

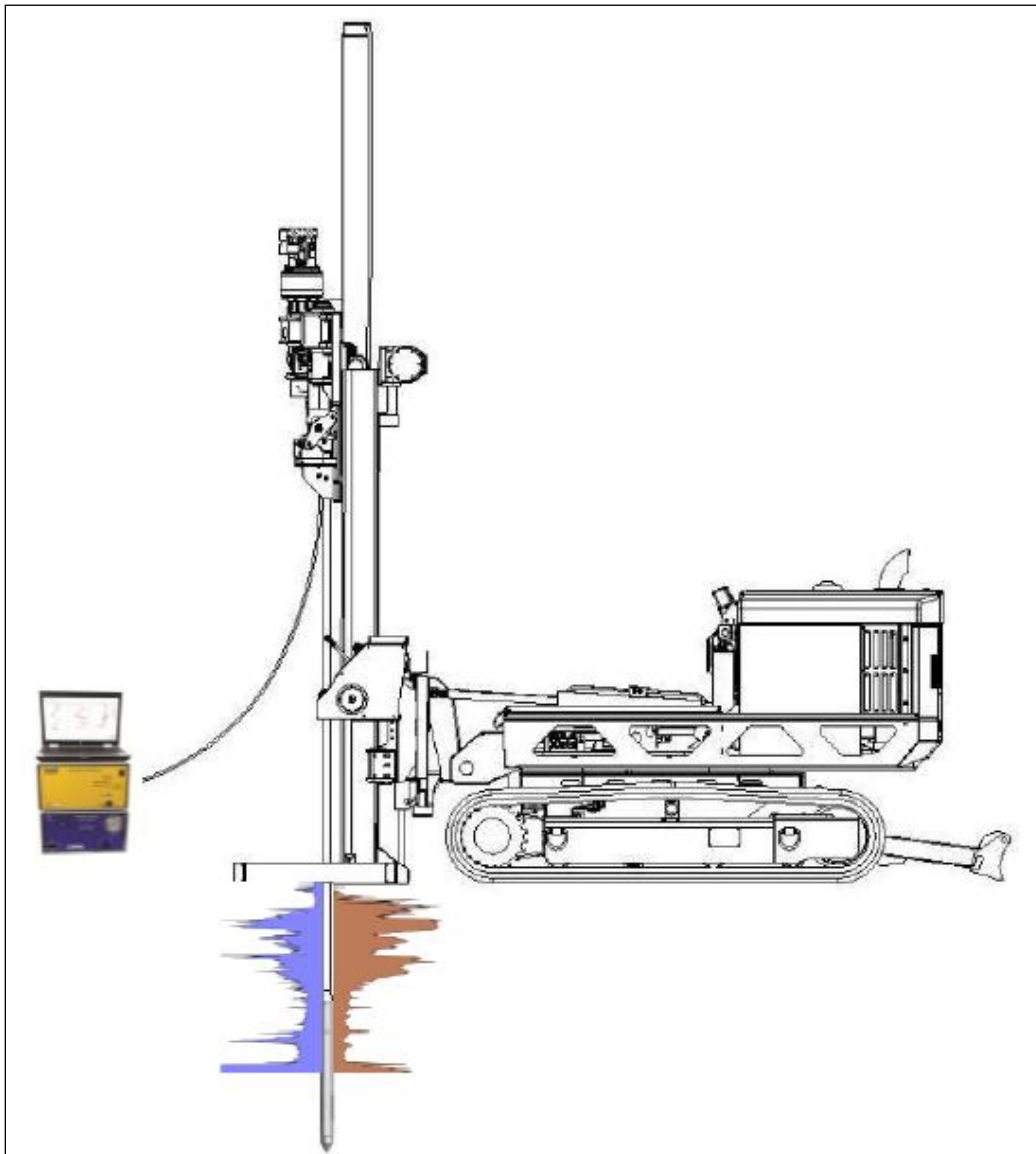


Geoprobe® Hydraulic Profiling Tool (HPT) System

Standard Operating Procedure

Technical Bulletin No. MK3137

Prepared: January 2015



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1.0 Objective

This document serves as the standard operating procedure for the Geoprobe® Hydraulic Profiling Tool (HPT) system. In this procedure, the HPT system is used to measure the pressure response of soil to injected water for identifying potential flow paths and to assist with characterization of soil type.

2.0 Background

2.1 Definitions

Geoprobe®*: A brand of high quality, hydraulically-powered machines that utilize both static force and percussion to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform soil core and soil gas sampling, groundwater sampling and testing, electrical conductivity and contaminant logging, grouting, and materials injection.

**Geoprobe® and Geoprobe Systems® are registered trademarks of Kejr, Inc., Salina, Kansas.*

Hydraulic Profiling Tool (HPT) System: A system manufactured by Geoprobe Systems® to evaluate the hydraulic behavior of subsurface soil. The tool is advanced through the subsurface at a constant rate while water is injected through a screen on the side of the probe. An in-line pressure sensor measures the pressure response of the soil to water injection. The pressure response identifies the relative ability of a soil to transmit water. Both pressure and flow rate are logged versus depth.

2.2 Introduction

The HPT system has been developed by Geoprobe Systems® for the geohydrologic characterization of soils. The HPT probe and logging system is able to quickly provide logs that are easily interpreted. HPT logs are used to indicate hydraulic conductivity, EC, hydrostatic profile, and areas of EC/permeability anomalies.

The HPT system is designed to evaluate the hydraulic behavior of unconsolidated materials. As the probe is pushed or hammered at 2cm/s, clean water is pumped through a screen on the side of the HPT probe at a low flow rate, usually less than 300mL/min. Injection pressure, which is monitored and plotted with depth, is an indication of the hydraulic properties of the soil. That is, a low pressure response would indicate a relatively large grain size, and the ability to easily transmit water. Conversely, a high HPT pressure response would indicate a relatively small grain size and the lack of ability to transmit water.

An electrical conductivity measurement array is built into the HPT probe. This allows the user to collect soil electrical conductivity (EC) data for lithologic interpretation. In general, the higher the electrical conductivity value, the smaller the grain size, and vice versa. However, other factors can affect EC, such as mineralogy and pore water chemistry (brines, extreme pH, contaminants). In contrast, HPT pressure response is independent of these chemical and mineralogical factors.

There are four primary components of the HPT system: the probe assembly, trunkline, HPT Flow Controller (K6300 Series), and Field Instrument (FI6000 series). These primary components are shown in Figure 2.1.

The probe assembly consists of the HPT probe and connection section. This assembly houses the downhole HPT pressure transducer, water and electrical connections, and the probe body with the injection screen and electrical conductivity array.

Injecting water at a constant rate is integral to system operation. The HPT Flow Module houses the pump and associated hand crank mechanism used for adjusting the output flow of the HPT pump. The flow module also contains the HPT flow measurement and injection line pressure transducers. HPT flow can be adjusted from approximately 50 to 500ml/min. The HPT pump is a positive displacement pumping device with minimal decrease in flow over the HPT operating pressure range. The flow module is equipped with an internal bypass that is factory set to open and return flow to the supply reservoir at a pressure of 120psi. When the soil resistance to water injection becomes sufficiently great, the HPT Flow Module bypass will open, returning some or all of the pumped flow to the supply reservoir. The flow meter only measures flow leaving the module to the HPT probe. The HPT Flow Module is connected to the Field Instrument via a data cable.

Water and power are transmitted from the controller to the probe assembly via the HPT trunkline. The probe rods must be pre-strung with the trunkline before advancing the probe.

Data collection occurs in real time by connecting the controller to the field instrument. The field instrument collects, stores and displays transducer pressure, flow rate and electrical conductivity, line pressure, probe rate, and diagnostic parameters, with depth via the field laptop.

Since the HPT pressure response is analogous to the soil's ability to transmit water (and therefore the to the soil's dominant grain size), the HPT system can be used to identify potential contaminant migration pathways. Similarly, it can help identify zones for remedial material injection or provide qualitative guidance on how difficult injection may be in different zones of the formation.

The HPT system may be used to direct other investigation methods, such as soil and groundwater sampling and slug testing. HPT pressure response and EC data can help target zones of geologic and hydraulic interest, minimizing the number of soil and groundwater samples required to adequately develop a site conceptual model. When hydraulic conductivity values are required, the

HPT system can also help the user identify zones to slug test, as well as the length of the screen required to adequately test the zone.

The HPT system also can be used to collect static water pressure data at discrete intervals during the logging process. These static pressure data can be used to calculate static water levels or to create a hydrostatic profile for the log.

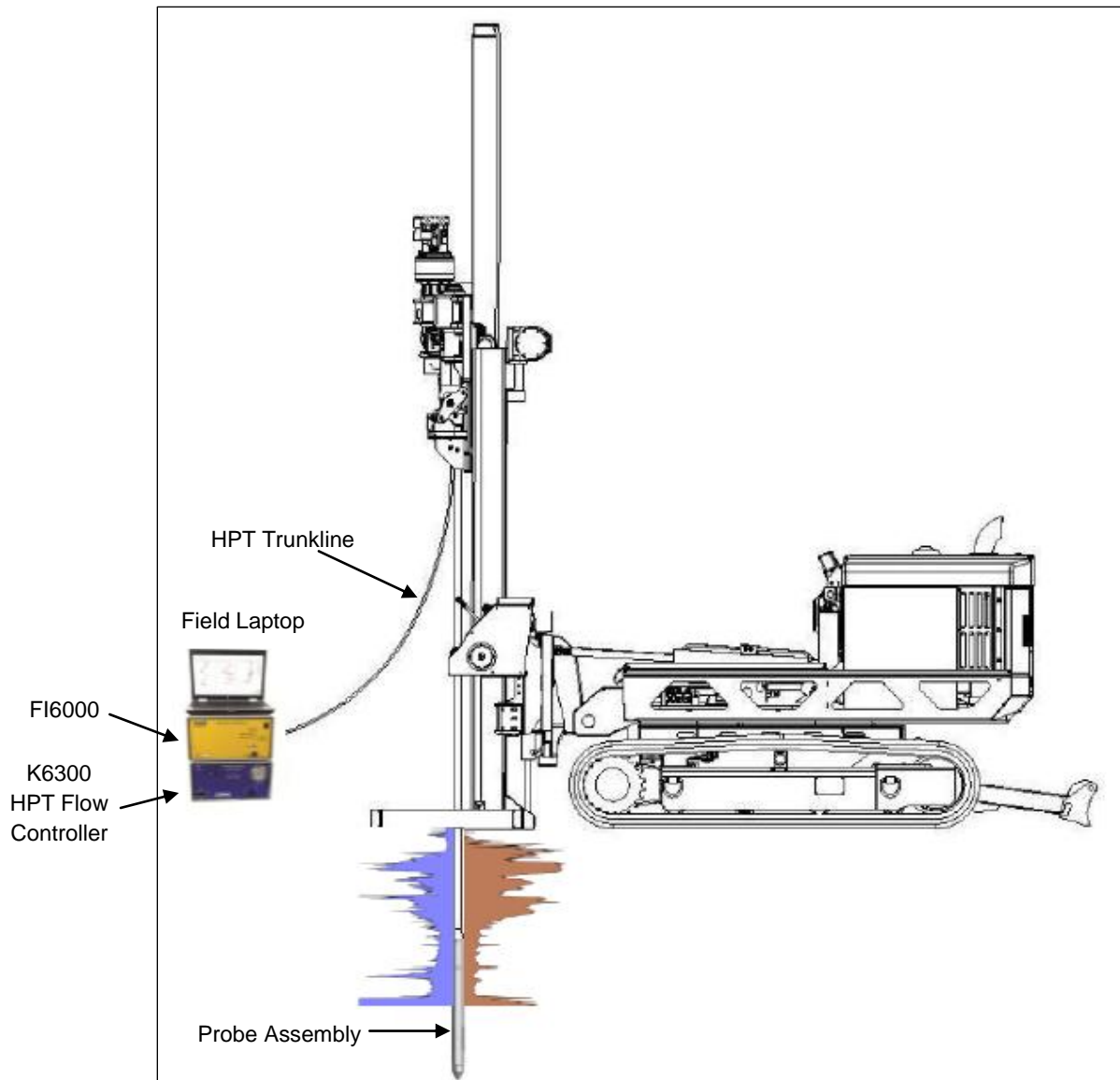


Figure 2.1: HPT Components

3.0 Tools and Equipment

The following equipment is required to perform and record an HPT log using a Geoprobe® 66- or 78-Series Direct Push Machine. Refer to Appendix I for identification of the specified parts.

<u>Basic HPT System Components</u>	<u>Quantity</u>	<u>Material Number</u>
Field Instrument, 120V (Model FI6000)	-1-	213940
Field Instrument, 220V (Model FI6003)	*	213941
HPT Acquisition Software	-1-	214128
HPT Flow Module, 120V (Model K6300)	-1-	214091
HPT Flow Module, 220V (Model K6303)	*	214093
HPT Probe, 1.75 inch	-1-	215667
MIP/HPT Connection Tube	-1-	206304
MIP/HPT Adapter 1.5 Pin x LB Box	-1-	203794
MIP/HPT Adapter 1.75ML Pin x LB Box	**	220966
HPT Probe, 2.25 inch	**	214097
2.25 Connection Tube	**	219455
2.25 Inch Water Seal Drive Head	**	212089
2.75 Inch Water Seal Drive Head	**	209796
HPT Reference Tube 1.75 in HPT Probe	-1-	212689
HPT Reference Tube 2.25 in HPT Probe	**	211762
HPT Trunkline 150 ft.	-1-	214095
HPT Trunkline 200 ft.	(optional)	214096
HPT Service Kit	-1-	205599
HPT Test Load	-1-	206552
EC Probe Test Jig	-1-	214237
EC Test Load	-1-	208075
EC Bypass Cable	-1-	204025
Stringpot, 100-inch	-1-	214227
Stringpot Cordset, 65-feet (19.8 m)	-1-	202884

*Use in place of 120V components if desired.

**Use in place of 1.75 inch probe and components if desired.

4.0 HPT Assembly

Refer to Appendix I

Threading the Rods

- Protect the end of the trunkline to be threaded through the rods with electrical tape or shrink tubing.
- Probe rods must alternate directions prior to threading the trunkline.
- The end of the HPT trunkline with chrome connectors is the downhole or probe end.
- The probe end of the trunkline will always enter the male end and exit the female end of the probe rods.
- The instrument end (no chrome connectors) will always enter the female end and exit the male end of the probe rods.
- After the trunkline is through the probe rods make sure the downhole end is threaded through the male end of the drive head and connection tube prior to connecting to the probe.
- The trunkline is now ready to connect to the instrument and HPT pressure sensor and probe.

5.0 Field Operation

5.1 Instrument Setup

1. Connect the HPT Controller (K6300), Field Instrument (FI6000) and laptop (Fig. 5.1) to an appropriate power source.
2. Connect the FI6000 to the K6300 using the 62-pin serial cable inserted into the acquisition port of each instrument.
3. Secure the EC wires into the Green terminal block connector and insert into the FI6000. The wires match to the EC dipoles in the following top down order when the probe tip is on the ground – white, black, yellow and blue (Fig 5.2).
4. Secure the HPT sensor wires to the appropriate inputs on the green terminal block connector and connect to the rear of the K6300. The top down order of the wires which is listed on the back of the instrument is: brown, orange, red and reserved (open).

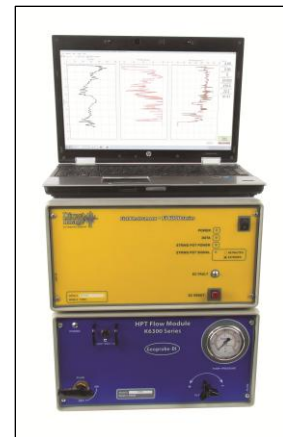


Figure 5.1: HPT Instrument Setup

5. Insert the nylon water line tubing from the trunkline into the water output connector on the back of the K6300.
6. Connect the HPT water supply hose into the input port on the rear of the K6300 and insert the filtered end of the supply line into a water supply tank. The bypass line connects to the bypass port and will follow the supply line back to the supply tank.
7. Connect the USB cable between the USB interface port on the rear of the FI6000 to USB input on the field laptop computer.

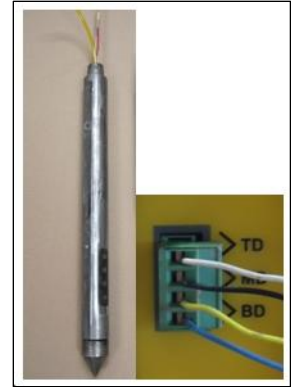


Figure 5.2: EC Wire Connections

8. A stringpot is required to measure depth. Bolt the stringpot onto the machine and the stringpot onto the bracket. Connect the plastic connector end of the stringpot cable to the “Stringpot” connector on the back of the Field Instrument and the metal connector to the stringpot. Pull the stringpot cable and attach to the stringpot piston weight which should be mounted to the probe machine foot and pull the keeper pin so the weight is free to move.

5.2 Starting the Software

1. Make sure the FI6000 and K6300 are connected together with the 62 pin cable, powered on and connected to the computer by the USB cable for the software to load properly.
2. Start the DI Acquisition Software which should open in HPT mode.
3. Select “Start New Log”. The software will request log information and have you browse for a storage location and create and save a file name for the log (Fig. 5.3).
4. Select “Next”. If the software has been run before it will show a list of previous settings including Probe Type, EC Configuration, Stringpot length, rod length and HPT Transducer. If any of these have changed or you are unsure select “No” but if they are all the same select “yes”. If you select “No” the software will have you select the proper settings after the EC Load Test, if you selected “Yes” the selection of these settings will be bypassed.

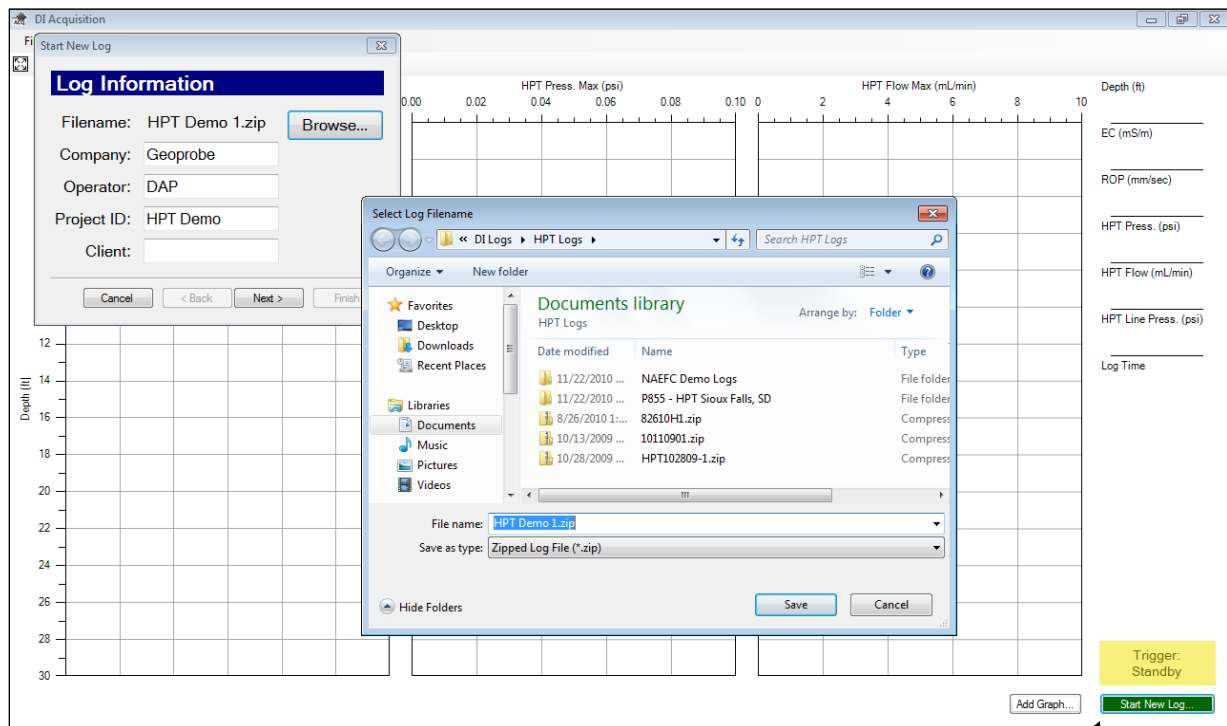


Figure 5.3: DI Acquisition Software – Start New Log Sequence

5.3 QA Testing the EC and HPT Systems

Both the EC and HPT components must be tested before and after each log. This is required to ensure that the equipment is working properly and capable of generating good data before and after the log.

A. Electrical Conductivity Load Test

1. Secure the EC 3 position test load connector (208075) to the test input jack on the back of the Field Instrument.
2. Secure the EC Probe Test Jig into the input on the EC 3 position test load.
3. Clean and dry the EC dipoles as well as several inches of the probe body above the pins.
4. Place the EC Test Jig (214237) so that the four springs on the test jig touch the four dipoles of the Wenner EC array (Fig. 5.4). Make sure the trunkline and test jig wires go in the same direction. The other spring on the test jig will ground the probe body above the Wenner array. Make sure the springs are pulled out far enough to make a solid contact on the dipoles.

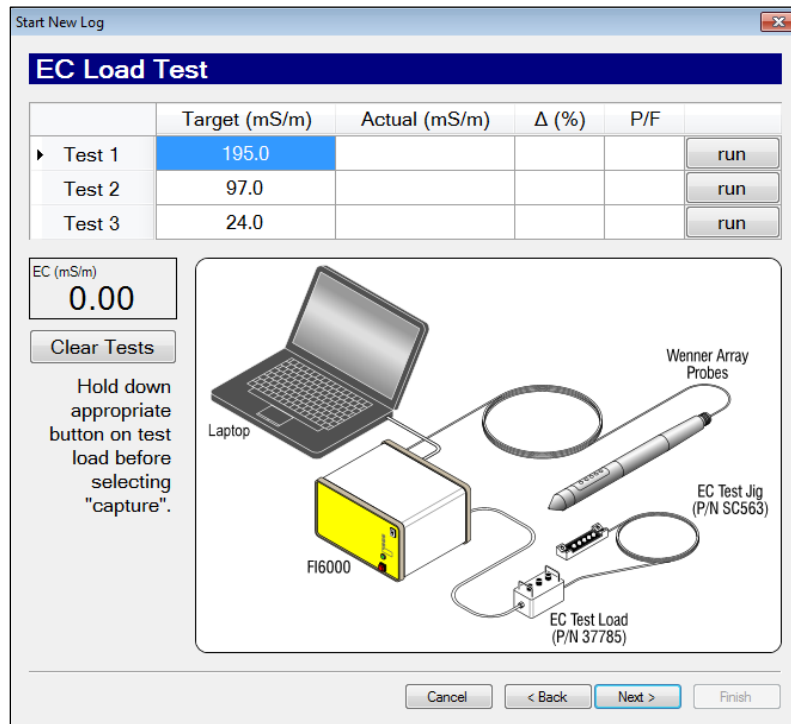


Figure 5.4: EC Load Test Screen

5. When you get to the EC Load Test Screen and the EC test load and test jig are in place on the probe press down on the test 1 button on the test load and select "run" of Test 1 (Fig. 5.4). After 5 seconds the actual value will acquire and will pass if within 10% of the target value. Continue on with Test 2 and 3.
6. If any of the EC load tests fail do not pass within the allowed 10% acceptance range you can make adjustments on the test jig and rerun the test by just re-clicking the "run" button for an individual test.
7. If the tests continue to fail, select "Next" and the software will conduct the "EC Troubleshooting Tests." The Instrument Calibration Tests (Fig. 5.5) checks of the calibration within the FI6000. If these are far out of range it will influence the EC Test load values and will need to return to Geoprobe® for repair. The "Probe Continuity and Isolation Tests" confirm each of the wires is a complete circuit and is fully isolated from one another. If a probe continuity test fails just outside the target range of <8ohms this is typically a contact issue with the test jig and the dipoles. If the continuity is in the thousands of ohms this is a break in the EC wire circuit – either in the probe, the trunkline or the connection between them.

Start New Log

EC Troubleshooting Tests

Instrument Calibration Tests

	Ω	P/F
▶ 10 Ω	10.2	PASS
100 Ω	99.6	PASS
1000 Ω	1037.0	

Probe Isolation Tests (< 15 k Ω fails)

	k Ω	P/F
▶ R-N		
R-W		
R-G		
R-B		
W-N		
W-G		
W-B		
G-N		
G-B		
B-N		

Probe Continuity Tests (> 8 Ω fails)

	Ω	P/F
▶ R-R		
W-W		
G-G		
B-B		

(After all tests have been run, double-clicking a test name will re-run that test.)

Figure 5.5: EC Troubleshooting Test Screen

8. When these tests are complete select next. In the next screen, the software will provide an EC option, if one is available. The EC Load Test will only work if EC can be operated in Wenner array meaning all of the EC wires in the continuity test pass with results <8ohms on the individual circuits. EC can be operated and collect good data in one of the dipole areas: top, middle or bottom dipole. If the R-R test fails but the others pass the software will provide the option in the next screen to run either middle dipole or bottom dipole arrays. If R-R and G-G are both an incomplete circuit then no EC array is available to run and a new probe must be connected or the problem fixed. In the Wenner configuration it requires 2 adjacent dipoles to operate in dipole mode. If an EC array is chosen and run in this last manner then all of the EC information collected will be bad data.

B. HPT Reference Testing

Reference testing is done to ensure that the HPT pressure sensor is in working order and to evaluate the condition of the HPT injection screen. The HPT reference test calculates atmospheric pressure which is required to obtain static water level readings and to determine the estimated K values for the log in our post log processing software the DI Viewer.

Reference Test Procedure

1. Connect a clean water source to the HPT controller and turn on the pump.
2. Allow water to flow through the system long enough so that no air remains in the trunkline or probe (air in the system can cause inaccurate flow and pressure measurements).
3. Insert the probe into the HPT reference tube and allow the water to flow out the valve adjusting the flow rate to between 250-300ml/min (Fig. 5.5). Ensure that the reference tube is close to vertical.
4. With a stable pressure reading and the water flowing out of the valve select "capture" - bottom with flow (Fig. 5.6)
5. Close the valve and allow the water to overflow the top of the tube. When the pressure stabilizes select "capture" - top with flow.
6. Shut off the water flow. When the pressure stabilizes select "capture" - top flow = 0.
7. Open the valve and allow the water to drain out. When the pressure stabilizes select "capture" - bottom flow = 0.

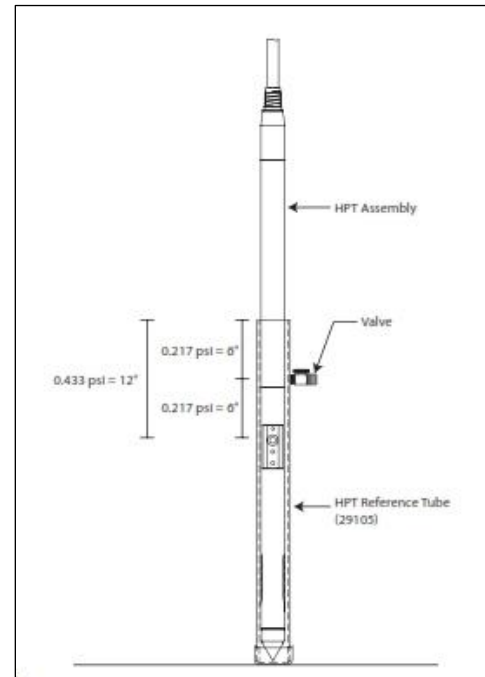


Figure 5.5: HPT Reference Test Setup

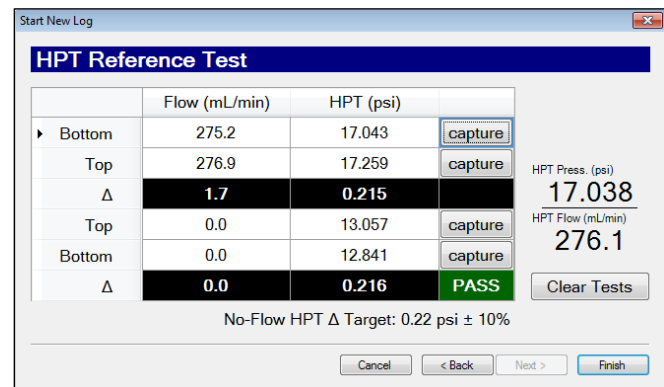


Figure 5.6: HPT Reference Test Screen

The HPT reference test reading flow = 0 is the true test of the condition of the pressure sensor and is the only sensor test to have a pass/fail reading on it. Ideally, the pressure difference between the top and bottom values will be 0.22psi (1.52kPa). Typical pressure readings of the sensor will be in the 12-15psi (83-104kPa) range.

5.4 Running an HPT Log

1. Place the rod wiper on the ground over the probing location and install the drive cushion in place of the anvil of the probing machine.
2. Place the probe tip in the center of the rod wiper, and place the slotted drive cap on top of the HPT probe.
3. Start the HPT water flow. **Note:** It is important that there is always water flowing when the probe is advanced to avoid soil particles from moving through the screen and causing problems with the pressure readings or causing a blockage behind the screen.
4. Adjust the probe so that it is vertical and advance the probe until the HPT screen is at the ground surface.
5. Click the trigger button in the lower right hand corner of computer screen. (The Trigger label will flash and the background will change from yellow to green).
9. Advance the probe at a rate of 2cm/s. If necessary, feather the hammer to maintain this advance rate.
10. Perform a dissipation test (Section 5.4) in a zone of higher permeability indicated by lower HPT pressure.
11. After completing the log, press the trigger button again and select "Stop Log".
12. Pull the rod string using either the rod grip pull system or a slotted pull cap. Run a post-log EC test and HPT response test (Section 5.2).

5.5 Performing a Dissipation Test

At least one dissipation test must be performed in order to calculate the static water level and estimated K readings from the log. Dissipation tests need to be performed below the water table and are best in zones of high permeability where the injection pressure can dissipate off quickly once the flow is shut off.

1. Stop in a zone of higher permeability which is indicated by lower HPT inject pressure.

2. Switch the DI Acquisition display view from the depth screen to the time screen by pressing the F10 key (F9 and F10 toggle between the depth and time screen of the acquisition software).
3. The screen will be grayed out which means that the data up to that point has not been saved. Select “Start Dissipation Test” which will turn the screen from gray to a white background indicating that you are now saving the time data.
4. Now shut the pump switch off and when the line pressure reaches zero, turn the flow valve off.
5. The HPT Pressure will begin to drop (dissipate the hydrostatic increase) and allow it to stabilize so very little visible drop in pressure is seen. When the pressure has fully dissipated turn the flow valve and the pump switch back on. When the flow and pressure are reestablished select “End Dissipation test.”
6. Select F9 to return to the depth screen and advancing the tool into the ground.

Note: Performing a dissipation test in zones of higher permeability may only take 30 seconds or so but if the HPT pressure was higher to start with it may take a long time up to several hours to dissipate off to equilibrium. This is why targeting the most permeable zone to perform the dissipation tests is most desirable.

6.0 HPT Log and Interpretation

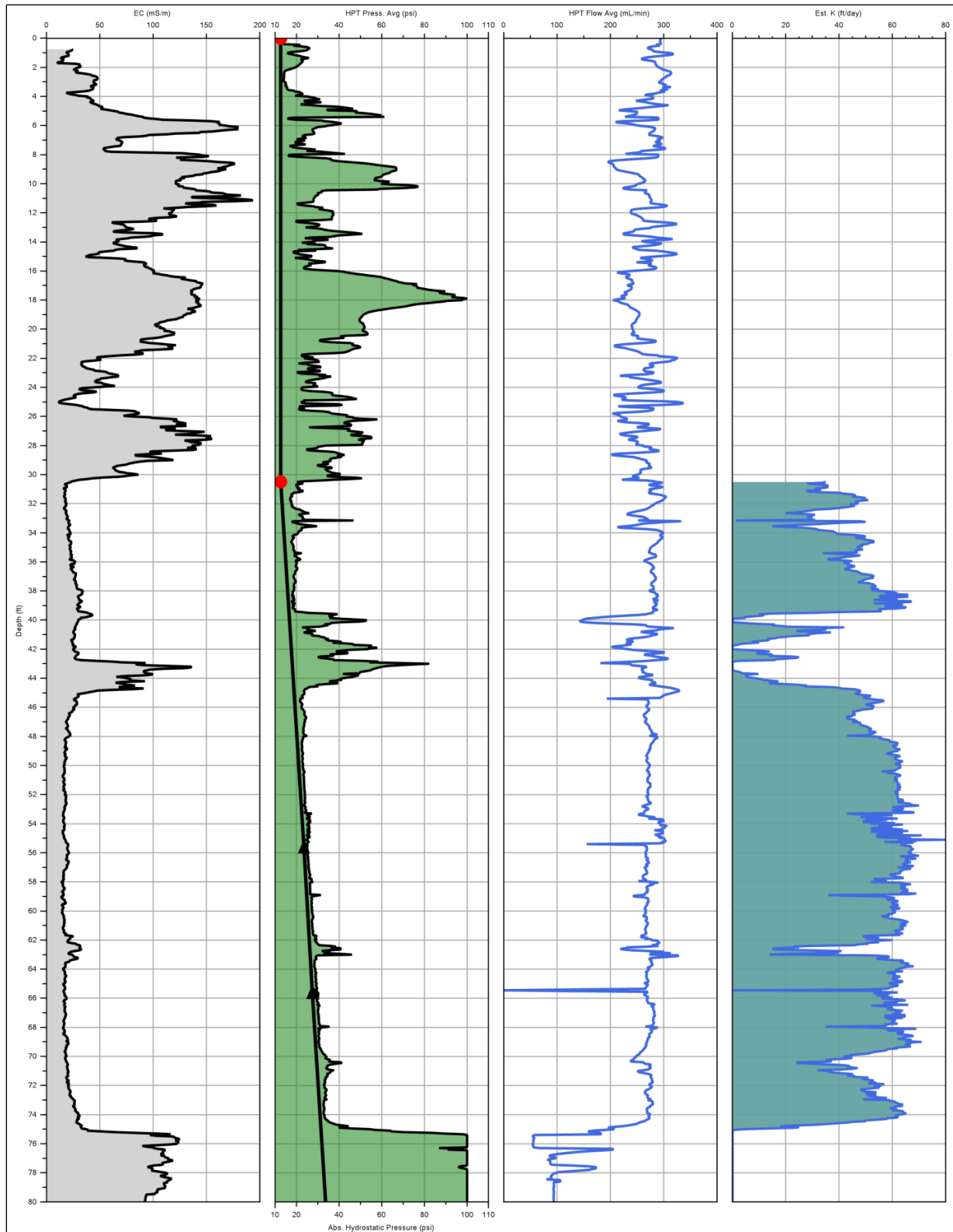


Figure 6.1: HPT Log file showing (left to right):
Electrical Conductivity (EC), HPT Injection Pressure with Hydrostatic Profile, HPT Flow, and Estimated K

A typical HPT log is shown in figure 6.1, which consists of both the HPT pressure response and electrical conductivity. In general, both HPT pressure and EC values increase with decreasing grain size, and decrease with increasing grain size. The log in Figure 6.1 shows good consistency between EC and HPT pressure for the majority of the log. It is only between 32'-42'bgs that we see some divergence of the graphs with higher HPT pressure while the EC readings remained low. This can happen for reasons such as poor mineralogy of the soil. Refusal was encountered in a shale layer beginning at 75'bgs and it can be noted that as we enter this layer the HPT flow gets suppressed as the pressure reaches a maximum value of 100psi (690kPa). The second graph of the log shows the hydrostatic profile on the secondary series of the graph. The hydrostatic profile has 2 black triangles which indicate where dissipation tests were run and used to calculate the profile. The red circle indicates the calculated water table based upon where the hydrostatic profile intersects atmospheric pressure. The fourth graph is the estimate K or groundwater flow graph. This is calculated based upon HPT pressure and HPT flow relationships. Less permeable soil will have less groundwater flow.

It is fairly common to see zones where EC readings and HPT pressure contradict one another. In cases where EC readings are low and HPT pressure trends higher as in the log in Figure 6.1 the following are possible reasons:

- Poor mineralogy of the soil particles resulting in silt and clay soils with very low EC readings. This is seen in many locations along the east coast of the United States.
- Silts intermixed with sand particles.
- Weathered bedrock may have low EC but would have low permeability.

Where we have cases of higher EC and lower HPT pressure typically is due to an ionic influence in the soil or groundwater. These higher EC readings can range from very slight to higher than typical soil readings. Very high EC readings can occur when the probe contacts metallic objects in the soil which will ground them out and typically will cause hard sharp spikes in the EC data.

- Chloride or other ionic contaminant (sea water, injection materials)
- Sea Water intrusion
- Wire, metal objects or Slag

In cases where HPT and EC do not confirm one another it is important to take confirmation soil and/or groundwater samples to help understand the difference between the two graphs.

7.0 Troubleshooting

7.1 Using the HPT Controller Test Load

The HPT Controller Test Load (206552) is included with the HPT Controller to help troubleshoot the HPT pressure sensor, trunkline, and controller. If there is a major problem with the HPT pressure sensor or the system wiring the system will not read anywhere close to atmospheric pressure with the probe at the surface. Commonly if the HPT sensor has broken the software will read either a maximum or minimum value which would be 100psi or 0psi (690kPa or 0kPa). If there is damaged wiring or nothing is connected to the controller the system typically reads 50psi (345kPa).

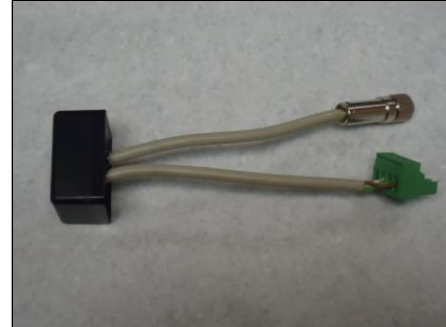


Figure 7.1: HPT Test Load (206552)

To use the test load, set up the system as previously described. Turn on both the field instrument and HPT controller and start the HPT software. Plug the green wire connector of the test load into the HPT sensor connector on the back of the HPT controller. If the pressure sensor value reads between 25-35psi (172 – 241kPa) the controller is able to properly read pressures so the problem is in the trunkline or the HPT sensor. If HPT controller has not moved from what it was reading or is way out from the expected value of the load test the HPT controller may require servicing. Contact Geoprobe Systems® for service.

Next, connect the HPT sensor wires of the trunkline to the controller with the green connector and then connect the chrome connector side of the test load to the female chrome connector on the downhole end of the trunkline in place of the pressure sensor. Again, the pressure value displayed on the field instrument should read between 25-35psi (172 – 241kPa) and should be the same as what was seen with the load test connected into the controller. If the load test read the expected value 25-35psi (172 – 241kPa) at both locations then both the trunkline and the controller are working properly and the problem is in the HPT sensor. If the test load read the expected value at the controller but not at the end of the trunkline, the trunkline may be defective and should be replaced. Before restringing another HPT trunkline, first connect the new trunkline sensor wires into the HPT controller and the downhole end into the test load. If the system now reads in the expected test load range the original trunkline needs replacing.

Finally, connect the pressure sensor to the trunkline. If it reads atmospheric pressure, approximately 12-15psi (83-104kPa), then the pressure transducer is functioning properly. However, if it does not, replace the sensor with a new one and re-check the pressure reading. Be sure to enter the new sensor calibration values into the software prior to starting the new log. Additional pressure sensors may be purchased from Geoprobe®.

7.2 Common Problems

Problem: The pressure transducer is connected to the trunkline, but the software is reporting a reading of ~ 50psi (345kPa).

Solution: Make sure all trunkline wires are secured to the green terminal blocks and plugged in to the back of the HPT controller and sensor chrome connectors are secure. Check components using the HPT Controller Test Load (Section 7.1).

Problem: The pressure transducer is connected to the trunkline, but the software is reporting a reading of 100psi or 0psi (690kPa or 0kPa).

Solution: Make sure all of the connections are good and recheck the pressure reading. If still bad connect a new HPT pressure sensor onto the trunkline and see if it reads atmospheric pressure. If not check all the components using the HPT Controller Test Load (Section 7.1).

Problem: The pressure with flow values keep drifting when water is flowing out the port or over the top of the reference tube.

Solution 1: If the trunkline was just connected and flow was just started air may still be in the lines. Allow the water to continue to flow through system which will purge out the remaining air. When it appears that most of the air is out of the lines press your thumb over the injection screen for a few seconds to help drive out any remaining air from the trunkline.

Solution 2: There may be debris behind the screen. Remove the HPT screen with the membrane wrench and turn the water flow on, use a small screwdriver to scrap out any debris in the screen socket as well as any that might be behind the screen. Replace the screen and retry the reference test with flow.

Solution 3: If the with flow pressure values continue to not settle down and provide close to the expected difference for a 6" water column then the problem may be inside the HPT control box. When you remove the cover of the HPT controller there will be a brass filter located on the left side when viewing from the front of the instrument (Fig 7.2). Particulates and precipitates can collect inside this filter causing problems with HPT pressure stability. Remove this filter and open up using appropriate wrenches. The filter can be easily cleaned by rinsing water over the screen. Reassemble and return to its proper location inside the control box. Resume reference testing the system.



Figure 7.2: Location of Inline Filter in K6300 and buildup of particulates in filter.

Problem: Atmospheric pressure values are way off from normal (12-15psi (83-104kPa)) after installing a new HPT sensor.

Solution: Check the calibration values that were entered into the software to ensure that they are correct.

Problem: Winterizing the HPT system for subfreezing work or air transport.

Solution: Pump RV antifreeze through the HPT pump and bypass pathway which can be done by blocking off the inject line. The trunkline can either be purge free of water by the pump or with an air compressor. NOTE: Never purge the HPT Controller of water using an air compressor this will damage sensor components in the controller.

Problem: HPT flow sensor reading 0ml/min

Solution: If the flow sensor reads 0 or some other stable number that does not correspond to actual water flow out the controller likely the flow sensor has been damaged. The flow sensor is very susceptible to damage from freezing. To repair the HPT flow sensor contact Geoprobe-DI technical support.

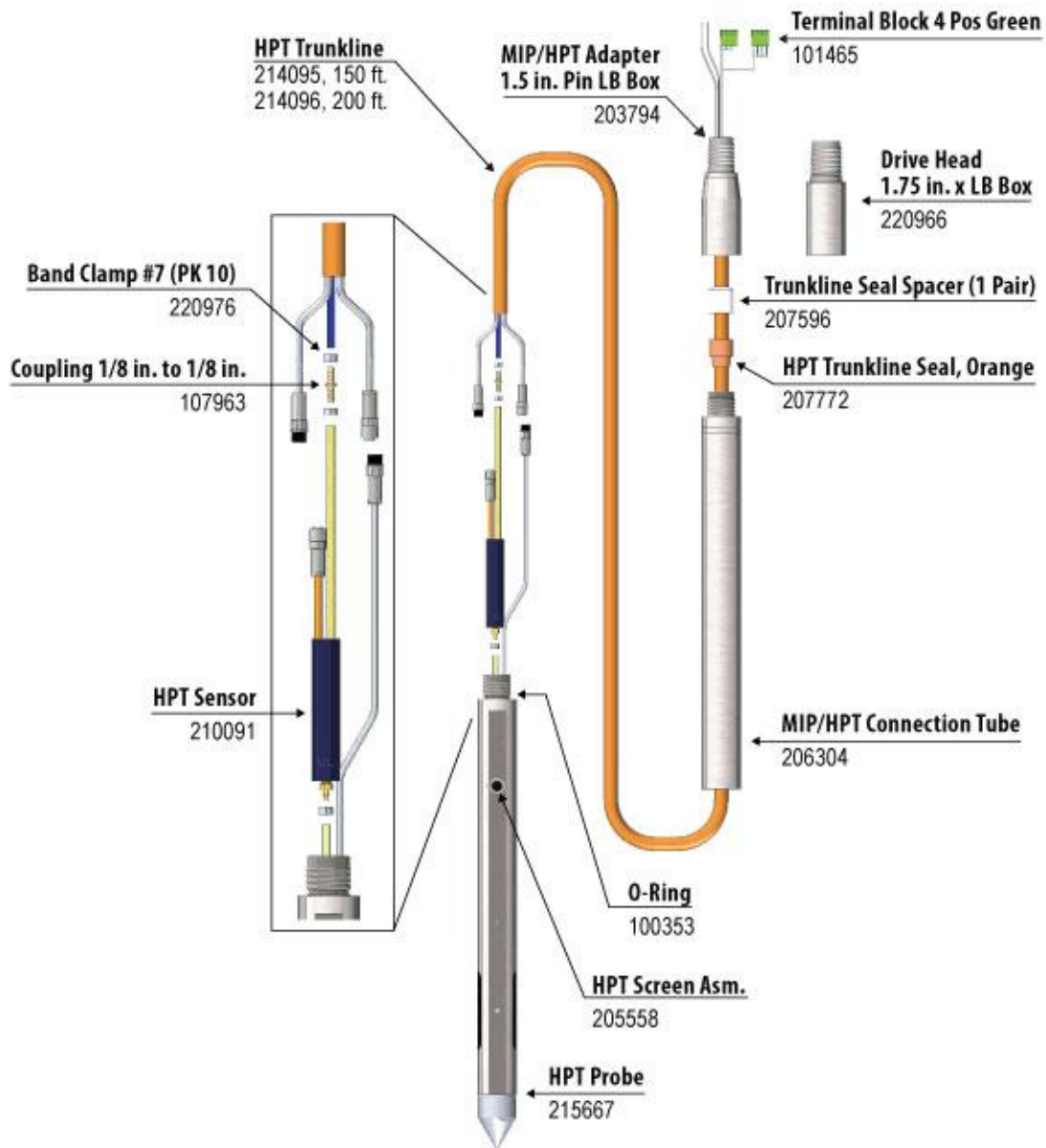
Problem: EC won't pass the QA tests.

Solution: Check the trunkline to probe EC connections ensuring they are tight. Run the troubleshooting tests (Section 5.3A), test EC on a new probe. If multiple probes and trunklines do not pass EC isolate the FI6000 instrument using the EC bypass cable (204025). The bypass cable is a six inch long cable that connects between the Test input and the EC probe connections on the back of the FI6000. Once connected start an EC or HPT log and fail the EC test load tests on purpose and run the EC troubleshooting tests (Figure 5.5). If the EC calibration or the EC continuity readings fail there could be an issue in the FI6000. In this case contact Geoprobe-DI technical support. If all of the troubleshooting tests pass then the problem is not in the instrument but in the trunkline, probe or their connections.

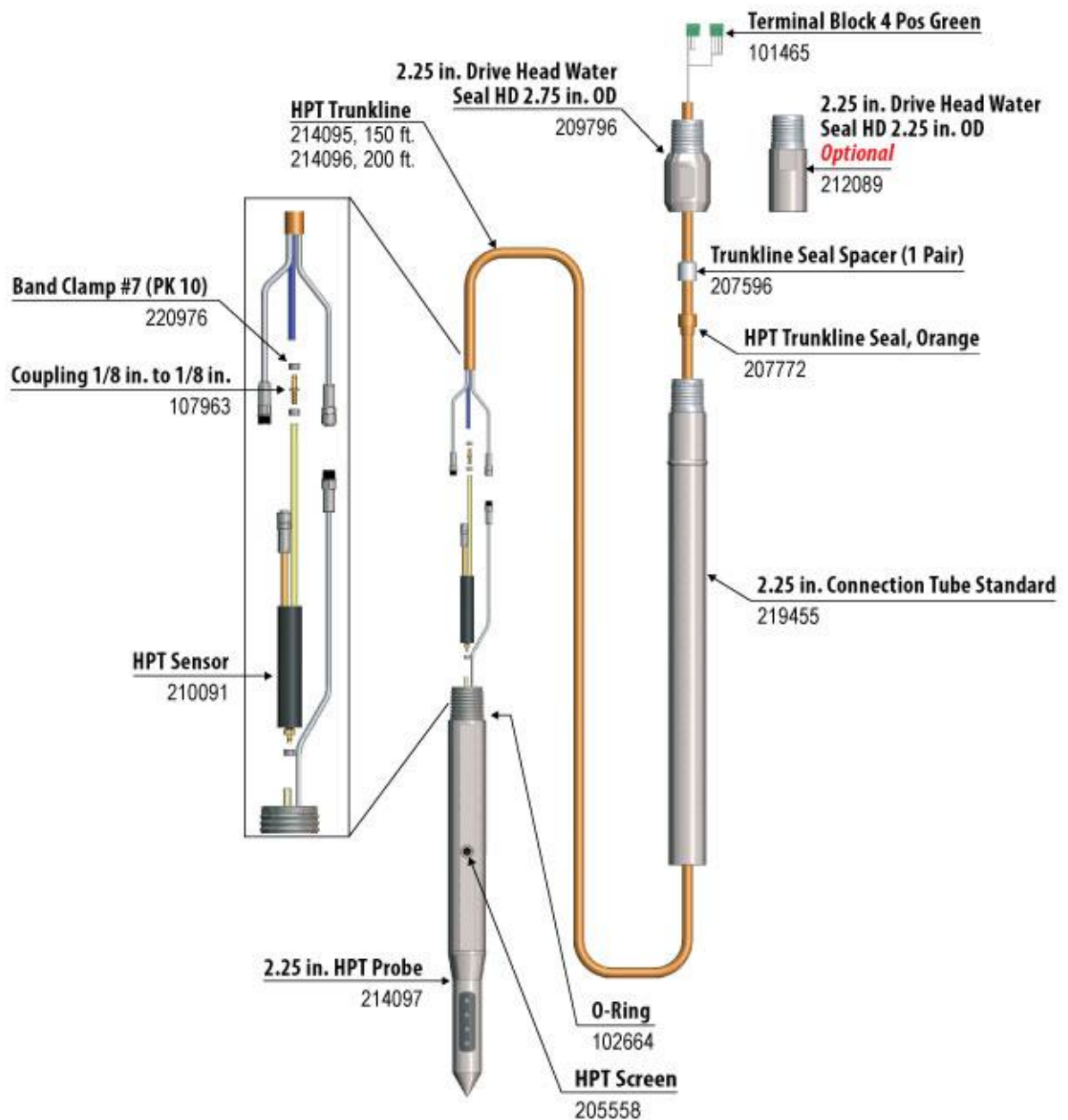
APPENDIX I

HPT Tool Configurations

HPT – K6050 (1.5 in / 1.75 in. system)



HPT – K8050 (2.25 in. system)



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