# INSTRUCTION MANUAL

## VIBRATING WIRE PIEZOMETER

## Model PW





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E1100D-140407

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# 1 APPLICATIONS

The PW series vibrating wire piezometer is designed to measure pore water or other fluid pressures. It is used to monitor engineering works such as hydraulic structures (dams, embankments, landfill dikes), foundations, retaining walls, excavations, tunnels, etc.

The vibrating wire technology used inside the PW piezometer provides the necessary ruggedness, reliability, stability and ease of remote monitoring.

# 2 PRODUCT

## 2.1 GENERAL DESCRIPTION

The PW piezometer is made from a rigid cylindrical body, enclosing the sensing element. The latter consists in a thin flexible diaphragm where a steel wire is attached. All parts of the sensor other than the wire are machined from a high-grade stainless steel, selected for its high yield and corrosion resistance.

A standard internal thermistor allows the measurement of the temperature. The PW piezometer is also fitted with a surge protector and resists electrical and radio frequency interferences as determined by tests compliant to IEEE and to CEI specifications.

The transducer is fitted with several protections against water intrusion: watertight connector, potting, watertight feed through header, and o-rings.

## 2.2 DESCRIPTION DETAILS AND SPECIFIC USES

Although the principle of all PW series piezometers is the same, there are some important differences in their designs to fit with their specific applications.

Moreover, at section 2.2.5 of this manual, you will find the vibrating wire multi-level piezometer, which is perfect for measuring pore water pressures at various depths beneath a single surface location. The time proven design of the PW series sensors allows them to be tied to the multi-level piezometer's core cable. For more information about the specifications of the multi-level piezometer, please read the datasheet.

### 2.2.1 MODELS PWS AND PWC

The PWS piezometer is designed to be embedded in earth fills and concrete, or inserted into boreholes and pipes as small as 19 mm (¾").

It consists of a small diameter cylindrical housing containing a pressure transducer and a thermistor. The cable output is protected by a cable gland and sealed with an epoxy compound.

A filter can be set in the front end of the housing and sealed with an o-ring. With the filter in place, the diaphragm is protected from solid particles, and senses only the fluid pressure to be measured. The filter housing is easily removable for calibration and saturation. It can also be replaced with a pipe-threaded adapter to use the gage as a pressure transducer (PWC Model).

**Figure 1: Model PWS piezometer**

### 2.2.2 MODEL PWF

The PWF piezometer is a thick walled version of the PWS piezometer for use in direct burial applications. Similar to the PWS model, a pipe-threaded adapter or a filter can be set in the front end of its housing.

### 2.2.3 MODEL PWP

The PWP piezometer is designed for driving into unconsolidated fine grain materials such as sand, silt or clay.

The external housing is a thick walled cylinder fitted with a conical head at one end, and a male-threaded adapter at the cable entry, fitting "EW" standard drill rods. Four portholes above the head hold stainless steel filters. The cable passes through the threaded end, and may be fed through push rods leading to the surface. The cable entry is sealed with a cable gland and an epoxy compound to avoid any water infiltration into the piezometer.

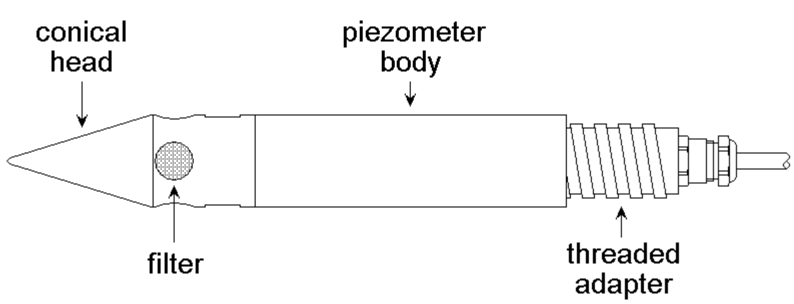



**Figure 2: Model PWP piezometer**

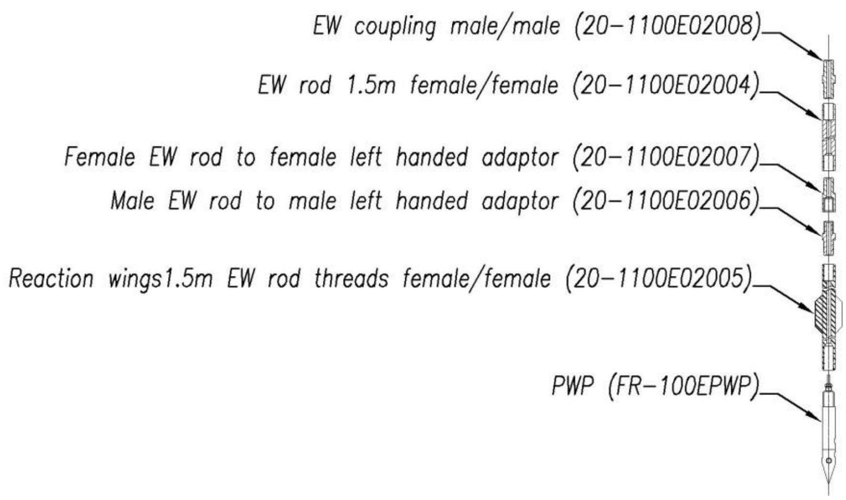


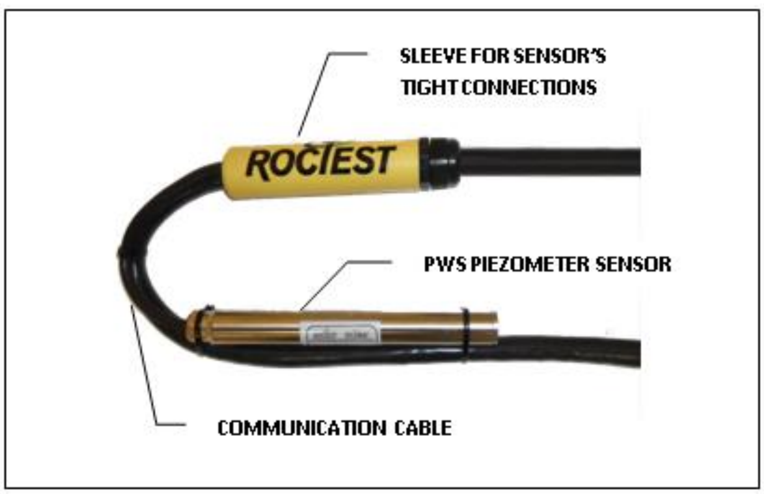

**Figure 2A: Model PWP piezometer with drive train retrieval option**

### 2.2.4 MODEL PWL

The PWL piezometer is a low pressure sensor. Similar to the PWS model, a pipe-threaded adapter or a filter can be set in the front end of its housing.

### 2.2.5 MULTI-LEVEL PIEZOMETER

The multi-level piezometer provides significant advantages in terms of time, resources and cost reduction related to installation, while providing quick and reliable reading at various depths.




Moreover, the multi-level piezometer allows the customer to define sensor spacing along the reading cable, providing precise depth control based on site specific requirements. Junctions between each piezometer and the main cable are reinforced using epoxy resin for a waterproof and durable seal. Additional information about installation is available in section 3.5.4.

### 2.2.6 FILTER TYPES

Two types of filters are available: high air entry ceramic or low air entry sintered stainless steel filters.

The table below summarizes the main differences between the two filter models.

| ***Stainless steel filter***<br>*low air pressure entry*<br>*pore diameter: ~50 µm* | ***Ceramic filter***<br>*high air pressure entry*<br>*pore diameter: ~1 µm* |
|---|---|
| Filter generally used. | Filter usually installed for use in unsaturated fine grain material. |
| Does not allow suction measurements.<br>If water level drops below the piezometer and that a suction builds up, the filter can de-saturate. But as soon as the water level comes up, it will re-saturate easily. | Allow measuring suction to -100 kPa.<br>If negative pressure is more important, the filter will de-saturate and readings will become incorrect. |
| Air entry pressure: ~10 kPa | Air entry pressure: ~450 kPa |
| Small time lag. | More important time lag. |
| Easy to saturate and install. | Need to be saturated under vacuum. |
| Allows fine grain infiltration. | Helps prevent fine grain infiltration. |

**Table 1: Differences between filter models**

Saturation of the filter is necessary to ensure hydraulic continuity between the piezometer diaphragm and the pore water in unsaturated soils. It reduces the possibility of filter clogging and also decreases response time.

## 2.3 OPERATION PRINCIPLE

The sensing element of the pressure transducer is a piano wire attached to a diaphragm. The latter is in contact with the fluid around, and a pressure variation changes the diaphragm position, affecting the wire tension. The tension is directly proportional to the square of the resonant or natural frequency of the wire.

In operation, plucking voltages are applied to a coil and a magnet located near the wire in a spectrum of frequencies, spanning the natural wire frequency, thus forcing the wire into vibration. The oscillation of the wire generates a voltage in the coil. This signal is amplified by the readout unit, which also discriminates against harmonic frequencies, to determine the resonant frequency of the wire.

The relationship between the period $N$ and the strain $\varepsilon$ in the vibrating wire is expressed by the following equation:

$$\varepsilon = K \cdot \frac{10^9}{N^2}$$

where $\varepsilon$ = strain in micro-strain

$N$ = vibration period in microseconds

$K$ = gauge constant, specific for each type of gauge

The vibrating wire technology offers the unique advantage of a frequency output signal virtually unaffected by line impedance, or contact resistance. Cable length of several kilometres can be used without signal deterioration.

A portable unit as the MB-3TL (or MB-6T(L)) can be used to read vibrating wire sensors. It proceeds to all necessary operations: wire excitation, signal conditioning and reading display. Please contact the Roctest Group for further information.

### 2.4 CALIBRATION

A calibration sheet is supplied with each sensor. It enables conversion of gross readings into pressure values and temperature correction.

All the sensors are individually calibrated over their working range before shipment. The calibration factors and the thermal coefficient are established by running the calibration data points through a linear or polynomial regression formula.

During the calibration process, the sensors undergo a mechanical cycling and are tested at 40°C.

## 3 INSTALLATION PROCEDURE

### 3.1 PRE-INSTALLATION ACCEPTANCE READING

Reading of all instruments should be taken as the piezometers are received to ensure they have not been damaged during shipment or handling on site.

Take a reading in linear units with the piezometer in air, without any filter and in the same position in which it is to be installed. Then compare it with the factory reading shown on the calibration sheet. The difference should not be more than twenty linear units. It can come from hits or vibrations during the shipment and/or from the fact that temperature and barometric pressure on site are certainly different than those at the factory, during calibration process. However, this has no effect on the linearity of the sensor.

Take a reading of the temperature gauge as well, to make sure the thermistor is working properly.

For details about how to take readings or how to convert frequency into linear units, please refer to section 4 (Reading Procedure).

## 3.2 FILTER INSTALLATION

### 3.2.1 LOW AIR ENTRY SINTERED STAINLESS STEEL FILTER

The filter is shipped already mounted on the piezometer body. It should be removed by holding the piezometer in one hand, pulling, and twisting the filter housing with the other hand.

*Note: The filter on a PWP piezometer is removed by unscrewing the conical head.*

Immerse the filter and the piezometer pointing upwards in clean water for approximately fifteen minutes. De-aired water can be used (water may be de-aired by boiling it for a few minutes or by applying a vacuum). Tap piezometer housing lightly to remove any air bubbles present.

Reassemble the filter working underwater. For lower pressure range transducers, while pushing on the filter assembly, check the readings on the readout unit to avoid pressure variations that exceed the piezometer range, which can damage the sensor.

As soon as the filter is saturated, it must stay submerged until installation.

### 3.2.2 HIGH AIR ENTRY CERAMIC FILTER

The filter is delivered cased in a metallic housing and pre-saturated in water. Final installation must be carried out under water to avoid any air intrusion.

- Connect the piezometer to a readout unit.
- Put the piezometer upside-down in a container filled with clean water. The piezometer tip should be up and completely submerged.
- With the piezometer submerged, firmly grasp the housing with both hands and push the filter assembly into its tip. Gradually increase the pushing force using thumbs until it is fully inserted. This step may take a while to be completed.

  Some resistance will be met; it is normal and due to the small porosity of the ceramic filter. While pushing on the filter assembly, check the readings on the readout unit to avoid excessive pressure variations that could damage the piezometer. Refer to the calibration sheet for pressure range.
- The filter installation is now completed.
- Keep the piezometer underwater for at least 24 hours before proceeding with field installation. This will allow the pressure induced by the filter installation to

decrease. When ready to be installed, the piezometer reading should be close to the one of acceptance test with the filter removed (see details in section 3.3).

## 3.3 INITIAL READING

Before installing the piezometer in its final location on site, an initial reading has to be taken to correctly convert readings in linear units into pressure measurements when the piezometer is in operation. This process is also necessary to be able to apply later temperature and barometric corrections.

Leave the instrument in water for two or three hours to let the temperature stabilize. It is preferable to leave it overnight, provided that arrangements are made to keep the water at more or less uniform temperature. All sudden changes of temperature and direct exposure to the sun must be avoided.

With the water temperature, ambient temperature and piezometer temperature in equilibrium, raise the piezometer by the electrical cable until it is out of the water but two centimetres. Take three successive readings to ensure a stable value and record it. This is the initial reading (called $L_0$). Record ambient temperature ($T_0$) and barometric pressure ($S_0$).

Compare readings in linear units before and after the filter installation. They should be similar. A small difference on raw readings comes from the fact that temperature and barometric pressure may have changed in the meantime. A difference of more than ten linear units may be a sign that the filter is not correctly saturated or that the pressure induced during its installation is not dissipated yet.

For details about how to take readings or how to convert frequency into linear units, please refer to section 4 (Reading Procedure).

A special calculation has to be done if using the polynomial relation to convert raw readings into pressure measurements. The coefficient $C'$ of the calibration sheet must be calculated because it depends on temperature and barometric pressure on site, which are different from those in factory. Use the following relation:

$$C' = -AL_0^2 - BL_0$$

where: $C'$ = new calibration factor in kilopascal

$A$, $B$ = calibration factors (see calibration sheet)

$L_0$ = initial reading in linear unit

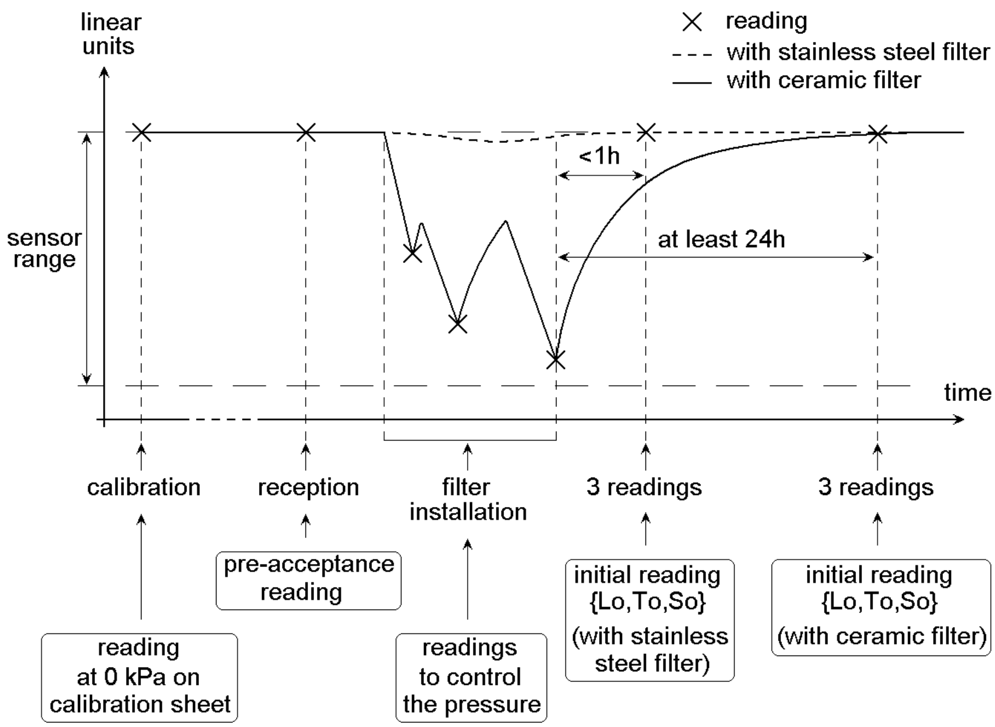



**Figure 3: Summary of the different readings**

*Note: It is not necessary to apply corrections to pressure calculation at that moment, but it is important to record both temperature and barometric pressure.*

## 3.4 ON-SITE CALIBRATION CHECK (OPTIONAL)

The best method for an on-site calibration check consists in proceeding as follow:

1. Attach the PWS and cable to a graduated tape
2. Remove the filter from the PWS
3. Lower the PWS near to the bottom of a standpipe or borehole filled with water
4. Allow 15-20 min for the piezometer to come to thermal equilibrium
5. Raise PWS by known depth increments and take pressure reading at each depth increment
6. Calculate the in-situ calibration factor and compare to the calibration factor on the calibration sheet. They should agree within +/- 1%. Repeat test if necessary.

Note that this verification is not as accurate as a calibration and it can be affected by the following:

- Density of water sometime is not 1 g/cc (e.g. in saline or turbid water).
- Also, in small diameter pipe/borehole, water level will change when raising the PWS.
- The gradient of temperature can be significant in a borehole, which will affect readings

## 3.5 SENSOR INSTALLATION

Vibrating wire piezometers are installed in various ways to suit each individual application. Specific guidelines for the piezometer installation have been set by various agencies and specialists. Standard methods are explained below.

### 3.5.1 INSTALLATION IN FILL

#### 3.5.1.1 COMPACTED CLAY

Excavate a trench or recess about 30 cm deep. Drive a cylindrical hole in the sidewall of the trench. The diameter hole should be slightly smaller than the piezometer's body.

To make sure the filter is in direct contact with the host material to get a good continuity with the saturated high air entry filter and the pore water, smear the filter with a thin paste of the saturated material. Push the piezometer into the side of the borehole.

Before backfilling, the cable must be laid with the utmost care. Loop the cable around the recess; make sure it rests on a bed of hand placed and compacted screened clay.

Make sure the cable does not cross over itself or other cables in the same area. Keep the cables apart.

Backfill the recess with screened clay containing no particles larger than 2.5 mm of diameter. The backfill should have a water content and density as the surrounding material.

Make sure the cable is protected from potential damages caused by angular material, compacting equipment or stretching due to subsequent deformations during construction or fill placement.

#### 3.5.1.2 GRANULAR MATERIALS

Install the piezometer as described above in a recess excavated for this purpose. Place the piezometer within the trench, loop cable and backfill with screened material containing the same moisture content and compacted to the same density as the surrounding fill.

In rock fill, it is necessary to place a graded filter around the piezometer. Use fine grain, clean sand around the instrument and increase the particle size as the backfill proceeds outwards to the rock fill. The sand placed in the recess around the instrument and cable should have a diameter between 0.5 mm and 2.5 mm of diameter.

### 3.5.2 INSTALLATION IN BOREHOLE

The method used to install a piezometer in a borehole depends on the particular conditions in which the installation must be carried out. Artesian conditions, borehole stability, available drilling equipment and sealing material are among the factors that will influence the method chosen. The method described below will cover most applications.

1. Drill the borehole below the required depth at which the piezometer is to be installed. Drive the casing thirty centimeters below the required piezometer elevation. Wash until the water (or biodegradable drilling mud) emerging from the borehole runs clear. This will prevent the backfill materials from sticking to and plugging the casing.

2. Raise the casing fifteen centimeters and pour sand below its bottom. Repeat the operation once and lower the piezometer to the top of the sand. Check the borehole depth after each operation.

3. While holding the instrument in place, repeat step 2 until thirty centimeters of sand are placed above the piezometer.

4. Raise the casing fifteen centimeters and pour compressed dry bentonite below its bottom. Repeat the operation until a seal of at least 1.2 m is in place. When pouring bentonite, keep the cable taut to prevent the bentonite from hooking up in the casing. Pour the bentonite slowly in the hole to avoid bridging. A brush or a thirty centimetre layer road salt can be used to unplug a blocked hole. Check the borehole depth after each operation.

5. Wait for the bentonite to set up. Two hours are generally enough. Refer to supplier's instructions for exact time. Keep the borehole filled with water. This will prevent the bentonite of drawing water from surrounding soil during its setting.

6. If only one piezometer is to be installed in the hole, backfill the casing with a bentonite/cement grout.

   If more than one piezometer is to be installed in the borehole, backfill with a bentonite/cement grout to an elevation of a meter and a half below the second piezometer. Then use 1.2 m of bentonite. Repeat operations 1 to 5 for the second piezometer. When all instruments are installed, backfill with a bentonite/cement grout.

7. Pull the casing without rotating it during removal. Top off the borehole with grout.

If the deepest piezometer has for purpose to measure the pore water pressure in a specific horizon, it is necessary to drive the casing below the instrument and set a 1.2 m bentonite seal at the bottom of the borehole. Pull the casing as the bentonite is set in place. Proceed by stages of fifteen centimeters. Be very careful not to plug or allow bentonite to stick to the inside walls of the casing. This is accomplished by making sure the bentonite level is at all times below the casing and by slowly dropping bentonite in single file down the hole. Trying to feed bentonite too rapidly will result in bridging in the casing or borehole. Tamping of compressed bentonite is not required. Prior to setting the sand in place, lower a cylindrical weight down the borehole to ensure that it is clear from any obstructions and, if necessary, rinse the borehole until clear water emerges.

*Note: It is also possible to place the piezometer into a sand filled canvas bag. The bag then acts as a sand filled intake zone.*

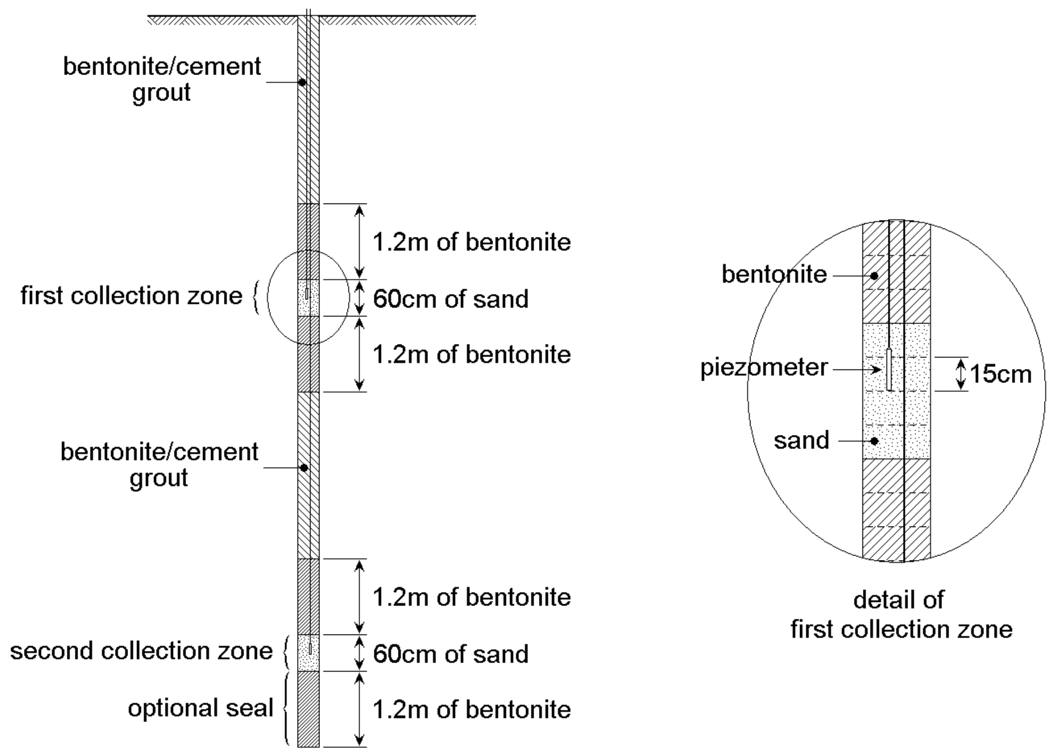



**Figure 4: Typical installation of piezometers in a borehole**

Note that an alternate way to install piezometers in boreholes is to fill the entire borehole with grout after having lowered the instruments. This method, known as the Fully Grouted Borehole Installation, is peculiar in that:

- Piezometers are installed with filter end upward.
- Proper care must be taken for preparing a grout mix that will mimic as well as possible the stiffness and permeability of the surrounding ground. This is achieved by selecting the proper water-cement ratio. Mixtures shown in the table below can be used as a starting point. The cement and water are mixed first. When proper ratio is reached, bentonite powder is slowly added until as heavy as feasible to pump.

| Suggested Grout Mixes | | | | | |
|---|---|---|---|---|---|
| **Material** | **Ratio by weight** | **Soil Hardness** | **Material** | **Ratio by weight** | **Soil Hardness** |
| Portland Cement | 1 | Hard to Medium | Portland Cement | 1 | Soft |
| Bentonite | 0.3 | Hard to Medium | Bentonite | 0.4 | Soft |
| Water | 2.5 | Hard to Medium | Water | 6.6 | Soft |

For more information about this method, please contact Roctest.

### 3.5.3 PIEZOMETERS DRIVEN IN SOFT GROUND

The PWP model is designed to be pushed into place from the surface in soft materials. For deeper installations where driving from the surface is impossible, the piezometer may be pushed into place from the bottom of a pre-drilled borehole.

The PWP model piezometer comes fitted with a male EW rod thread that screws directly onto EW rod.

The rods must form an effective seal above the piezometer. Should other rods be adapted to push the piezometer in place, it is important that the diameter of the first 1.2 m to 1.5 m of rod remains larger than the outside diameter of the piezometer housing. The first step of the installation is to lay a sufficient number of rods side by side, alternating a male thread beside a female thread.

The piezometer cable is threaded through the rods, leaving about a fifty centimeter loop of cable laying flat on the ground each time the cable emerges from one rod and enters a subsequent rod. Let about seven meters of free cable extends beyond the lower extremity of the first rod. This should provide sufficient slack to allow easy manipulation of the rods as they are screwed together and pushed in place.

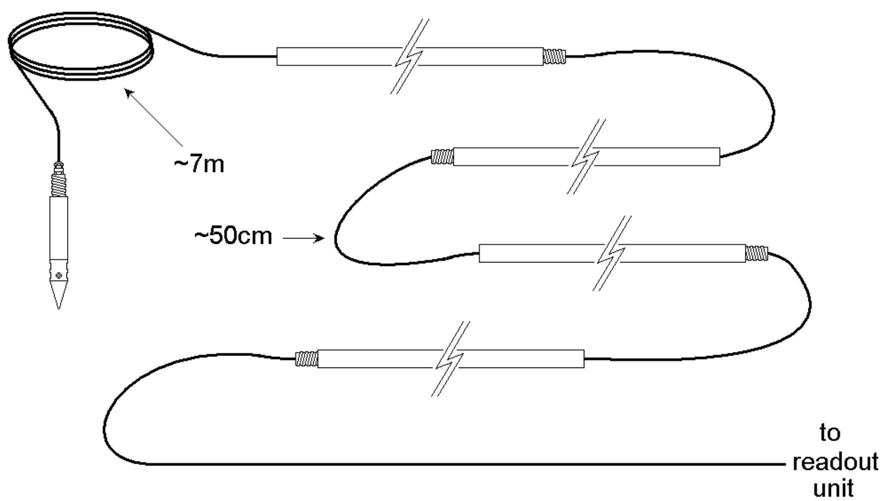



**Figure 5: Preparation before PWP installation**

Screw the lower rod onto the piezometer. Use a pipe-sealing compound on the threads to form a permanent seal, preventing pore water from flowing into the rod string, causing corresponding pressure drops.

Push the piezometer in place and monitor any pressure build-up at the tip. Should the pressure exceed the working pressure range, stop the driving and wait until the pressure dissipates.

It is necessary in soils with high salt content to use a nylon bushing between the piezometer and the push rods to prevent apparent pore water pressure increases caused by hydrogen gas generation due to galvanic corrosion, or pressure increases caused by any electro-osmotic effect on the pore water.

### 3.5.4 INSTALLATION OF A MULTI-LEVEL PIEZOMETER

The installation of a multi-level piezometer is quick and reliable since multiple piezometers are connected to a single communication cable, which is in turn connected to the data acquisition system (SENSLOG) or readout (MB-3TL or MB-6T(L)).

A typical installation of the multi-level piezometer uses a direct grouting installation so that only the multi-level piezometer string and a grout injection tube are required to complete the installation. Once the grout has hardened, the piezometers are isolated from one another, allowing precise measurements of pore water pressure changes at various depths.

## 3.6 DATUM READING

Due to the operations during the installation of the instruments, the pore water pressure may take time to come back to its natural state. This can take a few hours to a few days, depending of the soil permeability. After installation, take readings periodically to determine a correct datum reading. It is obtained when readings become stable over a period of a few days.

## 3.7 CABLE INSTALLATION

### 3.7.1 CABLE IDENTIFICATION

The signal coming from the sensor is transmitted through an electrical cable, which is generally supplied in rolls. The serial number is stamped on a tag that is fastened to the readout end of the cable. It is very important to clearly identify the instrument for wiring or reading purposes. If the sensor cable has to be cut or if the cable end is inaccessible, make sure to be able to identify it (by marking its serial number with a permanent marker or using a color code). If there are a lot of risks of cuts, the cable should be marked using metal tags at regular intervals along its entire length.

### 3.7.2 GENERALITIES ABOUT CABLE ROUTING

Route the cable towards the junction or switching panel. Make sure the cable is protected from cuts or abrasion, potential damages caused by angular material, compacting equipment or stretching due to subsequent deformations during construction or fill placement.

In embankments, cables may be embedded in fine embankment materials such as sand. A typical installation consists of positioning a series of cables between two 10 cm layers of embankment materials in a trench. Installation of cables to be embedded in concrete involves positioning and immobilizing the cables in such a way that damage during concrete placement and vibration is minimized.

Surface installations require continuous surveillance and protection from the earth moving equipment circulating on the field.

If necessary, run the cable through rigid or flexible ducts to the terminal location, but be careful of water seepage. To provide protection for cable running over concrete lifts, hand-placed concrete is sometimes used, depending on site conditions.

During cable routing, read the instruments at regular intervals to ensure a continued proper functioning.

Make sure the cable does not cross over itself or other cables in the same area.

Record the cable routing with care and transfer this routing to the drawings.

### 3.7.3 HORIZONTAL CABLE RUNS

Some of the more important considerations that must be given to horizontal cable runs are:

- Never excavate a trench straight through the clay core of a dam.
- Avoid crossing transition zones where large differential settlements could create excessive strain in the cable.
- Avoid cable splices. If necessary, refer to paragraph section 3.8 ( Splices).
- Do not lay cables one on top of the other.
- Use horizontal snaking or vertical snaking of the cable within the trenches. For most materials, a 2 m pitch with an amplitude of 40 cm is suitable. In very wet clays, decrease the pitch to 1 m. It enhances the elongation capability of the electrical cable.
- Use a combination of horizontal and vertical snaking at transition zones.

In rock filled dams with earth filled cores, it is frequently convenient to install cables in trenches located in the core and fine filter zones, or on ramps in the coarse filter and compacted rock filled shell zones. Individual cables should be spaced not less than 2 cm apart, and no cable should be closer than 15 cm to the edge of the prepared layer. In instances in which cables must be placed in a given array, the cables should be separated from each other by a vertical interval of not less than 15 cm of selected fine embankment material.

During the backfill of trenches in earth dams, a plug, approximately 60 cm wide, made of a mixture of 5% bentonite (by volume) from an approved source and exhibiting a free swell factor of approximately 60%, and 95% embankment material, can be placed in the trenches at intervals of not greater than 7.5 m. The bentonite plugs reduce the possibility of water seepage through the embankment core along the backfilled trenches.

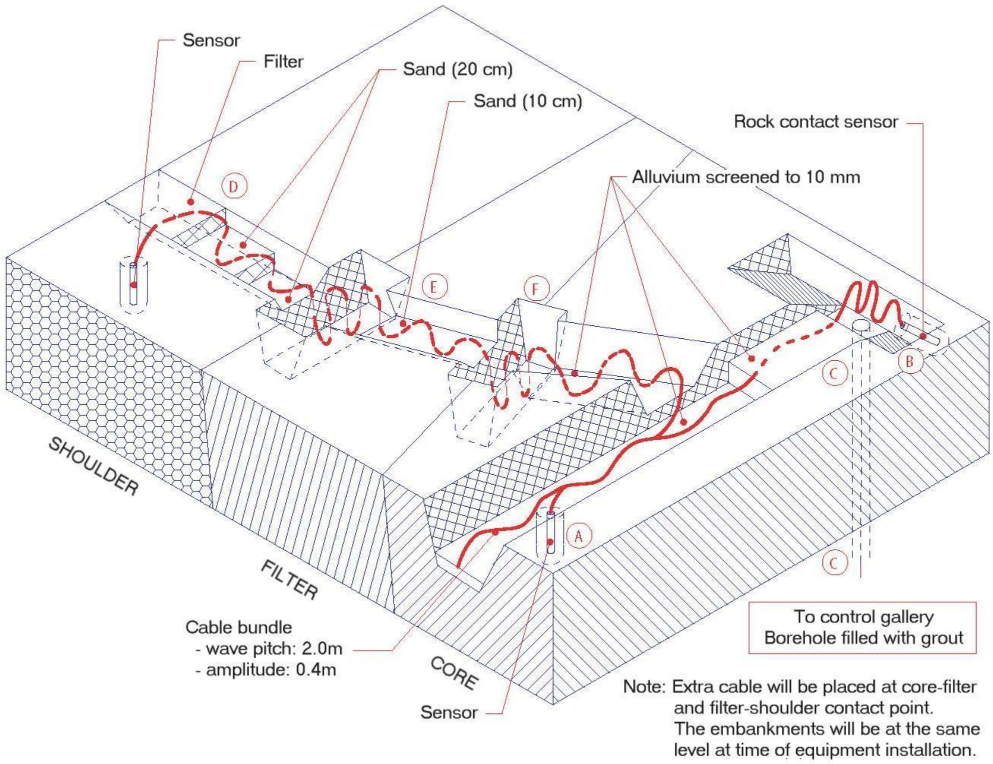



**Figure 6: General view of horizontal cable routing**

### 3.7.4 VERTICAL CABLE RUNS

The procedure shown below is an efficient and safe way to route cables from the sensor to the top of the embankment or of the dam.

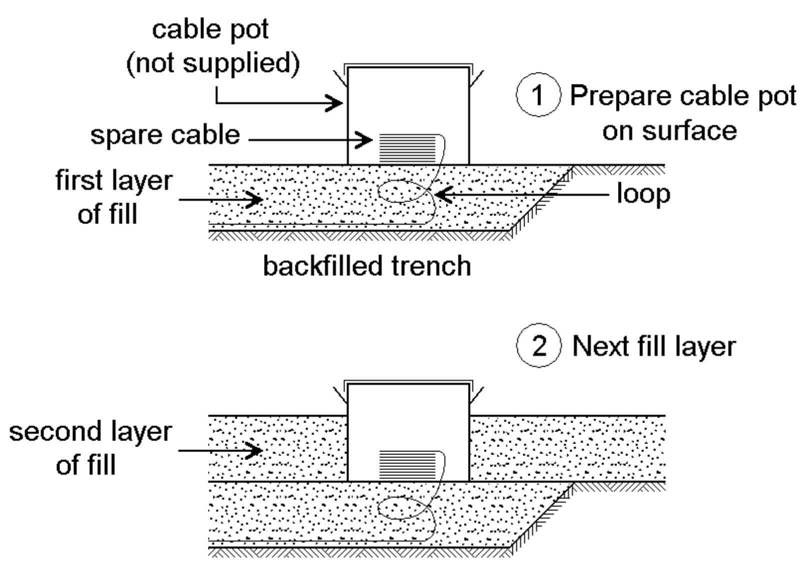



**Figure 7: Procedure to route cables vertically**

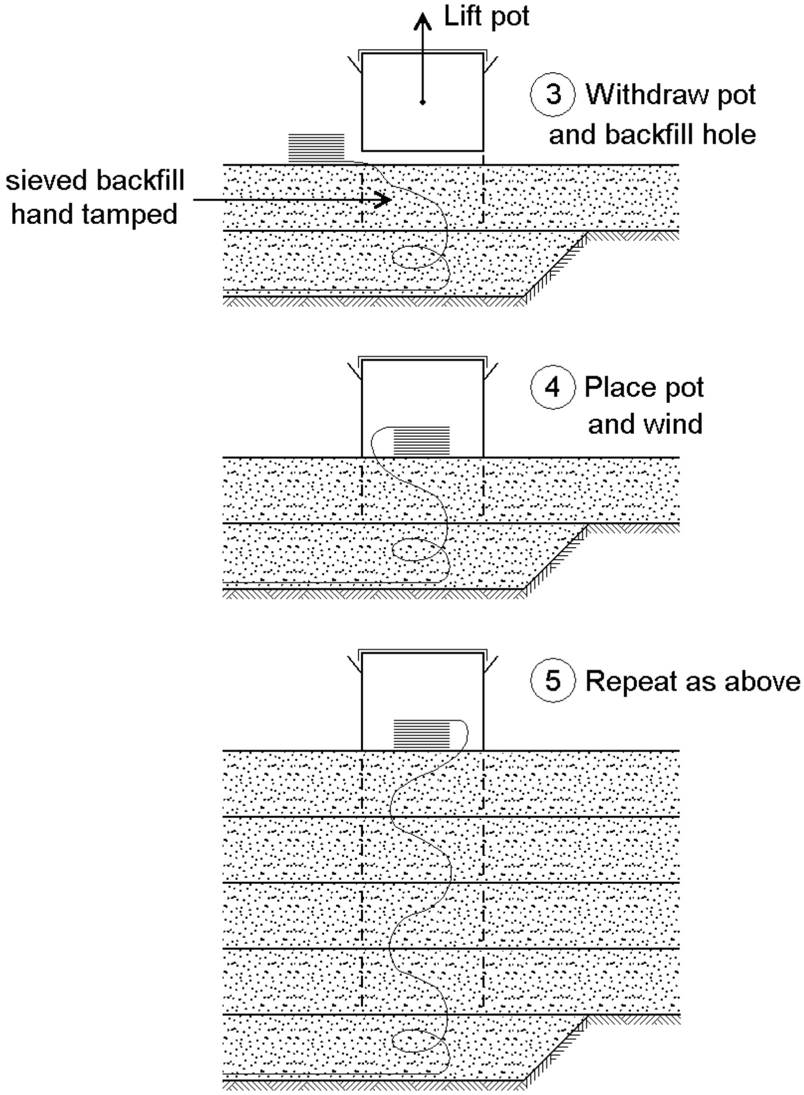



**Figure 7: Procedure to route cables vertically (continued)**

## 3.8 SPLICES

Generally, cable splices are to be avoided. If necessary, use only the manufacturer's approved standard or high-pressure splice kit. Splicing instructions are included with the splice kit.

Should the cable be cut, we recommend the use of our high pressure cable splice kits, especially if the splice is located underwater.

Because of the vibrating wire technology the sensor uses, the output signal is a frequency, not affected by the impedance of the cable. Therefore, splices have no effect on the quality of the readings.

Furthermore, in special cases on site (large distance between sensors, chain of instruments, readout position for example), splices are useful to limit the number of cables to lay. Actually, individual sensor cables can be merged into a multi-conductor cable using a splice or junction box.

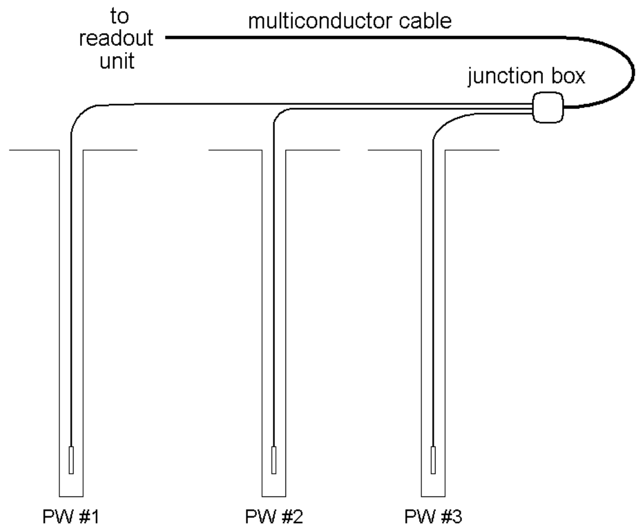



**Figure 8: Example of junction box use**

Please contact the Roctest Group for additional information about junction boxes and splice kits.

## 3.9 CABLE WIRING

Before cutting a cable, make sure of its identification. If a cable has to be cut to be connected to a junction box for example, cut it in such way to have enough length to obtain a correct installation (functional and aesthetic).

Strip back the conductor insulation by about 1 cm. If possible, tin the exposed conductors with a solder.

## 3.10 LIGHTNING PROTECTION

At all times during the installation, any cable that is exposed to potential damage by lightning must be protected.

A large grounded metal cage placed over the cable bundle, combined with direct grounding of all leads and shields is an effective way to prevent lightning damage to the instruments and cables during the installation process.

A surge and over voltage protection is included inside the body of the piezometer. It protects the vibrating wire and not the temperature sensor. It consists of a double gas tube surge arrestor.

Please contact the Roctest Group for additional information on protecting instruments, junction boxes and data logging systems against power surges, transients and electromagnetic pulses.

All junction boxes and data logging systems furnished by Roctest Group are available with lightning protection.

# 4 READING PROCEDURE

## 4.1 GENERALITIES

Readings can be taken manually with a portable readout unit model MB-3TL (or MB-6T(L)), or automatically when connected to a SENSLOG data acquisition system.

Each vibrating wire piezometer is equipped with a 3kΩ thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Therefore, the temperature can also be read using an ohmmeter.

Manual readings of pressure and temperature of a piezometer can be taken either directly on the cable end or through a switching panel using the MB-3TL (or MB-6T(L)) readout unit.

To facilitate reading a cluster of piezometers, the lead wires from each individual instrument can be connected to a switching panel. The wiring instructions for connecting the piezometers to the wiring block with the junction box are included in the junction/switchbox manual.

## 4.2 TAKING MEASUREMENTS

The MB-3TL (or MB-6T(L)) readout unit is supplied with a junction cable fitted with a mating female connector at one end and a set of four color coded alligator clips at the other. The conductor's insulation is color coded to match that of the alligator clips and the instrument cable conductors' insulation jacket.

Connect the alligator clips to the gage lead wire according to the table below.

| | **Connections** | | | | |
|---|---|---|---|---|---|
| **Cable** | Wire High (red) | Wire Low (black) | Temp. High (white) | Temp. Low / Shield (green) | |
| IRC-41A(P) | red | black | white | green | shield |

**Table 2: Wiring code for electrical cables**

Select proper setting of the readout for reading PW piezometer. Refer to the readout instruction manual.

Record LINEAR units and temperature readings as they appear on the display.

Physically, the NORMAL reading is the vibration period in µs of the wire (called $N$) and the LINEAR reading is proportional to the wire strain (called LU or $\varepsilon$).

**The jumper cables should never be short-circuited when they are connected to the readout unit front panel.**

### 4.3 QUICK VERIFICATION OF MEASUREMENTS

On-site, even before converting raw readings into engineering values, several checks can be done to prevent a bad measurement.

- Compare readings to previous ones. Are they in the same range? Are they changing slowly or abruptly? Consider external factors that can affect the measurements like construction activities, excavations or fills.

- In any case, it is advised to take several readings to confirm the measurement. Then, repeatability can be appreciated and dummy readings erased.

# 5 CONVERSION OF READINGS

### 5.1 PRESSURE VALUE

For the measurement of the pressure, the following equations apply using linear units displayed by the MB-3TL (or MB-6T(L)):

Linear equation: $$P = C_f (L - L_0)$$

where: $P$ = pressure in kilopascal

$C_f$ = calibration factor (see calibration sheet)

$L$ = current reading in linear units (LU)

$L_0$ = initial reading in linear units (LU)

<u>Polynomial equation:</u> $P = A \cdot L^2 + B \cdot L + C'$

where $P$ = pressure in kilopascal
$L$ = current reading in linear units (LU)
$A$, $B$ = calibration factors (see calibration sheet)
$C'$ = calculated constant in kilopascal

Examples:

The calibration sheet gives the following values:

$C_f$ = -3.8444E-01 kPa/LU
$A$ = -4.0179E-06 kPa/LU$^2$
$B$ = -3.6641E-01 kPa/LU

- Use of linear relation:

When the filter was in place, an initial reading was recorded:

$L_0$ = 2 895 LU

The current reading is:

$L$ = 2 455 LU

We get:

$$P = -3.8444 \cdot 10^{-1} \times (2455 - 2895) = 169.2 \text{ kPa}$$

- Use of polynomial relation:

When the filter was in place, an initial reading was recorded:

$L_0$ = 2 895 LU

The coefficient $C'$ has to be calculated: (see chapter 3.3 ( Initial reading))

$$C' = -AL_0^2 - BL_0 = -(-4.0179 \cdot 10^{-6}) \times 2895^2 - (-3.6641 \cdot 10^{-1}) \times 2895 = 1\ 094.4 \text{ kPa}$$

The current reading is:

$L$ = 2 455 LU

We get:

$$P = -4.0179 \cdot 10^{-6} \times 2455^2 + (-3.6641 \cdot 10^{-1}) \times 2455 + 1094.4 = 170.6 \text{ kPa}$$

*Note: Decreasing readings in linear units indicate increasing pressure.*

If the frequency is measured, convert it into linear units using the following equation:

$$L = K\frac{F^2}{1000}$$

where $L$ = reading in linear units

$K$ = gage constant for piezometer = 1.0156

$F$ = frequency in Hz

Example:

With $F$ = 1 625 Hz,

We get: $L = 1.0156 \times \frac{1625^2}{1000} =$ 2 681.8 LU

## 5.2 TEMPERATURE VALUE

Although the MB-3TL (or MB-6T(L)) readout box gives directly the temperature in °C and in °F (with the thermistor selector on position B), it can also be read with an ohmmeter.

To convert the resistance value into temperature reading, please refer to the instruction manual of the TH-T gauge available on our website.

## 5.3 TEMPERATURE AND BAROMETRIC CORRECTIONS

Temperature variations will slightly affect readings. A correction must be applied using formula below.

Standard piezometers are sealed and unvented. Consequently they respond to barometric changes. However this response will vary depending how they are installed. If they are buried or installed in a sealed borehole, it is likely that full effect of the barometric changes will not be felt immediately. It can be significantly attenuated. On the contrary, if the piezometers are installed in a standpipe or a well open to atmosphere, barometric changes will directly be felt. In that case, a systematic barometric correction is recommended following the formula given below. In situations where the effects of barometric changes on measurements are not clear, <u>it is suggested to independently record barometric and piezometric changes and correlate them to arrive at a correction factor.</u>

It is suggested to use a barometer on site for measuring changes in atmospheric pressures. Off-site reports from weather stations are not adequate for that purpose.

Very-low range piezometers are vented i.e. they are designed to eliminate barometric effects. In such case the sensor cavity in the piezometer is connected to atmosphere via a tube integral with the cable. A desiccant is connected to that tube to prevent moisture from infiltrating the piezometer. When the desiccant has turned to light pink, the desiccant must be changed.

Use the following relation to apply corrections:

$$P_c = P - C_T(T - T_0) - (S - S_0)$$

where $P_c$ = corrected pressure in kilopascal
$P$ = pressure previously calculated in kilopascal
$C_T$ = thermal coefficient (see calibration sheet), in kPa/°C
$T$ = current temperature reading in degrees Celsius
$T_0$ = initial temperature reading in degrees Celsius
$S$ = current barometric pressure reading in kilopascal
$S_0$ = initial barometric pressure reading in kilopascal

Example:

Initial reading : $T_0$ = 26.1 °C
$S_0$ = 105.64 kPa
Actual reading : $T$ = 18.5 °C
$S$ = 99.57 kPa

With: $P$ = 169.2 kPa

$C_T$ = -1.0679E-01 kPa/°C,

We get: $P_c = 169.2 - (-1.0679 \cdot 10^{-1}) \times (18.5 - 26.1) - (99.57 - 105.64) =$ 174.5 kPa

Be careful to work all the time with the same units to apply correctly the corrections.

# 6 TROUBLESHOOTING

Maintenance of vibrating wire transducers is required. Periodically check cable connections and terminals. The transducers themselves are sealed and cannot be opened for inspection.

## 6.1 UNSTABLE READING

- Check if the same troubles occur with other instruments. If so, compare cable routes or check the readout unit.
- Is the shield drain wire correctly connected to the readout unit?
- Isolate the readout unit from the ground by placing it on a piece of wood or similar non-conductive material.
- Check the battery of the readout unit.

- Check for nearby sources of electrical noise such as motors, generators, electrical cables or antennas. If they are nearby, shield the cable or move it.

- If a data logger is used to take the readings, are the swept frequency excitation settings well adjusted? Use the calibration sheet and the relation at the end of section 5.1 to verify that the frequency range matches the sensor one.

- The sensor may have gone outside its range. See previous records.

- The sensor body may be shorted to the shield. Check the resistance between the shield drain and the sensor housing. It should be infinite.

- Check the integrity of the cable.

- The sensor may have been damaged by shocks.

## 6.2 NO READING

- Check the battery of the readout unit.

- Check if the same troubles occur with other instruments. If so, the readout unit may be suspected and the factory should be consulted.

- If a datalogger is used to take the readings, are the swept frequency excitation settings well adjusted? Use the calibration sheet and the relation at the end of section 5.1 to verify that the frequency range matches the sensor one.

- The sensor may have gone outside its range. See previous records.

- Check the coil resistance. Nominal coil resistance is 190Ω ± 10Ω, plus cable resistance (22 gage copper = approximately 0.07Ω/m).

    - If the resistance is high or infinite, a cut cable must be suspected.
    - If the resistance is low or near zero, a short must be suspected.
    - If resistances are within the nominal range and no reading is obtained, the transducer is suspect and the factory should be consulted.

- Cuts or shorts are located, the cable may be spliced in accordance with procedures recommended by Roctest Group.

- The sensor may have been damaged by shocks or water may have penetrated inside its body. There is no remedial action.

## 6.3 TEMPERATURE TROUBLES

If troubles occur when reading the temperature, this is likely due to a cable cut or short because of the technology used (simple thermistor). Check the cable and splice it in accordance with recommended procedures.

If furthermore, no reading of pressure is got, water may have penetrated inside the sensor body. There is no remedial action.

## 6.4 OTHER TROUBLES

If pressure variations are suspicious, check if those variations are correlated to recorded temperature and/or barometric pressure. Check if corrections to raw pressure are applied correctly.

# 7 MISCELLANEOUS

## 7.1 ENVIRONMENTAL FACTORS

Since the purpose of 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 behaviour of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to: blasting, rainfall, tidal levels, excavation and fill levels and sequences, traffic, temperature and barometric changes, changes in personnel, nearby construction activities, seasonal changes, etc.

## 7.2 CONVERSION FACTORS

| | To Convert From | To | Multiply By |
|---|---|---|---|
| LENGTH | Microns<br>Millimeters<br>Meters | Inches<br>Inches<br>Feet | 3.94E-05<br>0.0394<br>3.2808 |
| AREA | Square millimeters<br>Square meters | Square inches<br>Square feet | 0.0016<br>10.7643 |
| VOLUME | Cubic centimeters<br>Cubic meters<br>Litres<br>Litres | Cubic inches<br>Cubic feet<br>U.S. gallon<br>Can–Br gallon | 0.06101<br>35.3357<br>0.26420<br>0.21997 |
| MASS | Kilograms<br>Kilograms<br>Kilograms | Pounds<br>Short tons<br>Long tons | 2.20459<br>0.00110<br>0.00098 |
| FORCE | Newtons<br>Newtons<br>Newtons | Pounds-force<br>Kilograms-force<br>Kips | 0.22482<br>0.10197<br>0.00023 |
| PRESSURE AND STRESS | Kilopascals<br>Bars<br>Inches head of water*<br>Inches head of Hg<br>Pascal<br>Kilopascals<br>Kilopascals<br>Kilopascals | Psi<br>Psi<br>Psi<br>Psi<br>Newton / square meter<br>Atmospheres<br>Bars<br>Meters head of water* | 0.14503<br>14.4928<br>0.03606<br>0.49116<br>1<br>0.00987<br>0.01<br>0.10197 |
| TEMPERATURE | Temp. in °F = (1.8 x Temp. in °C) + 32<br>Temp. in °C = (Temp. in °F – 32) / 1.8 | | |

* at 4 °C

E6TabConv-990505

**Table 3: Conversion factors**

# APPENDIX 1

## EXAMPLE OF CALIBRATION SHEET

ROCTEST TELEMAC

### CALIBRATION DATA SHEET
### VIBRATING WIRE PRESSURE TRANSDUCER

| | |
|---|---|
| *Model:* | **PWF** |
| *Serial number:* | **100C0529** |
| *Range:* | **500 kPa** |
| *Temperature:* | **23.9 °C** |
| *Barometric pressure:* | **102.5 kPa** |
| *Cable model:* | **IRC41A** |
| *Cable length:* | **85 m** |
| *Thermistor type:* | **3 kOhms** |

*Color code:* **red & black (coil) green & white (thermistor)**

| Applied pressure kPa | Reading linear unit LU | Error linear % FS | Error polynomial % FS |
|---|---|---|---|
| 0.00 | 2894.2 | -0.19 | -0.01 |
| 100.00 | 2637.0 | 0.03 | 0.00 |
| 200.01 | 2378.1 | 0.13 | -0.02 |
| 300.02 | 2119.1 | 0.21 | 0.06 |
| 400.00 | 1856.0 | -0.02 | -0.05 |
| 500.00 | 1593.8 | -0.18 | 0.00 |
| 499.99 | 1594.0 | -0.17 | 0.01 |
| 400.03 | 1856.8 | 0.05 | 0.01 |
| 299.99 | 2118.0 | 0.12 | -0.03 |
| 200.03 | 2378.2 | 0.14 | 0.00 |
| 99.96 | 2637.4 | 0.05 | 0.02 |
| 0.03 | 2894.4 | -0.17 | 0.01 |
| | Maximum error (%): | 0.21 | 0.06 |

*Calculated Pressure:*

$$P_c = P - P_T - (S - S_0)$$

$P$, $P_c$ = Raw pressure and corrected one
$P_T$ = Temperature correction
$S_0$, $S$ = Barometric pressure at installation and current one

| Linear regression | Polynomial regression |
|---|---|
| $P = C_f (L - L_0)$<br>$P_T = C_T (T - T_0)$ | $P = AL^2 + BL + C'$ (*)<br>$P_T = C_T (T - T_0)$ |
| $C_f$ = -3.8444E-01 kPa / LU<br>$C_T$ = -1.0679E-01 kPa / °C | A = -4.0179E-06 kPa / LU²<br>B = -3.6641E-01 kPa / LU<br>$C_T$ = -1.0679E-01 kPa / °C |
| *$L_0$ : Initial reading in LU* | (*) C' calculation: please refer to instruction manual, § Initial reading |
| *L : Reading in LU ; $T_0$, T : Temperatures in °C (initial, current)* | |

***Note*: LU = Linear Unit with K = 1.0156, position 4 on the MB-6T and MB-3TL readout units**

Certificate: 041405B.xls Traceability: TR-03-03

Calibrated by: Melina Morales Date: 2005/04/14

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# EC Declaration of Conformity

**Roctest Limited,** located at 680 Birch, St-Lambert, QC, Canada J4P 2N3

We hereby declare that the devices described below are in conformity with the directives listed. In the event of unauthorized modification of any devices listed below, this declaration becomes invalid.

**Type: VIBRATING WIRE PIEZOMETER**

**Product Model #: PW Series (PWS, PWC, PWF, PWP, and PWC)**

**Relevant EC Directives and Harmonized Standards:**

**2004/108/EC** Electromagnetic Compatibility directive, as amended by **EN61326-1, ed3**

**RocTest Limited** hereby declares under its sole responsibility that the products identified above comply with the protection requirements of the EMC directive. The manufacturer has applied the following standards:

**Harmonized Standards: EN 61326-1:2006 Lab Equipment, EMC**

IEC61000-6-3:2007 Emission standard for residential, commercial and light-industrial environments
IEC61000-4-2:2008 Electrostatic discharge immunity test
IEC61000-4-3:2006 Radiated, radio-frequency, electromagnetic field immunity test
IEC61000-4-4:2012 Electrical fast transient/burst immunity test
IEC61000-4-5:2005 Surge immunity test
IEC61000-4-6: 2008 Immunity to conducted disturbances, induced by radio-frequency fields
IEC61000-4-11:2004 Voltage dips, short interruptions and voltage variations immunity tests

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**Issued in:** Saint-Lambert, QC, Canada **Date:** November 01, 2013