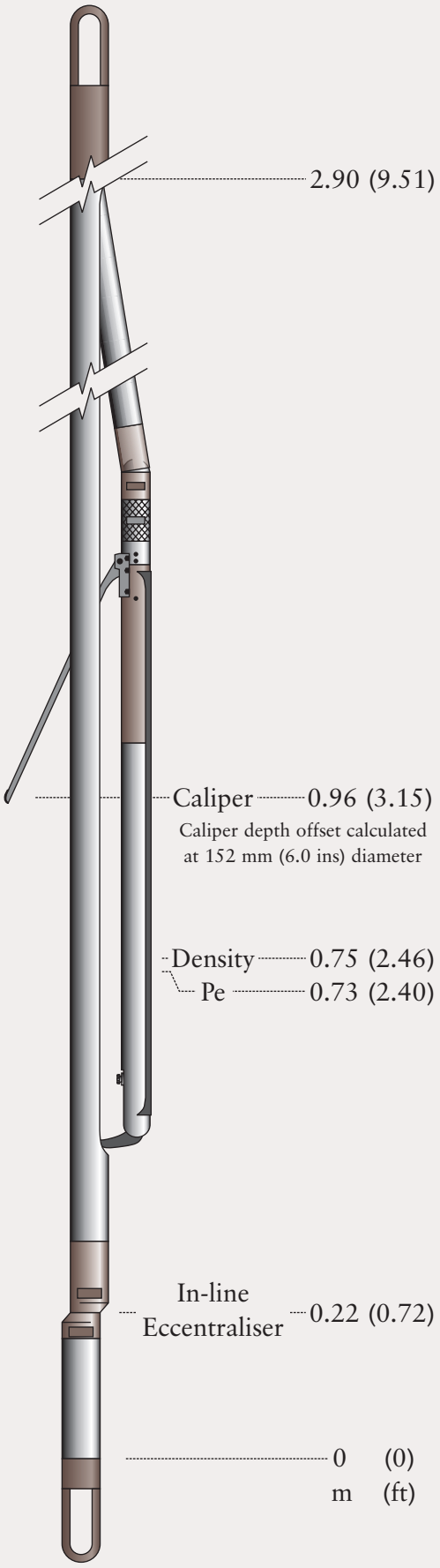
Measurements

- Near and Far Spaced Densities
- Compensated Density
- Degree of Compensation
- Photoelectric (Pe) curve
- Caliper and Hole Volume

Applications

- Porosity and Lithology in slim and conventional wells
- Out-of-Pipe logging past severe hole conditions
- Logging high dogleg severity wells

Compact PhotoDensity Sonde - MPD



Physical Dimensions

Length	2.90 m (9.51 ft)
Diameter	57 mm (2.25 in)
Weight (in air)	41 Kg (90 lb)

Ratings

Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter	70 to 400 mm (2.75 to 15.75 in) (63 mm (2.5 in) minimum inside drill pipe)

Curve Parameters

Range	Density	1200 to 3000 Kg/m^3 (1.2 to 3.0 gm/cm^3)
	Pe	0 to 10 barns/electron
Resolution	Density	1 Kg/m^3 (0.001 gm/cm^3)
	Pe	< 0.05 barns/electron
Vertical Resolution	Density	370 mm (14.6 in) in standard mode 150 mm (5.9 in) in VECTAR© mode
	Pe	200 mm
Depth of Investigation (radial, for 90 % signal)		
	Density	100 mm (3.9 in) at 2300 Kg/m^3 (2.3 gm/cm^3)

Compact Dual Neutron Sonde - MDN

Compact Dual Neutron tools provide porosity measurements in a uniquely wide range of well styles. They are fully characterised for air- and mud-filled environments, and fully combinable with other Compact format tools.

MDN tools benefit from the latest advances in modelling and detector technologies. This means they deliver excellent porosity sensitivity with a 65 % reduction in source activity, and consequential safety and transportation benefits. Simultaneous minimisation of environmental sensitivity means that borehole size corrections, for example, are smaller than for our conventionally sized tools. Full environmental corrections are applied automatically during acquisition.

Porosity is recorded simultaneously in apparent limestone, sandstone and dolomite porosity units. Enhanced resolution processing is available for high sample rate data.

The MDN is normally run with a V-bowspring. This is a double spring eccentraliser to force the tool against the borehole wall for maximum porosity sensitivity. In oval section wells it keeps the density tool (normally below the MDN) aligned along the short axis.

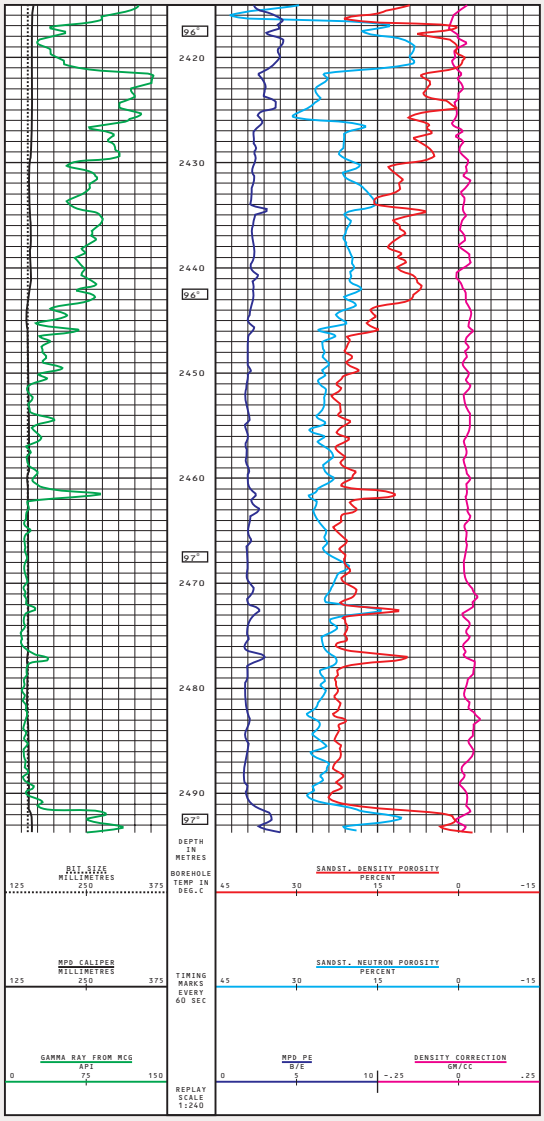
- *High sensitivity porosity measurements for conventional operations, high dogleg severity and out-of-pipe logging*
- *Reduced source activity*
- *Enhanced resolution option*

Measurements

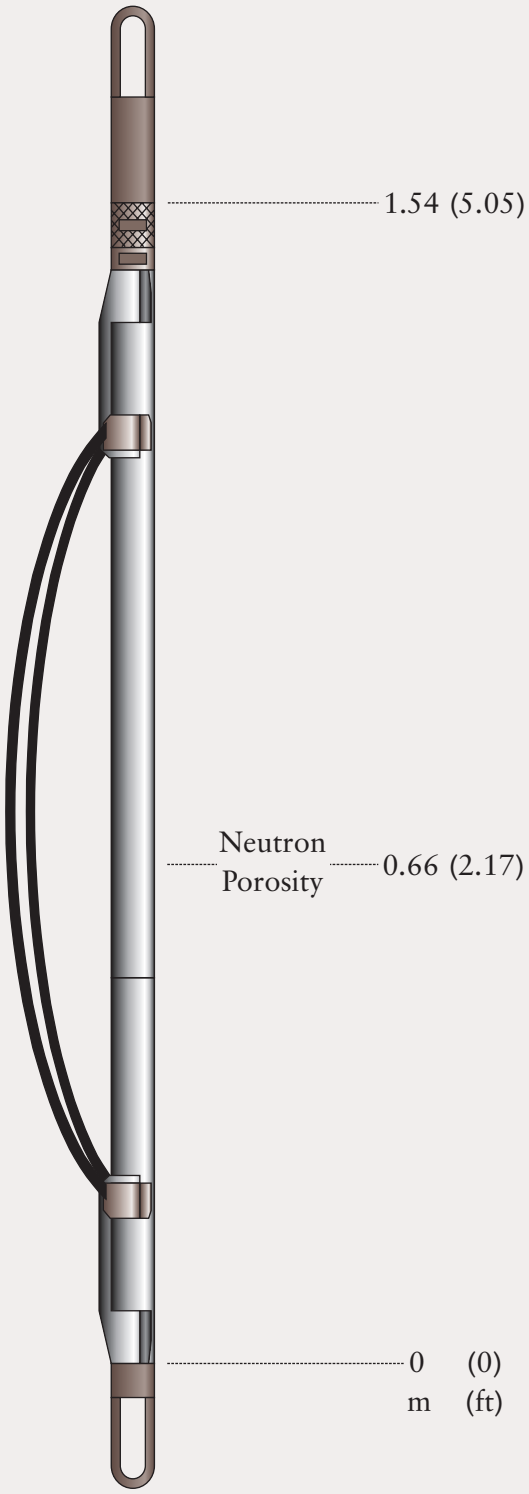
- Apparent Limestone, Sandstone and Dolomite Porosities

Applications

- Porosity and Lithology
- Gas identification (in conjunction with density porosity)
- Out-of-Pipe logging past severe hole conditions
- Logging high dogleg severity wells



Compact Dual Neutron Sonde - MDN



Physical Dimensions

Length	1.54 m (5.05 ft)
Diameter	57 mm (2.25 in)
Weight (in air)	23 Kg (51 lb)

Ratings

Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter	70 to 400 mm (2.75 to 15.75 in) in mud-filled wells (63 mm (2.5 in) minimum inside drill pipe)

Curve Parameters

Range	-3 to 100 limestone porosity units
Resolution	better than 0.05 at 20 p.u. and standard conditions
Vertical Resolution	610 mm (24 in) in standard mode 410 mm (16 in) in VECTAR© mode
Depth of Investigation (radial, for 90 % signal)	260 mm (10.2 in) at 20 p.u.

Compact Gamma - MCG & MGS

The **Compact Comms Gamma** tool (**MCG**) combines Gamma Ray, Temperature and CCL logs with power conversion and surface communications for all other measurements in a Compact tool string. It is always the top tool the string. The **Auxiliary Gamma Sub** (**MGS**) is shorter and can be placed anywhere in the string, allowing Gamma Ray and Temperature to be recorded close to the bottom of the well.

Gamma Ray quality matches or exceeds that from our conventionally-sized tools with more counts per API unit and excellent repeatability. A wrap-around calibrator simulates downhole fluxes for optimum calibration accuracy.

An integral power conditioner in the MCG automatically converts a wide range of cable head voltages to a standard value for all tools in the Compact string. This adds to system flexibility and reliability by eliminating the need to match surface power to particular logging cables. It also reduces rig up time when using third party wirelines, for example during coiled tubing operations.

The MCG also processes data from the following auxiliary measurements : SP originating from Induction (MAI) and Laterolog (MDL) tools, Tension from the Compact Tension Cable Head (MCB), Tension and Compression from Tension Compression Sub (TCS), Temperature and CCL.

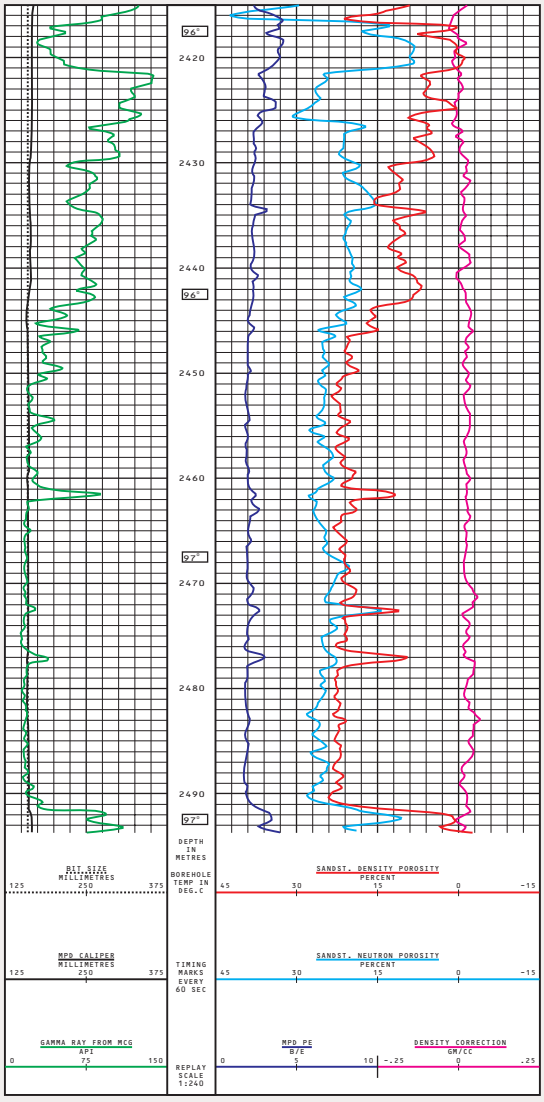
- *High precision Gamma Ray*
- *Power converter provides automatic matching to most logging cables*
- *CCL, Temperature and auxiliary measurement processing*

Measurements

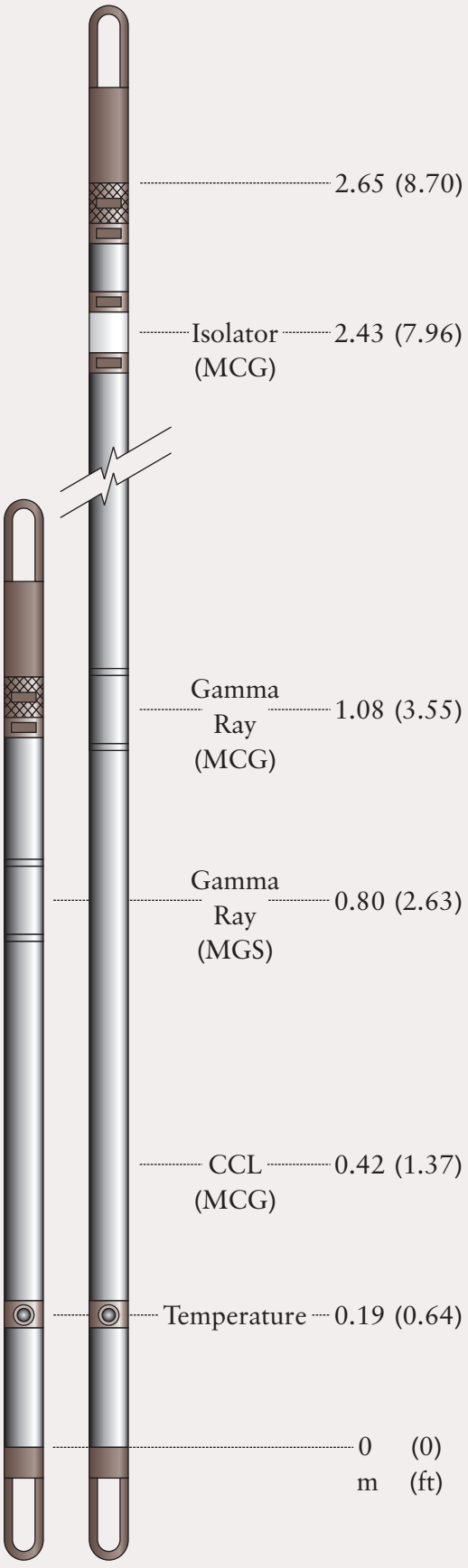
- Gamma Ray
- CCL (MCG only)
- Borehole Temperature

Applications

- Lithology analysis
- Correlation
- Temperature profile
- Cable matching (MCG only)
- (MCG is mandatory in all Compact tool strings)



Compact Gamma - MCG & MGS



Physical Dimensions

Length	2.65 m (8.70 ft) - MCG 1.04 m (3.41 ft) - MGS
Diameter	57 mm (2.25 in)
Weight (in air)	29 Kg (64 lb) - MCG 11 Kg (24 lb) - MGS

Ratings

Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter	70 to 400 mm (2.75 to 15.75 in)

Curve Parameters

Range	Gamma Ray	0 to no practical limit
	Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Resolution	Gamma Ray	0.7 API (typical)
	Temperature	0.02^0 C (0.03^0 F)

Compact Sonic Sonde - MSS

The MSS measures formation compressional slowness (inverse velocity) at five spacings with 1 and 2 foot vertical resolution. In CBL mode it records a 5 foot waveform and 3 and 5 foot amplitude logs from which attenuation can be generated directly (not all tools support this mode).

Data quality is maintained at very high levels over a broad range of environmental conditions thanks to a combination of high transmitter output, real time despiking and cycle stretch compensation. The latter gives improved accuracy and consistency by adjusting transit times based on information about waveform shapes close to the first arrivals.

Unlike traditional 3 ft-5 ft sonic tools, the MSS uses a single sided array with depth-derived cave compensation and tilt correction. This, together with a very short electronics package, makes the tool unusually short and light.

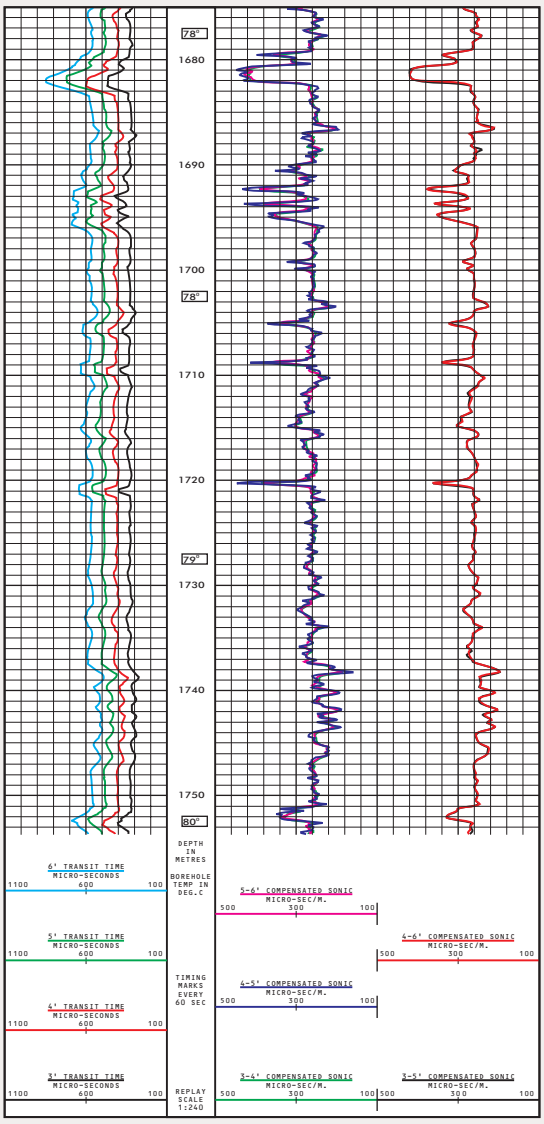
Measurements

- 3 ft-4 ft compensated Δt
- 3 ft-5 ft compensated Δt
- 4 ft-5 ft compensated Δt
- 4 ft-6 ft compensated Δt
- 5 ft-6 ft compensated Δt
- CBL amplitudes and waveforms

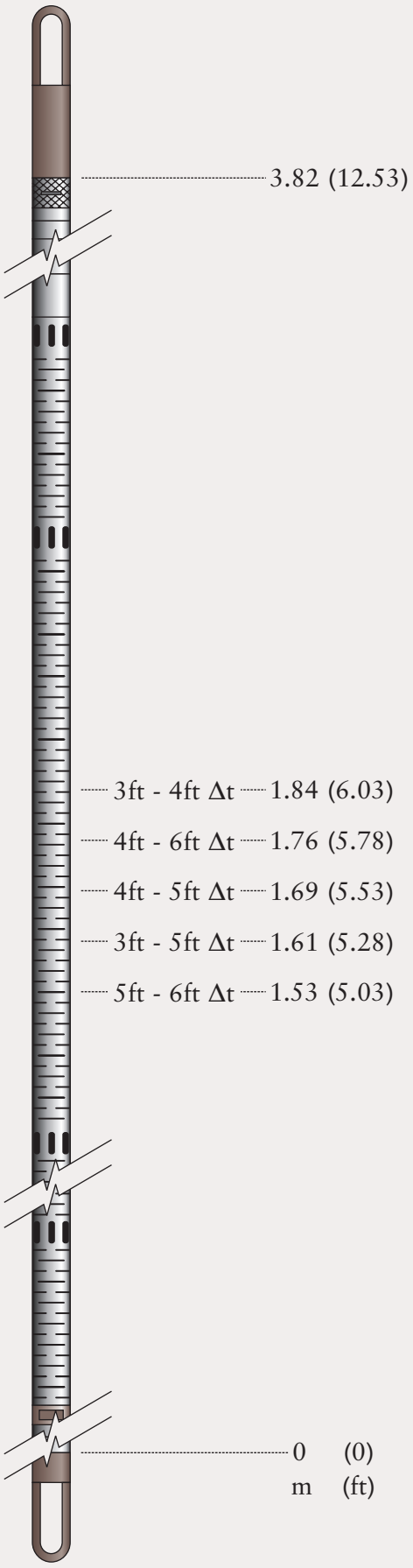
Applications

- Porosity and lithology
- Time to depth conversion
- Cement bond quality (CBL mode)

- *Compensated Δt measurements at multiple spacings*
- *CBL attenuation data derived directly*
- *Powerful transmitter, real time despiking and cycle stretch compensation*



Compact Sonic Sonde - MSS



Physical Dimensions

Length	MSS-A	3.82 m (12.53 ft)
	MSS-B	3.67 m (12.04 ft)
Diameter	57 mm (2.25 in)	
Weight (in air)	MSS-A	33 Kg (73 lb)
	MSS-B	30 Kg (66 lb)

Ratings

Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter	70 to 400 mm (2.75 to 15.75 in)

Curve Parameters

Range	130 to 820 μs/m (40 to 250 μs/ft)
Resolution	0.82 μs/m (0.25 μs/ft)
Vertical Resolution	300 mm (1 ft) and 600 mm (2 ft)
Depth of Investigation	For practical purposes, transit times in isotropic formations may be regarded as originating at the borehole wall. The actual depth of investigation depends on the radial velocity profile.

Compact Cement Bond Log - MSS (CBL mode)

When used in **CBL/VDL** acquisition mode, the **Compact MSS** tool records a waveform (normally from the 5 ft receiver) and up to four first arrival amplitude logs. The ratio of two amplitude curves defines an attenuation log which is sensitive to the quality of the cement bond.

The transmitters achieve high acoustic output for relatively low power consumption, giving high quality waveform data and extended battery life. The waveform time sampling increment is selectable.

CBL interpretations use relationships between signal strength and the percentage casing circumference that is bonded. For fully bonded casing, the cement's compressive strength is deduced from the amplitude or attenuation logs. Associated travel time logs provide additional quality control.

The waveform is displayed as a Variable Density Log (**VDL**), and allows interpretation of the cement to formation bond.

In memory mode, the tool requires no surface unit, cable or winch, and is run instead with **Compact MBS** (battery) and **MMS** (memory) subs. Memory CBLs run on slickline or cableless coiled tubing reduce the time, risk and cost of acquiring data acquisition.

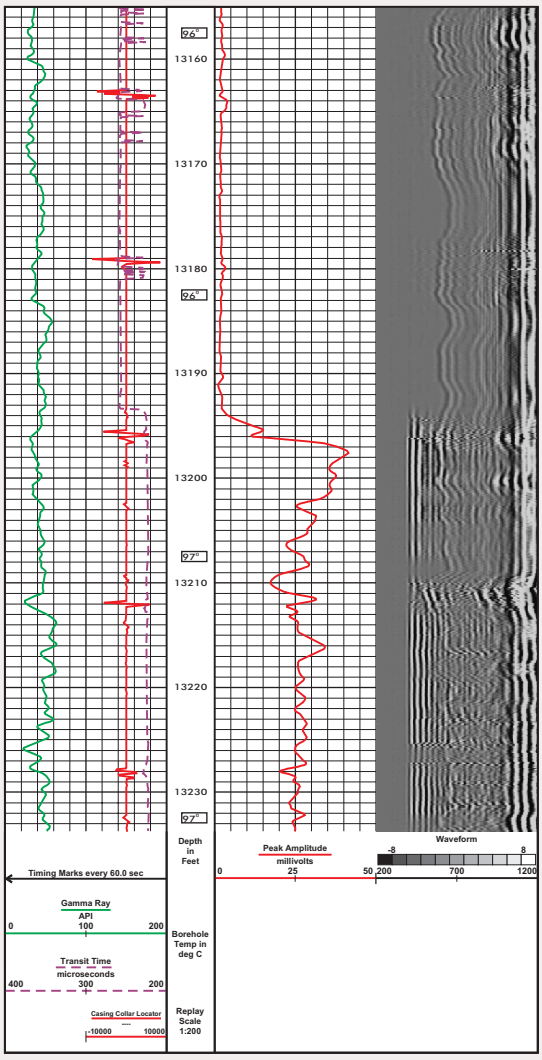
Measurements

- CBL amplitude
- CBL waveform
- Casing Collar Locator (on MCG)
- Gamma Ray (on MCG)

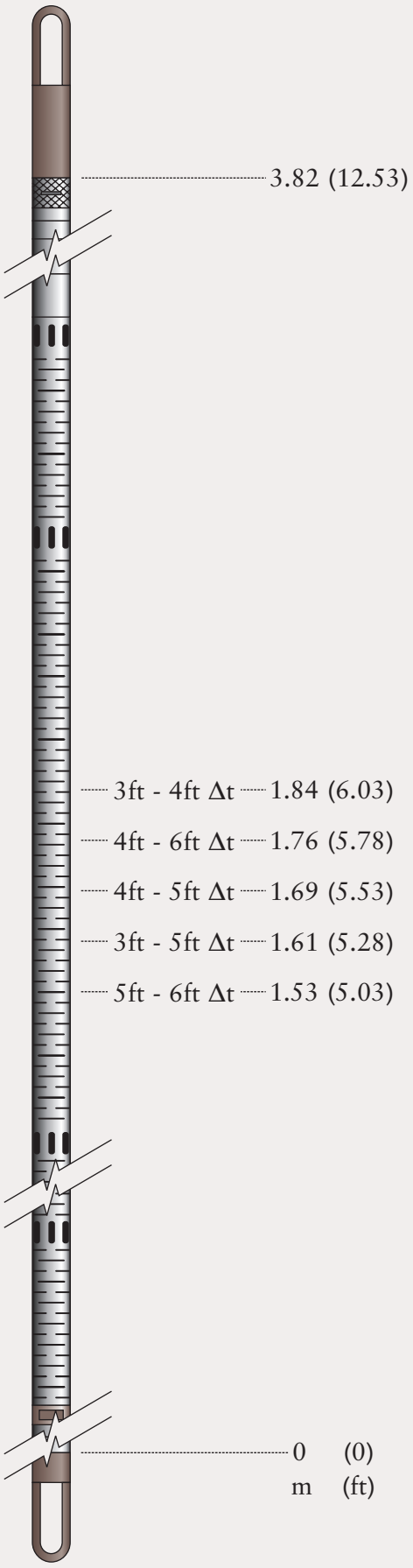
Applications

- Cement bond quality

- *Cablefree operation when used with MMS (Memory) and MBS (Battery) subs*
- *High output transmitters*
- *CBL attenuation log measured directly*
- *Percentage bond and bond strength from amplitude/VDL*



Compact Cement Bond Log - MSS (CBL Mode)



Physical Dimensions

Length	MSS-A	3.82 m (12.53 ft)
	MSS-B	3.67 m (12.04 ft)
Diameter	57 mm (2.25 in)	
Weight (in air)	MSS-A	33 Kg (73 lb)
	MSS-B	30 Kg (66 lb)

Ratings

Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter	70 to 400 mm (2.75 to 15.75 in)

Curve Parameters

Range (Waveform)	1 ms
Resolution (Waveform)	1 or 4 μs
Resolution (Transit Time)	0.25 μs
Depth of Investigation	For practical purposes, waveforms and transit times in isotropic formations may be regarded as originating at the borehole wall. The actual depth of investigation depends on the radial velocity profile.

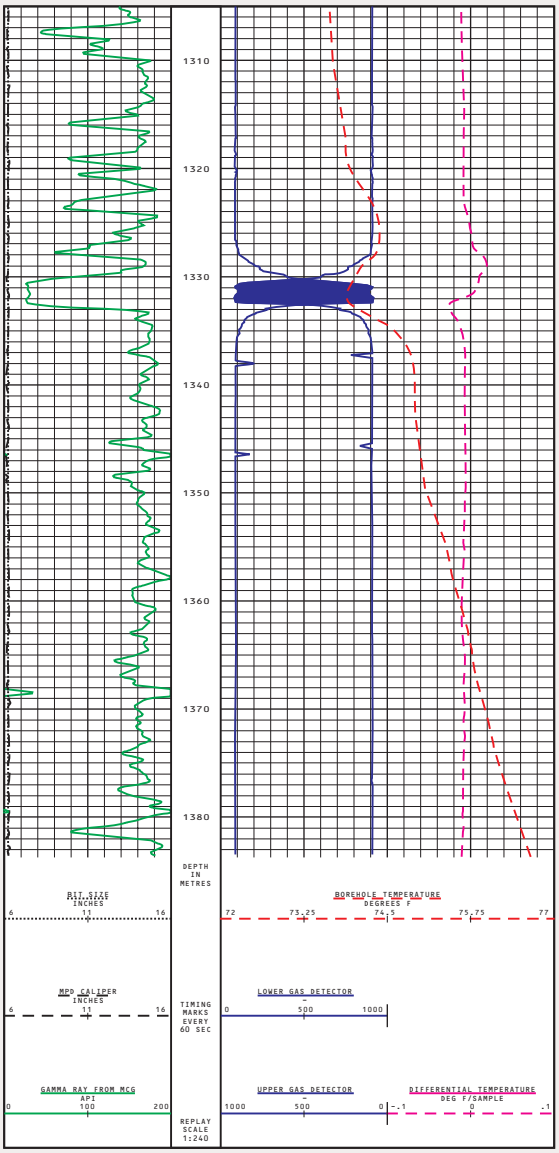
Compact Ultrasonic Gas Detector - MGD & MHT

The **Compact Ultrasonic Gas Detector (MGD)** responds to high frequency acoustic energy associated with the flow of gas into a well. A sophisticated signal processing scheme amplifies the gas signal and rejects noise associated with the movement of the tool and logging cable.

The tool uses two ultrasonic detectors separated by 775 mm (30.5 inches). Processed acoustic logs are depth aligned and displayed on opposing scales, causing curve convergence and/or crossover opposite gas inflow. Residual deflections associated with road noise are typically time synchronous, so appear to be separated by the transducer spacing on the depth aligned log. High and low gain versions of each curve allow the display to be optimized without risking signal saturation.

Gas flow is confirmed by an associated drop in bore-hole temperature, measured by the high resolution **Borehole Temperature (MHT)** sub run in combination with the MGD.

- *Detects gas entry in air-filled holes*
- *Dual detectors differentiate between gas and road noise*



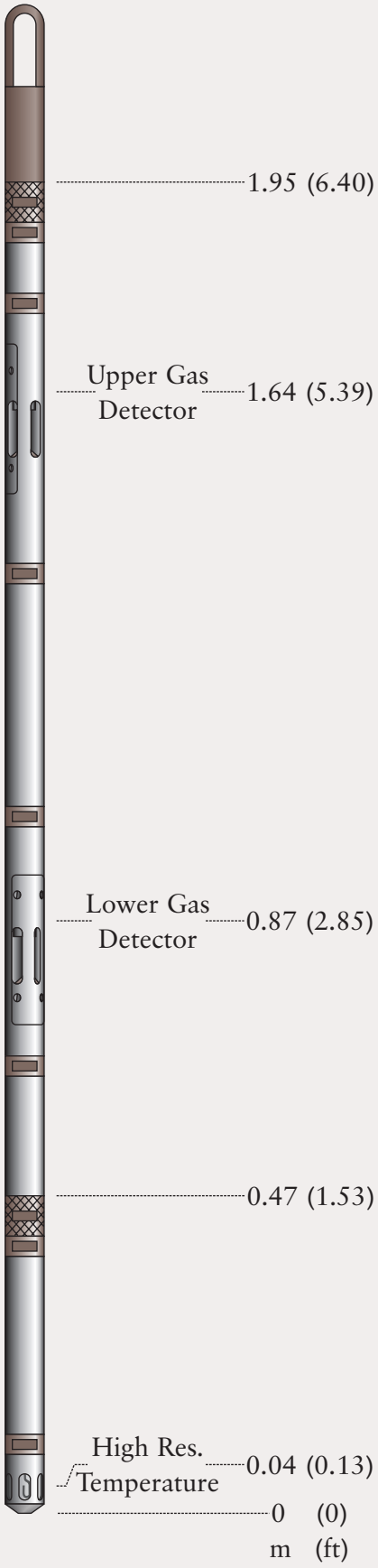
Measurements

- Upper and lower gas detection
- High and Low Gain channels
- Temperature

Applications

- High vertical resolution detection of gas entry into air-filled holes
- Detection of casing leaks
- Detects presence or absence of flow at perforations

Compact Ultrasonic Gas Detector - MGD & MHT



Physical Dimensions (MGD & MHT)

Length	1.95 m (6.40 ft)
Diameter	57 mm (2.25 in)
Weight (in air)	22 Kg (48 lb)

Ratings

Temperature (max)	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	27.5 MPa (4 kpsi)

Compact Two Arm Caliper - MTC

Compact Two Arm Caliper (MTC) tools are used to orient and/or eccentralise specific tool strings, in addition to producing logs of borehole diameter. They also provide powered eccentralisation in situations where conventional eccentralisers cannot be used (out-of-pipe logging, for example).

The lateral force from an MTC exceeds that from the Compact PhotoDensity (MPD) caliper; a combination of MTC and MPD therefore forces the density shoe to run up the short axis of an oval hole. This axis is normally less rugose and closer to bit size, resulting in optimum density and Pe log responses. The consequential X-Y caliper logs also provide more accurate hole volume estimations.

By removing one of the two caliper arms, the MTC may be used as a powered eccentraliser. Complex tool string geometries can be constructed using multiple MTCs.

MTCs are also used in tool strings containing no other caliper measurement in order to provide hole size input for environmental corrections and hole volume calculations.

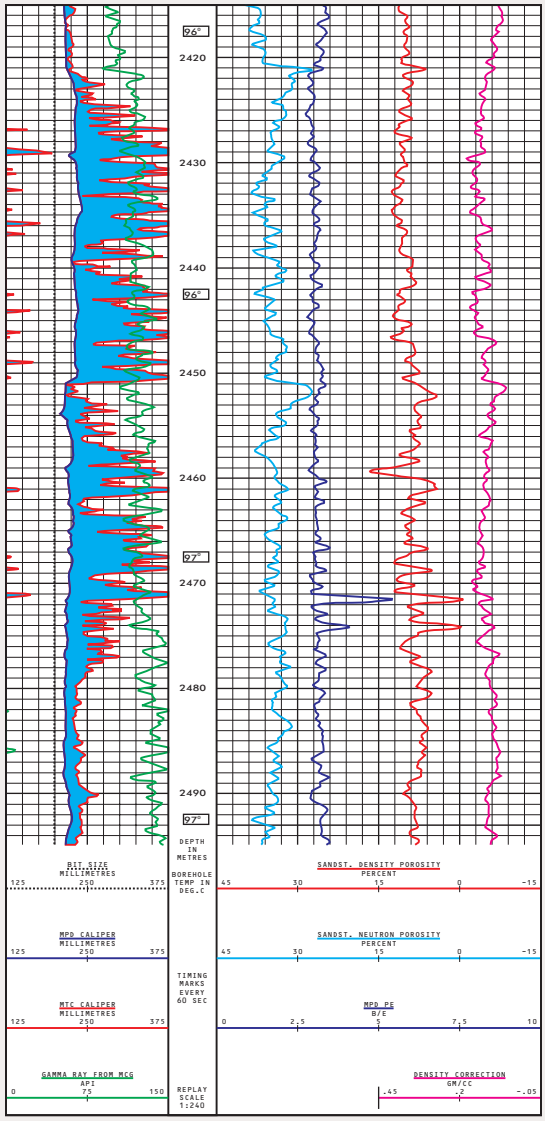
Measurements

- Well diameter

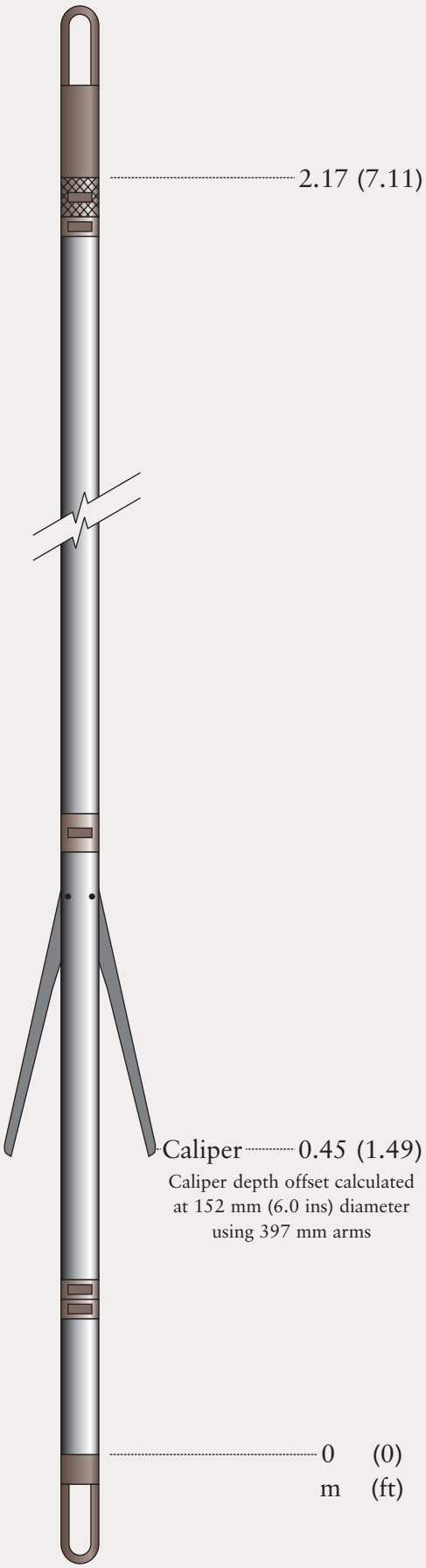
Applications

- Density tool orientation
- Powered eccentralisation
- Hole size determination
- Hole volume calculations

- *Density tool short axis orientation*
- *X-Y caliper for hole volume determinations*
- *Out-of-pipe logging by using powered eccentralisation*



Compact Two Arm Caliper - MTC



Physical Dimensions

Length	2.17 m (7.11 ft)
Diameter	57 mm (2.25 in)
Weight (in air)	28 Kg (62 lb)

Ratings

Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter	70 to 690 mm (2.75 to 27.1 in) covered by a range of 4 arm lengths : 204, 234, 397 and 458 mm

Curve Parameters

Range	60 to 690 mm (2.36 to 27.1 in) when used as a two arm centraliser 60 to 370 mm (2.36 to 14.7 in) when used as a single arm eccentraliser
Resolution	better than 2 mm (0.08 in)

Compact Memory Logging - CML

Open hole **Compact Memory Logging (CML)** is wireline logging without the wireline.

The tool string is powered by battery pack, and data are stored in non-volatile memory. Log values are recorded every half second, and converted into depth logs when the string is recovered to surface.

CML offers conveyance possibilities that save hours or days of rig time, and that allow wireline quality data to be recorded in wells not normally logged for technical or cost reasons. These new methods include :

Drill Pipe Conveyed CML - removing the wireline allows faster running in and out of the well, eliminates the time taken to pump a wet connect, and eliminates the lost time risk associated with potential cable damage.

Coiled Tubing Conveyed CML - allows conveyance by standard coil without an electric line. CBL logs can be run in tandem with other CT services, eliminating the time associated with a conventional CBL logging job.

Through Pipe / Slickline CML - runs Compact tools inside drill pipe past bad hole conditions or to bottom hole.

- *Faster conveyance*
- *Less equipment*
- *Fewer personnel*
- *Wireline quality data augments or replaces LWD*
- *Full range of Compact measurements*

CML®

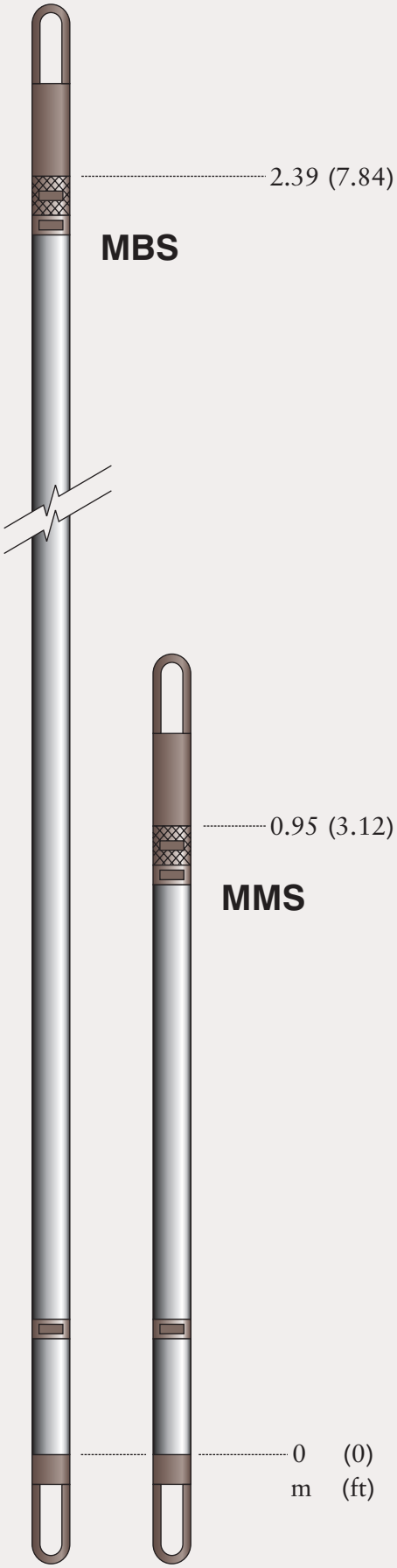
Measurements

- All Compact measurements can be run in CML mode

Applications

- For new generation of cableless open hole logging techniques
- For all well styles, particularly high angle and horizontal wells
- Augments or replaces LWD

Compact Battery & Memory Subs - MBS & MMS



Physical Dimensions

Length	MBS - 2.39 m (7.84 ft) MMS - 0.95 (3.12 ft)
Diameter	MBS & MMS - 57 mm (2.25 in)
Weight (in air)	MBS - 27 Kg (59 lb) MMS - 10 Kg (22 lb)

Ratings - MBS

Temperature (max)	MBS.A - 60^0 C (140^0 F) MBS.B - 110^0 C (230^0 F) MBS.C - 125^0 C (257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter (min)	70 mm (2.75 in)

Ratings - MMS

Temperature	-40^0 to 125^0 C (-40^0 to 257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter (min)	70 mm (2.75 in)

Parameters - MBS

Logging Life	20 hours (can be extended by stacking)
Voltage	380 volts

Parameters - MMS

Memory	MMS.A - 32 MB MMS.B - 96 MB
Logging Time	18 hrs (includes full waveform logging capability for the MMS.B)
Sampling	MMS.A - 0.5 secs MMS.B - Variable
Logging Speed for 10 cm sampling	12 m/min (2362 ft/hr)
Download Time	MMS.A - Logging Time / 8 MMS.B - Logging Time / 18

Compact Ancillary Equipment

Compact Ancillary Equipment provides for the safe and efficient deployment of **Compact** logging tools in diverse well geometries, through drill pipe, and on coiled tubing.

Slim Knuckle Joint - SKJ-B

SKJs are used between subs in short radius wells.

Length	0.66 m (2.17 ft)
Weight (in air)	10 Kg (22 lb)

Inter Sonde Crank - ISC-F

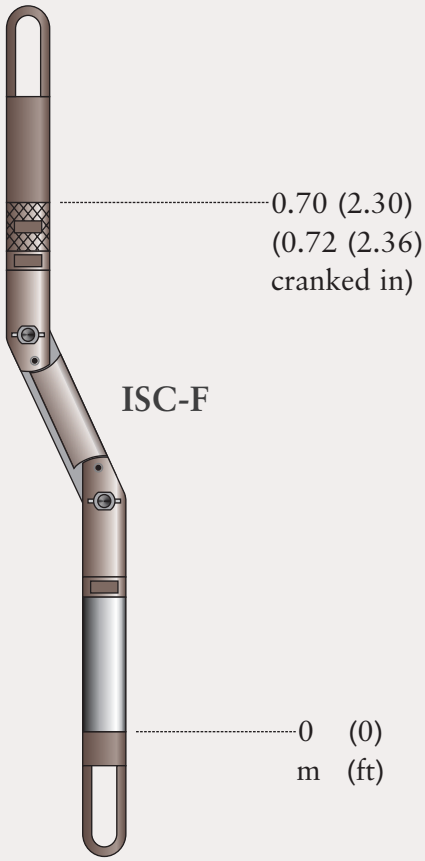
The **ISC** is used between tools that have different eccentralisation requirements.

Length	0.85 m (2.80 ft)
Weight (in air)	6 Kg (13 lb)

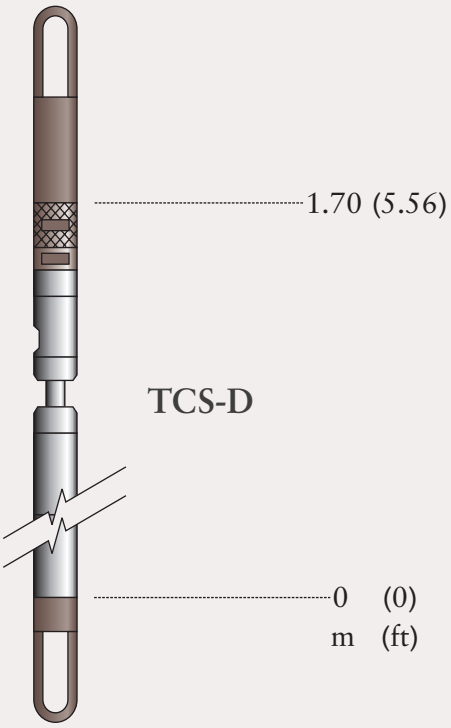
Coiled Tubing Deployment Bar - CTD (not shown)

The **CTD** allows tools to be deployed in under-balanced wells where the riser is not long enough to contain the full tool string. It consists of a pressure sealed through-wired bar to which the tools are connected. The central section of the bar has the same diameter as the coiled tubing. During make-up, this section is lowered into the BOP where a seal is achieved, allowing additional tools to be added on top of the CTD.

Length	2.17 m (7.13 ft)
Weight (in air)	20 Kg (44 lb)



Compact Ancillary Equipment



Tension Compression Sub - TCS-D

The **TCS** provides real time surface readout of downhole forces on the tool string and is used to prevent excessive loading on the tools. The integral knuckle joint provides articulation with very little increase in overall length.

Length	1.70 m (5.56 ft)
Weight (in air)	20.5 Kg (45 lb)

Swivel Head Adaptor - SHA-F

The **SHA** allows the tool string to rotate freely below the cable head. This is especially important when running directional tools (such as the density) that need to be oriented to the low side of a well for optimum performance.

Length	0.84 m (2.75 ft)
Weight (in air)	11.5 Kg (25 lb)

Coiled Tubing Adaptor Head - CTA (not shown)

The **CTA** provides the mechanical and electrical connection between coiled tubing, the through-tubing wireline and the tool string. Heads are available to connect directly to tubing from all major suppliers.

Length	0.45 m (1.48 ft)
Weight (in air)	5.5 Kg (12 lb)

Compact Ancillary Equipment

Inline Centraliser - MIS-A

The **MIS-A** is a through-wired centraliser/eccentraliser for out-of-drill-pipe logging operations. In dual leaf mode it is a powerful eccentraliser for the MDN tool. In centraliser mode, a six leaf spring array is used.

Length	1.74 m (5.71 ft)
Weight (in air)	15 Kg (33 lb)

Inline Standoff - MIS-B (not shown)

The **MIS** is a through-wired sprung standoff for out-of-drill-pipe logging operations. It has user selectable standoff radii of 0.5 and 1 inch.

Length	0.65 m (2.14 ft)
Weight (in air)	6 Kg (13 lb)

Inline Centraliser - MIS-C (not shown)

The **MIS-C** is a through-wired centraliser/eccentraliser for out-of-drill-pipe logging operations. It has a greater length than the MIS-A to enable operation in wells up to 16 inches in diameter.

Length	2.10 m (6.88 ft)
Weight (in air)	18 Kg (40 lb)

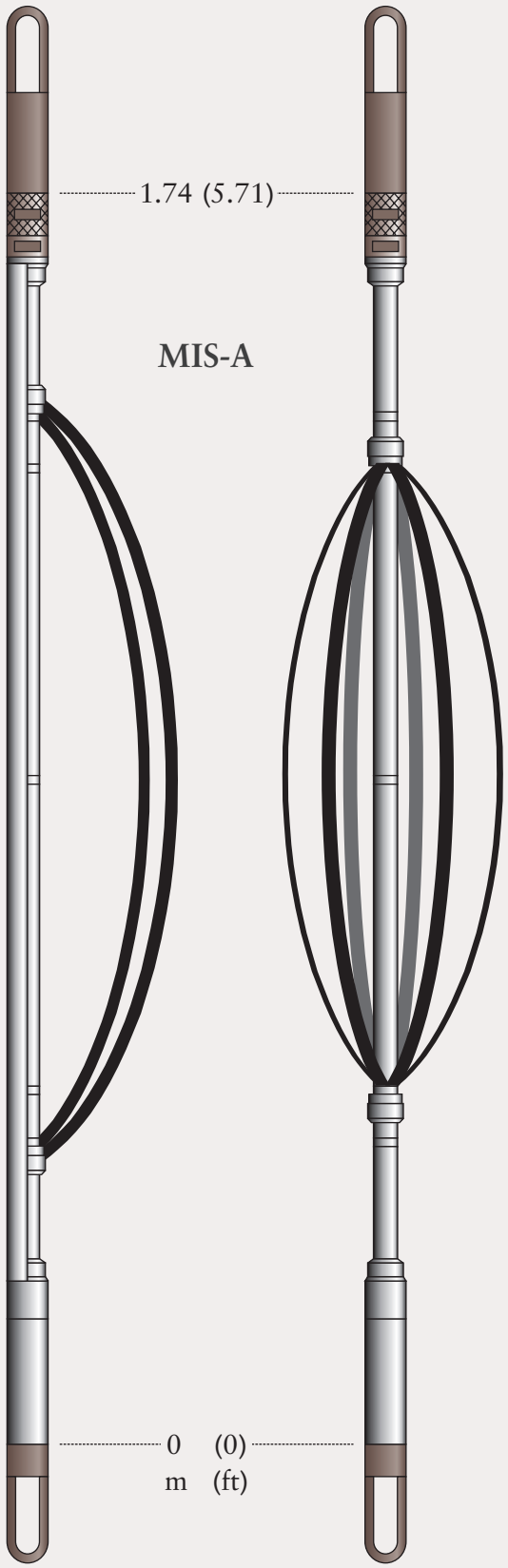
Hole Finder - MHF-A (not shown)

The Hole Finder is a short, semi-rigid conical end piece that attaches to the bottom of Compact tool strings to assist passage past ledges in the well bore.

Length	0.25 m (0.82 ft)
Weight (in air)	5 Kg (11 lb)

Ratings (all components)

Temperature (max)	125^0 C (257^0 F)
Pressure (max)	86 MPa (12.5 kpsi)



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Resistivity Services

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Array Induction Sonde - AIS

Induction tools provide formation resistivity data in wells containing air, oil or low salinity drilling muds.

The **Array Induction Sonde** is an advanced design with one transmitter and a receiver array to make multiple independent measurements of conductivity. Vertical and radial investigation characteristics (fixed in conventional designs) are controlled by sophisticated software that computes up to six resistivity curves, from the shallow Apparent Rxo to the very deep Apparent Rt.

In VECTAR© mode, the vertical resolution of each curve is matched to that of the shortest coil array. An invasion profile image is created by VIVID© processing : variations from the mean conductivity across the array are used to compute the rate of change of cond--uctivity behind the borehole wall. These rate changes are coloured to identify profile shape and, in particular, any annulus (indicates moveable hydrocarbons).

The AIS incorporates a Shallow Focussed Electric measurement for an independent high resolution determination of Rxo in conductive muds. The tool has integral SP, Gamma Ray and Temperature.

Two point calibration eliminates conventional sonde error, giving excellent high resistivity response. Moreover, it is shorter than conventional designs, so less rathole needs to be drilled.

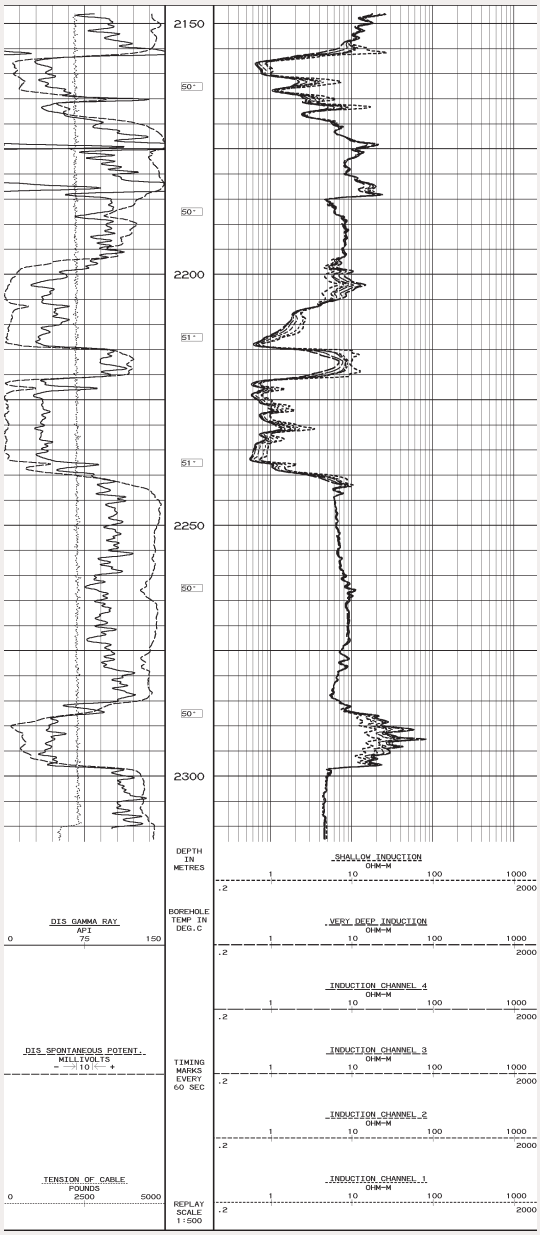
- *Multiple depths of investigation*
- *All curves have the same high resolution*
- *Annulus detection via invasion profile image*
- *Provides Apparent Rt and Rxo*

Measurements

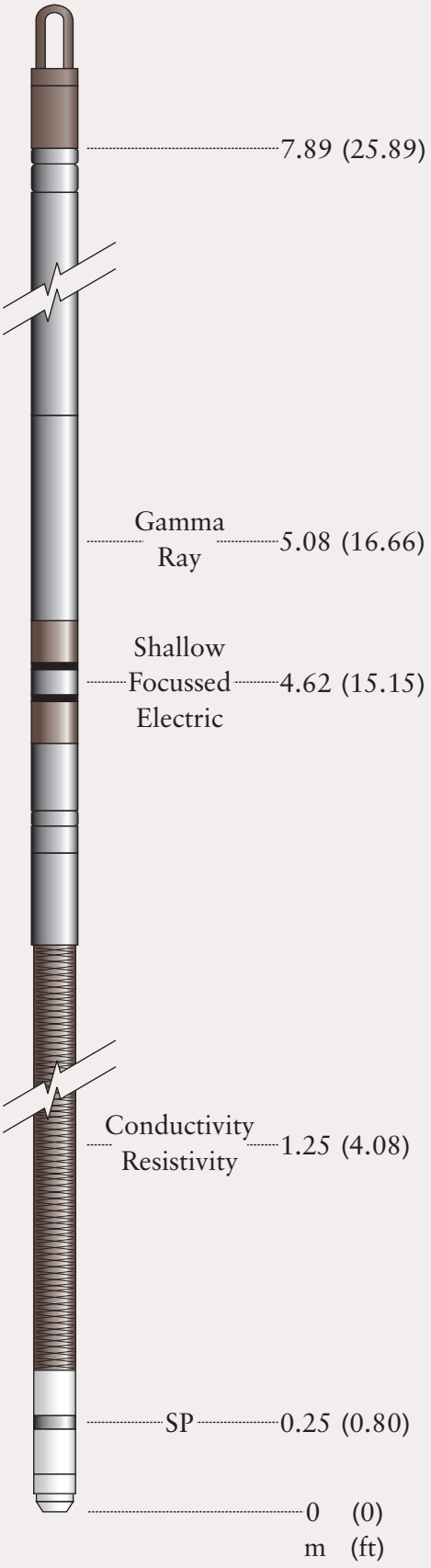
- Formation conductivity at multiple spacings
- High resolution Focussed Electric log for Rxo
- SP and Temperature
- Gamma Ray

Applications

- Water saturation
- Porosity
- Invasion profiling



Array Induction Sonde - AIS



Physical Dimensions

Length	7.89 m (25.89 ft)
Diameter	95 mm (3.74 in)
Weight (in air)	178 Kg (393 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	115 to 455 mm (4.5 to 18.0 in) where drilling mud Rt/Rm = 20. Performance above 455 mm is dependent on Rt/Rm ratio.

Curve Parameters

Range	Induction	0 to 10 S/m (∞ to 0.1 Ωm)
	SFE	0.02 to 20000 Ωm
Resolution	Induction	0.00025 S/m
	SFE	1 % of measured value
Vertical Resolution	Induction	1.0 m (3.3 ft) in VECTAR© mode and Rt > 200 Ωm
	SFE	0.1 m (0.3 ft)
Depth of Investigation (median radial)		
	For Rxo = Rt and Rt > 100 Ωm :	
	Induction	0.3 to 1.2 m (12 to 47 in)
	SFE	0.38 m (15 in)

Dual Laterolog Sonde - DLS

The **Dual Laterolog Sonde** provides Shallow and Deep penetration measurements in wells drilled with conductive (saline) muds. Current flow and measurement sequence are controlled digitally to give superior performance over a wide range of formation to mud resistivity contrasts, and to give immunity to electrode polarisation effects experienced by conventional designs.

The DLS has integral Gamma Ray, SP and Temperature measurements, and is normally run with the **Micro Resistivity Sonde (MRS)** for Rxo determination.

In addition to the primary measurements, a Groningen curve is provided, which is used in conjunction with the Deep to detect anomalous responses as the tool approaches non-conductive formations such as salt caps.

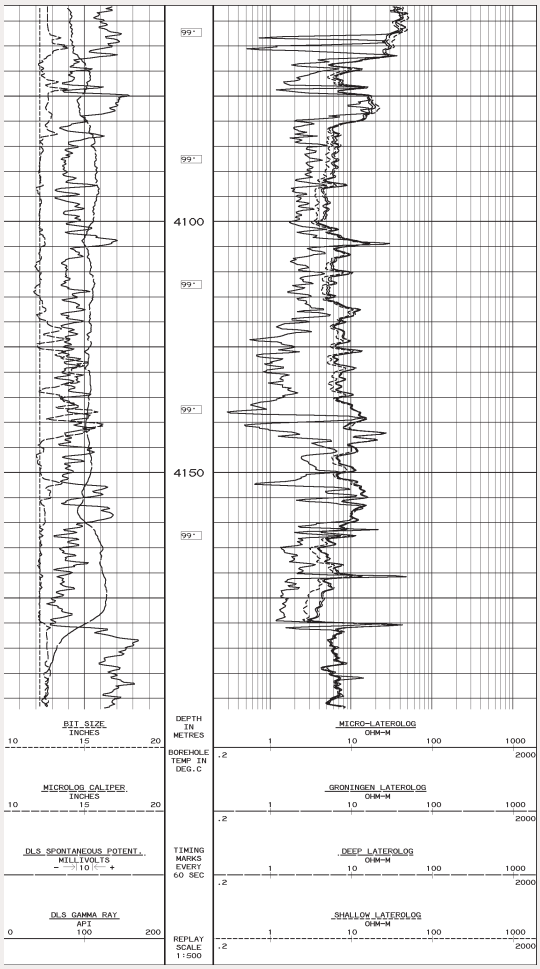
- *Digital operation for superior control of tool performance*
- *Integral SP, Gamma Ray and Temperature*
- *Groningen curve warns of onset of Groningen effect*

Measurements

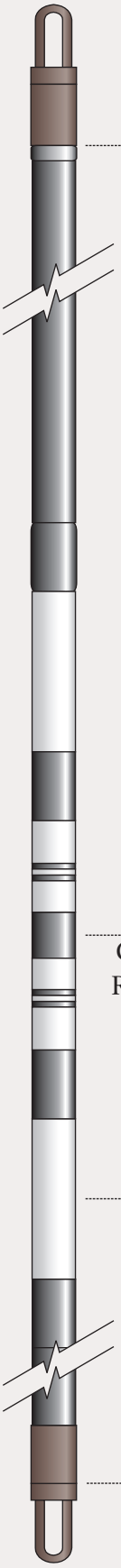
- Deep and Shallow resistivities
- Groningen resistivity
- SP
- Gamma Ray
- Temperature

Applications

- Sw determination
- Porosity
- Permeability



Dual Laterolog Sonde - DLS



Physical Dimensions

Length	9.60 m (31.50 ft) - MRS as lower guard 8.94 m (29.31 ft) - without MRS
Diameter	95 mm (3.74 in)
Weight (in air)	291 Kg (641 lb) - MRS as lower guard 230 Kg (507 lb) - without MRS

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	115 to 455 mm (4.5 to 18.0 in) Operation above 455 mm dependent on Rt/Rm contrast.

Curve Parameters

Range	0.1 to 40000 Ωm
Resolution	1.0 %
Vertical Resolution	0.6 m (2 ft)
Depth of Investigation (median radial)	For Rxo = Rt and Rt > 100 Ωm :

Deep Laterolog	1.27 m	(50 in)
Groningen	1.27 m	(50 in)
Shallow	0.41 m	(16 in)

Micro Resistivity Sonde - MRS

The **Micro Resistivity Sonde** provides permeability indication and invaded zone resistivity, Rxo, in wells drilled with saline muds. Water saturations computed from Rxo and Rt are used to indicate hydrocarbon moveability, whilst Rxo provides step profile invasion corrections for Dual Laterolog and Array Induction logs.

The tool comprises two measurement pads which are held against the borehole wall by a two arm caliper mechanism. One pad contains the **Microlaterolog**, the other the **Microlog** - the tool may be run with one or both pads in place.

The Microlog is an unfocussed shallow penetration device providing Micro Normal and Micro Inverse curves, the latter being slightly deeper reading. Separation of the curves indicates mudcake buildup and hence permeability. If mudcake thickness or resistivity are known then Rxo can be interpreted.

The Microlaterolog is a focussed measurement which has less sensitivity to mudcake, and responds directly to Rxo. A special small hole pad is available for 6 in (152 mm) hole sizes. All MRS measurements have excellent vertical resolution.

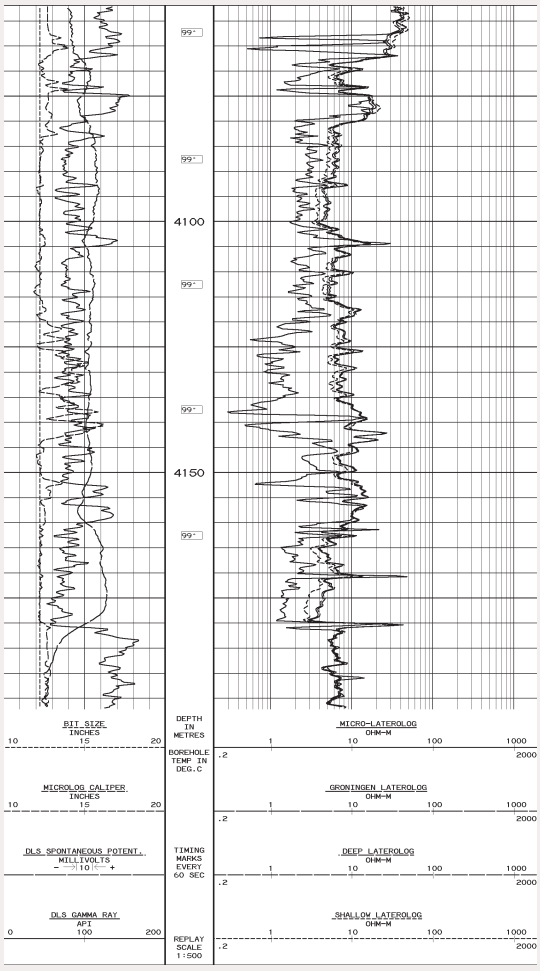
- *Rxo evaluation*
- *Micro Normal and Micro Inverse logs as permeability indicator*
- *Hydrocarbon moveability indication*
- *Excellent vertical resolution*

Measurements

- Microlaterolog
- Micro Normal
- Micro Inverse
- Caliper

Applications

- Invaded zone resistivity, Rxo
- Improved estimates of Rt
- Permeability indication
- Moveable hydrocarbons
- High resolution logging



Micro Resistivity Sonde - MRS

* Caliper depth offset calculated at 200 mm (7.9 ins) diameter

Physical Dimensions

Length	2.86 m (9.39 ft)
Diameter	130 mm (5.1 in) - Microlaterolog only 178 mm (7.0 in) - Microlaterolog and Microlog pads
Weight (in air)	96 Kg (212 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	150 to 500 mm (5.9 to 19.7 in) for the Microlaterolog only 190 to 520 mm (7.5 to 20.5 in) for the Microlaterolog and Microlog

Curve Parameters

Range	Microlaterolog	0.2 to 2000 Ωm
	Microlog	0.2 to 200 Ωm
Resolution	1.0 % of measured value	
Vertical Resolution	50 mm (2.0 in) at 40 samples/metre	
Depth of Investigation (median radial)		
	Microlaterolog	80 mm (3.1 in)
	Micro Normal	12 mm (0.5 in)
	Micro Inverse	25 mm (1.0 in)

Microlog Sonde - MLS

The **Microlog Sonde** comprises a caliper arm mechanism and measurement pad from which the shallow penetration **Micro Normal** and **Micro Inverse** resistivity measurements are made. Separation of the curves indicates mudcake buildup and hence permeability. If mudcake thickness or resistivity are known then Rxo can be interpreted.

It is commonly run with the Array Induction Sonde, but can also be run in other combinations where permeability indications and high resolution are important considerations.

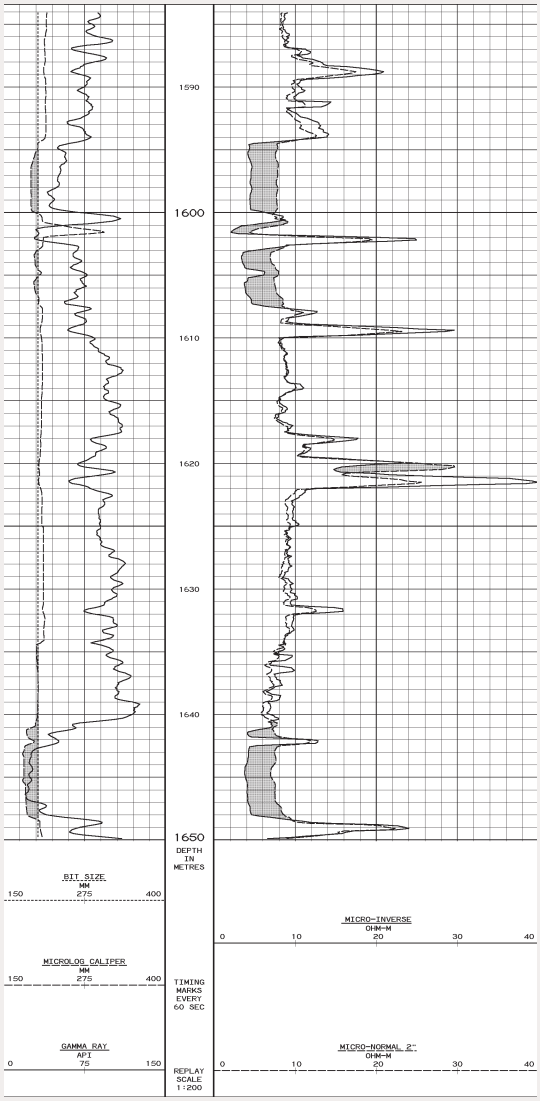
Measurements

- Micro Normal
- Micro Inverse
- Caliper

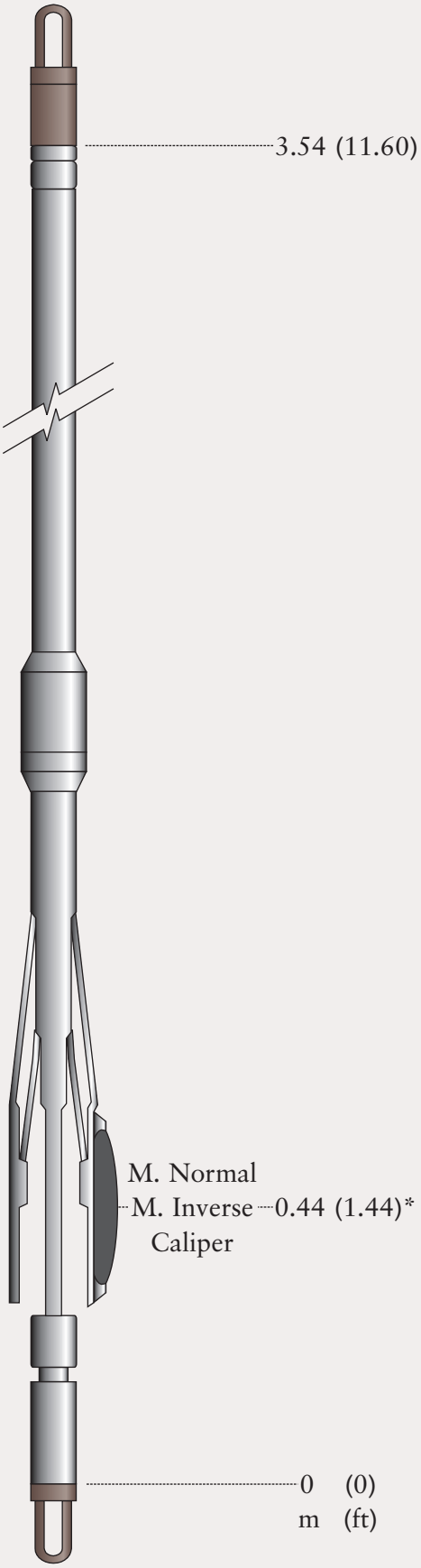
Applications

- Permeability identification
- High resolution logging

- *Rxo and permeability indication*
- *High resolution 2.5 cm depth sampling option*



Microlog Sonde - MLS



* Caliper depth offset calculated at 200 mm (7.9 ins) diameter

Physical Dimensions

Length	3.54 m (11.60 ft)
Diameter	130 mm (5.1 in)
Weight (in air)	105 Kg (231 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	86 MPa (12.5 kpsi)
Well Diameter	150 to 500 mm (5.9 to 19.7 in)

Curve Parameters

Range	0.2 to 200 Ωm	
Resolution	1.0 % of measured value	
Vertical Resolution	50 mm (2.0 in) at 40 samples/metre	
Depth of Investigation (median radial)		
	Micro Normal	12 mm (0.5 in)
	Micro Inverse	25 mm (1.0 in)

Mud Resistivity Sonde - RMS

The **Mud Resistivity Sonde** makes continuous measurements of the borehole fluid resistivity, Rm. The resulting log is used to generate precise environmental corrections for open hole resistivity logs.

The sonde is run in combination with the Array Induction Sonde, and permits dynamic mud corrections to be applied in real time.

The mud resistivity measurement is based on the four electrode principle. As such, it is largely immune to electrode polarisation effects, and provides a very accurate result. The electrodes are wrapped around a mandrel inside an insulating sleeve. The motion of the tool causes mud to flow through the sleeve and over the electrode array. The magnitude of the current flowing from the central sense electrode to the two outer electrodes is measured, together with the voltage difference between two monitor electrodes. Mud resistivity is computed from the sense current, monitor voltage and a known tool coefficient. The insulating sleeve ensures that the measurement is unaffected by the formation.

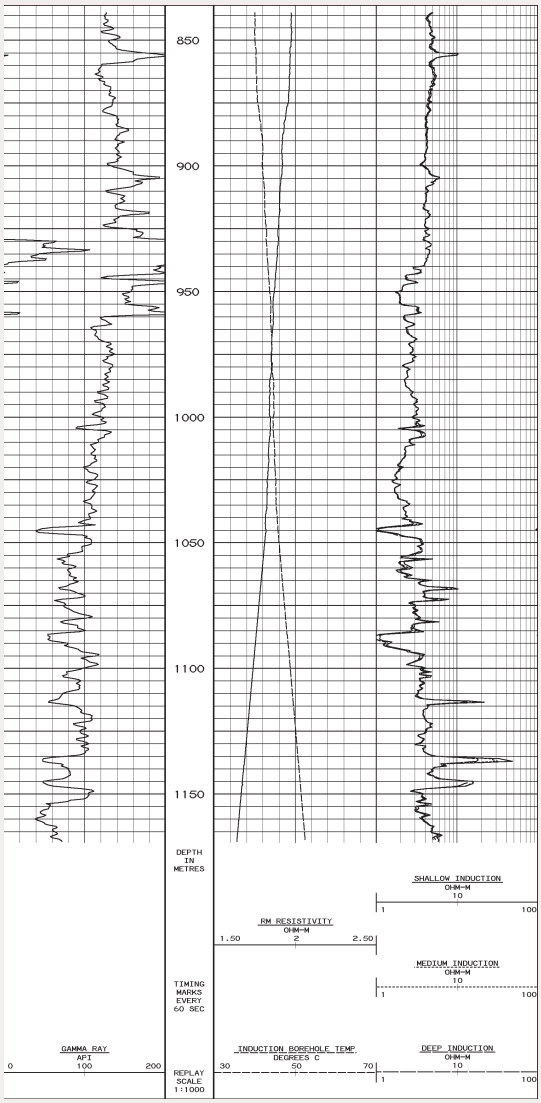
Measurements

- Rm

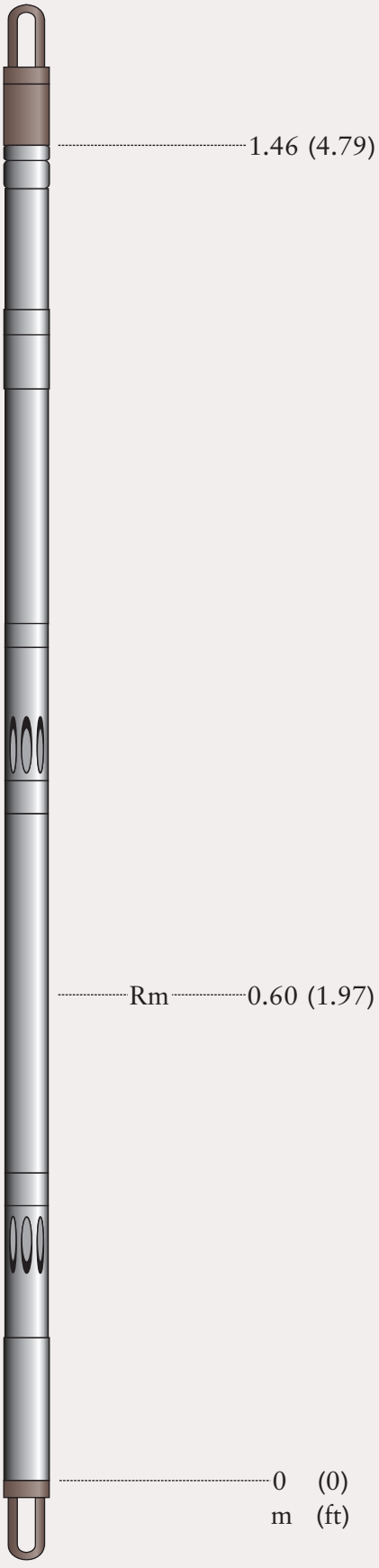
Applications

- Environmental correction option for the Array Induction Sonde

- *Continuous, in-situ Rm determination*
- *High accuracy from advanced 4-electrode array design*
- *For environmental correction of Array Induction and other resistivity logs*



Mud Resistivity Sonde - RMS



Physical Dimensions

Length	1.46 m (4.79 ft)
Diameter	95 mm (3.74 in)
Weight (in air)	44 Kg (97 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	115 mm (4.5 in) minimum

Curve Parameters

Range	0.01 to 100 Ωm
Resolution	0.05 %
Accuracy	Better than 1 % in the range - 0.1 to 10 Ωm at 150^0 C (302^0 F) Better than 2 % in the ranges - 0.01 to 0.1 Ωm at 150^0 C (302^0 F) and 10 to 100 Ωm at 150^0 C (302^0 F)

Porosity and Lithology Services

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Photo Density Sonde - PDS

The **Photo Density Sonde** measures formation density, caliper and photoelectric factor (Pe). It is run with the **Compensated Neutron Sonde (CNS)**, incorporating integral Gamma Ray, in a combination called the **Photo Nuclear Sonde (PNS)**. This is the principal tool for lithology/porosity determination in complex formations.

The design of the Photo Density Sonde reflects the critical importance of its measurements.

The shoe design and its mechanical couplings ensure that close contact is maintained with the borehole wall at all times, even when the well changes shape.

Tight and carefully shaped shielding ensures minimal sensitivity to the borehole fluid.

Both detectors have low Z (atomic number) windows to record the low energy gamma rays used in the computation of Pe. The higher counting rates at the near detector mean that the near Pe has excellent repeatability; near and far Pe curves are calibrated independently to give additional quality control.

The compensated density curve can be VECTAR© processed for enhanced vertical resolution. The Pe curves are intrinsically high resolution, as they are controlled by low energy gamma rays originating very close to the detectors.

Measurements

- Near and Far Spaced Densities
- Compensated Density
- Degree of Compensation
- Near and Far Pe
- Caliper / Hole Volume
- Temperature

Applications

- Porosity/Lithology
- Enhanced resolution logging
- Gas detection

- *Dual density and dual Pe for use in complex lithology environments*
- *Minimal borehole size and fluid effects*
- *VECTAR© processing for enhanced vertical resolution output*

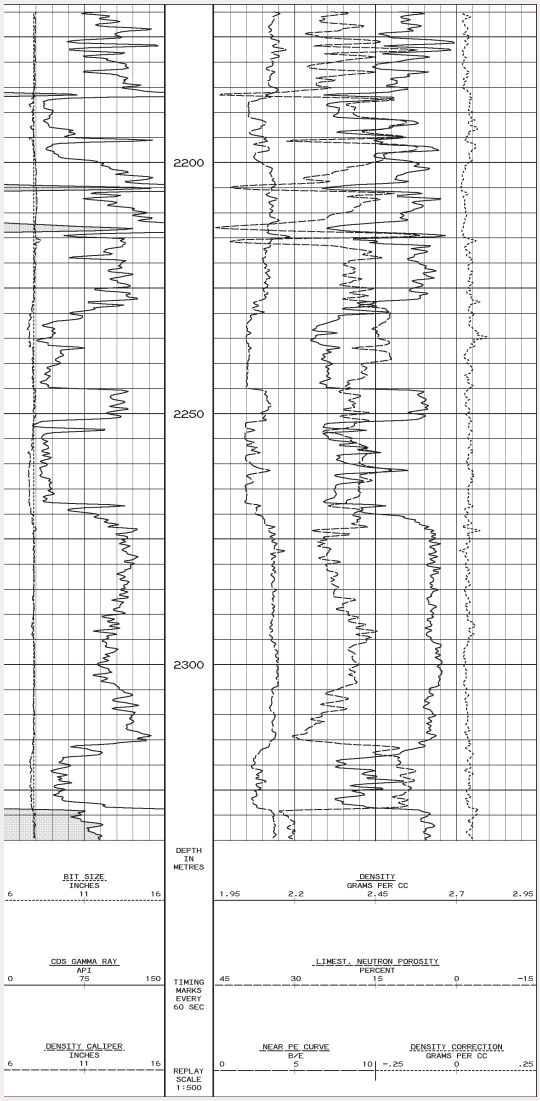
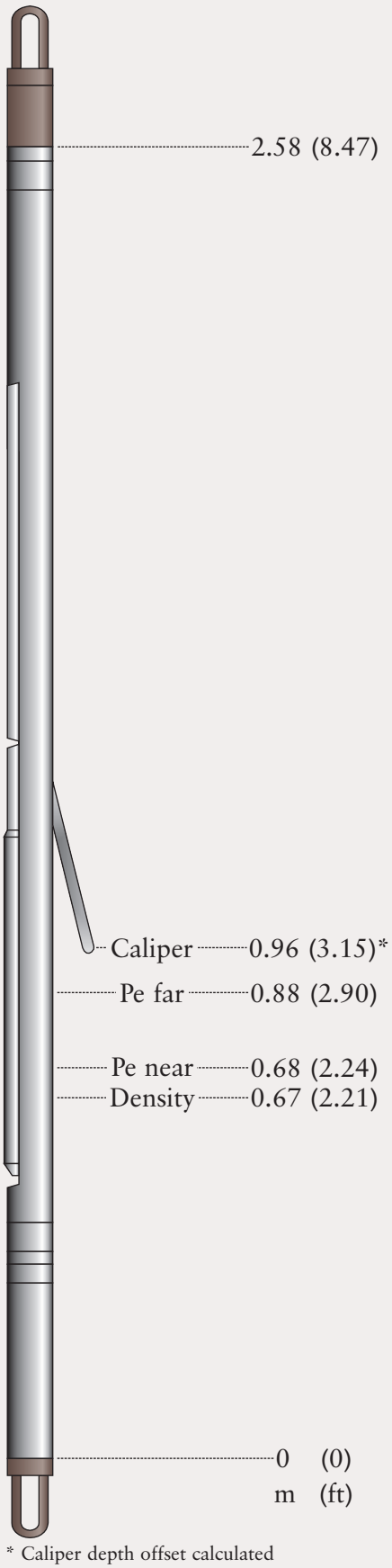


Photo Density Sonde - PDS



* Caliper depth offset calculated at 200 mm (7.9 ins) diameter

Physical Dimensions

Length	2.58 m (8.47 ft)
Diameter	101 mm (3.98 in)
Weight (in air)	101 Kg (222 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	120 to 400 mm (4.7 to 15.8 in) 560 mm (22 in) with large hole kit

Curve Parameters

Range	Density	1200 to 3000 Kg/m^3 (1.2 to 3.0 gm/cm^3)
	Pe	0 to 10 barns/electron
Resolution	Density	1 Kg/m^3 (0.001 gm/cm^3)
	Pe	< 0.05 barns/electron
Vertical Resolution	Density	370 mm (14.7 in) in standard mode 150 mm (5.9 in) in VECTAR© mode
	Pe	200 mm (7.9 in) in standard mode 50 mm (2.0 in) in VECTAR© mode
Depth of Investigation (radial, for 90 % signal)		
	Density	100 mm (3.9 in) at 2300 Kg/m^3 (2.3 gm/cm^3)
	Pe	50 mm (2.0 in) approx.

Compensated Neutron Sonde - CNS

The **Compensated Neutron Sonde** provides neutron porosity curves calibrated in apparent limestone units (curve mnemonic NPRL), sandstone (NPRS) and dolomite (NPRD) units. Used with compensated density data, these are amongst the most important measurements for the determination of porosity and lithology (including clay content), and for the detection of gas.

The service has been designed with the help of the latest computer modelling techniques, supported by extensive physical benchmarking in test pits and boreholes. The result is an excellent field log supported by the most comprehensive environmental corrections currently available. These ensure results of the highest quality even under the most demanding conditions.

The CNS responds to thermal neutrons, and as such is designed for liquid-filled holes. In air or gas filled wells, an alternative measure of porosity is available from the epithermal neutron flux. This is obtained from a CNS having an external cadmium-doped sleeve, a combination called the **Epithermal Neutron Sonde (ENS)**.

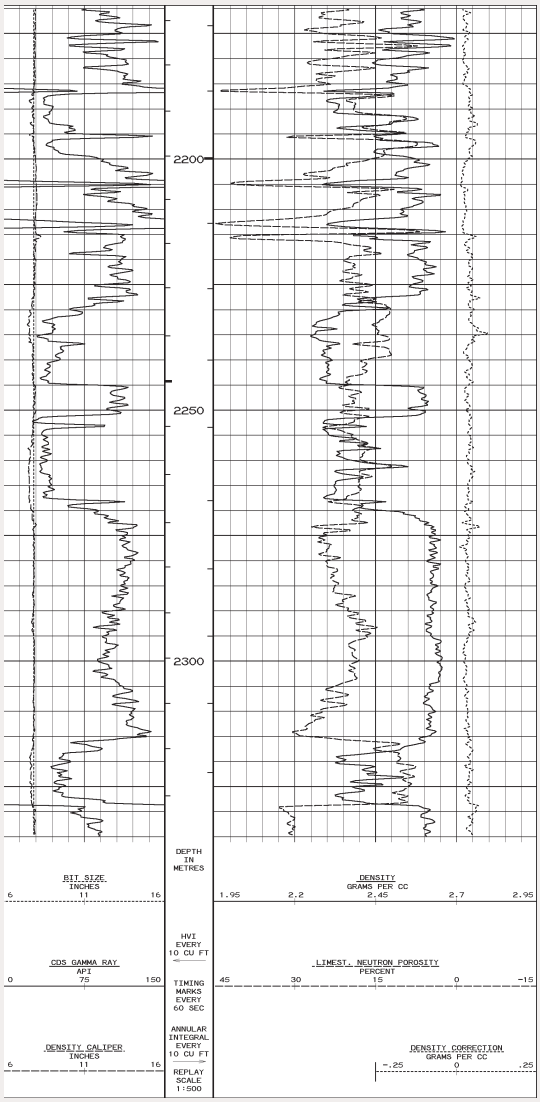
- *Characterised using the latest computer and physical modelling techniques*
- *Fluid- or air-filled hole capability*
- *VECTAR© processing for enhanced resolution output*

Measurements

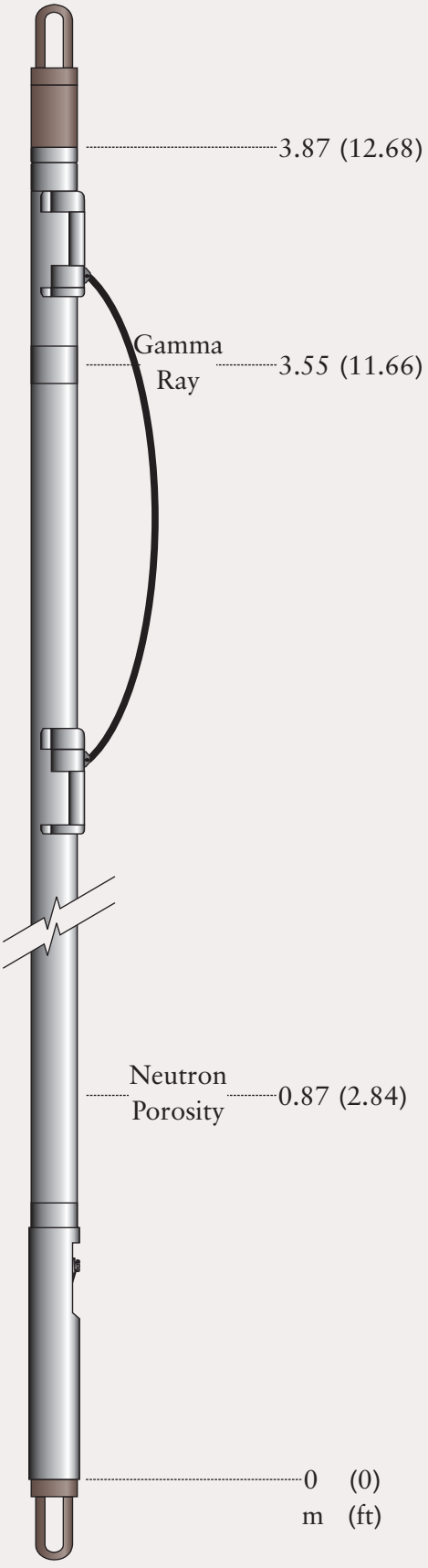
- Apparent Limestone, Sandstone and Dolomite porosity
- Gamma Ray
- Epithermal porosity from the Epithermal Neutron Sonde

Applications

- Porosity
- Lithology
- Gas detection



Compensated Neutron Sonde - CNS



Physical Dimensions

Length	3.87 m (12.68 ft)
Diameter	95 mm (3.74 in)
	102 mm (4.0 in) with epithermal shield
Weight (in air)	109 Kg (240 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	115 to 400 mm (4.5 to 15.8 in)
	560 mm (22 in) with large hole kit

Curve Parameters

Range	-3 to 100 limestone porosity units
Resolution	better than 0.05 p.u. at 20 pu and standard conditions
Vertical Resolution	750 mm (30 in) standard mode
	550 mm (22 in) VECTAR© mode
Depth of Investigation (radial, for 90 % signal)	
	260 mm (10.2 in) at 20 p.u.

Spectral Gamma Sonde - SGS

The **Spectral Gamma Sonde** measures the number and energy of naturally occurring gamma rays, from which the relative abundancies of formation potassium, uranium and thorium (K, U and Th) are determined. The measurements have the following applications :

Correlation - The integrated counts from the large 305 mm x 50 mm (12 in x 2 in) NaI crystal provide an extremely precise Total Gamma Ray log for correlation purposes.

Clay volume - Uranium is not present in the common clay minerals. Subtracting it from the Total Gamma Ray gives the Corrected Gamma Ray which gives better estimates of total clay volume.

Clay typing - The ratio of thorium to potassium, particularly in combination with Pe data from the Photo Density Sonde, provides information about the type of clay minerals in the formation, and allows improved understanding of formation permeability.

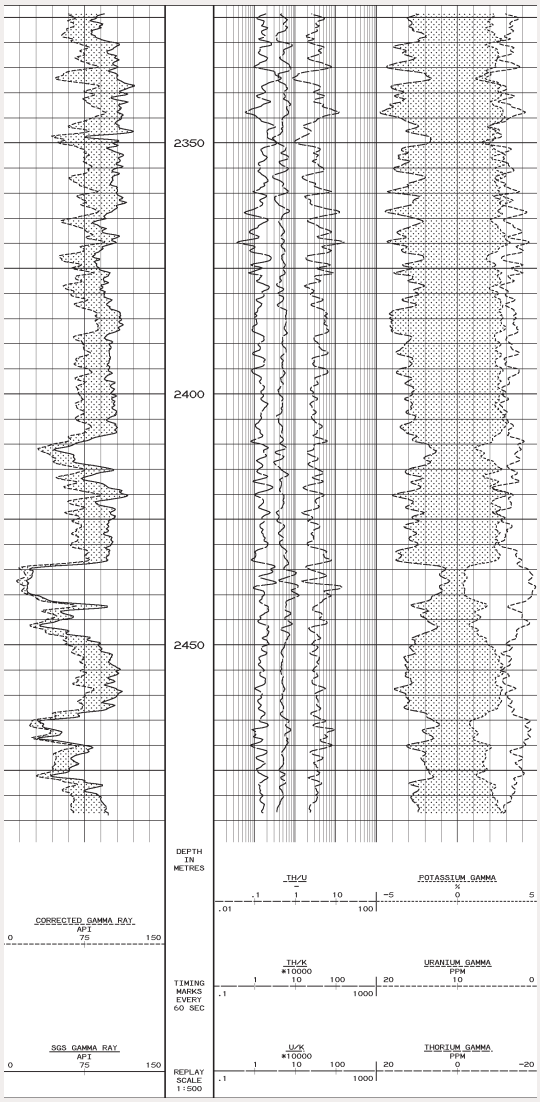
- *Large crystal for very precise Total Gamma Ray log*
- *Uranium corrected Gamma Ray for better estimate of total clay*
- *Relative proportions of Potassium, Thorium and Uranium*

Measurements

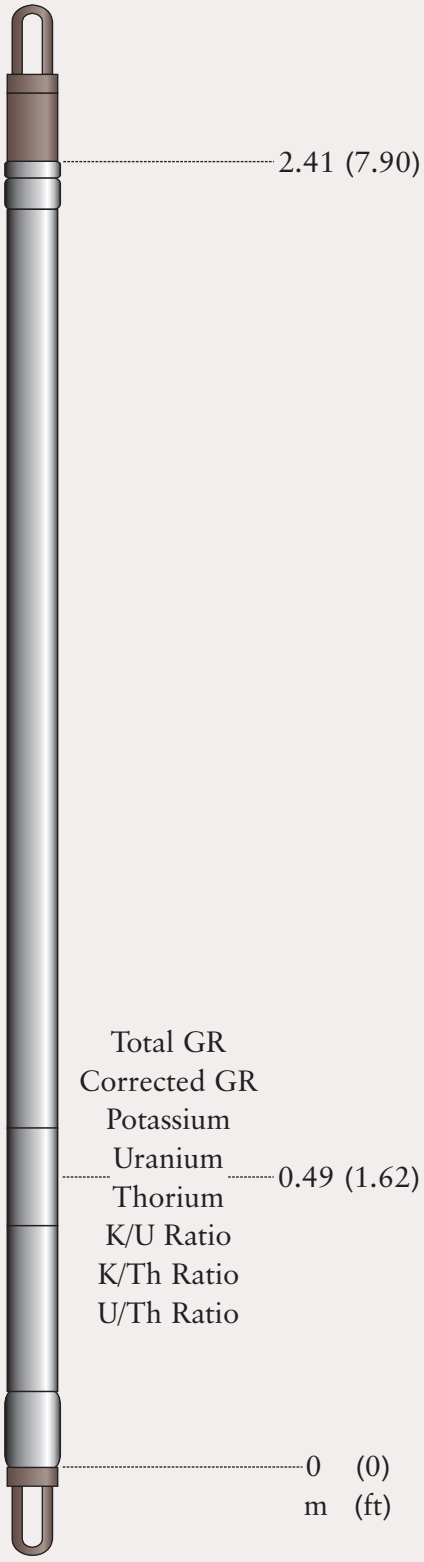
- Total Gamma Ray in API units
- Potassium, Uranium and Thorium concentrations
- Corrected Gamma Ray (Total - Uranium)

Applications

- Clay mineral identification
- Clay volume
- Permeability indication
- Correlation



Spectral Gamma Sonde - SGS



Physical Dimensions

Length	2.41 m (7.90 ft)
Diameter	95 mm (3.74 in)
Weight (in air)	74 Kg (163 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	115 to 530 mm (4.5 to 20.9 in)

Curve Parameters

Range	All curves : 0.0 to no practical limit
Resolution	Total Gamma : 0.2 API (typical)
Vertical Resolution	305 mm (12 in)

Two Arm Caliper - TAC

The **Two Arm Caliper** measures borehole diameter without exerting eccentralisation forces. As such, it is commonly used with oriented density tools to provide an orthogonal X-Y caliper pair. In oval holes this allows confirmation that the density shoe is correctly positioned across the short axis of the hole (for optimum shoe contact). The X-Y combination also provides a more accurate determination of hole volume.

The TAC is also used in tool stacks having no other caliper measurement and provides data for environmental corrections and hole volume calculations.

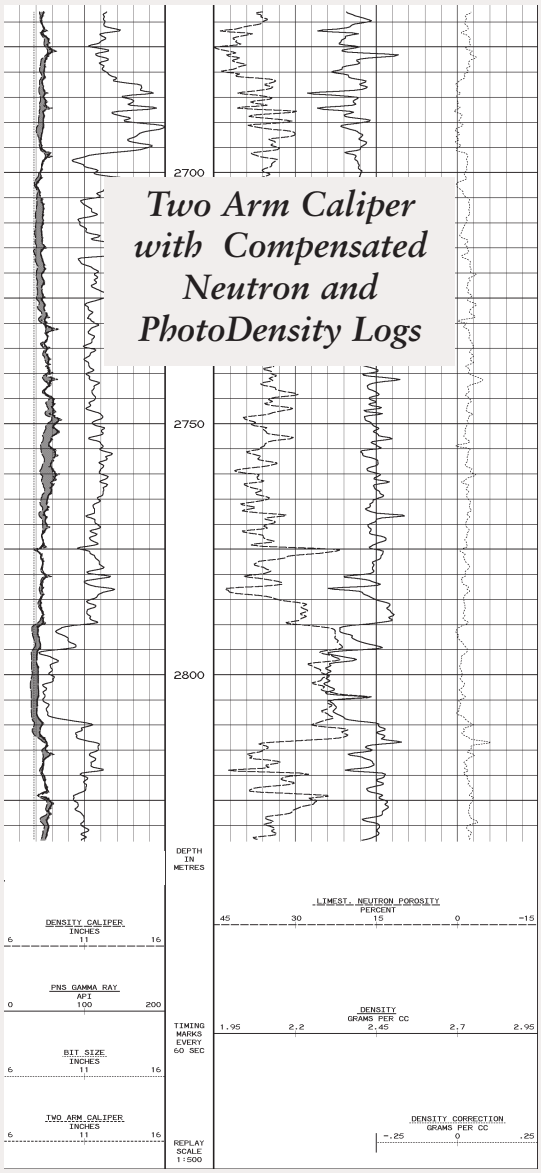
Measurements

- Well diameter

Applications

- Density tool orientation
- Hole size determination
- Hole volume determination

- *Orthogonal X-Y caliper pair when used in combination with an oriented density*
- *Accurate hole size and volume determination*



Two Arm Caliper with Compensated Neutron and PhotoDensity Logs

Two Arm Caliper - TAC

* Caliper depth offset calculated at 200 mm (7.9 ins) diameter

Physical Dimensions

Length	3.42 m (11.20 ft)
Diameter	100 mm (3.94 in)
Weight (in air)	101 Kg (223 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	120 to 430 mm (4.7 to 16.9 in)

Curve Parameters

Range	100 to 650 mm (3.9 to 25.6 in)
Resolution	better than 2 mm (0.08 in)

Acoustic Services

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Long Spaced Compensated Sonic Sonde - LCS

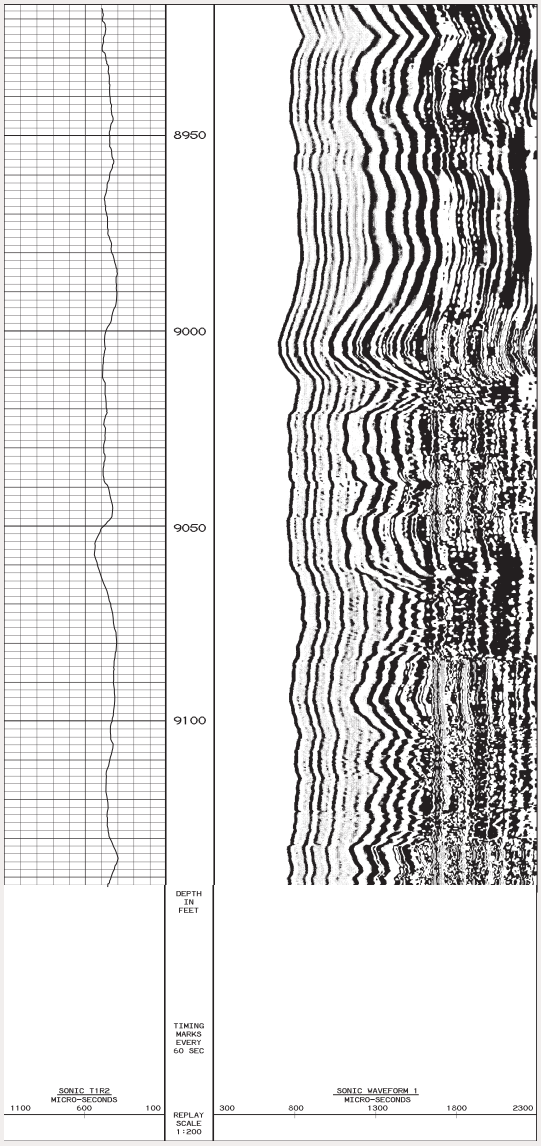
The **Long Spaced Compensated Sonic Sonde** provides compressional (P-wave) and shear (S-wave) Δt data for porosity, lithology, mechanical properties and AVO applications. It is also used as a Cement Bond Log.

The tool contains two transmitters and four receivers, giving eight independent transit times. In compressional Δt mode, pairs of first arrivals are combined to eliminate the fluid path and provide formation Δt measurements at spacings ranging from 3 ft to 10 ft (0.91 m to 3.05 m) from the transmitters. Usually presented are the high resolution 3 ft-4 ft curve, a 3 ft-5 ft curve compatible with CSS logs, and a long 8 ft-10 ft which provides better estimates of in-situ velocities in the presence of near wellbore damage. These curves are compensated for borehole cave effects using the depth derived compensation method.

In shear mode, waveforms are correlated to identify the shear moveout across the receiver array. P-wave and S-wave velocities are combined to compute Poisson's ratio. Shear, Bulk and Young's moduli are calculated with the addition of density data.

In CBL mode, Δt and peak amplitude come from the 3 ft spacing, and a VDL log from the 5 ft waveform.

- *Compressional and shear slowness logs*
- *Improved velocity estimates from damaged intervals*
- *Mechanical properties and Fracture Height processing*



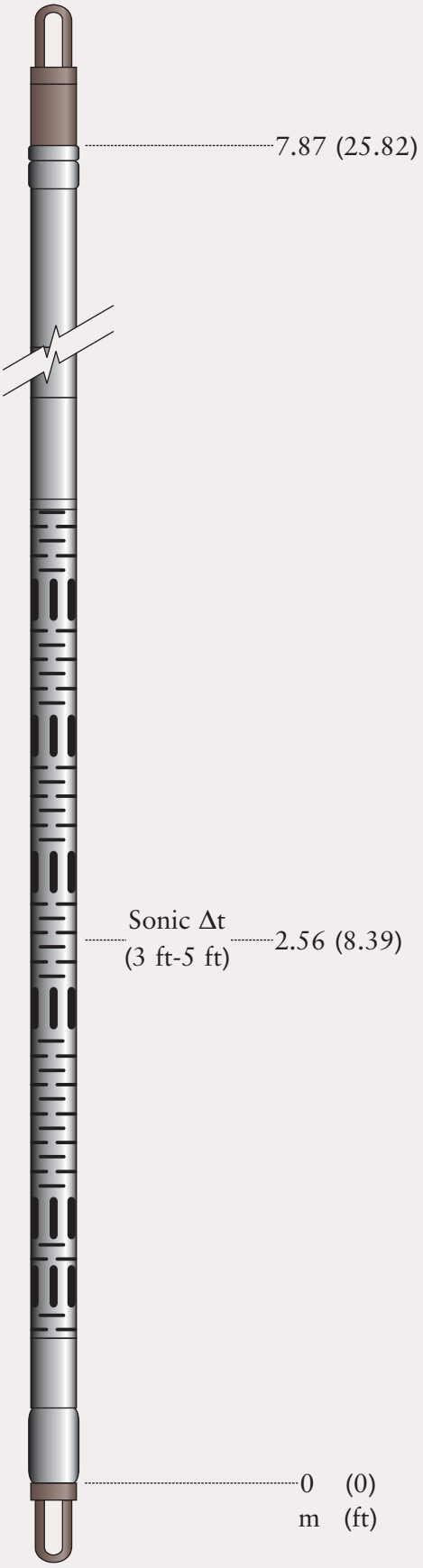
Measurements

- Compensated compressional Δt
- Default presentations of 3 ft-4 ft, 3 ft-5 ft and 8 ft-10 ft curves
- Integrated transit times
- Shear Δt
- Waveforms

Applications

- Porosity
- Fracture detection
- Seismic time to depth conversion
- Mechanical properties
- Fracture height analysis
- Cement bond quality

Long Spaced Compensated Sonic Sonde - LCS



Physical Dimensions

Length	7.87 m (25.82 ft)
Diameter	95 mm (3.74 in)
Weight (in air)	174 Kg (383 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	115 mm (4.5 in) min. - no practical maximum for an eccentred tool

Curve Parameters (Δt curves)

Range	0 to 820 μs/m (0 to 250 μs/ft)
Resolution	0.82 μs/m (0.25 μs/ft)
Vertical Resolution	600 mm (2 ft) and 300 mm (1 ft)
Depth of Investigation	For practical purposes, transit times in isotropic formations may be regarded as originating at the borehole wall. The actual depth of investigation depends on the radial velocity profile.

Compensated Sonic Sonde - CSS

The **Compensated Sonic Sonde** provides velocity data compensated for hole size variations, well fluid Δt and tool tilt, for use in porosity determination and seismic correlation. A high resolution **Microsonic** log and **Cement Bond Log** are also available.

In Δt mode two transmitters at opposite ends of the tool fire into alternate pairs of receivers located 3 ft (0.91 m) and 5 ft (1.52 m) from each transmitter. Differencing the arrival times at each receiver eliminates the common fluid path, whilst averaging the differences from upper and lower receiver pairs compensates for tool tilt and caving effects. This leaves a formation Δt with an effective vertical resolution of 2 ft (0.61 m).

In high resolution mode measurements are recorded from adjacent receivers 90 mm (3.5 ins) apart. These are used in a VECTAR© process to provide a compensated Microsonic of the same resolution.

Transmitter firing and recording cycles are controlled digitally, and dynamically varied according to logging speed and formation conditions. This minimises noise by ensuring that receivers are only active for short periods close to the expected arrival time of the sound pulse, and by trapping unrealistic transitions across bed boundaries.

In CBL mode, 5 ft (1.52 m) receiver waveforms and 3 ft (0.91 m) receiver amplitudes are used to assess the quality of cement bond in cased wells.

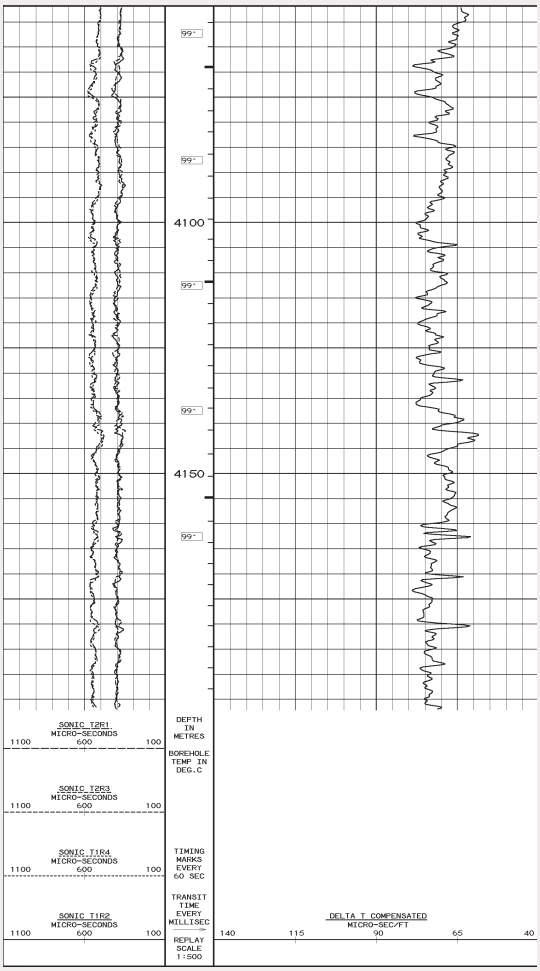
Measurements

- Compensated compressional Δt
- Integrated transit times
- High resolution sonic
- CBL amplitudes and waveforms

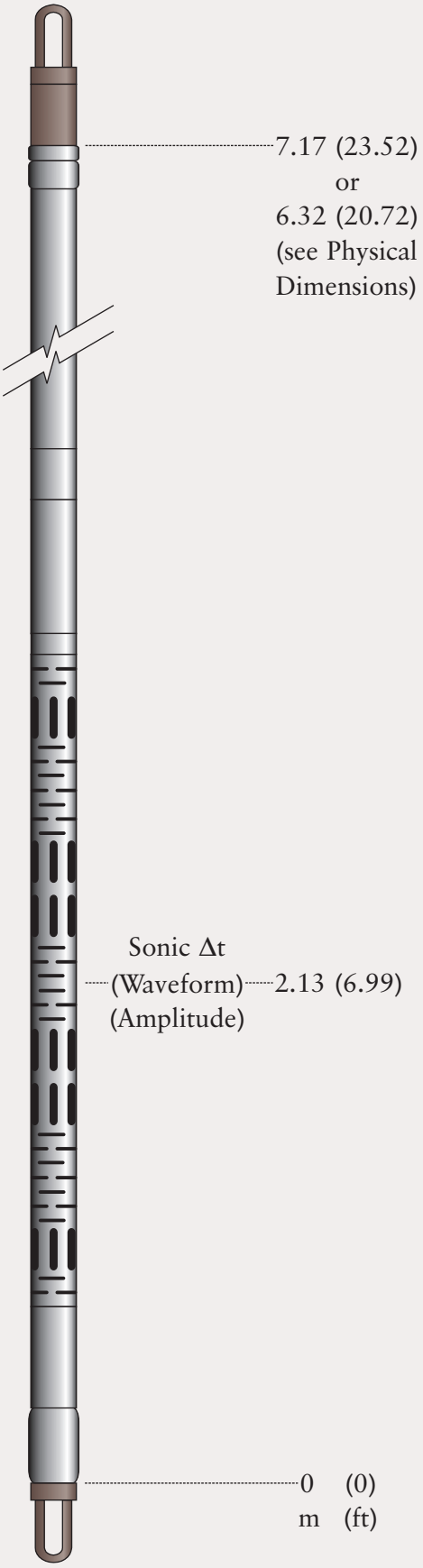
Applications

- Porosity/Lithology
- Seismic time to depth conversion
- Cement bond quality

- *Industry Standard 3 ft - 5 ft Δt log*
- *CBL and high resolution modes*
- *1 ft resolution Microsonic option*



Compensated Sonic Sonde - CSS



Physical Dimensions

Length	6.32 m (20.72 ft) 7.17 m (23.52 ft) with CBL sub
Diameter	95 mm (3.74 in)
Weight (in air)	161 Kg (355 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	115 mm (4.5 in) min. - no practical maximum for an eccentred tool

Curve Parameters

Range	0 to 820 μs/m (0 to 250 μs/ft)
Resolution	0.82 μs/m (0.25 μs/ft)
Vertical Resolution	600 mm (2 ft) standard mode 90 mm (3.5 in) VECTAR© mode
Depth of Investigation	For practical purposes, transit times in isotropic formations may be regarded as originating at the borehole wall. The actual depth of investigation depends on the radial velocity profile.

Ultrasonic Gas Detector - UGD

The **Ultrasonic Gas Detector (UGD)** measures the high frequency acoustic energy and thermal disturbance associated with the flow of gas into a well.

The tool contains two ultrasonic detectors separated by 27 inches (686 mm). Both output curves are depth aligned and displayed on opposing scales. The influx of gas causes a convergence of these curves and a crossover if the acoustic amplitudes are high. Deflections associated with road noise are typically time synchronous, so appear to be separated by the transducer spacing on the depth aligned log.

The presence of gas is confirmed by an associated drop in borehole temperature. This is measured by an integral sensor, or by the high resolution **Borehole Temperature (BHT)** sub run in combination with the UGD.

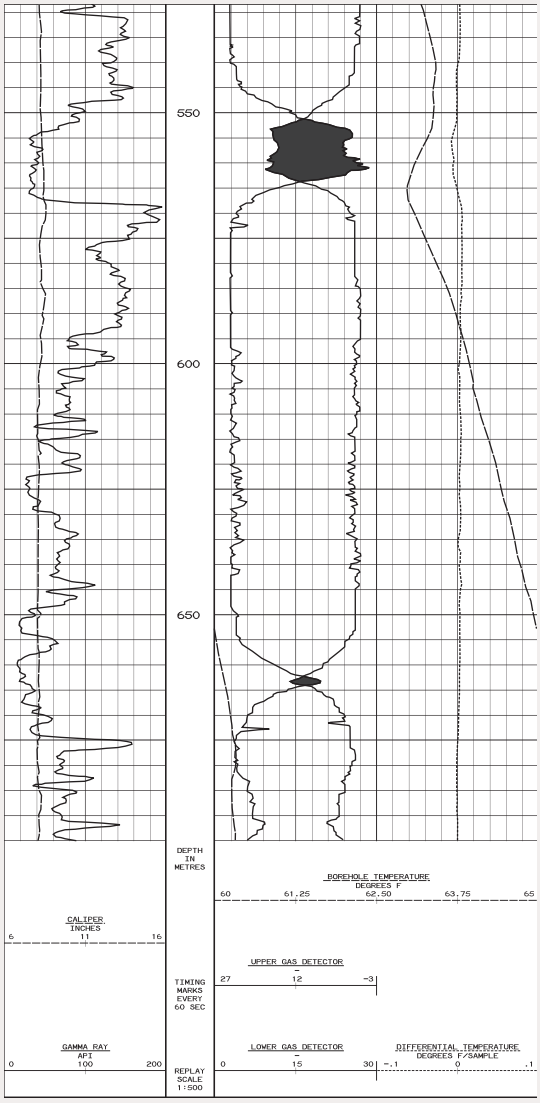
Measurements

- Upper and lower gas detection
- Temperature

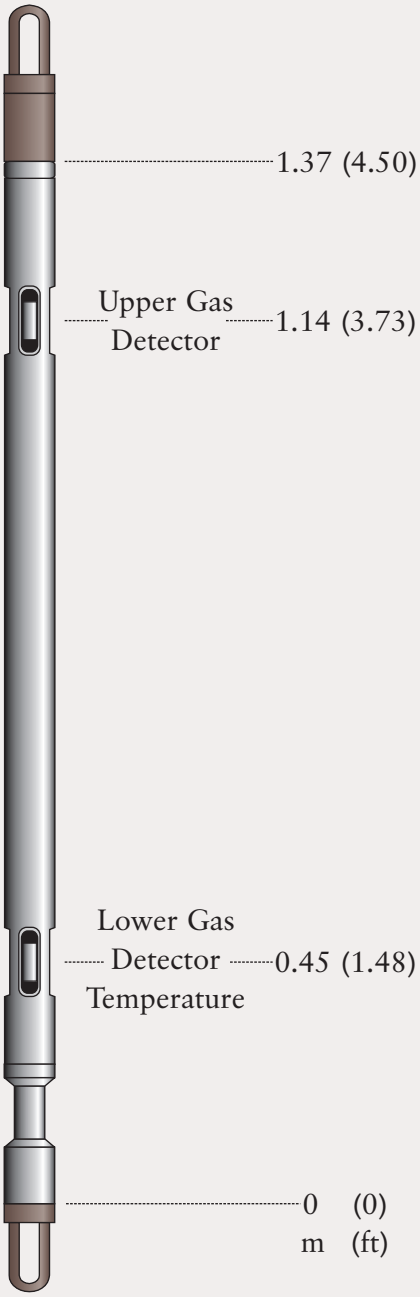
Applications

- High vertical resolution detection of gas entry into air-filled holes
- Detection of casing leaks
- Detects presence or absence of flow at perforations

- *Detects gas entry in air-filled holes*
- *Dual detectors differentiate between gas and road noise*



Ultrasonic Gas Detector - UGD



Physical Dimensions

Length	1.37 m (4.50 ft)
Diameter	90 mm (3.54 in)
Weight (in air)	57 Kg (125 lb)

Ratings

Temperature (max)	100^0 C (212^0 F)
Pressure (max)	21 MPa (3 kpsi)

Formation Imaging and Dipmeter Services

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Acoustic Scanning Tool - AST

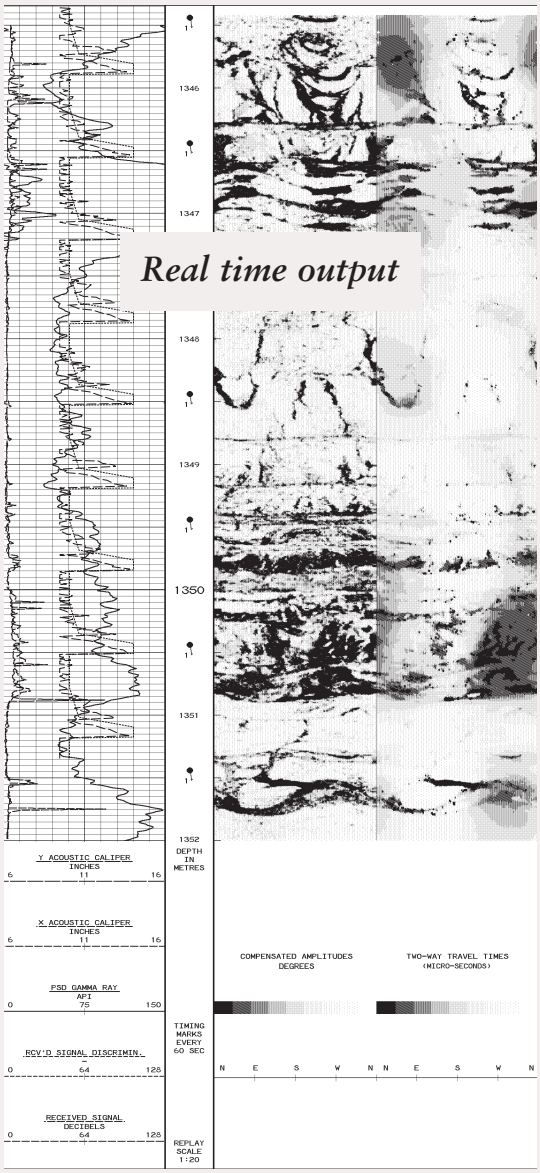
The **Acoustic Scanning Tool** emits acoustic pulses from a rotating transducer, and measures the amplitude and transit time characteristics of signals reflected from the borehole wall. These data are combined with tool orientation information, and transformed into continuous images of the borehole with full 360 degree coverage, showing bed boundaries, fractures, breakouts and other features of structural and sedimentological importance.

It is run with the **Borehole Geometry Navigation** sub **(BGN)** which records the tool navigation data needed to orient the images and dips picked from the images.

Excellent performance is maintained over the full range of borehole sizes and mud types by selecting a transducer optimised for the hole conditions. In large holes and/or heavy or oil-based muds, the tool can be run with an optional fluid excluder.

Real time display is supported by **PC *ImagePro*©** and **Q-Scan©** software. These display images with fixed or dynamic colour balancing, compute and classify dips, and use image enhancement and dip statistics as part of a comprehensive suite of analysis options.

- ***Continuous borehole wall images with 360 degree coverage***
- ***Dual transducers cover a range of borehole diameters***
- ***Real time oriented amplitude and transit time images***



Real time output

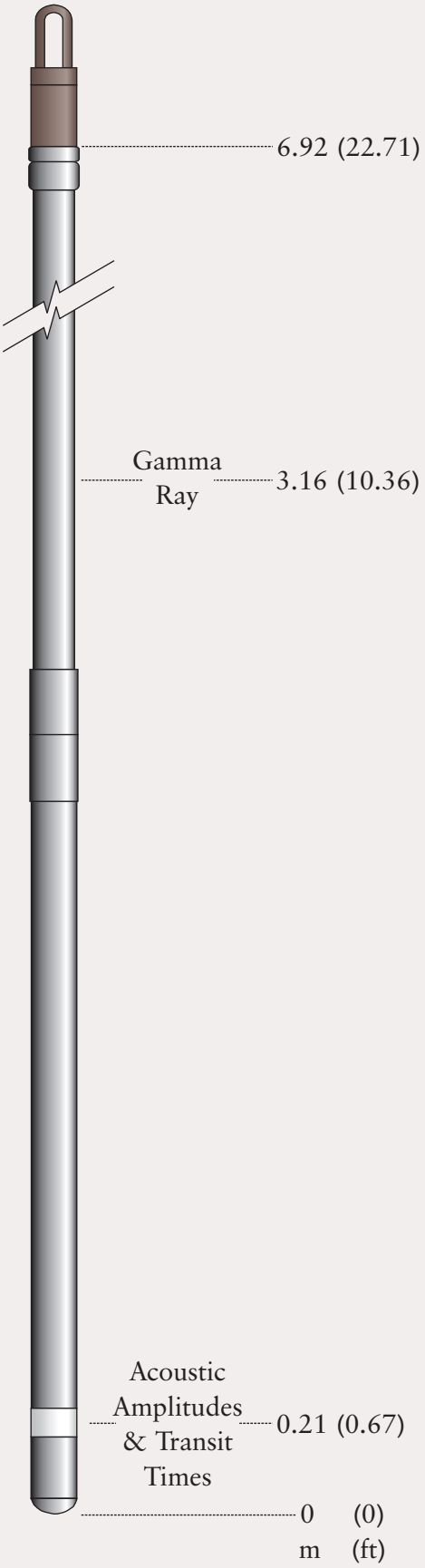
Measurements

- Normalised Amplitude image
- Normalised Transit Time image
- 360 degree caliper
- Borehole trajectory
- Gamma Ray

Applications

- Fracture identification and orientation
- Stress orientation from breakout
- Bed boundary orientation
- Sedimentological and structural studies

Acoustic Scanning Tool - AST



Physical Dimensions (incl. BGN)

Length	6.92 m (22.71 ft)
Diameter	95 mm (3.74 in) without fluid excluder
Weight (in air)	104 Kg (230 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	115 to 305 mm (4.5 to 12.0 in)

Curve Parameters

Range	Amplitude	64 dB
	Transit Time	0 to 255 microseconds
Resolution	Amplitude	0.25 dB
	Transit Time	1.0 microsecond
Circumferential Resolution		7 degrees - equivalent to 9 mm (0.35 in) in a 152 mm (6.0 in) water-filled well
Detection Threshold		The tool detects features smaller than 1 mm (0.04 in) in size in a 152 mm (6 in) diameter water-filled well.

Slim Acoustic Scanner - SAS

The **Slim Acoustic Scanner** gives high resolution formation images in wells as small as 76 mm (3.0 in) in diameter.

Amplitude and Transit Time images are constructed whilst recording data from a rotating acoustic transducer. Two transducers are available to cover two ranges of hole size. Their size, shape and operating frequency have been carefully chosen to give a good balance between spatial resolution and immunity to environmental factors. A special windowless housing enhances resolution and gives an excellent signal-to-noise ratio.

Analysis of the images reveals bed boundaries, fractures and other discontinuities in the rock, and borehole enlargements related to rock mechanical properties and earth stresses.

Real time display is supported by **PC *ImagePro*©** and **Q-Scan©** analysis software.

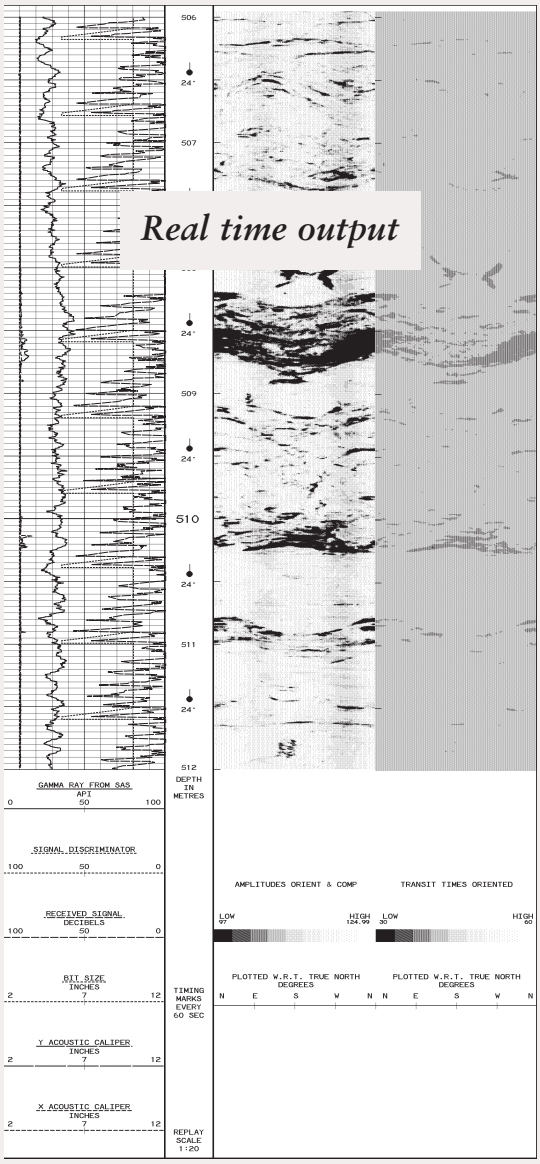
- *Slim hole formation imaging*
- *Choice of transducer for optimum hole size response*
- *Windowless transducer enhances resolution and improves signal-to-noise*

Measurements

- Normalised Amplitude image
- Normalised Transit Time
- 360 degree caliper
- Borehole trajectory
- Gamma Ray

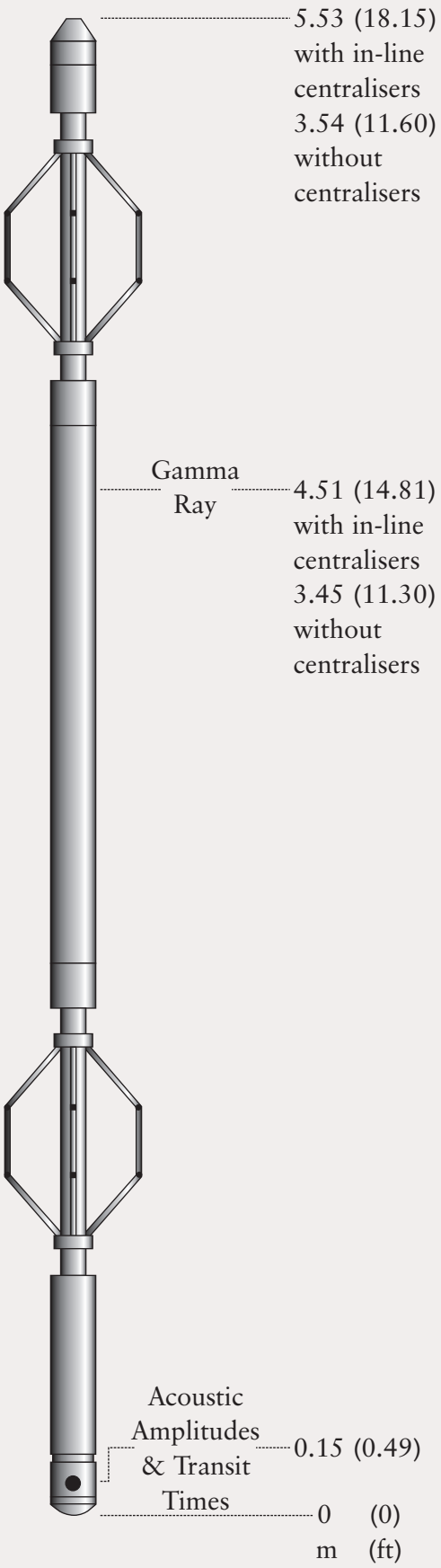
Applications

- Fracture identification and orientation
- Stress orientation from breakout
- Bed boundary orientation
- Sedimentological and structural studies



Real time output

Slim Acoustic Scanner - SAS



Physical Dimensions (incl. Navigation sub)

Length	5.53 m (18.15 ft) with centralisers 3.54 m (11.60 ft) without centralisers
Diameter	54 mm (2.13 in)
Weight (in air)	51 Kg (112 lb) with centralisers 34 Kg (74 lb) without centralisers

Ratings

Temperature	-20^0 to 70^0 C (-4^0 to 158^0 F) (extended range on request)
Pressure (max)	48 MPa (7 kpsi)
Well Diameter	76 to 254 mm (3.0 to 10.0 in)

Curve Parameters

Range	Amplitude	64 dB
	Transit Time	0 to 255 microseconds
Resolution	Amplitude	0.25 dB
	Transit Time	0.5 microseconds
Circumferential Resolution		7 degrees - equivalent to 9 mm (0.35 in) in a 152 mm (6.0 in) water-filled well
Detection Threshold		The tool detects features smaller than 1 mm (0.04 in) in a 152 mm (6 in) diameter water-filled well

Precision Strata Dipmeter - PSD

The **Precision Strata Dipmeter** makes detailed micro-resistivity measurements of the borehole wall. These are correlated to determine the orientation of bed boundaries and other features that intersect the well.

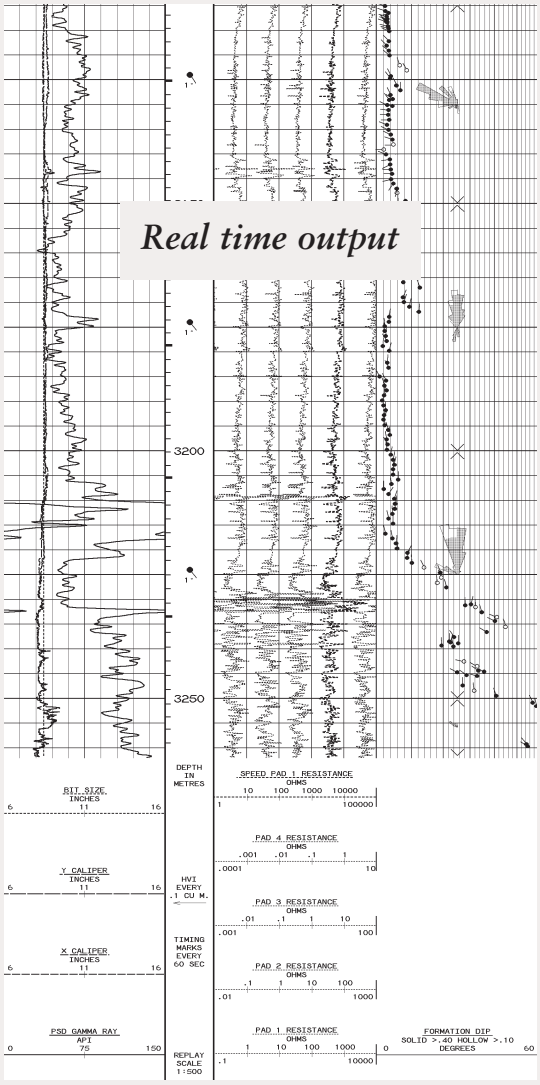
Saline well measurement is made by small electrodes on four pads. In non-conductive (oil) muds, current flows between knives on each pad and bowsprings higher up the tool - the **Scratcher Dipmeter Sonde (SDC).** Controllable side-wall force ensures contact even in poor conditions. Data rates up to 500 samples/m allow very short correlation intervals.

Above the caliper section is the **Borehole Geometry Navigation (BGN)** sub which has a Gamma Ray for correlation and accelerometers and magnetometers for tool orientation. A Z-axis accelerometer is used in the speed correction algorithm to ensure that samples are equally spaced along the borehole. Speed buttons on two orthogonal pads perform an extra check.

Dips are computed whilst logging, providing excellent quality control and instant results. Detailed interactive analysis is performed using the **PC *ImagePro*©** or **Q-Dip**© interpretation packages.

The **Borehole Geometry Sonde (BGS)** is a variant which provides oriented X-Y caliper only.

- *True formation dips available in real time*
- *Integral Gamma Ray*
- *Z-accelerometer for speed correction*
- *Independent X-Y calipers for borehole breakout analysis*
- *High sampling rate - up to 500/metre*



Real time output

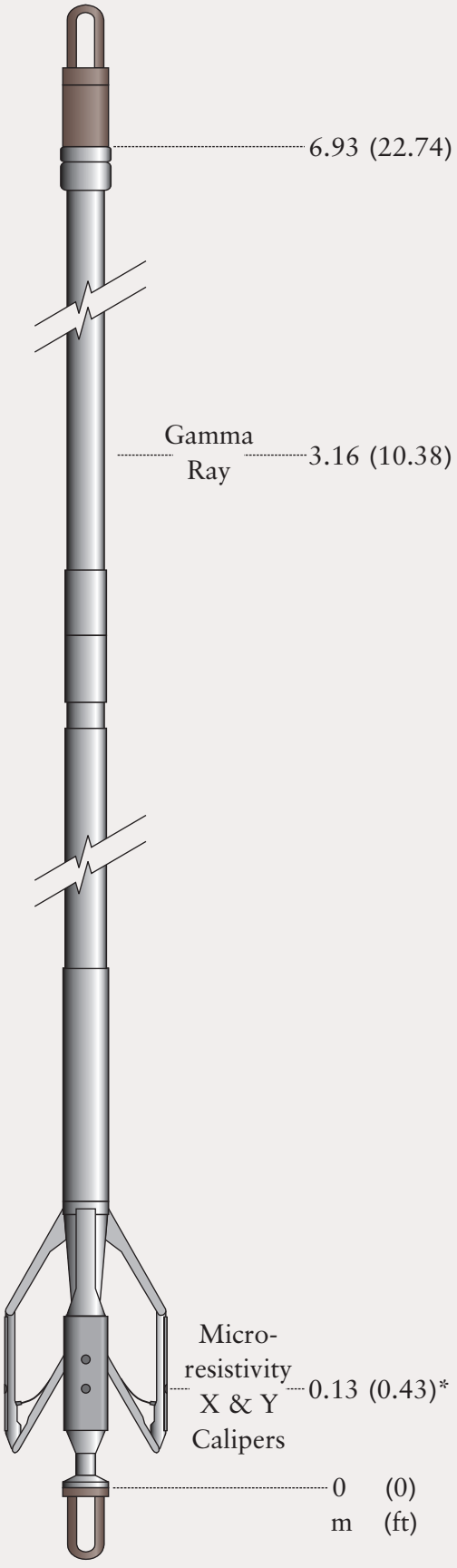
Measurements

- Microresistivity traces
- Borehole trajectory
- Gamma Ray
- X-Y caliper

Applications

- Formation dip and azimuth
- Sedimentological studies
- Palaeoenvironment studies
- Structural & breakout analyses
- TVD analysis

Precision Strata Dipmeter - PSD



* Caliper depth offset calculated at 200 mm (7.9 ins) diameter

Physical Dimensions (incl. BGN)

Length	6.93 m (22.74 ft)
Diameter	105 mm (4.13 in)
Weight (in air)	151 Kg (333 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	140 to 530 mm (5.5 to 20.9 in)

Curve Parameters

Range	Microresistivity	No practical limit (operates in saline muds, or oil muds in scratcher mode)
	Navigation	No practical limit
Resolution	Microresistivity	No practical limit
Vertical Resolution	Microresistivity	10 mm (0.4 in)
Depth of Investigation	Microresistivity	23 mm (0.9 in) nominal per pad

Multi Button Dipmeter - MBD

The **Multi Button Dipmeter** is a development of the successful Precision Strata Dipmeter. It makes highly detailed microresistivity measurements of the borehole wall which are correlated to determine the orientation of bed boundaries and other features that intersect the well. The MBD has four pads, each with three electrodes giving the following extra benefits :

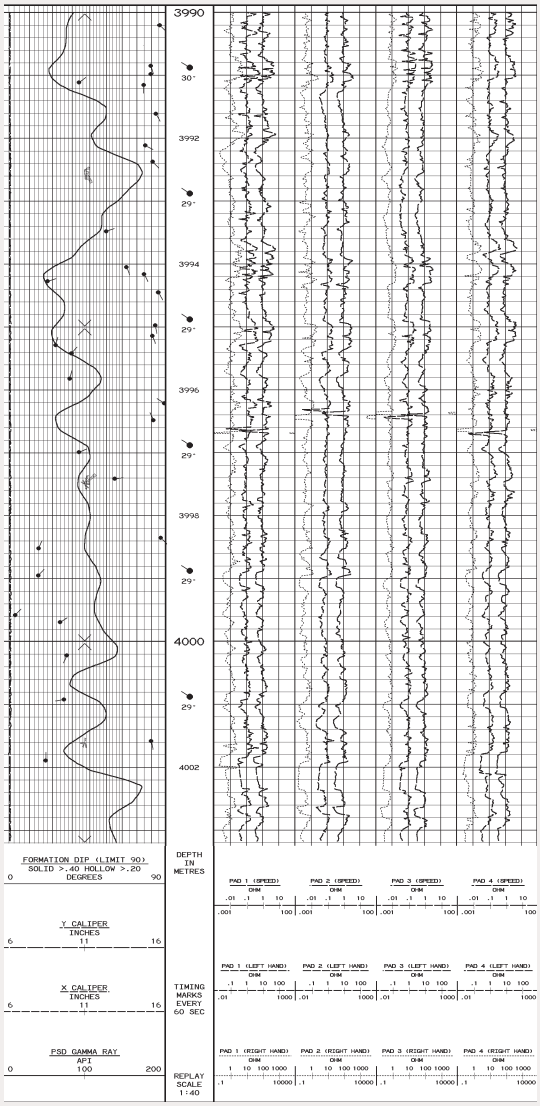
- more data redundancy for poor conditions
- more detailed analysis is possible with side-by-side buttons - in difficult conditions averaging can improve the signal-to-noise ratio
- 12 buttons are sufficient to create an image for quality controlling machine generated dips

The MBD uses short pads with controllable sidewall force for optimum wall contact. Data rates of 200 samples/m allow very short correlation intervals.

Above the caliper section is the **Borehole Geometry Navigation** sub **(BGN)**. This has an integral Gamma Ray for correlation and accelerometers and magnetometers for tool orientation. Z-axis accelerometer data is used in a speed correction algorithm to ensure equally spaced samples.

Dips are computed and quality controlled using the **PC *ImagePro***© or Q-Dip© interpretation packages.

- *Twelve buttons for extra coverage and data redundancy*
- *Integral Gamma Ray*
- *Z-accelerometer for speed correction*
- *Independent X-Y calipers for borehole breakout analysis*



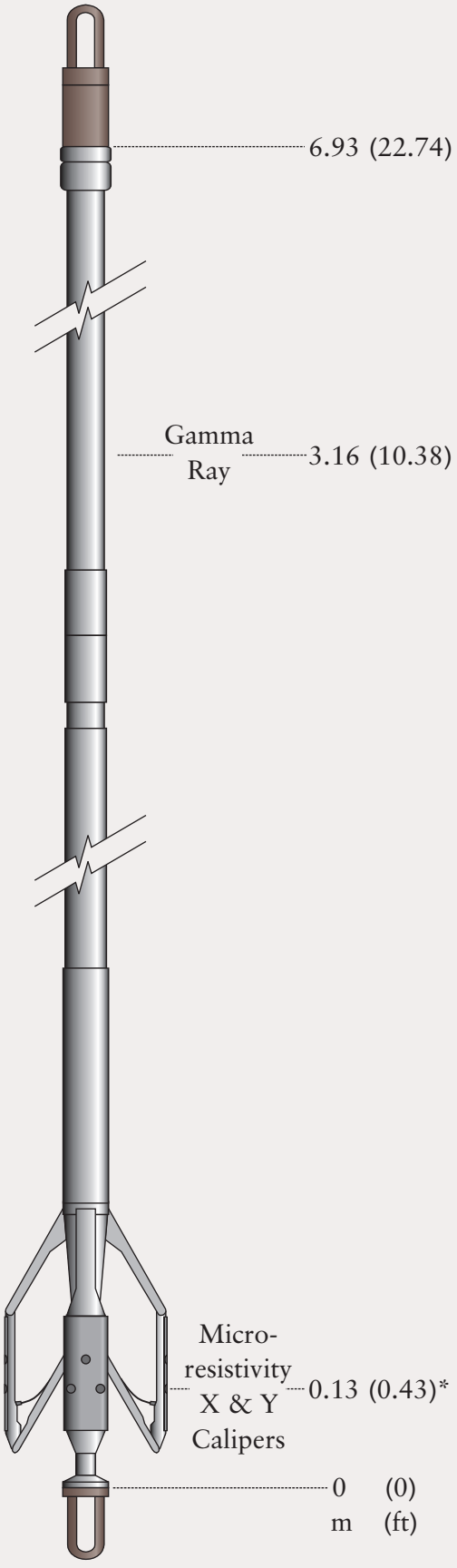
Measurements

- Microresistivity traces (12)
- Borehole trajectory
- Gamma Ray
- X-Y caliper

Applications

- Formation dip and azimuth
- Sedimentological studies
- Palaeoenvironment studies
- Structural & breakout analyses
- TVD analysis

Multi Button Dipmeter - MBD



* Caliper depth offset calculated at 200 mm (7.9 ins) diameter

Physical Dimensions (incl. BGN)

Length	6.93 m (22.74 ft)
Diameter	105 mm (4.13 in)
Weight (in air)	151 Kg (333 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	140 to 530 mm (5.5 to 20.9 in)

Curve Parameters

Range	Microresistivity	No practical limit
	Navigation	No practical limit
Resolution	Microresistivity	No practical limit
Vertical Resolution	Microresistivity	10 mm (0.4 in)
Depth of Investigation	Microresistivity	23 mm (0.9in) nominal per pad

Slim Quad Dipmeter - SQD

The **Slim Quad Dipmeter** is designed for operations in wells as small as 76 mm (3.0 in) in diameter. It provides four focussed microresistivity measurements and tool orientation data - these are used to compute formation dips and wellbore trajectory. Analysis of patterns generated by successive dips provides important information about depositional and structural environments.

The microresistivity measurements are made by small electrodes embedded in four pads on two pairs of orthogonal caliper arms. These are correlated to produce formation dips. The **PC *ImagePro*©** and **Q-Dip©** software products provided fully automated and interactive analysis options, as well as a comprehensive range of geological interpretation tools.

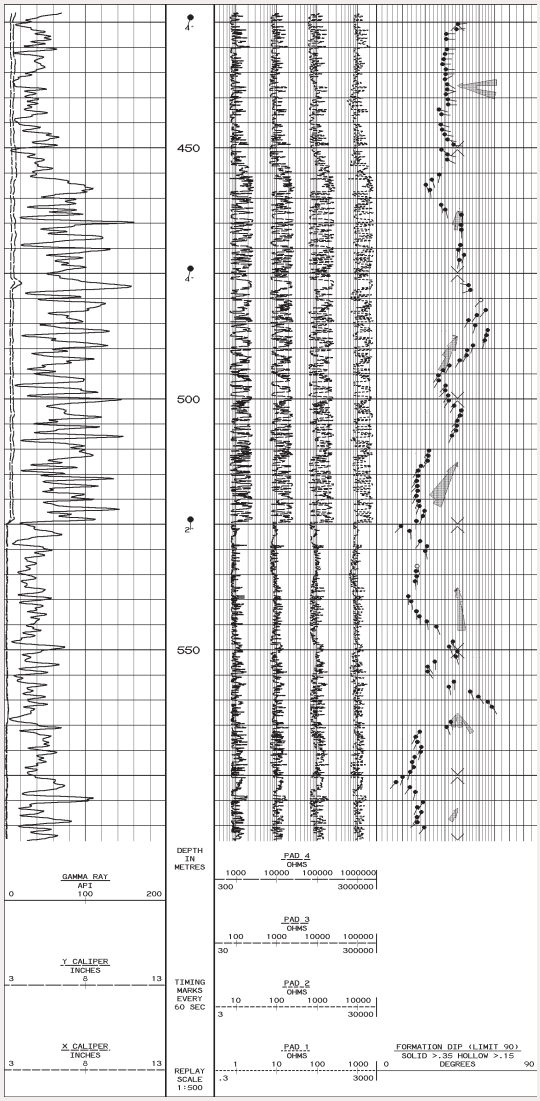
- *Slim hole formation dip analysis*
- *Robust 4-arm design*
- *Integral Gamma Ray*
- *Independent X-Y calipers for borehole breakout analysis*

Measurements

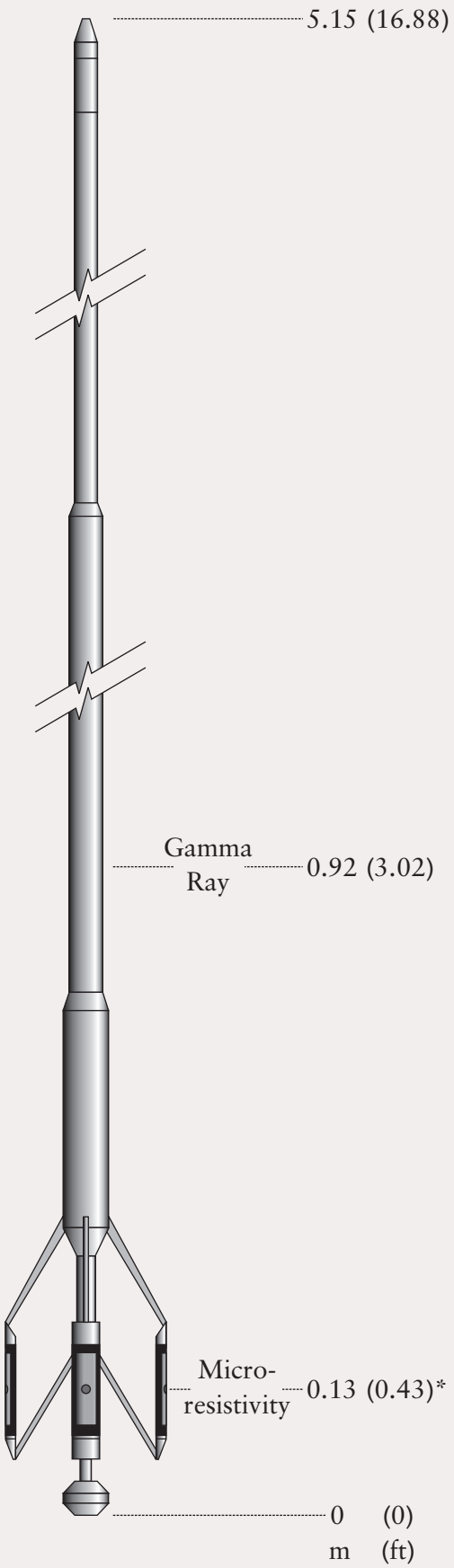
- Microresistivity traces
- Sonde navigation data (from the navigation sub)
- Gamma Ray
- X-Y caliper
- Borehole trajectory

Applications

- Formation dip and azimuth
- Sedimentological studies
- Palaeoenvironment studies
- Structural studies
- TVD analysis
- Breakout analysis



Slim Quad Dipmeter - SQD



* Caliper depth offset calculated at 102 mm (4.0 ins) diameter

Physical Dimensions (incl. Navigation sub)

Length	5.15 m (16.88 ft)
Diameter	57 mm (2.25 in)
Weight (in air)	32 Kg (70.5 lb)

Ratings

Temperature	-20^0 to 85^0 C (-4^0 to 185^0 F) (extended range on request)
Pressure (max)	51 MPa (7.5 kpsi)
Well Diameter	76 to 254 mm (3.0 to 10.0 in)

Curve Parameters

Range	Microresistivity	2 to 10000 Ωm (Rm = 10 Ωm) 0.05 to 2500 Ωm (Rm = 0.01 Ωm)
	Navigation - tilt	0 to 45^0 (standard)
	- tilt	0 to 90^0 (optional)
Resolution	No practical limit	
Vertical Resolution	10 mm (0.4 in)	
Depth of Investigation	6 mm (0.24 in) nominal per pad	

Formation Testing and Sampling Services

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Repeat Formation Sampler - RFS

The **Repeat Formation Sampler** makes accurate measurements of absolute formation pressures from which fluid types and their contact depths are determined. In addition, samples of formation fluids can be returned to the surface for chemical analysis.

Each pressure determination begins with a pre-test during which fluid is produced at a constant rate into a small pre-test chamber. Pressures recorded during this cycle are used to compute a drawdown permeability. A second permeability determination is made from the rate at which pressure subsequently builds up to its intrinsic formation value.

Formation pressure versus depth plots show pressure gradients, whose magnitudes depend on the density of fluids in the formation. This allows discrimination between water, oil and gas, and provides a mechanism for locating fluid contact depths.

Two styles of Open Hole RFS, plus a Cased Hole variant enable operations in a wide range of borehole environments. The Open Hole tools are: 140 mm diameter RFS-C and 120 mm RFS-D. The Cased Hole RFS is 140 mm in diameter. All use strain gauge and/or high accuracy quartz pressure gauge transducers.

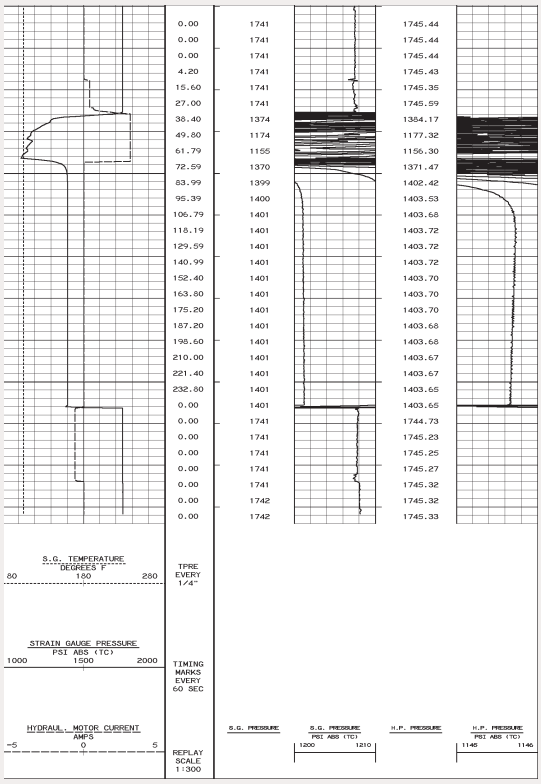
Measurements

- Gamma Ray
- Temperature
- Strain Gauge Pressure
- Quartz Gauge Pressure
- Fluid Samples

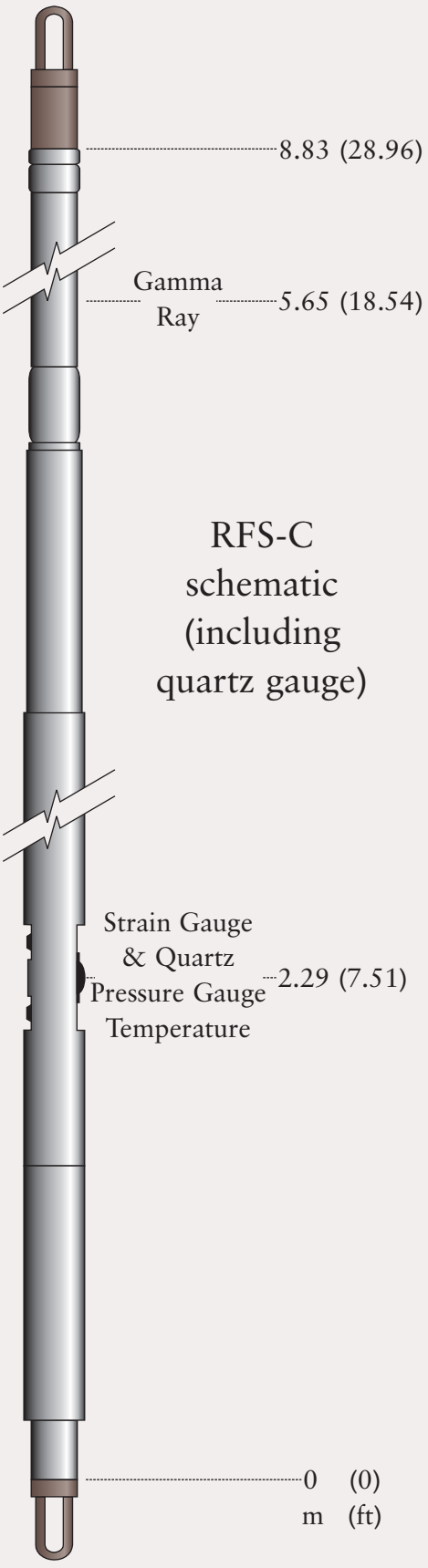
Applications

- Formation Pressures
- Formation Pressure Gradients
- Depth of Fluid Contacts
- Permeability
- Physical samples for analysis

- *Accurate formation pressures for fluid type identification and contact depths*
- *3 tool styles cover all operating conditions*
- *Integral Gamma Ray*
- *Quartz pressure gauges and/or strain gauges*
- *Cased hole and Slim hole options*



Repeat Formation Sampler - RFS



Physical Dimensions

Tool	Length* m (ft)	Diameter mm (in)	Weight* Kg (lb)
RFS-C	8.83 (28.96)	140 (5.51)	340 (750)
RFS-D	9.74 (31.96)	120 (4.72)	318 (700)
Cased Hole RFS	9.74 (31.96)	140 (5.51)	318 (700)

* Including Quartz Gauge, but excluding sample tanks

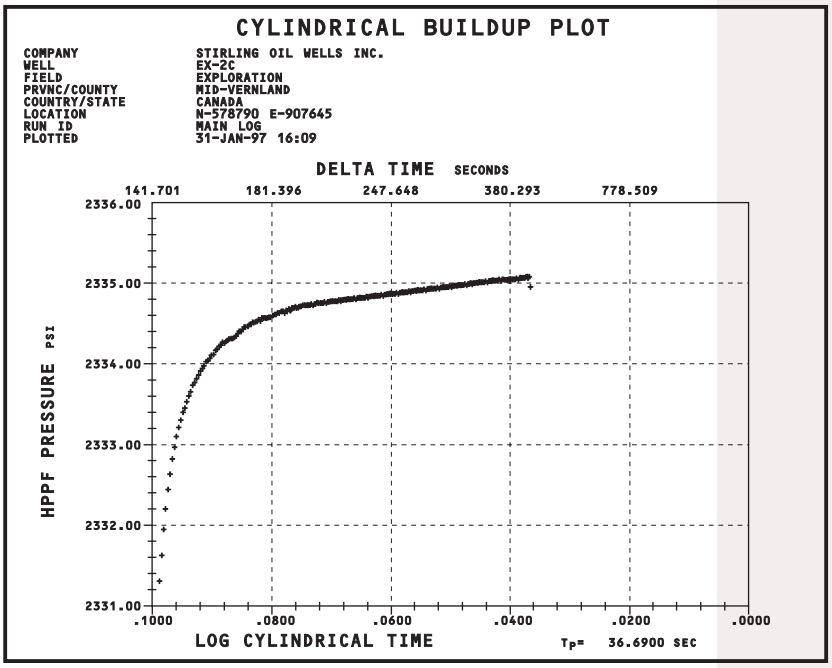
Ratings

Tool	Min. hole size mm (in)	Max. hole size mm (in)
RFS-C	170 (6.7)	260 (10.2) *
RFS-D	150 (6.0)	230 (9.1) *
Cased Hole RFS	150 (6.0)	200 (7.9) *

* Kit available for hole sizes up to 394 mm (15.5 in)

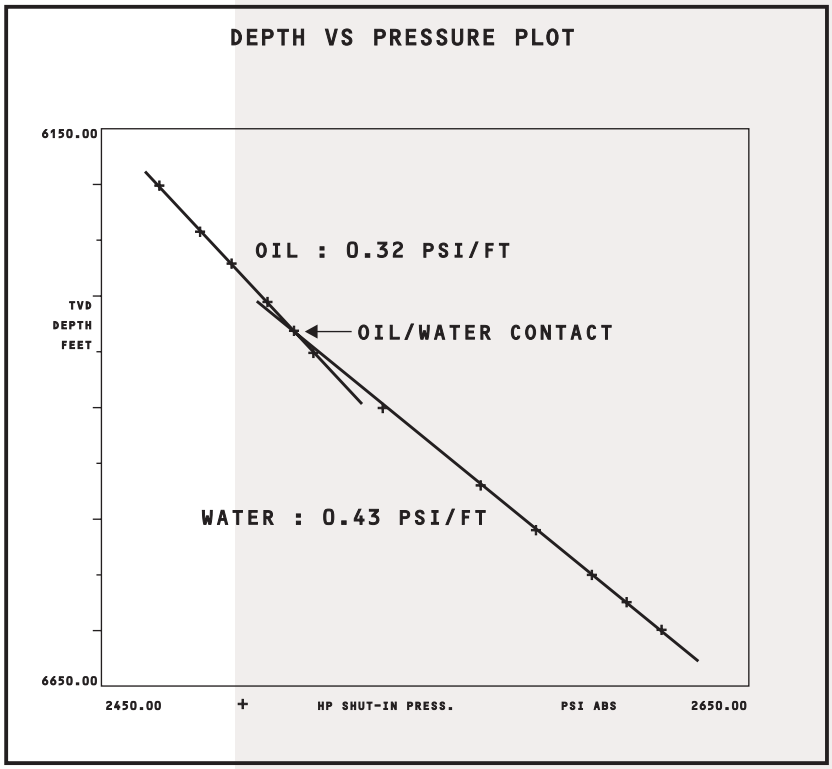
Temperature (max) 150^0 C (302^0 F)
Pressure (max) 103 Mpa (15 kpsi)

Repeat Formation Sampler - RFS

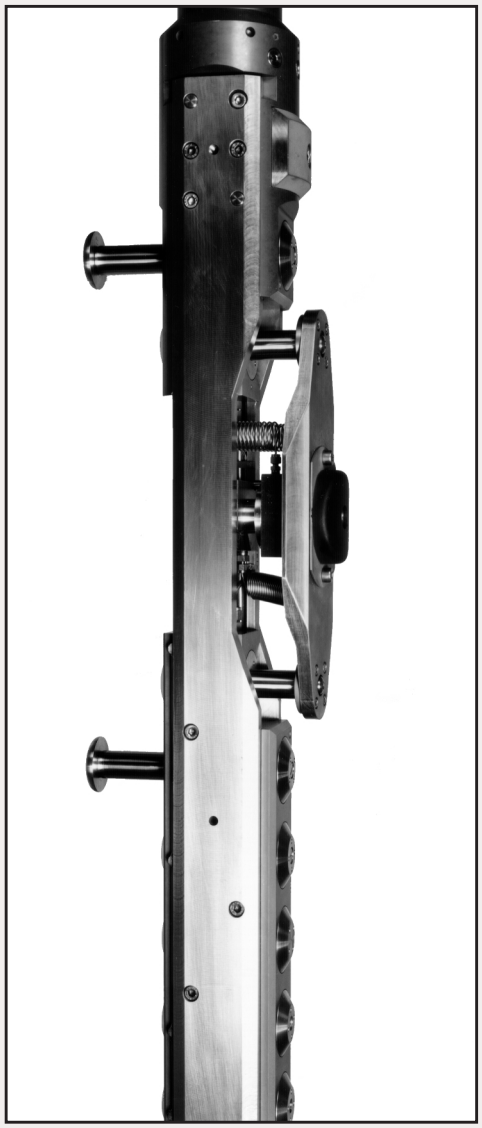


RFS pressure-time function plots are used to compute intrinsic formation pressures and to provide estimates of formation permeability. During acquisition, tests are terminated as soon as the computed formation pressures reach steady values - this can greatly reduce total logging times.

Formation pressures from the RFS plotted against true vertical depths define pressure gradients that reflect the composition of the reservoir fluids. The intersections of different gradients define the depths of fluid contacts.



Repeat Formation Sampler - RFS



RFS-D

Curve Parameters

Tool	Tank Volumes	Pretest Volume (max.)	No. of Tests	Minimum Test Depth above TD*
RFS-C	Any mix of 1 & $2^{3}/_{4}$ gallons	1 x 10 cc	Any	0.6 m (2.0 ft)
RFS-D	Any mix of 1 & $2^{3}/_{4}$ gallons	2 x 10 cc	Any	1.1 m (3.6 ft)
Cased Hole RFS	Any mix of 1 & $2^{3}/_{4}$ gallons	2 x 10 cc	2	1.1 m (3.6 ft)

* Excluding sample tanks and Quartz pressure gauge

Specification	Strain Gauge	Quartz Gauge
Calibrated Ranges	0 to 35, 0 to 70 and 0 to 103 Mpa (0 to 5, 0 to 10 and 0 to 15 kpsi)	1.4 to 75.5 Mpa (0.2 to 11 kpsi) [Operating range is 0 to 82.7 MPa (0 to 12 kpsi)]
Resolution	70 Pa (0.01 psi) for 1 second sampling	70 Pa (0.01 psi) for 1 second sampling
Accuracy	± 0.13 % of full scale	± 6.9 kPa (1.0 psi) [plus 0.01 % of reading] in the temperature range 35^{0} to 150^{0} C (95^{0} to 302^{0} F)
Repeatability	± 0.05 % of full scale	± 2.8 kPa (0.4 psi) at constant temperature or ± 6.9 kPa (1.0 psi) with variable temperature

Sidewall Core Gun - SCG

The **Sidewall Core Gun** fires specially designed hollow bullets into the formation. Each bullet remains attached to the gun with flexible steel wires, so it is recovered, together with its core plug, as the tool is raised.

The gun is positioned with the aid of the integral Gamma Ray measurement. Each bullet is selected and fired individually from the surface. Up to 24 cores are shot from each gun, and up to 4 guns (96 cores) may be run on each trip in the well.

The standard gun operates in hole sizes in the range 150 to 400 mm (5.9 to 15.8 in). A range of bullet assemblies is available depending on the hardness of the formation.

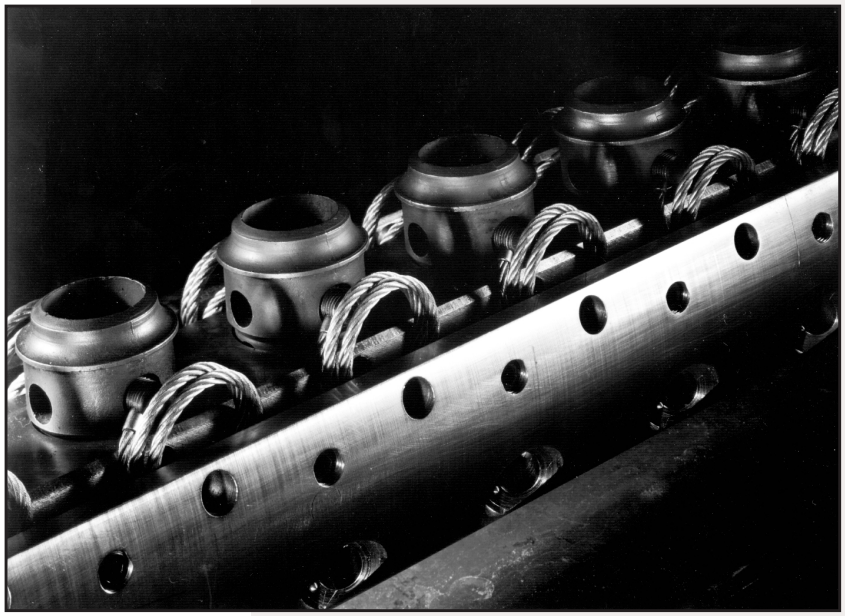
- *Up to 24 sidewall core samples per gun*
- *Up to 4 guns per trip into the well (96 cores)*
- *Bullets for both soft and hard rock types*
- *Gamma Ray*

Measurements

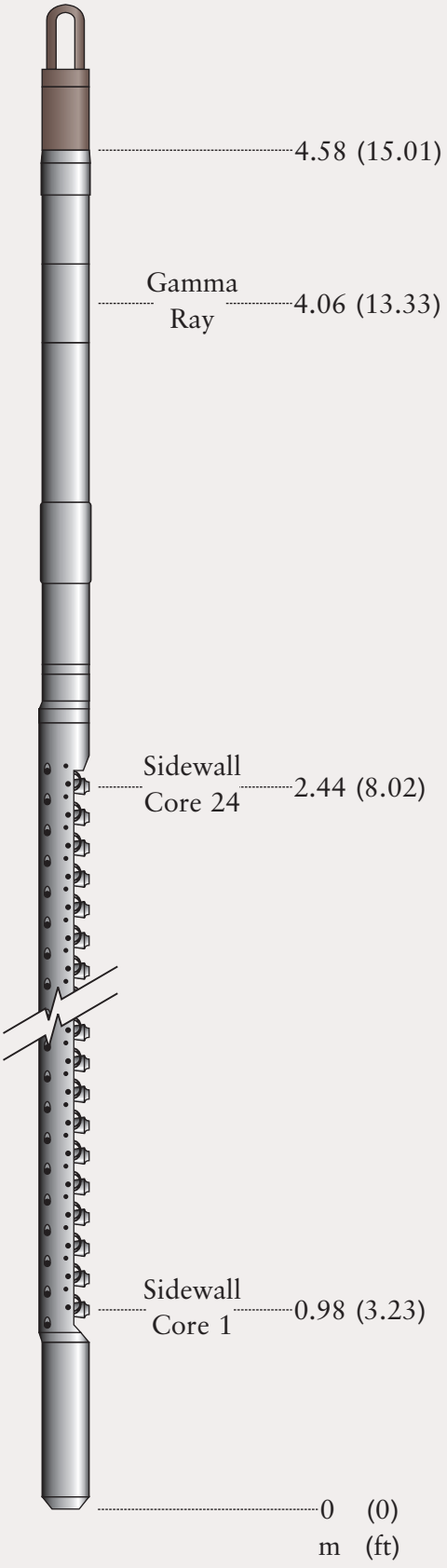
- Gamma Ray
- Sidewall core samples

Applications

- Correlation
- Lithological analysis of cores
- Palaeontological analysis of cores



Sidewall Core Gun - SCG



Physical Dimensions

Length	4.58 m (15.01 ft)
Diameter	102 mm (4.02 in)
Weight (in air)	171 Kg (376 lb)

Ratings

Temperature	-40^0 to 150^0 C (-40^0 to 302^0 F)
Pressure (max)	103 MPa (15 kpsi)
Well Diameter	150 to 400 mm (5.9 to 15.8 in)

Production Logging and Cased Hole Services

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Production Logging String - PLS

The **Production Logging String** comprises one or more production logging tools which may be run singly or in combination. They measure a wide range of parameters which indicate the nature and movement of fluids within and close to the wellbore. The logs are acquired on a zone by zone basis, and may be made whilst the well is shut in, or during production or injection.

PLS data is an essential part of reservoir management. Amongst its applications are :

- Monitoring of production and injection
- Quantification of reservoir characteristics
- Evaluation of completion effectiveness
- Detection of coning, breakthrough, thief zones and channelled cement
- Testing of reservoir models
- Provision of data for workover and enhanced recovery work

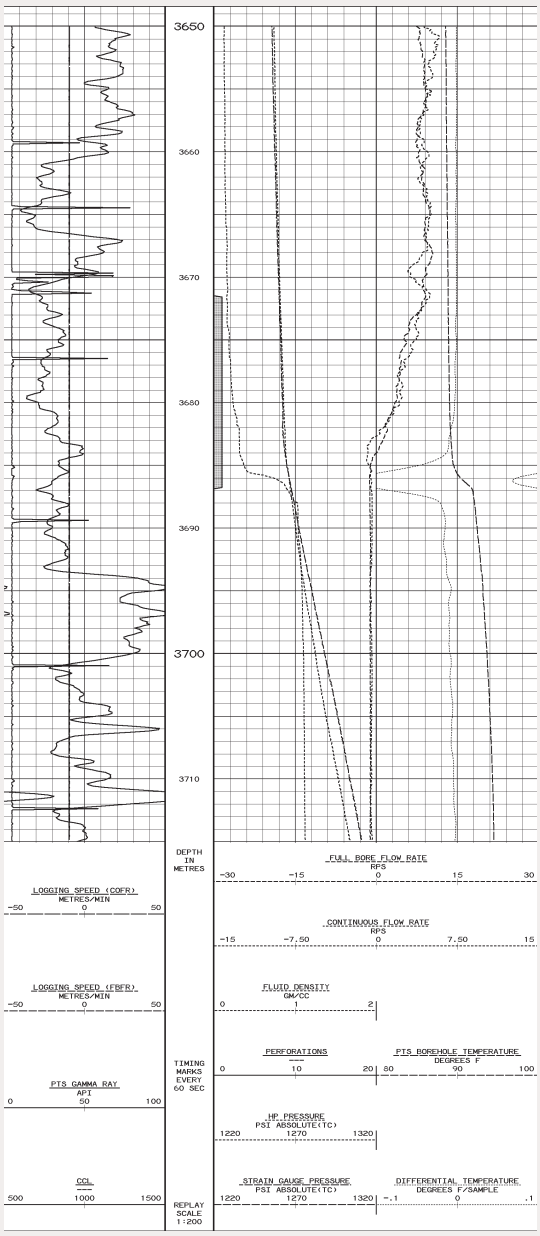
All tools in the PLS string use digital communications. This allows flexibility in the stacking of tools, and ensures reliable simultaneous recording. The following tools are available :

Pressure Temperature Sonde	PTS
Quartz Pressure Gauge	QPG
Fluid Density Sonde	FDS
In-line Flowmeter	IFS
Fullbore Flowmeter	FFS
Fluid Conductivity Sonde	FCS
Thermal Neutron Decay Sonde	TDS

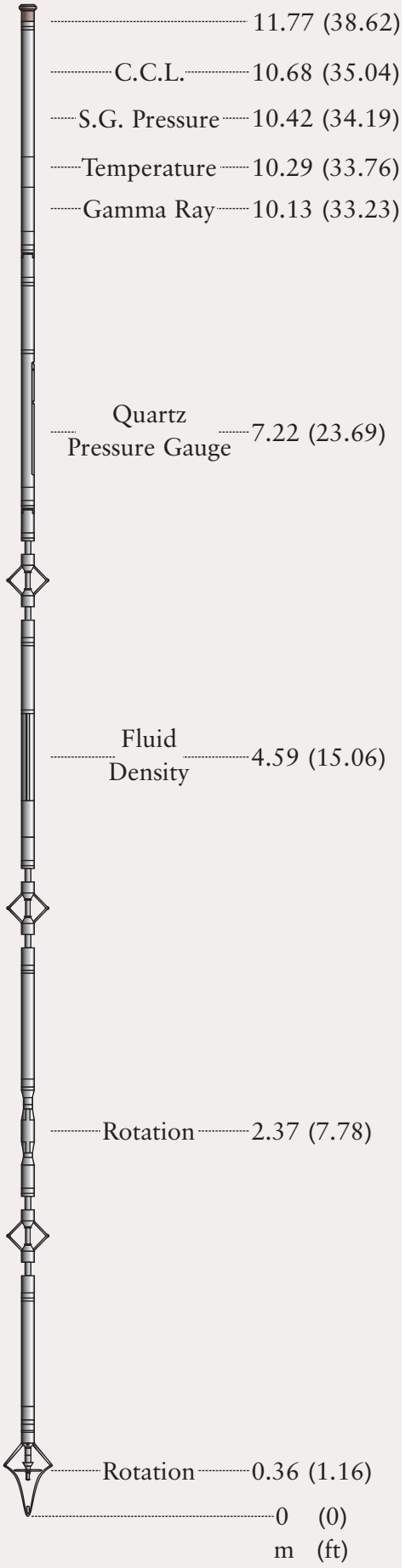
and may be run with the following ancillary equipment :

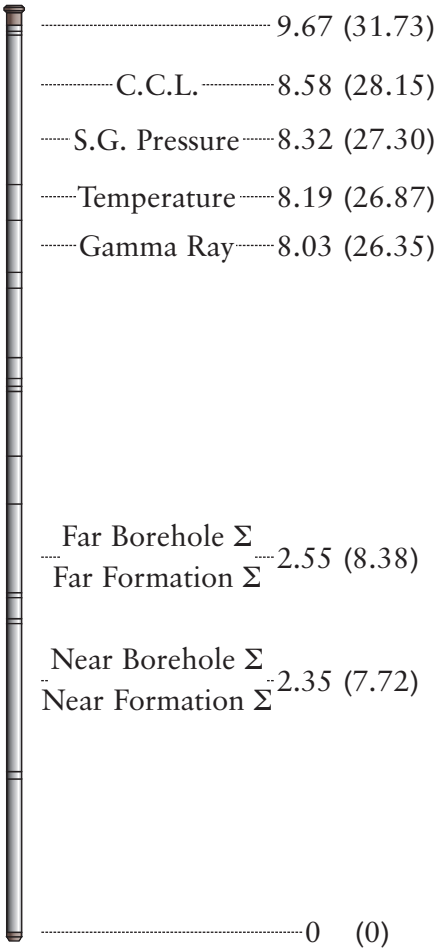
Roller Centralisers	PRC
Production Spring Centralisers	PSC
Production Knuckle Joints	PKJ
Conductor Weights	SBS

- *Comprehensive range of measurements*
- *Full digital communications for flexible and reliable performance*



Production Logging String - PLS





Typical PLS strings - left :

PTS	Pressure Temperature Sonde
PKJ	Production Knuckle Joint
QPG	Quartz Pressure Gauge
PKJ	Production Knuckle Joint
PRC	Production Roller Centraliser
FDS	Fluid Density Sonde
PRC	Production Roller Centraliser
IFS	Inline Flowmeter Sonde
PRC	Production Roller Centraliser
FFS	Fullbore Flowmeter Sonde

And above :

PTS	Pressure Temperature Sonde
TDS	Thermal Neutron Decay Sonde

Virtually any combination is permitted.

The PTS contains the digital communications systems for the entire PLS string. As such, the PTS must be included as the uppermost sonde in any PLS string. Conversely, the FFS must be the lowermost sonde when present in the string.

Pressure Temperature Sonde - PTS

The **Pressure Temperature Sonde** is the core tool in the production logging string. It provides the depth control data (Gamma Ray and Casing Collar Locator) as well as basic wellbore temperature and pressure data. The PTS may be run with any other PLS tool.

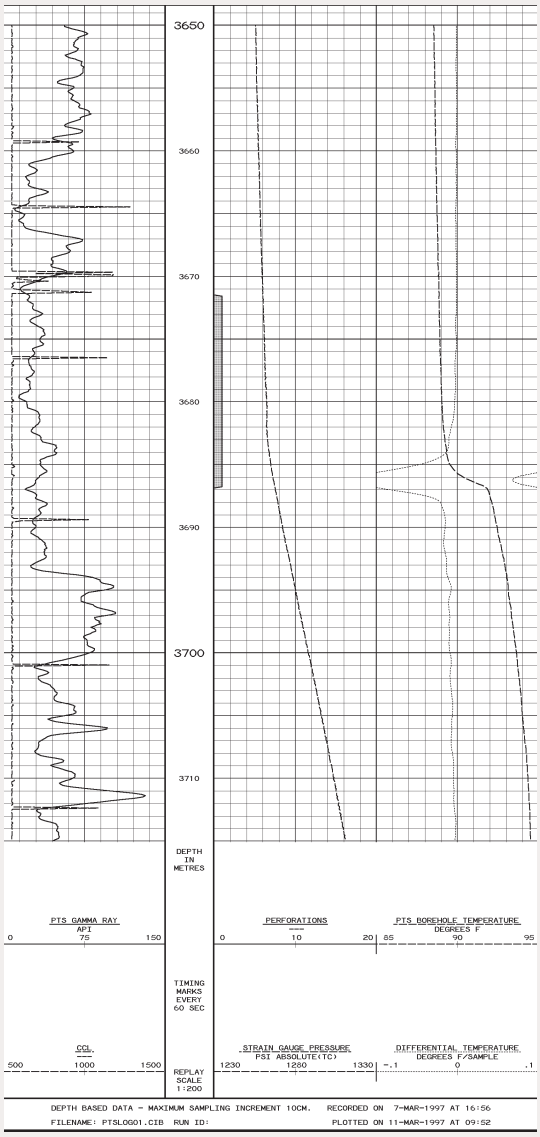
- ***Pressure, temperature and correlation logs***
- ***43 mm ($1^{11}/_{16}$ in) dia.***
- ***Fully combinable with all other PLS tools***

Measurements

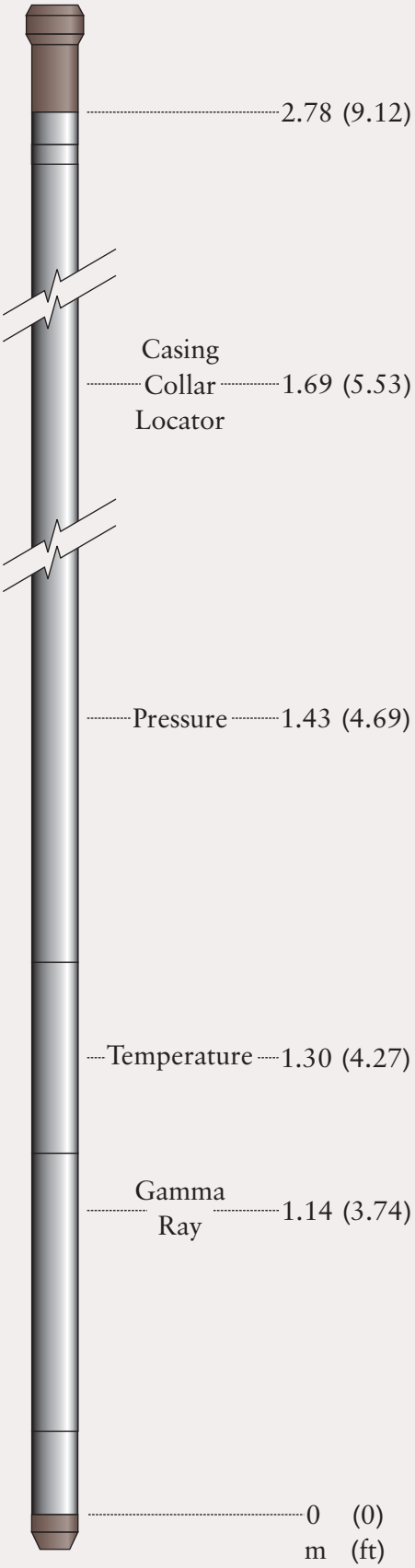
- Pressure
- Temperature
- Gamma Ray
- CCL

Applications

- Depth correlation
- Pressure buildup and drawdown
- Anomaly detection from temperature profile
- Gas entry
- Cement top detection



Pressure Temperature Sonde - PTS



Physical Dimensions

Length	2.78 m (9.12 ft)
Diameter	43 mm (1.69 in)
Weight (in air)	17 Kg (37 lb)

Ratings

Temperature (max)	150^0 C (302^0 F)
Pressure (max)	103 MPa (15 kpsi)

Curve Parameters

Range	Temperature	0 to 150^0 C (32 to 302^0 F)
	Pressure	0 to 34 MPa (0 to 5 kpsi)
	or	0 to 69 MPa (0 to 10 kpsi)
	or	0 to 103 MPa (0 to 15 kpsi)
Resolution	Temperature	0.05^0 C (0.09^0 F)
	Pressure	0.7 kPa (0.1 psi)
Accuracy	Temperature	± 0.5^0 C (0.9^0F)
	Pressure	± 0.13 % FSD
Repeatability	Temperature	± 0.1^0 C (0.2^0 F)
	Pressure	± 0.025 % FSD

Quartz Pressure Gauge - QPG

The **Quartz Pressure Gauge** provides extremely accurate fluid pressure measurements for the determination of flowing and shut-in pressures.

The gauges are mounted in a special carrier - the **Pressure Gauge Carrier (PGC)** - which is the interface to the digital communications package for surface read-out, and which allows combinations with other tools in the Production Logging String.

For maximum accuracy the temperature of the wellbore fluids needs to be stable - the PTS temperature sensor provides the data for automatic temperature correction. Late model gauges are used which have much improved thermal response times.

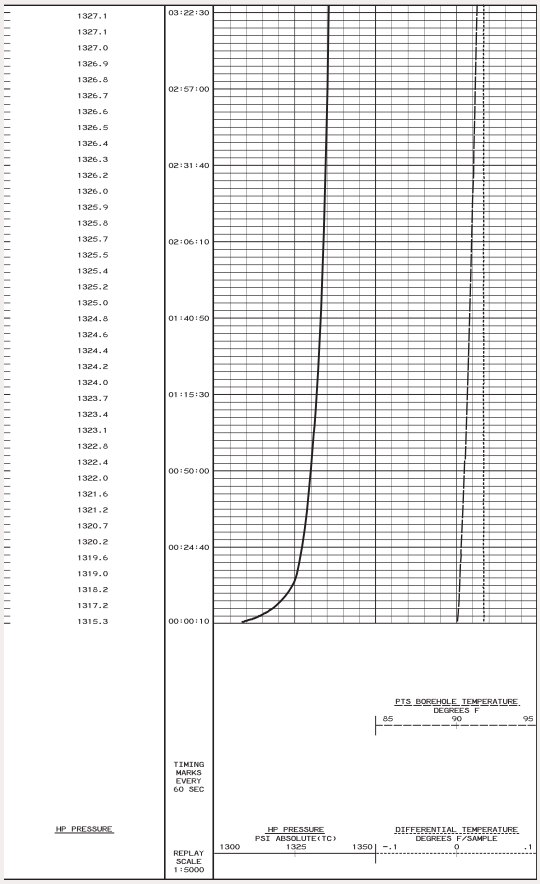
- ➤ *High accuracy pressure measurements for flowing and shut-in conditions*
- ➤ *Fully combinable with other PLS tools*

Measurements

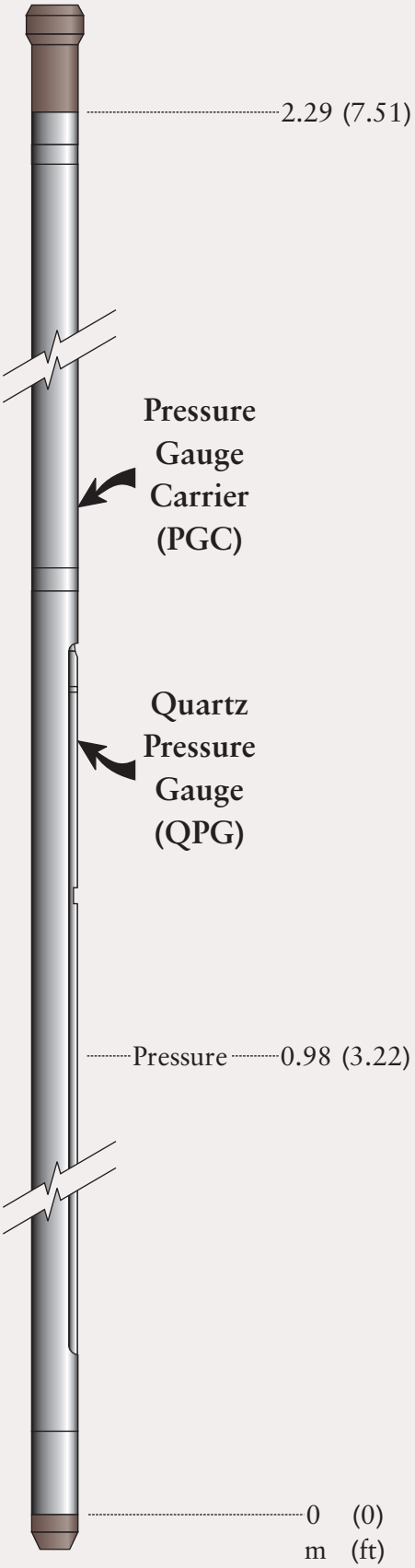
- ➤ Fluid Pressure

Applications

- ➤ Flowing and shut-in pressure determination
- ➤ Pressure transient analysis
- ➤ Delineation of reservoir geometry and characteristics
- ➤ Permeability determinations
- ➤ Boundary detection



Quartz Pressure Gauge - QPG



Physical Dimensions (PGC and QPG)

Length	2.29 m (7.51 ft)
Diameter	44.5 mm (1.75 in)
Weight (in air)	17 Kg (37 lb)

Ratings

Temperature (max)	150^0 C (302^0 F)
Pressure (max)	82.7 MPa (12 kpsi)

Curve Parameters

Range	Calibrated :	1.4 to 75.8 MPa (0.2 to 11 kpsi)
	Operating :	0 to 82.7 MPa (0 to 12 kpsi)
Resolution	7 Pa (0.001 psi) sampling for 1 second	
Accuracy	± 7 kPa (1.0 psi) + 0.01 % of reading for temperatures in the range 35^0 to 150^0 C (95^0 to 302^0 F)	
Repeatability	± 7 kPa (1.0 psi)	

Fluid Density Sonde - FDS

The **Fluid Density Sonde** responds to variations in the density of wellbore fluids. It operates in wells with deviations up to 65 degrees.

Density values are computed from accurate measurements of the displacement of a float within the body of the tool. The amount of displacement is proportional to the density of the fluid. The movement of the float is constrained by a second float connected rigidly to the first, and immersed in a high density fluid.

The output from the tool is calibrated to read fluid density directly. In deviated wells, the output is corrected by the cosine of the deviation angle.

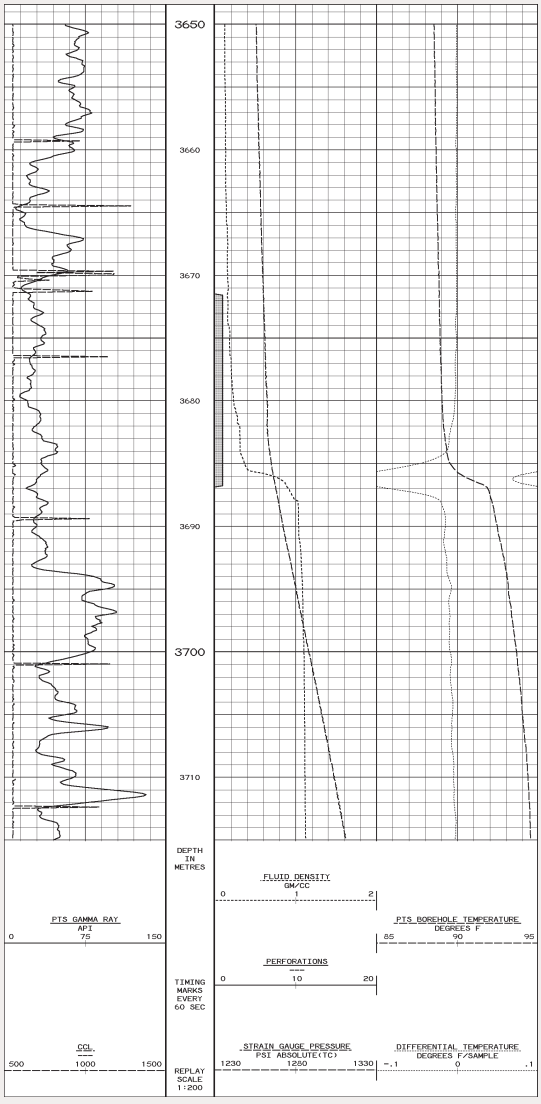
- *Accurate fluid density in wells deviated up to 65 degrees*
- *Location of water or gas entries and all fluid contacts*

Measurements

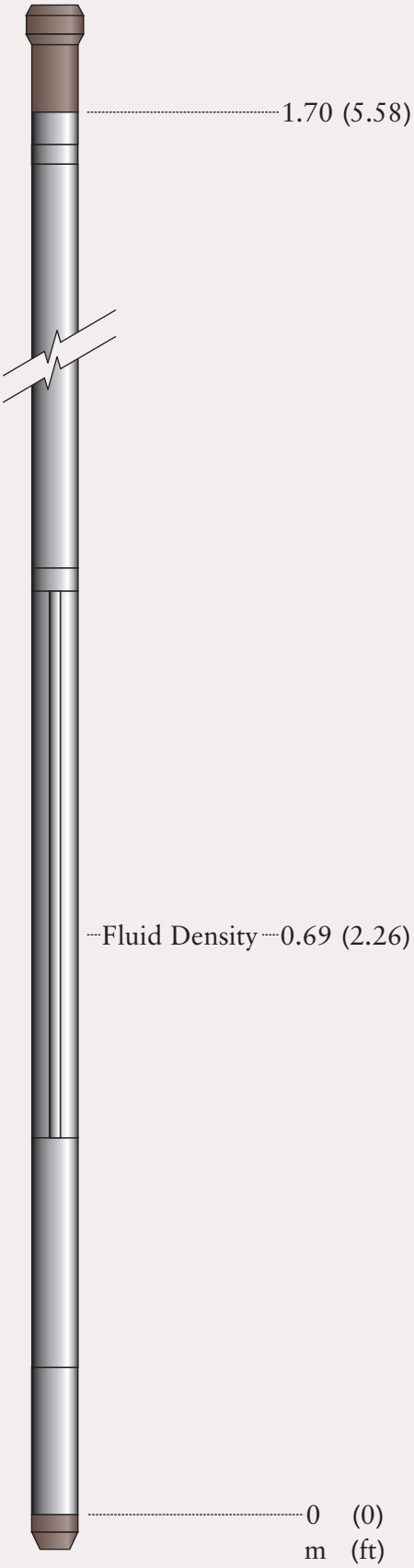
- Fluid Density

Applications

- Location of fluid contacts
- Location of water or gas entries
- Fluid characterisation



Fluid Density Sonde - FDS



Physical Dimensions

Length	1.70 m (5.58 ft)
Diameter	43 mm (1.69 in)
Weight (in air)	11 Kg (24 lb)

Ratings

Temperature (max)	150^0 C (302^0 F)
Pressure (max)	103 MPa (15 kpsi)

Curve Parameters

Range	0 to 1200 Kg/m^3 (0 to 1.2 gm/cm^3)
Resolution	5 Kg/m^3 (0.005 gm/cm^3)
Accuracy	± 40 Kg/m^3 (0.04 gm/cm^3)
Repeatability	± 30 Kg/m^3 (0.03 gm/cm^3)

Inline Flowmeter Sonde - IFS

The **Inline Flowmeter Sonde** uses a spinner mounted within the tool, and is particularly suited to medium and high flow rates.

The spinner and its housing have the same response characteristics regardless of the direction of fluid flow. Absolute flow rates are determined from an in-situ calibration performed at a number of logging speeds up and down the well. This automatically compensates for fluid viscosity and density effects.

Two sizes of IFS are available for different tubing or casing sizes.

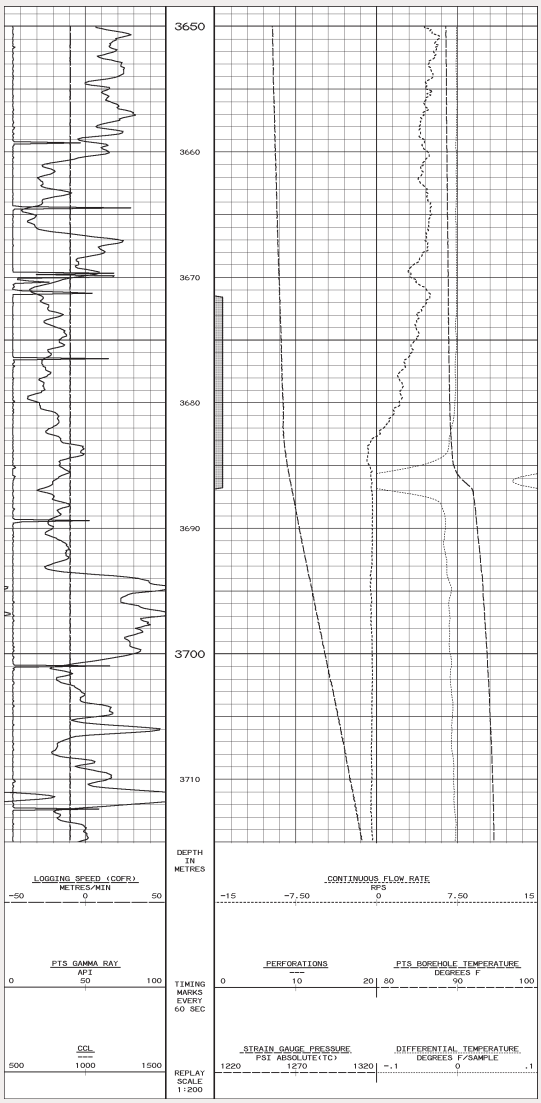
- *Flow measurements at medium to high rates*
- *Production and injection profiles*
- *Particularly suited to logging in tubing*

Measurements

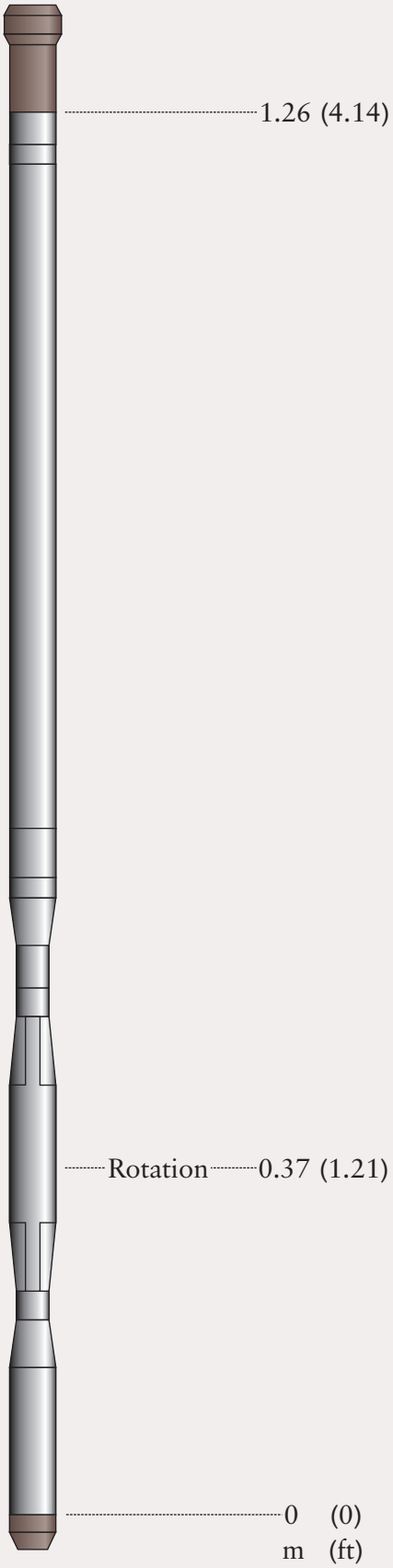
- Spinner rotation rate

Applications

- Flow measurements at medium to high flow rates
- Determination of production and injection profiles
- Detection of production loss due to thief zones or crossflow
- Detection of leaks through packers and plugs



Inline Flowmeter Sonde - IFS



Physical Dimensions

Length	1.26 m (4.14 ft)
Diameter	IFS.A 43 mm (1.69 in)
	IFS.B 54 mm (2.13 in)
Weight (in air)	9 Kg (20 lb) maximum

Ratings

Temperature (max)	150^0 C (302^0 F)
Pressure (max)	103 MPa (15 kpsi)

Curve Parameters

Range	2 to 300 m/min (about 300 to 60,000 bbl/d in 7 inch casing)
Resolution	0.1 m/min (above threshold velocity)
Accuracy	± the greater of 0.3 m/min or 3 % of measured velocity
Repeatability	± 1 % of measured velocity above threshold velocity

Fullbore Flowmeter Sonde - FFS

The **Fullbore Flowmeter Sonde** measures fluid flow using a large cross-section area spinner. The spinner assembly is collapsible for passage down the tubing and opens up inside the casing. It runs in precision bearings and employs Hall Effect transducers for low drag and low threshold velocity. The large size of the spinner renders it relatively immune to multiphase flow and velocity profiling effects. It must be the lowermost tool in the Production Logging String.

The tool comprises a spinner sub and an electronics sub. There are several sizes of spinner sub for optimum performance in a range of casing sizes.

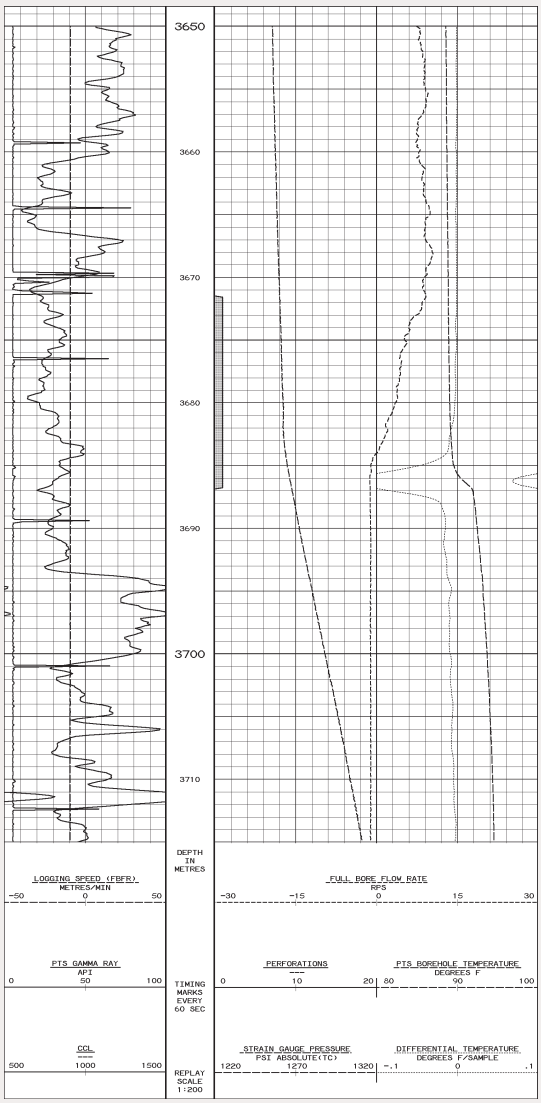
- *Flow measurements at low to medium rates*
- *Hall Effect transducers for low drag and low threshold velocity*

Measurements

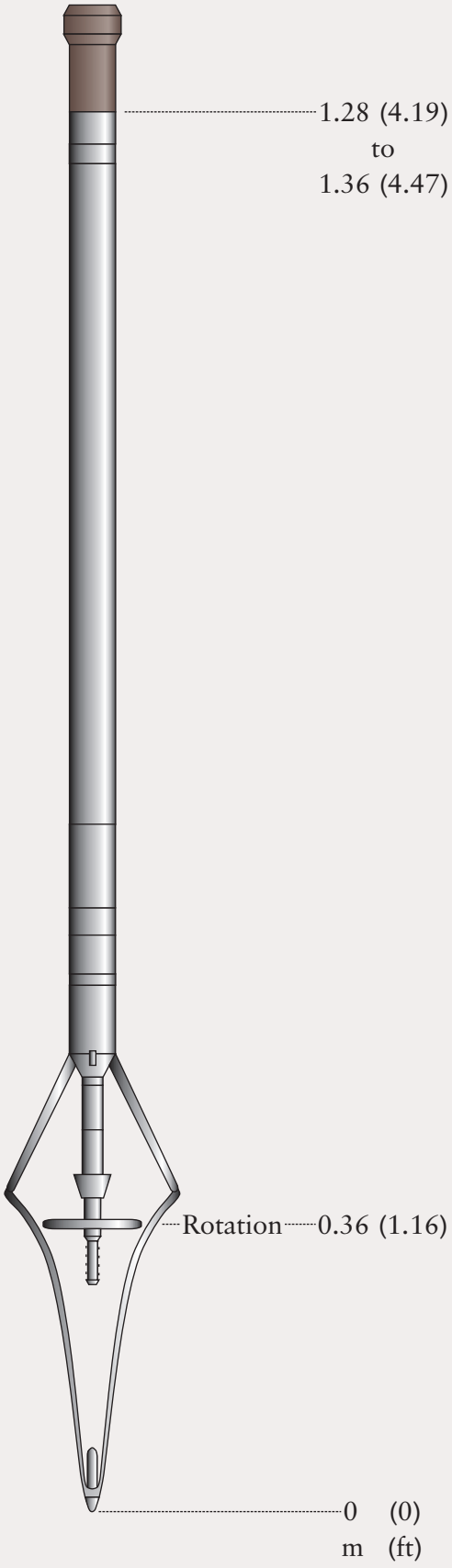
- Spinner rotation rate

Applications

- Flow measurements at low to medium flow rates
- Determination of production and injection profiles
- Detection of production loss due to thief zones or crossflow
- Detection of leaks through packers and plugs



Fullbore Flowmeter Sonde - FFS



Physical Dimensions

Spinner Sub	Length m (ft)	Diameter closed mm (in)	Minimum operating diameter mm (in)	Maximum operating diameter mm (in)
FSS-A	1.28 (4.19)	43 (1.69)	102 (4.02)	112 (4.41)
FSS-B	1.30 (4.27)	43 (1.69)	150 (5.91)	162 (6.38)
FSS-C	1.31 (4.30)	61 (2.40)	102 (4.02)	112 (4.41)
FSS-D	1.30 (4.27)	61 (2.40)	150 (5.91)	162 (6.38)
FSS-E	1.36 (4.47)	61 (2.40)	215 (8.46)	230 (9.05)
FSS-F	1.36 (4.47)	43 (1.69)	213 (8.38)	224 (8.82)

Weight (in air) 8 Kg (18 lb) maximum

Ratings

Temperature (max) 150^0 C (302^0 F)
Pressure (max) 103 MPa (15 kpsi)

Curve Parameters

Range 0.3 to 150 m/min (about 50 to 30,000 bbl/d in 7 inch casing)
Resolution 0.1 m/min (above threshold velocity)
Accuracy ± the greater of 0.3 m/min or 3 % of measured velocity
Repeatability ± 1 % of measured velocity above threshold velocity

Fluid Conductivity Sonde - FCS

The **Fluid Conductivity Sonde** is used to differentiate between fluid types by measuring their electrical conductivity. As such, it can be used as an alternative to fluid density measurements, particularly in highly deviated wells.

The tool contains a four electrode cell which provides continuous readings of conductivity whilst being immune to polarisation effects. It may be run alone, or more usually, in combination with other tools in the Production Logging String.

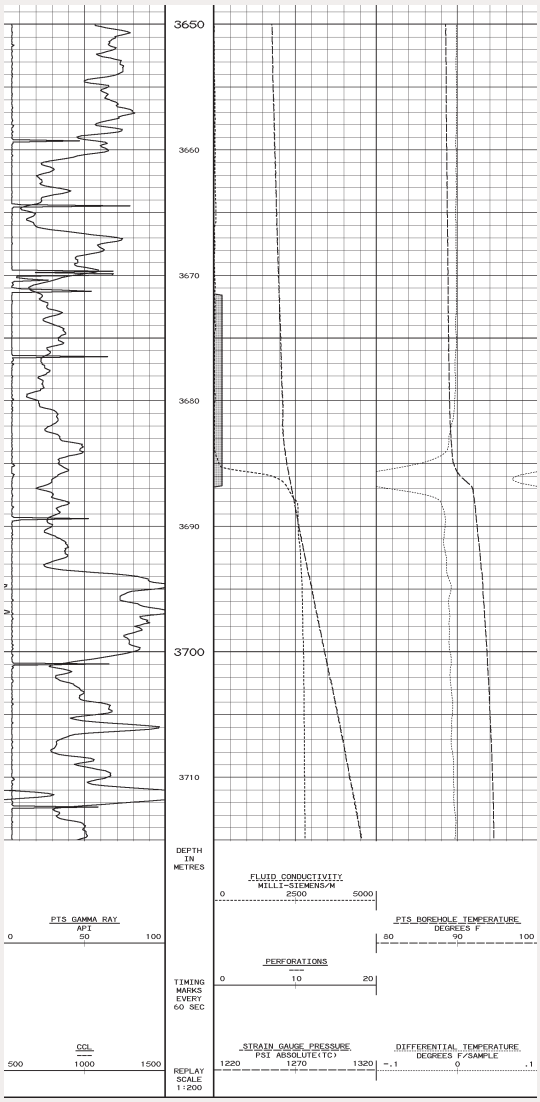
- ➤ *Wellbore conductivity and salinity profiles*
- ➤ *Four electrode cell - immune to the effects of polarisation*

Measurements

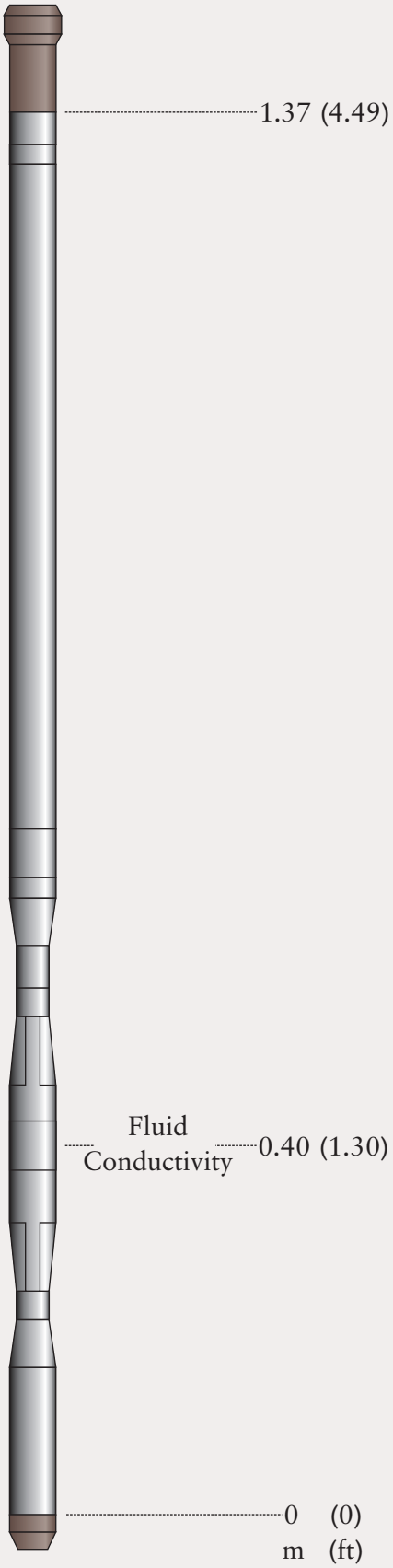
- ➤ Fluid conductivity

Applications

- ➤ Location of fluid interfaces
- ➤ Identification of fractured flow
- ➤ Conductivity/salinity profiles



Fluid Conductivity Sonde - FCS



Physical Dimensions

Length	1.37 m (4.49 ft)
Diameter	43 mm (1.69 in)
Weight (in air)	9 Kg (20 lb) maximum

Ratings

Temperature (max)	150^0 C (302^0 F)
Pressure (max)	103 MPa (15 kpsi)

Curve Parameters

	Low Range	Mid Range	High Range
Range	0.02 - 5 S/m	0.02 - 15 S/m	0.02 - 30 S/m
Resolution (@ 10 m/min)	0.4 mS/m	1.0 mS/m	2 mS/m
Accuracy	± 3 %	± 3 %	± 3 %
Repeatability	±2 %	± 2 %	± 2 %

Thermal Neutron Decay Sonde - TDS

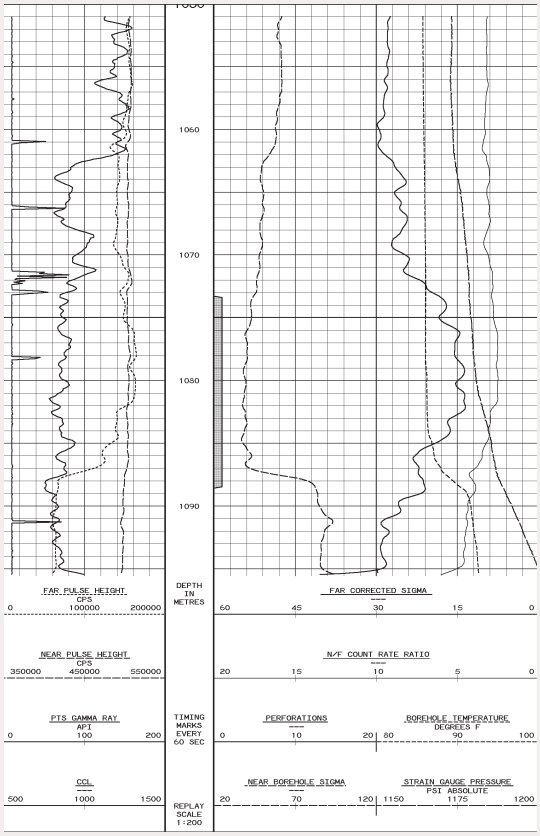
The **Thermal Neutron Decay Sonde** is the primary tool for water saturation measurement behind casing. Absolute saturations as well as changes in saturation and fluid levels can be determined.

An electronically controlled generator emits pulses of fast neutrons, and complete time spectra of their decay are recorded at two detectors. The spectra shapes depend on formation capture cross sections (Σ values), which depend in turn on the nature and volume of the pore fluids.

Formation and borehole Σ values are derived from **Compensated Mean Time (CMT)** processing. This proprietary algorithm produces results that are both accurate and highly repeatable - statistical precision is better than from any other method.

CMT decomposes spectra into early and late decays with superimposed background and diffusion effects. These are computed without iteration, and background noise is automatically taken into account. Early time decays are dominated by borehole and completion effects, and late time decays by formation effects. Late time Σ values are adjusted for early time effects in a compensation algorithm which does not need to assume that borehole decay is exponential. These are adjusted for diffusion by combining results from each detector.

- *Cased hole saturations and fluid contact monitoring from formation and bore-hole sigma data*
- *CMT processing gives excellent accuracy* **and** *precision*



Measurements

- Formation and borehole Sigma
- Porosity
- Gamma Ray
- Inelastic and captive count rates

Applications

- Behind casing Sw determination
- Reservoir monitoring
- Fluid contact monitoring

Thermal Neutron Decay Sonde - TDS

Physical Dimensions

Length	6.89 m (22.61 ft)
Diameter	43 mm (1.69 in)
Weight (in air)	41 Kg (91 lb)

Ratings

Temperature (max)	150^0 C (302^0 F)
Pressure (max)	103 MPa (15 kpsi)

Specifications

Source	14 MeV accelerator
Repetition Rate	1000 bursts/second
Time Spectra	Both detectors
Timing Sequence	1800 bursts followed by a 200 msec background count
Processing Method	Compensated Mean Time
Depth of investigation (at 50 % radial g.f.)	
	Σ Formation : 300 mm (11.8 in) approx. in 140 mm (5.5 in) casing, 25 mm (1.0 in) cement, saline formation fluid

Production Logging - Ancillary Equipment

Production Logging Strings may be configured with one or more items of ancillary equipment -

Production Roller Centralisers (PRC) for tool centralisation.
Production Knuckle Joints (PKJ) for logging in deviated wells.
Pressure Gauge Carrier (PGC) for running third party memory gauges.

Physical Dimensions (PRC)

Length	0.64 m (2.08 ft)
Diameter	43 mm (1.69 in)
Weight (in air)	4 Kg (9 lb)

(PKJ)

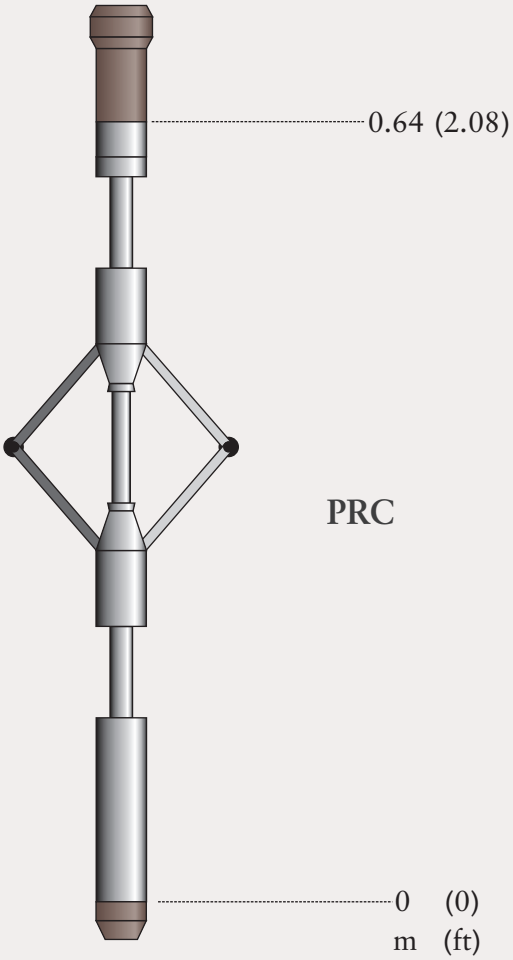
Length	0.23 m (0.75 ft)
Diameter	43 mm (1.69 in)
Weight (in air)	2 Kg (4 lb)

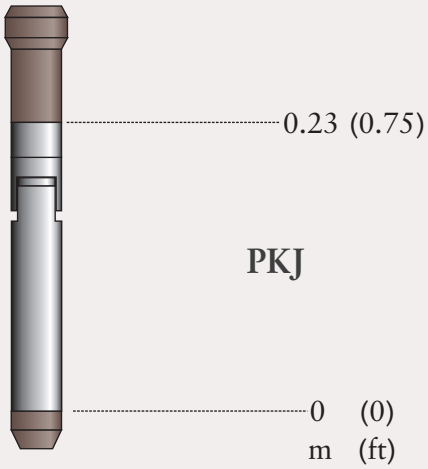
(PGC) - not shown

Length	2.29 m (7.51 ft)
Diameter	44.5 mm (1.75 in)
Weight (in air)	11 Kg (23 lb)

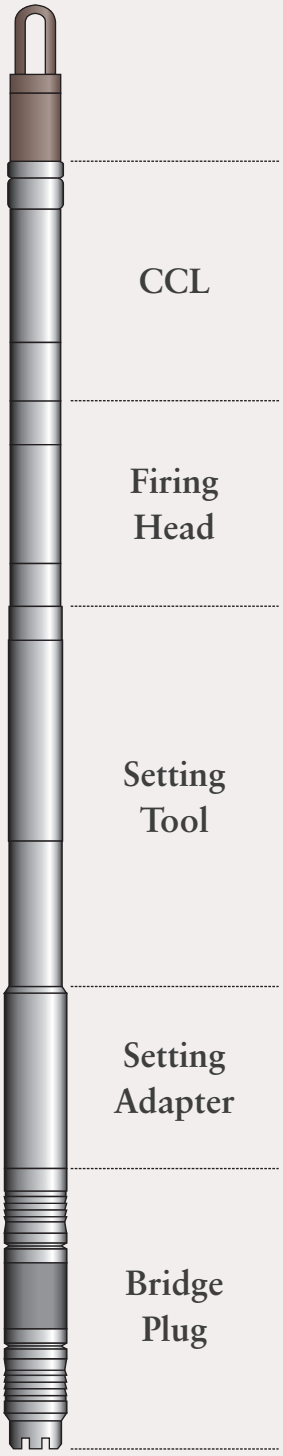
Ratings

Temperature (max)	150^0 C (302^0 F)
Pressure (max)	103 MPa (15 kpsi)





Plug and Packer Setting Tool - BST



The wireline conveyed **Plug and Packer Setting Tool** is a sure and proven method of setting any electric line set product, including bridge plugs, cement retainers and production packers.

It is gas actuated, allowing for a gradual development of the hydraulic setting force. The gas pressure results from the electrical ignition of an explosive system within the tool. The tool incorporates a manual bleeder valve to facilitate pressure release prior to disassembly.

Adaptor kits are used to enable the tool to run any commercially available plug, packer or retainer.

Physical Dimensions

	BST-A	BST-B	BST-C
Length	1.87 m (6.16 ft)	1.62 m (5.32 ft)	1.90 m (6.20 ft)
Diameter	43.6 mm (1.718 in)	69.9 mm (2.750 in)	96.5 mm (3.8 in)

Ratings

Temperature (max)	150^0 C (302^0 F)
Pressure (max)	103 MPa (15 kpsi)

Cement Bond Log - CBL

The **Cement Bond Log (CBL)** is an acquisition option from Compensated Sonic (CSS) or Long Spaced Compensated Sonic (LCS) tools operated in cased holes. It measures the amplitude of the first casing arrival at a 3 ft receiver, this being a function of the bond quality between casing and cement. The associated transit time is also recorded, and then used to verify that the correct amplitude peak has been selected.

The interpretation of the log is based on known relationships between signal amplitude and the percentage of the casing circumference that is bonded. Furthermore, when the casing is fully bonded, there is a relationship between amplitude and the compressive strength of the cement.

Waveform data from a 5 ft receiver is also utilised in the interpretation. This is displayed as a **Variable Density Log (VDL)** - it assists discrimination between casing and formation arrivals and provides qualitative indications of channeling.

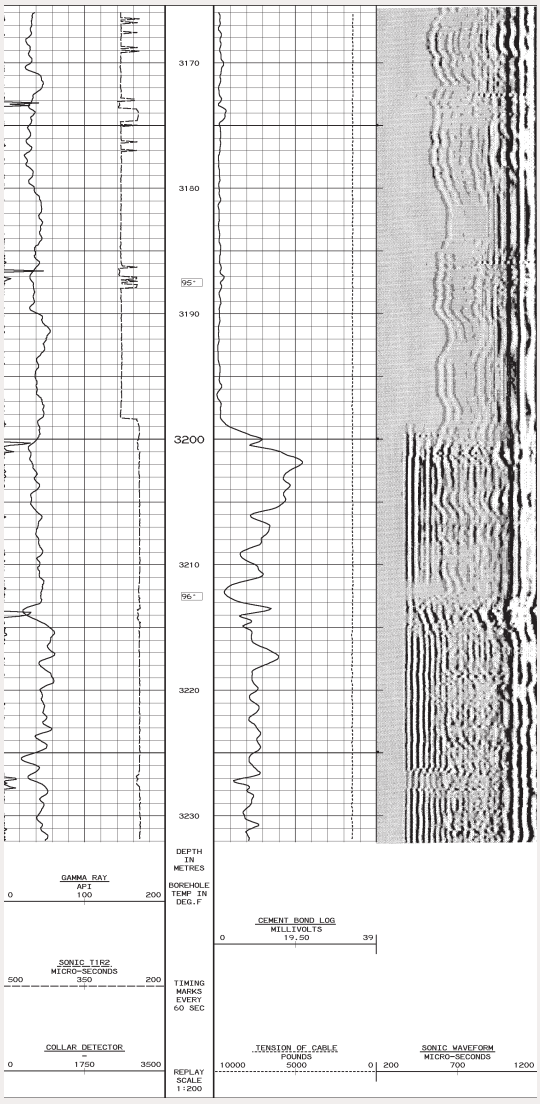
Measurements

- Casing arrival amplitude
- Transit time (3 ft receiver)
- VDL waveform (5 ft receiver)
- Casing Collar Locator
- Gamma Ray

Applications

- Determination of bond quality
- Cement compressive strength
- Location of cement tops

- *Acoustic amplitude indicates quality of cement bond*
- *VDL waveform and transit time logs for quality control*



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Perforating Services

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RF Safe Detonating System - RSD

The **RF Safe Detonating System** allows wireline perforating operations to be performed without interrupting normal rig or platform operations. It provides protection from all forms of stray currents, including electric welding, radio operations, cathodic protection and static discharges from human bodies.

The system uses two independent digital codes to protect against stray currents and unauthorised firing. The initial code gives access to the electronic detonator - it can be fired only after a second code has been correctly entered.

The system does not require additional downhole cartridges, and is installed like any other detonator. It can be used with any explosives-based service with the exception of the Sidewall Core Gun (SCG) service.

- *Safe for radio and microwave frequencies*
- *Safe for AC and DC stray currents*
- *No unauthorised firing*
- *Primary explosive protected by heavy walled steel tube*

Perforating Guns - Summary

Gun Type	Charge Weight grams	Shot Phasing degrees	Maximum Shot Density /ft	API RP-43 Section 1 Data	
				EHD inches	TTP inches
Expendable Hollow Carrier - EHC Series					
3 3/8 in	32.0	60	5	0.40	33.40
3 3/8 in	22.7	60	6	0.42	28.06
4 in	39.0	60	4	0.46	36.10
4 in	32.0	60	6	0.42	32.54
4 in	20.0*	60	9	0.85	7.25
4 1/2 in	39.0	60	5	0.37	48.13
4 1/2 in	23.0	150/30	12	0.41	22.53
4 1/2 in	32.0*	60	5	0.88	8.13
5 in	36.0	60	5	0.49	29.58
5 in	23.0	150/30	12	0.46	18.22
5 in	23.0*	150/30	12	0.77	6.87
6 in	32.0	135/45	12	0.45	24.09
7 in	39.0	135/45	12	0.45	33.41
7 in	60.0*	135/45	12	1.05	8.19
Retrievable Tubing Guns - RTG Series					
1 9/16 in	3.5	0/90/180	4	0.22	7.50
2 in	6.5	60	6	0.26	20.13
2 3/4 in	15.0	60	6	0.34	21.90
Through Tubing Retrievable Bar Guns - BJG Series					
1 11/16 in	8.4	0	6	0.23	18.39
2 1/8 in	15.0	0	6	0.35	26.20
2 1/8 in	26.4	60	4	0.34	36.44
Reusable Ported Hollow Steel Carriers - HSC Series					
3 3/8 in	16.0	120	4	0.40	19.05
4 in	22.0	120	4	0.42	28.32

Other shot densities and/or phasing may be available on request.

* Big Hole charge

Expendable Hollow Carrier - EHC

The **Expendable Hollow Carriers** are fully retrievable casing guns for debris-free perforating that cater for a wide variety of casing sizes and reservoir characteristics. They can be wireline or tubing conveyed. When wireline conveyed, they combine the advantages of state of the art TCP hardware with the speed and flexibility of electric line operation.

All charges are steel cased and inserted into tubular charge holders housed in a sealed carrier with exterior scallops directly opposite each charge. This system ensures that all debris from the charge is retained within the carrier.

EHC guns are available in diameters ranging from $3^{3}/_{8}$ inches (85.7 mm) to 7 inches (117.8 mm), with a wide variety of shot densities and phasing. They are standardly available in 7 ft, 11 ft, 15 ft and 21 ft lengths that can be tandemed together in any combination to match the perforating zone length.

- ➤ *Debris-free perforating*
- ➤ *High shot densities for increased productivity and reduced sand production*
- ➤ *Minimal casing and cement damage*
- ➤ *Special charges for deep penetration or big holes available*
- ➤ *Wireline or Tubing conveyed*

Expendable Hollow Carrier - EHC

Ratings

Temperature (max)	RDX -	163^0 C (325^0 F) for 1 hour
	HDX -	204^0 C (400^0 F) for 1 hour
Pressure (max)	137 MPa (20 kpsi)	
Minimum casing OD	3 3/8 in gun	- 127 mm (5 in)
	4 in gun	- 140 mm (5 1/2 in)
	4 1/2 in gun	- 168 mm (6 5/8 in)
	5 in gun	- 178 mm (7 in)
	6 in gun	- 219 mm (8 5/8 in)
	7 in gun	- 245 mm (9 5/8 in)

Gun Specifications

Firing direction bottom up, lowest carrier first

Maximum perforating interval per carrier
20 ft (6.1 m)

Maximum perforating interval per run (when wireline conveyed)
40 ft (12.2 m)

Charge Specifications

Gun Type	Charge Weight grams	Shot Phasing degrees	Maximum Shot Density /ft	API RP-43 Section 1 Data	
				EHD inches	TTP inches
3 3/8 in	32.0***	60	5	0.40	33.40
3 3/8 in	22.7	60	6	0.42	28.06
4 in	39.0	60	4	0.46	36.10
4 in	32.0	60	6	0.42	32.54
4 in	20.0*	60	9	0.85	7.25
4 1/2 in	39.0	60	5	0.37	48.13
4 1/2 in	23.0	150/30	12	0.41	22.53
4 1/2 in	32.0*	60	5	0.88	8.13
5 in	36.0	60	5	0.49	29.58
5 in	23.0	150/30	12	0.46	18.22
5 in	23.0*	150/30	12	0.77	6.87
6 in	32.0	135/45	12	0.45	24.09
7 in	39.0	135/45	12	0.45	33.41
7 in	60.0*	135/45	12	1.05	8.19

* Big Hole charge

Retrievable Tubing Gun - RTG

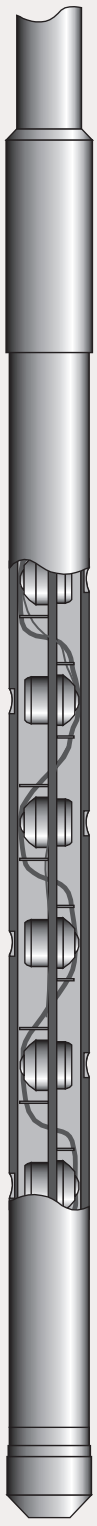
The **RTG** is a fully retrievable through tubing gun of the expendable hollow carrier type which provides debris-free perforating and a high degree of protection to the charges whilst running in.

The charges are loaded into holders housed in a sealed carrier with exterior scallops directly opposite each charge. This ensures that all debris from the charge is retained within the carrier.

RTG guns are available in three principal sizes : $1^{9}/_{16}$ inch guns for $2^{3}/_{8}$ and $2^{7}/_{8}$ inch tubing, 2 inch guns for $2^{7}/_{8}$ and $3^{1}/_{2}$ inch tubing, and $2^{3}/_{4}$ inch guns for tubing 4 inches in diameter and larger. Standard carrier lengths are 4 ft, 7 ft, 11 ft and 20 ft. These can be tandemed together to match the perforation zone interval.

- *Debris-free perforating*
- *Charges protected from well environment*
- *Fast running-in speeds*
- *Ideal for under-balanced perforating applications*

Retrievable Tubing Gun - RTG



Ratings

Temperature (max) RDX - 163^0 C (325^0 F) for 1 hour
HMX - 204^0 C (400^0 F) for 1 hour

Pressure (max) 137 MPa (20 kpsi)

Minimum allowable restriction

1 9/16 in gun	-	48.3 mm (1.90 in)
2 in gun	-	59.2 mm (2.33 in)
2 3/4 in gun	-	86.4 mm (3.40 in)

Gun Specifications

Firing direction bottom up - lowest gun first (select fire option available)

Maximum perforating interval per carrier
20 ft (6.1 m)

Maximum perforating interval per run
40 ft (12.2 m)

Charge Specifications

Gun Type	Charge Weight grams	Shot Phasing degrees	Maximum Shot Density /ft	API RP-43 Section 1 Data	
				EHD inches	TTP inches
1 9/16 in	3.5	0/90/180	4	0.22	7.50
2 in	6.5	60	6	0.26	20.13
2 3/4 in	15.0	60	6	0.34	21.90

Through Tubing Retrievable Bar Gun - BJG

The **BARJET (BJG)** system uses expendable steel-cased charges attached to a retrievable bar carrier, and is ideally suited to through tubing operations. The carrier is flexible, and is designed to pass easily through doglegs and corkscrewed tubing.

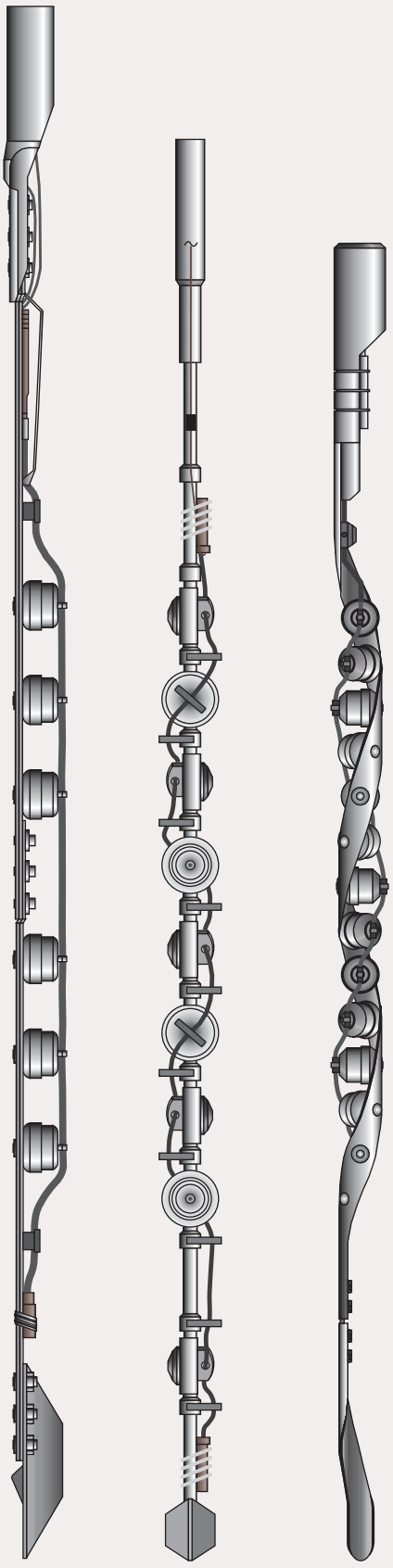
BARJET charges are larger than those in equivalent diameter scallop guns, and have a more powerful explosive load. The gun is typically run with zero degrees phasing, in which case, magnetic decentralisers ensure optimum performance. A reliable top-down firing sequence is used, and the carrier is retrieved leaving quantities of steel chips from the charges as debris.

Two gun sizes are available : the $1^{11}/_{16}$ inch gun for $2^{3}/_{8}$ and $2^{7}/_{8}$ inch tubing, and the $2^{1}/_{8}$ inch gun for $2^{7}/_{8}$ and $3^{1}/_{2}$ inch tubing. **Phased Link** and **Spiral** bar guns are available in some locations.

In addition to perforating for production, the guns can also be used to establish circulation through drill pipe or drill collars.

- ***Permits perforation below small ID restrictions***
- ***Passes easily through heavy muds, doglegs and corkscrews***
- ***Consistent hole characteristics***
- ***Very deep penetration option***

Through Tubing Retrievable Bar Gun - BJG



0° BJG BJG Link BJG Spiral

Ratings

Temperature (max)	RDX - 163° C (325° F) for 1 hour
	HMX - 204° C (400° F) for 1 hour
Pressure (max)	103 MPa (15 kpsi)
Minimum allowable restriction	
	$1\frac{11}{16}$ in gun 43.6 mm (1.718 in)
	$2\frac{1}{8}$ in gun 55.6 mm (2.188 in)
Recommended min casing OD	
	114 mm ($4\frac{1}{2}$ in) - note that debris may hinder gun retrieval if shot in smaller casing
Well fluid requirements	none

Gun Specifications

Firing direction	top-down
Magnetic decentralisation	top only
Maximum perforating interval per run	
	in liquid - no restriction other than lubricator length
	in gas - 6 m (20 ft)

Charge Specifications

Gun Type	Charge Weight grams	Shot Phasing degrees	Maximum Shot Density /ft	API RP-43 Section 1 Data	
				EHD inches	TTP inches
$1\frac{11}{16}$ in	8.4 (BJG Strip)	0	6	0.23	18.39
$1\frac{11}{16}$ in	11.5 (BJG Link)	from 30	6	0.29	11.15
$2\frac{1}{8}$ in	15.0 (BJG Strip)	0	6	0.35	26.20
$2\frac{1}{8}$ in	15.0 (BJG Link)	from 30	6	0.33	14.21
$2\frac{1}{8}$ in	26.4 (BJG)	60	4	0.34	36.44
$2\frac{1}{8}$ in	14.0 (BJG Spiral)	45	6	0.27	23.64

Hollow Steel Carrier - HSC

The **HSC** is a ported gun which is retrievable and reusable. It comprises a thick-walled carrier and threaded, pressure-sealing port plugs, leading to high performance with no debris or casing damage.

Charges are fully protected allowing high running speeds and excellent reliability. Maximum shot density is 4 shots per foot. They can be used with a select fire technique to provide multiple zone perforating on each trip into the well.

- *Debris-free*
- *Good casing and cement protection*
- *Fully protected charges*
- *Selective firing available*

Hollow Steel Carrier - HSC

Ratings

Temperature (max)	RDX - 163^{0}C (325^{0}F) for 1 hour
	HDX - 204^{0}C (400^{0}F) for 1 hour
Pressure (max)	137 MPa (20 kpsi)
Minimum casing OD	3 3/8 in gun - 127 mm (5 in)
	4 in gun - 140 mm (5 1/2 in)

Gun Specifications

Firing direction bottom up, lowest carrier first

Maximum perforating interval per carrier
10 ft (3.0 m)

Maximum perforating interval per run
40 ft (12.2 m)

Charge Specifications

Gun Type	Charge Weight grams	Shot Phasing degrees	Maximum Shot Density /ft	API RP-43 Section 1 Data	
				EHD inches	TTP inches
3 3/8 in	16.0	120	4	0.40	19.05
4 in	22.0	120	4	0.42	28.32

Tubing-Conveyed Perforating - TCP

Tubing-Conveyed Perforating allows intervals to be shot whilst in an underbalanced state. The pressure differential towards the wellbore ensures that perforations are cleaned of filtrate and other debris, with consequent improvements in productivity.

TCP makes use of large diameter casing guns to create deep, high shot density perforations. They are conveyed on the bottom of tubing, drill pipe or coiled tubing, and positioned with the aid of a correlation log.

Once in place, a packer is set and the fluid level in the tubing adjusted to achieve the pressure differential towards the wellbore. The guns are detonated mechanically or hydraulically.

The following firing heads are available :

Drop Bar
Retrievable Drop Bar
Absolute Pressure
Annular Pressure
Retrievable Absolute Pressure
Time Delay
Dual Firing
Pressure Assist Safety

Ancillary equipment includes :

Mechanical Tubing Release
Automatic Tubing Release
Debris Sub
Shock Sub
Underbalance Sub
Isolation Sub

Unlike wireline-conveyed perforating, TCP allows very long gun stacks to be deployed. This, together with the other reductions in operating time frequently results in significant savings in rig time.

For gun size and performance details, refer to the **Expendable Hollow Carrier (EHC)** service page.

- *Clean, filtrate-free perforations result from shooting in an underbalanced state*
- *Larger diameter guns for improved charge performance*
- *Very long gun combinations for multiple and/or long shooting intervals*
- *High shot density, multi-directional, debris-free guns for increased productivity*
- *Suitable for highly deviated wells*
- *Reduced rig time*

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Pipe Recovery Services

Freepoint and Pipe Recovery Services

When drill pipe, casing or tubing has become stuck, the **Freepoint Service** locates the freepoint, or depth above which the tubular is free to move. A range of options is then available to assist in pipe recovery.

The most common method employs an explosive charge detonated at a joint immediately above the freepoint - the **Backoff Service**. Simultaneous application of decoupling torque helps loosen the connection so that the free pipe can be backed off.

If this fails, jet cutters, chemical cutters or severing tools can be used to part the tubular.

Freepoint Tool - FPT

Freepoint Tools contain a sensitive strain gauge positioned between two anchors which fix the tool to the inside of the drill pipe or tubing such that any differential movement in the pipe is transmitted to the tool.

To locate the freepoint, a tensional or torsional force is applied to the pipe at the surface, and any downhole movement is measured by the strain gauge. Recordings at different depths will indicate the point below which the the pipe is stuck.

Two different anchor mechanisms are available - the first uses powered anchors which are retracted to aid free passage of the tool when running in, whilst the second uses pre-set springs which are partially collapsible for running in.

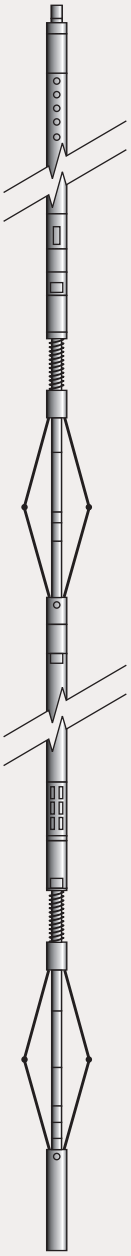
The Freepoint Service is a self-contained, lightweight and portable system which can also operate on third-party wirelines.

Physical Dimensions

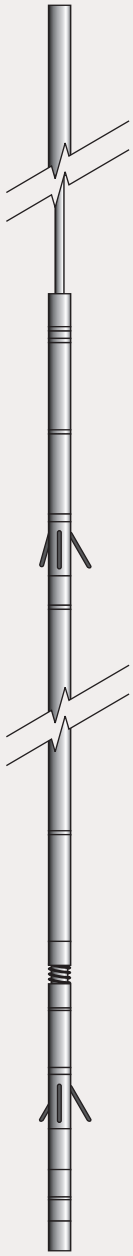
Length	FPT-B	3.56 m (11.67 ft)
	FPT-C	3.56 m (11.67 ft)
Diameter*	FPT-B	37 mm ($1^{7}/_{16}$ in)
	FPT-C	43 mm ($1^{11}/_{16}$ in)
Weight (in air)	FPT-B	18.2 Kg (40 lbs)
	FPT-C	23.9 Kg (53 lbs)

Ratings

Temperature (max)	177^{0} C (350^{0} F)
Pressure (max)	103 MPa (15 kpsi)
Minimum operating diameter	51 mm (2.0 in)
Maximum operating diameter	127 mm (5.0 in)



Sprung Tool
FPT-B



Motorised Tool
FPT-C

* Slim hole ($^{11}/_{16}$ and 1 inch OD) tools are available in some centres.

Backoff (String Shot) Service - BOS

The **Backoff (String Shot)** service uses a pre-determined quantity of detonating cord to deliver an explosive shock to stuck drill pipe, the objective being to allow recovery of the pipe.

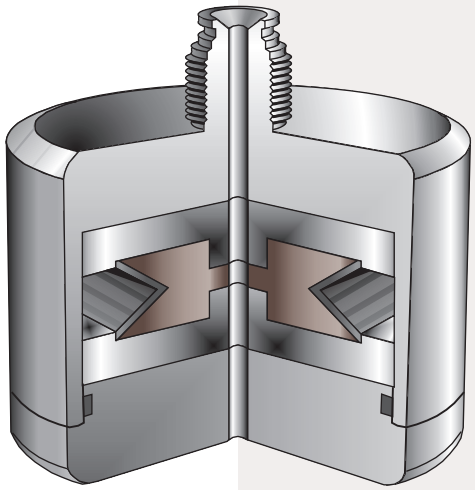
The shot is positioned at the pipe joint immediately above the freepoint determined by the FPT tool. It is detonated with the pipe joint at neutral weight, and with uncoupling torque applied at the surface.

The size of the shot is calculated according to the pipe size and weight, the depth of the stuck pipe and the nature of the wellbore fluid.

String shots are also used to free drill pipe from keyseats, to remove corrosion from pipe (for example, prior to the use of chemical cutters) and to reopen existing perforations.

Tubular Cutter - TCU

Tubular Cutters use circular, shaped charges to sever drill pipe, tubing or casing*. They are available in a wide variety of sizes for a wide range of tubular sizes. It is recommended that the cutter size nearest to the tubular internal diameter is used.



Tubing Cutter Specification

Cutter OD	Charge weight	Tubing size	Tubing ID	Tubing weight
inches (mm)	grams	inches (mm)	inches (mm)	lbs/ft (Kg/m)
$1^{13}/_{16}$ (46.0)	18.0	$2^{3}/_{8}$ (60.3)	1.995 (50.7)	4.70 (6.99)
$2^{1}/_{16}$ (52.4)	22.7	$2^{7}/_{8}$ (73.0)	2.259 (57.4)	8.70 (12.95)
$2^{1}/_{4}$ (57.2)	22.7	$2^{7}/_{8}$ (73.0)	2.441 (62.0)	6.50 (9.67)
$2^{5}/_{8}$ (66.7)	39.0	$3^{1}/_{2}$ (88.9)	2.750 (69.9)	12.95 (19.27)
2.70 (68.7)	39.0	$3^{1}/_{2}$ (88.9)	2.992 (76.0)	9.30 (13.84)

Drill Pipe and Casing Cutter Specifications - available on request.

* They typically produce a flared cut, and it may be necessary to smooth the top of the fish with an internal mill prior to pipe recovery.

Chemical Cutter Tool - CCT

The **Chemical Cutter Tool** provides clean, flare- and burr-free cutting of stuck tubulars, simplifying subsequent fishing operations, particularly when overshots are employed.

The cut is made by an activated chemical forced out of the tool under pressure, severing the pipe on contact. To start the process, an electrically initiated igniter causes a gas generator to exert pressure on the closed cylinder containing the chemical. When a critical pressure is attained, a membrane on the base of the cylinder ruptures, causing the cutting chemical to leave the tool at a very high velocity.

Ratings

Temperature (max) 150^0 C (302^0 F)
Pressure (max) 103 MPa (15 kpsi)

Recommended Cutter - Tubing

Tool Size		Tubing Size		Tubing ID	
ins	(mm)	ins	(mm)	ins	(mm)
$1^{11}/_{16}$	(42.9)	$2^3/_8$	(60.3)	1.939-1.995	(49.3-50.7)
$2^1/_8$	(54.0)	$2^7/_8$	(73.0)	2.441	(62.0)
$2^5/_8$	(66.7)	$3^1/_2$	(88.9)	2.922	(74.2)
$2^3/_4$	(69.9)	$3^1/_2$	(88.9)	2.922	(74.2)
$3^1/_8$	(79.4)	4	(101.6)	3.423	(86.9)
$3^5/_8$	(92.1)	$4^1/_2$	(114.3)	3.958	(100.5)

Recommended Cutter - Casing

Tool Size		Casing Size		Casing ID	
ins	(mm)	ins	(mm)	ins	(mm)
$3^5/_8$	(92.1)	$4^1/_2$	(114.3)	3.920-4.090	(99.6-103.9)
$4^{11}/_{16}$	(119.1)	$5^1/_2$	(139.7)	4.892-5.012	(124.3-127.3)

Tubing and Casing Puncher - TPU

The **Tubing & Casing Puncher** is a carrier-style through tubing perforating gun equipped with special charges designed to establish hydraulic communications between tubulars without damaging the outer string.

The appropriate charge is selected from the charge performance table. This specifies the penetration into new steel plate and the entry hole diameter. Charges are fired at 4 shots per foot and zero degree phasing. Guns are decentralised to ensure reliable penetration.

Ratings

Temperature (max)	177^0 C (350^0 F)
Pressure (max)	137 MPa (20 kpsi)

Specification

Gun Size	Entry Hole Diameter	Penetration in New Steel
inches (mm)	inches (mm)	inches (mm)
$1\,^9/_{16}$ (39.7)	0.34 (8.6)	$^1/_4$ - $^3/_8$ (6.3-9.5)
$1\,^9/_{16}$ (39.7)	0.21 (5.3)	$^3/_8$ - $^1/_2$ (9.5-12.7)
$1\,^9/_{16}$ (39.7)	0.21 (5.3)	$^1/_2$ - $^5/_8$ (12.7-15.8)
2 (50.8)	0.31 (7.9)	$^1/_4$ - $^3/_8$ (6.3-9.5)
2 (50.8)	0.40 (10.1)	$^3/_8$ - $^1/_2$ (9.5-12.7)
2 (50.8)	0.31 (7.9)	$^1/_2$ - $^5/_8$ (12.7-15.8)

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Computed Products

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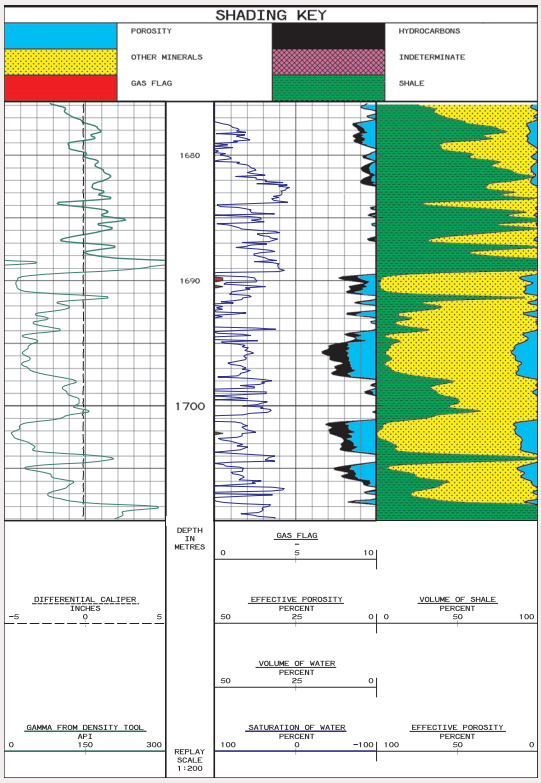
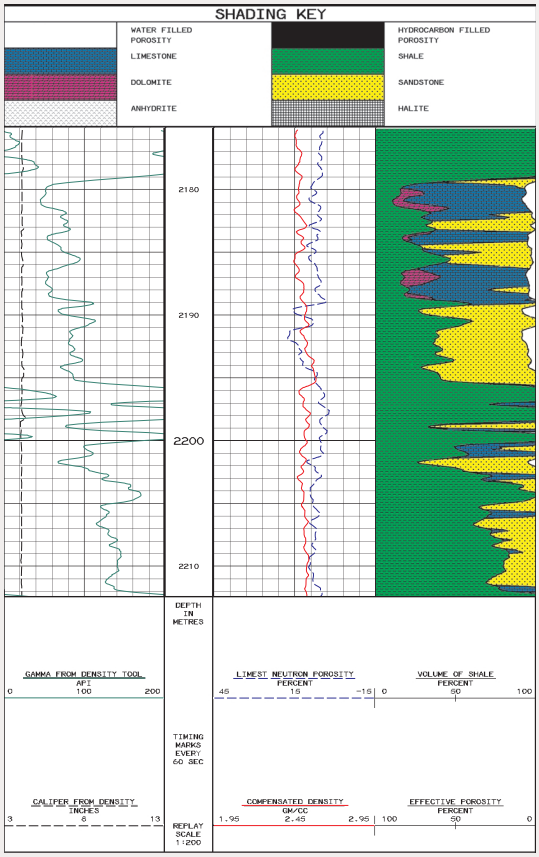
Shaly Sand Analysis - QLI

The **Shaly Sand Analysis (QLI)** uses a three part rock model comprising matrix (sand), shale and porosity. Porosity is obtained from any of the common indicators (density, neutron, density-neutron or sonic), and shale volume from gamma ray, SP or density-neutron crossplot. A bad hole porosity option substitutes sonic porosity if other measurements become unreliable due to hole conditions. Volumes of hydrocarbons and moved hydrocarbons are derived from any deep and shallow reading resistivity logs using Archie, Simandoux, Dual Water or Indonesia equations.

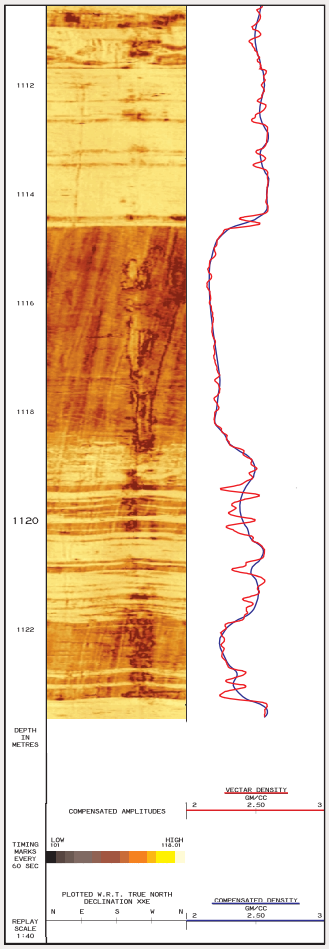


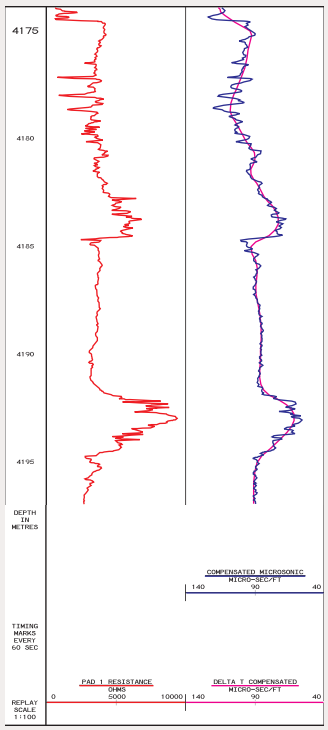
Complex Lithology Analysis - CLI

The **Complex Lithology Analysis (CLI)** splits the rock matrix into quartz sand, limestone and dolomite based on density, Pe and neutron porosity curves, with shale volumes and corrections calculated from the gamma ray or SP. The analysis also screens for halite and anhydrite. Hydrocarbon and moved hydrocarbon volumes are computed from any deep and shallow reading resistivity logs using Archie, Simandoux or Indonesia saturation equations.



VECTAR© Enhanced Resolution Services

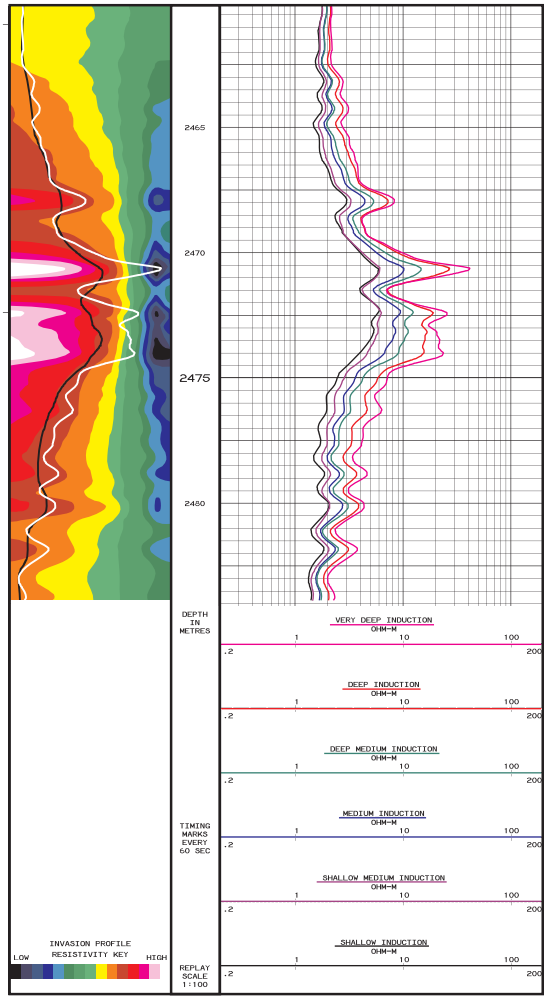




Upper left :
Compensated Density and VECTAR high resolution density with an AST amplitude image.

Lower left :
Compensated Sonic and Microsonic curves. Dipmeter pad trace shown for comparison.

Right :
Array Induction data. Compare the standard Deep (black) and VECTAR Deep (white) plotted over the Invasion Profile image. VECTAR also resolution matches all induction curves.



VECTAR© acquisition and processing enhances the resolution of many conventional logs by between 50 and 300 %, giving improved bed definition, core correlations and nett pay results in thinly bedded and complex reservoirs.

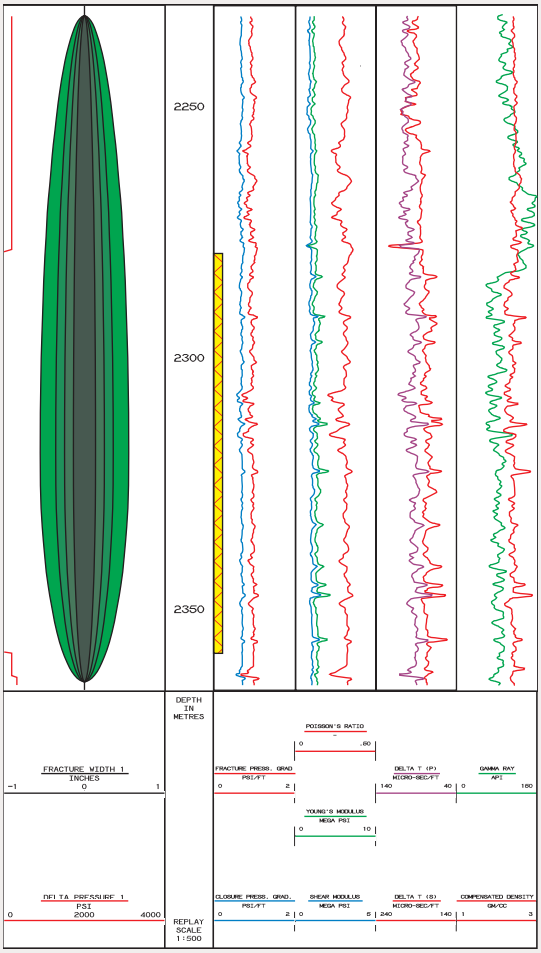
The VECTAR© technique extracts high resolution information from multi-detector measurements and adds it back to standard borehole compensated logs. It is available for Compensated Density and Compensated Neutron logs, for Sonic logs from the CSS and for all Array Induction logs, where it is also used in the generation of invasion profile images (VIVID©). In most cases, data needs to be acquired at higher than normal sample rates.

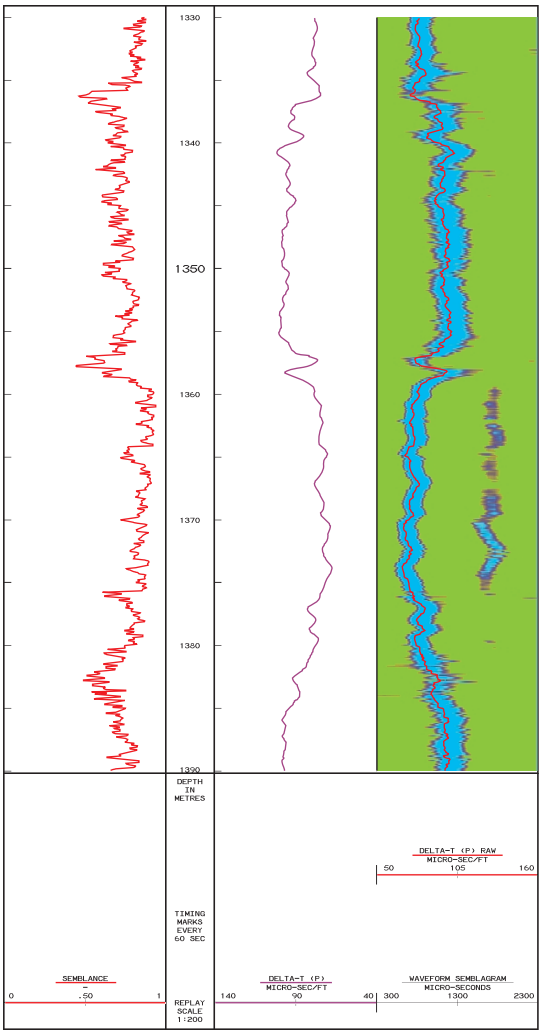
Acoustic Services Products - MPA - FHA - BCV

Fracture Height Analysis (**FHA** - right) predicts the vertical extent and width of an induced fracture as a function of applied pressure, the mechanical properties of the rock and the depths and lengths of associated perforated intervals.

It is based on classic poroelastic theory and a recent model of fracture behaviour. It uses dynamic elastic moduli from the **Mechanical Properties Analysis (MPA)** and the results of lithological analysis.

Compressional and shear slowness data from the LCS define the formation dynamic Poisson's Ratio used in formulating vertical and horizontal stress relationships. Adding formation density allows the remaining elastic moduli and fracture closure pressure to be computed. The delta pressure required to propagate a fracture follows from the addition of lithology dependent fracture toughness information.



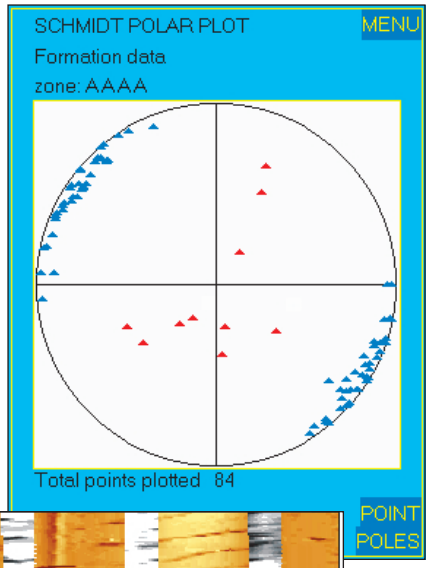


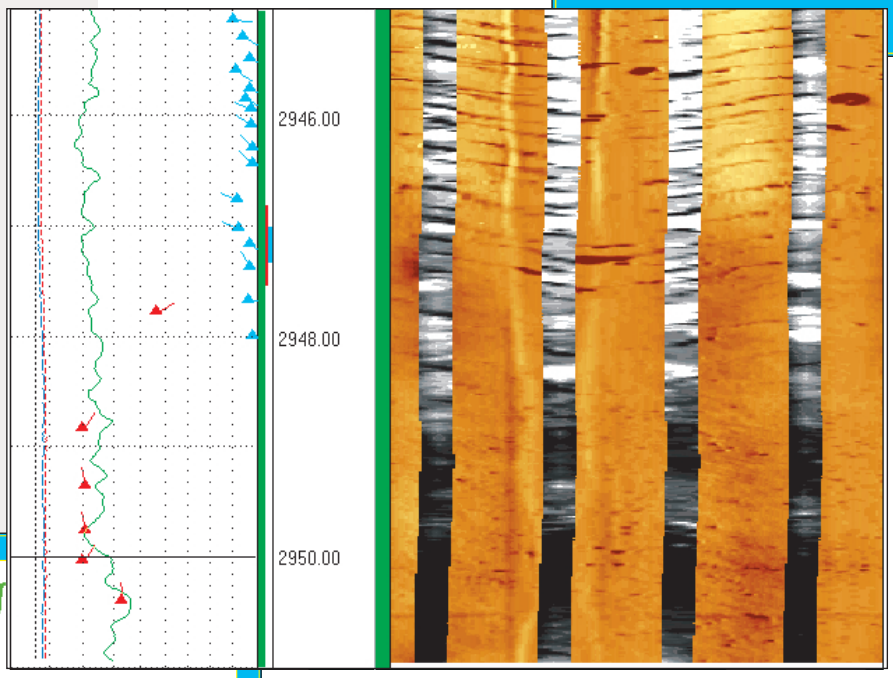
Behind Casing Velocity Analysis (**BCV** - left) generates formation slowness (inverse velocity) logs in cased wells. The algorithm windows LCS waveforms and searches for coherent arrivals across the receiver array. Velocities are picked from a semblagram that indicates the degree of waveform similarity as a function of moveout and depth. The semblagram also provides quality control across poorly bonded intervals where formation signals are weak.

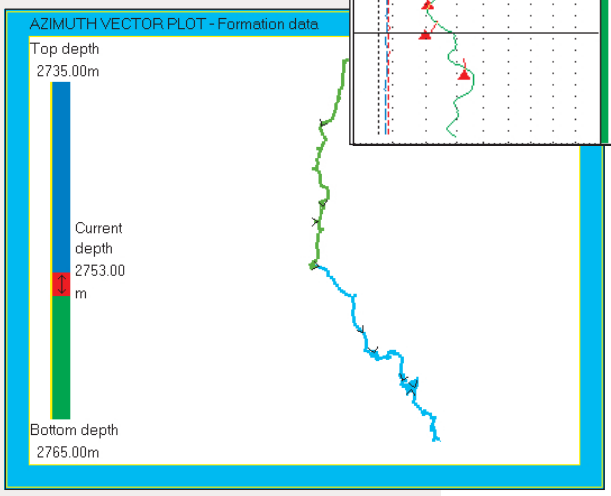
Formation Image and Dipmeter Analysis

Formation image and dipmeter data are valuable sources of geological information relating to structures (folds, faults, unconformities and structural dips), to sedimentary geology (facies, bedform orientations and palaeocurrent directions) and to stress orientations (breakouts).

Software solutions commence with wellsite quality control and quick look products, and extend to **Q-log**© and **PC ImagePro**© which provide different levels of automated and interactive analyses. The detailed results and statistics from these procedures form the raw materials used by specialist interpreters.







Mnemonics Index

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