ELECTRICAL PIEZOMETERS

User Manual

INDEX

Notes on the use of product

For a safe and efficient use of the instrument, please read carefully the following instructions before starting any operation.

Any use of the instrument other then the one described in this manual shall be considered at user's full responsibility.
The same applies for any unauthorized modifications.
In addition to the hereby listed standards, the user must comply with the provisions of the current legislation on the matter of personal safety and health of persons in the workplace.
SISGEO is not responsible for any trouble, breakdowns, accidents etc.. due to the lack of knowledge and/or confidence (or non-compliance with) with the requirements contained in this manual.

Check that the instrument has not been damaged during the transport.
Verify that the package includes all items as well as any requested optional accessories; if anything is missing, please promptly contact the manufacturer.
The user must strictly follow all the operations described in this manual.
Maintenance or repair of the instrument is allowed only to authorized operators.
These operators must be physically and intellectually suitable.
For information about instrument or order spare parts request, please always specify data written on the identification label.
When replacing parts, always use ORIGINAL SPARE PARTS.
The manufacturer reserves the right to make changes without prior notice for any technical or commercial requests.
We'll try anyway to keep the manuals updated in order to reflect product's revisions/updates.

Symbols

This symbol will be used used to catch reader's attention on the manual:

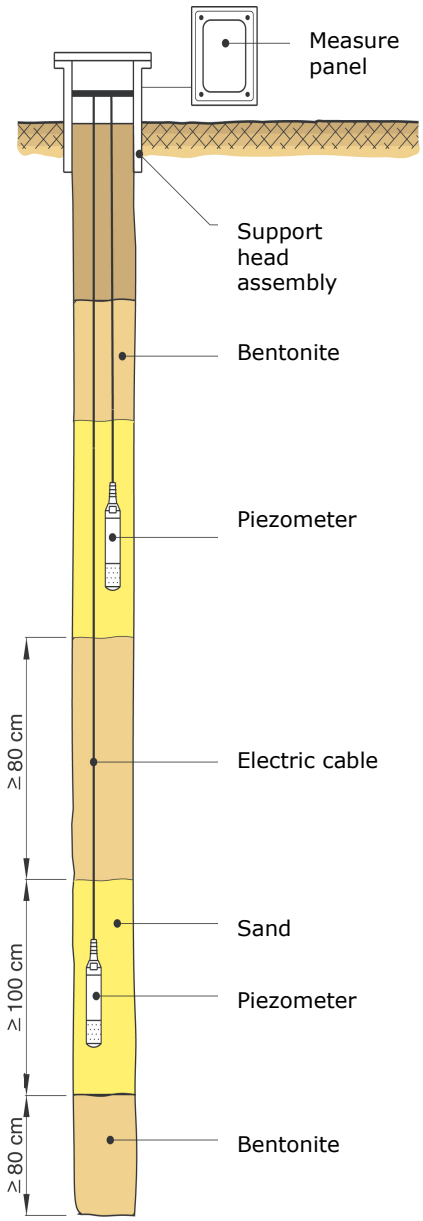
Pay special attention to the following instruction.

Identification

Instruments can be identified

- From a production lot number (written on the Compliance Certificate)
- From a serial number *(s/n)* engraved indelibly on the instrument
- From a label on the instrument
- From a label on the cable

Introduction



Electrical piezometers are largely used in civil and foundations engineering, to monitor groundwater level and to measure pore water pressure.

Electrical piezometers, called "closed circuit type", are installed in borehole, embankments or directly by drive-in if the ground features allow the operation.

How it works: the membrane deforms due to water pressure, causing the variation of an electric signal, measured with a measuring device.

SISGEO uses two kind of sensors:

- Vibrating wire
- Resistive

In the vibrating wire piezometers (VW) the membrane deformation causes the tension variation of a steel wire stretched between the membrane and the instrument body.

The vibration frequency is collected from a measuring device.

This instrument, moreover, includes a thermistor to measure the temperature.

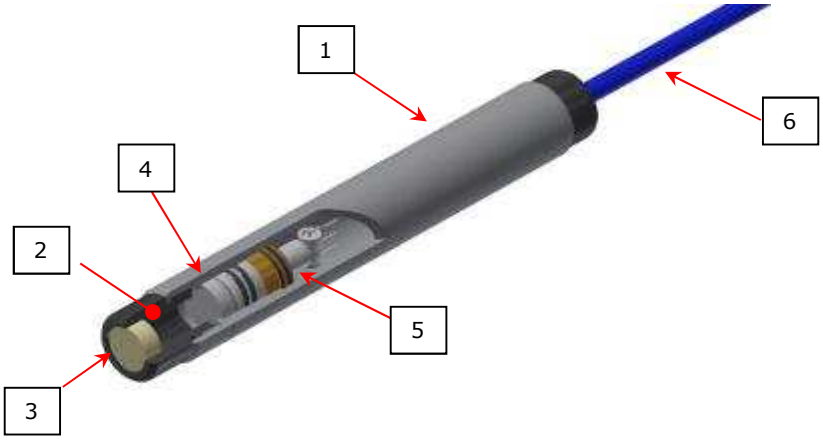
The resistive piezometers have a ceramic membrane with molded starin-gauge that change their resistance and the electric signal according to membrane deformations due to water pressure.

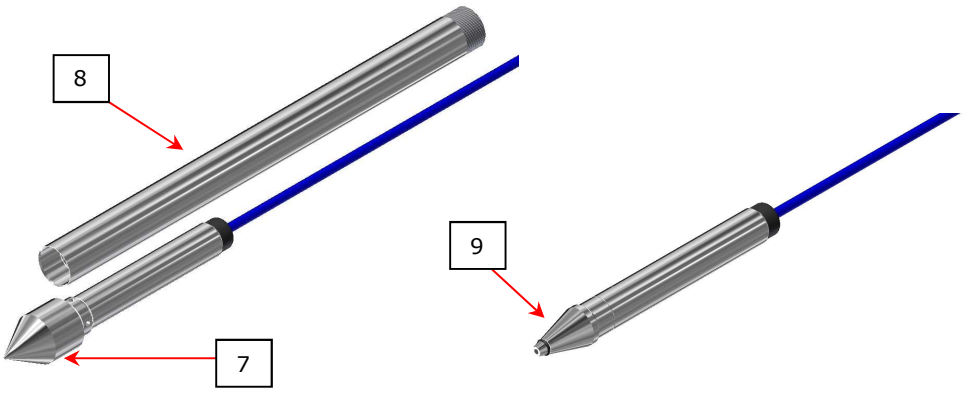
The VW piezometers assure an high reliability for long term measures; the resistive allow high insulation (for example in industrial plants) and the possibility to take dynamic measures.

Description

Electric piezometer consists in:

1. Stainless steel cylindrical body
2. Hydraulic chamber
3. Filter holder and filter
4. Measuring sensor (membrane)
5. Thermistor (only with VW type)
6. Electric cable for the connection with the readout
7. Conical filter tip (drive-in type)
8. Piezometer push-in rod (drive-in type)
9. Conical filter tip (removable type)





The filter is an important element and its choice depends on the use and the ground type.
The sintered stainless steel or vjon filters have a porosity of ca. 40µm, are called "Low Air Entry" (LAE) and are used for most standard applications.
Their saturation is performed easily on site.

Ceramic filters have a low porosity and shall keep the saturation of the hydraulic chamber also if submitted to negative pressures (suction).
They are employed when the piezometer is in "dry conditions" for a long time.
The ceramic filters are called "High Air Entry" (HAE).
The saturation of this kind of filters is not easy and has to be done with a suitable device.

Filters saturation

Filters saturation and assembly

The purpose of filters saturation is to remove the air in filters pores and replace it with water in order to have a faster answer to pressure variations and more accurate measures; moreover it prevents ground particles to obstruct filter pores.
The air entry is the pressure necessary to force the air through a porous filter completely saturated.
This value is commonly used in geotechnical field and it is proportional both to pores diameter and the fluid used for the saturation.
Typical values of "low air entry" are the ones between 3 and 30KPa while typical values of "high air entry" are the ones higher than 100KPa.

SISGEO recommends to perform the saturation on site just before the installation.

LAE Filters

Usually the filter must be left in a bucket full of water for at least 24 hours.
The saturation is better if the water has been previously de-aired bringing it to boil for at least 10 minutes and then left to cool.
Take a bucket with clean water then:

- submerge the filter holder with the filter;
- submerge the piezometer turned up and fill the hydraulic chamber;
- screw the filter holder on the piezometer, working underwater.

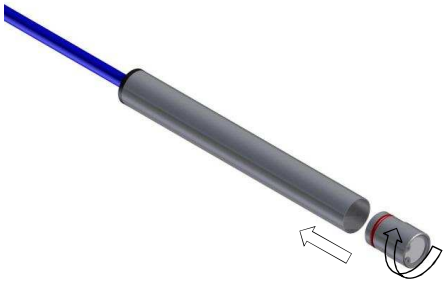
Follow the same operations for the assembly in case of saturated filters supplied by Sisgeo.

HAE Filters using SISGEO saturation device

- Remove the air from the chosen fluid, usually distilled water, bringing it to boil or vacuum until the air bubbles will disappear;
- fill in the saturation device;
- screw the filter holder with the filter on the saturation device;
- screw slowly the saturation device, and handle it until you could read (on the gauge) the value of ca. 3.5Bar;
- wait until filter's surface is not covered with fluid's drops;
- unscrew the filter holder and screw it on the piezometer working underwater in a bucket.

In case of HAE filters and for instruments with low full scale (<200kPa), is necessary, during the assembly, to connect the piezometer to a readout to check the induced pressure and screw slowly the holder on the piezometer in order to avoid overpressures that could damage it.

Filter saturation and assembly in SLIM piezometers (cod. PK20xxx)



For the saturation follow the instruction in the paragraph of LAE filters.
For the assembly, push and turn the holder on the piezometer body.
In case of HAE filters, the operation could take a few minutes.
The saturation is successful when the liquid leaks from the filter surface.

In case of HAE filters and for instruments with low full scale (<200kPa), is necessary, during the assembly, to connect the piezometer to a readout to check the induced pressure and screw slowly the holder on the piezometer in order to avoid overpressures that could damage it.

Preliminary checks

Before the installation is recommended to check the instrument connecting it to a readout (see "Taking measurements").

The read value has to be similar to the "zero value" written on the Calibration Report.
The possible differences could be due to height, barometric pressure and, for the VW type, temperature.
This operation is possible with saturated or unsaturated filter.
Please remember that the Calibration Report shows the conditions during the test, and it is issued at 115 m. s.l.
The atmospheric pressure lowers approximately 0.1kPa every 10m height.
We advise to leave the VW model temperature to stabilize for at least 20 minutes before taking any measure.
The acceptable differences between the measured value and the one shown on the Calibration Certificate with equal conditions are:

- Extensometer model :±1% of full scale =0.16mA
- VW model: ±100digits

For low full scale values, is necessary to consider the barometric pressure value.
Indeed, on a transducer of 0,2MPa a barometric pressure variation of 50mbar (0,005MPa) is like 2,5% of full scale (1 millibar is 1cm of water level).

Installation

Installation in boreholes

Installation procedures must be defined according to the grounds and the purpose of the measures.
In general terms you can use the following procedure:

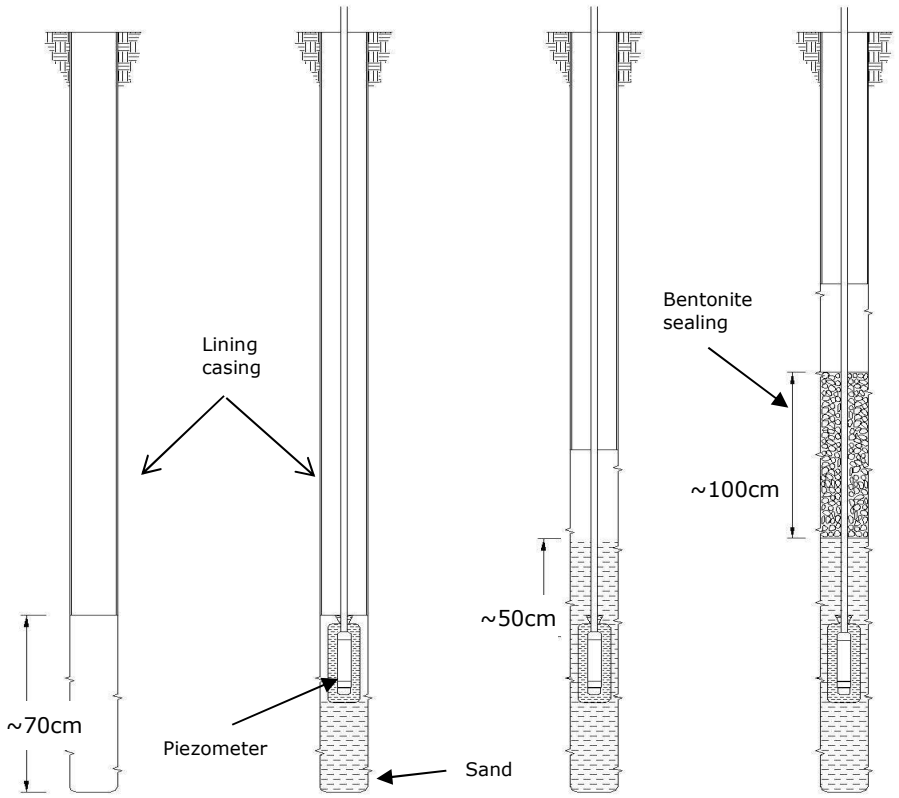
Boreholes can be executed with continuous core or non-core drilling.
We always recommend to steady the walls with a temporary casing, with an internal diameter not less than 85mm (1 piezometer for borehole), 110mm (2 piezometers for borehole).
Avoid the use of mud.
To install two piezometers in the same borehole are needed two filters and two caps: pay attention to stratigraphy and thickness of layers.

SISGEO recommends to install maximum two piezometers for each borehole.

To stabilize the bottom of the hole, without ground water, water level must be kept within the drilling, a little above the ground level.
This solution has to be used also during the installation steps.

Tools needed during installation: depth meter, pestle, bentonite pellets, bucket.

To install, proceed as shown in the picture:



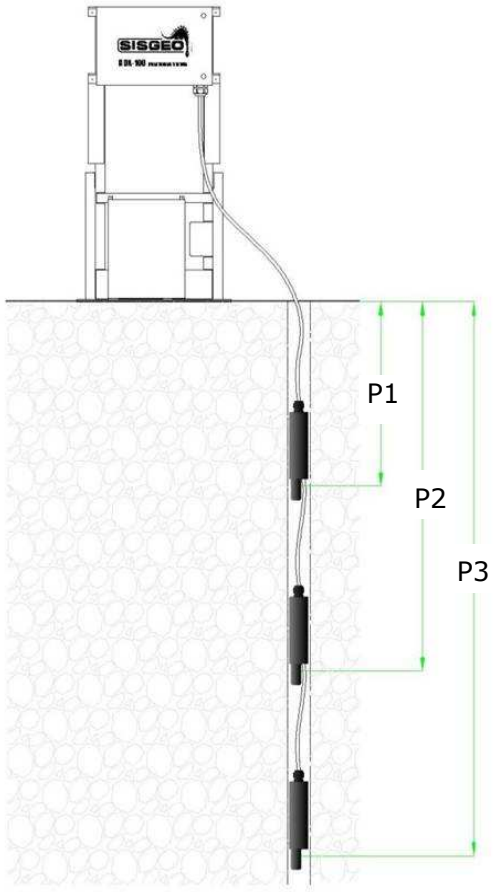
Suggestions:

- Identify the installation depth, on piezometer cable, starting from the membrane position engraved on the steel body.
- Before, through and after the installation check piezometer measurement.
- Wash the borehole until it leaks clear water.
- Fill in the geotextile bag with sand and insert the piezometer with the saturated filter; then put everything in a plastic bag filled with water and dip it in the casing full of water. Now break the plastic bag, pull out the piezometer and drop it slowly. These operations must be carried out always underwater.
- ∅ fine sand or gravel = ca. 2mm.
- Carry out the bentonite cap in several times (ca. 25÷30cm each time). Compact with a pestle. Pay attention to the cable.
- Verify cap solidity and depth with a depth meter.
- Approximate quantities for the grout mixture: 100l of water, 50Kg of concrete and 5Kg of bentonite
- Cable shall always be covered to avoid casual damages and protect the end from wet.

With an higher impermeable soil layer, the bentonite sealing should be carried out at the same level of the layer in order to restore the continuity.

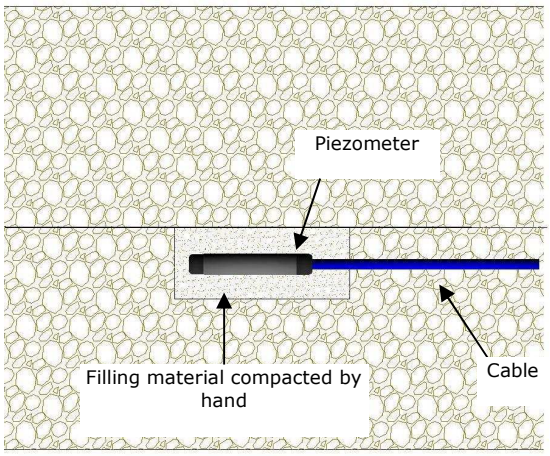
Multipoint Piezometer

Lately, as a result of studies, is taking over a new installation method called "fully grouted".
This method is very easy and fast.
It doesn't expect to use gravel and bentonite to create filter and sealed zones, but a mixture of water-cement-bentonite inside the borehole, with the right proportions according to the installation.
The mixture is injected straight to the drilling.
This allows to install more piezometers in the same hole, and also to install the piezometers in combination with an inclinometer casing.
Approximately the proportions (in weight) of the grout mixture are:
cement 1, water 2.5, bentonite 0.3
We recommend to mix in advance water and cement, and then add the bentonite.
Measures can be taken only after 28 days.
This kind of installation is suitable with multipoint piezometers, where is possible to install up to 8 piezometers in the same borehole.



Installation in fills and embankments
Piezometers can be installed in embankments or in core dams to measure the pore water pressure through the construction and working.
Pores of compacted unsaturated material contains both water and air and in fine-grained soil, the pressure difference between the pore water pressure and pore air pressure can be significant.
For clay embankments, piezometers must have an HAE filter, to ensure pore water pressure measure, and not air.
In granular materials as sand, gravel and rock fill you can use a LAE filter.

To install proceed as follows:



- Before, through and after the installation check the piezometer
- Dig a trench ca. 50 cm. width and 30-40 cm. deep.
- Saturate the piezometer as previously described.
- For installation in coarse material: insert the piezometer in a geotextile bag filled with sand.
- If the piezometer has an HAE filter and has to be installed in an unsaturated ground, assemble only the filter without using the geotextile bag.
- In coarse ground, dig a hole and insert the piezometer.
- Close the hole with the filling material compacting manually.
- In case of an embankment with big size materials, we recommend to cover the hole with saturated sand compacted by hands;
- For installation in unsaturated grounds, fix the piezometer in trench wall or dig a little hole and fix the piezometer;
- Lay out the electric cable within the trench in a snake-like mode, to avoid damages during the embankment settlement; with coarse ground, protect the cable with a conduit.
- Cover the cable with fine material in consecutive layers of 5-10 cm each and compact by hands.
- Arrange some bentonite pellets in regular intervals along the cable, in order to avoid water leaks and compact manually.
- Mark piezometer position and protect cable end from water seepage.

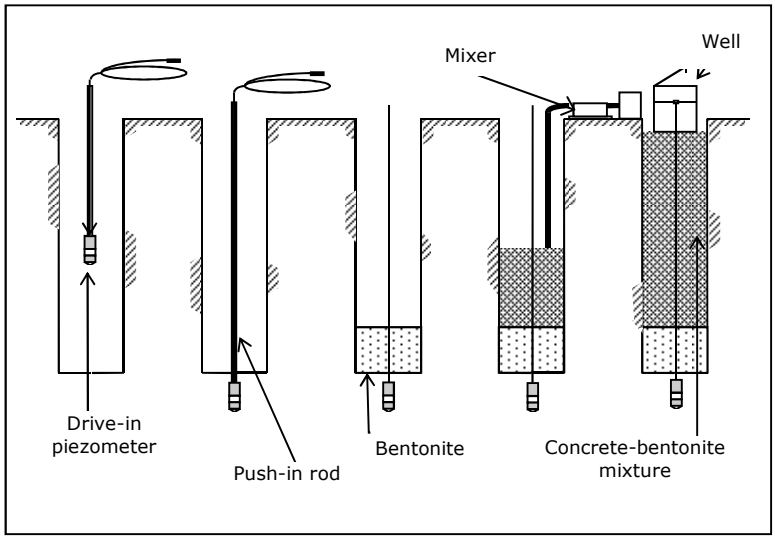
Drive-in piezometer installation

Drive-in piezometer, both ceramic and vibrating wire, is a special version suitable to be pushed directly in soft grounds.
The drilling equipment must tighten the push-in rods on the perimeter.
Otherwise it will be necessary to have a rod with a groove for the cable.

To install proceed as follows:

- Arrange the instrument according to usual procedures;
- Protect the end of the cable with some tape and insert the first push-in rod assembled on the first rod.

The installation can be started from the bottom of the borehole or from the ground level.



- For installation from borehole bottom, lower, in the hole, the push-in rods with the piezometer.
- Connect the piezometer to the readout and check non-stop the overpressure values resulting from the push, to avoid damages to the sensor: if necessary stop and wait for the excessive pressure to disperse.
- Push in until the chosen depth.
- Disconnect the piezometer; protect cables end with some tape and pull out the rods avoiding any stretch on the electric cable.
- Connect the piezometer and check the good functioning. Close the hole with bentonite balls or a mixture of water, concrete and bentonite.
- Wait until the values are stable (and the overpressure is dispersed) to take the zero reading.

Removable piezometer with conic filter tip installation

- Lower the piezometer and the weights within the pipe using the kevlar wire within the electric cable.
- Insert the piezometer in the Casagrande filter (previously installed).
- If the Casagrande filter is double tube, you must lower, in the ½ ” tube, the steel rod with conic cap and O-Ring, using the steel wire.

Taking measurements

Manual readings are taken connecting the conductors to a readout according to the following scheme:

Resistive piezometers Signal 4-20mA current loop	Red	+ Loop
	Black	- Loop
Vibrating wire piezometers (VW)	Red	VW
	Black	VW
	White	Thermistor
	Green	Thermistor

For the multipoint piezometers:

	VW	**VW**	**Thermistor**	**Thermistor**
P1	Brown	White/Brown	Black	Rose/Black
P2	Yellow	White/Yellow	Grey	White/Grey
P3	Black	Blue/Black	Rose	White/Rose
P4	Red	White/Red	Black	White/Black
P5	Violet	White/Violet	Black	Yellow/Black
P6	Orange	White/Orange	Black	Red/Black
P7	Blue	White/Blue	Green	White/Green
P8	Light Blue	White/Light blue	White	Green/White

Do not split the conductors to avoid confusion with the colors.

Note: to obtain reliable measures, with mA piezometers, we recommend a warm up time not less than 10 seconds.

For automatic measures, connect the instrument to a datalogger.

Data management

The following formulas allow to convert the electrical measures into engineering values:

Linear factor➔ $\mathbf{L_{eng} = L_{ele}/S\ [kPa]}$
Polynomial factors➔ $\mathbf{L_{eng} = (L_{ele}^2 \times A) + (L_{ele} \times B) + C\ [kPa]}$

L_{eng} = engineering reading
L_{elec} = electric reading
S = sensitivity factor
A, B, C = polynomial conversion factors

S, A, B, C factors are stated on DTE Calibration Report

The exercise readings refer to the initial reading (zero reading).

$$\mathbf{\Delta P_{kPa} = L_i - L_0}$$

L_0 = Zero reading [kPa]
L_i = Exercise reading [kPa]

Zero reading shall be taken carefully once the installation is performed and the instrument is in operating conditions.
For many applications is necessary to wait a few days to obtain a reliable zero value.

Example

Piezometer 700kPa (digit readings)
S = -4.9128digit/kPa
A = -5.222e-07; B =-1.955e-01; C =1.886e+03
L_0 = 7357digit ; L_1 = 6667digit

Using:
Linear factor (L_1-L_0)/S : (6667 *– 7357)/-4.9128 = 140.4494*
Polynomial factor [(L_1^2 x A)+(L_1x B)+C] – [(L_0^2 x A)+(L_0x B)+C]= *559.39 – 419.44 = 139.95kPa*

Temperature measure

Using a SISGEO readout, the temperature is read directly in C°.
If measured, the thermistor resistance value must be converted using the formula or the table shown in appendix 1.

If the piezometer is installed in an environment with uneven temperature, is necessary to correct pressure value already processed using the follow equation:

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

where:

$\mathbf{P_T}$ = correct pressure

$\mathbf{T_i}$ = excercise temperature;

$\mathbf{T_0}$ = zero temperature;

K = temperature factor (can be found on the piezometer calibration certificate)

Add the obtained correction to the pressure value found with the previous formula.

$$\mathbf{P_{tot} = (P + P_T)}$$

Example

K= 0.154344kPa/°C

Ti=28°C ; T0=15°C

PT=(28-15) x 0.154344 = 2.006kPa

Ptot = 139.95+2.006 = 141.956kPa

Troubleshooting

Considering its special application, eventual malfunctioning have to be found along the cable.

Vibrating wire piezometers:

Problem	Possible cause	Solution
Unstable measure	Cable shield not connected	Connect the shield
	Electromagnetic fields generated by engines, generator, antennas, welders or high voltage lines nearby	Identify and remove the cause. Shield the signal cable.
	Grounding not well done	Provide efficient grounding
Wire not detected	Cable cut or damaged. Measure the resistance between conductor Red and Black (150Ω ± 10%). Please consider cable length. The conductor resistance for model 0WE116000 is ca. 88 Ω/km	Repair the cable. Cable splicing kit available at SISGEO.
	Wiring not correct	Make proper wiring

Resistive piezometers

Problem	Possible cause	Solution
Unstable measure 0mA measure Overrange measure	Wiring not correct	Make proper wiring
	Cable cut or damaged	Repair the cable. Cable splicing kit available at SISGEO.

Maintenance

After-sales assistance for calibrations, maintenance and repairs, is performed by SISGEO's service department.
The authorization of shipment shall be activated by RMA "Return Manufacturer Authorization". Fill in the RMA module clicking on:

http://www.sisgeo.com/en/assistance/repairs/

Send back the instrument/equipment with the complete accessories, using suitable packaging, or, even better, the original ones.
The shipping costs shall be covered by the sender.

Please return to the following address with suitable delivery document:

SISGEO S.r.l.
Via F.Serpero, 4/F1
20060 MASATE (MI)

On the delivery document is mandatory to indicate the RMA code received.

Technical assistance e-mail: assistance@sisgeo.com

Appendix 1

THERMISTOR TEMPERATURE CONVERSION

Resistance to temperature equation:

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

Where:
T= temperature in °C
LnR= natural Log of the thermistor resistance
A= 1.4051×10^{-3} (coefficents calculated over the -50 to +70°C span)
B= 2.369×10^{-4}
C=1.019×10^{-7}

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
16.60K	-10	5971	10	2417	30	1081	50
15.72K	-9	5692	11	2317	31	1040	51
14.90K	-8	5427	12	2221	32	1002	52
14.12K	-7	5177	13	2130	33	965.0	53
13.39K	-6	4939	14	2042	34	929.6	54
12.70K	-5	4714	15	1959	35	895.8	55
12.05K	-4	4500	16	1880	36	863.3	56
11.44K	-3	4297	17	1805	37	832.2	57
10.86K	-2	4105	18	1733	38	802.3	58
10.31K	-1	3922	19	1664	39	773.7	59
9796	0	3784	20	1598	40	746.3	60
9310	-1	3583	21	1535	41	719.9	61
8851	2	3426	22	1475	42	694.7	62
8417	3	3277	23	1418	43	670.4	63
8006	4	3135	24	1363	44	647.1	64
7618	5	3000	25	1310	45	624.7	65
7252	6	2872	26	1260	46	603.3	66
6905	7	2750	27	1212	47	582.6	67
6576	8	2633	28	1167	48	562.8	68
6265	9	2523	29	1123	49	543.7	69
						525.4	70