Gravilog User's Manual

Gravilog Operation Manual p/n 876700 Rev. 3

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1. INTRODUCTION

Overview

The Scintrex Gravilog tool measures very precise relative gravity values when held stationary in a borehole. The data are presented as gravity or apparent density values derived from the gravity and position measurements.

Gravilog data are useful for several purposes including:

- Measurement of ore body density.
- Measurement of overburden density.
- Remote sensing of high-density contrast ore bodies.
- Assessing the density of off well conductors detected by electromagnetic or resistivity surveys.
- Assisting in the interpretation of surface gravity survey data.

The Gravilog density data can be used both as a substitute for $\gamma\gamma$ density logs that require a radioactive source and also combined with $\gamma\gamma$ density log data to enhance remote sensing applications.

Gravilog data is not affected by well casing, washouts, hole rugosity and mud invasion. The Gravilog density is a mass density that does not require conversion from electron density.

Gravilog density data must be corrected for nearby rugged terrain and non-vertical holes.

This manual describes the operational use of the Gravilog tool.

Gravilog Sensor and Tool

The Gravilog sensor is very similar to the Scintrex CG-6 sensor. A vertically aligned quartz spring holds a mass suspended between capacitance plates. The force of the spring counterbalancing gravity is augmented by an electrostatic feedback system. The gravity reading is proportional to the electrostatic voltage.

The Gravilog sensor is packaged in a pressure housing with control electronics, natural gamma detector, a wall lock arm and well bore pressure, temperature and inclination sensors.

Document Conventions

Dialog box menus, commands, dialog box titles, labels and options are bolded text in the user instructions. WARNING and IMPORTANT notes are highlighted in red.

2. SURVEY PLANNING

Survey Objective

Gravilog surveys are run for two basic objectives:

- Large volume density measurements.
- Remote sensing of ore deposits.

Survey planning involves finding the best combination of measurement accuracy, station locations, survey duration, practical aspects and timing.

Gravity measurements are made at stations in the well at fixed depth intervals.

The first considerations are if the measurement accuracies will enable the survey objectives to be achieved. This involves feasibility modeling studies to define the gravity response shape and amplitude with a reasonable estimate of ambient background noise. Often very quick 2.5D forward modeling will determine if a survey objective is achievable.

Survey Planning

For density measurements the station spacing should be chosen based on the required density accuracy.

In remote sensing, the measurements should adequately sample the response shape with sufficient accuracy.

The measurement accuracy depends on the repeatability of the Gravilog tool and the number of repeat measurements made at each station. It is normal to make at least three passes through the stations to define the drift correction and to achieve higher accuracy proportional to the inverse square root of the number of passes.

In borehole gravity surveys, interval depth accuracy is as important as the gravity measurement accuracy. This is because:

1. The combination of Free-air Gravity Gradient and the gravity gradient due to the rock density is about 100 microGal per meter.

2. The borehole gravity apparent density is calculated from both the gravity and depth measurements using the equation:

$$\rho_B = \frac{1}{4\pi K}\left(F - \frac{\Delta g}{\Delta z}\right)$$

Where:
K is the gravitational constant
F is the Free Air gradient
Δg and Δz are the differences in gravity and depth between adjacent stations. With appropriate values this becomes:

$$\rho_B = 3.68237 - 39.12731\frac{\Delta g}{\Delta z}$$

Where density is measured in g cm^{-3}, Δg in milliGal and Δz in meters.

The Gravilog tool has a repeatability calculated as the standard deviation of many readings taken at one station. The accuracy of survey gravity readings at a station is the repeatability divided by $\sqrt{N}$ where N is the number of gravity readings made at that station. The repeatability of the Gravilog in quiet conditions is <7 microGal. Three logging passes (N=3) are commonly made during a survey.

To maintain depth accuracy, gravity readings are always taken from the bottom of the well moving upwards to maintain the most uniform wireline cable tension.

To optimize density accuracy the largest station intervals possible should be used to resolve the layers of interest. 5 m station spacing is very close, 10-20 m station spacing is more normal, and 50-100 m intervals are used for thick layers and also give the highest density accuracy.

It should be determined that the Gravilog tool can fit in the well and that the pressure and temperature are below the operating limits of the tool.

The GraviLog sensor can deviate from vertical up to about 60 degrees. Make sure that in the zone of interest the deviation is below this limit. However, note that zones of high deviation usually contribute to much higher than normal depth errors which translate directly into higher than normal density errors.

In very close to vertical wells (<1 degree) the leveling system takes longer to find vertical.

As a guide to calculating survey duration, an average of three to four stations per hour can be measured in normal wells.

To estimate the survey time in hours, add:

- Two hours for rig up
- Twice the well depth in meters divided by 600.
- Number of stations times number of repeats divided by 4.
- One-hour rig down.

Standard Gravilog Survey Procedure

IMPORTANT	Read Appendix B Gravilog Safety And Survey Procedure for important personnel safety precautions and equipment safety guidelines and procedures.

3. GRAVILOG TOOL

Specifications And Dimensions

Table 3-1 Gravilog Tool System Specifications

Temperature Range	0°C to +75°C (32°F to 167°F)
Maximum Pressure	25,510 kPa (3700psi)
Inclination	Vertical (0°) to 60° from vertical
Outside Diameter	48.26 mm (1.9")
Length	4m (13.725')
Weight	55Kg (85lb)
Repeatability	<50nms^{-2} (5µGal)
Operates on four or seven conductor cables	

The tool incorporates a wall lock arm and natural gamma detector, well temperature, well pressure and inclination sensors. Refer to Figure 3-1.

The tool consists of several modules listed from the top module:

- Clamp module
- Pressure/Gamma module
- Electronics module
- Gravilog module
- Shock Mount

The distances between the sensors are used to correct the output readings to the gravity sensor depth as described in the RGS-Gravilog Data Acquisition Software User's Manual.

Table 3-2 Gravilog Tool Distances Between Sensors

Gravity sensor to tool bottom	18.96 cm
Gravity sensor to Gamma detector	203.25 cm
Gravity sensor to pressure sensor	243.28 cm
Gravity sensor to top Clamp module	323.75 cm
Gravity Sensor to top MSI tool head	338.20 cm
Gravity sensor to top MSI cable head spring	368.04 cm

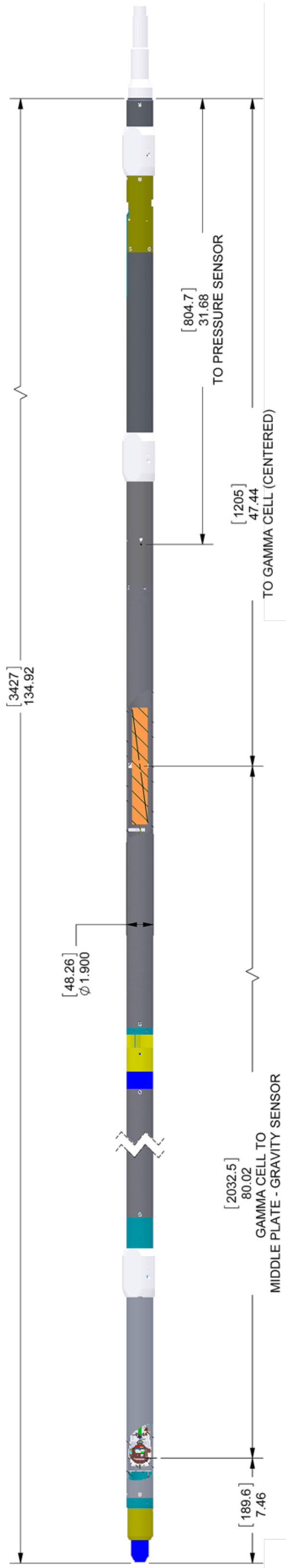

Figure 3-1 Gravilog Sensors Positions And Overall Dimensions (Scale 1:6)

Operating Principal

The Gravilog gravity sensor is basically a quartz spring holding a test mass. Refer to Figure 3-2. The position of the mass is sensed by a Capacitance Positioning Indicator (CPI) system. The output of the CPI is used as the feedback signal to electrostatically center the mass between two capacitance plates. The electrostatic centering voltage is calibrated against gravity and provides the gravity reading.

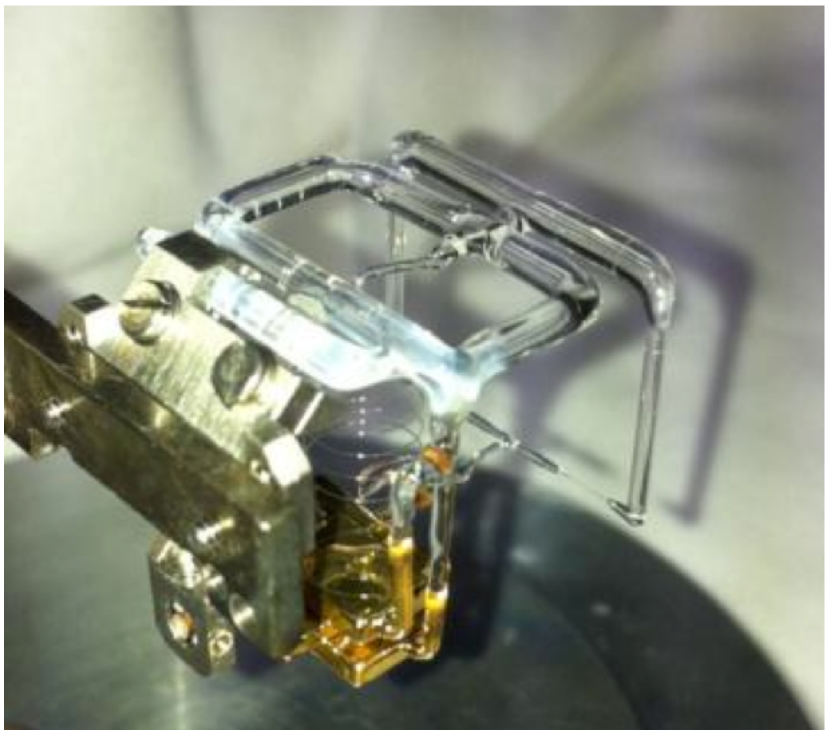

Figure 3-2 Gravilog Gravity Sensor

The gravity readings must be made with the spring and mass aligned vertically. The vertical alignment is made with respect to two orthogonal levels attached to the sensor mechanism housing. The sensor housing is shaped like a ball so the spring mechanism can be aligned to vertical when the tool is in a well deviated from vertical.

As the spring ages, it gradually stretches or relaxes, resulting in a slow steady increase, or drift, of the gravity readings with time. One of the standard corrections is to remove this drift from the data before further processing.

The gravity sensor temperature is maintained at a very precise temperature by an internal heater, preventing changes in the spring strength. This thermostat temperature also limits the maximum operating temperature of the tool.

If power to the tool is turned off or the tool is subjected to a large thermal shock such as moving rapidly to the bottom of a deep well, it will take the heater a little time to return the sensor to the correct operating temperature. The gravity readings will drift in a nonlinear fashion until the sensor temperature stabilizes.

To make a reading, the gravity sensor is first oriented within the tool pressure housing so the sensor spring is aligned in the direction of local gravity. The instantaneous gravity readings from the electrostatic feedback system are then recorded over enough time that extraneous tool accelerations can be filtered out to provide the required gravity precision.

Pre-mobilization Tool Checks

It is recommended that the tool be tested in the office before mobilizing on a survey. The tool can be read in its carrying case. Perform a tilt calibration, monitor drift and track the long-term drift between readings taken at the same location.

Records should be kept of gravity and tilt offsets that could reveal any damage due to shocks during transportation.

The entire system can be checked before mobilization by assembling the tool and running it through the wireline cable. This can be a useful test of the complete logging system allowing any problems to be corrected before arriving at the well site.

Tool Transportation

The tools should be transported in the shock mounted travel box provided by Scintrex (shown in Figure 3-3). If transportation is by road, the tool should be kept on power to decrease the temperature recovery time when the tool arrives at the site. The other sections of the down-hole tool are transported in a separate box. The Up-hole Console and Winch Controller each have their own box. A fourth box normally contains miscellaneous tools and electrical supplies.

Figure 3-3 Tool Transportation Packing Case

4. FIELD RIG-UP

Dummy Sonde Run

A dummy sonde run should be made before placing the Gravilog tool in the well. The dummy sonde is a solid metal tube the same outside diameter and length as the Gravilog tool. It must be run to the total depth of the Gravilog survey using a different wireline cable than the 4 conductor Gravilog cable.

Figure 4-1 shows a crew loading a dummy Gravilog probe into a metal cased inclined well. In this case the sheave wheel is placed directly on the top of the metal casing.

Figure 4-1 Loading Dummy Probe in an Inclined Metal Casing

Figure 4-2 shows the dummy tool being lowered into the well using a slick line and small sheave wheel attached to the well casing.

Figure 4-2 Running the Dummy Probe

Survey Setup

The Gravilog probe should be kept on heat at all times to reduce the length of warm up time needed in the hole before reading. There is a heating system provided that allows the probe to be kept on heat at all times during transport. It can be connected to a 12V vehicle power outlet as well as through a 110 - 240V AC power outlet.

- Choose a location for the winch with the center of the winch in line with the drill hole.
- Setup the operator’s computer and the uphole consoles where the winch and drill hole can be clearly seen. Refer to Figure 4-3 and Figure 4-4.
- If possible use the tripod as shown in Figure 4-3 and in Figure 4-4 for lowering the probe into the hole since it is very stable.
- The tripod should be used when the drill hole casing is plastic.
  - However, when the ground is very soft, the tripod is unstable and the survey depth less accurate. In this case, the sheave wheel should be attached directly to the casing.

Figure 4-3 Survey Setup Example

Figure 4-4 Survey Setup with A Plastic Casing and Tripod Mounted Sheave Wheel

The cable connections between the winch controller and the power supply are shown in Figure 4-5.

- The controller is placed on top of the power supply.
  - All the connectors are polarized and only fit into one connection on the power supply and the winch controller.

NOTE The winch controller connections marked "Winch Control" on the left and "Remote Control" are identical. Only the Winch Control connection on the left is used for Gravilog surveys.

- All of the cables shown in Figure 4-5 are connected to the winch except the two computer ports on the left side of the power supply.
- The MODEM COM1 port is connected to the com-1 port of the laptop.
  - The PRESS S/COM2 port is connected to the pressure sensor which is in turn connected to a USB port of the laptop.

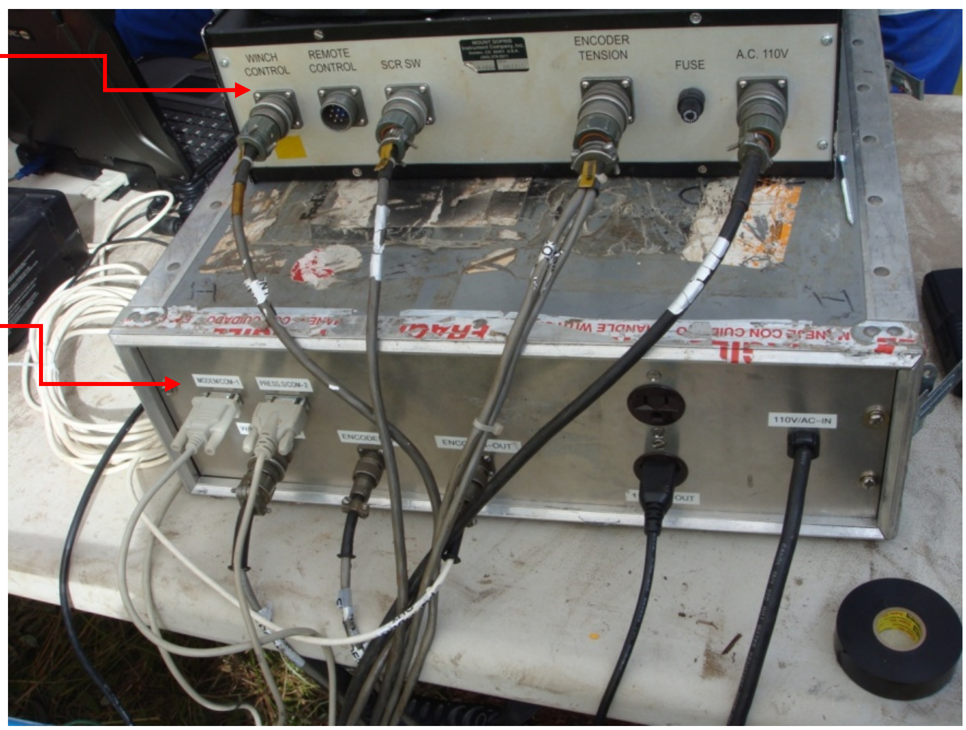

Figure 4-5 Cable Connections

There is a backup UPS power supply for the probe incase the generator fails. This is the black box shown in Figure 4-6.

The only connection that plugs into the UPS is the power supply for the probe.

NOTE	If the generator fails the UPS beeps and provides battery power for 10 to 15 minutes. During these 10 to 15 minutes, the probe temperature is controlled. After this time, the temperature of the probe starts to decrease. The probe must then be heated back up before the survey can continued.

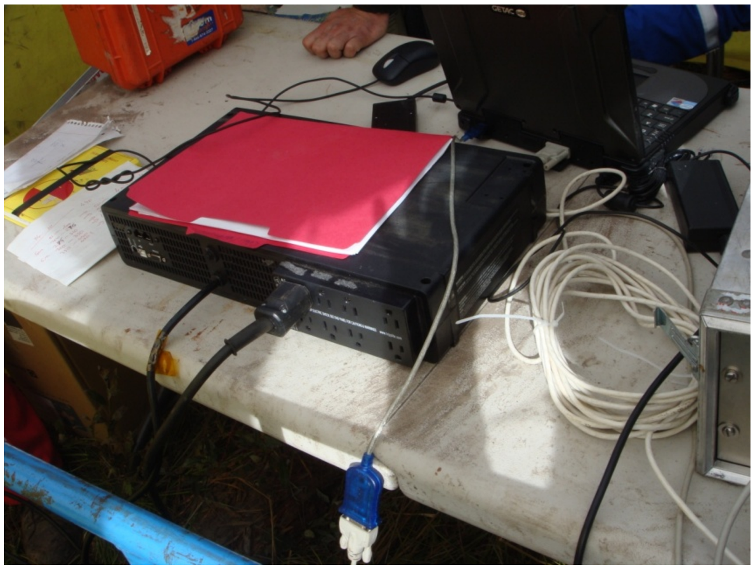

Figure 4-6 UPS Power Supply Backup for Down-hole Probe

Cable Head Test

The cable head should be tested for electrical continuity and isolation (leakage) before attaching to the probe.

IMPORTANT	Disconnect the down-hole line connector from the up-hole console before testing for leakage to prevent damage to the up-hole console and invalid test results.

Using a megger meter or equivalent high resistance leak detector, test all possible line pairs and ground at the bottom of the cable head. The resistance should be >70mΩ. If the leakage is <70mΩ, the source of the leakage should be found. This often involves re-heading the cable, particularly in humid environments.

Minimizing Cable Head Problems in Humid Locations

IMPORTANT To minimize cable head problems in humid locations it is a requirement that thread protector caps are kept on the cable-head and the tool top when they are not connected.

Minimize the time that the thread protectors are off during assembly and do not set the cable-head down without the thread protector cap in place.

Use a short spray of contact cleaner on the cable-head and tool top connections. Do not use a lot as this will cool the connector causing more condensation.

Probe Assembly

Once all other equipment is assembled and working properly, the probe can be assembled.

IMPORTANT The connectors inside the probe are delicate and need to be handled with care to ensure that they do not break.

The wires attached to these connectors are quire short and do not extend far from the probe. Do not pull on these wires when assembling the probe.

The Probe assembly is illustrated by the following figures. The uphole console and computer must be assembled and ready before rigging up the Gravilog tool. The Gravilog sensor is the last module to assemble to minimize the time the sensor is powered down. The remainder of the tool should be completely assembled before the Gravilog sensor is removed from the travelling box.

The required rig up tools shown in Figure 4-7, include Phillips head screwdrivers, good quality electrical tape, silicon grease, a C spanner and attachment screws.

Figure 4-7 Required Rig Up Tools

The separate modules that make up the down hole tool are shown in Figure 4-8.

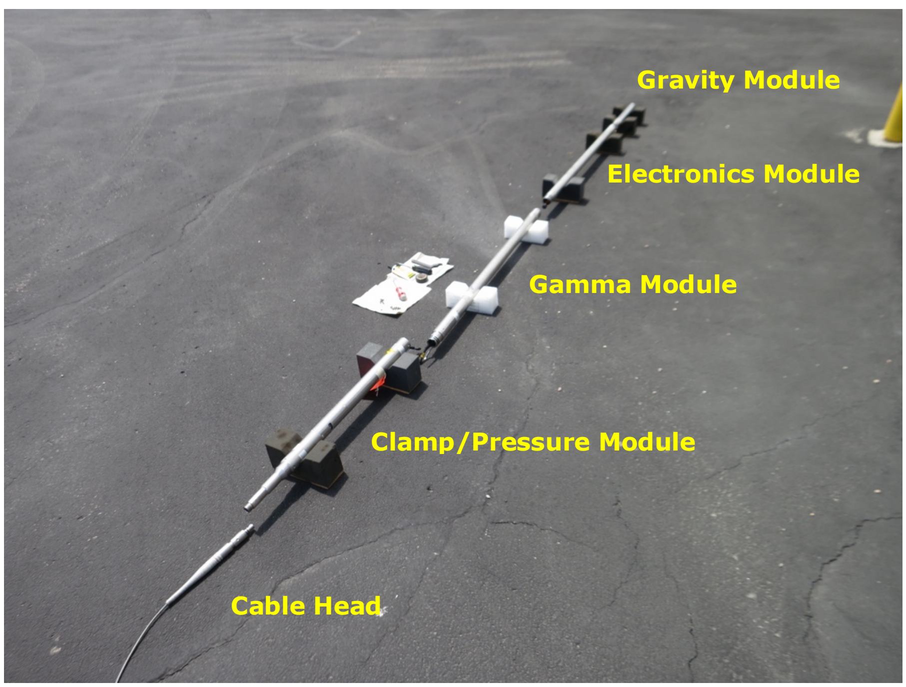

Figure 4-8 Down Hole Tool Separate Modules

From the cable head at the bottom left, the modules are:

- Clamp/Pressure module
- Gamma module
- Electronics module
- Gravilog module.

For each joint, check that the o-ring grooves are clean and do not have any nicks, scratches or abrasions. Use a good quality silicon grease to lubricate the o-rings before assembling the joint.

The tool should be assembled in the following order:

- Attach the clamp/pressure module to the gamma module. Refer to Figure 4-9.
- This joint has two cable connections that are connected before sliding the female type gamma module over the male pressure module.
- The modules are locked together with four (4) countersunk Phillips head machine screws. Note that these are the screws furthest from the cable head at this tool joint.

Figure 4-9 Clamp/Pressure Module to Gamma Module

- Attach the electronics module to the bottom of the gamma module. Refer to Figure 4-10.
- This joint has one cable connection and one o-ring.
- There is a notch inside the lip of the electronics module that must be aligned with a key inside the gamma tool.
- The electronics module should be pushed into the gamma module.
- The knurled cap on the gamma module is then turned by hand to screw the modules together.
  - Tighten using the C-spanner.

Figure 4-10 Attach Electronics Module

- Attach the cable head to the top of the clamp/pressure module. Refer to Figure 4-11.
  - Align the key to the notch inside the tool head.

Figure 4-11 Attach Cable Head to Top Of Clamp/Pressure Module

  - Wrap the cable head connection with electrical tape. Refer to Figure 4-12.

Figure 4-12 Wrap Cable Head Connection

- Check all connections are properly made from the electronics module to the up-hole power supply.
- It is important that the time the Gravilog sensor is powered off is short to minimize the thermal recovery time at the start of the survey.
- Disconnect the power to the Gravilog sensor travel case.
  - Raise the sensor from the carrying case using gloves.

WARNING	CAUTION HOT, Use gloves.

- Disconnect the three (3) cable connectors to the top of the sensor. Refer to Figure 4-13.

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Figure 4-13 Disconnect Cables from Gravilog

- Place the gravity module on the tool stands lined up with the electronics module.
- Connect the three (3) cable connectors from the electronics to the top of the Gravilog sensor. There is only one way the cables can connect.
  - Push the Gravity sensor into the base of the electronics. Refer to Figure 4-14.

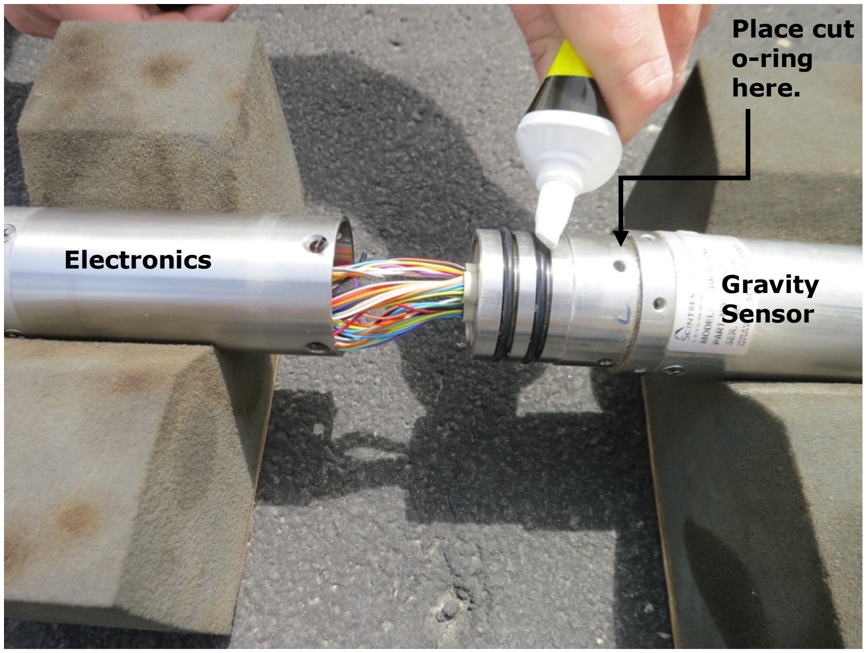

Figure 4-14 Push Gravity Sensor into Base of the Electronics

WARNING Mating the gravity and electronics modules requires a reasonably strong force to move past the o-rings.

Do not allow the gravity module to hit the base of the electronics module after the second o-ring is suddenly passed.

A way to prevent this is to take an old o-ring and cut one side so the o-ring can be placed around the top of the gravity module where the two modules come together. The cut o-ring will act as a shock absorber and is easily removed when the two modules are mated.

– Insert and tighten the four screws holding the electronics and Gravilog modules together. The two modules may need to be rotated to align the screw holes. Refer to Figure 4-15.

Figure 4-15 Align and Tighten Screws

- Attached the shock mount assembly to the base of the gravity module. Refer to Figure 4-16

Figure 4-16 Shock Mount Assembly

Voltage Supply

It is important that the power supply to the probe be connected promptly to minimize the temperature shock to the Gravilog sensor. To achieve this, the complete wireline system must be assembled and ready to power up before the Gravilog sensor is mated to the electronics module.

- Check the voltage supply is set to approximately 320V for the down-hole probe.
- Turn on the probe power on the up-hole console.
- When first turned on the current draw should be just over 0.1 Amps. As more heaters cycle in the current draw could go up as high as 0.5 amps if tool is cold. Power should settle at under 0.3 Amps when the tool is thermostatted.
  - The steady current draw is lower at higher down-hole temperatures. At down-hole temperatures near 75°C, the current draw could be as low as 0.13 Amps.

Winch Controller - Lower Probe into The Hole

NOTE When lowering the probe into the hole, caution must be taken not to damage the probe by bumping the tip of the probe against the drill hole casing. One person should lower the probe while another person makes sure the probe does not touch the hole as shown in Figure 4-18.

Setting Survey Depth

Survey depths are measured by the odometer wheel as the length of cable that is lowered into the hole. These depths are referred to as Slant or Measured Depths.

After placing the tool in the well with the top of the cable head level with the top of the casing, the correct tool depth must be set in the RGS-Gravilog software and the winch controller.

Log Zero Point

To ensure the Gravilog tool is depth correlated with other logs run in the same well it is important to know the log zero point, the point where slant depths are measured from. This depends on company convention and will normally be ground level at the well or the top of the casing. The log zero could also be from the drilling rig floor or Kelly Bushing in the case of holes drilled with larger drilling rigs. The log zero point is normally recorded on previous logs used as depth references.

It is useful to sketch a diagram of the tool position when the odometer is zeroed. This helps with data processing and avoids errors.

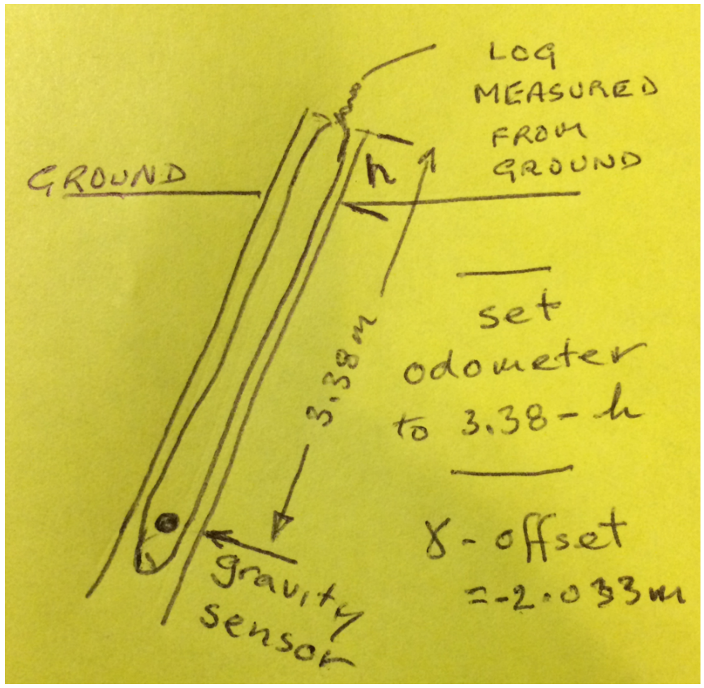

Figure 4-17 Example Tool Position Sketch Diagram

The odometer is set to the depth of the gravity sensor at the start of the survey.

In the sketch (Figure 4-17), since depth is measured from ground level, the odometer would be set to 3.38 – h meters, where h is the length of casing above ground.

Normally the only other depth that must be set is the distance of the gamma detector above the gravity sensor. This is set in the RGS-1-Gravilog software in the system settings / winch in the GR Offset as -2.033 meters. For shallow mining holes this should be the only depth setup required.

For deeper wells it is common to use the gamma log to make sure the gravity meter is at the same depth as earlier logs. If you have a peak on the Gravilog gamma log that is showing at a depth D meters shallower than the previous log depth for the same gamma peak, then you will have to add D meters to the Gravilog odometer.

The location (xyz) of the log zero in the survey coordinate system is needed for terrain corrections. The location is also needed if the well is slanting north or south to calculate latitude corrections. The inclination and azimuth of the well must be recorded unless there is a well survey that provides the three-dimensional coordinates of the well trajectory.

It is very useful for data processing to note the geographic datum used for the well position coordinates. Normally this is WGS84 if the coordinates are taken directly from a GPS receiver. Mine grids may use different local datums.

Required well data:

- Well head coordinates including ground level elevation.
- Well azimuth and inclination.
- Log zero point - ground level or casing top.
- Length of casing extending above ground level.

Figure 4-18 Inserting the Tool into the Hole

5. SURVEY EXECUTION

Operational Software Quick Check List

Refer to the RGS-Gravilog Data Acquisition Software User's Manual for RGS-Gravilog software operating instructions and software setup for the well survey location.

- Enter correct settings for new well.
- Re-check the computer date and time
  - Check against the GPS date and time.
  - Check that it is less than 30 seconds off from UTC.
- Enter well parameters (Latitude/Longitude, Well name etc).
- Execute 3 to 4 Phase Leveling.
- Enter new data file names.
- Enter all initial information into the log book.
- Every four hours backup three data files to a flash drive.

General Command Sequence

To make a gravity reading after arriving at a station:

- Clamp
- Gravity (Leveling sequence)
- Measure ON (Logging Data)
- Standby
- Positioning

Tool In Well

IMPORTANT Gravity measurements are made with the probe held stationary in the hole. Measurements are only made when the probe is pulled up to the gravity station to maintain constant cable tension that is important for depth control.

After the tool is in the well and depth is properly set:

- Lower the probe using Low Gear only.
  - Limit the maximum speed to 600 meters/hr. (10 meters/minute) going down-hole.
- Watch the cable tension to make sure the probe does not hang in the well with cable fed on top.
- Make sure the probe does not touch the bottom.
- Stop the probe at least three meters higher than the bottom of the hole as determined with the dummy sonde.

If there is an existing natural gamma log that is used as a depth reference:

- Run a tie-in gamma log to determine the depth offset between the probe and the reference log.
- Update the depth indication on the winch controller and in the RGS-Gravilog software.

If there is no depth reference log use the depth set at the top of the casing.

It is recommended to log gamma whenever moving up-hole as this can help data reduction and interpretation.

First Gravity Station

The first Gravity station needs to be a minimum of five meters above the hole bottom determined by the dummy run to ensure maximum cable tension. A 10 or 15 meters margin is better.

Carefully record gamma data during the first gravity log run because this data will become the base gamma ray log for all future logging runs.

Tilt Calibration Test

At the first station run a tilt calibration test and then record gravity to ensure that the tool has adjusted to the hole environment. Refer to Appendix A of the RGS-Gravilog Data Acquisition Software User's Manual for additional information and test execution instructions.

If the probe was off power for an extended time before placing it in the hole, the gravity readings will drift in a non-linear fashion. The start of the survey should be delayed until the drift has stabilized to a small linear value before starting the survey.

Other Corrections

A tidal correction is added to compensate for the gravitational attraction of the Sun and Moon. This correction depends on knowing the Latitude, Longitude, and UTC time accurately.

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6. RIG- DOWN

Rig-down Procedure

- Pull the probe up at normal speed to an indicated depth of 10m.
- Then raise the probe very slowly until the top of the cable head spring is level with the top of the casing.
  - At this point a sheave wheel attached to the casing may have to be moved to remove the probe from the hole.
- Take the tool from the hole taking care not to bump the bottom of the probe on any obstacle.
- Lay the probe on a set of probe stands and pull out some extra cable from the winch.

IMPORTANT	For your safety, turn the power to the probe **OFF** at the console before starting to disassemble the probe.

- Turn the probe power **OFF** at the console.
- Remove the Gravity sensor module from the tool and place it in the travel box and turn **ON** the sensor power. Refer to Figure 6-1.

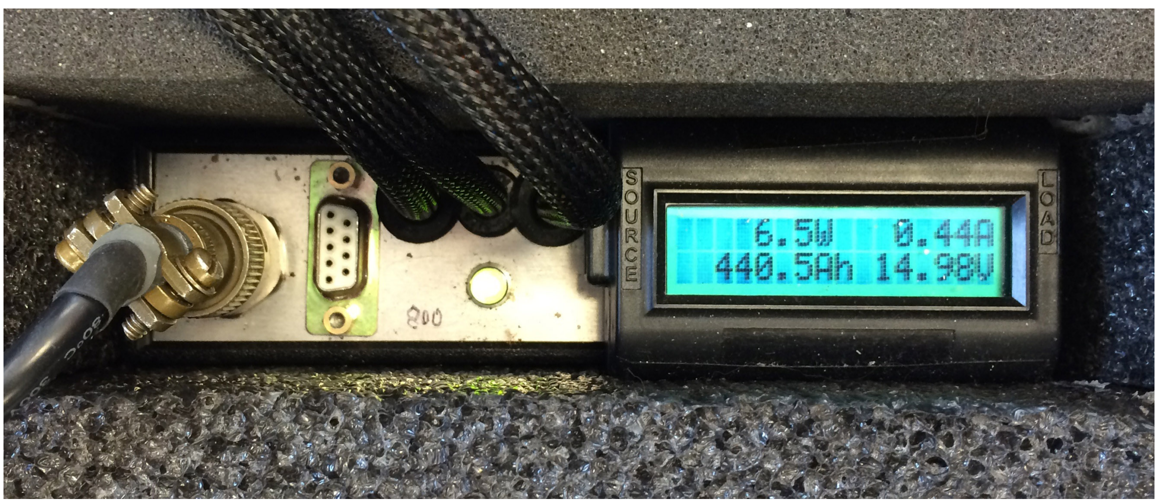

Figure 6-1 Gravilog Travel Box Power Supply Using The Main Power

- Clean the outside of the probe with cloth rags.
- Dry and clean the mating surfaces where the probe sections come apart.
- Disassemble the remainder of the probe and pack it in the travel case.

APPENDIX A DATA QUALITY CHECK SPREADSHEET

A spreadsheet can be very useful for quality control during a survey. A record of depth, gravity differences and apparent density should be updated after taking a reading and BEFORE moving the tool from the station. This can help to avoid many problems and the need to return to a station and repeat problem measurements.

In the example shown in Figure A-1, either the depth or the gravity value was in error on the first pass at 200 feet. The deepest station was also only a few feet above the bottom of the well and the scatter in density due to variable cable tension is apparent.

A sample plot of the density values from the example quality control spreadsheet is shown in Figure A-2.

Plan depth (ft)	Actual Depth (ft)	TCG (mGal)	delta G (mGal)	Density (mGal)
50	50	3546.899	5.481	2.253
200	200	3552.380	5.771	2.177
350	350	3558.151	5.263	2.310
500	500	3563.414	3.696	2.236
600	600	3567.110	3.586	2.279
700	700	3570.696	3.544	2.296
800	800	3574.240	3.504	2.312
900	900	3577.744	3.578	2.283
1000	1000	3581.322	3.507	2.310
1100	1100	3584.829	3.664	2.249
1200	1200	3588.493	3.416	2.346
1300	1300	3591.909	3.694	2.237
1400	1400	3595.603	3.544	2.296
1500	1500	3599.147	1.658	2.385
1550	1550	3600.805	1.805	2.270
1600	1600	3602.610	1.788	2.283
1650	1650	3604.398	1.775	2.294
1700	1700	3606.173	1.794	2.279
1750	1750	3607.967	1.759	2.306
1800	1800	3609.726	1.803	2.272
1850	1850	3611.529	1.794	2.279
1900	1900	3613.323	1.802	2.272
1950	1950	3615.125	1.801	2.273
2000	2000	3616.926		

Actual Depth (ft)	TCG (mGal)	delta G (mGal)	Density (mGal)
50	3546.593	5.714	2.192
200	3552.307	5.498	2.248
350	3557.805	5.253	2.312
500	3563.058	3.708	2.232
600	3566.766	3.616	2.268
700	3570.382	3.543	2.296
800	3573.925	3.502	2.312
900	3577.427	3.558	2.290
1000	3580.985	3.514	2.308
1100	3584.499	3.670	2.247
1200	3588.169	3.438	2.337
1300	3591.607	3.700	2.235
1400	3595.307	3.518	2.306
1500	3598.825	1.669	2.377
1550	3600.494	1.792	2.280
1600	3602.286	1.793	2.279
1650	3604.079	1.769	2.298
1700	3605.848	1.794	2.279
1750	3607.642	1.750	2.313
1800	3609.392	1.802	2.272
1850	3611.194	1.791	2.281
1900	3612.985	1.792	2.280
1950	3614.777	1.771	2.297
2000	3616.548		

Actual Depth (ft)	TCG (mGal)	delta G (mGal)	Density (mGal)
50	3546.097	5.702	2.195
200	3551.799	5.541	2.237
350	3557.340	5.260	2.311
500	3562.600	3.673	2.245
600	3566.273	3.568	2.287
700	3569.841	3.552	2.293
800	3573.393	3.507	2.310
900	3576.900	3.575	2.284
1000	3580.475	3.505	2.311
1100	3583.980	3.655	2.252
1200	3587.635	3.420	2.344
1300	3591.055	3.704	2.233
1400	3594.759	3.534	2.300
1500	3598.293	1.663	2.381
1550	3599.956	1.792	2.280
1600	3601.748	1.796	2.277
1650	3603.544	1.756	2.308
1700	3605.300	1.788	2.283
1750	3607.088	1.758	2.307
1800	3608.846	1.797	2.276
1850	3610.643	1.771	2.297
1900	3612.414	1.814	2.263
1950	3614.228	1.686	2.363
2000	3615.914		

Figure A-1 Example Quality Control Spreadsheet

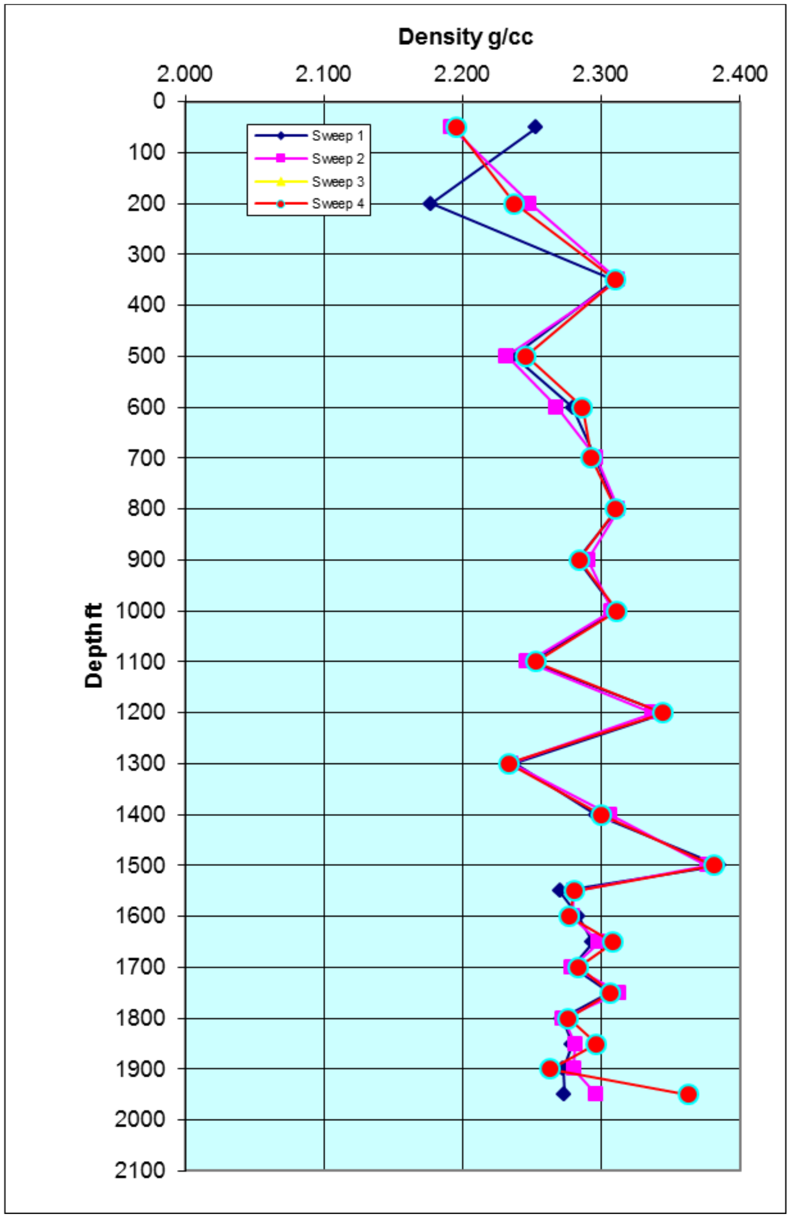

Figure A-2 Plot Of Density Values From Quality Control Spreadsheet

APPENDIX B GRAVILOG SAFETY AND SURVEY PROCEDURE

Transportation of Gravilog Sensor and Electronics:

- Due to its fragile nature the Gravilog modules (sensor and electronics) are carried in a shock mounted box and transported by truck or plane to the survey site.
- The Gravilog probe and peripheral equipment may be shipped separately but are brought to the survey site by the Scintrex crew from the airport or freight terminal.
- Scintrex Gravilog logging equipment consists of four plastic boxes of misc. electrical and mechanical equipment that should be easily accessible from logging unit/tool rig up area.
- Scintrex Gravilog electronics equipment are integrated and tested on the logging wire line rig. The wire-line cable is checked for continuity and leakage and to verify cable line assignments and telemetry.

Safety Precautions

- It is important that an on-site safety meeting take place before starting rig-up.
  - This meeting is conducted by the Lead Gravilog Engineer and attended by the Gravilog logging crew, the wireline crew and any client personnel that will access the well site during the logging operation.
  - The meeting is used to review and coordinate the logging activities and to discuss all potential safety hazards associated with the operation.
- Potential hazards during a logging operation are associated with machinery, electrical devices, weather, possible contact with contaminants, and prolonged exposure to the noise of machinery and gases as well as other hazards.
- All personnel involved in the logging operation have the responsibility to promptly report any unsafe condition promptly to the Lead Engineer and any personnel who may be affected by the unsafe situation.
- After the Lead Engineer concludes the safety briefing, the rig-up operations may commence.
  - The wireline equipment is normally assembled before it is safe to start assembling the Gravilog tool.

Personal Protective Equipment (PPE)

- All logging personnel are to wear approved safety hats, steel toe boots, safety glasses, durable cold weather clothing including insulated protective gloves.

- If required by the site conditions, the Lead Engineer shall provide instruction on the use of H_2S or CO_2 detectors.

Electrical

The Gravilog is a totally passive sensor and has NO radioactive sources as other density tools do. The tool is powered from 350V DC from inside the logging unit and should present only the standard electrical and mechanical hazards as any standard logging tool.

The Gravilog tool must be properly grounded during set-up.

- This is to be done by installing the grounding cable to the winch chassis at one end and to the grounding electrodes (rods or grounding plates) at the other end.
- These must be buried according to the CSA Standard C22.1HB-06 (current Rev). Rule 10-700 of the Standard describes the proper procedure for installation of the grounding rods, plates or bare wire.
- In addition to the above and where feasible, another grounding conductor should be connected to the steel casing at the top of the borehole.

Sound Levels

During survey operations, the wire line truck which carries the winch is running continually with additional power generators around the truck; the cumulative noise levels can be significant and prolonged exposure without proper hearing protection is a potential hazard for hearing loss.

IMPORTANT All Scintrex logging personnel must use approved hearing protection.

Tool Rig-up

Gravilog tool assembly is done by connecting three block sectional modules.

Module	Length	Weight
Gravity Sensor Module	2′-1/4″ long	3.36 lbs.
Scintrex Electronics Module	3′-3/4″ long	8 lbs.
Scintrex Side Wall Clamp Module	8′-1/4″ long	10 lbs.

Setting the tool horizontally on stands, the different blocks are assembled, starting with the connection of the Gravity Sensor Module to the Scintrex Electronics Module and terminating with the Scintrex Side Wall Clamp Module which may also contain the Gamma/CCL unit. Once the three modules are connected, the wire line adapter and cable head can be connected to the Gravilog tool.

NOTE Before the Gravilog module is connected to the wire line a low voltage (25V) check is done to make sure that the logging trucks' panel connections are OK.

After all electrical and mechanical connections have been secured, a powered up 300V- 350V DC test and the two-way telemetry communication test are conducted by Scintrex logging personnel while the tool remains stationary on the horizontal stands. The tests are observed for a period of 5-10 minutes,

- If the above test results are acceptable, then the Gravilog tool can be hoisted and placed into the well by the Scintrex logging personnel.
- Great care must be taken to ensure that the Gravilog tool is not bumped or jarred with any sudden acceleration. It is much more delicate and susceptible to damage than other logging tools.
- The wire line winch operator must be careful when the tool is approaching the drilling rig ramp and entering the casing or the top of open well holes.
- Scintrex logging personnel will give logging instructions and principles to the winch operator and other logging company personnel on the survey site regarding the highly specialized Gravilog tool.

Rig-up time is usually under two hours depending on the logging site.

Survey Operations

The Gravilog operator and the contract wire-line winch operator stay inside logging unit. The Gravilog tool is lowered to near bottom and depth is tied to existing logs. The tool is left at this depth for 6-8 hours for temperature stabilization. At the bottom station, the Gravilog meter calibrations are performed which take up to two hours to complete. Then readings and repeated readings are made at each depth station in small loops. The logging time depends on the number of gravity measurements and their distribution in the well. Logging operations can take up to 40 hours to complete for each well. The Gravilog and wireline company work in rotating shifts normally lasting 8 or 12 hours. The Gravilog personnel usually overlap for up to one hour at the shift change to update the new operator on any changes or problems.

Gravity readings are taken when the Gravilog tool is stationary and the sensor ball is freely moving. The sensor sometimes travels between depths (and during any transport) with the sensor ball mechanically immobilized to protect it from damage if shocks are anticipated. Measurement depths are approached slowly. The winch operators must learn NOT to overshoot the target depth.

At each depth the sensor is mechanically leveled to vertical; if necessary, the probes' sidewall clamp is engaged or the logging truck brake must be used. The sensor is then unclamped and then the range screw is adjusted to put the electronic feedback system into range. Once in range a recording ("record") of between two and six minutes is made depending on noise levels at that location in the well. Then the meter is unclamped and the winch operator is told to move to next higher depth.

Grounding Schematic