

Robertson Geo has the experience of wireline logging projects for mining and mineral exploration or planned expansion of existing sites gained from over four decades and many thousands of applications. Proven quality and reliability for the collation of subsurface borehole data offers an industry standard for cost and results effective technologies and service.



**ROBERTSON
GEO**

**MINING &
MINERALS**
Unlocking Your GeoData

Mining & Minerals

Publication No: 002 RGO/18

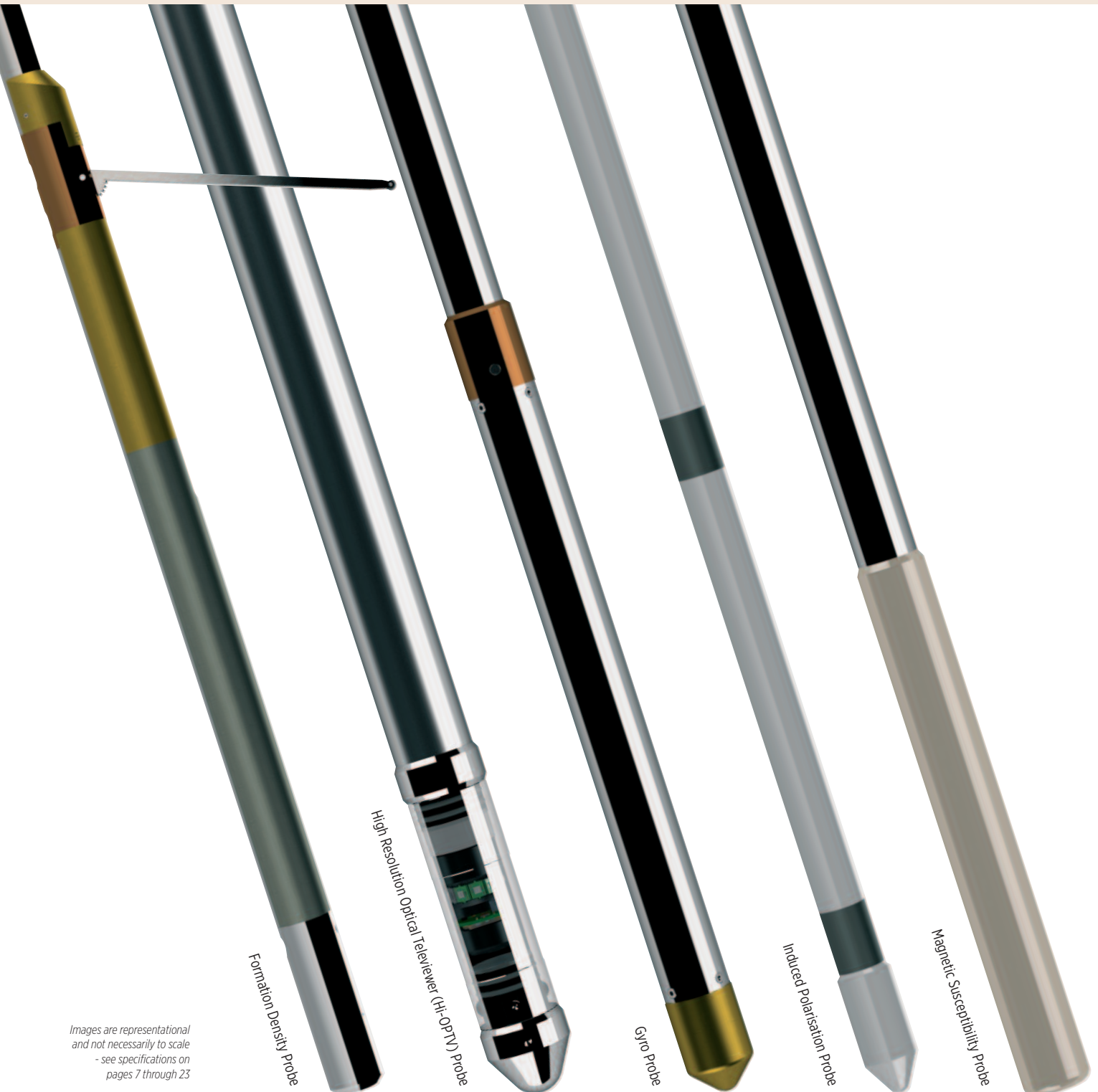


*Core Drilling for exploration
in Pilbara, Australia.*

Wireline logging is in global use, identifying the quality and quantity of potential economic resource, its accessibility and potential difficulties of its extraction.

Mining & Minerals

As the world's largest provider of slimhole logging instrumentation, Robertson Geo designs and builds its equipment and technologies at its manufacturing facility in Deganwy, North Wales UK. Purchasers of equipment include geological surveyors, water authorities, mining houses, civil engineering consultants, aid organisations, drilling contractors and oil companies worldwide.



*Images are representational
and not necessarily to scale
- see specifications on
pages 7 through 23*

With approaching 2,000 units supplied to the international Mining and Minerals markets, no-one has a better record of specialist expertise as an industry recognised service provider and equipment supplier of slimhole wireline logging instrumentation and technologies. In addition to logging service companies Robertson Geo clients include the top tier of exploration organisations including Glencore, BHP Billiton, Rio Tinto, Vale, Anglo American and CODELCO. Robertson Geo's own logging crews have undertaken many major service contracts internationally.



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Mining & Minerals

Logging is an established and very cost effective methodology for exploration and providing valuable mine safety information.

Compliance is the key to success, Robertson Geo's tool calibration and ISO 9001-2015 procedures provides reassurance that data acquisition complies with the various mandatory requirements for classification of Mineral Exploration Results, Mineral Resources and Ore Reserves to the level of confidence in geological knowledge and technical/economic considerations for Public Reports including the JORC, CIM, UNFC, CRIRSCO, PERC, SAMREC, SME and MRC standards. Robertson Geo is licensed to factory test and calibrate its nuclear tools with corresponding radioactive sources prior to shipping. Unless this is achieved, logging results cannot meet the necessary compliance standards.

A broad array of information can be drawn from a drilled borehole that can be enormously helpful for planned expansion of mining of existing sites or in new locations. Logging can identify the quality and quantity of a potential economic resource, its accessibility and the potential problems of extraction. It can be used to identify and correlate strata within an area using various physical characteristics either in isolation or together with core sample analysis.

Wireline logging data provides cost effective, in situ results on a continuous high-resolution scale with true vertical depths.

It is a proven and reliable source of quality data acquisition for a wide range of mining applications including:

- Coal and mineral exploration
- Location of ore bodies
- Mineral identification
- Fracture detection and analysis
- Mine related geotechnical studies
- Borehole direction surveys
- Mine related hydrogeological and contamination studies

Logging services

Robertson Geo engineers are experienced, highly trained and fully certified for underground and surface mine working and can be deployed to any global location.

The complete catalogue of equipment is available on a service basis operated by these field crews. They are capable of prolonged logging services with minimum outside support and are expert in data processing and interpretation.

These are very cost effective contracting services in circumstances where projects do not justify purchasing equipment and the necessary back up facilities.

Equipment supply

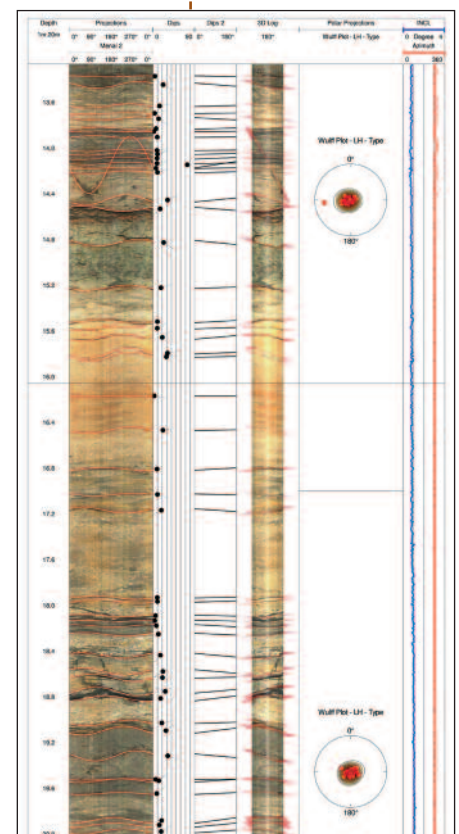
All Robertson Geo probes are fully tested and calibrated at the Deganwy facility prior to dispatch, eliminating testing time on site and ensuring the probes are fully operational prior to downhole use.

Depending on customer needs operational and customised training can be provided; this for winch use, probe deployment, logging techniques, data capture and equipment maintenance and troubleshooting.

Equipment rental

Robertson Geo equipment is available to rent with a minimum rental period of 3 days in the USA or 15 days elsewhere. Full systems (including winches) or individual probes can be rented as required with borehole and classroom based training made available for rental customers.

In-house data management and log processing services are available for rental equipment clients, at an additional cost.



Example of data created by the Hi-OPTV probe.

Further data examples are shown with each specification page for probes and where applicable surface equipment on pages 7 through 23.

Robertson Geo is the only logging services provider with a QMS certified to ISO 9001, comprehensively calibrating all of its logging systems and uniquely using an on-site borehole for testing at its Deganwy test well and calibration facility.

Probes

Formation Density: uses multiple detectors to provide an accurate borehole-compensated density measurement with excellent bed-boundary resolution. This can be used to determine lithology, density and porosity, ash content in coal, rock strength and elasticity parameters when combined with the sonic probe and detection of weathered or fractured zones. The probe is regarded as a classic coal exploration tool. *See page 7*

Dual Neutron: provides an accurately calibrated borehole compensated neutron porosity measurement in mud-filled open holes. It is the probe of choice for quantitative formation-fluid studies. *See page 8*

Spectral Gamma: analysis the energy spectrum of gamma radiation from the naturally occurring or man-made isotopes in the formation surrounding the borehole. The probe corrects for temperature drift in real-time by matching the acquired spectrum to base spectra of the main natural emitters, potassium, uranium and thorium determined during the tool master calibration.. Borehole corrections are available for casing thickness, borehole diameter, formation density and mud/fluid radioactivity for both centralized and side-walled tool positions. The probe is ideal for mineral detection, sedimentology, lithology determination and improved shale content computation. *See page 9*

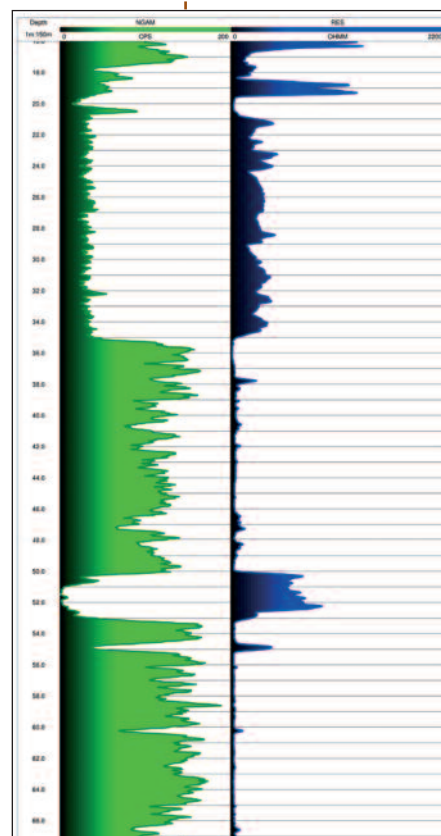
Full Waveform Sonic: this can be used in three modes depending on application - compensated sonic, full-wave form or cement bond mode. The probe can help determine lithology, porosity, rock strength and elasticity properties, correction of seismic velocity, fracture and permeability induction in hard rock, and poor and missing cement behind casing. *See page 10*

High Resolution Acoustic Televiewer (HRAT): is used for borehole imaging in fluid and mud filled boreholes. The probe provides a 360° 'unwrapped' and orientated ultrasound image of the borehole walls. The probe measures the amplitude and travel time of the reflected acoustic signal. The amplitude can help determine opened and filled fractures, whereas the travel time provides an accurate 360-arm caliper of the borehole and can help show diameter changes in open fractures and breakouts. *See page 11*

High Resolution Optical Televiewer (Hi-OPTV): provides a continuous very high-resolution oriented image of the borehole walls. The probe can be used in dry and water (clear fluid) filled boreholes. The probe offers a full colour image of the borehole, which can assist in mineral identification. *See page 12*

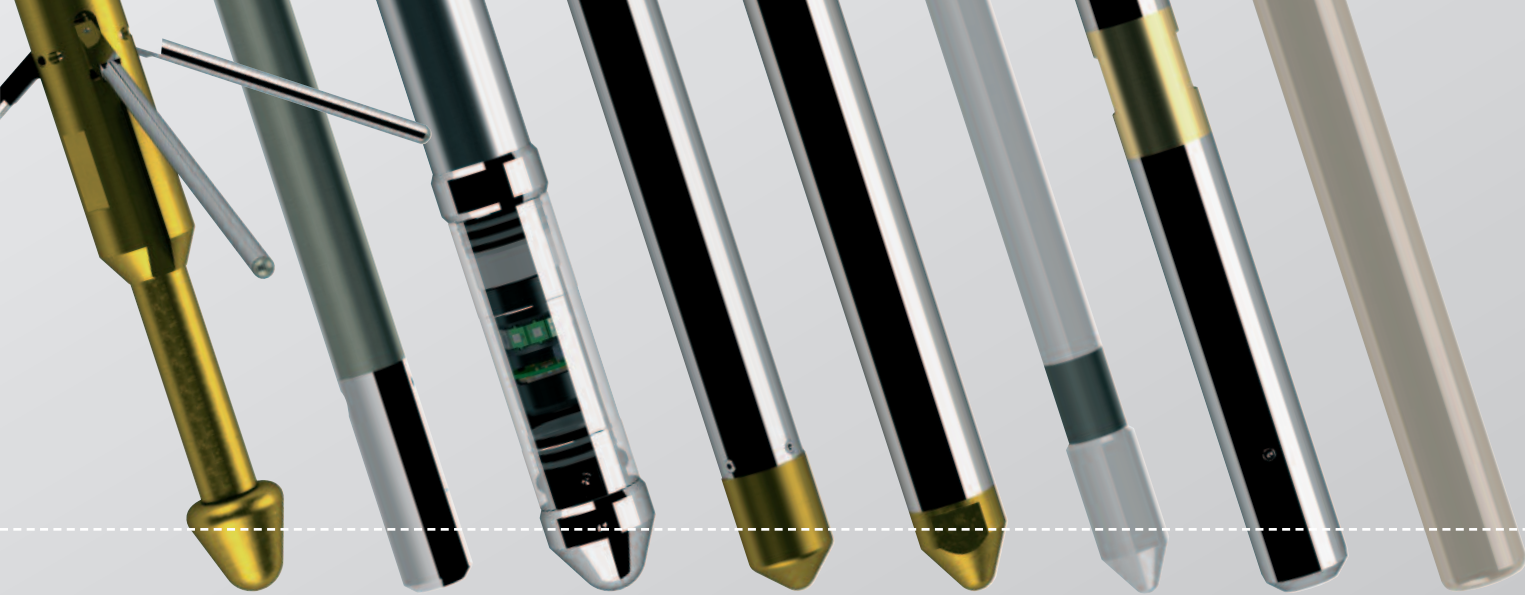
Focussed Electric (Guardlog): the focussed resistivity (LL3) measurement provides excellent vertical resolution and a reasonable depth of investigation. The probe is less affected by mud in the borehole, unlike normal resistivity logs. The probe can be used for strata correlation between boreholes, indication of permeable zones, bed-boundary and thickness measurements and moisture determination in coal. *See page 13*

Magnetic Susceptibility: this is a low frequency device and is specifically designed for mining applications. It is particularly used for uranium exploration. Susceptibility logs are highly sensitive to iron and show large contrasts accordingly to its oxidation state. The frequent occurrence of iron with other redox-sensitive metals can be a valuable indicator of the presence of other minerals. *See page 14*



Example of data created by the Focussed Electric (Guardlog) probe.

Further data examples are shown with each specification page for probes and where applicable surface equipment on pages 7 through 23.



Induced Polarisation: measures the charge separation or 'chargeability' in porous, water saturated, mineralised rocks caused by the passage of a low-frequency alternating current. The main cause of induced polarisation is a current-induced electron-transfer reaction between ions of an electrolyte in contact with grains of semi-conducting metallic minerals. *See page 15*

Dual Focussed Induction: provides two simultaneous conductivity logs, corresponding to 'medium' and 'deep' radii of investigation into the formation. The two depths of penetration are useful in porous, permeable formations where the displacement of formation fluids by drilling mud creates an 'invasion zone' with different electrical properties. The 1" focussed induction probe produces a single medium penetration conductivity log. It finds particular application in small diameter dry or plastic lined boreholes used for mineral exploration. *See page 16*

Verticality: the verticality of a borehole is key to determining the actual location and depth of a potential order body, as the vertical depth is often different to the drilled depth and is therefore critical for mine design. An alternative, the Gyro probe provides the same information in the presence of steel casing. *See page 17*

Gyro: acquires borehole inclination/azimuth logs in situations where metal casing or magnetic materials around the borehole prevent use of the standard verticality probe. The 3D-magnetometer version also acquires 3D-magnetic data for location of magnetic ore bodies. *See page 18*

3-Arm Caliper: measures the diameter of the borehole as a continuous record against depth. It is used as a check of borehole condition before casing operations or before running more expensive logging probes. It also provides a borehole volume for grout quantity design. *See page 19*

Other probes

Electric Log: the classic water-well combination probe combining shallow, medium and deep penetrating resistivity measurements with Self-Potential (SP).

Temperature Conductivity: provides a continuous, depth-based measurement of fluid temperature and conductivity. Both parameters can be output in absolute and in differential forms. A natural gamma detector is included for correlation purposes.

Impeller Flowmeter: provides a continuous log of vertical fluid velocity within a borehole. Two sizes of high sensitivity probes satisfy most borehole size requirements and expected flow rates.

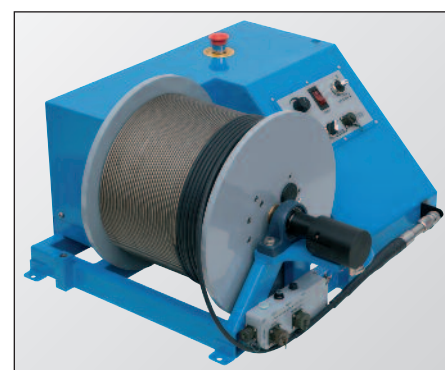
Heat-Pulse Flowmeter: used to detect low vertical flows within a borehole, below the threshold limits of conventional impeller tools. The probe is designed for stationary measurements only. Normal logging practice involves measurements at a series of depths across the zone of interest.

Surface equipment

Micrologger2: surface interface system for handling logging data acquisition, which supports all Robertson Geo probes, including acoustic and imaging tools.

Despite its small size, the Micrologger2 is equally at home as a portable system or with 2,000m of cable in a large truck. Its advanced features ensure long term reliability and freedom from drift or errors. *See page 20*

Winlogger: MS Windows based operating system for the Micrologger2, provides field acquisition capability. In-house processing, interpretation and reporting is undertaken. *See page 20*



Winches: Robertson Geo designs and builds its own range of winches of varying capacities for deploying subsurface probes on 4-core or co-axial cable.

- | | |
|--------------|----------------------|
| • Mini Winch | • 1000m/2000m Winch |
| • 500m Winch | • 2000m Marine Winch |
| • 600m Winch | • 3000m Winch |

From the battery-powered 175m Mini Winch to the heavy-duty 3,000m unit, each is precision engineered for reliable operation under arduous field conditions. Robertson Geo winches are feature-laden and include auto-level wind, tension measurement and integral depth encoder and are all compatible with the Micrologger2. *See pages 21-23*



Mining & Minerals Applications

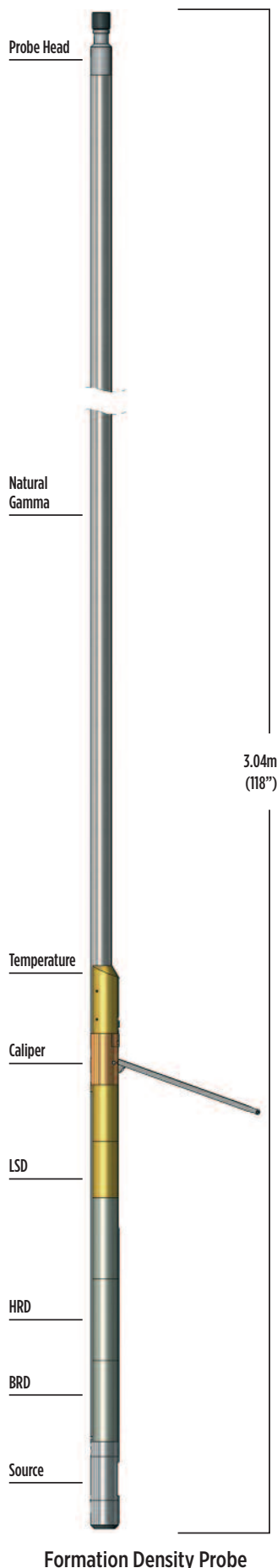
Representative examples to show **Essential**, **Intermediate** and **Advanced** systems as a benchmark for identifying the level of data and interpretation required for individual locations and characteristics.

Robertson Geo support teams are always available for further information and discussion when considering system applications at support@robertson-geo.com

Essential	Intermediate	Advanced
Micrologger2	Micrologger2	Micrologger2
Winch (Mini)	Winch (Mini/500m/600m)	Winch (500m/600m/2,000m)
Ultra Slim Natural Gamma Probe <i>and/or</i> Density Gamma Probe	Density Gamma Probe <i>and/or</i> Spectral Gamma Probe	Density Gamma Probe <i>and/or</i> Spectral Gamma Probe
Formation Density Probe	Formation Density Probe	Formation Density Probe
	Magnetic Susceptibility Probe	Dual Neutron Probe
	Induced Polarisation Probe	Full Waveform Sonic Probe
	Verticality Probe or Gyro Probe	Magnetic Susceptibility Probe
		Induced Polarisation Probe
		3-Arm Caliper Probe
		Verticality Probe or Gyro Probe
		High Resolution Acoustic Televier Probe <i>and/or</i> High Resolution Optical Televier Probe
Coal Mining	Coal Mining	Coal Mining
Micrologger2	Micrologger2	Micrologger2
Winch (Mini)	Winch (500m/600m)	Winch (500m/600m/2,000m)
Density Gamma Probe	Formation Density Probe	Formation Density Probe
3-Arm Caliper Probe	3-Arm Caliper Probe	3-Arm Caliper Probe
	Verticality Probe	Verticality Probe
	Full Waveform Sonic Probe	Full Waveform Sonic Probe
	Focussed Electric Probe	Focussed Electric Probe
	High Resolution Acoustic Televier Probe	High Resolution Acoustic Televier Probe
		Dual Neutron Probe
		4-Arm Dipmeter Probe

See probe and surface equipment specifications pages 7 through 23

Formation Density, Density Guardlog & Iron Ore Density



The Formation Density probe uses dual shielded detectors to provide a borehole-compensated density measurement with good bed-boundary resolution.

The Density Guardlog probe offers an additional LL3 focussed electrical measurement with good vertical resolution and depth of investigation. The Iron Ore Density probe includes extra collimation, different source-detector spacings and a higher activity source to extend the density range to 5g/cc for iron ore logging.

Principle of Measurement:

The probes contain a detachable ¹³⁷Cs gamma source and two scintillation gamma detectors. The active windows of the source and detectors are maintained in contact with the borehole wall by a motorised caliper arm. Gamma radiation back-scattered by the formation (Compton effect) reaches the detectors where the relative count rates provide a measure of formation density.

SPECIFICATION:

Features

- Compensated density output in engineering units (g/cc)
- Short-spacing detector for high vertical resolution
- Tungsten shielding reduces borehole effects
- Standard calibration blocks for field or base use

Measurements

- Bulk density
- High-resolution density (HRD)
- Natural gamma
- Caliper
- Options: Guard resistivity, Bed-resolution density (BRD), Temperature
- Dual calibrated density channels
- Fluid Temperature

Applications

Minerals:

- Density and porosity
- Lithology
- Bed thickness and boundary location
- Coal ash and moisture content

Engineering:

- Rock strength and elasticity parameters (with sonic log)
- Detection of weathered or fractured zones

Water:

- Location of aquifer and aquitard
- Detection of cavities and missing cement

Operating Conditions

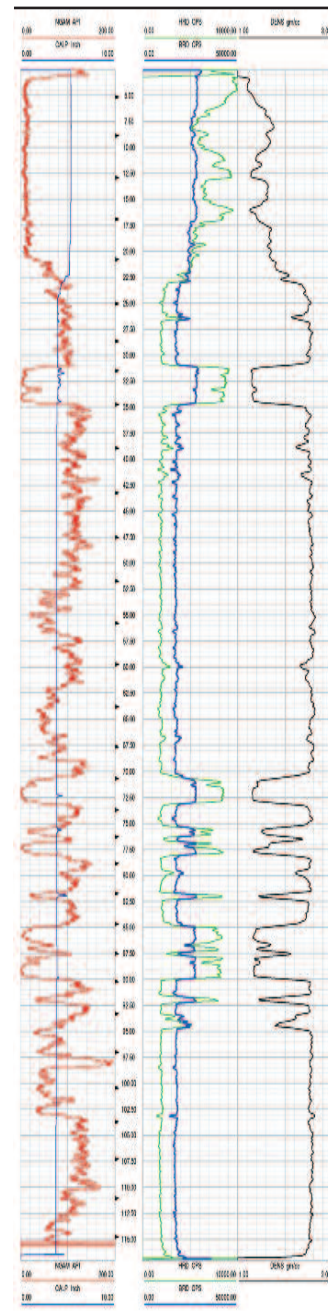
- Borehole type: All, including air filled (qualitative measurement only)
- Recommended Logging Speed: 4m/min

Specifications

- Diameter: 51mm
- Length: Formation Density 3.04m / Density Guardlog 2.89m
- Weight: 21kg (Density Guardlog 28.5kg)
- Temperature: 0-70°C (extended ranges available)
- Max. pressure: 20MPa
- Density range: 1.1 to 2.95g/cc (Formation Density and Density Guardlog probes)
1.5 to 5.0g/cc (Iron Ore Density probe)
- Caliper range: 50mm to 300mm
- Resistivity range: 1-10000 ohm-m

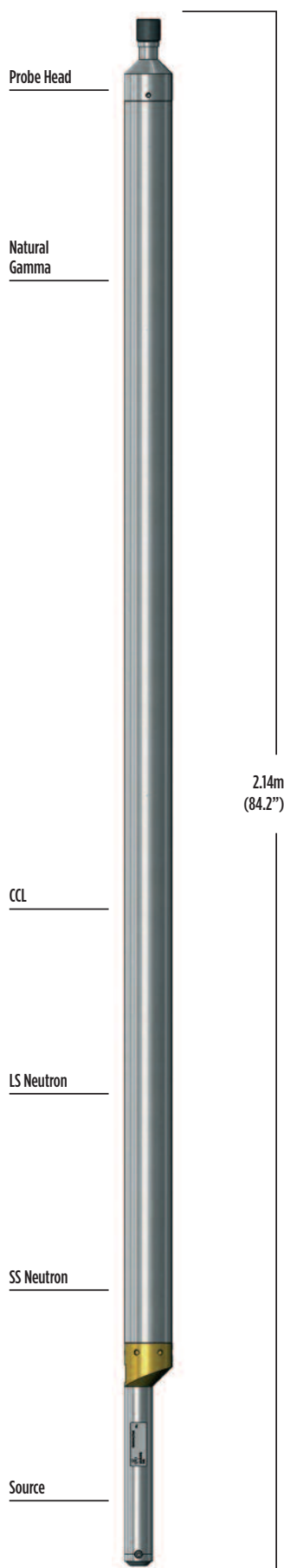
Part Numbers

- I002013 Formation Density probe
- I002016 – includes BRD and temperature
- I014720 Density Guardlog probe with BRD
- I018309 Iron Ore Density probe



Example of logging data

Dual Neutron



Dual Neutron Probe

The Dual Neutron probe provides a calibrated borehole-compensated neutron porosity measurement in mud-filled open holes.

It is the probe of choice for quantitative formation-fluid studies.

A single-detector neutron probe is also available for qualitative porosity logging under most borehole conditions including through steel or plastic casing and drill-pipe.

Principle of Measurement:

The Dual Neutron measurement uses two ^3He proportional detectors and a detachable, sealed $^{241}\text{Am-Be}$ neutron source. Fast neutrons emitted by the source are scattered and slowed to thermal levels, principally by hydrogen in the formation. The ratio of the neutron flux reaching the near and far detectors depends on the hydrogen index and porosity. Use of dual detectors and a ratio method provides a porosity measurement compensated for borehole diameter but not independent of it.

SPECIFICATION:

Features

- Real-time porosity measurement
- Compensation for borehole diameter

Measurements

- Compensated porosity
- Neutron (raw counts)
- Natural gamma
- Option: Casing-collar locator (CCL)

Applications

Minerals / Water / Engineering

- Lithology identification
- Location of aquifer and aquitard
- Fracture analysis in coals
- Correlation between open and cased-hole logs
- Strata correlation between wells

Operating Conditions

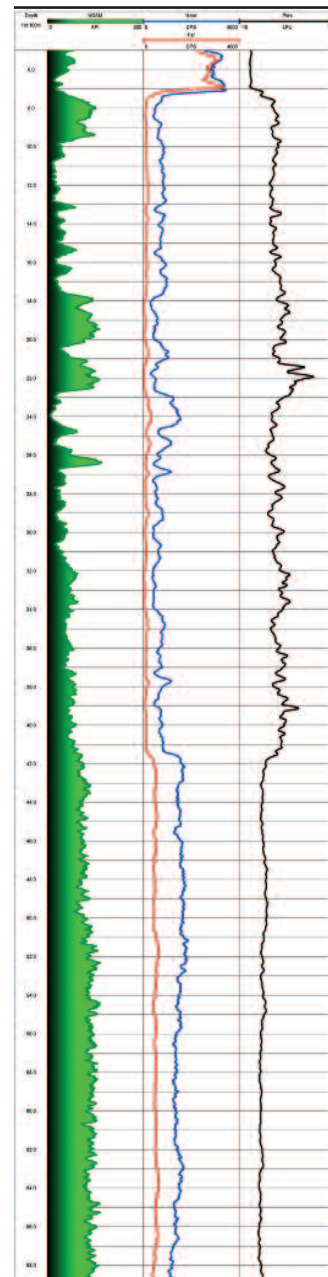
- Borehole type: open/cased, water-filled
- Centralisation: ex-centralised with bowspring
- Recommended Logging Speed: 4m/min

Specifications

- Diameter: 65mm
- Length: 2.14m
- Weight: 19.5kg
- Temperature: 0-70°C (0-125°C optional)
- Max. pressure: 20MPa
- Range: 15 to 45% Limestone Porosity Units (LPU)

Part Numbers

- 1002029 Dual Neutron probe with natural gamma
- 1002030 - includes CCL



Example of logging data

Spectral Gamma

Probe Head

1.72m
(67.7")

Detector

Spectral Gamma Probe

The Spectral Gamma probe analyses the energy spectrum of gamma radiation from naturally occurring or man-made isotopes in the formation surrounding a borehole.

The probe corrects for temperature drift in real-time by matching the acquired spectrum to the base spectra of the main natural emitters (potassium, uranium and thorium) determined during the tool master calibration. Available outputs are full-spectrum (static mode only) and continuous log measurements of elemental concentrations. Borehole corrections are available for casing thickness, borehole diameter, formation density and mud/fluid radioactivity for both centralized and side-walled tool positions.

Principle of Measurement:

Gamma photons produced by the decay of naturally occurring potassium, uranium, thorium and/or unstable man-made isotopes in the formation are detected by a large-volume gamma scintillation counter and converted to electrical pulses. The amplitude of the pulses depends on the photon energy. An analyzer within the probe separates the pulses into channels according to their amplitudes. Count-rates from groups of channels are converted in real-time by the surface software to concentrations of the originating elements using predetermined algorithms.

SPECIFICATION:

Features

- Large-volume scintillation detector for high sensitivity
- Temperature compensation ensures freedom from drift

Measurements

- Uranium (ppm)
- Thorium (ppm)
- Potassium (%)
- Gross Gamma
- Full spectrum display 100keV – 3MeV

Applications

Minerals / Water / Engineering

- Shale/Clay typing
- Correlation in complex situations
- Mineral detection
- Radioactive waste pollution measurement
- Lithology determination

Operating Conditions

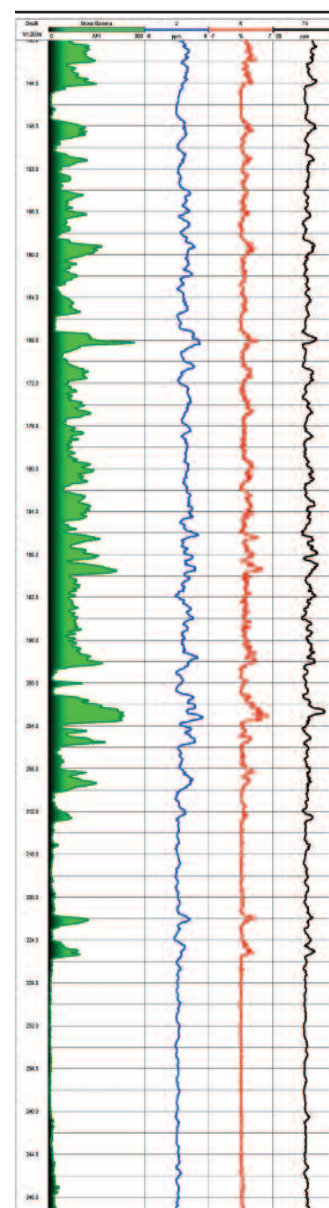
- Borehole type: open/cased, water/air filled
- Recommended Logging Speed: 1m/min

Specifications

- Diameter: 48mm or 60mm
- Length: 1.72m (for both types)
- Weight: 7kg (60mm version)
- Temperature: 0-70°C
- Max. pressure: 20MPa
- Detector: NaI(Tl) scintillator
- Detector Size: 38mm x 150mm
- Energy range: 100keV to 3MeV

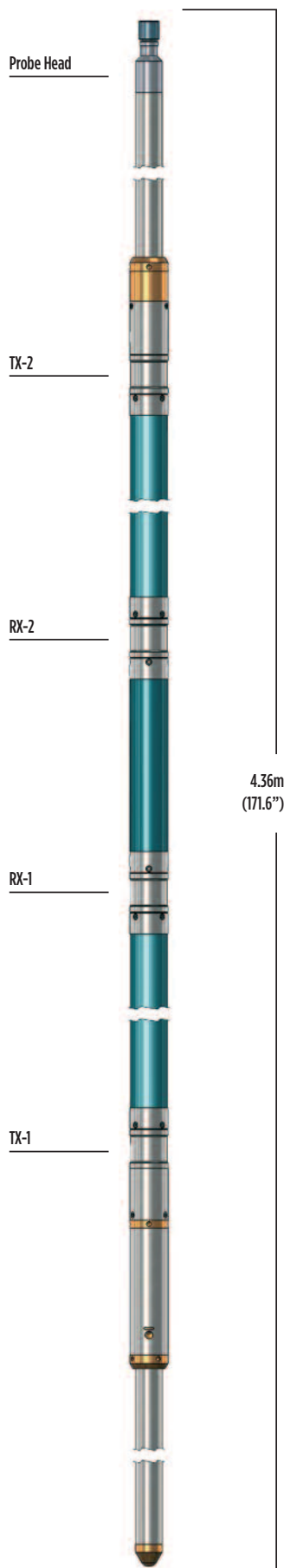
Part Numbers

- I017478 Spectral Gamma probe



Example of logging data

Full Waveform Sonic



Full Waveform Sonic Probe

The Full Waveform Sonic probe uses a dual-transmitter dual-receiver array to provide high quality formation acoustic-velocity data.

Options are available for display of full-waveform data and cement-bond data (CBL) in cased boreholes.

Principle of Measurement:

A piezoelectric transmitter stimulated by a high-voltage pulse radiates a high-frequency acoustic wavelet. This is coupled via the borehole fluid and formation to each receiver. An accurate quartz clock measures the first arrival transit time. The first arrival in open hole corresponds to the p-wave path in the formation.

Full Waveform Sonic mode: Two pairs of transmitters and receivers are used to allow cancellation of the borehole fluid path and determination of formation velocity (slowness). The full sonic waveform from both receivers is displayed as a variable-density log (VDL) or waveform ('wiggles') trace.

Cement Bond Log (CBL) mode: The probe records the amplitude and arrival time of the first casing arrival at the near receiver and full sonic waveforms from both receivers.

SPECIFICATION:

Features

- Down-hole digitisation of waveform data
- Compensation for poor centralisation or caving
- Variable density log (VDL) or wavelet ('wiggles') display

Measurements

- Formation velocity (slowness)
- Shear (S) velocity (where shear wave exists)
- Full waveform Time of first arrival (delta-t)
- Amplitude of first arrival (CBL)
- Integrated transit time
- Natural Gamma optional

Applications

Water / Minerals / Engineering

- Porosity
- Rock strength and elasticity (with density log)
- Correction of seismic velocity
- Fracture and permeability indication in hard rock
- Location of poor or missing cement behind casing

Operating Conditions

Borehole type:

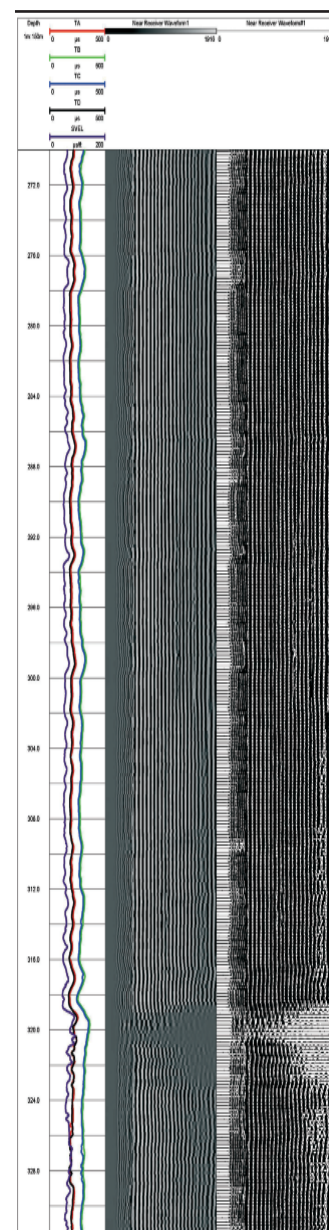
- Sonic: open-hole, water-filled
- CBL: cased-hole, water-filled
- Centralisation: required
- Recommended Logging Speed: 4m/min

Specifications

- Diameter: 60mm
- Length: 4.36m (4.78m with gamma)
- Weight: 30kg (33kg with gamma)
- Temperature: 0-70°C (extended ranges available)
- Max. pressure: 20MPa

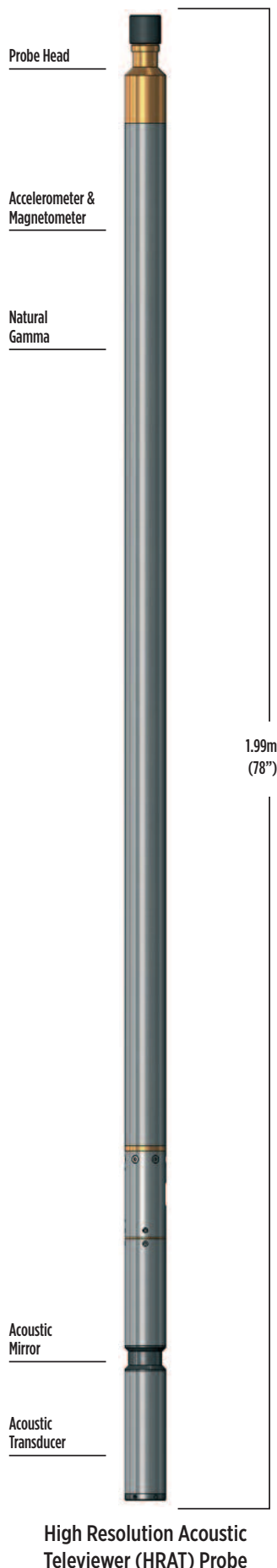
Part Numbers

- I002128 Full Waveform Sonic probe with CBL



Example of logging data

High Resolution Acoustic Televiewer (HRAT)



The High Resolution Acoustic Televiewer (HRAT) provides a continuous high-resolution oriented ultrasound image of the borehole wall.

The probe uses a fixed acoustic transducer and a rotating acoustic mirror to scan the borehole walls with a focussed ultrasound beam. The amplitude and travel time of the reflected acoustic signal are recorded as separate image logs.

Features such as fractures reduce the reflected amplitude and appear as dark sinusoidal traces on the log. The travel-time log is equivalent to a 360-arm caliper and shows diameter changes within open fractures and 'break-outs'. Directional information is also recorded and used to orient the images in real time.

SPECIFICATION:

Applications

- Fracture identification and orientation
- Stratigraphic studies
- Local stress studies (break-out)
- Core orientation
- Cased-hole studies

Operating Conditions

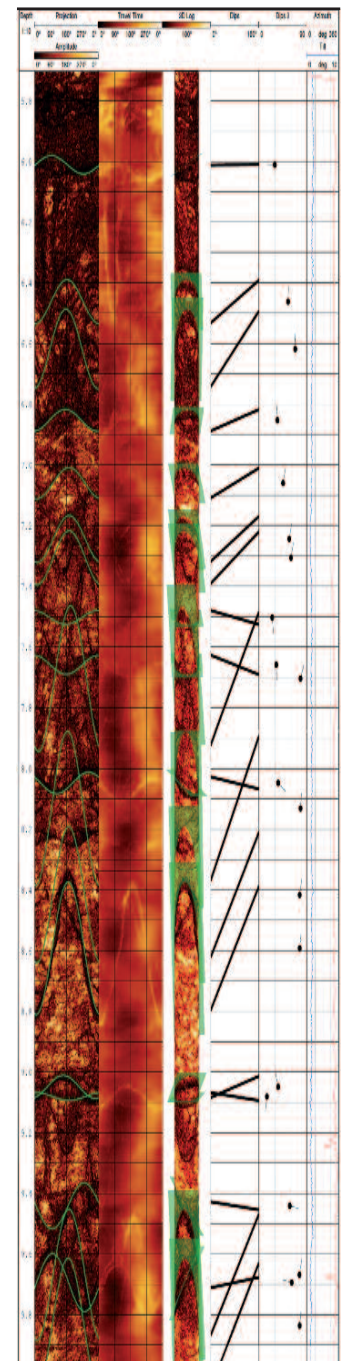
Borehole Type:	Fluid filled
Recommended Logging Speed:	2.5m/min

Specifications

Diameter:	42mm
Length:	1.55m or 1.99m (with natural gamma option)
Weight:	5kg
Transducer type:	1.5MHz piezo-composite
Rotation rate:	5 – 20rev/s
Sample rate:	up to 360/rev

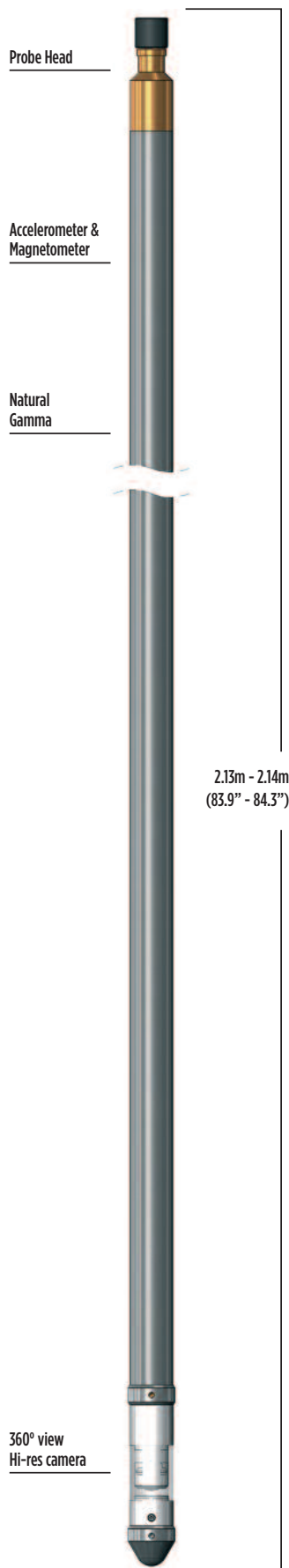
Part Numbers

I002184	HRAT probe
I002192	HRAT including natural-gamma



Example of logging data

High Resolution Optical Televiewer (Hi-OPTV)



High Resolution Optical
Televiewer (Hi-OPTV) Probe

The High Resolution Optical Televiewer (Hi-OPTV) provides a continuous very high resolution oriented image of the borehole walls using a conventional light source.

A unique optical system based on a fisheye lens allows the probe to survey 360 degrees simultaneously. This information is processed in real time to produce a complete 'unwrapped' image of the borehole oriented to magnetic north. The probe offers superior resolution to the High Resolution Acoustic Televiewer (HRAT) and produces images in real colour. While, unlike the HRAT, it can operate in air-filled boreholes, it is unsuitable for boreholes containing mud or cloudy fluids.

WellCad™ Image-processing software:

WellCad™ is a Windows-based package for processing, interpreting and displaying acoustic and optical televiewer image logs. Standard log presentations include tadpole and stick plots, stereographic projections of poles to planes and azimuth frequency diagrams. The synthetic core display allows convenient comparison of log and field data for orientation of fractured or incomplete core sections.

SPECIFICATION:

Applications

Fracture identification and orientation
Stratigraphic studies
Local stress studies (break-out)
Core orientation
Cased hole studies

Operating Conditions

Borehole Type: Air filled or clear fluid
Recommended Logging Speed: 3m/min

Specifications

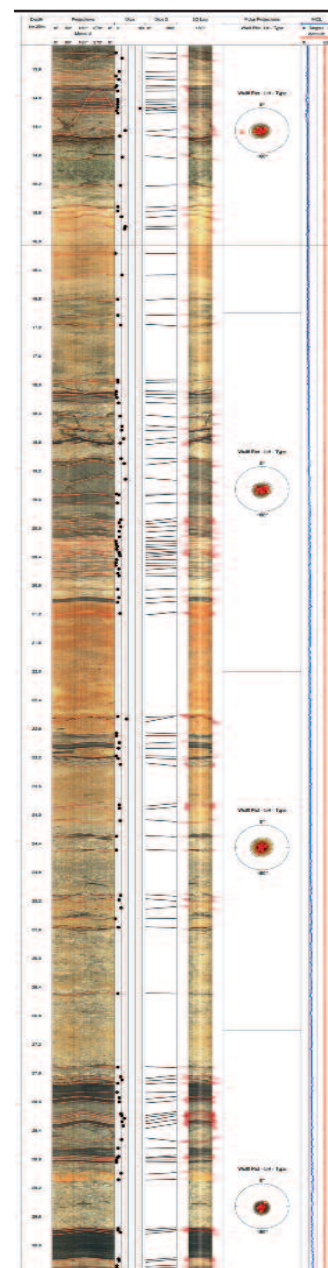
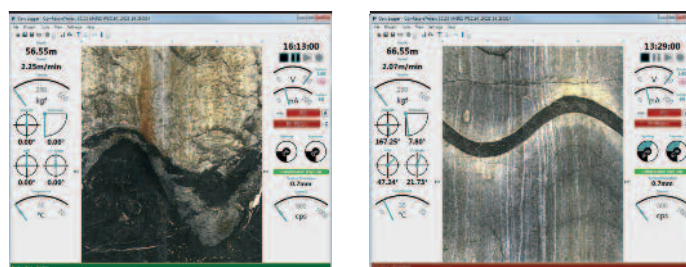
Length: 2.13m - 2.14m (10MPa/20MPa window)
Diameter: 46mm (10MPa) & 58mm (20MPa)
Weight: 6kg (10MPa) or 7.2kg (20MPa)
Temperature (max): 60°C
Circular resolution: user definable 360/540/720 /900/1080/1260/1440 pixels
Sensor type: 1280 x 1024 pixels CMOS image sensor
Colour resolution: 24 bit RGB

Part Numbers

I017187 Hi-OPTV probe (46mm)
I017188 Hi-OPTV probe (46mm) with gamma
I017125 Hi-OPTV probe (58mm)
I017216 Hi-OPTV probe (58mm) with gamma
I015464 Gamma Test Blanket

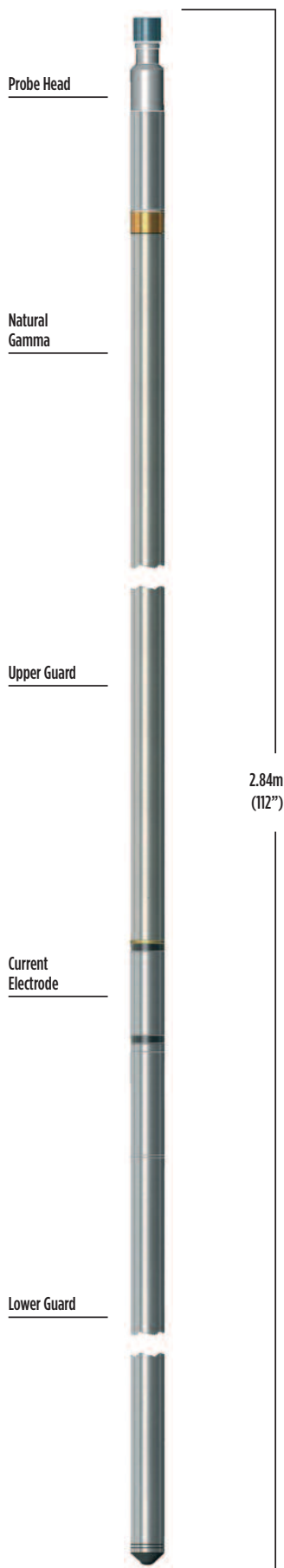
WellCAD™ Image-processing software

I000942 WellCAD™ Software
I000944 WellCAD™ Image Module



Examples of logging data

Focussed Electric (Guardlog)



Focussed Electric (Guardlog) Probe

The focussed resistivity (LL3) measurement provides excellent vertical resolution and a reasonable depth of investigation.

The Guardlog replaces the classic Electric Log in conditions of low mud resistivity and high formation resistivity.

Principle of Measurement:

The probe includes a central current-source electrode between two guard electrodes, maintained at the same potential by internal electronics. Current from the centre electrode is constrained to a thin disk by the presence of the guards and returns to the cable armour above a 10m insulated section. The potential of the central electrode with respect to a surface voltage-reference stake and the measured current are combined by a down-hole microprocessor to calculate apparent formation resistivity.

SPECIFICATION:

Features

- Good depth of penetration with excellent bed-boundary resolution
- Down-hole calibration check using internal resistor
- Digital down-hole measurement avoids errors due to cable effects in deeper boreholes
- Constant-power down-hole current source give 4 decades of measurement without range switching

Measurements

- Focussed resistivity
- Natural Gamma

Applications

Water

- Determination of water quality
- Indication of permeable zones and porosity

Minerals/Engineering

- Strata correlation between boreholes
- Indication of fractures and permeable zones
- Bed-boundary and thickness measurements
- Moisture determination in coal

Operating Conditions

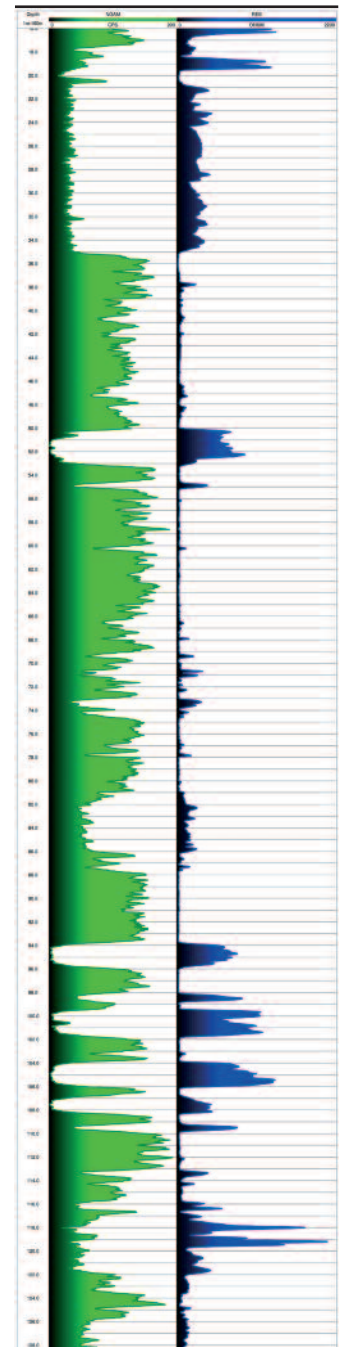
- Borehole type: open-hole, water-filled
- Centralisation: standoff recommended. The logging cable armour should be insulated for 10m above probe head
- Recommended Logging Speed: 4m/min

Specifications

- Diameter: 38mm
- Length: 2.84m
- Weight: 9.5kg
- Temperature: 0-70°C (extended ranges available)
- Max. pressure: 20MPa
- Resistivity range: 1 to 10,000 ohm-m

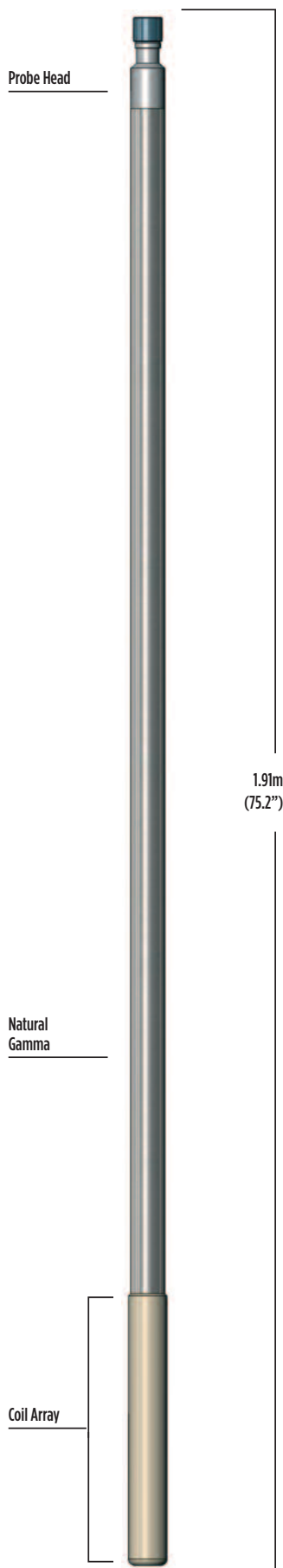
Part Numbers

- 1002078 Focussed Electric (Guardlog) probe includes natural gamma



Example of logging data

Magnetic Susceptibility



Magnetic Susceptibility Probe

The Magnetic Susceptibility probe is based on the industry-standard Bartington Instruments™ product.

It is a low-frequency device and is specifically designed for mining applications. The probe has excellent stability against pressure and temperature variations.

Principle of Measurement:

An oscillating magnetic field in the probe produces a current within a toroidal zone in the surrounding formation. The oscillating current produces a secondary field that is detected by the receiver coils. The 'in-phase' signal is a measure of susceptibility.

SPECIFICATION:

Features

- Operates in dry or water-filled boreholes
- Unaffected by plastic casing Ideal for use in small-diameter exploration boreholes
- Excellent thermal/pressure stability across specified operating range

Measurements

- Magnetic susceptibility
- Natural Gamma

Applications

The probe has particular use for detecting uranium where the log shows a negative correlation with uraniferous compounds. Susceptibility logs are highly sensitive to iron and show large contrasts according to its oxidation state. The frequent occurrence of iron with other redox-sensitive metals can provide a valuable indicator of the presence of other minerals.

Operating Conditions

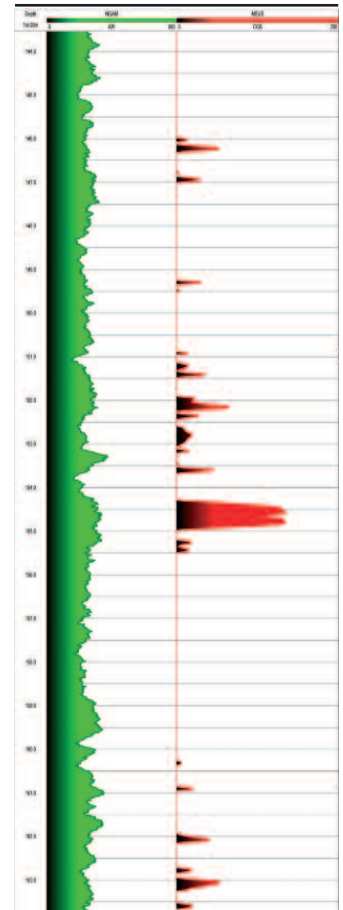
- Borehole type: open/cased (plastic), water/air-filled
- Centralisation: fin stand-off recommended
- Recommended Logging Speed: 3m/min

Specifications

- Diameter: 43mm
- Length: 1.91m
- Weight: 5.5kg
- Temperature: 0-70°C (extended ranges available)
- Max. pressure: 20MPa
- Operating frequency: 1.439kHz
- Range: 10^{-5} to 10^{-1} cgs (Gaussian)

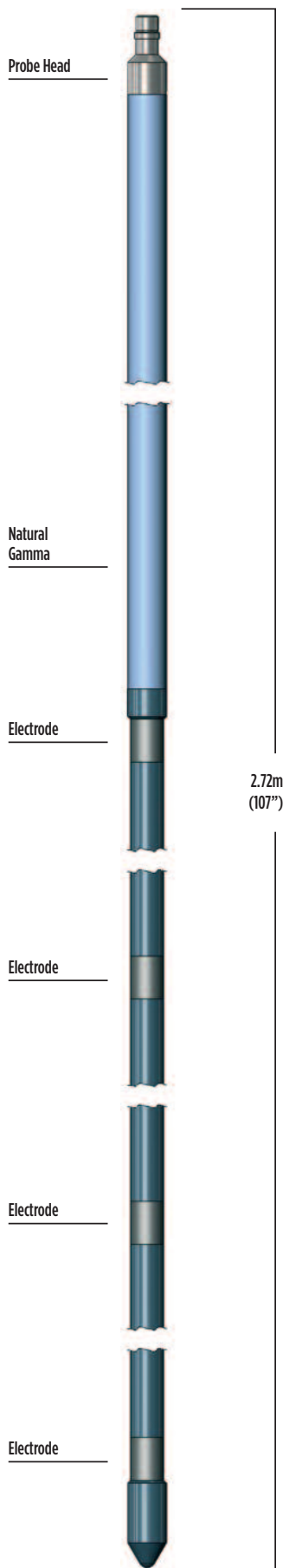
Part Numbers

- I002095 Magnetic Susceptibility probe with natural gamma



Example of logging data

Induced Polarisation



Induced Polarisation Probe

The Induced Polarisation probe measures the charge separation or 'chargeability' in porous, water-saturated, mineralised rocks caused by the passage of a low-frequency alternating current.

The main cause of induced polarisation is a current-induced electron-transfer reaction between ions of an electrolyte in contact with grains of semi-conducting metallic minerals.

Principle of Measurement:

The probe passes a controlled current through the formation between two outer electrodes and detects the variation with time of the resulting voltage measured between two inner electrodes after the device is removed. The integrated area under the voltage-time curve is a measure of chargeability.

SPECIFICATION:

Features

- Microprocessor-controlled drive voltage
- Down-hole integration and ratio computation

Measurements

- Chargeability
- Formation resistance
- Natural Gamma

Applications

Minerals

- Indication of mineralisation, particularly of disseminated sulphides
- Differentiation of haematite and magnetite

Water

- Qualitative permeability studies

Operating Conditions

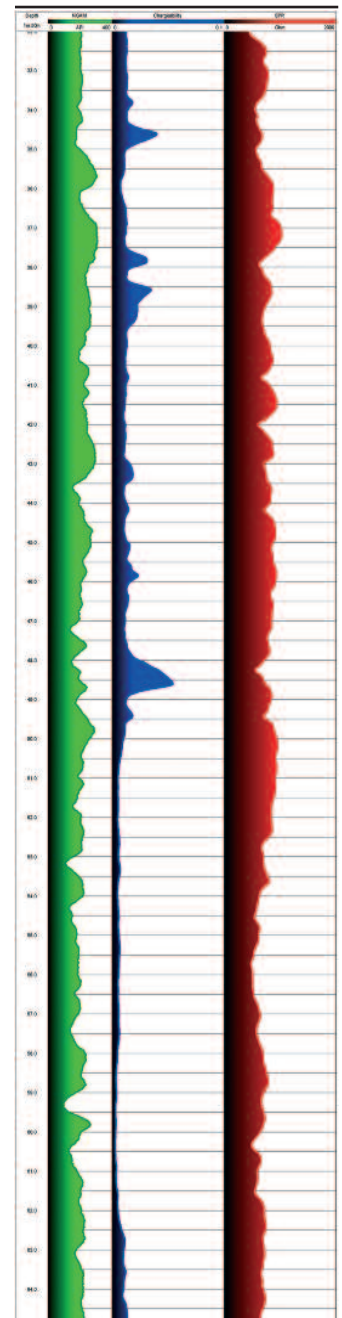
- Borehole type: open-hole, water-filled
- Recommended Logging Speed: 3m/min

Specifications

- Diameter: 45mm
- Length: 2.72m
- Weight: 11kg
- Temperature: 0-70°C (extended ranges available)
- Max. pressure: 20MPa

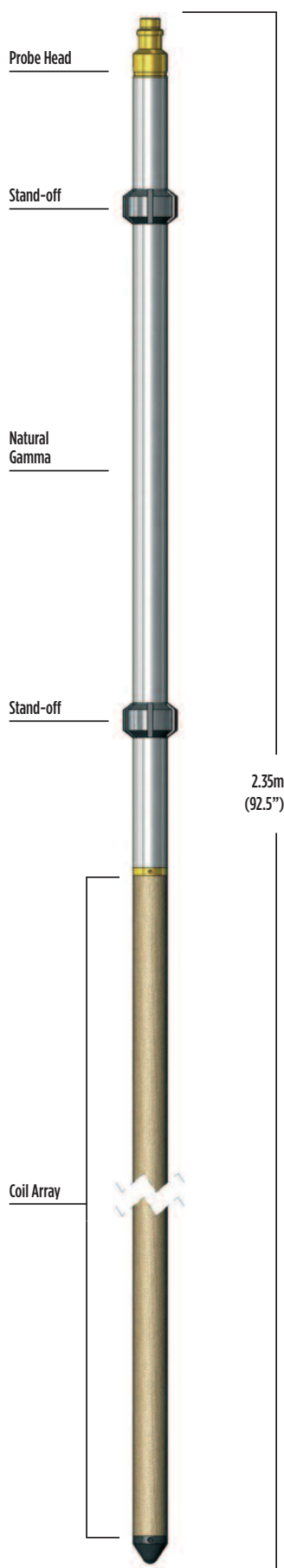
Part Numbers

- I002I02 Induced Polarisation probe with natural gamma



Example of logging data

Dual Focussed Induction | Ultra-Slim Induction



Dual Focussed Induction Probe

The Dual Focussed Induction probe provides two simultaneous conductivity logs, corresponding to “medium” and “deep” radii of investigation into the formation.

The two depths of penetration are useful in porous, permeable formations where displacement of formation fluids by drilling mud creates an “invasion zone” with different electrical properties. The 1” focussed induction probe produces a single medium penetration conductivity log. It finds particular application in small-diameter dry or plastic-lined boreholes used for mineral exploration and for conductivity/resistivity in dry holes.

Principle of Measurement:

An oscillating high-frequency magnetic field from a transmitter coil within the probe induces an alternating electrical current within the surrounding conductive formation. This current, in turn, induces voltages within receiver coils proportional to the formation conductivity. The transmitter-receiver spacings determine the depth of investigation of the measurements. Additional focussing coils minimise the contribution of the borehole signal.

SPECIFICATION:

Features

- Formation conductivity measurement in wet/dry boreholes or through plastic casing
- Separate deep and medium penetrating measurements give information on invaded zone
- Focussed measurements for minimum borehole signal PSD (phase-sensitive detector) discriminates between magnetic susceptibility and conductivity signals

Measurements

- Deep formation conductivity
- Medium formation conductivity
- Natural Gamma

Applications

Water

- Indicator of permeable zones and porosity
- Formation water salinity
- Long-term well monitoring

Mineral/Engineering

- Ore identification and quality
- Correlation

Other

- Indication of hydrocarbons

Operating Conditions

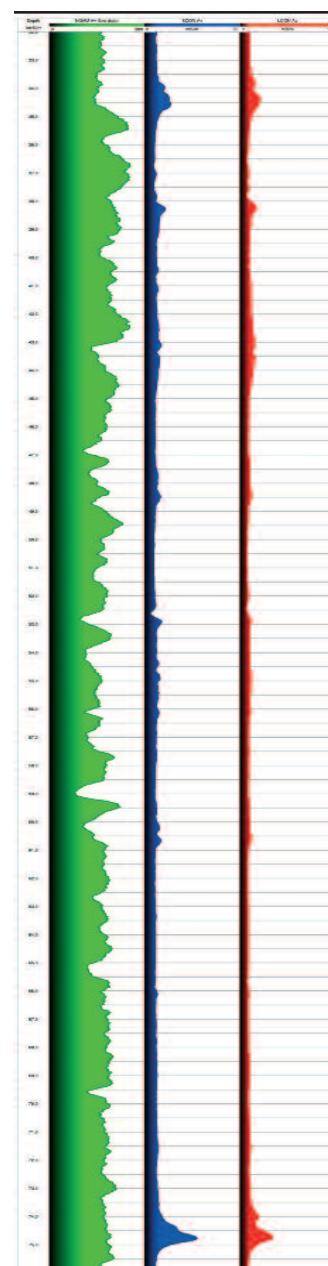
- Borehole type: open/plastic or grp cased, air/water-filled
- Recommended Logging Speed: 5m/min

Specifications

- Diameter: 38mm/25mm
- Length: 2.35m/1.95m
- Weight: 6kg
- Temperature: 0-70°C (extended ranges available)
- Max. pressure: 20MPa
- Number of coils: Dual Induction 7, Ultra-slim 4
- TX-RX spacings: ILM 50cm (20”), ILD 81cm (32”)
- Conductivity range: 3 to 3300mS/m

Part Numbers

- 1002087 Dual Focussed Induction probe with natural gamma
- 1002091 Ultra-Slim Induction probe with natural gamma



Example of logging data

Verticality

Probe Head

Natural
Gamma

Accelerometer &
Magnetometer

1.66m
(63.3")

Verticality Probe

The Verticality probe provides accurate, continuous measurements of borehole inclination and direction.

These are output directly as log traces or may be processed further to produce tabular and graphical outputs of borehole position, borehole drift and true vertical depth.

Principle of Measurement:

The probe includes a triaxial magnetometer to determine the bearing of a reference in the probe relative to magnetic North and three accelerometers to measure inclination. The outputs from the transducers are processed by a downhole microprocessor to give final borehole inclination and azimuth data in real time.

SPECIFICATION:

Features

- Small diameter for slimhole operations
- Continuous borehole orientation log
- Suitable for all borehole inclinations and directions

Measurements

- Borehole inclination
- Borehole direction
- Borehole drift
- True vertical depth
- Natural Gamma

Applications

Minerals / Water / Engineering

- Bed-thickness estimation
- Surveying and deviation checks
- True seam depth

Operating Conditions

- Borehole type: open/plastic-cased, water/air-filled
- Centralisation: non-magnetic centralisers required
- Recommended Logging Speed: 4m/min

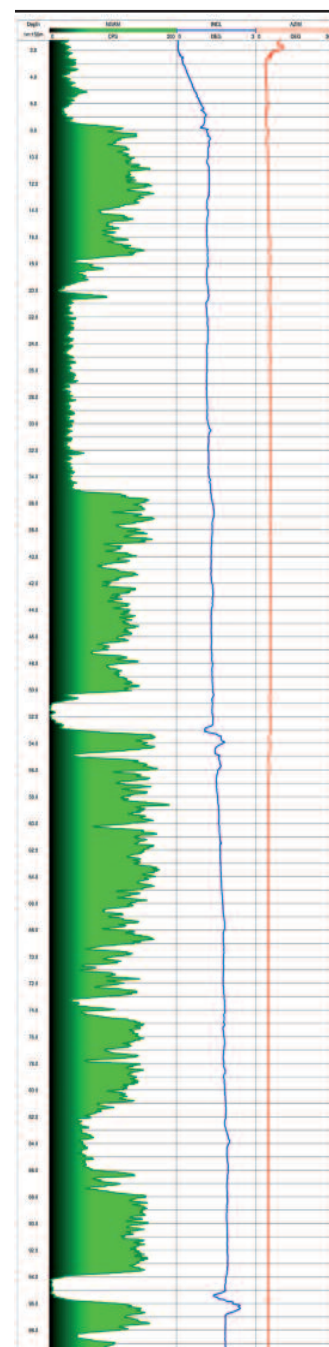
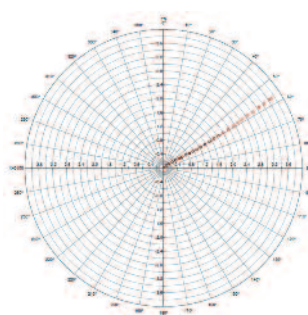
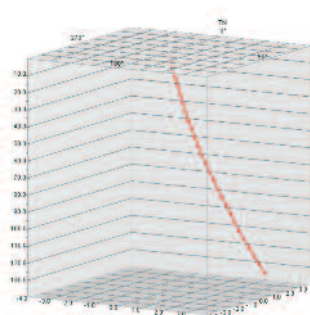
The operation of the probe is limited in steel casing or in the presence of magnetic minerals which affect the magnetometer. Under such conditions, only borehole inclination (without directional information) can be logged. The Gyro probe should be used in preference to the standard verticality probe in such cases.

Specifications

- Diameter: 42mm
- Length: 1.66m
- Weight: 5.5kg
- Temperature: 0-70°C (extended ranges available)
- Max. pressure: 20MPa
- Inclination range: Horizontal +/- 90°
- Azimuth range: 0 to 360°

Part Numbers

- I002141 Verticality probe with natural gamma



Examples of logging data

Probe Head

Accelerometer & Magnetometer

Gyroscope

2.29m
(90")

Gyro Probe

The Gyro probe acquires borehole inclination/azimuth logs in situations where metal casing or magnetic materials around the borehole prevent use of the standard verticality probe.

The Gyro Magnetometer version also acquires 3D-magnetic data for location of magnetic ore bodies.

Principle of Measurement:

The standard probe includes a gimbal-mounted directional gyroscope for orientational measurement and three accelerometers for inclination. In the Gyro Magnetometer probe, an additional triaxial fluxgate magnetometer continuously measures X, Y and Z magnetic components. These are used to compute the magnitude and direction of the magnetic field around the probe.

SPECIFICATION:

Features

- Continuous log of borehole inclination/azimuth
- Not influenced by metal casing or magnetic materials
- Low drift compared to 'rate' gyroscopes
- Natural-gamma measurement
- Magnitude and direction of surrounding magnetic field

Measurements

- Borehole inclination
- Borehole drift
- True vertical depth
- Natural Gamma
- Magnitude and direction of surrounding magnetic field

Applications

Water / Minerals / Engineering

- Verticality measurements in steel casing or in the presence of magnetic ores
- Detection of nearby magnetic ore bodies (Gyro Magnetometer probe)

Operating Conditions

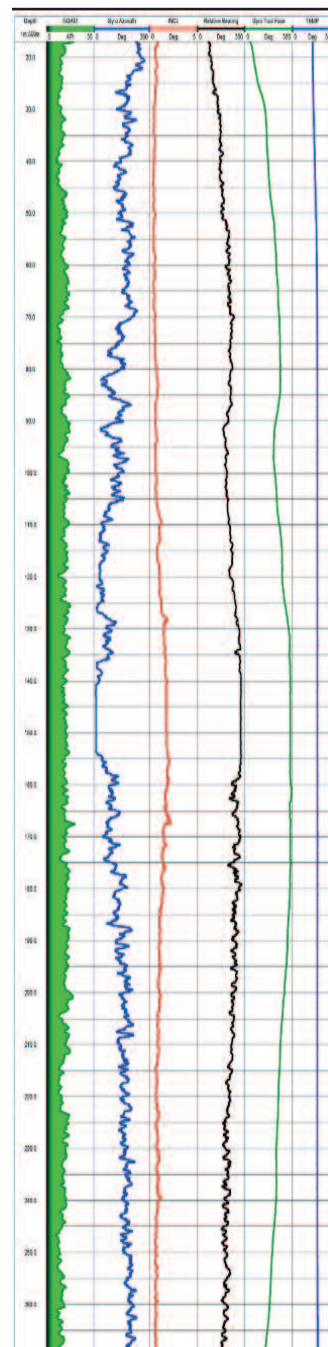
- Borehole type: open/cased hole; water/air-filled
- Centralisation: required
- Recommended Logging Speed: 3m/min

Specifications

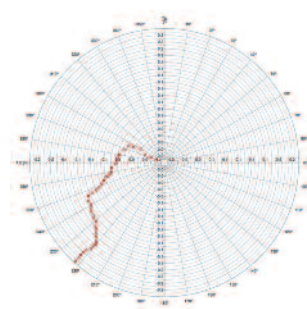
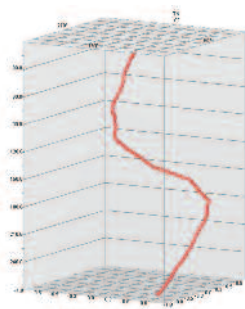
- Diameter: 45mm
- Length: 2.29m
- Weight: 12kg
- Temperature: 0-70°C (extended ranges available)
- Max. pressure: 20MPa
- Inclination range: 0 to 30°
- Azimuth range: 0 to 360°
- Magnetometer range: +/-100 μ T

Part Numbers

- I002150 Gyro probe with natural gamma
- I014559 Gyro Magnetometer probe with natural gamma

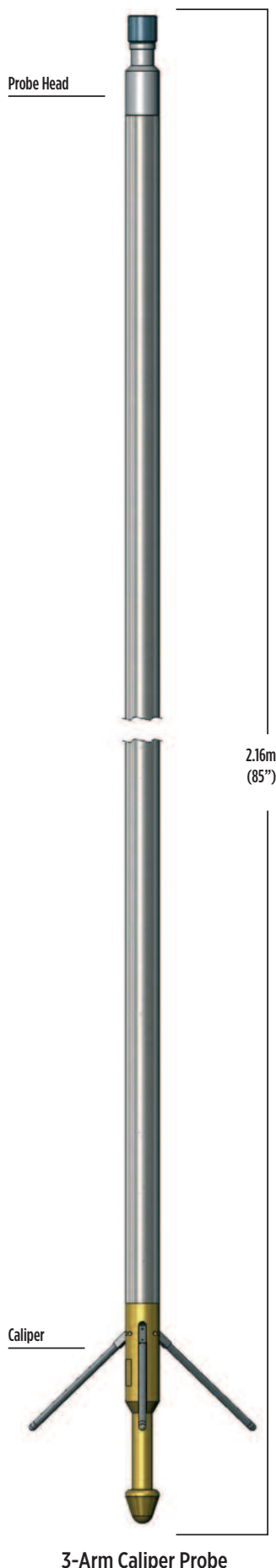


Examples of logging data



3-Arm Caliper

710mm, 1000mm and 1500mm ranges



The 3-Arm Caliper probe provides a single continuous log of borehole diameter as recorded by three mechanically coupled arms in contact with the borehole wall.

710mm, 1000mm and 1500mm range calipers are available to suit a range of well diameters. The caliper is a useful first log to determine the borehole conditions before running more costly probes or those containing radioactive sources.

Principle of Measurement:

Opening and closing of the motor-driver caliper arms is by surface command, allowing the probe to run into the borehole with the arms retracted. Once opened, the spring-loaded arms respond to borehole diameter variations as the probe is raised up the borehole.

SPECIFICATION:

Features

- Small diameter for slim-hole operation
- Extension arms supplied as standard for 38mm version
- Optional natural-gamma measurement
- Optional casing collar locator

Measurements

- CCL (optional)
- Borehole volume (derived)
- Natural Gamma (optional)
- Borehole volume

Applications

- Minerals/Water/Engineering
- Location of borehole collapse or obstructions
- Cement volume calculations for grouting
- Identification of hard and soft lithology
- Location of cracks, fissures, caving, faulting, casing breaks
- Correction of other logs affected by borehole diameter

Operating Conditions

- Borehole type: open/cased; water/air-filled
- Centralisation: recommended in large holes
- Centralisation: recommended in inclined holes
- Recommended Logging Speed: 5m/min

Specifications

- Temperature: 0-70°C (extended ranges available)
- Max. pressure: 20MPa

3-Arm Caliper (710mm range)

- Diameter: 38mm
- Length: 2.18m-2.68m (depending on CCL and extended arms)
- Weight: 7.5kg
- Range: 40-300mm and 40-710mm

3-Arm Caliper (1000mm range)

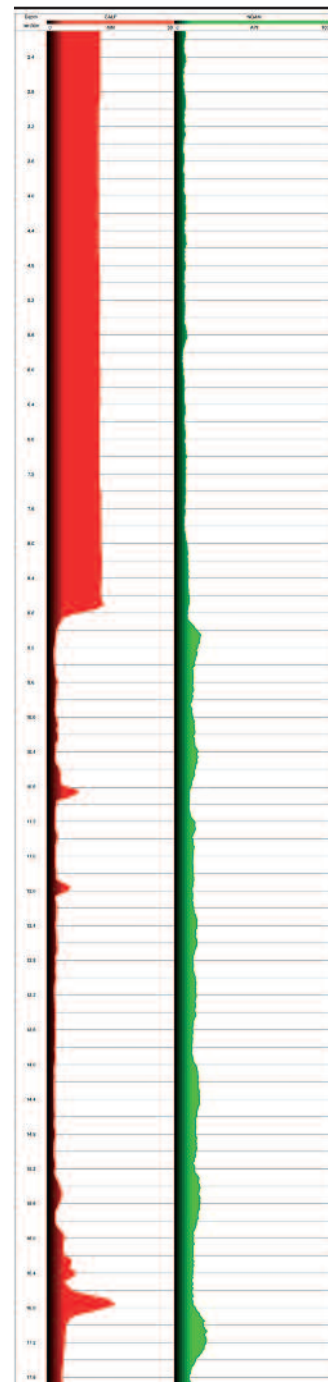
- Diameter: 60mm
- Length: 2.83m
- Weight: 15kg
- Range: 65-1000mm

3-Arm Caliper (1500mm range)

- Diameter: 80mm
- Length: 3.14m
- Weight: 17.5kg
- Range: 100 - 1600mm

Part Numbers

- 1002035 3-Arm Caliper (710mm range) with arm extension kit and calibrator
- 1002037 - including natural gamma
- 1002041 3-Arm Caliper (1000mm range) with calibrator
- 1002052 3-Arm Caliper (1500mm range)



Example of logging data

Mini Winch | 500m Winch | 600m Winch

Robertson Geo designs and builds its own range of winches of varying capacities for deploying subsurface probes on 4-core or co-axial cable.

Each winch is precision engineered for reliable use in the most challenging field applications. The winches are fully compatible with the Micrologger2 surface system and the full range of Robertson Geo probes, for depths of up to 3,000m.

Mini Winch

The Robertson Geo Mini Winch is portable, compact and robust. Its basic 'no-frills' design is aimed at long-term reliability under arduous conditions.

SPECIFICATION:

Specifications

Capacity:	175m (575') 4.72, (3/16") cable
Speed:	0 – 17.5m/min (0 – 57ft/min) on full drum (12VDC operation)
Motor:	550W (12 – 24VDC)
Size:	340(w) x 400(l) x 320(h) mm
Weight:	19kg excluding cable

Part Numbers

1013754	Mini Winch includes power and data cables
1001117	Mini Winch Tripod with Encoder



500m Winch

A robust heavy-duty unit, the 500m Winch can be operated from a vehicle battery and is ideal for heavier probes in shallow boreholes.

SPECIFICATION:

Specifications

Capacity:	530m (1738') 3/16" 4-core cable
Speed:	0 – 13m/min (0 – 43ft/min)
Motor:	180W at 12VDC
Size:	582(w) x 482(l) x 414(h) mm
Weight:	52kg excluding cable

Part Numbers

1001019	500m winch including tripod, power and data cable
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600m Winch

Of similar basic construction to the 500m winch, the 600m is mains/generator powered.

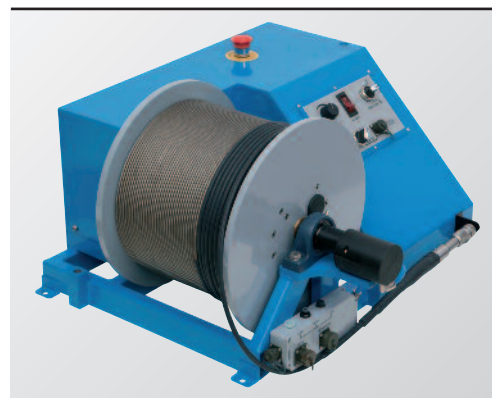
SPECIFICATION:

Specifications

Capacity:	630m (2066') 3/16" 4-core cable
Speed:	0 – 15m/min (0 – 49ft/min)
Motor:	540W at 110/220VAC
Size:	622(w) x 696(l) x 370(h) mm
Weight:	80kg excluding cable

Part Numbers

1001043	600m winch including tripod, power and data cable
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1000m/2000m Winch | 3000m Winch

Robertson Geo designs and builds its own range of winches of varying capacities for deploying subsurface probes on 4-core or co-axial cable.

Each winch is precision engineered for reliable use in the most challenging field applications. The winches are fully compatible with the Micrologger2 surface system and the full range of Robertson Geo probes, for depths of up to 3,000m.

1000m/2000m Winch

The standard unit for truck-mounted operations in deep boreholes, the 2000m winch includes an integral depth wheel and an automatic level wind.

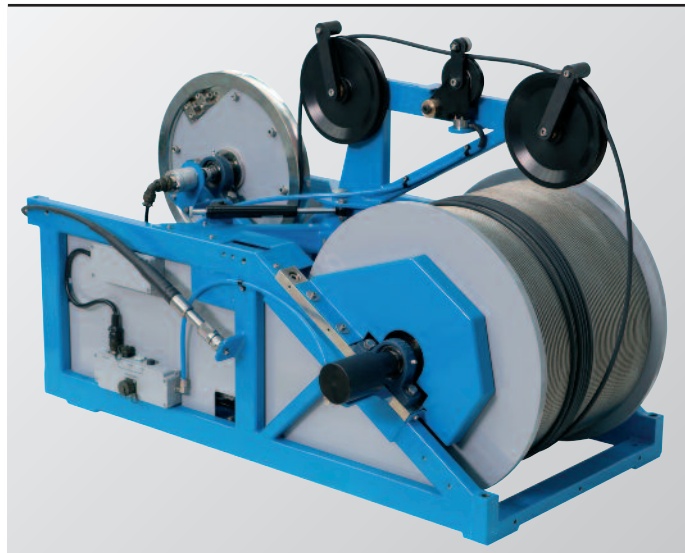
SPECIFICATION:

Specifications

Capacity:	2030m (6658') 3/16" 4-core cable 1030m (3378') 1/4" coaxial cable
Speed:	0 – 30m/min (0 – 99ft/min)
Motor:	2hp (1.5kW) at 110/220VAC
Size:	605(w) x 1060(l) x 735(h) mm
Weight:	142kg excluding cable

Part Numbers

1001021	2000m winch for 3/16" 4-core cable includes tripod, power and data cable
1001034	1000m winch for 1/4" coaxial cable includes tripod, power and data cable



3000m Winch

A heavy-duty electric draw-works designed for deeper hole and oil/gas investigations. *Please note the pressure limits of standard Robertson Geo slimhole tools.*

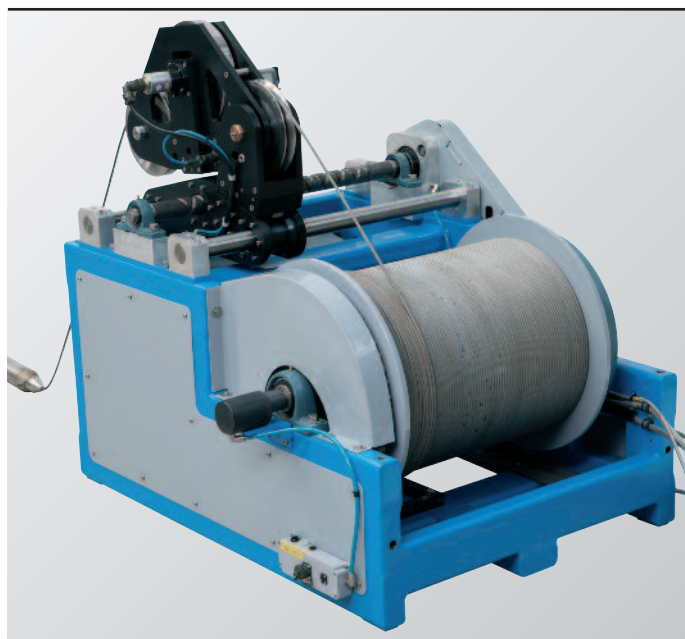
SPECIFICATION:

Specifications

Capacity:	3000m (9840') 3/16" cable
Speed:	0.2 – 34m/min rim: 0.5 – 100m/min
Pull:	1,350kgF Rim: 460kgF
Motor:	440VAC 3-Phase 4kVA
Dimensions:	1000(w) x 1100(l) x 900(h) mm
Weight:	415kg excluding cable

Part Numbers

1013866	3000m winch for 3/16" four-core system includes tripod, power and data cable
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2000m Marine Winch

Robertson Geo designs and builds its own range of winches of varying capacities for deploying subsurface probes on 4-core or co-axial cable.

Each winch is precision engineered for reliable use in the most challenging field applications. The winches are fully compatible with the Micrologger2 surface system and the full range of Robertson Geo probes, for depths of up to 3,000m.

2000m Marine Winch

Working experience by Robertson Geo offshore logging crews has led to the modification of the 2000m Winch and the introduction of a Marine variation to resist corrosive, saline conditions.

The communications box is waterproofed and filled with silicon to protect the electronics.

Grade 316 stainless steel has been introduced to replace standard steel components. 316 contains the alloy molybdenum, significantly enhancing corrosion resistance, especially for more saline or chloride exposed environments. 316 components include structural frames, depth wheel, panels, spacers, shafts and gears, sprockets and chains.

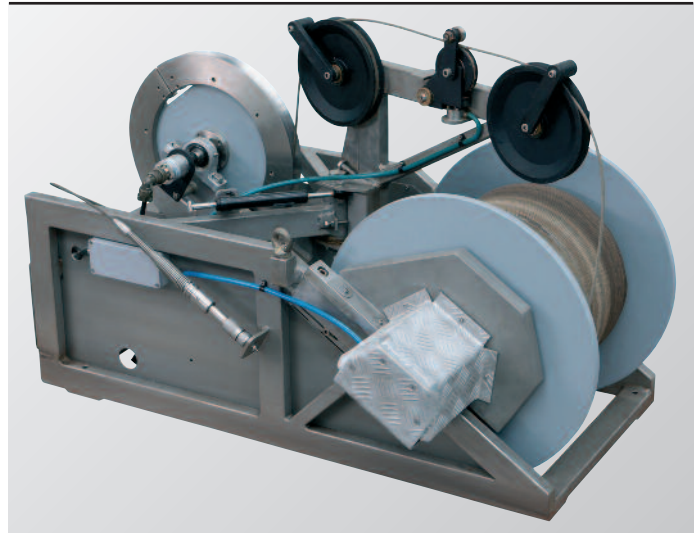
SPECIFICATION:

Specifications

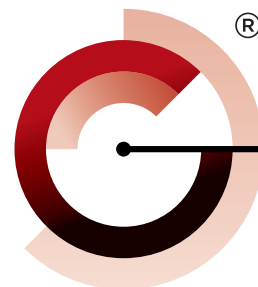
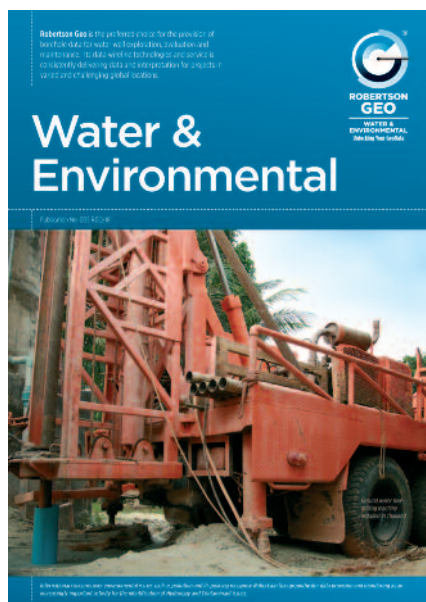
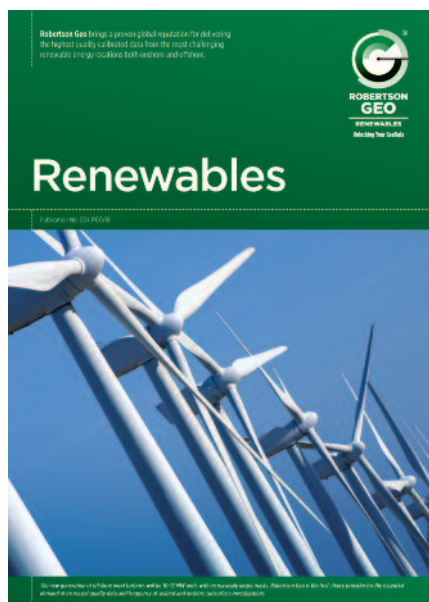
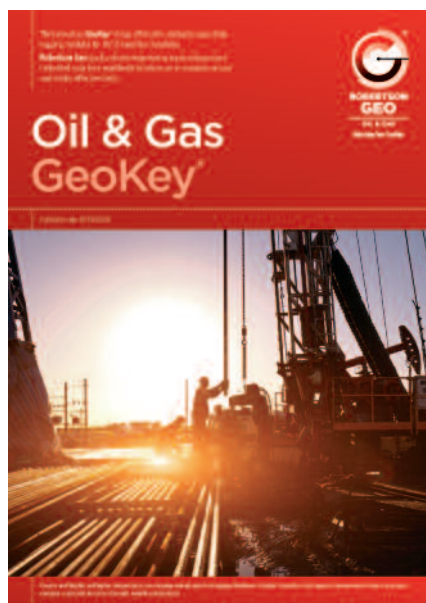
Capacity:	2030m (6658') 3/16" 4-core cable 1030m (3378') 1/4" coaxial cable
Speed:	0 – 30m/min (0 – 99ft/min)
Motor:	2hp (1.5kW) at 110/220VAC
Size:	605(w) x 1060(l) x 735(h) mm
Weight:	142kg excluding cable

Part Numbers

1019167	2000m Marine Winch
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**ROBERTSON
GEO**

Unlocking Your GeoData

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