PHASE 2 INITIAL BOREHOLE DRILLING AND TESTING, IGNACE AREA

WP05 Data Report – Geophysical Well Logging for IG_BH02

APM-REP-01332-0269 **December 2020**

Golder Associates Ltd.

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SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

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REPORT

Phase 2 Initial Borehole Drilling and Testing, Ignace Area

WP05 Data Report - Geophysical Well Logging for IG_BH02

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WP05 DATA REPORT
GEOPHYSICAL WELL LOGGING FOR IG_BH02

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1.0 INTRODUCTION

The Initial Borehole Drilling and Testing project in the Wabigoon and Ignace Area, Ontario is part of Phase 2 Geoscientific Preliminary Field Investigations of the NWMO's Adaptive Phased Management (APM) Site Selection Phase.

This project involves the drilling and testing of the first of three deep boreholes within the northern portion of the Revell batholith. The third drilled borehole, IG_BH02, is located a direct distance of approximately 23 kilometres (km) southeast of the Wabigoon Lake Ojibway Nation and a direct distance of 42 km northwest of the Town of Ignace. Access to the IG_BH02 drill site is via Highway 17 and primary logging roads, as shown on Figure 1.

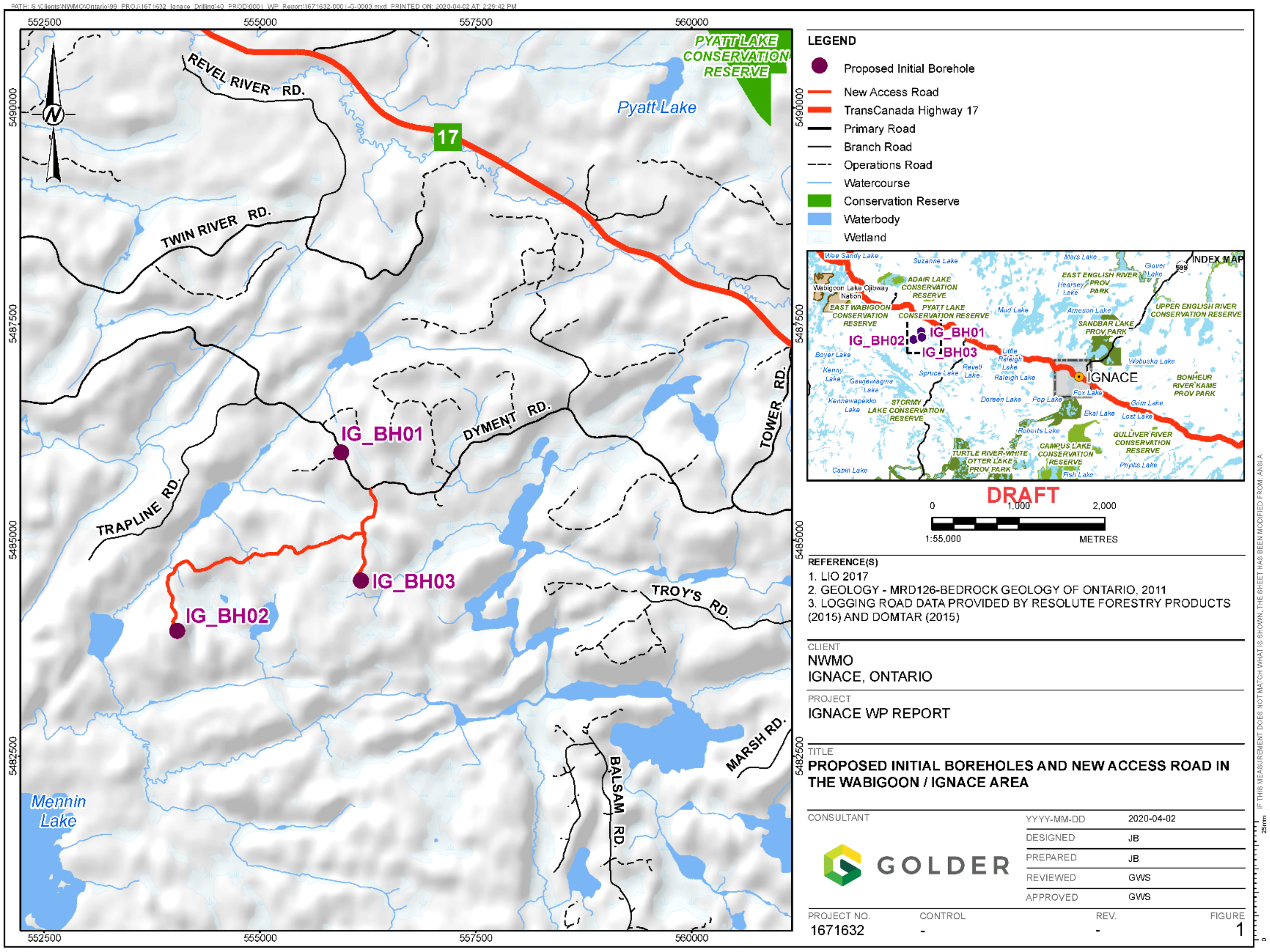

Figure 1: Location of IG_BH02 in relation to the Wabigoon / Ignace Area

The project was carried out by a team led by Golder Associates Ltd. (Golder) on behalf of the NWMO. This report describes the methodology, calibration/verification, acquisition and processing for Work Package 05 (WP05) Borehole Geophysical Logging. Information from Borehole Geophysical Logging will ultimately be used to help assess the local thickness of potentially suitable rock units, the geophysical properties of the rock units at depth, and the presence and types of structural features at depth. The geophysical logging provided high-quality, and high-resolution profiles of rock properties including engineering, lithological, hydrogeological, and structural properties.

2.0 BACKGROUND INFORMATION

2.1 Geological Setting

The approximately 2.7 billion year old Revell batholith is located in the western part of the Wabigoon Subprovince of the Archean Superior Province. The batholith is roughly elliptical in shape trending northwest, is approximately 40 km in length, 15 km in width, and covers an area of approximately 455 km^2. Based on geophysical modelling, the batholith is approximately 2 km to 3 km thick through the center of the northern portion (SGL, 2015). The batholith is surrounded by supracrustal rocks of the Raleigh Lake (to the north and east) and Bending Lake (to the southwest) greenstone belts (Figure 2).

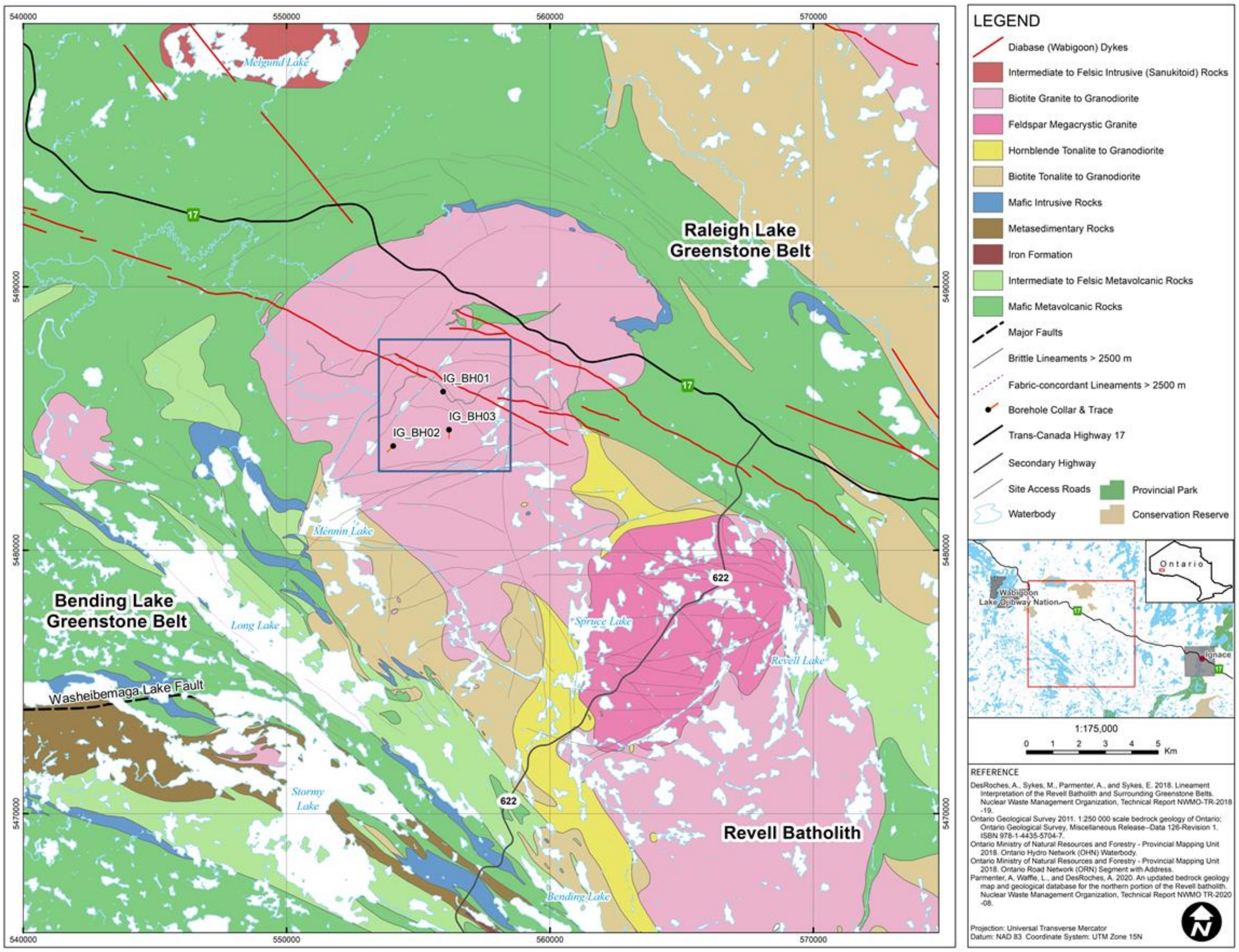

Figure 2: Geological setting and location of boreholes IG_BH01, IG_BH02 and IG_BH03 in the northern portion of the Revell batholith

IG_ BH02 is located within an investigation area of approximately 19 km^2 in size, situated in the northern portion of the Revell batholith. Bedrock exposure in the area is generally very good due to minimal overburden, few water bodies, and relatively recent logging activities. Ground elevations generally range from 400 to 450 m above sea level. The ground surface broadly slopes towards the northwest as indicated by the flow direction of the main rivers in the area. Local water courses tend to flow to the southwest towards Mennin Lake (Figure 1).

Four main rock units are identified in the supracrustal rock group: mafic metavolcanic rocks, intermediate to felsic metavolcanic rocks, metasedimentary rocks, and mafic intrusive rocks (Figure 2). Sedimentation within the supracrustal rock assemblage was largely synvolcanic, although sediment deposition in the Bending Lake area may have continued past the volcanic period (Stone 2009; Stone 2010a; Stone 2010b). All supracrustal rocks are affected, to varying degrees, by penetrative brittle-ductile to ductile deformation under greenschist- to amphibolite-facies metamorphic conditions (Blackburn and Hinz 1996; Stone et al. 1998). In some locations, primary features, such as pillow basalt or bedding in sedimentary rocks are preserved, in other locations, primary relationships are completely masked by penetrative deformation. Uranium-lead (U-Pb) geochronological analysis of the supracrustal rocks produced ages that range between 2734.6 +/-1.1 Ma and 2725 +/-5 Ma (Stone et al. 2010).

Three main suites of plutonic rock are recognized in the Revell batholith, including, from oldest to youngest: a Biotite Tonalite to Granodiorite suite, a Hornblende Tonalite to Granodiorite suite, and a Biotite Granite to Granodiorite suite (Figure 2). Plutonic rocks of the Biotite Tonalite to Granodiorite suite occur along the southwestern and northeastern margins of the Revell batholith. The principal type of rock within this suite is a white to grey, medium-grained, variably massive to foliated or weakly gneissic, biotite tonalite to granodiorite. One sample of foliated and medium-grained biotite tonalite produced a U-Pb age of 2734.2+/-0.8 Ma (Stone et al. 2010). The Hornblende Tonalite to Granodiorite suite occurs in two irregularly-shaped zones surrounding the central core of the Revell batholith. Rocks of the Hornblende Tonalite to Granodiorite suite range compositionally from tonalite through granodiorite to granite and also include significant proportions of quartz diorite and quartz monzodiorite. One sample of coarse-grained grey mesocratic hornblende tonalite produced a U-Pb age of 2732.3+/-0.8 Ma (Stone et al. 2010). Rocks of the Biotite Granite to Granodiorite suite underlie most of the northern, central and southern portions of the Revell batholith. Rocks of this suite are typically coarse-grained, massive to weakly foliated, and white to pink in colour. The Biotite Granite to Granodiorite suite ranges compositionally from granite through granodiorite to tonalite. A distinct potassium (K)-Feldspar Megacrystic Granite phase of the Biotite Granite to Granodiorite suite occurs as an oval-shaped body in the central portion of the Revell batholith (Figure 2). One sample of coarse-grained, pink, massive K-feldspar megacrystic biotite granite produced a U-Pb age of 2694.0+/-0.9 Ma (Stone et al. 2010).

The bedrock surrounding IG_BH02 is composed mainly of massive to weakly foliated felsic intrusive rocks that vary in composition between granodiorite and tonalite, and together form a relatively homogeneous intrusive complex. Bedrock identified as tonalite transitions gradationally into granodiorite and no distinct contact relationships between these two rock types are typically observed (SRK and Golder 2015; Golder and PGW 2017). Massive to weakly foliated granite is identified at the ground surface to the northwest of the feldspar-megacrystic granite. The granite is observed to intrude into the granodiorite-tonalite bedrock, indicating it is distinct from, and younger than, the intrusive complex (Golder and PGW 2017).

West-northwest trending mafic dykes interpreted from aeromagnetic data extend across the northern portion of the Revell batholith and into the surrounding greenstone belts. One mafic dyke occurrence, located to the northwest of IG_BH01, is approximately 15-20 m wide (Figure 2). All of these mafic dykes have a similar character and are interpreted to be part of the Wabigoon dyke swarm. One sample from the same Wabigoon swarm produced a U-Pb age of 1887+/-13 Ma (Stone et al. 2010), indicating that these mafic dykes are Proterozoic in age. It is assumed based on surface measurements that these mafic dykes are sub-vertical (Golder and PGW 2017).

Long, narrow valleys are located along the western and southern limits of the investigation area (Figure 1). These local valleys host creeks and small lakes that drain to the southwest and may represent the surface expression of structural features that extend into the bedrock. A broad valley is located along the eastern limits of the investigation area and hosts a more continuous, un-named water body that flows to the south. The linear and segmented nature of this waterbody's shorelines may also represent the surface expression of structural features that extend into the bedrock.

Regional observations from mapping have indicated that structural features are widely spaced (typical 30 to 500 cm spacing range) and dominantly comprised of sub-vertical joints with two dominant orientations, northeast and northwest trending (Golder and PGW 2017). Interpreted bedrock lineaments generally follow these same dominant orientations in the northern portion of the Revell batholith (Figure 2; DesRoches et al. 2018). Minor sub-horizontal joints have been observed with minimal alteration, suggesting they are younger and perhaps related to glacial unloading. One mapped regional-scale fault, the Washeibemaga Lake fault, trends east and is located to the west of the Revell batholith (Figure 2). Ductile lineaments, also shown on Figure 2, follow the trend of foliation mapped in the surrounding greenstone belts. Additional details of the lithological units and structures found at surface within the investigation area are reported in Golder and PGW (2017).

3.0 DESCRIPTION OF ACTIVITIES

Golder completed the geophysical logging in two stages. The geophysical logging team was mobilized to site in October 2019 to collect acoustic televiewer amplitude and travel-time data from the upper 100 m portion of the borehole prior to the surface casing being set. The main geophysical logging program from the bottom of the finished borehole to the bottom of the steel casing was conducted from November 27 to December 08, 2019 immediately after completion of drilling and flushing the borehole. Additional Heat Pulse Flow Meter and Acoustic televiewer logs were collected for the hole December 27 to December 28, 2019.

The main geophysical logging program was completed by Golder and its subconsultant DGI Geoscience (DGI). Golder personnel carried out the majority of the geophysical logs, and DGI carried out gamma-gamma, sonic, neutron and resistivity logs, under Golder supervision. The geophysical logging acquisition took place within the IG_BH02 work site at the drill rig, although some QA/QC procedures and calibrations were undertaken outside of the fenced compound to minimize interference from metal objects and electromagnetic fields.

3.1 Field Equipment

The following list presents the field equipment used to carry out geophysical logging:

- One (1) Mount Sopris Instruments (MSI) 4MXA-1000 1,000m single conductor wireline winch (Figure 3);
- One (1) Mount Sopris Instruments (MSI) 4WNA 1,800m four conductor wireline winch with WCA-1000 Winch Depth-Tension-Speed Controller (Figure 3);
- Two (2) Advanced Logic Technology (ALT) Matrix logging box (Figure 3);
- One (1) Advanced Logic Technology (ALT) SCOUT logging box (Figure 3);
- Two (2) Laptop computers with LoggerSuite 11.2 (ALT) software (Figure 4);
- Borehole wireline tripod and wheel (Figure 5);
- Borehole logging probes (see Table 1 in Section 3.4);
- Conductivity probe calibration ring;
- Caliper probe calibration jig;
- FTR probe calibration fluid;

- E-Log calibration box;
- MagSus calibration ring;
- Optical televiewer colour strip and housing;
- Televiewer orientation jigs;
- Tape measure (metric);
- Water level tape (metric);
- RST water level probe;
- Grundfos pump and controller;
- Portable shelter with table and chairs;
- Paper towels;
- Cable de-greaser;
- Alconox^{TM} detergent;
- Silicone grease;
- HQ centralizers;
- Extension cord;
- 2 kW generator;
- 5 kW generator;
- Rehead kits for the winches;
- Repacking syringe and accessories; and
- Tool kit consisting of tools necessary for troubleshooting and maintaining equipment.

All equipment was tested and calibrated (when necessary) prior to mobilization to site and was confirmed to be in working order.

3.2 Equipment Checks and Calibration

All geophysical logging equipment was checked prior to shipping to the field, as well as prior to its use. All applicable calibrations or verifications were performed following the procedures outlined in the probe-specific user manuals, which were kept in hard copy on site throughout the geophysical logging program. Specific calibration procedures, documentation, and checks of individual borehole probes are detailed in their logging procedures below. The results of calibration and verification checks are recorded in Appendix A, which includes all Calibration and Verification Forms, Data Quality Confirmation Forms, and Pre-use Check Forms.

Minor damage to probes or testing equipment were noted in field verification checks, and corrective action was taken, such as minor repairs or replacement of a component of the system. Issues with equipment encountered during logging included:

- Golder Heat Pulse Flow Meter probe did not pass the preuse check and was replaced with new Heat Pulse Flow Meter probe;
- Magnetic Susceptebility 2BSF-1000 probe (rented from Terraplus) did not pass the preuse check and was replaced with the rental HM-320 (rented from DGI Geoscience).

- As was described in WP05 Data Report – Geophysical Well Logging for IG BH03 (APM-REP-01332-0268) both Acoustic and Optical televiewers data had random glitches which caused probe telemetry and image to wrap at random depths that were originally believed to be the probes malfunctioning. The probes used were tested post-use at the site and deemed to be working properly. It is hypothesized that the centralizers were keeping the probes from spinning until enough rotational force was built up in the system that caused the probes to rotate faster than the hardware could measure, causing the noted glitches.

A description of field verification checks is included in more detail in Section 3.4, and in the probe-specific manuals in Appendix B of this report.

A check of the odometer wheel on the winch wireline was performed prior to use to ensure it was reporting accurate depths, and the results of this check were recorded in the Data Quality Confirmation Form, included in Appendix A.

The logging scientists maintained a Record of Geophysical Logging for each shift, which were provided to NWMO, and which recorded:

- The site conditions;
- The equipment setup arrangement;
- The reference point relative to ground surface;
- The probes used, including their make, model, serial numbers and detector offsets;
- The reported total depth of the borehole;
- The expected depths of investigation or log lengths;
- The static water level in the borehole;
- The reported depth to the bottom of the casing;
- Any reported zones of instability noted during drilling or coring; and
- Any damaged or malfunctioning equipment or components and the steps taken to rectify them.

The above information, where possible, was used to populate the headers of the individual LAS data files. The Records of Geophysical Logging are included in Appendix C.

3.3 Equipment Setup

Prior to setting up equipment on site, a Field Level Hazard Assessment (FLHA) was conducted to identify and eliminate or mitigate all safety hazards associated with the performance of the work. At each change of shift, the FLHA was updated to reflect any changes in site conditions or logging setup and the incoming cross-shift personnel were briefed of any new developments.

Figure 3: On the right: Mount Sopris 2MXA 1000m winch with Matrix logging box, on the left: Mount Sopris Instruments (MSI) 4WNA 1800m winch with WCA winch controller and SCOUT logging box.

The wireline winch and logging box were set up approximately 4 m from the borehole collar, next to the workstation, within a temporary heated shelter installed outside the drill rig, which allowed easy access to the borehole. The tripod was installed adjacent to the borehole within the drill rig, with the wheel centred over the casing. The wireline winch and tripod were installed in-line allowing the logging scientist to maintain visual contact with the borehole collar at all times. The high side of the borehole stickup was established as the reference plane to be used for levelling each probe and was measured at 0.30 m above ground surface for the first 2 shifts and 0.76 m above ground surface for the remaining 11 shifts. Static water levels over the duration of the geophysical logging program were also measured relative to this reference point. The wireline winch (Figure 3) and tripod (Figure 5) were secured to the work surface floor to ensure zero movement during the logging activities.

Figure 4: Laptop computer with LoggerSuite (ALT) software

Figure 5: Borehole wireline tripod and wheel

The wireline winch, logging box and the laptop were connected to each other and were powered using an external generator through an extension cord and power bar. Real-time telemetry and data monitoring was available through the software application, Matrix Logger (a module of the LoggerSuite Software program version 11.2) running on the dedicated laptop computer (Figure 4). An area within the shelter was cleared for assembly, pre-use checks, and calibration of borehole probes. An area designated for the calibration of the apparent conductivity probe was set up outside the fenced perimeter of the drilling zone more than 10 m from any metal object. During the apparent conductivity calibration and testing periods, the calibration ring was left at the same location to ensure repeatable calibration values for the post survey calibration.

3.4 Summary of Borehole Geophysical Logging

Geophysical well logging was conducted in accordance with the requirements of ASTM D5753-18 – Standard Guide for Planning and Conducting Geotechnical Borehole Geophysical Logging (ASTM, 2018). The geophysical well logging program consisted of 15 distinct logging tests using 13 different downhole probes. The logging probes were chosen to help assess the structural, hydrogeological, lithological, and geomechanical properties of the rock, as follows:

- Televiewer, deviation, and caliper logging was carried out to help assess structural properties of the rock, in conjunction with WP03, rock core logging and photography (Golder, 2020b).
- Apparent conductivity, natural gamma, E-log resistivity, spectral gamma, and magnetic susceptibility logging was carried out to help assess lithological properties of the rock, again in conjunction with WP03, rock core logging and photography (Golder, 2020b).
- Full waveform sonic (FWS) and gamma-gamma (density) logging was carried out to help assess the geomechanical properties of the rock, in conjunction with WP04B, geomechanical core testing (Golder, 2020c).
- Flowing fluid electrical conductivity (FFEC), fluid temperature and resistivity (FTR), neutron (porosity), and heat-pulse flowmeter (HPFM) logging was carried out to help assess hydrogeologic properties of the rock, in

conjunction with WP06, hydraulic testing (Golder, 2020d) and WP07, opportunistic groundwater sampling (Golder, 2020e).

The geophysical logging probes used in this investigation are listed in Table 1 below, in the order that the logs were acquired in the field. The logging sequence was selected to maximize data quality and minimize the risk of disturbing the borehole walls for subsequent logging probes. The table also provides the main acquisition parameters for each logging probe, including sample interval, logging speed and direction of acquisition (i.e., up or down)

Table 1: Geophysical Logging Probes and Acquisition Parameters

Geophysical Test	Probe Model	Sample Interval (m)	Logging Speed (m/min)	Logging Direction
Flowing Fluid Electrical Conductivity	2CAA-1000	0.05 / 0.10	10 / 20	Down / Up
Apparent Conductivity	2PIA-1000	0.05	4.5	Up
Gamma-Gamma (Density)	2GDA-1000	0.025	2.5	Up
Acoustic Televiewer	QLABI40-2G	0.0021	4	Up
Natural Gamma	2PGA-1000	0.025	2.25	Up
Neutron (Porosity)	LLP-2676 Dual Neutron	0.025	2.5	Up
Full-Waveform Sonic	FWS40	0.05	2	Up
Mechanical Caliper	2PCA-1000	0.01	2.5	Up
E-log Resistivity + SP + SPR	QL40-ELOG	0.05	3	Up
Spectral Gamma	2SNA-1000	0.025	2.25	Up
Fluid Temperature / Resistivity	2CAA-1000	0.0496	4	Down
Magnetic Susceptibility	HM 320	0.05	4.5	Up
Optical Televiewer	QLOBI40-2G	0.0016	2.5	Up
Heat-Pulse Flowmeter	HFP-2293	20	Stationary	Stationary
Deviation	QLOBI40-2G	0.10	10	Down and Up

The .TOL files containing the parameters and settings for each probe are provided in Appendix D. The geophysical logging results are provided in Appendix E. Geophysical log acquisition, processing and interpretation are described in the subsections below.

3.4.1 Geophysical Logging Depths

Two main factors affect the accurate reporting of the depth of geophysical log data, particularly in holes as deep as 1000.41 m. The steel cable is known to stretch according to the weight of the vertical length of wireline down the hole, as well as the weight of the probe itself. Additionally, the odometer wheel used to track the movement of the cable, and therefore the depth of the probe, has limitations in its precision, which compound over large depths to result in cumulative error at the bottom of a deep hole.

3.4.1.1 Wireline Cable Stretch Correction

After carefully analysing all processing procedures, and in consultation with NWMO, it was decided to not apply a cable stretch factor for IG_BH02 data. Final depth corrections were applied to all BH02 logs using the results of structural integration between televiewer logs and WP03 core logs and according to formulae described in Section 3.4.1.2.

3.4.1.2 Cumulative Odometer Error Correction

Depth correction factor was identified after integrating structural features from televiewer logs and core logs, completed as part of the single-hole geoscientific data integration. Because of the rigid nature of the drill rods, it was concluded that structure depths recorded during core logging were not subject to cumulative error, and that discrepancies between core and televiewer logged features were caused by the wireline winch odometer.

The difference in recorded depths between corresponding structures in the core and televiewer was plotted against the depth recorded in the televiewer logs. The resulting plot (Figure 6) shows a trend from which a correction factor was derived.

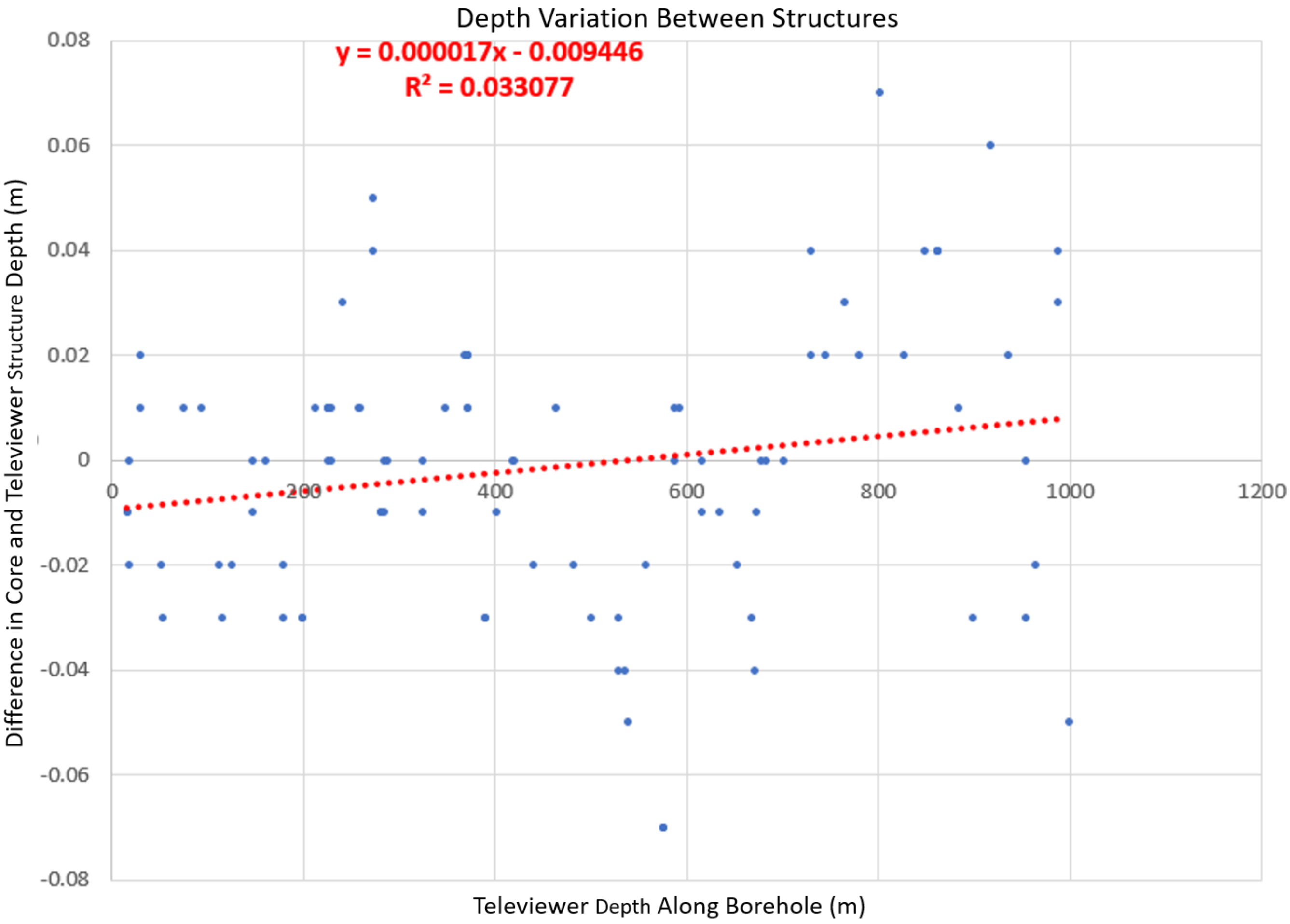

Figure 6: Comparison between depths of structures logged in core and televiewer (acoustic and optical) data

It was decided in consultation with the NWMO to apply this correction factor to the geophysical logs, according to the relationship:

$$Final\ Depth\ (m) = D * 0.000017 - 0.009446$$

where:

$$D = Corrected\ Depth\ (m)$$

This correction factor is interpreted to result from micro-slippage of the wireline winch odometer wheel and/or cable-stretch beyond the original formulae effective measurable range. The remaining discrepancies between core and televiewer structure depths, typically in the range of ±0.1 m, is attributed to imprecision in structure depth measurement on the core due to irregular or non-planar structure shapes.

3.4.1.3 After-Survey Depth Error

The difference between the initial reference depth of the probe relative to ground surface and the final reported depth at the reference point after completion of the logging is called the After-Survey Depth Error (ASDE). For this project, the tolerance for depth error is given as 30 cm (centimetres) plus 0.1% of the total depth of the borehole, meaning for a 1,000 m deep borehole, the maximum allowable ASDE is 1.30 m. This is a stricter tolerance than the allowable ASTM vertical depth error of 0.4%, or 4.0 m for a 1,000 m borehole (ASTM, 2018).

Logs which were collected in multiple sections were shifted to the ASDE of the shallowest section, and depth-matched across the other sections using common features. Table 2 shows the recorded ASDE values. Depth shifts were completed using these ASDE values to adjust the logs either upward (negative ASDE value) or downward (positive ASDE value) during the processing stage.

Table 2: After-survey Depth Errors Reported for Each Geophysical Log Acquired

Borehole Log	After-Survey Depth Error (m)
FFEC (71 mins)	0.00
FFEC (362 mins)	0.66
FFEC (425 mins)	0.00
FFEC (542 mins)	1.19
FFEC (635 mins)	0.00
FFEC (752 mins)	1.00
FFEC (1028 mins)	0.00
FFEC (1114 mins)	0.10
FFEC (1206 mins)	0.00
FFEC (1340 mins)	0.82
FFEC (1385 mins)	0.00
FFEC (1501 mins)	0.00
FFEC (1561 mins)	0.00
FFEC (1673 mins)	2.61
FFEC (1745 mins)	0.00
FFEC (1858 mins)	1.53

Table 2: After-survey Depth Errors Reported for Each Geophysical Log Acquired

Borehole Log	After-Survey Depth Error (m)
FFEC (1976 mins)	0.00
FFEC (2095 mins)	1.21
FFEC (2161 mins)	0.00
FFEC (2270 mins)	1.39
FFEC (2335 mins)	0.00
FFEC (2420 mins)	1.25
FFEC (2584 mins)	1.35
FFEC (2651 mins)	0.00
FFEC (2763 mins)	1.37
FFEC (2818 mins)	0.00
FFEC (2935 mins)	1.58
FFEC (2995 mins)	0.00
FFEC (3124 mins)	1.26
FFEC (9943 mins)	0.00
FFEC (11522 mins)	0.00
FFEC (13170 mins)	0.00
FFEC (14005 mins)	0.00
Electromagnetic Induction (Apparent Conductivity)	0.60
Gamma-Gamma Density	-0.51
Acoustic Televiewer	0.67
Natural Gamma	1.14
Neutron	-0.06
Full Waveform Sonic	0.16
Resistivity (E-LOG)	-1.03
Mechanical Caliper	0.59
Spectral Gamma	0.17
Fluid Temperature / Resistivity	0.00
Magnetic Susceptibility	0.72
Optical Televiewer (Deviation Run)	0.56
Optical Televiewer	0.56
Heat-Pulse Flowmeter	-0.29

In the instance where the ASDE was larger than 1.0 m, a short repeat section was logged over the edge of casing to confirm its depth. The FFEC logs with error were depth corrected based on adjacent runs.

3.4.2 Flowing Fluid Electrical Conductivity

In order to help characterize flowing zones within the borehole, flowing fluid electrical conductivity (FFEC) testing was carried out. FFEC testing uses the contrast between the electrical conductivity of the formation fluid and water column within the borehole to identify the location of flow into the borehole and to estimate the flow rate (Paillet et al., 2010). The method requires a measurable contrast in electrical conductivity between the formation and borehole column, and if this does not exist at certain intervals then the FFEC method may not be useful to characterize flow in these intervals. The contrast in electrical conductivity could be easily generated by prior flushing of the hole with fluorescein traced fluid of known electrical conductivity. Modelling the changes in fluid column electrical conductivity under static and pumping conditions, allows for calculation of the hydraulic transmissivity, and fluid inflow rate of the flowing fractures within the borehole. Running FFEC tests under static conditions illustrated ambient inflow of fluid, while stressing the borehole by lowering the water level illustrated the dynamic flow potential from the same inflowing fractures.

As part of this geophysical logging program, the Mount Sopris 2CAA-1000 Fluid Temperature / Resistivity probe (FTR) was used to measure the temperature and electrical conductivity of the borehole fluid during both ambient and dynamic (pumping) fluid flowing conditions. This Fluid Temperature / Resistivity probe is part of a combination probe, forming the bottom end of the 3-arm mechanical caliper probe. The probe was checked for functionality prior to shipping to site. Immediately prior to use, the probe was calibrated using two fluids of known conductivity, the first being fluid pumped from the borehole during flushing, and the second being the same fluid diluted with distilled water (0.113 mS/m and 1.17 mS/m, respectively). The calibration values are recorded in the pre-use Calibration and Verification Check form in Appendix A.

Prior to geophysical logging, the borehole was flushed with approximately 40,400 litres of water, representing over 4 borehole volumes (volume of the borehole without HQ rods). This was done to improve fluid clarity for the optical televiewer, as well as to replace the existing fluid column in the borehole with fluid of a consistent and known electrical conductivity of 7.3 mS/m based on final flushing measurements as reported in WP02 (Golder, 2020a). The flushing process took approximately two days, after which the rods were removed. Details about the flushing process are discussed in WP02, Borehole Drilling and Coring (Golder, 2020a).

Immediately following flushing and removal of the drill rods, the geophysical equipment was set up as described in Section 3.3. The probe was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Logger program was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction is specific to the tool and is calculated based on the stickup of the reference point measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications of the probe manuals (Appendix B).

The initial phase of FFEC testing was conducted under static (ambient) flowing conditions, over the course of 752 minutes. A total of six logs were collected during this phase of testing, including three complete down logs run at 10 m/min sampling every 5 cm, and three complete up logs run at 20 m/min sampling every 10 cm.

After static testing, the probe was stopped at 68.0 m and a Grundfos submersible pump was lowered into the borehole to 48.0 m. FFEC testing was carried out below 68.00 m, under pumping conditions to stimulate flow from fractures.

As the probe could not be returned to the surface between tests, due to the presence of the Grundfos submersible pump being located above it, the wireline was marked with tape at a reference point on surface when the probe was at a depth of 68.00 m to accurately measure the ASCE for each run.

Twenty-three additional FFEC logs were collected during the dynamic testing phase, over the course of ~2,200 minutes, between the pump depth (approximately 48 m) and the bottom of the borehole. These included eleven complete down logs, run at 10 m/min sampling every 5 cm, and twelve complete up logs, run at 20 m/min sampling every 10 cm. These logs are noted within Table 3.

Table 3 presents the Flowing Fluid Electrical Conductivity (FFEC) logs, including the logging time in minutes since start of testing, the logged depth interval, direction, sampling rate and the recorded After-Survey Depth Error (ASDE). The testing began 71 minutes after the last rods were pulled from the hole, and 470 minutes after the end of flushing. The first 9 logs were acquired during ambient conditions over a 1,000-minute period. The remaining 22 logs were acquired while pumping over a 3,000-minute period.

Table 3: FFEC Logging Details

Log Start Time (mins from start of FFEC)	Interval Top (m)	Interval Bottom (m)	Direction	Speed (m/min)	Sampling Rate (m)	Average Pump Rate (L/min)	After-Survey Depth Error (ASDE) (m)
71	2.21	1000	Down	10	5	-	0.00
362	1000	1.55	Up	20	10	-	0.66
425	2.21	1000	Down	10	5	-	0.00
542	1000	1.02	Up	20	10	-	1.19
635	2.21	1000.03	Down	10	5	-	0.00
752	1000.03	1.21	Up	20	10	-	1.00
1028	68	1000	Down	10	5	-	0.00
1114	1000	67.9	Up	20	10	-	0.10
1206	68	1000.06	Down	10	5	-	0.00
1340	1000.06	67.18	Up	20	10	-	0.82
1385	68	1000.11	Down	10	5	-	0.00
1501	1000	68	Up	20	10	-	0.00
1561	68	1000	Down	10	5	-	0.00
1673	1000	65.39	Up	20	10	-	-2.61
1745	68	1000	Down	10	5	-	0.00
1858	1000	66.47	Up	20	10	-	1.53
1976	68	1000	Down	10	5	-	0.00
2095	1000	66.79	Up	20	10	-	1.21
2161	68	1000.02	Down	10	5	-	0.00
2270	1000.02	66.61	Up	20	10	-	1.39
2335	68	1000.04	Down	10	5	-	0.00
2420	1000.04	66.75	Up	20	10	-	1.25
2584	1000.2	66.65	Up	20	10	-	1.35

Table 3: FFEC Logging Details

Log Start Time (mins from start of FFEC)	Interval Top (m)	Interval Bottom (m)	Direction	Speed (m/min)	Sampling Rate (m)	Average Pump Rate (L/min)	After-Survey Depth Error (ASDE) (m)
2651	68	1000.12	Down	10	5	-	0.00
2763	1000.12	66.63	Up	20	10	-	1.37
2818	68	1000.06	Down	10	5	-	0.00
2935	1000	66.42	Up	20	10	-	1.58
2995	68	1000	Down	10	5	-	0.00
3124	1000	66.74	Up	20	10	-	1.26
9943	1.53	600	Down	10	5	-	0.00
11522‡	500.02	1000.3	Down	10	5	-	0.00
13170	1.53	640.18	Down	10	5	-	0.00
14005	1.53	1000.33	Down	10	5	-	0.00

‡ indicates a log found to include invalid data and which was not used in analysis.

During the dynamic (pumping) phase of the FFEC logging, water levels were monitored and are shown on Figure 7. Due to the extremely low recharge rate encountered in the well the pump was only operated periodically to draw down the well to maintain a relatively constant water level.

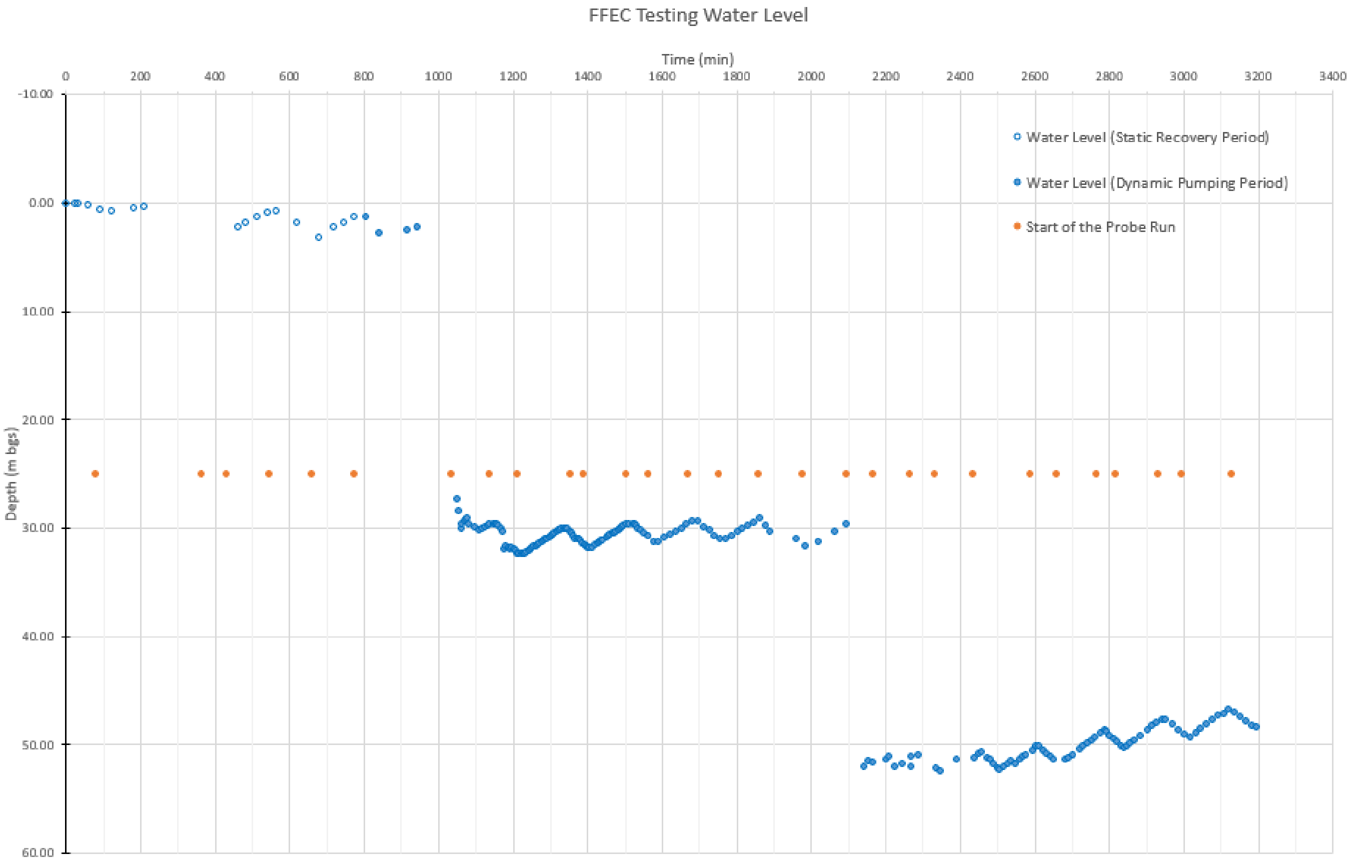

Figure 7: Water Level, measured during FFEC testing, from time of start of testing

Figure 7 shows the timeline of the FFEC testing, with 71 minutes being the beginning of the first test. The static testing phase lasted from 0 minutes to 1000 minutes. After the static testing the pump was lowered to 48 m and water level was lowered to 30 m. The pump was turned on periodically to maintain a relatively constant water level of 30 m in the borehole for testing between 1000 and 2100 minutes. The pump was then lowered to approximately 55 m and water level was then lowered to approximately 50 m and maintained until the completion of the FFEC testing.

The FFEC log data was imported into WellCAD as .TFD files and an interpolation function was applied to remove data spikes and gaps smaller than 1 metre. The logs were shifted to correct for the After-Survey Depth Error (ASDE), as listed in Table 3. A formula was then applied to correct the recorded depth as described in Section 3.4.1.3. The logs, once referenced to the corrected depth, were then exported as .WCA files, one for each logging run.

Each .WCA file was then imported back into one common WellCAD file where they were compared with each other and other geophysical logs, such as the optical televiewer image log. FFEC log depths were matched to common features to further refine their accuracy and one final depth correction was applied according to the results of structural integration between televiewer logs and core logs, using formulae described in Section 3.4.1.2.

To interpret the FFEC log results a numerical model was generated using multiple fluid conductivity logs under both ambient (static) and dynamic (pumping) conditions. The logs were first used to identify the discrete inflow points, corresponding to the peaks of the conductivity anomalies seen in the static logs. Four such points were identified, and a numerical model, described by Paillet (2012), was applied to simulate different inflow rates, fluid electrical conductivities, and hydraulic transmissivities. The modelling method assumes one-dimensional mass conservation and a constant longitudinal dispersion coefficient, due to the mixing caused by the repeated passage of the probe through the water column. The inflow rate from each point is also taken to be constant for the measurement period. The mixing volume used to model dispersion was 30 cm of borehole length (approximately 0.4 litres) and the modelled time-step was one minute.

Results from the FFEC modelling (see Appendix F) were imported into the same WellCAD file and compared to the Fluid Conductivity logs and optical televiewer Image log. Model injection points were then refined to reflect associated narrow fractured intervals. Final FFEC model values, as well as flow rates, incoming Fluid Electrical Conductivity, and Transmissivity, were displayed alongside field measured values. Representative logs from both static and dynamic pumping phases of the FFEC testing are presented on the Hydrogeology Log in Appendix E. Log times in Appendix F are given in minutes after the start of logging. For clarity, four representative logs were selected from the ambient phase of logging, six from the dynamic phase, and five from the model showing response under modelled dynamic conditions.

The Fluid Conductivity logs are overlaid in the Hydrogeology Log, included in Appendix E, in three groups based on whether they represent static flow (ambient) conditions, dynamic flow (pumping) conditions, or modelled dynamic flow (pumping) conditions. Within these three groups, logs are arranged in descending order of time, from early to late in the testing interval, showing the progression of changes in the conductivity profile with time.

The modelled FFEC logs match well with the observed anomalous pattern of the fluid conductivity logs, where each of the electrical conductivity anomalies can be correlated to a narrow fracture interval observed in the televiewer structural interpretation. There are six injection points considered in the model. The ambient logs show the conductivity anomalies maintaining the same amplitude and very little spreading out up and down the borehole over time, indicating very low flow into the borehole and very little mixing of formation and borehole fluids. The dynamic logs show higher amplitude anomalies similar or slightly increased amplitude anomalies with small upward and downward spreading over time, consistent with infiltration of formation water to the borehole and upward flow towards the pump. The addition of the downward spreading during the dynamic testing indicates that the pumping may have inadvertently further developed the borehole, opening flow zones that were not present during the static testing.

The FFEC model injection values shown in the Hydrogeology log are described in detail in Appendix F and are summarized in Table 4. The results suggest six inflow points, which are interpreted to be located at 381 m, 588 m, 620 m, 668 m, 680 m, and 730 m and have flow rates between -0.016 L/min and 0.200 L/min. The hydraulic transmissivity of these points were not able to be estimated for this borehole due to changes in the borehole hydraulic condition with time, as discussed in detail in Appendix F, however it is possible that the transmissivity of the 588 and 620 m zones may exceed 2.314 x 10^{-8} m^2/sec. value applied to the measured recovery rate under the assumption that no in situ hydraulic head differences exist.

Table 4: FFEC Model Injection Values

Depth (m)	Model Flow (L/min)	Conductivity (mS/m)	Transmissivity* (m^2/s)
381	0.02 +/- 0.02	75 +/- 30	Undetermined
588	0.20 +/- 0.05	300 +/- 10	Undetermined
620	-0.16 +/- 0.05	300 +/- 10	Undetermined
668	-0.008 ± 0.03	75 +/- 30	Undetermined
680	0.004± 0.03	75 +/- 50	Undetermined
730	<0.005	Undetermined	Undetermined
Total Inflow	**0.056 ± 0.03**	**-**	

*Transmissivity not able to be determined for this borehole as discussed in text

3.4.3 Electromagnetic Induction (Apparent Conductivity)

Electromagnetic induction data was acquired using a Mount Sopris Instruments (MSI) 2PIA-1000 probe, also known as an Apparent Conductivity probe. This probe was run to investigate the bulk (formation and fluid) electrical conductivity of the bedrock. Changes in electrical conductivity are used to identify changes in mineralization, such as the presence of conductive sulphides, or clay-bearing fracture zones.

The probe contains a transmitter and receiver coil and measures the apparent bulk conductivity of the borehole wall around the probe, in mS/m. The depth at which the measurement is given is the midway point between the two coils. Since the conductivity probe generates a primary magnetic field, which extends through the air or water within the borehole and into the surrounding formations, it is not necessary for the probe to be centralized in the borehole.

This probe is susceptible to drift in changing temperatures, so to ensure optimal data accuracy, it was acclimatized in the borehole fluid prior to calibration and logging, according to ASTM standard D6726-15 (Section 8.2). The probe was turned on and run in Time Mode to display real-time apparent conductivity values. The probe was then lowered to a point below the static water level and below the casing depth (91 m) where it was left to acclimatize for 30 minutes until the real-time apparent conductivity readings had stabilized, which indicated that it had equilibrated to the temperature of the borehole fluid.

The probe was then ascended and removed from the borehole. It was taken away from the drill rig to the conductivity calibration area which was at least 10 m away from the nearest large metal objects. The calibration measurements were completed as soon as possible after the probe was removed from the borehole fluid to minimize temperature changes caused by the cold air outside the logging shelter. The conductivity probe was placed in the calibration ring and probe measurements were carried out using two pre-set conductivity values on the variable dial of the ring (0 mS/m and 91 mS/m). The results were saved into the associated .TOL file and exported as a .TXT file for record keeping. The calibration records were documented in the Record of Geophysical Logging, as well as the Calibration and Verification Check Form, and provided to NWMO.

Following the calibration, the probe was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Logger program was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction was specific to the tool and was calculated based on the stickup of the reference point above ground surface as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator’s manuals in Appendix B.

During the descent, the probe was run in Time Mode to display real-time values in order to check the expected conductivity range of the bedrock. Based on the expected range, a range setting of the probe was selected following the procedures outlined in the user manual (Appendix B). The sensitivity range setting for the probe was set to the 0 to 100 mS/m range for increased probe sensitivity. The probe was descended to a depth of 500 m, turned on and the first log was started. The QA/QC log was recorded for 10% of the borehole depth, from 500 m to 400 m. The probe was run up at 4.5 m per minute and sampled every 5 cm. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole. After reaching the bottom of the borehole, the second file was started, recording up at the same speed and sampling interval.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent and ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the probe had entered the casing in which the readings were affected by the metallic casing, the second file was terminated. The probe was ascended to the level point, where the final level depth was recorded, and the probe was removed from the borehole. The probe was then run in Time Mode and placed back in the calibration ring in the same location as the initial calibration. The two pre-set values were checked and recorded in the Record of Geophysical Logging, and the Calibration and Verification Check Form. Temperature drift, which is caused by changes in measured values due to changing temperature of the probes internal electronics, was calculated, and drift correction applied using a linear data shift based on the difference between initial calibrated values and final check values, assuming the final check values are correct as the probe has had the most time for the internal electronics temperature to stabilize to the borehole fluid temperature.

The .TFD files were imported into WellCAD and the primary log compared favourably to the QA/QC log over the repeated interval from 400 m to 500 m. For the primary log, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The log was shifted to correct for the After-Survey Depth Error (ASDE) of 0.6 m that was recorded in the relevant Record of Geophysical Logging field notes. Based on the final calibration check the Apparent Conductivity log was bulk shifted +18 mS/m to correct for the temperature drift, as the probe had changed temperature in the borehole fluid from surface conditions present at time of testing and equilibrated to the borehole fluid temperature prior to the start of logging. Once drift and ASDE were corrected, the log was exported as a .WCA file.

The .WCA file was then imported back into one common WellCAD file where it was compared with other geophysical logs, such as the optical televiewer image log, resistivity logs, magnetic susceptibility log, and natural gamma log. Apparent Conductivity log depths were matched to common features to further refine the accuracy and one final depth correction was applied according to the results of structural integration between televiewer logs and core logs, using formulae described in Section 3.4.1.2. The final Apparent Conductivity log is displayed on the Lithology Log, in Appendix E.

Results from the Apparent Conductivity log are measured in millisiemens per metre, ranging from 2.34 mS/m to 20.86 mS/m. The average value is 12.32 mS/m. The general trend of the apparent conductivity curve is flat, with gradual decrease towards end of the borehole and no pronounced anomalies

More localized spikes in apparent conductivity, such as between 375 and 380 m, 535 to 537 m and at 668 to 675 m, correspond with dykes and veins apparent in the optical televiewer log and seen in natural gamma, gamma-gamma density, and neutron logs.

3.4.4 Gamma-Gamma Density

Near- and far-field bulk density data were acquired using the Mount Sopris 2GDA-1000 focused gamma-gamma probe. The gamma-gamma probe measures the electron density of the bedrock by using a radioactive source, Cesium 137, located on the same plane as the detectors, the surrounding bedrock is bombarded with intermediate gamma rays. The probe contains two CsI (Th) detectors spaced 20 cm and 35 cm from the source to measure “near” and “far” back-scatter of radiation, respectively. The probe is forced against the borehole wall using a single caliper arm ensuring the gamma rays interact with the formation in the correct plane.
The phenomenon of Compton scattering takes place in which the back-scattered gamma rays emerge from the borehole wall and are received by the detectors.

Prior to loading the radioactive source into the probe, the instrument was connected to the wireline and tested for operation at surface. The calibration of the density sensors was verified at DGI’s Operation Centre prior to mobilizing the instrument to site. The calibration utilized an aluminium test block with a known density of 2.6 grams per cubic centimetre (g/cm^3) and a test borehole in rock with a known density of 2.942 g/cm^3. The gamma-gamma density probe achieved calibration status with ±0.08 g/cm^3 in near and far density measurements of the aluminium block and ±0.001 g/cm^3 in measurements of the test borehole.

Once the probe was configured, the probe was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Logger program was corrected to report the depth of the measurement point of the tool in relation to ground surface, in this case bedrock surface. This depth correction was specific to the tool and was calculated based on the stickup of the reference point above ground surface as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator’s manuals in Appendix B.

The probe was descended to a depth of 200 m and a single caliper arm was deployed to ensure the probe was forced against the borehole wall, then the first log was started. The QA/QC log was recorded for 10% of the borehole depth, from 200 m bgs to 100 m bgs. The probe was run up at 2.5 m per minute and sampled every 2.5 cm. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole. After reaching the bottom of the borehole, the second file was started, recording up at the same speed and sampling interval.

The logs were recorded as .TFD files and the quality of the data was monitored to ensure valid telemetry and minimal data errors. The calibration of the caliper arm was checked against the same known diameters, then the probe was deactivated.

The .TFD files were imported into WellCAD. For the primary logs, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes. The logs, once referenced to the corrected depth, were then exported as .WCA files.

The .WCA files were then imported back into one common WellCAD file where they were compared with each other and the QA/QC log, to ensure repeatability. Final Near Density and Far Density logs were then compared to other geophysical logs, such as the optical televiewer Image log, Neutron log, and full waveform sonic velocity logs. Gamma-gamma density log depths were matched to common features to further refine the accuracy and one final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.1.2.

The final Near Density and Far Density curves are displayed on both the Lithology Log and the Engineering Log, in Appendix E. Both Near and Far Density logs are measured in grams per cubic centimetre (g/cc). The Near Density log ranges from 2.24 g/cc to 3.12 g/cc (below the casing), with an average of 2.78 g/cc. The Far Density log ranges from 2.45 g/cc to 3.07 g/cc (below the casing), and has an average value of 2.76 g/cc. The background value of the host tonalite ranges from 2.77 g/cc to 2.79 g/cc with three zones, showing an average of 2.77 g/cc and 2.76 g/cc from 78 to 192 m of near and far densities respectively, an average of 2.78 g/cc and 2.76 g/cc from 192 to 287 m of near and far densities respectively and an average of 2.79 g/cc and 2.77 g/cc from 287 to 1000 m of near and far densities respectively. Additionally, eight spikes ranging in thickness from 0.8 to 6.45 m are apparent associated with discrete changes in rock type as observed in optical televiewer logs and through geological core logging (WP03: Golder, 2020b), and typically range from 2.81 g/cc to 3.12 g/cc, or 0.07 g/cc to 0.3 g/cc above background.

3.4.5 Televiewer Logging

3.4.5.1 Acoustic Televiewer

The Advanced Logic Technology (ALT) ABI40-2G Acoustic Televiewer probe, also known as the Acoustic Borehole Imager (ABI), was used primarily to image discontinuities (e.g. joints, veins, etc.) intersecting the borehole wall. The ABI40-2G transmits a series of high frequency sonic pulses, reflected off of a rotating mirror, and receives the echo of those pulses from the borehole wall. By analysing the amplitude of the echo relative to the original pulse, as well as the time delay between the original pulse and the return, the ABI40-2G generates a series of thin slices of data which it stacks and translates into a pair of continuous images, the Amplitude and the Travel Time logs. Because of varying hardness, different rocks and minerals absorb or reflect different amounts of the original sonic pulse, thus the ABI40-2G’s Amplitude log shows an image of the varying hardness of the borehole wall, plotting these differences using a colour scale. A quartz vein, for example, will reflect more energy than the host shale bed, thus the ABI Amplitude image will show a bright reflection for the quartz and a dimmer reflection for the shale. The ABI40-2G’s Travel Time log is an image plotting the differences in echo delay, meaning an open fracture or void into which the sonic pulse had to travel farther before being reflected will appear in contrast to the nearer borehole wall.

Using a depth-dependant fluid velocity log derived from borehole diameter values measured by the mechanical caliper, the average travel time of the pulses at each recorded depth were converted into a distance, producing the Acoustic Caliper log, showing the calculated diameter of the borehole.

In order to translate the travel time of each pulse into distance, and properly analyse the strength of the pulse echoes, the ABI40-2G can only be run in water. Because the ABI40-2G does not use an optical camera, the borehole fluid may be murky without adversely affecting the image quality. Additionally, because of the geometry of the reflections of the pulses, the ABI40-2G must be well centralized in the borehole.
Three non-metallic centralizers with a fixed HQ diameter were affixed to the ABI40-2G to maintain centralization of the probe while logging. The use of these centralizers assumes a near-uniform diameter of the borehole.

The ABI40-2G acoustic televiewer contains internal electronics to record tilt, azimuth, and roll of the probe while operating using a 3-axis fluxgate magnetometer and a 3-axis accelerometer. These internal electronics were factory calibrated and the certificate of calibration is included in Appendix A. Prior to shipping and use, the probe was checked for functionality, with the results recorded in the pre-use Calibration and Verification Check form. The magnetometer measurements are susceptible to interference from highly magnetic rock, metallic casing, or geomagnetic interference (e.g. intense auroral activity or solar storms). Under those conditions, the orientation of the probe and its image must be estimated. To ensure no geomagnetic field disturbances, data from NRCAN were obtained prior to logging. Data measured data from the NRCAN magnetic field strength were obtained from the Brandon, Manitoba station for the duration of the field program. No geomagnetic interference was observed during the time of logging.

Once the probe was connected to the wireline, the probe was lowered into the casing until the top of the probe was flush with the reference point. In order to have data measured relative to ground surface (i.e., bedrock surface), corrections were applied to account for the offset distance between the reference point and the probe sensor, and the difference between the reference point and the ground surface. The offset of the probe sensor is outlined in the technical specifications and operator’s manuals in Appendix B.

Acoustic televiewer logging was completed in two stages, with the upper 100 m being logged prior to the drilling of the rest of the borehole. This was done to allow a section of the upper 100 m to be isolated from the rest of the borehole to prevent groundwater from flowing between near-surface and deeper fractures. The procedure for collecting acoustic televiewer in both stages were the same.

The appropriate .TOL file was selected from the tool list, the probe was turned on. The probe was run in Time-Mode, allowing it to transmit real-time images which were monitored by the logging scientist while the ABI40-2G descended down the borehole. This depth was later compared as a QA check to the depth of well casing documented during borehole drilling (WP02: Golder, 2020a) in order to verify the accuracy of the wireline odometer wheel.

The probe was descended the length of the borehole at up to 10 m per minute while the logger monitored the wireline tension and the real-time ABI40-2G images for potential obstructions and image centralization. The probe was descended to 90% of the depth of the borehole, turned on and the first log was begun. The QA/QC log was recorded up 10% of the depth of the borehole, from 900 m to 800 m. Once the log had recorded 10% of the borehole depth, the QA/QC file was terminated, and the probe was returned to surface. An additional log was recorded down the entire length of borehole, sampling at 0.05 m to record deviation. Once the probe reached the bottom of the hole, the deviation file was terminated, and the primary file was started. The ABI40-2G was run up the borehole at 1.4 m per minute, sampling every 2.1 mm (millimetres) with 288 ppt (points per turn) azimuthal resolution. A constant logging speed was used throughout entire length of borehole to ensure consistency.

As was described in WP05 Data Report – Geophysical Well Logging for IG BH03 (APM-REP-01332-0268) both Acoustic and Optical televiewers data had random glitches which caused probe telemetry and image to wrap at random depths that were originally believed to be the probes malfunctioning. The probes used were tested post-use at the site and deemed to be working properly. It is hypothesized that the centralizers were keeping the probes from spinning until enough rotational force was built up in the system that caused the probes to rotate faster than the hardware could measure, causing the noted glitches.

The entire hole was logged in a single run and then all sections with glitches were repeated with at least one good repeatable feature to depth shift files accordingly and to allow merging of data during processing phase. The full length of the borehole was surveyed in thirty-six overlapping intervals (including the QA/QC run from 200 m to 100 m and two runs for the top 100 m section) over the course of two shifts.

Logs were recorded as a .TFD file and the quality of the data was monitored throughout the ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed ascent. Once the probe had reached the casing, the log was terminated, and the probe deactivated. The probe was then ascended until it was level with the reference point and removed from the borehole. The difference between initial and final depths reported at the reference point, 0.67 m, was recorded as the After-Survey Depth Error (ASDE).

The .TFD files were imported into WellCAD then depth shifted and merged accordingly, including existing ABI logs from the top 100 m section. For the primary log data curves, an interpolation function was applied to remove data spikes and gaps smaller than 1 m, while for the Acoustic Amplitude and Travel Time logs, the Interpolate Bad Traces algorithm was run to remove blank traces.

Through calibration to the mechanical caliper a constant fluid velocity of 1,450 m/s was used to calculate the acoustic caliper log.

A high-pass normalization function was applied to the acoustic amplitude log, using a window of 5 degrees and 0.01 m, to improve image quality. A centralization function was applied to the acoustic travel time log to correct for minor offsets in image centralization.

One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, according to formulae described in Section 3.4.1.2. The acoustic televiewer images are displayed in the Structural Log, included in Appendix E, while the deviation curves are included in the Deviation Log.

3.4.5.2 Optical Televiewer

The Advanced Logic Technology (ALT) OBI40-2G Optical Televiewer probe, also known as the Optical Borehole Imager (OBI), consists of a camera which records images of the surrounding borehole by focusing downward on a conical mirror and lighting the hole with a ring of LED lights. The thin slices of images are stacked to form a continuous 24-bit RGB true colour image of the unwrapped interior of the borehole. Because the image is a 2-dimensional unwrapped cylinder, planar features (e.g. fractures) intersecting the borehole at an angle appear sinusoidal in the OBI40-2G image log.

The OBI logs are useful for observing layering, banding, foliation, fractures, voids and veins, in addition to obtaining information on visual characteristics such as oxidation staining, mineral infilling, alteration, etc. The probe also contains a 3-axis magnetometer and 3-axis accelerometer which records the tilt and azimuth of the hole, as well as the roll of the probe inside the hole. The magnetometer is susceptible to interference from highly magnetic rock, the metallic casing, or geomagnetic interference (such as intense auroral activity or solar storms). To maximize the accuracy of the deviation package, the NRCAN Space Weather Prediction Centres was consulted prior to logging to ensure no geomagnetic field disturbances. Data from the NRCAN magnetic field strength were obtained from the Brandon, Manitoba station for the duration of the field program.

The OBI40-2G optical televiewer probe’s deviation package was factory calibrated and the certificate of calibration was provided to NWMO. The probe was also checked for functionality before shipping and before logging, with the results recorded in the pre-use Calibration and Verification Check form, submitted to NWMO. Prior to use, the fidelity of the optical image was verified using a standardized Kodak strip of colour bars in a specialized canister which was placed over the end of the OBI40-2G, while the probe was still on surface. A file showing the colour bars was recorded for QA/QC purposes. A set of three specialized centralizers for HQ sized borehole were affixed to the OBI40-2G probe to maintain centralization of the probe while logging.

Once the probe was connected to the wireline, the probe was lowered into the casing until the top of the probe was flush with the reference point. In order to have data measured relative to ground surface (i.e., bedrock surface), corrections were applied to account for the offset distance between the reference point and the probe sensor, and the difference between the reference point and the ground surface. This depth correction was specific to the tool and was calculated based on the stickup of the reference point above ground surface as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator’s manual in Appendix B.

The appropriate .TOL file was selected from the tool list in the Logger program and the probe was then turned on. The probe was run at 10 m/min in Depth-Down Mode, recording deviation at 0.05 m intervals, and allowing it to transmit real-time images which were monitored by the logging scientist. During the descent, the logging scientist documented the depth to the bottom of well casing. This depth was later compared as a QA check to the depth of well casing documented during borehole drilling (WP02: Golder, 2020a) in order to verify the accuracy of the wireline odometer wheel. Once the probe reached the bottom of the borehole, the deviation file was terminated, and a new file was started. The probe was run up from the bottom of the borehole to maintain constant tension on the wireline and thus a consistent logging speed (2 m/min). While logging a deviation glitches in the logs, similar to what was noted in the Acoustic Televiewer data, and described in more detail in Section 3.4.5.1, were noticed in OBI Image log and it was decided, similar to the Acoustic Televiewer log, to proceed in logging an entire hole in a single run and then go back to repeat all sections where glitches were observed. All logs were sampled at 1.6 mm increments, using 600 ppt azimuthal resolution.

All logs were recorded as a .TFD files and the quality of the data was monitored throughout the ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed ascent. Once the probe was level with the reference point the final level depth was recorded to determine the After-Survey Depth Error (ASDE), the log was terminated, and the probe deactivated and removed from the borehole.

Because the OBI40-2G records and optical image through a camera lens it requires a transparent medium to see through. Data from the initial OBI40-G2 logging indicated the presence of turbid water in the borehole column from 55.0 m to 74.0 m. A second optical televiewer log was run, but water quality was not improved.

The .TFD files were imported into WellCAD then depth shifted and merged accordingly, including existing OBI logs from the top 100 m section. For the primary log data curves, an interpolation function was applied to remove data spikes and gaps smaller than 1 m, while for the Optical Image logs, the Interpolate Bad Traces algorithm was run to remove blank traces. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes. The logs, once drift corrected and referenced to the corrected depth, were then exported as .WCA files.

The .WCA files were then imported back into one common WellCAD file where they compared favourably with the QA/QC log. These logs were then compared and depth-matched to common features of other geophysical logs, such as the acoustic televiewer logs, and Mechanical Caliper log.

One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, according to formulae described in Section 3.4.1.2. The optical televiewer image is displayed for reference in the Structural Log, Lithology Log, Engineering Log, and Hydrogeology Log, included in Appendix E, while the deviation curves are included in the Deviation Log.

The optical image from the televiewer is particularly useful for identifying lithological and alteration zonations based simply on the colour image. In addition, the optical televiewer image was a key dataset used to interpret structural features throughout the length of the borehole. Description of this interpretation is included in Section 3.4.5.3.

3.4.5.3 Televiewer Structural Interpretation

Once the optical and acoustic televiewer logs were finalized, a structural analysis was completed using the structural interpretation module in WellCAD to obtain the depth, apparent dip, and dip direction (i.e., orientations relative to high side) of each interpreted structure (Figure 8).

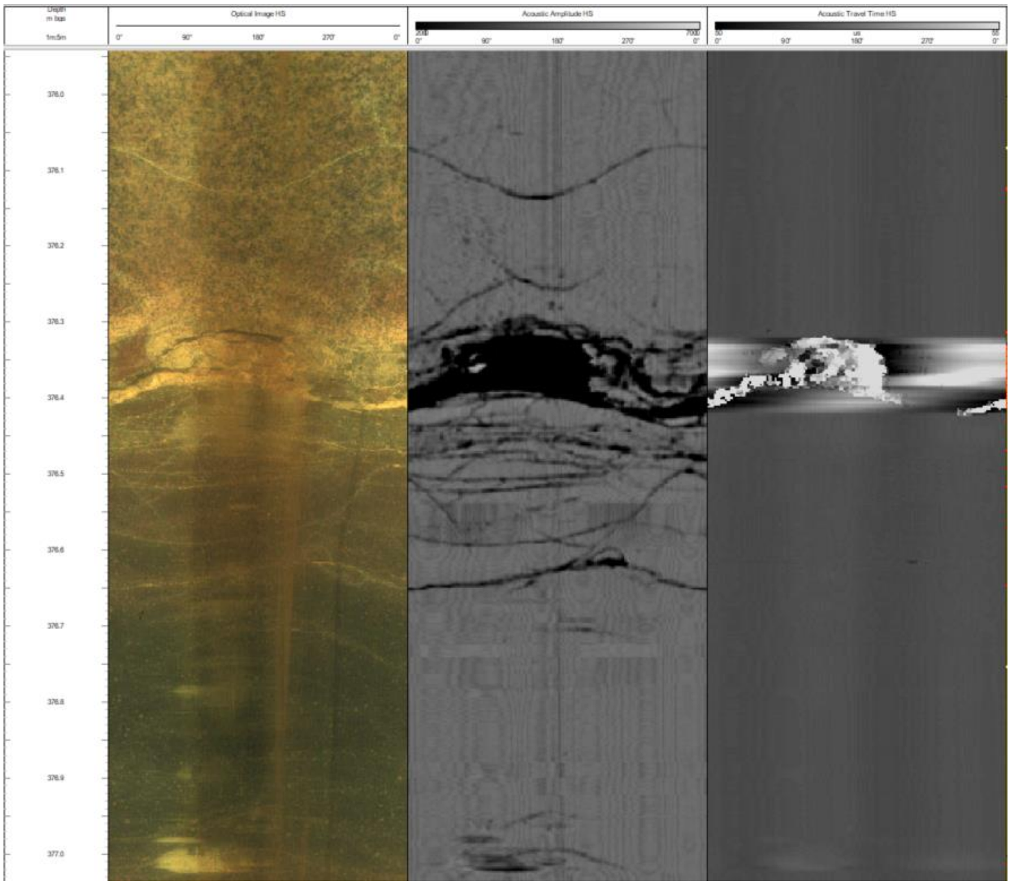

Figure 8: Optical and acoustic televiewer logs showing sinusoidal fracture planes intersecting the borehole wall

To complete the structure analysis a blank structure log was overlain on either televiewer image, switching between data sets as needed, to compare the pick of one feature over multiple images. The Acoustic Caliper log was selected to represent the borehole diameter used to calculate apparent dip, as this log spanned the entire depth of the borehole, including the top 100 m, which was not surveyed with the Mechanical Caliper. The structure dictionary was consistent with the terminology used during geological and geotechnical core logging outlined in WP03 (Golder, 2020b). However, only a subset of those structures was applicable to picking from the televiewer images. For each type of structure, a certainty value was assigned to address the clarity of the structure traced in the televiewer image (High, Medium and Low). For structures with a measurable thickness (e.g. veins, joints), apparent apertures were also traced as the width of the structure perpendicular to its orientation (see Figure 9).

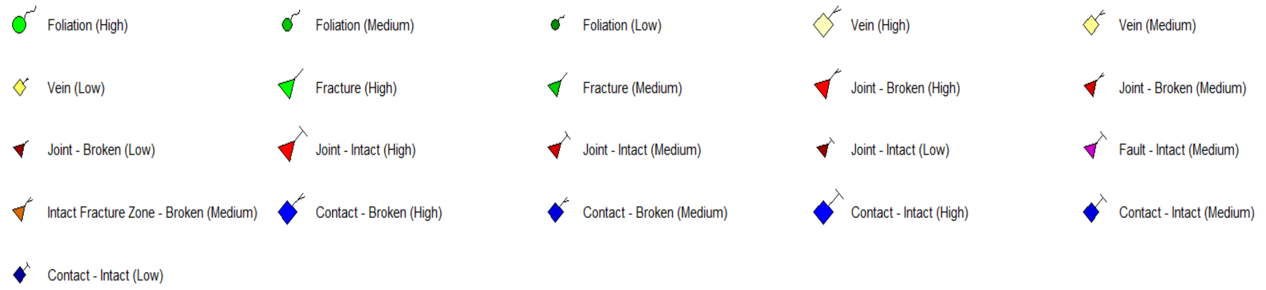

Figure 9: WellCAD Structure Dictionary showing used structures

A Breakout log was also created to allow for the picking of the minimal breakouts observed. Breakouts are defined as open vertical or sub-vertical structures in the borehole wall, aligning with the plane of minimum horizontal stress. Breakouts are formed where stresses around the borehole have exceeded the compressive strength of the rock. They can be seen in televiewer logs as pairs of vertical or sub-vertical features, and potentially in mechanical caliper logs as increases in borehole dimeter, depending on their size and orientation relative to the caliper arms. Breakouts can be traced on a breakout log by aligning a feature along the breakout axis and assigning it an aperture. No zones interpreted as Breakout were observed in the borehole log.

Interpreted structure orientations were corrected from apparent dip and dip direction to true dip and dip direction (i.e., relative to true north), using the Reflex SPRINT-IQ™ gyro Tilt and Azimuth logs (Golder, 2020a.). Final orientations of structures are presented as tadpoles (Tadpoles TD&DD in Appendix E), showing their dip magnitude along the X-axis and the tail showing their azimuth direction. The corrected structure log was then exported as a .CSV file where the Magnetic North azimuths were corrected with the local magnetic declination (1.361°W), as calculated by the Geological Survey of Canada, to yield True North azimuths. The structure types were converted from numerical labels to descriptive labels and the file was saved.

The Tadpoles TD&DD log was used to generate two frequency logs (Joints and Veins), measured in counts per metre. The frequency of Joints ranges from 0 counts/m to 14 counts/m, with an average of 0.49 counts/m. The frequency of Veins ranges from 0 counts/m to 9 counts/m, with an average of 0.46 counts/m. There are six main zones where the average joint / fracture frequency rises above one count per metre. These zones are detailed in Table 5.

Table 5: High Frequency Joint Zones

Interval Top (m)	Interval Bottom (m)	Fracture Frequency (counts / m)	Total Fracture Count	Comments
10	68	2.1	124	Near surface fracture zone
276	286	2.27	25	Multiple dykes
370	384	3.5	49	Multiple dykes
514	524	1.54	17	
536	540	5.25	21	Dyke
652	684	2.75	88	Multiple dykes

Most of the highly jointed intervals correspond to the presence of dykes or changes in lithology / contacts, while the upper 100 m is much more highly jointed due to surface decompression.

Five equal-angle (Wulff) stereonets, each spanning 200 m of the borehole were plotted to show the change in dip and dip direction of joints along the borehole. Structures picked from televiewer logs, as well as frequency logs and stereonets, are displayed in the Structural Log, included in Appendix E.

3.4.6 Natural Gamma

In crystalline rock, the gamma log is used principally for lithologic identification based on presence of minerals with natural radioactivity. The Mount Sopris 2PGA-1000 Natural Gamma probe was used to provide a measurement, recorded in counts per second (cps) that is proportional to the natural radioactivity of the bedrock.

The Mount Sopris 2PGA-1000 natural gamma probe uses a scintillation sodium iodide crystal to measure the incoming natural gamma radiation from the borehole walls. The gamma-emitting radio-isotopes that naturally occur in geologic materials are Potassium 40 and nuclides in the Thorium 232 and Uranium 238 decay series. Potassium 40 occurs with all potassium minerals including potassium feldspars. Thorium 232 is typically associated with biotite, sphene, zircon and other heavy minerals. Uranium 238 is typically associated granitoid rocks with uranium mineralization.

Once the probe was connected to the wireline, it was lowered into the casing until the top of the probe was flush with the reference point. In order to have data measured relative to ground surface (i.e., bedrock surface), corrections were applied to account for the offset distance between the reference point and the probe sensor, and the difference between the reference point and the ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point, as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator’s manuals in Appendix B.

A QAQC log was recorded for a 100 m interval between 600 m to 500 m. For this log the probe was run at 2.25 m per minute, sampling every 2.5 cm. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole and the continuous borehole log was initiated recording up the borehole at the same speed and sampling interval.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the ascent to ensure valid telemetry and minimal data errors, according to ASTM Standard D6274-10 (Section 9). Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the probe reached the top of the hole and was level with the reference point, the log was terminated, and the probe was deactivated and removed from the borehole.

The .TFD files were imported into WellCAD where the primary log compared favourably to the QA/QC log. For the primary log, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The log was shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes and exported as a .WCA file.

The .WCA file was then imported back into one common WellCAD file where it was compared with other geophysical logs, such as the optical televiewer image log, spectral gamma total counts log, and apparent conductivity log. Natural gamma log depths were matched to common features to further refine the accuracy and one final depth correction was applied according to the results of structural integration between televiewer logs and core logs, according to formulae described in Section 3.4.1.2.

The final Natural Gamma curve is displayed on the Lithology Log, in Appendix E. The data were measured in counts per second in the borehole, ranging from 19.22 cps to 228.39 cps, with an average value is 92.08 cps. The Natural Gamma values are on average 2.7 times higher than the Spectral Gamma total counts values, which is a result of counts falling outside the spectral energy classification window used during spectral gamma acquisition, which filters out counts with energy below 100 keV. Both the Natural Gamma and Spectral Gamma total counts logs match well for their respective ranges, showing the same pattern along the total depth of the borehole. The most apparent anomalies in the data tend to be associated with sharp changes in total counts associated with changes in biotite concentration. The most pronounced changes in the Natural Gamma log occur at the depth intervals between approximately 72 m and 81 m associated with casing and from 112 to 689 m pronounced localized decreases in Natural Gamma response of up to 50 cps are present (biggest one at 667.0 to 681.0 m), which are likely associated with an increase in biotite within the tonalite bedrock. Localized increases in gamma response of up to 90 cps occur between 521.0 m to 532.0 m, between 584.0 m and 589.0 m, between 860.0 m and 869.0 m which are likely associated with tonalite dykes. Elsewhere in the borehole more localized anomalies are also associated with intervals that have undergone alteration.

3.4.7 Neutron

The Mount Sopris LLP-2676 Dual Sensor Neutron probe uses an alpha emitting radioactive source, Americium 241 mixed with Beryllium and a single detector, to acquire relative neutron counts principally related to hydrogen ion concentration. Changes in neutron counts can be used to identify changes in rock geology.

Prior to mobilization, the probe was tested for proper calibration at DGI’s Operation Centre, using an open-air sample and a test block, in accordance with ASTM standard D6727-16 / D6727M-16. The calibration test passed with an average count of 87.229 cps in open air, and 1734.483 cps in the test block. Values and verification were recorded in the Calibration and Verification Check Form, included in Appendix A.

Once the probe was configured and calibration was verified, it was lowered into the casing until the top of the probe was flush with the reference point. In order to have data measured relative to ground surface (i.e., bedrock surface), corrections were applied to account for the offset distance between the reference point and the probe sensor, and the difference between the reference point and the ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point, as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator’s manuals in

Appendix B. The hole was logged over two shifts, with the primary log being collected in intervals from 1000 m to 414 mand from 481 m to surface. ASDE for this run was larger than 1.0 m, and a short repeat section was logged over the edge of casing to confirm the depth A QA/QC file was also recorded from 300 m to 200 m. The logs were collected in the up direction, with the probe being run at 2.5 m per minute, sampling every 2.5 cm.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent and ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the probe was level with the reference point, the file was terminated and saved to the laptop and backup drive, and the probe was deactivated and removed from the borehole. The neutron source was removed and returned to its protective case.

The .TFD files were imported into WellCAD where the primary logs compared favourably to the QA/QC log. For the primary logs, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes. A formula was then applied to correct the recorded depth as described in Section 3.4. Once referenced to the corrected depth, the logs were exported as .WCA files.

The .WCA files were then imported back into one common WellCAD file where they were compared with other geophysical logs, such as the optical televiewer image log, gamma-gamma density log, and natural gamma log. The two primary logs were merged, and common features were matched, to further refine the accuracy. One final depth correction was applied according to the results of structural integration between televiewer logs and core logs described in Section 3.4.

The final Short Sensor (SS) Neutron and Long Sensor (LS) Neutron curves are displayed on the Lithology Log, in Appendix E. The Neutron data is measured in counts per second, with the SS data ranging from 5,476.4 cps to 11,984.1 cps with an average value of 11,121.27 cps. and the LS data ranging from 23.4 cps to 883.4 cps, with an average value of 591.72 cps. The neutron curve tends to produce anomalies along the borehole length than inversely correlate with anomalies in the gamma-gamma density curve. Several pronounced decrease are present on both LS and SS curves with four biggest anomalies at 279 m to 287 m, 376 m to 381 m, 534 m to 539 m and 667 m to 684 m. This depth intervals are similarly reflected in the gamma-gamma density and total gamma curves. Based on core logging data (WP03: Golder, 2020b), this interval is associated with an increase in biotite within the tonalite bedrock. Numerous high-frequency anomalies, reflected as sharp 200 cps to 580 cps decreases in neutron counts, also occur along the borehole and coincide with peaks in the gamma-gamma density log.

A porosity log, calculated based on Neutron log data, is also presented on the Lithology Log, in Appendix E. The Porosity values are displayed in percent, ranging from 1.43% to 30.69%, with an average Porosity of 2.53%.

The porosity log was calculated using the formulae below:

$$Porosity = \Big((0.3329 * (X)) + 0.0127\Big) * 100$$

Where X is $1.01834652060312 * 10^{(-0.00263186129113282*LSN)}$ and where LSN is the LS Neutron counts. This formula was derived by DGI in consultation with Mount Sopris. The formula was generated using some of the other available geophysical logs for the borehole, including the density log and seismic velocity logs.

The Porosity curve is generally flat with several sharp spikes associated with density and resistivity spikes, as well as with lithology change. The most prominent correlation with an average porosity increase of 5% to 28 is shown at depth intervals of 279 m to 287 m, 376 m to 381 m, 534 m to 539 m, 667 m to 684 m. Other spikes with an average increase of 2% are also presented along the whole length of borehole and associated with lithology (dykes).

3.4.8 Full Waveform Sonic

Full waveform sonic logs provide data on the compression wave and shear wave velocity of the borehole wall. This data can be used in conjunction with density logs from the gamma-gamma density probe to calculate engineering properties like shear modulus, bulk modulus, young’s modulus, and Possion’s ratio, which are useful for distinguishing rock types.

The Mount Sopris FWS40 Full Waveform Sonic probe (FWS) utilizes a sonic transmitter and three receivers to measure the primary (compression) and secondary (shear) wave velocities of the rock formation. The transmitter and receiver portions of the probe are isolated from each other with a flexible sonic isolator which prevents the transmitted sonic pulses from travelling through the probe. As the calculations for wave velocity require a consistent separation from the transmitter and receivers relative to the borehole wall, centralizers are required for this probe.

Once the probe was assembled, affixed with centralizers, checked for functionality, and connected to the wireline, the probe was lowered into the casing until the top of the probe was flush with the reference point. In order to have data measured relative to ground surface (i.e., bedrock surface), corrections were applied to account for the offset distance between the reference point and the probe sensor, and the difference between the reference point and the ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point, as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator’s manuals in Appendix B. The probe was descended to 50% of the borehole depth, and a QA/QC log was recorded from 500 m to 400 m. The probe was run at 1.5 m per minute, sampling every 0.05 m. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole and the second file was begun, recording with the same speed and sampling interval. The primary log was recorded from 1,000 m bgs to 670 m bgs and the probe was returned to surface for shift change. Second primary log was recorded from 700m to 30 m during the following shift.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent and ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the probe was level with the reference point, the tool was deactivated, and the probe was removed from the borehole.

The .TFD files were imported into WellCAD where the primary logs compared favourably to the QA/QC log. For the primary logs, the Interpolate Bad Traces algorithm was applied to remove any gaps in the data. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes and then merged together. Once referenced to the corrected depth, the logs were exported as .WCA files.

The .WCA file was then imported back into one common WellCAD file where it was compared with other geophysical logs, such as the optical televiewer image log, gamma-gamma density log, and neutron log, and common features were matched to further refine the accuracy.

Compression and shear wave velocities were estimated in WellCAD by computing as semblance plot that evaluates the similarities in the full sonic waveforms across the array of receivers in the probe. Graphically, the FWS Semblance Plot is an image log where individual pixels are assigned a colour based on the amplitude of the semblance between the travel times recorded by each of the FWS receivers. The manually picked slowness curves were adjusted using the WellCAD extremum algorithm, and the logs were inverted to generate Compression Wave Velocity and Shear Wave Velocity logs. These logs were then used to calculate the Poisson's Ratio log, according to the formula (ALT 2011):

$$Poisson's\ Ratio = \frac{\frac{1}{2}\left(\frac{dts}{dtc}\right)^2 - 1}{\left(\frac{dts}{dtc}\right)^2 - 1}$$

where:

$$dtc = Compression\ Wave\ Slowness\ \ (\mu s/sm)$$

$$dts = Shear\ Wave\ Slowness\ (\mu s/sm)$$

The calculated Poisson's Ratio was then used in conjunction with the Shear Modulus to generate the Young's Modulus, according to the formula:

$$Young's\ Modulus\ (MPa) = 2 \times \mu \times (1 + \nu)$$

where:

$$\mu = Shear\ Modulus\ (MPa)$$

$$\nu = Poisson's\ Ratio$$

The Bulk Modulus was calculated according to the formula:

$$Bulk\ Modulus\ (MPa) = \rho_b \times \left(\frac{1}{dtc^2} - \frac{4}{3 \times dts^2}\right)$$

where:

$$\rho_b = Bulk\ Density\ (g/cc)$$

Using the Near Density log in conjunction with the Shear Wave slowness log, the Shear Modulus was calculated according to the relationship (ALT 2011):

$$Shear\ Modulus\ (MPa) = \frac{\rho_b}{dts^2}$$

The Near Density log was also used in conjunction with the Compression Wave Velocity log to calculate the Characteristic Acoustic Impedance, according to the following relationship:

$$Characteristic\ Acoustic\ Impedance\ (Rayls_{MKS}) = \rho_n \times v_P$$

where:

$$\rho_n = Near\ Density\ \ (kg/m^3)$$

$$v_P = Compression\ Wave\ Velocity\ (m/s)$$

One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.

The Full Waveform Sonic (FWS) image log and curves are displayed in the Engineering Log, included in Appendix E. The FWS logs include the Semblance Plot image, the picked Compression Wave and Shear Wave slowness curves, the calculated Compressive Wave Velocity and Shear Wave Velocity curves, the calculated elastic constant curves, and the calculated Characteristic Acoustic Impedance curve. Table 6 lists the FWS logs, along with their units, minimum and maximum values, as well as average values (where applicable).

Table 6: FWS Log Details

Log Name	Units	Min Value	Max Value	Average Value
Compression Wave Slowness	µs/m	169	286	188
Shear Wave Slowness	µs/m	282	467	302
Compression Wave Velocity	m/s	3498	5899	5332
Shear Wave Velocity	m/s	2141	3541	3311
Poisson’s Ratio	-	0.0142	0.3819	0.1847
Shear Modulus	MPa	12931	40666	30619
Young’s Modulus	MPa	32824	89329	72487
Bulk Modulus	MPa	15198	67398	38517
Characteristic Acoustic Impedance	Rayls (MKS)	$9.94*10^6$	$1.88*10^7$	$1.48*10^7$

The Semblance Plot is overlaid with the picked Compression Wave and Shear Wave slowness curves, which correspond to the two separate peak values shown in the Semblance Plot image. The corresponding Compression Wave Velocity and Shear Wave Velocity curves are overlaid for comparison. The Poisson’s Ratio curve is displayed next to the three overlain elastic constants curves, Shear Modulus, Young’s Modulus, and Bulk Modulus. Variations in the velocity curves and associated engineering property curves positively correlate to changes in the gamma-gamma density. Five spikes on Compression and Shear Wave Velocity curves correspond to spikes on Near and Far Density curves at 114 m bgs, 280-288 m bgs, 376-382 m bgs and 668-683 m bgs, 776-778 m bgs where average Compression and Shear Wave Velocities drops up to 20% and 28%, accordingly.

3.4.9 Mechanical Caliper

Caliper data is used to measure the average diameter of the borehole, showing voids, and open joints and fractures. Caliper data is necessary for accurate calculation of apparent structure dips, and for the determination of the borehole fluid velocity for the calculation of the acoustic caliper log.

The Mount Sopris 2PCA-1000 Mechanical Caliper probe uses three spring-driven arms, held against the borehole wall, to measure the average diameter of the borehole with depth. The short caliper arms were used given the diameter of the borehole. The caliper probe is run up from the bottom of the borehole such that the arms will expand into voids or fractures. The caliper probe is a combination tool with the fluid temperature / resistivity probe (FTR). The probe was checked for functionality prior to shipping to site and again once on site prior to use. Records of pre-use checks can be found in the pre-use Calibration and Verification Check Form, provided in Appendix A.

Before descending the probe into the borehole, the caliper was calibrated on surface using an associated calibration jig with two known diameters (6.1 cm and 10.2 cm), in accordance with ASTM standard D6167-11 (Section 8.2). The diameters of the calibration jig were recorded with the probe’s response and the results were saved into the associated .TOL file and exported as a .TXT file for record keeping. Calibration values were also recorded in the Calibration and Verification Check Form, provided in Appendix A. Following the calibration, the probe was lowered into the borehole until level with the reference point, and the depth was corrected to report the depth below ground surface of the measurement point of the caliper portion of the combination tool. The probe was then descended the full depth of the borehole. The associated .TOL file was then selected and the probe was activated. The full boot sequence was allowed, requiring 90 seconds as the caliper arms were opened, before the readings were valid. The probe was logged up from 600 m to 500 m as a QA/QC file. Once the QA/QC file was complete, the file was terminated, the probe arms were closed, and the probe was descended back to the bottom of the borehole. The primary caliper log was run up from the bottom of the borehole to 69.27 m (into the casing), at 2 m per minute, sampling every 1 cm.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed ascent.

Once the probe was level with the reference point, it was turned from Depth Up mode to Time Mode and the probe was removed from the borehole with the arms still extended. It was then checked in the calibration jig against the same two known diameter values. Changes in temperature of the probe caused the reported values to drift over the course of the log by -0.01 cm on the low end, and -0.06 cm on the high end. These values were used later in the processing stage to correct the caliper curve, by matching points of stable rock wall and casing to known diameter values.

The .TFD files were imported into WellCAD where the primary log compared favourably to the QA/QC log. For the primary log, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The log was shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes.

The .WCA file was then imported back into one common WellCAD file where it was compared with other geophysical logs, such as the optical televiewer image log, and acoustic caliper log. The log was depth matched with common features, to further refine the accuracy. One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.1.2.

The final Mechanical Caliper curve is displayed on the Lithology Log, in Appendix E and is overlaid with the Acoustic Caliper curve for comparison purposes. The borehole was drilled using a HQ drill bit with an outer diameter of 96.1 mm. The Mechanical Caliper log measured in mm through the borehole ranges from 76.03 mm to 101.56 mm, with an average value 97.48 mm. The Mechanical Caliper and Acoustic Caliper logs match well for their ranges, showing the same pattern along the length of the borehole. However, the acoustic caliper shows slightly lower (< 1.0 mm difference) borehole diameter below 400m as a result of a possible slight variation change in fluid velocity compared to the velocity of 1450 m/s used for calculation of the acoustic caliper.

3.4.10 Normal Resistivity, Self-Potential and Single Point Resistance

The Mount Sopris QL40 ELOG (resistivity) probe was used to collect a continuous record of the normal electrical resistivity, electrical resistance, and natural electrical potential of the borehole wall. The probe is comprised of 5 separate electrodes which are used to measure normal resistivity at 4 spacings (8 inch, 16 inch, 32 inch, and 64 inch). The tool also measures self-potential (SP), and single point resistance (SPR) between the uppermost electrode on the probe and a remote reference electrode installed at surface, in a shallow pit filled with bentonite mix located approximately 50 cm from the borehole. The resistivity probe is used with an electrically isolating bridle separating the probe from the wireline cable head.

The SP log provides a measure of the natural voltages within the borehole, which can be related to either electrochemical forces, such as differences in fluid electrical conductivities/salinities between the borehole fluid (flushed fluid) and the formation fluid and movement between the two, or electrokinetic forces, such as fluid flow from a fracture resulting in changes in hydraulic gradients. SP is measured between the 64” electrode and the armour of the probe near the wireline cable head.

The SPR log provides a qualitative indication of electrical resistance of the bedrock adjacent to the current electrode. The resistance measured represents the sum of the resistance between the surface reference electrode and the current electrode. Therefore, it is important to minimize the contact resistance of the surface electrode by seating it in a bentonite/clay mud cake and maintaining a constant temperature throughout the logging. The surface electrode was located within the warmed enclosure surrounding the borehole to maintain the temperature throughout the logging.

The QL40 ELOG was tested prior to use and calibrated using the ELOG calibration box with resistivities of 1 Ωm, 100 Ωm, 1,000 Ωm and 10,000 Ωm (ohm-metres). The record of calibration is provided in the Calibration and Verification Check Form.

Once the probe and bridle were connected to the wireline, the probe and bridle were lowered into the casing until the top of the bridle was flush with the reference point and the depth was corrected to report the depth of the bottom of the tool referenced to ground surface. Due to the multiple measurement points on the probe, the .TOL file determined the individual offsets of the electrodes automatically, using pre-determined channel shift values. The depth correction is specific to the tool and was calculated based on the stickup of the reference point, as measured during setup. The offset of the measurement point of each electrode on the tool is outlined in the technical specifications and operator’s manuals, in Appendix B, and is recorded in the .TOL file IG_BH02_WP05_GRIP_5578_R1a.tol , which is included in Appendix D. The surface electrode was connected to the Matrix logging box. The probe was descended to a depth of 600 m and the tool was turned on, Depth Mode was selected, and the first log was started. The QA/QC log was recorded up from 600 m to 500 m. The probe was run at 3.0 m per minute, sampling every 0.05 m. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole. Once the probe reached the bottom of the borehole, the second file was started, recording with the same speed and sampling interval. The hole was logged over multiple shifts to accommodate shift change and intermittent telemetry errors, resulting in four primary logs and one QA/QC log.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed ascent.

Once the bridle was level with the reference point, it was turned from Depth Up mode to Time Mode and the probe was removed from the borehole. It was then checked in the calibration box against the same known resistivity values. Changes in temperature of the probe caused minimal drift (<0.1%) over the course of the survey. The post-use calibration check values are recorded in the Calibration and Verification Check Form, in Appendix A.

The .TFD files were imported into WellCAD and the primary logs were compared to the QA/QC log to ensure repeatability. For the primary logs, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes. A formula was then applied to correct the recorded depth as described in Section 3.4. Once referenced to the corrected depth, the logs were exported as .WCA files.

The .WCA files were then imported back into one common WellCAD file where they were compared with other geophysical logs, such as the optical televiewer image log, magnetic susceptibility log, and apparent conductivity log. The resistivity logs were depth matched with common features, to further refine the accuracy. The logs were merged into final Self Potential, Single-Point Resistivity, and 8”, 16”, 32”, and 64” Resistivity logs. One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.1.2.

The final Resistivity, Self-Potential, Single Point Resistance curves are presented in the Lithology Log, included in Appendix E. The Self-Potential and SP Resistance curves are overlaid with the Apparent Conductivity curve for comparison purposes, while the 8”, 16”, 32”, and 64” Resistivity curves are displayed in logarithmic scale and overlaid with each other. The logs are shown in Table 7, along with their units, minimum and maximum values, as well as average and estimated background values (where applicable).

In general, the resistivity curve shows a steady decrease with depth, with numerous discrete downward spikes correlating to changes in lithology (e.g. 277-291 m bgs, 370-387 m bgs, 531-542 m bgs, 585-590 m bgs, and 666-684 m bgs) as observed in televiewer logs and core logging. Several of these spikes correlate with low neutron counts and high gamma-gamma density counts throughout the borehole.

The self-potential curve shows variability over much of the borehole, with a general decreasing trend from 75 m to 538 m. Sudden spikes in the self-potential often correlate to changes in lithology, with a primary example at 113 m and 279-289 m.

Single-point resistance to decrease down from 75 m to 538, below which it remains low, with small variations associated with slight increases in resistivity.

Table 7: ELOG Log Details

Log Name	Units	Min Value	Max Value	Average Value
Self-Potential	mV	388	664	475
Single Point Resistance	Ω	139	11,392	4,853
8” Resistivity	Ωm	0.24	24,801	10,006
16” Resistivity	Ωm	0.39	43,785	17,037
32” Resistivity	Ωm	0.81	67,151	24,692
64” Resistivity	Ωm	1.54	82,746	27,947

3.4.11 Spectral Gamma

The Mount Sopris 2SNA-1000 Spectral Gamma probe was used to measure the naturally occurring gamma radiation of distinct energy levels being emitted by the host rock, in order to derive the concentrations of Potassium (K), Uranium (U) and Thorium (Th) as well as their decay products. The logs are used for the identification of lithology, mineralogy and alterations. The probe consists of a scintillation sodium iodide crystal, which measures the incoming natural gamma radiation from the borehole walls and is resolved into a spectrum of energy levels associated with the specific radionuclides of Potassium, Uranium and Thorium. The gamma-emitting radio-isotopes that naturally occur in geologic materials are Potassium 40 and nuclides in the Thorium 232 and Uranium 238 decay series. Potassium 40 occurs with all potassium minerals including potassium feldspars. Thorium 232 is typically associated with biotite, sphene, zircon and other heavy minerals. Uranium 238 is typically associated granitoid rocks with uranium mineralization.

The spectral gamma probe was checked for functionality prior to shipping. The results of the functionality test are recorded in the pre-use Calibration and Verification Check Form, included in Appendix A.

Once the tool was connected to the wireline, the probe was powered up and checked for valid data. The probe was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Logger program was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point, as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator’s manuals in Appendix B.

The probe was descended down to a depth of 500 m and turned on and the first log was started. The QA/QC log was recorded up 10% of the borehole depth, from 500 m to 400 m. The probe was run at 2.25 m per minute, sampling every 2.5 cm. Once the QA/QC log was complete, the first file was terminated, and the probe was descended to the bottom of the hole. The second file was started, logging up into the borehole at the same speed and sampling interval.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent and ascent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the probe was level with the reference point, the second file was terminated, and the probe was deactivated and removed from the borehole.

The .TFD files were imported into WellCAD and the primary logs were compared to the QA/QC log to ensure repeatability. For the primary logs, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes Once referenced to the corrected depth, the logs were exported as a .WCA file.

The .WCA file was then imported back into one common WellCAD file where the logs were compared with other geophysical logs, such as the optical televiewer image log, and natural gamma log. The logs were depth matched with common features, to further refine the accuracy.

The K, U, and Th curves were generated through the WellCAD procedure for spectrum stacking over a 2-metre window, and a 10-metre window. To generate the individual curves an energy window of 1,360 keV to 1,560 keV was used for the K band, an energy window of 1,660 to 1,860 keV was used for the U band, and an energy window of 2,520 keV to 2,720 keV was used for the Th band, as described in the user’s manual for the probe (Appendix B) and which captures energy 100 keV either side of the peak associated with the band.
One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.1.2.

The Spectral Gamma curves are presented in the Lithology Log, included in Appendix E. The Spectral Gamma total counts curve is overlaid with the Natural Gamma curve for comparison purposes, while the stacked Potassium, Thorium, and Uranium counts logs are overlaid on each other. The Spectral Gamma logs are listed in Table 8, along with their units, minimum and maximum values, as well as average and estimated background values (where applicable).

Table 8: Spectral Gamma Log Details

Log Name	Units	Min Value	Max Value	Average Value
Spectral Gamma	total cps	2.33	129.05	37.38
K – Stacked – 2m	cps	0.11	1.31	0.67
Th – Stacked – 2m	cps	0.00	0.23	0.04
U – Stacked – 2m	cps	0.00	0.44	0.16
K – Stacked – 10m	cps	0.39	1.00	0.67
Th – Stacked – 10m	cps	0.00	0.08	0.03
U – Stacked – 10m	cps	0.03	0.28	0.16

The Natural Gamma and Spectral Gamma total counts logs match well for their ranges, showing the same trends, spikes, and plateaus. The Natural Gamma values are on average 2.7 times higher than the Spectral Gamma total counts values, which is a result of counts falling outside the spectral energy classification window used during spectral gamma acquisition, as the Spectral Gamma probe filters out any counts with an energy level less than 100 keV. Trends in both the Natural Gamma and Spectral Gamma total counts logs match well for their respective ranges, showing the same pattern along the total depth of the borehole. In general, the total gamma counts curve is negatively correlated with the presence of biotite in the host tonalite, with interpreted biotite-rich layers appearing as relatively low gamma plateaus. Overall the uranium and thorium curves show very low concentrations, however, the potassium curve appears to represent the bulk of the radioactive response.
In particular, where the total gamma counts decrease associated with biotite-rich intervals the potassium curve also shows an apparent decrease. The most prominent correlation is shown at depth intervals of 112 to 115 m bgs,177 to 178 m, 225 to 226 m, 257 to 259 m, 368 to 370, 535 to 538 m, and 668 to 677 m.

3.4.12 Fluid Temperature and Resistivity

The Mount Sopris 2CAA-1000 Fluid Temperature / Resistivity probe (FTR) is part of a combination probe, forming the bottom end of the 3-arm mechanical caliper probe. The FTR is run down the borehole within the fluid and records the fluid temperature and electrical resistivity as the fluid passes through the tool.

Immediately prior to use, the probe was calibrated using two fluids of known resistivity (8.5 Ωm and 88.5 Ωm). The calibration values are recorded in the Calibration and Verification Check form, as well as the exported calibration text file, provided to NWMO.

The probe was lowered into the casing until the top of the probe was flush with the reference point and the depth was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point above ground surface, as measured during setup. The offset of the measurement point of each tool is provided in the probe specific .TOL file, and outlined in the technical specifications and operator’s manuals in Appendix B.

Data logging began at the top of casing to obtain a complete profile of the borehole. Starting the log data in the air ensured that it recorded the transition between the air-filled portion and the fluid-filled portion of the borehole; a sharp change in resistivity and temperature indicates the top of static water level in the borehole. Temperature data in the air-filled portion reflects the ambient air temperature, however fluid resistivity values above the static water level are not valid. The primary log was recorded down at a speed of 4 m per minute, sampling every 5 cm.

Once the probe reached the bottom of the borehole, the first file was terminated, and the probe was ascended to a depth of 100 m. A new file was started, and the QA/QC log was recorded down for 10% of the borehole depth, from 100 m to 200 m, at the same speed and sampling rate. Once the QA/QC log was complete, the probe was returned to the surface.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent. Once the probe was level with the reference point the recording mode was switched from Depth Down mode to Time Mode and removed from the borehole.

The probe was then checked in the same two fluids of known resistivity and the results recorded in the Calibration and Verification Check form. The probe values drifted by an average of 1 Ωm over the course of testing.

The .TFD files were imported into WellCAD where the primary logs compared favourably to the QA/QC log. For the primary logs, an interpolation function was applied to remove data spikes and gaps smaller than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes. Once referenced to the corrected depth, the logs were exported as a .WCA file.

The .WCA file was then imported back into one common WellCAD file where the logs were compared with other geophysical logs, such as the optical televiewer image log, and FFEC logs. The logs were depth matched with common features, to further refine the accuracy. The Fluid Resistivity log was inverted to present Fluid Conductivity for comparison to FFEC logs. Fluid Resistivity Gradient and Temperature Gradient logs were created using the standard WellCAD formula. One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, using formulae described in Section 3.4.1.2.

The final Fluid Temperature, Fluid Resistivity, and Static Fluid Conductivity curves are displayed on the Hydrogeology Log, in Appendix E. The FTR curves are overlaid with each other and are presented next to the FFEC logs, with log start time in minutes, for comparison purposes. The FTR logs are listed in Table 9, along with their units, minimum and maximum values, as well as average values. The Fluid Temperature curve shows a steady increase from approximately 7°C at the water table, to 13.4°C at the bottom of the borehole.

Table 9: FTR Log Details

Log Name	Units	Min Value	Max Value	Average Value
Fluid Temperature (T=11522min)	°C	7.89	13.46	10.47
Fluid Resistivity (T=11522min)	Ωm	3.98	117.93	61.34
Static Fluid Conductivity (T=11522min)	mS/m	7.53	251.22	47.79

3.4.13 Magnetic Susceptibility

Magnetic susceptibility data was collected to measure the magnetic susceptibility of the rock. The HM 320 Magnetic Susceptibility probe contains a two coil system and is used to measure the dimensionless magnetic susceptibility constant *K* of the rock mass, which indicates the degree to which it can be magnetized in the presence of a magnetic field.

The probe calibration was verified prior to use using the manufacturer-supplied calibration block of known magnetic susceptibility (0.02262) and the null value in air. The results of the calibration are recorded in the Calibration and Verification Check form.

Once the probe's calibration was verified it was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Logger program was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point above ground surface, as measured during setup. The offset of the measurement point of each tool is outlined in the technical specifications and operator's manuals in Appendix B. The probe was descended to a depth of 400 m, turned on and the first log was started. The QA/QC log was recorded up the borehole for 10% of the borehole depth, from 400 m to 300 m. The probe was run at 4.5 m per minute, sampling every 5 cm. Once the QA/QC log was complete, the probe was descended to the bottom of the borehole. Once the probe reached the bottom of the borehole, the first file was terminated, and the second file was started, recording up at the same speed and sampling interval.

The logs were recorded as .TFD files and the quality of the data was monitored throughout the descent to ensure valid telemetry and minimal data errors. Wireline tension was also monitored to ensure continuous, unobstructed descent. Once the probe was level with the reference point, the final log was terminated, and the probe was turned from Depth Up mode to Time Mode and removed from the borehole.

The probe was then checked in the calibration block and in air and the results recorded in the Calibration and Verification Check form. The probe values drifted by an average of 0.65 over the course of testing.

The .TFD files were imported into WellCAD where the primary logs compared favourably to the QA/QC log. For the primary logs, an interpolation function was applied to remove data spikes and gaps larger than 1 m. The logs were shifted to correct for the After-Survey Depth Error (ASDE), recorded in the relevant Record of Geophysical Logging field notes, and the noted depth loss from the odometer wheel error was corrected based on the short repeat log. Once referenced to the corrected depth, the logs were exported as .WCA files.

The .WCA files were then imported back into one common WellCAD file where the logs were compared with other geophysical logs, such as the optical televiewer image log, natural gamma log, apparent conductivity log, and resistivity logs. One final depth correction was applied according to the results of structural integration between televiewer logs and core logs, as described in Section 3.4.1.2.

The final Magnetic Susceptibility curve is presented in the Lithology Log, included in Appendix E. Magnetic susceptibility is presented as SI unitless values), and ranges from -0.39×10^{-3} SI to 7.98×10^{-3} SI, with an average value of 0.56×10^{-3} SI.

In general, the magnetic susceptibility curve is flat, with sharp positive spikes associated with lithology change. The most prominent spikes associated with high biotite tonalites and amphibolite lenses at depth intervals of 535 to 538 m, 587 m, 671 to 677 m, 701 to 703 m, 861 to 862 m, 867 to 868 m and 953

3.4.14 Heat-Pulse Flowmeter

Fluid flow along borehole is useful for inferring where changes in hydraulic head are occurring, where water-bearing fractures are located, and whether systems of joints and fractures are hydraulically connected in proximity to the borehole. The Mount Sopris HFP-2293 Heat-Pulse Flow Meter probe (HPFM) was used to measure the vertical rate of fluid flow in a borehole by collecting data at discrete points along the borehole while the probe is motionless in the water column. The probe uses a rubber skirt to divert all flow at one horizon in the water column through the annulus of the probe, which it marks with a pulse of heat. Two thermistors, one located above and one below the annulus, are used to calculate the velocity and direction of motion of the heated water. This velocity is converted, using a calibration formula, into a flow rate. The probe is factory calibrated and is re-calibrated in the event it is sent for repair. The HPFM is designed to measure low flow conditions, from 0.113 to 3.785 litres per minute. The probe specifications note that the accuracy of the probe is within 5% of the actual flow rate in the mid measuring range, and within 15% at the extremes of the measuring range.

The HPFM was checked for functionality prior to shipping and again prior to use while on site. The pre-use checks are recorded in the pre-use Calibration and Verification Check form. The probe was also tested in the borehole under pumping conditions to simulate flow of known magnitude, and the results of the test are recorded in the Calibration and Verification Check form. All pre-use test results are reported in Appendix A.

An HQ diverter and centralizer were attached to the probe and it was connected to the wireline. The Matrix Heat software was started and the associated .TOL file was selected. The probe was lowered into the casing until the top of the probe was flush with the reference point and the depth in the Matrix Heat program was corrected to report the depth of the measurement point of the tool referenced to ground surface. This depth correction is specific to the tool and was calculated based on the stickup of the reference point above ground surface, as measured during setup. The offset of the measurement point of each tool was outlined in the technical specifications and operator’s manuals in Appendix B. The probe was then descended below the static water level and powered up. When the static water level was above the bottom of the casing, two measurements were taken within the casing to ensure good response in a zero-flow condition.

The initial HPFM testing was conducted under static conditions. A standardized measurement interval of 20 m was used to sample the flow in the borehole. Three separate records of 45 seconds each were gathered from each depth to ensure repeatability. After static testing, a Grundfos submersible pump was lowered into the borehole to 48.0 m bgs. A drawdown to 30 m was created to conduct the HPFM testing under pumping/dynamic conditions. Then a Grundfos submersible pump was lowered into the borehole to 57.0 m. A drawdown to 52 m was created to conduct the HPFM testing under pumping/dynamic conditions. A standardized measurement interval of 20 m was used to sample the flow in the borehole; however, sampling interval was reduced to 10 m and 5 m and 1 m at the depth where any flow would occur to better locate the source of the potential flow. Measurement of flow while pumping with the HPFM in the casing was used to check the operation of the HPFM and ensure the diverters were working properly to divert flow through the probe.

Responses observed outside the first 45 seconds can be attributed to the thermal movement of the heated slug of water and are not considered true flow measurements. The MatrixHeat manual (Appendix B) indicates that there is generally no useable data beyond 25 seconds.

Data was recorded as .MH files (ALT proprietary format). Wireline tension was also monitored to ensure continuous, unobstructed descent and ascent. Once the data had been gathered, the file was saved in Matrix Heat and the probe was powered down and ascended to the next measurement depth.

All the data files (.MH) were reviewed for consistency in pulse time picks, then the depths and flow values were exported as .CSV files. The .CSV file was reviewed manually to remove duplicate entries, which were the result of small (mm) changes in reported probe depth. Flow rates were converted from US gallons per minute to litres per minute. The separate .CSV files were combined to generate one single file.

The .CSV file was then imported into one common WellCAD file where the log was compared with other geophysical logs, such as the optical televiewer image log, FFEC logs, and modelled dynamic flow values. Although flow was observed under dynamic pumping conditions in the FFEC logs, no flow was measurable within the sensitivity range of the HPFM under ambient conditions, meaning if ambient flow existed, it was less than 0.113 litres per minute. The final depth correction was applied according to the results of structural integration between televiewer logs and core logs, according to formulae described in Section 3.4.1.2.

The final Heat-Pulse Flow Meter (HPFM) data is presented in the Hydrogeology Log, included in Appendix E. It is presented as the Heat Pulse Static Flow curve, in litres per minute, with indicators at each discrete sample depth. In testing of the open portion of the borehole no static flow was detected with the HPFM run, thus the curve is set to 0 L/min. The Heat Pulse Static Flow curve is overlaid on the FFEC Model Dynamic Flow curve for comparison purposes.

3.4.15 Borehole Deviation

To be able to correct apparent structures to true dip and dip direction, as well as to understand the overall tilt and azimuth of the borehole, multiple deviation logs were collected. These logs were compared to each other to identify and mitigate possible sources of error.

Borehole deviation data were recorded in IG_BH02 using tilt and azimuth information from the optical and acoustic televiewer logs. The tilt and azimuth logs were collected with the same setup procedure as outlined in Section 3.4.5.2, logging the complete borehole down at 10 m per minute, sampling every 5 cm, as well as up at 4 m per minute, sampling every 1.6 mm. As a result, two additional optical televiewer runs were completed to measure deviation. In total, three tilt and azimuth logs were acquired and used to calculate the trajectory of the borehole from ground surface to the bottom of hole (Table 10).

The individual Tilt and Azimuth logs were filtered using a 3-point moving window filter to remove data spikes and interpolated over gaps less than 1 m to remove data blanks. Distortion of the azimuth logs caused by the metallic casing was trimmed.

For the interval between 71 m and 1,001 m, tilt and azimuth logs from each of the five completed runs were combined into a single set of logs by calculating an average of the logs on a point-by-point basis. Once the average deviation logs for the interval from 71 m to 1,001 m were generated, they were merged with the upper 100 m deviation logs to produce a continuous set of deviation logs. The final Azimuth log was rotated 1.361° to correct for the local magnetic declination, in order to reference it to True North.

The averaged Tilt and Azimuth (True North referenced) logs were used to calculate approximate Easting and Northing displacement of the hole from the collar, as well as the True Vertical Depth below ground surface. These values were used to plot the preliminary trajectory of the borehole shown in a Bull's Eye plot in the header of the Deviation Log included in Appendix E. The individual logs are listed in Table 10, along with their logging direction, sampling rates, units, minimum and maximum values, as well as average values (where applicable).

Table 10: Deviation Log Details

Log Name	Sampling Rate (m)	Units	Min Value	Max Value	Average Value
ABI Azimuth 03-9+02-4	0.05	Deg	218.4	272.5	240.38
OBI Azimuth 09-1+09-3+02-1	0.05	Deg	219	263.3	240.11
ABI Azimuth stitched*	0.002	Deg	221.55	260.5	226.32
ABI Tilt 03-9+02-4	0.0016	Deg	17.70	38.90	27.57
OBI Tilt 09-1+09-3+02-1	0.0016	Deg	19.20	37.30	27.63
ABI Tilt stitched*	0.05	Deg	19.82	37.70	27.70

* stitched from 34 overlapping ABI logs (see 3.4.5.1)

The Deviation curves are presented in the Deviation Log, included in Appendix E. The various azimuth and tilt curves are overlaid with each other for comparison. The averaged azimuth log, corrected from High Side to True North (TN), and the averaged tilt log are also presented (Table 11). From the Average Azimuth TN and Tilt Average logs the Northing, Easting and True Vertical Depth (TVD) logs are calculated and presented in Table 11. The TVD log is used to calculate the Elevation log and the two are presented as depth column logs. The Easting and Northing logs are overlaid and presented beside curves showing the semi-major axis of the error ellipses calculated by WellCAD, based on the tilt and azimuth uncertainty values (±0.5° of tilt, ±1.2° of azimuth) found in the user manual for the televiewer probes, included in Appendix B. Error ellipses, also known as footprints, are an expression of the uncertainty of the measurement on the calculation of position along the borehole. The WellCAD algorithm is based on a probabilistic approach, meaning that the higher sampling of orientation measurements leads to less overall uncertainty and smaller ellipses, denoted by small semi-major axis values.

Table 11: Details of the Averaged Deviation Log

Log Name	Units	Min Value	Max Value	Average Value
Azimuth Average TN	deg	222.19	259.23	239.87
Tilt Average	deg	19.80	37.15	27.62

Table 12: Results of Eastings, Northings, and True Vertical Depth (TVD) Recorded at Bottom of Borehole

Log Name	Units	Total Value
Easting	m	-390.67
Northing	m	-222.45
TVD	m	880.73

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Stone, D., Halle, J. and Chaloux, E., 1998. Geology of the Ignace and Pekagoning Lake Areas, Central Wabigoon Subprovince; *in* Summary of Field Work and Other Activities 1998, Ontario Geological Survey, Misc. Paper 169.

Stone, D., Davis, D.W., Hamilton, M.A. and Falcon, A., 2010. Interpretation of 2009 Geochronology in the Central Wabigoon Subprovince and Bending Lake Areas, Northwestern Ontario, *in* Summary of Field Work and Other Activities 2010, Ontario Geological Survey, Open File Report 6260.

APPENDIX A

Calibration and Verification Forms, Data Quality Confirmation Forms, Pre-Use Check Forms

CALIBRATION AND VERIFICATION CHECK FORM

FORM: NWMO-IGNACE-1671632-WP05-F001

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*17/09/2019*
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Calibration of borehole geophysical probes:

Probe /Equipment Name	Date	Check By	Calibration Value 1	Calibration Value 2	Probe Temperature	Probe Value 1	Probe Value 2	Calibration File(s)
2CAA-1000 S/N:5032	27-Nov-19	OF, CM	8.5 Ohm*m	88.5 Ohm*m	11.8℃	8.6 Ohm*m	88.7 Ohm*m	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd
2CAA-1000 S/N:5032	27-Nov-19	OF, CM	6 ℃	34 ℃	11.8℃	8 ℃	33.6 ℃	IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd

Comments on tool calibration:

Logging scientist:

Olga Fomenko	OAFomenko	27 Nov 2019
Print name	Signature	Date

Client:	NWMO	**Job Number:**	1671632A
Location:	Ignace – IG_BH02	**Project:**	
Prepared by:	Olga Fomenko	**Verified by:**	

GOLDER

CALIBRATION AND VERIFICATION CHECK FORM

FORM: NWMO-IGNACE-1671632-WP05-F001

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *01 Dec 2019 / Shift 04*
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Calibration of borehole geophysical probes:

Probe /Equipment Name	Date	Check By	Calibration Value 1	Calibration Value 2	Probe Temperature	Probe Value 1	Probe Value 2	Calibration File(s)
QLABI S/N: 190404	01-Dec-19	OF	Roll: 0,90,180,270	Tilt: 0,90	11.8℃	Roll: 0,90,180,270	Tilt: 0,90	IG_BH02_WP05_QLABI_PostRoll_120119.tfd, IG_BH02_WP05_QLABI_PostTilt_120119.tfd
2PGA-1000 S/N 2622	01-Dec-19	CM	-	-	-	-	-	IG_BH02_WP05_2PGA-1000_PreUseCheck_120110.tfd

Comments on tool calibration:

Function Check for the Gamma.

Logging scientist:

Olga Fomenko — OAFomenko — Dec 1 2019
Print name — Signature — Date

Chris Marchildon — Chris Marchildon — Dec 1 2019
Print name — Signature — Date

Client: NWMO
Location: Ignace – IG_BH02
Prepared by: Olga Fomenko Chris Marchildon

Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Chris Phillips

CALIBRATION AND VERIFICATION CHECK FORM

FORM: NWMO-IGNACE-1671632-WP05-F001

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*02 Dec 2019 / Shift 05*
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Calibration of borehole geophysical probes:

Probe /Equipment Name	Date	Check By	Calibration Value 1	Calibration Value 2	Probe Temperature	Probe Value 1	Probe Value 2	Calibration File(s)
2LSA	02-Dec-19	OF	-	-	11.8℃	-	-	IG_BH02_WP05_2LSA_PreCalCheck_120219.tfd, IG_BH02_WP05_QLABI_PostTilt_120119.tfd
HPFL S/N 4736	02-Dec-19	OF	No flow	Flow	11.8℃	No flow	Flow	IG_BH02_WP05_HPFM_PreUse_120219.tfd

Comments on tool calibration:

Function Check for the Spectral Gamma.

Logging scientist:

Olga Fomenko	OAFomenko	Dec 2 2019
Print name	Signature	Date

Client:	NWMO	**Job Number:**	1671632A
Location:	Ignace – IG_BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Chris Phillips

GOLDER

CALIBRATION AND VERIFICATION CHECK FORM

FORM: NWMO-IGNACE-1671632-WP05-F001

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches
CC: Joe Carvalho
George Schneider

Date / Shift: *03 Dec 2019 / Shift 06*
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Calibration of borehole geophysical probes:

Probe /Equipment Name	Date	Check By	Calibration Value 1	Calibration Value 2	Probe Temp	Probe Value 1	Probe Value 2	Calibration File(s)
2PIA-1000	Dec 3, 2019	CM	0	91	4 degrees	.40-.50	91.30	IG_BH02_WP05_2PIA_Stabilization_120319.tfd, IG_BH02_WP05_2PIA_Preuse_120319.tfd, 2PIA-1000_Calibration_120419.txt
2LSA-1000	Dec 3, 2019	CM						IG_BH02_WP05_2LSA_PreUseCheck_120319.tfd

Comments on tool calibration:

Temp After Stabilization: 3 degrees Time: 23:32 – 12:01
Temp of Ring: -10 degrees Time: 12:05
Probe temp prior to going in the hole 0 degrees

Done out in middle of Compound away from metal outside Air temperature:
Stabilization was done at 90 m depth for 30 mins
2LSA-1000 pre use check

Logging scientist:

Chris Marchildon — Chris Marchildon — Dec 3 2019
Print name — Signature — Date

Client: NWMO
Location: Ignace – IG_BH02
Prepared by: Chris Marchildon

Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Chris Phillips

GOLDER

CALIBRATION AND VERIFICATION CHECK FORM

FORM: NWMO-IGNACE-1671632-WP05-F001

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: *04 Dec 2019 / Shift 07*
Work Package: WP05 – Borehole Geophysical Logging
Distributed By: Email

Calibration of borehole geophysical probes:

Probe /Equipment Name	Date	Check By	Calibration Value 1	Calibration Value 2	Probe Temp	Probe Value 1	Probe Value 2	Calibration File(s)
2PIA-1000	Dec 4, 2019	PG	0	463	0.5 degrees	1.0	463.8	IG_BH02_WP05_2PIA-1000_Preuse_120419.tfd, 2PIA-1000_Calibration_120419b.txt
2PIA-1000	Dec 4, 2019	PG	0	463	0.5 degrees	-8.1	454	IG_BH02_WP05_2PIA-1000_Postuse_120419.tfd, 2PIA-1000_Calibration_120419c.txt
2PCA-1000	Dec 4,2019	CM	6.1	10.2	-2 degrees	6.09	10.21	IG_BH02_WP05_2PCA-1000_Preuse_120419.tfd, 2PCA-1000_Calibration_120419.txt

Comments on tool calibration:

Temp After Stabilization: 0.5 degrees Time: 01:20
Temp of Ring: -9 degrees Time: 01:20

Done out in middle of Compound away from metal.
Note that probe calibrated between 0 and 463 instead of previous 0 and 91 since probe 'flat-lined' after initial calibration to -39 mS/m. ***Also note that although values of 0 and 463 were set on Cal ring and in Logger calibration settings menu, the output ascii files indicate settings of 0 and 91 (see files 2PIA-1000_Calibration_120419b.txt and 2PIA-1000_Calibration_120419c.txt). This was double-checked.

Logging scientist:

Peter Giamou Dec 4, 2019
Print name Signature Date

Chris Marchildon
Chris Marchildon Dec 4, 2019
Print name Signature Date

Client: NWMO
Location: Ignace – IG_BH02
Prepared by: Peter Giamou
Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Chris Phillips

CALIBRATION AND VERIFICATION CHECK FORM

FORM: NWMO-IGNACE-1671632-WP05-F001

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*04 Dec 2019 / Shift 07*
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Client:	NWMO	**Job Number:**	1671632A
Location:	Ignace – IG_BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Peter Giamou	**Verified by:**	Chris Phillips

CALIBRATION AND VERIFICATION CHECK FORM

FORM: NWMO-IGNACE-1671632-WP05-F001

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*05 Dec 2019 / Shift 08*
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Calibration of borehole geophysical probes:

Probe /Equipment Name	Date	Check By	Calibration Value 1	Calibration Value 2	Probe Temp	Probe Value 1	Probe Value 2	Calibration File(s)
2CAA-1000	Dec 4, 2019	CM	6.1	10.2	-7 ℃	6.09	10.21	2CAA-1000_Calibration_120419.txt
2PCA-1000	Dec 5, 2019	PG	6.1	10.2	5 ℃	6.08	10.15	2PCA-1000_Calibration_120519.txt
QLOBI S/N: 160403	05-Dec-19	OF	Roll: 0,90,180,270	Tilt: 0,90	16℃	Roll: 0,90,180,270	Tilt: 0,90	IG_BH02_WP05_QLOBI_PostRoll_120519.tfd, IG_BH02_WP05_QLOBI_PostTilt_120519.tfd

Comments on tool calibration:

Logging scientist:

Peter Giamou		Dec 5 2019
Print name	Signature	Date
Olga Fomenko	OAFomenko	Dec 05 2019
Print name	Signature	Date

Client:	NWMO	**Job Number:**	1671632A
Location:	Ignace – IG_BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Peter Giamou Olga Fomenko	**Verified by:**	Chris Phillips

GOLDER

CALIBRATION AND VERIFICATION CHECK FORM

FORM: NWMO-IGNACE-1671632-WP05-F001

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*06 Dec 2019 / Shift 09*
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Calibration of borehole geophysical probes:

Probe /Equipment Name	Date	Check By	Calibration Value Tilt	Calibration Value Roll	Probe Temp	Probe Value Tilt	Probe Value Roll	Calibration File(s)
QLOBI	Dec 6, 2019	PG	~0,90	~0,90,180, 270	10 degrees	4, 92	4.7, 91.7, 181.5, 270.3	IG_BH02_WP05_QLOBI_PostTilt_120619.tfd, IG_BH02_WP05_QLOBI_PostRoll_120619.tfd
MagSus	Dec 6, 2019	CM	0	10	-13	.01	10.01	IG_BH02_WP05_MagSus_Preuse_120619.tfd, IG_BH02_WP05_MagSus_Stabilization_120619.tfd, MagSus_Calibration_120619.txt
MagSus	Dec 7, 2019	PG	0	10	4	0	9.35	IG_BH02_WP05_MagSus_PostUse_120719.tfd

Comments on tool calibration:

Mag sus probe temp out of BH: -1.5
Mag Sus probe during calibration -13
Probe was stabilized for 1.5 hrs (see stabilization file)

Logging scientist:

Peter Giamou		Dec 6, 2019
Print name	Signature	Date
Chris Marchildon	Chris Marchildon	Dec 6, 2019
Print name	Signature	Date

Client:	NWMO	**Job Number:**	1671632A
Location:	Ignace – IG_BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Peter Giamou	**Verified by:**	Chris Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Nov 28, *2019 /01*

Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_2CAA_01-1_112819.tfd	Nov-28-19	PG	2.21	1000.00	997.79		CRP	
IG_BH02_WP05_2CAA_01-2_112819.tfd	Nov-28-19	PG	1000.00	1.55	998.45		CRP	
IG_BH02_WP05_2CAA_01-3_112819.tfd	Nov-28-19	OF	2.21	1000.00	997.79		CRP	
IG_BH02_WP05_2CAA_01-4_112819.tfd	Nov-28-19	OF	1000.00	1.02	998.98		CRP	
IG_BH02_WP05_2CAA_01-5_112819.tfd	Nov-28-19	OF	2.21	1000.03	997.82		CRP	
IG_BH02_WP05_2CAA_01-6_112819.tfd	Nov-28-19	OF	1000.03	1.21	998.82		CRP	
IG_BH02_WP05_2CAA_01-7_dyn_112819.tfd	Nov-28-19	CM	68.00	1000.00	932.00		CRP	
IG_BH02_WP05_2CAA_01-8_dyn_112819.tfd	Nov-28-19	CM	1000.00	67.90	932.10		CRP	
IG_BH02_WP05_2CAA_01-9_dyn_112819.tfd	Nov-28-19	CM	68.00	1000.06	932.06		CRP	
IG_BH02_WP05_2CAA_01-10_dyn_112819.tfd	Nov-28-19	CM	1000.06	67.18	932.88		CRP	
IG_BH02_WP05_2CAA_01-11_dyn_112819.tfd	Nov-28-19	CM	68.00	1000.11			CRP	

Comments on log quality and tool performance:

Peter Giamou November 28, 2019
Print name Signature Date

Chris Marchildon Chris Marchildon November 28, 2019
Print name Signature Date

Client: NWMO

Job Number: 1671632A

Location: Ignace – BH02

Project: Phase 2 Initial Borehole Drilling

Prepared by: PG/OF/CM

Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Nov 29, *2019 /02*
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_2CAA_02-1_112919.tfd	Nov-29-19	PG	1000.00	68.00	932.00	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-2_112919.tfd	Nov-29-19	PG	68.00	1000.00	932	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-3_112919.tfd	Nov-29-19	PG	1000.00	65.39	934.61	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-4_112919.tfd	Nov-29-19	PG	68.0	1000.00	932	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-5_112919.tfd	Nov-29-19	PG	1000.00	66.47	933.53	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-6_112919.tfd	Nov-29-19	OF	68.00	1000.00	932	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-7_112919.tfd	Nov-29-19	OF	1000.00	66.79	933.21	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-8_112919.tfd	Nov-29-19	OF	68.00	1000.02	932.02	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-9_112919.tfd	Nov-29-19	OF	1000.02	66.61	933.41	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-10_112919.tfd	Nov-29-19	OF	68.00	1000.04	932.04	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-11_112919.tfd	Nov-29-19	OF/CM	1000.04	66.75	933.29	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-12_112919.tfd	Nov-29-19	CM	1000.20	66.65	933.55	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-13_112919.tfd	Nov-29-19	CM	68.00	1000.12	932.12	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-14_112919.tfd	Nov-29-19	CM	1000.12	66.63	933.49	Nov-30-19	CRP	Acceptable
IG_BH02_WP05_2CAA_02-15_112919.tfd	Nov-29-19	CM	68.00	1000.06	932.06	Nov-30-19	CRP	Acceptable

Comments on log quality and tool performance:

Pump stopped working in the vicinity of log 12

Peter Giamou — November 29, 2019
Print name — Signature — Date

Olga Fomenko — OAFomenko — November 29, 2019
Print name — Signature — Date

Chris Marchildon — Chris Marchildon — November 29, 2019
Print name — Signature — Date

Client: NWMO
Location: Ignace – BH02
Prepared by: PG/OF/CM
Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Nov 30, *2019 /03*
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_2CAA_03-1_113019.tfd	Nov-30-19	PG	1000.00	66.42	933.58	Dec-1-19	CRP	Acceptable
IG_BH02_WP05_2CAA_03-2_113019.tfd	Nov-30-19	PG	68.00	1000.00	932.00	Dec-1-19	CRP	Acceptable
IG_BH02_WP05_2CAA_03-3_113019.tfd	Nov-30-19	PG	1000.00	66.74	933.26	Dec-1-19	CRP	Acceptable
IG_BH02_WP05_QLABI_03-4_113019.tfd	Nov-30-19	OF	1.24	293	291.8	Dec-1-19	CRP	Acceptable
IG_BH02_WP05_QLABI_03-5_113019.tfd	Nov-30-19	OF	293	800	507	Dec-1-19	CRP	Acceptable
IG_BH02_WP05_QLABI_03-6_113019.tfd	Nov-30-19	OF	800	699.99	100	Dec-1-19	CRP	Acceptable
IG_BH02_WP05_QLABI_03-7_113019.tfd	Nov-30-19	OF	699.99	998.62		Dec-1-19	CRP	Acceptable
IG_BH02_WP05_QLABI_03-8_113019.tfd	Nov-30-19	OF/CM	998.62			Dec-1-19	CRP	Acceptable

Comments on log quality and tool performance:

Peter Giamou — November 30, 2019
Print name — Signature — Date

Olga Fomenko — OAFomenko — November 30, 2019
Print name — Signature — Date

Client: NWMO
Location: Ignace – BH02
Prepared by: PG/OF
Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Dec 1, *2019*

Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_QLABI_04-1_120119.tfd	Dec-01-19	PG	487.10	1.11	485.99	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-2_120119.tfd	Dec-01-19	PG	76.00	69.0	7	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-3_120119.tfd	Dec-01-19	PG	733.00	726.00	7	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-4_120119.tfd	Dec-01-19	PG	686.00	672.00	14	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-5_120119.tfd	Dec-01-19	PG	617.00	610.99	6.01	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-6_120119.tfd	Dec-01-19	PG	601.00	587.00	14	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-7_120119.tfd	Dec-01-19	PG	578.00	565.00	13	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-8_120119.tfd	Dec-01-19	PG	487.00	480.00	7	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-9_120119.tfd	Dec-01-19	OF	420.00	397.39	22.61	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-10_120119.tfd	Dec-01-19	OF	402.00	393.99	8.01	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-11_120119.tfd	Dec-01-19	OF	380.00	368.00	12	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-12_120119.tfd	Dec-01-19	OF	372.00	362.99	9.01	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-13_120119.tfd	Dec-01-19	OF	358.00	340.50	17.5	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-14_120119.tfd	Dec-01-19	OF	331.00	321.42	9.58	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-15_120119.tfd	Dec-01-19	OF	323.00	313.79	9.21	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-16_120119.tfd	Dec-01-19	OF	307.00	297.97	9.03	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-17_120119.tfd	Dec-01-19	OF	288.00	277.99	10.01	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-18_120119.tfd	Dec-01-19	OF	263.00	252.80	10.2	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-19_120119.tfd	Dec-01-19	OF	237.00	225.99	11.01	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-20_120119.tfd	Dec-01-19	OF	217.00	203.5	13.5	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-21_120119.tfd	Dec-01-19	OF	194.00	182.5	11.5	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-22_120119.tfd	Dec-01-19	OF	169.00	155.87	13.13	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-23_120119.tfd	Dec-01-19	OF	141.00	126.78	14.22	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-24_120119.tfd	Dec-01-19	OF	115.00	108.97	6.03	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-25_120119.tfd	Dec-01-19	OF	92.00	74.38	17.62	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-26_120119.tfd	Dec-01-19	OF	78.50	72.00	6.5	Dec-2-19	CRP	Acceptable
IG_BH02_WP05_QLABI_04-27_120119.tfd	Dec-01-19	OF	78.50	73.26	5.24	Dec-2-19	CRP	Acceptable

Peter Giamou December 1, 2019
Print name Signature Date

Olga Fomenko OAFomenko December 1, 2019
Print name Signature Date

Client: NWMO

Location: Ignace – BH02

Prepared by: PG/OF

Job Number: 1671632A

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Dec 2, *2019 /05*
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_2LSA-1000_05-3_QAQC_120219.tfd	Dec-02-19	CM	500.00	399.96	100.04	Dec-03-19	CRP	Acceptable
IG_BH02_WP05_2LSA-1000_05-4_120219.tfd	Dec-02-19	CM/PG	1000.32	336.00	664.32	Dec-03-19	CRP	Acceptable

Comments on log quality and tool performance:

8 locations of bursts of invalid data (10-15 points in a row) were noted for repeat afterwards.

Peter Giamou — December 02, 2019
Print name — Signature — Date

Olga Fomenko — OAFomenko — December 02, 2019
Print name — Signature — Date

Chris Marchildon — Chris Marchildon — December 02, 2019
Print name — Signature — Date

Client: NWMO
Location: Ignace – BH02
Prepared by: PG/OF/CM
Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Dec 3, *2019 /06*
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_2LSA-1000_06-1_120319.tfd	Dec-03-19	PG	340.0	~244	~96	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_2LSA-1000_06-2_120319.tfd	Dec-03-19	PG	250.00	1.70	248.30	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_DualNeutron_6-3_120319.tfd	Dec-03-19	DGI	480.94	3.84	477.1	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_DualNeutron_6-4_ASDERepeat_120319	Dec-03-19	DGI	80.00	29.27	50.73	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_Density_6-5_QAQC_120319.tfd	Dec-03-19	DGI	200.07	99.04	101.03	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_Density_6-6_120319.tfd	Dec-03-19	DGI	280.01	3.02	276.99	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_2LSA-1000_06-7_120319.tfd	Dec-03-19	CM	789.00	769.99	10.01	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_2LSA-1000_06-8_120319.tfd	Dec-03-19	CM	745.00	734.00	11.00	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_2LSA-1000_06-9_120319.tfd	Dec-03-19	CM	707.00	694.99	12.01	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_2LSA-1000_06-10_120319.tfd	Dec-03-19	CM	655.00	641.00	14.00	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_2LSA-1000_06-11_120319.tfd	Dec-03-19	CM	621.00	605.00	15.00	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_2LSA-1000_06-12_120319.tfd	Dec-03-19	CM	585.00	570.00	15.00	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_2LSA-1000_06-13_120319.tfd	Dec-03-19	CM	555.00	540.00	15.00	Dec-04-19	CRP	Acceptable
IG_BH02_WP05_2LSA-1000_06-14_120319.tfd	Dec-03-19	CM	390.00	330.00	60.00	Dec-04-19	CRP	Acceptable

Comments on log quality and tool performance:

Logging program stopped displaying data during run, had to stop run 06-1
DGI tied back into casing as top of hole was off

Peter Giamou — December 03, 2019
Print name — Signature — Date

Olga Fomenko — OAFomenko — December 03, 2019
Print name — Signature — Date

Chris Marchildon — Chris Marchildon — December 03, 2019
Print name — Signature — Date

Client: NWMO
Location: Ignace – BH02
Prepared by: PG/OF/CM
Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Dec 4, *2019 /07*

Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_2PIA-1000_07-1_120419.tfd	Dec-04-19	PG	1.51	500.00	498.49	Dec-05-19	CRP	Acceptable
IG_BH02_WP05_2PIA-1000_07-2_QCQA_120419.tfd	Dec-04-19	PG	500.00	399.00	101.00	Dec-05-19	CRP	Acceptable
IG_BH02_WP05_2PIA-1000_07-3_120419.tfd	Dec-04-19	PG	399.00	1000.00	601.00	Dec-05-19	CRP	Acceptable
IG_BH02_WP05_2PIA-1000_07-4_120419.tfd	Dec-04-19	PG	1000.00	67.37	932.63	Dec-05-19	CRP	Acceptable

Comments on log quality and tool performance:

Peter Giamou — December 04, 2019
Print name — Signature — Date

Olga Fomenko — OAFomenko — December 04, 2019
Print name — Signature — Date

Chris Marchildon — Chris Marchildon — December 04, 2019
Print name — Signature — Date

Client: NWMO
Job Number: 1671632A
Location: Ignace – BH02
Project: Phase 2 Initial Borehole Drilling
Prepared by: PG/OF/CM
Verified by: Christopher Phillips

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Dec 5, *2019 /08*
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_2CAA-1000_08-1_120519.tfd	Dec-05-19	PG	500.02	1000.30	500.28	Dec-06-19	CRP	Acceptable
IG_BH02_WP05_2PCA-1000_08-2_120519.tfd	Dec-05-19	PG	1000.33	69.27	931.06	Dec-06-19	CRP	Acceptable
IG_BH02_WP05_2PCA-1000_08-3_120519.tfd	Dec-05-19	PG	79.01	69.60	9.41	Dec-06-19	CRP	Acceptable

Comments on log quality and tool performance:

Peter Giamou December 05, 2019
Print name Signature Date

Olga Fomenko OAFomenko December 05, 2019
Print name Signature Date

Chris Marchildon Chris Marchildon December 05, 2019
Print name Signature Date

Client: NWMO
Location: Ignace – BH02
Prepared by: PG/OF/CM
Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches
CC: Joe Carvalho
George Schneider

Date / Shift: Dec 6, *2019 /09*
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_QLOBI_09-1_Deviation_120619.tfd	Dec-06-19	PG	1.13	901.00	899.87	Dec-07-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_09-2_120619.tfd	Dec-06-19	PG	901.00	798.88	102.12	Dec-07-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_09-3_Deviation_120619.tfd	Dec-06-19	PG	799.03	999.10	200.07	Dec-07-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_09-4_120619.tfd	Dec-06-19	PG	998.03	496.27	501.76	Dec-07-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_09-5_120619.tfd	Dec-06-19	PG	501.80	0.34	501.46	Dec-07-19	CRP	Acceptable

Comments on log quality and tool performance:

Peter Giamou — December 06, 2019
Print name — Signature — Date

Olga Fomenko — OAFomenko — December 06, 2019
Print name — Signature — Date

Chris Marchildon — Chris Marchildon — December 06, 2019
Print name — Signature — Date

Client: NWMO
Location: Ignace – BH02
Prepared by: PG/OF/CM

Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Dec 7, *2019 /10*
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_2CAA-1000_10-1_120719.tfd	Dec-06-19	PG	1.53	640.18	638.65	Dec-07-19	CRP	Acceptable

Comments on log quality and tool performance:

Peter Giamou — December 07, 2019
Print name — Signature — Date

Olga Fomenko — OAFomenko — December 07, 2019
Print name — Signature — Date

Chris Marchildon — Chris Marchildon — December 07, 2019
Print name — Signature — Date

Client: NWMO
Location: Ignace – BH02
Prepared by: PG/OF/CM
Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	Dec 08, *2019 /12*
	Sarah Hirschorn	**Work Package:**	WP05 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_QLOBI_11-1_120819	Dec-08-19	PG	998.03	693.57	304.46	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-2_120819	Dec-08-19	PG	650.31	614.3	36.01	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-3_120819	Dec-08-19	PG	565.41	551.99	13.42	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-4_120819	Dec-08-19	PG	556.02	543.39	12.63	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-5_120819	Dec-08-19	PG	548	531.52	16.48	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-6_120819	Dec-08-19	PG	548.01	540.34	7.67	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-7_120819	Dec-08-19	PG	542.02	535.16	6.86	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-8_120819	Dec-08-19	PG	532.03	488.97	43.06	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-9_120819	Dec-08-19	PG	493	476.15	16.85	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-10_120819	Dec-08-19	PG	478.01	472.56	5.45	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-11_120819	Dec-08-19	PG	472.05	449.51	22.54	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_QLOBI_11-12_120819	Dec-08-19	PG	451.11	445.08	6.03	Dec-09-19	CRP	Acceptable
IG_BH02_WP05_HPFM_11-13_120819	Dec-08-19	OF	0	0	0	Dec-09-19	CRP	Did not pass
IG_BH02_WP05_HPFM_11-14_120819	Dec-08-19	OF	0	0	0	Dec-09-19	CRP	Did not pass
IG_BH02_WP05_HPFM_11-15_120819	Dec-08-19	OF	0	0	0	Dec-09-19	CRP	Did not pass

Comments on log quality and tool performance:

Peter Giamou　　　　December 08, 2019

Print name　　　Signature　　　Date

Olga Fomenko　　OAFomenko　　December 08, 2019

Print name　　　Signature　　　Date

Client:	NWMO	**Job Number:**	1671632A
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	OF, PG	**Verified by:**	Christopher Phillips

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Dec 27, *2019 /12*

Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_HPFM_12-1_122719.tfd	Dec-27-19	OF	40	400	360	Dec-28-19	CRP	Acceptable
IG_BH02_WP05_HPFM_12-1_122719.tfd	Dec-27-19	OF	420	660	240	Dec-28-19	CRP	Acceptable
IG_BH02_WP05_HPFM_12-1_122719.tfd	Dec-27-19	OF	660	1000	340	Dec-28-19	CRP	Acceptable
IG_BH02_WP05_HPFM_12-1_122719.tfd	Dec-27-19	OF	1000	520	480	Dec-28-19	CRP	Acceptable

Comments on log quality and tool performance:

Olga Fomenko OAFomenko December 27, 2019

Print name Signature Date

Client: NWMO

Location: Ignace – BH02

Prepared by: OF

Job Number: 1671632A

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: Dec 28, *2019 /13*
Work Package: WP05 – Borehole Geophysical Logging
Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH02_WP05_HPFM_13-1_122719.tfd	Dec-28-19	OF	80	580	500	Dec-29-19	CRP	Acceptable
IG_BH02_WP05_HPFM_13-2_122719.tfd	Dec-28-19	OF	280	90	190	Dec-29-19	CRP	Acceptable
IG_BH02_WP05_QLABI_13-3_122719.tfd	Dec-28-19	OF	450.06	427.80	22.26	Dec-29-19	CRP	Acceptable
IG_BH02_WP05_QLABI_13-4_122719.tfd	Dec-28-19	OF	430.03	299.37	130.66	Dec-29-19	CRP	Acceptable

Comments on log quality and tool performance:

Olga Fomenko OAFomenko December 28, 2019
Print name Signature Date

Client: NWMO
Job Number: 1671632A
Location: Ignace – BH02
Project: Phase 2 Initial Borehole Drilling
Prepared by: OF
Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *October 8, 2019 / AM*
Work Package: WP05 – Borehole Geophysical Logging

Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH03_WP05_2PCA_1-1_ 100819.tfd	08-Oct-19	CRP	99.70	-0.04	99.74	09-Oct-19	CRP	Acceptable

Comments on log quality and tool performance:

Logging Scientist:

Christopher Phillips — October 8, 2019
Print name — Signature — Date

Client: NWMO
Location: Ignace – BH02
Prepared by: Christopher Phillips
Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

QUALITY CONFIRMATION REPORT

FORM: NWMO-IGNACE-1671632-WP05-F004

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches
CC: Joe Carvalho
George Schneider

Date / Shift: *October 9, 2019 / PM*
Work Package: WP05 – Borehole Geophysical Logging
Distributed By: Email

Borehole Geophysical Logs:

Log Name	*Log Date*	*Logged By*	*From*	*To*	*Total Length*	*Review Date*	*Reviewed By*	*Data Quality*
IG_BH03_WP05_OBIDEV_2-1_ 100919.tfd	09-Oct-19	CRP	-0.2	99.71	99,91	Oct 09 19	CRP	Acceptable
IG_BH03_WP05_OBI_2.2.tfd	09-Oct-19	CRP	99.71	7.00	92.71	Oct 09 19	CRP	Acceptable
IG_BH03_WP05_OBI_2-3.tfd	09-Oct-19	CRP	30.00	-0.13	30.13	Oct 09 19	CRP	Acceptable
IG_BH03_WP05_ABI_2-4.tfd	09-Oct-19	CRP	99.73	75.94	23.79	Oct 09 19	CRP	Acceptable
IG_BH03_WP05_ABI_2-5.tfd	09-Oct-19	CRP	99.67	15.66		Oct 09 19	CRP	Acceptable
IG_BH03_WP05_ABI_2-6.tfd	09-Oct-19	CRP	20.00			Oct 09 19	CRP	Acceptable

Comments on log quality and tool performance:

Logging Scientist:

Christopher Phillips — October 9, 2019
Print name — Signature — Date

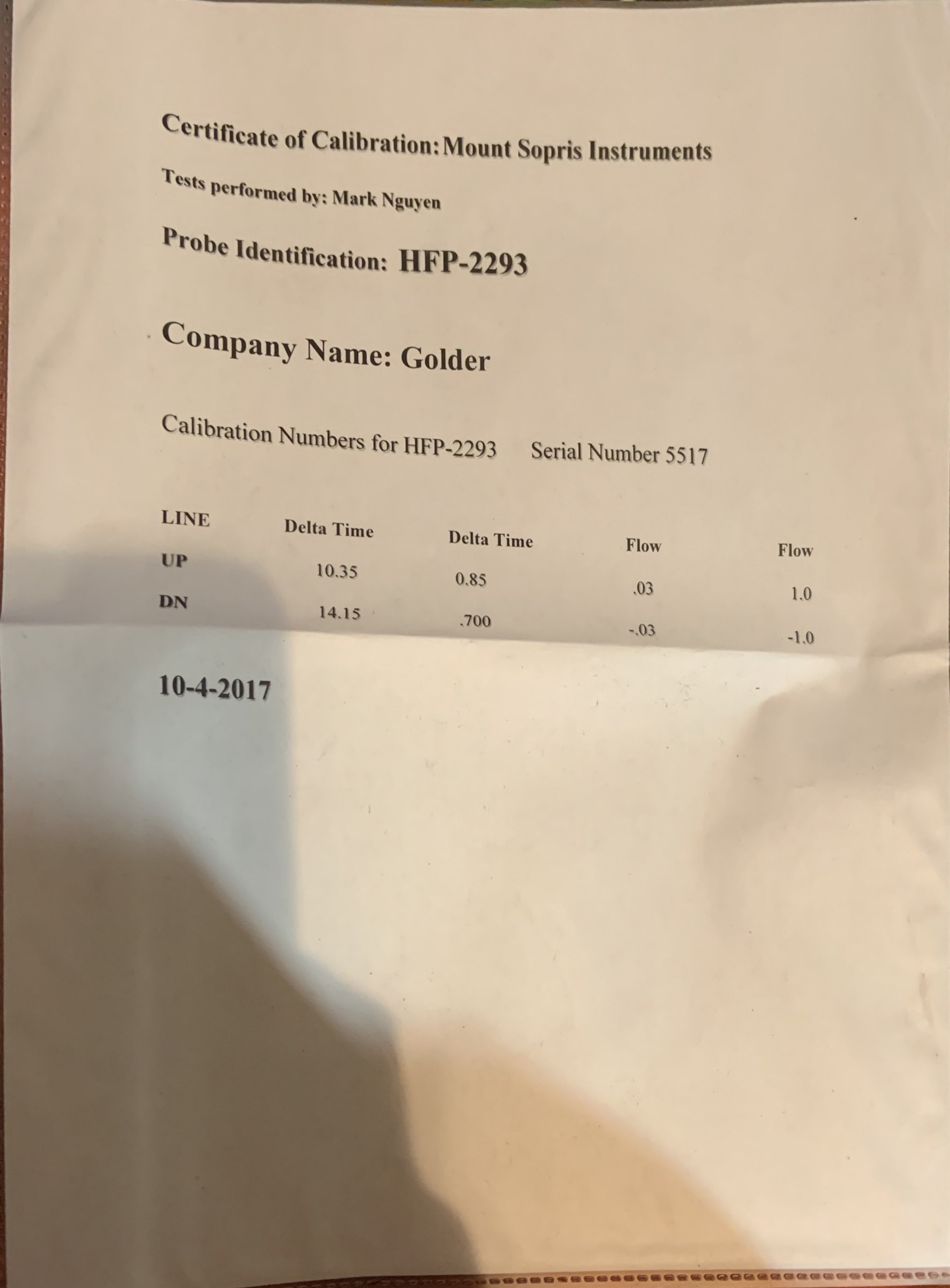
Client: NWMO
Location: Ignace – BH02
Prepared by: Christopher Phillips
Job Number: 1671632A
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

```
-----------------------------------------------------------------------
CALIBRATION REPORT : 2PCA-F Fres, Temp for Matrix (Combo) S/N: 5032 *** After Power
On, wait 90 seconds for data to be valid! ***
-----------------------------------------------------------------------

Name    : Temperature
Source  : MChProc
Alias   : Temperature
Units   : deg C
Calibration Date        : 27/11/19 21:18
Calibration Type        : Linear - 2 pts
CalA    : 0.0155224
CalB    : -16.4919
Reference1      : 6
Reference2      : 34
Value1  : 1449
Value2  : 3252.84
-----------------------------------------------------------------------

Name    : FRes
Source  : MChProc
Alias   : FRes
Units   : Ohm-m
Calibration Date        : 27/11/19 21:18
Calibration Type        : Linear - 2 pts
CalA    : -0.00380681
CalB    : 124.428
Reference1      : 8.5
Reference2      : 88.5
Value1  : 30452.8
Value2  : 9437.82
-----------------------------------------------------------------------
```

```
-----------------------------------------------------------------------
CALIBRATION REPORT : 2PCA Caliper S/N: 5032 (Use Power On to Open Arms)
-----------------------------------------------------------------------

Name    : Caliper
Source  : MChProc
Alias   : Caliper
Units   : cm
Calibration Date        : 08/10/19 17:32
Calibration Type        : Linear - 2 pts
CalA    : 0.00896539
CalB    : -27.6295
Reference1      : 10.2
Reference2      : 15.2
Value1  : 4219.5
Value2  : 4777.2
-----------------------------------------------------------------------
```

```
------------------------------------------------------------------------
CALIBRATION REPORT : 2PCA Caliper S/N: 5032 (Use Power On to Open Arms)
------------------------------------------------------------------------

Name    : Caliper
Source  : MChProc
Alias   : Caliper
Units   : cm
Calibration Date        : 04/12/19 21:18
Calibration Type        : Linear - 2 pts
CalA    : 0.00955711
CalB    : -29.9752
Reference1      : 6.1
Reference2      : 10.2
Value1  : 3774.7
Value2  : 4203.7
------------------------------------------------------------------------
```

```
-----------------------------------------------------------------------
CALIBRATION REPORT : 2PIA Conductivity S/N: 3513 (0-1000ms)
-----------------------------------------------------------------------

Name    : Apparent Conductivity
Source  : MCHProc
Alias   : Apparent Conductivity
Units   : mS/m
Calibration Date        : 04/12/19 01:05
Calibration Type        : Linear - 2 pts
CalA    : 0.213236
CalB    : -2663.84
Reference1      : 0
Reference2      : 463
Value1  : 12492.4
Value2  : 14663.8
-----------------------------------------------------------------------
```



Certificate of Calibration: Mount Sopris Instruments

Tests performed by: Mark Nguyen

Probe Identification: HFP-2293

Company Name: Golder

Calibration Numbers for HFP-2293 Serial Number 5517

LINE	Delta Time	Delta Time	Flow	Flow
UP	10.35	0.85	.03	1.0
DN	14.15	.700	-.03	-1.0

10-4-2017

```
------------------------------------------------------------------------
CALIBRATION REPORT : Auslog Mag Susc SN 513 Probe for Matrix
------------------------------------------------------------------------

Name    : Time
Source  : Tool
Alias   : Time
Units   : sec
Calibration Date        :
Calibration Type        : Linear - 2 pts
CalA    : 0.05
CalB    : 0
Reference1      : 0
Reference2      : 0
Value1  : 0
Value2  : 0
------------------------------------------------------------------------

Name    : Neg.count
Source  : Tool
Alias   : Neg.count
Units   : count
Calibration Date        :
Calibration Type        : Linear - 2 pts
CalA    : 1
CalB    : 0
Reference1      : 0
Reference2      : 0
Value1  : 0
Value2  : 0
------------------------------------------------------------------------

Name    : DC level
Source  : logger
Alias   : DC level
Units   : cps
Calibration Date        :
Calibration Type        : Linear - 2 pts
CalA    : 1
CalB    : 0
Reference1      : 0
Reference2      : 0
Value1  : 0
Value2  : 0
------------------------------------------------------------------------

Name    : Neg.dt
Source  : Tool
```

```
Alias   : Neg.dt
Units   : sec
Calibration Date        :
Calibration Type        : Linear - 2 pts
CalA    : 2.5e-007
CalB    : 0
Reference1      : 0
Reference2      : 0
Value1  : 0
Value2  : 0
-----------------------------------------------------------------------

Name    : Mag Susc
Source  : MChProc
Alias   : Mag Sus
Units   : SI x 10-3
Calibration Date        : 18/07/12 14:10
Calibration Type        : Linear - 2 pts
CalA    : 0.0091087
CalB    : -9.63364
Reference1      : 0
Reference2      : 10
Value1  : 1057.63
Value2  : 2155.48
-----------------------------------------------------------------------
```

FULL WAVEFORM SONIC OPERATIONAL CHECK - BENCH TEST

Date: September 20th, 2019
Operator: K. Smylie
Probe model: QL40-FWS – Full Waveform Sonic
Probe Serial Number (SN): 182511

Test #1 - Bench Test

Test File Name: n/a

Operational Test	Valid	Error
Tool Initialization	Yes	---
Tool Telemetry	Yes	---
Tx test	Yes	---
Rx1 Test	Yes	---
Rx2 Test	Yes	---
Rx 3 Test	Yes	---

Test Results:
☑ Passed
☐ Needs Service Repair

K. Smylie
Test Operator

Operation Center Supervisor

PROTECTED WHEN COMPLETED

NEUTRON CHECK - BENCH TEST #1

Date:	Sept. 18, 2019
Operator:	K. Smylie
Probe model:	Dual Neutron
Probe Serial Number (SN):	6604
Radioactive Source Type & Activity:	Am241Be
Radioactive Source SN:	71-1-1355G

Test #1 - Water

Porosity Value (%):	**100**

Test File Name: **000_WET_MSDDN_6604_71-1355G_D5_121219.tfd**

Neutron	SS Neu cnts	LS Neu cnts	Porosity
Min Counts:	3016.000	0.000	93.551
Max Counts:	3528.000	16.000	101.835
Average Counts:	3245.839	3.085	100.063
Standard Deviation:	74.828	2.485	1.470

Total number of sample data points: 2203

Test Results: ☑ Passed
☐ Needs Re-calibration

Kevin Smylie
Test Operator

Andrew Torgerson
Operation Center Supervisor

Roxanne Leblanc
Senior Data Analyst

DENSITY PROBE CALIBRATION CHECK - BENCH TEST #2

Date:	September 20th, 2019
Operator:	K. Smylie
Probe model:	QL40 DEN – Compensated Dual Density
Probe Serial Number (SN):	6366
Radioactive Source Type & Activity:	Cs137; 3.7GBq
Radioactive Source SN:	4081CO

Test #1 - Leucite Block

Leucite Block (g/cc):	**1.28**

Test File Name:

Near Density	g/cc	Far Density	g/cc
Min:	1.763	**Min:**	1.850
Max:	1.897	**Max:**	1.923
Average:	1.825	**Average:**	1.887
Difference:	0.545	**Difference:**	0.607

Total number of sample data points: 1011

Test Results:

☑ Passed

☐ Needs Re-calibration

Test #2 - Aluminum Block

Aluminum Block (g/cc):	**2.6**

Test File Name:

Near Density	g/cc	Far Density	g/cc
Min:	2.539	**Min:**	2.609
Max:	2.741	**Max:**	2.823
Average:	2.641	**Average:**	2.712
Difference:	0.041	**Difference:**	0.112

Total number of sample data points: 1241

Test Results:

☑ Passed

☐ Needs Re-calibration

Kevin Smylie
Test Operator

Operation Center Supervisor

Roxanne Leblanc
Senior Data Analyst

DGI Geoscience Inc.

PROTECTED WHEN COMPLETED

IP-RESISTIVITY PROBE CALIBRATION CHECK - BENCH TEST #2

Date: Sept. 20, 2019
Operator: C. Crawford
Probe model: QL40-IP – Induced Polarization
Probe Serial Number (SN): 5578

Test #2 - Calibration Box

Test File Name: **IP_5578_Res-Cal-Test_091819.tfd**

Calibrator Setting	SPR	R8"	R16"	R32"	R64"
1	1.13	1.16	1.42	1.92	3.70
10	10.84	9.97	10.73	11.47	13.22
100	105.53	95.63	99.38	97.01	98.91
1000	1098.60	1056.66	988.61	957.93	959.34
10000	9948.80	9985.00	9962.20	9949.70	9953.10

Test Results:
☑ Passed
☐ Needs Re-calibration

C. Crawford
Test Operator

Operation Center Supervisor

Roxanne Leblanc
Senior Data Analyst

DGI GEOSCIENCE INC.

Data QA/QC Record Sheet

Project: ___L-446 Golder - Mississauga NWMO______

Client: ___Golder – Mississauga NWMO____________

Date: _____12/04/2019__________________________

Reviewed by: ___Roxanne Leblanc_________________

PARAMETER:	
Probe (model/sn)	QL Density 6366
Source (sn)	4081CO
Survey File Name	IG_BH02_WP05_Density_6-6_120319.tfd
Depth Start zero	2.51
Depth Start data	200.07
Depth End Data	99.04
Depth End Zero	3.02
Data Point Errors (%)	0.00
QA/QC File Name	IG_BH02_WP05_Density_6-5_QAQC_120319.tfd
Depth Start zero	2.51
Depth Start data	280.01
Depth End Data	1.01
Depth End Zero	3.02
Data Point Errors (%)	0.00
Data Repeats (Survey vs QA/QC)	[✓ Yes] | No
Depth Shift Acceptable (Start Zero vs End Zero)	[✓ Yes] | No
Data points errors below 1%	[✓ Yes] | No

Comments:

1. Data point errors were below 1%.

Data QA/QC Record Sheet

Project: ___L-446 Golder - Mississauga NWMO______

Client: ___Golder – Mississauga NWMO____________

Date: _____12/04/2019_________________________

Reviewed by: ___Roxanne Leblanc_________________

PARAMETER:	
Probe (model/sn)	QL Density 6366
Source (sn)	4081CO
Survey File Name	IG_BH02_WP05_Density_7-5_120419.tfd
Depth Start zero	2.51
Depth Start data	999.4
Depth End Data	198.28
Depth End Zero	3.49
Data Point Errors (%)	0.015
Survey File Name	IG_BH02_WP05_Density_6-6_120319.tfd
Depth Start zero	2.51
Depth Start data	200.07
Depth End Data	99.04
Depth End Zero	3.02
Data Point Errors (%)	0.00
QA/QC File Name	IG_BH02_WP05_Density_6-5_QAQC_120319.tfd
Depth Start zero	2.51
Depth Start data	280.01
Depth End Data	1.01
Depth End Zero	3.02
Data Point Errors (%)	0.00

Data Repeats (Survey vs QA/QC)	[✓ Yes] | No
Depth Shift Acceptable (Start Zero vs End Zero)	[✓ Yes] | No
Data points errors below 1%	[✓ Yes] | No

Comments:

1. Data point errors were below 1%.

Data QA/QC Record Sheet

Project: ___L-446 Golder - Mississauga NWMO______

Client: ___Golder – Mississauga NWMO____________

Date: _____12/03/2019_________________________

Reviewed by: ___Roxanne Leblanc_________________

PARAMETER:	
Probe (model/sn)	Dual Neutron 6604
Source (sn)	71-1-409G
Survey File Name:	IG_BH02_WP05_DualNeutron_5-2_120219.tfd
Depth Start zero	2.27
Depth Start data	1000.00
Depth End Data	414.64
Depth End Zero	4.46
Data Point Errors (%)	0.008
QA/QC File Name	IG_BH02_WP05_DualNeutron_5-1_120219.tfd
Depth Start zero	2.27
Depth Start data	315.20
Depth End Data	199.99
Depth End Zero	4.46
Data Point Errors (%)	0.00
Data Repeats (Survey vs QA/QC)	Yes | [✓ No]
Depth Shift Acceptable (Start Zero vs End Zero)	Yes | [✓ No]
Data points errors below 1%	[✓ Yes] | No

Comments:

1. Data point errors were below 1%.
2. Data points do not overlap

3. Data shift is to large

Data QA/QC Record Sheet

Project: ___L-446 Golder - Mississauga NWMO______

Client: ___Golder – Mississauga NWMO____________

Date: _____12/04/2019_________________________

Reviewed by: ___Roxanne Leblanc_________________

PARAMETER:	
Probe (model/sn)	Dual Neutron 6604
Source (sn)	71-1-409G
Survey File Name:	IG_BH02_WP05_DualNeutron_5-2_120219.tfd
Depth Start zero	2.27
Depth Start data	1000.00
Depth End Data	414.64
Depth End Zero	4.46
Data Point Errors (%)	0.008
Survey File Name:	IG_BH02_WP05_DualNeutron_6-3_120319.tfd
Depth Start zero	2.27
Depth Start data	480.94
Depth End Data	3.84
Depth End Zero	3.84
Data Point Errors (%)	0.01
QA/QC File Name	IG_BH02_WP05_DualNeutron_5-1_120219.tfd
Depth Start zero	2.27
Depth Start data	315.20
Depth End Data	199.99
Depth End Zero	4.46
Data Point Errors (%)	0.00

QA/QC File Name	IG_BH02_WP05_DualNeutron_6-4_ASDERepeat_120319.tfd
Depth Start zero	2.27
Depth Start data	80.00
Depth End Data	29.27
Depth End Zero	2.33
Data Point Errors (%)	0.00
Data Repeats (Survey vs QA/QC)	Yes | [✓ No]
Depth Shift Acceptable (Start Zero vs End Zero)	Yes | [✓ No]
Data points errors below 1%	[✓ Yes] | No

Comments:

1. Data point errors were below 1%.

Data QA/QC Record Sheet

Project: ___L-446 Golder - Mississauga NWMO______

Client: ___Golder – Mississauga NWMO____________

Date: _____12/06/2019__________________________

Reviewed by: ___Roxanne Leblanc__________________

PARAMETER: QL-40 Induced Polarization (Resistivity)	
Probe (model/sn)	QL 5579
Source (sn)	N/A
Survey File Name:	IG_BH02_WP05_IPGR_8-5_120519.tfd
Depth Start zero	10.65
Depth Start data	1000.00
Depth End Data	256.58
Depth End Zero	11.65
Data Point Errors (%)	1.42
QA/QC File Name	IG_BH02_WP05_IPGR_8-4_120519.tfd
Depth Start zero	10.65
Depth Start data	1000.02
Depth End Data	975.56
Depth End Zero	11.65
Data Point Errors (%)	6.98
Data Repeats (Survey vs QA/QC)	[✓ Yes] | No
Depth Shift Acceptable (Start Zero vs End Zero)	[✓ Yes] | No
Data points errors below 1%	[✓ Yes] | No

Comments:

1. Data points errors are ABOVE 1%

Data QA/QC Record Sheet

Project: ___L-446 Golder - Mississauga NWMO______

Client: ___Golder – Mississauga NWMO____________

Date: _____12/07/2019_________________________

Reviewed by: ___Roxanne Leblanc_________________

PARAMETER: QL-40 Induced Polarization (Resistivity)	
Probe (model/sn)	QL 5579
Source (sn)	N/A
Survey File Name:	IG_BH02_WP05_IPGR_8-5_120519.tfd
Depth Start zero	10.65
Depth Start data	1000.00
Depth End Data	256.58
Depth End Zero	11.65
Data Point Errors (%)	1.42
Survey File Name:	IG_BH02_WP05_IPGR_9-7_120619.tfd
Depth Start zero	10.65
Depth Start data	294.98
Depth End Data	74.00
Depth End Zero	11.68
Data Point Errors (%)	2.15
QA/QC File Name	IG_BH02_WP05_IPGR_8-4_120519.tfd
Depth Start zero	10.65
Depth Start data	1000.02
Depth End Data	975.56
Depth End Zero	11.65
Data Point Errors (%)	6.98

QA/QC File Name	IG_BH02_WP05_IPGR_9-6_QAQC_120619.tfd
Depth Start zero	10.65
Depth Start data	602.00
Depth End Data	500.00
Depth End Zero	11.68
Data Point Errors (%)	0.93
Data Repeats (Survey vs QA/QC)	[✓ Yes] | No
Depth Shift Acceptable (Start Zero vs End Zero)	[✓ Yes] | No
Data points errors below 1%	[✓ Yes] | No

Comments:

1. Data point errors are high.

Data QA/QC Record Sheet

Project: ___L-446 Golder - Mississauga NWMO______

Client: ___Golder – Mississauga NWMO____________

Date: _____12/08/2019__________________________

Reviewed by: ___Roxanne Leblanc_________________

PARAMETER:	
Probe (model/sn)	Sonic 082202
Source (sn)	N/A
Survey File Name:	IG_BH02_WP05_ALTFWS_9-8_120619.tfd
Depth Start zero	2.12
Depth Start data	1000.00
Depth End Data	670.00
Depth End Zero	1.96
Data Point Errors (%)	0.28
Survey File Name:	IG_BH02_WP05_ALTFWS_10-3_120719.tfd
Depth Start zero	2.12
Depth Start data	700.02
Depth End Data	30.00
Depth End Zero	2.70
Data Point Errors (%)	4.64
QA/QC File Name	IG_BH02_WP05_ALTFWS_10-2_120719.tfd
Depth Start zero	2.12
Depth Start data	500.03
Depth End Data	399.99
Depth End Zero	2.70
Data Point Errors (%)	0.85

Data Repeats (Survey vs QA/QC)	[✓ Yes] | No
Depth Shift Acceptable (Start Zero vs End Zero)	[✓ Yes] | No
Data points errors below 1%	[✓ Yes] | No

Comments:

1. Data point errors were below 1%.

Stonehenge
Calibration report

Tool ID	4028
Calibration setup	Stonehenge (4π semi-infinite homogeneous source of known activity and density)
Date of calibration	2019-04-11
Version of report	1.0
Commissioned by	Golder Associates Inc.

Calibration by	**Validation by**
Ir. M.Tijs (Medusa Radiometrics BV)	Dr. E.J. van der Graaf (University of Groningen)

MEDUSA Radiometrics BV
PO box 623
9700 AP Groningen,
The Netherlands

www.medusa-radiometrics.com

Parts of this work were performed in collaboration with the Nuclear Accelerator Facility of the University of Groningen, The Netherlands

Contents

Fact sheet

General information	
Tool ID	4028
Model	2SNA-1000-S
Crystal type	NaI
Crystal dimensions	0.875" x 3"
Application	Borehole measurements
Calibration setup	Stonehenge (4π semi-infinite homogeneous source of known activity and density)
Read-out	ALT Matrix logger
Calibration duration	Approximately 2 hours
Date of calibration	2019-04-11
Commissioned by	Golder Associates Inc.

Calibration results	
Energy resolution @662 keV	10.8%
Overall scaling factor	84.7%
Energy scaling factors	
	a_0: -5.800
	a_1: 0.581
	a_2: 0.000
Standard spectra created	^{40}K, ^{232}Th and ^{238}U
Calibration file(s)	1) 4028_0.875x3NaI_11-04-19_KUTh.b2320.mcf

1 Summary

This report describes the calibration of a tool for the measurement of natural gamma radiation from soils and rock formations. The tool under consideration is a NaI “spectra gamma tool”, and does support energy-resolved measurement of radiation. The tool was calibrated against the Stonehenge setup, a semi-infinite cube of brick of density 2.32 kg/l.

The measurements were carried out on 2019-04-11, using the Stonehenge setup at the Medusa facility in Groningen, The Netherlands.

The results of the calibration are:

- The energy resolution of the system is 10.8% @ 662 keV (^{137}Cs);
- The overall scaling factor for the system is 84.7%. This implies that the system provides 84.7% of the theoretical maximum efficiency;
- The energy scaling factors of the system are (a_0=-5.800, a_1=0.581; a_2=0.000).

2 Assignment

The goal of the calibration is to retrieve a set of *standard spectra*; response curves of the tool against a source of unity activity and given geometry. In this case, the tool is calibrated against the Medusa Stonehenge facility.

2.1 Tool description

The tool is a 0.875" x 3" NaI detector and is intended for borehole measurements. The device was readout using ALT Matrix logger.

2.2 Tool drawings

No tool drawings were supplied by the client.

2.3 Measurement setup

The tool was inserted into the Stonehenge setup at the Medusa facility in Groningen, The Netherlands. Inside the setup, the tool was set to log in “time mode”, and during a period of approximately 2 hours, the system recorded gamma spectra.

3 Calibration

3.1 Stonehenge calibration setup

Figure 1. The Stonehenge calibration setup

The tool was calibrated using the Stonehenge calibration setup. Stonehenge is a brick castle (outer dimensions: 120x120x120 cm^3) with a horizontal square (20x20 cm^2) opening at the front in which a detector under test may be entered. The opening was closed on the front and the end by 20 cm thick blocks leaving only a 6x6 cm^2 square opening. The radionuclide concentrations of the bricks were measured using gamma ray spectrometry and are presented in Table 1.

Table 1. Radionuclide concentrations in Stonehenge bricks.

Radionuclide	Concentration (Bq/kg)	Concentration (ppm or %)	Concentration as oxides (ppm or %)
^{232}Th	52	13 ppm Th	14.64 ppm ThO_2
^{238}U	41	3.33 ppm U	3.94 ppm U_3O_8
^{40}K	535	1.69% K	2.08% K_2O

The Stonehenge calibration facility has been modeled using a Monte Carlo Simulation code (MCNPX). In the simulations, the bricks were assumed to be pure SiO_2 with a density of 2.32 kg dm^{-3}. Air was taken as a mixture of N_2 (79 % mass) and O_2 (21% mass) with a density of 1.293 kg m^{-3}.

3.2 Monte Carlo Models

Using the Monte Carlo code, a model was created for the 0.875" x 3" NaI crystal present in the tool. The model also includes most other components of the tool which may have an influence on the spectrum being collected.

For the model, response curves were simulated assuming 1 Bq/kg sources of ^{40}K, ^{238}U and ^{232}Th in the Stonehenge geometry. Such a response curve is called a pure spectrum or *standard spectrum* and represents the spectrum

---

one would measure in the hypothetical situation of a tool inside a Stonehenge-type geometry having an activity of 1 Bq/kg.

3.3 Calibration procedure

The next step in the calibration of a tool is to measure a gamma spectrum inside the Stonehenge setup. The spectrum measured is subsequently energy stabilized, normalized and approximated by the Monte Carlo calculated unbroadened histograms. In this approximation procedure, the following steps are applied:

1. Determination of the spectral resolution of the tool; the unbroadened response histograms are energy-broadened to fit the spectral resolution of the detector;

2. Determination of a general scaling factor describing the difference between a theoretical tool response (response without losses) and the actual response;

3. Determination of a function mapping the “raw” multichannel spectral data to an energy-calibrated spectrum. This procedure basically determines the function needed to map a channel in the MCA spectrum to energy in the energy spectrum. In most cases a quadratic mapping function is used, described by three parameters a_0, a_1 and a_2. These a-factors are the coefficients of the 2nd order function translating the channel numbers into energy.

    - a_0 represents the channel offset present in the multichannel system

    - a_1 represents the (temperature dependent) linear scaling factor;

    - a_2 represents an alinear correction to the channel-energy scaling

    In an ideal multi-channel system, the factors a_0 and a_2 would be zero and a_1 varies solely with the temperature of the system (c.f. Hendriks *et al*, 2001);

These steps are described in detail in Van der Graaf *et al*, 2008. The result of the calibration procedure is a set of standard spectra that can be used in Full Spectrum Analysis to analyze gammaray data measured in the field. The output of the calibration procedure is a Medusa Calibration File (MCF) that can be used in the Medusa spectral analysis software.

3.4 Calibration results

The spectra recorded were summed and analyzed according to the procedure listed above.

The results of the calibration are the following;

- The energy resolution of the system is 10.8% @ 662 keV (^{137}Cs);
- The overall scaling factor for the system is 84.7%. This implies that the system provides 84.7% of the theoretical maximum efficiency;
- The energy scaling factors of the system are (a_0=-5.800, a_1=0.581; a_2=0.000).

The figures below show the measured spectrum along with the unbroadened response histograms and the standard spectra.

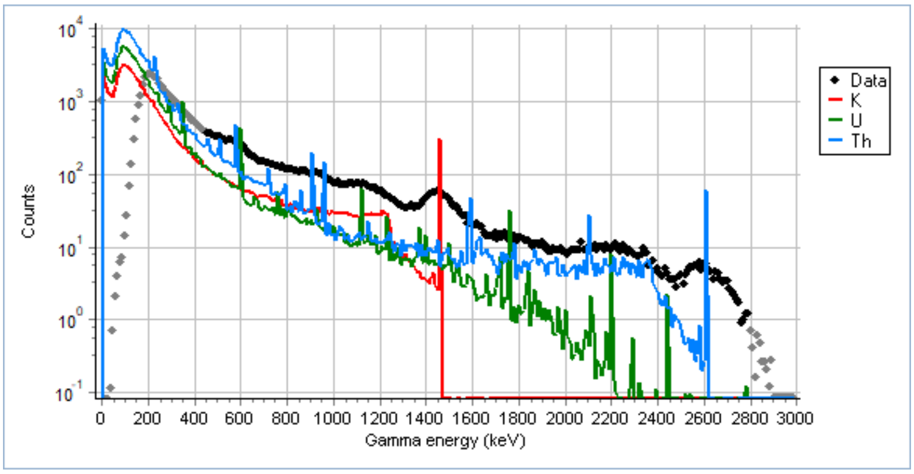


Figure 2. Unbroadened response histograms calculated using MCNPX for the 0.875" x 3" NaI system. The curves represent the response to a ^{40}K source (red curve), a ^{238}U source (green curve) and a ^{232}Th source (blue curve) respectively. Note the huge numbers of decay lines for the U and Th series. ^{40}K has a single decay line at E=1460 keV.

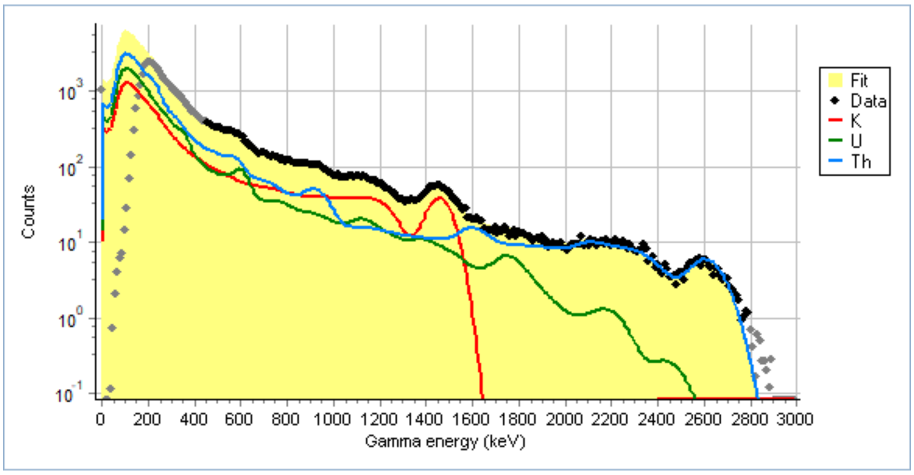


Figure 3. Spectrum measured inside Stonehenge (black dots), standard spectra (red, green and blue for ^{40}K, ^{238}U and ^{232}Th respectively) and resulting fit (yellow surface). The standard spectra are the broadened versions of the lines in the figure above.

3.5 Remarks

1. The overall scaling factor of 84.7% is good;

2. The offset and alinearity of the tool (factors a_0 and a_2) are well within the quality limits for a spectral gamma tool;

3. A few channels in the spectrum had an unexpectedly high number of counts resulting in an artificial peak (see figure 4 below). The origin of these counts is possibly an electronics issue.

   During the calibration process, data was collected in time mode, at an interval of either 1 or 10 seconds. With the interval set to 10 seconds, the peak was less distinct. The additional count rate attributed to the peak was 1.14 counts per second and 0.04 counts per second for a 1 second and a 10 second interval respectively (on a total of 48 counts per second for the complete spectrum).

   When putting a 10 kBq ^{22}Na source next to the tool, the count rate over the complete spectrum increases significantly, which resulted in a smooth spectrum without a visible peak, even for a 1 second interval.

   In the calibration process as described in this report, the 10 second interval spectra were used, where the additional counts were removed manually.

   It is not known if the channels with unexpected high count rates would also be present when the tool is operated in depth mode.

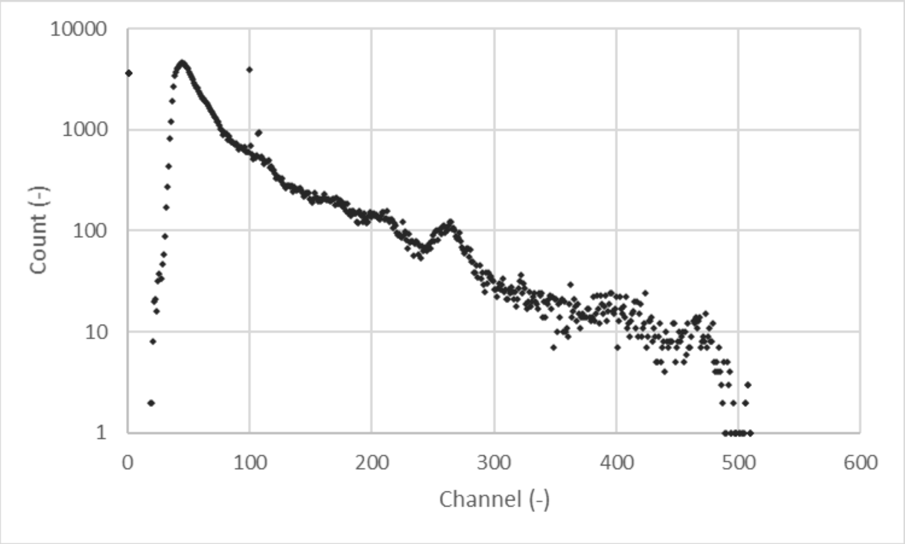


Figure 4. Spectrum measured inside Stonehenge in time mode with a 1 second interval. The unexpected counts are visible around channel 100 – 110.

4 Definition of calibration parameters

Energy resolution

The resolution of the spectrum describes the width of the photo peaks. The resolution is calculated as the full width at half maximum (FWHM) for a ^{137}Cs photo peak at 662 keV. The resolution depends on the configuration and electronics, but it is largely determined by the intrinsic properties of the scintillation crystal.

During the calibration, the resolution has been determined over the complete spectrum. The FWHM depends on the energy of the photo peak and is presented in this report for 662 keV.

Overall scaling factor

A Monte Carlo model has been created to describe the spectrometer to be calibrated. The Monte Carlo model is used to generate the histograms which describe the response of the system to the calibration set-up. Aside from the crystal itself, materials and dimensions of all other system parts may have an effect on the response of the system and need to be included into the model as well. The Monte Carlo model never perfectly describes the system and even systems from the same series may differ slightly. As a result, there is often a slight difference between the measured spectrum and the generated spectrum, which can be corrected for by applying a scaling factor. The scaling factor is typically close to 100%.

Energy spectrum

An energy spectrum consists of 300 channels with 10 keV per channel. An energy spectrum describes a range from 0 to 3000 keV.

Standard spectrum

The standard spectrum describes the response of the calibrated system for 1 unit of activity. Normally, the unit is provided in Bq/kg of a radionuclide in the geometry for which the system has been calibrated. A standard spectrum is also an energy spectrum.

A calibration file (MCF file) contains a set of standard spectra, one for each radio nuclide in the file.

a_0, a_1 and a_2 parameters

The a_0, a_1 and a_2 parameters are the coefficients of a 2nd order function translating the channel numbers of a measured spectrum into energy.

- a_0 represents the channel offset present in the multichannel system;
- a_1 represents the (temperature dependent) linear scaling factor;

- a_2 represents an alinear correction to the channel-energy scaling.

In an ideal system, the factors a_0 and a_2 would be zero and a_1 varies solely with the temperature of the system (c.f. Hendriks et al, 2001). In practice, most systems show some offset ($a_0 <> 0$) and/or some alinearity ($a_2 <> 0$).

The a_0, a_1 and a_2 parameters are independent of the length of the measured spectrum and always transfer a 512 channel measured spectrum into a 300 channel energy spectrum.

Each channel in the measured spectrum describes an energy range in the energy spectrum, the lower bound of which can be calculated using:

$$S_{lower}(i) = a_0 + f a_1 i + f^2 a_2 i^2$$

Here S_{lower} is the lower bound in the energy spectrum for channel i in the measured spectrum. f is a scaling parameter defined as 512 divided by the number of channels in the measured spectrum (for a measured spectrum with 256 channels, f would be 2). Note that the upper boundary of the energy range for channel i is equal to the lower boundary of the next channel:

$$S_{upper}(i) = S_{lower}(i + 1)$$

Gamman and the GammaBase DLL use a highly optimized version of the equations above to convert the measured spectrum to an energy spectrum.

5 References

Hendriks, P.G.H.M. 2003. *In-depth gamma-ray studies: Borehole measurements*. PHD-thesis, University of Groningen, Groningen, 189 pp.

Hendriks, P.H.G.M., Limburg, J. and de Meijer, R.J. 2001. Full-spectrum analysis of natural [gamma]-ray spectra. *Journal of Environmental Radioactivity*, **53**: 365-380.

Hendriks, P.H.G.M., Maucec, M. and de Meijer, R.J. 2002. MCNP modelling of scintillation-detector [gamma]-ray spectra from natural radionuclides. *Applied Radiation and Isotopes*, **57**: 449-457.

Pelowitz, D. B., ed., 2005. MCNPX User's Manual, Version 2.5.0, Los Alamos National Laboratory report LA-CP-05-0369.

Van der Graaf, E., J. Limburg, R.L. Koomans and M. Tijs. 2011.Monte Carlo based calibration of scintillation detectors for laboratory and in situ gamma ray measurements. Journal of Environmental Radioactivity, **102**: 270-282.

DENSITY PROBE CALIBRATION CHECK - BENCH TEST #2

Date:	September 20th, 2019
Operator:	K. Smylie
Probe model:	QL40 DEN – Compensated Dual Density
Probe Serial Number (SN):	6366
Radioactive Source Type & Activity:	Cs137; 3.7GBq
Radioactive Source SN:	4081CO

Test #1 - Leucite Block

Leucite Block (g/cc):	**1.28**

Test File Name:

Near Density	g/cc	Far Density	g/cc
Min:	1.763	**Min:**	1.850
Max:	1.897	**Max:**	1.923
Average:	1.825	**Average:**	1.887
Difference:	0.545	**Difference:**	0.607

Total number of sample data points: 1011

Test Results:

☑ Passed

☐ Needs Re-calibration

Test #2 - Aluminum Block

Aluminum Block (g/cc):	**2.6**

Test File Name:

Near Density	g/cc	Far Density	g/cc
Min:	2.539	**Min:**	2.609
Max:	2.741	**Max:**	2.823
Average:	2.641	**Average:**	2.712
Difference:	0.041	**Difference:**	0.112

Total number of sample data points: 1241

Test Results:

☑ Passed

☐ Needs Re-calibration

Kevin Smylie
Test Operator

Operation Center Supervisor

Roxanne Leblanc
Senior Data Analyst

FULL WAVEFORM SONIC OPERATIONAL CHECK - BENCH TEST

Date: September 20th, 2019
Operator: K. Smylie
Probe model: QL40-FWS – Full Waveform Sonic
Probe Serial Number (SN): 182511

Test #1 - Bench Test

Test File Name: **n/a**

Operational Test	Valid	Error
Tool Initialization	Yes	---
Tool Telemetry	Yes	---
Tx test	Yes	---
Rx1 Test	Yes	---
Rx2 Test	Yes	---
Rx 3 Test	Yes	---

Test Results:
☑ Passed
☐ Needs Service Repair

K. Smylie
Test Operator

Operation Center Supervisor

IP-RESISTIVITY PROBE CALIBRATION CHECK - BENCH TEST #2

Date:	Sept. 20, 2019
Operator:	C. Crawford
Probe model:	QL40-IP – Induced Polarization
Probe Serial Number (SN):	5578

Test #2 - Calibration Box

Test File Name: **IP_5578_Res-Cal-Test_091819.tfd**

Calibrator Setting	SPR	R8"	R16"	R32"	R64"
1	1.13	1.16	1.42	1.92	3.70
10	10.84	9.97	10.73	11.47	13.22
100	105.53	95.63	99.38	97.01	98.91
1000	1098.60	1056.66	988.61	957.93	959.34
10000	9948.80	9985.00	9962.20	9949.70	9953.10

Test Results:

☑ Passed

☐ Needs Re-calibration

C. Crawford

Test Operator

Operation Center Supervisor

Roxanne Leblanc

Senior Data Analyst

Certificate of Calibration: Mount Sopris Instruments

Tests performed by: Ngoc Nguyen

Probe Identification:HFP-2293

Company Name: TerraPlus

Calibration Numbers for HFP-2293 Serial Number 6106

LINE	Delta Time	Delta Time	Flow	Flow
UP	9.0	0.70	.03	1.0
DN	17.40	0.70	-.03	-1.0

12-07-2015

DGI Geoscience Inc.

PROTECTED WHEN COMPLETED

IP-RESISTIVITY PROBE CALIBRATION CHECK - BENCH TEST #2

Date: Sept. 20, 2019
Operator: C. Crawford
Probe model: QL40-IP – Induced Polarization
Probe Serial Number (SN): 5578

Test #2 - Calibration Box

Test File Name: **IP_5578_Res-Cal-Test_091819.tfd**

Calibrator Setting	SPR	R8"	R16"	R32"	R64"
1	1.13	1.16	1.42	1.92	3.70
10	10.84	9.97	10.73	11.47	13.22
100	105.53	95.63	99.38	97.01	98.91
1000	1098.60	1056.66	988.61	957.93	959.34
10000	9948.80	9985.00	9962.20	9949.70	9953.10

Test Results:

☑ Passed
☐ Needs Re-calibration

C. Crawford
Test Operator

Operation Center Supervisor

Roxanne Leblanc
Senior Data Analyst

DGI
DGI Geoscience Inc.

PROTECTED WHEN COMPLETED

NEUTRON CHECK - BENCH TEST #2

Date:	Dec. 12, 2019
Operator:	C. Crawford
Probe model:	Neutron
Probe Serial Number (SN):	6604
Radioactive Source Type & Activity:	Am241Be
Radioactive Source SN:	71-1409G

Test #1 - Water

000_WET_MSDDN_6604_71-1409G_D5_121219.tfd

Porosity Value (%):	**100**

Test File Name:

Neutron	%
Min Counts:	93.863
Max Counts:	102.182
Average Counts:	100.052
Standard Deviation:	1.538

Total number of sample data points: 1001

Test Results:
☑ Passed
☐ Needs Re-calibration

Test #2 - Porosity Block

DualNeutron_6604_71-1409G_ABCD_T1.tfd

Porosity Block (%):	**18.6**

Test File Name:

Neutron	%
Min Counts:	13.080
Max Counts:	22.659
Average Counts:	18.284
Standard Deviation:	1.510

Total number of sample data points: 612

Test Results:
☑ Passed
☐ Needs Re-calibration

Roxanne Leblanc

Test Operator
Operation Center Supervisor
Senior Data Analyst

DGI
DGI Geoscience Inc.

PROTECTED WHEN COMPLETED

NEUTRON CHECK - BENCH TEST #1

Date:	Sept. 18, 2019
Operator:	K. Smylie
Probe model:	Dual Neutron
Probe Serial Number (SN):	6604
Radioactive Source Type & Activity:	Am241Be
Radioactive Source SN:	71-1-1355G

Test #1 - Water

Porosity Value (%):	**100**

Test File Name: **000_WET_MSDDN_6604_71-1355G_D5_121219.tfd**

Neutron	SS Neu cnts	LS Neu cnts	Porosity
Min Counts:	3016.000	0.000	93.551
Max Counts:	3528.000	16.000	101.835
Average Counts:	3245.839	3.085	100.063
Standard Deviation:	74.828	2.485	1.470

Total number of sample data points: 2203

Test Results:

☑ Passed

☐ Needs Re-calibration

Kevin Smylie	Andrew Torgerson	Roxanne Leblanc
Test Operator	Operation Center Supervisor	Senior Data Analyst

DGI Geoscience Inc.

PROTECTED WHEN COMPLETED

FULL WAVEFORM SONIC OPERATIONAL CHECK - BENCH TEST

Date: September 20th, 2019
Operator: K. Smylie
Probe model: QL40-FWS – Full Waveform Sonic
Probe Serial Number (SN): 182511

Test #1 - Bench Test

Test File Name: n/a

Operational Test	Valid	Error
Tool Initialization	Yes	---
Tool Telemetry	Yes	---
Tx test	Yes	---
Rx1 Test	Yes	---
Rx2 Test	Yes	---
Rx 3 Test	Yes	---

Test Results:
☑ Passed
☐ Needs Service Repair

K. Smylie
Test Operator

Operation Center Supervisor

APPENDIX B

Probe Manuals

2GDA-1000
DX Series Density Probe

Mount Sopris Instrument Co., Inc.
Golden, CO U. S. A.
June 29, 2006

Table of Contents

General Information

Overview

The 2GDA-1000 DX series density probe section is a versatile tool that can be used in a wide variety of logging applications. The tool section measures compensated density (dual density), button guard resistivity, and caliper. Since the tool is part of the DX family of probes, it can be operated with any DX probe section. In this manner, additional measurements (such as natural gamma) can be added to the tool string.

The tool section is offered in several different versions. The standard 2GDA-1000 is a dual detector tool optimized for use with a 100-mCi ^{137}Cs source. The 2GDA-1000 source to detector offsets are 20 and 35 cm.

The button guard resistivity measurement uses the tool body as the guard electrode. Subsequently, this measurement is very well focused. The thin bed resolution is better than 2 cm. Proper return current isolation is required for an accurate measurement.

The tool section is designed for operation in 2 to 10 inch (5-25cm) boreholes. The maximum range of the caliper is 10 inches (25 cm)

Controls, Connectors, and Layout

The probe section must be connected to a 2SMA-1000 modem section to make up the minimal tool string. Additional sections (such as a 2SNA-1000 natural gamma section) may be inserted between the 2SMA-1000, modem section and the 2GDA-1000-density section.

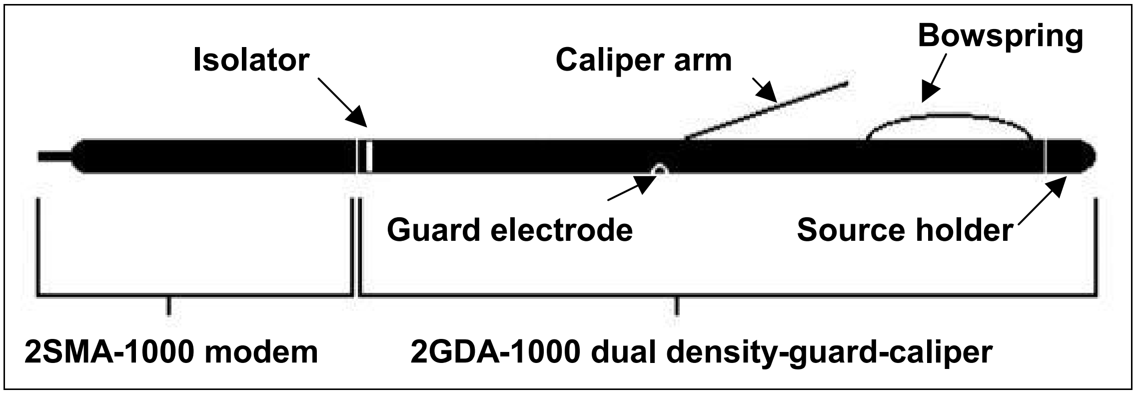


Figure 1: Diagram of the 2GDA-1000 probe.

The DX series probe sections utilize keyed 10-pin connection. For example, to connect the 2SMA-1000 and the 2GDA-1000 sections, insert the male end (lower end) of the 2SMA-1000 into the female end (upper end) of the 2GDA-1000. Rotate one of the sections until the alignment pin engages. Carefully press the two sections completely together. There may be some resistance when joining the sections together due to the o-ring seals in the connection. After the connection is fully seated, anchor the joint with the three hex head screws.

Before the tool can be used, the correct bow spring for the expected hole diameter source must be attached. This should be done before installing the radioactive source. The radioactive source holder is held to the tool with a T-mount for mechanical strength. There are three sets of bow springs, one for 3 - 6 inch (7.5 - 15cm) holes, one for 5 - 8 inch (12.5 - 20cm) holes and another set for 7 - 10 inch (17.5 - 25cm) holes.

Theory of Operation

The compensated density measurement is accomplished using a radioactive source and two radiation detectors. The detectors are designed for use with a ^{137}Cs source (emits 662 KeV gamma particles). They are set to respond to gamma particles having energies of 200 KeV or higher (the Compton energy band). The radiation detectors are comprised of two CsI(Th) scintillation crystals coupled to two photomultiplier tubes. The near detector scintillator is 0.5 inches long and 0.5 inches in diameter; the far scintillator is 1.5 inches long and 0.5 inches in diameter. The detectors are shielded so that they only respond to gamma radiation from the same side of the tool that source energy radiates from. Radiation emanating from the source travels into the formation (into the side of the borehole opposite the bow spring), and is backscattered by Compton scattering. The detectors sense this backscattered radiation. Compton scattering results from gamma radiation interacting with the electrons in the formation, so electron density is measured rather than bulk density.

The detector response is a function of density and the detector offset from the source. As shown in figure 2, for low densities (typically less than 1 g/cc) and close offsets (typically less than 8 cm for ^{137}Cs), the detector response increases with increasing density. The intuitive explanation of this phenomenon is that when density and spacing are small, more electrons cause more backscattering and more radiation at the detectors. As density and detector offset continue to increase, more of the radiation is absorbed and the response decreases with increasing density and spacing. The detector response at 4 cm from the source is on the positive slope of the curve below; that is, the response increases with increasing density. The response for detectors at 11cm or more from the source has a negative slope. The detector response decreases with increasing density for these offsets.

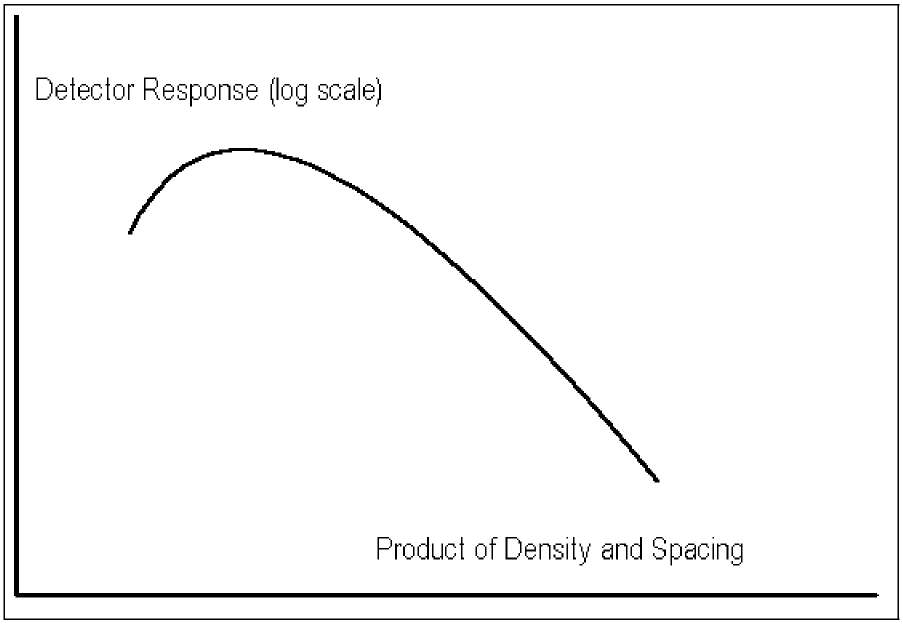


Figure 2: Generalized density detector response.

The volume of investigation for the long offset and short offset density measurements is different. The combination of these two measurements, together with a typical spine and rib chart shown in figure 3, are used to determine compensated electron density. This method compensates for variations in the borehole wall and any distance the tool may standoff from the borehole wall. The compensation assumes that the borehole is filled with water. The correction is different for air or mud filled holes. Calibration and compensation curves for each 2GDA-1000 are supplied in a Technical Addendum to this documentation. The information presented in the Technical Addendum are obtained by performing a 4th or 5th order multivariate regression on density survey data from the 2GDA-1000 at USGS (former U.S. Bureau of Mines) well log calibration facility at the Denver Federal Center. During characterization, data are collected at various densities, borehole diameters, and tool standoffs.

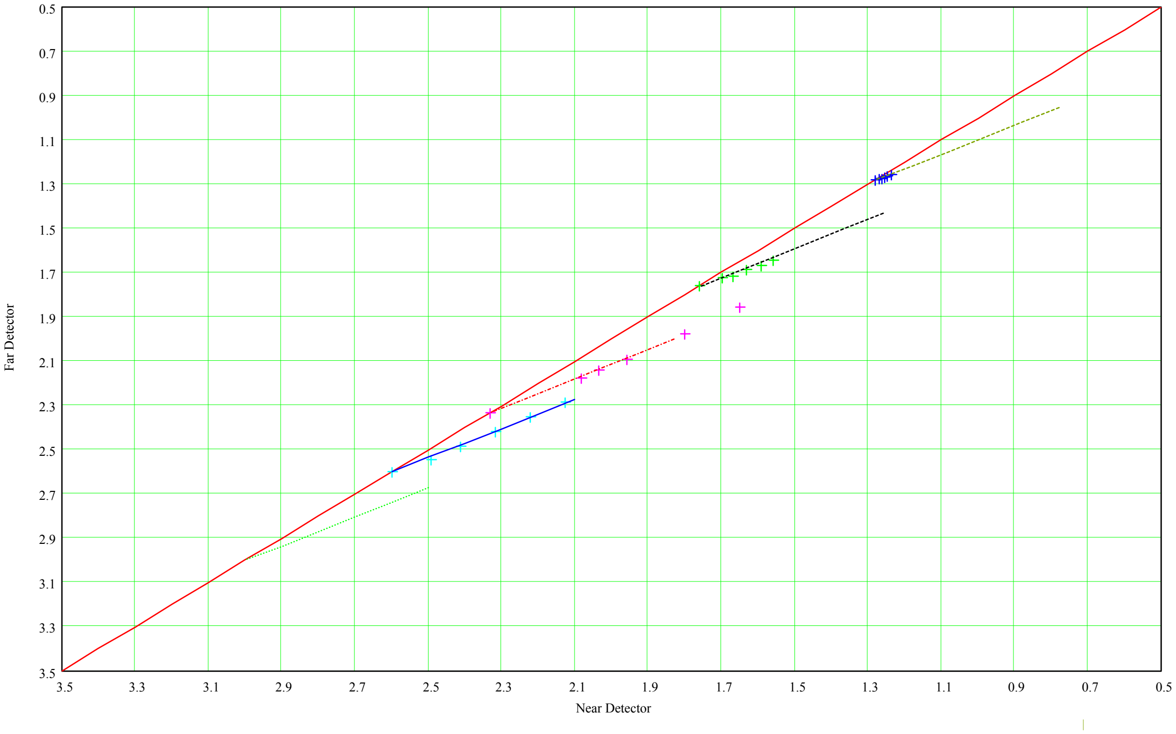


Figure 3: Density Compensation, g/cm^3.

A button electrode on the side of the tool makes the guard resistivity measurement. An AC survey current is emitted from this electrode into the formation. The guard electrode (the tool body) potential follows the button electrode potential and therefore keeps the current from the button electrode from diverging. The result is a highly focused resistivity measurement with a vertical resolution of about an inch (2.5 cm). The survey current path begins at the button electrode, goes out into the formation where the survey current eventually diverges, and returns back to the un-isolated portion of the logging cable. The volume penetrated by the button electrode's current beam (where the current density is high) is the volume investigated by the guard measurement.

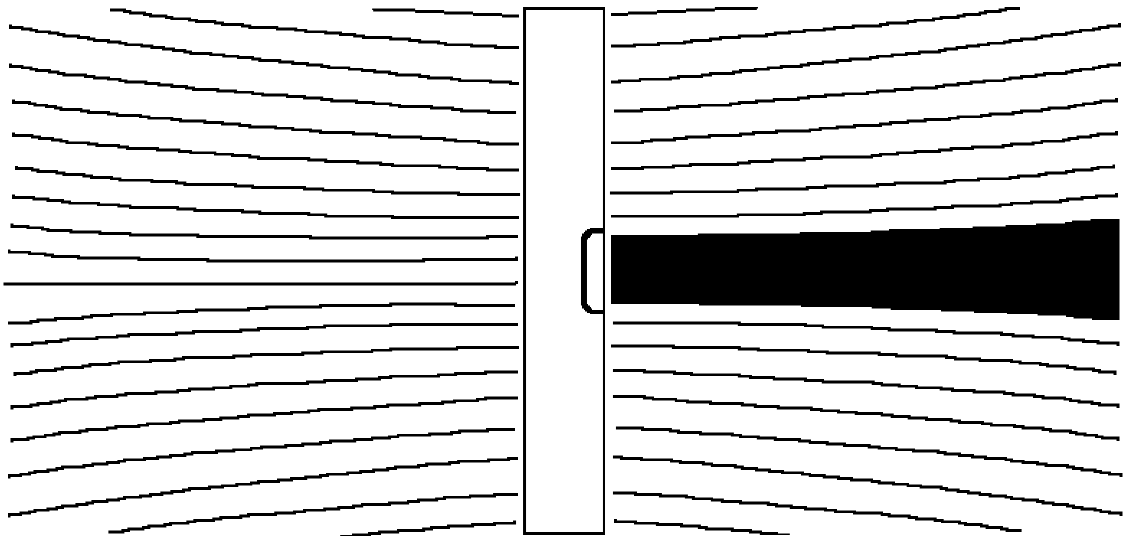


Diagram illustrating operation of the button guard resistivity measurement. Lines indicate direction of current flow from the guard electrode. Solid area is the volume of investigation for the button guard resistivity measurement.

Figure 4: Operation of the button guard resistivity measurement.

The resistivity measurement has been calibrated at the factory and is not a function of wireline length. The calibration information is stored on microchips in the probe, so no user action is required.

The caliper measurement is straightforward. The arm is actuated by a compressed spring. A position sensor (a linear potentiometer) connected to the caliper arm drive piston measures the actual arm position. The relationship between the borehole diameter and the drive piston position is not a linear relationship, but a second order correction by the acquisition software makes the response very linear. As with the guard resistivity, calibration constants are stored in the probe so that initial user calibration is not normally necessary. Depending on borehole conditions, the wear button on the arm will eventually change size, and re-calibration can be made using the MchNum calibration function and known calibration rings.

Specifications

Maximum pressure	3000 PSI
Operation temperature range	-20 to 70 degrees C
Storage temperature	-40 to 100 degrees C
Density range	1 - 4 g/cc
Density accuracy:	0.1 g/cc using a 100 mCi ^{137}Cs source
Density resolution:	0.05 g/cc using a 100 mCi ^{137}Cs source
Guard resistivity range	0-1000 ohm-m
Guard resistivity accuracy	1% of full scale
Guard resistivity measurement resolution	0.5 ohm-m
Guard resistivity vertical resolution	<2 cm
Caliper range	1.75 – 10 inches (4.5-25 cm)
Caliper accuracy	0.1 inch (2.5 mm)
Caliper resolution	0.025 inch (0.64 mm)
2SMA-1000 Modem Section	
Length (assembled)	24.625 inches (62.55 cm)
Diameter	1.5 inches (3.81 cm)
Weight	6 lbs (2.7 kg)
2GDA-1000 Density Section	
Length (when connected to a 2SMA-1000)	126 inches (320 cm)
Diameter	1.75 inches (4.45 cm)
Weight	38 lbs (17.3 kg)

Installation

Installing the 2GDA-1000

The DX series probe sections must use MSLog or Matrix as the data acquisition program. If you do not have the MSLog or Matrix acquisition software, contact Mount Sopris Instruments. After MSLog or Matrix is installed on the acquisition PC, and configured for you winch and logging cable, the 2GDA-1000 probe drivers need to be installed. Use the MSLConfig utility to install the necessary probe drivers or copy the 2GDA tol driver into the \matrix\tol\current directory. Note that there will be different probe drivers for the stand alone 2GDA-1000 or the combination 2SNA + 2GDA model.

The MGX II logger must have either the 5PMA-1000 or 5TMA-1000 modem installed. These modems are only available on the 5MCA-1000 consoles. Units with the modems installed will have the extension /TMA or /PMA appended to the model number. The model number is shown on the logger nameplate located near the power connector. If you don't have the proper modem installed, contact Mount Sopris Instruments.

Select and install the proper bow spring for the borehole diameter. To further refine the bowspring tension, several different springs are supplied which can be installed with the bowspring. The figures below show how to change out the springs, and install the different arms, using the allen keys supplied.

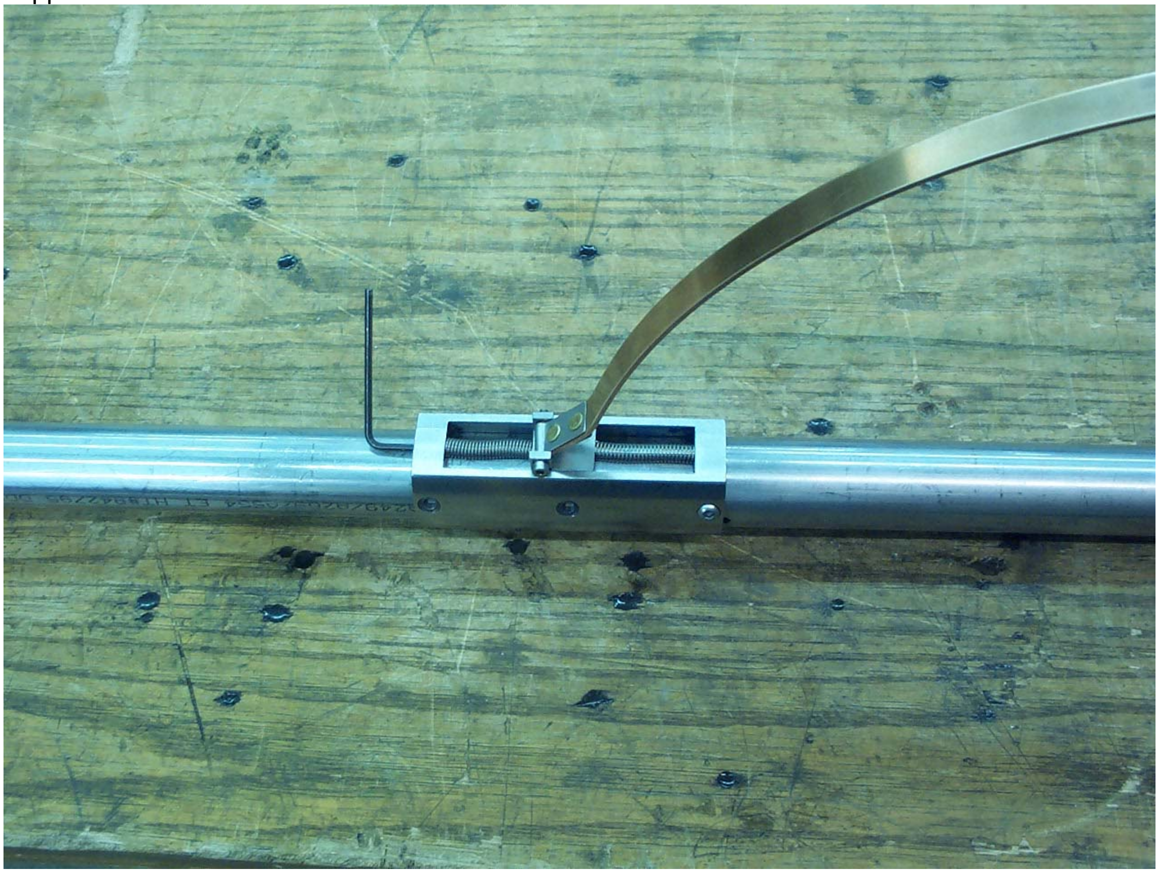


Figure 5 Adjustable top spring mount with bowspring attached

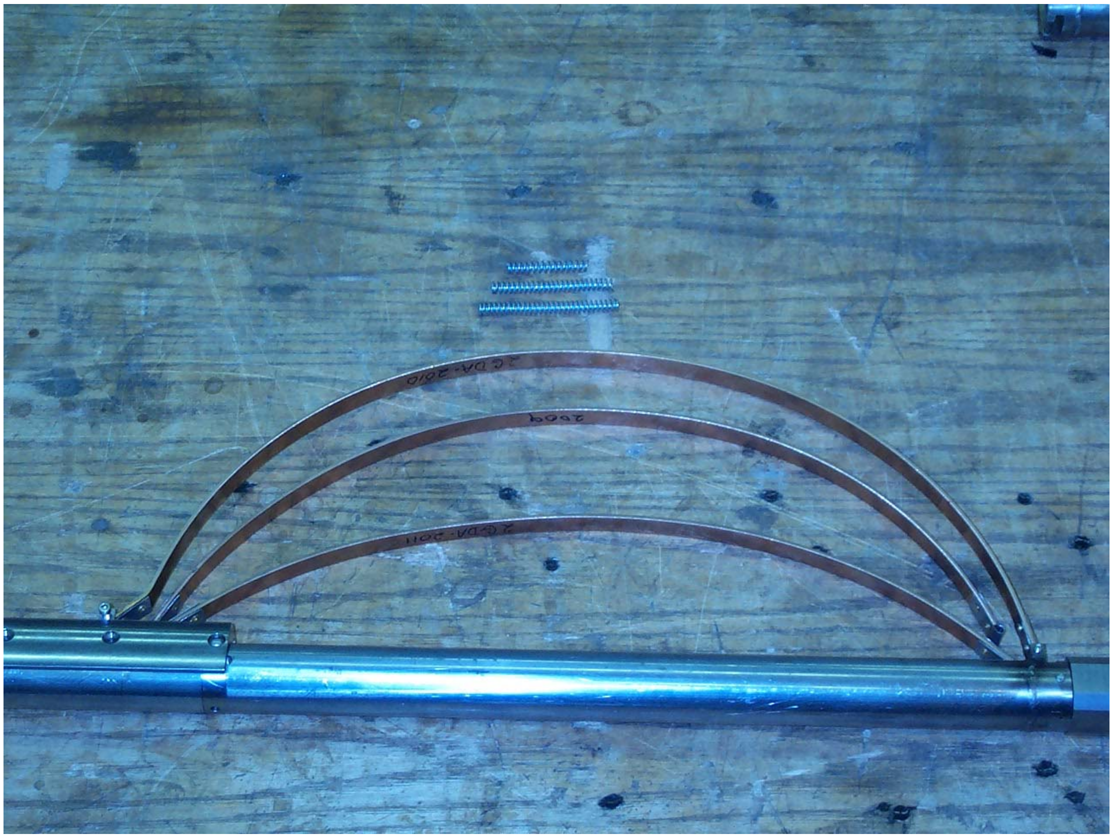


Figure 6 Bowsprings and tension springs for various hole sizes and conditions

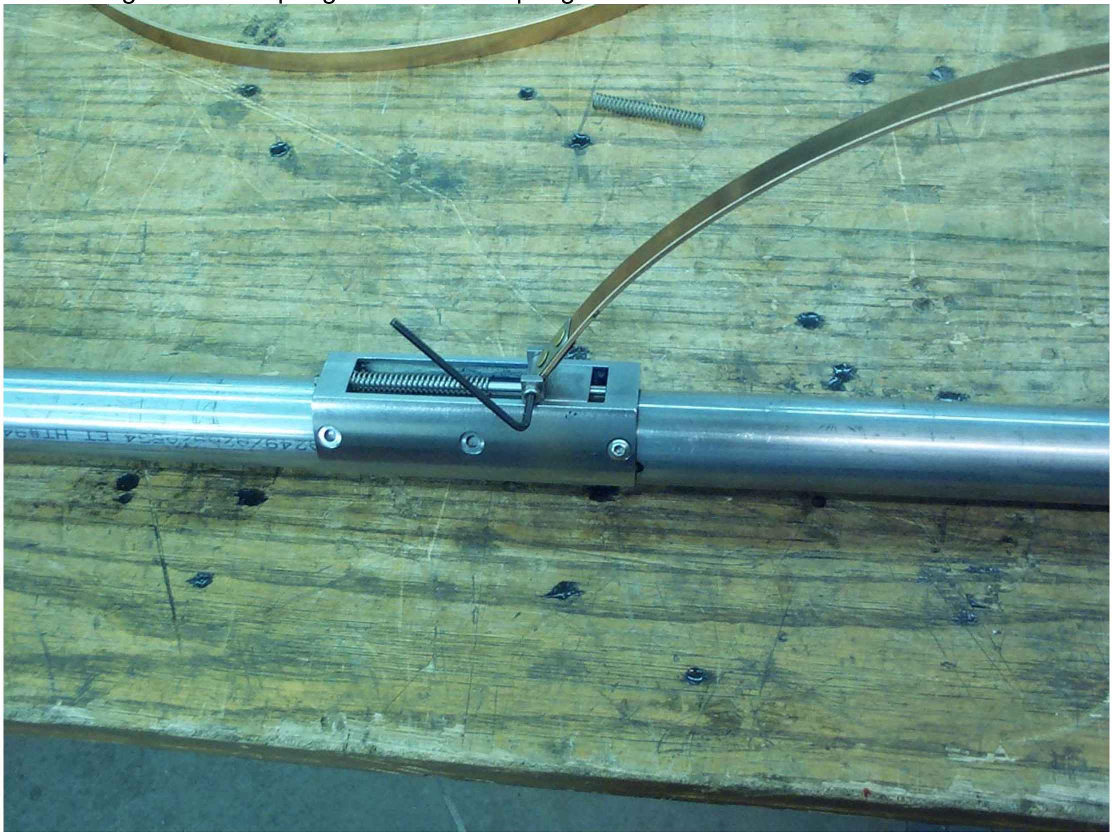


Figure 7 Tightening screw that holds top of bowspring in slider

The top mount can be located at three different distances from the bottom of the probe. The combination of different spring tensions, different mounting points, and different arm lengths should allow the user to find the best spring tension for the expected hole diameter and conditions. A good density measurement requires a good, steady contact between the detector and source section and the borehole wall. While the caliper provides some of this tension, the bowspring keeps the detector against the borehole wall in deviated or slightly enlarged hole sections, providing better data quality. The figure below shows the top bowspring mounting screw and the capture screw (with allen key inserted) that is used to change out the tensioning springs on the slider mechanism.

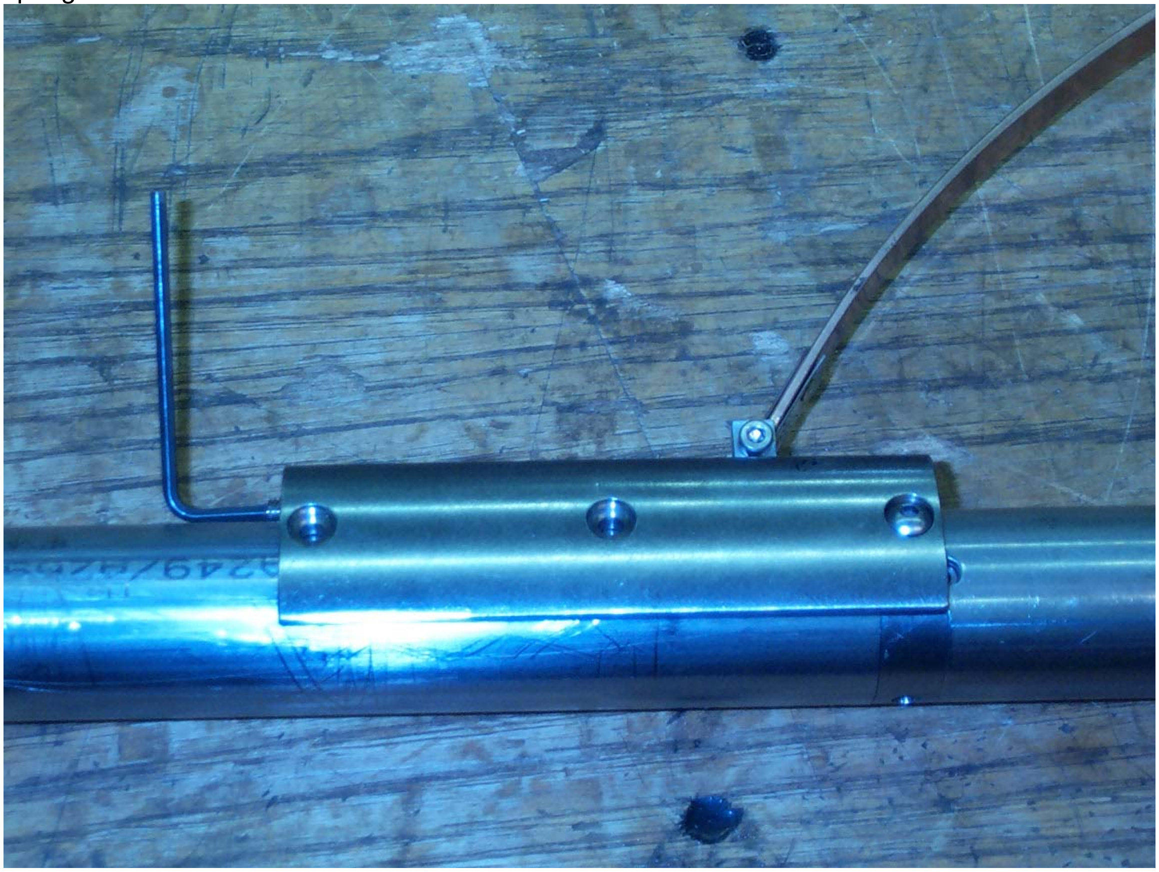


Figure 8 Top mount locating holes, and allen wrench used for tension spring changeout

Setting up Isolation for the Resistivity Measurement

In order for the guard measurement to function properly, the part of the tool and logging cable above the isolator (near the top of the DX section) must be electrically isolated. The 2SMA-1000 is wrapped in a neoprene sleeve. Before logging, make sure that the space between the neoprene jacket on the 2SMA and the isolator on the 2GDA-1000 is well covered with several layers of PVC electrical tape. Also, make sure that several layers of tape cover the tool, cable head, and cable to a length of 20 feet (7 meters) above the cable head. Remember that the tool will be rubbing against the side of the borehole, so make the isolation robust. If there is any break in this insulation, the resistivity measurement will not record accurate, calibrated data

Initial Radioactive Source Installation

If the radioactive source has not been installed in the source carrier, it should be done using the following procedure. Handling of radioactive materials is normally only allowed by persons trained and authorized by government license. It is assumed that this task, and insertion and removal of the source holder from the 2GDA probe will be handled by such qualified personnel.

Locate the necessary components before attempting to install the source. Items needed include a portable radiation counter to monitor source activity, a *medium strength*, thread locking compound (such as "blue LocTite"), a source handling tool and gripper screwdriver supplied by Mount Sopris, the source holder, the T-mount source holder, the source retainer screw, the source shield, and the radioactive source in its transport container.

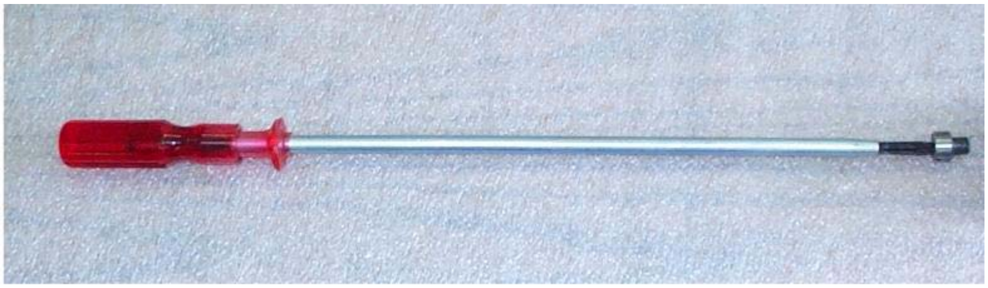
Place all components on a solid table, in an area where unauthorized personnel cannot enter. The standard practice of minimizing time and maximizing distance from the source should be followed. All unnecessary personnel should be asked to leave the area.

The source is machined with an 8/32 thread, which will be mated to a matching 8-32 set screw that is installed in the source retainer screw. Normally, the set-screw is pre-installed in the source retainer screw, leaving about 4-5 threads exposed for connection to the source. The photograph at right shows the source retainer screw with set-screw exposed. The radioactive source capsule is threaded onto the set-screw (after first applying a small amount of removable thread locking compound). This procedure is done using the special long-handled gripper screwdriver and source-handling tool, shown on the following page. Prepare the source retainer screw and set screw first.

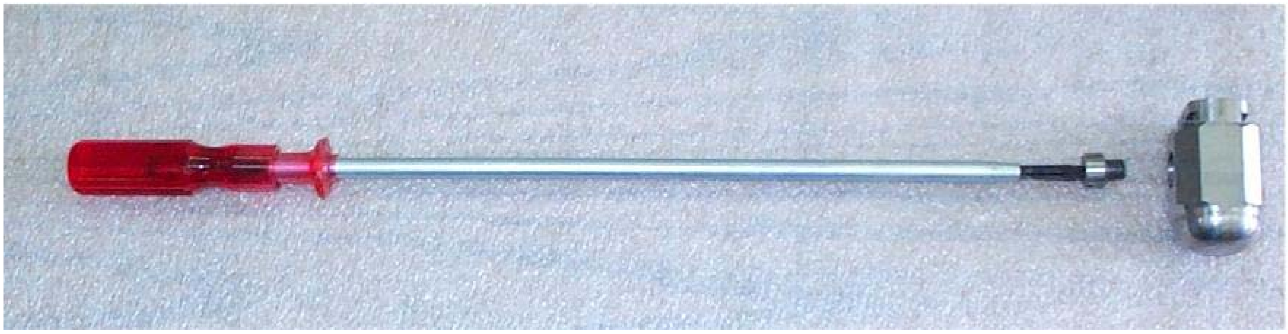
Source Handling Tool

Detail of source in source handling tool.

Then, the source should be loaded in the source handling tool with the 8-32 threaded hole up. The person loading the source then screws the source retainer screw on to the source, using the special gripper screwdriver shown below:



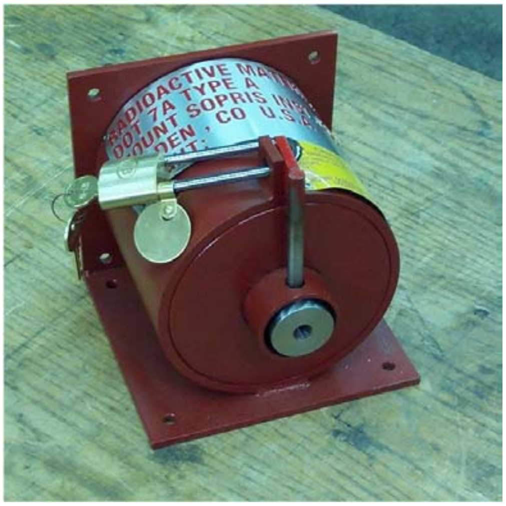
After the source is screwed on to the source retainer screw, the retainer screw is then screwed in to the source holder, as shown below:



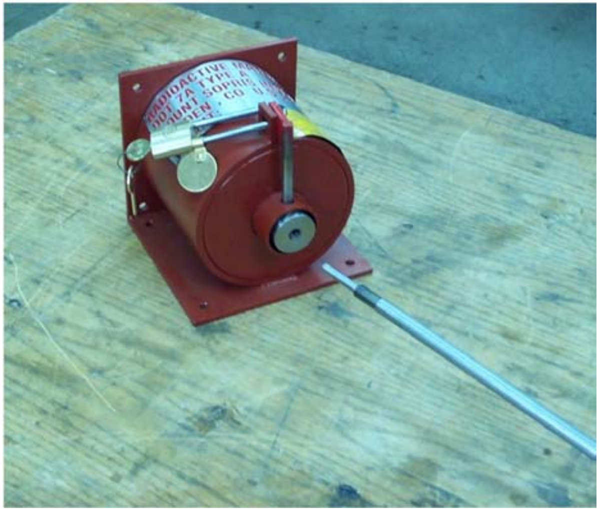
The source holder is then loaded into the source shield, where it is stored when not in use.

Installation of Source Carrier onto 2GDA Probe

A source spacer is used to position the source in the center of the shield and serves as the holder for the source when installing it on the probe. This differs from the older 2GDA design, which required that the user attaché the 2GDA probe to the source while it was in the shield. The new method uses a 3 foot long handling tool that fastens to the source, and the user then installs the source on the tool using the handling tool, as shown in the following pictures



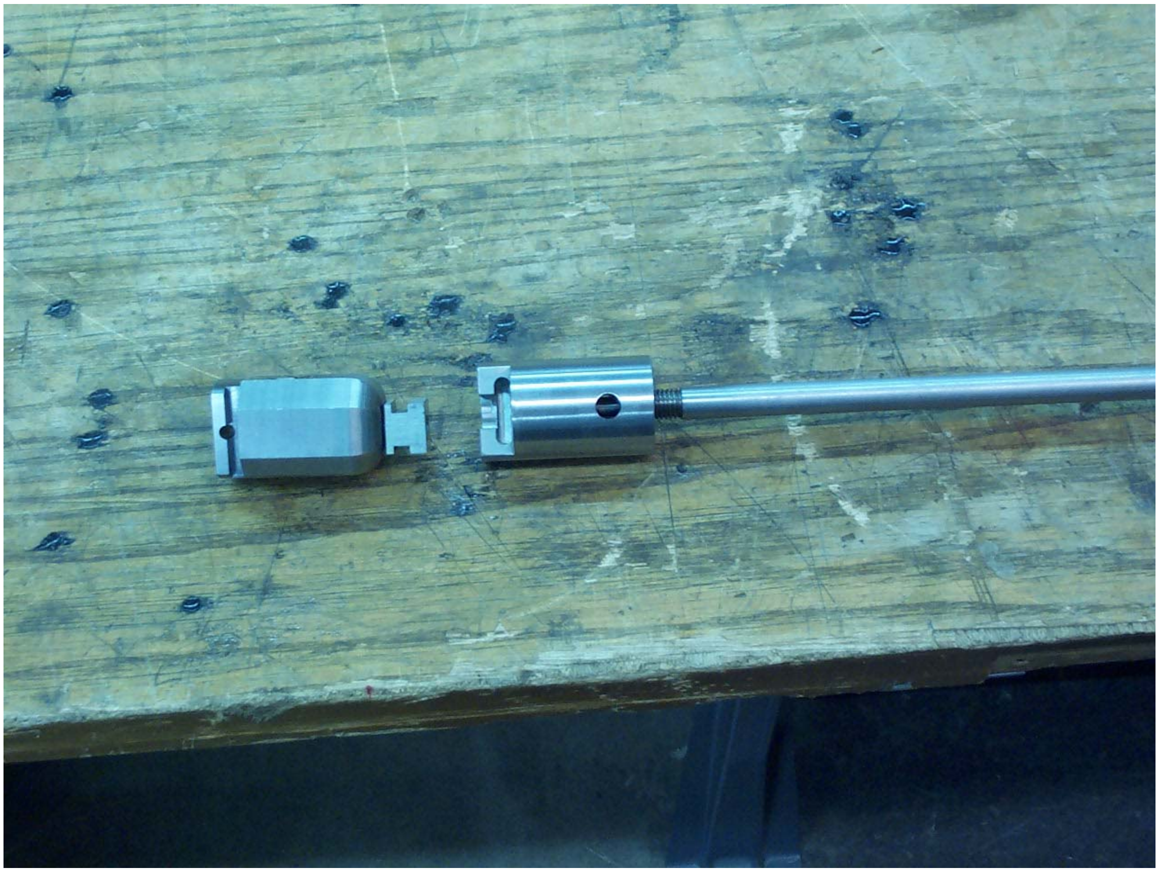
Shield with source and spacer installed



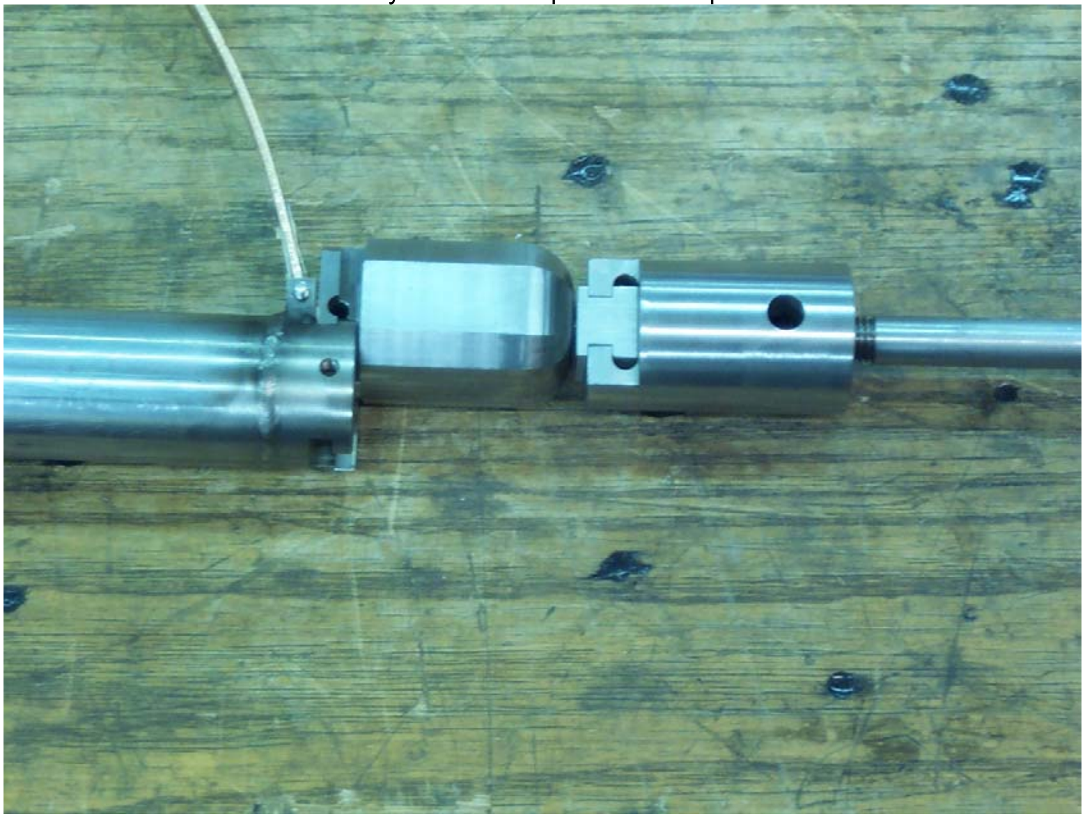
Source handling tool inserted into spacer

To load the source from the shield to the probe, the following procedure should be followed:

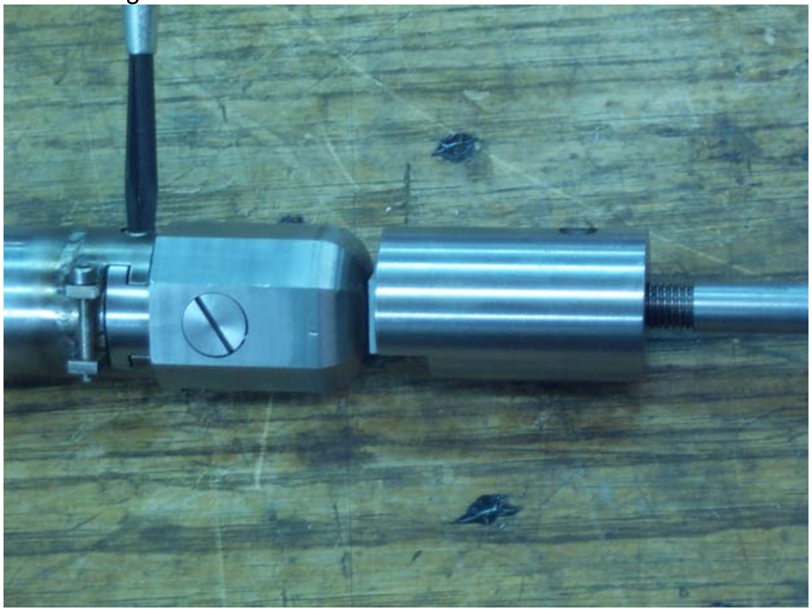
1. Clear the area of all non-essential personnel.
2. Connect the probe to the cable head, leaving plenty of slack cable to handle the probe.
3. Make sure all necessary surfaces are taped with electrical tape to assure good guard resistivity measurement. See previous section for details.
4. Place the source shield near the probe. **Make sure the borehole is covered!**
5. Lay out the required handling tools (source handling tool, and speciallong handled gripper screwdriver).
6. Remove the source holder screw from the t-mount at the bottom of the 2GDA probe.
7. Insert the screw into the special long handled gripper screwdriver and tighten by pushing down. While any screwdriver may be used for this task, the long handled gripper screwdriver maximizes distance from the source during loading, and minimizes exposure.
8. The source is attached to the shield with the spacer fitting that surrounds a mating boss on the source bottom. The handling tool is inserted through the center of the spacer, and the threads on the end are rotated clockwise to firmly engage the source carrier boss. The source carrier is then locked to the spacer so it can be removed from the shield and then transferred to the bottom of the 2GDA probe. The parts of this assembly are shown below:



9. Insert the source carrier into the mating tapered T-mount on the bottom of the 2GDA. It is best if the 2GDA is aligned so that the bowspring is facing up. This orientation allows the source carrier to be easily slid into the probe from top. See below.



10. Next, insert the locking screw using the long-handled screwdriver, and snug up the screw into the far side of the T-mount. Do not over tighten, but make sure the bottom of the screw comes to the outside of the T-mount. Remove the screwdriver from the lock screw. Remove the source handling tool and spacer from the end of the source carrier by twisting it counter clockwise. See below:



11. Remove the long-handled screwdriver and then lift the probe from the caliper area, keeping the source carrier at least 3 feet away from you. Carefully lower the probe into the borehole. It is best if two people perform this operation, but one person can do this if they plan there movements in advance.
12. To remove the source carrier after logging, clean the bottom section off to remove any mud or debris from the lock screw and T-mount area.
13. Lay the probe on a firm surface (tool stands are preferred, and use at least two, to prevent undue sagging of the probe housings. **Cover the borehole**!
14. With the probe bowspring facing up, attach the spacer and handling tool to the bottom of the source carrier and twist the handle clockwise to lock the spacer to the carrier.
15. Remove the source locking screw with the long handled screwdriver.
16. Slide the source carrier out of the T mount and return it to the shield.
17. Place the lock in the spacer hole, and lock the spacer and source in the shield
18. Remove the handling tool by unscrewing it counter clockwise.
19. Clean the bottom of the 2GDA T-mount area, so it will be ready for the next job.

Operating Procedure

Operation

The outline shown below describes the procedure that should be used for most logging operations.

1. Connect the logging cable head to the 2SMA-1000, modem and the rest of the probe string. For the Mount Sopris single conductor cable head, rotate the probe instead of the cable head to make the connection. Inspect the cable head O-ring before making the connection. Make sure that it is not worn, nicked or cut. Apply silicon grease to the o-ring surface. Insure that the mating parts of the cable head and the probe top are clean.
2. Install the bowsprings needed for the hole to be logged. Use the small bowspring for 2 – 8 inch (5 – 20 cm) holes, and the large bowspring for 4 – 10 inch (10 – 25 cm) holes. Make sure that the sliding end of the bowspring is free to slide. It may be necessary to re-stress the bowspring to maintain correct standoff tension.
3. In order for the guard measurement to function properly, the part of the tool and logging cable above the isolator (near the top of the DX section) must be electrically isolated. The 2SMA-1000 is wrapped in a neoprene sleeve. Before logging, make sure that the space between the neoprene jacket on the 2SMA and the isolator on the 2GDA-1000 is well covered with several layers of PVC electrical tape (see figure 5). Also, make sure that several layers of tape cover the tool, cable head, and cable to a length of 20 feet (7 meters) above the cable head. Remember that the tool will be rubbing against the side of the borehole, so make the isolation robust. . If there is any break in this insulation, the resistivity measurement will not function properly.

Figure 5: Proper isolation for resistivity measurement is shown in the view on the right.

4. Insure that the caliper section is properly cleaned greased. See the maintenance section for more information. Refer to the previous section on **Normal Source Loading Procedures** to install source and lower probe in the hole. Do <u>NOT</u> open the caliper while running down hole, as damage to mechanical and electrical parts may result
5. Start the acquisition software (MSLog), select the proper probe driver, and power up the tool. Usually the tool calibrations will be verified at this point. This is outlined in the next section.
6. Place the tool in the borehole. Make sure that the caliper arm is completely closed. Zero the tool at the zero depth reference. Lower the tool to the bottom of the well (or the deepest depth for the survey). Use the 'Tool Settings' dialog to open the caliper arm. Arm opens in ~90seconds.
7. Using MSLog, set the desired depth digitize interval, set the digitizing mode to 'depth up', and start recording a data file. Log up the borehole. As a rule, the logging speed should be about 15 ft.(5 m.)/min. Slower logging is necessary to improve the resolution and repeatability of the data
8. After logging, a repeat section may be recorded as a verification of tool accuracy. Remember to CLOSE the CALIPER before proceeding back down the borehole.

9. When finished logging, close the caliper arm, power down the tool, and remove it from the borehole. Place the tool on the ground or a cleaning stand so that the caliper arm is up, and the radiation is exiting the source holder down towards the ground. Rinse off the source section quickly and remove the source, following the procedure in Normal Source Loading Procedures..
10. After the source has been removed and stored, continue washing the probe, making sure that the t-mount, caliper section, and bow spring areas are rinsed free of mud and solids. Inspect the bowsprings and insulating tape for wear. Replace worn insulating tape as necessary.

Performance Checks and Calibrations

Calibration of the **density** measurement is not complicated. Follow the steps below:

1. Connect the probe to the cable head, and power up the tool as outlined the above operating procedure.
2. Grasp the tool near the probe top (to minimize radiation exposure) and place it on the Lucite density calibration block. A long table or probe stands will be needed to allow the probe to rest horizontally in the calibration blocks with no stress on the probe housings. Lay out the aluminum and Lucite blocks so that the probe can be easily moved between the two blocks and adjusted to rest horizontally in either block.
3. Slide the source out the end of the block and place the source shield near the end of the probe. Install the source as per the Normal Source Installation Procedures section.
4. Insert the probe into the calibration block with the bow spring pointing straight up. Make sure that the probe rests perfectly flat in the grooved radius in the block.
5. Use the clamps to secure the probe to the calibration block.
6. Click on the MChNum window. Right click on the system icon (the small icon in the upper left hand corner of the window). Click on ‘Use Calibrations’ to disable calibrations. Right click the system icon again and then click on ‘Calibration Settings’. The calibration window will pop up.
7. Set the time digitize interval, then set the sampling mode to ‘Time’. The time digitize interval may need to be increased until the NearCPS and FarCPS repeat within 1 or 2 percent.
8. On the calibration window, click on the ‘RawNearDen’ tab. Type ‘1.28’ into the reference edit box for the first point. Click the Use Current button for the first calibration point. This will cause the natural logarithm of the counts to be entered into the first point value edit box. Click on the ‘RawFarDen’ tab and repeat. For the far detector, the natural logarithm of 1/counts is entered into the edit box.
9. Place the tool on the aluminum calibration block, again grasping the tool near the cable head to minimize exposure to radiation.
10. Click on the ‘RawNearDen’ tab. Type ’2.60’ into the reference edit box for the second point. Click the Use Current button for the second calibration point. This will cause the natural logarithm of the counts to be entered into the second point value edit box. Click on the ‘RawFarDen’ tab and repeat. For the far detector, the natural logarithm of 1/counts is entered into the edit box.
11. Click MChNum system icon again and click on ‘Use Calibrations’ to enable calibrations.
12. On the MSLog panel, click the ‘Close All’ button on the ‘Browsers & Processors’ window. Next, restart all processors and browsers by clicking on the name of the browser or processor, and pressing the ‘Start’ button. Note: LASWriter only needs to be started if an LAS output file is desired.

Calibrating the **guard** measurement is not necessary. The guard has been calibrated at the factory and the calibration numbers are electronically stored inside the probe.

To test the operation of the guard measurement you can connect resistors to the A and Guard electrodes detailed in the schematic that follows.

To make the test you will need the following:

- Two 1% resistors, R1 = 432K Ohms and R2 = 75 Ohms, 1/8 watt or better are okay.

- Three clamps to connect the resistors to the probe and some hookup wire.
    - Metal, spring loaded, clamps available from most hardware stores are suitable. Be sure to remove the plastic covers from the tips except leave one tip protected for step 1 below.

1. Connect a clamp to the 2GDA-1000, A electrode so that only the pad is contacted, not the body of the tool. The A electrode is the center electrode of the array.
    a. Connect that electrode to one side of R1 Connect the other side of R1 to cable Armor. Armor is any bare metal on the probe above the isolator near the top of the 2GDA-1000.
2. Connect another clamp to the body of the 2GDA 1000 anywhere below the isolator.
    a. Connect that electrode to one side of R2. Connect the other side of R2 to cable Armor.
3. With the values listed above MSLog MCHnum should indicate approximately 485 Ohm-meters.
4. For approximately 53 Ohm-meters; R1 = 43.2k Ohms and R2 = 30 Ohms.

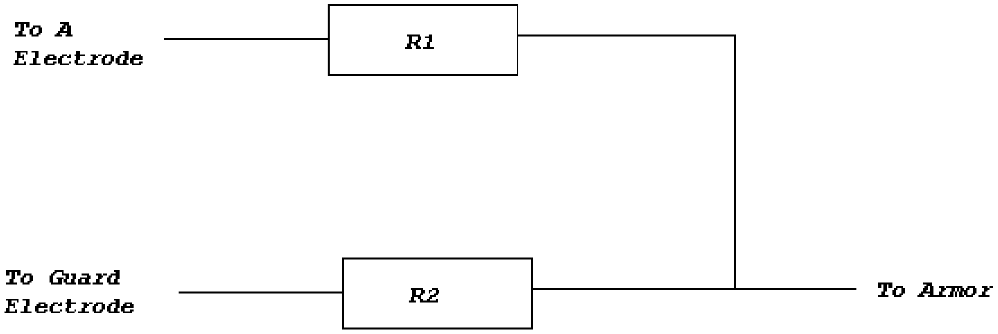


Figure 6 Guard test circuit.

Calibration of the **caliper** measurement generally is not necessary. The caliper has been calibrated at the factory and the calibration numbers are electronically stored inside the probe. If small adjustments need to be made to the caliper calibration, follow the steps below.

1. Connect the probe to the cable head, and power up the tool as outlined in the above operating procedure.
2. Place the probe on a table or stand that will allow the caliper arm to open fully without any external resistance.
3. Use the ‘Tool Settings’ dialog to open the caliper arm. This will take ~90 seconds.
4. Click on the MChNum window. Right click on the system icon (the small icon in the upper left hand corner of the window). Click on ‘Use Calibrations’ to disable calibrations. Right click the system icon again and then click on ‘Calibration Settings’. The calibration window will pop up.
5. Set the time digitize interval (set to 500 ms or 1s), then set the sampling mode to ‘Time’.
6. Place the caliper calibrator around the tool and slide it along the tool until the calibrator can engage the caliper arm. Set the caliper arm to the four-inch position on the calibrator.
7. On the calibration window, click on the ‘Caliper’ tab. If calibrating in inches, type ‘4.00’ into the reference edit box for the first point, otherwise type ’10.16’(cm) into the reference edit box. Click the Use Current button for the first calibration point. This will cause the caliper value sent by the probe to be entered into the first point value edit box.

8. Set the caliper arm to the eight-inch position on the calibrator.

If calibrating in inches, type ‘8.00’ into the reference edit box for the second point, otherwise type ’20.32’ (cm) into the reference edit box. Click the Use Current button for the second calibration point. This will cause the caliper value sent by the probe to be entered into the second point value edit box.

9. Click on the Unit button and enter ‘inches’ or ‘cm’ as desired.
10. Press the store button.
11. Click MChNum’s system icon again and click on ‘Use Calibrations’ to enable calibrations.
12. On the MSLog panel, click the ‘Close All’ button on the ‘Browsers & Processors’ window. Next, restart all processors and browsers by clicking on the name of the browser or processor, and pressing the ‘Start’ button. Note: LASWriter only needs to be started if an LAS output file is desired.
13. Check the calibration by setting the caliper arm to the six inch position and verifying the result indicated by MChNum’s Caliper field is 6.00 inches +/- 0.1 inches (15.24 cm +/- 0.254 cm).

Density Compensation notes

Density for the near and far detectors (NearDen, FarDen) is calculated as the log of the raw detector counts. Compensated Density (CompDen) is then calculated by the formula:
(2.975327597445237 x FarDen) - (1.971171233098749 x NearDen) - 0.014985496037274
This channel is calculated at a depth offset of 0.1575 Meters from the bottom of the tool.

The Compensation channel displayed in MchNum, labeled as Comp, uses the same depth offset as the CompDen channel. The formula for it is: (CompDen – FarDen)

Although it is not strictly necessary, to get the most depth accurate calculations, import the file into Wellcad and recalculate the CompDen and Compensattion channel from the NearDen and FarDen channels, with no depth shift.

Preventative Maintenance

Always keep the probe section connector covered when disconnected. This protects the connectors from mechanical abuse and corrosion. Use the probe section protector caps.

Remember that the gamma detectors are fragile. Use care when placing the tool in the borehole and when traveling down into the borehole. Also, store the tool in a secure place, preferably in a shock resistant container. During transport, logging tools typically endure more shock than when in the borehole.

Keep the caliper mechanism filled with grease at all times. By pumping more grease into the caliper, old dirty grease is flushed out. Continued use of a dirty caliper mechanism may cause the tool to leak. Before and after each usage of the probe, using a standard automotive grease gun and M6 x 1 thread fittings (replacement P.N. 28-957-001), apply grease to the two grease ports. These are located immediately above and below the arm pivot point. Close the arms to apply grease to the upper fitting and open the arms to apply grease to the lower fitting. Remove the two grease fittings and install M6 X 6 SS Set Screws (replacement P.N. 28-185-549) as plugs in the holes before operating the probe in a well. After each log, when possible, clean and flush mud and or contaminants out of the caliper arm assembly. When the caliper arms are open inspect the mechanism on the arms to see if there is adequate grease for lubrication. If not, re-apply grease.

We recommend Dow Corning DC-111 silicone grease for use in water wells. DC-111 is approved for incidental contact with food. There are a number of other greases that will work. High resistance to water washout and temperature range should be the prime considerations in their selection. Any grease used should be compatible with the Buna N O-rings. Buna N O-rings are recommended for: petroleum oils and fluids, cold water, silicone greases and oils, di-ester base lubricants (MIL-L-7808), ethylene glycol base fluids (hydrolubes). It is not recommended for: halogenated hydrocarbons (nitrobenzene, aniline), nitro hydrocarbons (nitrobenzene, aniline), phosphate ester hydraulic fluids (Skydrol, Fyrquel, Pydraul), ketones (MEK, acetone), strong acids, ozone, or automotive brake fluid.

Keep all thread and O-ring surfaces clean and dry. Re-apply grease or silicone compound (O-rings) on a regular basis. Always clean the tool after each use.

Wipe Tests

Most radioactive source licensees are required to perform periodic “wipe tests” on sealed radioactive sources used in well logging. Consult your license for details. To perform a wipe test on the sources normally used in the 2GDA-1000 probe, it is necessary do the following:

1. Place the source shield on a flat surface such as a sturdy table, and ask all unauthorized personnel to leave the area.
2. Use a survey meter to monitor radiation in the area.
3. Always wear a TLD or other exposure badge when handling sources, and especially when performing a wipe test.
4. Place all wipe test components on the same table where the wipe test will be performed, and have all necessary items in place. Make sure that the long handled gripper screwdriver is available and ready to remove the source retainer screw. (Refer to section on Initial Source Installation for more information on how the source is installed and removed from the source holder)
5. Remove the source spacer and source holder from the shield. Source holder is pictured below.
6. With the long handled gripper screwdriver, remove the source retainer screw from the source holder, and pull the screw and source out. Wipe the source cylinder quickly with the wipe test paper (usually moistened with alcohol).
7. Place the wipe test paper on the table, and reinsert the source and retainer screw in the source holder.
8. Return the source holder to the shield. You may use the source spacer as a handling tool to minimize direct handling of source holder.

9. Lock source and spacer into shield
10. Complete wipe test documentation and submit to wipe test vendor for processing.

Troubleshooting

Problems with the Probe

If necessary, only qualified persons should perform electronic troubleshooting.

Disassembly Instructions

To access the inside of the probe, the probe top can be removed from the main housing. To remove the probe top, first remove the three screws just below the black Delrin isolator (use an M3 hex wrench). After removing the three probe top screws, gently pull the probe top out of the housing and disconnect the probe top connector from the upper circuit board. Remove the upper housing locking screw (located just above the resistivity electrode) using an M2 hex wrench.

Next the housing can be unscrewed from the lower section of the probe. The caliper and resistivity circuit boards are located at the top end of the inner housing with the motor just below the circuit boards. In the middle of the probe are the hall-effect sensors that determine the open and closed state of the caliper. The linear potentiometer for the caliper measurement is located just above the housing threads. Feed through wiring connects to the gamma-gamma section below the caliper body.

Disassembly of the gamma detector section is not recommended. To access the gamma-gamma circuitry, remove the three radial screws (use an M3 hex wrench) just below the point where the caliper arm connects to the probe. Next, carefully pull the gamma-gamma section off of the caliper body and disconnect the wiring harness from the gamma circuit board. Remove the locking screw keeping the upper gamma housing from turning. Unscrew the upper gamma housing to expose the gamma-gamma circuit board. .

Common field correctable electronic problems are a broken or shorted wire. A visual inspection of the wiring should be performed before further testing is done.

If electronic testing is to be done, the user should have detailed electronic schematics before proceeding further.

Schematics

2GDA-1000

Drawing Number	Title

Appendix

Suggested QA Procedure

General notes for Quality Assurance (QA) are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. Mt. Sopris acquisition programs record the calibration constants that were used to acquire the data. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedures specify that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.

2PGA-1000
POLY- GAMMA PROBE

Mount Sopris Instrument Co., Inc.
Golden, CO U. S. A.
October 10 2002

Table of Contents

General Information

Overview

The 2PGA-1000 Poly-Gamma is a combination probe providing natural gamma, spontaneous potential (SP), and single point resistance (SPR), measurements. The operator must make these measurements in two separate runs. i.e. the gamma is made in one run and the S.P. , and SPR are made together on the second run. The Poly-Gamma probe is also the base foundation for the Poly series of probes. The Poly-Gamma when connected to a Poly-Resistivity probe is capable of making multiple Normal resistance measurements along with the, above-mentioned, Poly Gamma measurements, all in one run. The Poly-Gamma probe can be operated as a stand-alone probe on an MGX, MGX II or any other system capable of supplying the correct power. The Poly-Gamma connected to the Poly-Resistivity section can only be operated with the MGX II system.

The SP and SPR measurements must be run in open (uncased), fluid filled, boreholes. The natural gamma may be run in any borehole conditions within specifications.

Controls, Connectors, and Layout

Connectors for the tool are as follows. The probe top described below is a Mount Sopris standard single conductor probe top. Other variations of probe tops and wiring can be accommodated at the factory but will not be discussed in this document.

PROBE TOP CONNECTOR:

Pin	Signal	Origin
Probe top housing	Tool power ground	Armor
Center pin in probe top	Tool power positive	Center conductor

BOTTOM CONNECTOR:

This connector is made of rings and the numbering of the rings begins from the inner most ring.

Ring	Signal	Origin
1	SP, SPR or 64" Normal	Electrode below probe top
2	Center conductor	Center pin on probe top
3	Pulse return	Returns Gamma pulse to center cond.
4	Pulse	Output from Gamma circuit
5	Armor	Armor of probe top
6	Gate	From Poly Electric tool

Layout for the tool in general is as follows starting at the bottom of the tool. The bottom connector is below the scintillation crystal and Photo multiplier. Next is the electronic section for the gamma and electric measurements, followed by the electrode and probe top.

Theory of Operation

SINGLE POINT RESISTANCE

The single point resistance measurement is made by passing an AC current between a surface electrode or (mud plug), and the probe electrode. The probe electrode is located just below the probe top and should be the only piece of metal exposed during the logging process. The surface electronics rectifies the AC voltage between these two electrodes and by using Ohms law the system calculates the resistance between them.

Ohms law: $r = E / I$

r = resistance in ohms;
E = potential in volts;
I = current in amperes.

The SPR measurement is the sum of cable resistance, and the resistance based on the composition of the medium, the cross sectional area and length of the path through the medium. Therefore the single point resistance log is not quantitative.

SPONTANEOUS POTENTIAL

The spontaneous potential, also known as self-potential or SP uses the same electrodes as the SPR measurement. This natural potential, which originates from electrochemical differences between borehole and formation fluid, or electro-kinetic "streaming" is measured by the surface electronics. The circuit measures a DC voltage between the surface electrode and the probe electrode. This potential may be positive and /or negative with respect to the surface electrode.

GAMMA

The natural gamma measurement is made by the use of a Sodium Iodide crystal, which when struck by a gamma ray emits a pulse of light. This pulse of light is then amplified by a Photo multiplier tube, which outputs a current pulse. These pulses are then detected, shaped and transmitted up the cable line. The center of the Sodium Iodide crystal is approximately 20 inches, or 508 mm below the center of the R & SP electrode. The approximate location of the gamma detector is referenced by a band of colored tape on the housing of the probe. The user must maintain this band of tape, or marker, as it may tend to degrade with use of the tool. When a Poly Gamma tool is used in conjunction with the Poly Electric tool, the pulses are sent down to the circuitry in the Poly resistivity and sent up the cable in a digital format.

The Poly Gamma tool is capable of using a power source that is positive or negative with respect to the armor. This gives the tool more flexibility and reduces the risk of damage to the tool due to a wrong switch position or the choice of a wrong probe file. Worthy of note is the crystal detector and the Photo multiplier tube. Both of these devices are fragile at best and are quit costly to replace. Sopris has taken steps to afford these items as much protection as possible. These items are subject to be damaged by sudden shock so when shipping or transporting the tool ensure it has proper protection from vibration and shock to reduce the chances of damage.

2PGA-1000: Specifications:

Power Requirements

DC. voltage + or - at probe top. MIN. 52 VDC MAX. 88 VDC@ 35mA nominal, 100mA start up.

Tool Output

Positive pulse, 1.25uS wide, adjustable if required.

Gamma Detector

NaI (tl) .875" dia X 3.0" long 22.22mm dia. X 76.2mm long

Gamma Detector location

Using the center of the R & SP electrode measure towards the bottom of the tool 20”, or 508 mm.

Operating temperature range

14 to 120 degrees F -10 to 50 degrees C

Pressure rating

2000 PSI 13789 k PASCAL

Dimensions

Length	31.3 inches	79.5 cm	
Diameter	1.63 inches	4.1 cm	with neoprene heat shrink and PVC electrical tape
Weight	7 lbs	3.2 kg	

Installation

Installing the Poly - Gamma and support equipment

Before operating the Poly - Gamma probe, determine if the probe will be used as a stand-alone probe, or if it will be used in conjunction with a Poly Series probe.

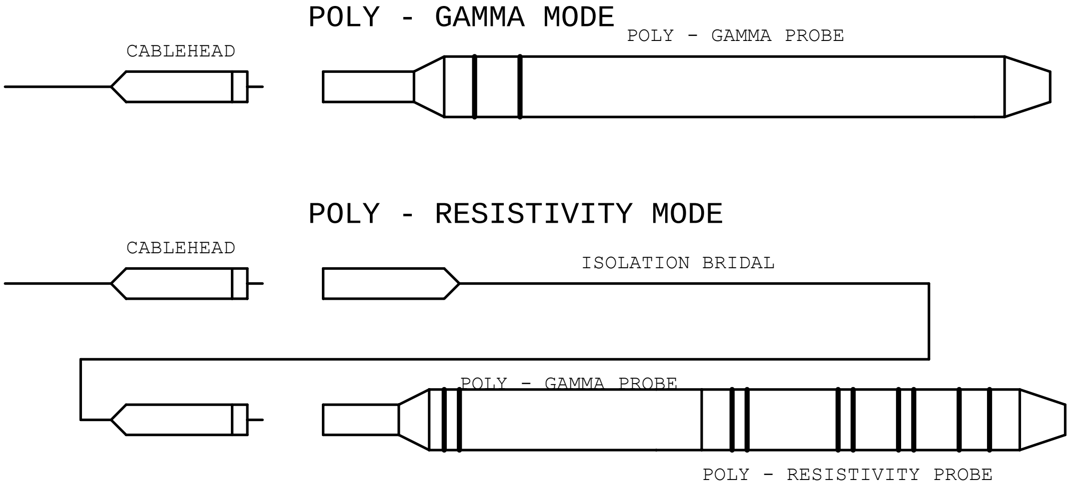
Poly - Gamma stand alone mode

In order to operate the probe in the borehole the lower thread protector must be installed in the bottom of the probe. This thread protector seals out any borehole fluid and shorts two of the rings on the bottom connector of the probe, to send the pulses from the gamma circuitry up the cable line. Remove the thread protector from the probe top then thread the probe top onto the cablehead of the winch assembly. Inspect the o-ring on the cablehead for cuts or abrasions before each use to ensure an adequate seal. If you are going to run a Spontaneous Potential log, the probe top and cablehead, including the spring, must be taped at least 2 feet above the measure electrode. Follow the operating instructions in this manual or in the logging software before logging in regards to this tool.

Poly - Resistivity mode

If the Poly - Gamma is to be used in conjunction with the Poly - Resistivity probe you will need to remove the thread protector from the bottom of the Poly - Gamma probe. Then remove the thread protector from the top of the Poly - Resistivity probe. Thread the two probes together and hand tighten this connection. With a roll of PVC electrical tape, cover all exposed metal surfaces at this connection, not the electrode located just below this connection. Next you will need to install the isolation bridal. This bridal comes as an accessory to the Poly - Resistivity probe and must be used in order to achieve a valid measurement. Install the bridal on the cablehead first by only rotating the bridal and not the cablehead. This is easily done by extending the bridal to its full length. Damage to the cablehead may occur if any other methods are used. Next remove the thread protector from the probe top of the Poly - Gamma and thread the probe onto the bridal assembly, rotating only the probe assemblies. Cover all exposed metal surfaces at this connection, but not the electrode, with PVC electrical tape. Follow the operating instructions in the Poly - Resistivity manual or in the logging software before logging.

CONNECTIONS FOR POLY - GAMMA



Operating Procedure

Operation

SP & SPR MEASUREMENTS

Operation of the Poly - Gamma probe is as follows. These operation instructions discuss running the SP & SPR measurements first, while logging down the borehole. When the desired logging depth has been reached, the system will then be set up to log the gamma measurement out of the borehole. These instructions are only for discussion and the user can determine for themselves which measurement will be taken in what order. After the user has determined from the **Installation** section what mode the tool will be used in, they will also need to set up the surface equipment properly. If the tool is to be used with an MGX version of surface logger, the surface electrode or mud plug must have a good, consistent electrical contact with the earth and the other end plugged into the banana jack located on the logger. Place the tool selection switch on the logger to the ELECTRIC position. Following the instructions for the logger and choosing the correct probe file, turn the PROBE POWER switch to the ON position. At this time the user may want to calibrate the system, which is discussed in detail in the MGX manual. If the system has been prepared for logging, lower the probe into the borehole and zero the tool for proper depth correlation. Follow the logging instructions for the MGX logger to begin the logging process. When the desired logging depth has been reached, turn the TOOL POWER switch to the OFF or center position.

GAMMA MEASUREMENTS

The gamma measurement will now be logged out of the borehole. Following the instructions for the logger, and choosing the correct probe file, place the tool selection switch to the PULSE 2 position and turn the TOOL POWER to the ON position. Follow the logging instructions for the MGX logger to begin the logging process. When the logging process has ended, ensure that the TOOL POWER switch is in the OFF or center position before removing the probe from the cablehead.

USE WITH AN MGX II SYSTEM

To use the Poly - Gamma with the MGX II logging system, obtaining both logs are much the same as described above with the MGX logger. The main difference is the MGX II system has no switches for tool selection or PROBE POWER switches. These functions are achieved on the MGX II logger internally, by the use of electronics and the MSLog software. Complete logging instructions for the MGX II are discussed in detail in the MGX II and MSLog manual and should be referred to if any question arise.

Performance Checks and Calibrations

Calibrations are performed at the factory and require a basic knowledge and understanding of the tool. In the event the user feels the tool needs to be calibrated it is advisable to speak with a representative of Mount Sopris. Performance checks for the gamma measurement can be made on the surface before logging. With the tool powered on and viewing data on the computer screen a small source of natural gamma radiation can be placed in close proximity to the detector area about 6 inches above the bottom of the probe. An increase in gamma counts will then be observed on the computer screen if the tool is working properly. To verify the electric measurements are working the user may use a calibration box, available from Mount Sopris, which when connected properly to the system, provides different resistance and voltage values for calibration. To check the Electrode of the tool for connection place an Ohmmeter set to read ohms on the center conductor of the probe top. Place the other meter lead on the electrode. The meter should read approximately 620 ohms.

Preventative Maintenance

The 2PGA-1000 Poly - Gamma requires little maintenance other than washing the probe off after each use. ***Never take the probe apart. This probe is very difficult to disassemble and requires special steps to be taken in order to gain access to the inside of the probe without damaging the electronics. If you have read this after attempting to disassemble the probe chances are the probe has experienced damage and will need repaired.*** Inspecting o-rings occasionally and keeping the threads on both ends of the probe clean, will minimize problems in the future. The heart of the gamma section is the Photo multiplier tube and the Sodium Iodide crystal. Both units are very fragile and can be damaged if the probe is dropped or sees very abrupt shock. Take great care while handling or packing the probe for transportation.

Troubleshooting

Problems with the Tool

In the event the tool develops a problem, follow the troubleshooting procedure listed below.
NEVER DIS-ASSEMBLE THE PROBE WITHOUT KNOWLEDGE OF PROCEDURE

GAMMA Problems

No counts from the probe.

1. Are the MGX switches set correctly? **PULSE 2** and **ON** positions.
2. Are the PROBE CURRENT and PROBE POWER LED's on?
3. Is the correct probe file being used? MGX and MGX II versions.
4. Check cable for conductive leakage across the center conductor to ARMOR. (20 Meg MIN.)
5. Is the thread protector installed in the bottom of the probe in the stand-alone mode?
6. Is the logger supplying the correct voltage as specified in this document?
7. If no result from the above , consult Mount Sopris.

SP & SPR Problems

Troubles with electric logs.

1. Check that the MGX or MGX II is connected properly.
2. Ensure surface electrode is placed in the ground and add some water to this area if possible.
3. Check switch setting on the logger, **ELECTRIC** and **ON** positions, and ensure the correct probe file is in use.
4. If no response from the above, remove the probe from the cablehead and with a DVM set to read ohms check the resistance from the center pin in the probe top to the electrode located below the probe top. The meter should read 620 Ohms.
5. While cablehead is disconnected from step 4 check the cable line for leakage from the center conductor to the ARMOR. (20 Meg MIN.)
6. If no result from the above consult Mount Sopris.

Disassembly Instructions

The 2PGA-1000 Poly -Gamma Probe should **never be disassembled** unless service is necessary. This is a very difficult probe to disassemble, and is highly recommended that any service be performed by Mount Sopris or a qualified technician. An M3 socket head cap screw has been placed near the top of the probe to prevent the housing from being accidentally turned off the probe top. If probe must be entered first remove the bull-nose from the bottom of the probe. Use a long M3 screw and anchor it into the center of the slip-ring connector in the bottom of the probe. Pull the slip-ring connector straight out and remove the connector from the rear. Now remove the M3 socket head screw from joint of the housing and probe top. Unscrew the housing from the probe top and slide housing off. Use care with the fragile PMT and crystal inside. Reverse steps to re-assemble.

Schematics

Available upon request

2PGA-1000

Drawing # 500S-2094 50002094A.S01 Title: Power Supply, Disc, Pulse Driver

Drawing # 500S-2094 50002094A.S02 Title: High Voltage Osc. And Dynode Multiplier

Drawing # 500S-2067 50002067A.S01 Title: High Voltage Interface

Drawing # 500K-2074 50002074A.S01 Title: Signal Cable Poly Gamma

Appendix

Suggested QA Procedure

General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. The Mt. Sopris family of Acquire programs records the calibration constants that were used to acquire the data. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

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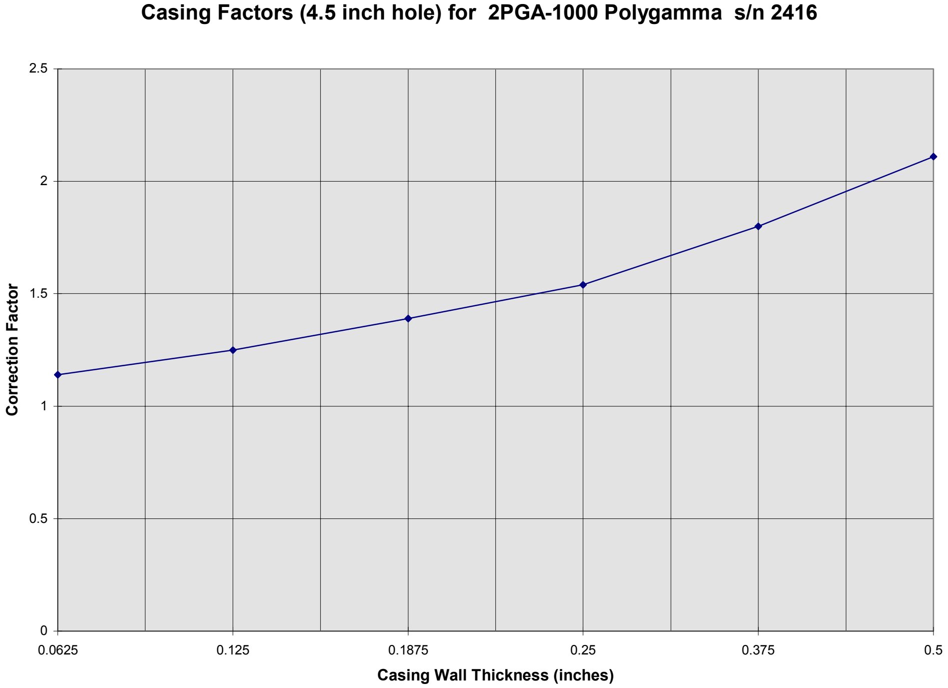
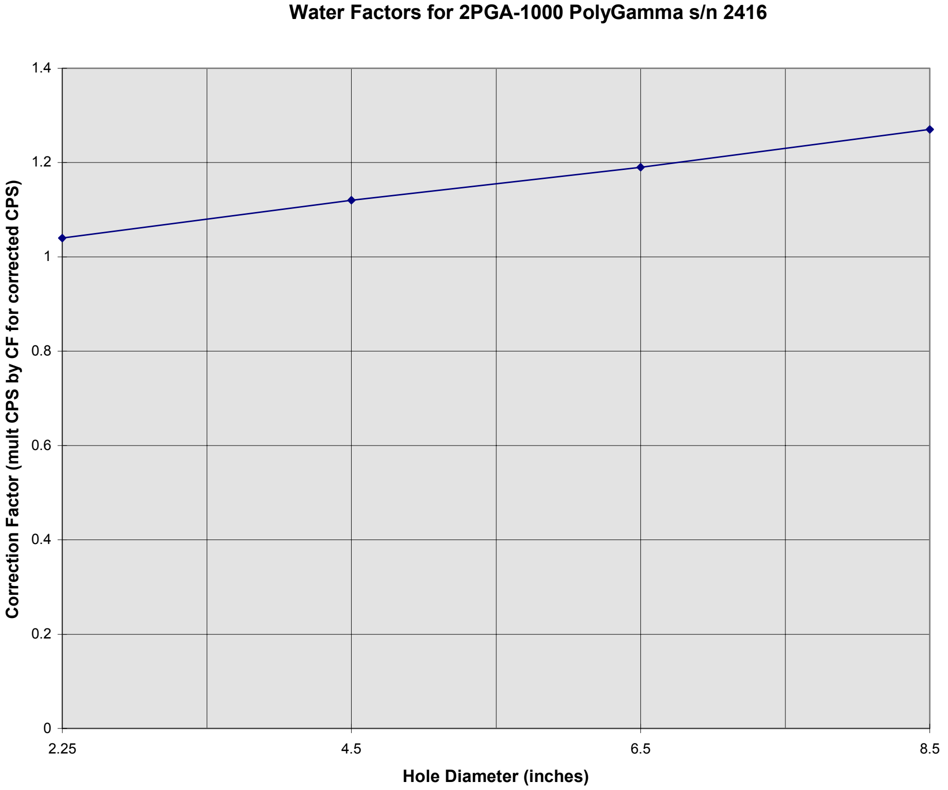
Casing and Water Factors for 2PGA-1000





2PIA-1000
POLY INDUCTION PROBE,
2EMA-1000 Conductivity Probe
(2EMB-1000 and 2EMC-1000)
EMP-2493 and EMP-4493

Mount Sopris Instrument Co., Inc.
Golden CO U.S.A.
September 5, 2002

Table of Contents

Tables and Figures

The majority of information in this manual is from:

Geonics Limited, 1992, “Geonics EM39 Borehole Conductivity Logger Operating Manual”, Geonics Limited, Mississauga, Ontario, Canada.
Geonics Limited, 1986 Technical Note TN-20, “Geonics EM39 Borehole Conductivity Meter Theory of Operation”, Geonics Limited, Mississauge, Ontario, Canada.

General Information

Overview

The 2PIA-1000, 2EMA-1000 and EMP-2493 probes measure the conductivity and magnetic susceptibility of the material around the probe. The 2PIA-1000, probe is provided with the standard Poly probe top, which will enable the user to run the induction tool beneath the 2PGA-1000, Poly - Gamma. It can be run stand alone when used with the 2ADP-1000 probe top adapter.

The 2EMA-1000, probe indicates a tool with the Mount Sopris Instruments single conductor probe top attached while the 2EMB-1000, version has the Mount Sopris 4 conductor probe top. The 2EMC-1000, version has the GOI 4 conductor probe top.

The EMP-2493 is the original designation for the 2EMA-1000 and the EMP-4493 is the four-conductor probe top version. The very first versions of these probes had a different pulse driver circuit than is now used in the 2EMA-1000. The original pulse driver put out a smaller pulse height. Many EMP-2493 have been updated with a pulse drive circuit with characteristics similar to the 2EMA-1000. If you have the original pulse drive electronics you should select the appropriate tool driver in MSLog otherwise the tool driver for the 2EMA-1000 is correct. In all other respects the EMP-2493 is the same as the 2EMA-1000 and comments concerning the 2EMB-1000 and 2EMC-1000 apply to the EMP-4493.

These probes are based on the Geonics EM-39 slimline induction tool. Conductivity is measured in millisiemens per meter (mS/m) and the Magnetic Susceptibility is measured in percent of primary magnetic field. The tool has been optimized for conductivity readings therefore Magnetic Susceptibility measurements may be qualitative rather than quantitative.

In the following document the probes will be referred to generically as the induction probe. Features specific to individual models will be referred to by model number as above. References to the 2EMA-1000 are applicable to the 2EMC-1000 and 2EMB-1000 other than the cable head type they are used with. Earlier versions of the probe such as the EMP-2493 are essentially the same except a few that have the original pulse drive circuitry.

Some models, except for the 2PIA-1000, have Magnetic Susceptibility outputs connected as the negative pulse output. Some tool, driver files have this channel enabled some do not. Consult Mount Sopris Instruments with questions.

Controls, Connectors, and Layout

Controls for the induction probe consist of a rotary switch located inside the probe. To manually set this range switch you will need to open the probe by unscrewing the housing at the joint just above where the black heat shrink ends at the probe top. Remove housing and locate the range select switch using Figure 1. Set the switch as per Table 2. To have the tool select two ranges automatically refer to Table 3. Note that when the automatic selection is desired the switch must be set to position 5, for the surface equipment to be able to switch ranges in the tool. The factory setting is position 5, for the range switch.

Connectors for the 2PIA-1000 consist of the slip ring connector on top of the probe top. This connector mates with an identical connector when the tool is attached to a 2PGA-1000 Poly - Gamma or a 2ADP-1000 Poly top adapter. The slip ring connector has 6 conductors, with 1 being the inner most ring and continuing to the outer ring which is number 6. The ring functions and labels are listed below

Ring	Signal	Origin
1	Not used	Not used
2	Power	CL, center cond.
3	Not used	Not used
4	External Pulse input	Poly Gamma tool, 2ADP
5	Power	Armor
6	Mag Sucep Pulse output	From the EM-39 tool

Table 1   2PIA-1000 Poly Probe Top Connector

Layout for the tool in general is as follows, starting at the bottom of the tool. On the bottom of the housing is a black Delrin thread protector that can be removed and replaced with the weight section provided with the probe. The top of the housing is about 16cm below the probe top. At the top of the probe is the thread protector and Poly or other style probe top. Internal electronics from the bottom of the tool consist of a series of coils and In-phase and Quadrature phase support electronics. Next would be the amplifier board connected to the anticoincidence board. These two boards perform the range switching and pulse driving capabilities of the tool.

Theory of Operation

The conductivity measurements are made by using a magnetic field to induce an electric field, which in turn produces electric currents in the material being surveyed. Because the magnitude of these currents is proportional to the conductivity of the material being measured, the magnetic field generated by the induced electric currents is measured. At high conductivities the accuracy of the induction tool diminishes due to skin effect.

The magnetic field at a given point is composed of the primary magnetic field and the magnetic field produced by the material as a result of being immersed in the magnetic field. The ratio between these fields is the magnetic susceptibility. The magnetic susceptibility measurement works best when the conductivity is low. A different probe model is available that has a modified coil array, which is optimized for the magnetic susceptibility measurements. Consult factory for more information about this type of tool.

The coil array in the induction probe has been designed so that it is not sensitive to material at a radial distance smaller than about 10 cm from the probe axis. The reason for this is to reduce sensitivity to the borehole fluid. The vertical resolution of the tool is 65 cm. This is measured as the vertical distance where the response is more than half the maximum response to an infinitely thin bed. The volume of investigation is similar to that of the 40 cm normal resistivity probe, therefore the induction tool and the normal resistivity tool give similar responses. The shape of the volume of the investigation is radically different between the two tools. See Geonics technical note TN-20 for more details on the theory of the induction logging and the response of the EM-39 conductivity probe.

The receiver circuit rectifies the received signal using a synchronous rectifier and generates two DC voltages, one proportional to the average value of the quadrature phase component of the received signal (with respect to the primary magnetic field), and another proportional to the in phase component of the received signal. The quadrature phase component is proportional to the conductivity and the in phase component is related to the magnetic susceptibility.

These DC voltages are then converted into pulse trains whose frequencies are proportional to the measurements. These pulses are sent up the logging cable for counting at the surface. The probe sends an ~ 12.5 KHz pulse train to indicate a measurement of zero, and ~ 17.5 KHz pulse train indicates a full, scale measurement. Positive pulses are sent and represent the millisiemens per meter (conductivity). Negative pulses are sent to indicate either the magnetic susceptibility if the tool is connected to a 2ADP-1000 adapter or the gamma count rate from the Poly - Gamma tool if the unit is connected to a 2PGA-1000.

The reason a zero count rate of 12.5 KHz was selected is that in the presence of metallic objects negative readings occur. These objects are commonly smaller than the volume of the investigation of the probe, thus the mechanism used to subtract the primary field and the response from borehole fluid can cause negative readings. This can be useful information.

Range of measurement is controlled, by changing the gain of the receiver circuit. The gain can be changed manually in the probe or by applying different polarities to the probe for power. These polarities set a latching relay in the tool, which controls the gain setting. Only two different ranges are achievable by this method.

Installation

WARNING Fragile

Because the tool housing is non-metallic, thin wall fiberglass it should be treated with extra care. Do not drop, bend, or otherwise stress the tool or leakage can result from fractures in the fiberglass housing or its metal joints.

Installing the 2PIA-1000

Installation of the probe only requires that you have decided to either run the tool under the Poly Gamma or as a standalone probe. In the standalone mode you should attach the 2ADP-1000 Poly to MSI single conductor cablehead adapter to the top of the probe. Next attach the probe string onto a Mount Sopris single conductor cablehead connected to the winch. The 2PIA-1000 probe is constructed of lightweight fiberglass and may need an additional weight section installed when logging in mud - filled boreholes. To do this, loosen the setscrew in the black Delrin cone on the bottom of the probe and unscrew the cone. Install the weight section in the reverse manner.

Installing the 2EMA-1000, EMP-2493

As this probe runs only stand alone you attach the probe to the appropriate cable head and winch. The 2EMA-1000 probe is constructed of lightweight fiberglass and may need an additional weight section installed when logging in mud - filled boreholes. To do this, loosen the setscrew in the black Delrin cone on the bottom of the probe and unscrew the cone. Install the weight section in the reverse manner. Select the appropriate tool driver.

Range Selection

Range selection is determined by the wiring of jumpers in the probe. If the probe has the factory setup then the polarity of the voltage to the probe selects one of two ranges. The third range can be manually selected by removing the housing of the probe and manually selecting the proper range with the range select switch as detailed below. The probe can also be set to operate in one range regardless of the polarity of the voltage applied to the probe top by setting the Range select switch to the desired position 2 through 4.

Probe Range Select Switch Position	Conductivity Range
2	0 - 10,000 milliSiemens/meter
3	0 - 1000 milliSiemens/meter
4	0 - 100 milliSiemens/meter
5*	Select Range “A” or “B” from the surface

Table 2 Range Select Switch

Range Selection	Range “A”	Range “B”
0-100 mS/m	JP12 to JP11	JP12 to JP13 *
0-1000 mS/m	JP10 to JP11 *	JP10 to JP13
0-10000 mS/M	JP11 to JP 9	JP9 to JP13

Table 3 Range Jumper Installation

Note: Only two jumpers are to be installed at any one time.
* denotes factory setting

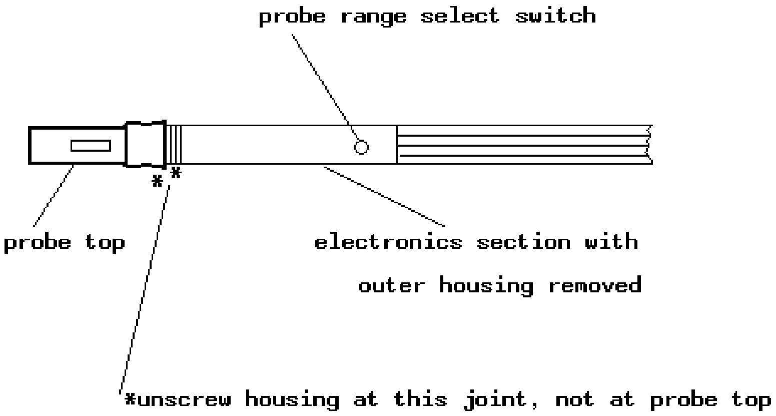


Figure 1 Probe Range Select Switch

Operating Procedure

Operation

The operating procedures described below will include MGX and MGX II versions. In most cases the range of measurement control will be done from the surface. If you choose to do this manually, refer to the Controls section of this manual.

MSLog

1. Select the correct tool driver from the Tool panel selection box. If the correct one is not available run MSLConfig to install it.
2. In the Tool panel, click the Power On button.
3. Click the Depth panel upper right corner icon. Click Zero Tool.
4. If you wish to fill out the header, in the Acquisition panel click Header button.
5. In the Acquisition panel, click Record and select a file name.
6. Turn on the desired, Depth Sampling mode.
7. If you are printing, turn on the printer in MCHCurve.
8. Log to the desired interval as normal. Refer to the MSLog manual for additional information on logging.
9. When done, in the Acquisition panel, click Stop.
10. In the Tool panel, click the Power Off button before removing the probe.

Logshell

If the probe or combination of the Poly gamma and Poly Induction are to be used with an MGX series logger, the **PULSE 2** position on the Probe Select switch must be used for logging. **Range ‘A’** is selected by placing the Probe Power switch in the **ON (Close)** position, while **Range ‘B’** is selected by placing the Probe Power switch in the **OFF (Open)** position.

If the probe is being operated with an UM-4591, a HLM-4180, a FLM-4180, or a GLM-4180, set the range of the probe by momentarily setting the caliper control to CLOSE to select range 'A', and OPEN to select range 'B'. Probe operation is then accomplished using the conventional settings on these modules. *This only applies to the 2EMC-1000 and 2EMB-1000 if they are properly wired for four-conductor operation.*

For use with the Series 5, Altlogger, the probe wiring may be configured in a number of ways depending on the 4pulse adapter configuration. Consult Mount Sopris Instruments.

If the probe or combination is to be operated with an MGX II logger, choose the corresponding probe driver for the proper range and combination of tools and the unit will provide proper power and polarity to the probe.

The probe can be logged at a speed of approximately 30 ft/min or 10 m/min with good results and no loss of resolution. The probe is extremely lightweight and may require the addition of an optional bottom weight when logging in heavy muds. Consult the factory for details. The zero point or depth reference of the probe is the thickened ring located 91.4 cm (36 in.) below the probe top joint.

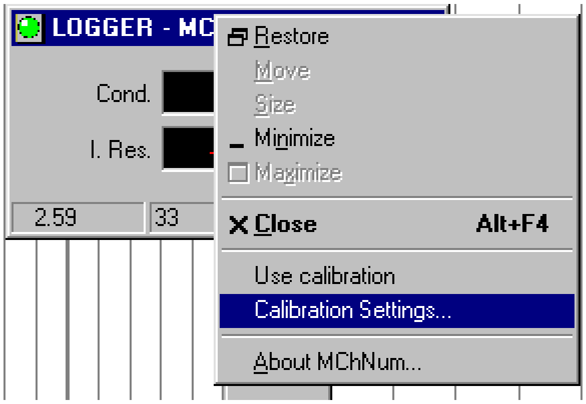
Performance Checks and Calibrations

Although the instrument is set to read correctly at the factory, it is necessary to check the instrument calibration before logging the tool. For highest accuracy, it is recommended to perform these calibrations prior to logging. Allow the probe to operate under power for at least 10 minutes, in borehole fluid, prior to making any calibrations

To calibrate the probe, connect the probe to the logging system as discussed in the Installation section of this document. Turn power to the probe on utilizing one of the various types of data acquisitions systems discussed in the Operating procedure section. Place the probe in borehole fluid and allow it to warm up. Pull the probe from the borehole and hold the probe at the cablehead/probe top joint and elevate the probe in a vertical direction so the bottom of the probe is pointing straight up in the air and is at least 3 meters above the ground. Ensure that the person and or device holding the probe in this position does not have any metal objects attached, such as a watch, screws, or duct-tape, as these items are conductive. Also ensure that the tools are at least 3 meters from any metal buildings, vehicles, even the logging unit. Set the data acquisition equipment to read zero conductivity at this point; this is the first calibration point. To obtain the second calibration point, two methods can be used. The first method discussed utilizes a calibration coil. This coil is placed over the conductivity probe. Located on the coil is a switch to choose different values for the second calibration point. Depending on the range setting of the tool certain values may over - range the tool, so it is important to know what range the tool is functioning in before making a calibration. When the probe value for the second calibration point has been chosen, set the acquisition equipment to read this value. If a calibration coil is unavailable set the acquisition system for the second calibration point to a value of the frequency of pulses from the tool at the zero point plus 5000 (i.e. if zero is 12500 counts then the second calibration number would be 17500. Also be sure that you adjust the scaling of the probe file to match the range of the tool (i.e. 100mS/m, 1000mS/m or 10000mS/m). The frequency output of the probe with respect to conductivity is quite linear and with only one point, zero, we can establish the full scale calibration point with reasonable accuracy by adding 5000 to the frequency that represents zero conductivity. For this method to work properly it is essential that the scaling or output of the probe file (i.e. RgtOut or High Ref. number is set equal to the range in which the tool is operating.

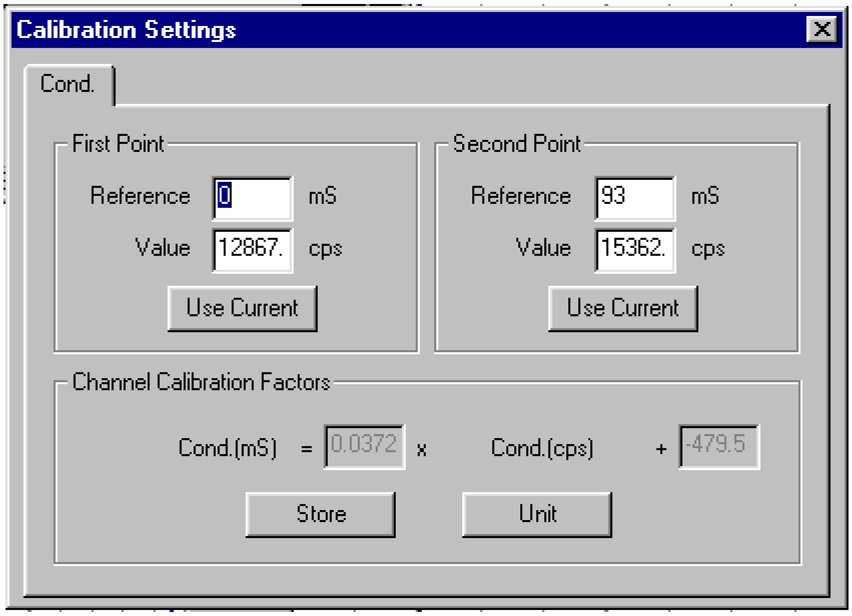
MSLog calibration

1) Turn Probe power On.
2) Turn Sampling to Time and On.
3) Lower the Probe without a weight into the borehole fluid and allow it to warm up for 10-15 minutes or until the Induction channel stops drifting.
4) Right click on MCHNum.
5) Uncheck Use calibration
6) Right click on MCHNum.



7) Click Calibration Settings..

8) Quickly pull the probe from the borehole and hold it into the air bottom end up. You should be away from any metal objects that would disturb the measurement.



First Point
Reference 0 mS
Value 12867. cps

Second Point
Reference 93 mS
Value 15362. cps

Cond.(mS) = 0.0372 x Cond.(cps) + -479.5

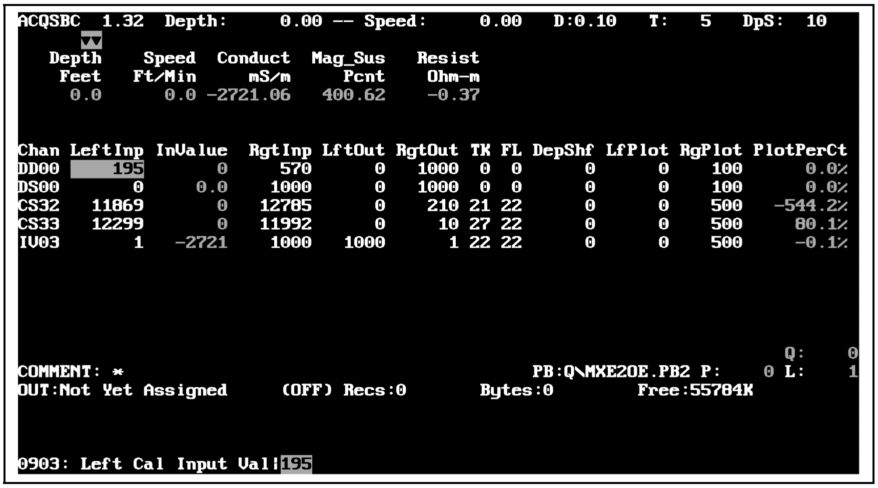
9) Press the First Point Use Current button to capture the frequency of the input at the zero Reference.
10) When you have a calibration standard
    a. Slide the calibration standard over the probe. Select the proper setting for the range of operation. In this example the 0-100 range is selected and the switch setting of 93 is entered in the Reference for the Second Point.
    b. Hold the probe with the calibration standard over the end into the air.
    c. Press the Second Point Use Current button to capture the frequency of the input at the 93 ms (in this example) Reference.
11) When you don't have a calibration standard.
    a. Note the First Point Value.
    b. Add 5000 to the First Point Value and enter it in the Second Point Value box.
    c. Enter the full, scale value for the operating range you have selected into the Second Point Reference box. In the example above you would enter 100.
12) Press Store to save the values to the tool driver file.
13) Press the X in the upper right corner of the browser to close the dialog.

14) On the MSLog Browsers and Processors menu press Close all.
15) Select each Browser or Processor from the menu individually and press the Start button. Wait until the browser or processor Connects then select the next one in the list, press Start and so on until all the processors and browsers are running. This is necessary so that the browsers and processors can read the new calibration information stored in the tool driver file in step 12 above.

Logshell calibration

The following is a brief, step by step, procedure for Logshell users of both the MGX and MGX II loggers. Items in ( ) will be information regarding the MGX II version of Logshell.

1) Connect the probe or probes to the Logger and activate LOGSHELL.
2) Select the **LOG** option from the menu and select the probe driver from the **Probe** menu.
3) Enter the data file name at the **DataFile** menu and set the depth at the **Depth** menu.



```
ACQSBC  1.32  Depth:     0.00 -- Speed:     0.00   D:0.10    T:   5   DpS:  10
     ▼▼
   Depth    Speed  Conduct  Mag_Sus   Resist
    Feet   Ft/Min     mS/m     Pcnt    Ohm-m
     0.0      0.0 -2721.06   400.62    -0.37


Chan LeftInp InValue  RgtInp LftOut RgtOut TK FL DepShf LfPlot RgPlot PlotPerCt
DD00     195       0     570      0   1000  0  0      0      0    100      0.0%
DS00       0     0.0    1000      0   1000  0  0      0      0    100      0.0%
CS32   11869       0   12785      0    210 21 22      0      0    500   -544.2%
CS33   12299       0   11992      0     10 27 22      0      0    500     80.1%
IV03       1   -2721    1000   1000      1 22 22      0      0    500     -0.1%




                                                                      Q:     0
COMMENT: *                                       PB:Q\MXE2OE.PB2 P:     0 L:     1
OUT:Not Yet Assigned      (OFF) Recs:0        Bytes:0         Free:55784K



0903: Left Cal Input Val¦195
```

4) When you have reached the ACQSBC or the (PolyLog) screen you are ready to check the probe calibration. For MGX users choose the proper **Probe Select Switch** position and the proper **Probe Power Switch** position for range selection.. For MGX II users, the system has already powered the probe and you must choose **Calibrate** from the menu.

5) The factory calibration factors for conductivity are seen in the **CS32** line. As seen in the figure, **LeftInp** is **11869**. This number is equivalent to 0 conductivity. This equivalence is set, by placing the number **0** in the **LftOut** column.

6) Verify the number **0** is in the **LftOut** column of the **CS32** line. If it is not, move the cursor to that position press <**0**> and then <**ENTER**>.

7) Hold the probe at the cable head/probe top joint and elevate the probe in a vertical direction so that the probe bottom is pointing straight up in the air and is at least three meters above the ground. Make sure that you do not have any metal objects such as a watch or a ring on the hand holding the probe and that no conductive objects are nearby. You may have to move a few yards away from any nearby buildings or power lines.

8) While the probe is held in the air, verify that the number in the **InValue** column of the **CS32** line matches the **LeftInp** number **11869**. If the number does not match, move the cursor to the **CS32** line, and while the probe is held in the air as described above, press **F3**. This copies the **InValue** number into the **LeftInp** column of the **current** line.

9) Set the MGX Probe Power switch so that it selects the 0-1000mS/m range. The default factory setting will be to operate with the switch in the **ON(Close)** position.

10) Place the calibration ring on the probe as shown in Figure 2.

11) As seen in the figure above, **RgtInp** is **12785**. This number is equivalent to 210mS/m conductivity. This equivalence is set, by placing the number **210** in the **RgtOut** column. Verify the number **210** is in the **RgtOut** column of the **CS32** line. If it is not, move the cursor to that position press <**210**> and then <**ENTER**>. With the calibration coil in

position **b**, note the number in the **InValue** column. Press <**F4**>. This copies the **InValue** number into the **RgtInp** column of the **current** line.

Note: In calibration coil position **a,** the coil can be used to calibrate the equipment to 12.4 mS/m, which is better for operating the probe int the 0 - 100 mS/m range. Repeat step 11 replacing the number **210** with **12.4**.

12) Perform this step only if a second calibration point is not available (if you don't have a test coil). Note the number in the **LeftInp** column of the **CS32** line. This is the zero input frequency. Add **5000**(cps) to this number. Move the cursor to the **RgtInp** column of the **CS32** line. Type the calculated number into that column and press <**ENTER**>. Move the cursor to the **RgtOut** column, press <**1000**> and <**ENTER**>.

Note: The frequency output of the probe with respect to conductivity is quite linear and with only one point, zero, we can establish the full scale calibration point with reasonable accuracy by adding 5000 to the frequency that represents zero conductivity. This second number then represents 1000mS/m in the example above. If a different scale is used, 5000 plus the zero value from the **LeftInp** column will be equal to that range full scale value i.e. 100 or 10,000mS/m. For this method to work accurately it is essential that the **RgtOut** column number is set equal to the range in which you are operating the probe!

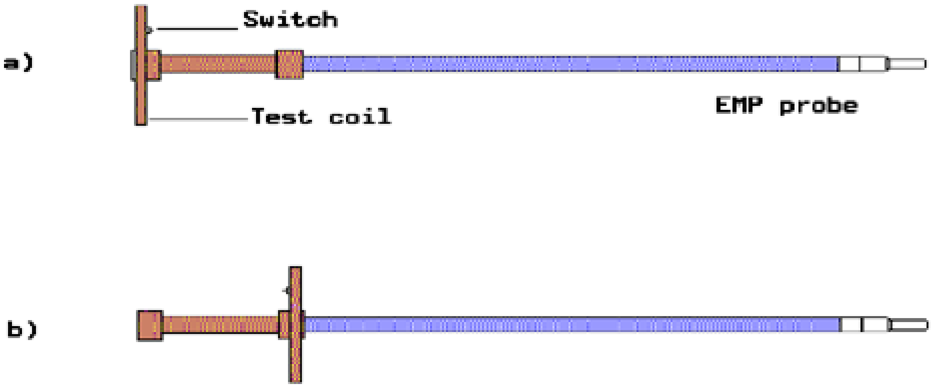


Figure 2 Calibration Set-up with Geonics Test Coil

Preventive Maintenance

The 2PIA-1000, probe, should provide long life with no maintenance. If the accuracy of the probe is suspect, proceed to align the probe as follows.

Adjusting the Anticoincidence Circuit:

1. Remove the housing from the probe top. Remove the outer shields by unsoldering the wire braid and green wire attached to the braid. Slide each shield down about 6 inches.
2. Locate R15 and R36 on the rectifier board then connect P29-2, P29-3 and P29-6 together. See Figure 4 for component placement.
3. Connect the probe to the logging cable and power up tool. Looking at the Input value on the acquisition screen adjust R3 and R7 for 12.5 KHz.
4. Turn off power to the tool. Remove the shorts on P29 and re-solder R15 and R36.
5. Reinstall the shield and **be sure to solder the green wire to the braid**. Inspect the O-ring on the probe top for cleanliness, cuts or abrasions then replace the housing.

Null Adjustment:

1. Remove the tool from its external housing. Locate and identify adjustment slots on the end of the probe. Use Figure 3 as a reference.
2. Connect the probe to the logging cable and power up tool. Get the tool at least 3 meters from any metal object and as high off the ground as reasonable.
3. Set the range switch on the probe to the 100mS/m range. See Figure 1 for switch location and Table 2 for switch position.
4. Adjust control 2 for conductivity and control 3 for magnetic susceptibility on the probe to obtain a zero of 12.5 KHz on both channels. See Figure 3 for controls. There could be interaction between controls therefore it may be necessary to repeat this process.
5. Turn off power to the tool. Reinstall the shield and be sure to solder the green wire to the braid. Inspect O-ring on the probe top for cuts or abrasions. Replace housing.

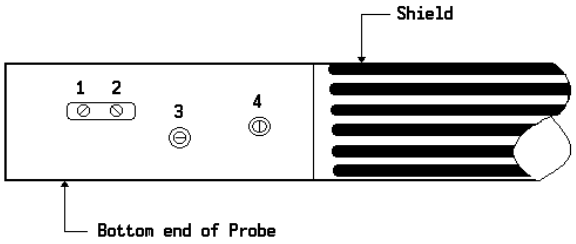


Figure 3 Linearity and Null Adjustment

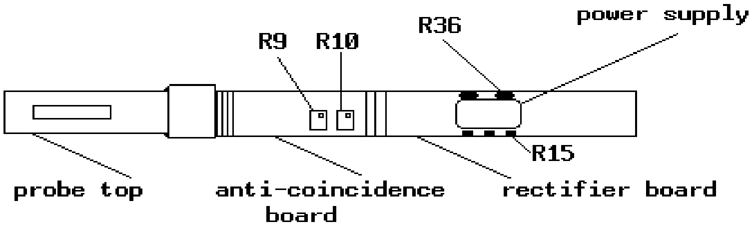


Figure 4 Location of Discrete Components

Troubleshooting

Problems with the Tool

In the event the tool develops a problem, follow the troubleshooting procedure listed below.

No data from the probe.

1. Are the MGX switches set correctly? **PULSE 2** and **ON or OFF** positions
2. Are the PROBE CURRENT and PROBE POWER LED's on? (MGX users)
3. MGX II users, is the correct probe driver chosen?
4. MGX II, is the TO PC light flashing?
5. Is the proper voltage applied to the cable line conductor wire? Approximately 68 volts D.C., for the MGX and 68 to 72 volts D.C. for the MGX II.
6. Are the cables between winch, MGX unit and the PC connected properly?
7. Check the logging cable for conductive leakage across the center conductor to ARMOR.
8. If an oscilloscope is available verify if the probe is sending pulses, if not consult Mount Sopris.
9. Is the slip ring connector on the probe top clean?

Disassembly Instructions

The 2PIA-1000, probe, should never be disassembled unless service is necessary. In the event service is necessary, it should be returned to Mount Sopris Instruments, or a qualified technician. In the event you need to get into the probe, unscrew the housing from the probe top at the junction about 2” just above where the black heat shrink ends on the housing. Before reinstalling the housing inspect the o-ring on the probe top for any damage like cuts or abrasions. This is very important. If the O-ring fails borehole fluid can fill the tool and damage the tool permanently. Flooded tools usually require complete replacement of the electronics.

WARNING: Because the tool housing is non-metallic, thin wall fiberglass it should be treated with extra care. Do not drop, bend, or otherwise stress the tool or leakage can result from fractures in the fiberglass housing.

Appendix

Suggested QA Procedure

General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. The Mt. Sopris family of Acquire programs records the calibration constants that were used to acquire the data. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedure specifies that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.

Technical Addendum

Induction Probe Calibration Procedure Update

Models affected: 2PIA-1000, 2EMA-1000, EMP-2493, and EMP-4493

The temperature of the induction tool is important when it's calibrated. Whenever there is a substantial difference between the temperature of the borehole and the temperature of the probe during calibration there can be a shift in the observed log, possibly resulting in negative conductivity numbers being reported for numbers near 0.

From experience with Geonics EM-39 based Mount Sopris Induction tools, the following method of calibration is suggested for the most reliable results.

We recommend that the probe be placed in the borehole, power applied, and the probe allowed to warm up for at least 10 to 15 minutes before calibration. After the warm up, stabilization period, the probe should be quickly removed from the borehole and a zero and second calibration point determined and recorded using the EMP-N294 Induction Probe Calibrator. Do this as rapidly as possible to make sure the probe does not have a chance to change temperature. This is a greater concern on sunny days. The probe can then be returned to the borehole for logging. If you do not do this, the probe calibration will drift until the probe thermally stabilizes.

After logging, another quick calibration can be performed to determine if there was any appreciable change in the calibration numbers. If there is a large difference, then it's likely the probe should have more time to stabilize in the borehole before calibration.

Operating in air filled versus water filled holes may require a different amount of time for the probe to stabilize. This is due to the fact that water provides a better heat sink, allowing the probe to come to thermal equilibrium sooner in water.

Specifications

Power Requirements
D.C. voltage at probe top Min. 30 VDC Max. 80 VDC @ 50mA to 90mA depending on tool configuration
Cable Armor Negative and Pos, not polarity dependant
Center conductor Pos and Negative, not polarity dependant

Tool Output
Pulse type, positive and negative going, 1.25uS wide from ~ 12.5 KHz to 17.5 KHz

Radius of Investigation
Radius of maximum sensitivity 28 cm
Minimum radius of sensitivity 10 cm

Vertical Resolution
65 cm

Ranges or Scales
100mS/m, 1000mS/m, 10000mS/m
Accuracy
5% of full scale

Resolution
0.02 % of full scale

Repeatability
+/- 2% full scale for temperature changes less than 10 degrees Centigrade

Noise level
Less than 0.5 mS/m

Measurement point
91.4 cm (36”) from the joint of the probe top
Temperature range
-30 to 50 degrees Centigrade
Operating frequency
39.2KHz

Primary field source
Self contained dipole transmitter
Sensor
Self contained dipole receiver
Coil separation
50 cm

Maximum depth
1000 m (water filled)

Length
170 cm

Diameter
3.65 cm

Weight
3.2 kg (without weight section)

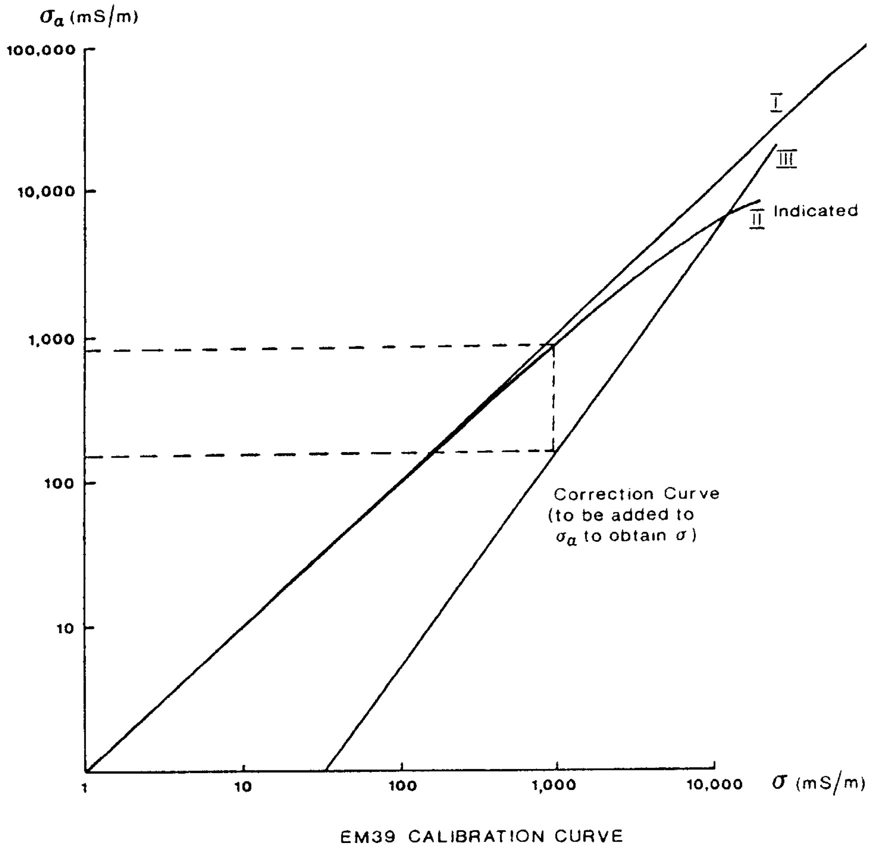


Figure 5 EMP/EM39 Calibration Curve

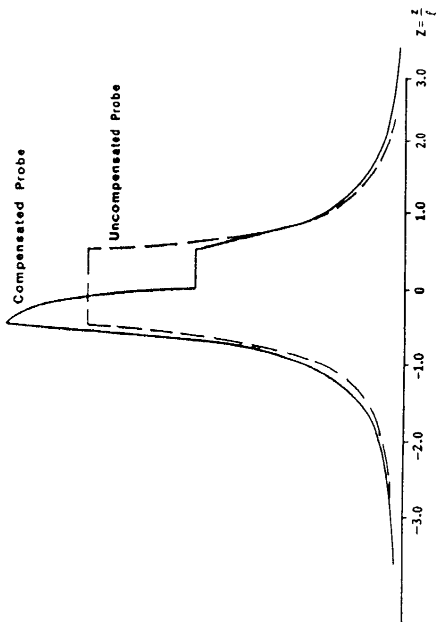


Figure 6 Vertical Response with λ = 58cm

Schematics

2PIA-1000 Poly Induction Probe

Drawing Number 500S-2078   50002078A.S01 - S03   Title: EMP/Poly EMP Anticoincidence

2PFA-1000 Fluid Resistivity/ Temperature Probe
(2SFA,B-1000, 2WQA,B,C-1000)

Mount Sopris Instrument Co., Inc.
Golden CO, U. S. A.
November 29, 2001

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General Information

Overview

The 2PFA-1000, combination temperature/fluid resistivity probe, provides valuable information for the hydrologist and groundwater scientist concerning borehole fluid character and flow. The 2PFA-1000 is configured as a “Poly” probe, with a quick-connect probe top that allows it to be easily attached to either a Poly gamma probe or fitted with a probe top adapter to run in stand alone mode. A second version of this probe, called the 2WQA, B, or C-1000 is a stand-alone probe with, a Mount Sopris single conductor, four-conductor, or GO/I four-conductor top. Finally, it is also available as a factory-mounted sub that is mounted permanently to the bottom of the Poly Electric or Poly Caliper probes.

Theory of Operation

The 2PFA and its various configurations include a seven electrode mirrored Wenner array for measuring borehole fluid resistivity and a temperature sensor based on a fast response semiconductor device whose output voltage changes linearly with temperature. The resistivity array is an internal cylindrical array open at the bottom of the probe. Borehole fluid passes by the array as the probe is lowered in the hole. The array is completely shielded from the outside borehole, so that only fluid resistivity is measured. The temperature sensor is located at the top of the sensor body, in the center of the three exit ports where the borehole fluid returns to the well bore. The “K” factor for the Wenner array is empirically derived, and is approximately 12, when checked for fluid resistivity ranging from 3 to 78 ohmmeters.

Specifications

Diameter	1.5 inches	38 mm
Length	depends on configuration (2WQA-1000 is 22inch, or 56cm)	
Weight	depends on configuration (2WQA-1000 is 5 lbs or 2.3 kg)	
Range		
Fluid Resistivity	0-100 Ohm-meters	
Temperature	-20 to +80 degrees Celsius	
Resolution		
Fluid Resistivity	0.05%	
Temperature	0.1 degrees Celsius	
Accuracy	Better than 1% (both sensors)	

Installation

The 2PFA-1000 uses the tapered lead 6-ring connector common to the Poly family of probes. It is connected to the Poly Gamma or the optional single conductor adapter by simply unscrewing the bull plug (CCW) and screwing the 2PFA-1000 CW onto the mating connector. A firm hand tight connection is all that is required. A layer of electrical tape can be applied if desired.

The 2SFA,B-1000 subs are installed at the factory, and should not be removed in the field unless proper procedures are available and performed by a qualified electronics technician.

The 2WQA,B,C -1000 versions use MSI single conductor, MSI 4 conductor, or Gearhart 4 conductor tops, ready to connect to their respective mating cable heads.

Operating Procedure

Operation

Operation of the 2PFA and its siblings requires that the probe be connected to the cable head. *Make sure that probe power is off before connecting or disconnecting the probe to avoid the chance of electrocution or damage to the equipment.* Normally, **no calibrations are necessary, as the probes are calibrated at the factory**. If re-calibration is desired, see below. Instructions for logging vary depending on your equipment. Follow the appropriate instructions below.

Logging Instructions for MSLog with the MGX II

1. Select the correct tool driver from the Tool panel selection box. If the correct one is not available, run MSLConfig to install it.
2. In the Tool panel, click the Power On button. **It is advisable to power the probe while it is in the hole for a few minutes to warm up the electronics before logging for optimum accuracy**.
3. Place the tool in the borehole and position the top of the tool at the zero depth point. Click the Depth panel upper right corner icon. Click Zero Tool. If you can not place the tool top at depth reference (perhaps the bridle will not go through a sheave), press the Change Depth button and enter the depth of the bottom of the tool.
4. If you wish to fill out the header, in the Acquisition panel click Header button.
5. In the Acquisition panel, click Record and select a file name.
6. Place the probe at the beginning of the interval to be logged. Usually, temperature – fluid resistivity logs are run from the top to the bottom to avoid disturbing the water column before measurement.
7. Turn on the desired, Depth Sampling mode.
8. If you are printing, turn on the printer in MCHCurve.
9. Log to the desired interval as normal. Refer to the MSLog manual for additional information on logging.
10. When done, in the Acquisition panel, click Stop.
11. In the Tool panel, click the Power Off button before removing the probe.

Logging Instructions for Logshell with the MGX II

1. Select the proper probe from the LOG menu. If the correct one is not available, use the CONFIGURE menu item to install it.
2. Use the DATA FILE menu option to name the output file.
3. When you select LOG from the LOG menu, the acquisition program will begin and power will be applied to the tool. **It is advisable to power the probe while it is in the hole for a few minutes to warm up the electronics before logging for optimum accuracy**.
4. Place the tool in the borehole and position the top of the tool at the zero depth point. Set the depth to zero using the SYSTEM CONTROL menu. If you can not place the tool top at depth reference (perhaps the bridle will not go through a sheave), enter the depth for the top of the probe.
5. Place the probe at the beginning of the interval to be logged. Usually, temperature – fluid resistivity logs are run from the top to the bottom to avoid disturbing the water column before measurement.
6. Turn on the output file using the DATA FILE menu item.
7. If you are printing, turn on the printer using the PLOT MENU.
8. Log to the desired interval as normal. Refer to the Logshell manual for additional information on logging.
9. When done, select the EXIT/POWER OFF menu item.

Logging Instructions for Logshell with the MGX

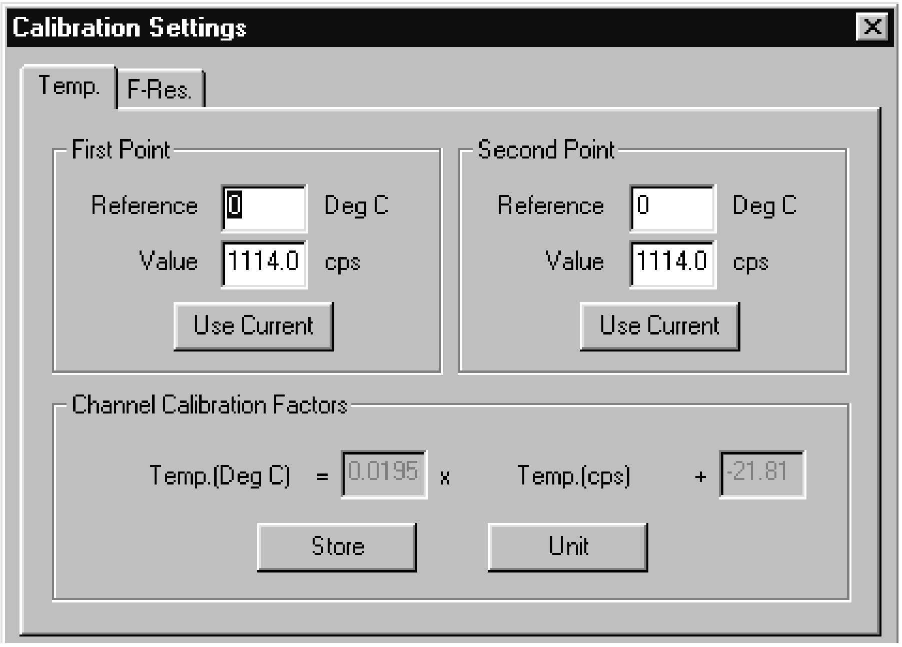
1. Select the proper probe from the LOG menu. If the correct one is not available, use the CONFIGURE menu item to install it.
2. Use the DATA FILE menu option to name the output file.
3. Place the tool in the borehole and position the depth reference point on the tool zero depth point. Set the depth to zero using the DEPTH menu. If you can not place the tool's depth reference at zero depth, enter the depth for reference point on the tool.
4. When you select LOG from the LOG menu, the acquisition program will begin. Place the PROBE SELECT switch in the PULSE 2 position. Place the PROBE POWER switch in the ON position. **It is advisable to power the probe while it is in the hole for a few minutes to warm up the electronics before logging for optimum accuracy**.
5. Place the probe at the beginning of the interval to be logged. Usually, temperature – fluid resistivity logs are run from the top to the bottom to avoid disturbing the water column before measurement.
6. Turn on the output file using the F6 key.
7. If you are printing, turn on the printer using the F7 key. Then start the plot using the F9 (logging down) or Alt-F9 (logging up) keys.
8. Log to the desired interval as normal. Refer to the Logshell manual for additional information on logging.
9. When done, place the PROBE POWER switch in the OFF position.

Performance Checks and Calibrations

The 2PFA series of probes and subs may be re-calibrated in the field, if desired. An accurate thermometer and fluid conductivity/resistivity cell is needed. A good temperature bath is also required, to allow a large mass of water to stabilize at a known temperature. Be sure that the thermometer is placed very close to the sensor to minimize errors. Standard chemical solutions can be purchased from lab supply vendors to calibrate the resistivity array. Contact Mount Sopris for details. Salt-water solutions can be mixed for this procedure, but changes in temperature during mixing can make true resistivity of such solutions difficult to measure.

Calibration Instructions for MSLog

1) Turn Probe power On.
2) Turn Sampling to Time and On.
3) Connect a calibration standard as described above.
4) Allow to warm up for 10-15 minutes.
5) Right click on MCHNum.
6) Uncheck Use calibration
7) Right click on the MCHNum title bar.
8) Click Calibration Settings.
9) Enter the value of the calibration standard (i.e. 5 ohm-m) in the Reference edit box for the first point.



First Point: Reference 0 Deg C; Value 1114.0 cps

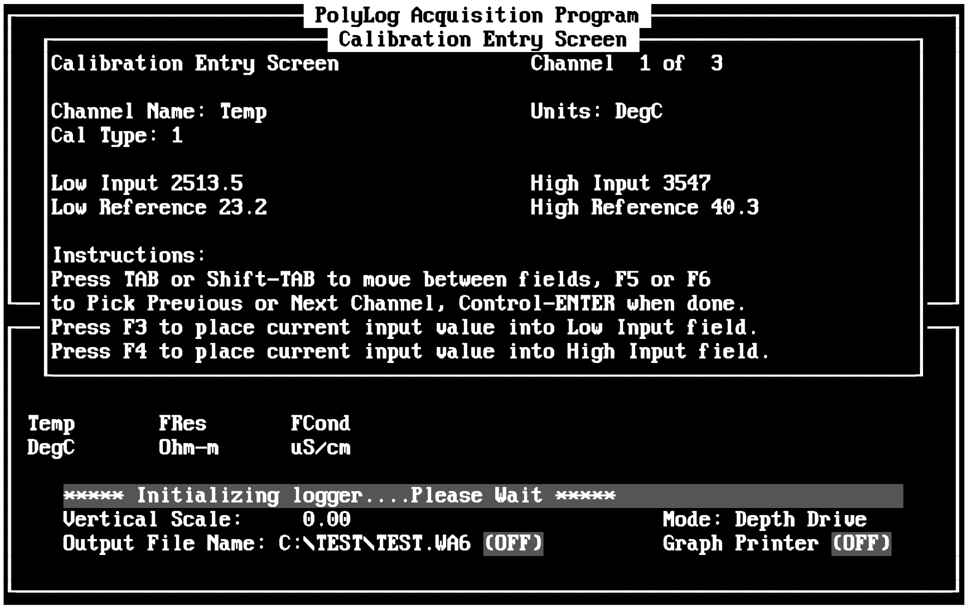
Second Point: Reference 0 Deg C; Value 1114.0 cps

Temp.(Deg C) = 0.0195 x Temp.(cps) + -21.81

10) Press the First Point Use Current button to capture the raw tool output for the first calibration point.
11) Connect a different calibration standard as described above.
12) Enter the value of the second calibration standard (i.e. 200 ohm-m for a 10 ohm calibration resistor connected to the 64 inch normal electrode) in the Reference edit box for the first point.
13) Press the Second Point Use Current button to capture the raw tool output for the second calibration point.
14) Press Store to save the values to the tool driver file.
15) Press the X in the upper right corner of the browser to close the dialog.
16) On the MSLog Browsers and Processors menu press Close all.
17) Select each Browser or Processor from the menu individually and press the Start button. Wait until the browser or processor Connects then select the next one in the list, press Start and so on until all the processors and browsers are running. This is necessary so that the browsers and processors can read the new calibration information stored in the tool driver file in step 12 above.

Calibration Instructions for Logshell with the MGX II

1) Turn Probe power On.
2) Connect a calibration standard as described above.
3) Allow to warm up for 10-15 minutes.
4) Select the CALIBRATE function in the POLYLOG menu. A screen will appear as follows:



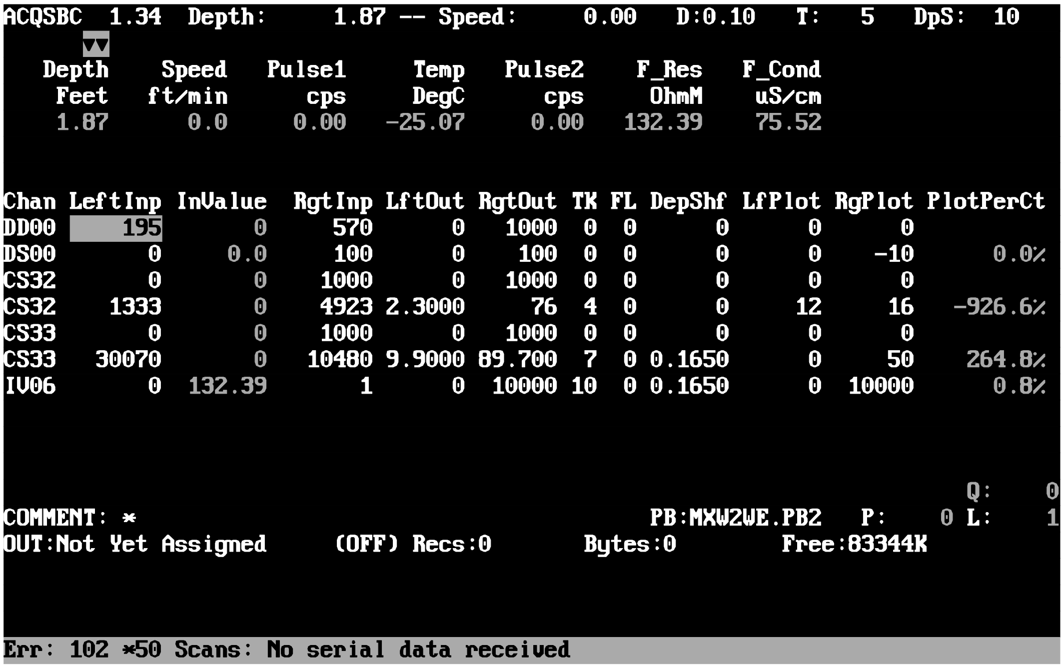
```
                     PolyLog Acquisition Program
                      Calibration Entry Screen
 Calibration Entry Screen                Channel  1 of  3

 Channel Name: Temp                      Units: DegC
 Cal Type: 1

 Low Input 2513.5                        High Input 3547
 Low Reference 23.2                      High Reference 40.3

 Instructions:
 Press TAB or Shift-TAB to move between fields, F5 or F6
 to Pick Previous or Next Channel, Control-ENTER when done.
 Press F3 to place current input value into Low Input field.
 Press F4 to place current input value into High Input field.

Temp      FRes      FCond
DegC      Ohm-m     uS/cm

   ***** Initializing logger....Please Wait *****
   Vertical Scale:     0.00                    Mode: Depth Drive
   Output File Name: C:\TEST\TEST.WA6 (OFF)    Graph Printer (OFF)
```

MGX II Example

5) Select either Fluid Resistivity or Temperature (F5 or F6 to toggle between selections). The Low and High Reference fields should be updated by the user, to display the measured low and high values, from your precision thermometer and resistivity meter.
6) Use the F3 (low end) and F4 (high end) keys to write the digital values corresponding to the actual values into the probe file. Check the calibration values several times to verify that they are stable.
7) Then press CONTROL ENTER to exit, and SAVE CALIBRATIONS to save. The new calibration values will be written into the probe file in the active directory. If the new calibration is to be used globally for all new logs, copy the probe file into the directory where LOGSHELL is installed to over-write the old probe file (*.PB4)

Calibration Instructions for Logshell with the MGX

1) Turn Probe power On.
2) Connect a calibration standard as described above.
3) Allow to warm up for 10-15 minutes.
4) Bring up the ACQUIRE Status screen (text screen) in the LOG mode, and you will see the following information:



```
ACQSBC  1.34  Depth:     1.87 -- Speed:     0.00   D:0.10   T:   5   DpS:  10
          ▼▼
   Depth    Speed   Pulse1     Temp   Pulse2     F_Res   F_Cond
    Feet   ft/min      cps     DegC      cps      OhmM    uS/cm
    1.87      0.0     0.00   -25.07     0.00    132.39    75.52


Chan LeftInp InValue   RgtInp LftOut RgtOut TK FL DepShf LfPlot RgPlot PlotPerCt
DD00     195       0      570      0   1000  0  0      0      0      0
DS00       0     0.0      100      0    100  0  0      0      0    -10      0.0%
CS32       0       0     1000      0   1000  0  0      0      0      0
CS32    1333       0     4923 2.3000     76  4  0      0     12     16   -926.6%
CS33       0       0     1000      0   1000  0  0      0      0      0
CS33   30070       0    10480 9.9000 89.700  7  0 0.1650      0     50    264.8%
IV06       0  132.39        1      0  10000 10  0 0.1650      0  10000      0.8%



                                                                         Q:    0
COMMENT: *                                   PB:MXW2WE.PB2   P:     0 L:     1
OUT:Not Yet Assigned     (OFF) Recs:0       Bytes:0       Free:83344K



Err: 102 *50 Scans: No serial data received
```

MGX Example

5) The example shows the ACQSBC status screen for a probe calibrated with the following values:

	LftInp	RgtInp	LftOut	RgtOut
Temperature (2nd line CS32)	1333 cps	4923 cps	2.30 deg. C	76 deg. C.
Fluid Resistivity (2nd line CS33)	30070 cps	10480 cps	9.90 ohm-m	89.7 ohm-m

6) The Inp values are the values sent up the cable by the probe, measured in cps (counts per second). The sensors send the data as DC pulses (positive for temperature and negative for fluid resistivity). The logger counts the pulses and sends them to the PC where they are displayed in the InValue column. The current value for a given temperature or fluid resistivity value is copied into the calibration field (LftInp or RgtInp) by pressing the F3 or F4 key. F3 copies the current value into the low end (LftInp) field and F4 key copies the current value into the high end (RgtInp) field. The values in these fields correspond to the real values measured with the calibration standards (precision thermometer and fluid resistivity meter).
7) The values read from the standards must be entered into the LftOut and RgtOut fields by highlighting these fields with the cursor and typing in the new values and hitting <enter>.
8) To save the calibration data, press F2. The newly calibrated file will be saved in the current directory. If this file is to be used for subsequent logging, copy to the directory where LOGSHELL was installed. You cannot calibrate the Fluid Conductivity channel (IV06) as it is derived mathematically from CS33.

Preventive Maintenance

The only maintenance required for the 2PFA probe series is to be sure to thoroughly clean the interior of the sensor array (electrodes and temperature sensor) with soft brush and clean fresh water and allow to dry before storing. All threads should be cleaned and greased, and all o-ring surfaces and o-rings should be cleaned and coated with silicone grease. Clean logging equipment provides trouble-free logging.

Schematics

Drawing Number	500S-2100.S01	Title	Pwr. Sup. and Temp. Cir.
Drawing Number	500S-2100.S02	Title	Current Generator Circuit
Drawing Number	500S-2100.S03	Title	Voltage Measuring Circuit
Drawing Number	500S-2100.S04	Title	Anti-Co and Pulse Driver Cir.
Drawing Number	Wiring Diagram	Title	2PFA-1000 Wiring Diagram
Drawing Number	Wiring Diagram	Title	2WQA-1000 Wiring Diagram
Drawing Number	Wiring Diagram	Title	2SFA-1000 Wiring Diagram
Drawing Number	Wiring Diagram	Title	2SFB-1000 Wiring Diagram

2SNA-1000-S
DX Series Spectral Gamma Probe

Mount Sopris Instrument Co., Inc.
Golden, CO U. S. A.
October 5, 2001

Table of Contents

General Information

Overview

The 2SNA-1000-S DX series spectral gamma probe section is a versatile tool that can be used in a wide variety of logging applications. The tool section measures natural gamma spectra, single point resistance, and spontaneous potential. Since the tool is part of the DX family of probes, it can be operated with any DX probe section. In this manner, additional measurements (such as density) can be added to the tool string.

Users can select from three operational modes (256, 512, or 1024 channel) based on their survey needs. The tool section is offered with several different options. The standard 2SNA-1000-S uses a 0.875 by 3 inch NaI(Tl) scintillator. The probe section is available with a BGO scintillator (2SNA-1000-SB) for more efficient detection of high energy gamma particles (and poorer energy resolution and accuracy).

The 2SNA-1000-S provides real time temperature compensation. The response from conventional tools drifts as temperature changes. This drift is extreme when using a BGO scintillator. The 2SNA-1000-S has been calibrated at the factory using several different sources and a swept temperature bath. Calibration coefficients resulting from these tests are stored inside the tool so that real time temperature compensation can be performed.

Controls, Connectors, and Layout

The 2SNA-1000-S probe section must be connected to a 2SMA-1000 modem section to make up the minimal tool string. Additional sections (such as a 2GDA-1000 density section) may be inserted in the tool string.

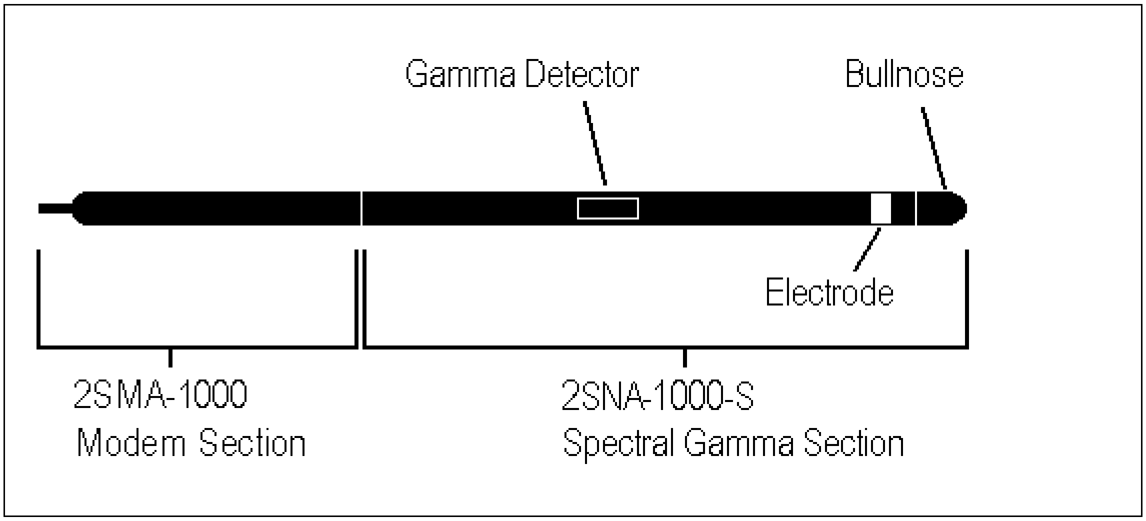


Figure 1: Diagram of the 2SNA-1000-S probe.

The DX series probe sections utilize keyed 10 pin connections. For example, to connect the 2SMA-1000 and the 2SNA-1000-S sections, insert the male end (lower end) of the 2SMA-1000 into the female end (upper end) of the 2SNA-1000-S. Rotate one of the sections until the alignment pin engages. Carefully press the two sections completely together. There may be some resistance when joining the sections together due to the O-ring seals in the connection. After the connection is fully seated, anchor the joint with the three hex head screws.

Theory of Operation

Naturally occurring radioisotopes emit many types of subatomic particles. Alpha, beta, and gamma particles are among the most common types of radiation and are seemingly well understood. When gamma particles travel through matter, they can interact with matter in one of three types of reactions: photoelectric, Compton scattering, and pair production. If a photon (gamma particle) survives one of these reactions, then it's energy will be less than it's pre-reaction energy. Figure 2 shows the resultant spectrum from a standard ^{137}Cs source which emits 662 KeV photons. The sharp peak that appears at 662 KeV is called the photopeak. The gamma rays that produced this peak did not react with matter as they traveled from the source to the detector, and they were totally absorbed by the gamma detector. The two smaller peaks to the left of the main peak are referred to as the Compton edge and the backscatter peak respectively. Gamma rays producing this part of the spectrum have been involved in Compton scattering reactions. Some of these reactions may have caused the particle to not be totally absorbed by the detector (scintillator crystal). The point that this simple example illustrates is that oftentimes, the particles from natural emitters will likely be involved in one or many reactions that complicate the resulting spectrum. This topic can be quite complex; and the reader can learn more from the many available textbooks on modern physics or particle physics.

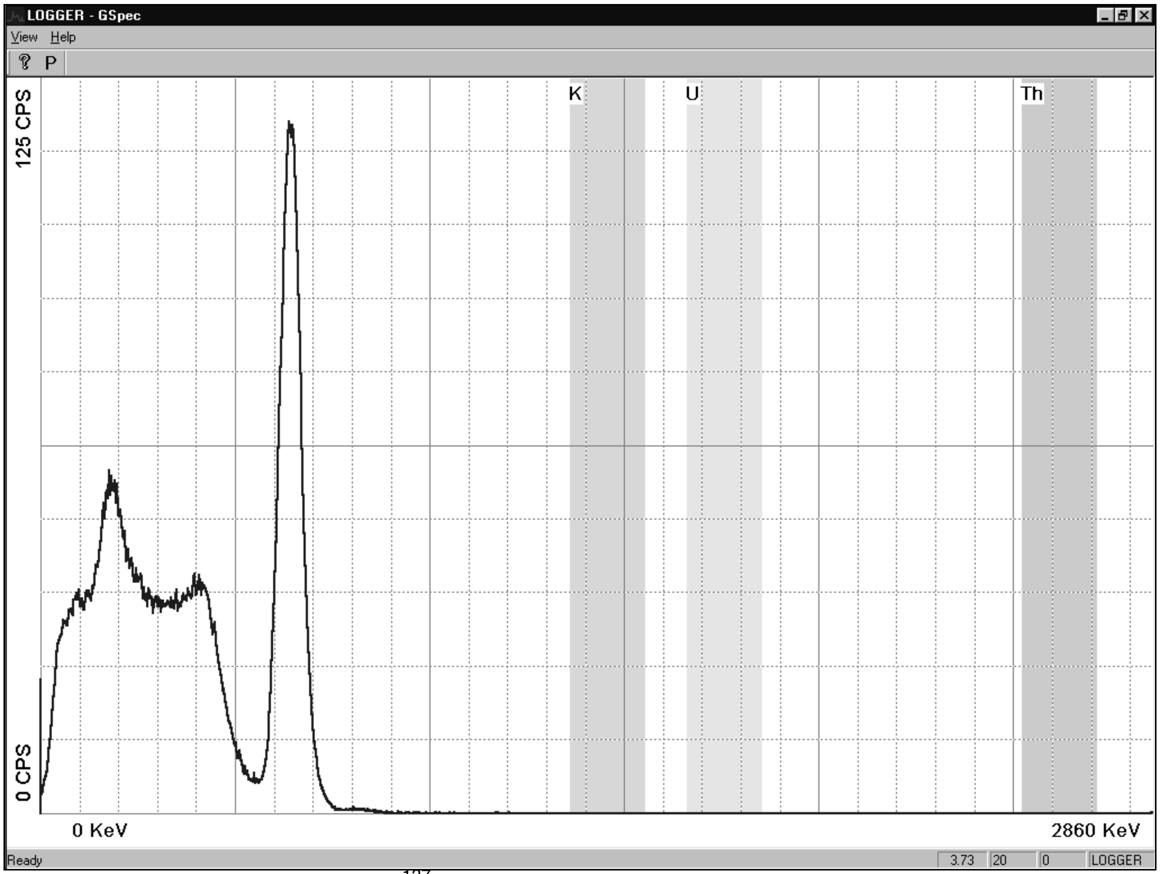


Figure 2: A typical spectrum from ^{137}Cs standard source showing a peak at 662 KeV.

The radius of investigation for the gamma detector is a function of the energy of the natural gamma radiation and the density of the surrounding medium. Higher energy particles tend to travel further before being completely absorbed through various reactions. A more dense formation will cause the natural radiation to be attenuated more quickly. Generally speaking, the radius of investigation is on the order of one to two feet (30-60 cm).

The gamma detector is made from a scintillator crystal and a photomultiplier tube. When a gamma particle is absorbed by the scintillator, the scintillator emits a small flash of light. The intensity of the light flash is proportional to the amount of energy absorbed by the scintillator. The light pulse is converted into an electric current and amplified by the photomultiplier tube. The amplitude of the electric current resulting from the incident photon is measured. A spectrum is built using the measured amplitude from many incident gamma particles. This spectrum is sent to the surface when the current time or depth digitize interval set by the operator has elapsed.

The 2SNA-1000-S performs real time temperature compensation. This is necessary because the amount of light produced by the scintillator varies with temperature. In fact, the temperature output from a BGO crystal varies by over 50% over the operating temperature range. Temperature compensation is based on calibration data stored inside the probe. The calibration data are determined at the factory by cycling the temperature over the operating range using several different radioactive standards.

Single point resistance is simply the resistance between the electrode at the bottom of the probe (the survey current source), and a fixed survey current return. The survey current return is usually either a fixed electrode on the surface (the surface electrode or mudplug), or the logging cable armor. The 2SNA-1000-S uses the logging cable armor. Since the survey current returns on a large area of the armor, the current density is low at the return and essentially all of the change in response comes from different resistances near the source electrode on the tool. The survey current is an AC current to prevent electrolysis of the survey electrodes. The radius of investigation for the single point resistance electrode is approximately 6-8 inches (15-20 cm).

Spontaneous potential is the DC potential between the probe electrode and a reference electrode located an infinite distance from the probe electrode. Since it is impossible to place an electrode at an infinite distance from the probe electrode, the reference electrode is often placed on the surface to reference the formation potential. The SP measurement then measures the potential difference between the borehole fluid and the non-invaded formation. The potential difference is, from a simplistic view, due to salinity differences between the borehole fluid and the non-invaded formation fluid. Most textbooks on geophysical logging contain a thorough review the causes of excursions on SP logs. The 2SNA-1000-S uses the armor as the reference electrode. Due to the long length of the armor, the potential on the armor is the average potential presented by the formation over the long length of exposed armor. Using the armor as the reference may change the offset value for the SP log, but not the amplitude of the individual excursions in the log.

Specifications

Maximum pressure	3000 PSI
Operation temperature range	0 to 60 degrees C
Storage temperature	-40 to 70 degrees C

Natural gamma energy range	0 - 3 MeV
Natural gamma energy accuracy	2% of full scale
Natural gamma energy resolution	10% full width half maximum
Sensor location (from bottom of probe)	22.83 inches (58 cm)

Single point resistance range	0-1000 ohms
Single point resistance accuracy	1% of full scale
Single point resistance resolution	0.5 ohm
Sensor location (from bottom of probe)	5.11 inches (13 cm)

Spontaneous potential range	-2000-2000 mV
Spontaneous potential accuracy	1% of full scale
Spontaneous potential resolution	0.5 mV
Sensor location (from bottom of probe)	5.11 inches (13 cm)

Length (assembled)	46.61 inches (118.4 cm)
Diameter	1.5 inches (3.81 cm)
Weight	11 lbs (4.99 kg)

Length (when connected to a 2SMA-1000)	71.26 inches (181 cm)
Diameter	1.5 inches (3.81 cm)
Weight	17 lbs (7.71 kg)

Installation

Installing the 2SNA-1000-S

The DX series probe sections must use MSLog as the data acquisition program. If you do not have the MSLog acquisition software, contact Mount Sopris Instruments. After MSLog is installed on the acquisition PC, and configured for your winch and logging cable, the 2SNA-1000-S probe drivers need to be installed. Use the MSLConfig utility to install the necessary probe drivers. Note that there will be different probe drivers for each specific 2SNA-1000-S model, and also the probe sections that will be connected to the 2SNA-1000-S.

The MGX II logger must have either the 5PMA-1000 or 5TMA-1000 modem installed. These modems are only available on the 5MCA-1000 consoles. Units with the modems installed will have the extension /TMA or /PMA appended to the model number. The model number is shown on the logger nameplate located near the power connector. If you don't have the proper modem installed, contact Mount Sopris Instruments.

Setting up Isolation for the Resistance and Self Potential Measurements

In order for the resistance and self potential measurements to function properly, the part of the tool and logging cable above the electrode (near the bottom of the 2SNA-1000-S section) must be electrically isolated. The 2SMA-1000 is wrapped in a neoprene sleeve. Before logging, make sure that any metal exposed above the electrode is well covered with several layers of PVC electrical tape. Cover any exposed metal from the electrode to the probe top. Remember that the tool may be rubbing against the side of the borehole, so make the isolation robust. If there is any break in this insulation, the resistance and spontaneous potential measurements may not record accurate, calibrated data.

Operating Procedure

Operation

The outline shown below describes the procedure that should be used for most logging operations. For a more detailed description of software operation, consult the MSLog user manual. This manual is available as 'help' in MSLog. To access the MSLog 'help', right click on the MSLog dashboard and select Help Index.

1. Connect the logging cable head to the 2SMA-1000 modem and the rest of the probe string. For the Mount Sopris single conductor cable head, rotate the probe instead of the cable head to make the connection. Inspect the cable head O-ring before making the connection. Make sure that it is not worn, nicked or cut. Apply silicon grease to the o-ring surface. Insure that the mating parts of the cable head and the probe top are clean.
2. In order for the resistance and self potential measurements to function properly, the part of the tool and logging cable above the electrode (near the bottom of the 2SNA-1000-S section) must be electrically isolated. The 2SMA-1000 is wrapped in a neoprene sleeve. Before logging, make sure that any metal exposed above the electrode is well covered with several layers of PVC electrical tape. Cover any exposed metal from the electrode to the probe top. Remember that the tool may be rubbing against the side of the borehole, so make the isolation robust. If there is any break in this insulation, the resistance and spontaneous potential measurements may not record accurate, calibrated data.
3. Start the acquisition software (MSLog), select the proper probe driver, and power up the tool. Usually the tool calibrations will be verified at this point. This is outlined in the next section.
4. Place the tool in the borehole. Zero the tool at the zero depth reference. Lower the tool until it is submerged. Wait for the tool to thermally equilibrate to the borehole fluid temperature. It is important to allow the tool to thermally equilibrate so that the real time calibrations are accurate. Allow 15-20 minutes for the tool to equilibrate.
5. Using MSLog, set the desired depth digitize interval, set the digitizing mode to 'depth up', 'depth down', or 'time' and start recording a data file. Log the borehole as desired. You may wish to log the entire borehole slowly. Alternatively, you may want to log in 'time' mode at a fixed depth for a particular zone of interest. As a rule, the logging speed should be fairly slow (~3 ft./min or ~1 m./min.) for reasonable statistics and repeatability of the recorded spectra. Slower logging be necessary to improve the resolution and repeatability of the data
6. When finished logging, power down the tool, and remove it from the borehole. Place the tool on the ground or a cleaning stand. Wash the probe with water (a portable sprayer works well), making sure that all mud and solids are rinsed away. Inspect the insulating tape for wear. Replace worn insulating tape as necessary.

Performance Checks and Calibrations

Calibration of the **spectral gamma** measurement should not normally be necessary. If calibration is needed, follow the steps below:

1. Connect the probe to the cable head, and power up the tool as outlined the above operating procedure.
2. Place a known gamma reference source as close as possible to the probe at a distance of 22.8 inches (58 cm) from the bottom of the probe.
3. Place the tool and the source in a water bath. Wait 15-20 minutes to allow the tool to thermally equilibrate. If the tool is not submerged, the tool may not warm up evenly, and the resulting calibration may not be valid when the tool is submerged.
4. Set the time digitize interval, then set the sampling mode to 'Time'. The time digitize interval may need to be increased until the spectrum displayed by GSpec is well defined

and repeatable. Place the mouse pointer on the photopeak of the spectrum and press the left mouse button. Record the channel number for this peak.

5. Place a second known gamma reference source as close as possible to the probe at a distance of 22.8 inches (58 cm) from the bottom of the probe.
6. Set the time digitize interval, then set the sampling mode to ‘Time’. The time digitize interval may need to be increased until the spectrum displayed by GSpec is well defined and repeatable. Place the mouse pointer on the photopeak of the spectrum and press the left mouse button. Record the channel number for this peak.

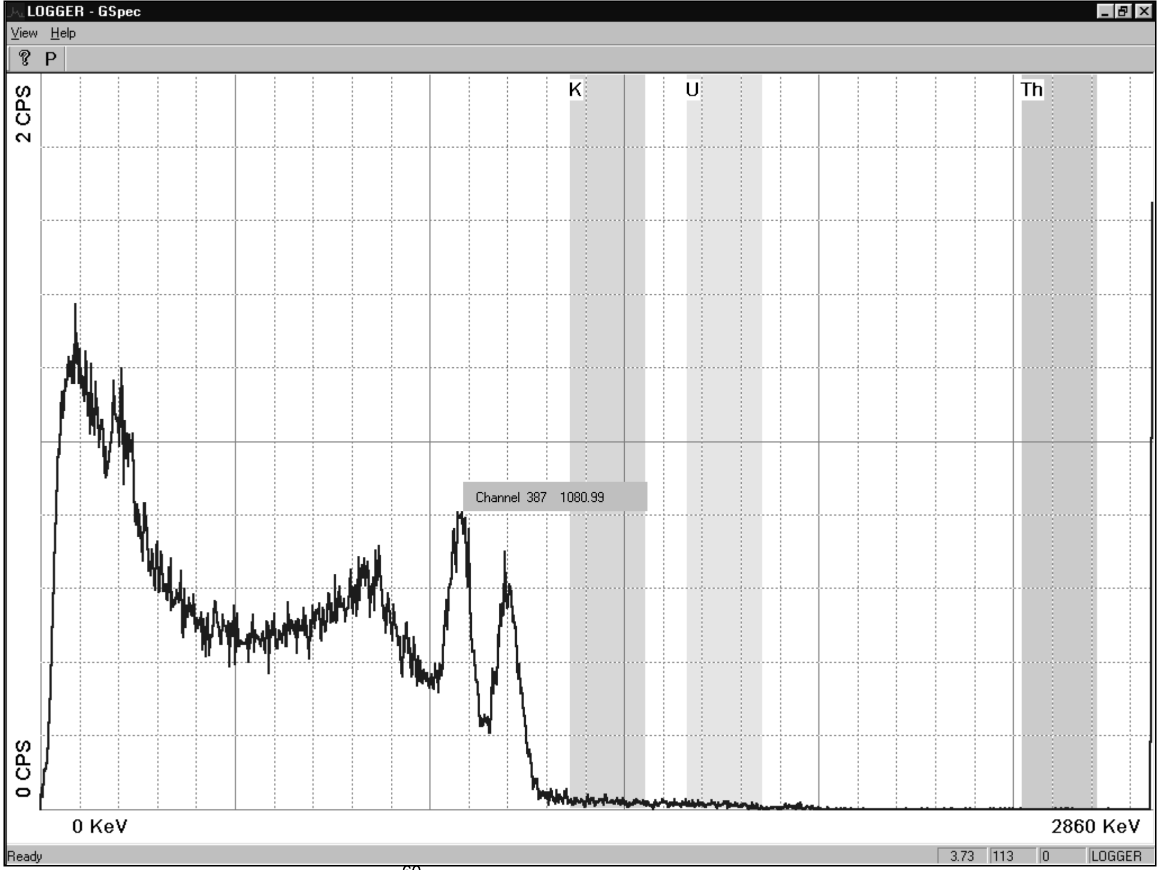
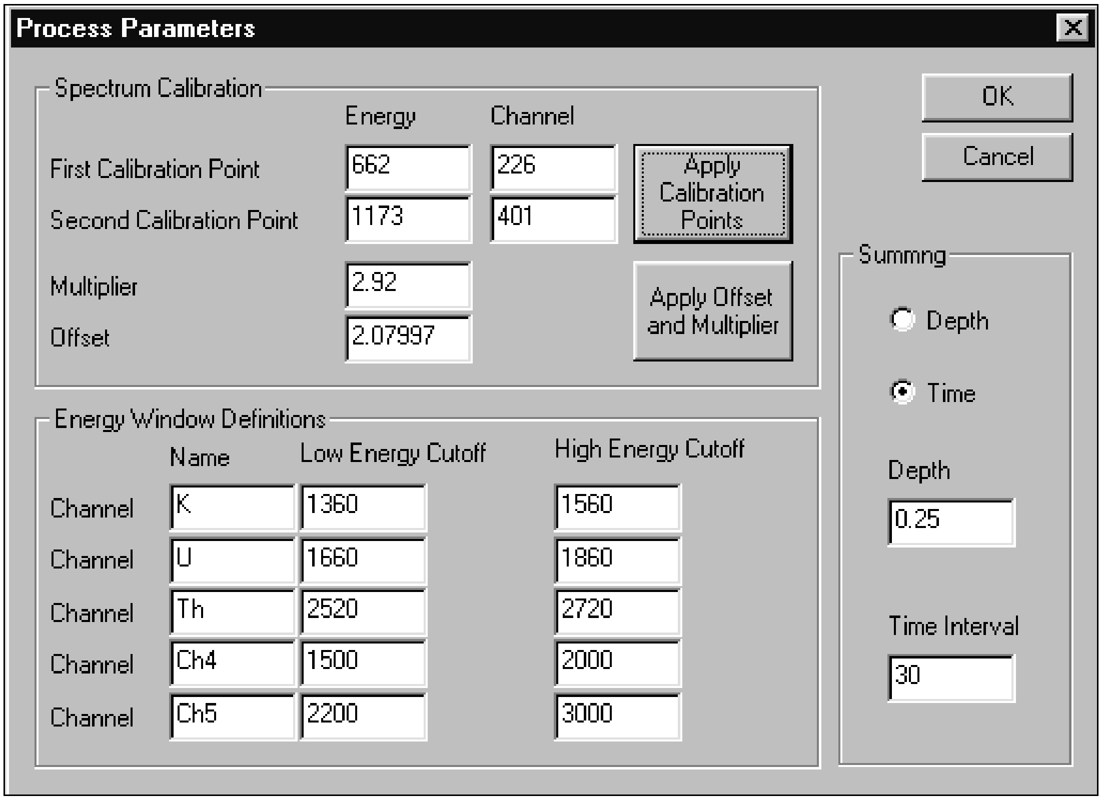


Figure 3: A typical spectrum from ^{60}Co standard source showing a peak at 1173 and 1333 KeV.

7. Click on the SpecProc window. Right click on the ‘P’ parameter tool bar button. Enter the energy for the first calibration source in the ‘First Calibration Point’ ‘Energy’ field (i.e. 662 for ^{137}Cs). Enter the window number recorded in step 3 in the ‘First Calibration Point’ ‘Channel’ field (i.e. 222 for ^{137}Cs). Enter the energy for the second calibration source in the ‘Second Calibration Point’ ‘Energy’ field (i.e. 1173 for ^{60}Co). Enter the window number recorded in step 5 in the ‘First Calibration Point’ ‘Channel’ field (i.e. 387 for ^{60}Co). See figure 4.



Spectrum Calibration

	Energy	Channel
First Calibration Point	662	226
Second Calibration Point	1173	401

Multiplier 2.92

Offset 2.07997

Energy Window Definitions

	Name	Low Energy Cutoff	High Energy Cutoff
Channel	K	1360	1560
Channel	U	1660	1860
Channel	Th	2520	2720
Channel	Ch4	1500	2000
Channel	Ch5	2200	3000

Summng

○ Depth

● Time

Depth 0.25

Time Interval 30

Figure 4: SpecProc calibration dialog box.

8. On the MSLog panel, click the ‘Close All’ button on the ‘Browsers & Processors’ window. Next, restart all processors and browsers by clicking on the name of the browser or processor, and pressing the ‘Start’ button. Note: LASWriter only needs to be started if an LAS output file is desired.
9. Check the calibration by placing a known gamma reference source as close as possible to the probe at a distance of 22.8 inches (58 cm) from the bottom of the probe. Verify that the photopeak appears at the correct energy.

Calibrating the **resistance** and **spontaneous potential** measurements is not necessary. They have been calibrated at the factory and the calibration numbers are electronically stored inside the probe.

Preventative Maintenance

Always keep the probe section connector covered when disconnected. This protects the connectors from mechanical abuse and corrosion. Use the probe section protector caps.

Remember that the gamma detector is fragile. Use care when placing the tool in the borehole and when traveling down into the borehole. Also, store the tool in a secure place, preferably in a shock resistant container. During transport, logging tools typically endure more shock than when in the borehole.

Keep all thread and O-ring surfaces clean and dry. Re-apply grease or silicone compound (O-rings) on a regular basis. Always clean the tool after each use.

Troubleshooting

Problems with the Probe

If electronic troubleshooting becomes necessary, it should only be performed by qualified persons.

If MSLog reports communications errors (such as parity-framing) and no data can be displayed, make sure that the probe is communicating properly. When the logger and the probe are communicating properly, the ‘to probe’ and ‘from probe’ lights should be flashing on the logger.

If communications are not functioning properly, make sure you are using the correct tool driver with MSLog. Also, check the condition of the wireline. The MSLog online help provides detailed instructions on this procedure. When running MSLog, right click on the dashboard and select Help Index. Then choose the Wireline and Cablehead Troubleshooting section.

Disassembly Instructions

To access the inside of the probe, the probe top can be removed from the main housing. To remove the probe top, first remove the three screws just below the section top. You will have to dig out the sealing compound out of the screw heads. This compound is used to discourage inadvertent disassembly. After removing the three probe top screws, gently pull the probe top out of the housing and disconnect the probe top connector from the upper circuit board. Remove the housing locking screw (located just above the resistivity electrode) using an M3 hex wrench.

Next the housing can be unscrewed from the lower section of the probe. The gamma circuit board is located at the top end of the inner housing with the gamma detector just below the circuit board. Disassembly of the gamma detector is not recommended. The lower most circuit board is for the resistance and spontaneous potential.

Common field correctable electronic problems are a broken or shorted wire. A visual inspection of the wiring should be performed before further testing is done.

If electronic testing is to be done, the user should have detailed electronic schematics before proceeding any further.

Schematics

2SNA-1000-S

Drawing Number	Title

Appendix

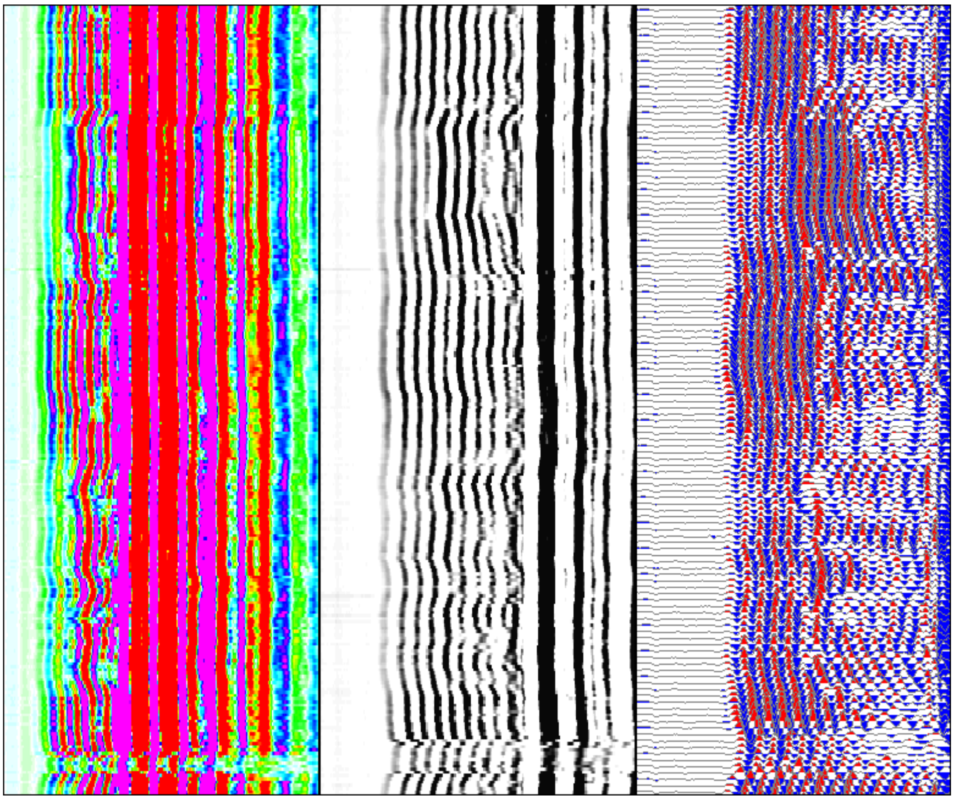
Suggested QA Procedure

General notes for Quality Assurance (QA) are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. Mt. Sopris acquisition programs record the calibration constants that were used to acquire the data. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedures specify that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.



User Guide

FWS 50 – Full Waveform Sonic

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v11.09.01

Table of Contents

1 General Information

The ALT full waveform sonic tool has been specifically designed for the water, mining and geotechnical industries. Its superior specification makes it ideal for cement bond logs, for the measurement of permeability index, and as a specialist tool to carry out deep fracture identification.

Advantages of the tool include:

- High energy of transmission to give a greater depth of penetration on longer spacing.
- Ability to record a long wave train for Tube wave train reflection which allows for the measurement of fracture aperture and permeability index.
- The absolute value of the amplitude of the received wave form is measurable thus allowing for the calibration of the amplitude.
- Truly modular construction allowing variation of receiver/transmitter combinations.
- Higher logging speeds when used in conjunction with the ALT Logger acquisition system due to the superior rate of data communication possible.

1.1 Technical Specification

Tool

Diameter:	Max 50mm
Length:	Depends on configuration; 1TX – 2RX @ 0.2m RX separation : 2.40m 1TX – 3RX @ 0.2m RX separation : 2.60m 1TX – 4RX @ 0.2m RX separation : 2.80m
Measurement point:	Transmitter location
Max. Temp:	70°C
Max.Pressure:	200bar

Cable:

Cable type:	Mono, Coaxial, 4 or 7 conductor
Digital data transmission:	Up to 500 Kbits per second depending on wireline
Compatibility:	ALTLogger – ABOX – Matrix

Sensors:

Transducers:	Ceramic piezoelectric with 15 kHz resonant frequency
Sonic Wave Sample Rate:	Configurable, minimum 2.5 µs
Sonic Wave Dyn. Range:	12 bits plus 4 bits gain
Sonic Wave Sample Length:	Configurable, up to 1024 samples

2 Measurement Principle

The FWS 50 tool measures the time it takes for a sound pulse to travel from a piezo electric transmitter to a receiver at a defined distance. Transmitter and receiver are mounted on the same tool. The transmitter pulse is very short (in the 15 kHz range) and of high amplitude. The so generated acoustic pulse travels through borehole fluid and rock in various different forms while undergoing dispersion and attenuation.
When part of the energy of the emitted sound pulse arrives at a receiver it does so at different times in form of different types of waves (Figure 2-1).

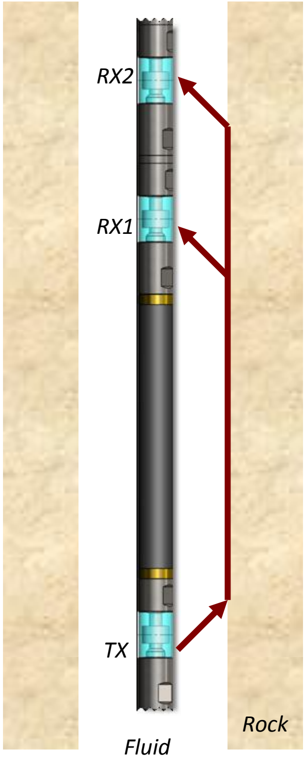


Figure 2-1 *Typical wave path for a 1 transmitter and 2 receiver tool*

Usually it is the compressional wave (P-wave) that travelled through the rock (or pipe) that arrives first followed by shear waves (S-wave), Rayleigh, Stoneley and mud waves. Figure 2-2 shows a typical sonic trace with received wave forms.

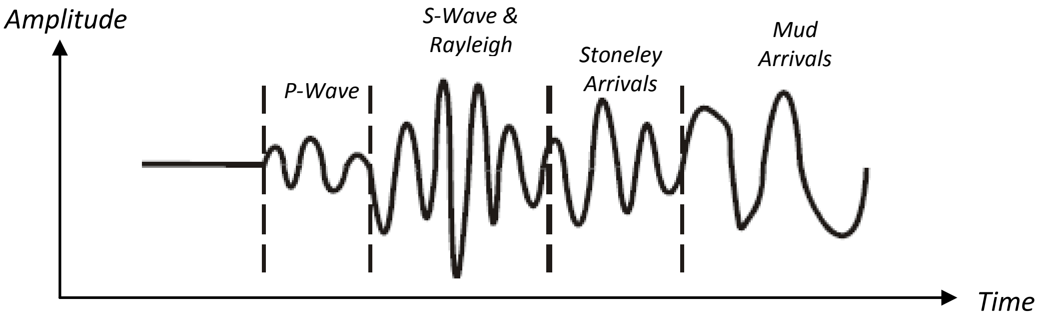


Figure 2-2 *Typical sonic trace with wave form arrivals*

The P-wave is usually the fastest wave but has small amplitudes. The next wave to arrive is the S-wave, which is slower than the P-wave but usually has higher amplitudes. After them come Rayleigh and Stoneley waves, which are associated with energy moving along the borehole wall. The last arrival (mud wave) is a pressure wave that travels through the borehole fluid in the borehole. They can be of high amplitude but always arrive after the two main waves – P- and S-wave.

3 Operating Procedure

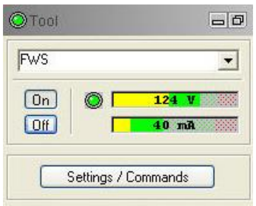
Note: Parts of the topics discussed in these sections below assume that the user is familiar with the ALTLog or MATRIX acquisition software. Refer to the corresponding operator manuals for more details. Information about assembly and configuration of tool stacks can be found in the same manuals.

3.1 Quick Start

1. Connect the FWS to your wireline and start the data acquisition software.

2. Select the relevant FWS 50 tool from the drop down list (Figure 3-1) in the software’s **Tool** panel (if your tool is not listed check that your tool configurations file is stored in the designated folder on your computer).

3. In the **Tool** panel switch on the tool (click **On** button) and verify that the power indicator shows a valid (green) level. The system goes through a short initialization sequence which sets the default parameters and communication settings held in the tool configuration file. The configuration returned by the tool is also checked during this procedure. (Setup the tool communication as explained in chapter **3.4** if an error message is displayed.)



FWS
124 V
40 mA

Figure 3-1 *Tool panel*

4. On the **Tool** panel (Figure 3-1) click the **Settings / Commands** button to configure your tool. (see chapter **3.4** for details).

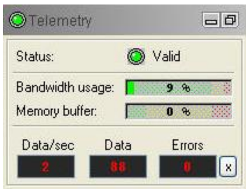
5. In the **Acquisition** panel (Figure 3-2) select the sampling mode (depth or time). Click on **Settings** and specify the corresponding sampling rate. Switch on the sampling (click the **ON** button).

6. Press the **Record** button in the **Acquisition** panel (Figure 3-2), specify a file name and start the logging.

Time 500 msec

Figure 3-2 *Acquisition panel*

7. During logging observe the controls in the **Telemetry** panel (Figure 3-3):
   - Status must be valid (green light);
   - Bandwidth usage in green range;
   - Memory buffer should be 0%;
   - Number of **Data** increases and number of **Errors** negligible.



Status: Valid
Bandwidth usage: 9 %
Memory buffer: 0 %
Data/sec 2
Data 88
Errors 0

Figure 3-3 *Telemetry panel*

8. To end the logging procedure press the **Stop** button in the **Acquisition** panel and turn off the sampling (click **OFF** button).

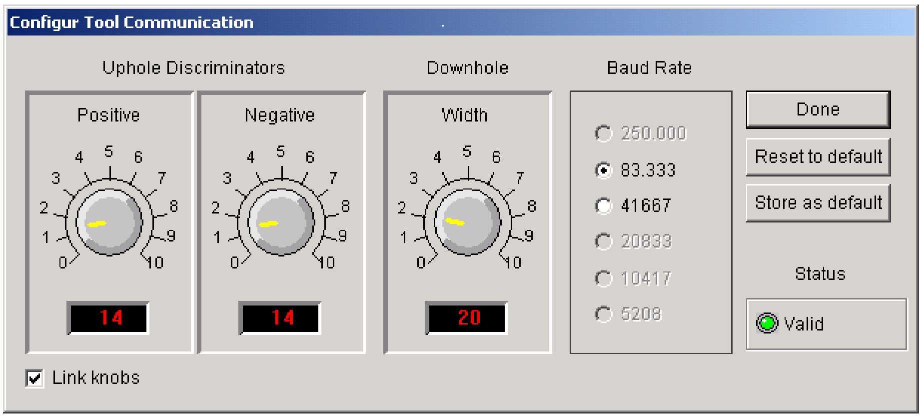
9. In the **Tool** panel power off the tool.

3.2 Tool Communication with ALT Logger

The telemetry provided through the ALTLogger is self-tuning**.** In case communication status is not valid the user can manually adjust the settings. In the **Telemetry** panel of the dashboard click on **Settings** to display the **Configure Tool Communication** dialog box (Figure 3-4).

A procedure to achieve valid communication is given below:

- Change the **Baudrate** to 41666 kbps.
- Verify that the **Downhole Pulse width** knob is set on 20 (default value). This value is the preferred one and is suitable for a wide range of wirelines. For long wireline (over 2000m), increasing the pulse width could help to stabilize the communication. The reverse for short wireline (less than 500m).
- Set the **Uphole** discriminators in the middle of the range for which the communication status stays valid.
- Increase the **Baudrate**, check the communication status stays valid and the **Bandwidth usage** (in **Telemetry** panel of the dashboard) is below the critical level.
- When **Uphole** discriminators are properly set, store the new configuration as default. The tool should go through the initialisation sequence the next time it is turned on.



Positive 14

Negative 14

Width 20

○ 250.000
● 83.333
○ 41667
○ 20833
○ 10417
○ 5208

Status ● Valid

☑ Link knobs

Figure 3-1 *Tool communication settings*

3.3 Tool Communication with MATRIX

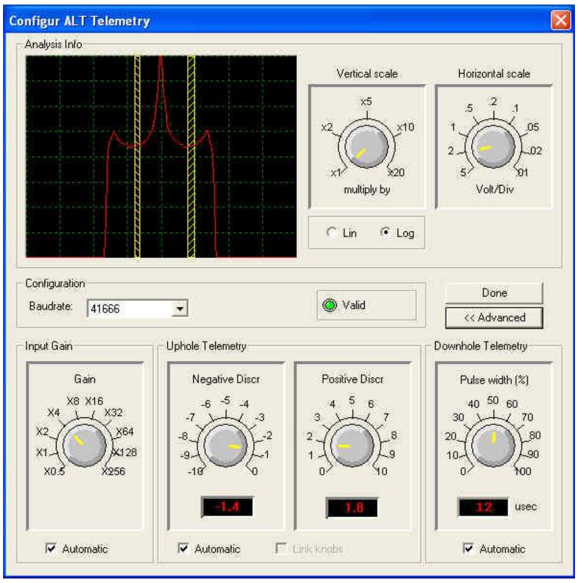
The tool telemetry can be configured through the **Telemetry** panel of the Matrix dashboard. By clicking on **Settings**, the operator has access to the **Configure ALT Telemetry** dialog box (**Figure 3-5**) providing various controls to adjust the telemetry settings and monitor its current status.

The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **lin**ear / **log**arithmic scale buttons.

The status of the configuration should be flagged as Valid (indicated by the LED being green). In any other case (LED red) the telemetry should be adjusted (we assume a pulse signal is displayed in the analysis view). Click on the **Advanced** button to display additional controls to tune the telemetry.

The Automatic settings option is the preferred mode and should allow the telemetry to be configured for a wide range of wirelines without operator input. For wirelines with a more limited bandwidth, the operator might need to turn off the automatic mode and adjust the telemetry settings manually.

For each wireline configuration, the discriminators (vertical yellow lines) for the **positive** and **negative** pulses must be adjusted in order to obtain a valid communication status (see Figure 3-5) for an example of a suitable discriminator position). There is also the option to alter the **baudrate** in order to optimize the logging speed. The input **gain** can be increased (long wirelines) or decreased (short wirelines) in order to set up the discriminator levels correctly.



Configur ALT Telemetry

Configuration

Baudrate: 41666

● Valid

Input Gain: ☑ Automatic

Uphole Telemetry: Negative Discr -1.4; Positive Discr 1.8; ☑ Automatic; ☐ Link knobs

Downhole Telemetry: Pulse width (%) 12 usec; ☑ Automatic

Vertical scale: ○ Lin ● Log

__Figure 3-5__ Matrix telemetry settings

Once the telemetry is correctly set, store the new settings as default. The tool should go through the initialization sequence in "Valid" status the next time the power is turned on.

3.4 Configuring Tool Parameters

The **Configure FWS Tool Parameters** dialog box (Figure 3-6) can be accessed by clicking on the **Settings / Command** button on the dashboard's **Tool** panel (Figure 3-1).

It is recommended that sampling is turned off before changing any of the parameters (Acquisition Panel - Figure 3-2).

3.4.1 Status LED

The LED in the lower right of the dialog box indicates whether or not the parameters set in the dialog box correctly reflect the actual tool configuration. **Green** indicates **Valid**. After each change made to the tool configuration parameters the LED turns orange displaying the message "Updating". If an Invalid response occurs it is likely that a problem occurred while transmitting the tool configuration information from tool to surface through the wireline. In this case repeat the setting.

3.4.2 Transmitter Selection

If your FWS tool is fitted with two transmitters you can choose to operate only one transmitter or both by turning the transmitter (Tx) mode knob labeled **Channel** (Figure 3-6). Turn it to position **A** or **B** to operate only a single transmitter or set it to **A & B** to fire both transmitters in alternating sequence. Transmitter A is the one located closest to the bottom of the tool.

3.4.3 Receiver Selection

The Configure Tool Parameters dialog box provides a control knob (**Rx**) to choose the receivers. For each receiver selected the **Gain** and **Rate1 & 2** parameters can be set individually.

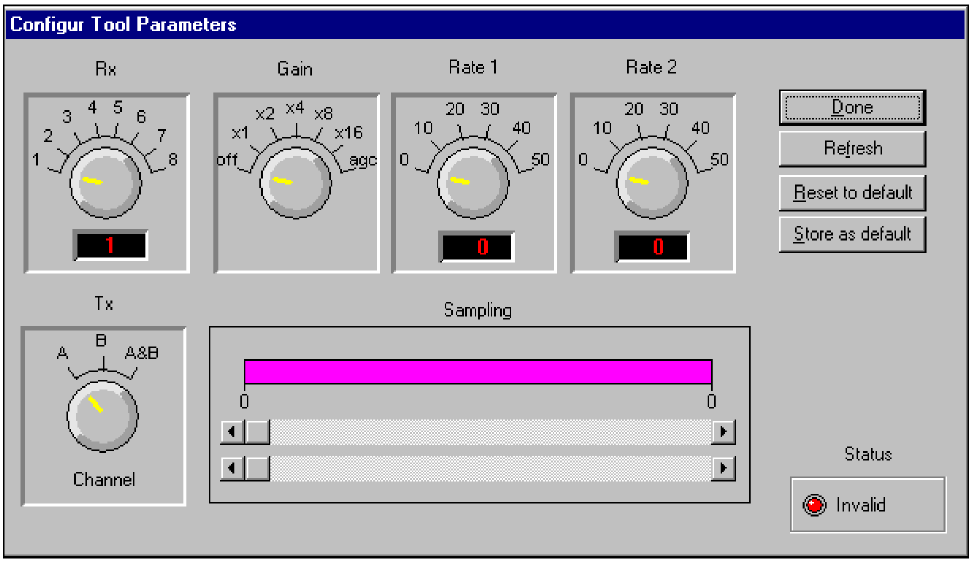


Figure 3-2 *Receiver Selection per transmitter*

3.4.4 Gain

Note: Select the receiver for which you would like to change the gain first.

Allows configuration of the gain applied to the received signal (for each receiver). The gain can be a fixed value ranging from **x1** to **x16** or it can be controlled by the tool using an **Automatic Gain Control** (**AGC**). There is also an “off” option which disables the gain system for the selected receiver so that no data is received on that channel. This is useful to reduce data file size for a multi-receiver tool when a high sampling rate is required.

The system default is set to **AGC**. In this mode the tool will constantly adjust the acoustic sensor gain to the best possible value. To achieve this, the system will increase the gain by 1dB if the previously digitised echo amplitude was below than the AGC lower threshold value or it will decrease the gain by 1dB if the amplitude value was above the AGC high threshold value.

Under normal operating circumstances it is recommended that the AGC is used.

3.4.5 Rate 1 & Rate 2

Note: Select the receiver for which you would like to change the time sampling rates first.

The sampled waveform can be digitized over two time windows for which different sampling rates can be applied. The length of the time windows can be adjusted in the **Sampling** control. The sampling rate is set for each window by turning the appropriate control knob (**Rate1** for the first time window, **Rate2** for the second). This allows the user to focus on a particular zone of interest. Rates are given in µS, i.e. a sample rate of 10 represents a sample every 10µS.

3.4.6 Sampling

Use the slider bars or arrow buttons to adjust the width of the two time windows (see **3.4.5**). Values displayed are in µS. The upper control can be used to set the time gate for the “early” window while the lower control allows setting the limits of the “late” window.

In order to apply the settings click on **Refresh** and check the **Status**. If the Status is valid click **Done** to close the dialog box. You may want to make the new settings your default configuration. In this case click on **Store as default**.
To load previously saved default settings click the **Reset to default** button.

3.5 Recorded Parameters, Processors and Browsers

3.5.1 Recorded parameters

Note: None of the data channels recorded has been shifted in depth. The transmitter location is considered as measurement point.

The following data channels are recorded by the tool. Depending on the number of transmitters and receivers used and the chosen receiver mode the number and naming of the recorded data channels may vary.

RX1-1A	Amplitudes of the sonic trace recorded at transmitter A and recorded at receiver 1 (time window 1)
RX2-1A	Amplitudes of the sonic trace recorded at transmitter A and recorded at receiver 2 (time window 1)
RX1-1B	Amplitudes of the sonic trace recorded at transmitter B and recorded at receiver 1 (time window 1)
RX1-2A	Amplitudes of the sonic trace recorded at transmitter A and recorded at receiver 1 (time window 2)

…

The naming convention for the data channels is:

RX*n-mT*

where ***n*** is the receiver number, ***m*** defines the time window (1 : “early”, 2 : “late”) and ***T*** defines the transmitter which generated the wave (A or B).

Please note that additional data channels can be produced by the FwsProc processor. Please refer to the following chapter.

3.5.2 FWS40Wave Browser

This family of windows supports the FWS acoustic tool and provides user controls for setting display characteristics of waveform traces.

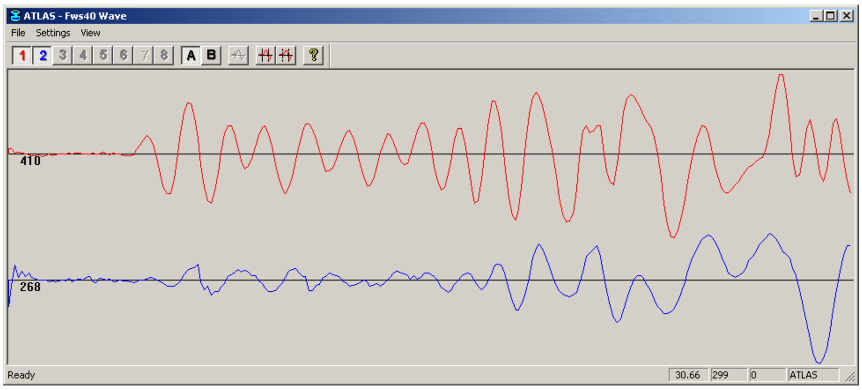


Figure 3-7 *Fws40 Wave browser*

Press the **dtpickup** preview icon from the toolbar in order to see the first arrival picks made by the system (see 3.5.3 FWS Processors).

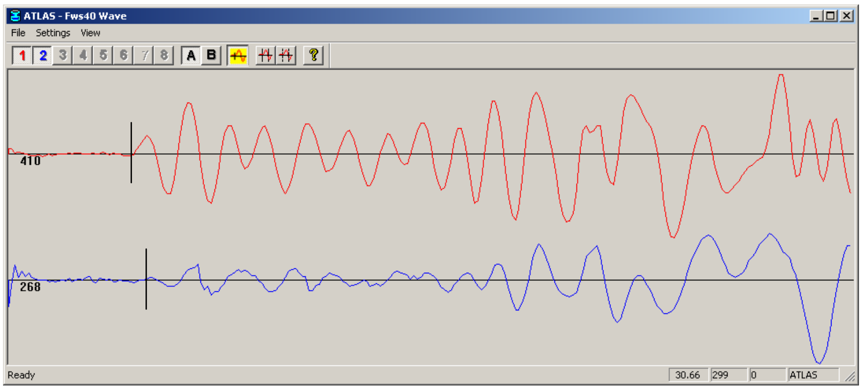
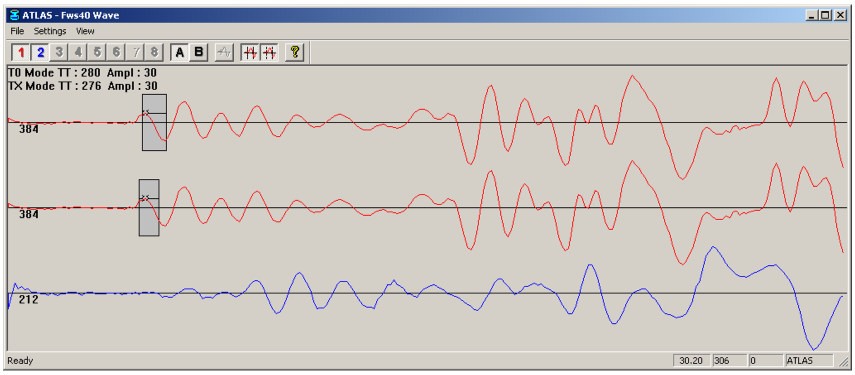


Figure 3-8 *Fws40 Wave browser with first arrivals*

To display the Fixed and Floating gates and derive amplitudes of the **cblproc** processor (see 3.5.3 Fws Processors) click the icons from the toolbar.



T0 Mode TT : 280 Ampl : 30
TX Mode TT : 276 Ampl : 30

Ready | 30.20 | 306 | 0 | ATLAS

Figure 3-9 *Fws40 Wave browser with Cement Bond process fixed and floating gates on receiver 1*

Additional settings for the wave display can be retrieved from the **Settings** menu.

3.5.3 FWS Processors

Processors perform real time operations on the recorded data. For the FWS 50 tool two processes are supported: Picking of the **First Arrival** and **Cement Bond** log processing.
If a processor window is not started automatically choose the corresponding entry from the dashboard's **Browser & processors** panel and click on the **Start** button.
To start or stop a process right click on the title bar of the processor window (Figure 3-10 and Figure 3-12) or select the **Parameters** option from the context menu to edit the processing parameters.
The **Parameters** dialog box will open providing a tab to adjust the processing parameters for each process (Figure 3-11 and Figure 3-13).

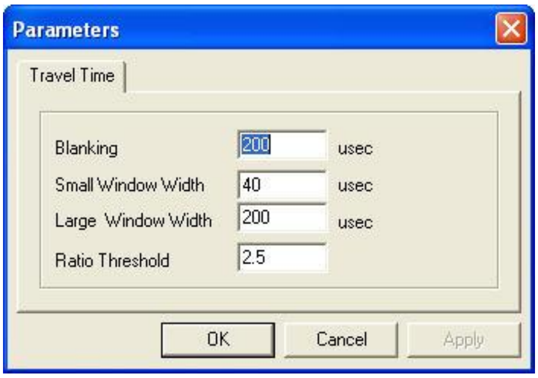
First Arrival Pickup
The **dtpickup** window (Figure 3-10) informs about the status of the processes.

Running

20.23 | 73 | 0 | ASTEROPE

Figure 3-10 *dtpickup window*

The preview window (Figure 3-8) shows the recorded traces and the determined first arrival picks (vertical lines). The first arrival time will be picked for each selected receiver and output as a data channel. The resulting data channels can be used in formulas to compute P-wave slowness and velocities.
Right click on the title bar of the dialog box to open the processing **Parameters** dialog box (Figure 3-11).



Blanking 200 usec
Small Window Width 40 usec
Large Window Width 200 usec
Ratio Threshold 2.5

Figure 3-11 *First Arrival Pickup process options*

The process iterates through each trace in the time dimension. For each data point the average of the data values in a time window centered on the actual data point (Small Window = signal window) will be calculated. Another average value will be calculated from the data points falling into a time window preceding the actual data sample (Large Window = noise window). The ratio of small window average and large window average (signal to noise) will be compared against a user specified threshold value. The first time sample for which the computed signal to noise ration exceeds the threshold will be considered as first arrival intercept.

$$\frac{Small\ Window\ Average}{Large\ Window\ Average} \rangle\ Ratio\ Threshold$$

Blanking
In the edit box, enter the time period in micro-seconds for which the first arrival detection will be skipped. Using this option, you can blank out noise occurring in the beginning of the traces.
Small Window Width
In the edit box, enter the Small Window time width in micro-seconds.
Large Window Width
In the edit box, enter the Large Window time width in micro-seconds.
Ratio Threshold
In the edit box, enter the Ratio Threshold value.

The following data channels will be created by the **dtpickup** process:

RX1-1A - dt	First arrival pick (in µs) at receiver 1
RX2-1A - dt	First arrival pick (in µs) at receiver 2
RX3-1A - dt	First arrival pick (in µs) at receiver 3
RX4-1A - dt	First arrival pick (in µs) at receiver 4

Cement Bond

The **cblproc** window (Figure 3-12) informs about the status of the processes.

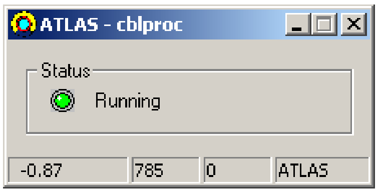


Figure 3-12 *cblproc window*

If a FWS tool is run in a borehole with cemented casing, the quality of the bond from casing to cement can be evaluated. The emitted acoustic signal travels through the casing, cement and formation before it reaches the receivers. The sonic waves travelling along the casing are attenuated when energy is lost to the environment behind the casing due to conversion of P- to S-waves, i.e. when the bond is good. As the compressional wave travelling through the casing is generally the first one to reach the nearest receiver, the Cement Bond Log is the recording of the amplitude of the first arrival of energy on the near receiver.
The first three peaks of the signal at the receiver are traditionally labeled E_1, E_2 and E_3 (Figure 3-13).

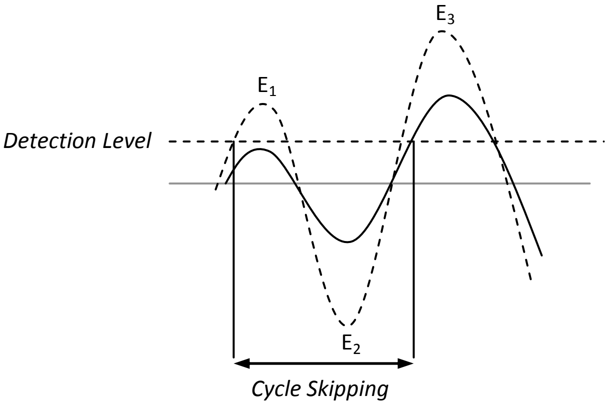
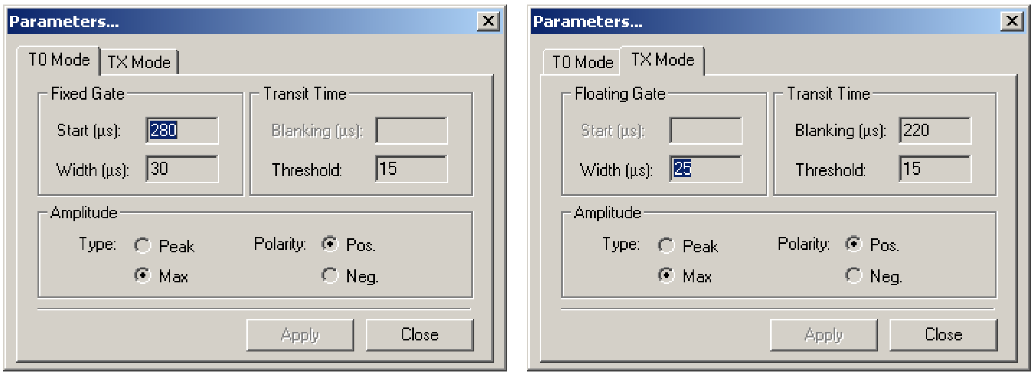


Figure 3-13 *Naming of signal peaks and principle of cycle skipping*

It is the goal of the Cement Bond processing to extract the amplitude of the E1 peak, which leads to judgment of the cement bond quality (low amplitude = good bond, high amplitude = bad bond).
In the case when the bond leads to amplitudes of E_1 so low that they are below the detection level, the first arrival pick would be triggered by E3 instead of E1. This is referred to as cycle skipping (Figure 3-13).
Two processes (Fixed and Floating Gate) will be run in parallel to extract the desired amplitude. In general the maximum amplitude within a time window (also referred to as gate) will be determined. The gate can be opened always at the same fixed time for all traces (Fixed Gate) or it can be opened at the time provided by a first arrival pick log (Floating Gate) – in the last case the starting time varies from trace to trace. If cycle skipping occurs the Fixed Gate method would return small amplitudes and the Floating Gate method high amplitudes, altogether indicating a very good bond (the E_1 amplitude was so low that the higher E_3 amplitude was detected by the Floating Gate method).

Right click on the title bar of the **cblproc** window to open the processing **Parameters** dialog box.
Two tabs allow configuration of the Fixed Gate (**T0 Mode**) and Floating Gate (**TX Mode**).



Fixed Gate
Start (µs): 280
Width (µs): 30
Transit Time
Blanking (µs):
Threshold: 15
Amplitude
Type: ○ Peak ● Max
Polarity: ● Pos. ○ Neg.

Floating Gate
Start (µs):
Width (µs): 25
Transit Time
Blanking (µs): 220
Threshold: 15
Amplitude
Type: ○ Peak ● Max
Polarity: ● Pos. ○ Neg.

Figure 3-3 *Fixed and Floating options*

For the Fixed Gate configuration you can enter:
Start(µs): Starting point of the detection gate.
Width(µs): Width of the gate.
Threshold: Amplitude of detection level.
Only signal amplitudes within the gate limits and above the defined detection level will be extracted and recorded.
Select whether the Peak or Max amplitude (Figure 3-14) should be picked.

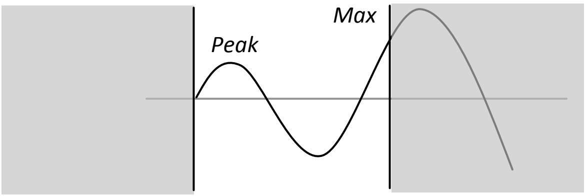


Figure 3-14 *Difference between Peak and Maximum*

For the Floating Gate configuration you can adjust the following parameters:
Blanking(µs): Only first arrival times beyond the banking period are considered as valid starting point for the gate.
Width(µs): Width of the gate.
Threshold: Amplitude of detection level.

The following data channels will be created by the **cblproc** process:

TT**0**	Start time of fixed gate (in µs)
TAmpl0	Time at which fixed gate amplitude was derived (in µs)
Ampl0	Amplitude from fixed gate
TTX	Start time of floating gate (in µs)
TAmplX	Time at which floating gate amplitude was derived (in µs)
AmplX	Amplitude from floating gate

The parameters values are recorded also in the data file as :

T0GateSart	Start time of fixed gate (in µs)
T0GateWidth	Fixed gate width (in µs)
T0Threshold	Amplitude detection level in the fixed gate
T0AmplMaxUsed	1 if the max amplituded is picked in the fixed gate
T0AmplPosUsed	1 if the peak amplituded is picked in the fixed gate
TXBlanking	Blanking used to define the start of the floating gate (in µs)
TXGateWidth	Floating gate width (in µs)
TXThreshold	Amplitude detection level in the floating gate
TXAmplMaxUsed	1 if the max amplituded is picked in the floating gate
TXAmplPosUsed	1 if the peak amplituded is picked in the floating gate

3.5.4 Fws40 Image Browser

This browser displays the waves acquired on each receiver in real time. The **1**, **2**, … **8** toolbar buttons allow selection of the waves detected by the different receivers to be displayed. The **A** and **B** toolbar buttons allow display of the received waves fired by the transmitter A or B respectively. The Extended Wave is displayed in the bottom part of the window. All these options are either available from the toolbar or from the menu.

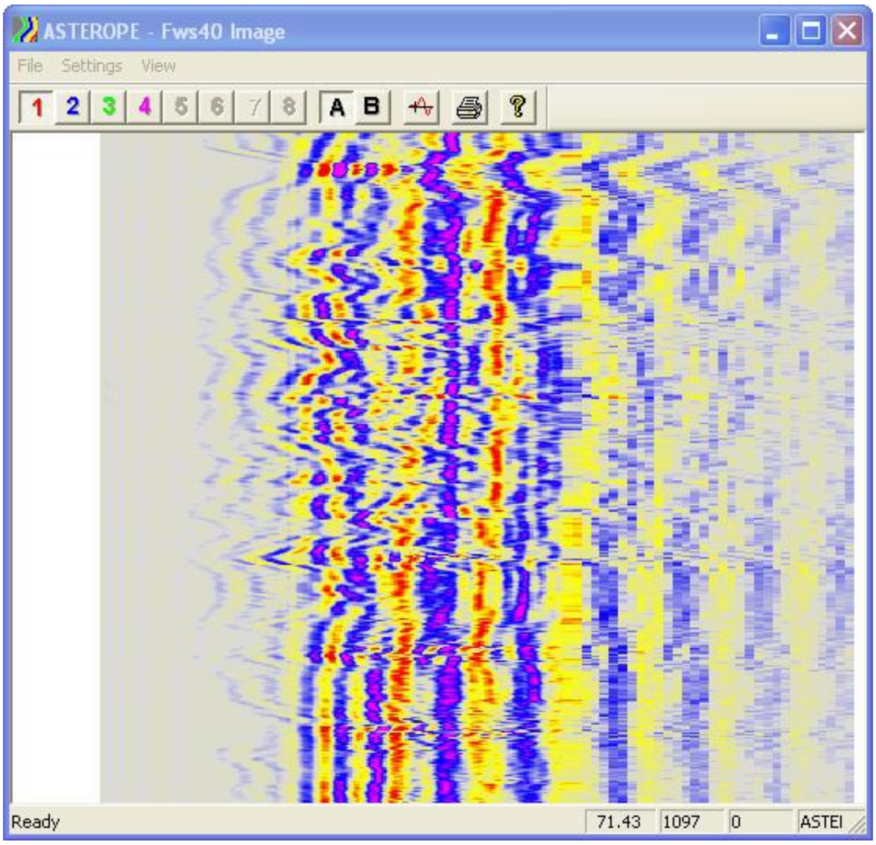
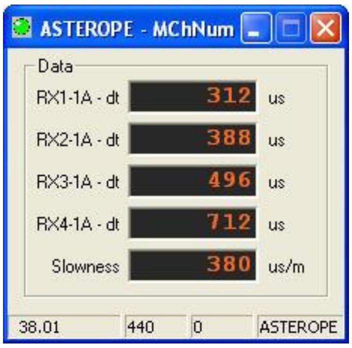


Figure 3-15 *Fws40 Image browser*

Under **Settings** further options to change the appearance of Depth axis and Image are available.

3.5.5 MChNum Browser

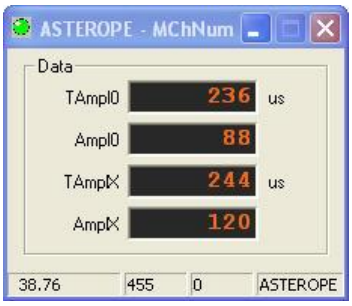
Figure 3-16 and **Figure 3-17** show a typical example of the numerical values displayed in the MChNum browser window during logging. The display can be modified by right-clicking on the browser window and selecting the **Display options…** entry.



RX1-1A - dt 312 us
RX2-1A - dt 388 us
RX3-1A - dt 496 us
RX4-1A - dt 712 us
Slowness 380 us/m

38.01 440 0 ASTEROPE

__Figure 3-16__ MChNum browser (OpenHole display)



TAmpl0 236 us
Ampl0 88
TAmplX 244 us
AmplX 120

38.76 455 0 ASTEROPE

__Figure 3-17__ MChNum browser (Cement Bond display)

4 Performance Check & Calibration

There is no specific performance check or calibration procedure recommended by ALT. When starting the sampling (tool powered on) the firing of the transmitter pulse should be heard even in air. A test borehole or water filled bucket can be used to check the correct operation of the tool over time.

5 Maintenance

Warning: Removing the electronic chassis from pressure housing without prior consultation with ALT will void the tool warranty.

5.1 Tool Handling

When handling the sonic tool remember the following points:

- If the tool is laid on stands, take care that the tool is not resting on a sensor window and if the tool is laid on the ground make sure that there are no sharp objects which may damage the sensors.
- When carrying the tool horizontally or winching the tool up to a sheave block, support the tool evenly taking care not to excessively bend the isolator section.

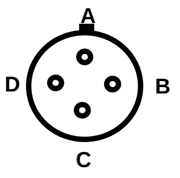
5.2 Tool Head

The cable head socket and connector pins of the tool head should be checked for cleanliness before each use of the tool. The pin insert has a locating mark which should line up with the slot that mates with the cable head.

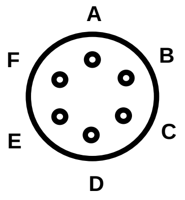
The tool head is fixed to the steel pressure housing by four hex screws and can be withdrawn from the pressure housing with a straight pull. The internal end of the tool head is fitted with a 6-way MIL socket. The internal electronic chassis is connected to this by a short flexible lead and plug which is disconnected to remove the head. When removing the tool head care must be taken not to over pull the head and damage this wire link.

Check seals and apply silicon grease before re-assembly. Silicon grease of a similar type to RS Components Ref 494-124 is suitable for this and other “O”ring seals.

5.3 Tool Head Wiring



Pin Insert
(viewed towards tool open end)



Cannon Connector
(as marked)

Pin Insert	Function	Colour Code	Cannon Connector
A	Tool Power/Data	Red	A
B	Tool Power/Data	Red	B
C	Tool Power/Data	Pink	C
D	Tool Power/Data	Pink	D
Armour-Gnd		Black	E
Armour-Gnd		Black	F

ALT Tool Head Configuration

5.4 Pressure Housing

After removal of the tool head, the pressure housing can be removed by undoing the four hex set screws fixing it to the sub at the top of the bottom sensor section. During re-assembly care should be taken not to over tighten these screws which may shear off if overloaded!

5.5 Transmitter/Receiver Section

This section of the tool is modular in construction facilitating the exchange of components or reconfiguration of the tool. The transmitter and receiver crystals are identical and interchangeable in the event of a transmitter failure. They are female threaded at both ends and mate with the male threaded connector of the spacer or bottom plug. Spacer pieces are manufactured with a slotted brass core surrounded by a polyurethane resin coating. The assembly must be disassembled from the top down, i.e. from the electronic chassis end. First unsolder the screened wires of the transmitter attached to the FWSEHT board, and receivers attached to the SONIC-IP processor boards taking note of polarity and position. Remove the electronic chassis by unscrewing the four hex screws fixing the chassis to the sub, then unscrew the pieces of the bottom section as required. Care must be taken not to damage the wiring passing up the centre of the section, and the two wires for a particular transmitter/receiver must be rotated about the remaining wires as the sensor is unscrewed. This job is more easily carried out by two people. Tools used to break the sections free should only be applied to the brass part of the spacer and excessive force is not necessary when reassembling.

In the single transmitter, multiple receiver configurations the transmitter is at the top of the sensor section to minimise noise on the receivers through crosstalk. The spacer between the transmitter and first receiver must be an acoustic isolator, spacers between second or third receivers may be of hollow stainless steel construction.

Care must be taken when handling the tool to minimise bending of the isolator section at all times.

5.6 Electronic Chassis

The electronic chassis is two stainless steel flat 10x3mm bars with intermediate spacers mounted between the circuit boards. Board mountings and chassis fixings should be periodically checked for tightness.

6 Troubleshooting

Observation	**To Do**
Tool not listed in Tool panel drop down list.	- Do you have a configuration file? - Has the configuration file been copied into the …/Tools folder (refer to MATRIX or ALTLog manual about details of the directory structure)?
Tool configuration error message when powering on the tool.	- Check all connections. - Adjust the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3) and store the new settings as default. Apply the appropriate tool settings for your logging run (see chapter 3.4).
Tool panel - No current.	- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system. - Verify cable head integrity. - Verify voltage output at the cable head (it should be 120V).
Tool panel - Too much current (red area).	**! Immediately switch off the tool !** **-**Possible shortcut (voltage down, current up): Check for water ingress and cable head integrity - wireline continuity. - Verify the interface cable between winch slip ring and data acquisition system is not loose at the connectors. Check for possible source of a shortcut. - If the above shows no issues, use test cable provided by ALT to verify tool functionality. - If the problem still occurs, please contact service centre.
Telemetry panel - status shows red.	- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3). - If problem cannot be resolved contact support@alt.lu .
Telemetry panel - memory buffer shows 100%.	- Indicates that the systems internal memory buffer is full. PC can’t receive incoming data streams fast enough. Ensure your PC has enough resources available.
Telemetry panel – bandwidth usage shows 100%. *(Overrun error message.)*	- Set the baudrate to highest value allowed by your wireline configuration. - Reduce logging speed, decrease azimuthal resolution and/or increase vertical sample step.
Telemetry panel - large number of errors.	- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3). - Check bandwidth usage and telemetry error status.

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HFP-2293
HEAT PULSE FLOW METER

Mount Sopris Instrument Co., Inc.
Golden, CO U. S. A.
October 10, 2002

Table of Contents

General Information

Overview

The Heat Pulse Flowmeter Model HFP-2293 is a tool designed to measure low flow rates in the borehole environment. In conjunction with a low flow rate reading the HFP-2293 will also give the direction of the flow of fluid, up or down in the borehole. Operating on a MGX or MGX II with single conductor wireline and supplied software, the tool is a very useful instrument in determining low flow rates.

As mentioned above the tool is supplied with PC based software, centralizers and a range of diverters for 4 inch through 8 inch holes. Diverters are devises that divert flow in the borehole through a column where the measurement is taken by the tool. The tool can also be run in a 2 inch undeviated hole without a diverter assembly to allow for a safety factor to determine the direction of flow in the borehole. Although running the tool in a 2 inch hole without a diverter will give you a flow rate, it is an uncalibrated reading and cannot be held to the specifications mentioned in this document. Any attempt to use this tool without a diverter or a diverter of improper size with respect to the borehole may result in erroneous data.

The HFP-2293 is also supplied with a trigger assembly. The trigger is a device that communicates to the probe through the cable line, to start a heat pulse measurement cycle. The trigger can be tied into the system via. the banana jacks on the MGX or MGX II.

This document describes the hardware of the HFP-2293 Heat Pulse Flowmeter, installation procedures, tool maintenance and logging procedures. There are separate documents for the operation of the different types of software depending on logger type and or firmware versions, and there will be references made in this document that will relate to the software document regarding certain logging procedures.

Controls, Connectors, and Layout

Controls for the HFP-2293 consist of a trigger assembly that allows the user a means to communicate to the tool to begin a heat pulse measurement cycle. This trigger assembly can be thought of as a simple switch, that when pressed, instructs the tool to fire the heat grid. This trigger assembly connects to the cable line at the surface. The connection can be made on the MGX at the banana jacks or through an area in the surface equipment where access to the cable lines can be made. The trigger assembly is shipped from the factory with banana plugs as a means of termination. For the connection described above, any connector may be used that is compatible with the surface equipment.

Connectors for the tool are as follows. The probe top described below is a Mount Sopris standard single conductor probe top. Other variations of probe tops and wiring can be accommodated at the factory but will not be discussed in this document.

PROBE TOP CONNECTOR:

Pin	Signal	Origin
Probe top housing	Tool power ground	Armor
Center pin in probe top	Tool power positive	Center conductor

Connectors on the tool that are exposed to the borehole environment are located on the bulkhead assemblies. These connectors allow a pressure sealed electrical connection to be made from the inside of the tool to the outside of the tool. These connectors are used for the sensors that measure the heat pulse, and the heater grid, which heats the borehole fluid. On the bulkheads, located under or covered by the filter screens, numbers are stamped by the corresponding connectors and labeled 1, 2 and 3. The connector labels must line up with one another from the top bulkhead to the bottom bulkhead.

Their connections are as follows.

TOP BULKHEAD:

Pin	Signal	Origin
1	Signal from sensors	Top thermistor
2	Connection to heat grid	High voltage capacitors
3	For future use	

BOTTOM BULKHEAD:

Pin	Signal	Origin
1	Signal from sensors	Bottom thermistor
2	GND for sensors and grid	Armor
3	N.C.	

Layout for the tool in general is as follows starting at the bottom of the tool. The lower section consists of the measurement column, diverter, heat grid and sensors. Above the lower section is the main housing of the probe where the electronic circuits reside. Above the housing is the probe top, which is the connection to the cable head tied to the winch assembly.

Theory of Operation

The Heat Pulse Flowmeter operation is as follows. The tool is lowered into the borehole via a cable attached to a winch. When the tool is in position to take a flow measurement the trigger assembly button is pressed. This sends a pulse down the center conductor which when detected by circuitry in the probe, fires the heat grid and signals the surface monitoring equipment and software to begin a flow measurement cycle. The grid heats a sheet of water that moves with the flow of the borehole to the upper or lower sensor. The difference in temperature between the sensors is detected by an amplifier. The output of this amplifier is then converted to a frequency. This frequency is then driven up the cable line and monitored by the surface equipment. When the tool is pulsed by the surface, the tool immediately begins to charge the capacitors that produce the voltage for the heat grid in preparation for the next measurement cycle. A complete flow measurement is made when the time has been accurately measured from when the heat grid was fired to when a peak temperature change, carried by the flow was detected by either the sensor located above or below the heat grid.

The P.C. based software supplied with the tool is very versatile in determining the flow of the borehole. There are two types of software available for use with the HFP-2293. Depending upon the type of data acquisition software used by the MGX II system, either Mslog or Logshell, the programs MSHeat for Windows is distributed or SBCFlow for Logshell users. The MSHeat program operates under the Windows environment. The software, SBCFLOW, is ACQSBC based and users of Mount Sopris MGX LOGSHELL software will be somewhat familiar with the look of the software once they are in the data acquisition portion. A document thoroughly describing the use of the software is also supplied with the tool. This document will again depend upon the type of data acquisition the MGX II system utilizes.

Specifications

The tool, in order to utilize the supplied software must operate with the Mount Sopris MGX hardware and software system. This system is comprised of an MGX logger or MGX II Console connected to a logging system and operating software.

Power Requirements

D.C. voltage at probe top.   MIN. 30 VDC   MAX. 68 VDC   @   200mA
Cable Armor   GND Center conductor   POWER

Tool Output

Pulse type, positive going, 1.25uS wide from 4.5 KHz to 37000 KHz.

Measuring Range

0.03 gpm to 1.0 gpm	0.113 lpm to 3.785 lpm
0.15 ft/min. to 13 ft/min.	0.046 m/min. to 3.962 m/min.

Resolution

5%

Accuracy

5% (Mid-Range)   to   15% (Extremes)

Pressure Rating

2000 PSI   or   13789 Pascal

Dimensions

Length	48 inches	122 cm
Diameter	1.63 inches	4.1 cm
Weight	12 lbs	5.5 kg

Installation

Installing the HFP-2293 and support equipment

Refer to documentation on the Data Acquisition software for proper installation onto PC.

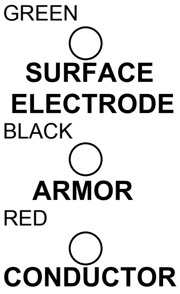
Before operating the Heat Pulse Flowmeter, a few simple steps must be performed to ensure that the equipment will function properly.

Installing the Trigger assembly

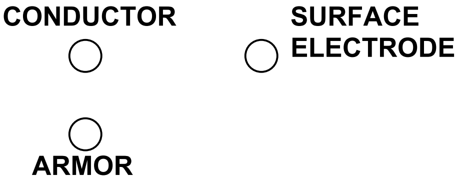
The trigger assembly provided with the HFP-2293 is a small hand held device with a push button switch in the top, a cable, about 6 ft. in length, and color-coded banana plugs on the end of this cable. The color-coded plugs or wires from these plugs must be tied into the cable lines at the surface. The MGX logging systems have these color coded banana jacks ensuring an easy installation of the trigger assembly. Remember to disconnect the trigger assembly from the logger after the use of the HFP-2293 or during the use of other types of probes. The black plug or wire connects to the banana jack labeled **ARMOR**. The red plug or wire connects to the banana jack labeled **CONDUCTOR**.

CONNECTIONS FOR TRIGGER ON MGX

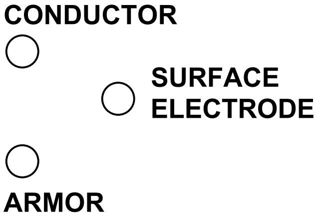
BANNANA JACKS
ON MGX-200 and 305 units



BANNANA JACKS
ON MGX-200 and 305 units



BANNANA JACKS
ON MGX II Consoles



Operating Procedure

Operation

Operation of the heat-pulse Flowmeter will begin by determining the size of the borehole to be logged. This is important in that the proper diverter size can be assembled on the probe to give the maximum sealing while in the borehole. Several different diverter sizes are supplied with the HFP-2293, for different sizes of hole diameters. The smallest set of diverter petals is 5 inches that are used in 3 to 4 inch borehole. The next set of diverter pedals are 7 inches and are used in 5 to 6 inch boreholes. The largest set is 9 inches and is used in 7 to 8 inch boreholes.

To install a set of diverters first remove the rings that capture the bottom centralizer using an Allen wrench set. Then remove the bottom screen by loosening the setscrews and sliding the screen off. Choose the desired size of diverter petals to be used. Next slide the stack of diverter petals over the bottom of the probe all the way to the top screen, and then reinstall the bottom screen, centralizer and centralizer rings. Tighten all setscrews. Next install the top centralizer by loosening the setscrews on the centralizer ring and slide it off the probe. If the hole is 6 inches or larger use the larger centralizer; if the hole is 5 inches down to 3 inches use the smaller top centralizer. Slide the centralizer over the top of the probe, reinstall the centralizer ring and tighten setscrews in the ring.

Install the trigger assembly into the logger, connect the probe to the cable line and prepare to log the hole. **For MGX users:** Turn the MGX PROBE SELECT switch to the Pulse 2 position; turn the PROBE POWER switch to the ON position. Bring up SBCFLOW on the P.C., and verify that the tool is sending pulses to the surface on counter CS32. If any other sequence is used besides the one previously discussed SBCFLOW will assume that it has received a fire pulse and system will be out of synchronization. **For MGX II users:** Choose the proper tool file for the M2FLOW program for Logshell or run the MSHeat program for Windows and verify that the calibrations are correct for the probe. Power the probe with the proper menu item or Windows button. The probe will take approximately 30 seconds to charge the high voltage capacitors and approximately a minute to stabilize internal circuitry. Lower the probe down the hole to the desired depth that a flow measurement will be taken. A caliper log run prior to the HFP-2293 may help indicate areas that contain washouts or fractures that will affect the sealing of the diverters. Refer to the operations manual for SBCFLOW, M2FLOW or MSHeat for more in-depth information and instructions. Make sure the software is ARMED and that the data on the screen is in a stable state. Now press the trigger button and observe the PC screen for the heat pulse peak as it passes by a sensor. For SBCFLOW and M2FLOW the waveform will go to the left of center for down flow and to the right of center for up flow. For MSHeat the data trace runs horizontal on the screen so an Up flow is indicated by the waveform moving upward form center and a Down flow moves downward from center. If no pulse is present check to see that there is an adequate pick window. If the pick window is long enough and no flow is present, move to another location and repeat the above steps.

When flow direction has been detected it has been determined through factory flow chambers and calibrations that an increase in the sealing capabilities of the diverters is achieved by positioning the diverter petals to bend into the flow. If the flow is down the borehole, then the correct positioning of the pedals would be up and this would be achieved by moving the probe down the hole. If the flow is up the borehole, the correct positioning of the petals would be down and this would be achieved by bringing the tool up the hole. It may be necessary to move the tool suddenly up or down to get the petals to reverse their direction to properly position them.

Recording of data and output plots are discussed in the all the HFP-2293 data acquisition documentation. One note that should be remembered is that the tool takes approximately 30 seconds to recharge after it has been pulsed. All acquisition software's indicate this charge time by flashing TEMPORARILY DISARMED or DISARMED at the top of the screen until the probe has had sufficient time to recharge the high voltage capacitors. This may not be as noticeable at slower flows as this amount of time is usually taken to determine and record the flow, but will be noticeable at faster flows. You may need to wait a few seconds for the probe to fully recharge.

Performance Checks and Calibrations

Calibrations are performed at the factory and require an elaborate setup. In the event the user feels the tool needs to be calibrated it is advisable to speak with a representative of Mount Sopris. Performance checks can be made in and out of the borehole. When the tool is in fluid, it is good practice to verify a frequency coming from the probe and that the firing or pulse circuit is functioning correctly before continuing down the borehole. The sensors can also be checked for operation near the surface by firing the heat grid while the tool is in fluid and moving the tool up the hole simulating down flow. Repeat the firing sequence, but move the tool down the hole simulating up flow. Note that to move the tool up or down for this test, do not use the winch. Move the tool by hand to simulate flow in the borehole.

Preventative Maintenance

The HFP-2293 requires little maintenance other than washing the probe off after each use. Keeping the screens and the heat grid free from debris will insure smooth operation in the field. If a high-pressure washer is used to clean the tool take care not to spray directly at or on the heat grid, as this is a delicate area. If the tool is to be stored in a horizontal position it is advisable to remove the centralizers and diverter petals so as not to deform them.

Troubleshooting

Problems with the Tool

In the event the tool develops a problem, follow the troubleshooting procedure listed below.

No pulses from the probe.
1. Are the MGX switches set correctly? **PULSE 2** and **ON** positions
2. Are the PROBE CURRENT and PROBE POWER LED's on?
3. Check the cable for conductive leakage across the center conductor to ARMOR.
4. If an oscilloscope is available verify if the probe is sending pulses, if not consult Mount Sopris.
5. If using M2FLOW or MSHeat, did you power the probe up with the software?

The probe will not fire for a measurement cycle.
1. Check that the trigger assembly is connected properly.
2. If step 1 is OK, connect a voltmeter on the banana plugs while they are still plugged into the MGX and the MGX is still on as if it were powering the probe. With the probe powered on, press the trigger button and observe that the voltage on the meter: approx. 60 volts, decreases to about 10 volts or less momentarily. Not all meters will react the same to this short period, but you should see a change on any meter regardless of its reading. This is a reasonable indication the trigger assembly is operating correctly.

3. If step 2 is OK consult Mount Sopris.

The probe appears to fire or be pulsed but no flow is detected.
1. This problem may indicate a failure in the high voltage section or it may indicate that the electronics is functioning correctly, but the heat grid may be broken or open. It is important to note that a no flow detected may also occur if the tool is in a no flow zone, or if the flow is to fast. So verification of this problem is more complete if the tool is in a zone with known flow. If a zone with flow is not known or available the tool can be fired and then moved by hand either up or down to simulate flow and see that the sensor or sensors are working. If the problem cannot be determined consult Mount Sopris.

Disassembly Instructions

The HFP-2293 probe should never be disassembled unless service is necessary. In the event service is necessary it should be performed by Mount Sopris or a qualified technician.

Schematics

HFP-2293

Available upon request

Drawing Number 50002015A.S01 - S02 Title: Firing Cir. Signal Amp, V/F and H.V. Reg. Trig., Pulse driver and Power supplies

Drawing Number 50002029A.S01 Title: Trigger HFP-2293

Appendix

Suggested QA Procedure

General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. The Mt. Sopris acquisition software provides records of the calibration constants. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedure specifies that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.

LLP-2676 Neutron Probe

Mount Sopris Instrument Co., Inc.
Golden CO, U. S. A.
April14, 2005

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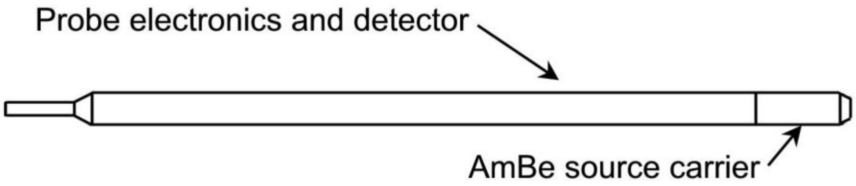
General Information

Overview

The LLP-2676 thermal neutron probe is a simple analog pulse probe, which measures the output of a He^3 detector inside the probe. The He^3 detector is powered by a regulated HV downhole power supply. The probe is powered by 30 VDC on the wire line, and requires ~40 mA of current to operate. The detector sends pulses through a charge sensitive amplifier and pulse shaper to provide 1.25 µsec pulses with ~7 V amplitude to the wire line for transmission up the cable. Depending on the source strength and borehole environment, count rates of between 100 and 10,000 may be expected.

The He^3 detector responds to the intensity of thermal neutron flux it receives from the borehole environment. Thermal neutrons are created by scattering of high energy neutrons emitted by a chemical source that is installed 35 cm below the mid-point of the detector.



Theory of Operation

In general, neutrons logging can be divided into three main categories. High-energy neutrons, from a chemical or electronic source, will react with material surrounding a borehole with several possible results. When neutrons react in elastic collisions (which is most likely to happen with atoms that have about the same mass as the neutron), they are said to be moderated, with each collision resulting in the neutron transferring some energy to the target nucleus. After a number of these collisions, the neutron will finally reach a “thermal” energy level. The Mount Sopris LLP-2676 probe contains a He^3 detector, which detects thermal neutrons quite efficiently.

When high energy neutrons are scattered by target nuclei, but only loose a portion of their energy, this process is known as inelastic scattering. The target nuclei are in an excited state and then will give off a characteristic gamma ray that can be measured by a spectral gamma detector. Such characteristic gammas can be related to the chemical composition of the surrounding formation.

The third type of neutron interaction that is commonly measured in a borehole environment is based on a process called thermal neutron absorption. In this case, the thermal neutrons are captured by a target nucleus, which results in a compound nucleus that de-excites instantaneously, with the emission of a number of characteristic gamma rays. In such a case, the capture gamma flux is measured versus time to produce a decay rate which is related to the capture cross section of the surrounding formation. This measurement can be used to infer which formations may contain salt water and which might contain hydrocarbons.

Neutron Production

There are two general methods used to supply high-energy neutrons in a borehole environment. The most common is with the use of a chemical source. Currently, a mixture of $_{241}$ Americium and Beryllium are used to produce neutrons for thermal and epithermal logging by bombarding the Beryllium with alpha particles supplied by the $_{241}$ Americium . A second method uses an electronic particle accelerator that accelerates deuterium and tritium ions into a target composed of the same material, resulting in a high flux of high-energy neutrons (around 14 MeV). Very high probe voltages are required for this process (>80 kV)

The Mount Sopris LLP-2676 generally uses a 37 GBq (1 Curie) $_{241}$ AmBe source.

Specifications

Diameter	41.3 mm (1.625 inches)
Length	111 cm (44 inches)
Weight	5.5 kg (12 pounds)
Source-Detector spacing	35 cm (15 inches)
Dose rate in shield at 1 meter	<1 mR/hr
Shield dimensions	35.6 cm (14 inc) sphere
Shield Weight	35 kg (78 pounds)
Operating temperature	-25 to 75 degrees C.
Source	37 GBq (1 curie) $_{241}$ AmBe
Detector	$_3$He at 4 atmospheres

Installation

Installing the source on the probe

The probe is delivered with a thread protector that covers the male thread that connects to the neutron source. The neutron source is stored in a shield that includes a spacer and a lock to prevent accidental release of the source from the shield.

The source shield should be locked in a secure area when not being used, and locked to the logging truck during transport. Local safety and transportation rules are the responsibility of the user. For a detailed discussion of source handling and transport regulations, consult the NRC website (or the local regulating body's available documentation).

Prior to loading the source onto the probe, place the source shield near the wellbore. Make sure the wellbore has a cover plate installed, so that the source cannot be accidentally dropped in the hole.

Clear the area of all non-essential personnel. Only persons trained and certified in the handling of radioactive materials should permitted to handle and load sources. The source handling tool is used to remove the source from the shield. Unlock the shield, remove the spacer, and insert the handling tool inside the shield. Turn the body of the handling tool until it fits over the hexagonal mating end of the source. Then turn the knurled handle in the center of the end of the handling tool to lock the source onto the handling tool. Once the source is firmly attached to the handling tool, the source can be then removed from the shield and screwed directly on to the LLP-2676 probe. Once the source is screwed firmly to the probe, the handling tool can be removed. It is normally a good idea to have already screwed the cable head onto the probe, and run the cable through all necessary sheave wheels, etc. before installing the source. However, the user can always re-insert the probe with source installed back into the shield if necessary.

The key to safe handling of radioactive sources during well logging operations is to plan your procedures, check all equipment before removing the source from the shield, and then move as quickly and efficiently as possible to install the source and lower the probe into the hole. Once the top of the probe is a few meters below ground level, there is no further radiation risk to the operator.

If an operator spends 15 seconds during this installation process, and a similar amount of time to remove the source and place it back in the shield, the dose rate will be 30 seconds X 16 mR/hr, or 0.13 mRem. Always remember to cover the hole after removing the probe and before removing the source from the probe.

Operating Procedure

Operation

The LLP-2676 probe is an analog pulse probe, and it is important to remember that the correct wireline length and type should be supplied to the logging system so that pulse discriminators are properly set with the software.

Logging is normally done in the up direction for better depth accuracy. A repeat section should be made in the bottom of the hole, if hole conditions permit. Maximum logging speed for good statistical accuracy is 5-6 m/minute (20 ft/min) maximum. A 10 cm (.2 ft) sample interval is more than adequate for the LLP-2676.

Expect to see a significant change in the neutron count rate at fluid level. The neutron measurement is only slightly affected by the presence of steel casing. It is not affected by PVC casing, although the volume of open hole behind the casing may affect the total count rate in any cased hole geometry.

Performance Checks and Calibrations

The easiest way to check the LLP-2676 before going to the field for a logging job is to install the source and place the source and probe back in the shield. The probe should see a count rate of from 50 to a few hundred cps.

Calibration of the neutron probe is based on measurement of count rates in known lithologies and porosities. The measurement of thermal neutrons is generally related to the amount of hydrogen nuclei in the surrounding material. Hydrogen is most common as a component of water in the borehole, and water in the pore space of the surrounding rock. Some hydrogen may also be present in the clays and other mineral compounds. In general, thermal neutron probes are logged in an attempt to measure fluid filled porosity or moisture content of downhole formations.

There are borehole models available in many parts of the world that can be used to calibrate thermal neutron logging probes. The API (American Petroleum Institute) maintains standard models in Houston, TX USA. Other models exist at the DOE facility in Grand Junction, CO USA. Other sites are available in Europe, Asia and Australia.

Mount Sopris has performed standard calibrations for the LLP-2676 at the API models in Texas, and has checked these results in the Grand Junction models. A secondary field calibrator is available that allows the user to match the master calibration in the field using a simple ratio method. It is not designed as a perfect quantitative calibration, but does allow the user to make good estimates of porosity, if lithology and borehole corrections are properly applied.

An example of the calibration performed at the Houston models is shown in the appendix. If a calibration is desired, consult Mount Sopris Engineering for more details (tech.support@mountsopris.com).

Preventative Maintenance

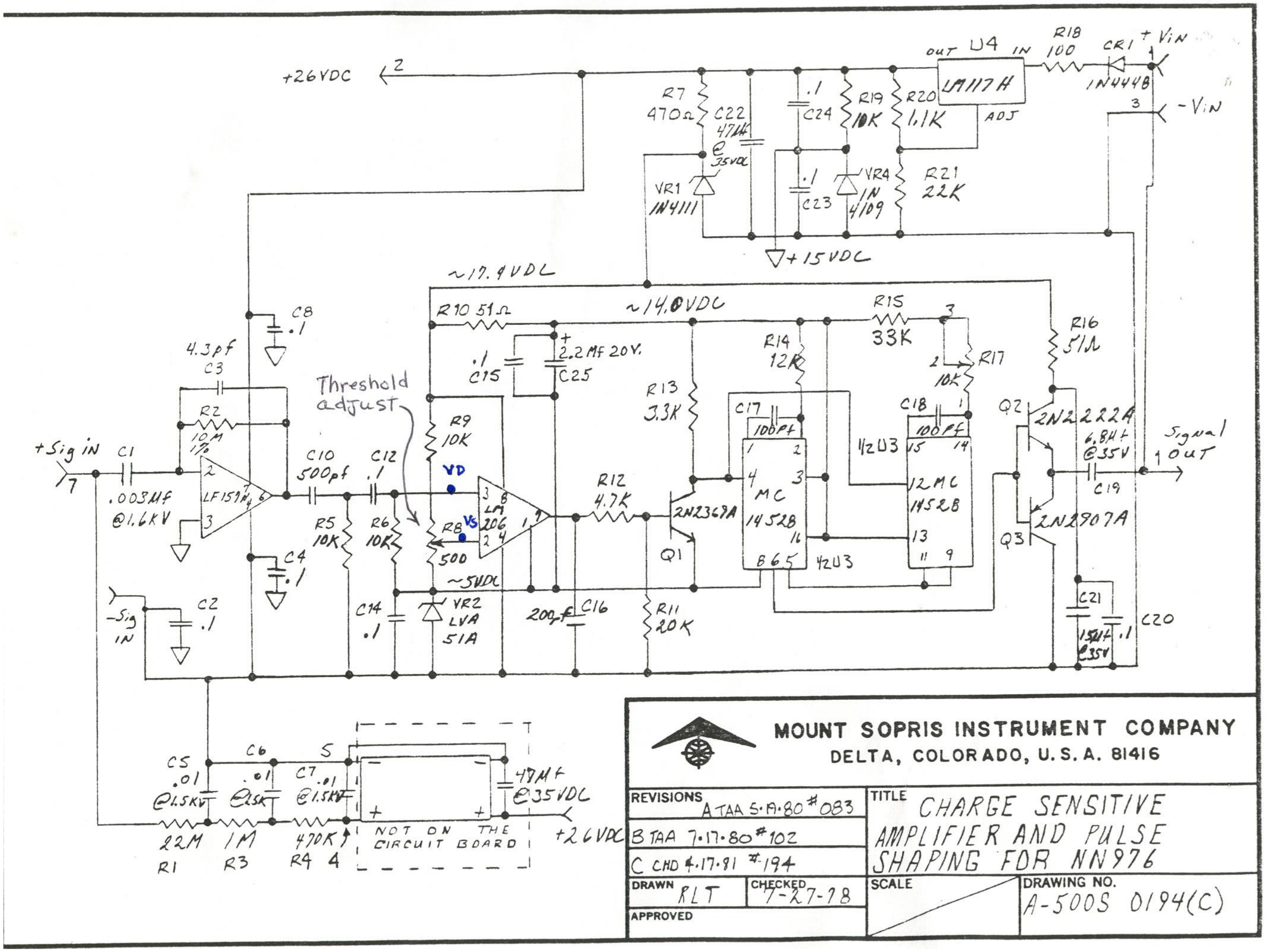
The LLP-2676 has no moving parts, and the only maintenance required is to clean and dry all thread surfaces after each use. This is particularly important on the source end of the probe, to make sure that there will be no problem screwing the source into the female probe thread. The o-ring seal area in the probe top should be wiped out with a clean cloth and dried before replacing the probe protector cap.

Disassembly Instructions

While there are no user serviceable parts inside the probe, the user can inspect the inside of the probe by removing the probe top from the housing. This is done by removing the 4 radial screws at the top of the probe. These screws are 8-32 x 3/8” English screws.

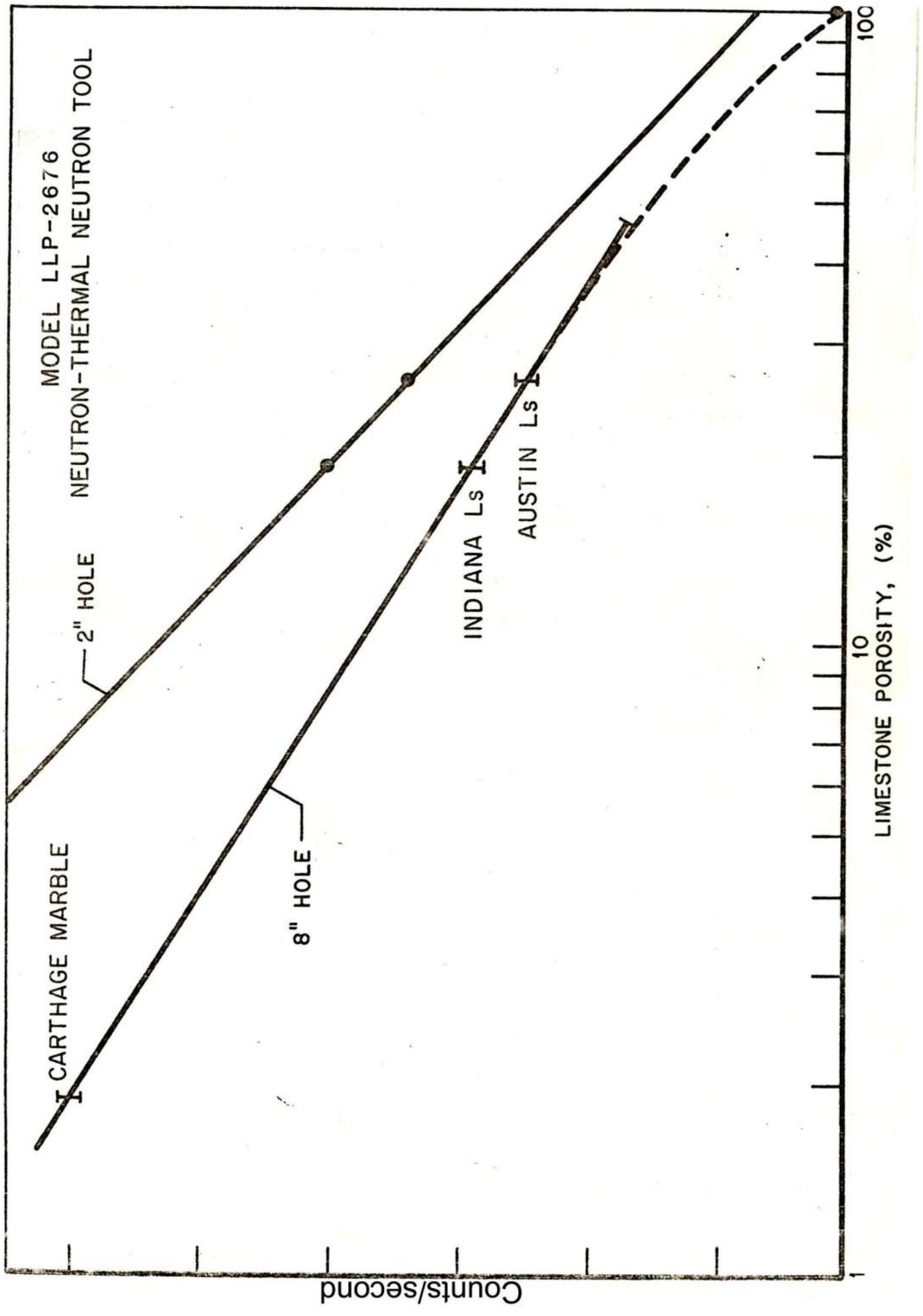
Schematics

Drawing Number 500S-0194 Title Charge sensitive amplifier and pulse shaper



Appendix

Example of neutron porosity calibration from Houston API models.



MatrixHeat v.3.3

Operator Manual

Advanced Logic Technology s.à,

Mount Sopris Instrument Co., Inc.

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March 21, 2013

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1. System Overview

I. Introduction

MatrixHeat software was developed to allow operation of the Mount Sopris heat-pulse flowmeter probe using the MATRIX Logger. Please refer to the Logger Software Operator Manual for details on the Matrix logger and its associated software.

The software takes advantage of the Microsoft Windows ™ family of operating systems. These multi-tasking software platforms can accommodate all the tasks necessary for maximum data security and ease of operation.

New features have been added to the MatrixHeat logging software:

- New binary data format with .MH file extension
- Probe firing via on-screen button; replaces thumb controlled hardware button
- Ability to scroll through data samples and re-pick heat pulse events
- Simplified user controls for calibrations and picking parameters
- On screen tabulation of each tool firing, with interactive viewing capability
- Export pick times and flow values
- Export traces
- Time stamped data
- No maximum time limit in the acquisition window

II. Required Components

To operate the heat-pulse flowmeter with the Matrix logger, the following items are required:

- Mount Sopris HFP-2293 or 4293 heat pulse flowmeter probe
- Calibration data for the heat pulse flowmeter probe
- Current **.tol** for the heat-pulse probe
- Matrix Logger with firmware numbers equal to or greater than:
    - System controller 112
    - Modem controller 115
    - PSU controller 100
- LoggerSuite operating software installed to provide USB drivers

III. Installation

Run the MatrixHeat setup program provided.

The default location for the installation is C:\MatrixHeat, you can accept this location or change it but make note of any changed location.

A desktop icon and Start Menu folder are created for MatrixHeat.

2. Software Architecture

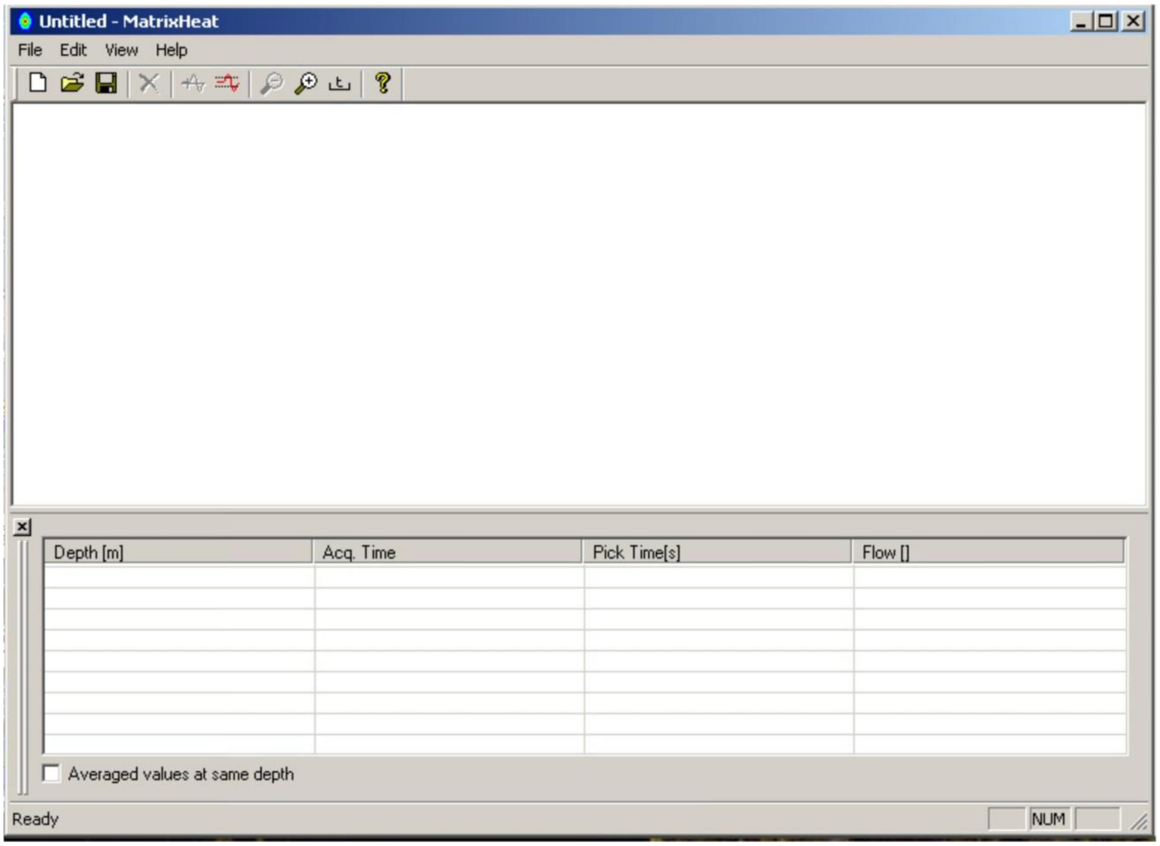
I. Introduction

The MatrixHeat software is a stand-alone product. It is required when operating the Mount Sopris Heat Pulse flowmeter on the Matrix logger.

MatrixHeat version 3.2.67 or later is required for operation on Windows 7 and Windows 8.

The Matrix Operating Software, Logger, is not used for this purpose. Clicking on the MatrixHeat shortcut or executable file in the MatrixHeat directory starts the software.

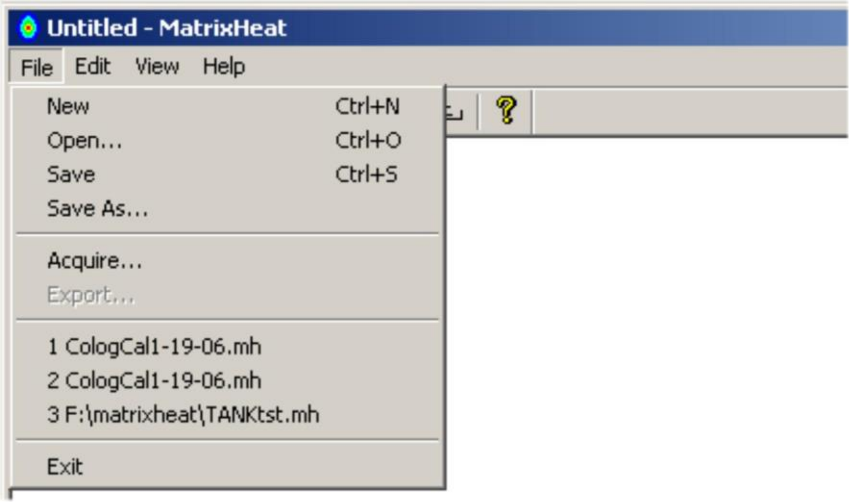
The program opens a screen like the one below:



Depth [m]	Acq. Time	Pick Time[s]	Flow []

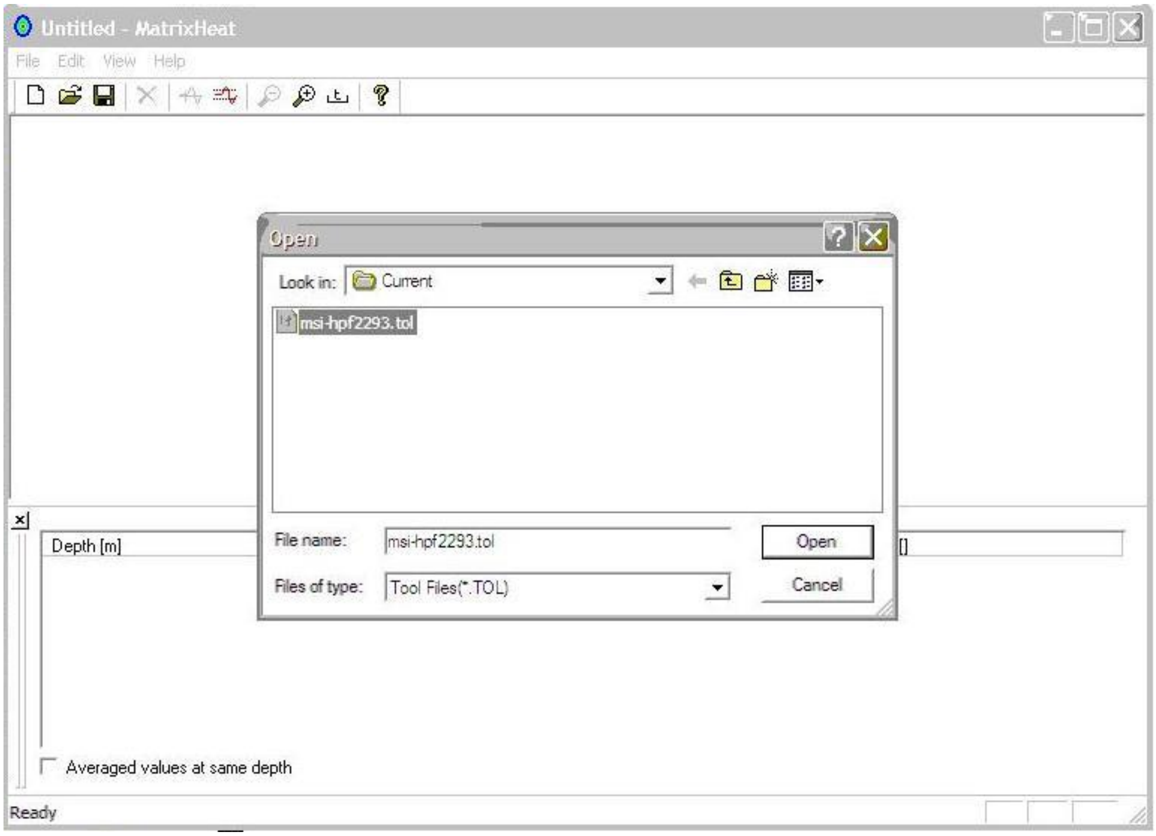
☐ Averaged values at same depth

To begin, click on File on the top menu bar:



To connect with the Matrix logger, select **Acquire**.

You will be asked to provide a tol file; you should see the HFP2293_mtx.tol TOL file listed. If not you will need to navigate to /MatrixHeat/Tol/Current. This tol file is specific to MatrixHeat software, and should only be installed in the /MatrixHeat/Tol/Current directory. Do not install any other non Heat Pulse tol files in this directory. It is possible to have more than one Heat Pulse tol file in the directory, if you have more than one probe, with more than one calibration. If the Matrix logger is detected by the USB routine on the PC, the tol file will be loaded, and the current depth value in the Matrix logger will be loaded.

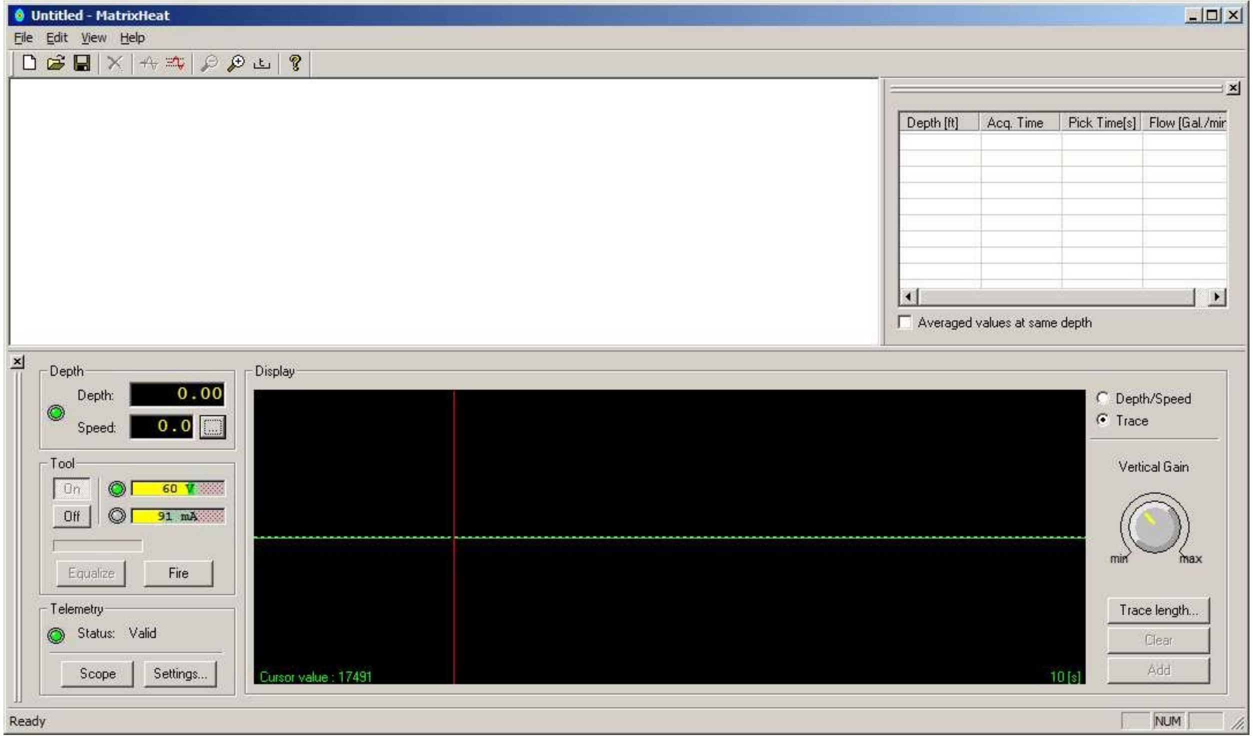


File name: msi-hpf2293.tol

Files of type: Tool Files(*.TOL)

NOTE: If the logger has been used with a different winch model, it may be necessary to exit the program and verify (with LoggerSettings.exe) that the proper depth encoder settings are programmed into the logger. Refer to the Logger Operating software manual for more details.

After the tol file has been selected, a screen like the one below will appear:



Depth: 0.00
Speed: 0.0
60 V
91 mA
Status: Valid
Cursor value : 17491
10 [s]
○ Depth/Speed
● Trace

II. Powering the Probe

Once all winch settings have been confirmed, the probe may be powered up using the Tool On/Off button on the left side of the screen. The correct power settings are read from the Tol file, and are automatically adjusted depending on the wireline type and length. In general, the probe operates on 60 VDC and 180 mA of current. Operating current is lower than charging current. Charging current is applied when the probe is first powered up, or immediately after the probe is fired. New in version 3 are current and Voltage displays. New in version 3.3.22.8 is an option to change the Display to Depth/Speed mode which is useful when operating the winch.

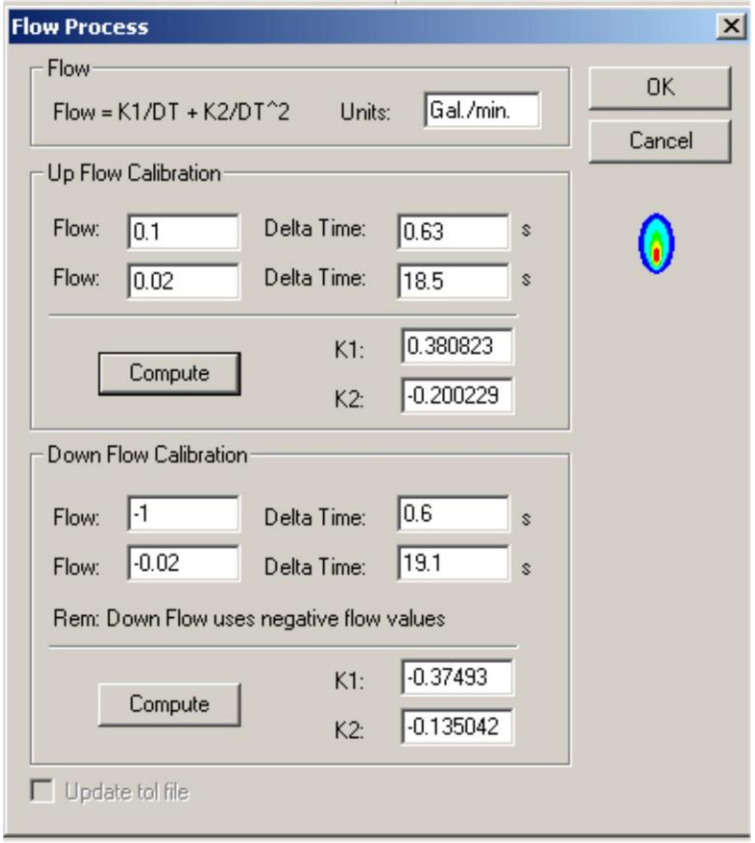
a) Checking calibrations

After the probe is powered up, it will take several minutes for the probe measuring array to stabilize and for the firing capacitors to charge up. This is a good time to confirm that the proper calibrations for the probe have been entered in the Tol file and saved.

ai Note: Calibration Settings

<u>For the Flow Calibration button to be active the probe must be fired at least one time and the data added</u> (click the **Add** button in the lower right side of the Acquisition screen). To access the calibrations screen, select Edit on the top task bar, and then select Flow Calibration as seen below:

Check the calibration values for the probe being used against the values on the calibration screen. An example follows:



Flow Process

Flow

Flow = K1/DT + K2/DT^2   Units: Gal./min.

Up Flow Calibration

Flow: 0.1   Delta Time: 0.63 s

Flow: 0.02   Delta Time: 18.5 s

K1: 0.380823

K2: -0.200229

Down Flow Calibration

Flow: -1   Delta Time: 0.6 s

Flow: -0.02   Delta Time: 19.1 s

Rem: Down Flow uses negative flow values

K1: -0.37493

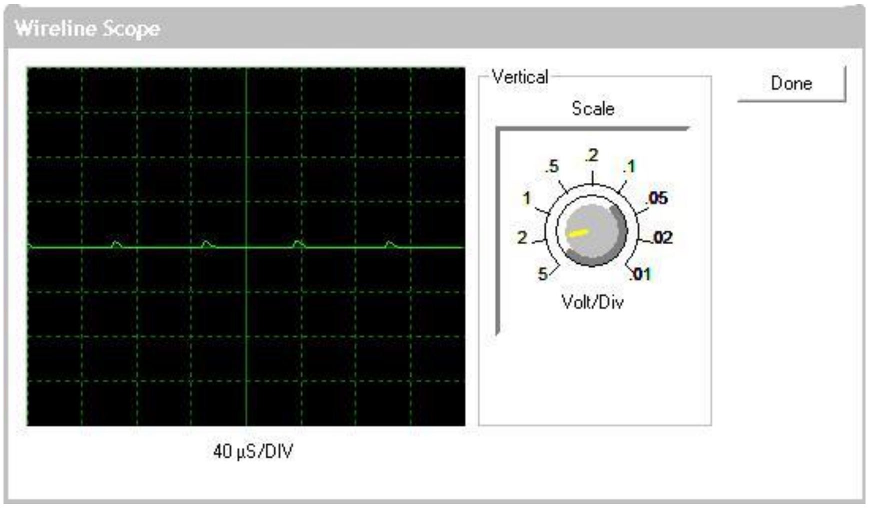
K2: -0.135042

☐ Update tol file

Please note that **Down Flow** values are considered to be ***Negative*** numbers.

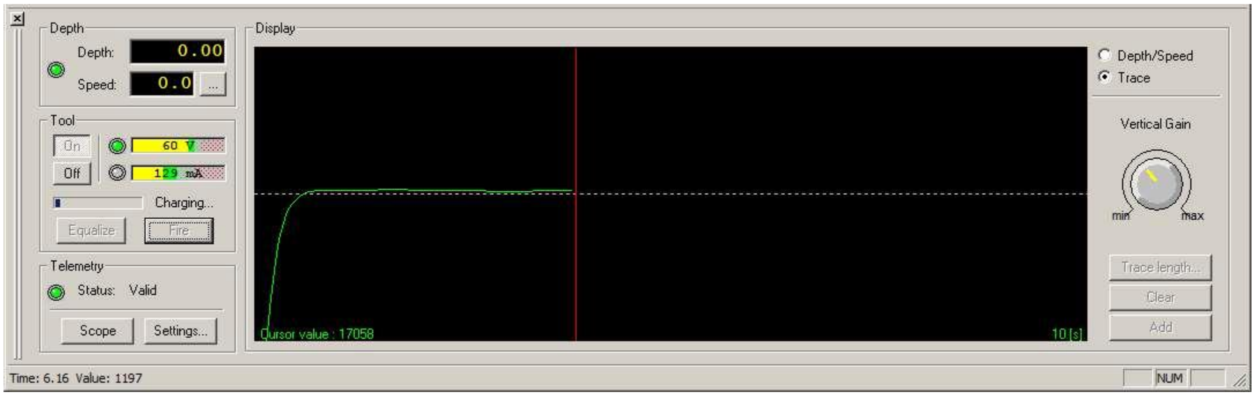
b) Checking proper probe operation

After entering the calibration numbers, it is recommended that the user check the probe data to confirm that it is operating properly, and is ready to begin a logging operation. The best way to see if the probe is sending data is by clicking on the Scope button. A screen like the one below will appear:



Probe data consists of a ~20 kHz positive pulse stream on the wireline, which will vary with the response of the sensor pairs to presence of a heat pulse moving past. If you don't see this kind of data on the wireline scope screen, the probe is not sending data.

After confirming that the probe is sending data, the user should check the main data display screen to verify that the pulse detection modem is in fact detecting the ~20 kHz signals. The following screen shows a properly functioning probe and modem, with a baseline frequency of around ~19 kHz. If a zero value is indicated on the lower portion of this screen, the modem needs to be adjusted. This might be the case for a long wireline.

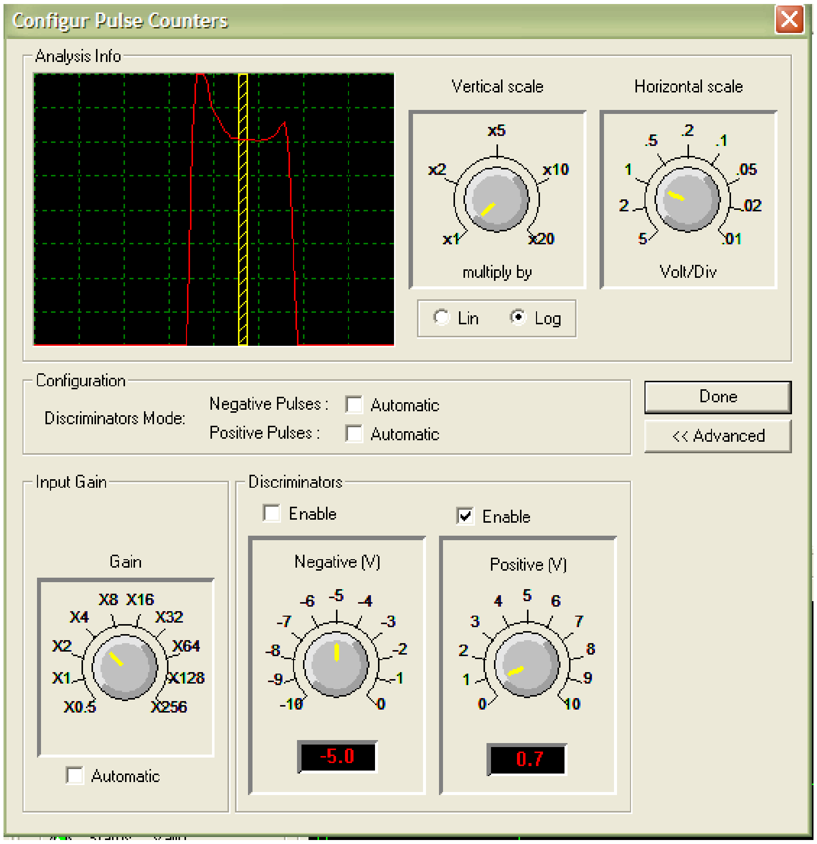


Depth: 0.00
Speed: 0.0
60 V
129 mA
Status: Valid
Cursor value : 17058
○ Depth/Speed
● Trace
Time: 6.16 Value: 1197

c) Adjusting the modem

If a normal (18-20 kHz) value is not indicated on the heat-pulse real time acquisition screen (shown above), modem adjustment may be required. To access the modem controls, click on the Settings... button, and then on “Advanced” to show the modem settings:

The advanced modem settings are embedded in the tol file, depending on the wireline type and



○ Lin ● Log

Discriminators Mode:
Negative Pulses : ☐ Automatic
Positive Pulses : ☐ Automatic

Input Gain: ☐ Automatic

Discriminators: ☐ Enable ☑ Enable

Negative (V): -5.0
Positive (V): 0.7

length. In general, the gain of the modem should be left in **manual** mode, and the positive discriminator should also be left in **manual** mode, such that it is centered in the middle of the modem display screen. The screen pictured above shows proper position and settings for the heat-pulse flowmeter operating on a 500 meter winch with 1/8” single conductor cable.

Moving the discriminator slightly closer to the center peak and away from the center of the signal valley may reduce spikey noise on the data trace particularly on coax wireline.

d) Zeroing the depth

Using the winch controls, lower the probe to the zero point. The probe zero point is the junction between the probe top and the cable head. Once the probe is placed at this point, referenced to the zero depth location, click on the "**…**" button on the depth window and a dialog box like the one below will appear:

Depth and Speed can be shown in the Display panel by selecting the **Depth/Speed** menu item located on the right side of the Display panel (v3.3.22.8 and later only). Select the **Trace** menu item to return to data display mode. Units for depth and speed will be those set in the Matrix Logger using LoggerSettings.

Depth: 2.61
Speed: 0.0
Status: No data
● Depth/Speed
○ Trace
Change depth
Depth 2.61 ft

Select Zero Tool, and the depth should automatically be set to 0.97 meters (or 3.18 feet), which is the mid-point of the sensor array. Keep in mind that the probe is actually 1.22 meters (4 feet) long.

Once the probe has been zeroed, it can be lowered to the first firing depth. In general, the first depth depends on user preference. It is sometimes preferred to begin measurements at the top of the borehole, so as not to disturb the fluid flow patterns in the lower sections. Movement of the probe (and the close fitting flow diverters) can temporarily influence the borehole flow regime.

To avoid interference from eddy currents that might be induced by lowering or raising the probe, the operator should wait a few minutes at each shot depth before firing the probe. This will provide the most accurate data, and avoid erroneous readings.

Note that the Depth/Speed colors are controlled within the Matrix.ini file located in the C:/MatrixHeat folder. The default color is red characters on black background.

III. Firing the probe

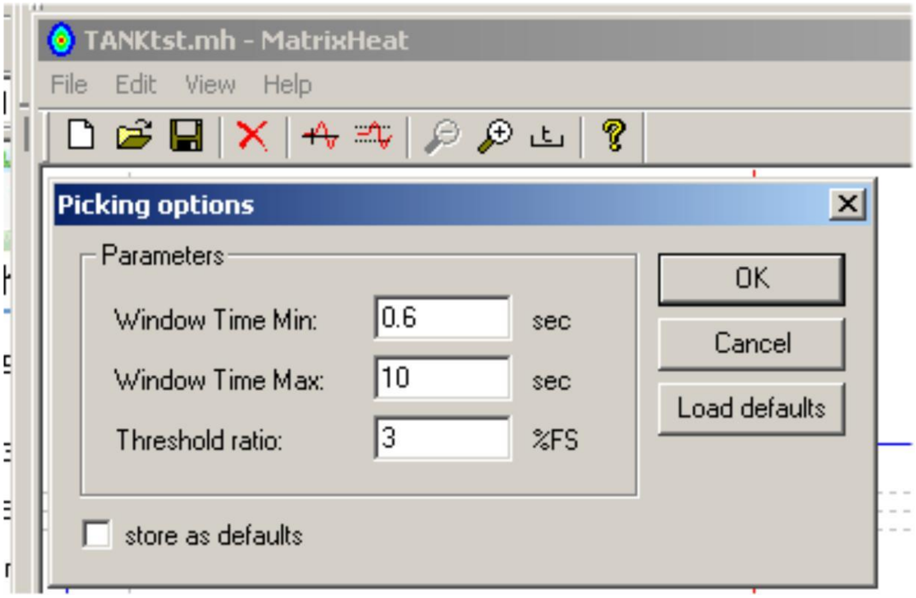
a) Picking Options

Before firing the probe, the operator should set the picking options to match the estimated heat pulse arrival time. In a new well, with no information, it is best to set the parameters so that a long time interval is available. Two Time Sample settings are required. One is in the Flow Pick window, and the other is in the Shot Window display. The Time Sampling for the Shot Window controls the actual length of the record. The Time Setting in the Flow Pick Window only controls the display of the saved flow trace. As the logging proceeds, the operator can "fine tune" these parameters to make the best use of time available. For faster flow rates, the time window can be decreased to save time. However, even for faster flows, the probe must recharge between shots, and this time is fixed.

To set picking options, click on the Pick Options icon on the top selection bar. The various selections on this are shown below:

Picking options can also be accessed by clicking on Edit, Picking Options.

The picking options window is shown below:



Window Time Min: 0.6 sec

Window Time Max: 10 sec

Threshold ratio: 3 %FS

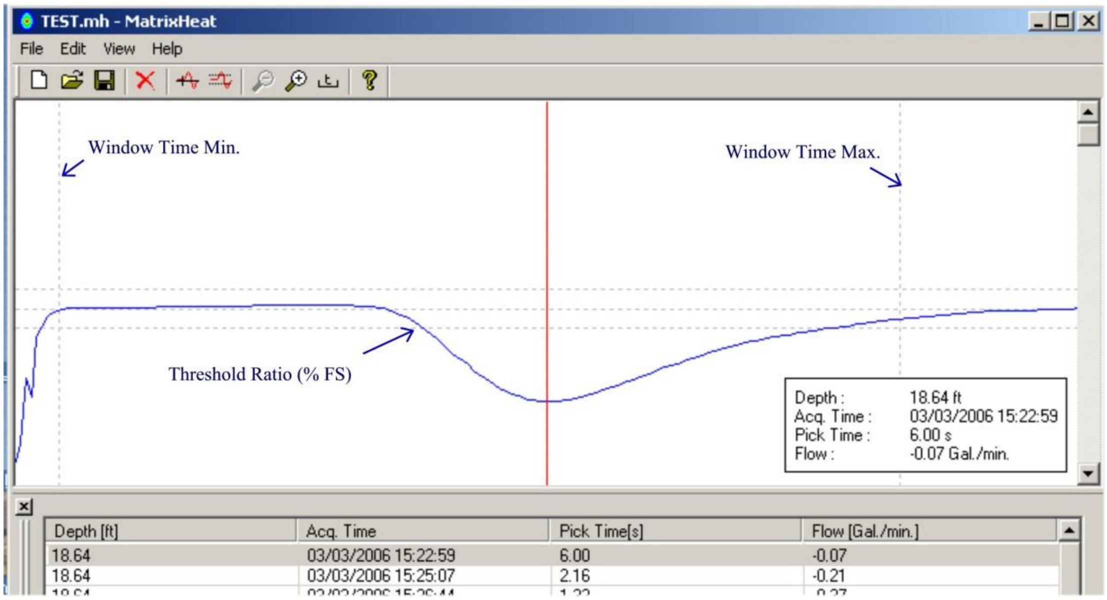
☐ store as defaults

The **Window Time Min** value should be kept low, in general. It is the minimum time after which a pick will be allowed. Normally, there is no measurable flow before 0.6 seconds, as the flow is so fast that the sensors cannot see the heat pulse.

The **Window Time Max** value is the maximum time in which a pick can be allowed. Once this value is reached, the program will stop recording, and automatically make a pick on the maximum or minimum peak produced by the heater grid within these times.

The **Threshold ratio** is the “detection level” above which the software is allowed to make a pick. For low heat pulse peaks, the level may need to be decreased, and for very high peaks, the level can be raised.

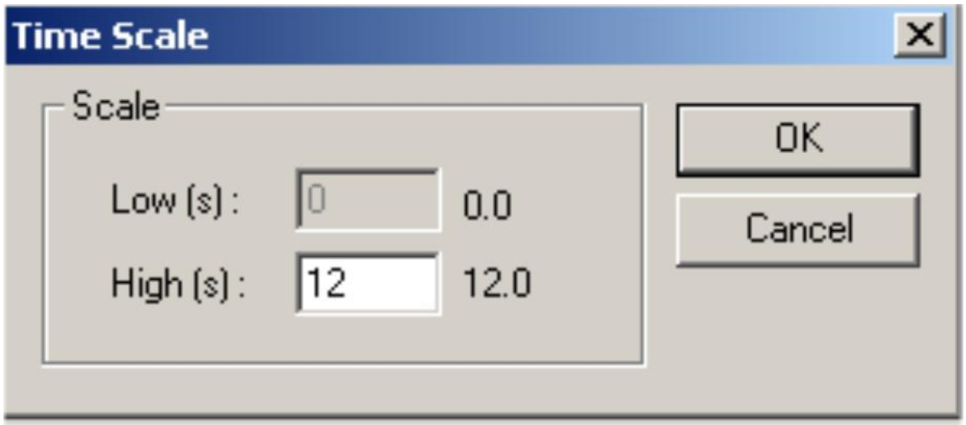
These three parameters are represented on the plot record by dashed lines. The Time windows are vertical, and the Threshold ratio is indicated by a pair of dashed horizontal lines equidistant from the zero baseline. An example is shown below:



Depth : 18.64 ft
Acq. Time : 03/03/2006 15:22:59
Pick Time : 6.00 s
Flow : -0.07 Gal./min.

Depth [ft]	Acq. Time	Pick Time[s]	Flow [Gal./min.]
18.64	03/03/2006 15:22:59	6.00	-0.07
18.64	03/03/2006 15:25:07	2.16	-0.21

The **Time Scale** parameter is set by clicking on the time scale icon on the menu bar. It brings up a window like the one below:



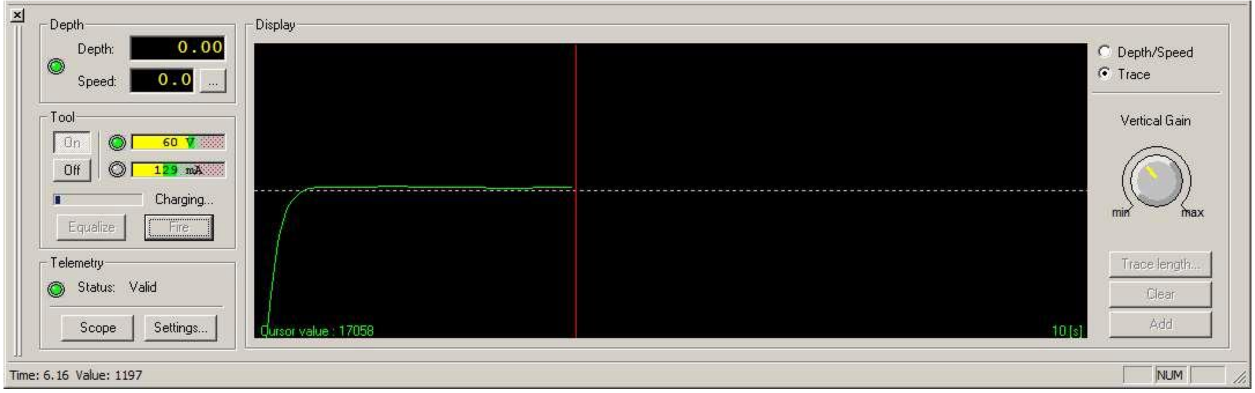
Low (s) : 0 0.0
High (s) : 12 12.0

This time scale is the maximum time scale that will be displayed on the Flow Picking screen. This Time Scale is not the same time scale that is presented on the Shot Window, which is described in the following section

A third icon on the main menu is the **AutoPick** selection. It is used to re-pick a heat pulse event in the data records, if the operator does not believe that the first pick was correct. It is used after picking parameters are adjusted, and when pressed, will automatically select a new pick, based on the new parameters.

b) Firing

Once all parameters are set, the probe can be fired. The fire button should only be pressed if a smooth baseline, with a frequency of around 20 kHz, +/- 2 kHz, is present in the shot window. If the baseline is wavy or changing with time, this is usually caused by probe induced flows. The operator should wait until this background “noise” is gone before firing. An example of a smooth baseline is shown on the next page:



Depth: 0.00
Speed: 0.0
60 V
129 mA
Charging...
Status: Valid
Cursor value : 17058
10 [s]
● Trace
Time: 6.16 Value: 1197

Note that the **Time Scale** on the Shot Window is set by clicking **Trace length..** button:

Depth: 0.00
Speed: 0.0
59 V
78 mA
Status: Valid
Sampling
Trace Length: 10 s
Cursor value : 16637
10 [s]
● Trace
Time: 6.16 Value: 1197

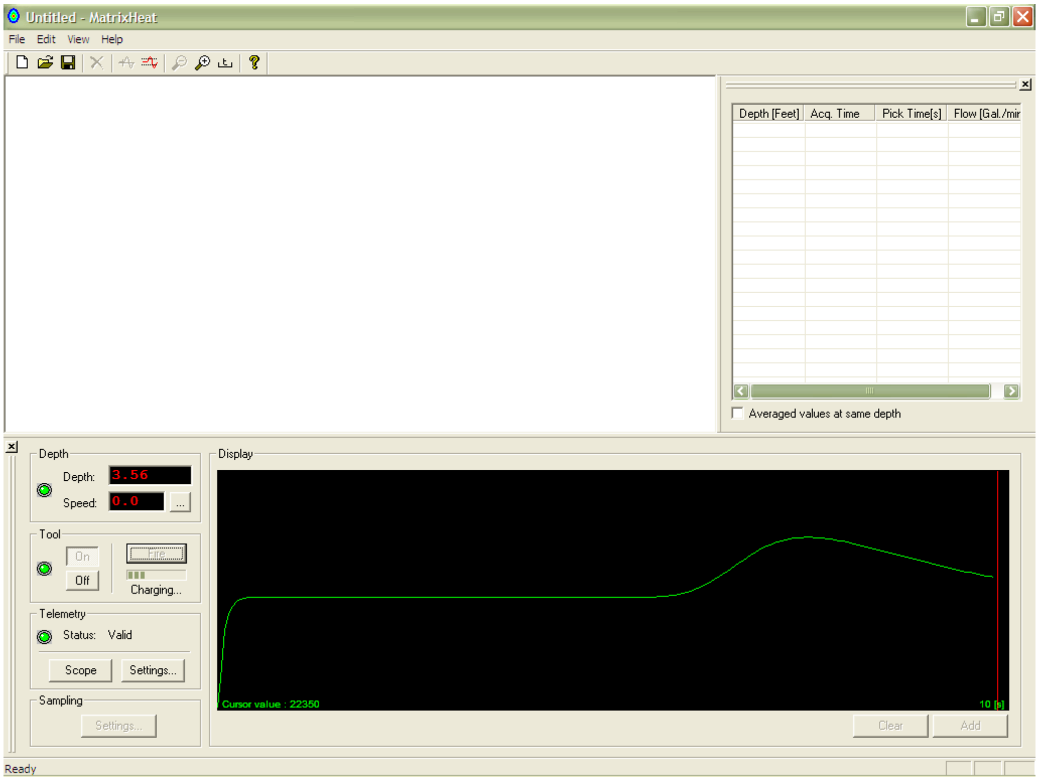
The length of the time scale on the Shot Window must be long enough to capture the heat pulse. If it is not, the operator should increase the time to make sure the pulse is detected, if one exists. Normally, there is no usable data past a time of 25 seconds. When the end of the time scale is reached, the system stops, and the probe begins its recharge cycle.

If the trace goes off the top or bottom edge as it draws across the screen turn the Vertical gain dial counter clockwise towards **min** to shrink the trace size. To increase the trace size, turn the dial clockwise towards **max**.

Once the probe fire button is pushed, a real time plot of frequency vs. elapsed time will appear in the shot window. This green line indicates the differential temperature being sensed between the two thermistors, which are located equidistant from the heater grid in the center of the probe. The direction of the flow is based on the net frequency response. If the frequency goes down, the flow is down. This is shown graphically on the shot window until the elapsed time passes the Time Scale setting chosen for the shot. After the firing event, the probe begins an automatic “charging cycle”, in preparation for the next shot.

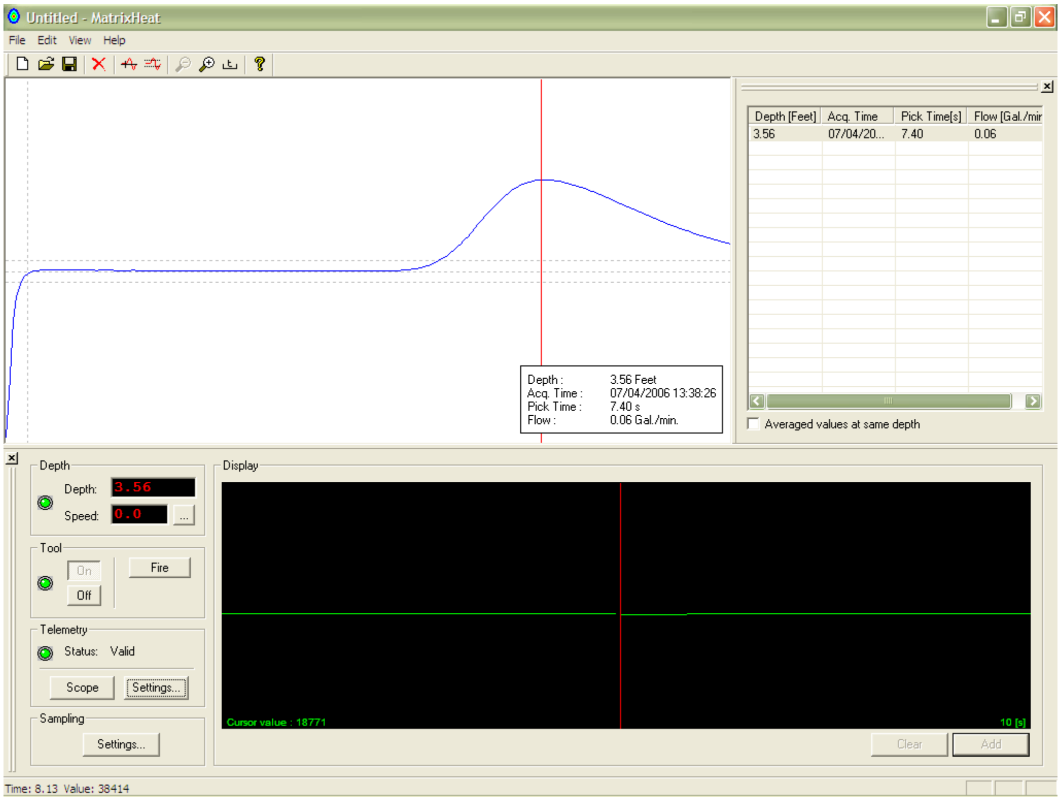
If the shot record appears to indicate a successful flow event, the operator should press the **Add** button at the lower right hand corner of the shot window. If the record is questionable, it can be deleted from the display with the **Clear** button.

An example of a real time shot record is shown on the following page.



Depth: 3.56
Speed: 0.0
Status: Valid
Cursor value : 22350

This sample record appears to be valid, so it is added to the Pick Window register by clicking the Add button. The record is then moved into the Pick register table, which shows the pick information and calculated flow rate for the current shot.

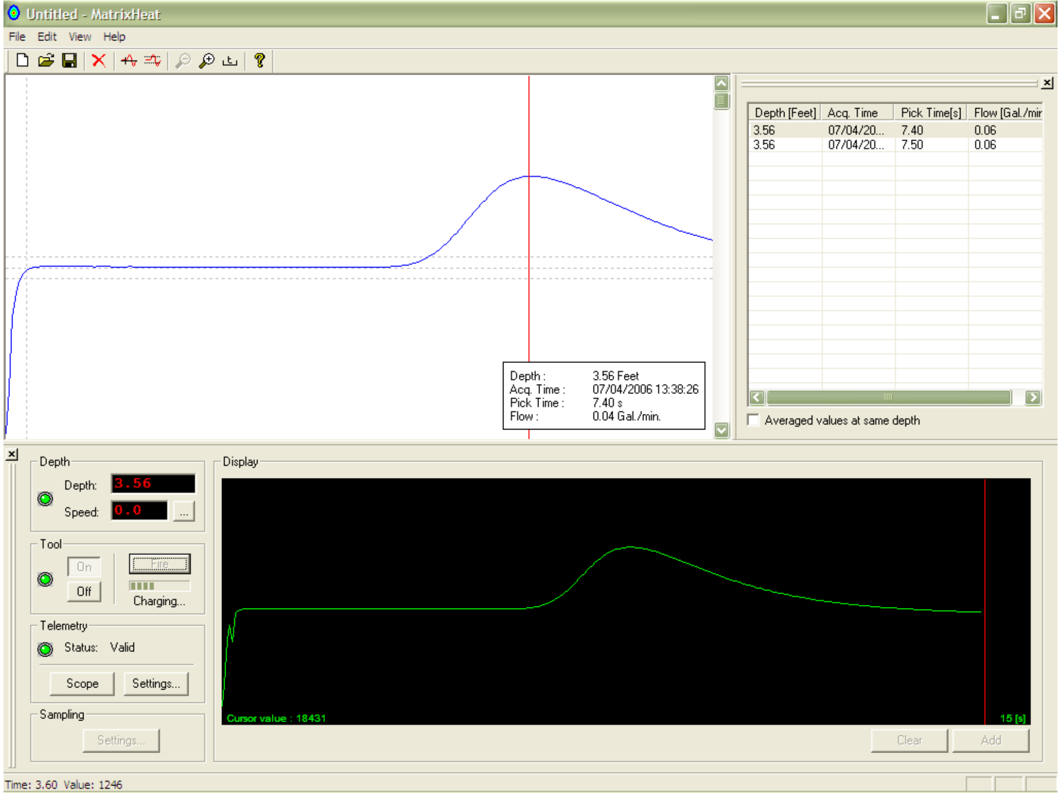


Depth [Feet]	Acq. Time	Pick Time[s]	Flow [Gal./mir
3.56	07/04/20...	7.40	0.06

Depth : 3.56 Feet
Acq. Time : 07/04/2006 13:38:26
Pick Time : 7.40 s
Flow : 0.06 Gal./min.

Depth: 3.56
Speed: 0.0
Status: Valid
Cursor value : 18771
Time: 8.13 Value: 38414

To fire the probe again, the user must wait until the probe capacitors are fully charged. This process is indicated in the window with the bar graph meter, right under the Fire button. It is a good idea to make at least two firings per station, to confirm the accuracy of the measurement. A second firing, in the same interval is shown below:



Depth [Feet]	Acq. Time	Pick Time[s]	Flow [Gal./mir
3.56	07/04/20...	7.40	0.06
3.56	07/04/20...	7.50	0.06

Depth : 3.56 Feet
Acq. Time : 07/04/2006 13:38:26
Pick Time : 7.40 s
Flow : 0.04 Gal./min.

Depth: 3.56
Speed: 0.0
Status: Valid

Cursor value : 18431
15 [s]

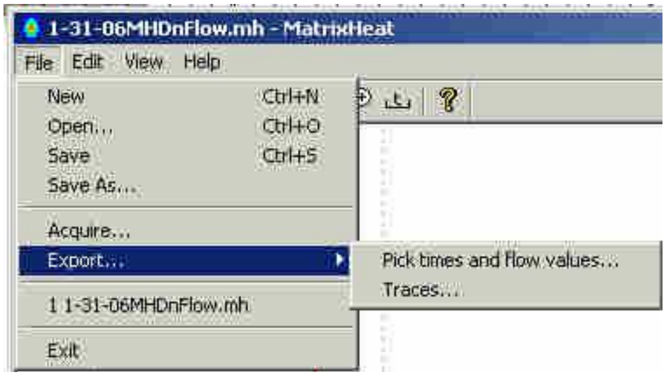
Time: 3.60 Value: 1246

c) Re-picking

In the event that the automatic peak picking did not actually pick on the correct pulse, it is possible to adjust the Min and Max time windows to “bracket” the correct pulse, and/or change the Threshold ratio and then press the autopick button again. It will re-pick a new time within the new parameters. In general, this should only be necessary when a large change in flow magnitude occurs.

Re-picking can be done at any time, simply by highlighting the shot on the list of data in the Pick Flow table. It is even possible to “re-process” picks later, using the program without the logger connected. Simply start the program, open the data file, and proceed as above.

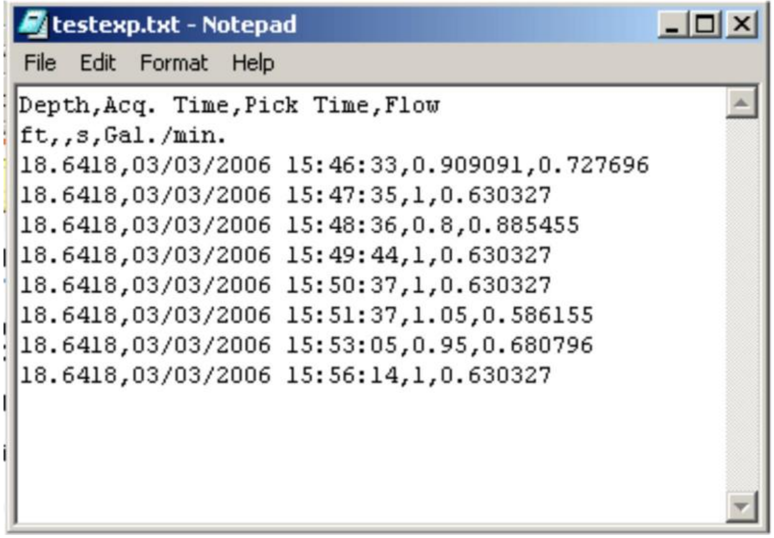
IV. Exporting Data



After a data file has been created, it should be saved as an ***.mh** file, by clicking on the main task bar File selection, and then on Save or Save As. This saves the data in a binary file that can then be displayed or re-processed using MatrixHeat.

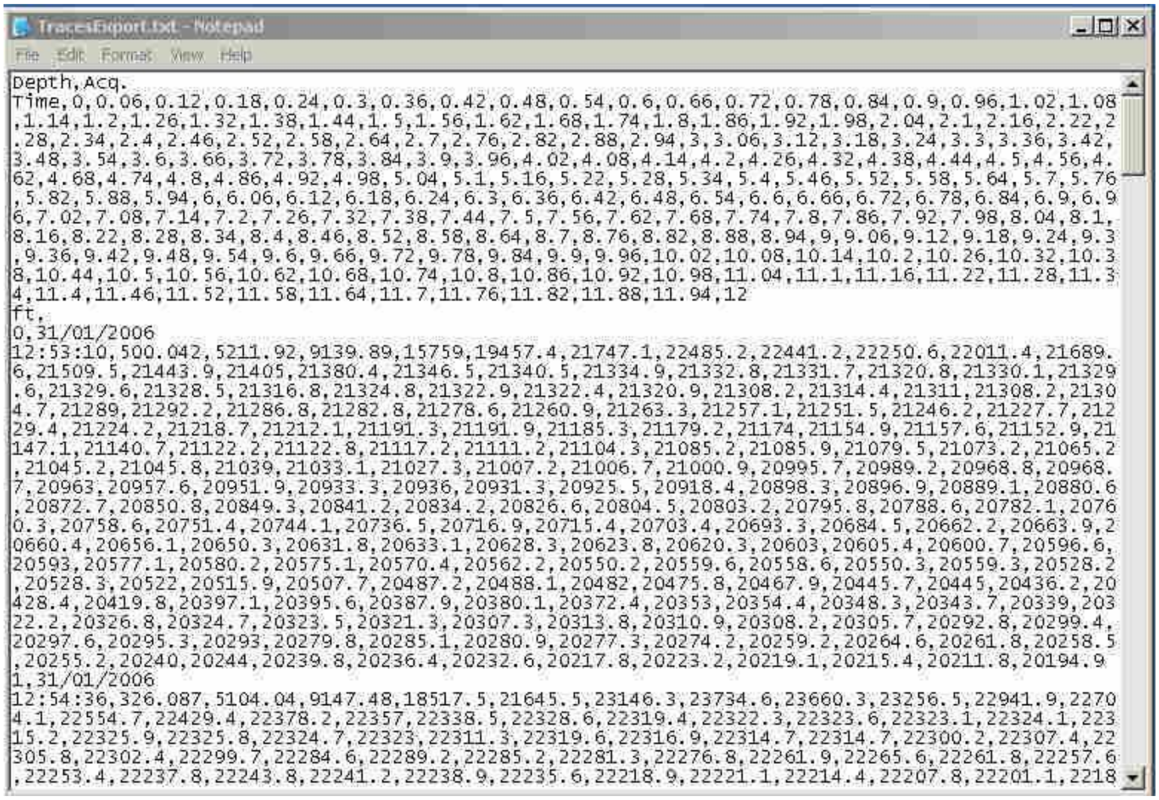
To obtain a text version of the data results, for use in other programs such as WellCAD, or Excel, select File, Export…Pick times and flow values, as shown in the image below:

Example of exported ***.txt** flle



```
Depth,Acq. Time,Pick Time,Flow
ft,,s,Gal./min.
18.6418,03/03/2006 15:46:33,0.909091,0.727696
18.6418,03/03/2006 15:47:35,1,0.630327
18.6418,03/03/2006 15:48:36,0.8,0.885455
18.6418,03/03/2006 15:49:44,1,0.630327
18.6418,03/03/2006 15:50:37,1,0.630327
18.6418,03/03/2006 15:51:37,1.05,0.586155
18.6418,03/03/2006 15:53:05,0.95,0.680796
18.6418,03/03/2006 15:56:14,1,0.630327
```

Figure 1 Export Pick times and flow values .txt file



```
Depth,Acq.
Time,0,0.06,0.12,0.18,0.24,0.3,0.36,0.42,0.48,0.54,0.6,0.66,0.72,0.78,0.84,0.9,0.96,1.02,1.08
,1.14,1.2,1.26,1.32,1.38,1.44,1.5,1.56,1.62,1.68,1.74,1.8,1.86,1.92,1.98,2.04,2.1,2.16,2.22,2
.28,2.34,2.4,2.46,2.52,2.58,2.64,2.7,2.76,2.82,2.88,2.94,3,3.06,3.12,3.18,3.24,3.3,3.36,3.42,
3.48,3.54,3.6,3.66,3.72,3.78,3.84,3.9,3.96,4.02,4.08,4.14,4.2,4.26,4.32,4.38,4.44,4.5,4.56,4.
62,4.68,4.74,4.8,4.86,4.92,4.98,5.04,5.1,5.16,5.22,5.28,5.34,5.4,5.46,5.52,5.58,5.64,5.7,5.76
,5.82,5.88,5.94,6,6.06,6.12,6.18,6.24,6.3,6.36,6.42,6.48,6.54,6.6,6.66,6.72,6.78,6.84,6.9,6.9
6,7.02,7.08,7.14,7.2,7.26,7.32,7.38,7.44,7.5,7.56,7.62,7.68,7.74,7.8,7.86,7.92,7.98,8.04,8.1,
8.16,8.22,8.28,8.34,8.4,8.46,8.52,8.58,8.64,8.7,8.76,8.82,8.88,8.94,9,9.06,9.12,9.18,9.24,9.3
,9.36,9.42,9.48,9.54,9.6,9.66,9.72,9.78,9.84,9.9,9.96,10.02,10.08,10.14,10.2,10.26,10.32,10.3
8,10.44,10.5,10.56,10.62,10.68,10.74,10.8,10.86,10.92,10.98,11.04,11.1,11.16,11.22,11.28,11.3
4,11.4,11.46,11.52,11.58,11.64,11.7,11.76,11.82,11.88,11.94,12
ft,
0,31/01/2006
12:53:10,500.042,5211.92,9139.89,15759,19457.4,21747.1,22485.2,22441.2,22250.6,22011.4,21689.
6,21509.5,21443.9,21405,21380.4,21346.5,21340.5,21334.9,21332.8,21331.7,21320.8,21330.1,21329
.6,21329.6,21328.5,21316.8,21324.8,21322.9,21322.4,21320.9,21308.2,21314.4,21311,21308.2,2130
4.7,21289,21292.2,21286.8,21282.8,21278.6,21260.9,21263.3,21257.1,21251.5,21246.2,21227.7,212
29.4,21224.2,21218.7,21212.1,21191.3,21191.9,21185.3,21179.2,21174,21154.9,21157.6,21152.9,21
147.1,21140.7,21122.2,21122.8,21117.2,21111.2,21104.3,21085.2,21085.9,21079.5,21073.2,21065.2
,21045.2,21045.8,21039,21033.1,21027.3,21007.2,21006.7,21000.9,20995.7,20989.2,20968.8,20968.
7,20963,20957.6,20951.9,20933.3,20936,20931.3,20925.5,20918.4,20898.3,20896.9,20889.1,20880.6
,20872.7,20850.8,20849.3,20841.2,20834.2,20826.6,20804.5,20803.2,20795.8,20788.6,20782.1,2076
0.3,20758.6,20751.4,20744.1,20736.5,20716.9,20715.4,20703.4,20693.3,20684.5,20662.2,20663.9,2
0660.4,20656.1,20650.3,20631.8,20633.1,20628.3,20623.8,20620.3,20603,20605.4,20600.7,20596.6,
20593,20577.1,20580.2,20575.1,20570.4,20562.2,20550.2,20559.6,20558.6,20550.3,20559.3,20528.2
,20528.3,20522,20515.9,20507.7,20487.2,20488.1,20482,20475.8,20467.9,20445.7,20445,20436.2,20
428.4,20419.8,20397.1,20395.6,20387.9,20380.1,20372.4,20353,20354.4,20348.3,20343.7,20339,203
22.2,20326.8,20324.7,20323.5,20321.3,20307.3,20313.8,20310.9,20308.2,20305.7,20292.8,20299.4,
20297.6,20295.3,20293,20279.8,20285.1,20280.9,20277.3,20274.2,20259.2,20264.6,20261.8,20258.5
,20255.2,20240,20244,20239.8,20236.4,20232.6,20217.8,20223.2,20219.1,20215.4,20211.8,20194.9
1,31/01/2006
12:54:36,326.087,5104.04,9147.48,18517.5,21645.5,23146.3,23734.6,23660.3,23256.5,22941.9,2270
4.1,22554.7,22429.4,22378.2,22357,22338.5,22328.6,22319.4,22322.3,22323.6,22323.1,22324.1,223
15.2,22325.9,22325.8,22324.7,22323,22311.3,22319.6,22316.9,22314.7,22314.7,22300.2,22307.4,22
305.8,22302.4,22299.7,22284.6,22289.2,22285.2,22281.3,22276.8,22261.9,22265.6,22261.8,22257.6
,22253.4,22237.8,22243.8,22241.2,22238.9,22235.6,22218.9,22221.1,22214.4,22207.8,22201.1,2218
```

Figure 2 Export Traces .txt file

In the traces export file above, the first and second line Depth,Acq.Time is a label followed by the acquisition time digitization sequence which beginning with 0 and ends with 12(seconds) on line 12. Note the trace amplitude values are sampled every 0.06 seconds with trace length time equal to the longest used during the acquisition.

Line 13 is ft. label, which depends on the Software Depth/Speed Units; see MatrixSettings.

Line 14 begins: 0,31/01/2006; which is depth, date

Line 15 begins: 12:53:10, 500.042; which is time stamp, first amplitude data point additional amplitude data points per time slice follow.

The next amplitude trace record is at line 32 the sequence of Line 14 and 15 is repeated on this and subsequent records. Traces may vary in length depending on the trace length used.

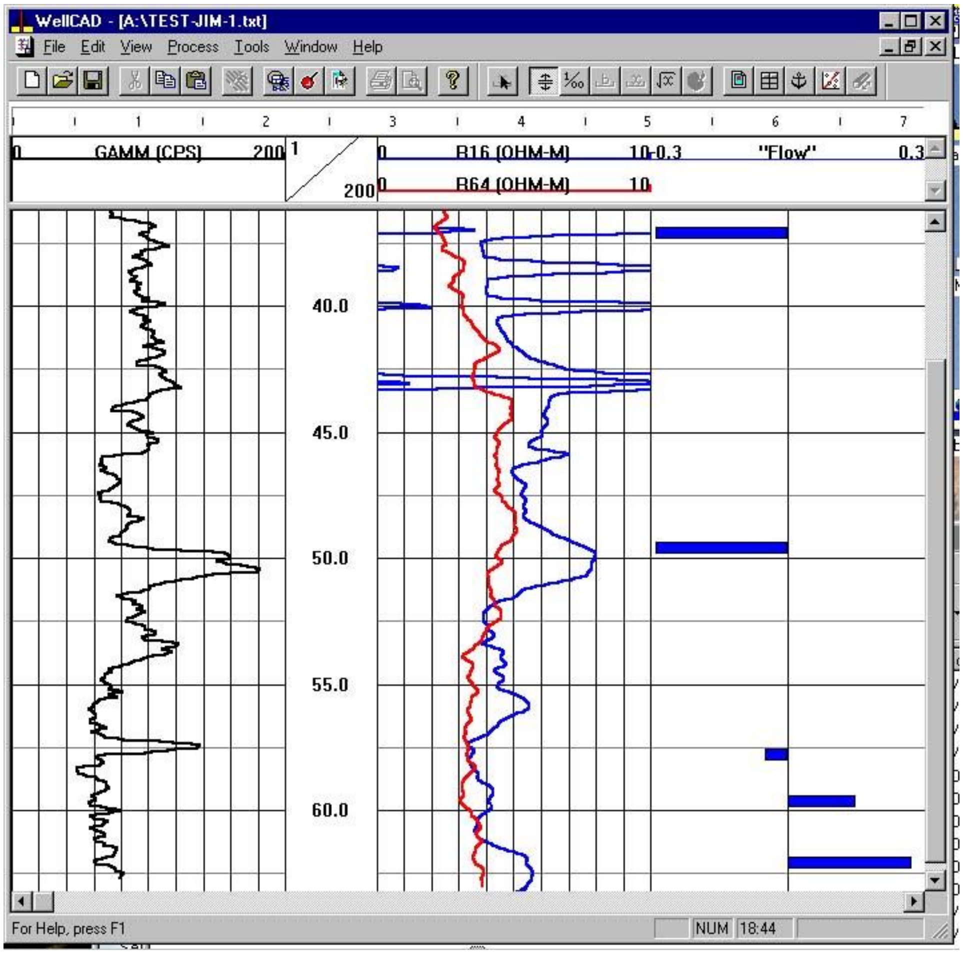
V. Appendix

a) Import to WellCad

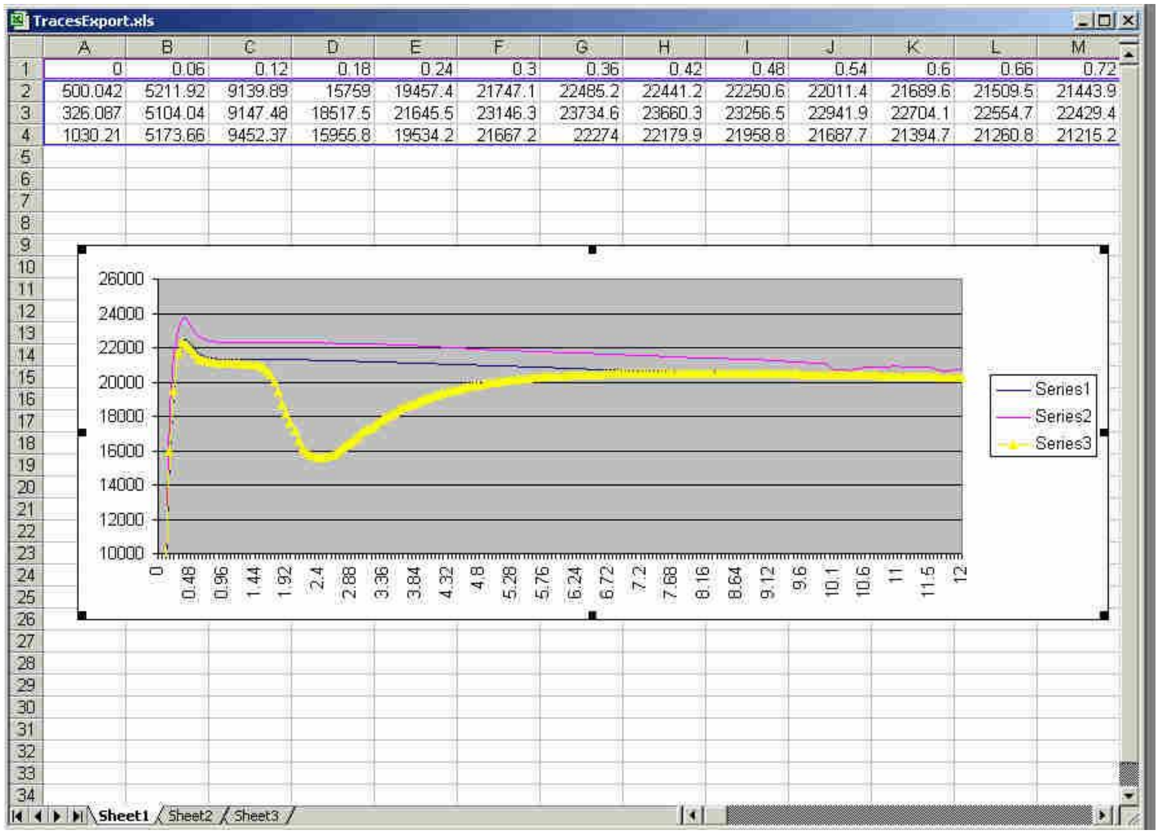
1. Locate the Pick-times **.txt** file that was exported from MatrixHeat and rename it with **.waf** extension instead of .txt.
2. Start WellCad and select the 'Import' command from the 'File' menu. Next select 'Single File'.
3. Answer the import wizard questions when prompted. Note that the first line contains titles and the second line contains units. Make sure that these boxes are checked in the import wizard. When the wizard asks what type of log to import select **Mud-log**.
4. After importing the text file, double click the scale header of the time or flow log. Under style, chose **'fixed w/ polarity**". Also, change the plotting scale the necessary negative to positive range.

Delete the unnecessary logs (time, speed) if desired. Set the depth scale and track positions as usual. Save the resultant **.wcl** file and plot as usual.

b) Example of WellCAD presentation of Heat Pulse Flow data as mud log



c) Example of Excel presentation of exported traces



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	0	0.06	0.12	0.18	0.24	0.3	0.36	0.42	0.48	0.54	0.6	0.66	0.72
2	500.042	5211.92	9139.89	15759	19457.4	21747.1	22485.2	22441.2	22250.6	22011.4	21689.6	21509.5	21443.9
3	326.087	5104.04	9147.48	18517.5	21645.5	23146.3	23734.6	23660.3	23256.5	22941.9	22704.1	22554.7	22429.4
4	1030.21	5173.66	9452.37	15955.8	19534.2	21667.2	22274	22179.9	21958.8	21687.7	21394.7	21260.8	21215.2

Figure 3 Excel plot of exported traces

To start this spreadsheet the time data from the exported traces, line two was copied into the spreadsheet at line one. After using the Data, Text to Columns tool to format the first line, three data sets from the exported traces file were copied and pasted into the following lines two through four.
A graph was created from the data with the x-axis representing the time axis.

Note that depth and time stamp were not included although they could have been.

d) MatrixHeat “.ini” files

Two “.ini” configuration files are used with MatrixHeat, matrixheat.ini and matrix.ini. These files are in the same folder as MatrixHeat.ini. There can be some crossover in their functionality but the following examples are normal.

Matrixheat.ini

```
[Tol Files]
RootDir=C:\MatrixHeat\TOL\Current

[FirstArrival]
; The following values are managed by the MatrixHeat dialogs
Threshold=3
TimeMin=0.6
TimeMax=10

[Recent File List]
```

Matrix.ini

```
[Dashboard Panels]
; The following values are described below
LedDisplayBkgColor=0
LedDisplayFontColor=ffff
```

e) Font and background color of numerical displays

The color of the background and characters in the Depth display can be controlled in the Matrix.ini file, which can be found in \MatrixHeat installation folder. Yellow characters on a black background seem to give the best contrast the settings for which are shown below.

Use the following keys in matrix.ini

```
[Dashboard Panels]
LedDisplayBkgColor=0
LedDisplayFontColor=ffff
```

The table below shows some common color codes:

Color	Color HEX	Color
⬛	#000000	Black
🟥	#0000FF	Red
🟩	#00FF00	Green
🟦	#FF0000	Blue
🟨	#00FFFF	Yellow
🟦	#FFFF00	Bright Blue
🟪	#FF00FF	Violet
◼	#C0C0C0	Grey
⬜	#FFFFFF	White

There are many other hues of colors available by adjusting the Hex numbers. If you use another resource that describes standard HTML font colors for browsers note that *the order of the HEX numbers shown above are reversed* from those standards.

f) Robertson Geologging Heat Pulse tool operation notes

MatrixHeat supports the operation of the Robertson Geologging Heat Pulse Flowmeter on a Matrix in which the associated, optional modem has been enabled. Contact Mount Sopris Instruments for further information.

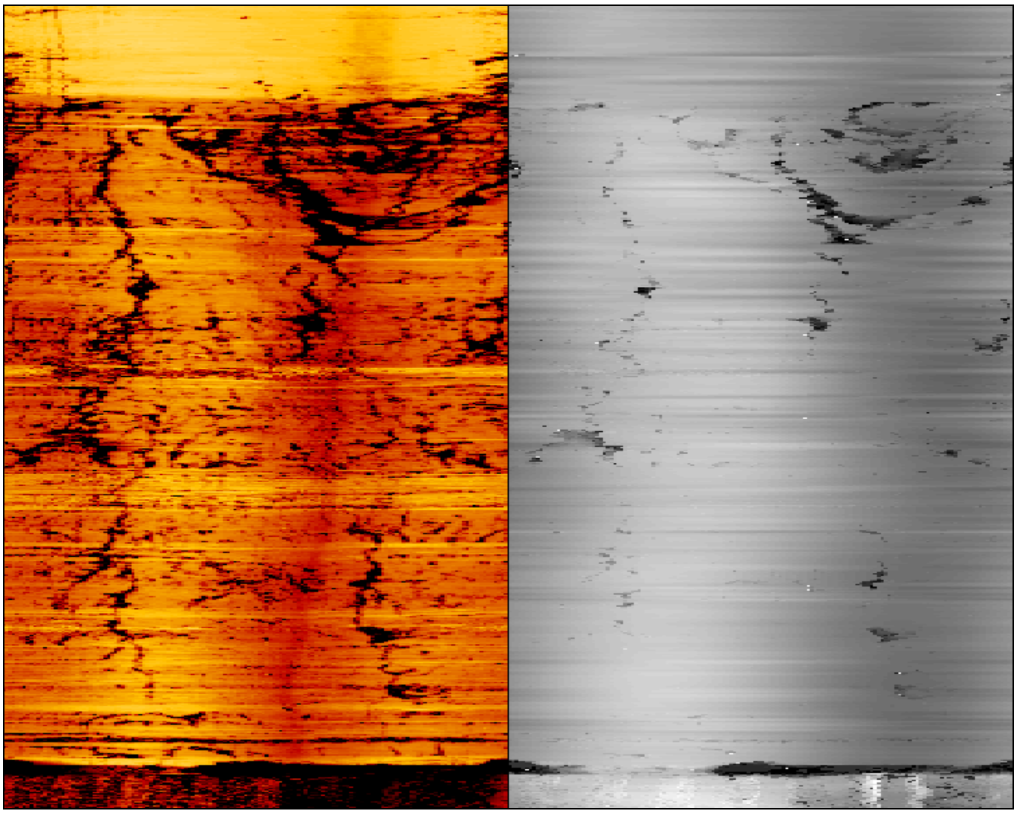
The tol file for the RG HFP tool is in the \MatrixHeat\tol\ folder; copy it to the \MatrixHeat\Tol\Current folder.

Warning: Do not turn the HFP-2293 on with the RG HPF tol file selected for acquisition as damage to the HFP-2293 tool will result due to the higher operating voltages for the RG HPF.

As the RG HPF tool isn't as stable as the Mount Sopris HFP-2293 it takes a little practice to figure out when the best time to fire it is depending on the values from the tool.

It is a two-step process; first the Stabilize button is pressed then perhaps pressed again about 5 seconds before firing the tool.

It should probably be stabilized and fired a couple more times to verify the flow signature.



User Guide

QL40 ABI (2G) Acoustical Borehole Imager

v13.09.02

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Table of Contents

1 General Information

The QL40 ABI is the latest generation of acoustic televiewer. Based on 20 years of experience and market leadership with BHTV technology, the new system consists of a completely redesigned acoustic sensor and new electronics. The electronic architecture uses a 96 dB-10Msps A/D converter directly coupled to a 150 Mflops DSP digital signal processor. The DSP is performing complex data processing operations in real time on each individual ultrasonic wave train and that allows a wider dynamic range of signal detection and easy field operation in a wide variety of logging applications.
The QL40 ABI tool is supplied as a bottom sub of the Quick Link (QL) product line and can be combined with other QL40 tools to form a tool string or it can be run as a stand alone tool. The ABI40 is the standalone - non stackable - version.

1.1 Overview

Acoustic borehole scanner tools generate an image of the borehole wall by transmitting ultrasound pulses from a fixed transducer with rotating mirror and recording the amplitude - travel time of the signals reflected at the interface between borehole fluid and the formation (borehole wall). The QL40 ABI has multi-echo capability. This is achieved by digitally recording the reflected acoustic wave train. On line analysis of the acoustic data is made by the DSP. Sophisticated algorithms allow the system to detect the reflection from the acoustic window and to separate and classify all subsequent echoes. Minimum input from the operator is needed to enable:

- Automatic or manual adaptation to variable borehole conditions.
- Improved dynamic range of signal detection.
- Very high travel time resolution.
- The implementation of different operating modes. For example, when run inside PVC casing, the tool can record both the echo of the PVC casing and that of the borehole wall. With multi-echoes processing, application of the tool may be extended to steel casing thickness and corrosion evaluation.
  Tool upgrades can be done by simply downloading new firmware to the tool from the surface computer.

1.2 Dimensions

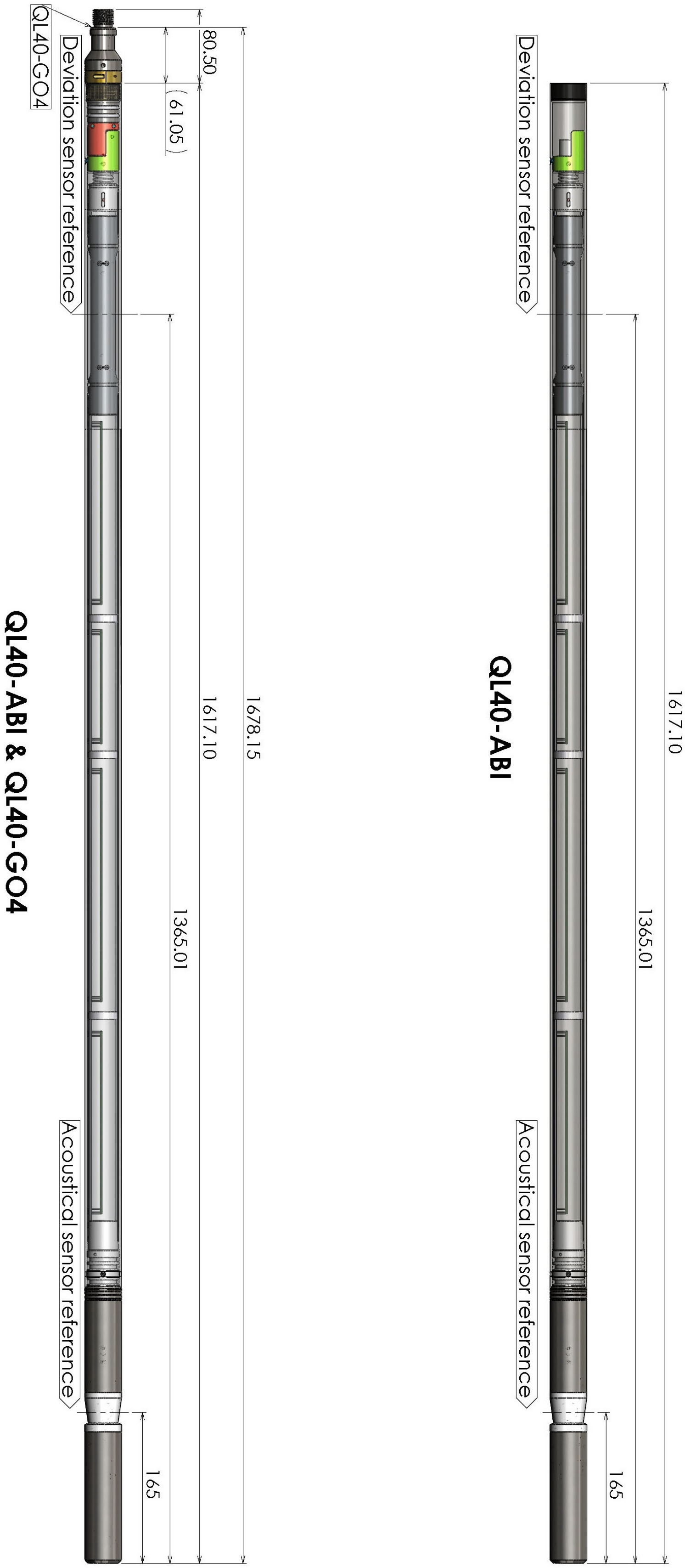


Figure 1-1 *QL40-ABI-2G dimensions*

1.3 Technical Specification

Tool

Diameter:	40mm
Length:	1.61m (63”)

Measurement point:	0.165m (from probe bottom)
Weight:	6.7 kg (14 .7 lbs)

Max. Temp:	70°C
Max.Pressure:	200bar

Cable:

Cable type:	Mono, Coaxial, 4 or 7 conductor
Digital data transmission:	Up to 500 Kbits per second depending on wireline
Compatibility:	ALTlogger – BBOX – Matrix

Acoustic sensor:

Figure 1-2 *Acoustic head*

Acoustic sensor:	Fixed transducer and rotating focusing mirror
Measurement range[1]:	2.5” – 20” (64mm-500mm)
Focusing diameter[2]:	6” (152mm)
Frequency:	1.2 Mhz
Acoustic beam width:	1.5 mm (at focal point)
Rotation speed:	Up to 35 revolutions per second - automatic
Azimuthal resolution:	72, 144, 216, 288, 360 operator defined
Caliper resolution:	0.08mm

Orientation sensor:

Sensor:	APS544
Location:	Middle point of sensor located at 1.365 m from tool bottom
Orientation:	3 axis fluxgate magnetometer, 3 accelerometers
Inclination accuracy:	0.5 degree
Azimuth accuracy:	1.2 degree

---

[1] Diameter range of the hole in which the measurement is possible (depends on borehole conditions).

[2] Diameter of the hole where the focusing of the acoustical beam is optimum.

Software requirements:

LoggerSuite:	11.1.1224 or higher
WellCAD	4.4.3303/13303 or higher

Logger Firmware requirements:

Matrix:	113 – 117 - 100
Jazz - BBOX	108

2 Measurement Principle

An understanding of the basic principles of operation of the televiewer is essential for successful use of the tool. The ABI produces images of the borehole wall which are based on the amplitude and time of travel of an ultrasonic beam reflected from the formation wall. The ultrasonic energy wave is generated by a specially designed piezoelectric ceramic crystal and has a frequency of around 1.2MHz. On triggering, an acoustic energy wave is emitted by the transducer and travels through the acoustic head and borehole fluid until it reaches the interface between the borehole fluid and the borehole wall. Here a part of the beam energy is reflected back to the sensor, the remainder continuing on into the formation medium at a changed velocity (Figure 2-1). By careful time sequencing the piezoelectric transducer acts as both transmitter of the ultrasonic pulse and receiver of the reflected wave. The travel time for the energy wave is the period between transmission of the source energy pulse and the return of the reflected wave measured at the point of maximum wave amplitude. The magnitude of the wave energy is measured in dB, a unit less ratio of the detected echo wave amplitude divided by the amplitude of the transmitted wave.

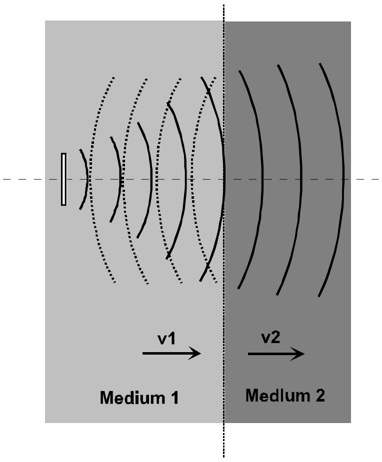


Figure 2-1 *Wave propagation*

2.1 Reflection coefficient

The strength of the reflected signal depends principally on the impedance contrast between the borehole fluid and the formation (Figure 2-1).
The reflection coefficient *r* is given by the following equation:
$r = (\rho_b v_b - \rho_m v_m) / (\rho_b v_b + \rho_m v_m)$

where ρ_b = density of formation
ρ_m = density of borehole fluid
v_b = velocity of sound of formation
v_m = velocity of sound of borehole fluid

The larger the reflection coefficient is the greater is the signal reflection and thus the ability to detect the signal. From the equation above it may be seen that when the properties of the borehole fluid and borehole wall are similar, i.e. $\rho_b v_b \approx \rho_m v_m$, the reflection coefficient *r* approaches zero and there is negligible reflection. In this situation determination of the true reflected wave is made more difficult.

2.2 Acoustic head operation

The acoustic wave is generated by applying a high voltage pulse across the two faces of a piezo ceramic disc. The applied voltage causes deformation within the crystal structure, either an expansion or contraction depending on the polarity of the applied voltage, with a resultant energy wave emitted normal to the free surface. It has been shown that the beam generated by this process has a maximum energy at a distance of twice the diameter of the disc and that after this point the beam tends to diverge. In order to optimize the beam energy at the point of investigation the ALT televiewer head has been designed as illustrated below (Figure 2-2).

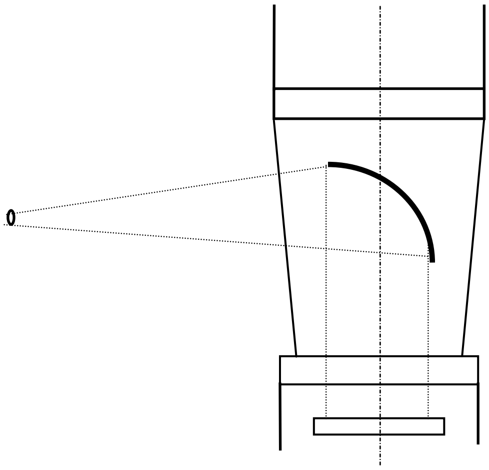


Figure 2-2 *Focussing arrangement*

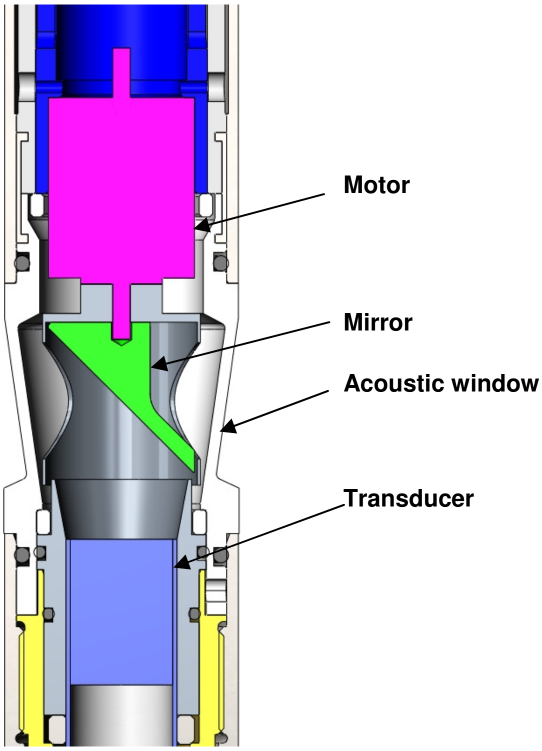


Figure 2-3 *QL40 ABI acoustic head architecture*

The acoustic wave propagates along the axis of the tool body and is then reflected perpendicular to this axis by a special reflector that focuses the beam to a high-energy point of +/- 1.5 mm diameter. The radial distance of the focal point from the axis of the tool is determined by the focal length of the mirror, +/- 75mm (for an acoustic head with a 6" focusing mirror).
The frequency of the transmitted wave is determined amongst other factors such as ceramic composition by the diameter of the piezo transducer, a smaller diameter giving a higher frequency. The ALT televiewer operates around 1.2MHz.

The reflector is mounted on the drive shaft of a stepper motor. This enables the position of measurement to be rotated through 360°. Sampling rates of 72, 144, 216, 288 and 360 measured points per revolution are available, thus at maximum resolution a near continuous image of the borehole wall is made. The higher sampling rate can be used for better resolution in larger diameter boreholes but is less useful in small diameters due to overlap of the sampling points.

3 Notes on QL tool assembly

The following explanations are only valid for the QL40 ABI tool versions. ABI40 “standalone” users can skip this chapter.

QL stands for **Q**uick **L**ink and describes an innovative connection between logging tools (subs) allowing to build custom tool stacks. QL40 describes a specific family of logging tools. Each sub is equipped with its own Telemetry board, Power supply element and A/D converter allowing an operation as stand-alone tool or as a stack in combination with other subs of the QL product family.
The QL40 probe line deals with two types of subs - Bottom Subs and Mid Subs.

Bottom Sub
A bottom sub is a tool that must have one or more sensors located at the bottom. It can be operated in combination with other QL subs connected to the top but it is not possible to connect another sub below. When used in stand-alone mode the bottom sub only needs a QL40 tool top adaptor, which fits the cable head.

Mid Sub
A mid sub is a tool that can be integrated anywhere within a stack of tools. When used at the bottom of a tool string a QL40 bottom plug must be used to terminate the string. If the mid sub is used as a stand-alone tool it needs a QL40 bottom plug at the lower end and a QL40 tool top adaptor at the top.

3.1 QL40 stack assembly

QL40 tool stacks are terminated by either a QL40 bottom sub or a QL40 bottom plug. At the top of the stack a QL40 tool top is required to connect the tool string to the cable head. Several tool tops are already available, special ones can be made on request.

To assemble and disassemble the subs the C-spanner delivered with the tool must be used (Figure 3-1). It is recommended that before each assembly the integrity of the O-rings (AS216 Viton shore 75) is verified. Prime the O-rings with the silicon grease that was supplied with the subs.

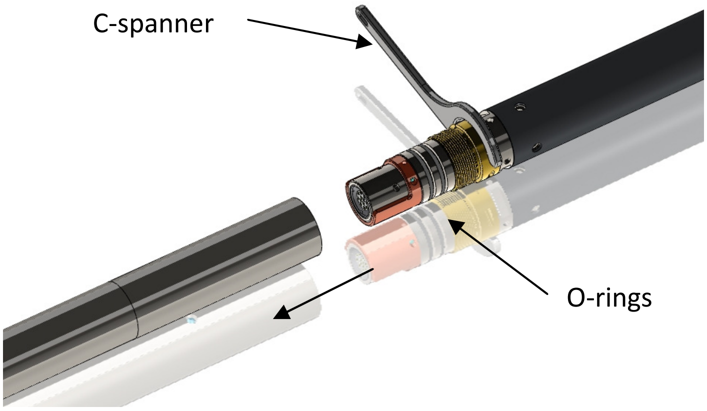


Figure 3-1 *C-spanner and O-rings of QL connection*

The following example of a QL40-ABI, QL40-GAM and QL40-GO4 (Figure 3-2) describes how to replace the QL40-ABI with a QL40-Plug in order to run the QL40-GAM sub stand-alone.

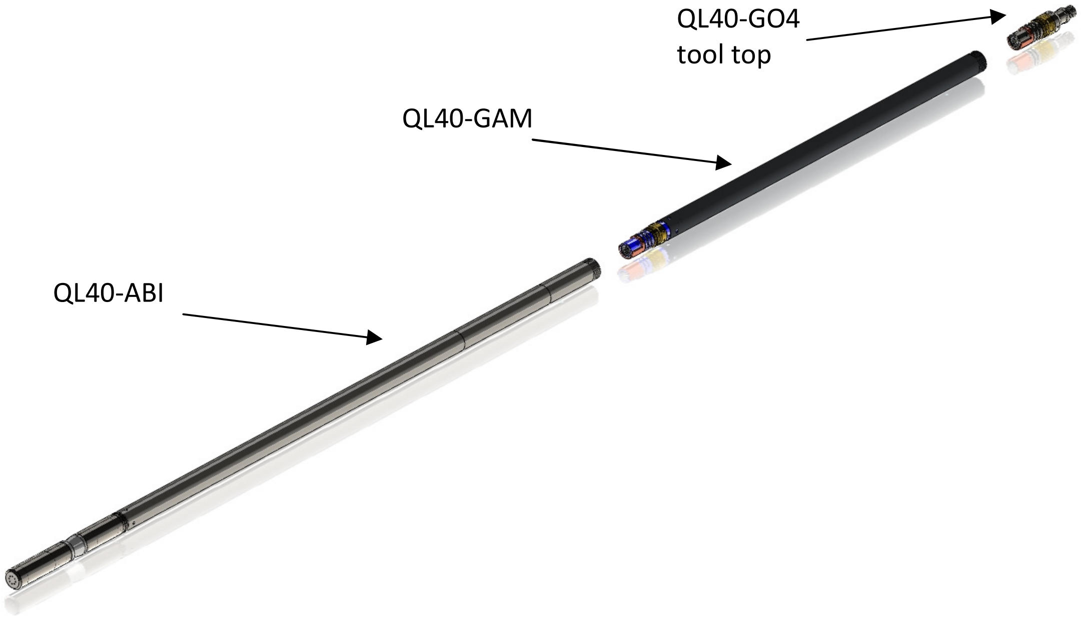


Figure 3-2 *Tool stack example*

To remove the QL40-ABI bottom sub attach the C-spanner to the thread ring as shown in Figure 3-3, unscrew the thread ring and remove the QL40-ABI bottom sub.

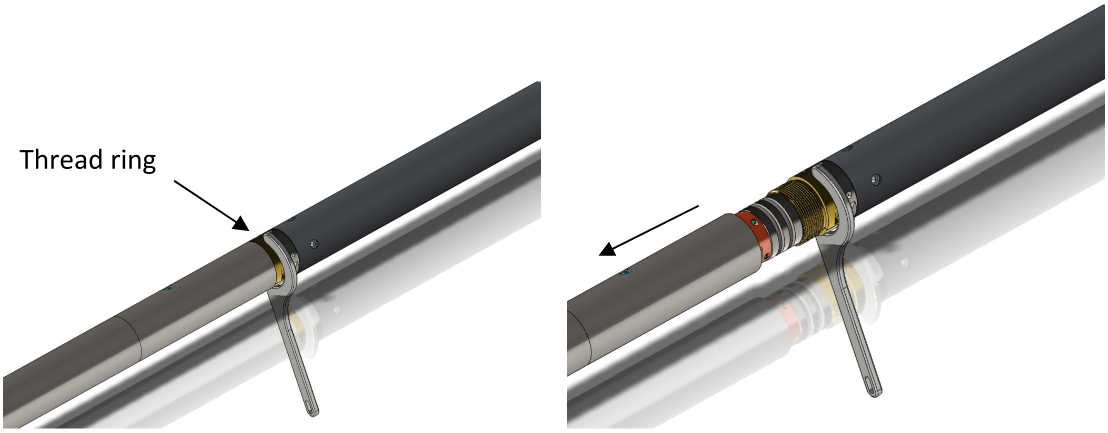


Figure 3-3 *Unscrewing the thread ring and removing the bottom sub*

After checking the O-ring integrity slip the QL40-Plug over the exposed QL connector (Figure 3-4) attach the C-spanner and screw the thread ring until the plug fits tight.

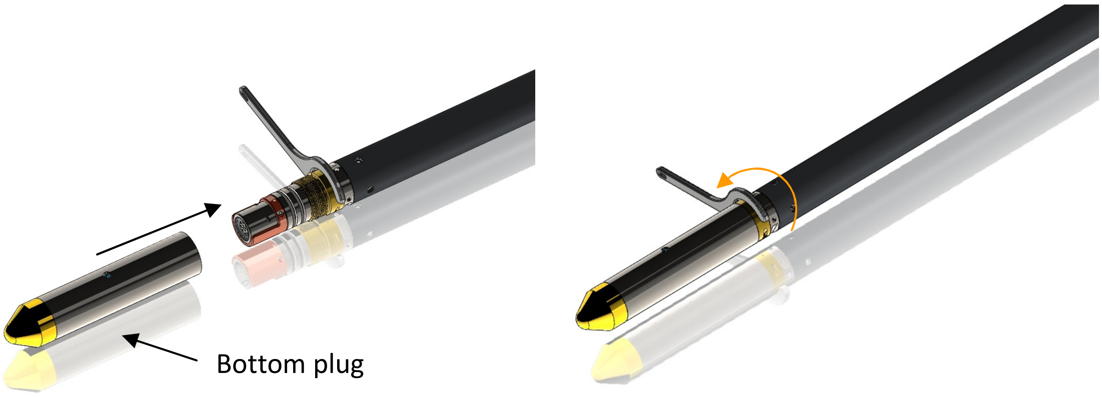


Figure 3-4 *Attaching the QL40-Plug*

The QL40-GAM can now be run stand-alone (Figure 3-5).

Figure 3-5 *QL40-GAM mid sub with tool top and bottom plug*

4 Operating Procedure

4.1 Preliminary note

Acoustic televiewer image quality is highly dependent upon tool centralisation.

One set of centralisers is supplied with the QL40 ABI and is suitable for all tools with an external diameter of 40mm. The standard assembly comprises upper and lower mounting rings with sets of 3”, 5” and 6” bowsprings. Two C spanners are provided for tightening the locking ring. Bowsprings for other borehole diameters are available on request.

The following points relating to the use of centralisers should be considered:

The centralisers should be fitted before mating the tool with the wireline cable head and should always be fitted from the cable head end to avoid damaging the acoustic window.

The compression ring of the centraliser, i.e. the one that is screwed tight, should always be fixed toward the **top** end of the sonde. This is to avoid catching on a downhole obstruction when winching up.

Use the C spanner to fasten the fixing rings but take care not to cross thread or over tighten them as this could damage the pressure housing

(The weak point of the bowsprings is the welded bearing pin. Take care during assembly as the weld can be broken by reverse bending.)

The QL40 ABI enables inspection behind PVC casing. In this situation, the PVC casing must be properly centred in the borehole and the tool correctly centralised in the casing to obtain satisfactory results.

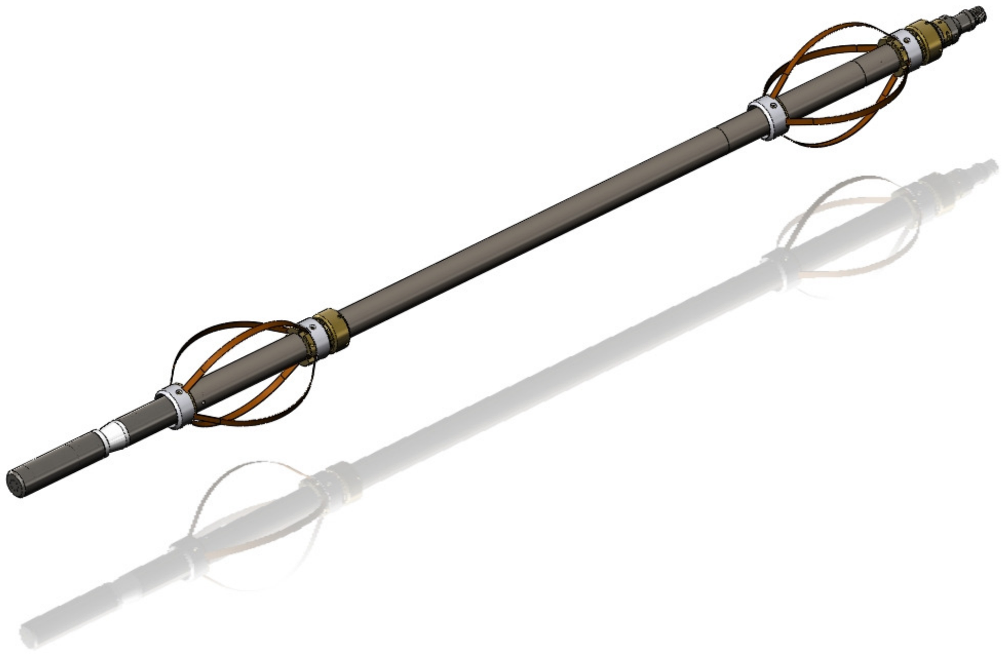


Figure 4-1 *QL40 ABI with mounted centralizers.*

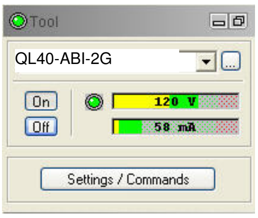
4.2 Quick Start

Note: Parts of the topics discussed in these sections below assume that the user is familiar with the data acquisition software. Refer to the corresponding operator manuals for more details. Information about assembly and configuration of tool stacks can be found in the same manuals.

1. Connect the tool to your wireline and start the data acquisition software.

2. Select the relevant QL40 ABI tool from the drop down list (Figure 4-2) in the software's **Tool** panel (if your tool is not listed check that your tool configurations file is stored in the designated folder on your computer).

3. In the **Tool** panel switch on the tool (click **On** button) and verify that the power indicator shows a valid (green) level. The system goes through a short initialization sequence which sets the default parameters and communication settings held in the tool configuration file. The configuration returned by the tool is also checked during this procedure. (Setup tool communication as explained in chapter **4.5** if error message is displayed.)



QL40-ABI-2G

120 V

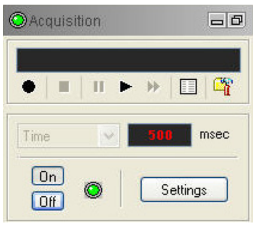
58 mA

Figure 4-2 *Tool panel*

4. On the **Tool** panel (Figure 4-2) click the **Settings / Commands** button to configure your tool for open hole/cased hole logging (see chapter **4.3** and **4.4** for details).

5. In the **Acquisition** panel (Figure 4-3) select the sampling mode ("depth" recommended). Click on **Settings** and specify the corresponding sampling rate. Switch on the sampling (click the **ON** button).

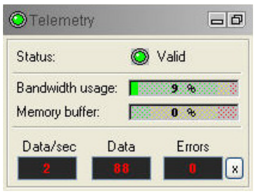
6. Press the **Record** button in the **Acquisition** panel (Figure 4-3), specify a file name and start the logging.



Time 500 msec

Figure 4-3 *Acquisition panel*

7. During logging observe the controls in the **Telemetry** panel:
   - Status must be valid (green light);
   - Bandwidth usage in green range;
   - Memory buffer should be 0%;
   - Number of **Data** increases and number of **Errors** negligible.
   - Verify motor status (synchronization) in MChNum browser is valid.
   - Do not log too fast! The **Data/sec** parameter must not exceed the speed of the motor rotating the mirror. Check against the **MotSpeed** displayed in the MChNum window.



Status: Valid

Bandwidth usage: 9 %

Memory buffer: 0 %

Data/sec 2

Data 88

Errors 0

Figure 4-4 *Telemetry panel*

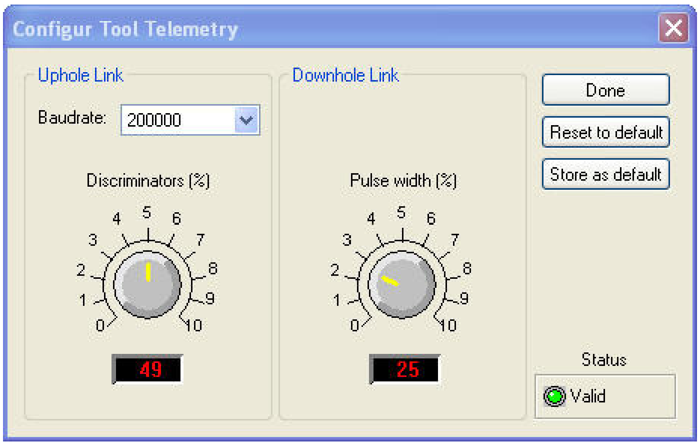
8. To end the logging procedure press the **Stop** button in the **Acquisition** panel and turn off the sampling (click **OFF** button).

9. In the **Tool** panel power off the tool.

4.3 Tool Communication with ALT Logger

The telemetry provided through the ALTLogger is self-tuning**.** In case communication status is not valid the user can manually adjust the settings. In the **Telemetry** panel of the dashboard click on **Settings** to display the **Configure Tool Telemetry** dialog box (Figure 4-5). A procedure to achieve valid communication is given below:

- Change the **Baudrate** to 41666 kbps.
- Verify that the **Downhole Pulse width** knob is set on 20 (default value). This value is the preferred one and is suitable for a wide range of wirelines. For long wireline (over 2000m), increasing the pulse width could help to stabilize the communication. The reverse for short wireline (less than 500m).
- Set the **Uphole** discriminators in the middle of the range for which the communication status stays valid.
- Increase the **Baudrate**, check the communication status stays valid and the **Bandwidth usage** (in **Telemetry** panel of the dashboard) is below the critical level.
- When **Uphole** discriminators are properly set, store the new configuration as default. The tool should go through the initialisation sequence the next time it is turned on.



Configur Tool Telemetry

Uphole Link

Baudrate: 200000

Discriminators (%) 49

Downhole Link

Pulse width (%) 25

Status

Valid

Figure 4-5 *Tool communication settings*

4.4 Tool Communication with MATRIX

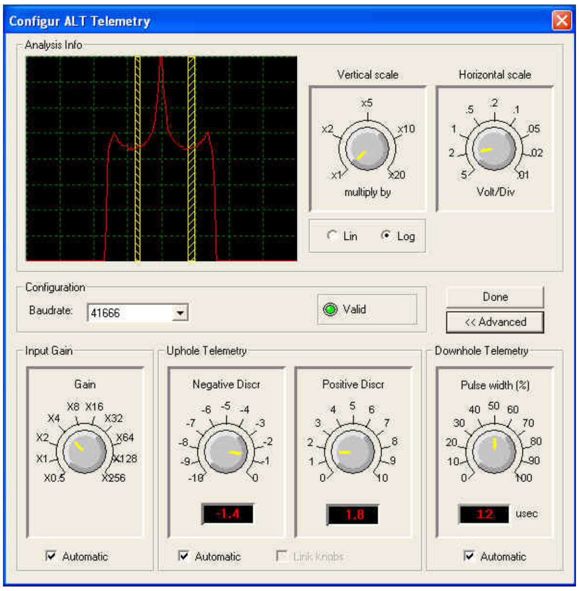
The tool telemetry can be configured through the **Telemetry** panel of the Matrix dashboard. By clicking on **Settings**, the operator has access to the **Configure ALT Telemetry** dialog box (Figure 4-6) providing various controls to adjust the telemetry settings and monitor its current status.

The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **lin**ear / **log**arithmic scale buttons.

The status of the configuration should be flagged as Valid (indicated by the LED being green). In any other case (LED red) the telemetry should be adjusted (we assume a pulse signal is displayed in the analysis view). Click on the **Advanced** button to display additional controls to tune the telemetry.

The Automatic settings option is the preferred mode and should allow the telemetry to be configured for a wide range of wirelines without operator input. For wirelines with a more limited bandwidth, the operator might need to turn off the automatic mode and adjust the telemetry settings manually.

For each wireline configuration, the discriminators (vertical yellow lines) for the **positive** and **negative** pulses must be adjusted in order to obtain a valid communication status (see Figure 4-6) for an example of a suitable discriminator position). There is also the option to alter the **baudrate** in order to optimize the logging speed. The input **gain** can be increased (long wirelines) or decreased (short wirelines) in order to set up the discriminator levels correctly.



○ Lin ● Log

Configuration

Baudrate: 41666

● Valid

Negative Discr: -1.4

Positive Discr: 1.8

Pulse width: 12 usec

Input Gain: ☑ Automatic

Uphole Telemetry: ☑ Automatic ☐ Link knobs

Downhole Telemetry: ☑ Automatic

Figure 4-6 *Matrix telemetry settings*

Once the telemetry is correctly set, store the new settings as default. The tool should go through the initialization sequence in “Valid” status the next time the power is turned on.

4.5 Configuring Tool Parameters

The **Configure ABI Tool Parameters** dialog box (Figure 4-7) can be accessed by clicking on the **Settings / Command** button on the dashboard's **Tool** panel or by clicking on the tool's bitmap located in the **Tool Stack Manager** window.

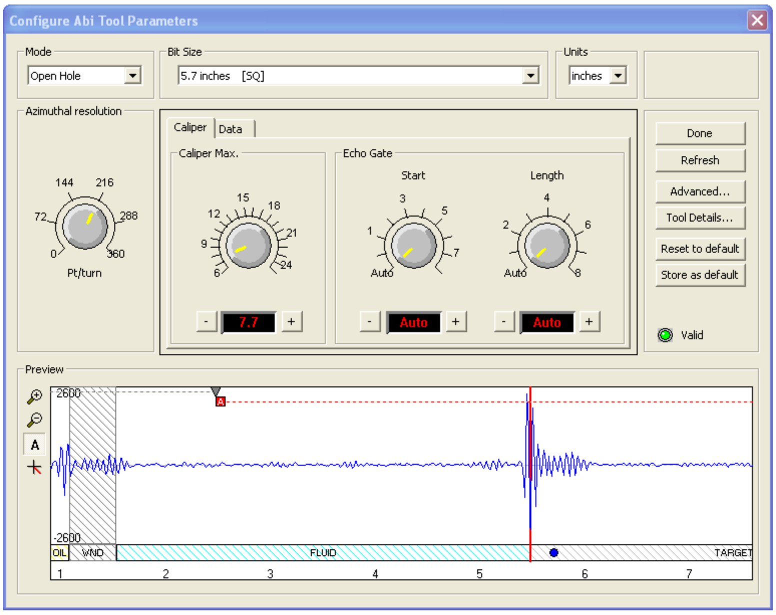
4.5.1 Operating Modes

Three operating modes are possible for recording acoustic images with the QL40 ABI:

- Open hole mode
- Behind PVC mode
- Cased hole mode

4.5.1.1.1 Open hole mode

This record mode is used in open-hole conditions or to record the inner face of a casing.



Configure Abi Tool Parameters

Mode: Open Hole

Bit Size: 5.7 inches [SQ]

Units: inches

Caliper Max.: 7.7

Echo Gate Start: Auto

Echo Gate Length: Auto

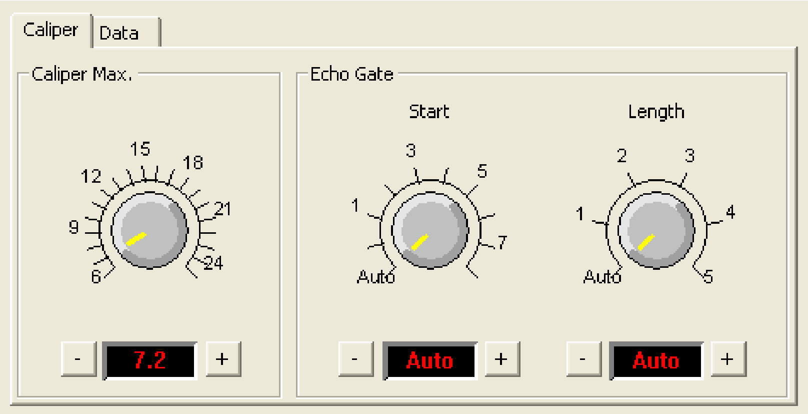
***Figure 4-7** Example of tool settings – Open hole mode*

When selecting a predefined bit size from the **"Bit Size"** dropdown list, the system configures in an automatic way the most adequate tool settings – *azimuthal resolution, caliper max, echo gates* - for the selected bit size or borehole nominal diameter. Note that User has always the choice to modify the tool settings as per his own requirements.

Imperial or **metric units** can be used for displaying the wave form preview and for configuring the caliper/echo gate settings.

The **"Open Hole"** mode gives access to two main tabs – **Caliper** and **Data** - for configuring the record:

Caliper tab:



Caliper Max.: 7.2

Start: Auto

Length: Auto

***Figure 4-8** Caliper and Echo Gate settings*

In the **Caliper** page, the **Caliper Max.** knob (Figure 4-8) controls the extension of the real time preview of the ultrasonic waveform. It must be adjusted for the borehole diameter to investigate to allow detection and recording of the main echo.

Echo Gate settings are set in the "Auto" mode by default. If required, User can define a **"Start"** gate and specify the **"Length"** interval for recording the reflected echo. The tool firmware will pick up the strongest amplitude in the signal train within the Echo Gate and records amplitude and tavel time of the borehole echo.

<u>Note that the **Echo Gate** settings can also be adjusted interactively in the waveform preview.</u>

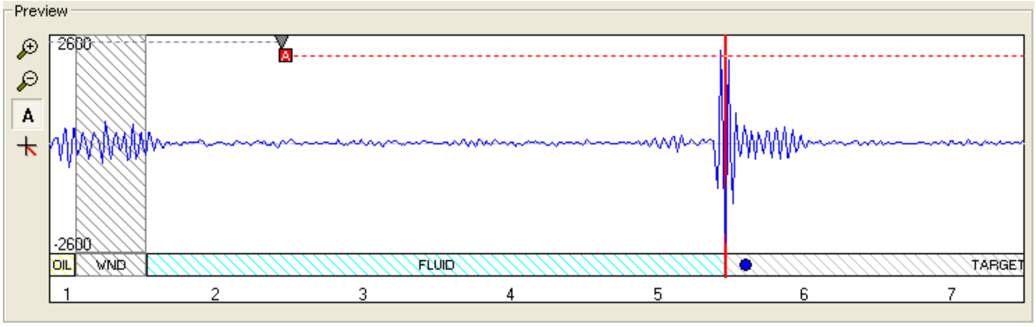


***Figure 4-9** Waveform preview - Echo gate Automatic setting*

For the open hole mode, the waveform preview allows the user to adjust the limits of two gates – the **Acoustic Window gate** and the **Echo Gate**. <u>The Acoustic Window is represented by a grey dashed line while the Echo Gate is shown as red dashed line.</u>

The Acoustic Gate allows determination of the tool's acoustic window reflection time.

The **Echo Gate "Start"** limit can be determined automatically or adjusted interactively in the preview. Square and triangle symbols indicate whether the limit of the **"Start"** gate is automatically set (square symbol - A-) or if the user can adjust the limit with the mouse cursor (triangle - ▼-).

Three modes are supported to set the **Start** time of the Echo Gate - <u>To toggle from one mode to another **right click** on the square or triangle symbol.</u>

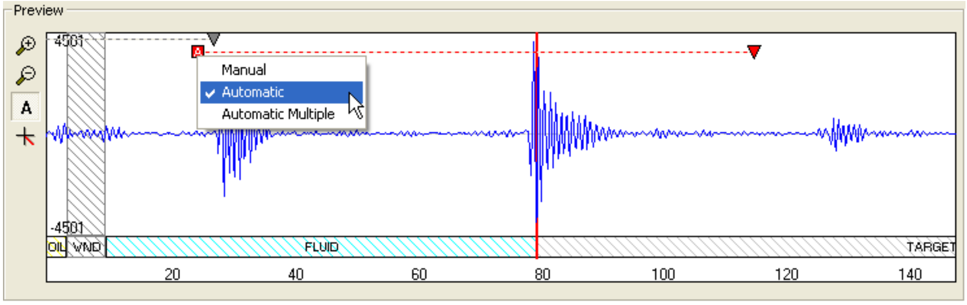


Figure 4-10 *Toggling between Echo Gate detection modes*

- <u>*Automatic*:</u> the system will automatically detect and record the highest amplitude occurring after the Acoustic Window Gate and the upper limit of the Echo Gate (Figure 4-11). Automatic is the recommended setting.

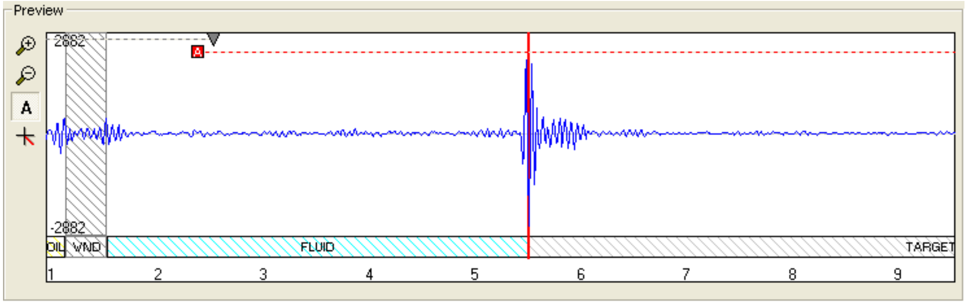


Figure 4-11 *Start gate set in automatic mode*

- <u>*Automatic Multiple*:</u> the system will automatically adjust the start time of the Echo Gate so that the first multiple of the Acoustic Window reflection is skipped. This setting is useful for large diameter boreholes when the amplitude of the first multiple of the Acoustic Window reflection is higher and arrives earlier than the echo from the borehole wall (Figure 4-12).

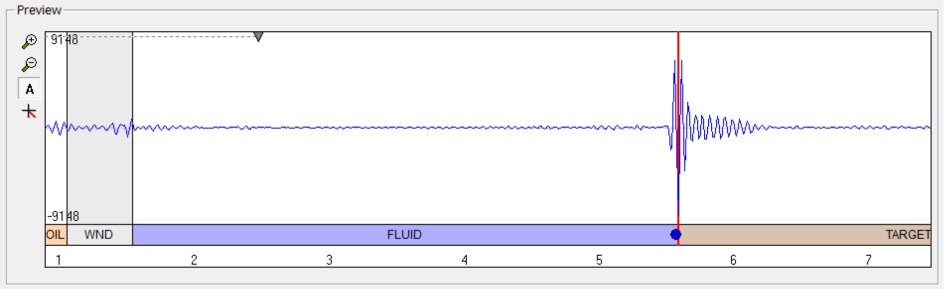


Figure 4-12 *Start gate set in automatic multiple mode*

- <u>*Manual*:</u> Manual adjustment of the Echo Gate start time is useful to exclude noise with amplitudes higher than the formation signal (e.g. exclude the reflection from the inside of a PVC casing) – (Figure 4-13).

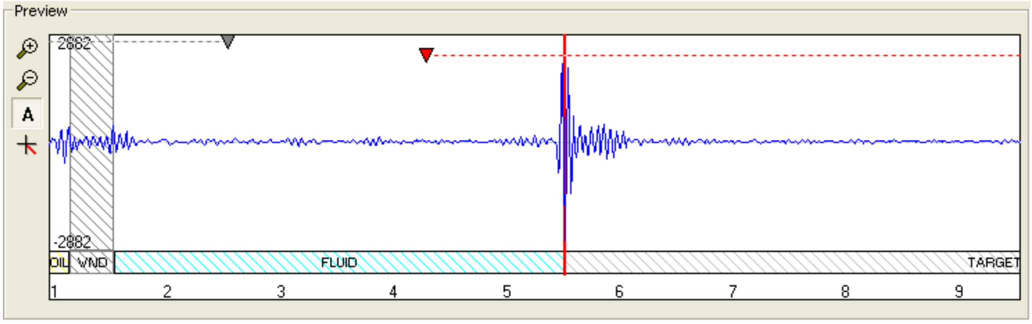


Figure 4-13 *Start gate set in manual mode*

Interactive adjustment in the waveform preview of the Echo Gate **Length** is also possible. It could be useful when multiple reflections with large amplitudes arrives towards the end of the gate period (e.g. exclude Acoustic Window reflection multiples when logging in soft formations).

<u>To toggle the Echo Gate **Length** from the automatic to the manual mode</u>, place your cursor at the right end of the red dashed line to display the double arrows symbol. Drag then the length limit to the desired position on the wave form preview.

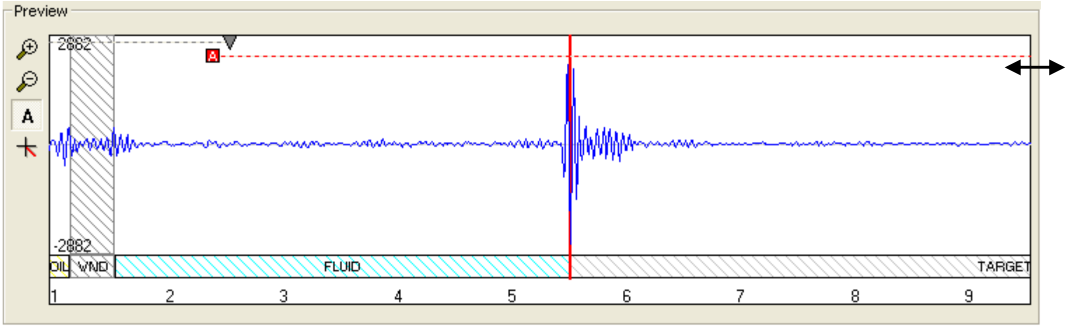


Figure 4-14 *Toggling the Echo Gate Length between automatic and manual mode*

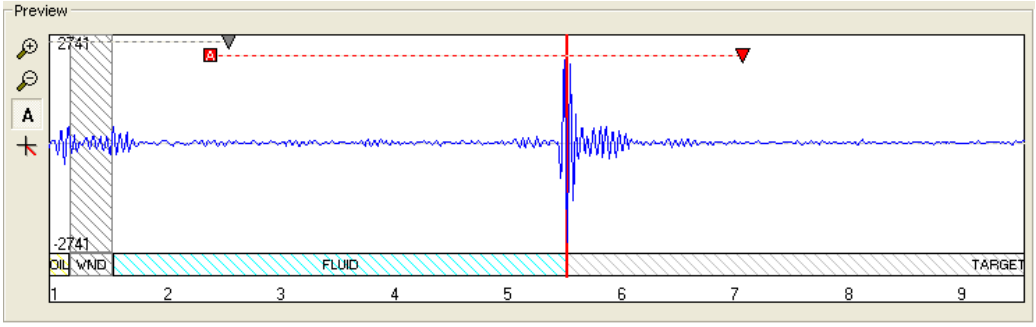
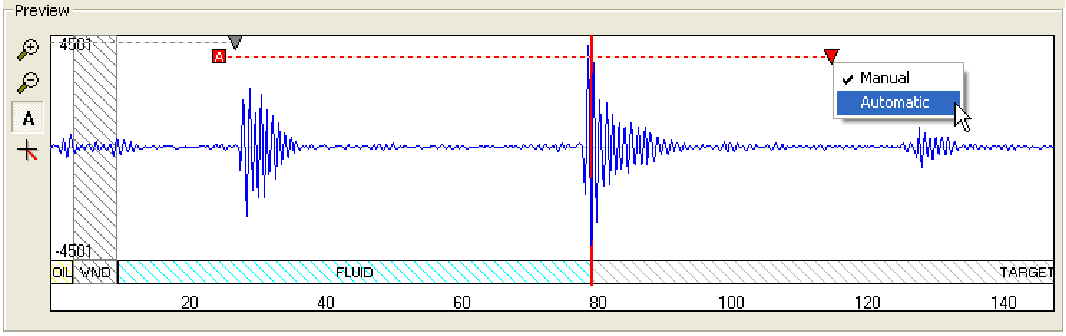


Figure 4-15 *Echo Gate Length set in manual mode*

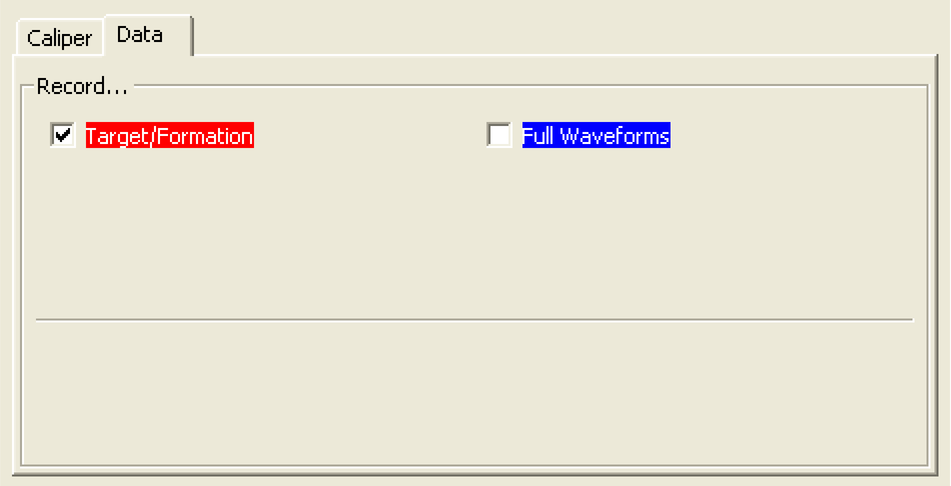
<u>To toggle the Echo Gate **Length** from manual to automatic mode</u>, right click on the corresponding triangle symbol.



Manual ✓

__Figure 4-16__ Toggling the Echo Length setting from manual to automatic

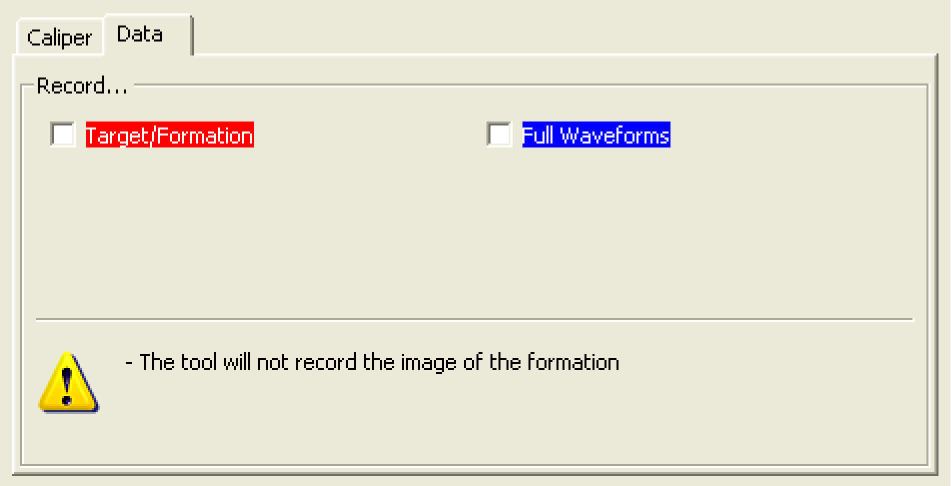
Data tab:



☑ Target/Formation ☐ Full Waveforms

__Figure 4-17__ Data record options for the Open hole mode

The **<u>“Target/Formation”</u>** record option <u>must always be checked.</u> If unchecked, no acoustic image will be recorded and the warning message below will be displayed.

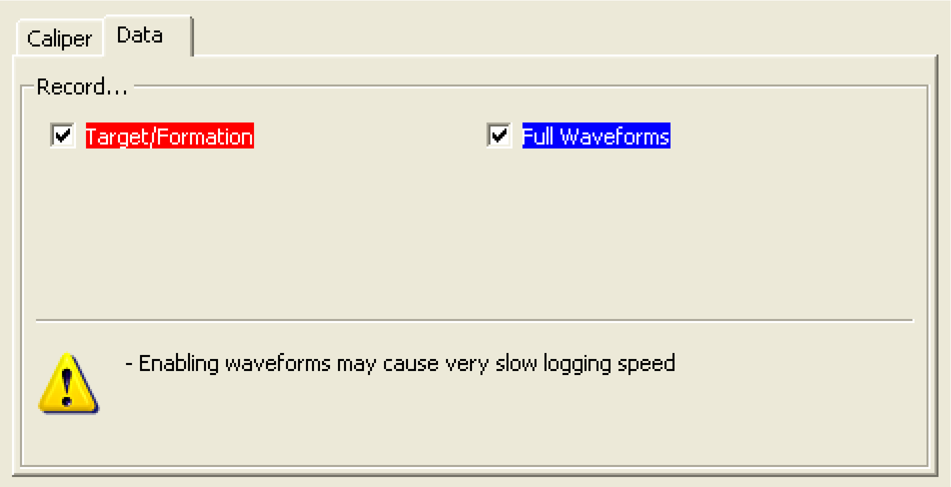


☐ Target/Formation ☐ Full Waveforms

- The tool will not record the image of the formation

__Figure 4-18__ Warning message when Target/Formation record is not checked

For diagnostic purposes or advanced processing, the **“Full Waveforms”** record option can be activated. The system will record the complete ultrasonic waveform shown in the preview window.
Note that recording the ultrasonic waveform will affect the telemetry performance and will slow down the logging speed.



Caliper | Data

Record...

☑ Target/Formation ☑ Full Waveforms

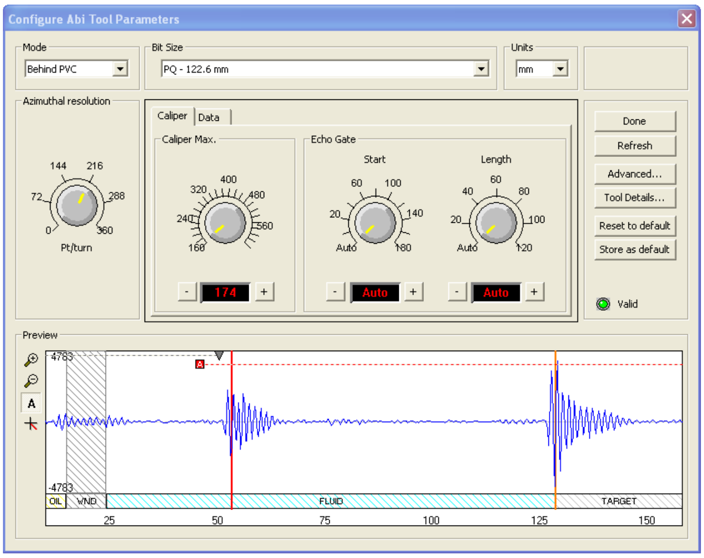
- Enabling waveforms may cause very slow logging speed

__Figure 4-19__ Full Waveforms record option selected

4.5.1.1.2 Behind PVC Mode

The **“Behind PVC”** mode is used in PVC cased boreholes. The main purpose is to log the borehole wall image located behind a PVC casing.
The algorithms implemented in the tool firmware detect and record all existing echoes on the ultrasonic waveforms. The detected echoes are then sorted and interpreted as a reflection from the casing or from the borehole wall (Figure 4-20).

Remind that for such application, the PVC casing must be properly centred in the borehole and the tool correctly centralised in the casing to obtain satisfactory results.



Configure Abi Tool Parameters

Mode: Behind PVC

Bit Size: PQ - 122.6 mm

Units: mm

Caliper Max.: 174

Echo Gate Start: Auto

Echo Gate Length: Auto

__Figure 4-20__ Behind PVC settings – automatic settings

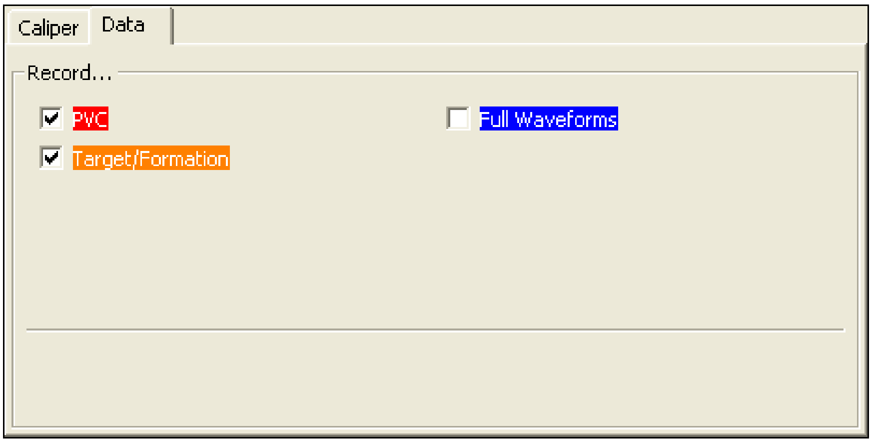
The **“Behind PVC”** mode gives access to two main tabs – **Caliper** and **Data** - for configuring the record:

Caliper tab:

The caliper settings described in section 4.5.1.1 are applicable for the “Behind PVC” mode.

Mainly two major echoes are detected on the waveform preview. The first one is the reflected echo from the inner side of the casing. It is highlighted by the red vertical line. The second reflected echo, corresponding to the borehole wall, is highlighted by the orange vertical line.

Data tab:



Record...

☑ PVC

☑ Target/Formation

☐ Full Waveforms

Figure 4-21 *Data record options for the Behind PVC mode*

By default, the system records both the PVC and the Target/Formation images.

The **“Target/Formation”** record option must always be checked. If unchecked, no acoustic image from the borehole wall will be recorded.

Option is given to the user to record or not the image of the inner face of the PVC casing. Recording the PVC image might be interesting to check the casing integrity or for looking at eventual encrustations.

For diagnostic purposes or advanced processing, the **“Full Waveforms”** record option can be activated. The system will record the complete ultrasonic waveform shown in the preview window.
Note that recording the ultrasonic waveform will affect the telemetry performance and will slow down the logging speed.

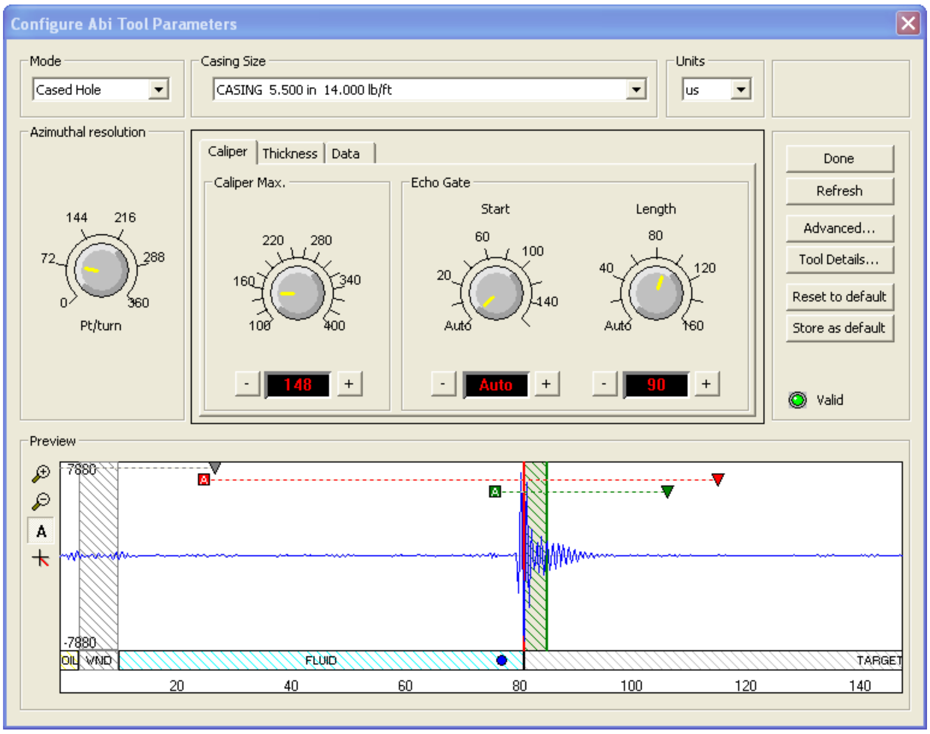
4.5.1.1.3 Cased hole mode

This acquisition mode is used to perform casing thickness measurements and corrosion evaluation in steel casings.

The operator will need to select from the dropdown casing list the nominal specifications of the casing under investigation (Figure 4-22).
When selecting a predefined **"Casing size"**, the system configures in an automatic way the most adequate tool settings – *azimuthal resolution, caliper max, echo gate, thickness, echo gate length* - for the casing external diameter and weight chosen.

User has also the choice to customize its own settings manually by adjusting the different knobs or interactively in the waveform preview window as described in a previous chapter.

Imperial or **metric units** can be used for displaying the wave form preview and for configuring the caliper - thickness settings.



Configure Abi Tool Parameters

Mode: Cased Hole

Casing Size: CASING 5.500 in 14.000 lb/ft

Units: us

Caliper Max.: 148

Echo Gate Start: Auto

Echo Gate Length: 90

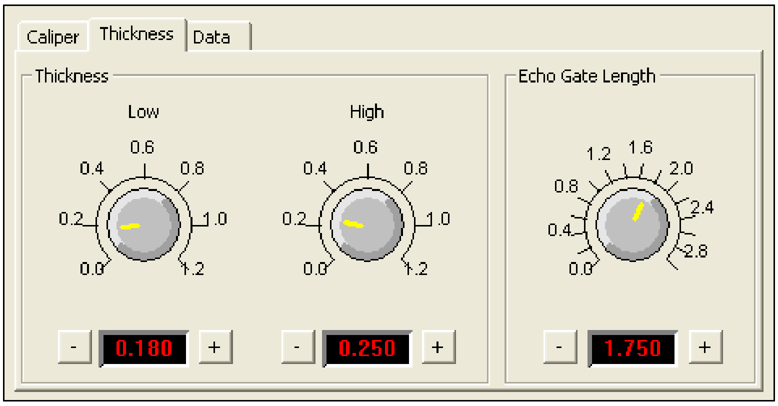
Figure 4-22 *Example of Cased hole settings*

Caliper tab:

The caliper settings described in section 4.5.1.1 are applicable for the "Cased hole" mode. Caliper settings must be adjusted for recording the echo reflected on the inner face of the steel casing.

Thickness tab:

From the thickness tab, the operator has the option to edit the internal (Low) and external (High) casing thickness dimensions manually for the record.
The Echo gate Length can be adjusted from this window or interactively from the wave form preview.



Low: 0.180

High: 0.250

Echo Gate Length: 1.750

Figure 4-23 *Thickness and Echo Gate Length settings*

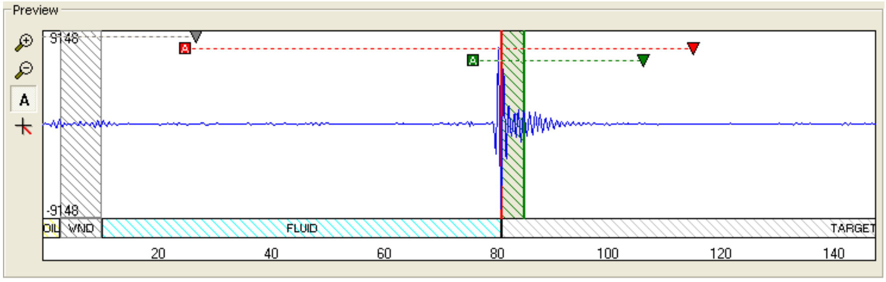
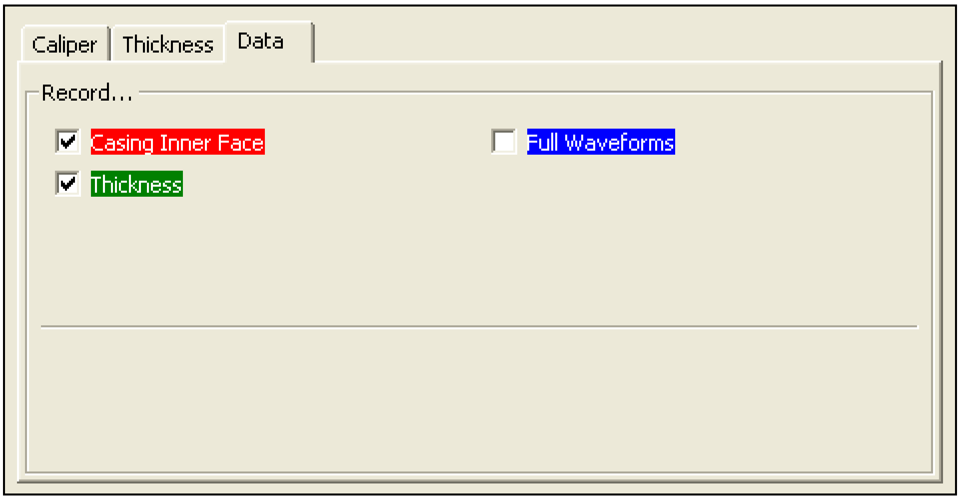


Figure 4-24 *Waveform preview – Thickness Echo Gate*

For cased hole application, in addition to the Acoustic Window and Echo Gates, a third gate - the **Thickness Echo Gate** (green dashed line – Figure 4-24) - is available for which only the end limit is user adjustable. Reduction of the gate length may be necessary if the ringing signal from the casing is superimposed by noise (e.g. multiples of the inner reflection) towards the end of the gate period.

The greyed - green hatched interval overlapping the recorded echo on the wave form preview is representing the casing thickness measured by the system for this specific ultrasonic trace and orientation.

Data tab:



☑ Casing Inner Face
☑ Thickness
☐ Full Waveforms

Figure 4-25 *Data record options for the Cased hole mode*

Option is given to the user to record or not the image of the inner face of the steel casing. Recording the casing inner face image is required for further internal caliper processing and for casing thickness/corrosion evaluation.

For diagnostic purposes or advanced processing, the **"Full Waveforms"** record option can be activated. The system will record the complete ultrasonic waveform shown in the preview window.
Note that recording the ultrasonic waveform will affect the telemetry performance and will slow down the logging speed.

4.5.2 Azimuthal resolution

The azimuthal resolution allows the operator to choose the number of points sampled per revolution of the focusing mirror. Sampling rates of 72, 144, 216, 288 and 360 measured points per revolution are available.

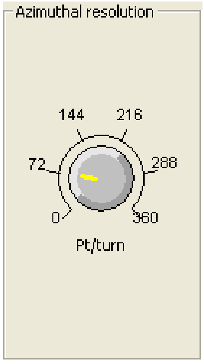


Figure 4-26 *choice of azimuthal resolutions*

The higher sampling rate can be used for better resolution in larger diameter boreholes but it might be less useful in small diameter hole as it would cause an overlap of sample points. The speed of rotation of the focusing mirror is directly linked to the azimuthal resolution and echo mode chosen.

4.5.3 Additional notes on the waveform preview

Beside the interactive settings of the echo gates, the waveform preview is offering other tools to enhance the display of the ultrasonic trace:

🔍	Zoom in the vertical scale of the echo amplitude
🔎	Zoom out the vertical scale of the echo amplitude
A	Set the vertical scale automatically with the best fit for the echo display
+	Display the wave azimuth control knob and scan option
●	Theoretical position of the main reflector for the corresponding bit or casing size selected

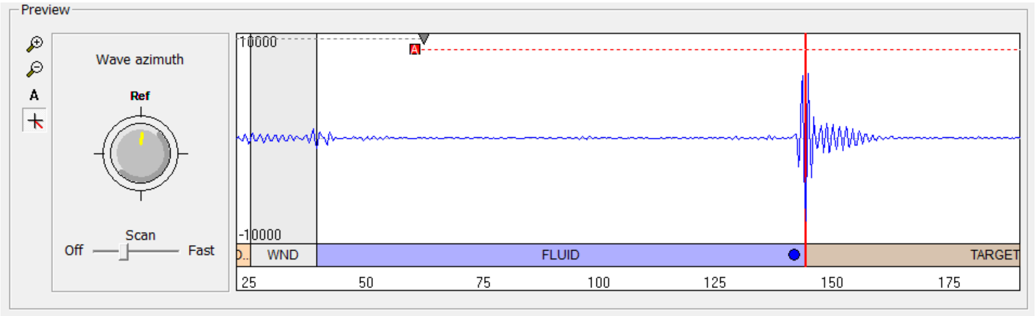


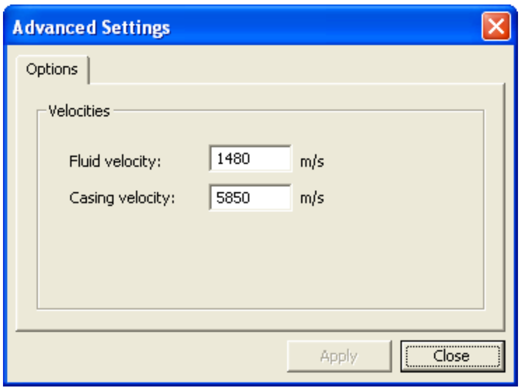
Figure 4-27 *Display of the wave azimuth control knob and scan option*

The **Wave Azimuth** knob in the full waveform preview box (Figure 4-27) gives the possibility to display the ultrasonic wave train in a preferential direction other than the reference position of the mirror.
The preview of the full waveform of the received signal is generated at the position indicated by the **Wave Azimuth** control knob. By turning the control knob, a different position relative to the tool internal reference side can be chosen.

To turn on an **automatic scan** move the slider bar handle from the **Off** position towards **Fast**. In that case the azimuthal scan position will continuously change with the azimuthal step increasing if the slider position is set towards **Fast.**

4.5.4 Advanced Settings

By clicking on **Advanced** in the “Tool Parameters” dialog box (Figure 4-28) the operator can edit the “Fluid and Casing velocity” constants to convert the acoustic travel time from µsec to metric or imperial units. The default values are 1480 m/s for the fluid velocity and 5850 m/s for the steel velocity.



Velocities

Fluid velocity: 1480 m/s

Casing velocity: 5850 m/s

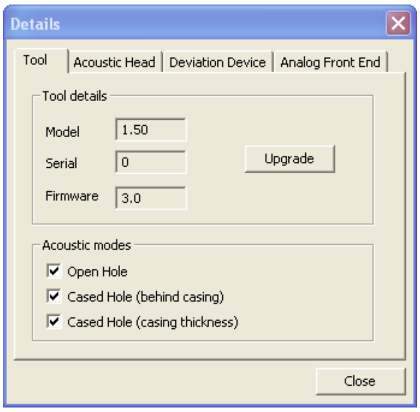
Figure 4-28 *Advanced settings*

4.5.5 Tool details

By clicking on the **Tool Details** button in the **Configure ABI Tool Parameters** dialog box four tabs (Figures 4-29 to 4-32) become available summarizing tool serial number, acoustic head details, deviation sensor model and analog front end. If necessary, newer tool firmware versions can be uploaded. The upgrade procedure will be explained in a later chapter.

Note: All the information displayed in the following dialog boxes can’t be edited

---



Tool details

Model 1.50

Serial 0

Firmware 3.0

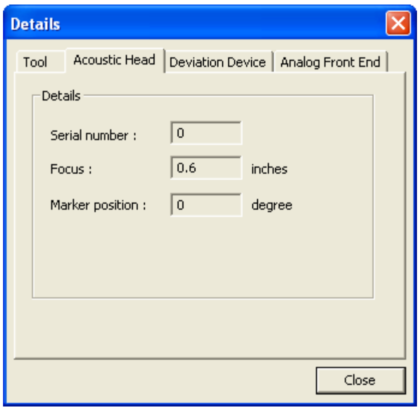
Acoustic modes

☑ Open Hole

☑ Cased Hole (behind casing)

☑ Cased Hole (casing thickness)

Figure 4-29 *Tool details*



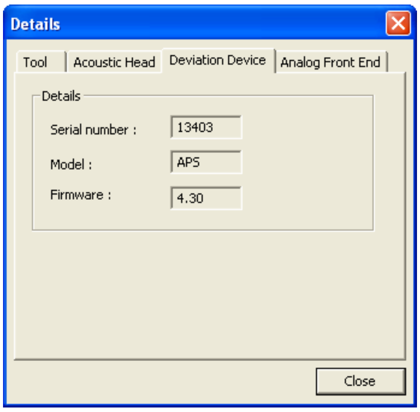
Details

Serial number : 0

Focus : 0.6 inches

Marker position : 0 degree

Figure 4-30 *Acoustic head details*



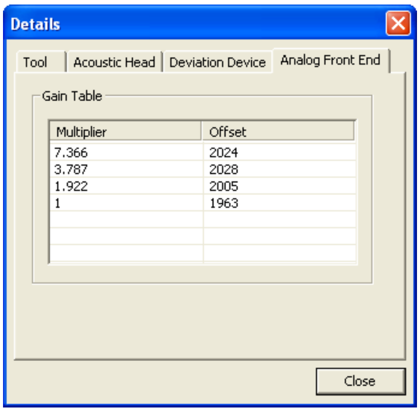
Details

Serial number : 13403

Model : APS

Firmware : 4.30

Figure 4-31 *Deviation sensor details*



Gain Table

Multiplier	Offset
7.366	2024
3.787	2028
1.922	2005
1	1963

Figure 4-32 *Analog Front End*

4.6 Recorded Parameters and Browsers

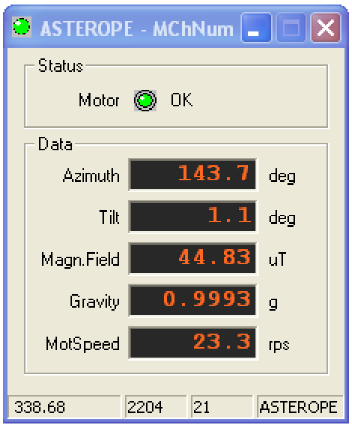
4.6.1 Recorded parameters

The following data channels are recorded by the tool:

TravelTime (1st echo):	Two Way Traveltime 1st echo - µsec
Amplitude (1st echo):	Amplitude 1st echo (NM = North Magnetic, HS = High Side)
TravelTime2 (2nd echo):	Two Way Traveltime 2nd echo - µsec
Amplitude2 (2nd echo):	Amplitude 2nd echo (NM = North Magnetic, HS = High Side)
ThicknessTTime:	Two Way Traveltime within casing - µsec
Score:	Quality Index for thickness signal detection
Azimuth:	Azimuth from Magnetic North – deg
Tilt:	Inclination from verticality – deg
Roll:	Tool relative bearing calculated from accelerometers - deg
Mroll:	Tool relative bearing calculated from magnetometers – deg
Magn.Field:	Magnetic field surrounding the borehole - µT
Gravity:	Absolute value of the Earth gravity – g
Orientation:	Orientation diagnostic code
WndTime:	Two way traveltime of acoustic window reflection – µsec
WndAmpl:	Amplitude of acoustic window reflection
System Status	General system diagnostic code
VTool:	Tool head voltage - V
V12:	Internal tool voltage - V
RTHead :	Temperature sensor resistance - ohms
TCPU :	CPU temperature - °C
T APS:	Temperature inside the deviation sensor - °C
T Head :	Acoustic head internal temperature - °C
MotSpeed:	Motor - Speed of rotation – rps
Motor:	Diagnostic code
Motor Period:	Time for a single revolution – sec

4.6.2 MChNum Browser Window

Figure 4-33 and 4-34 show typical examples of the numerical values displayed in the MChNum browser window during logging.

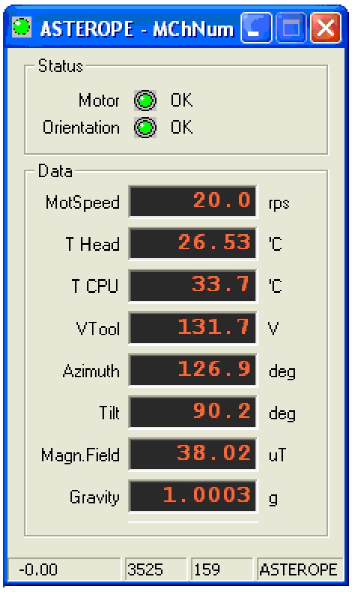


Motor OK
Azimuth 143.7 deg
Tilt 1.1 deg
Magn.Field 44.83 uT
Gravity 0.9993 g
MotSpeed 23.3 rps
338.68 | 2204 | 21 | ASTEROPE

Figure 4-33 *MChNum browser display – example 1*

Motor:	Motor synchronisation status
Azimuth:	Azimuth from Magnetic North - deg
Tilt:	Inclination from verticality - deg
Magn.Field:	Magnetic field surrounding the borehole - µT
Gravity:	Absolute value of the earth gravity - G
MotSpeed:	Motor - Speed of rotation – rps

To display additional parameters in the MChNum browser right click on the MChNum browser title and select **Display Options** to add/remove channels and Led status.



Motor OK
Orientation OK
MotSpeed 20.0 rps
T Head 26.53 'C
T CPU 33.7 'C
VTool 131.7 V
Azimuth 126.9 deg
Tilt 90.2 deg
Magn.Field 38.02 uT
Gravity 1.0003 g
-0.00 | 3525 | 159 | ASTEROPE

Figure 4-34 *Multi Channel Browser for Numerical Data (MChNum) displaying additional channels*

4.6.3 Surface Image Browser Window (AbiSurfaceImg)

The system returns an unwrapped image of the borehole wall based on the caliper and amplitude values of the recorded acoustic signal (Figure 4-35). The left column shows the caliper image and the right column the amplitude image.
These images consist of a succession of variable density colors. By double clicking on the log titles Minimum and Maximum scale values may be adjusted to enhance the log appearance.

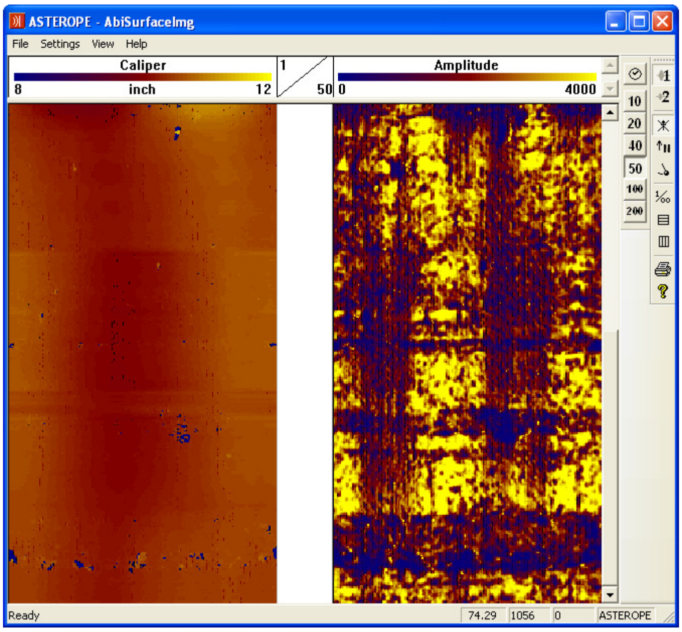


Figure 4-35 *ABI Surface Image browser window*

Note that the displayed units for the caliper log can be converted to either metric or imperial units via the menu bar's **Settings** option or by double clicking on the log title.

Echo selection :

1 Echo1 is displayed (borehole wall or inner side of the casing)

2 Display Echo2 (borehole wall behind a PVC casing)

Image orientation:

Image is non-oriented

Orient image to magnetic North

Orient image to High Side of the tool

There are two modes of tool data orientation: orientation to High Side and orientation to North. Orientation to High Side is used in inclined boreholes when magnetometers data are unavailable (for example in a cased hole).

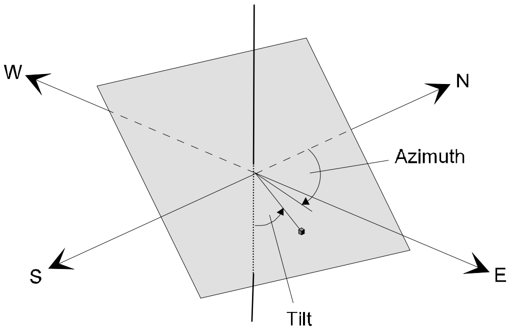


Figure 4-36 *Orientation to Magnetic North*

Vertical scales and grids:

10 20 40 50	Depth mode display and pre-defined depth scales
‰	Operator defined depth scales, interval spacings and settings
🕒	Time mode display

4.6.4 Thickness Image Browser Window (AbiThicknessImg)

In Cased Hole Mode, the ABI Thickness browser displays on the left column an unwrapped color coded image of the **casing *thickness*** processed by the system (Figure 4-37). The right column is a color-coded image of the ***score***. The ***score*** is a ***quality index*** on the thickness measurement. In a general way, high score values mean high reliability of the thickness measurement and the reverse.

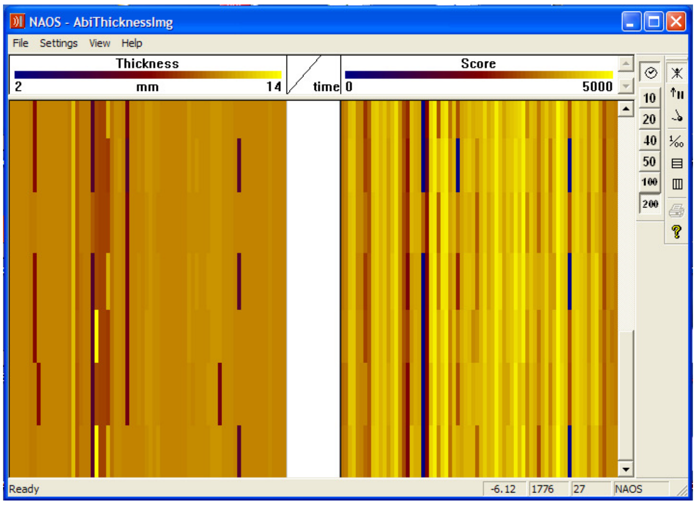


Figure 4-37 *ABI Thickness Image*

As for the Surface image browser, scales and units of the displayed parameters can be adjusted by double clicking on the log title or from the **Settings** option of the menu bar.

4.6.5 Caliper Browser Window (AbiCaliper)

Caliper browser - Open Hole Mode

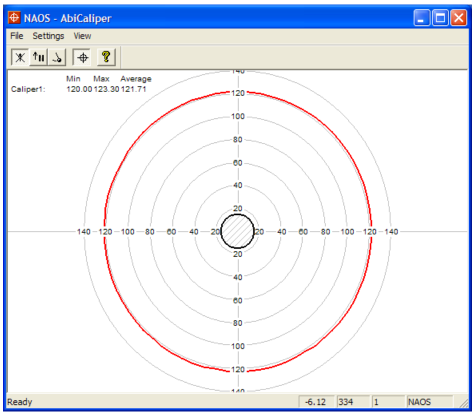
The open hole caliper view (Figure 4-38) shows in real-time a cross-section of the acoustic caliper. Scaling, concentric gridding and displayed units are adjustable from the tool bar **“Settings”** option.

The black circle shows the external limit of the acoustic window.
The red circle is the cross section of the acoustic caliper corresponding to the main reflector detected by the system (borehole wall or inner surface of a casing).

As for the image browsers, the caliper view can be oriented to Magnetic North, High side or displayed without orientation.

During the acquisition, it is possible to centralize the caliper cross section to remove the effect of decentralization of the tool in the borehole.
Clicking the symbol ⌖ can do this.

Statistical caliper figures (Min, Max, Average) are displayed on the left side of the dialog box.



	Min	Max	Average
Caliper1:	120.00	123.30	121.71

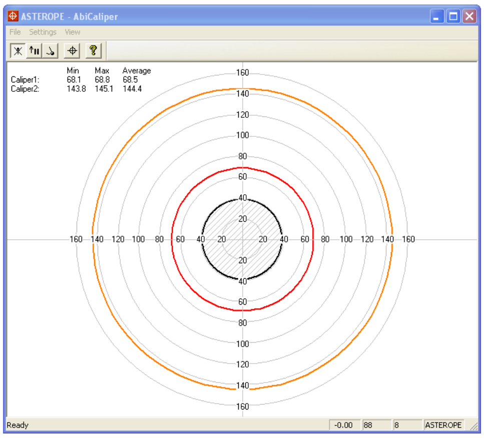
Figure 4-38 *ABI Caliper – Open Hole Mode*

Caliper browser – Behind PVC mode

The “Behind PVC” caliper view (Figure 4-39) shows in real-time a cross-section of the acoustic caliper of the PVC casing and borehole wall. Scaling, concentric gridding and displayed units are adjustable from the tool bar **“Settings”** option.

The red circle is the cross section of the acoustic caliper corresponding to the inner side of the PVC casing.
The orange circle is the cross section of the acoustic caliper corresponding to the borehole wall reflection.

As for the image browsers, the caliper view can be oriented to Magnetic North, High side or displayed without orientation.

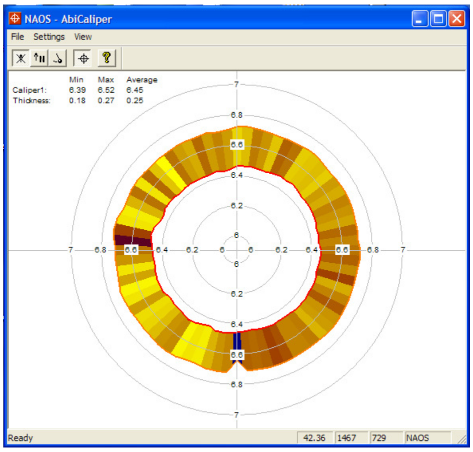


	Min	Max	Average
Caliper1:	68.1	68.8	68.5
Caliper2:	143.8	145.1	144.4

Figure 4-39 *ABI Caliper – Behind PVC Mode*

Caliper browser - Cased Hole Mode

Cross sections of both of the inner (red circle) and outer (orange circle) surface of the casing are shown in this browser (Figure 4-40), giving a good visualization of the casing thickness in real-time. The space between the 2 circles is filled with the corresponding color coded score values.
Orientation, scaling, concentric gridding and displayed units are adjustable from the menu bar's **Settings** option.



	Min	Max	Average
Caliper1:	6.39	6.52	6.45
Thickness:	0.18	0.27	0.25

Figure 4-40 *ABI Caliper – Cased Hole Mode*

5 Performance Check & Calibration

5.1 Mirror rotation

Direction of motor rotation is **clockwise viewed from top of tool** (Figure 5-1):
Placing 2 fingers[3] on the acoustic window may check mirror rotation. In time mode, record the 2 finger traces shown[4] on the Abi surface browser. Remove your right finger from the acoustic window; the corresponding right finger trace on the Abi surface image should disappear.

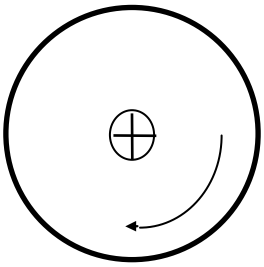


Figure 5-1 *Direction of mirror rotation*

5.2 Functionality test of the deviation system

5.2.1 Functionality test

The ABI‘s deviation system is factory calibrated and does not require further calibration. The functionality tests subsequently described have to be done to check that the tool is giving the correct deviation outputs:

To verify inclination at 0° and 90°, position the probe vertical (acoustic head pointing down) for 0° inclination and horizontal for 90° inclination. Note that uphole measurement is possible with the APS544 deviation system as it includes 3 accelerometers. In uphole, the inclination will be between 90° and 180° (probe vertical, acoustic head pointing up).

To verify azimuth accuracy, a good compass and an area free of magnetic materials must be used. Use a compass to orient North with the probe horizontal and verify that the azimuth reading is 0° ± 1°. Repeat the procedure for East, South and West directions.

5.2.2 Rolling test – azimuth and tilt check

Azimuth and tilt could be tested by rotating the tool about its long axis while maintaining both a constant inclination to the vertical, say 15°, and a fixed azimuth. The data imported into WellCAD should show a deviation of the azimuth less than the limit of ±1.5° and a deviation of the tilt less than the limit ±0.5°.

---

[3] Wet your fingers first for a better coupling
[4] Adjust the amplitude scale to enhance the finger traces

6 Maintenance

Warning: Removing the electronic chassis from pressure housing without prior consultation with ALT will void the tool warranty.

The ABI televiewer is a delicate instrument and should be treated with care at all times. Excessive shock or extreme temperatures should be avoided and the tool should always be transported in its transport case or a similarly cushioned enclosure. Never support the tool on the acoustic head. Experience shows that with attention to these points the QL40 ABI will give several years fault free operation.

The ABI televiewer separates into four basic parts

- The tool top adaptor
- The pressure housing
- The electronic chassis
- The acoustic head.

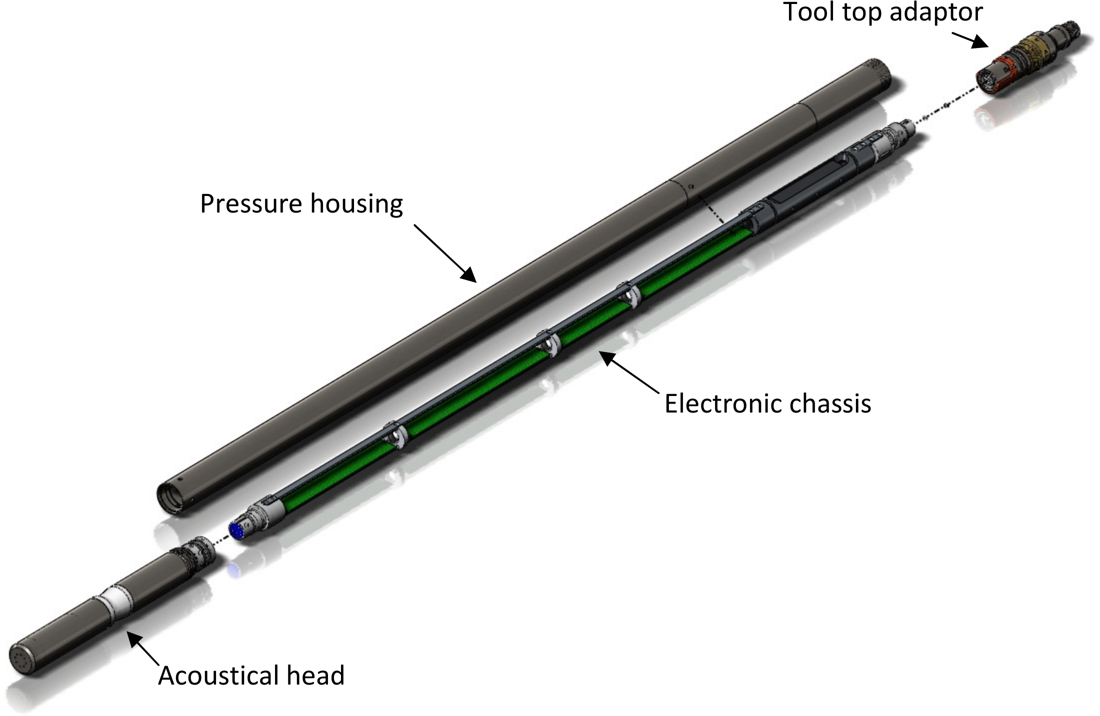


Figure 6-1 *ABI and tool top, exploded view*

Should it become necessary to open the tool, the tool parts must be separated in the following sequence:

1. Remove the tool top adapter
2. Remove the acoustic head
3. Remove the pressure housing

Disassembly of the electronic chassis from the pressure housing should never be attempted in the field.

6.1 Tool Top Adapter

The tool top adapter provides the connection between wireline cable head and chassis electronics and can be provided to suit 7 conductors, 4 conductors, mono or special wireline configurations. The adapter is fixed by the means of a threaded ring screwed in the pressure housing. To remove the tool top adapter, use the correct C spanners provided with the tool - see picture below (Figure 6-2).

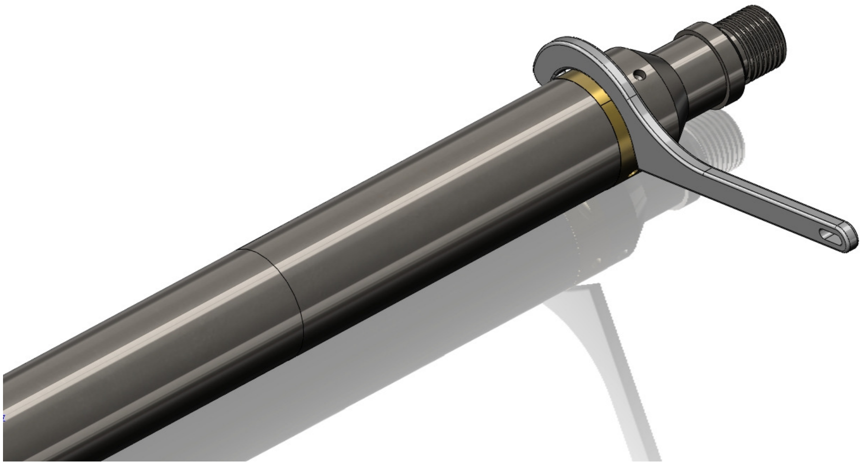


Figure 6-2 *Removing the tool top*

The wireline cable head socket and tool top adapter connector pins should be checked for cleanliness before each use of the tool. The pin inserts, whether 4 or 7 pin, have a locating mark indicating WL1 or A that should line up with the slot mating with the cable head.

Check O-Ring seals and apply silicon grease before re-assembly. Silicon grease of a similar type to RS Components Ref 494-124 is suitable for this and other O-Ring seals.
(Rem: O-Ring reference for tool top and for the quick link 40 is AS215 26,57 x 3,53 Viton Shore 75)

Figure 6-3 *QL40-GO4 Tool top adaptor*

Figure 6-4 QL40-GO7 tool top adaptor

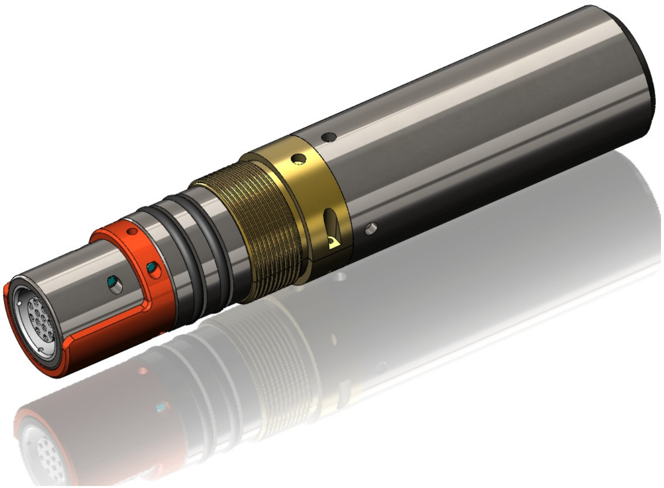


Figure 6-5 QL40-GO1 tool top adaptor

6.2 Acoustic head

Warning: The televiewer acoustic head is extremely delicate and must be treated gently at all times. Any laterally applied force on the end of the head is liable to cause damage!

The acoustic head is attached to the electronic chassis of the sonde by three 2.5mm hex set screws. To remove the entire televiewer head the tool top and pressure housing must first be removed as described below. Slacken off the fixing screws and slide the televiewer head off the connector. The connector has a keyway to locate the head with the correct orientation.

Figure 6-6 *Acoustical head*

Re-assembly is the same procedure in reverse order, but taking care not to force the head on to the connector. This will result in bent or broken connector pins! Check all “O” ring seals (Orings AS215, 26.57x3.53, viton, shore 75) and apply silicon grease to them.

The acoustic head needs to be properly maintained to give the best image results. Note the following points:

- Check that there are no air bubbles visible in the acoustic window. Air can separate out of the oil filling the head, notably after airfreight at low pressure, and can also work its way out of the inner parts of the motor. The presence of air in the head is indicated by a spotty image or streaking. These effects may come and go as the orientation of the tool is changed.
- Check that there is not excessive lateral movement on the end of the head. The bellows cap must be screwed up against the acoustic window but not excessively tight.
- If the acoustic signal is lost, check for isolation between pins A&B in the acoustic head. The most common reason for loss of signal is the cutting of the signal coax to the transducer in the head. This happens when the window is rotated relative to the head body. Check with a gentle twisting motion that the window does not rotate more than a degree or two relative to the tool body.

- At very low temperatures the oil in the acoustic head becomes viscous and this may prevent the mirror from rotating. In this case keep the tool and head warm before use.

6.2.1 Cleaning the acoustic head bottom section

The bottom section of the televiewer assembly houses a pressure compensating bellows that must be free to move. For this reason the bellows cover is removable to allow cleaning of the exterior of the bellows. The interior of the bellows and main body of the televiewer head is oil filled. Both, the end of the bellows cover and its side wall, have holes to allow pressure equalization, and these holes must be kept clear. The bellows cover is threaded at the top end and held by a screw thread on the main body below the nylon window. The cover should only be **hand tightened**.

Keep the bellows section clean. This will prevent the deterioration of glue seals and the bellows itself. Grit lodged in the folds of the bellows can cause perforation if left over a period of time.

When removing the cover, it is important to **hold the nylon mirror section only,** which is locked integrally with the main tool, while unscrewing the cover. Wrenches must **NOT** be used (Figure 6-7 and Figure 6-8).

Warning: Any Rotation of the nylon section relative to the main tool pressure housing will result in damage to the head and probable tool failure.

The necessity for cleaning will depend on the borehole fluid and borehole conditions. The bellows should only be cleaned when the sonde was used in heavily contaminated fluids, i.e. heavy muds or sediments, or when the fluid is known to be corrosive. In this case it is important to clean deposits off the bellows where it is glued to the flanges at either end. The bellows wall is thin and can become perforated if allowed to corrode.

Figure 6-7 *Unscrewing the bellows cover*

Figure 6-8 *Bellows cover removed*

6.3 Pressure Housing

The main pressure housing is locked on to the televiewer head by four 2.5mm hex cap screws. After removal of the tool top, the pressure housing can be removed after undoing these screws. When separating the two parts, place the tool on suitable stands, grip the pressure housing with one hand and the acoustic head close to the joint with the other and apply a straight pull. During re-assembly extreme care should be taken not to over tighten the fixing screws which may shear off if overloaded!

The outside of the pressure housing is marked with a Y symbol to indicate the position of the Y axis vertical and upward. The purpose of this is to simplify tool checking.

When re-assembling the pressure housing make sure that the reference mark is correctly aligned with the upper side of the deviation sensor.

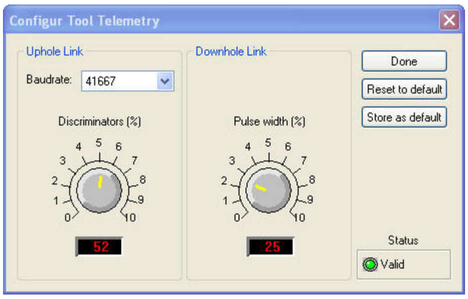
6.4 Upgrading ABI firmware

In accordance with the ALT policy of continuous development the ABI has been designed to allow firmware upgrades. The current version of firmware installed in a tool may be verified in the Tool Details window opened from the Tool Settings dialogue box.

Firmware upgrade procedure is as follows:
1. Checking the communication is valid.
2. Upgrading firmware

6.4.1 Checking the communication

1. Connect the ABI tool to your acquisition system.
2. Start ALTLog/Matrix software.
3. In the **Tool** panel select the appropriate tool and turn on the power.
4. In the **Communication** panel, select **Settings**. Check **baud rate** is set to **41666** and **communication status** is **valid** (Figure 6-9 or Figure 6-10).

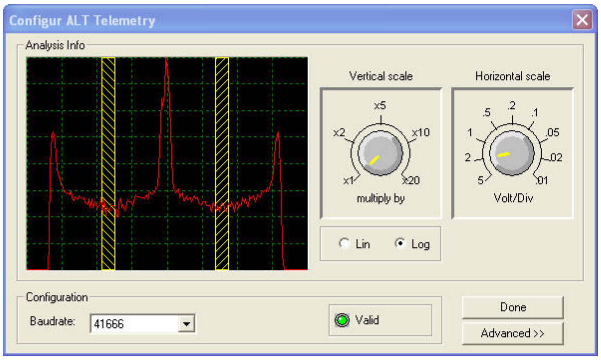


Uphole Link
Baudrate: 41667
Discriminators (%) 52

Downhole Link
Pulse width (%) 25

Status
● Valid

***Figure 6-9** Tool communication settings - ALTLog*



○ Lin ● Log

Baudrate: 41666

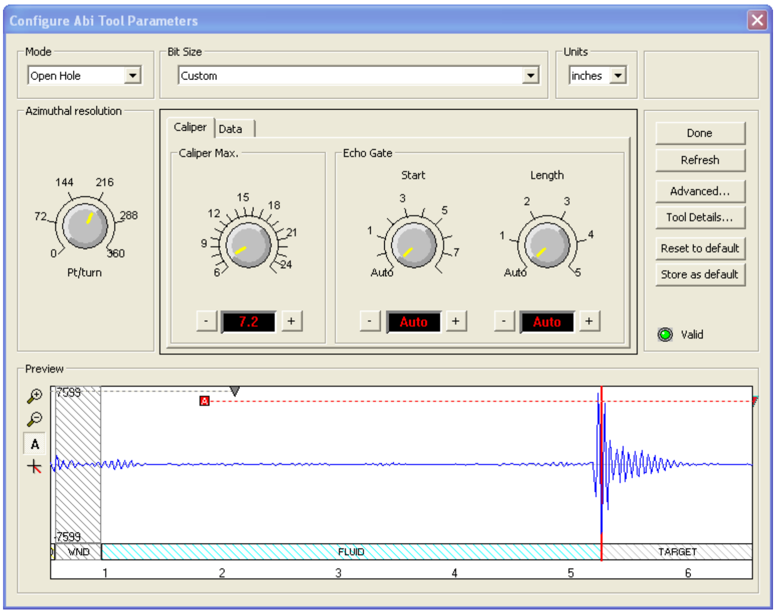
● Valid

***Figure 6-10** Tool communication settings - Matrix*

Warning: Telemetry must be tuned properly. Bad communication may abort the upgrade of the firmware!

6.4.2 Upgrading the firmware

In the **Tool** panel, select **Tool settings/commands**. Check that the communication status is valid (Figure 6-11).



Mode: Open Hole
Bit Size: Custom
Units: inches

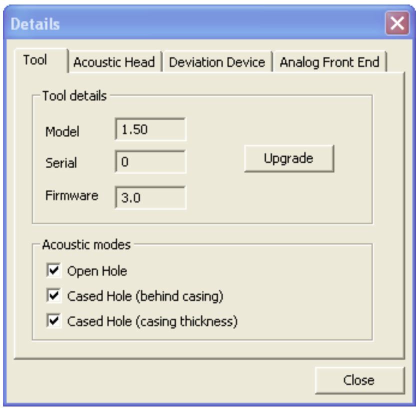
Caliper Max. 7.2

Echo Gate
Start Auto
Length Auto

● Valid

***Figure 6-11** Tool settings dialog box*

1. Click on **Tool Details**. Note that the firmware version currently in use is displayed in the firmware box. Click on the **Upgrade** button (Figure 6-12).



Tool details

Model 1.50

Serial 0

Firmware 3.0

Acoustic modes

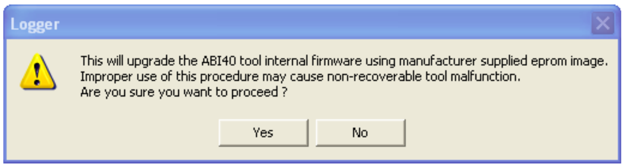
☑ Open Hole

☑ Cased Hole (behind casing)

☑ Cased Hole (casing thickness)

Figure 6-12 *Tool Details dialog box*

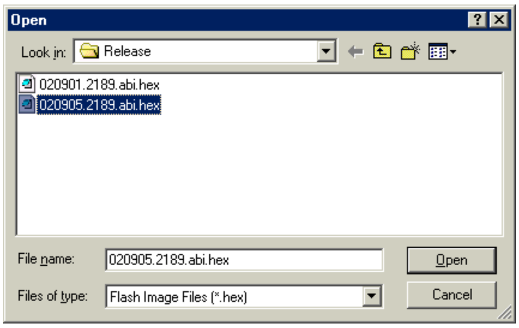
2. The following message will appear (Figure 6-13). Click **Yes** to validate your choice.



This will upgrade the ABI40 tool internal firmware using manufacturer supplied eprom image.
Improper use of this procedure may cause non-recoverable tool malfunction.
Are you sure you want to proceed ?

Figure 6-13 *Warning Message during firmware upload*

3. Select and open the appropriate **.hex** file provided (Figure 6-14). The upgrade will start.



Look in: Release

020901.2189.abi.hex

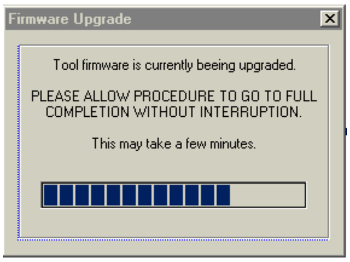
020905.2189.abi.hex

File name: 020905.2189.abi.hex

Files of type: Flash Image Files (*.hex)

Figure 6-14 *Select firmware upgrade*

4. During the upgrade procedure, the following message is displayed:



Tool firmware is currently beeing upgraded.

PLEASE ALLOW PROCEDURE TO GO TO FULL COMPLETION WITHOUT INTERRUPTION.

This may take a few minutes.

Figure 6-15 *Firmware upgrade progress window*

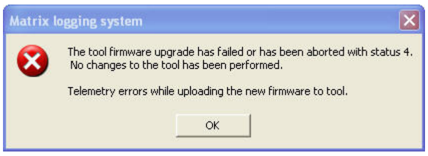
5. Once the upgrade has been successfully completed (Figure 6-16), click on **OK** to turn off the tool.

The tool firmware upgrade has been completed successfully.
The tool power will now be switched off.

Figure 6-16 *Successful upgrade*

6. Power on the tool to start the upgraded firmware. Check in **Tool settings/commands** and **Tool details** that the firmware version has been changed with the new one.

Note that this error message (Figure 6-17) will appear at end of the procedure when the tool firmware upgrade has failed or has been aborted. Check tool communication settings.



The tool firmware upgrade has failed or has been aborted with status 4.
No changes to the tool has been performed.

Telemetry errors while uploading the new firmware to tool.

Figure 6-17 *Error message*

7 Troubleshooting

Observation	**To Do**
Tool not listed in Tool panel drop down list.	- Do you have a configuration file? - Has the configuration file been copied into the …/Tools folder (refer to MATRIX or ALTLog manual about details of the directory structure)?
Tool configuration error message when powering on the tool.	- Check all connections. - Adjust the telemetry settings for your wireline configuration (see chapter 4.3 or 4.4) and store the new settings as default. Apply the appropriate tool settings for your logging run (see chapter 4.5).
Tool panel - No current.	- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system. - Verify cable head integrity. - Verify voltage output at the cable head (it should be 120V).
Tool panel - Too much current (red area).	**! Immediately switch off the tool !** **-**Possible short-circuit (voltage down, current up): Check for water ingress and cable head integrity - wireline continuity. - Verify the interface cable between winch slip ring and data acquisition system is not loose at the connectors. Check for possible source of a short-circuit. - If the above shows no issues, use test cable provided by ALT to verify tool functionality. - If the problem still occurs, please contact service centre.
Telemetry panel - status shows red.	- Verify the telemetry settings for your wireline configuration (see chapter 4.3 or 4.4). - If problem cannot be resolved contact support@alt.lu .
Telemetry panel - memory buffer shows 100%.	- Indicates that the systems internal memory buffer is full. PC can't receive incoming data streams fast enough. Ensure your PC has enough resources available.
Telemetry panel – bandwidth usage shows 100%. *(Overrun error message.)*	- Set the baudrate to highest value allowed by your wireline configuration. - Reduce logging speed, decrease azimuthal resolution and/or increase vertical sample step.
Telemetry panel - large number of errors.	- Verify the telemetry settings for your wireline configuration (see chapter 4.3 or 4.4). - Check bandwidth usage and telemetry error status.

Observation	**To Do**
Permanent No Sync message and red led status in MChNum browser. *Motor stalled and increase of current drawn by the tool.*	**! Immediately switch off the tool !** - Stepper motor and mirror synchronization issue. Contact ALT for Acoustic Head service.
WellCADimport : acoustic images not imported	- Check your WellCAD version (please refer to 1.3 Technical Specifications chapter).
WellCAD import : Magnetic North and High Side orientation options not available	- Check your WellCAD version (please refer to 1.3 Technical Specifications chapter).

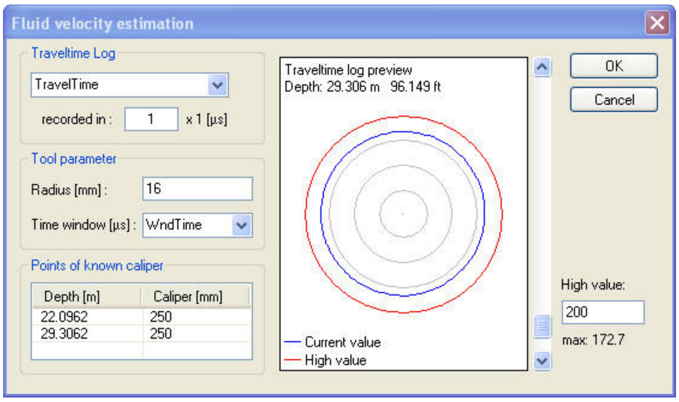
8 Notes on Data Processing

The processing of data acquired with the QL40 ABI and the ABI 40 tools is usually performed using the WellCAD software. We would like to refer the user to the WellCAD user guides for a detailed description of the software’s functionality. In particular *Book 3 - Image & Structure Module* should be of help when processing image data.
The following paragraphs will focus on three processes to process traveltime data for which the input of correct units and parameters is crucial in order to obtain accurate results.

8.1 Estimation of Fluid Velocity

The procedure described below outlines the estimation of the borehole fluid velocity which can be used as input for the computation of caliper data described hereafter.

1. From the **Process > Image Module > Image Logs** menu in WellCAD select the **Estimate Fluid Velocity** entry. The corresponding options dialog box will open (Figure 8-1).



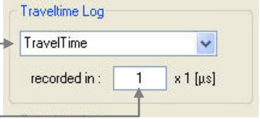
TravelTime
recorded in : 1 x 1 [µs]
Radius [mm] : 16
Time window [µs] : WndTime

Depth [m]	Caliper [mm]
22.0962	250
29.3062	250

Traveltime log preview
Depth: 29.306 m 96.149 ft
High value: 200
max: 172.7

Figure 8-1 *Fluid velocity estimation dialog box*

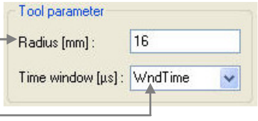
2. Select the TravelTime log from the corresponding drop down list in the dialog box.



TravelTime
recorded in : 1 x 1 [µs]

3. Set the unit the traveltime has been recorded in. For the QL40 ABI or ABI40 tool this manual refers to the unit is 1 µs. (Older tools measured in 0.1 µs. You can find out by double left clicking on the log title of the TravelTime log. The unit should show *µs*. If no unit is shown the measurement was made on *0.1 µs.*)

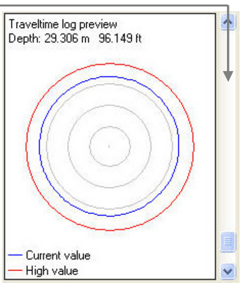
4. Enter the radius of the acoustic head at the measurement point into the corresponding edit box. For the ABI tools described here a value of 16 mm is appropriate.



Radius [mm] : 16
Time window [µs] : WndTime

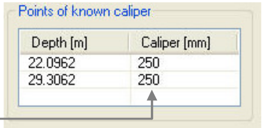
5. Select the Time window channel *WndTime* which contains the traveltimes from transducer to the acoustic head window and back (has been recorded by your tool along with the other measurements).

6. Use the scroll bar next to the preview of the cross sections generated from the traveltime data and find a depth at which the caliper of the pipe or borehole is known and best reflected by the measurement (for example the nominal internal diameter of casing or the bit size).



Traveltime log preview
Depth: 29.306 m 96.149 ft

7. Right click into **Points of known caliper** list and add a new row for a reference point. The depth value will automatically set to the depth of the preview. Enter the known caliper value in [mm].



Points of known caliper

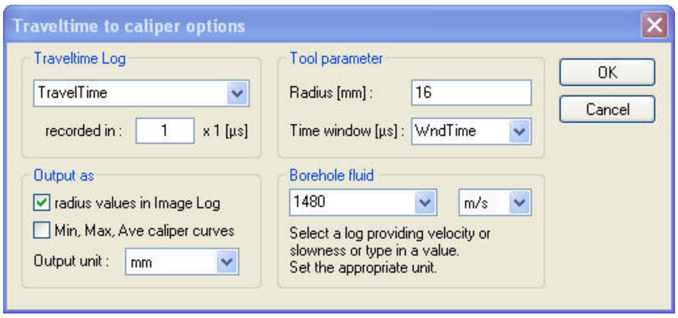
Depth [m]	Caliper [mm]
22.0962	250
29.3062	250

8. Try to set a least a reference point at or near the top and base of the well. Click **OK** when finished. A new log containing the estimated velocity profile will be created.

8.2 Computation of Caliper Data

The following steps summarize the steps to compute radius and caliper data from the acoustic traveltime recorded with your ABI tool:

1. Select the **Calculate Caliper** process from the **Process > Image Module > Image Logs** menu. The options dialog box (Figure 8-2) will open.



Traveltime to caliper options

Traveltime Log: TravelTime
recorded in : 1 x 1 [µs]

Tool parameter
Radius [mm] : 16
Time window [µs] : WndTime

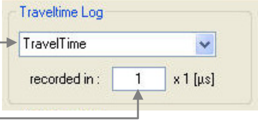
Output as
☑ radius values in Image Log
☐ Min, Max, Ave caliper curves
Output unit : mm

Borehole fluid
1480 m/s
Select a log providing velocity or slowness or type in a value.
Set the appropriate unit.

Figure 8-2 *Traveltime to caliper conversion dialog box*

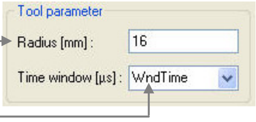
2. Select the TravelTime log from the corresponding drop down list in the dialog box.

3. Set the unit the traveltime has been recorded in. For the QL40 ABI or ABI40 tool this manual refers to the unit must be set to 1 µs. (Older tools measured in 0.1 µs. You can find out by double left clicking on the log title of the TravelTime log. The unit should show *µs*. If no unit is shown the measurement was made on *0.1 µs.*)



Traveltime Log: TravelTime
recorded in : 1 x 1 [µs]

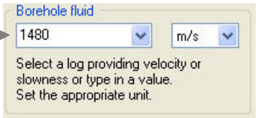
4. Enter the radius of the acoustic head at the measurement point into the corresponding edit box. For the ABI tools described here a value of 16 mm is appropriate.



Tool parameter
Radius [mm] : 16
Time window [µs] : WndTime

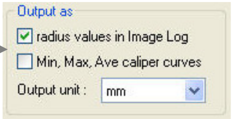
5. Select the Time window channel *WndTime* which contains the traveltimes from transducer to the acoustic head window and back (has been recorded by your tool along with the other measurements).

6. If you estimated a fluid velocity as described in the paragraph above or have measured values extend the drop down list and select the corresponding log. You can also enter a textbook value manually. Ensure the correct unit has been selected.



Borehole fluid
1480 m/s
Select a log providing velocity or slowness or type in a value.
Set the appropriate unit.

7. Select the output options and unit. You can create a new Image Log containing a radius value for each traveltime measurement. In addition you can create Min, Max and Average caliper curves.

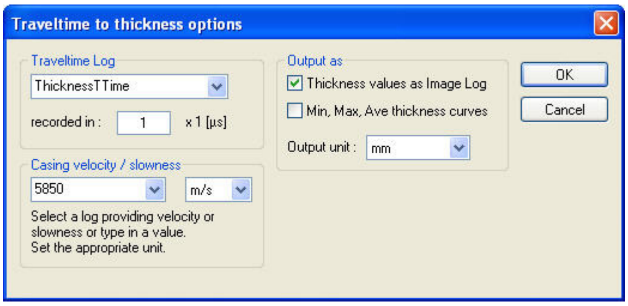


Output as
☑ radius values in Image Log
☐ Min, Max, Ave caliper curves
Output unit : mm

8. Click on **OK** to close the dialog box ad start the computation.

8.3 Calculation of Casing Thickness

If you made measurements in cased hole mode you will get a log containing the traveltime within the steel casing (thickness travel time). The procedure described below summarizes the conversion of the thickness traveltime into a true thickness value.



Traveltime to thickness options

Traveltime Log
ThicknessTTime
recorded in : 1 x 1 [µs]

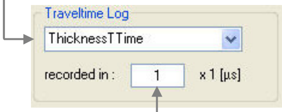
Casing velocity / slowness
5850 m/s
Select a log providing velocity or slowness or type in a value.
Set the appropriate unit.

Output as
☑ Thickness values as Image Log
☐ Min, Max, Ave thickness curves
Output unit : mm

Figure 8-3 *Traveltime to casing thickness conversion dialog box*

1. From the **Process > Image Module > Image Logs** menu in WellCAD select the Calculate Thickness… entry. The corresponding options dialog box will open (Figure 8-3).

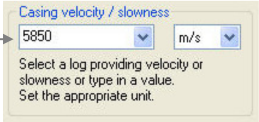
2. Select the ThicknessTTime log from the corresponding drop down list in the dialog box.



Traveltime Log
ThicknessTTime
recorded in : 1 x 1 [µs]

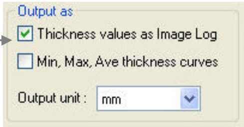
3. Set the unit the thickness traveltime has been recorded in. For the QL40 ABI or ABI40 tool this manual refers to the unit must be set to 1 µs. (Older tools measured in 0.01 µs. You can find out by double left clicking on the log title of the ThicknessTTime log. The unit should show *µs*. If no unit is shown the measurement was made on *0.01 µs*.)

4. Enter the velocity of sound in steel into the corresponding edit box. A typical value for steel is 5850 m/s. If you have a velocity profile available in a log extend the drop down list and select the corresponding channel.



Casing velocity / slowness
5850 m/s
Select a log providing velocity or slowness or type in a value.
Set the appropriate unit.

5. Choose the output option and unit. The thickness values can be given as a Image Log with on thickness value for each traveltime thickness measurement and as curve of the minimum, maximum and average thickness determined.



Output as
☑ Thickness values as Image Log
☐ Min, Max, Ave thickness curves
Output unit : mm

6. Click on **OK** to close the dialog box ad start the computation.

9 Appendix

9.1 Parts list

Detailed part numbers and descriptions are available for tool delivery and spare part kits. Please contact support@alt.lu for further details.

9.2 Technical drawings

The following technical drawings are available on request:

- 19” Rack connection diagram.
- Wiring Diagram.

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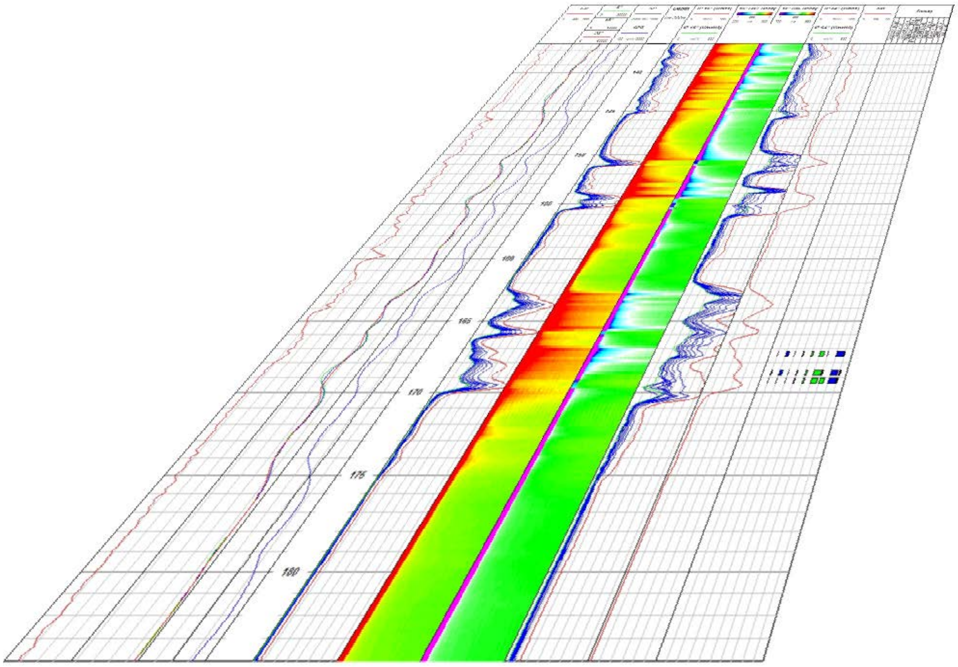

User Guide

QL40 ELOG/IP – Normal Resistivity and Induced Polarization Probe

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V2013.07.31

Table of Contents

1 General Information

QL stands for Quick Link and describes the latest line of stackable logging tools. This development is a joint venture of Mount Sopris Instruments (MSI) and Advanced Logic Technology (ALT). Innovative connections between tool elements (subs) allow users to build their own tool strings in the field.
The Tool Stack Factory – a sophisticated extension of the acquisition software – provides a convenient way to configure tool strings for operation.
Each sub has a Telemetry and Power supply element, the TelePSU, allowing them to operate individually without a separate telemetry sub. As a result all QL subs can be operated as standalone probes or in combination with other subs.

The **QL40-ELOG** sub provides four normal resistivity measurements, plus spontaneous potential (SP) and single point resistance (SPR). The QL40-ELOG can be operated as a stand-alone probe with isolation bridle and bottom sub or can be stacked above or below another sub. In general, the isolation bridle must be located directly above the QL40-ELOG sub. Isolation from armor is a critical requirement that cannot be overemphasized when running any resistivity probe. Incorrect measurements will result if isolation is not adequate.

The **QL40-ELOG** sub can be upgraded to a **QL40-ELOG/IP** sub upon request.
In this configuration, the **QL40-ELOG/IP** provides four normal resistivity measurements, plus spontaneous potential (SP) and single point resistance. In addition, the IP function provides two digital Induced Polarization channels. The IP uses the 16 and 64 inch electrodes as receivers, and the current electrode as an IP charging source. The probe measures the injection and relaxation voltages on both measure electrodes as a function of time. This measurement is digitized and presented as 10 channels of time based data per depth interval for each spacing. In addition, a high resolution A/D further breaks each channel into 10 more discrete samples, providing a “full wave” presentation of the injection and relaxation decay. A chargeability curve is also derived from the measurement.

1.1 Dimensions

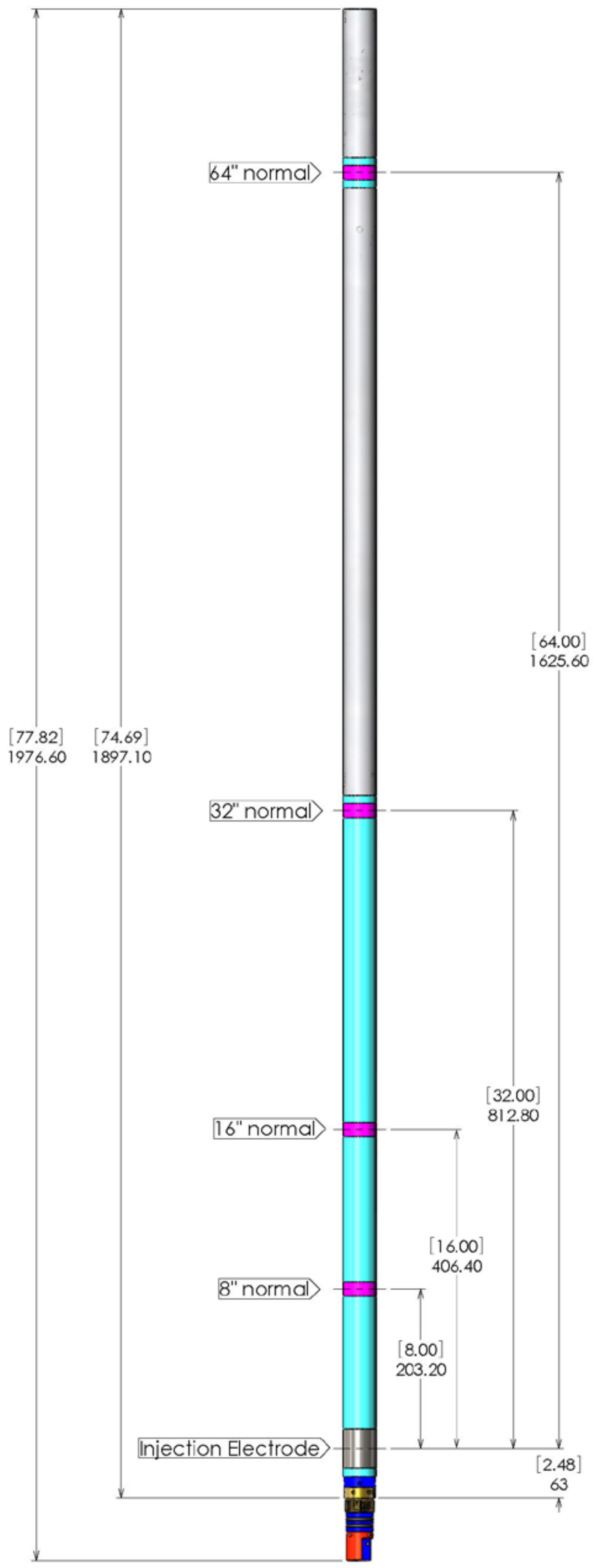


Figure 1-1 Tool general arrangement

1.2 QL40-ELOG/IP Technical Specifications

Tool

Diameter:	43mm (1.7”) with neoprene heat shrink
Length:	1.9m (74.8”)
Weight:	9 Kg (19.8 lbs)
Max. Temp:	70°C (158°F)
Max.Pressure:	200bar (2900 PSI)

Power requirements:

DC voltage at probe top	Nominal 120 VDC - Min.80 VDC – Max. 160 VDC
Current source	32V pp square wave (+:-16V) at up 500 mA

Cable:

Cable type:	Mono, Coaxial, 4 or 7 conductor
Digital data transmission:	Up to 500 Kbits per second depending on wireline
Compatibility:	ALTlogger – BBOX – Matrix

Electrode details:

Current electrode	50mm 304 stainless steel
Measure electrodes	18mm 304 stainless steel

Electrode reference measuring point (from bottom of bronze knurled ring):

Spontaneous Potential (SP)	1.69m
8” Normal	0.16m
16” Normal	0.26m
32” Normal	0.47m
64” Normal	0.87m
Single Point Resistance (SPR)	0.06m

Measurement specifications:

Spontaneous Potential (SP)

- Range: +/- 18V
- Resolution: 0.5 mV
- Accuracy: +/- 2.5 mV

8”-16”-32”-64”Normal Resistivities and Single Point Resistance

- Range: 0.1 to 100.000 Ohm.m
- Resolution:
  <0.04% of measured value (24 bi/0.5 ms ADC with real time downhole digital filtering
- Accuracy:
  <1% of measured value from 1 to 5.000 Ohm.m
  <5% of measured value from 5.000 to 50.000 Ohm.m

Induced Polarization (IP) measured on 16” and 64” electrodes

- User selectable injection/release times (100ms–250- 500ms)
- 10 equal time window chargeability per spacing
- Digitally controlled 8 watt downhole current generator
- Simultaneous full-wave digitizing of electrode voltages for both spacings
- 24 bit/0.5 ms ADC with downhole real-time filtering and processing
- Resolution: 1.2µV
- Input impedance: 1.4 M-Ohm

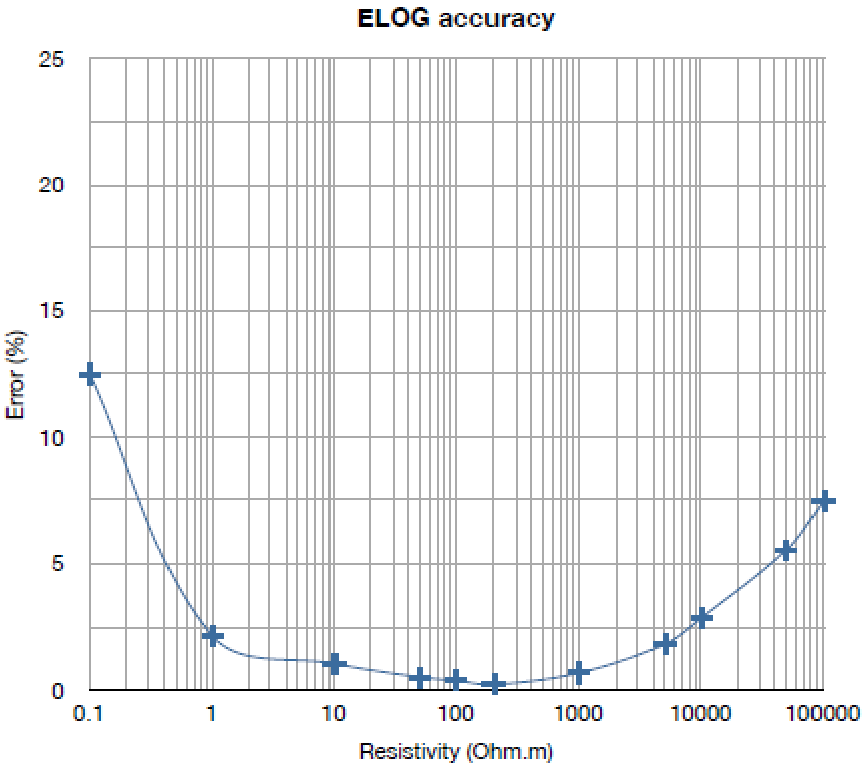


Figure 1-2 Accuracy versus resistivity

2 Measurement Principle

The **QL40-ELOG/IP** has 5 electrodes which are used for measuring normal resistivity at 4 spacings, spontaneous potential, and single point resistance. The QL40-ELOG/IP sub **<u>must have</u>** an isolation bridle placed above it to provide a remote reference electrode for the normal resistivity channels, and a remote return for the injection current.

The **SP** (spontaneous potential) is measured between the 64” normal measure electrode and armor. The data recorded as SP or VSP measures the natural voltages sensed by this electrode. These voltages can be related to both electrochemical and electrokinetic forces in the borehole. The electrochemical SP is developed when there is a difference between the formation fluid and borehole fluid salinities, and occurs normally when the measure electrode passes a clay or shaly zone, which acts as an ion selective membrane. The resulting current flow in a “cell” comprised of those three elements provides a negative SP if the borehole fluid is less conductive than the formation fluid. In fresh water zones, the SP is often positive. The electrokinetic SP can occur when borehole fluid mechanically invades porous and permeable formation, causing a current flow.

The **SPR** is measured between the **”A”** current injection electrode on the bottom of the probe and the isolated cable armor above the bridle. This SPR is a qualitative indication of the electrical resistance of the formation material immediately adjacent to the current electrode. The principal of measurement follows Ohm’s law, where R=V/I. As the current flows toward the armor return, the current density (I/cross-sectional area) decreases dramatically. This means that the majority of the resistance measured is influenced by the material closest to the current electrode. For this reason, the SPR is very sensitive to small changes in resistance close to the borehole.

The four **Normal Resistivity** measurements are made at the halfway between the “A” current injection electrode and each of the 4 “M” normal resistivity electrodes. The normal resistivity measurement includes a reference electrode, called “N”, which is assumed to be at electrical infinity compared to the measure electrodes. In this special application of Ohm’s law, V=IR still applies, but is re-written as R=V/I,

$$\frac{V}{I} = R = \frac{\rho \cdot l}{A} \quad \text{or} \quad \rho = \frac{A \cdot V}{l \cdot I} \quad \text{or} \quad \rho = G \cdot \frac{V}{I}$$

where G is called the geometric factor, and is related to the A-M spacing between electrodes. In metric units, G is approximately 12.5 * AM spacing. Note that for normal resistivity measurements, the result is true resistivity, ρ, expressed in ohm-m^2/m. It is important to remember that this application of Ohm’s law assumes that the formation is homogenous and infinite. Corrections for borehole size, borehole/formation fluid ratio, and bed thickness should be applied to get true formation resistivity. See appendix for references.

The SPR and normal resistivity measurements are made using a 50 ms long +/-16V square wave downhole current generator, which can supply up to 500 mA of survey current. The polarity of the current is alternated between + and – relative to armor to prevent polarization of the electrodes.

In the **IP mode** the **QL40-ELOG/IP** uses the 16 and 64 inch electrodes as receivers, and the current electrode as an IP charging source. The probe measures the injection and relaxation voltages on both measure electrodes as a function of time. This measurement is digitized and presented as 10 channels of time based data per depth interval for each spacing. In addition, a high resolution A/D further breaks each channel into 10 more discrete samples, providing a “full wave” presentation of the injection and relaxation decay. A chargeability curve is then derived from the measurement.

3 QL40 ELOG/IP assembly and set up

The QL40 ELOG/IP sub is delivered with the following accessories:

- Isolation bridle

Figure 2-1 *QL40 Isolation bridle*

- Isolated bottom plug

Figure 3-2 isolated *Bottom Plug*

- Calibration box, with a set of cables and clamps
  The calibration box is used to perform a calibration check before a logging operation. Refer to chapter 5 for *“Performance and calibration check”*.

Figure 3-3 *ELOG Calibrator, cables and clamps*

3.1 Note on use of the bridle

The bridle is comprised of 8 meters of insulated cable with a remote electrode located at the top called the “reference potential electrode” or “fish”. The standard bridle is provided with a GO4 male or MSI single connection at the top end and QL40 female connection at the sub end. The bridle is electrically and mechanically compatible with the **QL40 ELOG/IP** and **QL40 DLL3** subs.

The function of the bridle is to maintain a separation between the source of current - the injection electrode ” A” and the reference potential electrode in order to force the injected current to travel into the formation. The injected current returns to the cable armor beyond the bridle section.

In most configurations, the QL40 ELOG/IP must be operated with an isolation bridle. Refer to the table below to review the different valid configurations:

Acquisition system	Single conductor wireline	4 or 7 conductor wireline
Matrix	**Always** use the bridle	**Always** use the bridle
Altlogger	**Always** use the bridle	**Optional** - 8m of insulated wireline and mud stake on surface can be used as a substitution of the bridle
BBOX	**Always** use the bridle	**Optional** - 8m of insulated wireline and mud stake on surface can be used as a substitution of the bridle

3.2 QL40 ELOG/IP set up

The QL40 ELOG/IP sub can be used as a standalone tool or in a tool string when combined with other subs.

When used as a standalone tool, follow the assembly procedure below **:**

1. Screw the QL40 isolated bottom plug at the bottom end of the QL40 ELOG/IP sub

Figure 3-4 *Attaching the QL40-Bottom Plug*

2. Attach the isolation bridle at the top of the QL40 ELOG/IP sub

3. **Insulate with tape the mechanical joint between the sub and bridle .**
It is important that all metal parts are covered with tape (at the exception of the injection and measuring electrodes!) to prevent a direct current return to this point rather than to the cable armor .

Figure 3-5 *bridle connection and isolation*

4. **Insulate the bridle/cable head connection above the fish and 7 meters of wireline above the cable head**

When the QL40 ELOG/IP is used in combination with other subs, the bottom and top subs must be fully covered with an insulating sleeve. Refer to chapter 3.3 below for complementary information on the QL tools assembly.

3.3 Notes on QL tool assembly

QL stands for **Q**uick **L**ink and describes an innovative connection between logging tools (subs) allowing the assembly of custom tool stacks. QL40 describes a specific family of logging tools. Each sub is equipped with its own telemetry board, power supply element and A/D converter, permitting operation either as a stand-alone tool or stacked in combination with other subs of the QL product family.
The QL40 probe line accommodates two types of sub - Bottom Subs and Mid Subs.

Bottom Sub
A bottom sub is a tool that has at least one sensor that must be located at the bottom of the stack. It can be operated in combination with other QL subs connected to the top but it is not possible to connect another sub below. When used in stand-alone mode the bottom sub only needs the addition of a QL40 tool top adaptor that mates with the cable head.

Mid Sub
A mid sub is a tool that can be integrated anywhere within a stack of tools. When used at the bottom of a tool string a QL40 bottom plug must be used to terminate the string. If the mid sub is used as a stand-alone tool it needs a QL40 bottom plug at the lower end and a QL40 tool top adaptor at the top.

3.4 QL40 stack assembly

A QL40 tool stack may be terminated by either a QL40 bottom sub or a QL40 bottom plug. At the top of the stack a QL40 tool top is required to connect the tool string to the cable head. Several tool tops are already available; special ones can be made on request.

To assemble and disassemble the subs the C-spanner delivered with the tool must be used (Figure 3-1). It is recommended that before each assembly the integrity of the O-rings (AS216 Viton shore 75) is verified. Prime the O-rings with the silicon grease that was supplied with the subs.

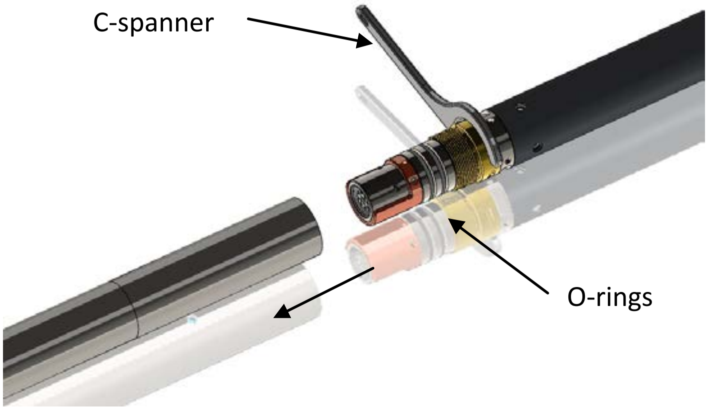


Figure 3-6 *C-spanner and O-rings of QL connection*

The following example of a QL40-ABI, QL40-GAM and QL40-GO4 (Figure 3-2) describes how to replace the QL40-ABI with a QL40-Plug in order to run the QL40-GAM sub stand-alone.

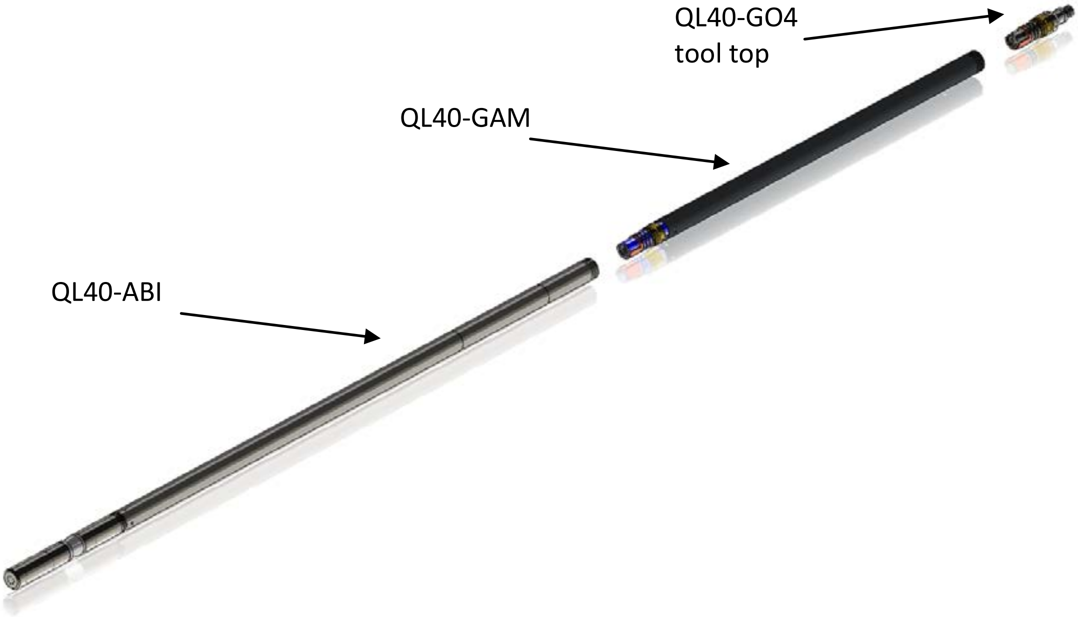


Figure 3-7 *Tool stack example*

To remove the QL40-ABI bottom sub attach the C-spanner to the thread ring as shown in Figure 3-3, unscrew the threaded ring, (anticlockwise about the tool axis when looking towards the bottom of the tool), and remove the QL40-ABI bottom sub.

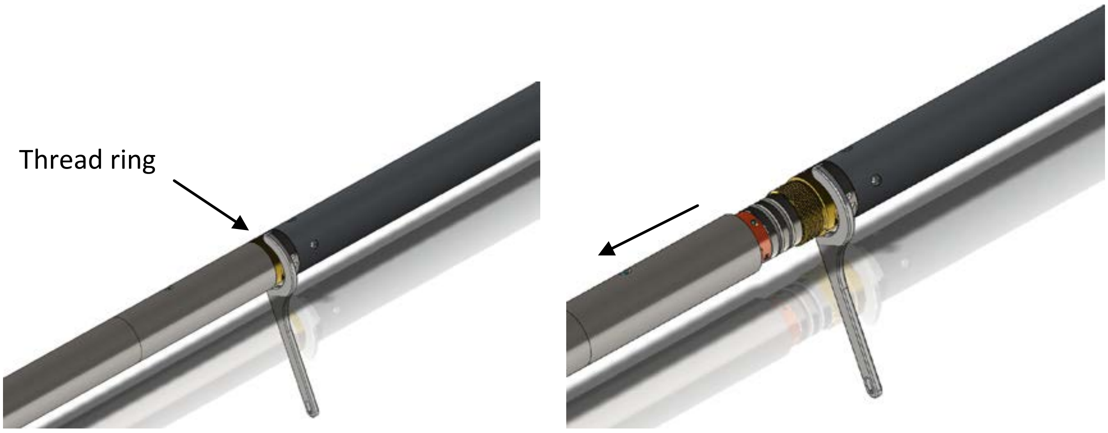


Figure 3-8 *Unscrewing the thread ring and removing the bottom sub*

After checking the O-ring integrity, align and slip the QL40-Plug over the exposed QL connector (Figure 3-4), attach the C-spanner and screw the threaded ring until the plug draws up tight to the ring.

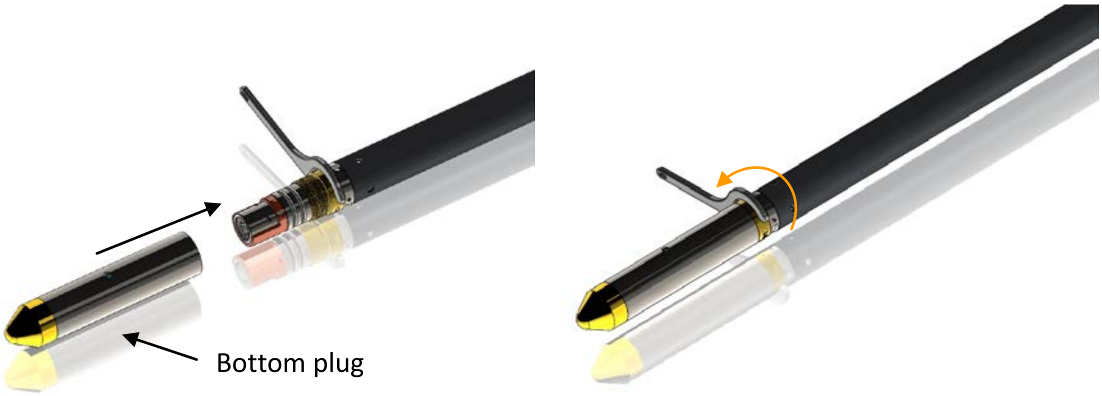


Figure 3-9 *Attaching the QL40-Plug*

The QL40-GAM can now be run stand-alone (Figure 3-12).

Figure 3-10 *QL40-GAM mid sub with tool top and bottom plug*

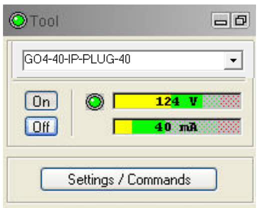
4 Operating Procedure

Note: Parts of the topics discussed in these sections below assume that the user is familiar with the **LoggerSuite** acquisition software. Refer to the corresponding operator manuals for more details. Information about assembly and configuration of tool stacks can be found in the same manuals.

4.1 Quick Start

1. Connect the QL40 ELOG/IP to your wireline and start the data acquisition software.

2. Select the relevant ELOG/IP tool from the drop down list (***Figure 4-1***) in the software's **Tool** panel (if your tool is not listed check that your tool configuration file is stored in the designated folder on your computer).



GO4-40-IP-PLUG-40

124 V

40 mA

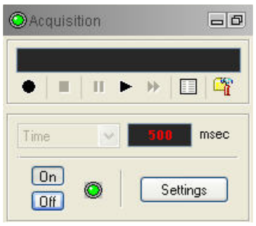
Figure 4-1 *Tool panel*

3. In the **Tool** panel switch on the tool (click **On** button) and verify that the power indicator shows a valid (green) level. The system goes through a short initialization sequence which sets the default parameters and communication settings held in the tool configuration file. The configuration returned by the tool is also checked during this procedure. (Setup tool communication as explained in chapter **4.4** if error message is displayed.)

4. On the **Tool** panel (***Figure 4-1***) click the **Settings / Commands** button to configure your tool for the ELOG and/or IP modes (see chapter **3.4** for details).

5. In the **Acquisition** panel (***Figure 4-2***) select the sampling mode (depth or time). Click on **Settings** and specify the corresponding sampling rate. Switch on the sampling (click the **ON** button).

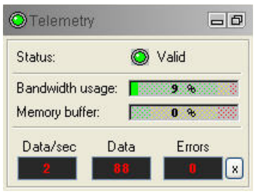
6. Press the **Record** button in the **Acquisition** panel (***Figure 4-3***), specify a file name and start the logging.



Time 500 msec

Figure 4-2 *Acquisition panel*

7. During logging observe the controls in the **Telemetry** panel:
    - Status must be valid (green light);
    - Bandwidth usage in green range;
    - Memory buffer should be 0%;
    - Number of **Data** increases and number of **Errors** negligible.



Status: Valid

Bandwidth usage: 9 %

Memory buffer: 0 %

Data/sec 2

Data 88

Errors 0

Figure 4-3 *Telemetry panel*

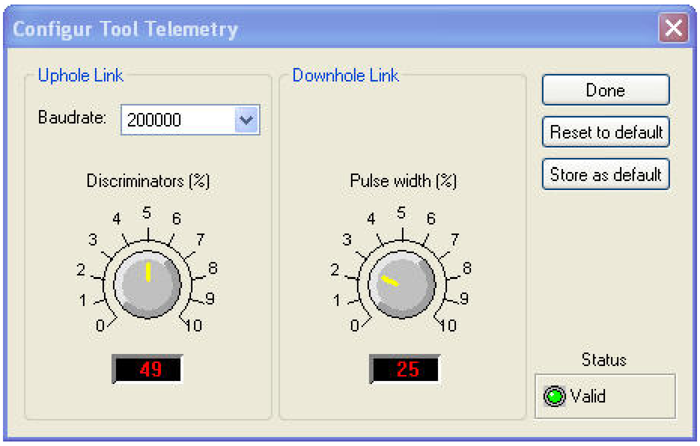
8. To end the logging procedure press the **Stop** button in the **Acquisition** panel and turn off the sampling (click **OFF** button).

9. In the **Tool** panel power off the tool.

4.2 Tool Communication with ALT Logger

The telemetry provided through the ALTLogger is self-tuning**.** In case communication status is not valid the user can manually adjust the settings. In the **Telemetry** panel of the dashboard click on **Settings** to display the **Configure Tool Telemetry** dialog box (***Figure 4-3***). A procedure to achieve valid communication is given below:

- Change the **Baudrate** to 41666 kbps.
- Verify that the **Downhole Pulse width** knob is set on 20 (default value). This value is the preferred one and is suitable for a wide range of wirelines. For long wireline (over 2000m), increasing the pulse width could help to stabilize the communication. The reverse is true for short wireline (less than 500m).
- Set the **Uphole** discriminators in the middle of the range for which the communication status stays valid.
- Increase the **Baudrate** to the desired value and observe that the communication status stays valid and the **Bandwidth usage** (in **Telemetry** panel of the dashboard) is below the critical level.
- When **Uphole** discriminators are properly set, store the new configuration as default. The tool should go through the initialisation sequence successfully the next time it is turned on.



Baudrate: 200000

Discriminators (%): 49

Pulse width (%): 25

Status: Valid

Figure 4-4 *Tool communication settings*

4.3 Tool Communication with MATRIX

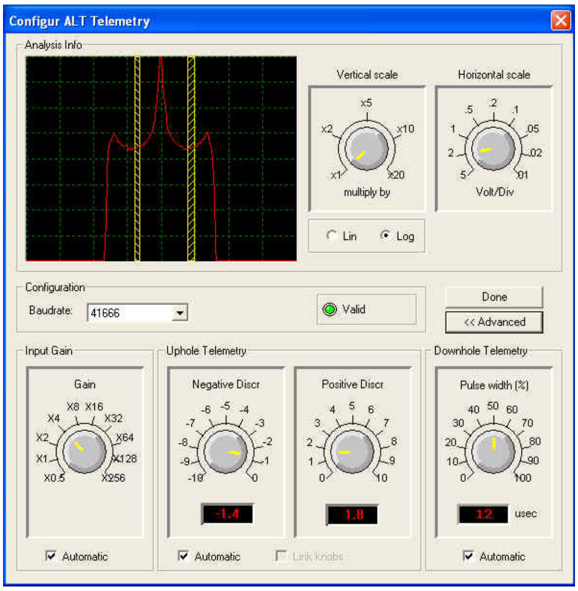
The tool telemetry can be configured through the **Telemetry** panel of the Matrix dashboard. By clicking on **Settings**, the operator has access to the **Configure ALT Telemetry** dialog box (***Figure 3-5***) providing various controls to adjust the telemetry settings and monitor its current status.

The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **lin**ear / **log**arithmic scale buttons.

The status of the configuration should be flagged as Valid (indicated by the LED being green). In any other case (LED red) the telemetry should be adjusted (we assume a pulse signal is displayed in the analysis view). Click on the **Advanced** button to display additional controls to tune the telemetry.

The Automatic settings option is the preferred mode and should allow the telemetry to be configured for a wide range of wirelines without operator input. For wirelines with a more limited bandwidth, the operator might need to turn off the automatic mode and adjust the telemetry settings manually. In general, the gain setting should not be left in the automatic mode once a valid setting has been determined. Uncheck the box to disable automatic gain.

For each wireline configuration, the discriminators (vertical yellow lines) for the **positive** and **negative** pulses must be adjusted in order to obtain a valid communication status (see ***Figure 4-5***) for an example of a suitable discriminator position). There is also the option to alter the **baudrate** in order to optimize the logging speed. The input **gain** can be increased (long wirelines) or decreased (short wirelines) in order to set up the discriminator levels correctly.



○ Lin ● Log

Baudrate: 41666

● Valid

☑ Automatic (Input Gain)

Negative Discr: -1.4

Positive Discr: 1.8

☑ Automatic ☐ Link knobs (Uphole Telemetry)

Pulse width: 12 usec

☑ Automatic (Downhole Telemetry)

Figure 4-5 *Matrix telemetry settings*

Once the telemetry is correctly set, store the new settings as default. The tool should go through the initialization sequence in “Valid” status the next time the power is turned on.

4.4 Configuring Tool Parameters

The **Configure IP Tool Parameters** dialog box can be opened by clicking on the **Settings/Commands** button in the **Tool** panel of the dashboard.

The **QL 40 ELOG/IP** tool can be operated in two modes by turning the knob control on the **Mode** section (Error! Reference source not found.):

- The “**Resis.Only**” mode records the 8”, 16”, 32”, 64” normal resistivity, SP and SPR
- The “**IP-100-250-500**” modes record both the normal resistivity, SP, SPR and the IP responses on the 16” and 64” measure electrodes

For IP measurements, the downhole current generator supplies a +/- 16VDC square wave pulse at up to 500 mA to each electrode. The user can select from three different injection / release times: 100ms, 250ms and 500ms. Each measurement cycle consists of an Injection phase of the selected time with a positive current followed by a release period of the same length during which the first set of 10 measurements is made, a second injection period of the selected time with a negative current followed by a release period during which the second set of 10 measurements is made. E.g. a complete measurement cycle at 250 ms injection / release time will take 1 sec.
Shorter injection / release times can be chosen for high conductivity formations. If the chargeability of the rock is expected to be poor, a longer injection / release time can be chosen.
In order to see the curves in the preview window, **turn ON** the **Sampling** in the Acquisition panel of the dashboard.
When in IP mode the **Full wave** preview window (Error! Reference source not found.) shows the potential difference measured between short spaced (SS - 16”, blue curve) and respectively long spaced (LS -64”, red curve) electrodes and the reference during the two injection and release times. Controls on the left of the preview window provide options to zoom in/out, fit preview to window, scale the display linear / logarithmic and enable/disable the display of short spaced and long spaced curves.

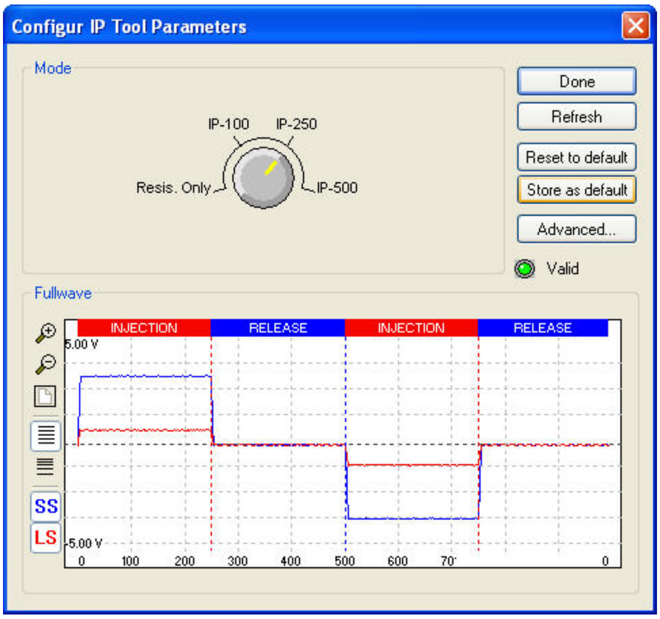
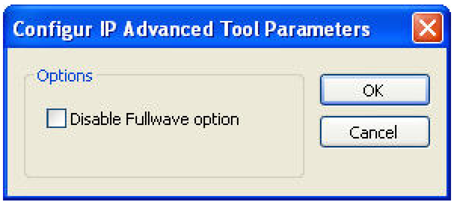


Figure 4-6 *Mode and Injection / Release time selection*

The Advanced Settings dialog box (**7**) can be displayed by clicking on the **Advanced** button.



☐ Disable Fullwave option

Figure 4-7 *Advanced Settings Dialog Box*

If this box is checked, the recorded data file will not include the full wave information. The default setting is to leave the box unchecked to enable the full wave recording.

4.5 Recorded Parameters, Processors and Browsers

4.5.1 Recorded parameters

When measurements are made in IP mode each Release period is subdivided into ten time windows. The measurements made during the same time window in both Release periods will be combined into the final IP response output.
The following data channels are recorded by the **QL40 ELOG/IP** tool (***Table 1***). Depending on the mode – IP or Resistivity – in which the tool is operated, different channels are recorded.

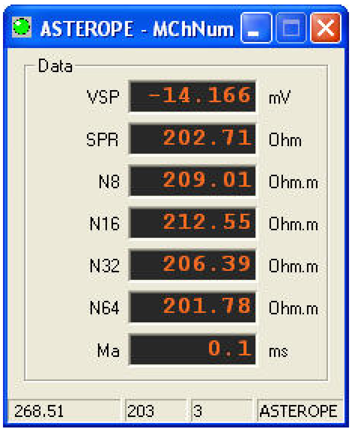
Time	[sec]
Temperature	Tool CPU temperature [°C]
VSP	Voltage Self Potential Sensor [mV]
VSPR	Voltage Single Point Resistance Sensor [V]
I	Injection Current [mA]
V8	Potential difference at 8” electrode [V]
V16	Potential difference at 16” electrode [V]
V32	Potential difference at 32” electrode [V]
V64	Potential difference at 64” electrode [V]

Vinj16	Potential difference at 16” during injection
Vinj64	Potential difference at 64” during injection
NbWinlin	Number of windows used for measurement during Release
Tlin.n *(n=1 to 10)*	Time for measurement in each window [ms]
WLin16.n *(n=1 to 10)*	Average reading from same time windows during the two 16” Release periods.
WLin64.n *(n=1 to 10)*	Average reading from same time windows during the two 64” Release periods.
Tinj	Injection time [sec]
TRel	Release time [sec]
SPR	Single Point Resistance [Ohm]
N8	8” normal resistivity [Ohm-m]
N16	16” normal resistivity [Ohm-m]
N32	32” normal resistivity [Ohm-m]
N64	64” normal resistivity [Ohm-m]
IPlin16.n *(n=1 to 10)*	Ratio of potential differences (Release over Injection) from each window at 16” electrode [mV/V]
IPlin64.n *(n=1 to 10)*	Ratio of potential differences (Release over Injection) from each window at 64” electrode [mV/V]
IPFW16	Ratio of potential differences (Release over Injection) at 16” electrode over entire Release time [mV/V]
IPFW64	Ratio of potential differences (Release over Injection)at 64” electrode over entire Release time [mV/V]
Ma	Apparent Chargeability [ms]

Table 1 *Recorded data channels*

4.5.2 MChNum Browser

Figure 4-8 shows a typical example of the numerical values displayed in the MChNum browser



VSP	-14.166	mV
SPR	202.71	Ohm
N8	209.01	Ohm.m
N16	212.55	Ohm.m
N32	206.39	Ohm.m
N64	201.78	Ohm.m
Ma	0.1	ms

268.51 203 3 ASTEROPE

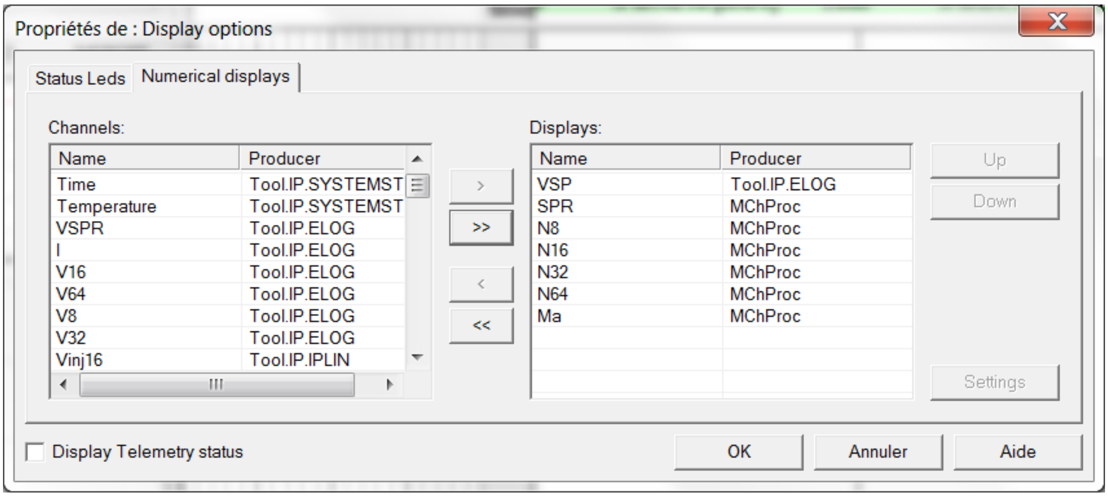
Figure 4-8 *MCHNum Browser Window*

VSP	Spontaneous Potential [mV]
SPR	Single Point Resistance [Ohm]
N8	8” normal resistivity [Ohm-m]

N16	16” normal resistivity [Ohm-m]
N32	32” normal resistivity [Ohm-m]
N64	64” normal resistivity [Ohm-m]
Ma	Apparent Chargeability [ms]

The other parameters listed in **Table 1** can be displayed in real time if required. Right click on MChNum browser and click on “Display options” from the menu.

Select in the “Display options properties” dialog box and add the additional channels to display.
It is possible to change the format of decimal digits displayed for a channel. Select the channel and click on “Settings” to configure the number of digits after the period.



Propriétés de : Display options

Channels:

Name	Producer
Time	Tool.IP.SYSTEMST
Temperature	Tool.IP.SYSTEMST
VSPR	Tool.IP.ELOG
I	Tool.IP.ELOG
V16	Tool.IP.ELOG
V64	Tool.IP.ELOG
V8	Tool.IP.ELOG
V32	Tool.IP.ELOG
Vinj16	Tool.IP.IPLIN

Displays:

Name	Producer
VSP	Tool.IP.ELOG
SPR	MChProc
N8	MChProc
N16	MChProc
N32	MChProc
N64	MChProc
Ma	MChProc

☐ Display Telemetry status

Figure 4-9 *Display options properties*

4.5.3 IpWave Browser

The IpWave Browser window consists of 3 panes (see **A**, **B** and **C** in **Figure 4-9**)

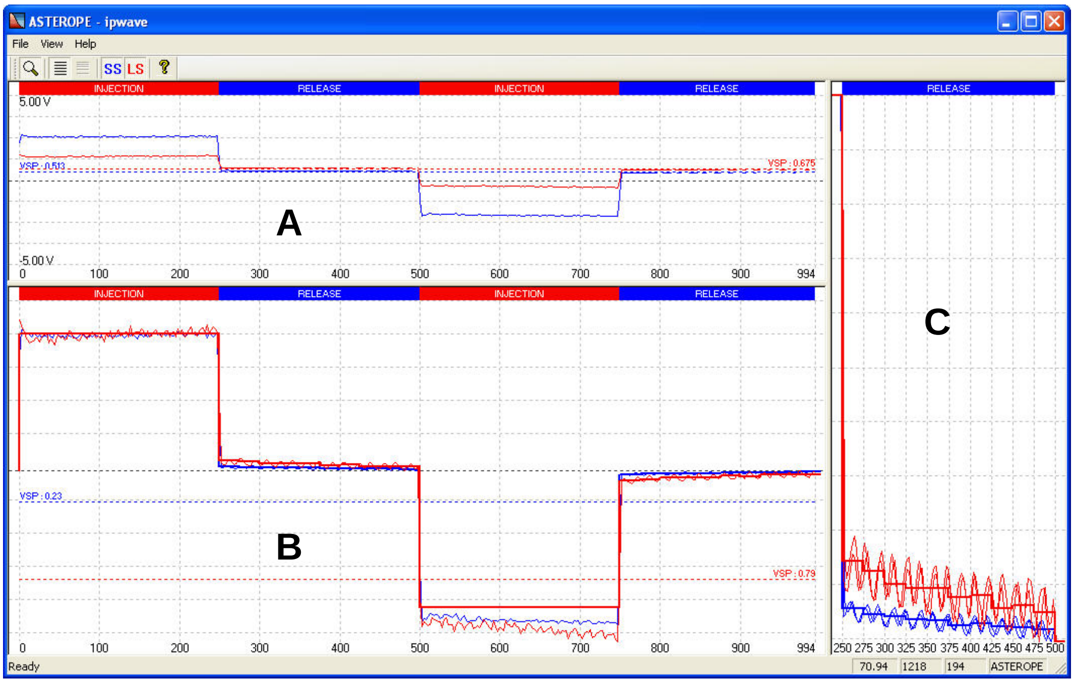


***Figure 4-10** IpWave Browser window with three different wave displays*

Pane **A** displays the potential difference measured at the 16” (blue curve) and 64” electrodes (red curve) during the two injection and release periods. In addition the Self Potential values measured at 16” and 64” electrodes are shown as base lines.

Pane **B** shows a normalized view of the raw potential measurements and the two SP baselines, which have been subtracted before normalization. The “edged” line in the browser window displays the normalized response integrated over the 10 time windows.

Pane **C** provides a combined view of the raw measurements during the two Release times and the average from each time window.

Controls in the toolbar of the window provide options to zoom, scale and enable / disable the curves.

4.5.3.1 Calculation of IP Chargeability Response

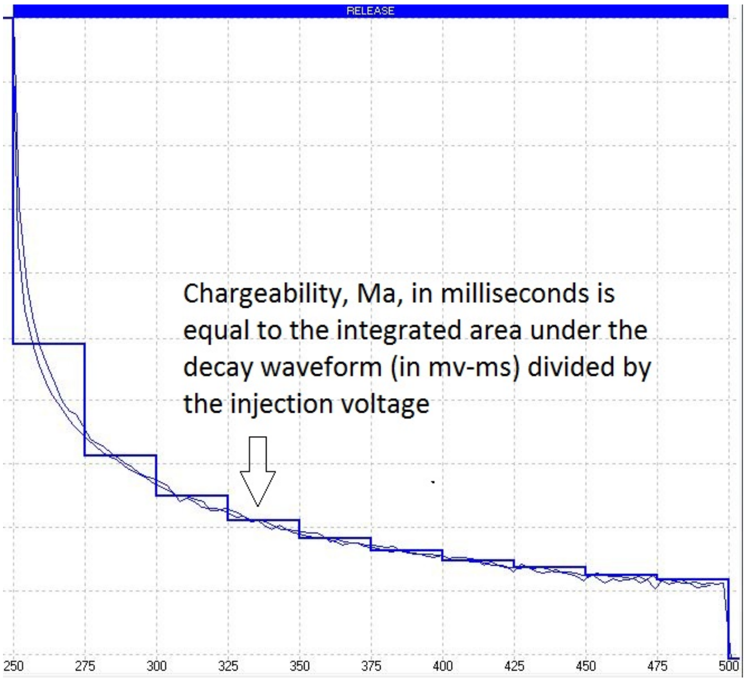
The chargeability, labeled Ma, is calculated by integrating the 10 average voltages in the release cycle (units are V-ms) and then dividing by the injection voltage. For a 250 ms inj/rel time, this means that the average release voltage, beginning with the first 25 ms window after injection is removed, is added to the next average release voltage from 25-50 ms, and so on, for those 10 cycles. The output Ma is presented for the SS (16”) spacing. The IPWave browser shows the same information for the LS (64”) channel.

Calculation of Ma, Chargeability

The chargeability for the SS channel is calculated using the following relationship:

Formula=0.001*{ch12}*({ch49}+{ch50}+{ch51}+{ch52}+{ch53}+{ch54}+{ch55}+{ch56}+{ch57}+{ch58}),

where ch12 is the release gate time (e.g. 25 ms for a 250 ms inj/rel setting, and ch49..ch58 are the normalized values for each gate, which is the gate average voltage, divided by the injection voltage.



Chargeability, Ma, in milliseconds is equal to the integrated area under the decay waveform (in mv-ms) divided by the injection voltage

Figure 4-11 *Release Decay Waveform – Chargeability (Ma) calculation*

4.5.4 MChCurve Browser

By default the MchCurve Browser window displays the curves shown in **Figure 4-11** – SP, SPR, normal resistivity and the IP responses from 16” and 64” electrodes.

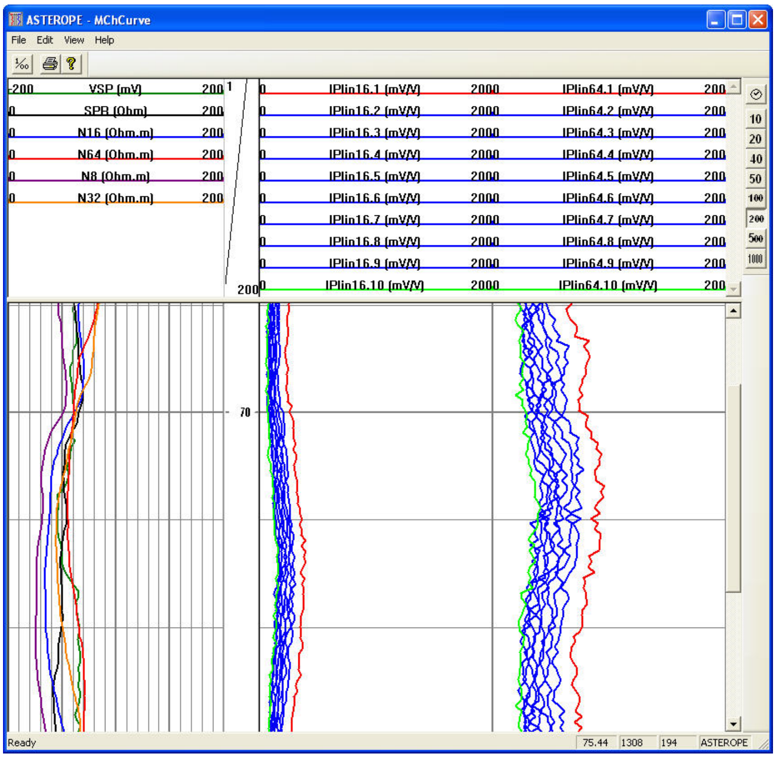


Figure 4-12 MchCurve Browser window

4.5.5 WellCAD Browser

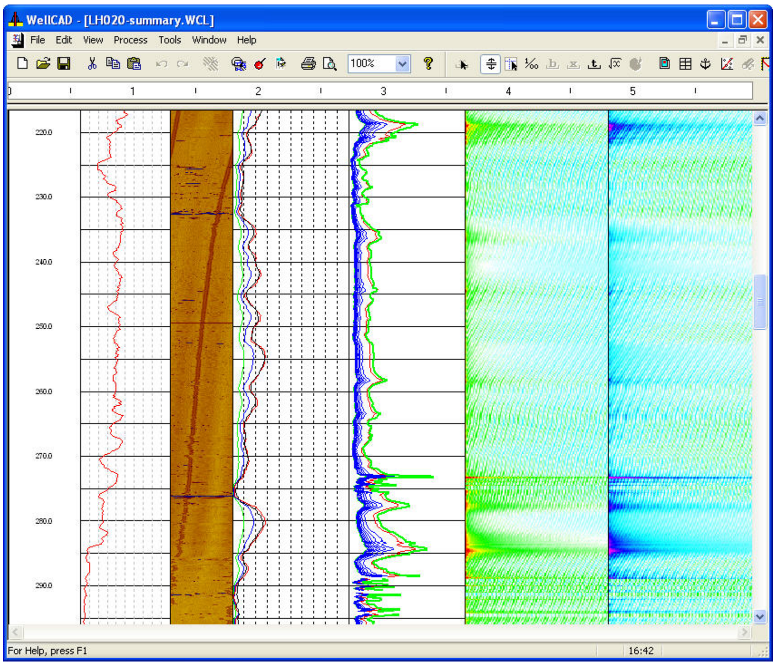


Figure 4-13 WellCAD browser

5 Performance Check & Calibration

Calibrations are performed at the factory. Each QL40-ELOG/IP is delivered with a calibrated "sub" file that must be used for that specific tool. It is also possible to calibrate the tool before a field operation using the suitable **ELOG Calibrator** – see below:

Figure 5-1 *ELOG Calibrator*

5.1 Calibration procedure

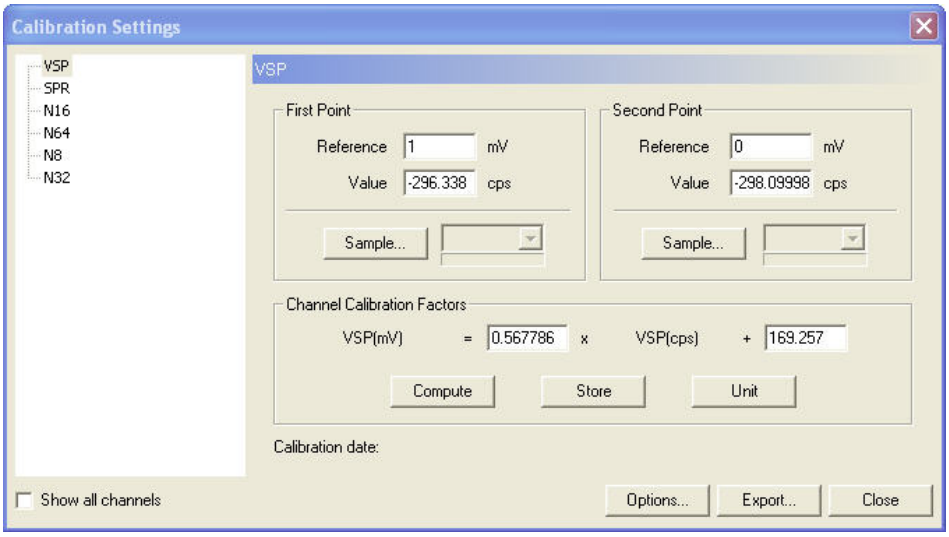
A calibration box is supplied with the QL40 ELOG/IP to verify the tool performance. Refer to the procedure described below:

1. Assemble the tool sub(s) and connect to the wireline
2. Connect the cables and clamps between the ELOG Calibrator and QL40 ELOG/IP tool as per the diagram shown on the box:

Figure 5-2 *ELOG Calibrator configuration diagram*

3. In the **Tool Panel**:
   Select the proper tool/stack;
   Turn tool power **On**
4. In the **Acquisition Panel** select **Time** and turn it **On**.
5. Verify the telemetry status in the **Telemetry Panel**. The LED must be green and status valid
6. Right click on MChNum browser
7. From the menu, uncheck "Use calibration" and click on "Calibration Settings"
8. <u>**For each resistivity channel (SPR, N8, N16, N32 and N64)**</u>, follow the steps below:

   ➢ From the "**Calibration Settings**" dialog box select the calibration page of the resistivity channel to calibrate



First Point: Reference 1 mV; Value -296.338 cps

Second Point: Reference 0 mV; Value -298.09998 cps

VSP(mV) = 0.567786 x VSP(cps) + 169.257

Calibration date:

☐ Show all channels

Figure 5-3 *Example of calibration page*

   ➢ Edit the first reference value (say 100 ohm.m)
   ➢ Connect the measuring electrodes on the ELOG Calibrator for this first reference resistivity value (100 ohm.m)
   ➢ Click on **SAMPLE** to get the corresponding value in cps
   ➢ Edit the second reference value (say 10,000 ohm.m)
   ➢ Connect the measuring electrodes on the ELOG Calibrator for this first reference resistivity value (10,000 ohm.m)
   ➢ Click on **SAMPLE** to get the corresponding value in cps
   ➢ Click on **COMPUTE** and then on **STORE** to save the calibration factors of the measured channel

9. The "**IP**" response can also be checked by connecting the injection (SPR), 16" and 64" electrodes for the **IP measurement configuration.** A **chargeability of 10ms** should be read in the **MChNum browser**.

6 Maintenance

Warning: Removing the electronic chassis from pressure housing without prior consultation with ALT/MSI will void the tool warranty.

The QL40 series tools require periodic maintenance. Make sure the threads on the brass nut on the sub bottom are free of sand, mud or other dirt. A thin layer of anti-seize is recommended. When disassembling the sub string, dry the joint as it is separated to prevent fluid from entering the sub top and getting into the electrical connector inside.
After replacing top and bottom protectors it is good to wash the probe off after each use.
Never take the probe apart. This probe is very difficult to disassemble and requires special steps to be taken in order to gain access to the inside of the probe without damaging the electronics. If you have read this after attempting to disassemble the probe chances are the probe has experienced damage and will need to be sent to the factory to be repaired.
Inspect o-rings occasionally and keep the threads on both ends of the probe clean, to minimize problems in the future.

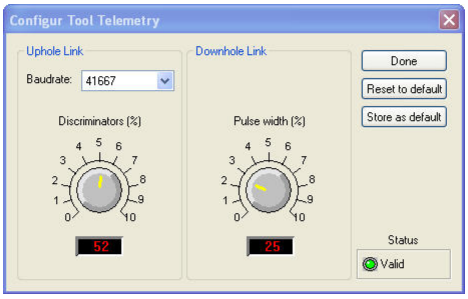
6.1 Upgrading firmware

In accordance with the ALT policy of continuous development the tool has been designed to allow firmware upgrades.

Firmware upgrade procedure is as follows:
1. Confirm that the communication is valid.
2. Upgrade firmware

6.1.1 Checking the communication

1. Connect the tool to your acquisition system.
2. Start ALTLog/Matrix software.
3. In the **Tool** panel select the appropriate tool and turn on the power.
4. In the **Communication** panel, select **Settings**. Check **baud rate** is set to **41666** and **communication status** is **valid** (Figure 6-1 or Figure 6-2).



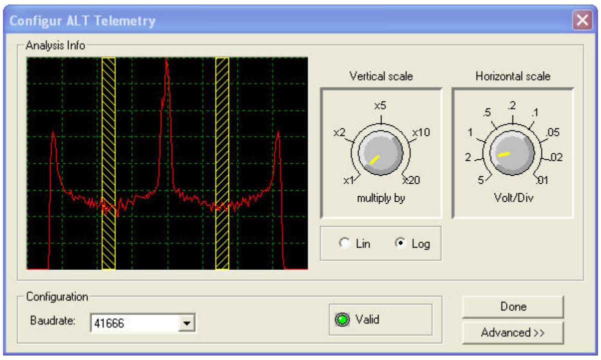
Configur Tool Telemetry

Uphole Link
Baudrate: 41667
Discriminators (%): 52

Downhole Link
Pulse width (%): 25

Status: Valid

Figure 6-1*Tool communication settings - ALTLog*



Baudrate: 41666

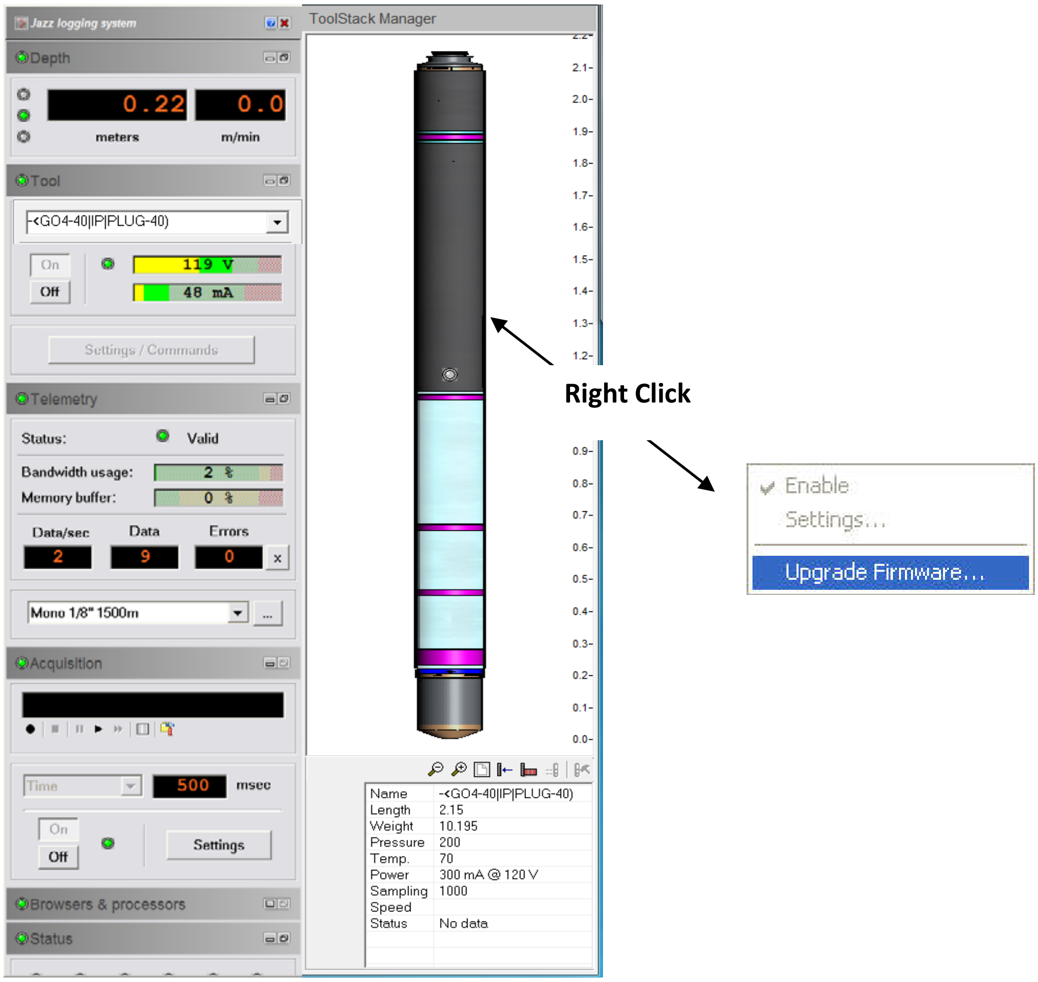
Valid

***Figure 6-2** Tool communication settings - Matrix*

Warning: Telemetry must be tuned properly. Bad communication may abort the upgrade of the firmware!

6.1.2 Upgrading the firmware

1. **Right Click** on the tool preview in the **ToolStack Manager** view and select **Upgrade Firmware** from the context menu.



Right Click

Depth: 0.22 meters, 0.0 m/min

Tool: -<GO4-40|IP|PLUG-40)

119 V

48 mA

Status: Valid

Bandwidth usage: 2 %

Memory buffer: 0 %

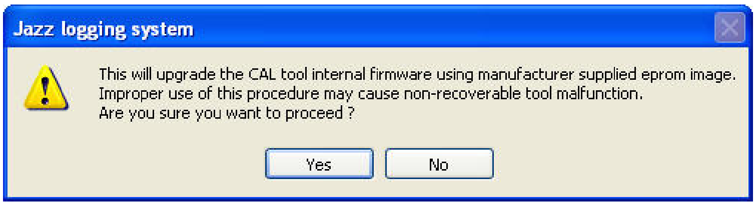
Data/sec	Data	Errors
2	9	0

Mono 1/8" 1500m

500 msec

Name	-<GO4-40|IP|PLUG-40)
Length	2.15
Weight	10.195
Pressure	200
Temp.	70
Power	300 mA @ 120 V
Sampling	1000
Speed	
Status	No data

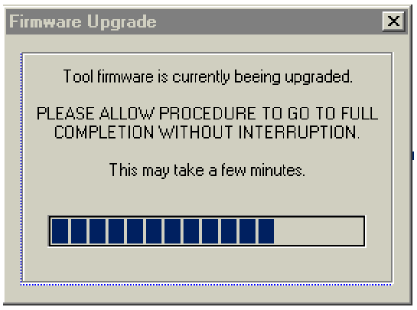
2. The following message will appear (Figure 6-3). Click **Yes** to validate your choice.



This will upgrade the CAL tool internal firmware using manufacturer supplied eprom image.
Improper use of this procedure may cause non-recoverable tool malfunction.
Are you sure you want to proceed ?

Figure 6-3 *Warning Message during firmware upload*

3. Select and open the appropriate **.hex** file provided. The upgrade will start.
4. During the upgrade procedure, the following message is displayed:



Tool firmware is currently beeing upgraded.

PLEASE ALLOW PROCEDURE TO GO TO FULL COMPLETION WITHOUT INTERRUPTION.

This may take a few minutes.

Figure 6-4 *Firmware upgrade progress window*

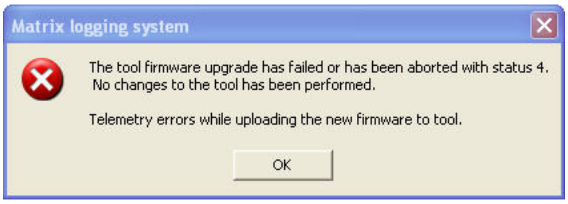
5. Once the upgrade has been successfully completed (Figure 6-5), click on **OK** to turn off the tool.

The tool firmware upgrade has been completed successfully.
The tool power will now be switched off.

Figure 6-5 *Successful upgrade*

6. Power on the tool to start the upgraded firmware.

Note that the following error message (Figure 6-6) will appear at the end of the procedure when the tool firmware upgrade has failed or has been aborted. Verify the tool communication settings in this case.



The tool firmware upgrade has failed or has been aborted with status 4.
No changes to the tool has been performed.

Telemetry errors while uploading the new firmware to tool.

Figure 6-6 *Error message*

7 Troubleshooting

The **QL40ELOG/IP** probes require a proper current return to armor, and a proper isolation for approximately 7 meters above the probe for correct operation. The downhole tool current (I) must be a reasonable value to insure correct measurements are being made. This value will fluctuate from 10 mA in very high resistivity rock, to as much as 500 mA in very conductive rock. If such values are not obtained during logging, there may be a problem with the cable armor connections at the winch or logger.

NEVER DIS-ASSEMBLE THE PROBE WITHOUT CONSULTING THE FACTORY FIRST

Disassembly Instructions

The **QL40-ELOG/IP** Probe should **never be disassembled** unless service is necessary. This is a very difficult probe to disassemble, and is highly recommended that any service be performed by Mount Sopris, ALT or a qualified technician.

Observation	**To Do**
Tool not listed in Tool panel drop down list.	- Do you have a configuration file? - Has the configuration file been installed with the LoggerSettings application (refer to LoggerSettings and LoggerSuite manuals for more information)
Tool configuration error message when powering on the tool.	- Check all connections. - Adjust the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3) and store the new settings as default. Apply the appropriate tool settings for your logging run (see chapter 3.4).
Tool panel - No current.	- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system. - Verify cable head integrity. - Verify voltage output at the cable head (it should be 120V).
Tool panel - Too much current (red area).	**! Immediately switch off the tool !** **-**Possible shortcut (voltage low, current high): Check for water ingress and cable head integrity - wireline continuity. - Verify the interface cable between winch slip ring and data acquisition system is not loose at the connectors. Check for possible source of the short circuit. - If the above shows no issues, use test cable provided by ALT to verify tool functionality. - If the problem still occurs, please contact service centre.
Telemetry panel - status shows red.	- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3).

	- If problem cannot be resolved contact support@alt.lu or tech.support@mountsopris.com
Telemetry panel - memory buffer shows 100%.	- Indicates that the systems internal memory buffer is full. PC can’t receive incoming data streams fast enough. Ensure your PC has enough resources available.
Telemetry panel – bandwidth usage shows 100%. *(Overrun error message.)*	- Set the baudrate to highest value allowed by your wireline configuration. - Reduce logging speed or increase vertical sample step.
Telemetry panel - large number of errors.	- Verify the telemetry settings for your wireline configuration (see chapter 3.2 or 3.3). - Check bandwidth usage and telemetry error status.

8 Appendix

8.1 Parts list

Item No.	Qty	Part No.	Description
1	1	1673840	Silicone grease Molykote111
2	2	55459	DIN 1810B 40-42 Hook wrench w.pin
3	6	AS215-V-75°	Oring Viton shore 75° - 26.57 x 3.53
4	1	L0034-086	Grease Lubriplate

8.2 Bridle wiring configurations

8.2.1 QL40-IS4 bridle configuration for 4 conductor wireline

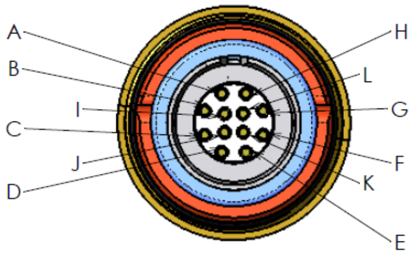


Figure 8-1 *Bridle bottom connection to tool*

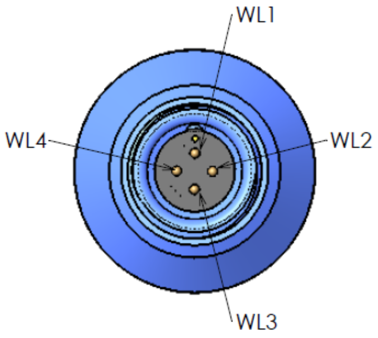
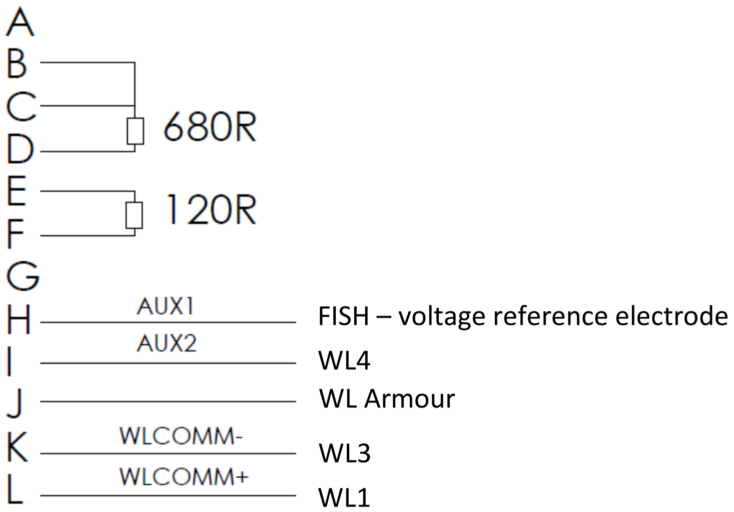


Figure 8-2 *Bridle top connection to cable head*



8.2.2 QL40-IS1 (MSI) and QL40-IS2 (GO1) bridle configurations for single conductor wireline

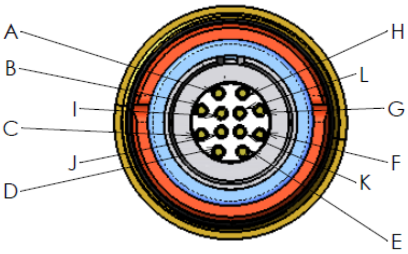


Figure 8-3 *QL40-IS1 and IS2 bridle bottom connection to tool*

Figure 8-4 *QL40-IS1 bridle top connection to cable head*

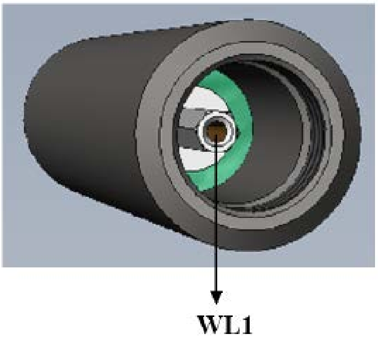
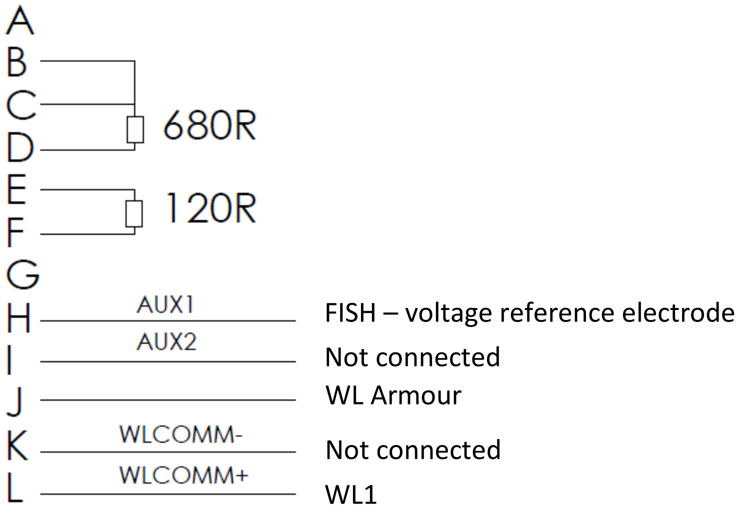


Figure 8-5 *QL40-IS2 bridle top connection to cable head*



User Guide

QL40 OBI-2G Optical Borehole Imager

MOUNT SOPRIS
INSTRUMENTS

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v14.12.17

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Table of Contents

1 General Information

The QL40 OBI-2G is the new generation of slimhole Optical Borehole Imager. The new system consists of a completely redesigned optical assembly and electronics. It implements a high resolution CMOS digital image sensor combined with a fisheye lens. The tool produces an extraordinarily clear, sharp, 360° continuous - unwrapped digital picture of the borehole wall, either in air or clear water. Resolutions up to 1800 pixels over the borehole circumference can be achieved making it ideal for lithological, mineralogical and structural analyses.

A built in high precision orientation sensor incorporating a 3-axis fluxgate magnetometer and 3 accelerometers allows orientation of the images to a global reference and determination of the borehole’s azimuth and inclination.

The QL40 OBI-2G is supplied as a bottom sub of the Quick Link (QL) product line and it can either be combined with other QL40 tools to form a tool string or be run as a standalone tool.

Applications:

- *Detailed and oriented structural information*
- *Reference for core orientation*
- *Fracture detection and evaluation*
- *Breakout analysis*
- *Detection of thin beds*
- *Determination of bedding dip*
- *Lithology and mineralogical characterization*
- *Casing inspection*

Measurement features:

- *360° RGB true colors oriented image*
- *Borehole azimuth and tilt*
- *Relative bearing*
- *3 accelerometer calibrated components*
- *3 magnetometer calibrated components*
- *Temperature of CMOS image sensor*

Operating conditions:

- *Dry or clear water filled borehole*
- *Centralizers required*
- *Borehole diameter range: 2 ½" to 21"*
- *Logging speed:* function of image resolution and wireline electrical properties

  i.e: 6 m/min with 900 pixels azimuthal resolution, 2 mm vertical sampling rate @ 100 Kbps

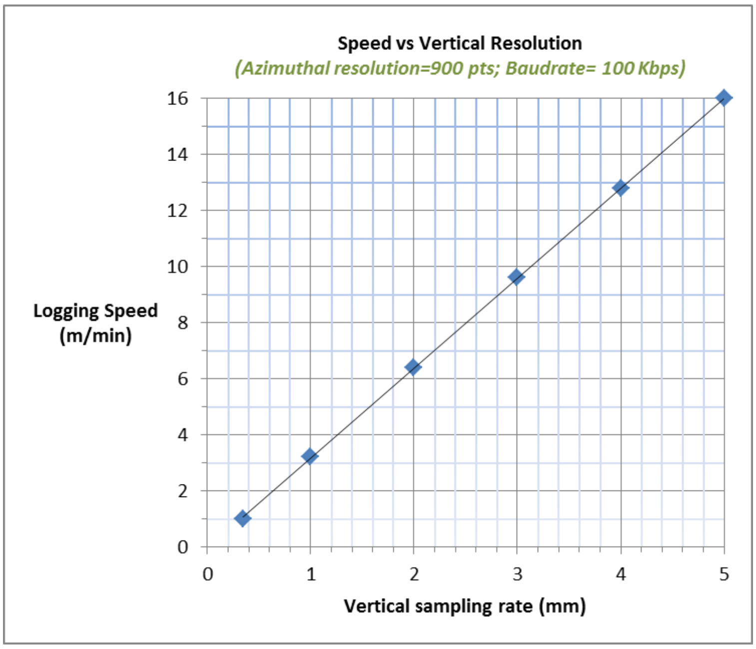


Figure 1-1-1 *Logging Speed vs Vertical Sampling Rate (900 pxls-100 Kbps)*

1.1 Dimensions

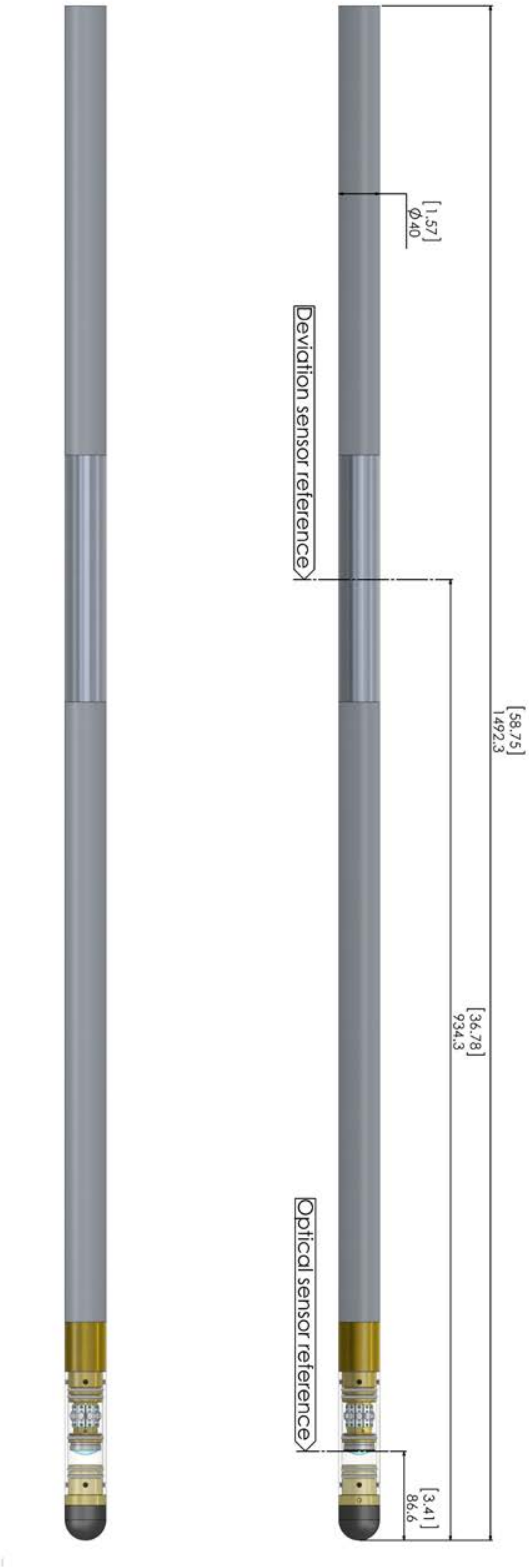


Figure 1-1 *QL40 OBI-2G overview*

1.2 Technical Specifications

Diameter:	40 mm (1.6”)
Length:	1.47 m (57.9”)
Weight:	5.3 kg (11.7 lbs)
Max. Temperature:	70°C (158°F)
Max. pressure:	200 bar (2900 PSI)

Optical system

Sensor:	1/3” high sensitivity CMOS digital image sensor
Color resolution :	24 bits RGB true colors
Responsivity :	5.48v/lux-sec
Azimuthal resolutions :	120, 180, 360, 600,900, 1800 points
Vertical resolution :	User defined. Function of depth encoder resolution

Light source

Light source:	High efficiency LEDs
Color temperature:	5600 K
Light intensity:	750 lm
Color rendering index:	80 %
Power max.:	5.60 W

Compatibility

Wirelines:	Multi conductor, mono or coaxial
Acquisition systems:	ALTLogger, BBOX and Matrix
Min. software configuration:	LoggerSuite 11.2 – WellCad 5.0 build 1103

Orientation sensor

Sensor:	APS544 – 3 axis magnetometer and 3 accelerometers
Azimuth accuracy:	+/- 1.2 deg
Tilt accuracy:	+/- 0.5 deg

2 Measurement Principle

The tool incorporates a 1/3-inch CMOS digital image sensor with an active pixel array of 1.2 Mp and fisheye matching optics. The digital image sensor captures the reflection of the borehole wall through the fisheye lens. The light source is provided by 10 high efficiency LEDs.

The displayed log image is derived from a single annulus extracted from the active pixel array. Azimuthal resolutions available are 120, 180, 360, 600, 900 and 1800 pixels per recorded circle. By using processed digital images in combination with deviation sensor data, the tool can generate an unwrapped 360° oriented image.

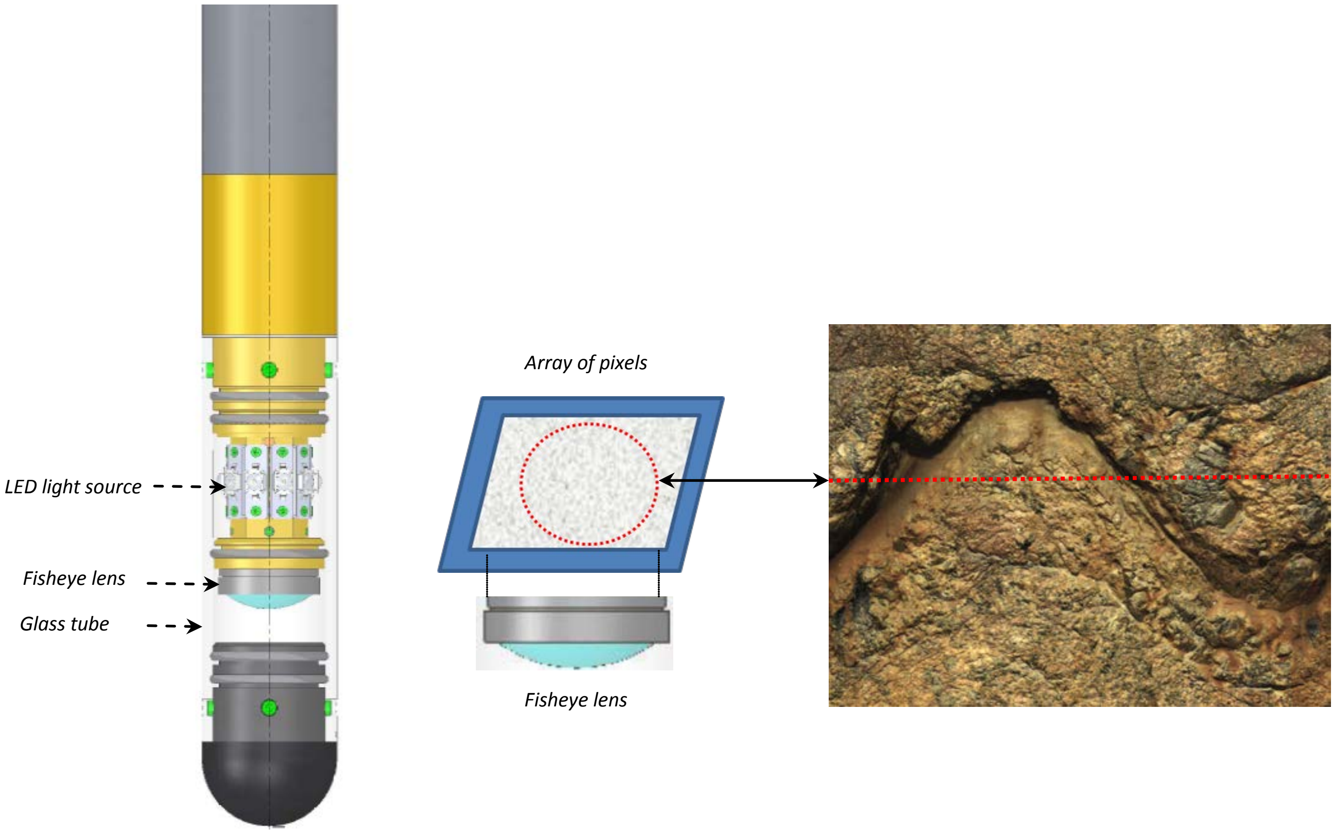


Figure 2-1 *Optical assembly and principle of measurement*

3 Notes on QL tool assembly

The following explanations are only valid for the QL40 OBI tool. OBI40 users can skip this chapter.

QL stands for **Q**uick **L**ink and describes an innovative connection between logging tools (subs) allowing to build custom tool stacks. QL40 describes a specific family of logging tools. Each sub is equipped with its own Telemetry board, Power supply element and A/D converter allowing an operation as stand-alone tool or as a stack in combination with other subs of the QL product family.
The QL40 probe line deals with two types of subs - Bottom Subs and Mid Subs.

Bottom Sub
A bottom sub is a tool that must have one or more sensors located at the bottom. It can be operated in combination with other QL subs connected to the top but it is not possible to connect another sub below. When used in stand-alone mode the bottom sub only needs a QL40 tool top adaptor, which fits the cable head.

Mid Sub
A mid sub is a tool that can be integrated anywhere within a stack of tools. When used at the bottom of a tool string a QL40 bottom plug must be used to terminate the string. If the mid sub is used as a stand-alone tool it needs a QL40 bottom plug at the lower end and a QL40 tool top adaptor at the top.

3.1 QL40 stack assembly

QL40 tool stacks are terminated by either a QL40 bottom sub or a QL40 bottom plug. At the top of the stack a QL40 tool top is required to connect the tool string to the cable head. Several tool tops are already available, special ones can be made on request.

To assemble and disassemble the subs the C-spanner delivered with the tool must be used (Figure 3-1). It is recommended that before each assembly the integrity of the O-rings (AS216 Viton shore 75) is verified. Prime the O-rings with the silicon grease that was supplied with the subs.

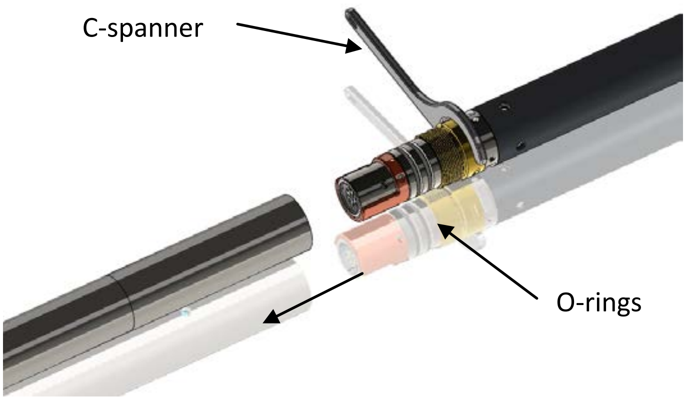


Figure 3-1 *C-spanner and O-rings of QL connection*

The following example of a QL40-ABI, QL40-GR and QL40-GO4 (Figure 3-2) describes how to replace the QL40-ABI with a QL40-Plug in order to run the QL40-GR sub stand-alone.

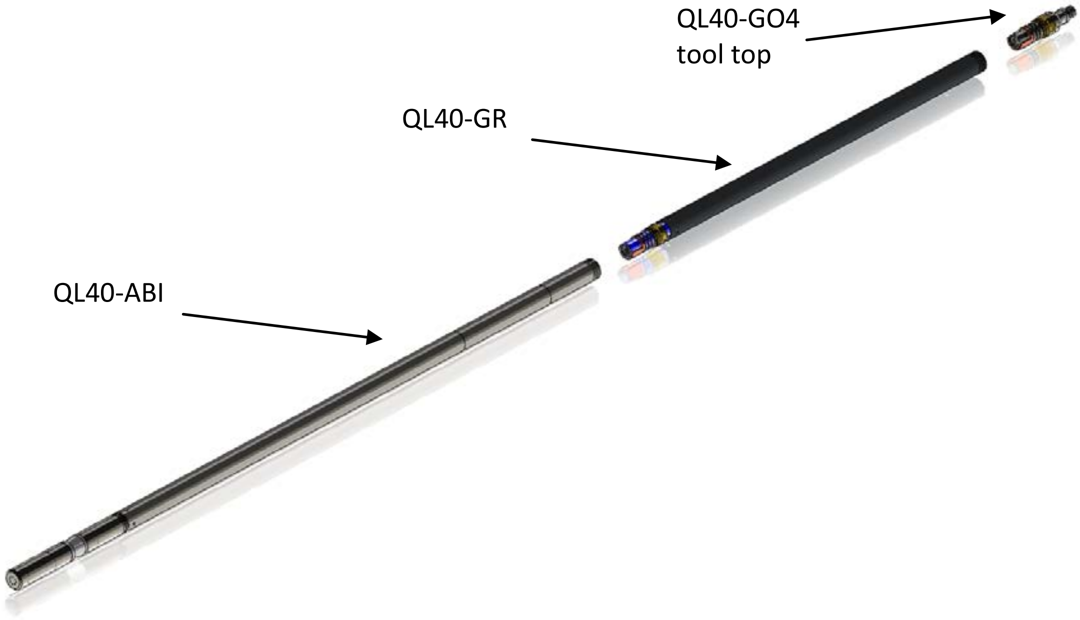


Figure 3-2 *Tool stack example*

To remove the QL40-ABI bottom sub attach the C-spanner to the thread ring as shown in Figure 3-3, unscrew the thread ring and remove the QL40-ABI bottom sub.

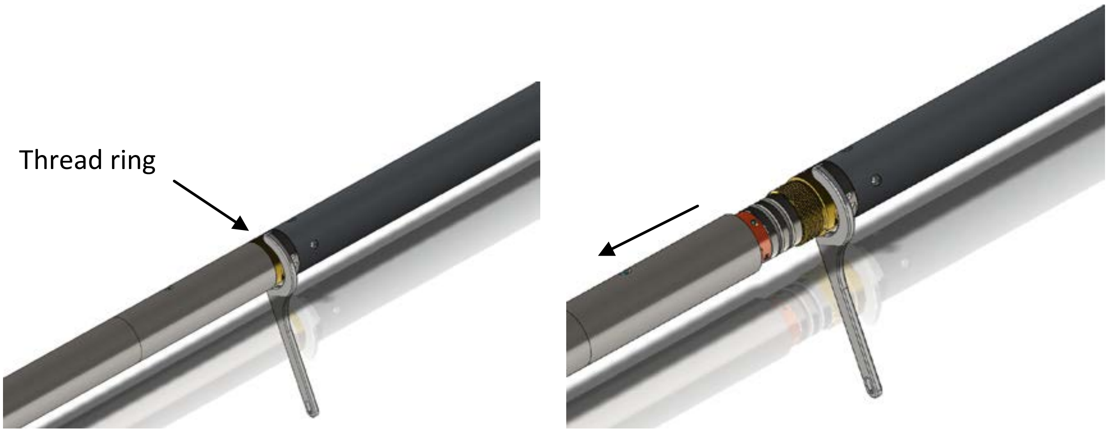


Figure 3-3 *Unscrewing the thread ring and removing the bottom sub*

After checking the O-ring integrity slip the QL40-Plug over the exposed QL connector (Figure 3-4) attach the C-spanner and screw the thread ring until the plug fits tight.

Figure 3-4 *Attaching the QL40-Plug*

The QL40-GR can now be run stand-alone (Figure 3-5).

Figure 3-5 *QL40-GR mid sub with tool top and bottom plug*

4 Operating Procedure

Note: Parts of the topics discussed in these sections below assume that the user is familiar with the data acquisition software. Refer to the corresponding operator manuals for more details. Information about assembly and configuration of tool stacks can be found in the same manuals.

4.1 Quick Start

1. Connect the tool to your wireline and start the data acquisition software.

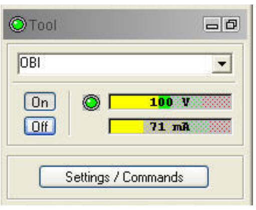


Figure 4-1 *Tool panel*

2. Select the relevant OBI tool from the drop down list (Figure 4-1) in the software’s **Tool** panel (if your tool is not listed check that your tool configurations file is stored in the designated folder on your computer).

3. In the **Tool** panel switch on the tool (click **On** button) and verify that the power indicator shows a valid (green) level. The system goes through a short initialization sequence which sets the default parameters and communication settings held in the tool configuration file. The configuration returned by the tool is also checked during this procedure. (Setup the tool communication as explained in section **4.2** if an error message is displayed.)

4. On the **Tool** panel (Figure 4-1) click the **Settings / Commands** button to configure your tool (see chapter **4.5** for details).

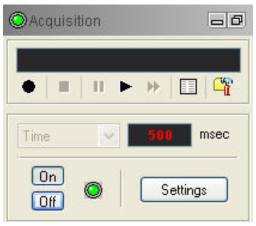


Figure 4-2 *Acquisition panel*

5. In the **Acquisition** panel (Figure 4-2) select the sampling mode (depth or time). Click on **Settings** and specify the corresponding sampling rate. Switch on the sampling (click the **ON** button).

6. Press the **Record** button in the **Acquisition** panel (Figure 4-2), specify a file name and start the logging.

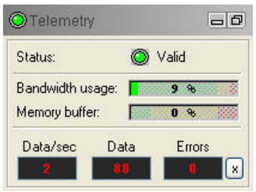


Figure 4-3 *Telemetry panel*

7. <u>**During logging**</u> observe the controls in the **Telemetry** panel (Figure 4-3):
   - Status must be valid (green light);
   - Bandwidth usage in green range;
   - Memory buffer should be 0%;
   - Number of **Data** increases and number of **Errors** negligible.

   <u>In the OBI40Img browser the processor “workload” and camera “frame rate” must stay below 100%</u>

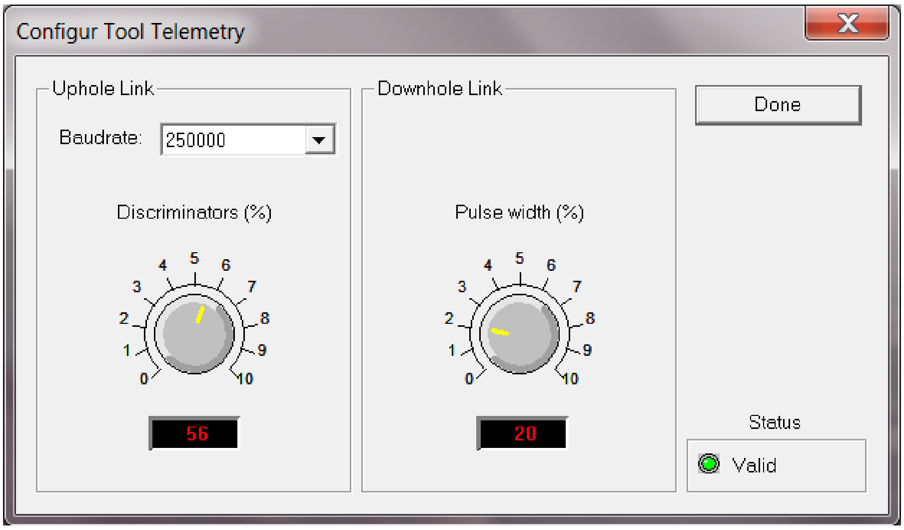
8. To end the logging procedure press the **Stop** button in the **Acquisition** panel and turn off the sampling (click **OFF** button).

9. In the **Tool** panel power off the tool.

4.2 Tool Communication with ALT Logger

The telemetry provided through the ALTLogger is self-tuning**.** In case communication status is not valid the user can manually adjust the settings. In the **Telemetry** panel of the dashboard click on **Settings** to display the **Configure Tool Telemetry** dialog box (Figure 4-4).
A procedure to achieve valid communication is given below:

- Change the **Baudrate** to 41666 kbps.
- Verify that the **Downhole Pulse width** knob is set on 20 (default value). This value is the preferred one and is suitable for a wide range of wirelines. For long wireline (over 2000m), increasing the pulse width could help to stabilize the communication. The reverse for short wireline (less than 500m).
- Set the **Uphole** discriminators in the middle of the range for which the communication status stays valid.
- Increase the **Baudrate**, check the communication status stays valid and the **Bandwidth usage** (in **Telemetry** panel of the dashboard) is below the critical level.
- When **Uphole** discriminators are properly set, store the new configuration as default. The tool should go through the initialisation sequence the next time it is turned on.



Configur Tool Telemetry

Uphole Link

Baudrate: 250000

Discriminators (%): 56

Downhole Link

Pulse width (%): 20

Status: Valid

Figure 4-4 *Tool communication settings*

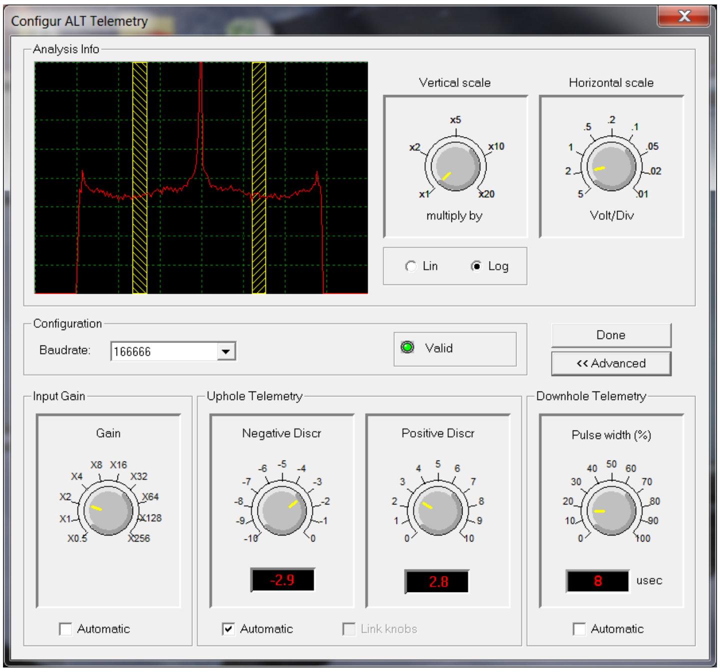
4.3 Tool Communication with MATRIX

The tool telemetry can be configured through the **Telemetry** panel of the Matrix dashboard. By clicking on **Settings**, the operator has access to the **Configure ALT Telemetry** dialog box (Figure 4-5) providing various controls to adjust the telemetry settings and monitor its current status.
The **Analysis View** displays the current discriminator levels (vertical yellow lines) and a histogram of the up-hole data signal. The scales of the **Analysis View** can be adjusted using the **Vertical Scale** and **Horizontal Scale** knobs and the **lin**ear / **log**arithmic scale buttons.
The status of the configuration should be flagged as Valid (indicated by the LED being green). In any other case (LED red) the telemetry should be adjusted (we assume a pulse signal

is displayed in the analysis view). Click on the **Advanced** button to display additional controls to tune the telemetry.

The Automatic settings option is the preferred mode and should allow the telemetry to be configured for a wide range of wirelines without operator input. For wirelines with a more limited bandwidth, the operator might need to turn off the automatic mode and adjust the telemetry settings manually.

For each wireline configuration, the discriminators (vertical yellow lines) for the **positive** and **negative** pulses must be adjusted in order to obtain a valid communication status (see Figure 4-5) for an example of a suitable discriminator position). There is also the option to alter the **baudrate** in order to optimize the logging speed. The input **gain** can be increased (long wirelines) or decreased (short wirelines) in order to set up the discriminator levels correctly.



○ Lin ● Log

Baudrate: 166666

● Valid

Negative Discr: -2.9

Positive Discr: 2.8

Pulse width: 8 usec

Input Gain: ☐ Automatic

Uphole Telemetry: ☑ Automatic ☐ Link knobs

Downhole Telemetry: ☐ Automatic

Figure 4-5 *Matrix telemetry settings*

Once the telemetry is correctly set, store the new settings as default. The tool should go through the initialization sequence in “Valid” status the next time the power is turned on.

4.4 Use of centralizers

Optical televiewer image quality is highly dependent upon tool centralization.

One set of centralizers is supplied with the OBI that is suitable for all tools with an external diameter of 40mm. The standard assembly comprises upper and lower mounting rings with sets of bow springs. Two C spanners are provided for tightening the locking ring. Bowsprings for other borehole diameters are available on request.

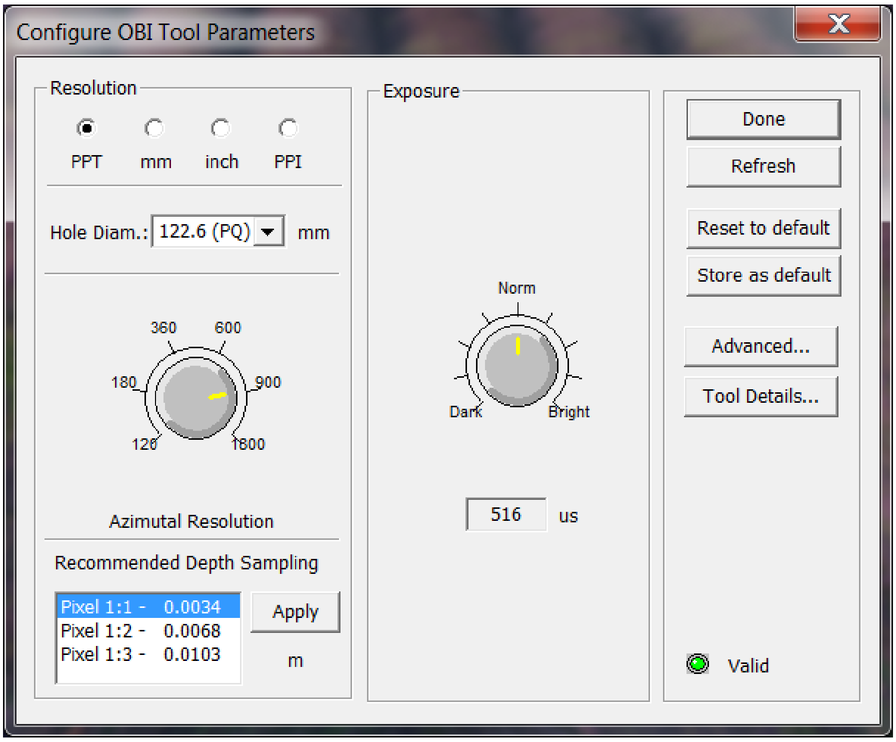
The following points relating to the use of centralizers should be considered:

The centralizers should be fitted before mating the tool with the wireline cable head and should always be fitted from the cable head end to avoid damaging the optical window. In case magnetic centralizers are used (the ALT centralizers are non magnetic) avoid mounting a centralizer over the deviation sensing point which is located in the middle of the roughened area on the pressure housing.

The “compression” ring of the centralizer, i.e. the one that is screwed tight, should always be fixed toward the **top** end of the probe. This is to avoid catching on a downhole obstruction when winching up.
Use the C spanner to fasten the fixing rings but take care not to cross thread or over tighten them as this could damage the pressure housing
(The weak point of the bowsprings is the welded bearing pin. Take care during assembly as the weld can be broken by reverse bending.)

4.5 Configuring Tool Parameters

The **Tool Parameters** dialog box for the QL40 OBI-2G is shown below (Figure 4-6). It can be accessed by clicking the **Settings / Commands** button from the **Tool Panel**. Changes and the effect of new settings on the image are displayed in real time in the **OBI image** browser.



● PPT ○ mm ○ inch ○ PPI

Hole Diam.: 122.6 (PQ) mm

516 us

Recommended Depth Sampling

Pixel 1:1 - 0.0034
Pixel 1:2 - 0.0068
Pixel 1:3 - 0.0103
m

● Valid

Figure 4-6 Tool parameters dialog box

4.5.1 Image resolution

The azimuthal resolution of the image can be defined by the operator. The choice of azimuthal resolutions is now extended to 1800 pixels over the borehole circumference.

Multiple options are possible for displaying the azimuthal resolution: points per turn (PPT), millimetres (mm), inches (inch) or points per inch (PPI).
By editing or selecting a nominal borehole diameter in the *caliper window*, the system computes automatically the azimuthal resolution values for each display options.

The system suggests in addition a *recommended vertical depth sampling rate for the selected azimuthal resolution* and offers a choice of different image ratios (ratio between horizontal and vertical resolutions). A link can be activated to apply automatically the recommended vertical sampling rate in the “*acquisition*” panel of the dashboard. Note that User is always free to edit manually the vertical depth sampling rate from the “settings” option in the “acquisition” panel of the dashboard.

Important remark:

The digital images recorded by the QL40 OBI-2G are compressed in real time to increase the transfer rate of the images to the surface acquisition system. To optimize the compression process, the tool records eight optical data frames per vertical sample. ***For this reason, the vertical sampling value to edit must be multiplied by a factor of eight. I.e. in practice, if the User wants to record an image with an effective 1mm vertical depth sampling rate, a value of 8mm (8x1mm) must be manually entered in the “acquisition” window of the dashboard.***

4.5.2 Exposure

The “Exposure” control knob allows optimization of the exposure time set for the image sensor when capturing an image of the borehole wall under a given light level. (By default the lighting intensity is set at 100%, see Section 4.5.4). The exposure value is displayed below the knob in µsec.
Practically speaking, the exposure must be adjusted adequately for the borehole conditions: diameter, dry or water filled, rock colors.
By experience a lower exposure value is required in small diameter borehole, whitish formations and dry conditions. The reverse is applicable.

A good way to set the exposure time is to check the luminance distribution in the histogram view available with the “ObiHisto” browser (refer to chapter 4.6.3). The spectrum of the luminance should normally be centered on the luminance scale axis (Figure 4-7). A situation where the luminance spectrum is too far to the right on the luminance scale corresponds to an image saturated with light.

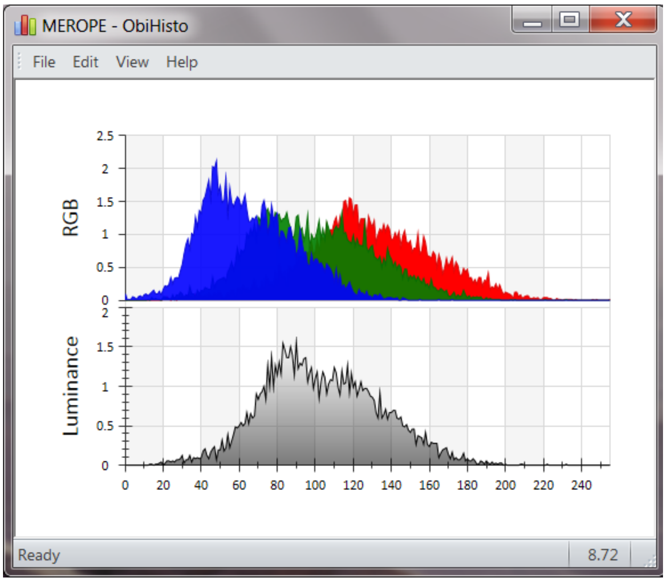


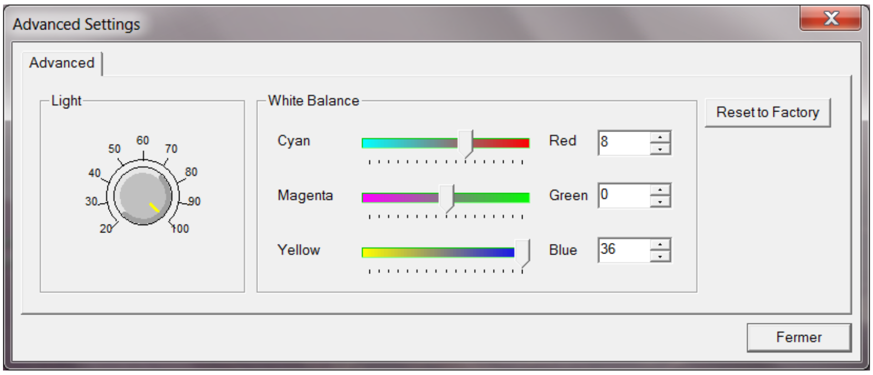
Figure 4-7 *Example of a correct luminance distribution and exposure level*

4.5.3 Tool parameters buttons

- **Refresh**: Click to refresh the settings of the dialog box.
- **Store as default**: Selected settings can be saved as defaults in the tool's default settings memory. The default settings are the tool settings loaded during the tool initialization sequence after the tool has been powered on.
- **Restore to default**: Load the default values from the tool's default settings memory.

4.5.4 Advanced settings

By default the light level is always set to 100%. It is the recommended light level for most borehole conditions.
In a situation where the image is overexposed to light, first, the exposure control knob must be adjusted. If, when the lower exposure value is used the image is still too bright, the light level can be decreased.



Red 8
Green 0
Blue 36

Figure 4-8 *Advanced settings dialog box*

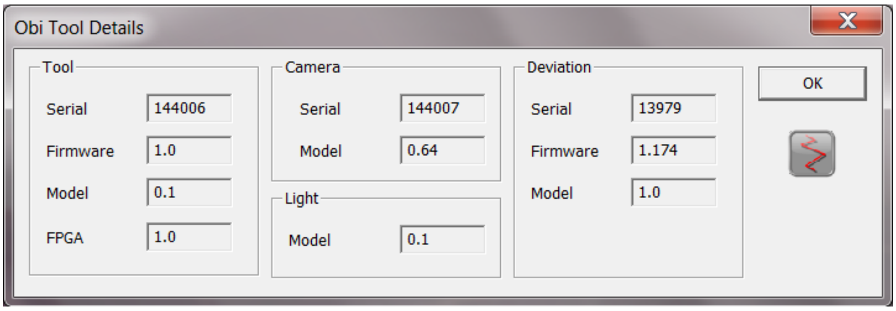
The white balance controls the ratio between the three main colors (red, green, blue). In other words, the white balance calibrates the white color of an object or image.

The calibration of the white balance requires specific equipment and is performed at manufacturing time. No change should be applied to the white balance settings when the tool is operated under normal conditions.

- **Reset to factory:** Load the original image sensor settings stored in the tool's memory during factory calibration.

4.5.5 Tool details

The **Tool Details** window lists the tool parts serial number, firmware and hardware versions.



Obi Tool Details

Tool
Serial 144006
Firmware 1.0
Model 0.1
FPGA 1.0

Camera
Serial 144007
Model 0.64

Light
Model 0.1

Deviation
Serial 13979
Firmware 1.174
Model 1.0

Figure 4-9 *Advanced settings*

4.6 Recorded Parameters, Processors and Browsers

4.6.1 Recorded parameters

Besides the image, the following data channels are recorded by the tool.

TCam[1]	Temperature of the image sensor - °C
FRate	Image sensor frame rate per second - fps
Workload	Percentage of the processor workload used for the image compression – %
Azimuth	Azimuth from Magnetic North – deg
Tilt	Inclination from verticality – deg
Roll	Tool relative bearing calculated from accelerometers - deg
MRoll	Tool relative bearing calculated from magnetometers - deg
MagnField	Magnetic field surrounding the borehole - µT
Gravity	Absolute value of the Earth gravity – g
TAPS	Temperature inside the deviation sensor - °C

---

[1] *The light source of the QL40 OBI-2G is switched off automatically when TCam reaches 105°C which is the maximum operation temperature of the image sensor.*

4.6.2 "Obi40Img" Browser

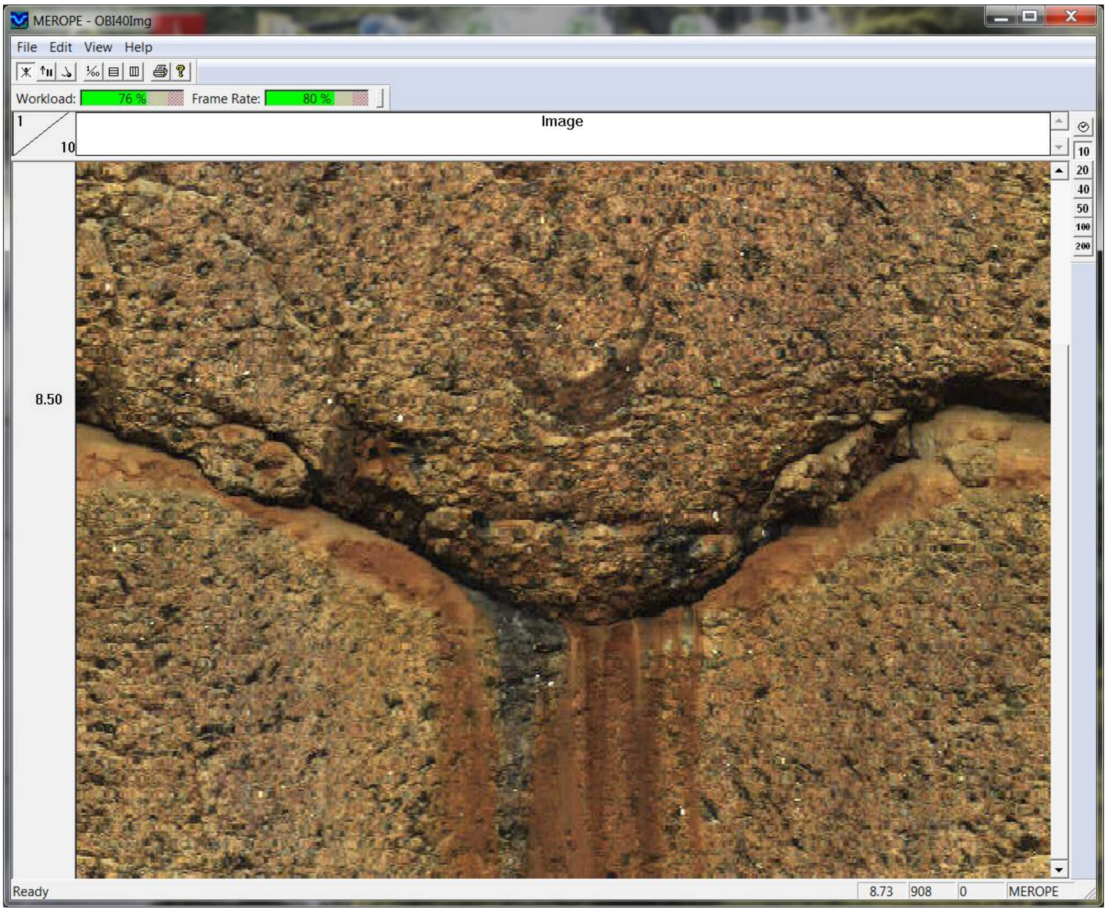
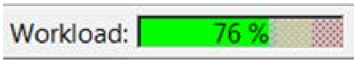
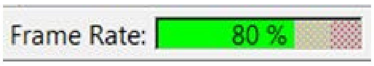


***Figure 4-10** OBI40 image browser*

A real-time 360° unwrapped image is displayed in the OBI40 image browser window (Figure 4-10). This browser has control buttons for choosing the system of orientation, time or depth mode, depth scale, grids and printing.

At the top of the browser, two bar meters monitor in real time the camera processor workload and frame rate in percent.





The bar meters must be used to control the logging speed during a record. To avoid bad records it is recommended to keep the percentage values in the green range.

Image orientation:

Image is non-oriented

Orient image to magnetic North

Orient image to High Side of the tool

There are two modes of tool data orientation: Orientation to High Side and orientation to North (Figure 4-14). Orientation to High Side is used in inclined boreholes when magnetic data is unavailable (for example in a cased hole).

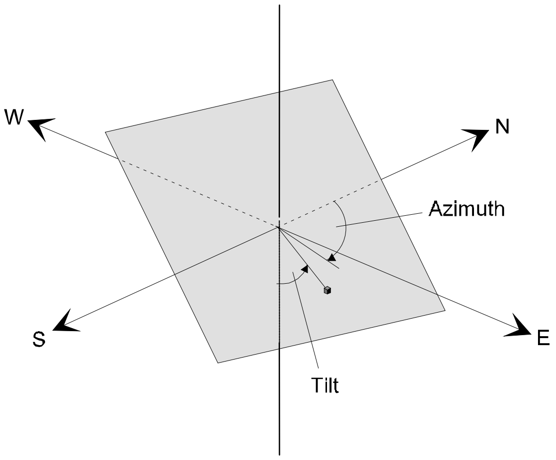


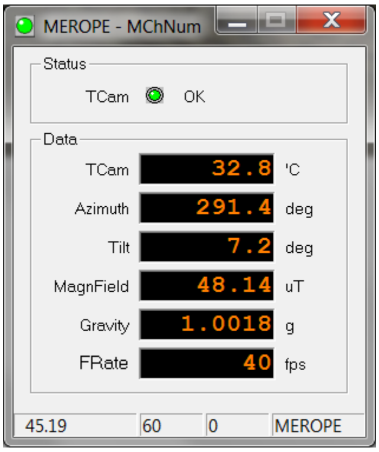
***Figure 4-11** Orientation to Magnetic North*

Vertical scales and grids:

10 20 40 50	Depth mode display and pre-defined depth scales
‰	Operator defined depth scales, interval spacing and settings
⏲	Time mode display

4.6.2 “MChNum” Browser

Figure 4-12 shows a typical example of the numerical values displayed in the MChNum browser.



Status

TCam ● OK

Data

TCam	32.8	'C
Azimuth	291.4	deg
Tilt	7.2	deg
MagnField	48.14	uT
Gravity	1.0018	g
FRate	40	fps

45.19 | 60 | 0 | MEROPE

***Figure 4-12** MChNum browser*

TCam:	Temperature of image sensor - °C
Azimuth:	Azimuth from Magnetic North - deg
Tilt:	Inclination from verticality - deg
Magn.Field:	Magnetic field surrounding the borehole - µT
Gravity:	Absolute value of the earth gravity - G
FRate	Image sensor frame rate per second - fps

Right click on the MChNum browser title and select **Display Options to** add / remove channels.

4.6.3 “ObiHisto” browser

An histogram view is available to visualize the luminance and RGB colors distribution during the acquisition. The histogram view helps the user to set the adequate exposure level for the borehole conditions. Refer to chapter 4.5.2 to set adequately the exposure and luminance parameters.

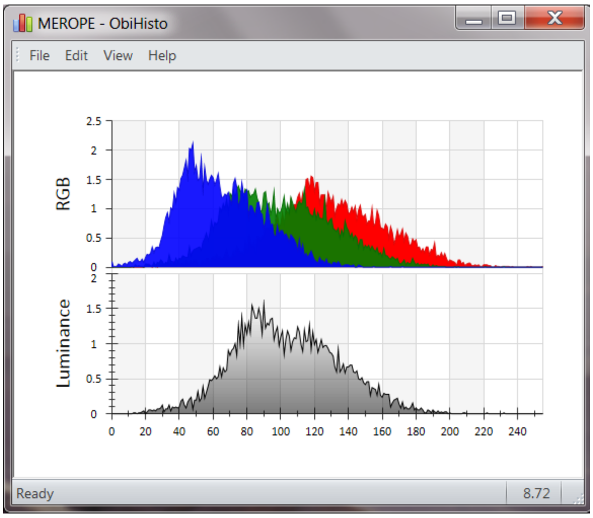


Figure 4-13 *Histogram view of the luminance and RGB colors*

The ObiHisto browser offers the option to zoom a defined area on the histogram view. To proceed left click on the histogram view and drag the mouse to highlight the area to zoom.

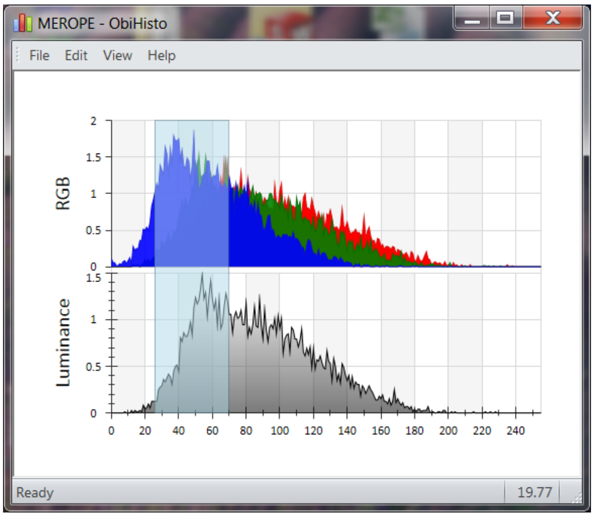


Figure 4-14 *Left click and drag the mouse to select a zoom window*

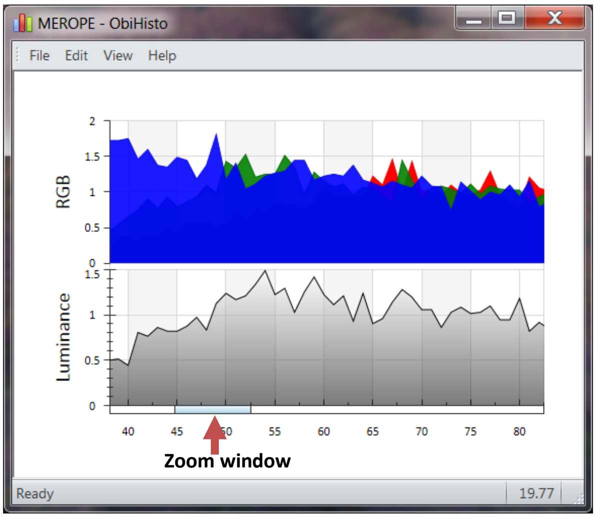


Figure 4-15 *Zoomed area in the histogram view*

The “zoom window” visible as a light blue rectangle (Figure 4-15) can be dragged on the horizontal axis to display the luminance and RGB colors distribution at the zoom scale.

To come back to the original histogram view right click on the ObiHisto browser.

Some additional options are available in the “File” and “Edit” menu to export (.bmp format) or copy the histogram view in a separate document.

5 Performance Check & Calibration

5.1 Testing the Deviation System

The QL40 OBI-2G deviation system is factory calibrated and does not require further calibration.

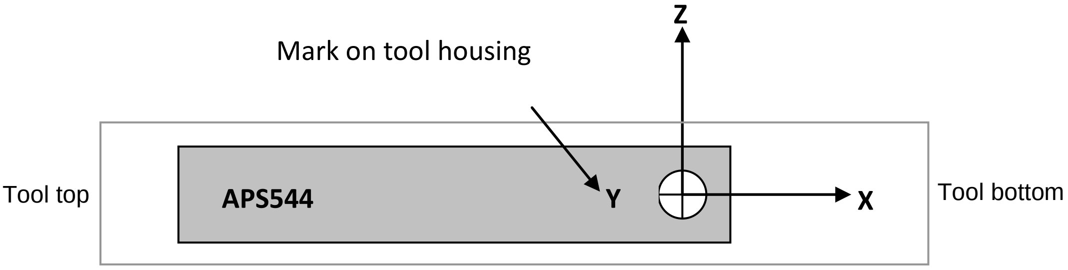


Figure 5-1 *Deviation sensor reference axis system*

The functionality test described hereafter should be executed to check that the tool is giving the correct deviation outputs:
To check Roll and Tilt outputs, place the probe on a flat surface with the Y mark engraved on the tool housing pointing up (Y axis of the coordinate system is pointing down, Figure 5-1).
Verify that the Roll and Tilt outputs are as follows:
Roll = 90° ± 0.5°
Tilt = 90° ± 0.5°
Next, roll the probe counterclockwise (looking towards the tool bottom) about its X axis in increments of 90° and verify that for each position the roll angle increments in succession to 0°, 270° and 180° while the tilt remains 90° ± 0.5°.
To verify inclination at 0° and 90°, position the probe so that the X axis is pointed down (0° inclination) and then horizontal (90°).
To verify azimuth accuracy, a good compass and an area free from magnetic materials should be used. Use a compass to orient the probe horizontal and North and verify that the azimuth reading is 0° ± 1°. Repeat the procedure for East, South and West directions.

5.2 Rolling Test – Azimuth And Tilt Check

Azimuth and tilt can be tested by rotating the tool about its long axis while maintaining both a constant inclination to the vertical, say 15°, and a fixed azimuth. The data imported into WellCAD should show a deviation of the azimuth less than the limit of ±2.5° and a deviation of the tilt less than the limit ±0.5°.

6 Maintenance

The QL40 OBI-2G optical televiewer is a delicate instrument and should be treated with care at all times. Excessive shock or temperatures should be avoided and the tool should always be carried in its transport case or a similarly cushioned enclosure. Never support the tool on its optical head that is the weakest part of the tool, and be particularly careful to avoid scratching the optical window.

6.1 Tool Top Adapter

The tool top adapter provides the connection between wireline cable head and chassis electronics and can be provided to suit 7 conductors, 4 conductors, mono or special wireline configurations. The adapter is fixed by the means of a threaded ring screwed in the pressure housing. To remove the tool top adapter, use the correct C spanners provided with the tool - see picture below (Figure 6-2).

Figure 6-1 *Removing the tool top*

The wireline cable head socket and tool top adapter connector pins should be checked for cleanliness before each use of the tool. The pin inserts, whether 4 or 7 pin, have a locating mark indicating WL1 or A that should line up with the slot mating with the cable head.

Check O-Ring seals and apply silicon grease before re-assembly. Silicon grease of a similar type to RS Components Ref 494-124 is suitable for this and other O-Ring seals.
(Rem: O-Ring reference for tool top and for the quick link 40 is AS215 26,57 x 3,53 Viton Shore 75)

6.1.1 Locking Ring assembly Maintenance

Tools required:

1.5mm Allen wrench
2 ea 40-42mm spanner wrench
Clean rags

Replacement Parts:

ALT26005, Large Threaded Ring, Qty 2
28-174-995 M2x8 SHCS, Qty 2

Disassembly:

Unscrew and remove the two M2x8 socket head cap screws and separate the two halves.
Four guide pins align the two ring halves and tend to hold them together after the screws are removed. To pry the halves apart you can use a pair of spanner wrenches inserted into the wrench holes on opposite sides of the ring mating surfaces to pull them apart slightly.
<u>Do this carefully to prevent bending the guide pins</u>.

Figure 6-2 *Disassembly of the locking ring –step 1*

Place something small in the opening and move the spanners to the other side and pry it open slightly. This should be enough to release the two rings as below.

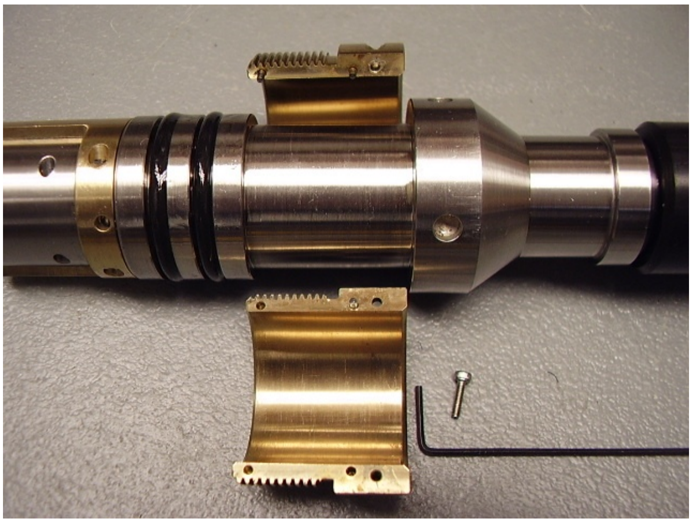


Figure 6-3 *Disassembly of the locking ring –step 2*

Clean inside surfaces thoroughly and reassemble, coating the inside with a very light film of anti-seize compound. Nickel based compounds are best, to prevent any sticking between the brass and steel surfaces

6.2 Pressure housing

Warning: Removing the electronic chassis from pressure housing without prior consultation with ALT will void the tool warranty.
Disassembly of the electronic chassis from the pressure housing should never be attempted in the field.

Should it become necessary to open the tool, the tool parts must be separated in the following sequence:

1. Remove the tool top adapter
2. Unscrew the pressure housing from the optical system brass interface

Before screwing back the pressure housing make sure that the threads on the brass interface are clean and properly greased with anti-seized compound. Once fully screwed on verify the correct alignment between the pressure housing and orientation key of the multi-pin Lemo connector as shown on Figure 6-4.

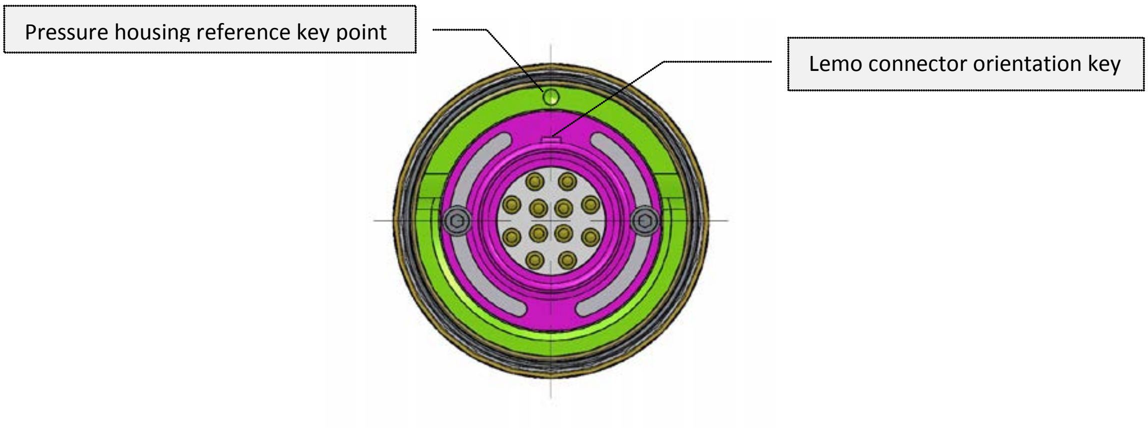


Figure 6-4 *Pressure housing top view* - *Correct orientation of the pressure housing and Lemo connector*

6.3 Optical system

It is strongly recommended to inspect the integrity of the glass sleeve before each run. **Never immerse the tool in a borehole if any defect or crack is visible in order to avoid irreversible damage to the tool.** Replace the sleeve with a spare one if necessary.

O’rings must be checked on a regular basis and replaced if required with AS122-V-75 (Oring viton 28.25x2.62 75°).

Always use the ALT standard key screws B48-22 to fix the glass sleeve on the tool. The size and shape of the screws are specifically designed for this purpose. Spare screws are usually provided with the tool spare kit.
Note that the use of a different screw model may damage the glass sleeve when exposed to pressure and will void the tool warranty.

7 Troubleshooting

Observation	**To Do**
Tool not listed in Tool panel drop down list.	- Do you have a configuration file? - Has the configuration file been copied into the …/Tools folder (refer to logger manual about details of the directory structure)?
Tool configuration error message when powering on the tool.	- Check all connections. - Adjust the telemetry settings for your wireline configuration (see chapter 4.2 or 4.3) and store the new settings as default. Apply the appropriate tool settings for your logging run (see chapter 4.5).
Tool panel - No current.	- Verify that the wireline armour is connected to the logging system. Test your interface cable between winch and data acquisition system. - Verify cable head integrity. - Verify voltage output at the cable head (it should be 120V).
Tool panel - Too much current (red area).	**! Immediately switch off the tool !** -Possible short circuit (voltage down, current up): Check for water ingress and cable head integrity - wireline continuity. - Verify the interface cable between winch slip ring and data acquisition system is not loose at the connectors. Check for possible source of a shortcut. - If the above shows no issues, use test cable (provided by ALT/MSI as an option) to verify tool functionality. - If the problem still occurs, please contact service centre.
Telemetry panel - status shows red.	- Verify the telemetry settings for your wireline configuration (see chapter 4.2 or 4.3). - If problem cannot be resolved contact support@alt.lu or tech.support@mountsopris.com
Telemetry panel - memory buffer shows 100%.	- Indicates that the systems internal memory buffer is full. PC can't receive incoming data streams fast enough. Ensure your PC has enough resources available.
Telemetry panel – bandwidth usage shows 100%. *(Overrun error message.)*	- Set the baudrate to highest value allowed by your wireline configuration. - Reduce logging speed, decrease azimuthal resolution and/or increase vertical sample step.
Telemetry panel - large number of errors.	- Verify the telemetry settings for your wireline configuration (see chapter 4.2 or 4.3). - Check bandwidth usage and telemetry error status.

Black image – the light source stopped working.	Verify the temperature of the image sensor in the MCHNUM browser. The light source is automatically switched off when the temperature of the image sensor reaches 105°C. Cool down the tool.

8 Appendix

8.1 Parts list

Detailed part numbers and descriptions are available for tool delivery and spare part kits. Please contact support@alt.lu or tec.support@mountsopris.com for further details.

8.2 Technical drawings

The following technical drawings are available on request:

- Wiring Diagram.

Index

2PCA-1000 PolyCaliper Probe and 2CAA-1000 Caliper Probe

Mount Sopris Instrument Co., Inc.
Golden, CO U. S. A.
July 23, 2001

Table of Contents

General Information

Overview

The 2CAA-1000 Caliper and the 2PCA-1000 PolyCaliper probes measure borehole diameter with three linked arms operating a single resistive sensor. The 3 Arm Caliper data can be scaled and calibrated in inches or in centimeters. The output of the caliper has been optimized with a microprocessor generated linearization scheme to improve the accuracy of the probe over the full range of motion. The output from the probe is an anti-coincidence pulse train that has been a Mount Sopris single conductor standard for many years. The 2CAA-1000 Caliper probe requires 60-65 volts D. C. at 85 mA max. and the 2PCA-1000 requires 80-85 volts D. C. at 85 mA max. The probe can be operated with an MGX or MGXII series logger. The MGX requires operator selection of probe power. The MGX II manages the power requirements automatically.

Options

The 2PCA-1000 PolyCaliper probe can be equipped with a fluid resistivity - temperature extension (2SFB-1000) allowing the tool to be logged down measuring the fluid resistivity and temperature and then logged up measuring caliper and gamma using the 2PGA-1000 PolyGamma probe. The PolyCaliper probe can also be run without the gamma probe by using the 2ADP-1000 Poly probe to MSI single conductor adapter. Without this adapter, the PolyCaliper probe can only be run with the PolyGamma probe on the MGXII logging system. Using the 2ADP-1000 adapter the 2PCA-1000 can be operated on the older MGX logging systems.

The 2CAA-1000 Caliper probe can also be equipped with a fluid resistivity temperature extension (2SFB-1000). This system can be run with the older MGX version or the newer MGXII logging systems.

The fluid resistivity - temperature extension is a factory-installed option. Contact factory for details.

Caliper arm extensions are available for measuring holes larger than 17”. The caliper arm can be unscrewed from the short pivot arm and can be replaced with an extension. The arms are then screwed on to the end of the extension. This will allow the caliper to measure up to 30 inches. The minimum hole diameter in which the caliper can be run with the extension arms is 2.25”.

Theory of Operation

The caliper measurement is made with arms attached to a mechanical assembly that drives a linear potentiometer. A constant reference voltage is applied across the potentiometer. The D. C. output voltage from the wiper of the potentiometer is converted to a frequency. A microprocessor applies a quadratic correction to this frequency so that the frequency is linearly related to borehole diameter. Depending on the polarity of the probe power, the microprocessor selects two frequencies to be transmitted up the cable line. The frequencies correspond to the caliper and natural gamma measurements (when 2PGA-1000 is attached), or the temperature and fluid resistivity measurements (when the 2SFB-1000 is attached). The processor controls the pulse driver circuit that sends positive pulses up the cable line for the first frequency, and negative pulses for the second frequency. An anti-coincidence circuit insures that a positive and negative pulse will not occur simultaneously. The microprocessor also controls the motor that opens and closes the caliper mechanism. The mechanism opens or closes as appropriate when power is applied.

Specifications

	2CAA-1000		**2PCA-1000 w/2ADP adapter (no Gamma)**	
Length:	59.5”	151 cm	60.5"	153 cm
Diameter:	1.5"	38.1mm	1.5"	38.1mm
Weight:	13.0 lbs.	5.9 Kg	13.0lbs	5.9 Kg

The PolyGamma probe adds about 6 lbs (2.72Kg) and 24” (61cm)
The temperature - fluid resistivity extension adds 3 lbs (1.36Kg) about 12.25” (31cm)

Caliper measurement: 1.5" to 17"
38.1mm to 431.8mm

Operating Procedure With the MGX logger

Operation

> **Caution!** Never lower the probe in the hole with the arms open. Caliper logs must be made while logging up, as moving the probe in the down direction with the arms open can damage the caliper mechanism.

Probe File (driver) selection

Name	**Measurement**	**Reference**
2CAA-1000 Caliper	3-Arm Caliper	4.55 Ft (or 1.39M) from Top

If the probe is to be operated with a system other than the MGX series loggers consult the factory for proper operating procedures. If the fluid resistivity - temperature extension has been installed and you wish to make these measurements while descending select the **2CAA-1000/F Temp. F. Res** probe file. Apply power to the probe by moving the probe select switch to Pulse 2 and the probe power to - (Closed). A startup cycle time of 2 minutes must elapse before the probe will be ready to log. Log the probe. Reference the Logshell documentation for additional information.

To log the caliper up the hole select the proper probe file **2CAA-1000 Caliper**. Follow the LOGSHELL instructions to execute the logging program, and either calibrate the probe (see below) or proceed to the bottom of the hole. The system must be in the log acquisition mode to be able to measure depth while descending. When bottom is reached, move the MGX Probe Select to the Pulse 2 (MOTOR) position and put the Probe Power switch in the OPEN position. This will open the caliper arms, which will take approximately 2 minutes. Notice the Probe Current light is on while the arms are opening or closing until the arms are fully opened or closed. When the Probe Current light dims or goes out, a confirmation frequency will be sent for a few seconds. This frequency will be 500 Hz after opening and 1000 Hz after the arms are closed. The probe will then begin sending caliper data as the probe is logged up the hole. Recommended logging speed is 15-20 fpm (4-6 mpm). Always slow down when entering casing to avoid possible damage to the casing shoe or the caliper.

Once logging has been completed turn off the data acquisition recording capabilities and exit the file. Place the Probe Power switch to the CLOSE position. This will close the caliper arms in about a minute and a half, indicated by the Probe Current becoming dimmer.

Calibrations

The 2CAA-1000 calibrations should be checked through the LOGSHELL software before logging. Follow the procedure above for opening the caliper, and see the section in the LOGSHELL manual for calibrations. Calibration rings should be selected which bracket the range for the log. The normal operating mode of the MGX system updates data each time the probe moves past a given depth interval. When calibrating a caliper on the surface, it is not necessary to operate the winch to update the data, as this is automatically done every 5 seconds, the default, whether the probe is moving or not. In LOG mode (as if you were getting ready to log the hole), place the small ring on the caliper and allow the arms to centrally locate within the ring. Wait about 15 seconds for the reading to stabilize. Move the cursor in the ACQSBC status screen to LftOut and type in the value (in inches or mm) that corresponds to the small ring diameter. Press F3 to copy the current value from the A/D into the LftInp column. This sets the low-end calibration value in real units to the low-end frequency generated by the probe. Next place the large ring on the probe, center the arms, and wait about 15 seconds for the reading to stabilize. Move the cursor to RgtOut, type in the value for the large ring, and press F4 to copy the current A/D value into the RgtInp column. You may wish to repeat this a few times to check the calibration. When you are satisfied that the calibrations are accurate and repeatable, Press F2 to save the cal values in the probe file. This file will be saved in the current directory, and after logging you will need to copy it to the ACQ directory to update the original probe file values that came with the LOGSHELL program. The fluid resistivity measurements should not need to be calibrated. They can be checked with fluid of known resistivity & temperature. Note that the resistivity of the fluid changes as a function of temperature.

Operating Procedure With the MGXII logger

Operation

.

Caution! Never lower the probe in the hole with the arms open. Caliper logs must be made while logging up, as moving the probe in the down direction with the arms open can damage the caliper mechanism.

Probe File (driver) selection

Select the appropriate probe file for the configuration to be operated as listed below. The required Probe files need to have been previously installed via the Logshell Configuration Menu.

To measure caliper

Name	**Measurement**	**Reference**
2PCA-1000 PolyCaliper w/ Gamma	Caliper, Gamma	Probe Top
2PCA-1000 Caliper*	Caliper	Probe Top
2CAA-1000 Caliper	Caliper	Probe Top

To measure Fluid resistivity

Name	**Measurement**	**Reference**
2PCA-1000/F PolyCaliper*	Temp, F_Res	Probe Top
2PCA-1000/F PolyCaliper w/ Gamma	Temp, F_Res	Probe Top
2CAA-1000/F Caliper	Temp, F_Res	Probe Top

- *Requires 2ADP-1000 Polyprobe to MSI single conductor adapter.

Follow the LOGSHELL instructions to execute the logging program, and either calibrate the probe (see below) or proceed to the bottom of the hole. Refer to the Logshell documentation for procedures on opening the probe (see Special Functions section) Once the arms are open the probe may be logged.

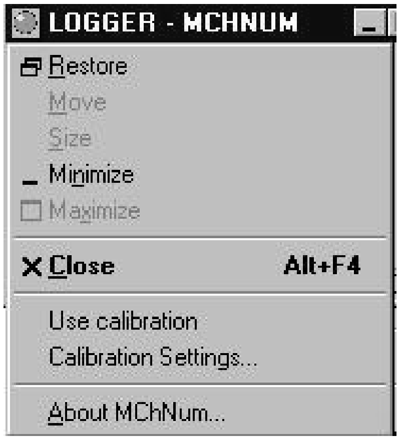
Calibrations

The 2PCA-1000 will need to be calibrated through the LOGSHELL or MSLog software before logging. Follow the procedure above for opening the caliper, and see the sections in either the LOGSHELL or MSLog manuals for calibrations. The normal operating mode of the MGX II system updates data each time the probe moves past a given depth interval. When calibrating a caliper on the surface, it is not necessary to operate the winch to update the data, as this is automatically done when using Logshell every 1 second, which cannot be changed, whether the probe is moving or not. If MSLog is used the user will need to place the acquisition in the Time Mode.

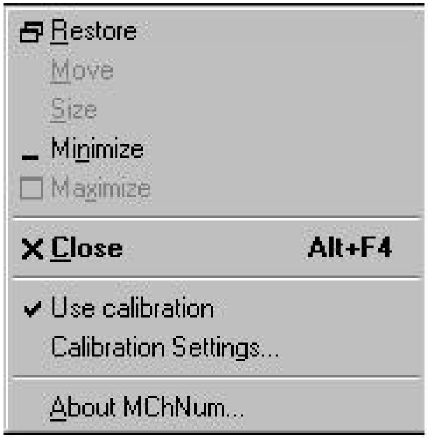
The probe is shipped with a small and a large diameter calibration ring available for calibrating the caliper. **For Logshell users;** In LOG mode (as if you were getting ready to log the hole), place the small ring on the caliper and allow the arms to centrally locate within the ring. Select the Calibrate menu item on the Main PolyLog Menu. Select the EDIT VALUES menu item and enter the values for the Low Reference and High Reference in their respective fields. These values should represent the size of your calibration rings in the engineering units you have chosen (usually inches or centimeters). You move between fields using the TAB key (Shift TAB to move back). Place the small ring on the caliper and center it between the three arms. Press F3 to write the current value of the A/D into the Low Input field. Replace the small ring with the larger ring, and Press F4 to write the current value of the A/D into the High Input field. You may wish to check each ring a few times to verify the calibration. It will take 1 second for the data to update in this mode, so be sure to wait long enough for the value to stabilize. When you are satisfied that the calibrations are accurate and repeatable, Press <Control Enter> to exit the menu and Select the SAVE VALUES bar to save the cal values in the probe file. This file will be saved in the current directory, and after logging may want to copy it to the LS directory to update the original probe file values that came with the LOGSHELL program.

The fluid resistivity and temperature measurements can be calibrated as described in the users manual for this probe extension. They can be checked with fluid of known resistivity & calibrated thermometer. Note that the resistivity of the fluid changes as a function of temperature.

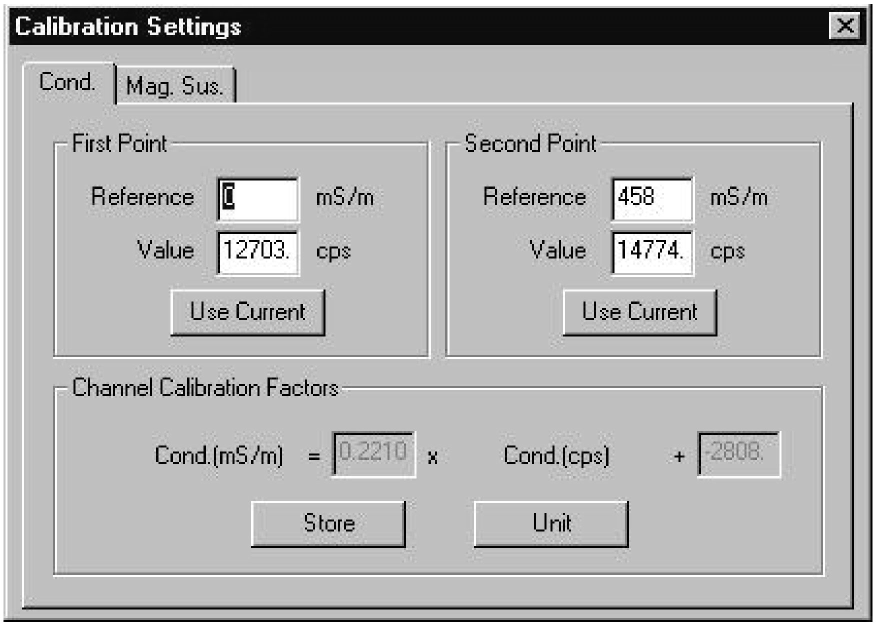
Calibration Settings for MSLog Users



Be sure that the Use Calibration ✔is OFF before proceeding! Click on the Calibration Settings line. In this dialog box, the user can select the channel to calibrate, enter the appropriate calibration values, and then store the entered values in the TOL file. The example on the following page shows a screen for an EM probe calibration, where the user placed the probe in a zero conductivity medium and pressed the button marked "Use Current Value" to set one end of the calibration, and then placed the calibration ring on the probe with a 458 mS/m response and pressed the "Use Current Value" button to set the other end of the calibration. Similar calibrations can be performed for a caliper probe, using two different known calibration ring sizes. When finished with a channel, the user should press the Store button. After finishing the calibration, the user should close the window, and **CLICK on Use Calibration, so the ✔is checked.** If another browser, like MCHCURVE, is running, the user will have to Stop and Start the browser again to make it read the new calibrated values.



Sample Calibration Screen



First Point

Reference 0 mS/m

Value 12703. cps

Second Point

Reference 458 mS/m

Value 14774. cps

Channel Calibration Factors

Cond.(mS/m) = 0.2210 x Cond.(cps) + -2808.

Caution: The user must follow the above procedures to the letter to ensure accurate and correct calibrations. Pay close attention to the reference to the check mark (✔) setting in front of USE Calibrations. It is OFF during calibration and ON during logging.

Preventive Maintenance

The 2CAA-1000 should provide long life with only minor maintenance required to the mechanical end of the probe. Before and after each usage of the probe, using a standard automotive grease gun and M6 x 1thread fittings (replacement P.N. 28-957-001), apply grease to the two grease ports. These are located immediately above and below the arm pivot point. Close the arms to apply grease to the upper fitting and open the arms to apply grease to the lower fitting. Remove the two grease fittings and install M6 X 6 SS Set Screws (replacement P.N. 28-185-549) as plugs in the holes before operating the probe in a well. After each log, when possible, clean and flush mud and or contaminants out of the caliper arm assembly. When the caliper arms are open inspect the mechanism on the arms to see if there is adequate grease for lubrication. If not re apply grease.

We recommend Dow Corning DC-111 silicone grease for use in water wells. DC-111 is approved for incidental contact with food. There are a number of other greases that will work. High resistance to water washout and temperature range being the prime considerations in their selection. Any grease used should be compatible with the Buna N o-rings. Buna N o-rings are recommended for: Petroleum oils and fluids, cold water, silicone greases and oils, Di-ester base lubricants (MIL-L-7808), Ethylene glycol base fluids (Hydrolubes). It is not recommended for: Halogenated hydrocarbons (nitrobenzene, aniline), Nitro hydrocarbons (nitorbenzene, aniline), Phosphate ester hydraulic fluids (Skydrol, Fyrquel, Pydraul), Ketones (MEK, acetone), strong acids, ozone, and automotive brake fluid.

Keep all thread and o-ring surfaces clean and dry. Re-apply grease or silicone compound (o-rings) on a regular basis. If 2SFB-1000 is attached always flush and clean the fluid resistivity/temperature sensor section after each use, and dry thoroughly before storage to insure accurate measurements.

If electronic troubleshooting becomes necessary it should only be performed by qualified persons or someone that is comfortable with the task.

To access the inside of the probe, the probe top can be removed from the main housing. For the 2CAA-1000, three screws are removed by rotating them counter (anti) clockwise using an M3 hex wrench. For the 2PCA-1000, the three captive screws are rotated clockwise, using an M4 hex head wrench, until they clear the outer housing.

WARNING: The three screws in the 2PCA-1000 Poly top are tight when they are fully counter (anti) clockwise. If they are turned to far clockwise the 2PCA-1000 probe housing will disconnect from the Poly top and can then fall off. **Before disassembling the probe, contact the factory for assistance.**

Next the housing can be unscrewed from the lower section of the probe. The PCB is located at the top end of the inner housing with the motor just below the PCB. In the middle of the PCB are rods, which drive measurement circuits and sensors for control switches that control the open and close positions. Just above where the housing threads are located is the linear potentiometer. When required, feed through wiring is then carried to the bottom of the probe for the 2SFB-1000.

Common electronic problems are a broken or shorted wire. A visual inspection of the wiring should be performed before further testing is done.

If electronic testing is to be done a copy of the schematics is highly recommended before proceeding any further. Depending on the nature of the problem checking things like regulator voltages and pulse outputs is recommended to locate the problem.

Schematics

Drawing Number	Title
0500S-2097 - 1	Poly Caliper power supply
0500S-2097 - 2	Poly Caliper limit switch & v/f
0500S-2097 - 3	Poly Caliper processor & driver circuit

Appendix

Suggested QA Procedure

Regular calibration of the caliper response will provide accurate, high quality hole diameter information. Be sure to use calibration standards which are rigid and whose dimensions can be traced to a high degree of precision. The caliper mechanism will normally have some “play” due to mechanical tolerances, but the spring tension will provide for accurate measurements with a minimum of maintenance. Cleaning and greasing the mechanical section on a routine basis will insure repeatable results.

General notes for Quality Assurance are presented here for users who need to utilize these techniques when collecting data. These users will need to periodically calibrate their equipment using equipment whose calibration is traceable to an approved standard. Details of these calibrations must be recorded.

When an instrument is calibrated, records need to be kept regarding the calibration standard(s) used and what was changed on the instrument to calibrate it. Typically, the corrections made to the instrument, involve changing constants that are used to scale the raw instrument reading so that the proper value is reported. The constants must be recorded during a calibration procedure. The Mt. Sopris acquisition software provides records of calibration constants. This aids the QA process, but does not replace the need for recording these constants at the time of calibration. The reason for this is that the length of time since the last calibration is unknown with only this information.

The device providing the standard must be traceable to an accepted standard. Examples of organizations providing standards for measuring instrumentation are: The U. S. National Bureau of Standards; The American Petroleum Institute; and the American Society for Testing Materials. For example, if the voltmeter or the density standard used for calibration is not traceable to an approved organization, such as those listed above, the calibration should not be considered valid. Records should be kept indicating the last time that standard being used for calibration was calibrated or checked against an approved standard. The QA procedure necessary for some programs mandate that the calibration standards be periodically checked against a standard approved by a proper agency.

A QA procedure may dictate that data taken from a given locale be associated with records indicating the exact time and location that the data was collected. The data itself may have to be collected in a certain format to meet requirements. Often, QA procedure specifies that surveys must be repeated and the data from the successive surveys compared. This technique is used to eliminate poor or invalid data.

MODERN BOREHOLE LOGGING SYSTEMS AND SERVICES

W&R
instruments

HM – 320

MAGNETIC SUSCEPTIBILITY PROBE

Serial No. A513

Technical Data Manual

W&R instruments s.r.o. * Ječná 29a * 621 00 Brno * Czech Republic
Phone/fax: ++420 541 634 204 * e-mail: sales@wr-instruments.com * www.wr-instruments.com

GENERAL

The probe HM-320 is designed for measurement of magnetic susceptibility of rocks in boreholes. The susceptibility is an excellent indicator of lithology. That measured to distinguish the types of rocks in the borehole profile in a complex of sedimentary rocks , igneous or metamorphic rocks up to magnetite rocks. The response of the probe is practically instantaneous (<0.5s).

SPECIFICATIONS

Probe Parameters:

Diameter	32 mm
Length	99 cm
Weight	2 kg
Max. Working Temperature/Pressure	70°C/10 MPa
Min.No. of Cable Conductor	2
Supply Voltage Range	30 - 45 V_{DC}
Maximum/Nominal Current Consumption	110/70 mA_{DC}
Supply Voltage Polarity	+ on central cond. - on probe shell

Measuring Parameters:

Sensor	two coil system
Intercoil Spacing	10 cm
Operating Frequency	≈ 1700 Hz
Range	10^{-5} - 0,5 SI unit
Accuracy	3 %
Communication (negative pulse)	0 - 20 000 cps

Data Transfer Parameters:

Pulses of amplitude of 20Vpp and width 5 µsec superimposed to the positive supply voltage (30 - 45 V_{DC}).

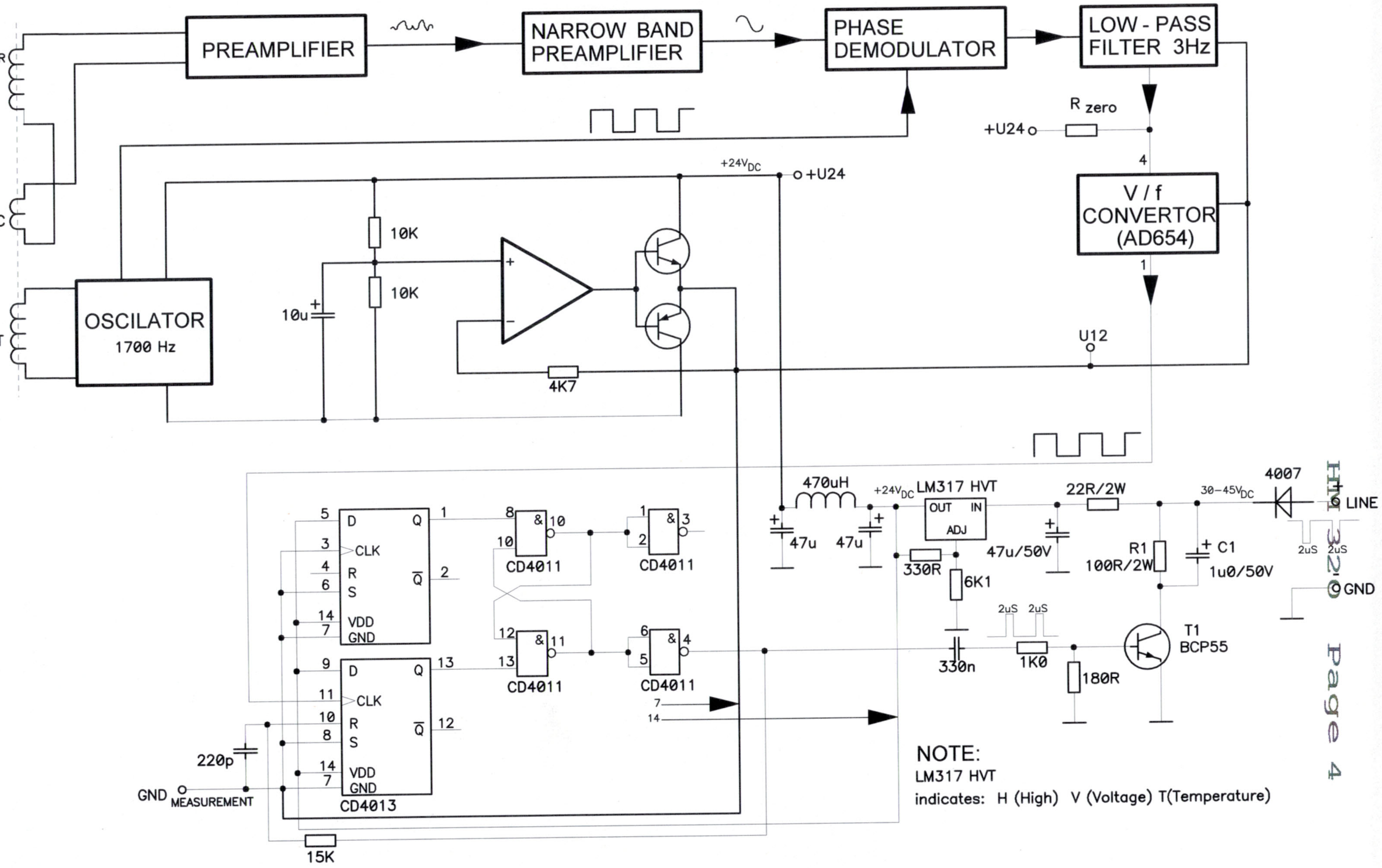
Accessories:

Magnetic Etalons: ....10 ·...........10^{-3} SI units

DESCRIPTION OF THE PROBE ELECTRONICS

Transmitting coil L_T, placed in the lower part of the probe, forms together with IC4 an oscillator (see page 4) which generates an exciting electromagnetic field of the system. Receiving coil L_R placed at the middle part of the probe, is connected to the input amplifier IC1. Compensating coil L_C, placed in the same position as the transmitting coil is also connected to the input amplifier. Direct signal from L_T to L_R is compensated by the voltage obtained on the divider R1 - R2. The coil L_R with capacitor C_7 form a serial resonating circuit and therefore a measured mag. susceptibility signal is of the same phase as a voltage in compensating and transmiting coil. The measured signal, amplified by IC1 and IC2 is fed to the input resistances of phase demodulator (R5, R8). The phase demodulator, that processes signal mag. susc., is controlled by rectangular voltage from the output of IC4. The value of DC voltage of demodulator output is directly proportional to measured mag. susceptibility of rocks. Frequency level of the V/F convertor IC5 is shifted by means of voltage on R_{15} in such a way the zero signal voltage on V/F convertor input is shifted approximately by 1% of the convertor's dynamic range. The signal from output of V/F convertor is shaped to the width of 2µsec and is-via transistor T2 it is superimposed the power supply conductor of the cable.

PROBE HM 320



NOTE:
LM317 HVT
indicates: H (High) V (Voltage) T(Temperature)

CALIBRATION

The probe is powered by supply of voltage 30 - 45 V_{DC} via resistor of approx. 20 Ohms value. A frequency counter is connected to the output of the probe. The discrimination level of the frequency counter must be manually set at negative pulses.

Calibration procedure:

1. Zero check with the probe placed in free space with no metal objects in proximity; for the zero the output frequency is set by the manufacturer to ...746...cps.

2. Frequency response of the probe is calibrated by putting consequently mag. etalons to the center of the probe coil system. Single etalons or their combination may be used. Frequency swing was set by the manufacturer to .....56,4..... cps./10^{-3} SI units.

Comment: The center of the coil system is 26.. cm from the tip of the probe.

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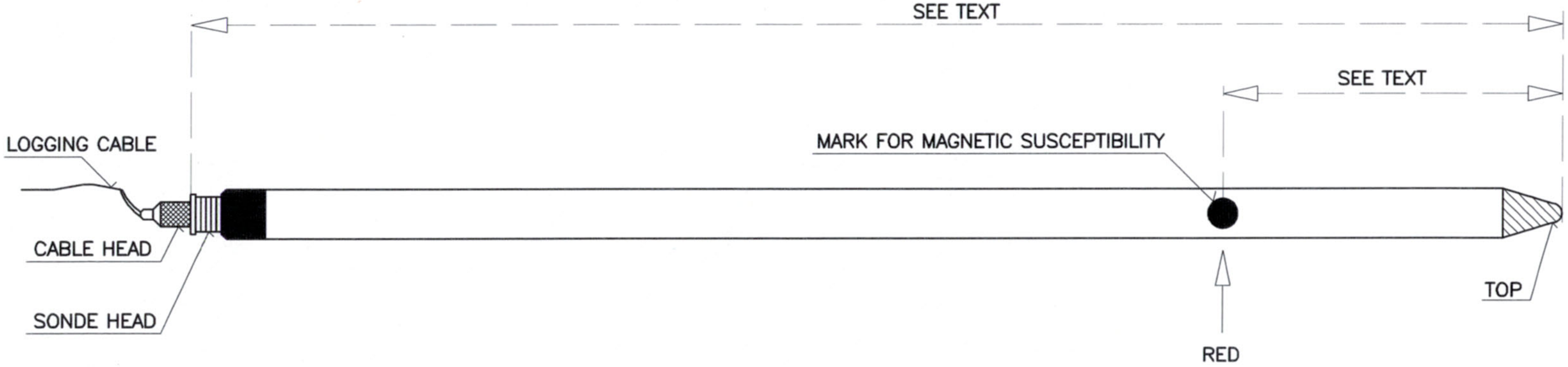
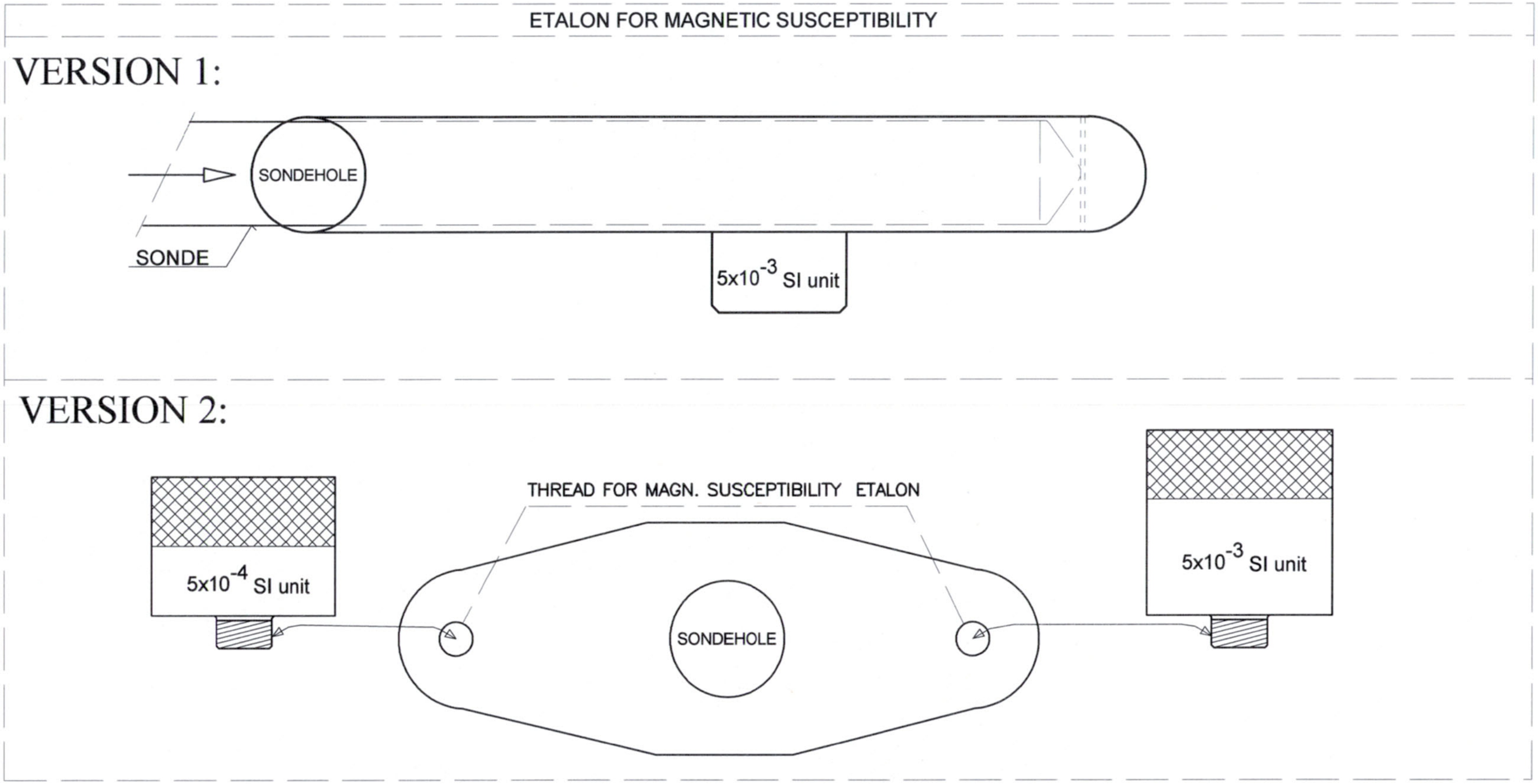
Ječná 29a, 621 00 BRNO

13 -06- 2011

Tesař

CALIBRATION of MAGNETIC SUSCEPTIBILITY PROBE - HM 320 (E)





fosc =1569Hz

PROBE: HM 320

DATE: 14.06.2011

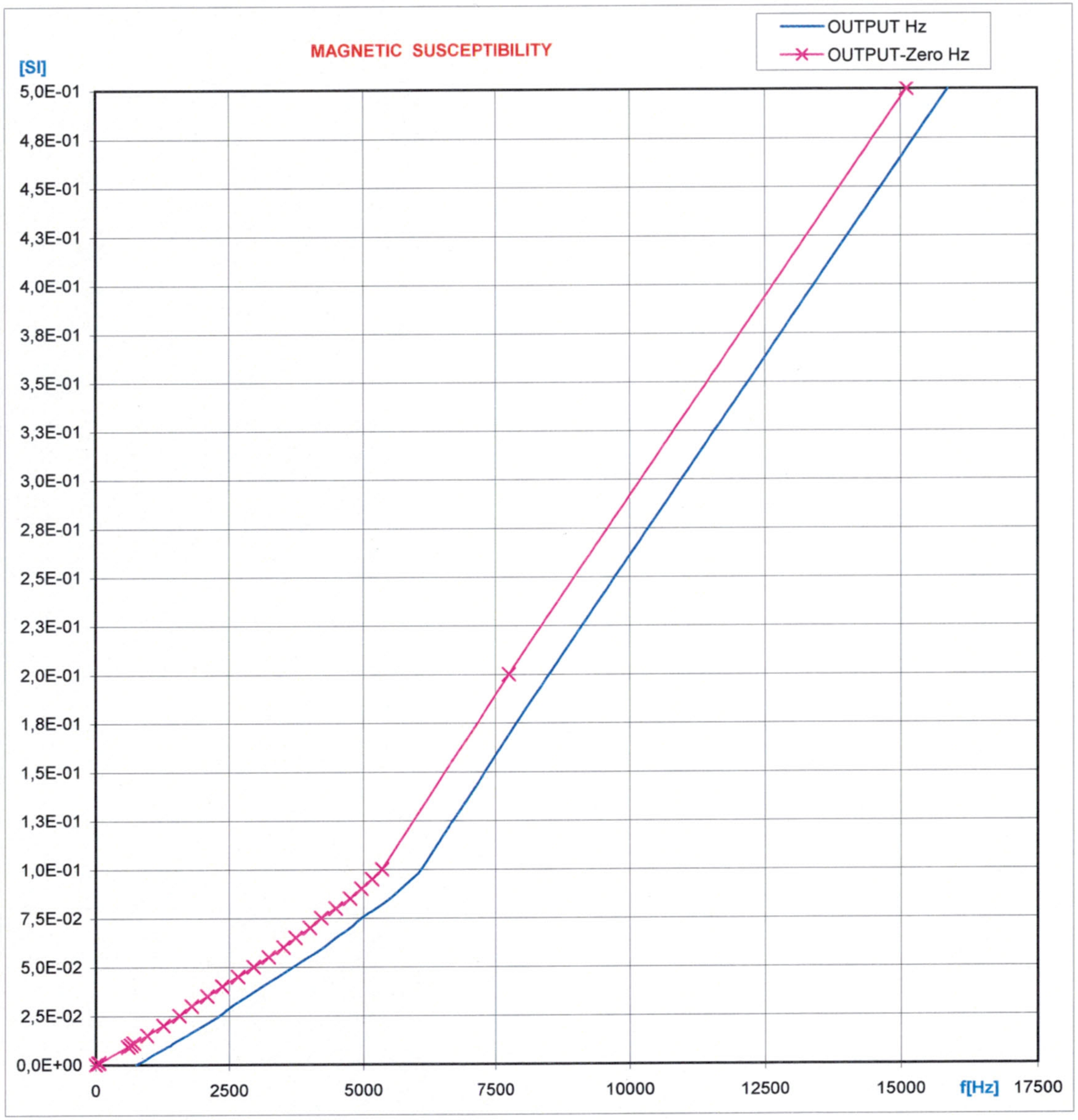
SN.: A513 (AUSLOG)

The measurement center of coil system is 26cm from the tip of the probe.

MAGNETIC SUSCEPTIBILITY MEASUREMENT

(negative pulses - amplitude: 20Vpp / width: 5µS)

ETALON	OUTPUT	OUTPUT-Zero	Frequency swing
SI	Hz	Hz	Hz/10E-3 SI
0	746	0	*
8,20E-04	803	57	69,51
8,70E-04	807	61	70,11
1,00E-03	812	66	66,00
9,10E-03	1347	601	66,04
1,00E-02	1405	659	65,90
1,10E-02	1451	705	64,09
1,50E-02	1706	960	64,00
2,00E-02	2020	1274	63,70
2,50E-02	2320	1574	62,96
3,00E-02	2547	1801	60,03
3,50E-02	2838	2092	59,77
4,00E-02	3120	2374	59,35
4,50E-02	3415	2669	59,31
5,00E-02	3702	2956	59,12
5,50E-02	3986	3240	58,91
6,00E-02	4268	3522	58,70
6,50E-02	4492	3746	57,63
7,00E-02	4759	4013	57,33
7,50E-02	4967	4221	56,28
8,00E-02	5238	4492	56,15
8,50E-02	5502	4756	55,95
9,00E-02	5711	4965	55,17
9,50E-02	5909	5163	54,35
1,00E-01	6099	5353	53,53
2,00E-01	8514	7768	38,84
5,00E-01	15863	15117	30,23



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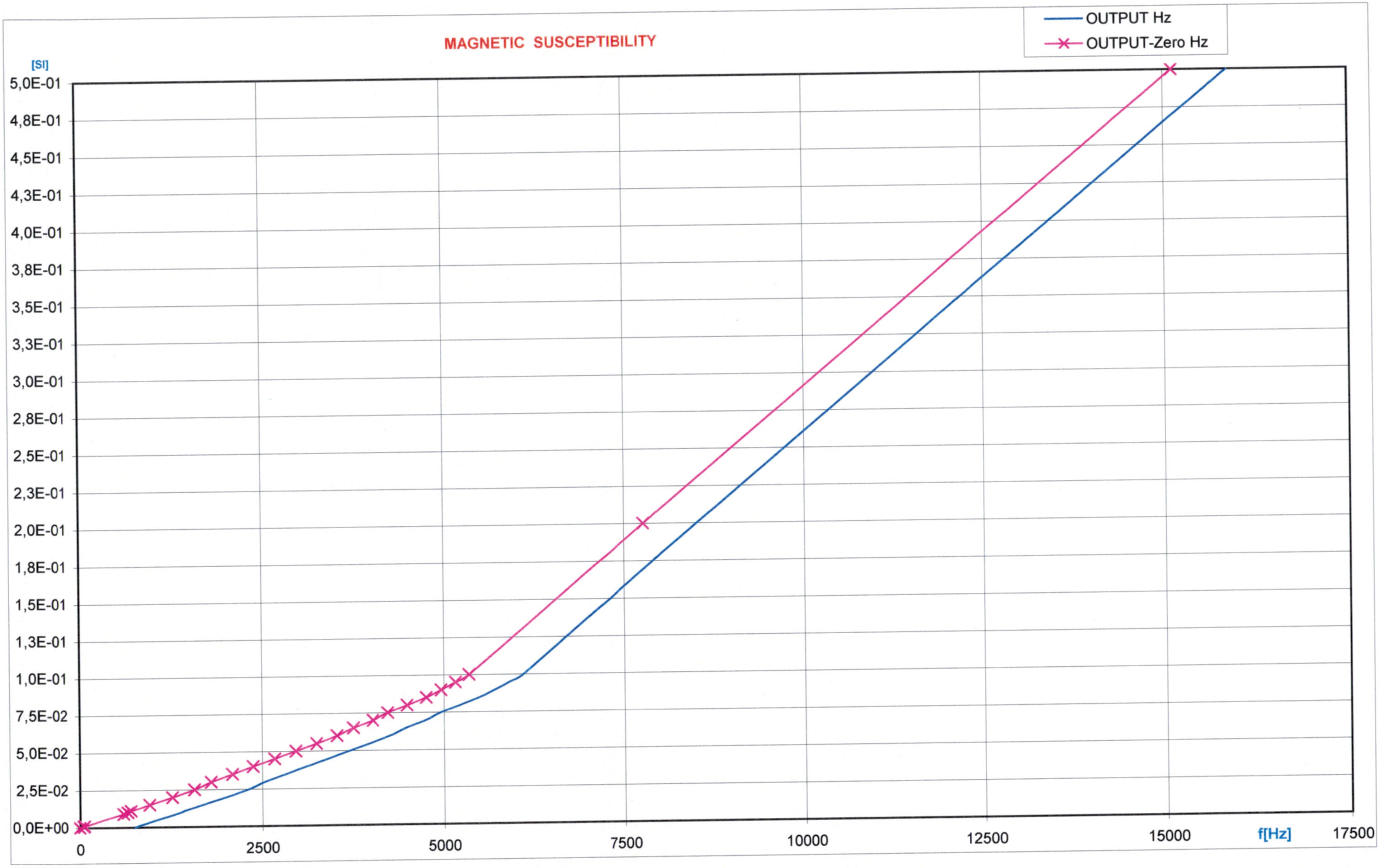

13 -06- 2011

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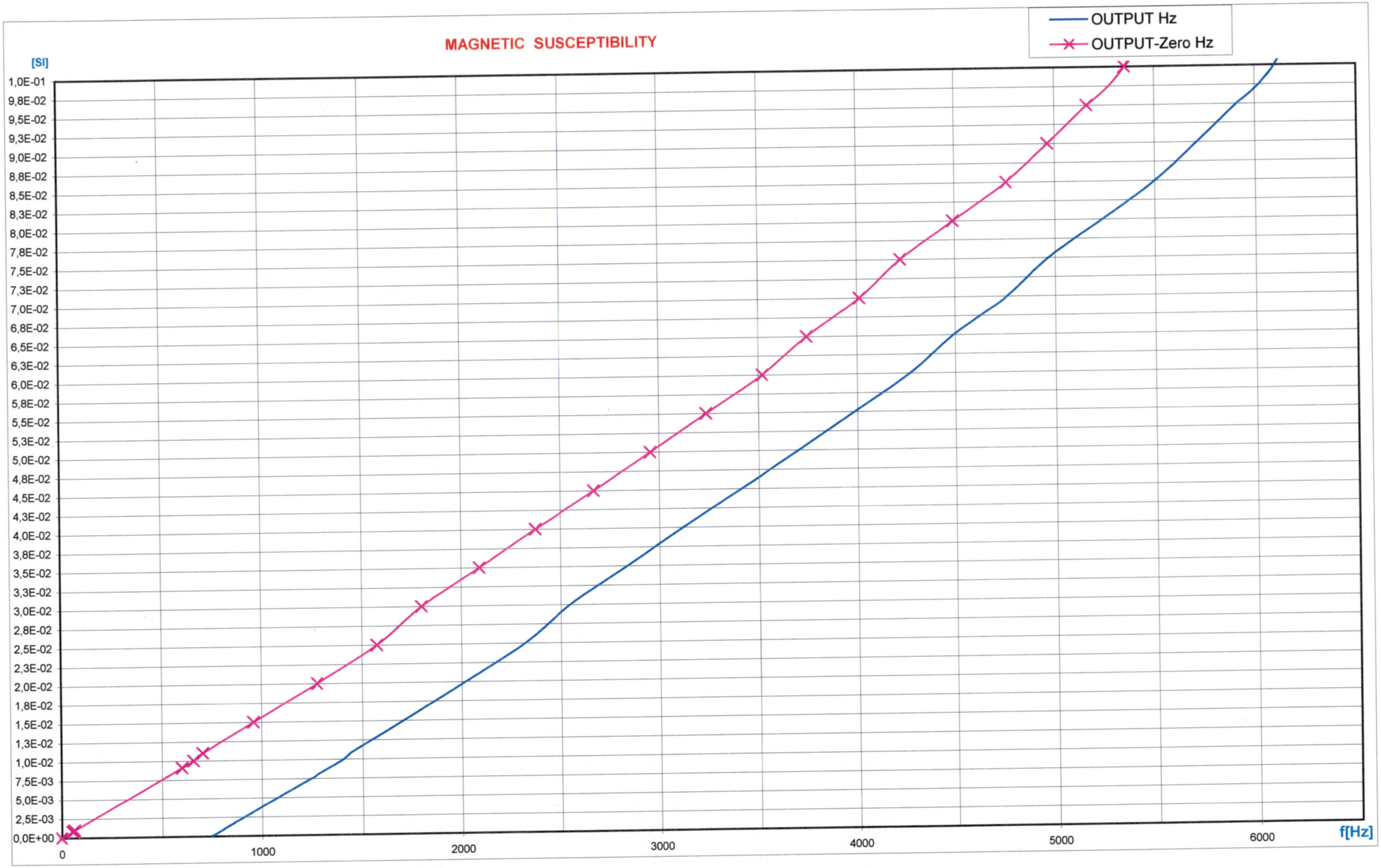
Ječná 29a, 621 00 BRNO



13 -06- 2011

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Ječná 29a, 621 00 BRNO

The instrument
was
developed and manufactured
by

W&R instruments s.r.o

Ječná 29 a , 62100 BRNO
Czech Republic

Phone/Fax: ++420 541 634 204
++420 532 150 204
e-mail : sales@wr-instruments.com
http://www.wr-instruments.com

APPENDIX C

Records of Geophysical Logging

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

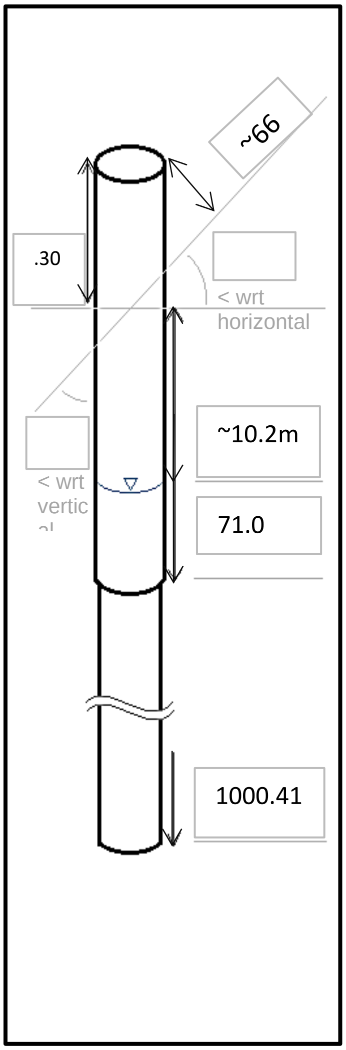
TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches
CC: Joe Carvalho
George Schneider

Date / Shift: *28 Nov 2019/01*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Tool Data

Run	Probe Name	Serial Number	Tool Offset (m)	Sampling Interval (m)	Logging Speed (m/min)	Expected Run	
						Top	Bottom
01-1	2CAA-1000	5032	2.21	0.0496	10	2.21	1000
01-2	2CAA-1000	5032	2.21	0.0496	20	1000	1.55
01-3	2CAA-1000	5032	2.21	0.0496	10	2.21	1000
01-4	2CAA-1000	5032	2.21	0.0496	20	1000	1.02
01-5	2CAA-1000	5032	2.21	0.0496	10	2.21	1000.03
01-6	2CAA-1000	5032	2.21	0.0496	20	1000.03	1.21
01-7	2CAA-1000	5032	2.21	0.0496	10	68	1000
01-8	2CAA-1000	5032	2.21	0.0496	20	1000	67.9
01-9	2CAA-1000	5032	2.21	0.0496	10	68	1000.06
01-10	2CAA-1000	5032	2.21	0.0496	20	1000.06	67.18
01-11	2CAA-1000	5032	2.21	0.0496	10	68	1000.11



Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou

Job Number: 1671632a
Project: WP5 Borehole Geophysical Logging
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *28 Nov 2019/01*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.30**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**-0.20**	**BH Winch Offset from Borehole (m)**	**~4m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**71.0**		

Client: NWMO
Job Number: 1671632a
Location: Ignace – BH02
Project: WP5 Borehole Geophysical Logging
Prepared by: Olga Fomenko, Peter Giamou
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 01.1 Field Notes

Probe	2CAA-1000
Start Time	01:40
End Time	06:00
Run Direction	Down
Probe Temp Before	-0.8
Probe Temp After	n/a
Location Temp Before	10.8
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21
START (data)	2.21
END (data)	1000.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_01-1_112819.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 01.2 Field Notes

Probe	2CAA-1000
Start Time	06:25
End Time	07:20
Run Direction	Up
Probe Temp Before	-0.8
Probe Temp After	?
Location Temp Before	10.8
Location Temp After	?
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21
START (data)	1000.00
END (data)	1.55
Probe Point at Collar (end) or Wireline Marker	1.55
File Name	IG_BH02_WP05_2CAA_01-2_112819.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *28 Nov 2019/01*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run 01.3 Field Notes

Probe	2CAA-1000
Start Time	07:30
End Time	09:22
Run Direction	Down
Probe Temp Before	-0.8
Probe Temp After	?
Location Temp Before	10.8
Location Temp After	?
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21
START (data)	2.21
END (data)	1000.0
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_01-3_112819.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou

Job Number: 1671632a
Project: WP5 Borehole Geophysical Logging
Verified by: Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 01.4 Field Notes

Probe	2CAA-1000
Start Time	09:25
End Time	
Run Direction	Up
Probe Temp Before	-0.8
Probe Temp After	?
Location Temp Before	10.8
Location Temp After	?
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	
START (data)	1000.00
END (data)	1.02
Probe Point at Collar (end) or Wireline Marker	1.02
File Name	IG_BH02_WP05_2CAA_01-4_112819.tfd
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Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 01.5 Field Notes

Probe	2CAA-1000
Start Time	11:20
End Time	13:05
Run Direction	Down
Probe Temp Before	-0.8
Probe Temp After	?
Location Temp Before	10.8
Location Temp After	?
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	
START (data)	2.21
END (data)	1000.03
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_2CAA_01-5_112819.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 01.6 Field Notes

Probe	2CAA-1000
Start Time	13:15
End Time	14:17
Run Direction	Up
Probe Temp Before	-0.8
Probe Temp After	?
Location Temp Before	10.8
Location Temp After	?
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	
START (data)	1000.03
END (data)	1.21
Probe Point at Collar (end) or Wireline Marker	1.21
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Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn Aaron DesRoches	**Date / Shift:**	*28 Nov 2019/01*
		Work Package:	WP5 – Borehole Geophysical Logging
CC:	Joe Carvalho George Schneider	**Distributed By:**	Email

Run 01.7 Field Notes

Probe	2CAA-1000
Start Time	17:35
End Time	19:17
Run Direction	Down
Probe Temp Before	-0.8
Probe Temp After	?
Location Temp Before	10.8
Location Temp After	?
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	
START (data)	68.00
END (data)	1000.00
Probe Point at Collar (end) or Wireline Marker	
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Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 01.8 Field Notes

Probe	2CAA-1000
Start Time	19:18
End Time	20:17
Run Direction	Up
Probe Temp Before	-0.8
Probe Temp After	?
Location Temp Before	10.8
Location Temp After	?
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	
START (data)	1000.00
END (data)	67.9
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_2CAA_01-8_112819.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 01.9 Field Notes

Probe	2CAA-1000
Start Time	20:23
End Time	22:08
Run Direction	Down
Probe Temp Before	-0.8
Probe Temp After	?
Location Temp Before	10.8
Location Temp After	?
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	
START (data)	68.00
END (data)	1000.06
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_2CAA_01-9_112819.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 01.10 Field Notes

Probe	2CAA-1000
Start Time	22:55
End Time	23:21
Run Direction	Up
Probe Temp Before	-0.8
Probe Temp After	?
Location Temp Before	10.8
Location Temp After	?
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	
START (data)	1000.06
END (data)	67.18
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_2CAA_01-10_112819.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 01.11 Field Notes

Probe	2CAA-1000
Start Time	23:30
End Time	01:10
Run Direction	Down
Probe Temp Before	-0.8
Probe Temp After	?
Location Temp Before	10.8
Location Temp After	?
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	
START (data)	68.00
END (data)	1000.11
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_2CAA_01-11_112819.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

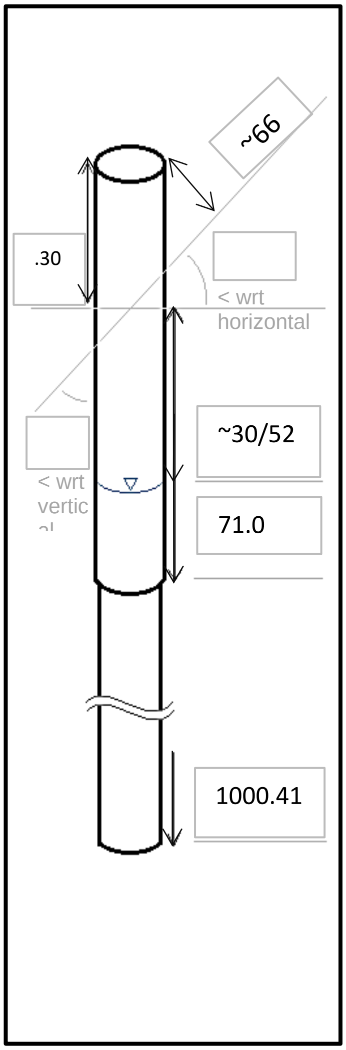
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *29 Nov 2019/01*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Tool Data							
Run	**Probe Name**	**Serial Number**	**Tool Offset (m)**	**Sampling Interval (m)**	**Logging Speed (m/min)**	**Expected Run**	
						Top	**Bottom**
02-1	2CAA-1000	5032	2.21	0.0496	20	1000.00	68.00
02-2	2CAA-1000	5032	2.21	0.0496	10	68.00	1000.00
02-3	2CAA-1000	5032	2.21	0.0496	20	1000.00	65.39
02-4	2CAA-1000	5032	2.21	0.0496	10	68.00	1000.00
02-5	2CAA-1000	5032	2.21	0.0496	15	1000.00	66.47
02-6	2CAA-1000	5032	2.21	0.0496	10	68.00	1000.00
02-7	2CAA-1000	5032	2.21	0.0496	18	1000.00	66.79
02-8	2CAA-1000	5032	2.21	0.0496	10	68.00	1000.02
02-9	2CAA-1000	5032	2.21	0.0496	20	1000.02	66.61
02-10	2CAA-1000	5032	2.21	0.0496	10	68.00	1000.04
02-11	2CAA-1000	5032	2.21	0.0496	20	1000.04	66.75
02-12	2CAA-1000	5032	2.21	0.0496	20	1000.20	66.65
02-13	2CAA-1000	5032	2.21	0.0496	10	68.00	1000.12
02-14	2CAA-1000	5032	2.21	0.0496	20	1000.12	66.63
02-15	2CAA-1000	5032	2.21	0.0496	10	68.00	1000.06



Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: WP5 Borehole Geophysical Logging
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches
CC: Joe Carvalho
George Schneider

Date / Shift: *29 Nov 2019/01*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.30**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**-0.20**	**BH Winch Offset from Borehole (m)**	**~6.5m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**71.0**		

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: WP5 Borehole Geophysical Logging
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*29 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.1 Field Notes

Probe	2CAA-1000
Start Time	01:23
End Time	02:20
Run Direction	Up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21
START (data)	1000.00
END (data)	68.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-1_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn Aaron DesRoches	**Date / Shift:**	*29 Nov 2019/01*
		Work Package:	WP5 – Borehole Geophysical Logging
CC:	Joe Carvalho George Schneider	**Distributed By:**	Email

Run 02.2 Field Notes

Probe	2CAA-1000
Start Time	02:23
End Time	04:04
Run Direction	Down
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21
START (data)	68.00
END (data)	1000.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-2_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*29 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.3 Field Notes

Probe	2CAA-1000
Start Time	04:10
End Time	05:13
Run Direction	Up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21
START (data)	1000.00
END (data)	65.39
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-3_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*29 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.4 Field Notes

Probe	2CAA-1000
Start Time	05:31
End Time	07:11
Run Direction	Down
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/68.0
START (data)	68.0
END (data)	1000.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-4_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

500 m mark at 499.67

Pump House frozen.

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*29 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.5 Field Notes

Probe	2CAA-1000
Start Time	07:20
End Time	09:07
Run Direction	Up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/68.0
START (data)	1000.00
END (data)	66.47
Probe Point at Collar (end) or Wireline Marker	66.47
File Name	IG_BH02_WP05_2CAA_02-5_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

500 m mark at – missed it

Wl tape stopped working at 07:53 am – a bit of delay
Issue fixed

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*29 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.6 Field Notes

Probe	2CAA-1000
Start Time	09:15
End Time	10:52
Run Direction	Down
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/68.0
START (data)	68.0
END (data)	1000.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-6_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

500 m mark at 499.76

After that run we will change drawdown from 30 m to 52 m

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*29 Nov 2019/01*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.7 Field Notes

Probe	2CAA-1000
Start Time	11:15
End Time	12:20
Run Direction	up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/68.0
START (data)	1000.00
END (data)	66.79
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-7_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

500 m mark at 498.74

Started pumping at 11:15 and stopped at 11:40 am (approx. 500 m deep)

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*29 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.8 Field Notes

Probe	2CAA-1000
Start Time	12:25
End Time	14:04
Run Direction	Down
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/68.0
START (data)	68.0
END (data)	1000.02
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-8_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

500 m mark at 499.65

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*29 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.9 Field Notes

Probe	2CAA-1000
Start Time	14:05
End Time	15:03
Run Direction	up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/68.0
START (data)	1000.02
END (data)	66.61
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-9_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:
500 m mark at 498.61

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*29 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.10 Field Notes

Probe	2CAA-1000
Start Time	15:13
End Time	16:52
Run Direction	Down
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/68.0
START (data)	68.0
END (data)	1000.04
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-10_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

500 m mark at 499.67

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *29 Nov 2019/01*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run 02.11 Field Notes

Probe	2CAA-1000
Start Time	16:55
End Time	17:43
Run Direction	Up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/68.0/66.75
START (data)	1000.04
END (data)	66.75
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-11_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: WP5 Borehole Geophysical Logging
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*29 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.12 Field Notes

Probe	2CAA-1000
Start Time	19:28
End Time	20:20
Run Direction	Up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/ 500/498.61
START (data)	1000.20
END (data)	66.65
Probe Point at Collar (end) or Wireline Marker	68.00
File Name	IG_BH02_WP05_2CAA_02-12_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Originally a down run but lost power to matrix and probe etc pushed down to bottom of the hole and came up

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*29 Nov 2019/01*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.13 Field Notes

Probe	2CAA-1000
Start Time	20:40
End Time	22:25
Run Direction	Down
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/ 500/499.55
START (data)	68.00
END (data)	1000.12
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_02-13_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*29 Nov 2019/01*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.14 Field Notes

Probe	2CAA-1000
Start Time	22:27
End Time	23:16
Run Direction	Up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/ 500/498.54
START (data)	1000.12
END (data)	66.63
Probe Point at Collar (end) or Wireline Marker	68.00
File Name	IG_BH02_WP05_2CAA_02-14_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*29 Nov 2019/01*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 02.15 Field Notes

Probe	2CAA-1000
Start Time	23:18
End Time	1:00
Run Direction	Down
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21/ 500/499.67
START (data)	68.00
END (data)	1000.06
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_2CAA_02-15_112919.tfd
Initial Calibration	IG_BH02_WP05_2CAA_RES_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_TEMP_PreCalCheck_112719.tfd, IG_BH02_WP05_2CAA_PreCalCheck_112719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

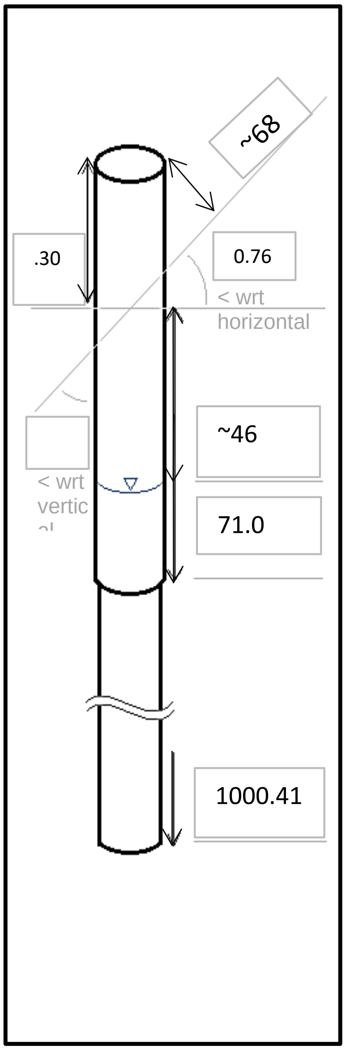
TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches
CC: Joe Carvalho
George Schneider

Date / Shift: *30 Nov 2019/03*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Tool Data

Run	Probe Name	Serial Number	Tool Offset (m)	Sampling Interval (m)	Logging Speed (m/min)	Expected Run	
						Top	Bottom
03-1	2CAA-1000	5032	2.21	0.0496	15	1000.00	66.42
03-2	2CAA-1000	5032	2.21	0.0496	9	68.00	1000.00
03-3	2CAA-1000	5032	2.21	0.0496	15	1000.00	66.74
03-4	QLABI	190404	1.24	0.05	13	1.24	293
03-5	QLABI	190404	1.24	0.05	13	293	800
03-6	QLABI	190404	1.24	0.002	2.3	800	699.99
03-7	QLABI	190404	1.24	0.05	15	699.99	998.62
03-8	QLABI	190404	1.24	0.002	2.3	998.62	630
03-9	QLABI	190404	1.24	0.05	10	1.24	998.04
03-10	QLABI	190404	1.24	0.002	2.3	998.04	485.45



Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Job Number: 1671632a
Project: WP5 Borehole Geophysical Logging
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*30 Nov 2019/03*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.30**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**-0.20**	**BH Winch Offset from Borehole (m)**	**~6.5m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**71.0**		

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*30 Nov 2019/03*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 03.1 Field Notes

Probe	2CAA-1000
Start Time	01:13
End Time	02:11
Run Direction	Up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21
START (data)	1000.00
END (data)	66.42
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_03-1_113019.tfd
Initial Calibration	
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*30 Nov 2019/03*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 03.2 Field Notes

Probe	2CAA-1000
Start Time	02:14
End Time	03:59
Run Direction	Down
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21
START (data)	68.00
END (data)	1000.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_03-2_113019.tfd
Initial Calibration	
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *30 Nov 2019/03*

Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run 03.3 Field Notes

Probe	2CAA-1000
Start Time	04:03
End Time	05:09
Run Direction	Up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.30
Probe Point at Collar (start) or Wireline Marker	2.21
START (data)	1000.00
END (data)	66.74
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_03-3_113019.tfd
Initial Calibration	
Final Calibration	

Comments:

Client: NWMO

Location: Ignace – BH02

Prepared by: Olga Fomenko, Peter Giamou

Job Number: 1671632a

Project: WP5 Borehole Geophysical Logging

Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*30 Nov 2019/03*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 03.4 Field Notes

Probe	QLABI
Start Time	13:25
End Time	14:09
Run Direction	Down
Probe Temp Before	11.8
Probe Temp After	
Location Temp Before	17.4
Location Temp After	
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.24
START (data)	1.24
END (data)	293.59
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_QLABI_03-4_113019.tfd
Initial Calibration	IG_BH02_WP05_QLABI_PreTilt_113019.tfd, IG_BH02_WP05_QLABI_PreRoll_113019.tfd
Final Calibration	

Comments:

Something weird happened to logger so I stopped the file.

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*30 Nov 2019/03*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 03.5 Field Notes

Probe	QLABI
Start Time	14:09
End Time	14:48
Run Direction	Down
Probe Temp Before	11.8
Probe Temp After	
Location Temp Before	17.4
Location Temp After	
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.24
START (data)	294.82
END (data)	800.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_QLABI_03-5_113019.tfd
Initial Calibration	IG_BH02_WP05_QLABI_PreTilt_113019.tfd, IG_BH02_WP05_QLABI_PreRoll_113019.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*30 Nov 2019/03*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 03.6 Field Notes

Probe	QLABI
Start Time	14:50
End Time	15:34
Run Direction	Up
Probe Temp Before	11.8
Probe Temp After	
Location Temp Before	17.4
Location Temp After	
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.24
START (data)	800.00
END (data)	699.99
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_QLABI_03-6_QAQC_113019.tfd
Initial Calibration	IG_BH02_WP05_QLABI_PreTilt_113019.tfd, IG_BH02_WP05_QLABI_PreRoll_113019.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*30 Nov 2019/03*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 03.7 Field Notes

Probe	QLABI
Start Time	15:35
End Time	15:59
Run Direction	Down
Probe Temp Before	11.8
Probe Temp After	
Location Temp Before	17.4
Location Temp After	
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.24
START (data)	699.99
END (data)	998.62
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_QLABI_03-7_113019.tfd
Initial Calibration	IG_BH02_WP05_QLABI_PreTilt_113019.tfd, IG_BH02_WP05_QLABI_PreRoll_113019.tfd
Final Calibration	

Comments:

Had to stop the probe at 998.62 because there is mud and smth else at the bottom of the hole and we can not deep the ABI head in it.

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*30 Nov 2019/03*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 03.8 Field Notes

Probe	QLABI
Start Time	16:00
End Time	18:39
Run Direction	Down
Probe Temp Before	11.8
Probe Temp After	
Location Temp Before	17.4
Location Temp After	
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.24
START (data)	998.62
END (data)	630.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_QLABI_03-8_113019.tfd
Initial Calibration	IG_BH02_WP05_QLABI_PreTilt_113019.tfd, IG_BH02_WP05_QLABI_PreRoll_113019.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*30 Nov 2019/03*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 03.9 Field Notes

Probe	QLABI
Start Time	20:34
End Time	21:43
Run Direction	Down
Probe Temp Before	11.8
Probe Temp After	
Location Temp Before	17.4
Location Temp After	
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.24
START (data)	1.24
END (data)	998.04
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_QLABI_03-9_Deviation_113019.tfd
Initial Calibration	IG_BH02_WP05_QLABI_PreTilt_113019.tfd, IG_BH02_WP05_QLABI_PreRoll_113019.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	WP5 Borehole Geophysical Logging
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *30 Nov 2019/03*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run 03.10 Field Notes

Probe	QLABI
Start Time	21:44
End Time	01:49
Run Direction	Up
Probe Temp Before	11.8
Probe Temp After	
Location Temp Before	17.4
Location Temp After	
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.24
START (data)	998.04
END (data)	485.45
Probe Point at Collar (end) or Wireline Marker	499.51/500
File Name	IG_BH02_WP05_QLABI_03-10_113019.tfd
Initial Calibration	IG_BH02_WP05_QLABI_PreTilt_113019.tfd, IG_BH02_WP05_QLABI_PreRoll_113019.tfd
Final Calibration	

Comments:

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou

Job Number: 1671632a
Project: WP5 Borehole Geophysical Logging
Verified by: Christopher Phillips

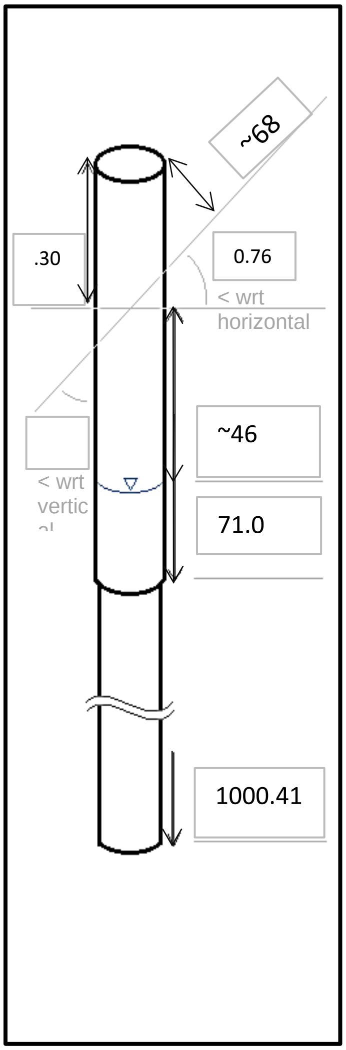
RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*1 Dec 2019/04*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Tool Data

Run	Probe Name	Serial Number	Tool Offset (m)	Sampling Interval (m)	Logging Speed (m/min)	Expected Run	
						Top	**Bottom**
04-1	QLABI	190404	1.24	0.002	2.3	487.10	1.11
04-2	QLABI	190404	1.24	0.002	2.3	76.00	69.00
04-3	QLABI	190404	1.24	0.002	2.3	733.00	726.00
04-4	QLABI	190404	1.24	0.002	2.3	686.00	672.00
04-5	QLABI	190404	1.24	0.002	2.3	617.00	610.99
04-6	QLABI	190404	1.24	0.002	2.3	601.00	587.00
04-7	QLABI	190404	1.24	0.002	2.3	578.00	565.00
04-8	QLABI	190404	1.24	0.002	2.3	487.00	480.00
04-9	QLABI	190404	1.24	0.002	2.3	420.00	397.39
04-10	QLABI	190404	1.24	0.002	2.3	402.00	393.99
04-11	QLABI	190404	1.24	0.002	2.3	380.00	368.00
04-12	QLABI	190404	1.24	0.002	2.3	372.00	362.99
04-13	QLABI	190404	1.24	0.002	2.3	358.00	340.50
04-14	QLABI	190404	1.24	0.002	2.3	331.00	321.42
04-15	QLABI	190404	1.24	0.002	2.3	323.00	313.79
04-16	QLABI	190404	1.24	0.002	2.3	307.00	297.97
04-17	QLABI	190404	1.24	0.002	2.3	288.0	277.99
04-18	QLABI	190404	1.24	0.002	2.3	263.00	252.80
04-19	QLABI	190404	1.24	0.002	2.3	327.00	225.99
04-20	QLABI	190404	1.24	0.002	2.3	217.00	203.50
04-21	QLABI	190404	1.24	0.002	2.3	194.00	182.00



Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou, Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón

Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho

George Schneider

Date / Shift: *1 Dec 2019/04*

Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

04-22	QLABI	190404	1.24	0.002	2.3	169.00	155.087
04-23	QLABI	190404	1.24	0.002	2.3	141.00	126.78
04-24	QLABI	190404	1.24	0.002	2.3	115.0	108.97
04-25	QLABI	190404	1.24	0.002	2.3	92.00	74.38
04-26	QLABI	190404	1.24	0.002	2.3	78.50	72.00
4-27	QLABI	190404	1.24	0.002	2.3	78.50	72.26
4-28	2PGA-1000	2622	.57	.025	2.5	600.05	500.00
4-29	2PGA-1000	2622	.57	.025	2.5	1000.31	-0.57

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.76**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**-0.20**	**BH Winch Offset from Borehole (m)**	**~3.5m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**74.0**		

Client: NWMO

Location: Ignace – BH02

Prepared by: Olga Fomenko, Peter Giamou, Chris Marchildon

Job Number: 1671632a

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches
CC: Joe Carvalho
George Schneider

Date / Shift: *1 Dec 2019/04*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run 4.1 Field Notes		**Run 4.2 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	1:55/5:29	**Start Time/ End Time**	5:29/6:10
Run Direction	up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	n/a/ n/a
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a/ n/a
Probe Point at Collar (start) or Wireline Marker	1.24	**Probe Point at Collar (start) or Wireline Marker**	1.24
START (data)/ END (data)	487.10 /1.11	**START (data)/ END (data)**	76.0/69.0
Probe Point at Collar (end) or Wireline Marker	1.11	**Probe Point at Collar (end) or Wireline Marker**	1.34
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-1_120119.tfd		IG_BH02_WP05_QLABI_04-2_120119.tfd	
Run 4.3 Field Notes		**Run 4.4 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	7:25/ 7:28	**Start Time/ End Time**	7:36/ 7:43
Run Direction	Up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	1.24	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	733.00/ 726.00	**START (data)/ END (data)**	686.00/ 672.00
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-3_120119.tfd		IG_BH02_WP05_QLABI_04-4_120119.tfd	

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou, Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*1 Dec 2019/04*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 4.5 Field Notes		**Run 4.6 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	7:57/ 8:00	**Start Time/ End Time**	8:03/ 8:10
Run Direction	Up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	n/a	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	617.00/ 610.99	**START (data)/ END (data)**	601.00/ 587.00
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-5_120119.tfd		IG_BH02_WP05_QLABI_04-6_120119.tfd	

Run 4.7 Field Notes		**Run 4.8 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	8:13/ 8:20	**Start Time/ End Time**	8:33/ 8:37
Run Direction	up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	n/a	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	578.00/565.00	**START (data)/ END (data)**	487.00/480.00
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-7_120119.tfd		IG_BH02_WP05_QLABI_04-8_120119.tfd	

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou, Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*1 Dec 2019/04*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 4.9 Field Notes		**Run 4.10 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	9:03/9:18	**Start Time/ End Time**	9:19/ 9:23
Run Direction	Up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	n/a	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	420.0/ 397.39	**START (data)/ END (data)**	402.00/ 393.99
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-9_120119.tfd		IG_BH02_WP05_QLABI_04-10_120119.tfd	
Run 4.11 Field Notes		**Run 4.12 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time		**Start Time/ End Time**	
Run Direction	up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	n/a	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	380.00/ 368.00	**START (data)/ END (data)**	372.00/ 362.99
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-11_120119.tfd		IG_BH02_WP05_QLABI_04-12_120119.tfd	

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou, Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*1 Dec 2019/04*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 4.13 Field Notes		**Run 4.14 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	9:39/ 9:48	**Start Time/ End Time**	9:51/ 9:56
Run Direction	up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	n/a	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	358.0/ 340.50	**START (data)/ END (data)**	331.00/ 321.42
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-13_120119.tfd		IG_BH02_WP05_QLABI_04-14_120119.tfd	
Run 4.15 Field Notes		**Run 4.16 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	9:57/ 10:06	**Start Time/ End Time**	10:08/ 10:13
Run Direction	up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	n/a	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	323.0/ 313.79	**START (data)/ END (data)**	307.0/ 297.97
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-15_120119.tfd		IG_BH02_WP05_QLABI_04-16_120119.tfd	

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou, Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*1 Dec 2019/04*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 4.17 Field Notes		**Run 4.18 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	10:16/ 10:23	**Start Time/ End Time**	10:26/ 10:38
Run Direction	up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	n/a	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	288.0/ 277.99	**START (data)/ END (data)**	263.0/ 252.80
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-17_120119.tfd		IG_BH02_WP05_QLABI_04-18_120119.tfd	
Run 4.19 Field Notes		**Run 4.20 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	10:41/ 10:46	**Start Time/ End Time**	10:48/ 11:00
Run Direction	up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	n/a	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	237.0/ 225.99	**START (data)/ END (data)**	217.0/ 203.5
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-19_120119.tfd		IG_BH02_WP05_QLABI_04-20_120119.tfd	

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou, Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *1 Dec 2019/04*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run 4.21 Field Notes		**Run 4.22 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	11:07/ 11:13	**Start Time/ End Time**	11:16/ 11:23
Run Direction	up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	n/a	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	194.00/ 182.5	**START (data)/ END (data)**	169.00/ 155.87
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-21_120119.tfd		IG_BH02_WP05_QLABI_04-22_120119.tfd	

Run 4.23 Field Notes		**Run 4.24 Field Notes**	
Probe	QL40 ABI-2G	**Probe**	QL40 ABI-2G
Start Time/ End Time	11:26/ 11:37	**Start Time/ End Time**	11:39/ 11:42
Run Direction	up	**Run Direction**	up
Probe Temp Before/ After		**Probe Temp Before/ After**	
Location Temp Before/After	n/a	**Location Temp Before/After**	n/a
Probe Point at Collar (start) or Wireline Marker	n/a	**Probe Point at Collar (start) or Wireline Marker**	n/a
START (data)/ END (data)	141.00/ 126.78	**START (data)/ END (data)**	115.0/ 108.97
Probe Point at Collar (end) or Wireline Marker		**Probe Point at Collar (end) or Wireline Marker**	
Comments:		**Comments:**	
IG_BH02_WP05_QLABI_04-23_120119.tfd		IG_BH02_WP05_QLABI_04-24_120119.tfd	

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou, Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *1 Dec 2019/04*

Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run 4.25 Field Notes

Probe	QL40 ABI-2G
Start Time/ End Time	11:45/ 11:55
Run Direction	up
Probe Temp Before/ After	
Location Temp Before/After	n/a
Probe Point at Collar (start) or Wireline Marker	n/a
START (data)/ END (data)	92.0/ 74.38
Probe Point at Collar (end) or Wireline Marker	
Comments:	
IG_BH02_WP05_QLABI_04-25_120119.tfd	

Run 4.26 Field Notes

Probe	QL40 ABI-2G
Start Time/ End Time	11:57/ 12:03
Run Direction	up
Probe Temp Before/ After	
Location Temp Before/After	n/a
Probe Point at Collar (start) or Wireline Marker	n/a
START (data)/ END (data)	78.50/ 72.00
Probe Point at Collar (end) or Wireline Marker	1.17
Comments:	
IG_BH02_WP05_QLABI_04-26_120119.tfd	

Run 4.27 Field Notes

Probe	QL40 ABI-2G
Start Time/ End Time	12:17/ 12:20
Run Direction	up
Probe Temp Before/ After	/10.8
Location Temp Before/After	/ 17.8
Probe Point at Collar (start) or Wireline Marker	1.24
START (data)/ END (data)	78.50/ 73.26
Probe Point at Collar (end) or Wireline Marker	1.34
Comments:	
IG_BH02_WP05_QLABI_04-27_120119.tfd	

Run 4.28 Field Notes

Probe	2PGA-1000
Start Time/ End Time	19:51/21:03
Run Direction	Up
Probe Temp Before/ After	11.8/
Location Temp Before/After	17.5/
Probe Point at Collar (start) or Wireline Marker	.57
START (data)/ END (data)	600.05/500.00
Probe Point at Collar (end) or Wireline Marker	
Comments:	See next run
IG_BH02_WP05_2PGA_QAQC_04-28_120119.tfd	

Client: NWMO

Location: Ignace – BH02

Prepared by: Olga Fomenko, Peter Giamou, Chris Marchildon

Job Number: 1671632a

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*1 Dec 2019/04*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 04.29 Field Notes

Probe	2PGA-1000
Start Time	21:35
End Time	
Run Direction	Up
Probe Temp Before	11.8
Probe Temp After	-5
Location Temp Before	17.5
Location Temp After	16
Offset	-
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	.57, 499.20/500
START (data)	1000.31
END (data)	-0.57
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_2PGA_04-29_120119.tfd
Initial Calibration	IG_BH02_WP05_2PGA-1000_PreUseCheck_04-29_120119.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou, Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

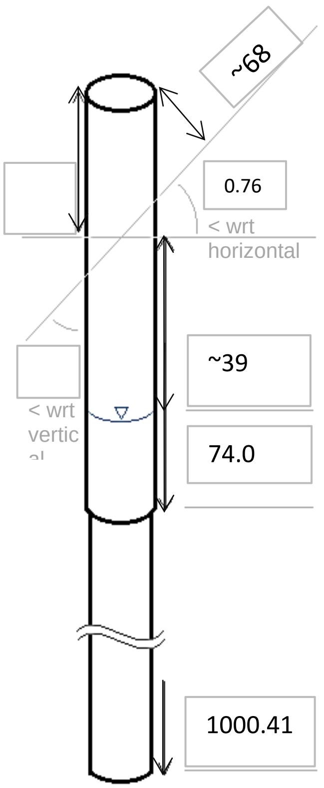
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *02 Dec 2019/05*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Tool Data							
Run	**Probe Name**	**Serial Number**	**Tool Offset (m)**	**Sampling Interval (m)**	**Logging Speed (m/min)**	**Expected Run**	
						Top	**Bottom**
05-1	DualNeutron	6604	2.27	0.025	2.5	315.20	199.99
05-2	DualNeutron	6604	2.27	0.025	2.5	1000.00	416.64
05-03	2SNA-1000	4116	1.59	0.025	2.3	399.96	500.00
05-04	2SNA-1000	4116	1.59	0.025	2.3	336.00	1000.32



Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*02 Dec 2019/05*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.76**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**38.76**	**BH Winch Offset from Borehole (m)**	**~7m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**71.0**		

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: *Date/Shift*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run XX.X Field Notes

Probe	Neutron
Start Time	7:45 AM for zero, Survey 10:25AM - 11:20AM
End Time	6:10PM
Run Direction	5-1 up
Probe Temp Before	5°C
Probe Temp After	9°C
Location Temp Before	Bottom 10cm of tool
Location Temp After	Bottom 10cm of tool
Offset	
Stick Up	0.76m
Probe Point at Collar (start) or Wireline Marker	2.27
START (data)	315.20
END (data)	199.99
Probe Point at Collar (end) or Wireline Marker	4.64
File Name	IG_BH02_WP05_DualNeutron_5-1_120219
Initial Calibration	
Final Calibration	

Comments:

2.5cm Increments, ASDE greater than 1.3m so we will do a minimum of 50m repeat ~~tomorre~~ tomorrow.

Client: NWMO
Location:
Prepared by:

Job Number: 1671632A
Project:
Verified by:

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: Dec 2019
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run	**Field Notes**
Probe	Dual Neutron
Start Time	
End Time	
Run Direction	Up
Probe Temp Before	6°C
Probe Temp After	9°C
Location Temp Before	Bottom 10cm of probe
Location Temp After	Bottom 10cm of Probe
Offset	
Stick Up	0.76m
Probe Point at Collar (start) or Wireline Marker	2.27m
START (data)	1000.00
END (data)	414.64
Probe Point at Collar (end) or Wireline Marker	4.64
File Name	IG_BH02_WP05_DualNeutron_5-2_120219
Initial Calibration	
Final Calibration	

Comments:

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon
Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*02 Dec 2019/05*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 05.3 Field Notes

Probe	2SNA-1000
Start Time	19:35
End Time	20:54
Run Direction	Up
Probe Temp Before	21.5
Probe Temp After	n/a
Location Temp Before	22.7
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	500.00
END (data)	399.96
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2SNA_05-3_QAQC_120219.tfd
Initial Calibration	IG_BH02_WP05_2SNA_PreCalCheck_120219.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *02 Dec 2019/05*

Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run 05.4 Field Notes

Probe	2SNA-1000
Start Time	21:50
End Time	03:10
Run Direction	Up
Probe Temp Before	21.5
Probe Temp After	2
Location Temp Before	22.7
Location Temp After	29.5
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	1000.32
END (data)	336.00
Probe Point at Collar (end) or Wireline Marker	0.55
File Name	IG_BH02_WP05_2SNA_05-4_120219.tfd
Initial Calibration	IG_BH02_WP05_2SNA_PreCalCheck_120219.tfd
Final Calibration	

Comments:
Recorded locations of bursts of invalid data (10-15 points in a row) for potential repeat afterwards.

Client: NWMO

Location: Ignace – BH02

Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

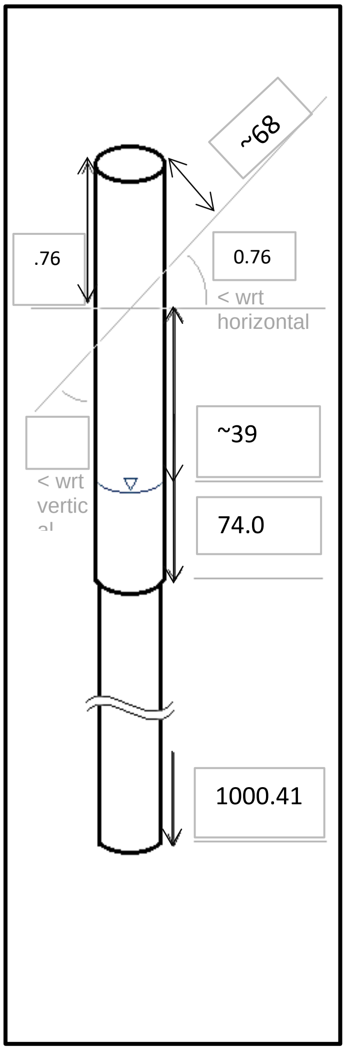
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *03 Dec 2019/06*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Tool Data

Run	Probe Name	Serial Number	Tool Offset (m)	Sampling Interval (m)	Logging Speed (m/min)	Expected Run	
						Top	Bottom
06-1	2SNA-1000	4116	1.59	0.025	2.5	340.00	~244
06-2	2SNA-1000	4116	1.59	0.025	2.5	250.00	1.70
06-03	Dual Neutron	6604	2.27	0.025	2.5	480.94	3.84
06-04	Dual Neutron	6604	2.27	0.025	2.5	80.00	29.27
06-05	Density	6366	2.51	0.025	2.5	200.07	99.04
06-06	Density	6366	2.51	0.025	2.5	280.01	3.02
06-07	2SNA-1000	4116	1.59	0.025	2.5	780.00	769.99
06-08	2SNA-1000	4116	1.59	0.025	2.5	745.00	734.00
06-09	2SNA-1000	4116	1.59	0.025	2.5	707.00	694.99
06-10	2SNA-1000	4116	1.59	0.025	2.5	655.00	641.00
06-11	2SNA-1000	4116	1.59	0.025	2.5	621.00	605.00
06-12	2SNA-1000	4116	1.59	0.025	2.5	585.00	570.00
06-13	2SNA-1000	4116	1.59	0.025	2.5	555.00	540.00
06-14	2SNA-1000	4116	1.59	0.025	2.5	390.00	330.00



Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *03 Dec 2019/06*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.76**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**38.76**	**BH Winch Offset from Borehole (m)**	**~7m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**71.0**		

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*03 Dec 2019/06*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 06.1 Field Notes

Probe	2SNA-1000
Start Time	05:04
End Time	06:06
Run Direction	Up
Probe Temp Before	21.5
Probe Temp After	n/a
Location Temp Before	22.7
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	340.00
END (data)	~244
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2SNA_06-1_120319.tfd
Initial Calibration	IG_BH02_WP05_2LSA_PreCalCheck_120219.tfd
Final Calibration	

Comments:

Logging program stopped displaying data during run, had to stop.

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*03 Dec 2019/06*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 06.2 Field Notes

Probe	2SNA-1000
Start Time	06:18
End Time	07:57
Run Direction	Up
Probe Temp Before	21.5
Probe Temp After	5.5
Location Temp Before	22.7
Location Temp After	39.5
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	250.00
END (data)	1.70
Probe Point at Collar (end) or Wireline Marker	1.70
File Name	IG_BH02_WP05_2SNA_06-2_120319.tfd
Initial Calibration	IG_BH02_WP05_2LSA_PreCalCheck_120219.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *Dec 2019*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run	**Field Notes**
Probe	Dual Neutron
Start Time	9:15am
End Time	12:30PM
Run Direction	UP 6-3
Probe Temp Before	6°C
Probe Temp After	Measured after 6-4
Location Temp Before	Bottom 10cm of Probe
Location Temp After	Bottom 10cm of Probe
Offset	
Stick Up	0.76m
Probe Point at Collar (start) or Wireline Marker	2.27
START (data)	480.94
END (data)	3.84
Probe Point at Collar (end) or Wireline Marker	3.84
File Name	IG_BH02_WP05_DualNeutron_6-3_120319
Initial Calibration	
Final Calibration	

Comments:
ASDE was more than 1.3m so we did a repeat run.

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: *Dec 2019*

Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run	**Field Notes**
Probe	Dual Neutron
Start Time	
End Time	1PM
Run Direction	Up 6-4
Probe Temp Before	
Probe Temp After	9°C
Location Temp Before	Bottom 10cm of probe
Location Temp After	Bottom 10cm of probe
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	2.27
START (data)	80.06
END (data)	29.27
Probe Point at Collar (end) or Wireline Marker	2.33
File Name	IG_BH02_WP05_Dual Neutron_6-4_120319
Initial Calibration	
Final Calibration	

Comments:

Repeat Run

Client: NWMO

Location: Ignace – BH02

Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: Dec 2019
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run	**Field Notes**
Probe	Gamma Gamma Density
Start Time	2:25PM
End Time	3:15PM
Run Direction	Up G-5
Probe Temp Before	5°C
Probe Temp After	
Location Temp Before	Above caliper arm
Location Temp After	
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	2.51
START (data)	200.07
END (data)	99.04
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_Density_G-5_120319
Initial Calibration	
Final Calibration	

Comments:

QAQC Run

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: Dec 2019
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run	Field Notes
Probe	Gamma Gamma Density
Start Time	
End Time	5:45PM
Run Direction	Up 6-6
Probe Temp Before	
Probe Temp After	10°C
Location Temp Before	
Location Temp After	Above Caliper arm
Offset	
Stick Up	0.76m
Probe Point at Collar (start) or Wireline Marker	
START (data)	280.01
END (data)	3.02
Probe Point at Collar (end) or Wireline Marker	3.02
File Name	I6_BH02_WP05_Density_6-6_120319
Initial Calibration	
Final Calibration	

Comments:

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon
Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*03 Dec 2019/06*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 06.7 Field Notes

Probe	2SNA-1000
Start Time	20:03
End Time	20:10
Run Direction	Up
Probe Temp Before	11.2
Probe Temp After	13.3
Location Temp Before	29.7
Location Temp After	28.7
Offset	1.59
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	780.00
END (data)	769.99
Probe Point at Collar (end) or Wireline Marker	1.42
File Name	IG_BH02_WP05_2SNA_06-7_120319.tfd
Initial Calibration	IG_BH02_WP05_2LSA_PreUseCheck_120319.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*03 Dec 2019/06*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 06.8 Field Notes

Probe	2SNA-1000
Start Time	20:13
End Time	20:18
Run Direction	Up
Probe Temp Before	11.2
Probe Temp After	13.3
Location Temp Before	29.7
Location Temp After	28.7
Offset	1.59
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	745.00
END (data)	734.00
Probe Point at Collar (end) or Wireline Marker	1.42
File Name	IG_BH02_WP05_2SNA_06-8_120319.tfd
Initial Calibration	IG_BH02_WP05_2LSA_PreUseCheck_120319.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*03 Dec 2019/06*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 06.9 Field Notes

Probe	2SNA-1000
Start Time	20:23
End Time	20:30
Run Direction	Up
Probe Temp Before	11.2
Probe Temp After	13.3
Location Temp Before	29.7
Location Temp After	28.7
Offset	1.59
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	707.00
END (data)	694.99
Probe Point at Collar (end) or Wireline Marker	1.42
File Name	IG_BH02_WP05_2SNA_06-9_120319.tfd
Initial Calibration	IG_BH02_WP05_2LSA_PreUseCheck_120319.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*03 Dec 2019/06*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 06.10 Field Notes

Probe	2SNA-1000
Start Time	20:34
End Time	20:41
Run Direction	Up
Probe Temp Before	11.2
Probe Temp After	13.3
Location Temp Before	29.7
Location Temp After	28.7
Offset	1.59
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	655.00
END (data)	641.00
Probe Point at Collar (end) or Wireline Marker	1.42
File Name	IG_BH02_WP05_2SNA_06-10_120319.tfd
Initial Calibration	IG_BH02_WP05_2LSA_PreUseCheck_120319.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*03 Dec 2019/06*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 06.11 Field Notes

Probe	2SNA-1000
Start Time	20:57
End Time	21:05
Run Direction	Up
Probe Temp Before	11.2
Probe Temp After	13.3
Location Temp Before	29.7
Location Temp After	28.7
Offset	1.59
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	621.00
END (data)	605.00
Probe Point at Collar (end) or Wireline Marker	1.42
File Name	IG_BH02_WP05_2SNA_06-11_120319.tfd
Initial Calibration	IG_BH02_WP05_2LSA_PreUseCheck_120319.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*03 Dec 2019/06*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 06.12 Field Notes

Probe	2SNA-1000
Start Time	21:09
End Time	21:18
Run Direction	Up
Probe Temp Before	11.2
Probe Temp After	13.3
Location Temp Before	29.7
Location Temp After	28.7
Offset	1.59
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	585.00
END (data)	570.00
Probe Point at Collar (end) or Wireline Marker	1.42
File Name	IG_BH02_WP05_2SNA_06-12_120319.tfd
Initial Calibration	IG_BH02_WP05_2LSA_PreUseCheck_120319.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*03 Dec 2019/06*
		Work Package:	WP5 – Borehole Geophysical Logging
CC:	Aaron DesRoches Joe Carvalho George Schneider	**Distributed By:**	Email

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Run 06.13 Field Notes

Probe	2SNA-1000
Start Time	21:25
End Time	21:34
Run Direction	Up
Probe Temp Before	11.2
Probe Temp After	13.3
Location Temp Before	29.7
Location Temp After	28.7
Offset	1.59
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	555.00
END (data)	540.00
Probe Point at Collar (end) or Wireline Marker	1.42
File Name	IG_BH02_WP05_2SNA_06-13_120319.tfd
Initial Calibration	IG_BH02_WP05_2LSA_PreUseCheck_120319.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*03 Dec 2019/06*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 06.14 Field Notes

Probe	2SNA-1000
Start Time	22:15
End Time	22:46
Run Direction	Up
Probe Temp Before	11.2
Probe Temp After	13.3
Location Temp Before	29.7
Location Temp After	28.7
Offset	1.59
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.59
START (data)	390.00
END (data)	330.00
Probe Point at Collar (end) or Wireline Marker	1.42
File Name	IG_BH02_WP05_2SNA_06-14_120319.tfd
Initial Calibration	IG_BH02_WP05_2LSA_PreUseCheck_120319.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

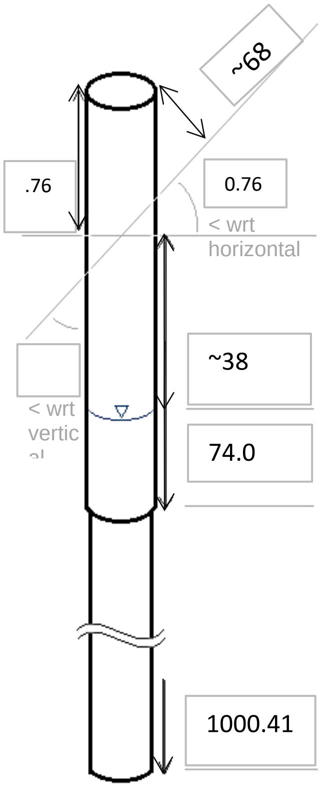
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *04 Dec 2019/06*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Tool Data

Run	Probe Name	Serial Number	Tool Offset (m)	Sampling Interval (m)	Logging Speed (m/min)	Expected Run	
						Top	Bottom
07-1	2PIA-1000	3513	1.51	0.05	15	1.51	500.00
07-2	2PIA-1000	3513	1.51	0.05	4.5	500.00	399.00
07-3	2PIA-1000	3513	1.51	0.05	15	399.00	1000.00
07-4	2PIA-1000	3513	1.51	0.05	4.5	1000.00	67.37
07-5	Density	6360	2.51	0.025	2.25	999.40	198.28
07-6	2CAA-1000	5050	1.53	0.0496	10	1.53	600.00
07-7	2PCA-1000	5032	1.53	.01	2.5	600.01	500.02



Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *04 Dec 2019/06*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.76**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**38.76**	**BH Winch Offset from Borehole (m)**	**~7m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**74.0**		

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*04 Dec 2019/06*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 07.1 Field Notes

Probe	2PIA-1000
Start Time	01:22
End Time	01:58
Run Direction	Down
Probe Temp Before	0.5
Probe Temp After	n/a
Location Temp Before	20.5
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.51
START (data)	1.51
END (data)	500.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2PIA_07-1_120419.tfd
Initial Calibration	IG_BH02_WP05_2PIA-1000_Preuse_120419.tfd / 2PIA-1000_Calibration_120419b.txt
Final Calibration	IG_BH02_WP05_2PIA-1000_Postuse_120419.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*04 Dec 2019/06*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 07.2 Field Notes

Probe	2PIA-1000
Start Time	02:00
End Time	02:22
Run Direction	Up
Probe Temp Before	0.5
Probe Temp After	n/a
Location Temp Before	20.5
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.51
START (data)	500.00
END (data)	399.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2PIA-1000_07-2_QCQA_120419.tfd
Initial Calibration	IG_BH02_WP05_2PIA-1000_Preuse_120419.tfd / 2PIA-1000_Calibration_120419b.txt
Final Calibration	IG_BH02_WP05_2PIA-1000_Postuse_120419.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*04 Dec 2019/06*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 07.3 Field Notes

Probe	2PIA-1000
Start Time	02:23
End Time	03:07
Run Direction	Down
Probe Temp Before	0.5
Probe Temp After	n/a
Location Temp Before	20.5
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.51
START (data)	399.00
END (data)	1000.00
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2PIA_07-3_120419.tfd
Initial Calibration	IG_BH02_WP05_2PIA-1000_Preuse_120419.tfd / 2PIA-1000_Calibration_120419b.txt
Final Calibration	IG_BH02_WP05_2PIA-1000_Postuse_120419.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*04 Dec 2019/06*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 07.4 Field Notes

Probe	2PIA-1000
Start Time	03:12
End Time	06:35
Run Direction	Up
Probe Temp Before	0.5
Probe Temp After	4
Location Temp Before	20.5
Location Temp After	32.8
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.51
START (data)	1000.00
END (data)	67.37
Probe Point at Collar (end) or Wireline Marker	0.91
File Name	IG_BH02_WP05_2PIA_07-4_120419.tfd
Initial Calibration	IG_BH02_WP05_2PIA-1000_Preuse_120419.tfd / 2PIA-1000_Calibration_120419b.txt
Final Calibration	IG_BH02_WP05_2PIA-1000_Postuse_120419.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	Dec 2019
		Work Package:	WP5 – Borehole Geophysical Logging
CC:	Aaron DesRoches Joe Carvalho George Schneider		
		Distributed By:	Email

Run 07.5 Field Notes

Probe	Gamma Gamma (Density)
Start Time	Zero at surface = 8:20am, Start run at 10:10am
End Time	3:50 PM
Run Direction	UP
Probe Temp Before	6°C
Probe Temp After	
Location Temp Before	50cm up from caliper arm
Location Temp After	
Offset	
Stick Up	0.76m
Probe Point at Collar (start) or Wireline Marker	2.51m
START (data)	999.40m - Standard 1m off bottom for nuclear probe
END (data)	198.28m
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_Density_7-5_120419
Initial Calibration	
Final Calibration	

Comments:

Overlapped previous run by 80m as we believe the zero or ASDE will be more than 1.30m

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*04 Dec 2019/06*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 07.6 Field Notes

Probe	2CAA-1000
Start Time	22:05
End Time	23:05
Run Direction	Down
Probe Temp Before	-2
Probe Temp After	
Location Temp Before	20.5
Location Temp After	
Offset	------
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.53
START (data)	1.53
END (data)	600.00
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_2CAA_07-6_120419.tfd
Initial Calibration	Calibration done as part of the FFEC testing
Final Calibration	

Comments:

Ran on the 1000 m winch

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*04 Dec 2019/06*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 07.7 Field Notes

Probe	2PCA-1000
Start Time	23:12
End Time	23:54
Run Direction	Up
Probe Temp Before	-2
Probe Temp After	
Location Temp Before	20.5
Location Temp After	
Offset	------
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.53
START (data)	600.01
END (data)	500.02
Probe Point at Collar (end) or Wireline Marker	N/A
File Name	IG_BH02_WP05_2PCA-1000_QAQC_07-7_120419.tfd
Initial Calibration	IG_BH02_WP05_2PCA-1000_Preuse_120419.tfd, 2PCA-1000_Calibration_120419.txt
Final Calibration	

Comments:

Ran on the 1000 m winch

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

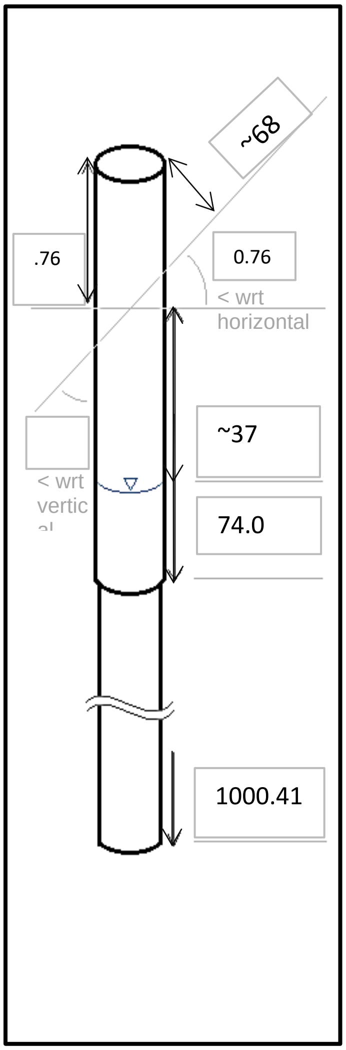
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *05 Dec 2019/07*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Tool Data							
Run	**Probe Name**	**Serial Number**	**Tool Offset (m)**	**Sampling Interval (m)**	**Logging Speed (m/min)**	**Expected Run**	
						Top	**Bottom**
08-1	2CAA-1000	5032	1.97	0.01	2.5	500.02	1000.30
08-2	2PCA-1000	5032	1.97	0.01	2.5	1000.33	69.27
08-3	2PCA-1000	5032	1.97	0.01	2.5	79.01	69.60
08-4	IPGR	Res 5578 GR 6586	10.65	0.05	3	975.56	1000.02
08-5	IPGR	Res 5578 GR 6586	10.65	0.05	3	1000.0	
08-6	QLOBI	160403	1.13	0.05	7-10	1.53	902.5



Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*05 Dec 2019/07*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.76**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**37.28**	**BH Winch Offset from Borehole (m)**	**~5m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**74.0**		

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*05 Dec 2019/07*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 08.1 Field Notes

Probe	2CAA-1000
Start Time	00:03
End Time	00:47
Run Direction	Down
Probe Temp Before	-7
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.97
START (data)	500.02
END (data)	1000.30
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_2CAA_08-1_120519.tfd
Initial Calibration	2CAA-1000_Calibration_120419.txt
Final Calibration	2PCA-1000_Calibration_120519.txt

Comments:

Collected FTR data on down run, then caliper on up run.

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *05 Dec 2019/07*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run 08.2 Field Notes

Probe	2PCA-1000
Start Time	01:00
End Time	06:57
Run Direction	Up
Probe Temp Before	-7
Probe Temp After	5
Location Temp Before	n/a
Location Temp After	9
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.97
START (data)	1000.33
END (data)	69.27
Probe Point at Collar (end) or Wireline Marker	1.63
File Name	IG_BH02_WP05_2PCA_08-2_120519.tfd
Initial Calibration	2CAA-1000_Calibration_120419.txt
Final Calibration	2PCA-1000_Calibration_120519.txt

Comments:
Collected FTR data on down run, then caliper on up run.

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*05 Dec 2019/07*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 08.3 Field Notes

Probe	2PCA-1000
Start Time	07:00
End Time	07:05
Run Direction	Up
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.97
START (data)	79.01
END (data)	69.60
Probe Point at Collar (end) or Wireline Marker	1.63
File Name	IG_BH02_WP05_2PCA_08-3_120519.tfd
Initial Calibration	2CAA-1000_Calibration_120419.txt
Final Calibration	2PCA-1000_Calibration_120519.txt

Comments:
Good zero run.

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: Dec 2019
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run	**Field Notes**
Probe	E-Log Resistivity
Start Time	Probe zeroed at 9:10am.
End Time	
Run Direction	UP
Probe Temp Before	5°C
Probe Temp After	
Location Temp Before	Between 32" and 64" reciever
Location Temp After	
Offset	
Stick Up	0.76m
Probe Point at Collar (start) or Wireline Marker	10.65
START (data)	1000.02
END (data)	975.56
Probe Point at Collar (end) or Wireline Marker	/
File Name	IG_BH02_WP05_IPGR_8-4-120519
Initial Calibration	
Final Calibration	

Comments:
Greased the cable head this morning, taped entire probe up and tested On surface. Had errors, tried sending probe to 90m so it was out of casing and in water. No Luck so we removed tool and took off FTC sub. Probe worked good from here.

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon
Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: Dec 2019

Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run	**Field Notes**
Probe	E-Log Resistivity
Start Time	
End Time	
Run Direction	Up
Probe Temp Before	
Probe Temp After	
Location Temp Before	
Location Temp After	Between 64" and 32" Receiver
Offset	
Stick Up	0.76m
Probe Point at Collar (start) or Wireline Marker	
START (data)	1000.00
END (data)	
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_IPGR_8-5_120519
Initial Calibration	
Final Calibration	

Comments:

Probe had some errors on 8-4 run up, so we tuned telemetry and sent probe back to botton, worked better.

Client: NWMO

Location: Ignace – BH02

Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*05 Dec 2019/07*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 08.6 Field Notes

Probe	QLOBI
Start Time	18:55
End Time	20:40
Run Direction	Down
Probe Temp Before	n/a
Probe Temp After	n/a
Location Temp Before	n/a
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	1.13
END (data)	902.5
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_QLOBI_08-6_120519.tfd
Initial Calibration	
Final Calibration	

Comments:

Failed run, too many errors. Do not use.

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

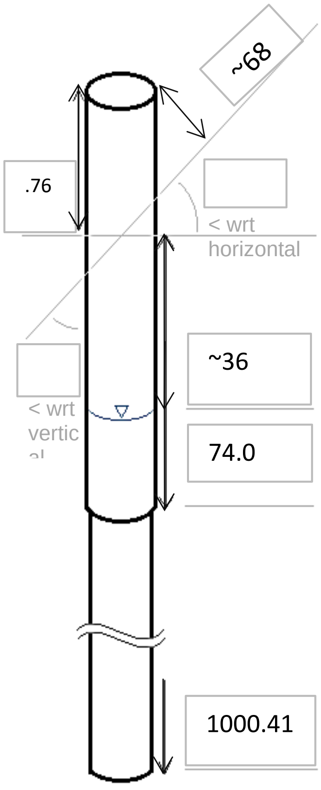
TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Date / Shift: *06 Dec 2019/09*
Work Package: WP5 – Borehole Geophysical Logging

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Distributed By: Email

Tool Data							
Run	**Probe Name**	**Serial Number**	**Tool Offset (m)**	**Sampling Interval (m)**	**Logging Speed (m/min)**	**Expected Run**	
						Top	**Bottom**
09-1	QLOBI	160403	1.13	0.05	7-10	1.13	901.00
09-2	QLOBI	160403	1.13	0.01	3	901.00	798.88
09-3	QLOBI	160403	1.13	0.05	7-10	799.03	999.10
09-4	QLOBI	160403	1.13	0.01	4	998.03	496.27
09-5	QLOBI	160403	1.13	0.01	4	501.80	0.34
09-6	IPGR	5578	10.65	0.05	3	500.00	602.00
09-7	IPGR	5578	10.65	0.05	3	74.00	294.98
09-8	FWS	82202	2.12	0.05	2	670.00	1000.00
09-9	MagSus	513	.90	0.10	10	80.00	400.01
09-10	MagSus	513	.90	0.05	4.5	400.01	300.02
09-11	MagSus	513	.90	0.10	10	300.02	1000.33
09-12	MagSus	513	.90	0.05	4.5	1000.33	71.85



Client: NWMO
Job Number: 1671632a
Location: Ignace – BH02
Project: Phase 2 Initial Borehole Drilling
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *06 Dec 2019/09*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Borehole Data

Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.76**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**37.28**	**BH Winch Offset from Borehole (m)**	**~5m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**74.0**		

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*06 Dec 2019/09*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 09.1 Field Notes

Probe	QL40 OBI-2G
Start Time	00:30
End Time	02:10
Run Direction	Down
Probe Temp Before	-9
Probe Temp After	n/a
Location Temp Before	13.7
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	1.13
END (data)	798.88
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_QLOBI_09-1_Deviation_120619.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120619.tfd, IG_BH02_WP05_QLOBI_PostRoll_120619.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*06 Dec 2019/09*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 09.2 Field Notes

Probe	QL40 OBI-2G
Start Time	02:16
End Time	02:51
Run Direction	Up
Probe Temp Before	-9
Probe Temp After	n/a
Location Temp Before	13.7
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	901.00
END (data)	798.88
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_QLOBI_09-2_QAQC_120619.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120619.tfd, IG_BH02_WP05_QLOBI_PostRoll_120619.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*06 Dec 2019/09*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 09.3 Field Notes

Probe	QL40 OBI-2G
Start Time	02:55
End Time	03:22
Run Direction	Down
Probe Temp Before	-9
Probe Temp After	n/a
Location Temp Before	13.7
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	799.03
END (data)	999.10
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_QLOBI_09-3_Deviation_120619.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120619.tfd, IG_BH02_WP05_QLOBI_PostRoll_120619.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *06 Dec 2019/09*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run 09.4 Field Notes

Probe	QL40 OBI-2G
Start Time	03:27
End Time	05:28
Run Direction	Up
Probe Temp Before	-9
Probe Temp After	n/a
Location Temp Before	13.7
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	998.03
END (data)	496.27
Probe Point at Collar (end) or Wireline Marker	n/a
File Name	IG_BH02_WP05_QLOBI_09-4_120619.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120619.tfd, IG_BH02_WP05_QLOBI_PostRoll_120619.tfd

Comments: Run stopped at 500m mark. Split in half for easier file management.

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*06 Dec 2019/09*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 09.5 Field Notes

Probe	QL40 OBI-2G
Start Time	05:31
End Time	07:32
Run Direction	Up
Probe Temp Before	-9
Probe Temp After	10
Location Temp Before	13.7
Location Temp After	14
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	501.80
END (data)	0.34
Probe Point at Collar (end) or Wireline Marker	0.34
File Name	IG_BH02_WP05_QLOBI_09-5_120619.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120619.tfd, IG_BH02_WP05_QLOBI_PostRoll_120619.tfd

Comments: Continuation of 9-4 up run. Split in half for easier file management.

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: Dec 2019

Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run	Field Notes
Probe	E-Log Resistivity
Start Time	8:45am survey start
End Time	
Run Direction	Up 9-6
Probe Temp Before	-8°C
Probe Temp After	
Location Temp Before	On Gamma Section
Location Temp After	
Offset	
Stick Up	0.76m
Probe Point at Collar (start) or Wireline Marker	10.65
START (data)	602.00
END (data)	600.00
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_IPGR_9-6_120619
Initial Calibration	
Final Calibration	

Comments:

QAQC Run

Client: NWMO

Location: Ignace – BH02

Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*Dec 2019*
		Work Package:	WP5 – Borehole Geophysical Logging
CC:	Aaron DesRoches Joe Carvalho George Schneider	**Distributed By:**	Email

Run	**Field Notes**
Probe	E-Log
Start Time	
End Time	11:30am at surface
Run Direction	Up 9-7
Probe Temp Before	
Probe Temp After	3°C
Location Temp Before	
Location Temp After	On gamma Section
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	
START (data)	294.98
END (data)	74.00
Probe Point at Collar (end) or Wireline Marker	11.68m
File Name	IG_BH02_WP05_IPGR_9-7_120619
Initial Calibration	
Final Calibration	

Comments:

ASDE within limit

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: Dec 2019
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run	**Field Notes**
Probe	Full Wave Sonic
Start Time	12:00PM zero'd in hole
End Time	17:35 probe at surface
Run Direction	Up 9-8
Probe Temp Before	2°C
Probe Temp After	-1°C
Location Temp Before	Top 50cm of tool
Location Temp After	" "
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	2.12
START (data)	1000.00
END (data)	670.00
Probe Point at Collar (end) or Wireline Marker	1.96
File Name	IG_BH02_WP05_ALTFWS_9-8_120619
Initial Calibration	
Final Calibration	

Comments:
Will finish run and QAQC file tomorrow.

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon
Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*06 Dec 2019/09*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 09.9 Field Notes

Probe	MagSus
Start Time	20:35
End Time	21.08
Run Direction	Down
Probe Temp Before	-1.5 out of hole -13 during calibration and prior to hole
Probe Temp After	
Location Temp Before	24.9
Location Temp After	
Offset	.90
Stick Up	.76
Probe Point at Collar (start) or Wireline Marker	.46
START (data)	80.00
END (data)	400.01
Probe Point at Collar (end) or Wireline Marker	N/A
File Name	IG_BH02_WP05_MagSus_09-9_120619.tfd
Initial Calibration	IG_BH02_WP05_MagSus_Preuse_120619.tfd, IG_BH02_WP05_MagSus_Stabilization_120619.tfd, MagSus_Calibration_120619.txt
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *06 Dec 2019/09*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run 09.10 Field Notes

Probe	MagSus
Start Time	21:09
End Time	21.33
Run Direction	Up
Probe Temp Before	-1.5 out of hole -13 during calibration and prior to hole
Probe Temp After	
Location Temp Before	24.9
Location Temp After	
Offset	.90
Stick Up	.76
Probe Point at Collar (start) or Wireline Marker	.46
START (data)	400.01
END (data)	300.02
Probe Point at Collar (end) or Wireline Marker	N/A
File Name	IG_BH02_WP05_MagSus_QAQC_09-10_120619.tfd
Initial Calibration	IG_BH02_WP05_MagSus_Preuse_120619.tfd, IG_BH02_WP05_MagSus_Stabilization_120619.tfd, MagSus_Calibration_120619.txt
Final Calibration	

Comments:

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*06 Dec 2019/09*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 09.11 Field Notes

Probe	MagSus
Start Time	21:42
End Time	23.02
Run Direction	Down
Probe Temp Before	-1.5 out of hole -13 during calibration and prior to hole
Probe Temp After	
Location Temp Before	24.9
Location Temp After	
Offset	.90
Stick Up	.76
Probe Point at Collar (start) or Wireline Marker	.46
START (data)	300.02
END (data)	1000.33
Probe Point at Collar (end) or Wireline Marker	N/A
File Name	IG_BH02_WP05_MagSus_09-11_120619.tfd
Initial Calibration	IG_BH02_WP05_MagSus_Preuse_120619.tfd, IG_BH02_WP05_MagSus_Stabilization_120619.tfd, MagSus_Calibration_120619.txt
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*06 Dec 2019/09*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 09.12 Field Notes

Probe	MagSus
Start Time	23:07
End Time	02:30
Run Direction	Up
Probe Temp Before	-1.5 out of hole -13 during calibration and prior to hole
Probe Temp After	-4
Location Temp Before	24.9
Location Temp After	27
Offset	0.90
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	0.46
START (data)	1000.33
END (data)	71.85
Probe Point at Collar (end) or Wireline Marker	-0.26
File Name	IG_BH02_WP05_MagSus_09-12_120619.tfd
Initial Calibration	IG_BH02_WP05_MagSus_Preuse_120619.tfd, IG_BH02_WP05_MagSus_Stabilization_120619.tfd, MagSus_Calibration_120619.txt
Final Calibration	IG_BH02_WP05_MagSus_PostUse_120719.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

GOLDER

RECORD OF GEOPHYSICAL LOGGING

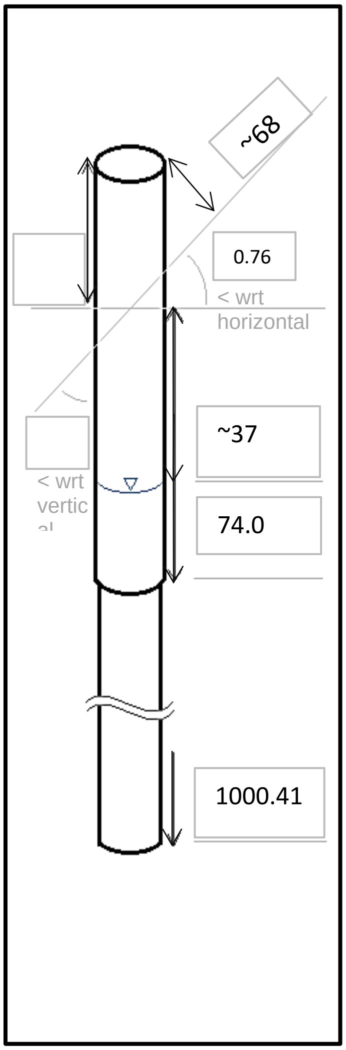
FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*07 Dec 2019/10*
		Work Package:	WP5 – Borehole Geophysical Logging
CC:	Aaron DesRoches Joe Carvalho George Schneider	**Distributed By:**	Email

---

Tool Data

Run	Probe Name	Serial Number	Tool Offset (m)	Sampling Interval (m)	Logging Speed (m/min)	Expected Run	
						Top	Bottom
10-1	2CAA-1000	5032	1.53	0.0496	4	1.53	640.18
10-2	FWS	82202	2.12	0.05	2	399.99	500.03
10-3	FWS	82202	2.12	0.05	2	700.02	30.00
10-4	2CAA-1000	5032	1.97	0.0496	10	1.53	1000.30
10-5	2PCA-1000	5040	1.97	0.01	2.5	675.02	1000.33
10-6	2PCA-1000	5040	1.97	0.01	2.5	1000.33	700.05



Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*07 Dec 2019/10*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.76**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**36.75**	**BH Winch Offset from Borehole (m)**	**~5m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**74.0**		

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*07 Dec 2019/10*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 10.1 Field Notes

Probe	2CAA
Start Time	03:52
End Time	06:30
Run Direction	Down
Probe Temp Before	-7
Probe Temp After	7
Location Temp Before	27
Location Temp After	28.8
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	0.46
START (data)	1.53
END (data)	640.18
Probe Point at Collar (end) or Wireline Marker	1.39
File Name	IG_BH02_WP05_2CAA_10-1_120719.tfd
Initial Calibration	IG_BH02_WP05_2CAA-1000_Preuse_120719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Date / Shift: Dec 2019
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run	**Field Notes**
Probe	Full Wave Sonic (FWS)
Start Time	7:35am zero
End Time	
Run Direction	Up 10-2
Probe Temp Before	-6°C
Probe Temp After	
Location Temp Before	Top of tool
Location Temp After	
Offset	
Stick Up	0.76m
Probe Point at Collar (start) or Wireline Marker	2.12
START (data)	500.03
END (data)	399.99
Probe Point at Collar (end) or Wireline Marker	
File Name	I6_BH02_WP05_FWS_10-2_120719
Initial Calibration	
Final Calibration	

Comments:

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou, Chris Marchildon
Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH03-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches
CC: Joe Carvalho
George Schneider

Date / Shift: Dec 2019
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Run	Field Notes
Probe	FWS
Start Time	
End Time	3:40PM zero at surface
Run Direction	Up 10-3
Probe Temp Before	
Probe Temp After	0°C
Location Temp Before	
Location Temp After	Top of probe
Offset	
Stick Up	0.76m
Probe Point at Collar (start) or Wireline Marker	2.70
START (data)	700.02
END (data)	30.00
Probe Point at Collar (end) or Wireline Marker	2.70
File Name	IG-BH02_WP05_FWS-10-3_120719
Initial Calibration	
Final Calibration	

Comments:

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*07 Dec 2019/10*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 10.4 Field Notes

Probe	2CAA
Start Time	17:47
End Time	19:32
Run Direction	Down
Probe Temp Before	4
Probe Temp After	7
Location Temp Before	27
Location Temp After	29
Offset	1.97
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.53
START (data)	1.53
END (data)	1000.33
Probe Point at Collar (end) or Wireline Marker	.94
File Name	IG_BH02_WP05_2CAA_10-4_120719.tfd
Initial Calibration	IG_BH02_WP05_2CAA-1000_Preuse_120719.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*07 Dec 2019/10*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 10.5 Field Notes

Probe	2PCA-1000
Start Time	19:38
End Time	21.53
Run Direction	Up
Probe Temp Before	4
Probe Temp After	7
Location Temp Before	27
Location Temp After	29
Offset	1.97
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.53
START (data)	1000.33
END (data)	675.02
Probe Point at Collar (end) or Wireline Marker	.94
File Name	IG_BH02_WP05_2PCA_10-5_120719.tfd
Initial Calibration	2PCA-1000_Calibration_120719_b.txt, IG_BH02_WP05_2PCA-1000_Preuse_120719_b.tfd
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*07 Dec 2019/10*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 10.6 Field Notes

Probe	2PCA-1000
Start Time	22:01
End Time	12:45
Run Direction	Up
Probe Temp Before	4.0
Probe Temp After	7.0
Location Temp Before	27
Location Temp After	29
Offset	1.97
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.53
START (data)	700.05
END (data)	64.01
Probe Point at Collar (end) or Wireline Marker	.94
File Name	IG_BH02_WP05_2PCA_10-6_120719.tfd
Initial Calibration	2PCA-1000_Calibration_120719_b.txt, IG_BH02_WP05_2PCA-1000_Preuse_120719_b.tfd
Final Calibration	IG_BH02_WP05_2PCA-1000_Postuse_120719_b.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

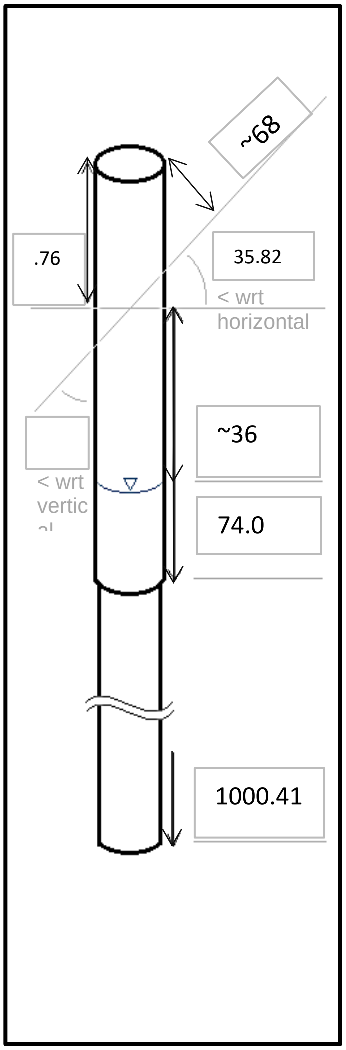
FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches
CC: Joe Carvalho
George Schneider

Date / Shift: *08 Dec 2019/11*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Tool Data							
Run	**Probe Name**	**Serial Number**	**Tool Offset (m)**	**Sampling Interval (m)**	**Logging Speed (m/min)**	**Expected Run**	
						Top	**Bottom**
11-1	QL40OBI2G	160403	1.13	0.01	3.5	998.03	693.57
11-2	QL40OBI2G	160403	1.13	0.01	3.5	650.31	614.30
11-3	QL40OBI2G	160403	1.13	0.01	3.5	565.41	551.99
11-4	QL40OBI2G	160403	1.13	0.01	3.5	556.02	543.39
11-5	QL40OBI2G	160403	1.13	0.01	3	548.00	531.52
11-6	QL40OBI2G	160403	1.13	0.01	3	548.01	540.34
11-7	QL40OBI2G	160403	1.13	0.01	3	542.02	535.16
11-8	QL40OBI2G	160403	1.13	0.01	3	532.03	488.97
11-9	QL40OBI2G	160403	1.13	0.01	3	493.00	476.15
11-10	QL40OBI2G	160403	1.13	0.01	3	478.01	472.56
11-11	QL40OBI2G	160403	1.13	0.01	3	472.05	449.51
11-12	QL40OBI2G	160403	1.13	0.01	3	451.11	445.08
11-13	QL40OBI2G	160403	1.13	0.01	3	444.96	440.27



Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*08 Dec 2019/11*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.76**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**35.82**	**BH Winch Offset from Borehole (m)**	**~5m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**74.0**		

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*08 Dec 2019/11*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 11.1 Field Notes

Probe	QL40 OBI-2G
Start Time	02:48
End Time	04:18
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	998.03
END (data)	693.57
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-1_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

GOLDER

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*08 Dec 2019/11*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 11.2 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	650.31
END (data)	614.30
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-2_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*08 Dec 2019/11*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 11.3 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	05:04
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	565.41
END (data)	551.99
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-3_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Date / Shift: *08 Dec 2019/11*
Work Package: WP5 – Borehole Geophysical Logging

CC: Aaron DesRoches
Joe Carvalho
George Schneider

Distributed By: Email

Run 11.4 Field Notes	
Probe	QL40 OBI-2G
Start Time	
End Time	05:14
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	556.02
END (data)	543.39
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-4_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client: NWMO
Job Number: 1671632a
Location: Ignace – BH02
Project: Phase 2 Initial Borehole Drilling
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*08 Dec 2019/11*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 11.5 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	05:29
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	548.0
END (data)	531.52
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-5_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*08 Dec 2019/11*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 11.6 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	05:35
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	548.01
END (data)	540.34
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-6_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*08 Dec 2019/11*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 11.7 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	05:44
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	542.02
END (data)	535.16
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-7_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*08 Dec 2019/11*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 11.8 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	06:07
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	532.03
END (data)	488.97
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-8_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*08 Dec 2019/11*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 11.9 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	06:25
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	493.00
END (data)	476.15
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-9_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *08 Dec 2019/11*
Work Package: WP5 – Borehole Geophysical Logging
Distributed By: Email

Run 11.10 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	04:35
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	478.01
END (data)	472.56
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-10_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko, Peter Giamou
Chris Marchildon

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*08 Dec 2019/11*
		Work Package:	WP5 – Borehole Geophysical Logging
CC:	Aaron DesRoches Joe Carvalho George Schneider	**Distributed By:**	Email

---

Run 11.11 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	06:58
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	n/a
Location Temp Before	30
Location Temp After	n/a
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	472.05
END (data)	449.51
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-11_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou Chris Marchildon	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*08 Dec 2019/11*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 11.12 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	07:05
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	5
Location Temp Before	30
Location Temp After	11.5
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	451.11
END (data)	445.08
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-12_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*08 Dec 2019/11*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 11.13 Field Notes

Probe	QL40 OBI-2G
Start Time	
End Time	
Run Direction	Up
Probe Temp Before	-1
Probe Temp After	5
Location Temp Before	30
Location Temp After	11.5
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	1.13
START (data)	444.96
END (data)	440.27
Probe Point at Collar (end) or Wireline Marker	0.57
File Name	IG_BH02_WP05_QLOBI_11-13_120819.tfd
Initial Calibration	IG_BH02_WP05_QLOBI_PreTilt_120519.tfd, IG_BH02_WP05_QLOBI_PreRoll_120519.tfd
Final Calibration	IG_BH02_WP05_QLOBI_PostTilt_120819.tfd, IG_BH02_WP05_QLOBI_PostRoll_120819.tfd

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko, Peter Giamou	**Verified by:**	Christopher Phillips
	Chris Marchildon		

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

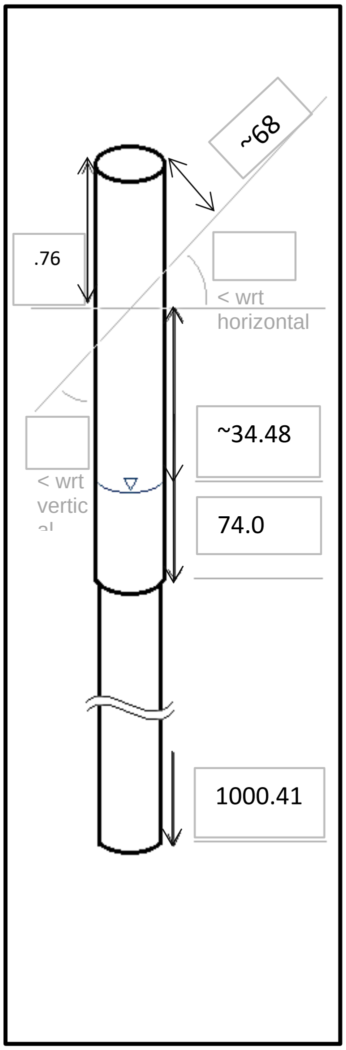
Aaron DesRoches
CC: Joe Carvalho
George Schneider

Date / Shift: *27 Dec 2019/12*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Tool Data

Run	Probe Name	Serial Number	Tool Offset (m)	Sampling Interval (m)	Logging Speed (m/min)	Expected Run	
						Top	Bottom
12-1	HPFM	5517	0.53	20	0	40	400
12-2	HPFM	5517	0.53	20	0	420	660
12-3	HPFM	5517	0.53	20	0	660	1000.05
12-4	HPFM	5517	0.53	20	0	1000.15	520.0



Client: NWMO
Location: Ignace – BH02
Prepared by: Olga Fomenko

Job Number: 1671632a
Project: Phase 2 Initial Borehole Drilling
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn
Aaron DesRoches

CC: Joe Carvalho
George Schneider

Date / Shift: *27 Dec 2019/12*

Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Borehole Data

Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.76**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**34.48**	**BH Winch Offset from Borehole (m)**	**~5m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**74.0**		

Client: NWMO

Location: Ignace – BH02

Prepared by: Olga Fomenko

Job Number: 1671632a

Project: Phase 2 Initial Borehole Drilling

Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*27 Dec 2019/12*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 12.1 Field Notes

Probe	HPFM static
Start Time	09:40
End Time	11:40
Run Direction	Down
Probe Temp Before	10
Probe Temp After	
Location Temp Before	23
Location Temp After	24
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	0.53
START (data)	40.00
END (data)	400.00
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_HPFM_12-1_122719.tfd
Initial Calibration	Factory Calibrated
Final Calibration	

Comments: telemetry status overrun, matrix restart
Encoder wheel stopped counting – have to go up to rezero

WL is 34.48

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón Sarah Hirschorn	**Date / Shift:**	*27 Dec 2019/12*
		Work Package:	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 12.2 Field Notes

Probe	HPFM static
Start Time	12:40
End Time	13:50
Run Direction	Down
Probe Temp Before	10
Probe Temp After	
Location Temp Before	23
Location Temp After	24
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	0.53
START (data)	420.00
END (data)	660.00
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_HPFM_12-2_122719.tfd
Initial Calibration	Factory Calibrated
Final Calibration	

Comments:
overrun

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*27 Dec 2019/12*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 12.3 Field Notes

Probe	HPFM static
Start Time	13:50
End Time	15:40
Run Direction	Down
Probe Temp Before	10
Probe Temp After	
Location Temp Before	23
Location Temp After	24
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	0.53
START (data)	660.00
END (data)	1000.05
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_HPFM_12-3_122719.tfd
Initial Calibration	Factory Calibrated
Final Calibration	

Comments:

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*27 Dec 2019/12*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 12.4 Field Notes

Probe	HPFM Dynamic
Start Time	16:40
End Time	19:00
Run Direction	Up
Probe Temp Before	10
Probe Temp After	
Location Temp Before	23
Location Temp After	24
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	0.53
START (data)	1000.15
END (data)	520.00
Probe Point at Collar (end) or Wireline Marker	0.82
File Name	IG_BH02_WP05_HPFM_12-4_122719.tfd
Initial Calibration	Factory Calibrated
Final Calibration	

Comments:

Dynamic

WL at 55m

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO: Maria Sánchez-Rico Castejón
Sarah Hirschorn

Aaron DesRoches

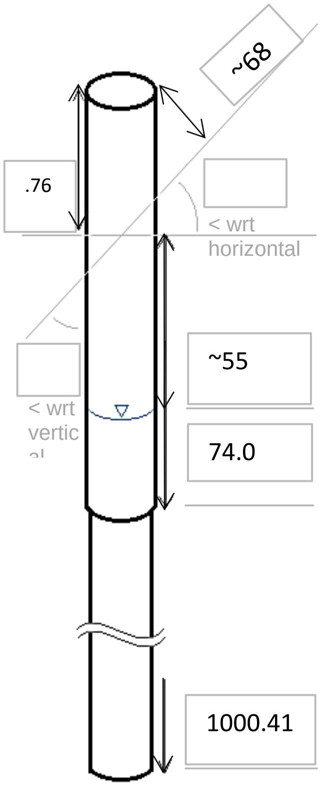
CC: Joe Carvalho
George Schneider

Date / Shift: *28 Dec 2019/13*
Work Package: WP5 – Borehole Geophysical Logging

Distributed By: Email

Tool Data

Run	Probe Name	Serial Number	Tool Offset (m)	Sampling Interval (m)	Logging Speed (m/min)	Expected Run	
						Top	Bottom
13-1	HPFM	5517	0.53	20	0	80.00	580.00
13-2	HPFM	5517	0.53	20,10,5,1	0	280.00	90.00
13-3	QLABI	190404	1.27	0.002	1.2	450.06	427.80
13-4	QLABI	190404	1.27	0.002	1.2	430.03	299.37



Client: NWMO
Job Number: 1671632a
Location: Ignace – BH02
Project: Phase 2 Initial Borehole Drilling
Prepared by: Olga Fomenko
Verified by: Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Dec 2019/13*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Borehole Data			
Depth Reference	**Ground Surface**	**Casing Diameter (mm)**	**127**
Stickup (m)	**0.76**	**Inclination**	**67.8 Degrees**
Water Level (m bgs)	**55**	**BH Winch Offset from Borehole (m)**	**~5m**
Borehole Total Depth (m bgs)	**1000.41**	**Open Hole Diameter (mm)**	**HQ3 - 96 mm**
Casing Depth (m bgs)	**74.0**		

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Dec 2019/13*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 13.1 Field Notes

Probe	HPFM Dynamic
Start Time	07:14
End Time	10:00
Run Direction	Down
Probe Temp Before	10
Probe Temp After	
Location Temp Before	23
Location Temp After	24
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	0.53
START (data)	80.00
END (data)	580.00
Probe Point at Collar (end) or Wireline Marker	
File Name	IG_BH02_WP05_HPFM_13-1_122719.tfd
Initial Calibration	Factory Calibrated
Final Calibration	

Comments: WL at 7 am was 49 m, started pumping at 7:14 to 7:30-40 am to 55 m

Pumped again at 420 m deep 9:05-9:10 am, WL is about 55m

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Dec 2019/13*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 13.2 Field Notes

Probe	HPFM Dynamic
Start Time	10:40
End Time	13:30
Run Direction	Up
Probe Temp Before	10
Probe Temp After	
Location Temp Before	23
Location Temp After	24
Offset	
Stick Up	0.76
Probe Point at Collar (start) or Wireline Marker	0.53
START (data)	280.00
END (data)	90.00
Probe Point at Collar (end) or Wireline Marker	0.82
File Name	IG_BH02_WP05_HPFM_13-2_122719.tfd
Initial Calibration	Factory Calibrated
Final Calibration	

Comments: Flow zones to refine: 80-100,160-140,200-280

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

RECORD OF GEOPHYSICAL LOGGING

FORM: NWMO-IGNACE-BH02-1671632-WP05-F003

TO:	Maria Sánchez-Rico Castejón	**Date / Shift:**	*28 Dec 2019/13*
	Sarah Hirschorn	**Work Package:**	WP5 – Borehole Geophysical Logging
	Aaron DesRoches		
CC:	Joe Carvalho		
	George Schneider	**Distributed By:**	Email

Run 13.3-4 Field Notes

Probe	QLABI-2G	
Start Time	15:26	
End Time	16:37	
Run Direction	Down	
Probe Temp Before	10	
Probe Temp After		
Location Temp Before	23	
Location Temp After	24	
Offset		
Stick Up	0.76	
Probe Point at Collar (start) or Wireline Marker	1.27	
START (data)	13-3:450.06	13-4:430.03
END (data)	13-3:427.80	13-4:299.37
Probe Point at Collar (end) or Wireline Marker	1.78	
File Name	IG_BH02_WP05_QLABI_13-3_122719.tfd, IG_BH02_WP05_QLABI_13-4_122719.tfd	
Initial Calibration	Factory Calibrated	
Final Calibration		

Client:	NWMO	**Job Number:**	1671632a
Location:	Ignace – BH02	**Project:**	Phase 2 Initial Borehole Drilling
Prepared by:	Olga Fomenko	**Verified by:**	Christopher Phillips

APPENDIX D

Probe .TOL Files

```
[Description]
ToolName=2PCA-F Fres, Temp for Matrix (Combo) S/N: 5032 *** After Power On, wait
90 seconds for data to be valid! ***
DriverName=MULTICH

;5-15-06 auto voltage, recip.ch, patcher ind., offsets pls x
;6-07-07 no DC ch, CalibrationEnable= updates pls
;6-28-07 add laswriter pls
;2-08-08 std adapter config pls
;7-23-08 review and approve jrs
;12-10-08 changed to conditional time jrs
; **************************************************************
; Data browsers
;
[Process]
Process1=mch/MChProc.exe
Process2=mch/MChNum.exe
Process3=mch/MChCurve.exe
Process4=mch/Laswriter.exe
;Process5=mch/RecDebug.exe

[Process Info]
Process1=processor,start
Process2=browser,start
Process3=browser,start
Process4=browser,start
;Process5=browser,Nostart

; **************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=1000
DepthSamplingRate=0.1


; **************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=69
Current=250
ToolTopNominalVoltage=68
ToolTopNominalCurrent=80
AutoAdjust=yes
VoltMeterYellow=55
VoltMeterGreen=80
VoltMeterRed=100
```

```
AmpMeterYellow=60
AmpMeterGreen=95
AmpMeterRed=100

[Patcher]
;positive voltage
Coupler=Inductive
PowerZero=WLArm
TNeg=WL1

; ***************************************************************
; Tool telemetry protocol
;
[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=1
Gain=x1
PositivePulseEnable=yes
NegativePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=yes

[ToolAdapterConfig0]
Name=Mini Winch 200-300M 1/8,1/10" single
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=3200
NegativePulseDiscriminatorLevel=-1920
```

```
[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
Description=
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=5248
NegativePulseDiscriminatorLevel=-3968

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=4352
NegativePulseDiscriminatorLevel=-2816

; **************************************************************
; Caliper
;
[Caliper]
Caliper=no

; **************************************************************
; Tool channels description & calibration
;
[MultiCh]
NbCh=10
NbRawCh=6
NbProcessedCh=4
ToolLength=1.97

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=Mt/min
CalA=1
CalB=0
```

```
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3

[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.count
Producer=Tool
ChShift=0
Unit=count
Offset=7
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.count
Producer=Tool
ChShift=0
Unit=count
```

```
Offset=9
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch5]
DisplayEnable=no
CalibrationEnable=no
Name=Pos.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=13
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch6]
DisplayEnable=no
CalibrationEnable=no
Name=Neg.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=17
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch7]
DisplayEnable=yes
CalibrationEnable=yes
;Formula=if({Ch6} > 0, ({Ch4}-1)/{Ch6},0)
Formula=if({Ch4} > 65534, ({Ch4}-1)/{Ch6},{Ch4}/{Ch2})
Name=Temperature
Producer=MChProc
ChShift=0.08
Unit=deg C
CalA=0.0187482
CalB=-24.1407
Reference1=7.3
Reference2=72
NumberFormat=%6.2f
Low=0
High=50
```

```
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=5
Left=40
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=15
CalDate=06/10/05 09:48
DisplayedName=Temperature

[Ch8]
DisplayEnable=yes
CalibrationEnable=yes
;Formula=if({Ch5} > 0, ({Ch3}-1)/{Ch5},0)
Formula=if({Ch3} > 65534, ({Ch3}-1)/{Ch5},{Ch3}/{Ch2})
Name=FRes
Producer=MChProc
ChShift=0.05
Unit=Ohm-m
CalA=-0.00708144
CalB=219.702
Reference1=1.49
Reference2=81.9
NumberFormat=%6.2f
Low=0
High=50
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=5
Left=40
Right=100
PenStyle=solid
PenWidth=2
PenColor=400040
Filter=26/04/06 14:50
DisplayedName=FRes

[Ch9]
DisplayEnable=yes
CalibrationEnable=no
Formula=1 / {Ch8} * 10000
Name=FCond
```

```
Producer=MChProc
ChShift=0.05
Unit=uS/cm
Offset=28
DataType=double
CalA=1
CalB=0
NumberFormat=%6.2f
Low=0
High=2000
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=200
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=8000
Filter=5
DisplayedName=FCond
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch10]
DisplayEnable=yes
CalibrationEnable=no
Formula=({Ch9}*({Ch7}+21.5))/46.5
Name=FCond 25'C
Producer=MChProc
ChShift=0.05
Unit=uS/cm
CalA=1
CalB=0
NumberFormat=%6.2f
Low=0
High=2000
NbDecade=1
```

```
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=200
Left=0
Right=30
PenStyle=dash
PenWidth=2
PenColor=8000
Filter=5

; ***************************************************************
; Data browsers default settings
;

[RecDebug]
XOffset=135
YOffset=162
XSize=579
YSize=562
Minimized=no

[MChNum]
XOffset=553
YOffset=287
XSize=230
YSize=190
Minimized=no
NumDisplay1=Ch7
NumDisplay2=Ch8
NumDisplay3=Ch9
NumDisplay4=Ch10
NbNumDisplay=4
NumDisplay5=Ch3
NumDisplay6=Ch4

[MChCurve]
DepthScale=100
ForceTimeMode=yes
DepthSpacing=10
Grid=yes
GridSpacing=1
DepthColLeft=0.3
DepthColRight=0.4
XOffset=226
YOffset=2
XSize=746
YSize=545
```

```
Minimized=no

[MChProc]
XOffset=201
YOffset=201
XSize=302
YSize=147
Minimized=yes

[LASWriter]
XOffset=400
YOffset=88
XSize=284
YSize=206
Minimized=no
```

```
[Description]
ToolName=2PCA Caliper S/N: 5032 (Use Power On to Open Arms)
DriverName=MULTICH

;4-28-06 auto voltage,recip.ch patcher ind. pls x
;6-23-06 Caliper QC x
;5-30-07 remove dc channel pls
;2-08-08 std adapter config pls
;7-11-08 verified mini,4mxa,4mxc tel set pls
;7-23-08 review and approve jrs
; 10-29-08 changed  ch logic divisor to test for 65535 count  pls

; **************************************************************
; Data browsers
;
[Process]
Process1=mch\mchproc.exe
Process2=mch\mchnum.exe
Process3=mch\mchcurve.exe
Process4=mch\laswriter.exe
;Process5=mch\recdebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
Process4=Browser,Start
;Process5=Browser,NoStart

; **************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=500
DepthSamplingRate=0.01

; **************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=68.2577
Current=250
ToolTopNominalVoltage=68
ToolTopNominalCurrent=80
AutoAdjust=yes
VoltMeterYellow=60
VoltMeterGreen=90
VoltMeterRed=150
```

```
AmpMeterYellow=15
AmpMeterGreen=50
AmpMeterRed=90

[Patcher]
; negative voltage
Coupler=inductive
TPos=WLArm
PowerZero=WL1

; *************************************************************
; Tool telemetry protocol
;
[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=2
Gain=x1
PositivePulseEnable=no
NegativePulseEnable=yes
PositivePulseAutomaticDiscriminator=no
NegativePulseAutomaticDiscriminator=yes

[ToolAdapterConfig0]
Name=Mini Winch 200-300M 1/8,1/10" single
Gain=X2
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=15870
NegativePulseDiscriminatorLevel=-3072
```

```
[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
Description=
Gain=X4
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=32767
NegativePulseDiscriminatorLevel=-7817

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=15863
NegativePulseDiscriminatorLevel=-3456


; **************************************************************
; Caliper
;
[Caliper]
Caliper=yes
WarnBeforePowerOn=yes
OpenVoltage=76
OpenCurrent=250
OpenTime=90
RestorePowerWhenCaliperOpen=yes
CloseVoltage=76
CloseCurrent=250
CloseTime=90
RestorePowerWhenCaliperClosed=no

[CaliperOpenPatcher]
;Negative power
Coupler=inductive
TNeg=WLArm
PowerZero=WL1
CIn=WL1

[CaliperClosePatcher]
```

```
;positive power
Coupler=inductive
TNeg=WL1
PowerZero=WLArm

; *************************************************************
; Tool channels description & calibration
;
[MultiCh]
NbCh=5
NbRawCh=4
NbProcessedCh=1
ToolLength=1.687

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=CAL - Speed
Producer=Logger
ChShift=0
Unit=Mt/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=95
Right=135
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=0

[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=CAL - Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
```

```
CalB=0
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=CAL - Neg.count
Producer=Tool
ChShift=0
Unit=count
Offset=9
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=CAL - Neg.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=17
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch3} > 65534, ({Ch3}-1)/{Ch4},{Ch3}/{Ch2})
Name=Caliper
Producer=MChProc
ChShift=0.257
Unit=cm
DataType=double
CalA=0.00864006
CalB=-24.7335
Reference1=10.2
Reference2=15.2
NumberFormat=%6.2f
PenColor=0
PenStyle=solid
PenWidth=2
Left=95
Right=135
```

```
Low=0
High=10
GridEnable=yes
Grid=2
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=0
CalDate=27/10/13 08:49
DisplayedName=Caliper
QCLow=1
QCHigh=150
QCInRangeColor=1
QCOutRangeColor=2
QCInRangeText=Open
QCOutRangeText=Red = Opening
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Red = Opening
QCMedRangeText=Open
QCHighRangeText=Red = Opening
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

; **************************************************************
; Data browsers default settings
;

[MChNum]
NbLedDisplay=1
LedDisplay1=Ch5
XOffset=252
YOffset=303
XSize=230
YSize=164
Minimized=no
NumDisplay1=Ch5
NbNumDisplay=1
NumDisplay2=Ch3

[MChCurve]
XOffset=669
YOffset=0
XSize=931
YSize=870
Minimized=no
```

```
DepthScale=40
ForceTimeMode=yes
DepthSpacing=4
Grid=yes
GridSpacing=0.4
DepthColLeft=0.3
DepthColRight=0.4

[LASWriter]
XOffset=0
YOffset=0
XSize=284
YSize=213
Minimized=no

[RecDebug]
XOffset=304
YOffset=239
XSize=609
YSize=555
Minimized=no

[MChProc]
XOffset=86
YOffset=471
XSize=228
YSize=115
Minimized=yes
```

```
[Description]
ToolName=2PEA-F Electrical Resisitivity S/N: 2658 (0-2500 Ohm.m)
DriverName=MULTICH

;11-01-06  telemetry settingsn pls
;5-30-07 fcond ch and formula correction, calibrationenable= pls
;;1-28-08 std adapter config, res labels pls hdw test
;7-23-08 review and approve. jrs  changed Arps formula for Flcond@25 C.
;8-13-08 DataType=double fixed in processed ch pls
;4-20-09 fix Fcond ChShift=0.05 pls
; **************************************************************
; Data browsers
;
[Process]
Process1=mch\mchproc.exe
Process2=mch\mchnum.exe
Process3=mch\mchcurve.exe
Process4=mch\laswriter.exe
;Process5=mch\recdebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
Process4=Browser,Start
;Process5=Browser,NoStart

; **************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=1000
DepthSamplingRate=0.05

; **************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=102
Current=300
ToolTopNominalVoltage=83
ToolTopNominalCurrent=150
AutoAdjust=yes
VoltMeterYellow=75
VoltMeterGreen=115
VoltMeterRed=125
AmpMeterYellow=40
AmpMeterGreen=220
```

```
AmpMeterRed=250


; ***********************************************************
; Tool telemetry protocol
;
[Protocol]
LengthMode=Fixed
Length=120
LengthMax=120
ChecksumMode=none
TimeOut1=1000
TimeOut2=500
SamplingCmdLength=4
SamplingCmd=48,83,66,13

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=MSIFSK
NbConfig=3
DefaultConfig=1
DataBits=8
StopBits=1
Parity=even

[ToolAdapterConfig0]
Name=Mini Winch 200-300M 1/8, 1/10" single
Description=
TxAmplitude=8228

[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
Description=
TxAmplitude=8228

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
TxAmplitude=13531


[Patcher]
Coupler=capacitive
PowerFilter=WL1
PowerZero=WLArm
```

```
CIn=WL4,MudPlug
COut=WL1
PolyelectricMode=high


; **************************************************************
; Caliper
;
[Caliper]
Caliper=no

; **************************************************************
; Tool channels description & calibration
;

[MultiCh]
ToolLength=2.2
NbCh=18
NbRawCh=11
NbProcessedCh=7

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=Mt/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3

[Ch2]
DisplayEnable=yes
CalibrationEnable=yes
```

```
Name=Gamma
Producer=Tool
ChShift=1.534
Unit=cps
Offset=84
DataType=MGXIIFloat
CalA=1.0
CalB=0
NumberFormat=%5.1f
Low=0
High=200
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=20
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=1
DisplayedName=Gamma

[Ch3]
DisplayEnable=yes
CalibrationEnable=yes
Name=SP
Producer=Tool
ChShift=2.06
Unit=mV
Offset=36
DataType=MGXIIFloat
CalA=1.0
CalB=0
NumberFormat=%6.1f
Low=-100
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=0
Right=30
PenStyle=solid
PenWidth=1
PenColor=0
```

```
Filter=2
DisplayedName=SP
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch4]
DisplayEnable=yes
CalibrationEnable=no
Name=Current
Producer=Tool
ChShift=0.42
Unit=mA
Offset=24
DataType=MGXIIFloat
CalA=1.0
CalB=0
NumberFormat=%7.1f
DisplayedName=Current
Low=0
High=50
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=0
Right=30
PenStyle=solid
PenWidth=1
PenColor=0
Filter=2
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
```

```
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch5]
DisplayEnable=no
CalibrationEnable=no
Name=VR
Producer=Tool
ChShift=0.42
Unit=mV
Offset=0
DataType=MGXIIFloat
CalA=1.0
CalB=0
NumberFormat=%6.2f
DisplayedName=VR
Low=0
High=1
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=0
Right=100
PenStyle=solid
PenWidth=1
PenColor=0
Filter=1

[Ch6]
DisplayEnable=no
CalibrationEnable=no
Name=V8
Producer=Tool
ChShift=0.52
Unit=mV
Offset=96
DataType=MGXIIFloat
CalA=1.0
CalB=0
NumberFormat=%6.0f

[Ch7]
DisplayEnable=no
CalibrationEnable=no
Name=V16
```

```
Producer=Tool
ChShift=0.622
Unit=mV
Offset=48
DataType=MGXIIFloat
CalA=1.0
CalB=0
NumberFormat=%6.2f

[Ch8]
DisplayEnable=no
CalibrationEnable=no
Name=V32
Producer=Tool
ChShift=0.825
Unit=mV
Offset=108
DataType=MGXIIFloat
CalA=1.0
CalB=0
NumberFormat=%6.2f

[Ch9]
DisplayEnable=no
CalibrationEnable=no
Name=V64
Producer=Tool
ChShift=1.232
Unit=mV
Offset=60
DataType=MGXIIFloat
CalA=1.0
CalB=0
NumberFormat=%6.2f

[Ch10]
DisplayEnable=yes
CalibrationEnable=yes
Name=Fres
Producer=Tool
ChShift=0.05
Unit=Ohm-m
Offset=12
DataType=MGXIIFloat
CalA=1
CalB=0
Reference1=0
Reference2=100
```

```
NumberFormat=%6.2f
PenColor=0
PenStyle=solid
PenWidth=1
Left=70
Right=100
Low=0
High=20
GridEnable=no
Grid=2
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=1
DisplayedName=Fres
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch11]
DisplayEnable=yes
CalibrationEnable=yes
Name=Temp
Producer=Tool
ChShift=0.08
Unit=DegC
Offset=72
DataType=MGXIIFloat
CalA=1
CalB=0
Reference1=0
Reference2=100
NumberFormat=%6.2f
PenColor=4080ff
PenStyle=dot
PenWidth=2
Left=70
Right=100
Low=10
High=30
```

```
GridEnable=no
Grid=10
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=1
DisplayedName=Temp
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no


;**********************************
[Ch12]
DisplayEnable=yes
CalibrationEnable=yes
Name=SPR
Formula={Ch5}/{Ch4}
Producer=MChProc
ChShift=0.42
Unit=Ohm
DataType=double
CalA=1.0
CalB=0
NumberFormat=%7.1f
Low=0
High=250
NbDecade=3
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=0
Filter=2
DisplayedName=SPR
```

```
[Ch13]
DisplayEnable=yes
CalibrationEnable=yes
Name=R8
Formula={Ch6}/{Ch4}*2.5
Producer=MChProc
ChShift=0.52
Unit=Ohm-m
DataType=double
CalA=1.0
CalB=0
NumberFormat=%7.1f
Low=0
High=250
NbDecade=3
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=12.5
Left=40
Right=100
PenStyle=solid
PenWidth=1
PenColor=400040
Filter=2
DisplayedName=R8
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch14]
DisplayEnable=yes
CalibrationEnable=yes
Name=R16
Formula={Ch7}/{Ch4}*5
Producer=MChProc
ChShift=0.622
Unit=Ohm-m
DataType=double
CalA=1.0
```

```
CalB=0
NumberFormat=%7.1f
Low=0
High=250
NbDecade=3
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=40
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff0000
Filter=2
DisplayedName=R16
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch15]
DisplayEnable=yes
CalibrationEnable=yes
Name=R32
Formula={Ch8}/{Ch4}*10
Producer=MChProc
ChShift=0.825
Unit=Ohm-m
DataType=double
CalA=1.0
CalB=0
NumberFormat=%7.1f
Low=0
High=250
NbDecade=3
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=40
```

```
Right=100
PenStyle=dash
PenWidth=2
PenColor=8000ff
Filter=2
DisplayedName=R32
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch16]
DisplayEnable=yes
CalibrationEnable=yes
Name=R64
Formula={Ch9}/{Ch4}*20
Producer=MChProc
ChShift=0.123
Unit=Ohm-m
DataType=double
CalA=1.0
CalB=0
NumberFormat=%7.1f
Low=0
High=250
NbDecade=3
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=40
Right=100
PenStyle=dot
PenWidth=2
PenColor=0
Filter=2
DisplayedName=R64
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
```

```
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch17]
DisplayEnable=yes
CalibrationEnable=no
Name=FCond
Formula=1 / {Ch10} * 10000
Producer=MChProc
ChShift=0.05
Unit=uS/cm
DataType=double
CalA=1.0
CalB=0
NumberFormat=%6.2f
Low=0
High=2000
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=200
Left=0
Right=30
PenStyle=dot
PenWidth=2
PenColor=0
Filter=5
DisplayedName=FCond
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch18]
DisplayEnable=no
```

```
CalibrationEnable=no
Formula=({Ch17}*({Ch11}+21.5))/46.5
Name=FCond 25'C
Producer=MChProc
ChShift=0.05
Unit=uS/cm
DataType=double
CalA=1
CalB=0
NumberFormat=%6.1f
Low=0
High=2000
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=100
Left=0
Right=30
PenStyle=dot
PenWidth=2
PenColor=8000
Filter=2
DisplayedName=FCond 25'C
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

; **************************************************************
; Data browsers default settings
;

[MChNum]
NbNumDisplay=11
NumDisplay1=Ch2
NumDisplay2=Ch3
NumDisplay3=Ch4
NumDisplay4=Ch12
NumDisplay5=Ch13
NumDisplay6=Ch14
```

```
NumDisplay7=Ch15
NumDisplay8=Ch16
NumDisplay9=Ch10
NumDisplay10=Ch11
NumDisplay11=Ch17
NumDisplay12=Ch18

XOffset=219
YOffset=297
XSize=230
YSize=396
Minimized=no

[MChCurve]
XOffset=343
YOffset=4
XSize=748
YSize=734
Minimized=no
DepthScale=200
ForceTimeMode=yes
DepthSpacing=10
Grid=yes
GridSpacing=1
DepthColLeft=0.3
DepthColRight=0.4

[LASWriter]
XOffset=0
YOffset=0
XSize=284
YSize=213
Minimized=yes

[RecDebug]
XOffset=75
YOffset=194
XSize=609
YSize=562
Minimized=no

[MChProc]
XOffset=284
YOffset=441
XSize=228
YSize=115
Minimized=yes
```

```
[Description]
ToolName=2PGA Gamma S/N: 2622
DriverName=MULTICH

;
;4-26-06 auto voltage, recip ch, patcher ind pls x
;11-01-06  telemetry settingsn pls
;5-30-07 no recip, CalibrationEnable= update pls
;1-17-08 std adapter config pls
;2-01-08 scales no dtc pls hdw test
;3-13-08 change back to recip to eliminate saturation in high cps situations  jrs
;7-14-08 verify mini,4mxa,4mxc tel set pls
;8-040-8 review and approve jrs
**************************************************************
; Data browsers
;
[Process]
Process1=mch\mchproc.exe
Process2=mch\mchnum.exe
Process3=mch\mchcurve.exe
;Process5=mch\recdebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
;Process5=Browser,NoStart

; **************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=500
DepthSamplingRate=0.025


; **************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=75
Current=250
ToolTopNominalVoltage=68
ToolTopNominalCurrent=41
AutoAdjust=yes
VoltMeterYellow=60
VoltMeterGreen=80
VoltMeterRed=100
```

```
AmpMeterYellow=30
AmpMeterGreen=60
AmpMeterRed=100

[Patcher]
Coupler=Inductive
PowerZero=WLArm
TNeg=WL1

; ***************************************************************
; Tool telemetry protocol
;
[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=1
Gain=x1
PositivePulseEnable=yes
NegativePulseEnable=no
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=no

[ToolAdapterConfig0]
Name=Mini Winch 200-300M 1/8,1/10" single
Description=
Gain=X1
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=3200
NegativePulseDiscriminatorLevel=-5700
```

```
[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
Description=
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=12728
NegativePulseDiscriminatorLevel=-1536

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=7808
NegativePulseDiscriminatorLevel=-4597

; *************************************************************
; Caliper
;
[Caliper]
Caliper=no

; *************************************************************
; Tool channels description & calibration
;
[MultiCh]
NbCh=5
NbRawCh=4
NbProcessedCh=1
ToolLength=0.79

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=GAM - Speed
Producer=Logger
ChShift=0
Unit=Mt/min
CalA=1
CalB=0
```

```
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3

[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=GAM - Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=GAM - Pos.count
Producer=Tool
ChShift=0
Unit=count
Offset=7
DataType=word
CalA=1
CalB=0
NumberFormat=%6.2f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=GAM - Pos.dt
Producer=Tool
ChShift=0
Unit=sec
```

```
Offset=13
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
Formula=if({Ch4} > 0, ({Ch3}-1)/{Ch4},0)
Name=Natrual Gamma
Producer=MChProc
ChShift=0.135
Unit=cps
Offset=15
DataType=double
CalA=1
CalB=0
NumberFormat=%6.2f
Low=0
High=200
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=10
Left=175
Right=215
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3
DisplayedName=Gamma
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no
;DisplayedName=GR


; **************************************************************
; Data browsers default settings
```

```
;

[RecDebug]
XOffset=1
YOffset=147
XSize=810
YSize=689
Minimized=yes

[MChNum]
XOffset=270
YOffset=460
XSize=230
YSize=115
Minimized=no
NbNumDisplay=1
NumDisplay1=Ch5


[MChCurve]
DepthScale=100
ForceTimeMode=no
DepthSpacing=5
Grid=yes
GridSpacing=0.5
DepthColLeft=0.3
DepthColRight=0.4
XOffset=913
YOffset=0
XSize=687
YSize=870
Minimized=no

[MChProc]
XOffset=277
YOffset=636
XSize=228
YSize=119
Minimized=no
```

```
[Description]
ToolName=2PIA Conductivity S/N: 3513 (0-1000ms)
DriverName=MULTICH

;4-27-06 auto voltage,recip.ch patcher ind. pls x
;11-01-06 telmetry update ps
;6-05-07 no DC ch update PS

[Process]
Process1=mch\MchProc.exe
Process2=mch\Mchnum.exe
Process3=mch\Laswriter.exe
Process4=mch\MchCurve.exe
;Process5=mch\RecDebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
Process4=Browser,Start
;Process5=Browser,NoStart

[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

[Default]
TimeSamplingRate=1000
DepthSamplingRate=.05

[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=2
Gain=x0
PositivePulseEnable=yes
NegativePulseEnable=no
PositivePulseAutomaticDiscriminator=yes
NegativePulseAutomaticDiscriminator=no
```

```
[ToolAdapterConfig0]
Name=Winch 305M 1/10" single
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=5632
NegativePulseDiscriminatorLevel=-32767

[ToolAdapterConfig1]
Name=Winch 500M 1/10" single
Description=
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=5504
NegativePulseDiscriminatorLevel=-32767

[ToolAdapterConfig2]
Name=Winch 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=yes
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=3712
NegativePulseDiscriminatorLevel=-16256


[PowerSupply]
Voltage=75
Current=250
ToolTopNominalVoltage=75
ToolTopNominalCurrent=60
AutoAdjust=yes
VoltMeterYellow=60
VoltMeterGreen=80
VoltMeterRed=150
AmpMeterYellow=25
AmpMeterGreen=50
```

```
AmpMeterRed=80

[Patcher]
;Positive Voltage
Coupler=inductive
PowerZero=WLArm
TNeg=WL1

[Caliper]
Caliper=no
CaliperWaitTime=0

[MultiCh]
NbCh=6
NbRawCh=4
NbProcessedCh=2
ToolLength=1.73
TimeAvailable=no
TimeDataType=word
EnableSpeedCh=yes

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=COND - Speed
Producer=Logger
ChShift=0
Unit=M/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3
Reference1=1
Reference2=0
CalDate=05/12/05 12:37
```

```
[Ch2]
DisplayEnable=no
CalibrationEnable=no
Name=COND - Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.050
CalB=0
NumberFormat=%5.3f

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=COND - Pos.count
Producer=Tool
ChShift=0
Unit=count
Offset=7
DataType=word
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=COND - Pos.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=13
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch5]
DisplayEnable=yes
CalibrationEnable=yes
Formula=if({Ch4} > 0, ({Ch3}-1)/{Ch4},0)
Name=Apparent Conductivity
Producer=MCHProc
ChShift=0.72
Unit=mS/m
Offset=
```

```
DataType=double
CalA=0.2
CalB=-2481.86
Reference1=0
Reference2=1000
NumberFormat=%6.2f
PenColor=ff
PenStyle=solid
PenWidth=2
Left=40
Right=100
Low=0
High=1000
GridEnable=yes
Grid=100
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=2
CalDate=19/10/16 19:33
DisplayedName=Apparent Conductivity


[Ch6]
DisplayEnable=yes
CalibrationEnable=no
Formula=1 / {Ch5} * 1000
Name=COND - Ind Res
Producer=MCHProc
ChShift=0.70
Unit=Ohm-m
Offset=
DataType=double
CalA=1
CalB=0
Reference1=0
Reference2=1
NumberFormat=%6.2f
PenColor=a00000
PenStyle=solid
PenWidth=2
Left=0
Right=30
Low=0
High=50
GridEnable=yes
Grid=5
NbDecade=1
```

```
ReverseScale=no
Mode=Linear
Filter=2
;DisplayedName=COND - Ind Res

[MChNum]
Minimized=no
XOffset=290
YOffset=463
XSize=230
YSize=143
NumDisplay1=Ch5
NumDisplay2=Ch6
NbNumDisplay=2

[LASWriter]
XOffset=160
YOffset=113
XSize=284
YSize=213
Minimized=no

[MChCurve]
DepthScale=50
ForceTimeMode=no
DepthSpacing=0.00125
Grid=yes
GridSpacing=0.000125
XOffset=679
YOffset=0
XSize=687
YSize=728
Minimized=no
DepthColLeft=0.3
DepthColRight=0.4

[MSIProc]
XOffset=218
YOffset=202
XSize=228
YSize=115
Minimized=no

[RecDebug]
XOffset=0
YOffset=0
XSize=570
YSize=514
```

```
Minimized=yes

[MChProc]
XOffset=291
YOffset=346
XSize=228
YSize=119
Minimized=no
```

```
[Description]
ToolName=2SNA-S Spectral Gamma S/N: 4116
DriverName=2SNA1000S

;
;5-09-06 patcher Cin=WLArm pls x
;6-05-07 CalibrationEnable= update pls

; **************************************************************
; Data browsers
;
[Process]
Process1=sna1000s\sna1000sproc.exe
Process2=sna1000s\sna1000spectra.exe
Process3=mch\mchnum.exe
Process4=mch\mchcurve.exe
Process5=mch\LasWriter.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
Process4=Browser,Start
Process5=Browser,Start
; **************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRateMin=1000
TimeSamplingRate=1000
TimeSamplingRateMax=5000
DepthSamplingRate=0.1
SpectrumSize=512

; **************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=121
Current=200
ToolTopNominalVoltage=105
ToolTopNominalCurrent=125
AutoAdjust=yes
VoltMeterYellow=105
VoltMeterGreen=135
VoltMeterRed=150
AmpMeterYellow=60
AmpMeterGreen=170
```

```
AmpMeterRed=200

[Patcher]
Coupler=Capacitive
PowerFilter=WL1
PowerZero=WLArm
CIn=WLArm
COut=WL1

; ***************************************************************
; Tool telemetry protocol
;
[Protocol]
NbOfProtocol=1
SerialMode=Asynchronous
LengthMode=VariableWord
LengthAddress=0
LengthMultiplier=1
LengthOffset=0
LengthMax=2200
ChecksumMode=none
TimeOut1=800
TimeOut2=200
SamplingCmdLength=1
SamplingCmd=255

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=MSIFFSK
NbConfig=1
DefaultConfig=0
DataBits=8
StopBits=1
Parity=even

[ToolAdapterConfig0]
Name=Winch 500M 1/8" single
Description=
TxAmplitude=14804


; ***************************************************************
; Caliper
;
[Caliper]
```

```
Caliper=no

; ***************************************************************
; Tool channels description & calibration
;

[SNA1000S]
Multiplier=3000
Offset=0
IFG=no

[MultiCh]
NbCh=13
NbRawCh=13
NbProcessedCh=0
ToolLength=1.81

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0.0
Unit=m/min
NumberFormat=%6.2f
PenColor=0
PenStyle=solid
PenWidth=1
Left=0
Right=30
Low=0
High=10
GridEnable=yes
Grid=2
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=1
DisplayedName=Speed

[Ch2]
DisplayEnable=yes
CalibrationEnable=no
Name=SP
Producer=Tool
ChShift=0.13
Unit=mV
Offset=32
```

```
DataType=mgxiifloat
Low=-100
High=100
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=20
Left=0
Right=30
PenStyle=solid
PenWidth=1
PenColor=0
Filter=1
DisplayedName=SP

[Ch3]
DisplayEnable=no
CalibrationEnable=no
Name=Temp
Producer=Tool
ChShift=0.58
Unit=degC
Offset=62
DataType=mgxiifloat

[Ch4]
DisplayEnable=no
CalibrationEnable=no
Name=HV
Producer=Tool
ChShift=0.58
Unit=Volts
Offset=74
DataType=mgxiifloat

[Ch5]
DisplayEnable=no
CalibrationEnable=no
Name=Resistance
Producer=SNA1000SProc
ChShift=0.13
Unit=Ohms
CalA=1
CalB=0
NumberFormat=%5.1f
Reference1=1
Reference2=0
```

```
CalDate=13/10/05 04:25

[Ch6]
DisplayEnable=yes
CalibrationEnable=yes
Name=GR total
DisplayName=Total Gamma
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f
Low=0
High=200
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=20
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=1
DisplayedName=GR total

[Ch7]
DisplayEnable=yes
CalibrationEnable=no
Name=K
DisplayName=K
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f
Low=0
High=2
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=0.2
Left=40
Right=100
```

```
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=1
DisplayedName=K
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch8]
DisplayEnable=yes
CalibrationEnable=no
Name=U
DisplayName=U
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f
Low=0
High=2
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=40
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff0000
Filter=1
DisplayedName=U
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
```

```
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch9]
DisplayEnable=yes
CalibrationEnable=no
Name=Th
DisplayName=Th
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f
Low=0
High=2
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=40
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff00
Filter=1
DisplayedName=Th
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch10]
DisplayEnable=no
CalibrationEnable=no
Name=Ch4
DisplayName=
```

```
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch11]
DisplayEnable=no
CalibrationEnable=no
Name=Ch5
DisplayName=
Producer=SNA1000SProc
ChShift=0.58
Unit=cps
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch12]
DisplayEnable=no
CalibrationEnable=no
Name=Voltage
Producer=Tool
ChShift=0.58
Offset=8
DataType=mgxiifloat
Unit=mV
CalA=1
CalB=0
NumberFormat=%5.0f

[Ch13]
DisplayEnable=no
CalibrationEnable=no
Name=Current
Producer=Tool
ChShift=0.13
Offset=20
DataType=mgxiifloat
Unit=mA
CalA=1
CalB=0
NumberFormat=%5.0f


; ***************************************************************
; Data browsers default settings
```

```
;

[SNA1000SProc]
IFG=no
EnableStackAutoReset=yes
StackSize=100
Ch1Name=K
Ch1Lo=1360
Ch1Hi=1560
Ch1Color=ffc8c8
Ch2Name=U
Ch2Lo=1660
Ch2Hi=1860
Ch2Color=c8ffc8
Ch3Name=Th
Ch3Lo=2520
Ch3Hi=2720
Ch3Color=c8c8ff
Ch4Name=Csi
Ch4Lo=600
Ch4Hi=770
Ch4Color=ffc8ff
Ch5Name=Ch5
Ch5Lo=0
Ch5Hi=0
Ch5Color=c8ffff
Ch1Display=yes
Ch2Display=yes
Ch3Display=yes
Ch4Display=no
Ch5Display=no
XOffset=369
YOffset=21
XSize=228
YSize=176
Minimized=no

[SNA1000Spectra]
CountLow=0.1
CountHigh=20
CountScaleAuto=yes
LinearCountScale=no
DisplayRawSpectrum=no
DisplayStackedSpectrum=yes
DisplayEnergyWindows=no
CountGrid=10
DisplayCountGrid=no
XOffset=226
```

```
YOffset=265
XSize=843
YSize=459
Minimized=no

[MChNum]
NbNumDisplay=10
NumDisplay1=Ch3
NumDisplay2=Ch4
NumDisplay3=Ch2
NumDisplay4=Ch5
NumDisplay5=Ch6
NumDisplay6=Ch7
NumDisplay7=Ch8
NumDisplay8=Ch9
NumDisplay9=Ch12
NumDisplay10=Ch13
XOffset=677
YOffset=0
XSize=230
YSize=368
Minimized=no

[MChCurve]
DepthScale=200
ForceTimeMode=yes
DepthSpacing=10
Grid=yes
GridSpacing=1
XOffset=790
YOffset=7
XSize=576
YSize=699
Minimized=no
DepthColLeft=0.3
DepthColRight=0.4

[RecDebug]
XOffset=206
YOffset=216
XSize=786
YSize=689
Minimized=no


[LASWriter]
XOffset=430
YOffset=39
```

```
XSize=284
YSize=206
Minimized=no
```

```
[Description]
ToolName = MSI1-GR-DEN
DriverName = TOOLSTACK
FamilyName =
Sub1 = Tool Top,MSI1,Generic MSI1-Speed,
Sub2 = Nuclear,GR,6579,MULTICH
Sub3 = Nuclear,DEN,6366,MULTICH

[Default]
TimeSamplingRate=1000
DepthSamplingRate=0.05

[MultiCh]
NbCh =23
ToolLength = 2.952

[ToolId]
GR = 16
DEN = 27

[GR.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

[DEN.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

; MSI1 channels ------------------------

[Ch1]
Name=Speed
Producer=Logger
ChShift=0
Unit=m/min
CalibrationEnable=no
NumberFormat=%.2f
DisplayEnable=no
CalA=1
CalB=0

; GR channels ------------------------

[Ch2]
Name=Time
Producer=Tool.GR.SYSTEMSTATUS
ChShift=2.02
Unit=sec
```

```
Offset=0
DataType=dword
CalA=0.001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch3]
Name=TCPU
Producer=Tool.GR.SYSTEMSTATUS
ChShift=2.045
Unit='C
Offset=4
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch4]
Name=EHT
Producer=Tool.GR.CHANNELS
ChShift=2.02
Unit=Volts
Offset=0
DataType=word
CalA=-4.00718
CalB=0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no
Reference1=0
Reference2=-1005
CalDate=02/04/13 14:54

[Ch5]
Name=COUNT
Producer=Tool.GR.CHANNELS
ChShift=2.015
Unit=
Offset=2
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
```

```
DisplayEnable=no

[Ch6]
Name=GR
Producer=MChProc
Formula={ch5}/{ch2}
ChShift=2.02
Unit=API
CalA=1.254
CalB=0
CalibrationEnable=yes
CalibrationType=GR
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff

; DEN channels ------------------------

[Ch7]
Name=Time
Producer=Tool.DEN.SYSTEMSTATUS
ChShift=0
Unit=sec
Offset=0
DataType=dword
CalA=0.001
CalB=0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch8]
Name=TCPU
Producer=Tool.DEN.SYSTEMSTATUS
ChShift=0
Unit='C
Offset=4
```

```
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch9]
Name=MOT
Producer=Tool.DEN.SYSTEMSTATUS
ChShift=0
Unit=
Offset=6
DataType=byte
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no
QCLow=1.5
QCHigh=2.5
QCLowRangeColor=5
QCMedRangeColor=5
QCHighRangeColor=3
QCLowRangeText=OPENING
QCMedRangeText=CLOSING
QCHighRangeText=IDLE
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch10]
Name=HV
Producer=Tool.DEN.CHANNELS
ChShift=0
Unit=Volts
Offset=0
DataType=WORD
CalA=4.87465
CalB=1.53203
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch11]
Name=SSDCNT
Producer=Tool.DEN.CHANNELS
ChShift=0.171
```

```
Unit=counts
Offset=2
DataType=DWORD
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch12]
Name=LSDCNT
Producer=Tool.DEN.CHANNELS
ChShift=0.246
Unit=counts
Offset=6
DataType=DWORD
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch13]
Name=CALCNT
Producer=Tool.DEN.CHANNELS
ChShift=0.437
Unit=counts
Offset=10
DataType=DWORD
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch14]
Name=CALCPS
Producer=MChProc
Formula={ch13}/{ch7}
ChShift=0
Unit=cps
CalibrationEnable=no
CalibrationType=
CalA=1
CalB=0
NumberFormat=%6.2f
DisplayEnable=no
```

```
[Ch15]
Name=CAL
Producer=MChProc
Formula=(-1.2E-09*{ch14}*{ch14}+0.000804*{ch14}+2.66215849)
ChShift=0.437
Unit=cm
CalA=0.974155
CalB=-3.96451
CalibrationEnable=yes
Reference1=10.16
Reference2=25.4
CalDate=11/06/18 16:04
NumberFormat=%6.1f
DisplayEnable=yes
PenColor=0
PenStyle=solid
PenWidth=2
Left=0
Right=20
Low=0
High=50
GridEnable=yes
Grid=5
NbDecade=1
ReverseScale=no
Mode=Linear

[Ch16]
Name=SSDCPS
Producer=MChProc
Formula={ch11}/{ch7}
ChShift=0.171
Unit=cps
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%6.2f
DisplayEnable=yes

[Ch17]
Name=RHOSSD
Producer=MChProc
Formula=if({ch16}>0,ln({ch16}),0)
ChShift=0.171
Unit=g/cc
CalibrationEnable=yes
CalA=-1.318
CalB=13.522
```

```
Reference1=1.26
Reference2=2.6
NumberFormat=%6.2f
DisplayEnable=yes
PenColor=ff8000
PenStyle=solid
PenWidth=2
Left=40
Right=70
Low=1
High=3
GridEnable=no
Grid=10
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=1
CalDate=11/06/18 16:04

[Ch18]
Name=LSDCPS
Producer=MChProc
Formula={ch12}/{ch7}
ChShift=0.246
Unit=cps
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%6.2f
DisplayEnable=yes

[Ch19]
Name=RHOLSD
Producer=MChProc
Formula=if({ch18}>0,ln({ch18}),0)
ChShift=0.246
Unit=g/cc
CalibrationEnable=yes
CalA=-0.3109
CalB=4.3266
Reference1=1.26
Reference2=2.6
NumberFormat=%6.2f
DisplayEnable=yes
PenColor=ff
PenStyle=solid
PenWidth=3
Left=40
```

```
Right=70
Low=1
High=3
GridEnable=yes
Grid=0.2
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=8
CalDate=11/06/18 16:04

[Ch20]
Name=RHOB
Producer=MChProc
Formula=((0.77 * {ch19}) +(0.228 * {ch17}))
ChShift=0.1575
Unit=g/cc
CalibrationEnable=no
CalA=1
CalB=0
Reference1=0
Reference2=1
NumberFormat=%6.2f
DisplayEnable=yes
PenColor=40ff00
PenStyle=solid
PenWidth=4
Left=70
Right=100
Low=1
High=3
GridEnable=no
Grid=0.2
NbDecade=1
ReverseScale=no
Mode=Linear
Filter=1

[Ch21]
Name=DRHO
Producer=MChProc
Formula={ch20}-{ch19}
ChShift=0.1575
Unit=g/cc
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%6.2f
```

```
DisplayEnable=no

; MSI1 channels calibrations ------------------------

; GR channels calibrations ------------------------

; DEN channels calibrations ------------------------

[Process]
Process1 = Processor,Start,mch\MChProc.exe
Process2 = Browser,Start,mch\MChCurve.exe
Process3 = Browser,Start,mch\MChNum.exe

[MChProc]
Minimized=yes

[MChCurve]
DepthScale=100
GridSpacing=0.5
XOffset=555
ForceTimeMode=yes
YSize=664
DepthColLeft=0.3
XSize=811
DepthSpacing=5
DepthColRight=0.40
Minimized=yes
YOffset=58
Grid=yes

[MChNum]
NumDisplay1=Ch6
NbNumDisplay=5
NumDisplay2=Ch15
NumDisplay3=Ch20
NumDisplay4=Ch16
NumDisplay5=Ch18
LedDisplay1=Ch9
NbLedDisplay=1
XOffset=1126
YOffset=370
XSize=230
YSize=277
Minimized=no

[WellCAD]

; END OF MERGED SUBS SECTIONS ////////////////////////////////////////
```

```
Template1=
[Ch22]
Name=ToolPowerVoltage
Producer=Logger
Unit=V
ChShift=0
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
[Ch23]
Name=ToolPowerCurrent
Producer=Logger
Unit=mA
ChShift=0
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
ß▯      §   ▯ ▯
                       ã▯         ▯ ▯
 :   Ÿ▯
   12<9:220'd▯   ▯▯dcef🡅   ▯   T    ”                          €?▯   m▯   ▯4!'<-
u9:22<;2u&,&!08/
  ▯   C:\Logger\matrix.inið▯  [System]
PipeTimeOut=15000
ServerAddress=127.0.0.1
ServerName=DGI1603
AddressMask=




[Tol Files]
RootDir=C:\Logger\Tools
BitmapDir=C:\Logger\Tools\bitmap
TemplateDir=C:\Logger\Tools\Templates
ToolstackDir=C:\Logger\Tools\My Stacks
HeaderDir=C:\Logger\Tools\Headers
CalibrationDir=C:\Logger\Tools\Calibrations
QLStandaloneToolDir=C:\Logger\Tools\QL-Standalone
AdapterDir=C:\Logger\Tools\adapter\matrix
StandaloneToolDir=C:\Logger\Tools\Standalone\matrix
```

```
[Dashboard Panels]
Depth=yes
Tension=yes
Winch=yes
Tool=yes
Telemetry=yes
Acquisition=yes
Browsers & processors=yes
Status=yes
LedDisplayBkgColor=0
LedDisplayFontColor=7fff
AcqStandbyMsg=
AcqStandbyMsgBlinkingEnable=no

[Printer]
PrinterType=System
ReplayDelay=1000
HeaderForm=Default.wch
HeaderContent=Default.wchc

[FAC40Img]
RefreshRate=1000
AmplitudePalette=0,255,255,255,63,0,0,0
TravelTimePalette=0,255,255,255,63,0,0,0

[MChCurve]
RefreshRate=1000
HGridMajorWidth=2
HGridMajorColor=808080
HGridMinorWidth=1
HGridMinorColor=808080

[MChNum]
WarnOnStoreCalibration=yes
AutoClear=yes
DisplayTelemetyStatus=no

[Browsers]
RootDir=C:\Logger
[Depth]
DepthUnit=1
DepthUnitString=m
DepthFormat=%.2f
SpeedUnitString=m/min
SpeedFormat=%.1f
```

```
[Description]
ToolName = MSI1-GR-FWS40-PLUG-40
DriverName = TOOLSTACK
FamilyName =
Sub1 = Tool Top,MSI1,Generic MSI1-Speed,
Sub2 = Nuclear,GR,6579,MULTICH
Sub3 = Sonic,FWS40,182511,FWS
Sub4 = Misc,PLUG-40,,

[Default]
TimeSamplingRate=1000
DepthSamplingRate=0.05

[MultiCh]
NbCh =16
ToolLength = 3.239

[ToolId]
GR = 16
FWS40 = 30

[GR.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

[FWS40.ModuleId]
SYSTEMSTATUS = 1

; MSI1 channels ------------------------

[Ch1]
Name=Speed
Producer=Logger
ChShift=0
Unit=m/min
CalibrationEnable=no
NumberFormat=%.2f
DisplayEnable=no
CalA=1
CalB=0

; GR channels ------------------------

[Ch2]
Name=Time
Producer=Tool.GR.SYSTEMSTATUS
ChShift=2.307
Unit=sec
```

```
Offset=0
DataType=dword
CalA=0.001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch3]
Name=TCPU
Producer=Tool.GR.SYSTEMSTATUS
ChShift=2.332
Unit='C
Offset=4
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch4]
Name=EHT
Producer=Tool.GR.CHANNELS
ChShift=2.307
Unit=Volts
Offset=0
DataType=word
CalA=-4.00718
CalB=0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no
Reference1=0
Reference2=-1005
CalDate=02/04/13 14:54

[Ch5]
Name=COUNT
Producer=Tool.GR.CHANNELS
ChShift=2.302
Unit=
Offset=2
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
```

```
DisplayEnable=no

[Ch6]
Name=GR
Producer=MChProc
Formula={ch5}/{ch2}
ChShift=2.307
Unit=API
CalA=1.254
CalB=0
CalibrationEnable=yes
CalibrationType=GR
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff

; FWS40 channels ------------------------

[Ch7]
Name=RX1-1A - dt
Producer=FwsProc
Unit=us
ChShift=0.33
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%g

[Ch8]
Name=RX2-1A - dt
Producer=FwsProc
Unit=us
ChShift=0.33
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%g
```

```
[Ch9]
Name=RX3-1A - dt
Producer=FwsProc
Unit=us
ChShift=0.33
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%g

[Ch10]
Name=TAmpl0
Producer=FwsProc
Unit=us
ChShift=0.33
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%g

[Ch11]
Name=Ampl0
Producer=FwsProc
Unit=
ChShift=0.33
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%g

[Ch12]
Name=TAmplX
Producer=FwsProc
Unit=us
ChShift=0.33
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%g

[Ch13]
Name=AmplX
Producer=FwsProc
Unit=
ChShift=0.33
CalA=1
CalB=0
```

```
CalibrationEnable=yes
NumberFormat=%g

[Ch14]
Name=Slowness
Producer=MChProc
Formula=({ch8} - {ch7})/0.2
ChShift=1.03
Unit=us/m
CalibrationEnable=no
NumberFormat=%0.f

; PLUG-40 channels ------------------------

; MSI1 channels calibrations ------------------------

; GR channels calibrations ------------------------

; FWS40 channels calibrations ------------------------

; PLUG-40 channels calibrations ------------------------

[Process]
Process1 = Processor,Start,Fws40\FwsProc.exe
Process2 = Processor,Start,mch\MChProc.exe
Process3 = Browser,Start,mch\MChCurve.exe
Process4 = Browser,Start,mch\MChNum.exe
Process5 = Browser,Start,Fws40\FwsWave.exe

[FwsProc]
FirstArrivalProcessWave=0
XOffset=456
YSize=139
XSize=255
CementBondProcessWave=0
Minimized=no
YOffset=221

[MChProc]
Minimized=yes

[MChCurve]
DepthScale=100
GridSpacing=0.5
XOffset=842
ForceTimeMode=no
YSize=585
DepthColLeft=0.3
```

```
XSize=477
DepthSpacing=5
DepthColRight=0.4
Minimized=no
YOffset=3
Grid=yes

[MChNum]
NumDisplay1=Ch6
NbNumDisplay=9
NumDisplay2=Ch7
NumDisplay3=Ch8
NumDisplay4=Ch9
NumDisplay5=Ch10
NumDisplay6=Ch11
NumDisplay7=Ch12
NumDisplay8=Ch13
NumDisplay9=Ch14
XOffset=790
YOffset=57
XSize=230
YSize=340
Minimized=no

[FwsWave]
XOffset=218
YSize=744
XSize=1156
Minimized=yes
YOffset=-8
DisplayRx8=no
DisplayRx7=no
DisplayRx6=no
DisplayRx5=no
DisplayRx4=no
DisplayRx3=yes
DisplayRx2=yes
DisplayRx1=yes
DisplayTxB=no
DisplayTxA=yes

[WellCAD]

; END OF MERGED SUBS SECTIONS ////////////////////////////////////////

Template1=
[Ch15]
Name=ToolPowerVoltage
```

```
Producer=Logger
Unit=V
ChShift=0
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
[Ch16]
Name=ToolPowerCurrent
Producer=Logger
Unit=mA
ChShift=0
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
ß▯      9▯  ▯ ▯
                       ã▯         ▯ ▯      5 ▯ ▯

   12<9:220'd▯   ▯▯dcef⬆   ▯   T    ”                         €?▯   m▯   ▯4!'<-
u9:22<;2u&,&!08/
  ▯   C:\Logger\matrix.inið▯  [System]
PipeTimeOut=15000
ServerAddress=127.0.0.1
ServerName=DGI1603
AddressMask=




[Tol Files]
RootDir=C:\Logger\Tools
BitmapDir=C:\Logger\Tools\bitmap
TemplateDir=C:\Logger\Tools\Templates
ToolstackDir=C:\Logger\Tools\My Stacks
HeaderDir=C:\Logger\Tools\Headers
CalibrationDir=C:\Logger\Tools\Calibrations
QLStandaloneToolDir=C:\Logger\Tools\QL-Standalone
AdapterDir=C:\Logger\Tools\adapter\matrix
StandaloneToolDir=C:\Logger\Tools\Standalone\matrix




[Dashboard Panels]
Depth=yes
Tension=yes
Winch=yes
```

```
Tool=yes
Telemetry=yes
Acquisition=yes
Browsers & processors=yes
Status=yes
LedDisplayBkgColor=0
LedDisplayFontColor=7fff
AcqStandbyMsg=
AcqStandbyMsgBlinkingEnable=no

[Printer]
PrinterType=System
ReplayDelay=1000
HeaderForm=Default.wch
HeaderContent=Default.wchc

[FAC40Img]
RefreshRate=1000
AmplitudePalette=0,255,255,255,63,0,0,0
TravelTimePalette=0,255,255,255,63,0,0,0

[MChCurve]
RefreshRate=1000
HGridMajorWidth=2
HGridMajorColor=808080
HGridMinorWidth=1
HGridMinorColor=808080

[MChNum]
WarnOnStoreCalibration=yes
AutoClear=yes
DisplayTelemetyStatus=no

[Browsers]
RootDir=C:\Logger
[Depth]
DepthUnit=1
DepthUnitString=m
DepthFormat=%.2f
SpeedUnitString=m/min
SpeedFormat=%.1f
```

```
[Description]
ToolName = NWMO-MSI1-BRIDLE-GR-IP-PLUG-40
DriverName = TOOLSTACK
FamilyName =
Sub1 = Tool Top,MSI1,Generic MSI1-Speed,
Sub2 = Resistivity,BRIDLE,,
Sub3 = Nuclear,GR,6579,MULTICH
Sub4 = Resistivity,IP,5578,IP
Sub5 = Misc,PLUG-40,,

[Default]
ReleaseTime=250
EnableAdvancedSettings=yes
TimeSamplingRate=1000
InjectionTime=250
DepthSamplingRate=0.05

[MultiCh]
NbCh =107
ToolLength = 11.092

[ToolId]
GR = 16
IP = 22

[GR.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

[IP.ModuleId]
SYSTEMSTATUS = 1
ELOG = 5
IPLIN = 7
IPLOG = 8
IPFW16 = 10
IPFW64 = 11
IPFWV16 = 12
IPFWV64 = 13
IPFWVSPR = 14
IPFWISPR = 15

; MSI1 channels ------------------------

[Ch1]
Name=Speed
Producer=Logger
ChShift=0
Unit=m/min
```

```
CalibrationEnable=no
NumberFormat=%.2f
DisplayEnable=no
CalA=1
CalB=0

; BRIDLE channels ------------------------

; GR channels ------------------------

[Ch2]
Name=Time
Producer=Tool.GR.SYSTEMSTATUS
ChShift=2.275
Unit=sec
Offset=0
DataType=dword
CalA=0.001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch3]
Name=TCPU
Producer=Tool.GR.SYSTEMSTATUS
ChShift=2.3
Unit='C
Offset=4
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch4]
Name=EHT
Producer=Tool.GR.CHANNELS
ChShift=2.275
Unit=Volts
Offset=0
DataType=word
CalA=-4.00718
CalB=0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no
```

```
Reference1=0
Reference2=-1005
CalDate=02/04/13 14:54

[Ch5]
Name=COUNT
Producer=Tool.GR.CHANNELS
ChShift=2.27
Unit=
Offset=2
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch6]
Name=GR
Producer=MChProc
Formula={ch5}/{ch2}
ChShift=2.275
Unit=API
CalA=1.254
CalB=0
CalibrationEnable=yes
CalibrationType=GR
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff

; IP channels ------------------------

[Ch7]
Name=Time
Producer=Tool.IP.SYSTEMSTATUS
Unit=sec
```

```
ChShift=0.19
DataType=DWord
Offset=0
CalA=0.001
CalB=0
CalibrationEnable=no
NumberFormat=%.3f
DisplayEnable=no

[Ch8]
Name=TCPU
Producer=Tool.IP.SYSTEMSTATUS
Unit='C
ChShift=0.19
DataType=word
Offset=4
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch9]
Name=VSP
Producer=Tool.IP.ELOG
Unit=mV
ChShift=1.879
DataType=long
Offset=0
CalA=0.567786
CalB=169.257
CalibrationEnable=yes
NumberFormat=%8.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=8000
Grid=20
Left=0
ReverseScale=no
GridEnable=yes
PenWidth=2
Right=30
DisplayEnable=yes
NbDecade=1
Low=-200
Reference1=1
Reference2=0
```

```
CalDate=08/04/19 10:48

[Ch10]
Name=VSPR
Producer=Tool.IP.ELOG
Unit=V
ChShift=0.253
DataType=long
Offset=4
CalA=1.21986e-006
CalB=-0.0881887
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no
Reference1=16.021
Reference2=0.58
CalDate=08/04/19 10:48

[Ch11]
Name=I
Producer=Tool.IP.ELOG
Unit=mA
ChShift=0.19
DataType=long
Offset=8
CalA=6.05846e-005
CalB=-0.0243914
CalibrationEnable=no
NumberFormat=%8.1f
DisplayEnable=no
Reference1=497.305
Reference2=0
CalDate=08/04/19 10:48

[Ch12]
Name=V16
Producer=Tool.IP.ELOG
Unit=V
ChShift=0.456
DataType=long
Offset=12
CalA=1.22267e-006
CalB=0.00022898
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no
Reference1=2.948
Reference2=0.00053
```

```
CalDate=08/04/19 10:48

[Ch13]
Name=V64
Producer=Tool.IP.ELOG
Unit=V
ChShift=1.065
DataType=long
Offset=16
CalA=1.21614e-006
CalB=0.000225844
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no
Reference1=0.714
Reference2=0.00042
CalDate=08/04/19 10:48

[Ch14]
Name=V8
Producer=Tool.IP.ELOG
Unit=V
ChShift=0.354
DataType=long
Offset=20
CalA=1.1993e-006
CalB=-0.000195303
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no
Reference1=5.682
Reference2=0.00055
CalDate=08/04/19 10:48

[Ch15]
Name=V32
Producer=Tool.IP.ELOG
Unit=V
ChShift=0.659
DataType=long
Offset=24
CalA=1.19357e-006
CalB=0.000284389
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no
Reference1=1.42
Reference2=0.00052
```

```
CalDate=08/04/19 10:48

[Ch16]
Name=Vinj16
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=4
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch17]
Name=NbWinlin
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.19
DataType=byte
Offset=12
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch18]
Name=Tlin.1
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=Long
Offset=13
CalA=0.0001
CalB=0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch19]
Name=WLin16.1
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=17
```

```
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch20]
Name=Tlin.2
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=25
CalA=0.0001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch21]
Name=WLin16.2
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=29
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch22]
Name=Tlin.3
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=37
CalA=0.0001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch23]
Name=WLin16.3
Producer=Tool.IP.IPLIN
```

```
Unit=
ChShift=0.456
DataType=long
Offset=41
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch24]
Name=Tlin.4
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=49
CalA=0.0001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch25]
Name=WLin16.4
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=53
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch26]
Name=Tlin.5
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=61
CalA=0.0001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no
```

```
[Ch27]
Name=WLin16.5
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=65
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch28]
Name=Tlin.6
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=73
CalA=0.0001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch29]
Name=WLin16.6
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=77
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch30]
Name=Tlin.7
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=85
CalA=0.0001
```

```
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch31]
Name=WLin16.7
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=89
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch32]
Name=Tlin.8
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=97
CalA=0.0001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch33]
Name=WLin16.8
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=101
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch34]
Name=Tlin.9
Producer=Tool.IP.IPLIN
Unit=ms
```

```
ChShift=0.19
DataType=long
Offset=109
CalA=0.0001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch35]
Name=WLin16.9
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=113
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch36]
Name=Tlin.10
Producer=Tool.IP.IPLIN
Unit=ms
ChShift=0.19
DataType=long
Offset=121
CalA=0.0001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch37]
Name=WLin16.10
Producer=Tool.IP.IPLIN
Unit=
ChShift=0.456
DataType=long
Offset=125
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no
```

```
[Ch38]
Name=WLin64.1
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=21
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch39]
Name=WLin64.2
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=33
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch40]
Name=WLin64.3
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=45
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch41]
Name=WLin64.4
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=57
CalA=1.0
CalB=0.0
```

```
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch42]
Name=WLin64.5
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=69
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch43]
Name=WLin64.6
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=81
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch44]
Name=WLin64.7
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=93
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch45]
Name=WLin64.8
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
```

```
DataType=long
Offset=105
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch46]
Name=WLin64.9
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=117
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch47]
Name=WLin64.10
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=129
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch48]
Name=Tinj
Producer=Tool.IP.IPLIN
Unit=s
ChShift=0.19
DataType=Word
Offset=0
CalA=0.001
CalB=0
CalibrationEnable=no
NumberFormat=%g
DisplayEnable=no

[Ch49]
```

```
Name=TRel
Producer=Tool.IP.IPLIN
Unit=s
ChShift=0.19
DataType=Word
Offset=2
CalA=0.001
CalB=0
CalibrationEnable=no
NumberFormat=%g
DisplayEnable=no

[Ch50]
Name=Vinj64
Producer=Tool.IP.IPLIN
Unit=
ChShift=1.065
DataType=long
Offset=8
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.0f
DisplayEnable=no

[Ch51]
Name=SPR
Producer=MChProc
Unit=Ohm
ChShift=0.253
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%4.2f
High=200
PenStyle=solid
Mode=Linear
PenColor=0
Grid=20
Left=0
ReverseScale=no
GridEnable=yes
PenWidth=2
Right=30
DisplayEnable=yes
NbDecade=1
Formula=1000*{ch10}/{ch11}
Low=0
```

```
[Ch52]
Name=N16
Producer=MChProc
Unit=Ohm.m
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%4.2f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=20
Left=0
ReverseScale=no
GridEnable=yes
PenWidth=2
Right=30
DisplayEnable=yes
NbDecade=1
Formula=5107*{ch12}/{ch11}
Low=0

[Ch53]
Name=N64
Producer=MChProc
Unit=Ohm.m
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%4.2f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff
Grid=0
Left=0
ReverseScale=no
GridEnable=no
PenWidth=2
Right=30
DisplayEnable=yes
NbDecade=1
Formula=20428*{ch13}/{ch11}
Low=0
```

```
[Ch54]
Name=N8
Producer=MChProc
Unit=Ohm.m
ChShift=0.354
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%4.2f
High=200
PenStyle=solid
Mode=Linear
PenColor=800080
Grid=0
Left=0
ReverseScale=no
GridEnable=no
PenWidth=2
Right=30
DisplayEnable=yes
NbDecade=1
Formula=2553*{ch14}/{ch11}
Low=0

[Ch55]
Name=N32
Producer=MChProc
Unit=Ohm.m
ChShift=0.659
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%4.2f
High=200
PenStyle=solid
Mode=Linear
PenColor=80ff
Grid=0
Left=0
ReverseScale=no
GridEnable=no
PenWidth=2
Right=30
DisplayEnable=yes
NbDecade=1
Formula=10214*{ch15}/{ch11}
Low=0
```

```
[Ch56]
Name=IPlin16.1
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff
Grid=0
Left=35
ReverseScale=no
GridEnable=yes
PenWidth=2
Right=67.5
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch19}/{ch16}
Low=0

[Ch57]
Name=IPlin16.2
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=35
ReverseScale=no
GridEnable=no
PenWidth=2
Right=67.5
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch21}/{ch16}
Low=0
```

```
[Ch58]
Name=IPlin16.3
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=35
ReverseScale=no
GridEnable=no
PenWidth=2
Right=67.5
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch23}/{ch16}
Low=0

[Ch59]
Name=IPlin16.4
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=35
ReverseScale=no
GridEnable=no
PenWidth=2
Right=67.5
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch25}/{ch16}
Low=0
```

```
[Ch60]
Name=IPlin16.5
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=35
ReverseScale=no
GridEnable=no
PenWidth=2
Right=67.5
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch27}/{ch16}
Low=0

[Ch61]
Name=IPlin16.6
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=35
ReverseScale=no
GridEnable=no
PenWidth=2
Right=67.5
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch29}/{ch16}
Low=0
```

```
[Ch62]
Name=IPlin16.7
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=35
ReverseScale=no
GridEnable=no
PenWidth=2
Right=67.5
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch31}/{ch16}
Low=0

[Ch63]
Name=IPlin16.8
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=35
ReverseScale=no
GridEnable=no
PenWidth=2
Right=67.5
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch33}/{ch16}
Low=0
```

```
[Ch64]
Name=IPlin16.9
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=35
ReverseScale=no
GridEnable=no
PenWidth=2
Right=67.5
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch35}/{ch16}
Low=0

[Ch65]
Name=IPlin16.10
Producer=MChProc
Unit=mV/V
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff00
Grid=0
Left=35
ReverseScale=no
GridEnable=no
PenWidth=2
Right=67.5
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch37}/{ch16}
Low=0
```

```
[Ch66]
Name=IPlin64.1
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff
Grid=0
Left=67.5
ReverseScale=no
GridEnable=yes
PenWidth=2
Right=100
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch38}/{ch50}
Low=0

[Ch67]
Name=IPlin64.2
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=67.5
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch39}/{ch50}
Low=0
```

```
[Ch68]
Name=IPlin64.3
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=67.5
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch40}/{ch50}
Low=0

[Ch69]
Name=IPlin64.4
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=67.5
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch41}/{ch50}
Low=0
```

```
[Ch70]
Name=IPlin64.5
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=67.5
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch42}/{ch50}
Low=0

[Ch71]
Name=IPlin64.6
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=67.5
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch43}/{ch50}
Low=0
```

```
[Ch72]
Name=IPlin64.7
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=67.5
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch44}/{ch50}
Low=0

[Ch73]
Name=IPlin64.8
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=67.5
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch45}/{ch50}
Low=0
```

```
[Ch74]
Name=IPlin64.9
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff0000
Grid=0
Left=67.5
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch46}/{ch50}
Low=0

[Ch75]
Name=IPlin64.10
Producer=MChProc
Unit=mV/V
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%4.3f
High=200
PenStyle=solid
Mode=Linear
PenColor=ff00
Grid=0
Left=67.5
ReverseScale=no
GridEnable=no
PenWidth=2
Right=100
DisplayEnable=yes
NbDecade=5
Formula=1000*{ch47}/{ch50}
Low=0
```

```
[Ch76]
Name=Ma16
Producer=MChProc
Unit=ms
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%.1f
DisplayEnable=no
Formula=0.001*{ch18}*({ch56}+{ch57}+{ch58}+{ch59}+{ch60}+{ch61}+{ch62}+{ch63}+{ch6
4}+{ch65})

[Ch77]
Name=Ma64
Producer=MChProc
Unit=ms
ChShift=1.065
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%.1f
DisplayEnable=no
Formula=0.001*{ch18}*({ch66}+{ch67}+{ch68}+{ch69}+{ch70}+{ch71}+{ch72}+{ch73}+{ch7
4}+{ch75})

[Ch78]
Name=IPFW16
Producer=Tool.IP.IPFW16
ChShift=0.456
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch79]
Name=IPFW64
Producer=Tool.IP.IPFW64
ChShift=1.065
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch80]
```

```
Name=IPFWV16
Producer=Tool.IP.IPFWV16
ChShift=0.456
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch81]
Name=IPFWV64
Producer=Tool.IP.IPFWV64
ChShift=1.065
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch82]
Name=IPFWVSPR
Producer=Tool.IP.IPFWV16
ChShift=0.253
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch83]
Name=IPFWISPR
Producer=Tool.IP.IPFWV64
ChShift=0.253
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch84]
Name=RTD16POS
Producer=IpProc
ChShift=0.456
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no
```

```
[Ch85]
Name=RTD16POS_VSP
Producer=IpProc
Unit=mV
ChShift=0.456
CalibrationEnable=no
DisplayEnable=no

[Ch86]
Name=RTD16POS_RSS
Producer=IpProc
Unit=
ChShift=0.456
CalibrationEnable=no
DisplayEnable=no

[Ch87]
Name=IPFW16_POSREL
Producer=IpProc
ChShift=0.456
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch88]
Name=IPFW16_POSREL_FIT
Producer=IpProc
ChShift=0.456
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch89]
Name=RTD16NEG
Producer=IpProc
ChShift=0.456
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch90]
```

```
Name=RTD16NEG_VSP
Producer=IpProc
Unit=mV
ChShift=0.456
CalibrationEnable=no
DisplayEnable=no

[Ch91]
Name=RTD16NEG_RSS
Producer=IpProc
Unit=
ChShift=0.456
CalibrationEnable=no
DisplayEnable=no

[Ch92]
Name=IPFW16_NEGREL
Producer=IpProc
ChShift=0.456
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch93]
Name=IPFW16_NEGREL_FIT
Producer=IpProc
ChShift=0.456
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch94]
Name=RTD64POS
Producer=IpProc
ChShift=1.065
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch95]
Name=RTD64POS_VSP
Producer=IpProc
```

```
Unit=mV
ChShift=1.065
CalibrationEnable=no
DisplayEnable=no

[Ch96]
Name=RTD64POS_RSS
Producer=IpProc
Unit=
ChShift=1.065
CalibrationEnable=no
DisplayEnable=no

[Ch97]
Name=IPFW64_POSREL
Producer=IpProc
ChShift=1.065
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch98]
Name=IPFW64_POSREL_FIT
Producer=IpProc
ChShift=1.065
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch99]
Name=RTD64NEG
Producer=IpProc
ChShift=1.065
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch100]
Name=RTD64NEG_VSP
Producer=IpProc
Unit=mV
ChShift=1.065
```

```
CalibrationEnable=no
DisplayEnable=no

[Ch101]
Name=RTD64NEG_RSS
Producer=IpProc
Unit=
ChShift=1.065
CalibrationEnable=no
DisplayEnable=no

[Ch102]
Name=IPFW64_NEGREL
Producer=IpProc
ChShift=1.065
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch103]
Name=IPFW64_NEGREL_FIT
Producer=IpProc
ChShift=1.065
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
DisplayEnable=no

[Ch104]
Name=Ma16'
Producer=IpProc
Unit=ms
ChShift=0.456
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%.1f
DisplayEnable=no

[Ch105]
Name=Ma64'
Producer=IpProc
Unit=ms
ChShift=1.065
CalA=1
```

```
CalB=0
CalibrationEnable=no
NumberFormat=%.1f
DisplayEnable=no

; PLUG-40 channels ------------------------

; MSI1 channels calibrations ------------------------

; BRIDLE channels calibrations ------------------------

; GR channels calibrations ------------------------

; IP channels calibrations ------------------------

; PLUG-40 channels calibrations ------------------------

[Process]
Process1 = Processor,Start,Ip\IpProc.exe
Process2 = Processor,Start,mch\MChProc.exe
Process3 = Browser,Start,mch\MChCurve.exe
Process4 = Browser,Start,mch\MChNum.exe
Process5 = Browser,Start,Ip\IpWave.exe
Process6 = Browser,Start,Ip\IpInversion.exe

[IpProc]
XOffset=1087
YSize=230
XSize=470
Minimized=yes
YOffset=723

[MChProc]
Minimized=yes

[MChCurve]
DepthScale=100
GridSpacing=0.5
XOffset=437
ForceTimeMode=no
YSize=728
DepthColLeft=0.3
XSize=848
DepthSpacing=5
DepthColRight=0.35
Minimized=yes
YOffset=0
Grid=yes
```

```
[MChNum]
XOffset=446
YSize=312
XSize=230
Minimized=no
YOffset=0
NumDisplay1=Ch6
NumDisplay2=Ch9
NumDisplay3=Ch51
NumDisplay4=Ch54
NumDisplay5=Ch52
NumDisplay6=Ch55
NumDisplay7=Ch53
NumDisplay8=Ch76
NbNumDisplay=8

[IpWave]

[IpInversion]
XOffset=516
DisplayFitCurvesPerPolarity=no
YSize=1459
XSize=1694
Minimized=yes
YOffset=38

[WellCAD]

; END OF MERGED SUBS SECTIONS ////////////////////////////////////////

Template1=
[Ch106]
Name=ToolPowerVoltage
Producer=Logger
Unit=V
ChShift=0
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
[Ch107]
Name=ToolPowerCurrent
Producer=Logger
Unit=mA
ChShift=0
CalA=1
CalB=0
```

```
CalibrationEnable=no
DisplayEnable=no
ß       >e    
                       ã          % 9 õ

   12<9:220'd   dcef🡅      T    ”                        €?   m   4!'<-
u9:22<;2u&,&!08/
     C:\Logger\matrix.inið  [System]
PipeTimeOut=15000
ServerAddress=127.0.0.1
ServerName=DGI1603
AddressMask=




[Tol Files]
RootDir=C:\Logger\Tools
BitmapDir=C:\Logger\Tools\bitmap
TemplateDir=C:\Logger\Tools\Templates
ToolstackDir=C:\Logger\Tools\My Stacks
HeaderDir=C:\Logger\Tools\Headers
CalibrationDir=C:\Logger\Tools\Calibrations
QLStandaloneToolDir=C:\Logger\Tools\QL-Standalone
AdapterDir=C:\Logger\Tools\adapter\matrix
StandaloneToolDir=C:\Logger\Tools\Standalone\matrix




[Dashboard Panels]
Depth=yes
Tension=yes
Winch=yes
Tool=yes
Telemetry=yes
Acquisition=yes
Browsers & processors=yes
Status=yes
LedDisplayBkgColor=0
LedDisplayFontColor=7fff
AcqStandbyMsg=
AcqStandbyMsgBlinkingEnable=no

[Printer]
PrinterType=System
ReplayDelay=1000
HeaderForm=Default.wch
```

```
HeaderContent=Default.wchc

[FAC40Img]
RefreshRate=1000
AmplitudePalette=0,255,255,255,63,0,0,0
TravelTimePalette=0,255,255,255,63,0,0,0

[MChCurve]
RefreshRate=1000
HGridMajorWidth=2
HGridMajorColor=808080
HGridMinorWidth=1
HGridMinorColor=808080

[MChNum]
WarnOnStoreCalibration=yes
AutoClear=yes
DisplayTelemetyStatus=no

[Browsers]
RootDir=C:\Logger
[Depth]
DepthUnit=1
DepthUnitString=m
DepthFormat=%.2f
SpeedUnitString=m/min
SpeedFormat=%.1f
```

```
[Description]
ToolName=HPF2293 Heat Pulse Flowmeter for Matrix
DriverName=MSIHPF

;2-08-08 std adapter config, format statement pls
; **************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=50

; **************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=60
Current=180

; **************************************************************
; Tool telemetry protocol
;
[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=2

[ToolAdapterConfig0]
Name=Mini Winch 200-300M 1/8, 1/10" single
Gain=X1
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
```

```
PositivePulseDiscriminatorLevel=2885
NegativePulseDiscriminatorLevel=-16256

[ToolAdapterConfig1]
Name=4MXA 500M 1/8" single
Description=
Gain=X2
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=no
PositivePulseDiscriminatorLevel=2381
NegativePulseDiscriminatorLevel=-2110

[ToolAdapterConfig2]
Name=4MXC 1000M 1/8" single
Description=
Gain=X4
PositivePulseEnable=yes
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=no
NegativePulseAutomaticDiscriminator=no
AutomaticGain=yes
PositivePulseDiscriminatorLevel=2380
NegativePulseDiscriminatorLevel=-2110



[Patcher]
Coupler=inductive
TNeg=WL1
PowerZero=WLArm


; ****************************************************************
; Tool description & calibration
;
[MultiCh]
; length set to the heating grid (TL:1.22m, HG:0.25m)
ToolLength=0.97

[Flow Calibration]
FlowUnits=Gal./min.
FlowNumberFormat=%5.3f
K1Up=0.237644
K2Up=0.449885
UpTime1=0.700
```

```
UpFlow1=1
UpTime2=7.85
UpFlow2=0.05
K1Down=-0.356615
K2Down=-0.563715
DownTime1=1.05
DownFlow1=-1
DownTime2=13.20
DownFlow2=-0.05


[RecDebug]
XOffset=423
YOffset=-7
XSize=609
YSize=562
Minimized=no
```

```
[Description]
ToolName = GR-Neutron
DriverName = TOOLSTACK
FamilyName =
Sub1 = Tool Top,MSI1,Generic MSI1-Speed,
Sub2 = Nuclear,GR,6579,MULTICH
Sub3 = Nuclear,DUAL NEU,6604,MULTICH

[Default]
TimeSamplingRate=1000
DepthSamplingRate=0.05

[MultiCh]
NbCh =16
ToolLength = 2.707

[ToolId]
GR = 16
DUAL NEU = 32

[GR.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

[DUAL NEU.ModuleId]
SYSTEMSTATUS = 1
CHANNELS = 2

; MSI1 channels -------------------------

[Ch1]
Name=Speed
Producer=Logger
ChShift=0
Unit=m/min
CalibrationEnable=no
NumberFormat=%.2f
DisplayEnable=no
CalA=1
CalB=0

; GR channels -------------------------

[Ch2]
Name=Time
Producer=Tool.GR.SYSTEMSTATUS
ChShift=1.775
Unit=sec
```

```
Offset=0
DataType=dword
CalA=0.001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch3]
Name=TCPU
Producer=Tool.GR.SYSTEMSTATUS
ChShift=1.8
Unit='C
Offset=4
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch4]
Name=EHT
Producer=Tool.GR.CHANNELS
ChShift=1.775
Unit=Volts
Offset=0
DataType=word
CalA=-4.00718
CalB=0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no
Reference1=0
Reference2=-1005
CalDate=02/04/13 14:54

[Ch5]
Name=COUNT
Producer=Tool.GR.CHANNELS
ChShift=1.77
Unit=
Offset=2
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
```

```
DisplayEnable=no

[Ch6]
Name=GR
Producer=MChProc
Formula={ch5}/{ch2}
ChShift=1.775
Unit=API
CalA=1.254
CalB=0
CalibrationEnable=yes
CalibrationType=GR
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff

; DUAL NEU channels ------------------------

[Ch7]
Name=Time
Producer=Tool.DUAL NEU.SYSTEMSTATUS
ChShift=0.171
Unit=sec
Offset=0
DataType=dword
CalA=0.001
CalB=0.0
CalibrationEnable=no
NumberFormat=%8.3f
DisplayEnable=no

[Ch8]
Name=TCPU
Producer=Tool.DUAL NEU.SYSTEMSTATUS
ChShift=0.21
Unit='C
Offset=4
```

```
DataType=word
CalA=0.217226
CalB=-61.11
CalibrationEnable=no
NumberFormat=%5.1f
DisplayEnable=no

[Ch9]
Name=SSN CNT
Producer=Tool.DUAL NEU.CHANNELS
ChShift=0.135
Unit=
Offset=0
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch10]
Name=LSN CNT
Producer=Tool.DUAL NEU.CHANNELS
ChShift=0.373
Unit=
Offset=4
DataType=dword
CalA=1.0
CalB=0.0
CalibrationEnable=no
NumberFormat=%5.0f
DisplayEnable=no

[Ch11]
Name=SS Neu cnts
Producer=MChProc
Formula={ch9}/{ch7}
ChShift=0.135
Unit=CPS
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
```

```
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=200
Reference2=1000
CalDate=22/05/19 09:04

[Ch12]
Name=LS Neu cnts
Producer=MChProc
Formula={ch10}/{ch7}
ChShift=0.373
Unit=CPS
CalA=1
CalB=0
CalibrationEnable=no
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=40
Reference2=200
CalDate=22/05/19 09:04

[Ch13]
Name=SS Neutron
Producer=MChProc
Formula={ch9}/{ch7}
ChShift=0.135
Unit=Porosity
CalA=1
CalB=0
CalibrationEnable=yes
```

```
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=200
Reference2=1000
CalDate=22/05/19 09:04

[Ch14]
Name=LS Neutron
Producer=MChProc
Formula={ch10}/{ch7}
ChShift=0.373
Unit=Porosity
CalA=1
CalB=0
CalibrationEnable=yes
NumberFormat=%6.2f
DisplayEnable=yes
Low=0
High=250
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Reference1=40
Reference2=200
CalDate=22/05/19 09:04

; MSI1 channels calibrations ------------------------

; GR channels calibrations ------------------------
```

```
; DUAL NEU channels calibrations ------------------------

[Process]
Process1 = Processor,Start,mch\MChProc.exe
Process2 = Browser,Start,mch\MChCurve.exe
Process3 = Browser,Start,mch\MChNum.exe

[MChProc]
Minimized=yes

[MChCurve]
DepthScale=100
GridSpacing=0.5
XOffset=436
ForceTimeMode=yes
YSize=744
DepthColLeft=0.3
XSize=938
DepthSpacing=5
DepthColRight=0.4
Minimized=no
YOffset=-8
Grid=yes

[MChNum]
NumDisplay1=Ch6
NbNumDisplay=5
NumDisplay2=Ch11
NumDisplay3=Ch12
NumDisplay4=Ch13
NumDisplay5=Ch14
XOffset=517
YOffset=82
XSize=230
YSize=228
Minimized=no

[WellCAD]

; END OF MERGED SUBS SECTIONS ////////////////////////////////////////

Template1=Dual Neutron GR NWMO Baby.wdt
[Ch15]
Name=ToolPowerVoltage
Producer=Logger
Unit=V
ChShift=0
```

```
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
[Ch16]
Name=ToolPowerCurrent
Producer=Logger
Unit=mA
ChShift=0
CalA=1
CalB=0
CalibrationEnable=no
DisplayEnable=no
ß□      Î□  □ □
                        ã□        □ □ □ □  ¢□

   12<9:220'd□   □□dcef🡅   □   T    ”                        €?□   m□   □4!'<-
u9:22<;2u&,&!08/
  □   C:\Logger\matrix.inið□  [System]
PipeTimeOut=15000
ServerAddress=127.0.0.1
ServerName=DGI1603
AddressMask=




[Tol Files]
RootDir=C:\Logger\Tools
BitmapDir=C:\Logger\Tools\bitmap
TemplateDir=C:\Logger\Tools\Templates
ToolstackDir=C:\Logger\Tools\My Stacks
HeaderDir=C:\Logger\Tools\Headers
CalibrationDir=C:\Logger\Tools\Calibrations
QLStandaloneToolDir=C:\Logger\Tools\QL-Standalone
AdapterDir=C:\Logger\Tools\adapter\matrix
StandaloneToolDir=C:\Logger\Tools\Standalone\matrix




[Dashboard Panels]
Depth=yes
Tension=yes
Winch=yes
Tool=yes
Telemetry=yes
Acquisition=yes
```

```
Browsers & processors=yes
Status=yes
LedDisplayBkgColor=0
LedDisplayFontColor=7fff
AcqStandbyMsg=
AcqStandbyMsgBlinkingEnable=no

[Printer]
PrinterType=System
ReplayDelay=1000
HeaderForm=Default.wch
HeaderContent=Default.wchc

[FAC40Img]
RefreshRate=1000
AmplitudePalette=0,255,255,255,63,0,0,0
TravelTimePalette=0,255,255,255,63,0,0,0

[MChCurve]
RefreshRate=1000
HGridMajorWidth=2
HGridMajorColor=808080
HGridMinorWidth=1
HGridMinorColor=808080

[MChNum]
WarnOnStoreCalibration=yes
AutoClear=yes
DisplayTelemetyStatus=no

[Browsers]
RootDir=C:\Logger
[Depth]
DepthUnit=1
DepthUnitString=m
DepthFormat=%.2f
SpeedUnitString=m/min
SpeedFormat=%.1f
```

```
; DESCRIPTION
----------------------------------------------------------------------------------
--
[Description]
ToolName                = ABI40
SerialNumber            = 154105
FamilyName              = Imaging
DriverName              = TOOLSTACK
SubDriverName           = ABI2G40

; DIMENSIONS
----------------------------------------------------------------------------------
---
[Dimension]
Length                  = 1.618
Weight                  = 6.524
OD                              = 40
TemperatureRating       = 70
PressureRating          = 200
ToolJoint               = QL40-12
BottomSub               = yes
TopSub                  = no
TelemetrySub            = yes
Bitmap                  = QL40-ABI.bmp

; ASSOCIATED SUBS
--------------------------------------------------------------------------------
[AssociatedSubs]
Sub1                    =


; POWER SUPPLY
----------------------------------------------------------------------------------
-
[PowerSupply]
Mode=Voltage
Voltage                 = 120
Current                 = 150
VoltageRange            = 0,80,160,180
CurrentRange            = 0,15,80,100

; TELEMETRY
----------------------------------------------------------------------------------
----
[ToolAdapter]
Name                    = ALTShallow

[Protocol]
```

```
                        IG_BH02_WP05_QL40-ABI2G-154105_R1a
ID                      = 117
TimeOut1                = 250
TimeOut2                = 20
BaudrateHandler         = 28335,20000000

; TOOL SETTINGS
---------------------------------------------------------------------------------

[Default]
TimeSamplingRate=500
DepthSamplingRate=0.004
AcousticMeasPerRev=144
AcousticTime=1900
AcousticWindowGateLength=272
AcousticEchoMode=1
AcousticEchoGateMode=1
AcousticEchoGateOrigin=446
AcousticEchoGateLength=755
AcousticWaveformAzimuth=45
AcousticWaveformAzimuthInc=0
AcousticThicknessEchoLength=100
AcousticThicknessResFrequLow=160
AcousticThicknessResFrequHigh=1024

; Tool channels description & calibration
--------------------------------------------------------
[Id]
SYSTEMSTATUS  = 1
TEMPERATURE   = 2
APS544        = 3

WAVE          = 4
ECHO1         = 5
ECHO2         = 6
THICKNESS     = 7

[MultiCh]
NbRawCh=23
NbProcessedCh=2

; system status

[Ch1]
Name=System Status
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=
Offset=0
```

```
DataType=byte
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%3.0f
DisplayEnable=no

[Ch2]
Name=Motor
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=
Offset=0
DataType=bit(0)
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%3.0f
DisplayEnable=no
QCLow=0.5
QCHigh=1.5
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=No Sync
QCMedRangeText=OK
QCHighRangeText=No Sync
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch3]
Name=Orientation
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=
Offset=0
DataType=bit(1)
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%3.0f
DisplayEnable=no
QCLow=0.5
QCHigh=1.5
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
```

```
QCLowRangeText=OFFLINE
QCMedRangeText=OK
QCHighRangeText=OFFLINE
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch4]
Name=Motor Period
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=sec
Offset=1
DataType=word
CalibrationEnable=no
CalA=0.0001
CalB=0
NumberFormat=%6.4f
DisplayEnable=no

[Ch5]
Name=VTool
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=V
Offset=3
DataType=word
CalibrationEnable=no
FactoryCalibrationEnable=yes
CalA=0.00529977
CalB=-15.1953
NumberFormat=%5.1f
DisplayEnable=no
Reference1=148.1
Reference2=79.6
CalDate=21/05/13 12:05

[Ch6]
Name=V12
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=V
Offset=5
DataType=word
CalibrationEnable=no
FactoryCalibrationEnable=yes
CalA=0.000302359
CalB=0
```

```
NumberFormat=%5.2f
DisplayEnable=no
Reference1=12.1
Reference2=0
CalDate=21/05/13 12:06

; temperature

[Ch7]
Name=RThead
Producer=Tool.TEMPERATURE
ChShift=0.166
Unit=Ohm
Offset=0
DataType=word
CalibrationEnable=no
FactoryCalibrationEnable=yes
CalA=0.00129334
CalB=94.845
NumberFormat=%7.2f
DisplayEnable=no
Reference1=96.316
Reference2=176.48
CalDate=21/05/13 12:14

[Ch8]
Name=T CPU
Producer=Tool.TEMPERATURE
ChShift=0.37
Unit='C
Offset=4
DataType=word
CalibrationEnable=no
FactoryCalibrationEnable=yes
CalA=0.0078125
CalB=-273
NumberFormat=%5.1f
DisplayEnable=no
Reference1=-273
Reference2=239
CalDate=23/12/11 09:25

; Aps544

[Ch9]
Name=Roll
Producer=Tool.APS544
ChShift=0.166
```

```
Unit=deg
Offset=0
DataType=short
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.1f
DisplayEnable=no

[Ch10]
Name=MRoll
Producer=Tool.APS544
ChShift=0.166
Unit=deg
Offset=2
DataType=short
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.1f
DisplayEnable=no

[Ch11]
Name=Tilt
Producer=Tool.APS544
ChShift=0.166
Unit=deg
Offset=4
DataType=short
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.1f
Low=0
High=15
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=2.5
Left=70
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff
DisplayEnable=yes

[Ch12]
```

```
Name=MagnField
Producer=Tool.APS544
ChShift=0.166
Unit=uT
Offset=6
DataType=short
CalibrationEnable=no
CalA=0.01
CalB=0
NumberFormat=%6.2f
DisplayEnable=no

[Ch13]
Name=Azimuth
Producer=Tool.APS544
ChShift=0.166
Unit=deg
Offset=8
DataType=short
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.1f
Low=0
High=360
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=45
Left=40
Right=70
PenStyle=solid
PenWidth=2
PenColor=ff0000
DisplayEnable=yes

[Ch14]
Name=Gravity
Producer=Tool.APS544
ChShift=0.166
Unit=g
Offset=10
DataType=short
CalibrationEnable=no
CalA=0.0001
CalB=0
NumberFormat=%6.4f
```

```
DisplayEnable=no

[Ch15]
Name=T APS
Producer=Tool.APS544
ChShift=0.166
Unit='C
Offset=12
DataType=short
CalibrationEnable=no
CalA=0.01
CalB=0
NumberFormat=%6.2f
Low=0
High=300
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=8000
Filter=1
DisplayEnable=yes

; window arrival details

[Ch16]
Name=WndTime
Producer=Tool.ECHO1
ChShift=0.166
Unit=us
Offset=6
DataType=word
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.2f
DisplayEnable=no

[Ch17]
Name=WndAmpl
Producer=Tool.ECHO1
ChShift=0.166
Unit=
```

```
Offset=8
DataType=word
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%6.2f
DisplayEnable=no

; Echo1

[Ch18]
Name=TravelTime
Producer=Tool.ECHO1
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

[Ch19]
Name=Amplitude
Producer=Tool.ECHO1
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

; Echo2

[Ch20]
Name=TravelTime
Producer=Tool.ECHO2
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

[Ch21]
Name=Amplitude
Producer=Tool.ECHO2
```

```
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

; Thickness

[Ch22]
Name=ThicknessTTime
Producer=Tool.THICKNESS
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

[Ch23]
Name=Score
Producer=Tool.THICKNESS
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

; ****************************************
; Formula channels

[Ch24]
Name=MotSpeed
Producer=MChProc
Formula=1/{Ch4}
ChShift=0.166
Unit=rps
CalibrationEnable=no
CalA=1.0
CalB=0.0
NumberFormat=%4.1f
DisplayEnable=no

[Ch25]
```

```
Name=T Head
Producer=MChProc
Formula=(0.39083-sqrt(0.152748+0.000231*(100-{Ch7})))/0.0001155
ChShift=0.166
Unit='C
NumberFormat=%7.2f
CalibrationEnable=no
CalA=1.0
CalB=0.0
Low=0
High=300
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=1
DisplayEnable=yes

; PROCESSORS & BROWSERS
--------------------------------------------------------------------------
[Process]
Process1=Processor,Start,mch\MChProc.exe
Process2=Browser,Start,mch\MChNum.exe
Process3=Browser,Start,abi43\AbiSurfaceImg.exe
Process4=Browser,NoStart,abi43\AbiThicknessImg.exe
Process5=Browser,Start,abi43\AbiCaliper.exe
Process6=Browser,NoStart,mch\MChCurve.exe

[MChProc]
Minimized=yes
XOffset=953
YOffset=510
XSize=302
YSize=147

[MChNum]
XOffset=444
YOffset=505
XSize=230
YSize=113
Minimized=no
NbLedDisplay=2
```

```
LedDisplay1=Ch2
LedDisplay2=Ch3
NbNumDisplay=8
NumDisplay1=Ch24
NumDisplay2=Ch25
NumDisplay3=Ch8
NumDisplay4=Ch5
NumDisplay5=Ch13
NumDisplay6=Ch11
NumDisplay7=Ch12
NumDisplay8=Ch14

[AbiSurfaceImg]
GridSpacing=0.5
Grid=yes
ForceTimeMode=yes
XSize=731
DepthSpacing=5
YSize=1164
DepthScale=100
Minimized=no
XOffset=1189
YOffset=2

[AbiCaliper]
High=300
FluidVelocity=1450
Unit=usec
Grid=50
XSize=614
YSize=594
Minimized=no
XOffset=574
YOffset=0
ToolOD=39
CasingVelocity=5850
Low=0

[AbiThicknessImg]
XOffset=454
YOffset=381
XSize=567
YSize=359
Minimized=yes
DepthScale=200
ForceTimeMode=yes
DepthSpacing=10
Grid=no
```

```
GridSpacing=1
ScorePalette=0,0,0,128,32,128,0,0,63,255,255,0
ScoreMin=0
ScoreMax=5000
CasingVelocity=5850
ThicknessUnit=mm
ThicknessMin=2
ThicknessMax=14
ThicknessPalette=0,0,0,128,32,128,0,0,63,255,255,0
OrientTo=nothing

[MChCurve]
XOffset=889
YOffset=592
XSize=1029
YSize=571
Minimized=yes
DepthScale=100
ForceTimeMode=yes
DepthSpacing=5
Grid=yes
GridSpacing=0.5
DepthColLeft=0.3
DepthColRight=0.4
```

```
; DESCRIPTION
----------------------------------------------------------------------------------
--
[Description]
ToolName                = ABI40
SerialNumber            = 190404
FamilyName              = Imaging
DriverName              = TOOLSTACK
SubDriverName           = ABI2G40

; DIMENSIONS
----------------------------------------------------------------------------------
---
[Dimension]
Length                  = 1.618
Weight                  = 6.524
OD                              = 40
TemperatureRating       = 70
PressureRating          = 200
ToolJoint               = QL40-12
BottomSub               = yes
TopSub                  = no
TelemetrySub            = yes
Bitmap                  = QL40-ABI.bmp
ToolJointTop            = QL40-12;QLBUS0,QLBUS1,QLBUS2,QLBUS3
ToolJointBottom         = NONE;QLABIHEAD
Wiring                  = QL

; ASSOCIATED SUBS
--------------------------------------------------------------------------------
[AssociatedSubs]
Sub1                    =


; POWER SUPPLY
----------------------------------------------------------------------------------
-
[PowerSupply]
Mode=Voltage
Voltage                 = 120
Current                 = 150
VoltageRange            = 0,80,160,180
CurrentRange            = 0,15,80,100

; TELEMETRY
----------------------------------------------------------------------------------
----
[ToolAdapter]
```

```
Name                    = ALTShallow

[Protocol]
ID                      = 117
TimeOut1                = 250
TimeOut2                = 20
BaudrateHandler         = 28335,20000000
PilotFrame              = 7

; TOOL SETTINGS
---------------------------------------------------------------------------------

[Default]
TimeSamplingRate=500
DepthSamplingRate=0.004
AcousticMeasPerRev=144
AcousticTime=1900
AcousticWindowGateLength=272
AcousticEchoMode=1
AcousticEchoGateMode=1
AcousticEchoGateOrigin=446
AcousticEchoGateLength=755
AcousticWaveformAzimuth=45
AcousticWaveformAzimuthInc=0
AcousticThicknessEchoLength=200
AcousticThicknessResFrequLow=160
AcousticThicknessResFrequHigh=1024

; Tool channels description & calibration
--------------------------------------------------------
[Id]
SYSTEMSTATUS  = 1
TEMPERATURE   = 2
APS544        = 3

WAVE          = 4
ECHO1         = 5
ECHO2         = 6
THICKNESS     = 7

[MultiCh]
NbRawCh=23
NbProcessedCh=2

; system status

[Ch1]
Name=System Status
```

```
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=
Offset=0
DataType=byte
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%3.0f
DisplayEnable=no

[Ch2]
Name=Motor
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=
Offset=0
DataType=bit(0)
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%3.0f
DisplayEnable=no
QCLow=0.5
QCHigh=1.5
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=No Sync
QCMedRangeText=OK
QCHighRangeText=No Sync
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch3]
Name=Orientation
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=
Offset=0
DataType=bit(1)
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%3.0f
DisplayEnable=no
QCLow=0.5
```

```
QCHigh=1.5
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=OFFLINE
QCMedRangeText=OK
QCHighRangeText=OFFLINE
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch4]
Name=Motor Period
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=sec
Offset=1
DataType=word
CalibrationEnable=no
CalA=0.0001
CalB=0
NumberFormat=%6.4f
DisplayEnable=no

[Ch5]
Name=VTool
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=V
Offset=3
DataType=word
CalibrationEnable=no
FactoryCalibrationEnable=yes
CalA=0.00529977
CalB=-15.1953
NumberFormat=%5.1f
DisplayEnable=no
Reference1=148.1
Reference2=79.6
CalDate=21/05/13 12:05

[Ch6]
Name=V12
Producer=Tool.SYSTEMSTATUS
ChShift=0.166
Unit=V
Offset=5
DataType=word
```

```
CalibrationEnable=no
FactoryCalibrationEnable=yes
CalA=0.000302359
CalB=0
NumberFormat=%5.2f
DisplayEnable=no
Reference1=12.1
Reference2=0
CalDate=21/05/13 12:06

; temperature

[Ch7]
Name=RThead
Producer=Tool.TEMPERATURE
ChShift=0.166
Unit=Ohm
Offset=0
DataType=word
CalibrationEnable=no
FactoryCalibrationEnable=yes
CalA=0.00129334
CalB=94.845
NumberFormat=%7.2f
DisplayEnable=no
Reference1=96.316
Reference2=176.48
CalDate=21/05/13 12:14

[Ch8]
Name=T CPU
Producer=Tool.TEMPERATURE
ChShift=0.37
Unit='C
Offset=4
DataType=word
CalibrationEnable=no
FactoryCalibrationEnable=yes
CalA=0.0078125
CalB=-273
NumberFormat=%5.1f
DisplayEnable=no
Reference1=-273
Reference2=239
CalDate=23/12/11 09:25

; Aps544
```

```
[Ch9]
Name=Roll
Producer=Tool.APS544
ChShift=0.166
Unit=deg
Offset=0
DataType=short
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.1f
DisplayEnable=no

[Ch10]
Name=MRoll
Producer=Tool.APS544
ChShift=0.166
Unit=deg
Offset=2
DataType=short
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.1f
DisplayEnable=no

[Ch11]
Name=Tilt
Producer=Tool.APS544
ChShift=0.166
Unit=deg
Offset=4
DataType=short
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.1f
Low=0
High=15
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=2.5
Left=70
Right=100
PenStyle=solid
PenWidth=2
```

```
PenColor=ff
DisplayEnable=yes

[Ch12]
Name=MagnField
Producer=Tool.APS544
ChShift=0.166
Unit=uT
Offset=6
DataType=short
CalibrationEnable=no
CalA=0.01
CalB=0
NumberFormat=%6.2f
DisplayEnable=no

[Ch13]
Name=Azimuth
Producer=Tool.APS544
ChShift=0.166
Unit=deg
Offset=8
DataType=short
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.1f
Low=0
High=360
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=45
Left=40
Right=70
PenStyle=solid
PenWidth=2
PenColor=ff0000
DisplayEnable=yes

[Ch14]
Name=Gravity
Producer=Tool.APS544
ChShift=0.166
Unit=g
Offset=10
DataType=short
```

```
CalibrationEnable=no
CalA=0.0001
CalB=0
NumberFormat=%6.4f
DisplayEnable=no

[Ch15]
Name=T APS
Producer=Tool.APS544
ChShift=0.166
Unit='C
Offset=12
DataType=short
CalibrationEnable=no
CalA=0.01
CalB=0
NumberFormat=%6.2f
Low=0
High=300
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=8000
Filter=1
DisplayEnable=yes

; window arrival details

[Ch16]
Name=WndTime
Producer=Tool.ECHO1
ChShift=0.166
Unit=us
Offset=6
DataType=word
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.2f
DisplayEnable=no

[Ch17]
```

```
Name=WndAmpl
Producer=Tool.ECHO1
ChShift=0.166
Unit=
Offset=8
DataType=word
CalibrationEnable=no
CalA=1
CalB=0
NumberFormat=%6.2f
DisplayEnable=no

; Echo1

[Ch18]
Name=TravelTime
Producer=Tool.ECHO1
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

[Ch19]
Name=Amplitude
Producer=Tool.ECHO1
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

; Echo2

[Ch20]
Name=TravelTime2
Producer=Tool.ECHO2
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0
```

```
[Ch21]
Name=Amplitude2
Producer=Tool.ECHO2
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

; Thickness

[Ch22]
Name=ThicknessTTime
Producer=Tool.THICKNESS
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

[Ch23]
Name=Score
Producer=Tool.THICKNESS
ChShift=0.166
Unit=
Offset=0
DataType=blob
CalibrationEnable=no
CalA=1
CalB=0

; ***************************************
; Formula channels

[Ch24]
Name=MotSpeed
Producer=MChProc
Formula=1/{Ch4}
ChShift=0.166
Unit=rps
CalibrationEnable=no
CalA=1.0
CalB=0.0
```

```
NumberFormat=%4.1f
DisplayEnable=no

[Ch25]
Name=T Head
Producer=MChProc
Formula=(0.39083-sqrt(0.152748+0.000231*(100-{Ch7})))/0.0001155
ChShift=0.166
Unit='C
NumberFormat=%7.2f
CalibrationEnable=no
CalA=1.0
CalB=0.0
Low=0
High=300
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=1
DisplayEnable=yes

; PROCESSORS & BROWSERS
---------------------------------------------------------------------------
[Process]
Process1=Processor,Start,mch\MChProc.exe
Process2=Browser,Start,mch\MChNum.exe
Process3=Browser,Start,abi43\AbiSurfaceImg.exe
Process4=Browser,NoStart,abi43\AbiThicknessImg.exe
Process5=Browser,Start,abi43\AbiCaliper.exe
Process6=Browser,NoStart,mch\MChCurve.exe

[MChProc]
Minimized=yes
XOffset=953
YOffset=510
XSize=302
YSize=147

[MChNum]
XOffset=444
YOffset=505
```

```
XSize=230
YSize=113
Minimized=no
NbLedDisplay=2
LedDisplay1=Ch2
LedDisplay2=Ch3
NbNumDisplay=8
NumDisplay1=Ch24
NumDisplay2=Ch25
NumDisplay3=Ch8
NumDisplay4=Ch5
NumDisplay5=Ch13
NumDisplay6=Ch11
NumDisplay7=Ch12
NumDisplay8=Ch14

[AbiSurfaceImg]
GridSpacing=0.5
Grid=yes
ForceTimeMode=yes
XSize=731
DepthSpacing=5
YSize=1164
DepthScale=100
Minimized=no
XOffset=1189
YOffset=2

[AbiCaliper]
High=300
FluidVelocity=1450
Unit=usec
Grid=50
XSize=614
YSize=594
Minimized=no
XOffset=574
YOffset=0
ToolOD=39
CasingVelocity=5850
Low=0

[AbiThicknessImg]
XOffset=454
YOffset=381
XSize=567
YSize=359
Minimized=yes
```

```
DepthScale=200
ForceTimeMode=yes
DepthSpacing=10
Grid=no
GridSpacing=1
ScorePalette=0,0,0,128,32,128,0,0,63,255,255,0
ScoreMin=0
ScoreMax=5000
CasingVelocity=5850
ThicknessUnit=mm
ThicknessMin=2
ThicknessMax=14
ThicknessPalette=0,0,0,128,32,128,0,0,63,255,255,0
OrientTo=nothing

[MChCurve]
XOffset=889
YOffset=592
XSize=1029
YSize=571
Minimized=yes
DepthScale=100
ForceTimeMode=yes
DepthSpacing=5
Grid=yes
GridSpacing=0.5
DepthColLeft=0.3
DepthColRight=0.4
```

```
; DESCRIPTION
----------------------------------------------------------------------------------
--
[Description]
ToolName                = OBI40
SerialNumber            = 160403
FamilyName              = Imaging
DriverName              = TOOLSTACK
SubDriverName           = OBI2G

; DIMENSIONS
----------------------------------------------------------------------------------
---
[Dimension]
Length                          = 1.475
Weight                          = 5.3
OD                                      = 40
TemperatureRating       = 70
PressureRating          = 200
ToolJoint                       = QL40-12
BottomSub                       = yes
TopSub                          = no
TelemetrySub            = yes
Bitmap                          = QL40-OBI2G.bmp

; ASSOCIATED SUBS
--------------------------------------------------------------------------------
[AssociatedSubs]
Sub1                    =


; POWER SUPPLY
----------------------------------------------------------------------------------
-
[PowerSupply]
Mode                            = Voltage
Voltage                         = 120
Current                         = 300
VoltageRange            = 0,80,150,180
CurrentRange            = 0,75,160,200

; TELEMETRY
----------------------------------------------------------------------------------
----
[ToolAdapter]
Name                    = ALTShallow

[Protocol]
```

```
ID                      = 118
DataTimeOut1            = 100
DataTimeOut2            = 10
ParamTimeOut1           = 3000
ParamTimeOut2           = 250
BaudrateHandler         = 28335,20000000
PilotFrame              = 7

; TOOL SETTINGS
---------------------------------------------------------------------------------

[Default]
TimeSamplingRate=500
DepthSamplingRate=0.016
MeasPerRev=900
Exposure=516
MarkerPos=0.0

; Tool channels description & calibration
--------------------------------------------------------
[Id]
SYSTEMSTATUS  = 1
APS544        = 3

IMAGE         = 8

[MultiCh]
NbRawCh=11
NbProcessedCh=0

; system status

[Ch1]
Name=TCAM
Producer=Tool.SYSTEMSTATUS
ChShift=0.065
Unit='C
Offset=1
DataType=word
CalibrationEnable=no
CalA=0.1
CalB=0.0
NumberFormat=%6.1f
DisplayEnable=no
DisplayedName=TCAM
Low=0
High=70
NbDecade=1
```

```
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=10
Left=70
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff0000
Filter=1
QCLow=0
QCHigh=95
QCLowRangeColor=1
QCMedRangeColor=1
QCHighRangeColor=2
QCLowRangeText=OK
QCMedRangeText=OK
QCHighRangeText=OVERHEAT
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no

[Ch2]
Name=Workload
Producer=Tool.SYSTEMSTATUS
ChShift=0.065
Unit=%
Offset=3
DataType=byte
CalibrationEnable=no
CalA=1
CalB=0.0
NumberFormat=%3.0f
DisplayEnable=no

[Ch3]
Name=FRate
Producer=Tool.SYSTEMSTATUS
ChShift=0.065
Unit=fps
Offset=4
DataType=byte
CalibrationEnable=no
CalA=1
CalB=0.0
NumberFormat=%3.0f
DisplayEnable=no
```

```
; aps544

[Ch4]
Name=Roll
Producer=Tool.APS544
ChShift=0.065
Unit=deg
Offset=0
DataType=short
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.1f
DisplayEnable=no
DisplayedName=Roll
Low=0
High=360
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=70
Right=100
PenStyle=solid
PenWidth=1
PenColor=0

[Ch5]
Name=MRoll
Producer=Tool.APS544
ChShift=0.065
Unit=deg
Offset=2
DataType=short
CalibrationEnable=no
CalA=0.1
CalB=0
NumberFormat=%6.1f
DisplayEnable=no
DisplayedName=MRoll
Low=0
High=360
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
```

```
Left=70
Right=100
PenStyle=solid
PenWidth=1
PenColor=0

[Ch6]
Name=Tilt
Producer=Tool.APS544
ChShift=0.065
Unit=deg
Offset=4
DataType=word
CalibrationEnable=no
CalA=0.1
CalB=0.0
NumberFormat=%7.1f
DisplayEnable=yes
DisplayedName=Tilt
Low=0
High=15
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=2.5
Left=40
Right=70
PenStyle=solid
PenWidth=2
PenColor=ff

[Ch7]
Name=MagnField
Producer=Tool.APS544
ChShift=0.065
Unit=uT
Offset=6
DataType=short
CalibrationEnable=no
CalA=0.01
CalB=0
NumberFormat=%6.2f
DisplayEnable=yes
DisplayedName=MagnField
Low=45
High=55
NbDecade=1
```

```
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=1
Left=70
Right=100
PenStyle=solid
PenWidth=2
PenColor=4080

[Ch8]
Name=Azimuth
Producer=Tool.APS544
ChShift=0.065
Unit=deg
Offset=8
DataType=word
CalA=0.1
CalB=0.0
CalibrationEnable=no
NumberFormat=%7.1f
DisplayEnable=yes
DisplayedName=Azimuth
Low=0
High=360
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=40
Right=70
PenStyle=solid
PenWidth=2
PenColor=ff0000

[Ch9]
Name=Gravity
Producer=Tool.APS544
ChShift=0.065
Unit=g
Offset=10
DataType=short
CalA=0.0001
CalB=0
CalibrationEnable=no
NumberFormat=%6.4f
DisplayEnable=yes
```

```
DisplayedName=Gravity
Low=0.9
High=1.1
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=70
Right=100
PenStyle=solid
PenWidth=2
PenColor=80ff

[Ch10]
Name=TAPS
Producer=Tool.APS544
ChShift=0.065
Unit='C
Offset=12
DataType=word
CalA=0.01
CalB=0.0
CalibrationEnable=no
NumberFormat=%7.2f
DisplayEnable=no
DisplayedName=TAPS
Low=0
High=70
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=0
Left=70
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff00

; image

[Ch11]
Name=Image
Producer=Tool.IMAGE
ChShift=0.065
Unit=
Offset=0
```

```
DataType=blob
CalibrationEnable=no
NumberFormat=%g
DisplayEnable=no

; PROCESSORS & BROWSERS
---------------------------------------------------------------------------
[Process]
Process1=Browser,Start,mch\MChNum.exe
Process2=Browser,Start,obi40\Obi40Img.exe
Process3=Browser,Start,mch\MChCurve.exe
Process4=Browser,NoStart,obi40\ObiHisto.exe

[WellCAD]
Template1=

[MChNum]
XSize=304
YSize=321
Minimized=no
XOffset=500
YOffset=672
LedDisplay1=Ch1
NbLedDisplay=1
NumDisplay1=Ch1
NumDisplay2=Ch8
NumDisplay3=Ch6
NumDisplay4=Ch7
NumDisplay5=Ch9
NbNumDisplay=5

[Obi40Img]
XSize=949
GridSpacing=0.5
Grid=yes
ForceTimeMode=yes
YSize=618
DepthSpacing=5
DepthScale=100
Minimized=no
XOffset=965
YOffset=547
WorkloadMeterRange =0,90,100,120
FrameRateMeterRange =0,100,100,120

[MChCurve]
XSize=952
ForceTimeMode=yes
```

```
Grid=yes
GridSpacing=0.5
YSize=545
DepthSpacing=5
DepthColRight=0.4
DepthScale=100
Minimized=no
XOffset=965
YOffset=0
DepthColLeft=0.3

[ObiHisto]
XOffset                 = 471
YOffset                 = 41
XSize                   = 1186
YSize                   = 929
Minimized               = yes
```

```
[Description]
ToolName=Auslog Mag Susc SN 513 Probe for Matrix
DriverName=MULTICH

;
;7-11-06 auto voltage, recip ch, patcher ind pls x
;

; **************************************************************
; Data browsers
;
[Process]
Process1=mch\mchproc.exe
Process2=mch\mchnum.exe
Process3=mch\mchcurve.exe
Process4=mch\recdebug.exe

[Process Info]
Process1=Processor,Start
Process2=Browser,Start
Process3=Browser,Start
Process4=Browser,NoStart

; **************************************************************
; Tool default power-up settings
;
[Default]
TimeSamplingRate=500
DepthSamplingRate=0.1


; **************************************************************
; Tool power supply requirements
;
[PowerSupply]
Voltage=35
Current=250
ToolTopNominalVoltage=30
ToolTopNominalCurrent=80
AutoAdjust=yes
VoltMeterYellow=20
VoltMeterGreen=50
VoltMeterRed=100
AmpMeterYellow=45
AmpMeterGreen=60
AmpMeterRed=100

[Patcher]
```

```
Coupler=Inductive
PowerZero=WLArm
TNeg=WL1

; **************************************************************
; Tool telemetry protocol
;
[Protocol]
LengthMode=VariableWord
LengthAddress=3
LengthMultiplier=1
LengthOffset=0
LengthMax=32
ChecksumMode=Sum16
TimeOut1=1000
TimeOut2=100

; Tool Adapter default settings
;
[ToolAdapter]
Name=Matrix
Address=100
Modem=PulseCounter
NbConfig=3
DefaultConfig=1
Gain=x1
PositivePulseEnable=no
NegativePulseEnable=yes
PositivePulseAutomaticDiscriminator=no
NegativePulseAutomaticDiscriminator=yes

[ToolAdapterConfig0]
Name=Winch 200M 1/10" Mono
Description=
Gain=X2
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=6144
NegativePulseDiscriminatorLevel=-1536

[ToolAdapterConfig1]
Name=Winch 500M 1/8" Mono
Description=
Gain=X2
PositivePulseEnable=no
```

```
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=8959
NegativePulseDiscriminatorLevel=-32767

[ToolAdapterConfig2]
Name=Winch 1000M 1/10" Mono
Description=
Gain=X2
PositivePulseEnable=no
PositivePulseAutomaticDiscriminator=no
NegativePulseEnable=yes
NegativePulseAutomaticDiscriminator=yes
AutomaticGain=no
PositivePulseDiscriminatorLevel=3070
NegativePulseDiscriminatorLevel=-4480


; **************************************************************
; Caliper
;
[Caliper]
Caliper=no

; **************************************************************
; Tool channels description & calibration
;
[MultiCh]
NbCh=6
NbRawCh=5
NbProcessedCh=1
ToolLength=0.9

[Ch1]
DisplayEnable=no
CalibrationEnable=no
Name=Speed
Producer=Logger
ChShift=0
Unit=Mt/min
CalA=1
CalB=0
NumberFormat=%5.3f
Low=0
High=100
NbDecade=1
```

```
Mode=Linear
ReverseScale=no
GridEnable=no
Grid=10
Left=0
Right=30
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=3

[Ch2]
DisplayEnable=no
Name=Time
Producer=Tool
ChShift=0
Unit=sec
Offset=5
DataType=word
CalA=0.05
CalB=0
NumberFormat=%5.3f
Reference1=1
Reference2=0
CalDate=06/12/19 20:14

[Ch3]
DisplayEnable=no
Name=Neg.count
Producer=Tool
ChShift=0
Unit=count
Offset=9
DataType=word
CalA=1
CalB=0
NumberFormat=%6.2f

[Ch4]
DisplayEnable=no
Name=DC level
Producer=logger
ChShift=0
Unit=cps
Offset=11
DataType=short
CalA=1
CalB=0
```

```
NumberFormat=%5.0f

[Ch5]
DisplayEnable=no
Name=Neg.dt
Producer=Tool
ChShift=0
Unit=sec
Offset=17
DataType=dword
CalA=0.25E-6
CalB=0
NumberFormat=%9.60f

[Ch6]
DisplayEnable=yes
Formula=if({Ch5} > 0, ({Ch3}-1)/{Ch5},0)
Name=Mag Susc
Producer=MChProc
ChShift=0.2
Unit=SI x 10-3
Offset=
DataType=double
CalA=0.0091087
CalB=-9.63364
Reference1=0
Reference2=10
NumberFormat=%6.2f
Low=-5
High=50
NbDecade=1
Mode=Linear
ReverseScale=no
GridEnable=yes
Grid=50
Left=40
Right=100
PenStyle=solid
PenWidth=2
PenColor=ff
Filter=2
DisplayedName=Mag Sus
CalDate=06/12/19 20:14
QCLow=0
QCHigh=0
QCLowRangeColor=2
QCMedRangeColor=1
QCHighRangeColor=2
```

```
QCLowRangeText=Invalid
QCMedRangeText=Valid
QCHighRangeText=Invalid
QCLowRangeBeep=no
QCMedRangeBeep=no
QCHighRangeBeep=no


; ***************************************************************
; Data browsers default settings
;

[RecDebug]
XOffset=1
YOffset=147
XSize=810
YSize=689
Minimized=yes

[MChNum]
XOffset=317
YOffset=409
XSize=230
YSize=115
Minimized=no
NumDisplay1=Ch6
NbNumDisplay=1

[MChCurve]
DepthScale=10
ForceTimeMode=no
DepthSpacing=0.04
Grid=yes
GridSpacing=0.004
DepthColLeft=0.3
DepthColRight=0.4
XOffset=685
YOffset=31
XSize=805
YSize=728
Minimized=yes

[MChProc]
XOffset=0
YOffset=0
XSize=228
YSize=116
Minimized=no
```

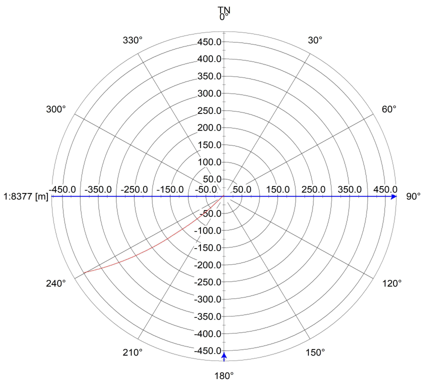
APPENDIX E

Geophysical Logs

Geophysical Record of Borehole: IG_BH02

Log Title: Deviation Log
Project Number: 1671632A-3501
Client: Nuclear Waste Management Organization
Date: April 2020

Bull's Eye



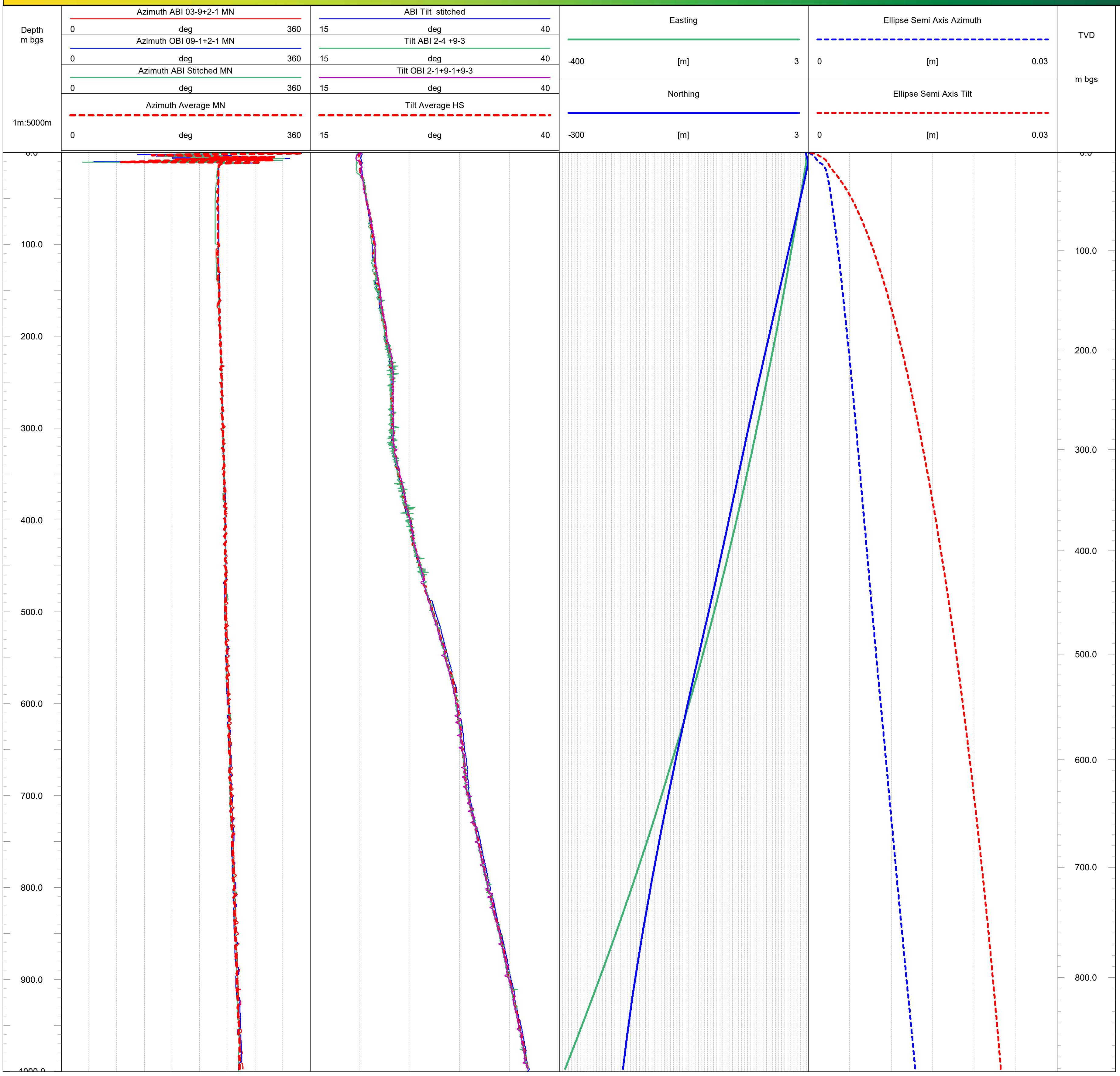
Datum: NAD83, UTM Zone 15N
Easting: 554,034.24 m
Northing: 5,483,950.56 m
Elevation: 435.81 m asl

Mean Inclination: 62 deg
Mean Azimuth (TN): 239 deg MN

Location: Ignace, Ontario
Log Date: December 2019
Logged By: PG/CM/OF

Depth Reference: "0" at Ground
Drilled Depth: 1000.41 m bgs
Borehole Diameter: 96 mm
Casing Diameter: 102 mm
Casing Depth: 71 m bgs
Static Water Level: Variable

Notes: Magnetic Declination calculated to be 1.361 degrees West for the site during the period of measurement.
Magnetic North indicated by green arrow on Bull's Eye plot.
Geomagnetic activity was monitored daily and no anomalies were reported.
Acoustic and Optical Televiewer deviation package accuracy is +/- 1.2 degrees for Azimuth and +/- 0.5 degrees for Tilt.`



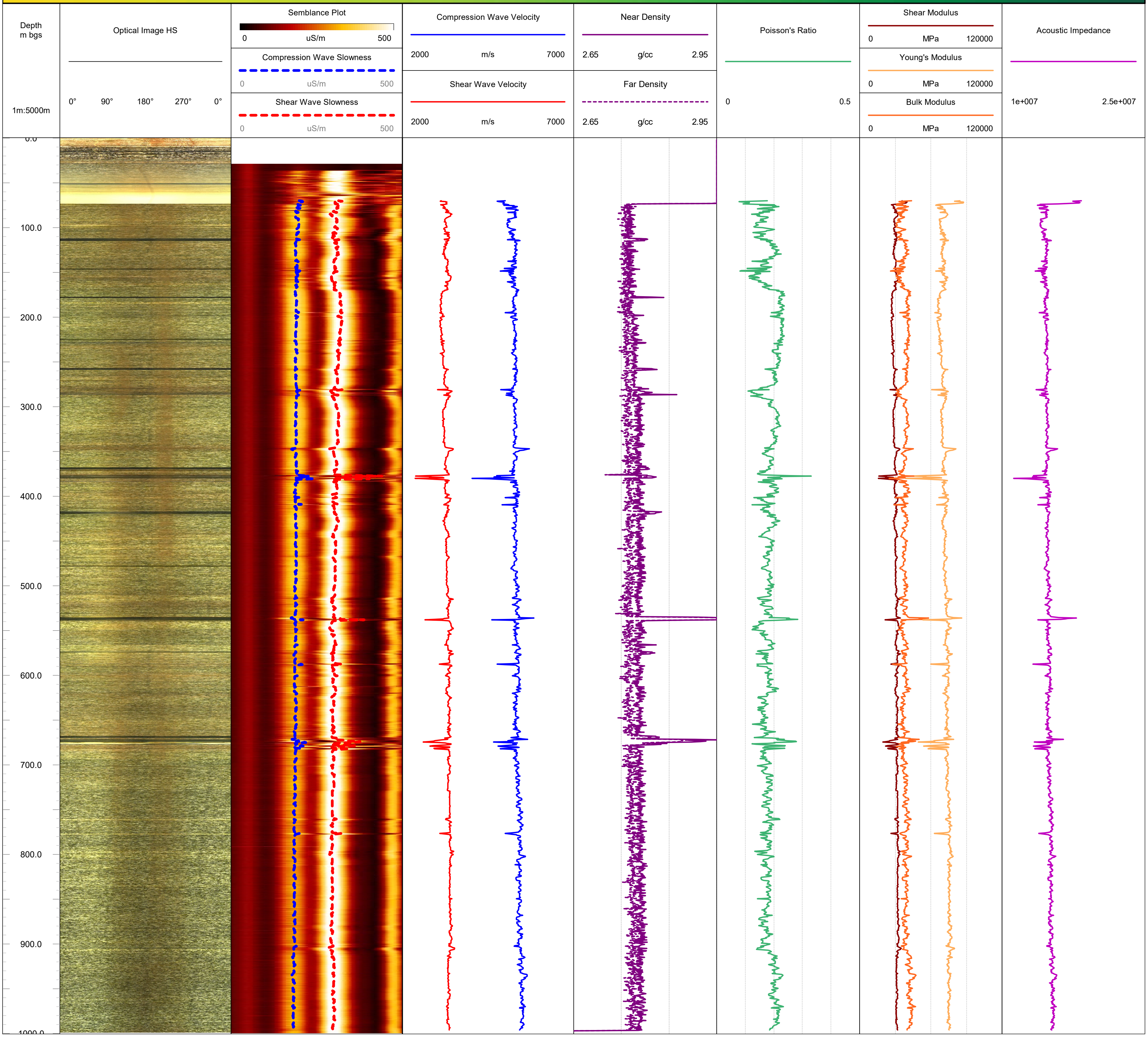
GOLDER

Geophysical Record of Borehole: IG_BH02

Log Title:	Engineering Log
Project Number:	1671632A-3501
Client:	Nuclear Waste Management Organization
Date:	June 2020

Datum:	NAD83, UTM Zone 15N	**Depth Reference:**	"0" at Ground	**Casing Depth:**	71 m bgs	**Location:**	Ignace, Ontario
Easting:	554,034.24 m	**Drilled Depth:**	1000.41 m bgs	**Water Level:**	Variable	**Log Date:**	December 2019
Northing:	5,483,950.56 m	**Borehole Diameter:**	96 mm	**Borehole Inclination:**	62 deg		
Elevation:	435.81 m asl	**Casing Diameter:**	102 mm	**Borehole Azimuth:**	239 deg MN	**Logged By:**	PG,CM,OF

Notes: Optical televiewer image combined from separate runs (top run from 0 m to 100 m and 18 runs from 71 m to 1000 m).
Acoustic televiewer image combined from separate runs (top run from 0 m to 100 m and 32 runs from 71 m to 1000 m).



GOLDER

Geophysical Record of Borehole: IG_BH02

Log Title: Hydrogeology Log
Project Number: 1671632A-3501
Client: Nuclear Waste Management Organization
Date: June 2020

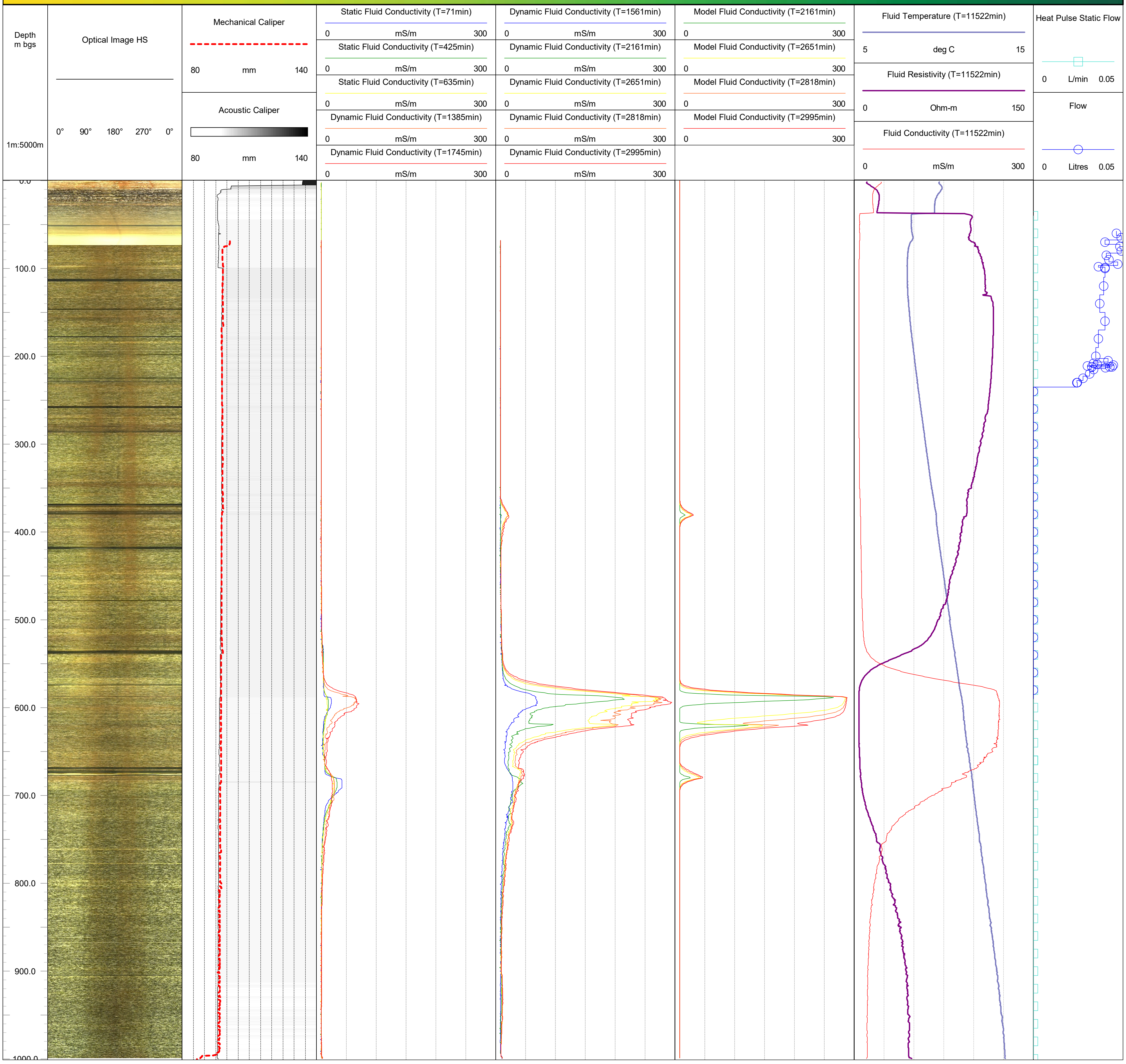
Datum: NAD83, UTM Zone 15N
Easting: 554,034.24 m
Northing: 5,483,950.56 m
Elevation: 435.81 m asl

Depth Reference: "0" at Ground
Drilled Depth: 1000.41 m bgs
Borehole Diameter: 96 mm
Casing Diameter: 102 mm

Casing Depth: 71 m bgs
Water Level: Variable
Borehole Inclination: 62 deg
Borehole Azimuth: 239 deg

Location: Ignace, ON
Log Date: Nov 28 - Dec 29
Logged By: PG, OF, CM

Notes: Fluid conductivity measurements lose accuracy below 10 mS/m.
Final drilling rods were removed at T=0min
Pumping began at T=1047min
Final FTR log run 11,522min after first static test, 7 days after end of pumping
Optical televiewer image combined from separate runs (top run from 0 m to 100 m and 18 runs from 71 m to 1000 m)
Acoustic televiewer image combined from separate runs (top 2 runs from 0 m to 100 m and 34 runs from 71 m to 1000 m)



Geophysical Record of Borehole: IG_BH02

Log Title: Lithology Log
Project Number: 1671632A-3501
Client: Nuclear Waste Management Organization
Date: June 2020

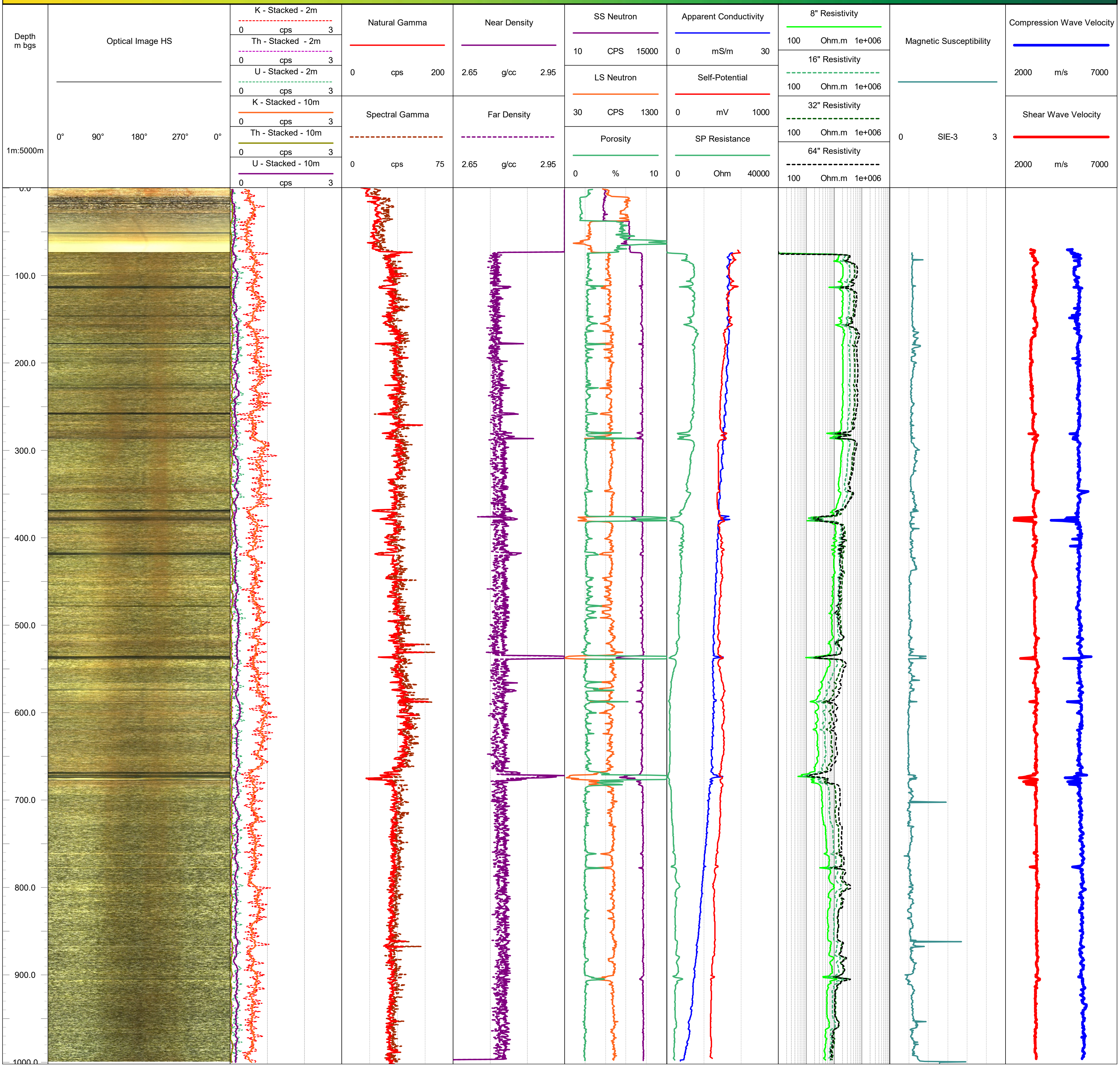
Datum: NAD83, UTM Zone 15N
Easting: 554,034.24 m
Northing: 5,483,950.56 m
Elevation: 435.81 m asl

Depth Reference: "0" at Ground
Drilled Depth: 1000.41 m bgs
Borehole Diameter: 96 mm
Casing Diameter: 102 mm

Casing Depth: 71 m bgs
Water Level: Variable
Borehole Inclination: 62 deg
Borehole Azimuth: 239 deg

Location: Ignace, Ontario
Log Date: December 2019
Logged By: PG/CM/OF

Notes: Optical televiewer image combined from separate runs (top run from 0 m to 100 m and 18 runs from 71 m to 1000 m).
Acoustic televiewer image combined from separate runs (top 2 run from 0 m to 100 m and 32 runs from 71 m to 1000 m).

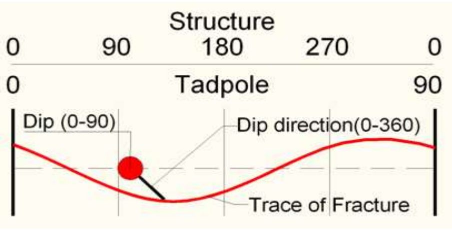


GOLDER

Geophysical Record of Borehole: IG_BH02

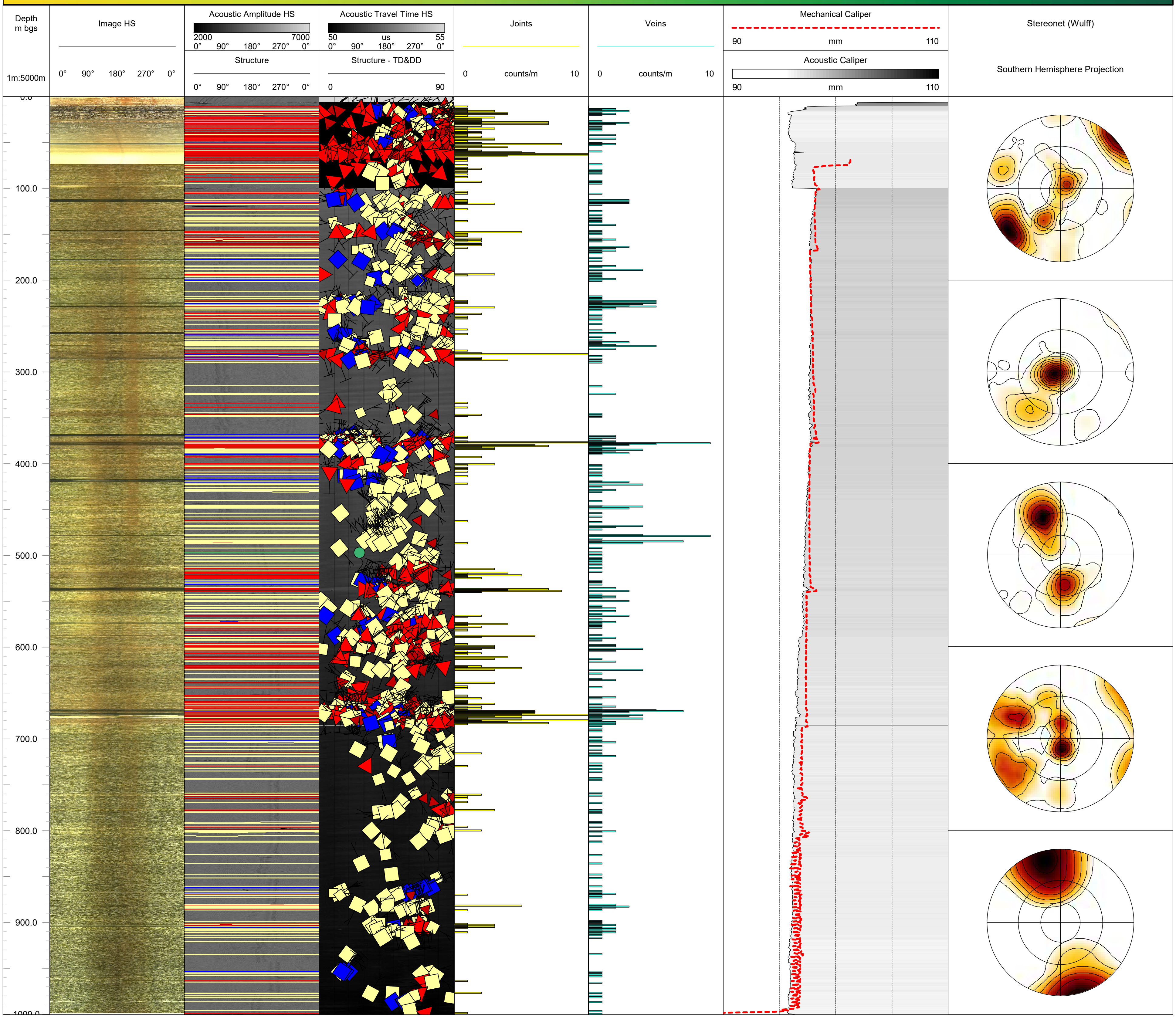
Log Title: Structural Log
Project Number: 1671632A-3501
Client: Nuclear Waste Management Organization
Date: July 2020

Datum:	NAD83, UTM Zone 15N	**Depth Reference:**	"0" at Ground	**Casing Depth:**	71 m bgs	**Location:**	Ignace, Ontario
Easting:	554,034.24 m	**Drilled Depth:**	1000.41 m bgs	**Water Level:**	Variable	**Log Date:**	December 2019
Northing:	5,483,950.56 m	**Borehole Diameter:**	96 mm	**Borehole Inclination:**	62 deg		
Elevation:	435.81 m asl	**Casing Diameter:**	102 mm	**Borehole Azimuth:**	239 deg MN	**Logged By:**	PG,CM,OF



- Foliation (High)
- Foliation (Medium)
- Foliation (Low)
- Vein (High)
- Vein (Medium)
- Vein (Low)
- Joint Intact (High)
- Joint Intact (Medium)
- Joint Intact (Low)
- Joint Broken (High)
- Joint Broken (Medium)
- Joint Broken (Low)
- Contact Broken (High)
- Contact Broken (Medium)
- Contact Broken (Low)
- Contact Intact (High)
- Contact Intact (Medium)
- Contact Intact (Low)

Notes: Optical televiewer image combined from separate runs (top run from 0 m to 100 m and 18 runs from 71 m to 1000 m).
Acoustic televiewer image combined from separate runs (top 2 runs from 0 m to 100 m and 32 runs from 71 m to 1000 m).



APPENDIX F

FFEC Modelling Report

Dilution experiment modeling and analysis for FEC profiles in BH02

The dilution experiment in borehole BH02 was a departure from the usual form of the experiment where the evolution of fluid electrical conductivity (FEC) profiles over time is measured after an initial column profile is established using water of a consistently lower FEC than water flowing in from the formation (Tsang et al 1990; Paillet, 2012). Standard dilution logging calls for repeat profiling after the start of steady pumping to stimulate inflow to the column. When flow zones contributing flow during pumping are not very productive, it is usual to stimulate steady upflow with steady recovery after an abrupt lowering of water level in the column. In the case of BH02 the initial static water level was difficult to establish (because of the generally slow recovery of water level after disturbance and assumed to be around 25 m below the surface) and an initial drawdown to about 30 m failed to generate anything but a minuscule rate of inflow to casing. Water level was taken down to about 52 m after about 2000 minutes and a recovery rate of about 0.02 lpm was observed (approximately 9 m of recovery in a 10 cm diameter borehole over an additional 3000-minute measurement period). Some small, irregularly defined variations in the FEC column of the profile resulted from either a very low recovery rate or disturbance to the borehole by repeated passage of the logging probe during the initial 2000 minutes. The dilution model application was made by assuming a static column until the drawdown was increased to about 52 m and then assuming a steady "pumping" applied by recovery after that time. The slight evolution of the FEC column during the first 2000 minutes of the experiment presents a departure from the ideal experiment but these departures were only a small fraction of the larger FEC excursions measured after 2000 minutes.

The evolution of the FEC column profiles in the time before the additional drawdown was applied show some small excursions that might be associated with inflowing formation water and a systematic upward drift of values in the lower portion of the borehole. The signatures might indicate the general depths of flow zones but cannot be identified as expected signatures of inflow and movement along the borehole. FEC profiles made after 2000 minutes with the additional drawdown of more than 20 m do show systematic inflow and propagation signatures that can be fit to a dilution model and that include FEC values up to two orders of magnitude greater than those obtained in the earlier profiles.

Looking at these later FEC profiles, flow zones are identified at 381, 588, 620, 668, 680, and 730 m in depth (table 1). Of these, the excursion at 730 m is so small as to be barely detectable and so poorly defined as to be excluded from modeling efforts. The zone is noted as a possible inflow zone with inflow at least one order of magnitude less than the smallest values given in table 1. Note that a small component of flow across the borehole and along the flow zone (denoted as horizontal flow) has been added to improve the match between model and FEC data profiles.

The dilution model results are unusual in that the model clearly and unambiguously shows downflow over an interval extending from the 588 m inflow zone to beyond the 620 m zone in spite of significant drawdown in the column. Most of the downflow exits at that latter depth, but the evolution of the FEC profiles shows that a little downflow continues down past that point. FEC profiles often do not indicate where flow is exiting the borehole because that depth may not be marked by an excursion away from the initial profile. Looking at the FEC data, the curves are drifting slowly downward at 650 m so outflow must occur below that depth. An abrupt break at 668 m at the top of the FEC excursion extending up from the 680 m zone is taken as the location for the outflow. The distribution of borehole flow indicated by this modeling is shown in figure 1. The interval above the major inflow at 588 m shows no flow at all in figure 1, but enough inflow comes in at the 381 m depth to account for the slow upflow into casing. The total solute inflow and the shape of FEC excursion at that depth is so ill-defined that there is great uncertainty in the model fit such that a wide range of combinations of inflow rate and inflowing FEC can yield the same amount of cumulative solute in approximately 1000 minutes of inflow.

A single flow zone contributing upflow of 0.02 lpm (the measured recovery rate after 2000 minutes) under 27 m of drawdown in a 10-cm borehole would be assigned a transmissivity of 0.0012 m^2/day. The presence of downflow in borehole BH02 indicates that there are significant ambient head differences along the well bore, and these different values compound the estimation of transmissivity in each of several zones since they all experience different amounts of drawdown with respect to the their far-field values during the experiment. Overall, the low rate of recovery after significant water level drawdown would indicate that individual zone transmissivity could not be much greater than an estimate of total borehole transmissivity from a single zone. Assuming the zones at 588 and 620 m have transmissivity values of at most 0.005 m^2/day, then a head difference of at least 10 m between the two zones would be needed to produce the downflow inferred from the dilution log data under drawdown conditions.

One important feature of the FEC data sets obtained in BH02 is that even stronger downflow driven by ambient hydraulic head differences should have been measured under the reduced drawdown before the increase after about 2000 minutes according to borehole flow model analysis (Paillet, 1998). If it is assumed that there was negligible inflow from any zone under the initial drawdown estimated at 5 m and then the inflows listed in table 1 under 27 m of drawdown, then the subtraction of inflows method (Molz et al, 1989; Paillet 2004) for multiple-zone boreholes would imply negative total transmissivity (inflow decreases with increasing driving head) for borehole BH02. This is physically impossible without violating Darcy's Law, so it is assumed that something changed in borehole conditions as a result of the suddenly increased borehole drawdown. One possibility is that the abrupt increase in drawdown flushed material blocking either or both of the flow zones at 588 and 620 m resulting in an effective increase in the permeability of one or both zones – a form of inadvertent well development. Since no ambient flow profile is available for comparison to the inadvertently developed flow profile relevant to the data obtained after 2000 minutes (Paillet, 2000), it is possible that the transmissivity of the 588 and 620 m zones may exceed the 0.002 m^2/day value applied to the measured recovery rate under the assumption that no in situ hydraulic head differences exist. It is otherwise impossible to provide accurate estimates of transmissivity for each of the flow zones listed in table 1 without having measurements of inflow for each of the sones under two different steady flow conditions.

Flow Zone m	Inflow Rate lpm	Inflow Zone FEC mS/m	Horizontal Flow lpm
381	0.02 +/- 0.02	75 +/- 30	0.0
588	0.20 +/- 0.05	300 +/- 10	0.2
620	-0.16 +/- 0.05	300 +/- 10	0.2
668	-0.08 +/- 0.03	75 +/- 30	0.0
680	0.04 +/- 0.03	75 +/- 50	0.0
730	<0.005	undetermined	undetermined

Table 1 – Summary of dilution model parameters used to model the BH02 dilution experiment (note that negative inflow represents outflow from the borehole).

Figure 1 – BH02 flow profile determined from dilution model of borehole FEC profile evolution over time.

Figure 2 – Model FEC profiles for the first and final (t = 2165 and 2995 min) fluid column data over the 550-650 m interval illustrating the uncertainty in model parameters (inflow or outflow rates and FEC of inflowing water).

References

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Tsang, C.F., P. Huschmied and F.V. Hale, 1990, Determination of fracture inflow parameters from a borehole fluid conductivity method, *Water Resources Research*, 26, 561-578.

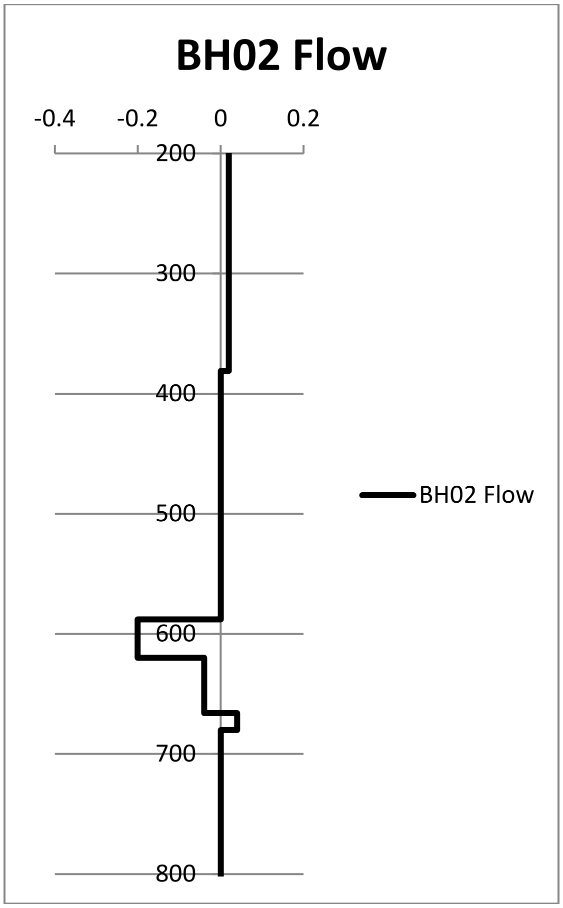

Figure 1 - Vertical flow profile given by dilution flow model for BH02; note that downflow in the 588-620 m interval is ten times the observed upflow in casing.

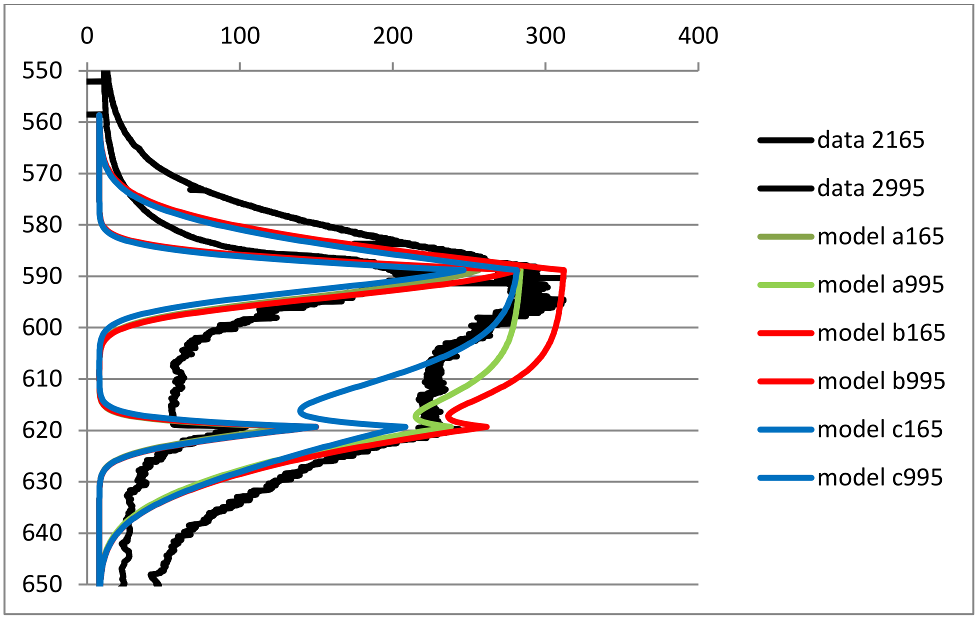

Figure 2 - Sensitivity test with alternate models compared to 2165 and 2995 minute data sets. Model a is the model fit used here. Model b is the same model with the zone FEC increased from 300 to 330 mS/m and clearly overshoots the data. Model c has the downflow in the 588-620 m interval decreased from -0.20 to -0.15 lpm and clearly does not move out fast enough to keep up the with FEC profiles.

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