TOTAL PRESSURE CELLS

VWTPC-4000

INSTRUCTION MANUAL

NOTES:

CONTENTS

1.0 INTRODUCTION

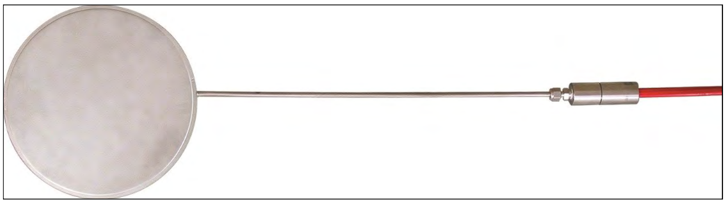
This manual is intended for all users of **VWTPC-4000 Total Pressure Cells** manufactured by **Geosense®** and provides information on their installation, operation and maintenance**.**

It is VITAL that personnel responsible for the installation and use of the Total Pressure cells READ and UNDERSTAND the manual, prior to working with the equipment.

1.1 General Description

The inclusion of an incompressible fluid filled cell in a 'plastic' or fine granular medium will allow the measurement of the total pressure acting within the material at a particular location.

In practice, the 'fluid filled cell' is formed by a pair of steel plates welded around their circumference and filled with either water or oil. A short connecting tube links the cell to a pressure transducer so that the pressure can be read from a remote location.



The design of **Geosense® VWTPC-4000 Total Pressure Cells** incorporates one active side, the other side being a stiff side. This allows our cells to be installed in most locations without modification. The stiff side of the cell is used to support the cell and the active side is responsive to total pressure changes.

Some of the primary uses of the Total Pressure cells are for the measurement of stress changes in soil and fill materials associated with :-

Dam Embankments
Road Embankments
Reclamation Projects
Bridge Abutments

Particular features of the **Geosense® VWTPC-4000 Total Pressure Cells** are:-

Reliable long term performance
Rugged; suitable for demanding environments
High accuracy
Insensitive to long cable lengths

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The Pressure sensor is based upon ‘industry standard’ Vibrating Wire technology. When electronically excited, the sensor produces an output signal in the form of an alternating current. The frequency of the alternating current can then be readily converted to a fluid pressure by applying individual calibration factors.

Frequency signals are particularly suitable for the demanding environment of civil engineering applications, since the signals are capable of long transmission distances without degradation. They are also somewhat tolerant of damp wiring conditions and resistant to interference from external electrical noise.

The **Geosense®** range of **VWTPC-4000 Total Pressure Cells** are supplied in various configurations and pressure ranges to suit most installation environments and techniques. Each VW Total Pressure Cells is fitted with a length of connecting cable, an internal temperature sensor and a surge arrestor.

1.2 Theory of Operation

The cell comprises two circular steel plates, one thin and the other ticker, welded together around their periphery, leaving a thin space between the plates. The void is then filled with an relatively incompressible de-aired fluid. This fluid filled space is connected via a pressure tube to a vibrating wire pressure sensor which measures the pressure acting on the cell.

The fluid is de-aired so that it becomes incompressible, thereby generating a hydraulically ‘hard’ instrument that requires almost no volume change to accurately register significant pressure changes. Pressure applied to the active surface is balanced by a corresponding build up of internal fluid pressure which is measured by the sensor.

Total Pressure cells can be installed singly or in arrays (clusters). Each cell in an array would be orientated differently to detect pressures acting in a particular direction. Arrays help an Engineer determine the direction of Principle Stresses.

In order to calculate the **EFFECTIVE** pressure (that generated by the solids only), it will be necessary to measure both the Total Pressure and the WATER PRESSURE. The effective pressure is calculated by subtracting the pore (water) pressure from the total pressure. For this purpose, it is common to install a piezometer close to a cell or array (or cluster) of cells.

These cells are **NOT SUITABLE** for casting into concrete structures as they do not incorporate a facility to compensate for concrete shrinkage.

2.0 CONFORMITY

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Declaration of Conformity

We Geosense Ltd at above address declare under our sole responsibility that the Geosense products detailed below to which this declaration relates complies with protection requirements of the following harmonized EU Directives,

The Electromagnetic Compatibility Directive 2014/30/EU

Restriction on the use of certain Hazardous Substances RoHS2 2017/2102/EU

Waste electrical & electronic equipment WEEE 2012/19/EU

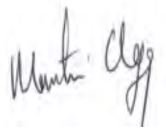
Equipment description	**Vibrating Wire Total Pressure Cell**
Make/Brand	**Geosense**
Model Numbers	VWTPC-4000, VWTPC-4010

Compliance has been assessed with reference to the following harmonised standards:

EN 61326-1:2006 Electrical equipment for measurement, control and laboratory use.
EMC requirements. General requirements.

EN 61010 (2010) Safety requirements for electrical equipment for measurement, control, and laboratory use. General requirements

A technical file for this equipment is retained at the above address.



Martin Clegg

Director
Rougham, December 2020

3.0 MARKINGS

Geosense® VWTPC-4000 Total Pressure Cells are labelled with the following information:-

Manufacturers name

Product type

Model

Maximum pressure rating

Serial number

4.0 DELIVERY

This section should be read by all users of **Geosense® VWTPC-4000 Total Pressure Cells.**

4.1 Packaging

Geosense® VWTPC-4000 Total Pressure Cells are specially packed for transportation to site. Packaging is suitably robust to allow normal handling by transportation companies. Inappropriate handling techniques may cause damage to the packaging and the enclosed equipment. The packaging should be carefully inspected upon delivery and any damage MUST be immediately reported to both the transportation company and **Geosense®**.

4.2 Handling

Whilst they are a robust devices, **Geosense® VWTPC-4000 Total Pressure Cells** are precision measuring instruments. They and their associated equipment should always be handled with care during transportation, storage and installation.

Once the shipment has been inspected (see below), it is recommended that **Geosense® VWTPC-4000 Total Pressure Cells** remain in their original packaging for storage or transportation.

Cable should also be handled with care. Do not allow it to be damaged by sharp edges, rocks for example, and do not exert force on the cable as this my damage the internal conductors and could render the installation useless.

4.3 Inspection

It is important to check all the equipment in the shipment as soon as possible after taking delivery and well before installation is to be carried out.

- Check that all the components detailed on the documents are included in the shipment.
- Check that the equipment has not been physically damaged.

ALL **Geosense® VWTPC-4000 Total Pressure Cells** carry a **unique** identification serial number which is located on the cable close to the pressure sensor body, on the cell and at the free end of the cable (see above / right). All are supplied with individual calibration sheets that include their serial numbers and original copies of these will shipped with the cells.

Calibration Sheets contain VITAL information and they MUST be stored in a safe place. Only copies should be taken to site.

CHECK the Cells '**Site Zero Readings'** against the factory '**Zero Readings'** on arrival to ensure they have not changed due to damage during transportation. To do this, connect a Vibrating Wire readout to the bare cable ends (Black and Red conductors). – See individual readout manuals for connection guidance.

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__NB__ The Geosense readout Model* ***VWR1* *displays the readings in Linear B units and Frequency. See Section 6 of this manual for more information on units and conversion routines.*

Prior to carrying out a '**Site Zero Pressure Reading**' CHECK, ensure that the **VWTPC-4000 Total Pressure Cells** have been stored in a reasonably stable temperature for at least 2 hours.

Record the values displayed on the readout together with the units), against the Total Pressure Cell serial numbers. If these 'out of the box' CHECK readings show significant differences (+/- 100 digits) to the **zero pressure** values on the calibration sheets, contact **Geosense**® for assistance. (It should be noted that the 'CHECK Readings WILL be affected by the cell temperature, the atmospheric pressure & the altitude).

If components are missing or damaged, contact the delivery company, the supplier and / or **Geosense**®.

4.4 Storage

All equipment should be stored in an environment that is protected from direct sunlight. It is also recommended that cables be stored in a dry environment to prevent moisture migrating along inside them in the event of prolonged submersion of the exposed conductors.

Exposure to sub-zero temperatures may cause damage to the cells if they are water filled.

Storage areas should be free from rodents as they have been known to damage connecting cables.

No other special requirements are needed for medium or long-term storage although temperature limits should be considered when storing or transporting associated components, such as readout equipment.

5.0 INSTALLATION

This section of the manual is intended for all users of **Geosense® VWTPC-4000 Total Pressure Cells** and is intended to provide guidance with respect to their installation.

It must be remembered that no two installations will be the same and it is inevitable that some 'fine tuning' of the following procedures will be required to suit specific site conditions.

It is VITAL that personnel responsible for the installation and use of the Total Pressure cells READ and UNDERSTAND this manual, prior to working with the equipment.

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As stated before, it is vital to check all the equipment in the shipment soon after taking delivery and well before installation is to be carried out. Check that all components that are detailed on the shipping docum ents are included.

Where piezometers are to be installed as part of a Total Pressure cell array, please refer to the **Geosense® VWP-3000 series Vibrating Wire Piezometer** installation manual for detailed guidance on their preparation and installation.

5.1 ZERO PRESSURE READINGS

Vibrating wire pressure transducers differ from most other pressure sensors in that they indicate a reading with no pressure applied. In fact, they also differ in so much as their readings reduce as pressure is applied.

ZERO PRESSURE readings can vary significantly between sensors.

Consequently it is

ESSENTIAL TO TAKE 'ZERO PRESSURE' READINGS
BEFORE
INSTALLATION

As with all transducers, do not directly handle the transducer body when recording the base readings, as this will cause local temperature gradients across the transducer that will distort the readings.

The ‘on-site’ “**ZERO PRESSURE**” readings for the **Geosense® VWTPC-4000 Total Pressure Cells** should be obtained as follows:

1. Fill a large tank with clean, potable water, ideally of a temperature close to that of the groundwater. It would also be possible to use a concrete curing tank in a site laboratory.

2. Ensure that the tank is away from any heat sources and shaded from the direct sun so as to maintain a reasonably constant temperature throughout the water. Stir the water occasionally to ensure an even temperature. Place the Total Pressure cell into the water in the tank, ensuring that it is completely covered.

3. With the transducer, cell and connecting tube submerged in the water, allow the cell to remain in the water for a **minimum** of 2 hours so that any temperature gradients in the elements dissipate. An overnight submersion is sometimes convenient.

4. Carefully raise the cell to just beneath the water surface and support it there. Avoid handling it too much so as to maintain the temperature stability. Ensure the other components remain submerged.

5. At the free end of the cable, connect the red and black leads to a vibrating wire readout unit and occasionally monitor the transducer output by turning on the readout and observing the display (see the readout user manual for assistance). After 10 or 20 readings, be sure to turn off the readout or disconnect the wire so as to avoid ‘heating’ the Vibrating Wire element.

6. Leave the transducer completely submerged in water for a minimum of 60 minutes (preferably all day or over night) and until the output of the transducer is unchanged over a period of 2-5 minutes.

7. Turn on the readout and record a reading. After one minute, repeat and record another reading. Repeat again, checking that the readings displayed are within +/- 0.5 ‘Digits’ of each other.

8. Record these readings together with the date and time.

9. Obtain and record the barometric (atmospheric) pressure for future use. It is best to use a site based reading but a local metrological station may be used.

10. The cells are now ready for installation. They can be stored in the tank or in the site store.

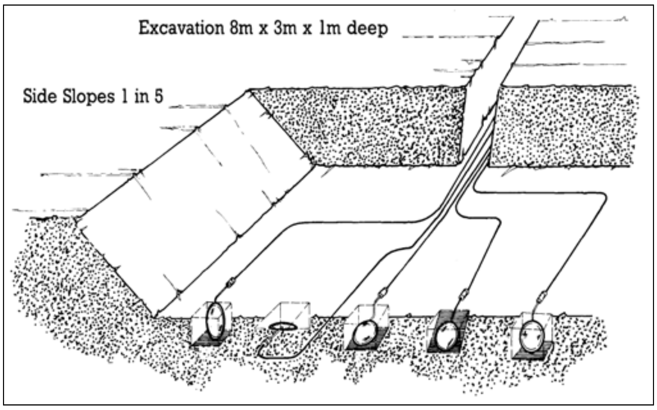
11. Take care that the cable are not damaged in storage or when being transported to the site.

NEVER lift the cells by the transducer or the cable.

ALWAYS use the cell body to lift the cells and take care not to ‘Kink’ the connecting tube.

5.2 Inclusion Installations

This type of installation is where the cells are installed within a uniform material. They are, in effect, included within a material. Embankment installations are the most common application of this type of installation.



Wherever possible, cells should be installed into compacted fill material. This helps to eliminate the possibility of the cell being either damaged or displaced by the material or plant as it is compacted around it.

Generally, fill is placed in layers, each layer being compacted as filling progresses. Once one layer has been compacted to a specified density, another layer is placed and similarly compacted.

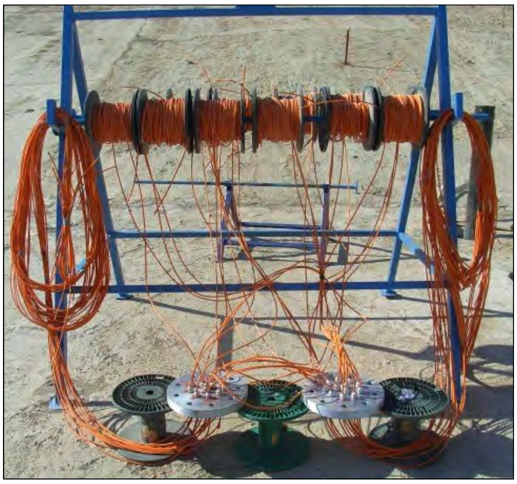
As a guide, for embankment construction (particularly dams), the fill should first be placed and compacted to a elevation that is between 0.7 and 1.2m **above** the intended cell installation elevation.

The orientation of the cells must be decided prior to any excavation. The aim must be to preserve the ‘cell bearing surface’ in its compacted condition so that the cell can rest against it and remain fully supported. Mechanical plant must not disturb the bearing surface so the preparation of the pits must be carefully supervised.

Trenches in the fill can be excavated by mechanical plant. These do not have to reach the same depth as the cells, so a 0.5m trench would be adequate.

It is very important to ensure that any pit or trench excavated in the compacted material of an embankment can be backfilled and re-compacted to a similar standard. Consequently, trenches and pits must have sloping (battered) sides (minimum 1:1) so that any fill placed and compacted on top of the trenches and pits has the effect compacting the fill in the trenches and pits.

In addition, for dams, serious consideration must be given to the prevention of water migration along any trench or cable route. It is suggested that Bentonite filled cut-off trenches be included on any trench in the core that runs perpendicular to an embankment.



Cable support / protection Frame

If instrument cables are to be extended then this is best carried out prior the installation works. If instrument cables are to linked to cables that have already been installed, this is best carried out to suit the site operations, taking care to form a waterproof joint. All joints should be sealed using epoxy resins in a mould.

It is very important to remove the risk of tension stresses in cable joints. This is achieved by forming a full loop in the cable, where joint is positioned half way around the loop.
Cables should be measured out, cut in accordance with the planned cable route, allowing

at least 10% extra for snaking and other obstacles. The cables should be marked at intervals along their length, using unique identifying markings. Typically, coloured tape can be used to create a code that relates to a particular sensor number and location.

STEP - BY - STEP Example:

1. Once this required fill level has been achieved and compacted, an installation pit or pits should be carefully excavated using mechanical plant.

2. Excavate the connecting cable trenches and batter the side of the pit(s) and trenches

3. Bring the pressure cells and any associated piezometers to site, together with installation tools

4. Excavate the bearing surface of the cell pits by hand. For horizontal installations this is straight forward, ensuring the surface is horizontal. The 'Active' surface of the cell will be upwards, away from the excavated surface so it is important to create a flat surface for the cell to rest against. Small hand tools should be used to carefully level and flatten the surface.

5. Where the cell is to be installed vertically, excavate the fill to produce an un-disturbed vertical face against which the cell can be placed. Once again, the cell will be placed with its 'back' against the excavated surface and its 'active' surface towards the excavation.

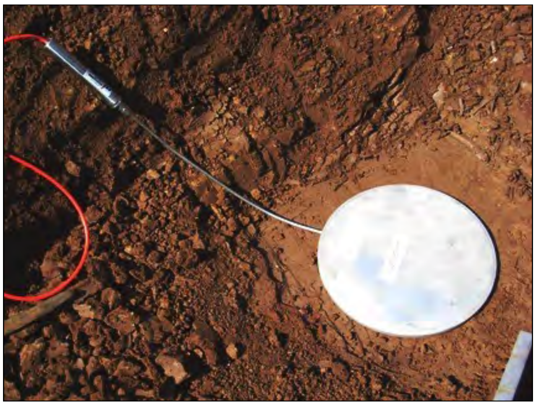
6. The preparation of the bearing surface for 45 degree cells is more difficult. Careful control of angle, direction and elevation needs to be maintained.

   Hand tools and patience are required to prepare a good foundation for the cells.

   Good installation helps to make interpretation of the readings easier.

7. Once the bearing surface is ready, place the cell on the prepared surface as a final check.

8. Note the serial number of the cell and check that the cables have been given suitable identification markings.



9. Using specially selected material carefully compact a layer of fill around the edge of the cell using a small soft headed hammer to compact the material.

When this has been completed the cell will be held in position .

Ask a surveyor to provide the final elevation and position co-ordinates for inclusion on the installation report.

10. Ask a surveyor to provide the final elevation and position co-ordinates for inclusion on the installation report.

11. Using specially selected 'stone free' fill cover the cell to a depth of approximately 50mm. Compact this fill using only light hand tools.

12. Add 100mm more ‘selected fill’ over the cell and then compact using heavier hand tools.

13. If a piezometer is to be installed in the same excavation, a small void should be excavated near (normally within 1m) of the cell for its installation. The piezometer is normally installed either vertically or at about 45 degrees to vertical, with the filter uppermost.

FOR PIEZOMETER PREPARATION PLEASE SEE THE GEOSENSE® VW WIRE PIEZOMETER INSTALLATION MANUAL

14. Check that the cable route away from the piezometer allows of any compression and settlement, without causing damage to the cable or its connection to the piezometer.

15. Carefully place ‘selected stone free’ fill around the piezometer, using some water to soften the material if necessary and to partially saturate the fill local to the piezometer.

16. Add and CAREFULLY compact fill BY HAND using small tools until there is a MINIMUM of 200mm cover over the piezometer tip.

    Only then use heavier compaction tools and ‘less refined’ fill materials.

17. During compaction, it is a good idea to take regular ‘check readings’ , as work proceeds.

18. Routing and laying of the cables should now be carried out. The cables do not have to be routed at the same depth as the cells are installed. Cable trenches are generally 0.5 meters below the surface. A 100mm layer of stone free material should be placed and compacted in the bottom of the trench, prior to placing any cables.

In most installations, cables are laid in the same fill material as the embankment. The material would be specially graded so as to remove any stones greater than 5mm diameter or sharp partials.

Cables are laid parallel to each other and are generally separated by 50 to 100mm of fill.

A 100mm layer of selected fill would be placed over the cables and compacted using hand tools.

19. Where cables pass through granular materials, they must be surrounded with graded sand.

If cables are routed through rock fill or other coarse fill, they must be surrounded with graded sand and the sand wrapped in a ‘Geotextile’ material to prevent sand migration. The Geotextile should, in turn, be surrounded by graded fill, and **not** placed directly into coarse rock fill.

20. Place sand by hand, grading or sieving it to remove oversize stones.

21. Continue using a hand operated compactor until a minimum of 500mm of fill has been placed and compacted over the cell and 200mm over the cables.

22. Once sufficient cover has been placed the instruments and instruments cables, mechanical hand operated tools can now be used to compact the 'less refined' fill.

23. When the fill level reaches the level of the surrounding fill, heavy mechanical plant must be used to complete compaction prior to continuing the general filling operations.

24. When the fill level reaches the level of the surrounding fill, heavy mechanical plant must be used to complete compaction prior to continuing the general filling operations.

5.3 Interface Cell Installations

Cells that are to be used to measure the contact pressures at 'hard / soft' interfaces should be prepared in the same manner as described for the cells installed in uniform materials (Section 5.2). Generally the 'hard' material would be concrete and the 'soft' materials would be clays or fine granular materials.

Preparation for their installation is, however, more involved than for those being installed into uniform materials. It is strongly advised that the cell be installed **'into'** the concrete so that the active face of the cell is FLUSH with the surface of the concrete, rather than being fixed **'onto'** the surface. The connecting tube, transducer and cable must also be protected by embedding them **'into'** the harder surface. This ensures that any movement of the softer material against the harder material (settlement for example) does not dislodge or damage the cell or its connecting tube / cable.

There are two approaches to the installation of the cells and their cables:-

Cast in-place ... Installed during the placing of concrete where the cells are fixed to the surface of the shuttering and the cables routed within the concrete.

Post Concreting ... Installed after the concrete structure has been cast. This is achieved by breaking out a suitable void in the concrete surface or forming a shallow void and bedding the cell into it. Similarly, a channel would be broken out or a shallow void formed into which the connecting cable would be bedded. The bedding material for the cell and cable is commonly a 'low shrinkage' mortar.

This method is sometimes preferred where steel faced shuttering is used since supporting the cell inside the shutter for the 'Cast in Place' method may damage the surface of the shutter.

If cells are to be installed at an interface, it is suggested that they be supplied with mounting 'lugs' welded to their circumference, as this will make fixing them much easier. However, this is sometimes not possible so installation details below show both options.

Preparation for the installation of the cells in either of the above situations is obviously quite different and will vary from application to application. The sketches below are intended to show the general arrangement that should be adopted for both installation types.

Where cable needs to be extended, this can be carried out either prior to the installation of the cell or afterwards, as the construction operations continue.

The connecting tube that links the pressure cell to the transducer is made from malleable stainless steel and can be carefully bent, but only in a gentle curve. Sharper bends may block the inner bore and prevent the instrument from working.

5.3.1 Cast in-place installation

In this type of installation, the cell will be fixed to the shuttering prior to placing the concrete. The cell can be fixed with the shuttering in place or prior to placing the shuttering.

Once the shuttering has been fabricated, the intended location of the cells should be marked on the inside face of the shuttering.

A suitable method of fixing the cells to the shuttering should be devised prior to installation. This should hold the cell in the intended position and firmly up against the shuttering during the concreting operation. Where possible, this may involve using supporting bolts through holes drilled in the shuttering.

Where possible, steps should be taken on prevent concrete from entering the small void between the face of the cell and the shuttering. Any void between cell face and the shuttering can be packed with heavy grease or a mastic seal can be formed around the contact circumference prior to fixing the cell. Both would be removed after the shuttering is stripped.

Lugged Total Pressure

When the “**ZERO PRESSURE READINGS”** for the cells have been determined, the cells can be transported to site. The serial numbers of the transducers should be checked and noted, along with the installation locations. The ‘transducers’ should then be covered with a foam or ‘cushion’ layer to provide protection during the concreting operations. As the tube is very robust it is not necessary to cover it.

The cell can now be fixed in place on the shuttering. The tube that links the cell to the transducer can be bent in a gentle curve so that the transducer and tube are not too close to the concrete surface. A minimum cover of 25mm is recommended. The transducer must be supported so that the connecting tube does not get damaged.

This support can be temporary until the reinforcement is placed. Here the transducer / tubing can be LOOSELY SUPPORTED on the steelwork but care must be taken NOT TO FIX them to the steelwork as it may move during concreting and this could damage the instruments.

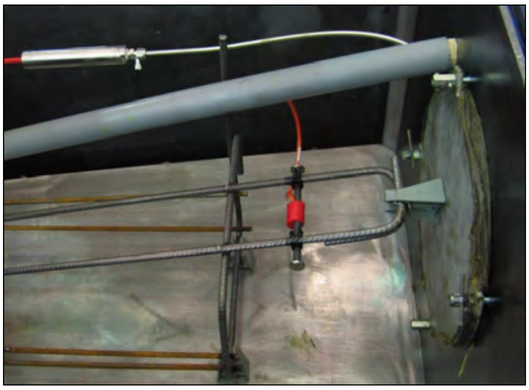
Once the installation is complete, a ‘check’ reading should be taken using a Vibrating Wire readout, to confirm the cell is operational and that its signal is stable.

The connecting cable should then be extended along a pre-defined route towards the readout location. This may be carried out in a single operation or may be a ‘step-by-step’ activity, as the concrete is cast. Where cables emerge from one casting and are to enter another they should be provided with adequate protection. It would be advantageous to route the cable to an accessible reading point within one casting, if at all possible.

It is STRONGLY advised that cables SHOULD NOT cross expansion joints except where a special cable pocket has been included.

Cell locations and the cable route should be documented and MUST be well marked. The concrete placing team MUST be informed that there are specific areas containing sensitive equipment that MUST NOT be damaged by the concreting operations.

A reading should be taken just prior to concreting and just after the concreting works have been completed.



VWTPC-4010 installed in pre-cast mould together with strain gauge

5.3.2 Post concreting installation

In existing structures of where the construction programme prevents the positioning of the cells during casting, the cells can be fixed INTO the concrete elements by creating shallow voids into which they are fixed.
These voids can be formed using void formers fixed to the shuttering at the required location prior to concreting or 'broken out' once the concrete is in place.

The position of the pressure cells should be marked onto the concrete / hard surface, along with the position of the connecting tube, the transducer and the intended cable route.

A shallow void, approximately twice the thickness of the cell in depth and just larger than its diameter, should be cut out of the surface of the concrete. In addition, slots should be cut so that the connecting tube and transducer (complete with a thin layer of foam) must be fixed well BELOW the surface of the concrete. The transducer and tube must be a minimum of 25mm below the concrete surface once fixed into position. A slot also needs to be cut into the concrete from the transducer location, along the intended cable route. The slot must be deep enough for the cable to sit a minimum 25mm below the concrete surface.

Where cables are to be extended, this should generally be carried out prior to the fixing of the cell and its cable. Cable joints within the concrete are best avoided, except where unavoidable and must be covered by a minimum of 25mm of concrete. It is preferable that transducers have sufficient cable fitted at the factory.

It is necessary to develop a suitable method holding the cell in position while the bonding mortar cures. This would vary from application to application where temporary fixing are employed to support the cell. The photographs below shows a typical method that could be adopted.

The connecting tube should never be used to lift or support the cell

A reading should be taken just prior to fixing the cell into position and just after the works have been completed

5.4 Cable

5.4.1 Cable Installation

The cable should be protected from accidental damage caused by moving equipment. This is best done by putting the excess cable inside a junction box (Cables may be spliced to lengthen them, without affecting gage readings. Waterproof the splice kits are available from the factory.

5.4.2 Cable marking.

Cables should be marked with unique identification. Markings should be repeated at regular intervals along the cable where multiple cables are to be grouped together, so that in the event of cable damage, there may be a chance that the identification could be exposed and the cables re-joined. Multiple cable marks are particularly important close to the end of the cable. The spacing of markings can vary according to specific site requirements but a guide of 5m to 10m is commonly applied (available on request).

5.5 Tools List

Obtain any tools necessary to carry out the installation. The following is a brief list of **some** of the tools typically used during the installation of Vibrating Wire Total Pressure cells.

- **Excavation Tools** (hand and mechanical)
- **Short Spirit Level** - to check the installation orientation.
- **Hammers** - for compaction
- **Compaction equipment** (hand and mechanical)
- **Wire cutters and strippers**
- **Vibrating Wire Readout unit** for checking the transducer function
- **Cable Marking** system / equipment (eg coloured PVC Tapes)
- **Tie wire/ Cable ties** - for supporting cells, transducers and cables.
- **Cable joints** - to join cables if required
- **Fixing bolts** - for mounting 'lugged' cells

6.0 DATA HANDLING

The function of an instrument is to provide useful and reliable data. Accurate recording and handling of the data is essential if it is to be of any value.

6.1 Monitoring the Total Pressure Cell Readings

Geosense® VWTPC-4000 Total Pressure Cells include both pressure and temperature sensors. If cells are installed in a zone where the temperature is likely to fluctuate significantly, values of both pressure and temperature data should be recorded. They can then be used to assess any temperature effects on the pressure readings.

6.1.1 Portable Readouts

Geosense® offer a range of readout and data logging options. Specific operation manuals are supplied with each readout device.

Below is a brief, step-by-step procedure for use with the **Geosense® VWR1**portable readout.

1. Connect the signal cable from the sensor to the readout following the wiring colour code. Conductor colours may vary depending upon the extension cable used. Commonly these are:

RED	=	VW +
BLACK	=	VW -
GREEN	=	Temp
WHITE	=	Temp

2. Switch on the readout unit

3. To acquire readings press the **acq.** button on the left

The readout displays vibrating wire values in frequency (Hz) and B units (Hz^2/1000), Digits) and a temperature readings in ºC and resistance Ω.

Whilst it is not critical that the polarity be observed for most Vibrating Wire instruments, a better signal may be obtained if the correct polarity is maintained. Since the temperature sensor is a Thermistor, its connection polarity is not important.

6.1.2 Automatic data acquisition

A number of automatic data loggers (**GeoLoggers**) are manufactured by **Geosense®** which automatically excite, interrogate and record the reading from Vibrating Wire instruments in both single and multi-channel configurations.

GeoLoggers include the Linx, GL800/1000, G8 Plus.

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6.2 Data Reduction

The tension in a vibrating 'sensor wire' can be measured by detecting the frequency (note) at which it naturally vibrates. This tension can be detected and described in various ways. The following is a description of the measured units commonly used by the instrumentation industry.

Frequency Units (Hz). If the wire is 'excited' electronically, the frequency at which it vibrates. The units used to express frequency are Hertz (Hz) or kilo Hertz (kHz).

The disadvantage of these units is that there is no 'linear' relationship between 'change in Hertz' to 'change in wire tension'.

Linear Digits (B). In order to overcome the problem of a linear relationship described above, the frequency value can be squared, thereby rendering it linear, but quite large. To reduce its size, it is commonly divided by 1000 (or multiplied by 10^{-3}). The expression $Hz^2/1000$ (or $Hz^2 \times 10^{-3}$) is the most commonly adopted as a 'linear' digital output.

Period Units (P). Some readout devices utilise the 'counter' function available in many common integrated circuits.

Period Units represent the time taken for the wire to vibrate over one full oscillation, expressed in seconds. Due to the very small size of the number generated most equipment manufacturers display the unit multiplied by either 1000 (10^3) or 10000000 (10^7).

The relationship between Period units and Frequency units is expressed as

$$\text{Period} = \frac{1}{\text{Frequency}}$$

For some instruments, Period units are convenient to measure but they do not readily translate to a straight line calibration. Some readouts, mainly older models, read only Period units.

To convert the readings to and 'Engineering Value', calibration factors must be applied to the recorded values. Commonly, instruments are tested to produce a 'straight line' relationship and a 'linear calibration' factor is derived from the 'slope of the line'. To apply this factor, the readings must be in a 'Linear' format.

If the readout display is in Period units (e.g. 0.03612 or 3612 - depending upon the readout used) the first step to producing an engineering value is to convert the reading to Linear Digits ($Hz^2/1000$) . Two examples of this calculation can be seen below. The first (1) where the readout includes a decimal point and displays the Period in ***Seconds***$^{-2}$ and the second (2) where the readout displays the Period in ***Seconds***$^{-7}$

(1) Readout Display = 0.03612

Linear Digits ($Hz^2/1000$) = $(1 / 0.03612 \times 10^{-2})^2 / 1000$

= 7664.8

(Continued on page 27)

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(2) Readout Display = 3612
Linear Digits ($Hz^2/1000$) = $(1 / 3612 \times 10^{-7})^2 / 1000$
= 7664.8

If the readout displays 'Frequency' values, (e.g. 2768.5 Hz) only a simple calculation is required to convert the readings to Linear Digits.

Linear Digits ($Hz^2/1000$) = $(2768.5)^2 / 1000$
= 7664.6

Certain data loggers store Vibrating Wire data in Linear Digits but further divided by 1000. In this instance, the data values would have to be multiplied by 1000 to maintain the standard Linear Digits ($Hz^2/1000$) format for standard calculations.

Where 'calibration testing' does not produce a straight line relationship, a 'polynomial calibration' can be derived and applied to the recorded data.

Conversion of Readings into Engineering Units

For most Vibrating Wire sensors, the calibration factors are unique and are detailed on the sensor calibration sheet that is supplied with all Geosense Vibrating Wire Pressure Cells.

There are many ways to achieve the conversion from recorded data to useful engineering values. The following are included as a guide only and as a basis for alternative approaches.

Linear Calculation

This is the most simple calculation to convert 'raw' data to engineering units. It can be easily carried out using a simple calculator. It assumes that the reading is in Linear Digits ($Hz^2/1000$). Where this is not the case, the reading should be converted to these units prior to application of the calibration factors. For most applications this equation is perfectly adequate and is carried out as follows:

Pressure (psi) = Linear Factor for psi (k) x (Current Reading - Base Reading).

Geosense® prefers to employ the linear calibration equation, wherever possible, as it reflects the 'initial' or 'base' readings and conditions that are recorded on site.

Polynomial Calculation

The polynomial calculation can be more precise as it accommodates any slight deviation from a perfect linear correlation. However to use the polynomial equation the "C" Constant for the environment must be calculated using a "Site Zero" Reading at atmospheric pressure.
Once the Site "C" Constant is established the polynomial formula can be used to convert Raw Data to Engineering Units.

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$$Site\ C = (-A \times Site\ Zero\ Reading^2) - (B \times Site\ Zero\ Reading)$$

The above formula essentially gives the relative change in the variable being measured.

Where the pressure is required in an alternative format, mH_2O, MPa or kPa for example, some alternative factors are included on the calibration sheets. For other units a simple conversion using standard conversion factors can be either applied to each factor or at the end of the equation. (for example ...1 psi = 0.7031 mH_2O).

$$Engineering\ Unit = (A \times Reading^2) + (B \times Reading) + Site\ C$$

$$Eng\ Unit = (A \times Reading^2) + (B \times Reading) + (-A \times Site\ Zero\ Reading^2) - (B \times Site\ Zero\ Reading)$$

$$Eng\ Unit = A \times (Reading^2 - Site\ Zero\ Reading^2) + B \times (Reading - Site\ Zero\ Reading)$$

An instrument calibration sheet similar to the example in the appendix of this manual includes the following information:

Model	This refers to the **Geosense**® model number.
Serial Number	This is a unique sensor identification number that can be found on the cable just behind the transducer body and, for long cables, at the end of the cable.
Works ID	Unique works batch and range code
Cal Date	Date the calibration was performed
Baro	Barometric Pressure at the time of calibration
Temp °C	Temperature at which the Pressure cell was calibrated
DPI No.	Serial number of the Digital Pressure Indicator used in conjunction with the pressure generator
Readout No.	Serial Number of the readout used to display the transducer output
R/O Cal Date	The date on which the Readout was calibrated to a traceable standard
Applied Pressure	Pressure applied to the transducer as part of the calibration cycle in both psi and kPa
Readings [digit]	Readings from the transducer as pressure is applied and as pressure is reduced, in steps. The average is calculated.
Calculated Pressure	Calculation of the applied pressure using the calculated Linear and Polynomial for comparison with the actual Applied Pressure.
Non Lin. % FSO	Non Linearity expressed as a percentage of the transducers Full Scale.
Calibration Factors	'Linear' and 'Polynomial' factors for common units. Examples of other calculated values are detailed below.

The following are examples of data reduction calculations and are based upon the Total Pressure cell and pressure transducer to which the attached example and calibration sheets refers.

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(Continued from page 28)

A. An example of the Total Pressure Cell calculation from Linear Digits ($Hz^2/1000$) to kPa using a Polynomial equation is given below:-

Calibration Factors for kPa	A	= - 6.3014 $^{-7}$
	B	= - 0.1685013
	C	= 1664.594

Current Reading in Linear Digits = 9244.3

Equation

Pressure in kPa = [A x (Reading)^2] + [B x Reading] + C
= [- 6.3014 $^{-7}$ x (9244.3)^2] + [- 0.1685013 x 9244.3] + 1664.594
= - 53.85 - 1557.67 + 1664.59
= 53.07 kPa

B. An example of the Piezometer calculation from Linear Digits ($Hz^2/1000$) to mH2O, using a Linear equation is given below:-

Calibration Factor for mH_2O	A	= - 6.3014 $^{-7}$
	B	= - 0.1685013
	C	= 1664.594

Current Reading in Linear Digits = 9244.3

Equation

Pressure in kPa = [A x (Reading)^2] + [B x Reading] + C
= [- 6.3014 $^{-7}$ x (9244.3)^2] + [- 0.1685013 x 9244.3] + 1664.594
= - 53.85 - 1557.67 + 1664.59
= 53.07 kPa

B. An example of the calculation from Period units (Seconds $^{-7}$) to Metres of Water (mH_2O) using a Linear equation is given below:-

Site Zero Reading	= 3235
Zero Converted to Linear Digits	= 9555.5
Calibration Factor for mH_2O (K)	= - 0.18159
Current Reading	= 3289
Current Reading in Linear (B) Digits	= 9244.3

Equation

Water Pressure mH_2O = K x (Current Reading - Base Reading)
Water Pressure mH_2O = -0.018159 x (9244.3 - 9555.5)
Water Pressure mH_2O = 5.651m

Since this type of cell is most often used to determine the ACTUAL pressure, this is calculated by subtracting any pore pressure (measured by a local piezometer) from the calculated TOTAL pressure.

Total Pressure - Pore Pressure = Actual Pressure

MGS QUALITY PROCEDURE
Form No MGS /QF/144
ISS. 1
DATE : 23/05/12
SIG. SKH

VW TOTAL PRESSURE CELL CALIBRATION SHEET

Model	TPC-4000	Cal date	10-May-12	DPI No.	610
Serial	TP1651	Baro	1028.0	Readout No.	VR0602
Works ID	317155	Temp °C	18.2	R/O Cal. date	12/07/2011
Customer	Larzeh Sakht Savalan				

Applied pressure		Readings [digit]			Calculated Pressure		Error % fso	
psi	kPa	I up	I down	avg.[digit]	lin.[kPa]	polyn.[kPa]	linear	polynomial
0.000	0.000	9479	9479	9479.0	4.25	-0.15	0.21%	-0.01%
29.007	200.000	9042	9043	9042.5	202.32	200.55	0.12%	0.03%
58.013	400.000	8608	8608	8608.0	399.48	399.76	-0.03%	-0.01%
87.020	600.000	8169	8169	8169.0	598.69	600.45	-0.07%	0.02%
116.026	800.000	7732	7732	7732.0	796.98	799.64	-0.15%	-0.02%
145.033	1000.000	7293	7293	7293.0	996.19	999.16	-0.19%	-0.04%
174.039	1200.000	6851	6851	6851.0	1196.75	1199.45	-0.16%	-0.03%
203.046	1400.000	6407	6407	6407.0	1398.23	1400.05	-0.09%	0.00%
232.052	1600.000	5960	5960	5960.0	1601.06	1601.39	0.05%	0.07%
261.059	1800.000	5515	5516	5515.5	1802.76	1801.01	0.14%	0.05%
290.065	2000.000	5074	5074	5074.0	2003.10	1998.69	0.15%	-0.07%

Calibration of master DPI valid from 30 Sep 2009. UKAS Certificate of Calibration 06470 issued by Chamois Metrology (UKAS Accredited Calibration Laboratory 0822)

CALIBRATION FACTORS

Linear factor (k)

kPa per digit	psi per digit	mH_2O per digit
-0.453768294	-0.065811	-0.046271

Polynomial factors

	kPa	psi	mH_2O
A	-1.52016E-06	-2.20472E-07	-1.5501E-07
B	-0.431643859	-0.062602	-0.044015
C	4227.990059	613.1965278	431.135001

Note: Digits are $Hz^2 \times 10^{-3}$ units.

(please consult the User Manuals for conversion of alternative reading units)

Polynomial calculation [kPa] = A * (Reading)2 + B * (Reading) + C

Linear calculation [kPa] = k (kPa) * (Current Reading - Site Zero Reading)

THIS CERTIFICATE IS VALID ONLY WHEN CARRYING THE OFFICIAL ORIGINAL STAMP OF MGS-GEOSENSE BELOW

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6.3 Thermistor temperature table

USING STEINHART & HART LOG

Thermistor Type. 3k @ 25ºC

Resistance/ temperature equation:-

$$T= (1 / (A + B (LnR) + C(LnR)^3)) -273.2$$

Where:-

T = Temperature in degrees Centigrade
LnR= Natural log of Thermistor resistance.
$A= 1.4051 * 10^{-3}$
$B= 2.369*10^{-4}$
$C=1.019*10^{-7}$

(Applicable to the range –50 to + 150 Centigrade only)

Resistance versus temperature table

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	30	525.4	70	153.2	110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149

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6.4 Temperature Correction

Corrections for temperature are not easily quantified because the pressure cell, when in use is surrounded and confined by soil or soil and concrete each with its own differing temperature coefficient of expansion.

However the effect is usually small, especially at depths where the temperature is fairly constant. If temperature fluctuations are great, then the thermistor should be used to measure temperatures and an Engineering approach taken to see if any compensation should be applied (see section 6.1)

It is recommended that during the site "**ZERO PRESSURE**" readings prior to installation that the cell output readings are observed and recorded versus temperature variation when it can be reasonably assumed that the load on the cell is not changing.

6.5 Barometric Correction

Whilst the pressure transducer attached will be affected by atmospheric changes Total Earth Pressure Cells are typically buried under several metres of soil or concrete and any fluctuations are unlikely to be greater than ±2-3 kPa, correction is generally not required.

If a correction for these fluctuations is required then it will be necessary to record the barometric pressure at the time of each reading.

7.0 MAINTENANCE

For most applications, the Vibrating Wire Total Pressure cell is a maintenance free device. This is because it is intended for sub-surface installation and would normally be irretrievably sealed into soil or concrete.

Maintenance of wiring connections between the Total Pressure cell and any terminal panels / or loggers should involve occasional tightening of any screw terminals to prevent loose connections or cleaning terminals to prevent the build up of corrosion. In addition, checks should be made to ensure that any exposed cables are not ‘at risk’ from accidental or malicious damage. Animals, such as rodents, must be kept away from exposed cables.

8.0 TROUBLESHOOTING

It is generally accepted that when a Vibrating Wire instrument is producing a stable reading on a suitable readout, the value will be correct. Only on very rare occasions will this be untrue.

In almost all cases, a fluctuating reading is a sign of a faulty signal from the sensor. The fault could be in either the sensor, the connecting cable, any switch boxes or the readout.

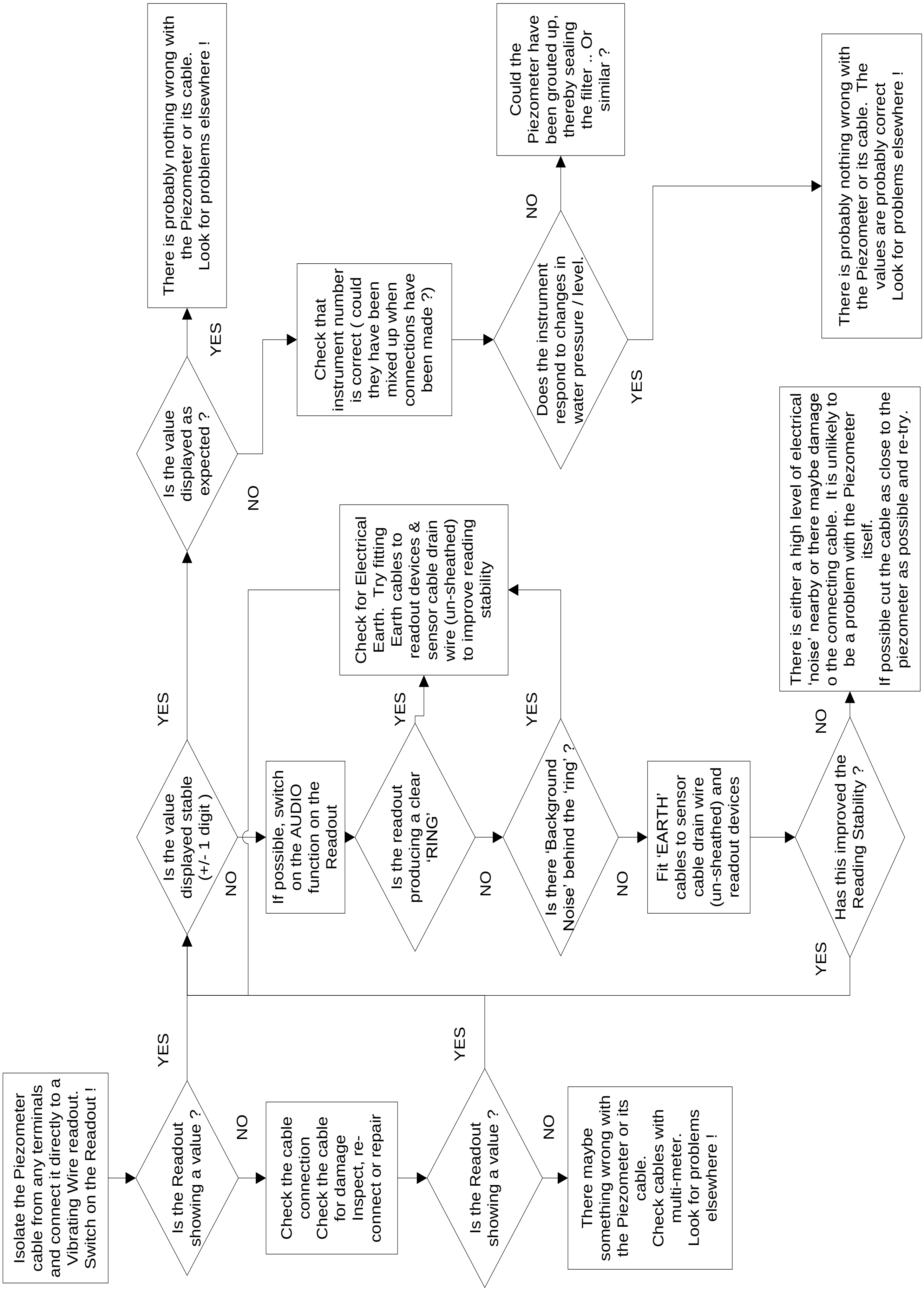
The most effective way to fault find an instrument is to isolate it’s connecting cable from all other instruments and connections. Then, using a hand held readout, connect to the cable. Where possible, begin fault finding at the sensor itself or as close to it as can be achieved. Alternatively, work back towards the sensor, to locate the fault.

Using a readout equipped with an ’Audio’ function will help with fault finding operations. The sound of the signal generated by the transducer (or its ‘Ping’) can help determine the condition of the sensor and, in some cases, its connecting cable.

A multi-meter can be used to check the continuity of the cable linking the sensor to the terminal location.

- The electrical resistance between the two conductors of the Vibrating Wire connection should be between 100 and 300 Ohms.

- The resistance between the two conductors of the Thermistor should be between 2000 and 5000 Ohms.


Isolate the Piezometer cable from any terminals and connect it directly to a Vibrating Wire readout. Switch on the Readout !
Is the Readout showing a value ?
YES
NO
Check the cable connection
Check the cable for damage
Inspect, re-connect or repair
Is the Readout showing a value ?
YES
NO
There maybe something wrong with the Piezometer or its cable.
Check cables with multi-meter.
Look for problems elsewhere !
Is the value displayed stable (+/- 1 digit)
YES
NO
Is the value displayed as expected ?
YES
NO
There is probably nothing wrong with the Piezometer or its cable.
Look for problems elsewhere !
Check that instrument number is correct (could they have been mixed up when connections have been made ?)
Does the instrument respond to changes in water pressure / level.
YES
NO
Could the Piezometer have been grouted up, thereby sealing the filter .. Or similar ?
There is probably nothing wrong with the Piezometer or its cable. The values are probably correct
Look for problems elsewhere !
If possible, switch on the AUDIO function on the Readout
Is the readout producing a clear 'RING'
YES
NO
Check for Electrical Earth. Try fitting Earth cables to readout devices & sensor cable drain wire (un-sheathed) to improve reading stability
Is there 'Background Noise' behind the 'ring' ?
YES
NO
Fit 'EARTH' cables to sensor cable drain wire (un-sheathed) and readout devices
Has this improved the Reading Stability ?
YES
NO
There is either a high level of electrical 'noise' nearby or there maybe damage o the connecting cable. It is unlikely to be a problem with the Piezometer itself.
If possible cut the cable as close to the piezometer as possible and re-try.

9.0 SPECIFICATION

Model	VWTPC 4000	VWTPC 4010
Pressure range	345, 518, 690 kPa	345, 518, 690 kPa
	10.34, 13.79, 20.7, 34.5MPa	10.34, 13.79, 20.7, 34.5MPa
Over range	150% FS	150% FS
Signal output	2000 - 3500 Hz	2000 - 3500 Hz
Resolution	± 0.025% FS	± 0.025% FS
Accuracy[1]	± 0.1% FS	± 0.1% FS
Linearity	<0.5% FS	<0.5% FS
Outside diameter	165, 245, 320mm	120, 230, 320mm
Active diameter	150, 230, 305mm	150, 230, 305mm
Lug size	-	25 x 25 x 5mm
Lug hole diameter	-	10mm
Fixing centres		190, 270, 345mm
Thickness	7mm	10.5mm
Operating temp.	-20°C to +80°C	-20°C to +80°C

[1] Calibrated accuracy of pressure sensor

10.0 SPARE PARTS

As a Vibrating Wire Total Pressure cell is a sealed unit, it is neither serviceable nor does it contain any replaceable parts.

Civil engineering sites are hazardous environments and instrument cables can be easily damaged if they are not adequately protected. **Geosense®** can therefore provide the following parts that may be required to effect repairs to instrument cables:

- PU coated 4 Core cable with foil shield and copper drain.
- PVC coated, armoured, 4 Core cable suitable for direct burial.
- Epoxy jointing kit for forming a waterproof cable joint.

Please contact **Geosense®** for price and availability of the above components.

11.0 RETURN OF GOODS

11.1 Returns procedure

If goods are to be returned for either service/repair or warranty, the customer should contact Geosense for a **Returns Authorisation Number,** request a **Returned Equipment Report Form QF034** and, where applicable, a **Returned Goods Health and Safety Clearance Form QF038** prior to shipment. Numbers must be clearly marked on the outside of the shipment.

Complete the **Returned Equipment Report Form QF034**, including as much detail as possible, and enclose it with the returned goods.

All returned goods are also to be accompanied by a completed **Returned Goods Health and Safety Clearance Form QF038** attached to the outside of the package (to be accessible without opening the package) and a copy of both forms should be faxed or emailed in advance to the factory.

11.1.1 Chargeable Service or Repairs

Decontamination
In some environments in which equipment is used, it is inevitable that they will be contaminated when returned. **Geosense®** is duty bound to de-contaminate any such equipment and there is a standard charge for de-contamination, (please contact **Geosense®** for details).

Inspection & estimate
It is the policy of **Geosense®** that an estimate is provided to the customer prior to any repair being carried out. A set charge for inspecting the equipment and providing an estimate is also chargeable.

11.1.2 Warranty Claim

(See Limited Warranty Conditions)
This covers defects which arise as a result of a failure in design or manufacturing. It is a condition of the warranty that the Vibrating Wire cell must be installed and used in accordance with the manufacturer's instructions and has not been subject to misuse.

In order to make a warranty claim, contact **Geosense®** and request a **Returned Equipment Report Form QF034.** Tick the warranty claim box and return the form with the goods as above. You will then be contacted and informed whether your warranty claim is valid.

11.2 Packaging and Carriage

All used goods shipped to the factory **must** be sealed inside a clean plastic bag and packed in a suitable carton. If the original packaging is not available, **Geosense®** should be contacted for advice. **Geosense®** will not be responsible for damage resulting from inadequate returns packaging or contamination under any circumstances.

11.3 Transport & Storage

All goods should be adequately packaged to prevent damage in transit or intermediate storage.

12.0 LIMITED WARRANTY

The manufacturer, Geosense, warrants the **Geosense® VWTPC-4000 Total Pressure Cells** manufactured by it, under normal use and service, to be free from defects in material and workmanship under the following terms and conditions:-

Sufficient site data has been provided to **Geosense** by the purchaser as regards the nature of the installation to allow **Geosense** to select the correct type and range of **VWTPC-4000 Total Pressure Cells** and other component parts.

The **Geosense® VWTPC-4000 Total Pressure Cells** equipment shall be installed in accordance with the manufacturer's recommendations.

The equipment is warranted for 1 year from the date of shipment from the manufacturer to the purchaser.

The warranty is limited to replacement of part or parts which, are determined to be defective upon inspection at the factory. Shipment of defective part or parts to the factory shall be at the expense of the Purchaser. Return shipment of repaired/replaced part or parts covered by this warranty shall be at the expense of the Manufacturer.

Unauthorised alteration and/or repair by anyone which, causes failure of the unit or associated components will void this **LIMITED WARRANTY** in its entirety.

The Purchaser warrants through the purchase of the Geosense® VWTPC-4000 Total Pressure Cells cell equipment that he is familiar with the equipment and its proper use. In no event shall the manufacturer be liable for any injury, loss or damage, direct or consequential, special, incidental, indirect or punitive, arising out of the use of or inability to use the equipment sold to the Purchaser by the Manufacturer.

The Purchaser assumes all risks and liability whatsoever in connection with the **Geosense® VWTPC-4000 Total Pressure Cells** equipment from the time of delivery to Purchaser.

Geosense Ltd

Nova House . Rougham Industrial Estate . Rougham . Bury St Edmunds . Suffolk . IP30 9ND . England .

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