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Instruction Manual

Model 4500

series

Vibrating Wire Piezometers

(Doc Rev U 3/09)

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1. THEORY OF OPERATION

Geokon Model 4500 Vibrating Wire Piezometers are intended primarily for long-term measurements of fluid and/or pore pressures in standpipes, boreholes, embankments, pipelines and pressure vessels. Several models of the 4500 series are available (see Appendix A). Contact Geokon sales engineers for specific application information.

The instrument utilizes a sensitive stainless steel diaphragm to which a vibrating wire element is connected. See Figure 1-1. In use, changing pressures on the diaphragm cause it to deflect, and this deflection is measured as a change in tension and frequency of vibration of the vibrating wire element. The square of the vibration frequency is directly proportional to the pressure applied to the diaphragm. Two coils, one with a magnet, another with a pole piece, are located close to the wire. In use, a pulse of varying frequency (swept frequency) is applied to the coils and this causes the wire to vibrate primarily at its resonant frequency. When excitation ends the wire continues to vibrate and a sinusoidal AC electrical signal, at the resonant frequency, is induced in the coils and transmitted to the readout box where it is conditioned and displayed.

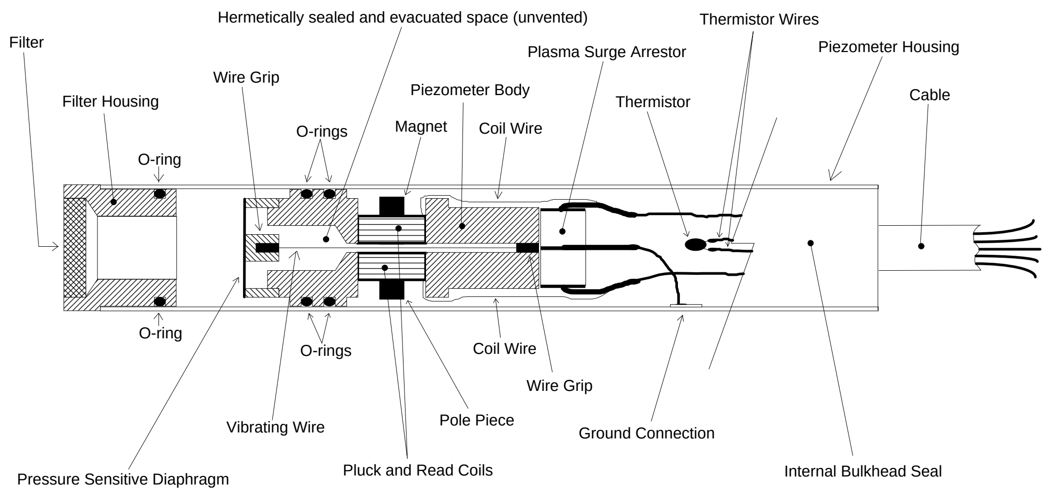

Figure 1-1 Vibrating Wire Piezometer

To prevent damage to the sensitive diaphragm a filter is used to keep out solid particles. Figure 1-1 illustrates. Standard filters are 50 micron stainless steel; high air entry value tips are available on request.

All exposed components are made of corrosion resistant stainless steel and, if proper installation techniques are used, the device should have an unlimited life. In salt water it may be necessary to use special materials for the diaphragm and housing.

Portable readout units are available to provide the excitation, signal conditioning and readout of the instrument. Datalogging systems are also available for remote unattended data collection of multiple sensors. Contact Geokon for additional information.

Calibration data are supplied with each piezometer for conversion of gage readings to engineering units such as pressure or level. See Section 4.

2. INSTALLATION

(For Quick Installation Instructions see AppendixE)

2.1 Preliminary Tests

Upon receipt of the piezometer the zero reading should be checked and noted (see Sections 3.1 to 3.3 for readout instructions). A thermistor is included inside the body of the piezometer (Figure 1-1) for the measurement of temperature (see Section 3.4 for instructions).

Calibration data are supplied with each gage and a zero reading, at a specific temperature and barometric pressure, is included. Zero readings at the site should coincide with the factory readings within 20 digits after barometric and temperature corrections are made. The factory elevation is +580 ft. Before March 21, 1995 factory barometric pressure readings were corrected to sea level; readings after this date represent absolute pressure. (Barometric pressure changes with elevation at a rate of ≈½ psi per 1,000 ft.) See Figure 2-1 for a sample calibration sheet.

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Vibrating Wire Pressure Transducer Calibration

Model Number: 4500S-100 Pressure Range: 100 psi

Serial Number: 48056 Mfg. Number: 8-3275

Customer: Temperature: 21.1 °C

Cust. I.D. #: n/a Barometric Pressure: 998.1 mbar

Job Number: 13053 Date: Nov. 7, 1998

Cal. Std. Control #(s): 183, 468 Technician:

Pressure (psi)	Reading 1st Cycle	Pressure (psi)	Reading 2nd Cycle	Average Pressure	Average Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0	9136	0	9141	0	9139		0.18	-0.04
20	8453	20	8456	20	8455	684	0.03	0.08
40	7772	40	7774	40	7773	682	-0.19	-0.01
60	7085	60	7083	60	7084	689	-0.19	-0.01
80	6392	80	6390	80	6391	693	-0.08	-0.03
100	5694	100	5687	100	5691	701	0.25	0.03

Linear Gage Factor (G): 0.029021 (psi/digit) Regression Zero: 9145

Polynomial Gage Factors: A: -1.40E-07 B: -0.026943 C:* 257.8826

Thermal Factor (K): -0.004326 (psi/°C)

Calculated Pressures: **Linear,** $P = G(R_0 - R_1) + K(T_1 - T_0) - (S_1 - S_0)$**

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)$**

***Barometric compensation is not required with vented transducers.*

Factory Zero Reading:

GK-401 Pos. B or F(R_0): 9128 Temp(T_0): 21.8 °C Baro(S_0): 1001.4 mbar Date: Jan. 27, 1997

**The user is advised to establish zero conditions in the field by recording the reading at a known temperature and barometric pressure.*

Wiring Code: Red and Black: Gage White and Green: Thermistor Bare: Shield

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

Figure 2-1 Sample Calibration Sheet

2.1.1 Establishing an Initial Zero Reading

Vibrating Wire Piezometers differ from other types of pressure sensors in that they indicate a reading at zero pressure. **Therefore it is imperative that an accurate initial zero pressure reading be obtained for each piezometer as this reading will be used in all subsequent data reduction.**

There are different ways of doing this but the essential element in all methods is that the piezometer be allowed to thermally stabilize in a constant temperature environment while the pressure on the piezometer is barometric only. Because of the way the piezometer is constructed it takes about 5 to 15 minutes for the temperature of all the different elements to equalize.

It will be necessary to measure the barometric pressure only if the piezometer is un-vented and if it will be installed in a location that is subject to barometric pressure changes that require correction, such as in an open well. *A piezometer sealed in place at depth could be recording pressures in groundwater that is not hydraulically connected to the atmosphere, and, for which, barometric pressure compensation would be inappropriate.*

The recommended way to achieve temperature stability is to hang the piezometer in the borehole at a point just above the water and wait until the piezometer reading has stopped changing. Now take the zero reading and read the temperature, indicated by the thermistor inside the piezometer.

Another way is to place the piezometer under water in a bucket and allow 5 to 15 minutes for the temperature to stabilize, then lift the piezometer out of the water and immediately take a reading. When doing this, lift the piezometer by the cable only, do not handle the piezometer housing as body heat from the hand could cause temperature transients. Use the thermistor inside the piezometer to measure the water temperature.

Another way is to simply read the piezometer while in the air while making sure that the temperature has had time to stabilized. If this method is chosen be sure that the piezometer is protected from sunlight or sudden changes of temperature: Wrapping it in some insulating material is recommended.

Yet another way is to lower the piezometer to a known depth as marked out on the piezometer cable, (The diaphragm inside the piezometer is located approximately ¾ inch (15mm), from the tip. Then use a dip meter to accurately measure the depth to the water surface. Now, after temperature stabilization, read the piezometer pressure and, using the factory calibration constants and a knowledge of the pressure (height x density) of the water column above the piezometer, calculate either the equivalent zero pressure reading, if the linear regression is used, or the factor, C, if the second order polynomial is used.

A question may arise as to what to do with the filter stone while taking zero readings. If a standard stainless steel filter is being used, it will not matter if the filter stone is saturated or not. But if ceramic high air entry filter stone is in use then it must be saturated while taking the zero readings and must not be allowed to dry out to the extent that surface tension effects can affect the zero reading.

Caution. – do not allow the piezometer to freeze once it has been filled with water.

2.1.2 Checking the Calibration

The following procedure is recommended to verify the calibration factor as supplied on the calibration sheet (Figure 2-1). It should be borne in mind that the piezometer measures water pressure and that the conversion to a water level requires an accurate knowledge of the density of the water.

1. The best method is to remove the filter housing and filter stone from off the tip of the piezometer: Pulling on the knurled ring will accomplish this. Alternatively, saturate the filter stone and fill the space between it and the diaphragm with water (Section 2.6).

2. Lower the piezometer to a point near the bottom of a water-filled borehole, or below the surface of a body of water. The use of a dip meter to measure the actual depth of the water in the borehole will be very desirable.

3. Allow 15-20 minutes for the piezometer to come to thermal equilibrium. Using a readout box record the reading at that level.

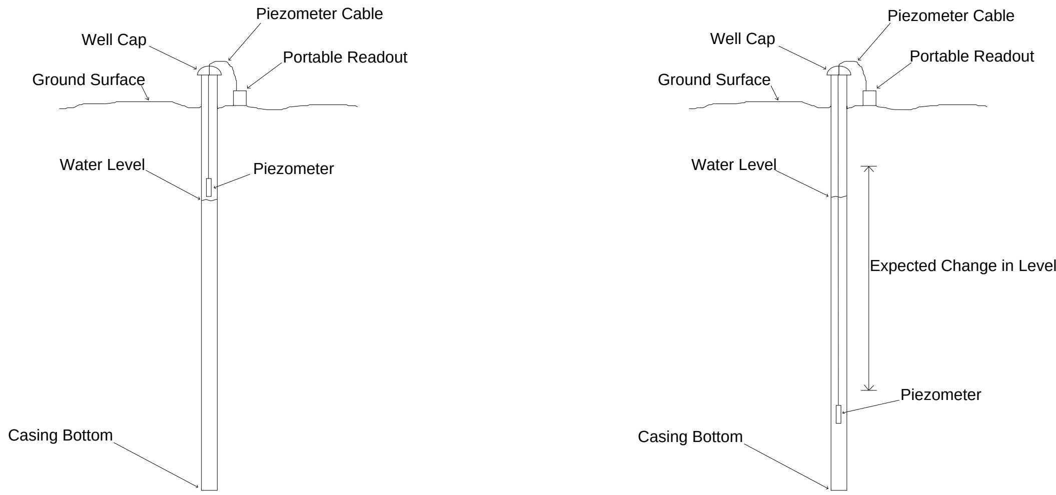
4. Raise the piezometer by known depth increments. Record the pressure reading at each depth increment. Calculate the in-situ calibration factor and compare to the calibration factor on the calibration sheet. The two values should agree within ± 0.5%. Repeat test if necessary.

There are a couple of things that can affect the in-situ calibration:

- The density of the in-situ water may not be 1gm/cc if it is saline or turbid. If this is the case then the factory calibration factor, should be adjusted to take into account the actual water density.
- **The water level inside the borehole may vary during the test due to the displacement of the water level as the cable is raised and lowered in the borehole**. This effect will be greater where the borehole diameter is smaller. For example, a Model 4500S-50 piezometer lowered 50 feet below the water column in a 1 inch (.875 inch ID) standpipe will displace the water level by more than 4 feet! If a dip-meter is available it should be used to confirm the water levels at each depth increment.

2.2 Installation in Standpipes or Wells

- A zero reading is first established (follow the procedures outlined in Section 2.1.1). The filter stone is saturated (follow the procedures in Section 2.6). Make a mark on the cable which will lie opposite the top of the standpipe, (well), when the piezometer has reached the desired depth. (The piezo diaphragm lies ¾ inch above the tip of the piezo).



Zero Reading

Typical Installation

Figure 2-2 Typical Level Monitoring Installations

Be sure the cable is securely fastened at the top of the well or readings could be in error due to slippage of the piezometer into the well.

It is not recommended that piezometers be installed in wells or standpipes where an electrical pump and/or cable is present or 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 the same sequence as above should be noted and special care should be taken to avoid cutting the cable jacket with the packer since this could introduce a possible pressure leakage path.

2.3 Installation in Boreholes

Geokon piezometers can be installed in boreholes in either single or multiple installations per hole, in cased or uncased holes. See Figure 2-3. Careful attention must be paid to borehole sealing techniques if pore pressures in a particular zone are to be monitored.

Boreholes should be drilled either without drilling mud or with a material that degrades rapidly with time, such as Revert™. The hole should extend from 6 inches to 12 inches below the proposed piezometer location and should be washed clean of drill cuttings. The bottom of the borehole should then be backfilled with clean fine sand to a point 6 inches below the piezometer tip. The piezometer can then be lowered, as delivered, into position. Preferably, the piezometer may be encapsulated in a canvas-cloth bag containing clean, saturated sand and then lowered into position. While holding the instrument in position (a mark on the cable is helpful) clean sand should be placed around the piezometer and to a point 6 inches above it. Figure 2-3 details two methods of isolating the zone to be monitored.

Installation A

Immediately above the "collection zone" the borehole should be sealed with either alternating layers of bentonite and sand backfill tamped in place for approximately 1 foot followed by common backfill or by an impermeable bentonite-cement grout mix. If multiple piezometers are to be used in a single hole the bentonite-sand plugs should be tamped in place below and above the upper piezometers and also at intervals between the piezometer zones. When designing and using tamping tools special care should be taken to ensure that the piezometer cable jackets are not cut during installation.

Installation B

Immediately above the "collection zone" the borehole should be filled with an impermeable bentonite grout.

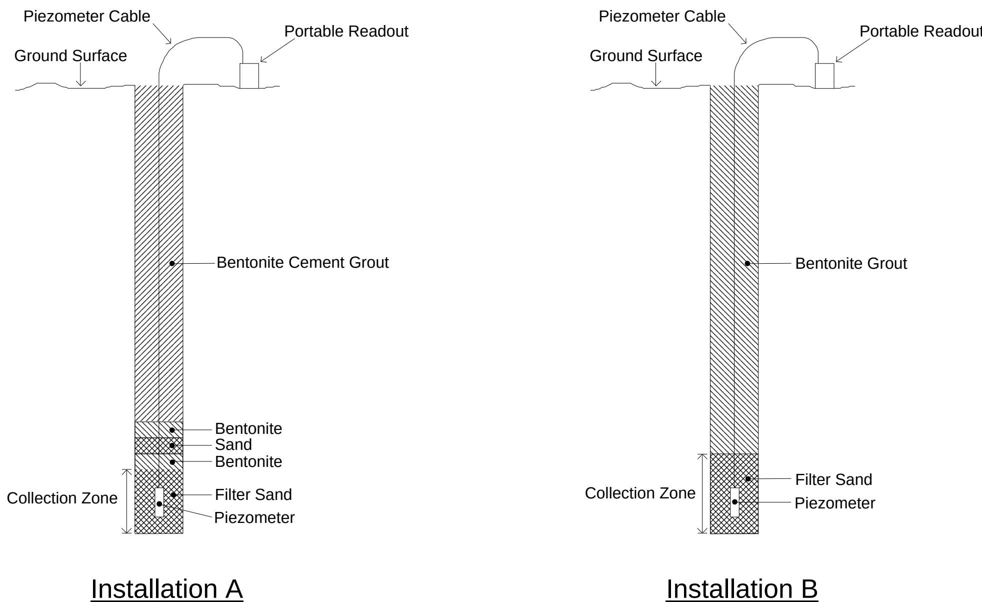


Figure 2-3 Typical Borehole Installations

Installation C

It should be noted that since the vibrating wire piezometer is basically a no-flow instrument, collection zones of appreciable size are not required and the piezometer can, in fact, be placed directly in contact with most materials provided that the fines are not able to migrate through the filter. The latest thinking, (*Mikkelson and Green, Piezometers in Fully Grouted Boreholes.Proceedings of FMGM 2003, Field Measurements in Geomechanics, Oslo, Norway, Sept. 2003. Contact Geokon for a copy o f this paper)*

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.
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-cement ratio. This is accomplished **by mixing the cement with the water first.** The most effective way of mixing is in a 50 to 200 gallon barrel or tub using the drill-rig pump to circulate the mix. Any kind of bentonite powder used to make drilling mud, combined with Type 1 or 2 Portland cement can be used. The exact amount of bentonite added will vary somewhat. The table below shows 2 possible mixes for strengths of 50 psi and 4 psi.
Add the measured amount of clean water to the barrel then gradually add the cement in the correct weight ratio. Next add the bentonite powder, slowly, so clumps do not form. Keep adding bentonite until the watery mix turns to an oily/slimy consistency. Let the grout thicken for another five to ten minutes. Add more bentonite as required until it is a smooth thick cream like 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.

Application	**Grout for Medium to Hard Soils**		**Grout for Soft Soils**	
Materials	Weight	Ratio by Weight	Weight	Ratio by Weight
Water	30 gallons	2.5	75 gallons	6.6
Portland Cement	94 lbs (1 sack)	1	94 lbs (1 sack)	1
Bentonite	25 lbs (as required)	0.3	39 lbs (as required)	0.4
Notes	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 4psi, similar to very soft clay.	

<u>Table 1 showing Cement/bentonite/water ratios for two grout mixes.</u>

(For more details on this method of installation ask for a copy of the FMGM paper)

2.4 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.

In 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 sub-atmospheric 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 which should be carefully placed in direct contact with the compacted fill material (see Installation A of Figure 2-4). 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 coarse tip measures the air pressure when there is a difference between the pore air pressure and the pore water pressure, and that the difference between the two pressures is due to the capillary suction in the soil. The general consensus is that the difference is normally of no consequence to embankment stability. As a general rule the coarse (low air entry) tip is suitable for most routine measurements and, in fine cohesive soils, sand pockets should not be used around the piezometer tip (see Installation B of Figure 2-4). In high traffic areas and in material which exhibit pronounced "weaving", a heavy-duty armored cable should be used.

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.

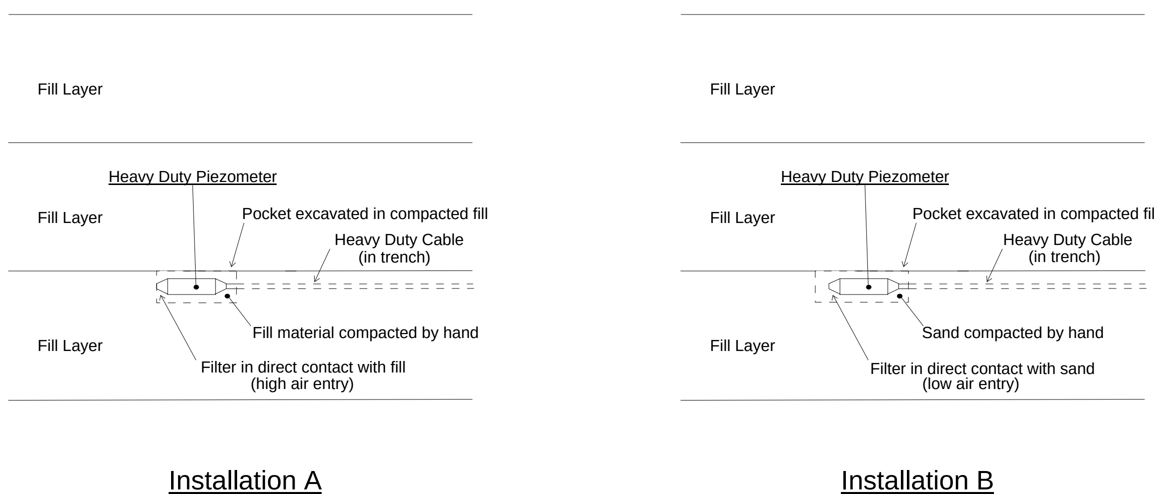


Figure 2-4 Typical Dam Installations

2.5 Installation by Pushing or Driving into Soft Soils

The Model 4500DP piezometer is designed for pushing into soft soils. See Figure 2-5. 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. The units can also be driven but the possibility of a zero shift due to the driving forces exists.

The piezometer should be connected to the readout box and monitored during the driving process. If measurement pressures reach or exceed the calibrated range, the driving should be stopped and the pressures allowed to dissipate before continuing.

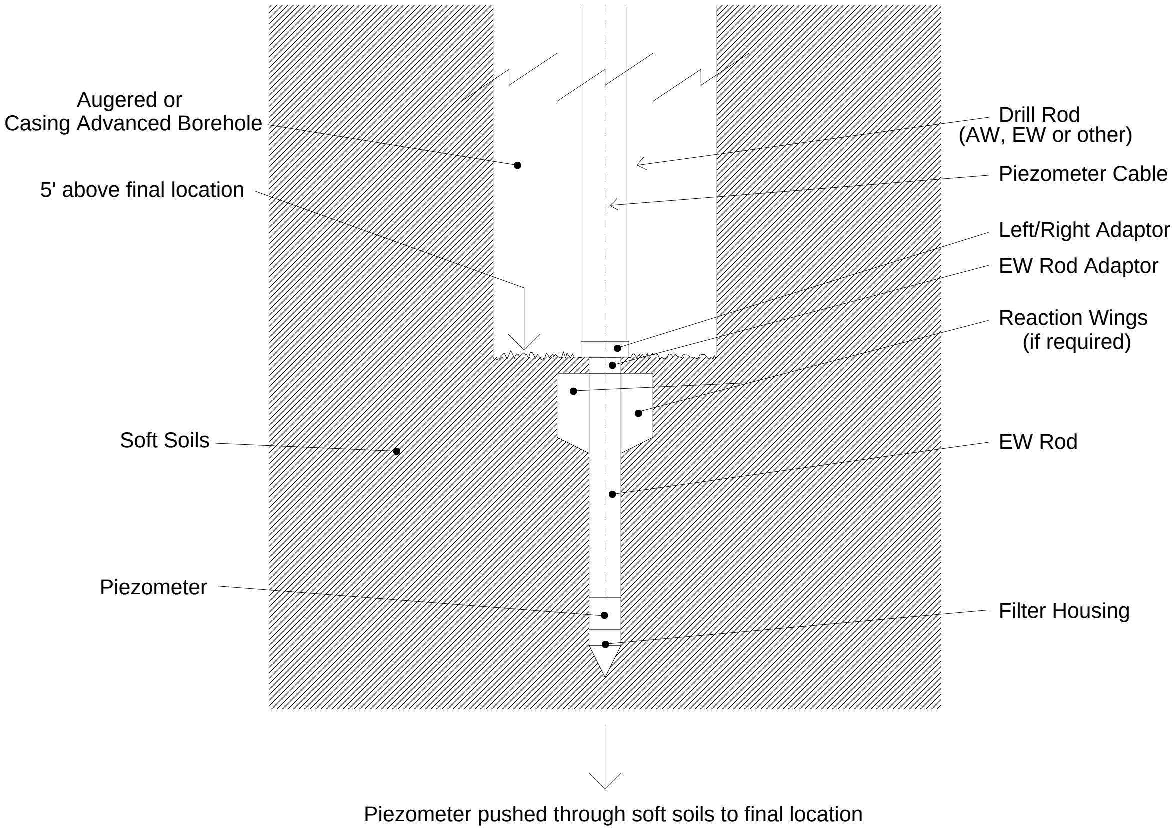


Figure 2-5 Typical Soft Soils Installation

The drill rod can be left in place or it can be removed. If it is to be removed then a special 5 foot section of EW (or AW) rod with 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 left hand thread will then loosen. The wings prevent the special EW rod from turning. A special LH/RH adapter is available from Geokon. The adapter is retrieved along with the drill string.

2.6 De-airing Filter Tips

Caution. – do not allow the piezometer to freeze once it has been filled with water.
Most Geokon filter tips can be removed for saturating and re-assembly. The procedures are as follows:

2.6.1 Low Air Entry Filter, Model 4500S and 4500PN

For accurate results, total saturation of the filter is necessary. For the low air entry filter normally supplied, this saturation occurs as the tip 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 of time, this air will dissolve into the water until the space and the filter is entirely filled with water. To speed up the saturation process, remove the filter assembly and fill the space above the diaphragm with water, then slowly replace the filter housing allowing the water to squeeze through the filter stone. With low pressure range piezometers (<10 psi) take readings with a readout box while pushing the filter housing on so as not to over-range the sensor.

To maintain saturation, the unit should be kept under water until installation.

If the 4500S piezometer is to be used in standpipes and raised and lowered many times the filter may loosen. 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.

Screens are also available for standpipe installations. Screens are less likely than standard filters to become clogged where salts in the water can be deposited if the filter is allowed to dry out completely.

2.6.2 Removable Ceramic Filter, Model 4500S

The ceramic filter on the 4500S piezometer is also removable for de-airing. Because of the high air entry characteristics, de-airing is particularly important for this filter assembly. Filters with different air entry values require different procedures.

1 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. Re-assemble the filter housing and piezometer under the surface of a container of de-aired water. Be sure that no air is trapped in the transducer cavity. While pushing the filter on use a readout box to monitor the diaphragm pressure. Allow over-range pressure to dissipate before pushing further.

4. To maintain saturation, the unit should remain immersed until installation.

2 Bar and Higher

The proper procedure for de-airing and saturating these filters is somewhat complex and should be done either at the factory by Geokon or by carefully following the instructions below:

1. Place the assembled piezometer, filter down, in a vacuum chamber with 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 the maximum vacuum has been achieved, allow de-aired water to enter the chamber and reach an elevation a few inches above the piezometer filter.

4. Close off the inlet port. Release the vacuum.

5. Observe the transducer output. It will take as long as 24 hours for the filter to completely saturate (5 bar) and the pressure to rise to zero.

6. 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.

2.6.3 Model 4500DP

The 4500 Drive Point is de-aired in the same way as the above models by first unscrewing the point of the piezometer assembly and then following the instruction for the 4500S.

2.7 Model 4500H Transducer

When connecting the Model 4500H transducer to external fittings, the fitting should be tightened into the ¼"-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 over-range and permanently damage the transducer. If in doubt, attach the gage 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.

2.8 Splicing and Junction Boxes

Because the vibrating wire output signal is a frequency rather than current or voltage, variations in cable resistance have little effect on gage readings and, therefore, splicing of cables has no effect either and, in some cases, may be beneficial. For example, if multiple piezometers are installed in a borehole, and the distance from the borehole to the terminal box or datalogger is great, a splice (or junction box, see Figure 2-6) could be made to connect the individual cables to a single multi-conductor cable. This multi-conductor cable would then be run to the readout station. For such installations it is recommended that the piezometer be supplied with enough cable to reach the installation depth plus extra cable to pass through drilling equipment (rods, casing, etc.).
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 itself in strength and electrical properties. Contact Geokon for splicing materials and additional cable splicing instructions

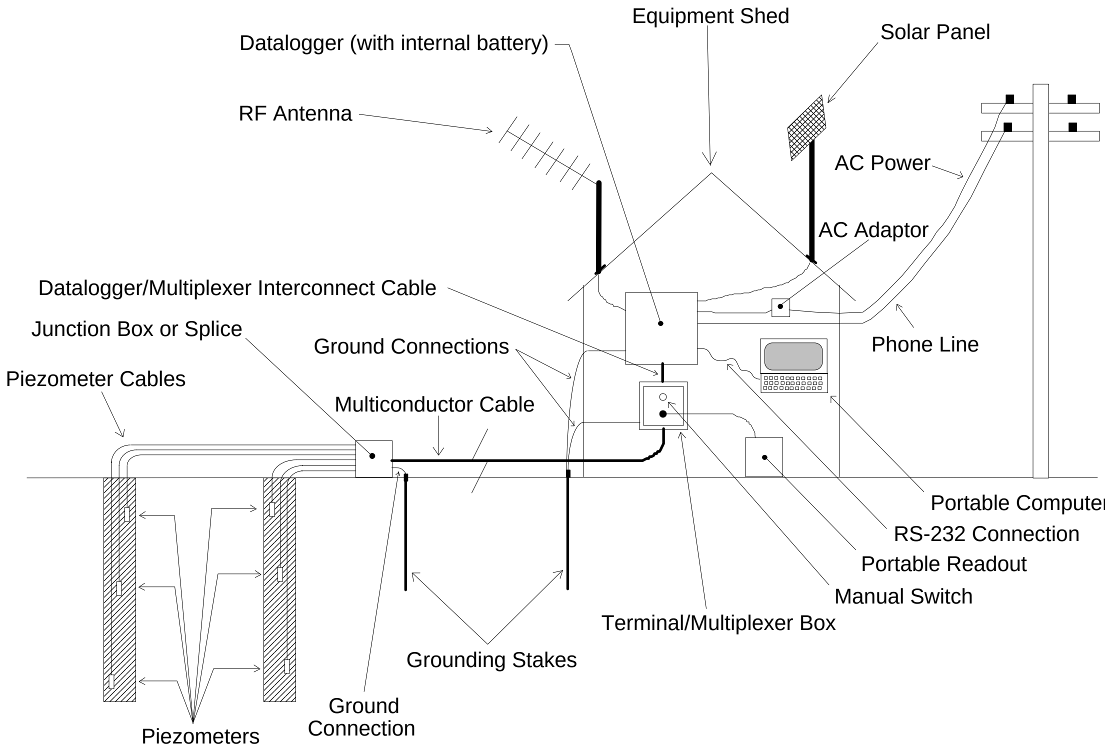


Figure 2-6 Typical Multi-Piezometer Installation

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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 2-6. Contact Geokon for specific application information.

2.9 Lightning Protection

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

A tripolar plasma surge arrestor (Figure 1-1) is built into the body of the piezometer and protects against voltage spikes across the input leads. Following are additional lightning protection measures available;

1. 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.

2. 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 gage connections has provision for installation of plasma surge arrestors (similar to the device inside the piezometer).

- 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.

3. 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 2-7). This is the recommended method of lightning protection.

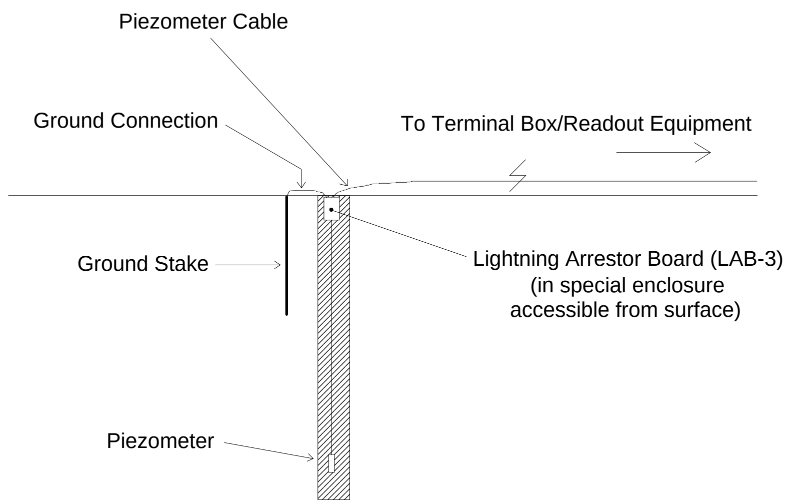


Figure 2-7 Recommended Lightning Protection Scheme

3. TAKING READINGS

3.1 Operation of the GK-401 Readout Box

The GK-401 is a basic readout for all vibrating wire gages.

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the green lead for the shield drain wire. The GK-401 cannot read the thermistor (see Section 3.4).

1. Turn the display selector to position "B" (or "F"). Readout is in digits (Equation 4-1).

2. Turn the unit on and a reading will appear in the front display window. The last digit may change one or two digits while reading. Record the value displayed. If zeros are displayed or the reading is unstable see section 5 for troubleshooting suggestions.

3. The unit will automatically turn itself off after approximately 4 minutes to conserve power.

3.2 Operation of the GK-403 Readout Box

The GK-403 can store gage readings and also apply calibration factors to convert readings to engineering units. Consult the GK-403 Instruction Manual for additional information on Mode "G" of the Readout. The following instructions will explain taking gage measurements using Modes "B" and "F" (similar to the GK-401 switch positions "B" and "F").

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the white and green leads are for the thermistor and the blue for the shield drain wire.

1. Turn the display selector to position "B" (or "F"). Readout is in digits (Equation 4-1).

2. Turn the unit on and a reading will appear in the front display window. The last digit may change one or two digits while reading. Press the "Store" button to record the value displayed. If the no reading displays or the reading is unstable see section 5 for troubleshooting suggestions. The thermistor will be read and output directly in degrees centigrade.

3. The unit will automatically turn itself off after approximately 2 minutes to conserve power.

3.3 Operation of the GK404 Readout Box

The GK404 is a palm sized readout box which displays the Vibrating wire value and the temperature in degrees centigrade.
The GK-404 Vibrating Wire Readout arrives with a patch cord for connecting to the vibrating wire gages. One end will consist of a 5-pin plug for connecting to the respective socket on the bottom of the GK-404 enclosure. The other end will consist of 5 leads terminated with alligator clips. Note the colors of the alligator clips are red, black, green, white and blue. The colors represent the positive vibrating wire gage lead (red), negative vibrating wire gage lead (black), positive thermistor lead (green), negative thermistor lead (white) and transducer cable drain wire (blue). The clips should be connected to their respectively colored leads from the vibrating wire gage cable.

Use the **POS** (Position) button to select position **B** and the MODE button to select **Dg** (digits).
Other functions can be selected as described in the GK404 Manual.

The GK-404 will continue to take measurements and display the readings until the OFF button is pushed, or if enabled, when the automatic Power-Off timer shuts the GK-404 off.
The GK-404 continuously monitors the status of the (2) 1.5V AA cells, and when their combined voltage drops to 2V, the message **Batteries Low** is displayed on the screen. A fresh set of 1.5V AA batteries should be installed at this point

3.4 Measuring Temperatures

Each vibrating wire piezometer is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Usually the white and green leads are connected to the internal thermistor. High temperature versions use a different thermistor than the standard versions.
The GK-403 and GK 404 readout boxes when used with the **standard** temperature thermistor will display the temperature in °C automatically. They will **not** do this with high temperature thermistors. The GK 401 readout box will not read temperatures directly, instead an ohmmeter must be used.

1. Connect the ohmmeter to the two thermistor leads coming from the piezometer. (Since the resistance changes with temperature are so large, the effect of cable resistance is usually insignificant. For long cables a correction can be applied – equal to 16 ohms per thousand feet.)

2. For standard temperature models, look up the temperature for the measured resistance in Table B-1.Page 21 Alternately the temperature could be calculated using Equation B-1. For high temperature models use Table B2 or the equation B2 given on page 22.

4. DATA REDUCTION

4.1 Pressure Calculation

The digits displayed by the Geokon Models GK-403 or GK-404 Readout Boxes on channel B are based on the equation

$$\text{Digits} = \left(\frac{1}{\text{Period}}\right)^2 \times 10^{-3} \quad \text{or} \quad \text{Digits} = \frac{\text{Hz}^2}{1000}$$

Equation 4-1 Digits Calculation

For example, a piezometer reading 8000 digits corresponds to a period of 354μs and a frequency of 2828 Hz. Note that in the above equation, the period is in seconds: the readout boxes display microseconds.
Since digits are directly proportional to the applied pressure,

Pressure = (Initial Reading - Current Reading) × Calibration Factor

or

$$\mathbf{P = (R_0 - R_1) \times G}$$

Equation 4-2 Convert Digits to Pressure

Since the linearity of most sensors is within 0.2% FS the errors associated with non-linearity are of minor consequence. However, for those situations requiring the highest accuracy it may be desirable to use a second order polynomial to get a better fit of the data points. The use of a second order polynomial is explained in Appendix D.

The calibration sheet, a typical example of which is shown in figure 2.1 on page 4, shows the data from which the linear gage factor and the second order polynomial coefficients are derived. Columns on the right show the size of the error incurred by assuming a linear coefficient and the improvement which can be expected by going to a second order polynomial . In many cases the difference is minor. The calibration sheets gives the pressure in certain engineering units. These can be converted to other engineering units using the multiplication factors shown in Table 4-1 below.

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	.0024583	.0294996	.0000968	.0968	.03342	.0013158	1	.0009869	.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	.0024908	.0298896	.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	.00000981	.009807	.003386	.000133	.101320	.0001	.1	.001	1

Table 4-1 Engineering Units Multiplication Factors

Note: Due to changes in specific gravity with temperature the factors for mercury and water in the above table are approximations!

4.2 Temperature Correction

Careful selection of materials is made in constructing the vibrating wire piezometer to minimize thermal effects, however, most units still have a slight temperature coefficient. Consult the supplied calibration sheet to obtain the coefficient for a given piezometer.

Since piezometers are normally installed in a tranquil and constant temperature environment, corrections are not normally required. If however, that is not the case for a selected installation, corrections can be made using the internal thermistor (Figure 1-1) for temperature measurement. See Section 3.4 for instructions regarding obtaining the piezometer temperature.

Temperature correction equation is as follows;

Temperature Correction = (Current Temperature - Initial Temperature) × Thermal Factor

or

$$\mathbf{P_T = (T_1 - T_0) \times K}$$

Equation 4-3 Temperature Correction

The calculated correction would then be **added** to the Pressure calculated using Equation 4-2. If the engineering units were converted remember to apply the same conversion to the calculated temperature correction!

For example, assume the initial temperature was 22° C, the current temperature is 15° C, and the thermal coefficient is –0.004326 PSI per °C rise (Figure 2-1). The temperature correction is +0.03 PSI.

4.3 Barometric Correction (required only on un-vented transducers)

Since the standard piezometer is hermetically sealed and un-vented, it responds to changes in atmospheric pressure. That being the case, corrections may be necessary, particularly for the sensitive, low pressure models. For example, a barometric pressure change from 29 to 31 inches of mercury would result in ≈1 PSI of error (or ≈2.3 feet if monitoring water level in a well!). Thus it is advisable to read and record the barometric pressure every time the piezometer is read. A separate pressure transducer (piezometer), kept out of the water, may be used for this purpose.
Barometric correction equation is as follows;

Barometric Correction = (Current Barometer - Initial Barometer) × Conversion Factor

or

$$P_B = (S_1 - S_0) \times F$$

Equation 4-4 Barometric Correction

Since barometric pressure is usually recorded in inches of mercury a Conversion Factor is necessary to convert to PSI. The Conversion Factor for inches of mercury to PSI is .491. Table 4-1 lists other common Conversion Factors.

The calculated correction is usually **subtracted** from the Pressure calculated using Equation 4-2. If the engineering units were converted remember to apply the same conversion to the calculated barometric correction!

The user should be cautioned that this correction scheme assumes ideal conditions. In reality, conditions are not always ideal. For example, if the well is sealed, barometric effects at the piezometer level may be minimal or attenuated from the actual changes at the surface. Thus errors may result when applying a correction which is not required. We recommend, in these cases, to independently record barometric pressure changes and correlate these with observed pressure changes to arrive at a correction factor.

An alternative to making barometric correction is to use piezometers that are vented to the atmosphere as noted section 4.3.1. However, vented piezos only make sense if the piezo is in an open well or standpipe and the user is only interested in the water level. Otherwise, if the piezo is buried it is not certain that the full effect of the barometric change will be felt immediately at the piezo and is more likely to be attenuated and delayed, in which case a vented piezo would automatically apply a correction that is too large and too soon. Having an on-site barometer with un-vented piezos also has the advantage that you can see the barometric change and judge to what extent it may have affected the piezo reading.

Equation 4-5 describes the pressure calculation with temperature and barometric correction applied.

$$P_{corrected} = ((R_0 - R_1) \times G) + ((T_1 - T_0) \times K) - ((S_1 - S_0) \times F)$$

Equation 4-5 Corrected Pressure Calculation

4.3.1 Vented Piezometers

Vented piezometers are designed to eliminate barometric effects. The space inside the transducer is not hermetically sealed and evacuated (see Figure 1-1), but is connected via a tube (integral with the cable) to the atmosphere. A chamber containing desiccant capsules is attached to the end of the tube to prevent moisture from entered the transducer cavity. Vented piezometers require more maintenance then non-vented types, and there is always a danger that water can find its way into the inside of the transducer and ruin it. As supplied, the outer end of the desiccant chamber is closed by means of a seal screw to keep the desiccant fresh during storage and transportation. **THE SEAL SCREW MUST BE REMOVED BEFORE THE PIEZOMETER IS PUT INTO SERVICE!** The desiccant capsules are blue when fresh, they will gradually turn pink as they absorb moisture. When they have turned light pink in color they should be replaced. Contact Geokon for replacement capsules.

4.4 Environmental Factors

Since the purpose of the piezometer installation is to monitor site conditions, factors which may affect these conditions should always be observed and recorded. Seemingly minor effects may have a real influence on the behavior of the structure being monitored and may give an early indication of potential problems. Some of the factors include, but are not limited to; blasting, rainfall, tidal levels, excavation and fill levels and sequences, traffic, temperature and barometric changes (and other weather conditions), changes in personnel, nearby construction activities, seasonal changes, etc.

5. TROUBLESHOOTING

Maintenance and troubleshooting of vibrating wire piezometers is confined to periodic checks of cable connections and maintenance of terminals. The transducers themselves are sealed and not user serviceable. Following are typical problems and suggested remedial action.

- **Piezometer fails to give a reading**

1. Check the resistance of the coils by connecting an ohmmeter across the gage terminals. Nominal resistance is 180Ω (±5%), plus cable resistance at approximately 16Ω per 1000' of 22 AWG wire. If the resistance is very high or infinite the cable is probably broken or cut. If the resistance is very low the gage conductors may be shorted. If a cut or a short is located in the cable, splice according to instructions in Section 2.8.
2. Check the readout with another gage.
3. The Piezometer may have been over-ranged or shocked. Inspect the diaphragm and housing for damage. Contact the factory.

- **Piezometer reading unstable**

1. Connect the shield drain wire to the readout using the green (GK-401) or the blue (GK-403) clip.
2. Isolate the readout from the ground by placing it on a piece of wood or similar non-conductive material.

3. Check for sources of nearby noise such as motors, generators, antennas or electrical cables. Move the piezometer cables if possible. Contact the factory for filtering and shielding equipment available.
4. The Piezometer may have been damaged by over-ranging or shock.
5. The body of the Piezometer may be shorted to the shield. Check the resistance between the shield drain wire and the Piezometer housing.

- **Thermistor resistance is too high**

1. Likely 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 2.8.

- **Thermistor resistance is too low**

1. Likely there is a short. Check all connections, terminals and plugs. If a short is located in the cable, splice according to instructions in Section 2.8.
2. Water may have penetrated the interior of the piezometer. There is no remedial action.

APPENDIX A - SPECIFICATIONS

Model	4500S	4500AL[1]	4500AR	4500B	4500C	4500DP	4580[2]
Available Ranges (psi)	0-50 0-100 0-150 0-250 0-500 0-750 0-1000 0-1500 0-3000 0-5000 0-10000 0-15000	0-5 0-10 0-25		0-50 0-100 0-250	0-50 0-100 0-250	0-10 0-25 0-50 0-150 0-250 0-500 0-750 0-1000 0-1500 0-3000 0-5000 0-10000	0-1 0-5
Resolution	0.025% FS	0.025% FS	0.025% FS	0.025% FS	0.05% FS	0.025% FS	0.01% FS
Linearity	< 0.5% FS[3]	< 0.5% FS[3]	< 0.5% FS[3]	< 0.5% FS[3]	< 0.5% FS[3]	< 0.5% FS[3]	< 0.5% FS[3]
Accuracy	0.1% FS[4]	0.1% FS[4]	0.1% FS[4]	0.1% FS[4]	0.1% FS[4]	0.1% FS[4]	0.1% FS
Over-Range	2 × FS	2 × FS	2 × FS	2 × FS	2 × FS	2 × FS	2 × FS
Thermal Coefficient	<0.025% FS/ °C	<0.05% FS/ °C	<0.05% FS/ °C	<0.025% FS/ °C	<0.05% FS/ °C	<0.025% FS/ °C	<0.025% FS/ °C
Temperature Range	-20°C to +80°C	-20°C to +80°C	-20°C to +80°C	-20°C to +80°C	-20°C to +80°C	-20°C to +80°C	-20°C to +80°C
OD	.75" 19.05 mm	1" 25.40 mm	.75" 19.05 mm	.687" 17.45 mm	.437" 11.10 mm	1.3” 33.3mm	1.5" 38.10 mm
Length	5.25" 133 mm	5.25" 133 mm	10” 254 mm	5.25" 133 mm	6.5" 165 mm	7.36” 187 mm	6.5" 165 mm

Table A-1 Vibrating Wire Piezometer Specifications

Accuracy of Geokon test apparatus: 0.1%

Contact Geokon for specific application information.

Notes:

[1] Accuracy of test apparatus: 0.05%

[2] Other ranges available upon request.

[3] 0.1% FS linearity available upon request.

[4] Derived using 2nd order polynomial.

APPENDIX B – STANDARD TEMPERATURE THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3

Resistance to Temperature Equation B1:

$$T = \frac{1}{A + B(LnR) + C(LnR)^3} - 273.2$$

Where; T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance
$A = 1.4051 \times 10^{-3}$ (coefficients calculated over the –50 to +150° C. span)
$B = 2.369 \times 10^{-4}$
$C = 1.019 \times 10^{-7}$

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	4500	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 B-1 **STANDARD TEMPERATURE** Thermistor Resistance versus Temperature

High Temperature Thermistor Linearization using SteinHart-Hart Log Equation

Thermistor Type: Thermometrics BR55KA822J

Basic Equation B2:

$$T = \frac{1}{A + B(LnR) + C(LnR)^3} - 273.2$$

Where: T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance
$A = 1.02569 \times 10^{-3}$
$B = 2.478265 \times 10^{-4}$
$C = 1.289498 \times 10^{-7}$

Note: Coefficients calculated over -30° to +260° C. span.

Table B2

Temp	R (ohms)	LnR	LnR^3	Calculated Temp	Diff	FS Error	Temp	R (ohms)	LnR	LnR^3	Calculated Temp	Diff	FS Error
-30	113898	11.643	1578.342	-30.17	0.17	0.06	120	407.62	6.010	217.118	120.00	0.00	0.00
-25	86182	11.364	1467.637	-25.14	0.14	0.05	125	360.8	5.888	204.162	125.00	0.00	0.00
-20	65805	11.094	1365.581	-20.12	0.12	0.04	130	320.21	5.769	191.998	130.00	0.00	0.00
-15	50684.2	10.833	1271.425	-15.10	0.10	0.03	135	284.95	5.652	180.584	135.00	0.00	0.00
-10	39360	10.581	1184.457	-10.08	0.08	0.03	140	254.2	5.538	169.859	140.01	-0.01	0.00
-5	30807.4	10.336	1104.068	-5.07	0.07	0.02	145	227.3	5.426	159.773	145.02	-0.02	-0.01
0	24288.4	10.098	1029.614	-0.05	0.05	0.02	150	203.77	5.317	150.314	150.03	-0.03	-0.01
5	19294.6	9.868	960.798	4.96	0.04	0.01	155	183.11	5.210	141.428	155.04	-0.04	-0.01
10	15424.2	9.644	896.871	9.98	0.02	0.01	160	164.9	5.105	133.068	160.06	-0.06	-0.02
15	12423	9.427	837.843	14.98	0.02	0.01	165	148.83	5.003	125.210	165.08	-0.08	-0.03
20	10061.4	9.216	782.875	19.99	0.01	0.00	170	134.64	4.903	117.837	170.09	-0.09	-0.03
25	8200	9.012	731.893	25.00	0.00	0.00	175	122.1	4.805	110.927	175.08	-0.08	-0.03
30	6721.54	8.813	684.514	30.01	-0.01	0.00	180	110.95	4.709	104.426	180.07	-0.07	-0.02
35	5540.74	8.620	640.478	35.01	-0.01	0.00	185	100.94	4.615	98.261	185.10	-0.10	-0.04
40	4592	8.432	599.519	40.02	-0.02	-0.01	190	92.086	4.523	92.512	190.09	-0.09	-0.03
45	3825.3	8.249	561.392	45.02	-0.02	-0.01	195	84.214	4.433	87.136	195.05	-0.05	-0.02
50	3202.92	8.072	525.913	50.01	-0.01	-0.01	200	77.088	4.345	82.026	200.05	-0.05	-0.02
55	2693.7	7.899	492.790	55.02	-0.02	-0.01	205	70.717	4.259	77.237	205.02	-0.02	-0.01
60	2276.32	7.730	461.946	60.02	-0.02	-0.01	210	64.985	4.174	72.729	210.00	0.00	0.00
65	1931.92	7.566	433.157	65.02	-0.02	-0.01	215	59.819	4.091	68.484	214.97	0.03	0.01
70	1646.56	7.406	406.283	70.02	-0.02	-0.01	220	55.161	4.010	64.494	219.93	0.07	0.02
75	1409.58	7.251	381.243	75.01	-0.01	0.00	225	50.955	3.931	60.742	224.88	0.12	0.04
80	1211.14	7.099	357.808	80.00	0.00	0.00	230	47.142	3.853	57.207	229.82	0.18	0.06
85	1044.68	6.951	335.915	85.00	0.00	0.00	235	43.673	3.777	53.870	234.77	0.23	0.08
90	903.64	6.806	315.325	90.02	-0.02	-0.01	240	40.533	3.702	50.740	239.69	0.31	0.11
95	785.15	6.666	296.191	95.01	-0.01	0.00	245	37.671	3.629	47.788	244.62	0.38	0.13
100	684.37	6.528	278.253	100.00	0.00	0.00	250	35.055	3.557	45.001	249.54	0.46	0.16
105	598.44	6.394	261.447	105.00	0.00	0.00	255	32.677	3.487	42.387	254.44	0.56	0.19
110	524.96	6.263	245.705	110.00	0.00	0.00	260	30.496	3.418	39.917	259.34	0.66	0.23
115	461.91	6.135	230.952	115.00	0.00	0.00							

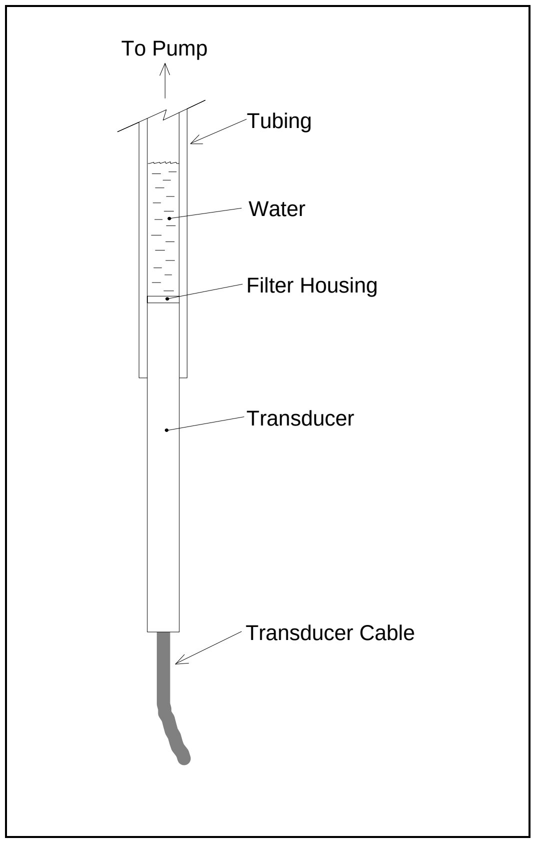
Table B2 High Temperature. Temperature v Thermistor Resistance

APPENDIX C - NOTES REGARDING THE MODEL 4500C

Installation

The construction of this very slender vibrating wire transducer, requires a miniaturization of the internal parts and consequently they are somewhat delicate. Despite every precaution it is possible for the zero to shift during shipment due to rough handling. However, tests have shown that the zero may shift but the calibration factors do not change. Therefore it is doubly important that the initial no load zero reading be taken prior to installation. **And it is also important to handle the transducer gently during the installation procedure.**

If the pressures to be measured are less than 5 psi the filter stone in the filter housing must be saturated. ***However, the filter stone and housing are not removable in the 4500C. Any attempt to remove the filter stone or the housing will destroy the transducer!***



To saturate the filter a hand vacuum pump and short length of tubing (½" surgical tubing) is required. Attach the tube to the transducer as shown in the figure. Fill the tubing with approximately 2" (5 cm) of water. Hold the transducer so that the water rests on the filter. Attach the other end of the tube to the hand vacuum pump. While holding the transducer so that the water rests on the filter (and doesn't enter the pump!), squeeze the hand pump to initiate vacuum in the tubing. This will draw the air out of the filter and the space behind it. The water will replace it. A vacuum of 20-25" Hg. (50-65 cm Hg.) is sufficient for proper evacuation.

A hand pump that has been used successfully is the mityvacII® by Neward Enterprises, Inc. of Cucamonga, CA, USA. Hand pumps and tubing are available from the factory.

Data Reduction

Data reduction follows the same procedures as outlined in Section 4 of this manual.. Use Table 4-1 to convert psi to other engineering units.

APPENDIX D - NON LINEARITY AND THE USE OF A SECOND ORDER POLYNOMIAL TO IMPROVE THE ACCURACY OF THE CALCULATED PRESSURE

Most vibrating wire pressure transducers are sufficiently linear (± 0.2 % FS) that use of the linear calibration factor satisfies normal requirements. However, it should be noted that the accuracy of the calibration data, which is dictated by the accuracy of the calibration apparatus, is always ± 0.1 % FS.

This level of accuracy can be recaptured, even where the transducer is non-linear, by the use of a second order polynomial expression which gives a better fit to the data then does a straight line.

The polynomial expression has the form:

$$\text{pressure} = AR^2 + BR + C$$

where R is the reading (digits channel B) and A,B,C, are coefficients. The figure on page 24 shows a calibration sheet of a transducer which has a comparatively high non-linearity. The figure under the "Linearity (%FS)" column is

$$\frac{\text{Calculated pressure- True pressure}}{\text{Full-scale Pressure}} \times 100\% = \frac{G(R_0 - R_1) - P}{F.S} \times 100\%$$

Note The linearity is calculated using the regression zero for R_0

For example when P= 40 psi, G (R_0 - R_1) = 0.029021(9145-7773), gives a calculated pressure of 39.817 psi. The error is 0.183 psi equal to 5 inches of water.

Whereas the polynomial expression gives a calculated pressure of $A(7773)^2 + B(7773) + C$ = 39.996 psi and the actual error is only 0.004 psi or 0.1 inch of water.

Note. If the polynomial equation is used it is important that the value of C, in the polynomial equation, be taken in the field, following the procedures described in section 2.1.1. The field value of C is calculated by inserting the initial zero reading into the polynomial equation with the pressure, P, set to zero.

It should be noted that where changes of water levels are being monitored it makes little difference whether the linear coefficient or the polynomial expression is used.

GEOKON

Vibrating Wire Pressure Transducer Calibration

Model Number: 4500S-100 | Pressure Range: 100 psi

Serial Number: 48056 | Mfg. Number: 8-3275

Customer: | Temperature: 21.1 °C

Cust. I.D. #: n/a | Barometric Pressure: 998.1 mbar

Job Number: 13053 | Date: Nov. 7, 1998

Cal. Std. Control #(s): 183, 468 | Technician:

Pressure (psi)	Reading 1st Cycle	Pressure (psi)	Reading 2nd Cycle	Average Pressure	Average Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0	9136	0	9141	0	9139		0.18	-0.04
20	8453	20	8456	20	8455	684	0.03	0.08
40	7772	40	7774	40	7773	682	-0.19	-0.01
60	7085	60	7083	60	7084	689	-0.19	-0.01
80	6392	80	6390	80	6391	693	-0.08	-0.03
100	5694	100	5687	100	5691	701	0.25	0.03

Linear Gage Factor (G): 0.029021 (psi/digit) **Regression Zero: 9145**

Polynomial Gage Factors: A: -1.40E-07 B: -0.026943 C:* 257.8826

Thermal Factor (K): -0.004326 (psi/°C)

Calculated Pressures: **Linear,** $P = G(R_0 - R_1) + K(T_1 - T_0) - (S_1 - S_0)$**

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)$**

***Barometric compensation is not required with vented transducers.*

Factory Zero Reading:

GK-401 Pos. B or F(R_0): 9128 Temp(T_0): 21.8 °C Baro(S_0): 1001.4mbar Date: Jan. 27, 1997

**The user is advised to establish zero conditions in the field by recording the reading at a known temperature and barometric pressure.*

Wiring Code: Red and Black: Gage White and Green: Thermistor Bare: Shield

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

Vibrating Wire Pressure Transducer Calibration Sheet

APPENDIX E - QUICK INSTRUCTIONS FOR INSTALLING A VIBRATING WIRE PIEZOMETER.

- Take a zero reading at zero, (atmospheric), pressure. Make sure that the temperature has not changed for 15 minutes previously. (Or until the piezo reading has stabilized). Check that this zero reading is compatible with the zero on the calibration sheet

- Record the barometric pressure and the temperature at the time the zero reading is taken.

- Carefully measure the length of the cable and make a mark on the cable which will lie opposite the top of the borehole, well, or standpipe when the piezometer has reached the desired depth. (The piezo diaphragm lies ¾ inch above the tip of the piezo).

- Saturate the piezometer filter. (Section 2.6)

- Follow the instruction of Section 2.2 for installation in standpipes or wells or Section 2.3 for boreholes.

APPENDIX F - MODEL 4500AR PIEZOMETER

The Model 4500 AR piezometer is designed to be used with readouts systems that can read frequency but do not have the capability to “pluck’ the VW gage. This sensor has built-in electronics that cause the gage wire to vibrate in a continuous mode at its resonant frequency. The output from the sensor is a 5 volt DC square wave at this frequency.
A DC input voltage in the range of 6- 24 volts is required to operate the gage. The current consumption is approximately 21 mA at 12VDC. The gage output is independent of the input voltage. Multiple sensors powered simultaneously can be read at quite fast rates, up to 5 sensors per second and dynamic measurements on a single sensor can be made up to about 20Hz.
The gage is installed in the field in the same way that the Model 4500 standard piezometer is installed. (See Section 2)

Piezometer Wiring: The 3-pair cable is wired in pairs with each pair comprising one colored and one black lead.

Red	**+6-24 VDC Power**
Red’s black	**Ground**
White	**Output**
White’s black	**Output Ground**
Green	**Thermistor +**
Green’s black	**Thermistor –**
Bare	**Shield**

Upon power up the gage will immediately start to “ring” at the resonant frequency and will continue to do so until the power is removed. Continuous operation will have no effect on the gage life.
Note
The sensor comprises two transducers, the VW pressure sensor and a thermistor for measuring temperature. The signals from the VW transducer are high level frequency and will interfere with the thermistor output if left powered during the period that the thermistor is being read. If the temperature reading is important the power to the pressure sensor should be switched off while the reading is taken.