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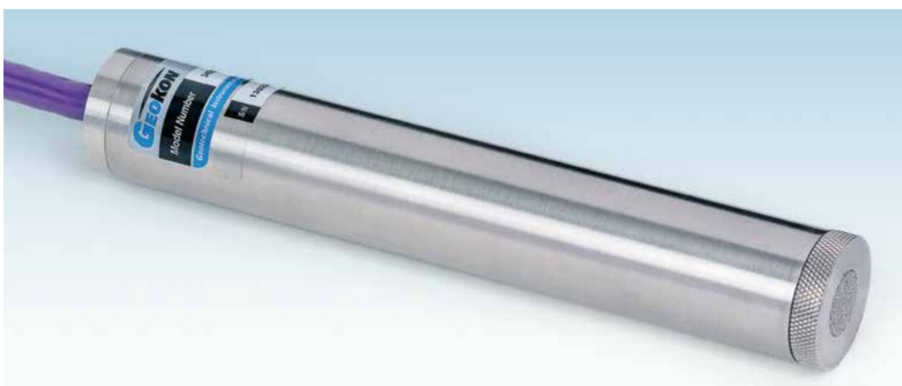
Instruction Manual

Model 3400 series

Semiconductor Piezometer



(REV I, 04/30/2019)

Warranty Statement

Geokon warrants its products to be free of defects in materials and workmanship, under normal use and service for a period of 13 months from date of purchase. If the unit should malfunction, it must be returned to the factory for evaluation, freight prepaid. Upon examination by Geokon, if the unit is found to be defective, it will be repaired or replaced at no charge. However, the WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion or current, heat, moisture or vibration, improper specification, misapplication, misuse or other operating conditions outside of Geokon's control. Components which wear or which are damaged by misuse are not warranted. This includes fuses and batteries.

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TABLE of CONTENTS

FIGURES

TABLES

EQUATIONS

1. THEORY OF OPERATION

Geokon Model 3400 Piezometers are intended for dynamic measurements of fluid and/or pore water pressures in standpipes, boreholes, embankments, pipelines, pressure vessels, reservoirs, etc. They are also used for static pressure movement where the readout system is incompatible with vibrating wire type transducers. The piezometer assembly is shown in Figure 1.

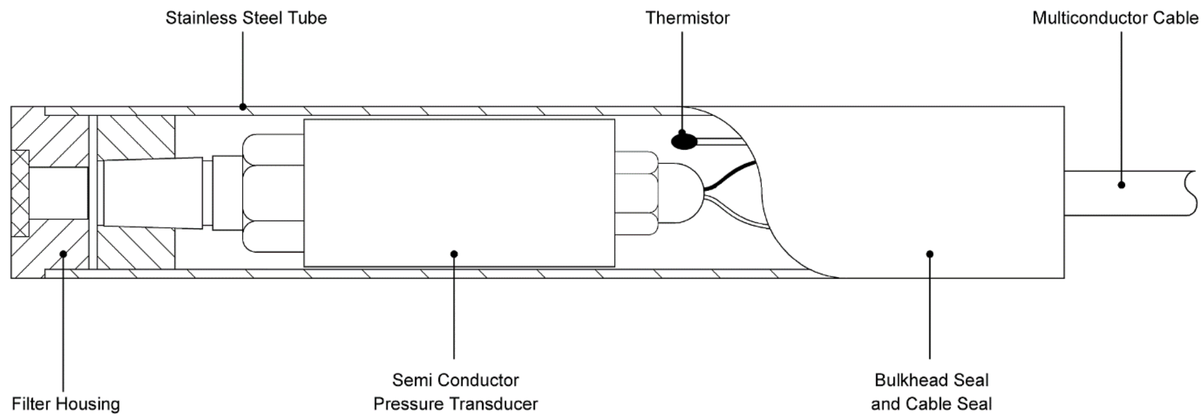

Figure 1 - Model 3400 Piezometer Assembly

The basic pressure transducer is semiconductor based. The output from the transducer may be 100 mV/volt, 0 to 5 volts, or 4 to 20 mA at the option of the user. The transducer is packaged inside a 1.25" (32 mm) diameter stainless steel tube (standard 304 SS or optional 316 SS for aggressive environments). At one end of this tube is a filter housing to allow the passage of water while preventing the entry of soil particles. At the other end is located a bulkhead seal and cable entry seal to prevent water from reaching the backside of the transducer. A thermistor included inside the main housing allows the measurement of temperature.

The output cable is multi conductor with from two to four shielded pairs depending on the transducer output. Voltage types are generally read using remote sensing techniques. Low-pressure models may also be vented to the atmosphere through a vent tube inside the cable. Venting of the transducer is necessary if the effects of barometric pressure changes on the transducer are to be eliminated.

Where venting is used, the outer end of the vent tube is connected to a desiccant chamber to prevent moisture from migrating to the transducer interior.

2. PRELIMINARY TESTS

- Upon receipt of the piezometer, connect it to the readout using the wiring charts shown in Appendix C, and check that the zero-pressure reading is within 1% F.S. of the value shown on the calibration report after due correction for barometric pressure, elevation above sea level and temperature.

- Apply a pressure or vacuum to the piezometer and check that the readout response is reasonable.

- Check the insulation resistance. Use an ohmmeter to measure the resistance between any conductor and the shield. The resistance should be greater than 50 megohms.

- If an attempt is made to check the calibration, make sure that the applied pressure is accurate. Be aware that calibrations performed by raising and lowering the piezometer inside a borehole or well can be compromised by a displacement of the water level caused by changing volumes of immersed cable.

Calibrations performed in this way should be done with the filter housing removed. If the filter is left in place, be sure that it is completely saturated and that the space between filter and transducer is filled with water. Be sure to allow enough time (15 to 20 minutes) for the piezometer to reach thermal equilibrium before beginning the test.

3. SATURATING FILTER TIPS

Warning! Do not allow the piezometer to freeze once the filter stone has been saturated!
See Section 4.9 for information about protecting the piezometer from freezing.

Most filter tips can be removed for saturation and then reassembled. To maintain saturation, the unit should be kept underwater until installation. If the piezometer is used in a standpipe where it will be raised and lowered frequently, the filter housing may loosen over time, and a permanent filter assembly may be required. The removable filter may be fixed permanently by prick punching the piezometer tube approximately 1/16" to 1/8" behind the filter assembly joint.

Salts in the water can be deposited into the filter stone causing it to become clogged if it is allowed to dry out completely. Filter stones may be replaced with screens for standpipe installations. Screens available from Geokon are less likely than standard filters to collect salt and become clogged.

3.1 Saturating Low Air Entry (Standard) Filters

For accurate results, total saturation of the filter is necessary. As the piezometer is lowered into the water, water is forced into the filter, compressing the air in the space between the filter stone and the pressure sensitive diaphragm. After a period, this air will dissolve into the water, filling the filter and the space above it entirely with water.

To speed up the saturation process, remove the filter from the piezometer by carefully twisting and pulling on the filter housing assembly (or unscrewing the point of the piezometer for model 3400DP). Hold the piezometer with the filter facing up and fill the space above the diaphragm with water. Slowly replace the filter housing, allowing the water to squeeze through the filter stone as it is installed. For piezometers with a range of less than 10 psi, take readings with a readout box while reinstalling the filter housing to ensure the piezometer is not overranged.

3.2 Saturating High Air Entry Ceramic Filters

Because of the high air entry characteristics of the ceramic filter, de-airing is particularly important. Different air entry values require different saturation procedures.

3.2.1 One Bar Filters

1) Remove the filter from the piezometer by carefully twisting and pulling on the filter housing assembly.

2) Boil the filter assembly in de-aired water.

3) Reassemble the piezometer under the surface of a container of de-aired water. Use a readout box while installing the filter to monitor the diaphragm pressure. If the piezometer begins to overrange, allow the pressure to dissipate before pushing further.

4) Be sure that no air is trapped in the transducer cavity.

3.2.2 Two Bar and Higher Filters

The proper procedure for de-airing and saturating these filters is somewhat complex; therefore, it is recommended that saturation be done at the factory by Geokon. If saturation must be done in the field, carefully follow the instructions below:

1) Place the assembled piezometer, filter down, in a vacuum chamber that has an inlet port at the bottom for de-aired water.

2) Close off the water inlet and evacuate the chamber. The transducer should be monitored while the chamber is being evacuated.

3) When maximum vacuum has been achieved, allow de-aired water to enter the chamber until it reaches an elevation a few inches above the piezometer filter.
4) Close off the inlet port.

5) Release the vacuum.

6) Observe the transducer output. It may take up to 24 hours for the filter to completely saturate and the pressure to rise to zero.

7) After saturation, the transducer should be kept in a container of de-aired water until installation. If de-aired at the factory a special cap is applied to the piezometer to maintain saturation.

3.3 Model 3400DP

The 3400DP Drive Point Piezometer is de-aired in the same way as the 3400 models by first unscrewing the point of the piezometer assembly and then following the instruction for the 3400.

4. INSTALLATION

Before attempting an installation be sure that the filter stone is completely saturated (see Section 3) and that the space between the filter stone and the transducer diaphragm is filled with water. **Warning! Do not allow the piezometer to freeze once the filter stone has been saturated!**

4.1 Establishing a Zero Pressure Reading

It is essential, in many cases, to establish an accurate zero pressure reading at the job site under known conditions of barometric pressure and temperature. The following procedures are important.

1) Either remove the filter housing completely (preferred) or make sure that the filter stone is saturated and that the space between the filter and transducer diaphragm is filled with water.

2) Lower the piezometer into the borehole or well until it is just above the water level.

3) Allow 15 to 20 minutes for the temperature to stabilize before taking the reading.

4.2 Installation in Boreholes

Geokon piezometers can be installed in cased or uncased boreholes, in either single or multiple piezometer configurations. If pore pressures in a particular zone are to be monitored, careful attention must be paid to the borehole sealing technique.

The borehole should extend 6 to 12 inches below the proposed piezometer location. Boreholes should be drilled without using drilling mud, or by using a material that degrades rapidly with time, such as Revert™. Wash the borehole clean of drill cuttings. Backfill the borehole with clean fine sand to a point six inches below the desired piezometer tip location. The piezometer can then be lowered into position. (Preferably, the piezometer will be encapsulated in a canvas bag containing clean, saturated sand.) While holding the instrument in position, (a mark on the cable is helpful) fill the borehole with clean fine sand to a point six inches above the piezometer.

Three different methods of isolating the zone to be monitored are detailed below.

Installation A:

Immediately above the area filled with clean fine sand, known as the “collection zone”, the borehole should be sealed by an impermeable bentonite cement grout mix, or with alternating layers of bentonite and sand backfill, tamped in place for approximately one foot, followed by common backfill. (See Figure 2.)

If multiple piezometers are to be used in a single hole, the bentonite and sand should be tamped in place below and above the upper piezometers, as well as at interval between the piezometer zones. When using tamping tools special care should be taken to ensure that the piezometer cable jackets are not cut during installation, as this could introduce a possible pressure leak in the cable.

Installation B:

The borehole is filled from the "collection zone" upwards with an impermeable bentonite grout. (See Figure 2.)

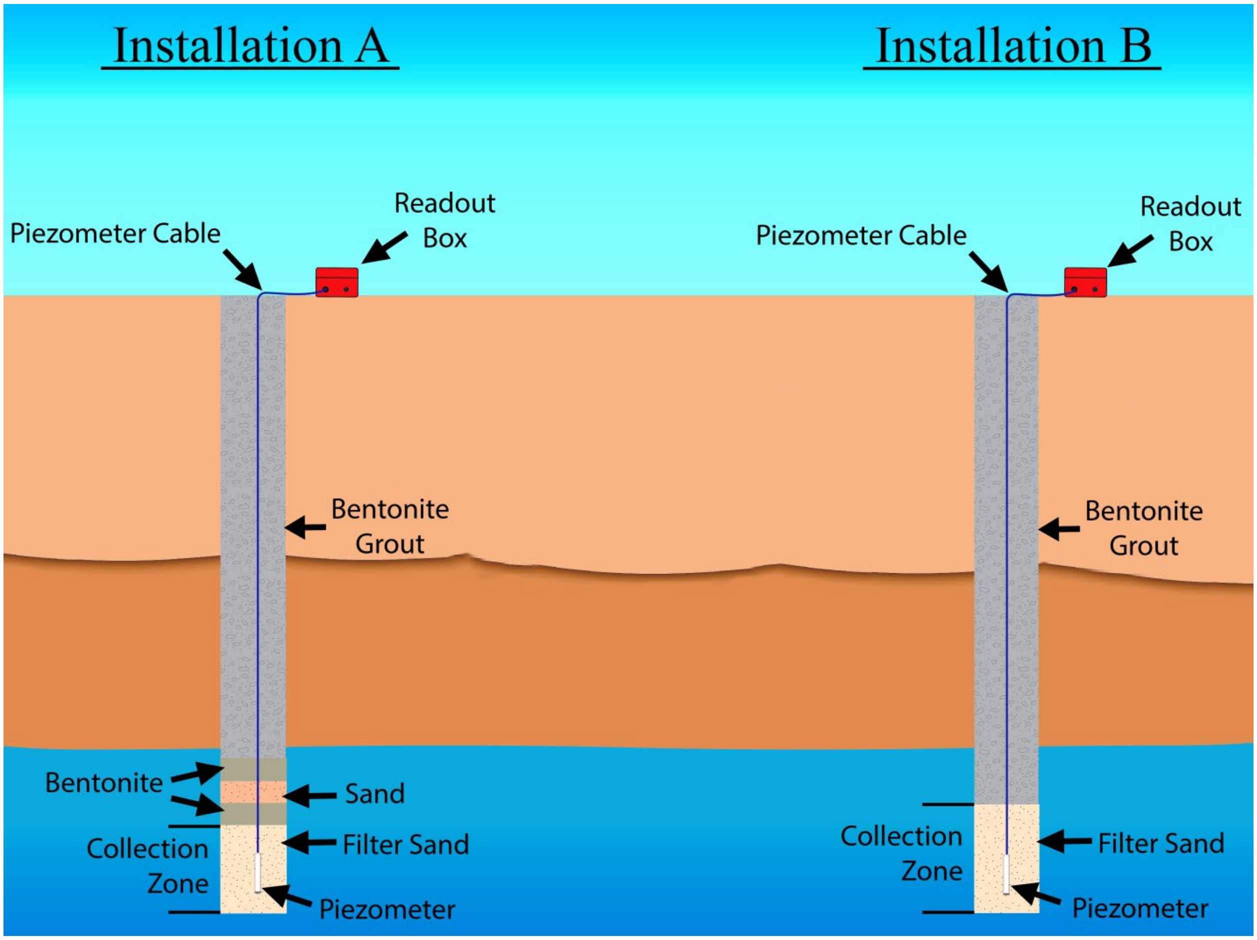

Figure 2 - Typical Borehole Installations

Installation C:

It should be noted that since the piezometer is essentially a no flow instrument, collection zones of appreciable size are not required. The piezometer can be placed directly in contact with most materials, provided that the fines are not able to migrate through the filter. The latest thinking is that it is not necessary to provide sand zones and that the piezometer can be grouted directly into the borehole using a bentonite cement grout only. However, good results have been obtained by placing the piezometer inside a canvas bag filled with sand before grouting.

The general rule for installing piezometers in this way is to use a bentonite grout that mimics the strength of the surrounding soil. The emphasis should be on controlling the water to cement ratio. This is accomplished by *mixing the cement with the water first.* The most effective way of mixing the two substances is to use a drill rig pump to circulate the mix in a 50 to 200-gallon barrel or tub.

Any kind of bentonite powder combined with Type I or Type II Portland cement can be used to make drilling mud. The exact amount of bentonite needed will vary somewhat. Table 1 shows two possible mixes for strengths of 50 psi and 4 psi.

	50 PSI Grout for Medium to Hard Soils		4 PSI Grout for Soft Soils	
	Amount	Ratio by Weight	Amount	Ratio by Weight
Water	30 gallons	2.5	75 gallons	6.6
Portland Cement	94 lb. (one sack)	1	94 lb. (one sack)	1
Bentonite	25 lb. (as required)	0.3	39 lb. (as required)	0.4
Note:	The 28-day compressive strength of this mix is about 50 psi, similar to very stiff to hard clay. The modulus is about 10,000 psi		The 28-day strength of this mix is about four psi, similar to very soft clay.	

Table 1 - Cement/Bentonite/Water Ratios

Add the measured amount of clean water to the barrel then gradually add the cement in the correct weight ratio. Slowly add the bentonite powder so that clumps do not form. Keep adding bentonite until the watery mix turns to an oily/slimy consistency. Let the grout thicken for 5 to 10 minutes. Add more bentonite as required until it is a smooth, thick cream, similar to pancake batter. It is now as heavy as it is feasible to pump.

When pumping grout (unless the tremie pipe is to be left in place,) withdraw the tremie pipe after each batch, by an amount corresponding to the grout level in the borehole.

CAUTION! If the grout is pumped into the hole, rather than tremie piped, there is a danger that the piezometer will be overranged and damaged. Pumping directly into the bottom of the borehole should be avoided. It is good practice to read the piezometer while pumping.

For more details on grouting, refer to "Piezometers in Fully Grouted Boreholes" by Mikkelson and Green, FMGM proceedings Oslo 2003. Copies are available from Geokon.

4.3 Installation in Fills and Embankments

Geokon piezometers are normally supplied with direct burial cable suitable for placement in fills such as highway embankments and dams, both in the core and in the surrounding materials.

For installations in non-cohesive fill materials, the piezometer may be placed directly in the fill, or, if large aggregate sizes are present, in a saturated sand pocket in the fill. If installed in large aggregate, additional measures may be necessary to protect the cable from damage.

In fills such as impervious dam cores, where subatmospheric pore water pressure may need to be measured, (as opposed to the pore air pressure,) a ceramic tip with a high air entry value is often used. This type of filter should be carefully placed in direct contact with the compacted fill material. (See Figure 3).

Cables are normally installed inside shallow trenches with the fill material consisting of smaller size aggregate. This fill is carefully hand compacted around the cable. Bentonite plugs are placed at regular intervals to prevent migration of water along the cable path. In high traffic areas and in materials that exhibit pronounced "weaving", heavy-duty armored cable should be used.

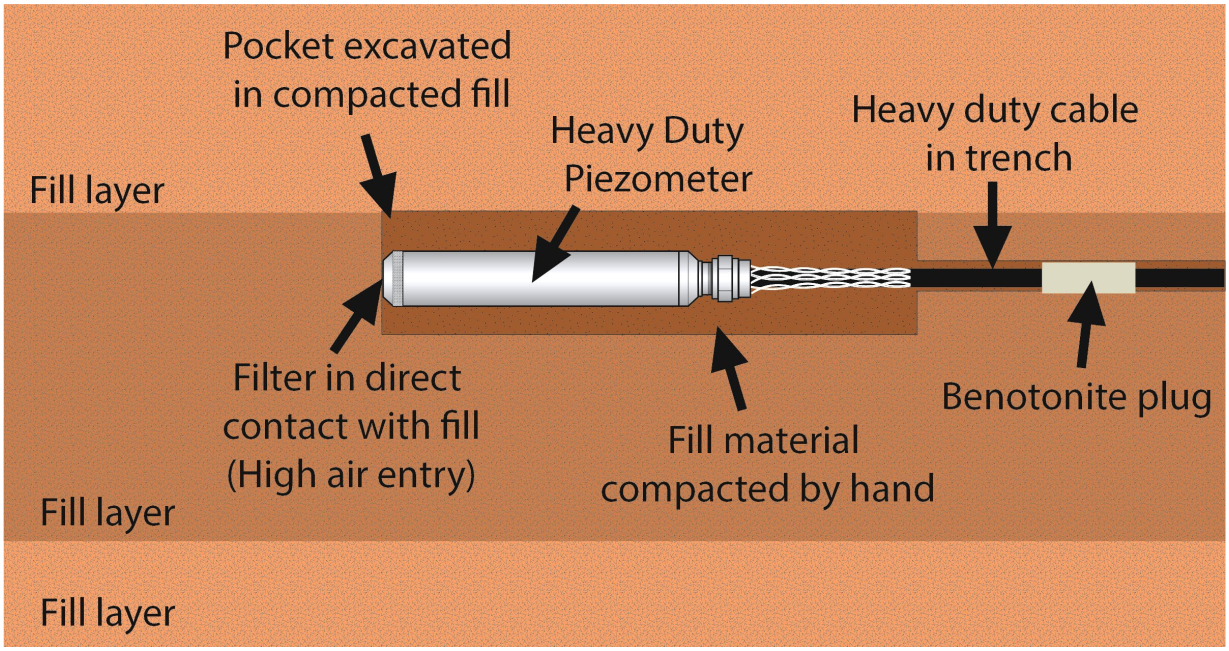

Figure 3 - High Air Entry Filter

In partially saturated fills (if only the pore air pressure is to be measured,) the standard tip is satisfactory. It should be noted that the standard coarse tip (low air entry) measures the air pressure when there is a difference between the pore air pressure and the pore water pressure. The difference between these two pressures is due to the capillary suction in the soil. The consensus is that the difference is normally of no consequence to embankment stability.

The coarse tip filter is suitable for most routine measurements. Both the installation shown in Figure 3 and the installation shown in Figure 4 may be used with the standard piezometer filter.

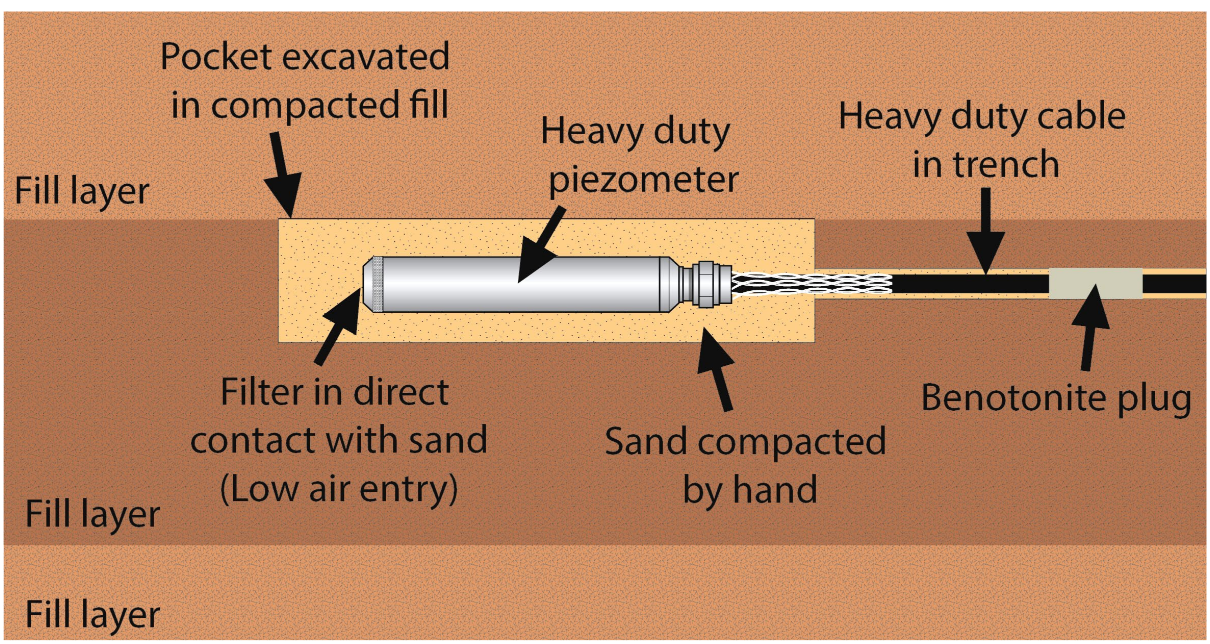

Figure 4 - Low Air Entry Filters ONLY

4.4 Installation by Pushing or Driving into Soft Soils

The Model 3400DP piezometer is designed to be pushed into soft soils. In soft soils, it can be difficult to keep a borehole open. The 3400DP may eliminate the need for a borehole altogether. The unit is connected directly to the drill rod (AW, EW, or other) and pressed into the ground, either by hand or by means of the hydraulics on the rig. (See Figure 5.) The units can also be driven into the soil, but there is a possibility that the driving forces may shift the zero reading.

The ground conditions need to be relatively soft for the 3400DP to be effective. Soft soils (like clays or silts) with SPT blow counts under 10 are ideal. In stiffer soils, it is possible to drill a hole and then push the 3400DP only a few feet below the bottom of the hole, but if the soil is too stiff, the sensor may overrange or break.

The piezometer should be connected to a readout box and monitored during the installation process. If pressures reach or exceed the calibrated range, the installation should be stopped. Allow the pressure to dissipate before continuing.

The drill rod can be left in place or it can be removed. If it is to be removed, a special five-foot section of EW (or AW) rod with reaction wings and a left-hand thread are attached directly to the piezometer tip. This section is detached from the rest of the drill string by rotating the string clockwise. The reaction wings prevent the EW rod from turning. A LH/RH adapter is available from Geokon. This adapter is retrieved along with the drill string.

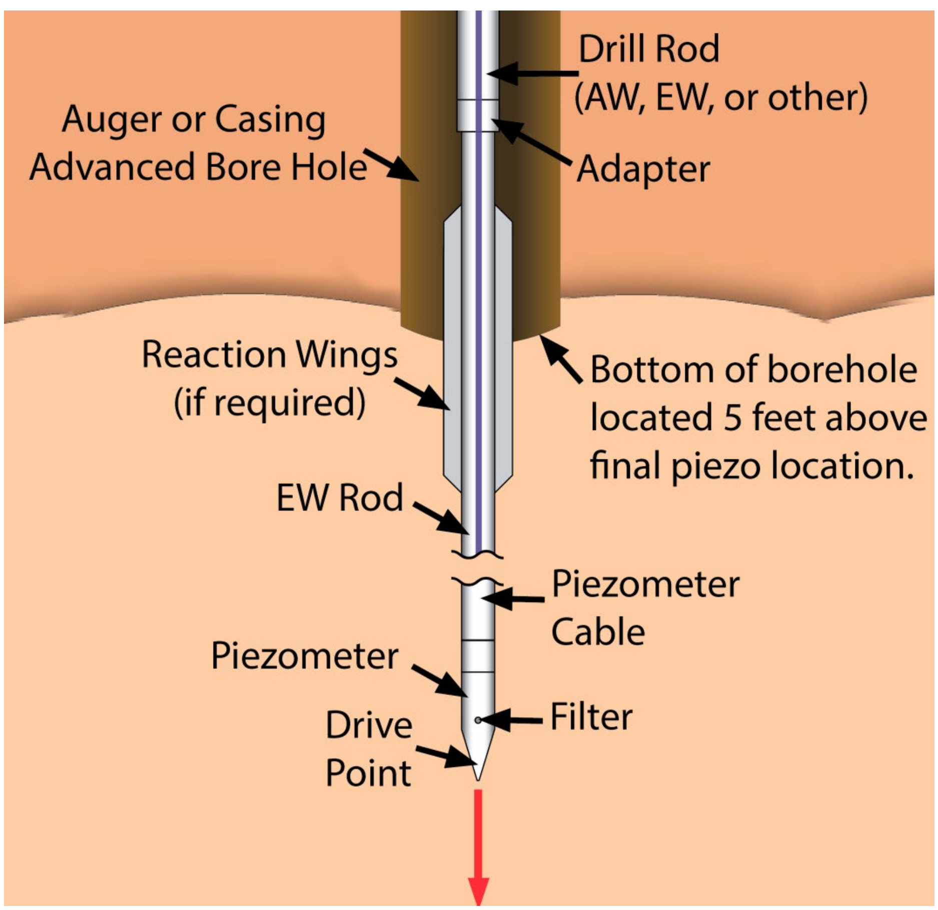

Figure 5 - Typical Soft Soils Installation

4.5 Installation in Standpipes or Wells

1) Saturate the filter stone (see Section 3) and establish a zero-pressure reading (see Section 4.1). **(Warning! Do not allow the piezometer to freeze once the filter stone has been saturated!)**

2) Mark the cable where the top of the well or standpipe will reside once the piezometer has reached the desired depth. (The piezometer diaphragm is located 3/4 of an inch above the tip of the piezometer.)

3) Lower the piezometer into the standpipe/well.

4) Be sure the cable is securely fastened to prevent the piezometer from sliding further into the well and causing an error in the readings.

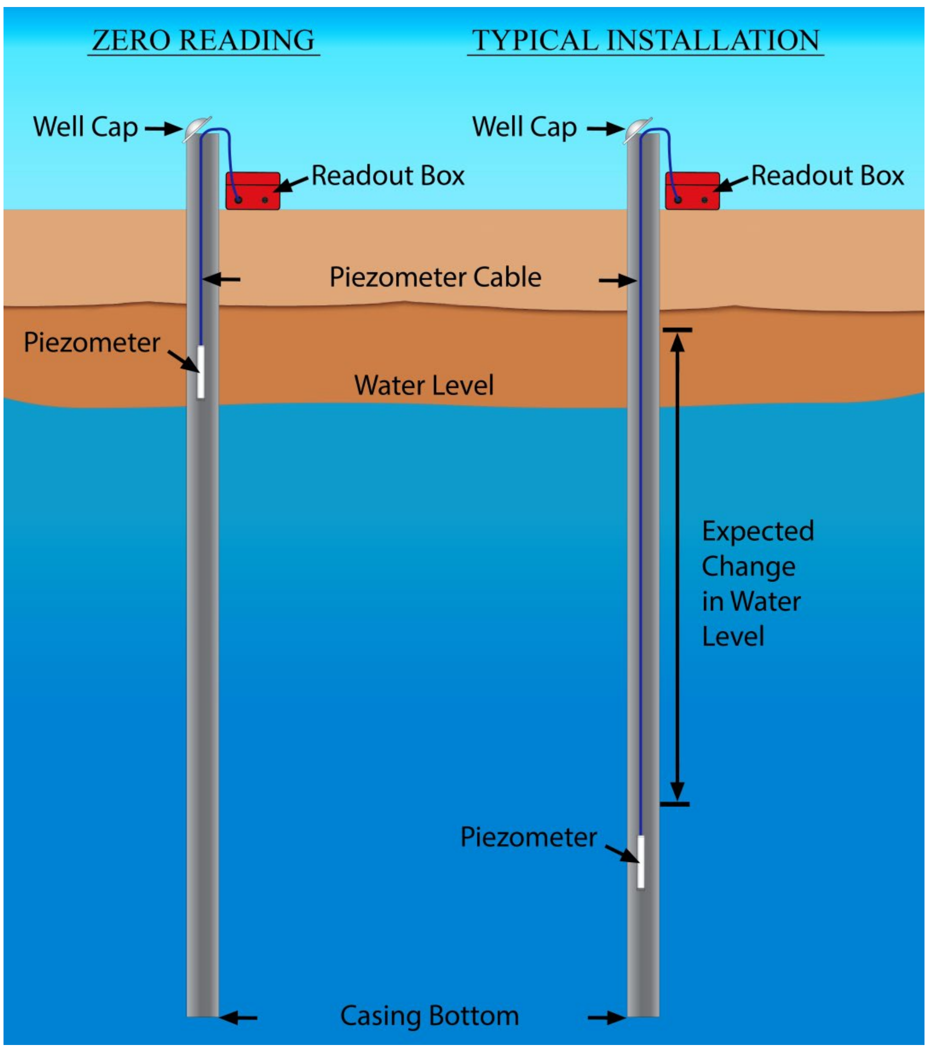

Figure 6 - Typical Level Monitoring Installation

It is not recommended that piezometers be installed in wells or standpipes where an electrical pump or cable is nearby. Electrical interference from these sources can cause unstable readings. If unavoidable, it is recommended that the piezometer be placed inside a piece of steel pipe. In situations where packers are used in standpipes, special care should be taken to avoid cutting the cable jacket with the packer, as this could introduce a possible pressure leak in the cable.

4.6 Model 3400H Transducer

When connecting the Model 3400H transducer to external fittings, the fitting should be tightened into the 1/4"-NPT thread with a wrench on the flats provided on the transducer housing. Also, avoid tightening onto a closed system since the process of tightening the fittings could overrange and permanently damage the transducer. If in doubt, attach the gauge leads to the readout box and take readings while tightening. Teflon tape on the threads makes for easier and more positive connection to the transducer.

4.7 Splicing and Junction Boxes

Cable splicing should be kept to a minimum since changes in cable resistance can cause changes in calibration if remote sensing techniques or 4-20 mA output are not in use.

The Model 3400 utilizes a semiconductor transducer and, as such, has low-level output signals. **If cables are damaged or improperly spliced, the outputs can be seriously degraded. Therefore, it is absolutely necessary to provide a high degree of cable protection. If cables must be spliced, only recognized high quality techniques should be used.** The splice should be waterproofed completely. Geokon recommends the use epoxy encasing splice kits, which are available from the factory.

Figure 7 - Typical Multi-Piezometer Installation

The cable used for making splices should be a high-quality twisted pair type with 100% shielding (with integral shield drain wire). When splicing, it is very important that the shield drain wires be spliced together! Splice kits recommended by Geokon incorporate casts placed around the splice then filled with epoxy to waterproof the connections. When properly made, this type of splice is equal or superior to the cable in strength and electrical properties. Contact Geokon for splicing materials and additional cable splicing instructions.

Junction boxes and terminal boxes are available from Geokon for all types of applications. In addition, portable readout equipment and datalogging hardware are available. See Figure 7 for examples. Contact Geokon for specific application information.

4.8 Electrical Noise

Care should be exercised when installing instrument cables to keep them as far away as possible from sources of electrical interference such as power lines, generators, motors, transformers, arc welders, etc. Cables should never be buried or run with AC power lines. The instrument cables will pick up the 50 or 60 Hz (or other frequency) noise from the power cable and this will likely cause a problem obtaining a stable reading. Contact the factory concerning filtering options available for use with the Geokon dataloggers and readouts should difficulties arise.

4.9 Freezing Protection

If the water around the piezometer freezes this could damage the piezometer diaphragm causing a large shift in the zero-pressure reading. If the piezometer is to be used in locations that are subject to freezing, Geokon can provide a special modification that will protect the piezometer diaphragm.

4.10 Lightning Protection

In exposed locations, it is vital that the piezometer be protected against lightning strikes.

If the instruments will be read manually with a portable readout (no terminal box) a simple way to help protect against lightning damage is to connect the cable leads to a good earth ground when not in use. This will help shunt transients induced in the cable to ground thereby protecting the instrument.

Terminal boxes available from Geokon can be ordered with lightning protection built in. There are two levels of protection:

- The terminal board used to make the gauge connections has provision for installation of plasma surge arrestors.
- Lightning Arrestor Boards (LAB-3) can be incorporated into the terminal box. These units utilize surge arrestors and transzorbs to further protect the piezometer.

In the above cases, the terminal box would be connected to an earth ground.

Improved protection using the LAB-3 can be had by placing the board in line with the cable as close as possible to the installed piezometer (see Figure 8). This is the recommended method of lightning protection.

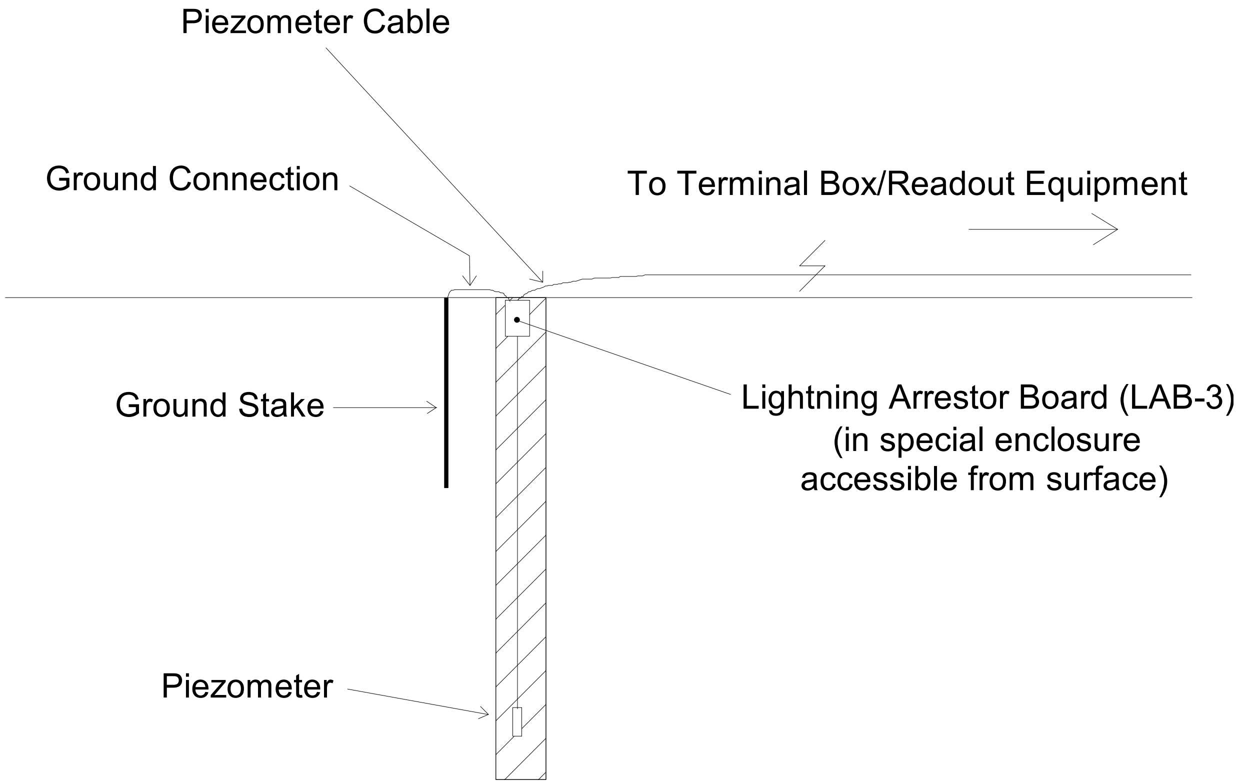

Figure 8 - Recommended Lightning Protection Scheme

5. READOUT PROCEDURES

Connect the piezometer to the readout instrument using the appropriate wiring chart given in Appendix C.

5.1 Initial Readings

Initial readings must be taken and carefully recorded along with the barometric pressure and temperature at the time of installation. Follow the instructions of Section 4.1.

5.2 Input Voltage

The Model 3400 Piezometer uses a semiconductor strain gauge type transducer with an output of either 0-100 mV (Model 3400-1), 0-5 volts (Model 3400-2), or 4-20 mA (Model 3400-3).
For the 100 mV type, the output voltage is directly proportioned to both pressure and input voltage, therefore it is very important that the input voltage be accurately controlled @ 10V DC. If any other voltage is used, the gauge factor G must be adjusted accordingly in the manner shown on the calibration report. The 0-5 volt and 4-20mA sensors require an unregulated input of 7-35 VDC.

5.3 Converting to Pressures

Formulae for converting readout voltages to pressure are shown on the calibration reports. Both linear and polynomial expressions are shown. For better accuracy, the polynomial expression should be used with a proviso that the value for the C coefficient be derived in the field by taking an initial reading when the sensor is subject to atmospheric pressures only as described in Section 4.1. Then substituting this initial value into the formula and setting the value of P to zero will yield the correct value for C.

5.4 Measuring Temperatures

Each piezometer is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Appendix C shows which cable conductors are connected to the thermistor. These conductors should be connected to a digital ohmmeter.

To read temperatures using an ohmmeter:

1) Connect an ohmmeter to the green and white thermistor leads coming from the strain gauge. Since the resistance changes with temperature are large, the effect of cable resistance is usually insignificant. For long cables a correction can be applied, equal to approximately 14.7 Ω per one thousand feet (48.5Ω per km). Multiply this factor by two to account for both directions.

2) Look up the temperature for the measured resistance in Appendix B, Table 5.

5.5 Calibration

Calibration Reports are supplied with the sensors. Typical calibration reports for the three types of Model 3400 semiconductor piezometers are shown in Figure 9, Figure 10, and Figure 11.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Pressure Transducer Calibration Report

Model Number: 3400-1

Date of Calibration: October 09, 2012

Serial Number: 1234234

Temperature: 22.7 °C

Pressure Range: 100 kPa

Barometric Pressure: 1002 mbar

Calibration Instruction: CI-VW Pressure Transducers

Technician:

Applied Pressure (kPa)	Gage Reading (mV) 1st Cycle	Gage Reading (mV) 2nd Cycle	Average Gage Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0	-0.004	-0.007	-0.006		0.05	0.02
20	19.954	19.946	19.950	19.96	0.02	-0.03
40	39.933	39.966	39.950	20.00	0.06	0.00
60	59.850	59.900	59.875	19.93	0.06	0.00
80	79.750	79.800	79.775	19.90	0.03	0.02
100	99.570	99.620	99.595	19.82	0.08	-0.01

Linear Gage Factor (G): 1.004 (kPa / mV) **Regression Zero: 0.042**

Polynomial Gage Factors: A: 4.86E-05 **B: 0.9989** **C: 0.0221**

Calculated Pressures: **Linear, $P = G(R_1 - R_0) \times 10/ V_I$**

Polynomial, $P = AR_P^2 + BR_P + C$ $[R_P = R_1 \times 10/ V_I]$

Input Voltage, V_I: 10 VDC

Wiring Code: See manual for further information.

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

Figure 9 - Typical Calibration Report for Model 3400-1 with 100mV Output

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Pressure Transducer Calibration Report

Model Number: 3400-2

Date of Calibration: September 10, 2012

Serial Number: 1227298

Temperature: 23.7 °C

Pressure Range: 6 MPa

Barometric Pressure: 994 mbar

Calibration Instruction: CI-VW Pressure Transducers

Technician:

Applied Pressure (MPa)	Gage Reading (Volts) 1st Cycle	Gage Reading (Volts) 2nd Cycle	Average Gage Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0.0	0.001	0.001	0.001		0.10	-0.01
1.2	1.009	1.008	1.009	1.01	0.04	0.03
2.4	2.008	2.011	2.010	1.00	0.06	-0.01
3.6	3.009	3.011	3.010	1.00	0.06	-0.01
4.8	4.009	4.008	4.009	1.00	0.02	0.00
6.0	5.003	5.005	5.004	1.00	0.08	0.00

Linear Gage Factor (G): 1.1995 (MPa / Volt) **Regression Zero: 0.006**

Polynomial Gage Factors: A: 1.50E-03 **B: 1.1920** **C: -0.0019**

Calculated Pressures: **Linear, $P = G(R_1 - R_0)$**

Polynomial, $P = AR_1^2 + BR_1 + C$

Input Voltage: 24 VDC

Wiring Code: See manual for further information.

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

Figure 10 - Typical Calibration Report for Model 3400-2 with 0 to 5 Volt Output

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Pressure Transducer Calibration Report

Model Number: 3400-3

Date of Calibration: September 17, 2012

Serial Number: 1226986

Temperature: 22.3 °C

Pressure Range: 600 kPa

†Barometric Pressure: 998.4 mbar

Calibration Instruction: VW Pressure Transducers

Technician:

Pressure (kPa)	Reading 1st Cycle	Reading 2nd Cycle	Average Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0	3.976	3.987	3.982		0.03	0.02
120	7.178	7.178	7.178	3.20	-0.02	-0.02
240	10.380	10.378	10.379	3.20	-0.05	-0.03
360	13.590	13.593	13.592	3.21	0.00	0.01
480	16.802	16.805	16.804	3.21	0.04	0.05
600	20.002	19.997	20.000	3.20	-0.01	-0.03

Linear Gage Factor (G): 37.44 (kPa/ mA) **Regression Zero: 3.976**

Polynomial Gage Factors: A: -2.71E-03 B: 37.51 C:* -149.17

Calculated Pressures: Linear, $P = G(R_1 - R_0)$

Polynomial, $P = AR_1^2 + BR_1 + C$

Input Voltage: 24 VDC

Wiring Code: See manual for further information.

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

Figure 11 - Typical Calibration Report for Model 3400-3 with 4 to 20mA Output

6. DATA REDUCTION

6.1 Pressure Calculation

The pressure measured by the piezometer is determined by the following linear equation:

$$\text{Pressure} = (\text{Current Reading} - \text{Initial Reading}) \times \text{Gauge Factor}$$

Or

$$P = (R_1 - R_0) \times G$$

Equation 1 - Convert Digits to Pressure

Where;
P is the applied pressure in kPa or psi.
R_0 is the initial output in millivolts, volts, or milliamps.
R_1 is the current output in millivolts, volts, or milliamps.
G is the gauge factor, as shown on the supplied calibration report.

For Example;
Model 3400-1-100KPA Input Voltage = 12.0 volts
R_0 = -0.0.006 mV
R_1 = 18.0 mV
G = 1.004 kPa/mV
P = 1.004 (18.0 – (– 0.006)) x 10/12= 15 kPa

The Initial Reading (R_0) is normally obtained at the time of installation, as described in Section 4.1. To convert the output to other engineering units, multiply the Calibration Factor by the conversion multiplier listed in Table 2.

From → To ↓	psi	"H_2O	'H_2O	mm H_20	m H_20	"HG	mm HG	atm	mbar	bar	kPa	MPa
psi	1	.036127	.43275	.0014223	1.4223	.49116	.019337	14.696	.014503	14.5039	.14503	145.03
"H_2O	27.730	1	12	.039372	39.372	13.596	.53525	406.78	.40147	401.47	4.0147	4016.1
'H_2O	2.3108	.08333	1	.003281	3.281	1.133	.044604	33.8983	.033456	33.4558	.3346	334.6
mm H_20	704.32	25.399	304.788	1	1000	345.32	13.595	10332	10.197	10197	101.97	101970
m H_20	.70432	.025399	.304788	.001	1	.34532	.013595	10.332	.010197	10.197	.10197	101.97
"HG	2.036	.073552	.882624	.0028959	2.8959	1	.03937	29.920	.029529	29.529	.2953	295.3
mm HG	51.706	1.8683	22.4196	.073558	73.558	25.4	1	760	.75008	750.08	7.5008	7500.8
atm	.06805	.002458	.029499	.0000968	.0968	.03342	.001315	1	.000986	.98692	.009869	9.869
mbar	68.947	2.4908	29.8896	.098068	98.068	33.863	1.3332	1013.2	1	1000	10	10000
bar	.068947	.002490	.029889	.0000981	.098068	.033863	.001333	1.0132	.001	1	.01	10
kPa	6.8947	.24908	2.98896	.0098068	9.8068	3.3863	.13332	101.320	.1	100	1	1000
MPa	.006895	.000249	.002988	.0000098	.009807	.003386	.000133	.101320	.0001	.1	.001	1

Table 2 - Engineering Units Multiplication Factors

6.2 Temperature Correction

The basic transducers are thermally compensated over normal temperatures. Temperature correction is not required unless the temperature is changing rapidly. If this occurs, time should be allowed for the transducer to reach thermal equilibrium.

6.3 Barometric Corrections

If the piezometers are unvented, they will respond directly to barometric fluctuations. If a correction is required, it will be necessary to record the barometric pressure at the time of each pressure reading. The change in Barometer (S_1-S_0), must be subtracted from the measured pressure change (P).

7. TROUBLESHOOTING

Maintenance and troubleshooting of Model 3400 Piezometer is confined to periodic checks of cable connections. Once installed, the piezometers are often inaccessible and remedial action is limited. Consult the following list of problems and possible solutions should difficulties arise. Consult the factory for additional troubleshooting help.

Symptom: Piezometer Readings are Unstable

- ✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, transformers, arc welders, and antennas. Make sure the shield drain wire is connected to ground whether using a portable readout or datalogger.
- ✓ Does the readout work with another piezometer? If not, the readout may have a low battery or be malfunctioning. Consult the appropriate readout manual for charging or troubleshooting directions.
- ✓ Is the filter clogged? Remove piezo (if possible) and inspect.

Symptom: Piezometer Fails to Read

- ✓ Is the cable cut or crushed? This can be checked with an ohmmeter (voltage output sensors only). If the resistance reads very high or infinite (megohms), a cut wire must be suspected. If the resistance reads very low ($<100\Omega$), a short in the cable is likely.
- ✓ Does the readout or datalogger work with another piezometer? If not, the readout or datalogger may be malfunctioning. Consult the readout or datalogger manual for further direction.

Symptom: Thermistor resistance is too high

- ✓ It is likely that there is an open circuit. Check all connections, terminals, and plugs. If a cut is located in the cable, splice according to instructions in Section 4.7.

Symptom: Thermistor resistance is too low

- ✓ It is likely that there is a short. Check all connections, terminals, and plugs. If a short is located in the cable, splice according to instructions in Section 4.7.
- ✓ Water may have penetrated the interior of the piezometer. There is no remedial action.

APPENDIX A. SPECIFICATIONS

A.1 3400 Series Specifications

Input	
Pressure Range	Vacuum to 400 bar (6000 psi)
Proof Pressure	2 x Full Scale(FS) (1.5 x FS for 400 bar, >=5000 psi)
Burst Pressure	>35 x FS <= 6 bar (100 psi) >320 x FS <= 60 bar (1000 psi) >5 x FS <= 400 bar (6000 psi)
Fatigue Life	Designed for more than 100 million FS cycles
Performance	
Long Term Drift	0.2% FS/year (non-cumulative)
Accuracy	< 0.1%FS (Dependent on readout instrument)
Thermal Error	1.5% FS typical (optional 1% FS)
Compensated Temperatures	-20° to 80° C (-5° to 180° F)
Operating Temperatures	-40° to 125° C ((-22° to 260°) for elec. codes A, B, C, 1 -20° to 80° C (-5° to 180° F) for elec. codes 2, D, G, 3 -20° to 50° C (-5° to 125° F) for elec. codes F, M, P Amplified units > 100C maximum 24 Vdc supply
Zero Tolerance	1% of span
Span Tolerance	1% of span
Mechanical Configuration	
Pressure Port	see ordering chart
Wetted Parts	17-4 PH Stainless Steel
Electrical Connection	see ordering chart
Enclosure	316 ss, 17-4 PH ss IP65 for elec. codes A, B, C, D, G, 1, 2, 3 IP67 for elec. code "F" IP68 for elec. codes M, P IP30 for elec. code "3" with flying leads
Vibration	35 g peak sinusoidal, 5 to 2000 Hz
Acceleration	100 g steady acceleration in any direction 0.032% FS/g for one bar (15 psi) range decreasing logarithmically to 0.0007% FS/g for 400 bar (6000 psi) range.
Shock	Withstands free fall to IEC 68-2-32 procedure 1
Approvals	CE
Weight	Approximately 100 grams (Additional cable: 75 g/m)

Table 3 - Model 3400 Specifications

Millivolt Output Units	
Output	100mV ± 1mV
Supply Voltage (VS)	10Vdc (15Vdc max.) Regulated
Bridge resistance	2600-6000 ohms
Voltage Output Units	
Output	0-5 Vdc
Supply Voltage (Vs)	10Vdc (7 - 35 Vdc) @6mA
Supply Voltage Sensitivity	0.01% FS/Volt
Min. Load Resistance	(FS output / 2) kohms
Current Output Units	
Output	4-20mA (2 wire)
Supply Voltage(VS)	24 Vdc, (7-35 Vdc)
Supply Voltage Sensitivity	0.01% FS/Volt
Max Loop Resistance	(Vs-7) x 50 ohms.

Table 4 - Output Units Specifications

A.2 Thermistor (See Appendix B. also)

Range: -80 to +150 °C
Accuracy: ±0.5 °C

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3
Resistance to Temperature Equation:

$$T=\frac{1}{A+B(LnR)+C(LnR)^3}-273.15\ °C$$

Equation 2 - Resistance to Temperature

Where;
T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance
A = 1.4051×10^{-3}
B = 2.369×10^{-4}
C = 1.019×10^{-7}
Note: Coefficients calculated over the −50 to +150° C. span.

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	3400	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	**3000**	**25**	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Table 5 - Thermistor Resistance Versus Temperature

APPENDIX C. WIRING CHARTS

C.1 Millivolts per Volt Output

Geokon Cable #04-375V9 (Violet)	Internal Sensor Wiring	Function/Description
Red	Red	Power +
Red's Black	Black	Power -
White	White	Signal +
White's Black	Black	Signal -
Green	Red	Remote Sense +
Green's Black	Black	Remote Sense -
Blue	N/C	Thermistor
Blue's Black	N/C	Thermistor
Shields (5)	N/C	Ground

Table 6 - mV/V Output Wiring

Note:
Input voltage for Model # 3400-1, mV/V output is 10V d.c.
(Power -, Signal -, Remote Sense -, are connected internally.)

C.2 Zero to Five Volt DC Output

Geokon Cable #04-375V9 (Violet)	Internal Sensor Wiring	Function/Description
Red	Red	Power +
Red's Black	Black	Power -
White	White	Signal +
White's Black	Black	Signal -
Blue	N/C	Thermistor
Blue's Black	N/C	Thermistor
Shields (5)	N/C	Ground

Table 7 - 0-5VDC Output Wiring

Note:
Input voltage for Model # 3400-2, 0–5VDC output is 6.5–35V d.c.

C.3 Four to 20 Milliamp Output

Geokon Cable #02-250V6 (Blue)	Internal Sensor Wiring	Function/Description
Red	Red	Power +
Black	Black	Power -
White	N/C	Thermistor
Green	N/C	Thermistor
Shields (1)	N/C	Ground

Table 8 - 4-20mA Output Wiring

Note:
Input voltage for Model # 3400-3, 4–20mA output is 6.5–35V d.c.