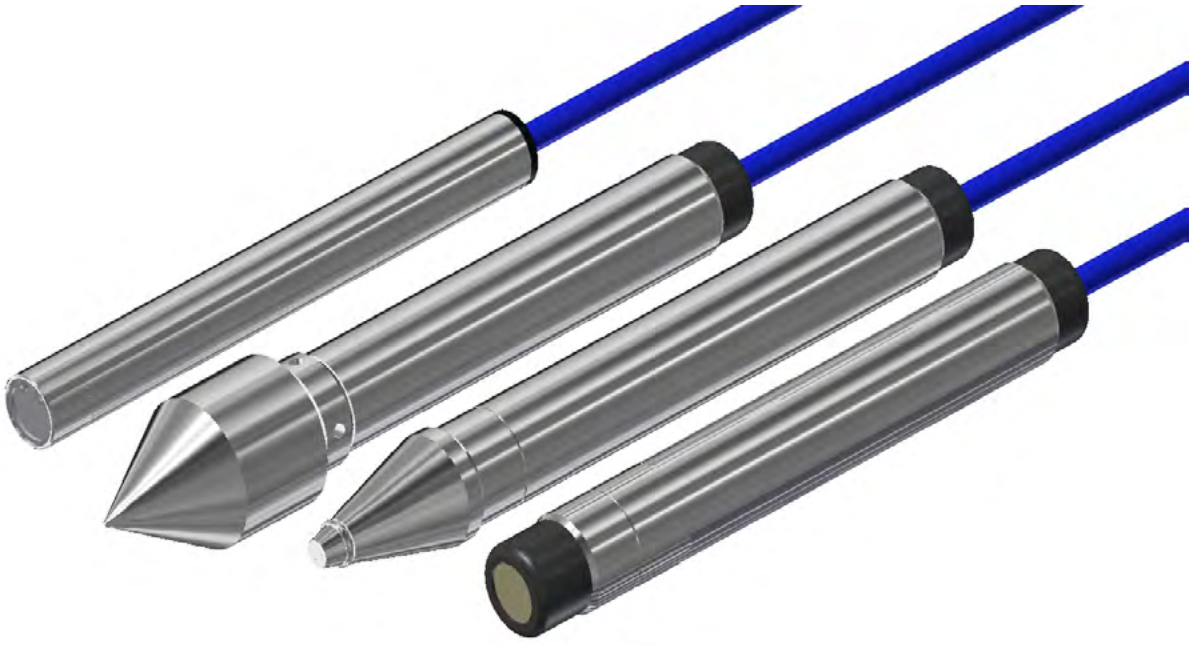
SPECTO TECHNOLOGY
A WORLD OF SOLUTIONS

# _ELECTRICAL PIEZOMETERS

USER MANUAL



SISGEO

# INDEX

### *Notes on the use of product*

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

Any use of the product other than 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 product 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 device 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*

Below are the symbols used to catch reader's attention on the manual:

Pay particular attention to the following instruction.

### *Identification*

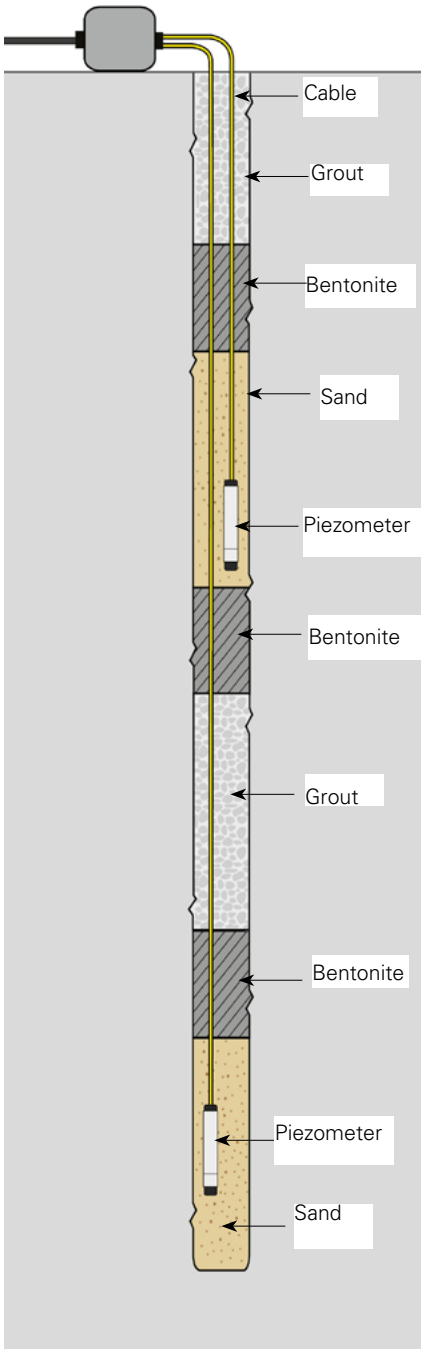
Instruments can be identified

- **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**

### *Note*

The present Manual is issued by SISGEO in English Language and translated in other different languages.
In order to avoid discrepancies and disagreements on the interpretation of the meanings, Sisgeo Srl declares that English Language prevails

# 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 readout.

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

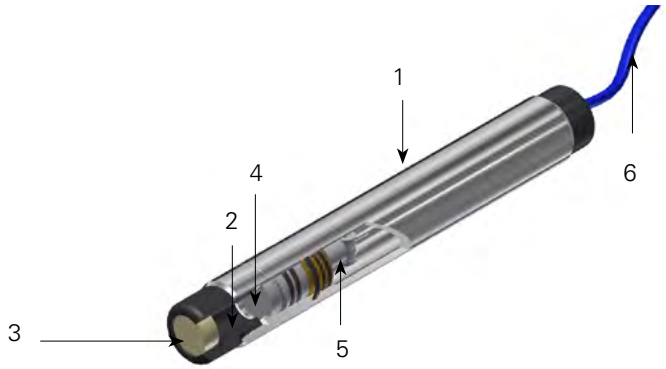
On the **resistive piezometer**, strain gauges are silk-screen printed on a ceramic membrane sealed by molten glass to the ceramic housing sensor. The strain gauge change their resistance and the electric signal according to membrane deformations due to water pressure.

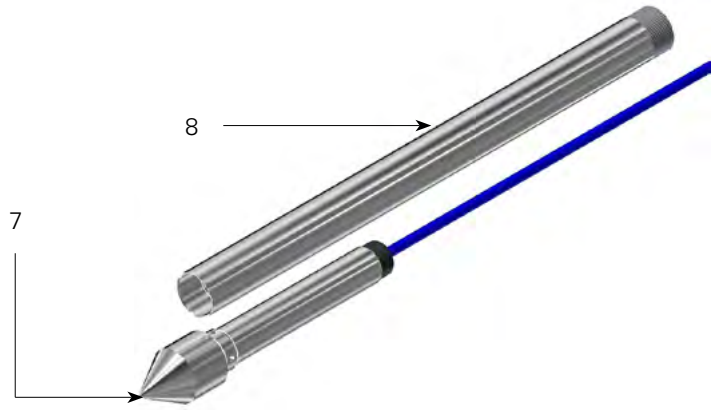
The VW piezometers assure an high reliability for long term measures; the resistive allow high insulation (for example in industrial plants) and the possibility to take dynamic measures.

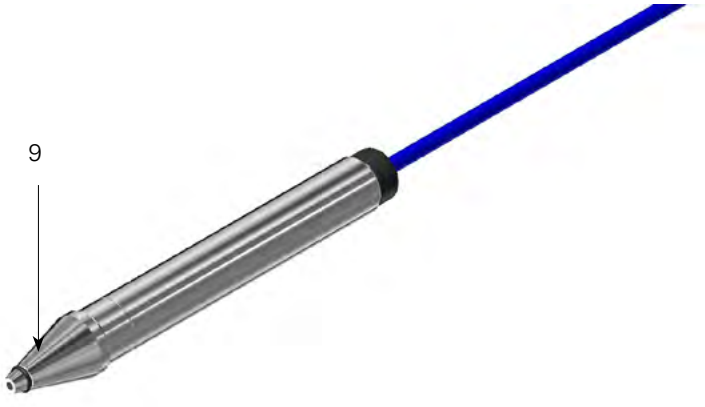
## DESCRIPTION

**Electrical piezometer** consists in:

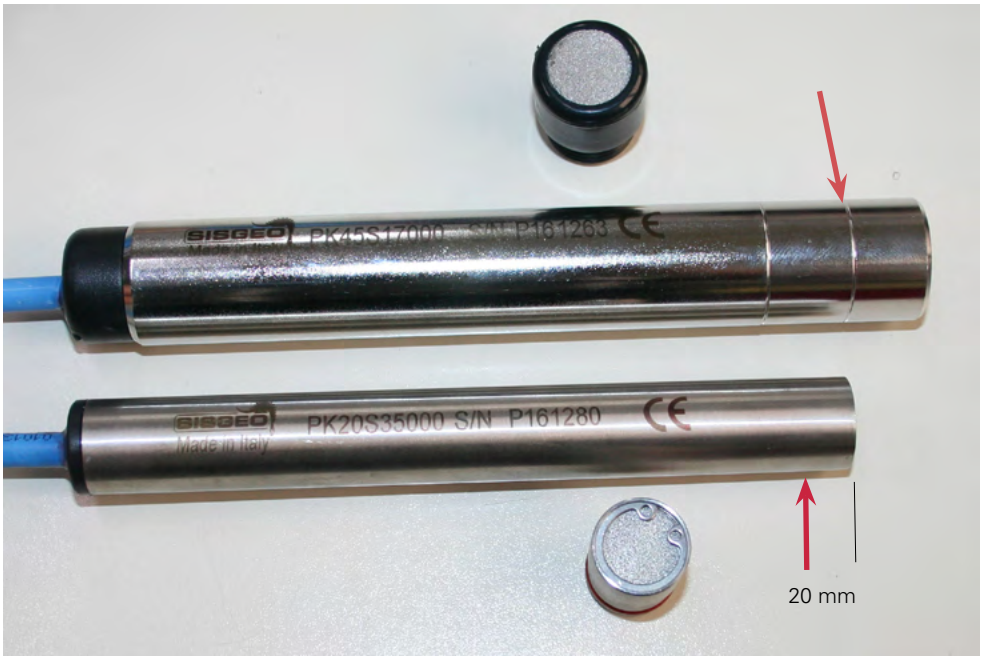
1. Stainless steel cylindrical body
2. Hydraulic chamber
3. Filter holder and filter
4. Measuring sensor (membrane)
5. Thermistor (only with VW type)
6. Electric cable for the connection with the readout
7. Conical filter tip (drive-in type)
8. Piezometer push-in rod (drive-in type)
9. Conical filter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



The position of the membrane is detailed in the picture below.




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

"High Air Entry" (**HAE)** filters are made in ceramic, 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 saturation of this kind of filters is not easy and has to be done with a saturation 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 parameters 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 between 3 and 30KPa while typical values of "high air entry" are higher than 100kPa.

SISGEO recommends to perform the saturation on site just before the installation, using clean water in order to prevent corrosion.

**LAE Filters**

Usually the filter must be left in a bucket full of water at least 24 hours.
Take a clean 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.

**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 wait 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 we recommend to check the instrument connecting it to a readout (see "Taking measurements").

The value read on the readout 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 115m.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 Report 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 mbar is 1cm of water level).

## INSTALLATION

**Installation in boreholes**

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

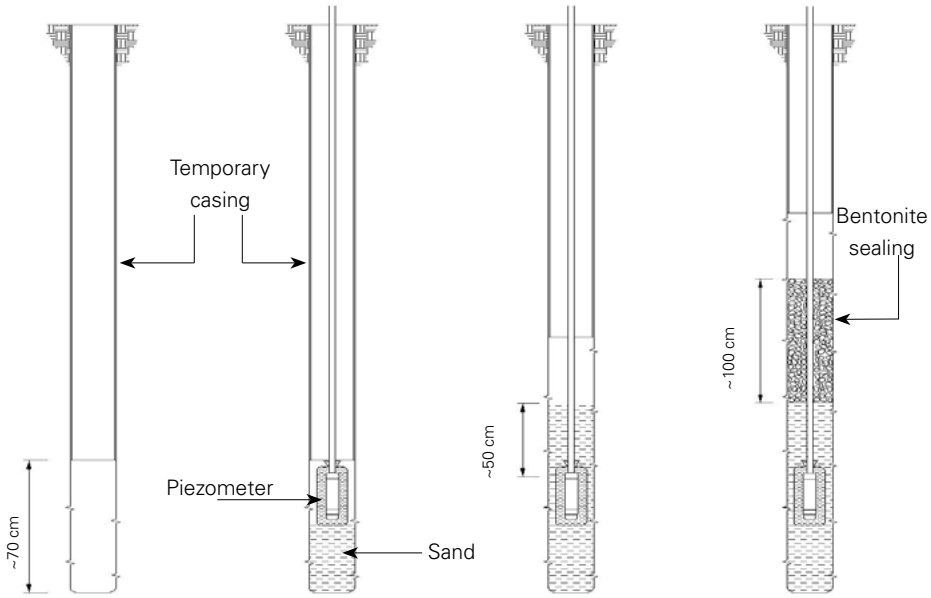
Boreholes can be executed with continuous core or non-core drilling.
We always recommend to steady the walls with a temporary casing, with an internal diameter not less than 85mm (1 piezometer for borehole), 110mm (2 piezometers for borehole).
The use of mud shall be avoided.
In order to install two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

Sisgeo recommends to install maximum two piezometers for each borehole to avoid to damage the cable during the compacting bentonite cap.

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

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

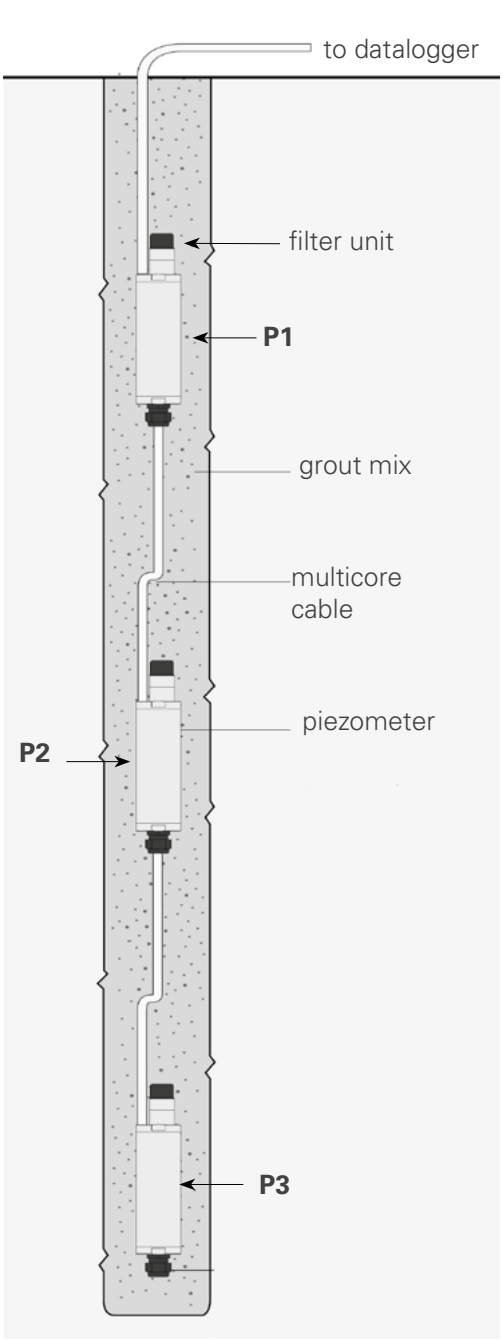
To install, please proceed as shown in the picture:




Suggestions:

- Identify the installation depth, on piezometer cable, starting from the membrane position (see "Description")
- Before, during and after the installation, check the piezometer measurement.
- Clean the borehole until it leaks clear water.
- Fill in the geotextile bag with clean, fine sand and insert the piezometer with its saturated filter; lower the geotextile bag into the borehole full of water. These operations must be carried out always underwater.
- Ø 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.
- Cable shall always be covered to avoid casual damages and its end must be protected from humidity.

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**

The fully-grouted installation method provides a reliable way to install piezometers in the same borehole, each measuring pore-water pressure at a different elevation.

It eliminates problems with placing sand intake zones, bentonite seals, and channeling of water along signal cables.

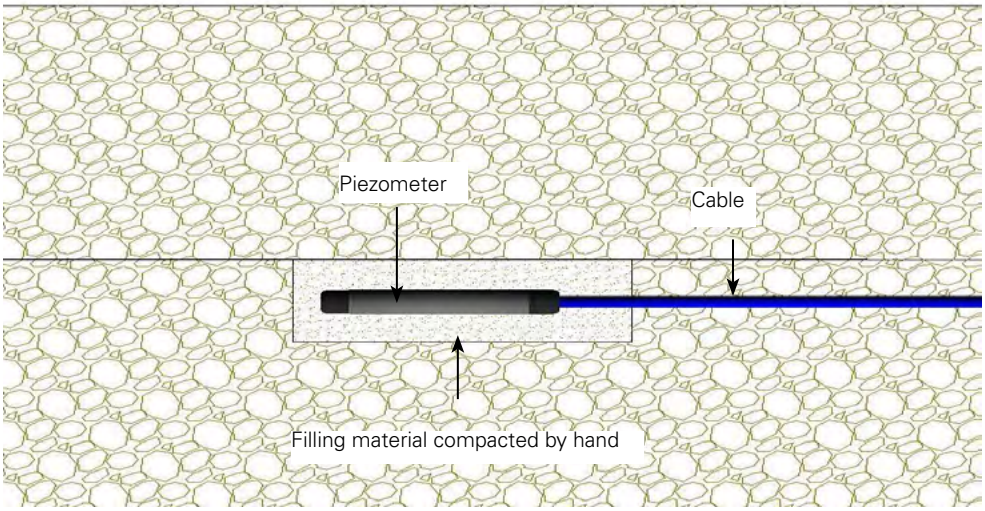
The working principle is based on the idea that in a low permeability grout, radial pressure gradient around the piezometer tip is magnitudes higher than the vertical pressure gradient along the borehole, and that the response of the piezometer is controlled by the higher pressure gradient.

Grout mix (water-cement-bentonite) should be controlled by weight and proportioned to give the desired strength of the set grout.
(See Mikkelsen - Piezometers in Fully Grouted Boreholes - FMGM 2003).

**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:

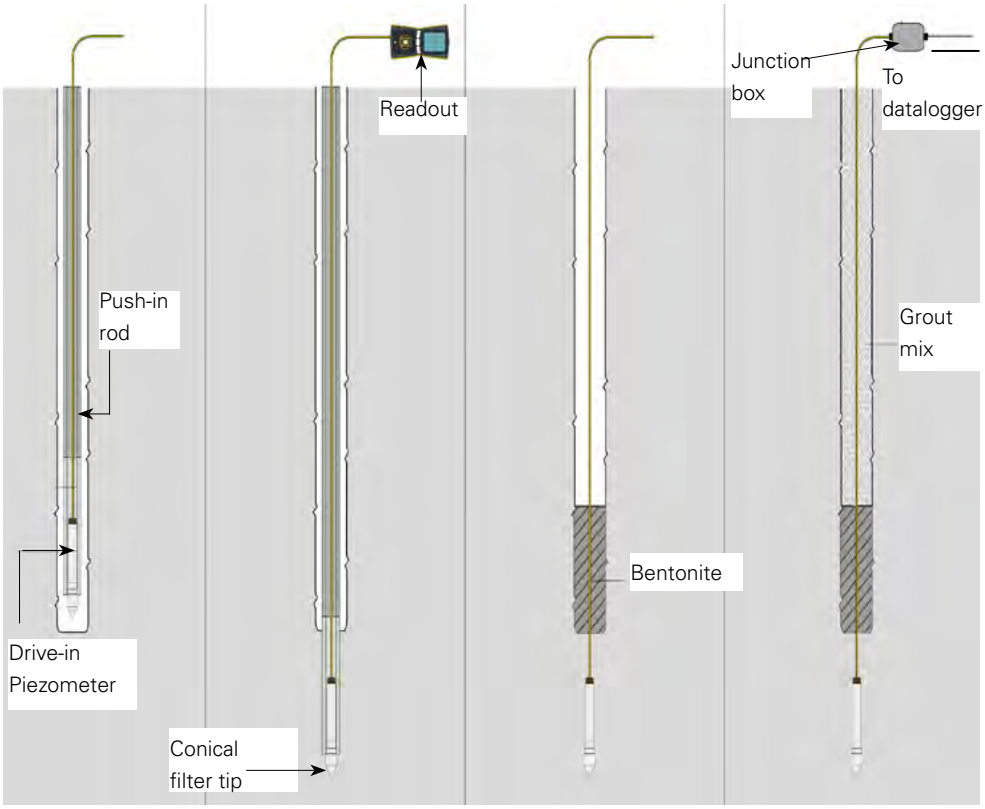



- Before, through and after the installation check the piezometer
- Dig a trench of ca. 50 cm. width and 30-40 cm. deep.
- Saturate the piezometer as previously described.
- For installation in coarse material insert the piezometer in a geotextile bag filled with sand.
- If the piezometer has an HAE filter and must 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 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 5-10 cm layers of fine material and compact by hands.
- Arrange some bentonite pellets in regular intervals along the cable, in order to avoid water leaks and compact manually.
- Mark the 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.

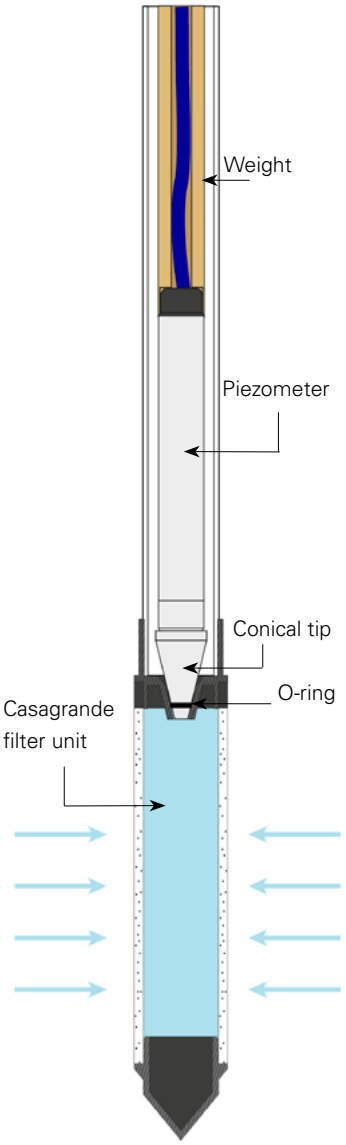
To install proceed as follows (please check also the following picture for reference):




- 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 the 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**

Please proceed as follows (check the picture for reference):

- 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 has double tube, you must lower, in the ½ " tube, the steel rods with conic cap and O-Ring, using the steel wire.

**Grouting Mix**

Grouting mix, for common practice water/cement/bentonite, depends from many factors related to the application and soil condition.
For this reason is not possible to fix a unique ratio mix.
As general recommendation, the grout should reply the soil properties of strength and permeability.
Only as indicative example, following a table with ratio mix for different soil suggested by Mikkelsen/Green - FMGM 2003.

| Hard and Medium Soil | | |
|---|---|---|
| Materials | Weight (kg) | Ratio by Weight |
| Water | 125 | 2.5 |
| Cement | 50 | 1 |
| Bentonite | ~15 | 0.3 |
| The 28 days compressive strength is about 345 kPa. The modulus is about 69 MPa | | |

| Soft Soil | | |
|---|---|---|
| Materials | Weight (kg) | Ratio by Weight |
| Water | 330 | 6.6 |
| Cement | 50 | 1 |
| Bentonite | ~20 | 0.4 |
| The 28 days compressive strength is about 27.6 kPa. | | |

The mix should be made according to the following advices:

- Use mixer, pump and tremie pipe adequate to the mix.
- Add carefully bentonite to the water first in order to avoid that cement PH stops the bentonite expansion.
- Let bentonite to hydrate for 10/30 minutes (using pre-activated bentonite); the consistency should be similar to yogurth.
- Prepare a mix of water and cement until obtain homogenous mix. To avoid lumps use a sieve.
- Add hydrated bentonite to water/cement mix.
- Another common way to make grout is to mix cement with water first and then add bentonite. in this case the ratio water/cement is known and the strenght is predictable.
- Bentonite could be added according to the equipment available until is reached the suitable consistency. the final amount of bentonite could change according to the kind and model used.

## TAKING MEASUREMENTS

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

| | | |
|---|---|---|
| Resistive piezometers<br><br>Signal 4-20mA current loop | Red | + Loop |
| | Black | - Loop |
| | Shield | Shield |

| | | |
|---|---|---|
| Vibrating wire piezometers (VW) | Red | VW |
| | Black | VW |
| | White | Thermistor |
| | Green | Thermistor |
| | Shield | Shield |

For the multipoint piezometers
From 1 to 4 piezometers using a multicore cable code 0WE1160000:

| | VW | VW | Thermistor | Thermistor |
|---|---|---|---|---|
| P1 | Brown | White/Brown | Green | White/Green |
| P2 | Yellow | White/Yellow | Grey | White/Grey |
| P3 | Blue | White/Blue | Rose | White/Rose |
| P4 | Red | White/Red | Black | White/Black |

From 5 to 8 piezometers using a multicore cable code 0WE1320000:

| | 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 |

Notes:
- Use the shield for a correct ground.
- Do not split the conductors to avoid confusion with the colors.
- To obtain reliable measures, with mA piezometers, we recommend a warm up time not less than 10 seconds.

## DATA MANAGEMENT

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

Using Linear factor $\quad L_{eng} = (L_i - L_0) / S$

Using Polynomial factor $\quad L_{eng} = (L_{el}^2 \times A) + (L_{el} \times B) + C$

$L_{eng}$ = Engineering unit
$L_{el}$ = Electric unit
S = linear sensitivity factor
A, B, C, = polynomial conversion factors

S, A, B, C, are stated on Calibration Report.

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

$$\Delta P = L_i - L_0$$

P = Pressure
$L_0$ = Zero reading
$L_i$ = Excercise reading

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

Example

VW Piezometer 700 kPa (digit readings)
S = -4.9128 digit/kPa
A = -5.222e-07 kPa/(digit)$^2$ ; B = -1.955e-01 [kPa/digit] ; C =1.886e+03 [kPa]
$L_0$ = 7357digit ; $L_1$ = 6667digit

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

To have more precise absolute value, we suggest to use a "C" factor calculated on site instead the "C" reported into Calibration Report using the following formula:

$C = -A \cdot [digit]^2 - B \cdot [digit]$

where digit is the reading of the piezometer on site before installation.

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:

$$P_T = (T_i - T_0)\, Kt$$

where:
$P_T$ = correct pressure
$T_i$ = excercise temperature;
$T_0$ = zero temperature;
Kt = temperature factor (can be found on the piezometer calibration report)
Add the obtained correction to the pressure value found with the previous formula.

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

Example
K= 0.154344kPa/°C
$T_i$=28°C ; $T_0$=15°C
$P_T$=(28-15) x 0.154344 = 2.006kPa
$P_{tot}$ = 139.95+2.006 = 141.956kPa

## TROUBLESHOOTING

Considering its special application, any 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 badly 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. 88Ω/km. | Repair the cable. Cable splicing kit available at Sisgeo. |
| | Wiring not connect | 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 SERVICE

After-sales assistance for calibrations, maintenance and repairs, is performed by SISGEO's service department.
The authorization for shipment shall be activated by RMA "Return Manufacturer Authorization". Create your account and then fill in the RMA module you can find on:

*http://www.sisgeo.com/assistance.html*

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 correct delivery documentation:

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

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

# 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= 1.4051x10-3 (coefficents calculated over the -50° to +70°C span)
B= 2.369x10-4
C=1.019x10-7

| 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 |