

# Standard Vibrating Wire Piezometer User Manual





### **What's this manual about?**

This manual tells you about the Standard Vibrating Wire Piezometer and how to use it to measure pore water pressures in fully or partially saturated soil.

### **Who does this apply to?**

Installers, field engineers and technicians who need to acquire pore water pressure measurements in fully or partially saturated soil.

# Welcome!

Thank you for choosing the Standard Vibrating Wire (VW) Piezometer.

This manual has been written to provide you with relevant information and to guide you in best practice when using a Vibrating Wire Piezometer in order for you to gain the most from our product.

Please read this manual thoroughly before use to help avoid any problems and keep it handy during installation.

### **Standard Vibrating Wire Piezometer**

The Standard Duty Vibrating Wire Piezometer accurately measures pore water pressures in fully or partially saturated soil and is designed for pressure ranges from -50 to 4,000 kPa.

The small diameter piezometer is hermetically sealed and combines in-built temperature compensation with an integral thermistor for temperature monitoring and an over voltage surge arrestor to offer protection from indirect lightning strikes.

The transducer is fitted with either a low air entry sintered steel or a high air entry ceramic filter and is manufactured from high quality 316 grade Stainless Steel, providing long-term stability and reliability.

A cone shaped nose piece is available for push-in installations.

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## OVERVIEW & INTRODUCTION

### Important information

The following symbols are used throughout this manual



IMPORTANT  
INFORMATION



QUESTION



WARNING



TIP



**! Important:** Failure to adhere to the warnings in this manual may result in network disruption and possible data loss.

Failure to observe the warning may result in injury, product malfunction, unexpected readings or damage to the product that may invalidate its warranty.



Tips give additional information that may be helpful when using a Standard Vibrating Wire Piezometer.


### PRODUCT CHANGES

Soil Instruments Limited has an on-going policy of design review and reserves the right to amend the design of their product and this instruction manual without notice.

### WARRANTY

Please refer to Soil Instruments Limited terms and conditions of sale for warranty information. Batteries are a consumable item and are excluded from any warranty.

### DISPOSAL

Products marked with the  symbol are subject to the following disposal rules in European countries:

- This product is designated for separate collection at an appropriate collection point
- Do not dispose of as household waste
- For more information, contact Soil Instruments Limited or the local authority in charge of waste management.

## System Description

### Things You Need to Know

#### FEATURES

- Small diameter
- Uses proven Vibrating Wire (VW) technology
- Manufactured from high grade 316 Stainless Steel for extended operation
- In built temperature compensation
- Hermetically sealed
- Suitable for long-term monitoring
- No electronic components in sensor module
- Capable of measuring negative pore pressures to -50 kPa
- Fitted with thermistors for temperature monitoring

#### BENEFITS

- Accurate, repeatable readings over long cable lengths
- Long working life, long-term stability and reliability
- Fast response to pressure changes
- Design prevents case stresses from affecting readings
- Over-voltage surge arrestor protects against electrical damage
- Connecting cable is strong, screened and flexible

## System Components

### OVERVIEW

The piezometer comprises a porous tip element connected to a Vibrating Wire (VW) Transducer. The transducer body is constructed throughout from high integrity materials; the sensing wire, diaphragm and anchor are enclosed in an independent unit. An electrical surge protector is included in the design to prevent coil damage should excessive voltages be induced into the connecting cable during electrical storms.

The transducer consists of a rigid cylinder, sealed at one end by a watertight bulkhead and at the other by a thin diaphragm which serves as an elastic, force sensing member. A thin steel wire strung between these two points is tensioned and firmly anchored during manufacture. A coil/magnet assembly set at the mid-position on the wire provides the means of exciting the wire into oscillation, the frequency of which is dependent on wire tension.

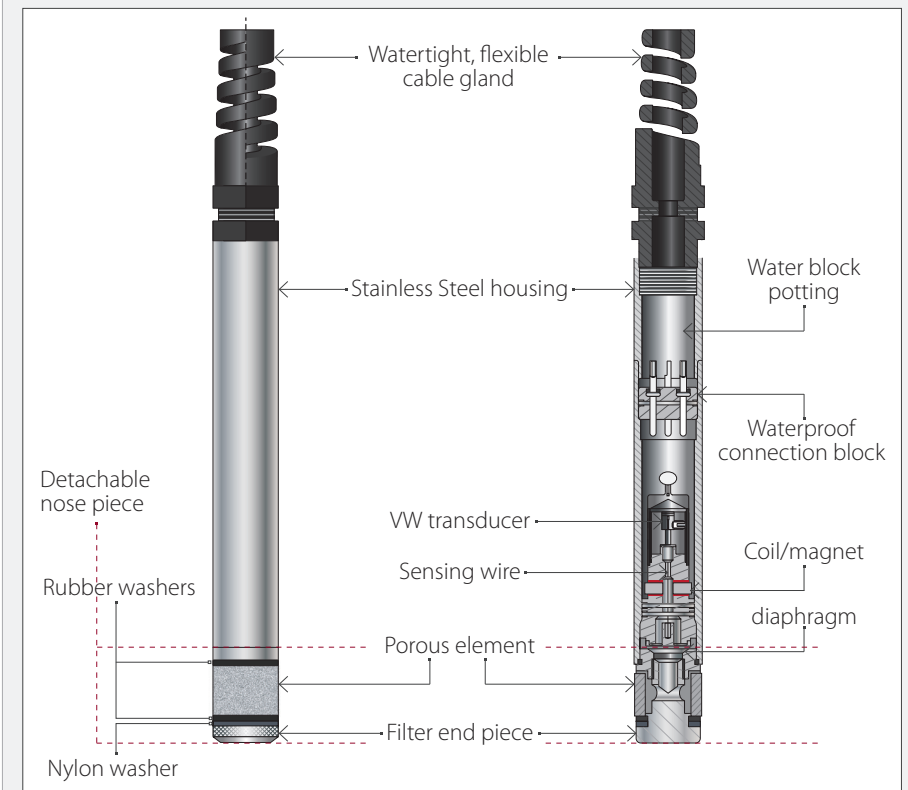
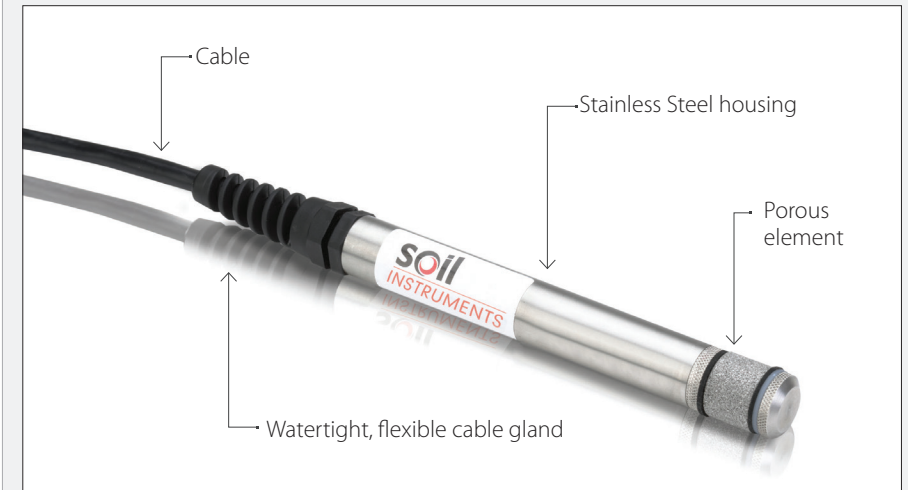
Pore water pressure acting on the diaphragm causes it to deflect, changing the tension of the wire and the resonant frequency. The readout unit supplies an electrical pulse to the coil/magnet assembly which plucks the wire, causing it to vibrate at its resonant frequency.

The coil/magnet assembly acts as a pickup as the oscillations of the wire through the magnetic field induce an alternating current in the coil which is detected by the readout. The readout converts the sinusoidal alternating voltage to a square waveform which may easily be timed using a frequency oscillator. In this way the period of oscillation may be accurately measured.

The relationship between a change in the period of oscillation and the strain of the wire is non-linear. Basic readout units simply give a reading in period units, which must be manually converted, to the appropriate units by use of formulae. More sophisticated readout units such as Soil Instruments **'VWnote'** are programmable to give a direct reading in the appropriate engineering units. **'VWnote'** is also able to store a series of readings in a non-volatile memory for future transfer to a PC.

Please refer to Datasheets **'RO-1-VW-NOTE Vibrating Wire Note'** and **'RO-1-VW-READ Vibrating Wire Readout'** for details on Soil Instruments Vibrating Wire handheld readouts.

## Standard Vibrating Wire Piezometer Components



## VW PIEZOMETER PREPARATION GUIDE

### Preparation of Equipment Prior to Installation



Follow the precautions outlined in this manual at all times to ensure the correct working order of your instrument.



It is essential that the equipment covered by this manual is handled, operated and maintained by competent and suitably qualified personnel.



To guide you in the competence required for installing each instrument in our product range, Soil Instruments provide you with a recommended skill level in all of our manuals and datasheets.

Soil Instruments recommend an **intermediate** skill level for installing a Standard Vibrating Wire Piezometer.



The ceramic filter **MUST** be soaked in clean water for a minimum of **24 HOURS** prior to installation.

#### REMOVAL & ASSEMBLY OF FILTER

As soon as the equipment arrives, check that all the necessary parts are in correct working order, even if the installation is not going to be carried out immediately.

Prior to installation, the following tasks are necessary:

STEP	ACTION
1	Locate a suitable clean container, large enough to immerse the entire piezometer and fill with clean water
2	Unscrew the detachable nose piece containing the filter from the main sensor body
3	Immerse the nose piece containing the filter <b>upright</b> in the container of clean water and soak for a <b>minimum of 24 hours</b>

STEP	ACTION
4	Shortly before proceeding with the installation, immerse the piezometer body in the same container of water and invert to expel any air, repeat if necessary to ensure that all the air has been removed
5	Invert the detachable nose piece containing the filter to expel any air and screw the nose piece back on to the piezometer body, keeping both sections immersed in the water during attachment

**PRE-INSTALLATION BASE READING** Please refer to Datasheets '*RO-1-VW-NOTE Vibrating Wire Note*' and '*RO-1-VW-READ Vibrating Wire Readout*' for details on Soil Instruments Vibrating Wire handheld readouts.



It is necessary to establish a base reading for each instrument prior to installation.

STEP	ACTION
1	Ensure that the piezometer is totally immersed in clean water to a depth of a few centimetres only and is shielded from direct sunlight
2	Connect the instrument cable to Vibrating Wire Readout such as ' <i>VWnote</i> ' or ' <i>VWread</i> ' and record the reading in frequency or period units
3	Wait for 15 minutes for the transducer to adjust to the temperature of the water and repeat the reading operation.



A value identical to the first reading indicates that the transducer has adjusted to the water temperature.

4	Continue reading (if necessary) until stability is observed
5	Record the reading with the current barometric pressure and water temperature

## VW PIEZOMETER INSTALLATION GUIDE

### Standard Vibrating Wire Piezometer Installation Procedure



Follow the precautions outlined in this manual at all times to ensure the correct working order of your instrument.



It is essential that the equipment covered by this manual is handled, operated and maintained by competent and suitably qualified personnel.



To guide you in the competence required for installing each instrument in our product range, Soil Instruments provide you with a recommended skill level in all of our manuals and datasheets.

Soil Instruments recommend an **intermediate** skill level for installing a Standard Vibrating Wire Piezometer.

#### DRILLING THE BOREHOLE

A borehole with the diameter of 75 - 150mm is either driven into soils using shell and auger drilling or into rock using rotary water flush drilling.



**Air flushing and subsequent entrapment of air in the ground should be avoided.**



The sides of the borehole in the vicinity of the piezometer tip should be free from mud cake and debris. If the hole requires casing, this should be withdrawn to keep pace with the installing operation.

On completion of the borehole it is strongly recommended to flush with fresh water to remove any silt or debris that may be present in the borehole. A head of water will ease installation of the piezometer; however this is not appropriate in highly impermeable soils.



If the borehole is completely dry add a little water to cover the instrument during installation.

### Installing the Piezometer

#### BOREHOLE INSTALLATION

Place coarse clean filter sand through the water, ideally with a tremie pipe and compact to the proposed base of the piezometer tip. Allow a suitable amount of time for the sand to settle, particularly if the water level is high.



**When marking the proposed depth of the piezometer, make sure you take into account the borehole casing above ground level.**

Mark the proposed depth of the tip on the piezometer cable using coloured P.V.C. adhesive tape, remembering to take account of any borehole casing remaining above ground level.

Just prior to installation measure the water level in the borehole. Very carefully lower the piezometer down the borehole until the tape mark coincides with the top of the casing.

Take a reading on the piezometer, allowing time for temperature equilibrium to be established. Compare the calculated head of water with the measured water level.



Comparing the calculated head of water with the measured water level is a very useful operational test.

Place further filter sand until the tip is covered by at least 150mm.



**If using a punner to compact the filter material, take extra precaution not to damage the cable.**



Remember to allow time for the sand to settle as it is difficult to remove surplus sand without causing considerable disturbance.

A plug to prevent entry of grout into the filter should be placed in the form of bentonite pellets, or alternatively balls of stiff bentonite no larger than 50mm diameter, may be dropped through the water and tamped into place.

Backfilling is completed to ground level with an impervious grout, generally a bentonite-cement mix through a tremie pipe, positioned above the bentonite plug and withdrawn as grouting proceeds.



If more than one instrument is being installed it is vitally important to clearly identify the cables using colour coded P.V.C. adhesive tapes.

#### INSTALLATION IN FILL

This is essentially similar to installation in shallow soil foundations. In clay fill, the piezometer may either be placed in a sand pocket or in direct contact with the fill material. This latter operation is performed using a mandrel to form an impression into which the piezometer is placed. In rock fill the tip should be surrounded by clean coarse filter sand.

#### Installation of Heavy Duty Push-In Piezometer

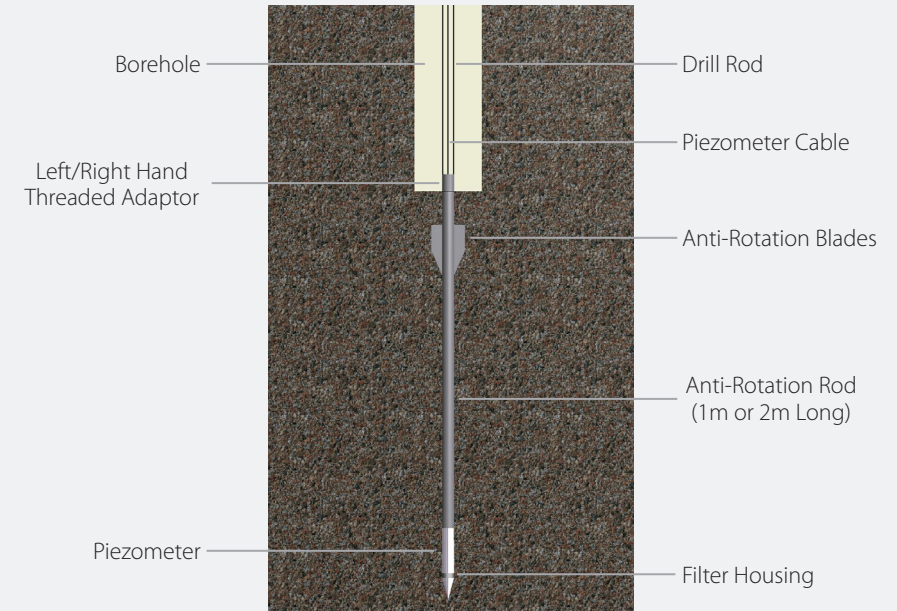
##### IMPORTANT INSTALLATION INFORMATION

The push-in Piezometer is designed for pushing into soft soils using drill rods either by hand or using the hydraulics of the rig. The Piezometer should be monitored during the pushing process to ensure that pressures do not exceed the calibrated range of the piezometer. Should the pressures reach or exceed the calibrated range the process should be stopped to allow the pressure to dissipate before continuing.

If the drill rods are to be removed then a bladed anti rotation rod with a left hand/right hand threaded adaptor should be used. This will allow the drill rods to be rotated clockwise and detached from the bladed anti rotation rod. The left hand/right hand threaded adaptor will be recovered with the drill rods for reuse. The filter tip should be saturated prior to installation as per the standard piezometer.

See diagram of Installation by pushing into soft soils for more details.

#### Installation by Pushing Into Soft Soils



#### Multi-Level Piezometers

##### OVERVIEW

Multi-Level VW Piezometers are used to monitor pore-water pressure at different elevations in the borehole.

The multi-level system simplifies the process of installing multiple piezometers in a single borehole.

The placement pipes ensure that the piezometers are placed at the intended elevations.

The piezometer is held filter end up so that water will not drain from the piezometer during installation.

The signal cables run inside the placement pipes rather than through the backfill eliminating leakage paths along the cables and also protects the cable.

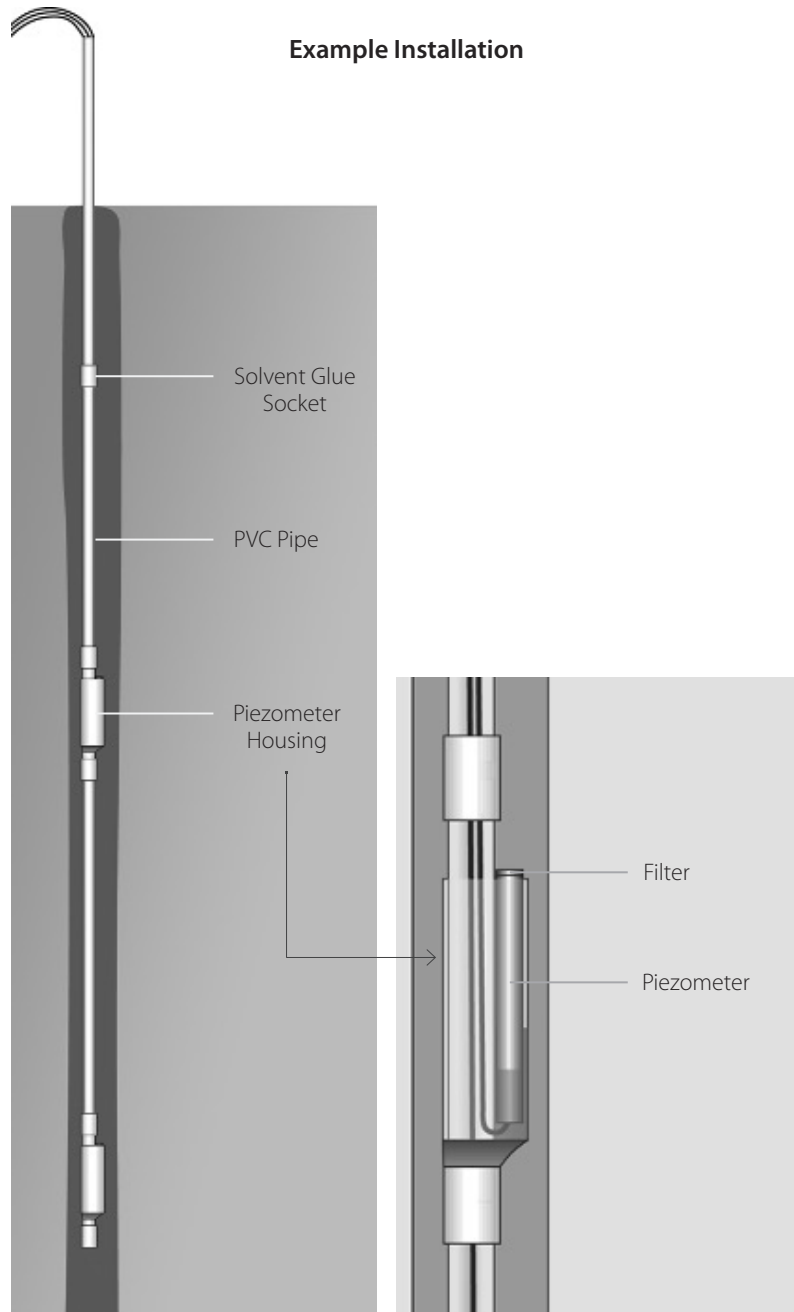
Multi-Level piezometers are installed using the fully grouted borehole method.

The entire borehole is backfilled filled with a bentonite cement grout along with the placement pipes.

This isolates the intake zone of each piezometer and also eliminates the need for placing sand and bentonite plugs.



## Example Installation



## Installation

### IMPORTANT INSTALLATION INFORMATION

Check project specifications to find the intended depth of each piezometer.

Check cable lengths of piezometers (look on the serial number label) and mark them for order of installation.

Establish the pre installation base reading as described in the earlier section of this manual.

Lay out piezometers (no need to uncoil the cable yet. Use a measuring tape to place each piezometer at the proper distance from the "surface".

Lay out placement pipe alongside the piezometers and mark each length where it should be cut.

Cut the pipe to the marked lengths; make sure to label the pipes for correct assembly.

Lay out the piezometers, lengths of placement pipe, and couplings.

Record the serial numbers and position of each piezometer; identify the cable ends so that they are identifiable once installed.

Push the cable upwards through the adjoining pipe and next multi-level housing.

Tap the cables together for easier pushing or pulling.

Repeat until all cables have been threaded through all the pipe lengths, couplings, and piezometer housings.

Consider PVC solvent cementing one pipe with each piezometer housing to ease handling later.

Follow the manufacturer's instruction for gluing the joints using the solvent cement.

Stack the partially assembled piezometers near the borehole. Connect a safety line to the bottom piezometer.

If you are using a flexible external grout pipe, attach it to the bottom pipe.

Position the piezometer and pipe over the borehole, remove the filter (knurled ring) from the piezometer, fill the cavity with clean water, and replace the filter.

Insert the first piezometer into the borehole; clamp the pipe at the top of the borehole so you can add the next pipe or the next piezometer.

Continue assembling the system, gluing all joints and filling the filter cavities with water.

Repeat these steps until you place the final piezometer.

## GROUTING

Backfill the entire borehole with a bentonite-cement grout.

If the borehole is less than 30m (100 feet) deep, you can usually grout the borehole through the placement pipe.

If the borehole is more than 30m (100 feet) deep, an exterior grout pipe is more practical.

If you use a flexible hose for grouting, you should install it with the piezometers.

If you use a rigid pipe for grouting, you can insert it after the piezometers are in place.

Pump the grout through the placement pipe or through an external grout pipe.

Keep grouting pressure below 700 kPa (100 psi).

Stop pumping when grout appears at the top of the borehole.

Cut off the excess pipe, being careful not to damage the cables. Terminate the installation as specified; be sure to protect the serial number labels on the ends of the cable.

## GROUT RECIPES

The following mixes are general guides and you should consult your site consultant for their recommended mixes. Read the notes below:

Mix cement with water first, then add the bentonite to produce a grout with the consistency of heavy cream.

If you add bentonite first, the mix will be too thick when cement is added. To thin the mix, you'll have to add water.

This increases permeability, which is not desirable in this application, it also increases the risk of a flash-set.

So mix cement with water first, and then add bentonite.

There is no exact quantity of bentonite needed.

The amount will vary with the bentonite itself, the method of mixing, and the pH of the water.

If you have a Marsh funnel, the Marsh number of the liquid grout should be about 55 seconds.

## Grout Mix for Hard to Medium Soils

MATERIALS	WEIGHT	RATIO BY WEIGHT
Portland cement	25kg (1 bag)	1
Water	62.5 Litres	2.5
Bentonite	7.5kg (as required)	0.3

## Grout Mix for Soft Soils

MATERIALS	WEIGHT	RATIO BY WEIGHT
Portland cement	25kg (1 bag)	1
Water	165 Litres	6.6
Bentonite	10kg (as required)	0.4

**TAKING READINGS** Drilling and backfilling a borehole temporarily changes the pore-water pressure in the ground.

In the case of multi-level piezometers, a period of time is required for the grout to cure.

Wait for the natural pore-water pressure to recover before taking initial readings.

Recovery of the natural pore-water pressure may take a day or longer, depending on the permeability of the soil.

Recovery is indicated by stable readings over a period of a few days.

## Installation and Termination of Cable

### OVERVIEW

Connecting cable is laid in a trench deep enough to provide protection from mechanical damage. In certain situations the cables may be run in protective conduits or cast into concrete, however, great care should be taken to protect cables at interfaces between such relatively rigid conduits and flexible soil areas if this method is used. The choice of suitable protection material surrounding the cable along the trench length will depend on local factors, but in all cases should be fine grained with a particle size less than 0.5mm and not contain any sharp particles. Fine sand is preferable in free draining areas, but should be replaced by screened silt or clay based soil where lower permeability is required.



**Failure to use the correct protection material may result in piping along the trench lines.**



You **MUST** use **screened connecting cable** and use an electrical jointing kit, ensuring you follow the manufacturer's instructions precisely.

#### INSTALLATION IN TRENCHES

The screened connecting cable is compacted within the trench, ensuring that it is protected by 150mm of stone-free material, normally sand, silt or clay **above** and **below** the cable itself. Although sand is often the most convenient to use; only silt clay or clay should be used where the creation of a drainage path would be undesirable.



If the trench passes through an impervious clay core of an embankment dam, additional cut-offs across the trench may be necessary. If the trench is to be backfilled using rock fill or coarse granular material, the thickness of the protective layer over the cables should be increased to 250mm.

The trench cable must be connected to the borehole cable by use of a proper electrical jointing kit. It is strongly recommended to avoid any cable joints, however if this is not possible, the same jointing kit must be used.



The effectiveness of these joints largely depends on the care with which the jointing operation is carried out.

The cables should be laid loosely within the trench and snaked to prevent any strain due to ground movements; in most cases a wavelength of 3m and amplitude of 200mm should be sufficient. In certain cases it may be advisable to separate the cables from each other within the base of the trench. The cables should be looped on crossing an interface where differential ground movements might be anticipated and may also be looped at cable joints to avoid any unnecessary stresses. The cables should be identified using coloured P.V.C. tape applied at regular intervals.

The correct functioning of the instrument **MUST** be checked before backfilling the trench.



Compaction of backfill should be carried out using only hand operated equipment.

It may be advisable to clearly mark out or survey the position of the instrument trench, particularly if there is to be further excavation or borehole drilling in the vicinity. A record of the trench position and depth should be kept and pegged out.

#### TERMINATION OF CABLES

The cables are normally terminated in multi-channel terminal units. The terminal units have a hinged cover secured by two screws and the cables enter through waterproof glands.



Please refer to Datasheet '*RO TB-JB-TJ - Terminal and Junction Boxes*' for details on Soil Instruments terminal and junction boxes.

To wire the cables into a terminal unit, follow the step guide below.

STEP	ACTION
1	Unscrew and open the hinged cover
2	Unscrew the four fixing screws holding the terminal panel and carefully remove it without straining the connecting leads
3	Prepare the cables by stripping and cutting back approximately 20mm of the outer insulation and screen
4	Remove the inner sheath and strip back 5mm of the conductor insulation
5	Slacken the entry glands and insert the cables
6	Make connections to the terminal blocks
7	Re-tighten the glands to grip the cables
8	Replace the terminal panel and secure
9	Connect the readout unit to each instrument in turn to check connections

Please refer to Datasheets 'RO-1-VW-NOTE Vibrating Wire Note' and 'RO-1-VW-READ Vibrating Wire Readout' for details on Soil Instruments Vibrating Wire handheld readouts.

## TEMPERATURE & PRESSURE EFFECTS & DATA REDUCTION

### Effect of Temperature and Pressure

#### TEMPERATURE CHANGE

The materials used in the construction of the transducer are carefully chosen and controlled in order to reduce the effect of ambient temperature changes on readings. In addition, the strain wire assembly is evacuated when it is sealed during manufacture, which considerably reduces internal air pressure on the diaphragm when the piezometer is heated, which might give rise to false negative readings in extremes.

The significance of temperature change is always with respect to the temperature difference between the current time and the time of the pre-installation base reading. As a rule of thumb, installed temperature changes of less than 10° C are not, for practical purposes, significant.

If large temperature changes are to be expected in the ground where the piezometers are to be installed, then consideration must be given to specifying the incorporation of a thermistor coil in each transducer, or the separate installation of another temperature measuring device in order to provide the temperature data required for corrections to be applied.



Temperature gradients across the unit, triggered by rapid changes in ambient temperature will produce considerable reading error. For this reason it is essential that pre-installation base readings are only taken after sufficient time has been allowed for the transducer to stabilise at the ambient temperature. Piezometers **MUST** be immersed in shallow water and shaded from direct sunlight until readings settle.

### USE OF TEMPERATURE CORRECTION COEFFICIENTS

At the time of ordering, instruments may be specified, calibrated with individual temperature correction coefficients.

If supplied with this coefficient, then the coefficient may be applied using the following formulae and example:

$$ET = E + TK (T1-T0)$$

Where;

ET is the temperature corrected Engineering reading,  
TK the temperature coefficient,  
T1 the current instrument temperature and  
T0 the base or zero reading temperature (both in degrees C and recorded from the instruments internal thermistor).

The temperature coefficient, TK, will be in units of Engineering per degree c, as per the calibration certificate.

Ensure that the temperature coefficient is converted to the same units of Engineering as per the calculated E, via a conversion factor before applying the temperature correction.

### EFFECT OF BAROMETRIC PRESSURE

External pressure applied to the diaphragm of the transducer modifies the wire tension and therefore its resonant frequency. Such a change is used to determine the magnitude of the applied pressure.

Since the unit is evacuated and sealed during manufacture, subsequent external variations in barometric pressure will cause a differential force to act across the diaphragm which will affect the tensioned wire proportionally.

The effect is most significant with thin diaphragms (low range units).

For example;

**For a 50mH2O transducer, a ±10 millibar change in ambient barometric pressure, (equivalent to 100 mm of water head), relative to the encased pressure within the unit will modify the reading by the equivalent of ±100 mm of water head, even though the external water head to be measured remains constant.**

In such applications where such relatively small variations are considered to be significant, correction of reading errors due to barometric pressure changes should be applied respectively. For this purpose a note of barometric pressure on the day of the pre-installation base reading is required and also an accurate barometer must be available on site.

### Data Interpretation

**DATA REDUCTION** The mathematical relationship between the frequency of vibration of a tensioned wire and the force applying the tension is an approximate straight line relationship between the square of the measured frequency and the applied force.

Engineering units of measurement maybe derived from the frequency based units measured by vibrating wire readouts in 3 traditional ways;

From '**period**' units and from '**linear**' ( $f^2/1000$ ) units using two methods; a simple linear equation or a polynomial equation.

### CALCULATING ENGINEERING UNITS FROM FREQUENCY BASED UNITS

'**Engineering**' units of measurement maybe derived from the frequency based units measured by Vibrating Wire readouts in three traditional ways;

From '**period**' units ( $t \times 10^7$ ) and from '**linear**' ( $f^2/1000$ ) units using two methods, a simple '**linear**' equation or a '**polynomial**' equation.

### CALCULATION USING PERIOD UNITS

The following formula is used for readings in '**period**' units.

$$E = K (10^7/P0^2 - 10^7/P1^2)$$

Where;

'**E**' is the pressure in resultant '**engineering**' units,  
'**K**' is the '**period gauge factor**' for units of calibration (taken from the calibration sheet)

'**P0**' is the installation '**period**' base or '**zero**' reading

'**P1**' is the current '**period**' reading.

This method of calculation is used by Soil Instruments Vibrating Wire Loggers (models RO-1-VW-1 or 2 and with serial numbers starting VL or TVL) internal processors, for calculating and displaying directly on the loggers LCD screen, the required '**engineering**' based units. The loggers require '**period**' base or zero reading units for entering into their channel tables to calculate and display the required '**engineering**' units correctly.

If an '**engineering**' based unit is required other than the units of calibration, then the correct '**K**' factor will have to be calculated using the standard relationship between '**engineering**' units. For example, if the units of '**engineering**' required were in inches and the calibration units were millimetres, we can find out that 1mm is equal to 0.03937", so we would derive the '**K**' factor for inches by multiplying the '**K**' factor for millimetres by 0.03937.

### CALCULATION USING LINEAR UNITS

The following formula is used for readings in 'linear' units.

$$E = G (R_0 - R_1)$$

Where;

'E' is the resultant 'engineering' unit,  
 'G' the 'linear gauge factor' for the units of calibration (taken from the calibration sheet)  
 'R0' is the installation 'linear' base or 'zero' reading  
 'R1' is the current 'linear' reading.

Again the 'linear gauge factor' for units other than the units of calibration would need to be calculated using the same principles as stated in the last paragraph of the 'period unit' section.

'Linear' units may be applied to the following 'polynomial' equation, for calculation of 'engineering' units to a higher order of accuracy.

$$E = (AR_1^2 + BR_1 + C)$$

Where;

'E' is the resultant 'engineering' unit  
 'A', 'B' and 'C' the 'polynomial gauge factors' 'A', 'B' and 'C', (taken from the calibration sheet)  
 'R1' is the current 'linear' reading.

The value 'C' is an offset value and relates to the zero value experienced by the transducer at the time of calibration.

This value should be recalculated at the installation time as follows;

$$C = - (AR_0^2 + BR_0)$$

Where;

'A' and 'B' are as above  
 'R0' is the installation 'linear' base or 'zero' reading.

Please note that the sign of the recalculated value of 'C' should be the same as the original value of 'C', so if the original is negative then the recalculated value should also be a negative.

Conversion to 'engineering' units other than the units of calibration, would best be done after conversion, using a factor calculated using the same principles as stated in the last paragraph of the 'period unit' section.

### LINEAR UNIT CALCULATION USING A POLYNOMIAL EQUATION

## APPENDICES

### Appendix A - Conversion Table

Pressure, Stress & Modulus of Elasticity											
	MN/m <sup>2</sup> or MPa	kN/m <sup>2</sup> or kPa	kp or kgf/cm <sup>2</sup>	bar	atm	m H <sub>2</sub> O	ft H <sub>2</sub> O	mm Hg	tonf/ft <sup>2</sup>	psi or lbf/in <sup>2</sup>	lbf/ft <sup>2</sup>
1	1000	1000	10.197	10.000	9.869	102.2	335.2	7500.6	9.320	145.04	20886
0.001	1	1	1.019 x 10 <sup>-2</sup>	0.0100	9.87 x 10 <sup>-3</sup>	0.1022	0.3352	7.5006	0.0093	0.14504	20.886
9807 x 10 <sup>-2</sup>	98.07	98.07	1	0.9807	0.9678	10.017	32.866	735.56	0.9139	14.223	2048.1
0.100	100.0	100.0	1.0197	1	0.9869	10.215	33.515	750.06	0.9320	14.504	2088.6
0.1013	101.33	101.33	1.0332	1.0132	1	10.351	33.959	760.02	0.9444	14.696	2116.2
9788 x 10 <sup>-3</sup>	9.7885	9.7885	9.983 x 10 <sup>-2</sup>	9.789 x 10 <sup>-2</sup>	9.661 x 10 <sup>-2</sup>	1	3.2808	73.424	9.124 x 10 <sup>-2</sup>	1.4198	204.45
2.983 x 10 <sup>-3</sup>	2.9835	2.9835	3.043 x 10 <sup>-2</sup>	2.984 x 10 <sup>-2</sup>	2.945 x 10 <sup>-2</sup>	0.3048	1	22.377	2.781 x 10 <sup>-2</sup>	0.43275	62.316
1.333 x 10 <sup>-4</sup>	0.1333	0.1333	1.3595 x 10 <sup>-3</sup>	1.333 x 10 <sup>-3</sup>	1.315 x 10 <sup>-3</sup>	1.362 x 10 <sup>-2</sup>	4.469 x 10 <sup>-2</sup>	1	1.243 x 10 <sup>-3</sup>	1.934 x 10 <sup>-2</sup>	2.7846
0.1073	107.3	107.3	1.0942	1.0730	1.0589	10.960	35.960	804.78	1	15.562	2240.0
6.895 x 10 <sup>-3</sup>	6.895	6.895	7.031 x 10 <sup>-2</sup>	6.895 x 10 <sup>-2</sup>	6.805 x 10 <sup>-2</sup>	0.7043	2.3108	51.714	6.426 x 10 <sup>-2</sup>	1	144.00
4.788 x 10 <sup>-5</sup>	4.788 x 10 <sup>-2</sup>	4.788 x 10 <sup>-2</sup>	4.883 x 10 <sup>-4</sup>	4.788 x 10 <sup>-4</sup>	4.725 x 10 <sup>-4</sup>	4.891 x 10 <sup>-3</sup>	1.605 x 10 <sup>-2</sup>	0.3591	4.464 x 10 <sup>-4</sup>	6.944 x 10 <sup>-3</sup>	1

## Appendix B – Troubleshooting Guide

Before any of the steps below are followed, a Vibrating Wire readout unit should be used to verify the stability of the reading.

The method used to verify the signal will be dependent on which type of VW readout is being used.



Please refer to the manufacturers' user manual for details on the method required for verifying signal strength.

Please refer to Datasheets *RO-1-VW-NOTE Vibrating Wire Note* and *RO-1-VW-READ Vibrating Wire Readout* for details on Soil Instruments Vibrating Wire handheld readouts.

Wildly fluctuating readings from the sensor (or an unsteady audio signal) are both indications of possible problems with the instrument or related electrical cables.



If the readout is giving faulty readings or audio signals from all of the sensors, a faulty readout unit and/or lead must be suspected. Another lead/readout unit should be used to check the readings. If there is a fault with the readout unit, please contact '[www.soilsupport.com](http://www.soilsupport.com)' for assistance.

STEP	ACTION
1	<p>The resistance across the two conductors of the electrical cable should be tested using a multimeter. Check the resistance across the two conductors, either at the end of the cable if available, or at the corresponding terminals if wired into a Datalogger.</p> <p>The resistance across the two conductors should be approximately 120Ω to 180Ω. The majority of this resistance will come from the sensor, approximately 130Ω, with the remainder from the electrical cable connected to the transducer (for 22 gauge copper, resistance is approximately 1Ω /15m).</p> <p>Before proceeding, the continuity should be checked between conductors and the earthing screen of the electrical cable.</p> <p><b>If continuity exists, a damaged cable is confirmed.</b></p>

STEP	ACTION
2	<p>If the resistance across the two conductors is much higher than the values quoted in 'STEP 1', or is infinite, <b>a severed cable must be suspected.</b></p> <p>If the location of the cable damage is found, the cable can be spliced in accordance with recommended procedure.</p>
3	<p>If the resistance across the two conductors is much lower than the values quoted in 'STEP 1', (less than 80 Ω) <b>it is likely that cable damage has occurred causing a 'short' in the circuit.</b></p> <p>It is possible to calculate approximately how far from the cable end (or readout location) the suspected fault is. If the resistance of a known length of conducting cable is measured, a resistance/length unit can be found. This figure can be used to calculate the length of the conductor cable in between the readout location and the break in the circuit. If the location of the cable damage is found, the cable can be spliced in accordance with recommended procedure.</p>



This method is only applicable if the 'short' occurs between the two conductors of the electrical cable. Since cables are generally buried or hidden it is may not be possible to confirm a 'short' is of this nature using this method.

STEP	ACTION
4	<p>If the resistance is within the values quoted in 'STEP 1' and no continuity exists between the conductor and the earth screen <b>AND</b> the reading from the sensor is unstable or wildly fluctuating, it must be assumed that the integrity of the circuit is good and the fault lies within the crackmeter. In this case please contact our support team at '<a href="http://soilsupport.com">soilsupport.com</a>'.</p>

## Appendix C - Sample Calibration Certificate



Bell Lane, Uckfield, East Sussex  
 TN22 1QL United Kingdom t: +44 (0) 1825 765044 e: info@soil.co.uk w: www.soil.co.uk  
 Soil Instruments Ltd. Registered in England. Number: 07960087. Registered Office: 34 Bell Lane, Uckfield, East Sussex, TN22 1QL, UK

### VIBRATING WIRE INSTRUMENTS CALIBRATION CERTIFICATE


**Instrument Type** : W9 Vibrating Wire Piezometer **Serial No.** : 053048  
**Instrument Range** : 0.00 to 300.0 kPa **Calibration Date** : 05/08/2015  
**Gauge Factors in kPa** **Ambient Temperature** : 25°C  
**Period Gauge Factor (K): 1627.8840000** **Barometric Pressure** : 1011 mbar  
**Linear Gauge Factor (G): (kPa/digit)0.1627900** **Calibration Technician** : Steve Hill  
**Polynomial Gauge Factor A: -0.000000746368600** **Calibration Equipment:**  
 Mensor APC 600  
 AVW200 Data Logger  
**Polynomial Gauge Factor B: -0.1550534000**  
**Polynomial Gauge Factor C\*\*: 974.044300** **Regression Zero** : 6105.1

Applied (kPa)	Reading (Period)	Reading F <sup>2</sup> /1000	Calculated (Linear)	Error %FS (Linear)	Linear Increment	Calculated (Polynomial)	Error %FS (Polynomial)
0.00	4048.0	6102.8	0.369	0.12	0.0	-0.013	0.00
30.00	4110.0	5919.8	30.159	0.05	-183.0	30.004	0.00
60.00	4175.2	5736.5	59.998	0.00	-183.3	60.020	0.01
90.00	4243.6	5553.1	89.853	-0.05	-183.4	90.002	0.00
120.00	4315.6	5369.4	119.758	-0.08	-183.7	119.983	-0.01
150.00	4391.6	5185.1	149.759	-0.08	-184.3	150.011	0.00
180.00	4471.8	5000.7	179.778	-0.07	-184.4	180.005	0.00
210.00	4556.8	4815.9	209.861	-0.05	-184.8	210.012	0.00
240.00	4646.8	4631.1	239.944	-0.02	-184.8	239.969	-0.01
270.00	4742.8	4445.6	270.141	0.05	-185.5	269.988	0.00
300.00	4845.2	4259.7	300.403	0.13	-185.9	300.021	0.01

Formulae: Linear\* E = G(R0 - R1)  
 Polynomial\*\* E = AR<sup>2</sup> + BR1 + C

\* The zero reading should be established on site by the user on installation.  
 \*\* The site value of C must be calculated using the formula C = -(AR<sup>2</sup> + BR0)

The instrument detailed herein has, as applicable, been tested and calibrated in accordance with procedures, which are part of our ISO 9001:2008 Quality Management System, and unless otherwise indicated, performs within ± 0.10% (Polynomial) as specified. Thus, the instrument conforms in all respects to our relevant specifications and drawings.

Certified:  Line MANAGER

## Appendix D - CE Declaration



### EC Declaration of Conformity

Soil Instruments Ltd., located at 34 Bell Lane, Uckfield, East Sussex, TN22, 1QL, United Kingdom.  
 We hereby declare that the devices described below are in conformity with the directives listed. In the event of unauthorised modification of any devices listed below, this declaration becomes invalid.

Type: STANDARD VIBRATING WIRE PIEZOMETER  
 Product Model: W9 series

#### Relevant EC Directives and Harmonized Standards:

**2004/108/EC** Electromagnetic Compatibility directive, as amended by **EN61326-1, ed3**  
 The product(s) to which this declaration relates is in conformity with the essential protection requirements of 2004/108/EC Electromagnetic Compatibility directive, as amended by EN61326-1, ed3. The products are in conformity with the following standards and/or other normative documents:

#### EMC: 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

I hereby declare that the equipment named above has been designed to comply with the relevant sections of the above referenced specifications. The items comply with all applicable Essential Requirements of the Directives.

Philip Day

Date: 30 July 2015



Manufacturing Manager,

Issued in: Bell Lane, Uckfield, East Sussex, TN22, 1QL, United Kingdom



SUPPORT

[www.soilsupport.co.uk](http://www.soilsupport.co.uk)

+44 (0) 1825 765044

**soil**  
**INSTRUMENTS**

Bell Lane, Uckfield, East Sussex

TN22 1QL United Kingdom

t: +44 (0) 1825 765044

e: [info@soilinstruments.com](mailto:info@soilinstruments.com)

w: [www.soilinstruments.com](http://www.soilinstruments.com)

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