V1.0 July 2020

HIGH TEMPERATURE VW PIEZOMETERS

VWPHT-3600

INSTRUCTION MANUAL

CONTENTS

1.0 INTRODUCTION

This manual is intended for all users of High Temperature Vibrating Wire Piezometers **VWPHT-3600 Series** manufactured by **Geosense®** and provides information on their principle, installation, operation and maintenance.

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

1.1 General Description

Geosense® VWPHT-3600 Series High Temperature Piezometers are suitable for the extreme environments of temperature and pressure found within applications such as geothermal heat and enhanced oil recovery systems including steam assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS).

They are capable of monitoring high temperatures up to 250°C and pressures up to 34.5 MPa. They are available in two models VWPHT-3600 for temperatures up to 200°C and VWPHT-3610 for temperatures up to 250°C

Manufactured from high temperature and corrosion-resistant materials throughout, together with a comprehensive temperature calibration, they provide high accuracy stable long-term data with no zero drift.

The specially-designed Tubular Encapsulated Cable (TEC) is both high temperature resistant and highly flexible for easy installation within boreholes or above ground.

Each VW piezometer is fitted with a length of high temperature connecting cable, and an internal high temperature thermistor.

A filter is used to protect and separate the sensing diaphragm from the surrounding materials. It is a sintered Stainless Steel 50 micron (µm) filter, sometimes referred to as Low (resistance to) Air Entry (LAE). The filter is mounted within a Stainless Steel housing that is fitted onto the end of the sensor body.

Operating / calibration range

During calibration, the **Geosense®** range of **VWPHT-3600 Series High Temperature Piezometers / Transducers** are calibrated over a series of different temperatures to prove their function over a wide temperature range and provide the input data for any temperature compensation that may be required.

Piezometers and Transducers are all tested to 1.5 times (150%) their standard, calibrated, working range to prove their function at overpressure.

The calibration values will not be valid when the upper calibration value is exceeded. However, the validity of the calibration will not be affected, providing the overpressure % does not exceed 50 % (applied pressure is 150% working range).

1.2 Theory of Operation

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The Vibrating Wire Piezometer consists of a tensioned steel wire, anchored at one end to a flexible diaphragm (the sensing element) and at the other end to the inner body, all sealed into a stainless steel shell. The internal parts of all **Geosense®** piezometers and transducers are identical. Only the thickness of the diaphragm, the geometry of the shell and the filter arrangements change.

Two opposing coils are located within the inner body, close to the axis of the sensing wire. When a brief voltage excitation, or swept frequency excitation is applied to the coils, a magnetic field is generated causing the wire to oscillate at its resonant frequency. The wire continues to oscillate for a short period through the 'field' of the permanent magnets in the coils, thus generating an alternating current (sinusoidal) output.

The frequency of the generated current output is detected and processed by a vibrating wire readout unit, or by a data logger equipped with a vibrating wire interface, where it can be converted into 'Engineering' units of pressure.

As pressure is applied to the exposed side of the flexible diaphragm (gas or liquid), the diaphragm deflects, causing a change in the tension of the sensing wire behind it. The change in tension of the wire results in a change in the resonant frequency at which the wire oscillates. The change in the square of the frequency of oscillation is directly proportional to the pressure applied.

2.0 CONFORMITY

Geosense Ltd
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IP30 9ND
Email: info@geosense.co.uk, Web: www.geosense.co.uk.

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

Equipment description	**Vibrating Wire Piezometers**
Make/Brand	**Geosense**
Model Numbers	**VWPHT-3600, VWPHT-3610**

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

EN 61326-1:2013 Electrical equipment for measurement, control and laboratory use.
EMC requirements. General requirements.

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

Martin Clegg
Director

July 2020

3.0 MARKINGS

Geosense® VWPHT-3600 Series High Temperature Piezometers / Transducers are labelled with the following information:-

Product Name

Product Type

Calibrated Operating Range

Individual Serial Number

Manufacturers Name & Address

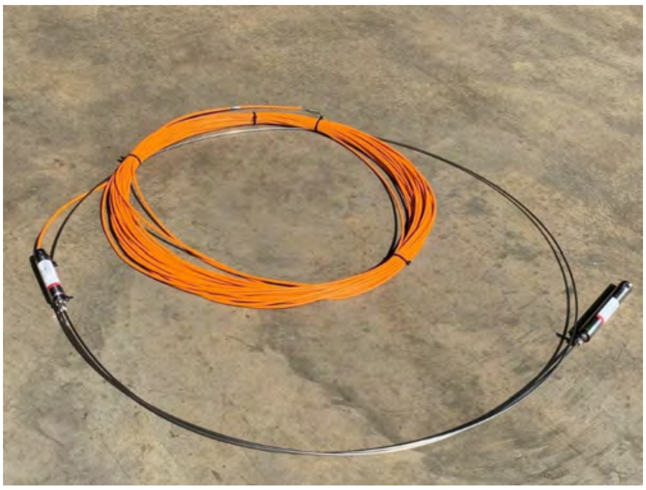
CE Mark

THE POSITION OF LABELS MAY VARY ACCORDING TO THE CABLE REQUIREMENTS.

THE LABEL ON THE PIEZOMETER BODY SHOULD BE REMOVED PRIOR TO INSTALLATION

CABLE

The Tubular Encapsulated Cable (TEC) is supplied in a coil and can have bare conductors, a connector or spliced onto a standard VW cable as shown below.



4.0 DELIVERY

This section should be read by all users of **VWPHT-3600 High Temperature Piezometer Series** manufactured by **Geosense®**

4.1 Packaging

VWPHT-3600 High Temperature Piezometers are 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 reported to both the transportation company and **Geosense®**.

4.2 Handling

Whilst they are a robust devices, **VWPHT-3600 High Temperature Piezometers** 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 piezometers remain in their original packaging for storage or onward 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 may damage the internal conductors and could render an installation useless.

4.3 Inspection / functionality check readings

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. If any components are missing or damaged, please contact **Geosense®**.

ALL **Geosense® VWPHT-3600 High Temperature Piezometers** carry a **unique** identification serial number which is included on the label on the piezometer plus the splice connector (where fitted) and at the free end of the cable. All VW piezometers are supplied with individual calibration sheets that include their serial numbers and these are shipped with the piezometers.

Cable marks also carry the model type and the length of cable fitted at the factory.

CHECK the piezometer readings against the factory 'Zero Readings' on arrival to ensure they have not changed significantly due to damage during transportation. This is a basic 'out of the box' functional check.

Prior to carrying out a reading check, ensure that the piezometers have been stored in a reasonably stable temperature for at least 30 - 60 minutes.

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4.3 Inspection/functionality contd…

To carry out the check, connect a Vibrating Wire readout to the bare cable ends (Red connector to Red wire and Black connector to Black wire) – The Green and White connectors / wires are for the temperature sensor and are not required for this checking exercise - see the readout manual for connection guidance.

Record the values (and units) displayed on the readout together with the piezometer serial numbers.

The “CHECK” readings should coincide with the factory zero on the calibration sheet within +/- 50 Digits (see the example calibration sheet in Section 9) .

The elevation of the **Geosense®** factory is +60 metres above sea level and barometric pressures change with altitude by approximately 1.2kPa per 100 metres.

*however, copies may be obtained from Geosense, in case of loss

The ‘CHECK Readings WILL be affected by temperature changes and slightly by changes in atmospheric pressure

Calibration Sheets contain VITAL information about the piezometer. They MUST be stored in a safe place.
Only COPIES of calibration certificates should be taken to site
The original certificates should be stored safely*.

4.4 Storage

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

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.

If a piezometer is supplied with a pre-saturated filter or has been saturated on site, it must be kept at a temperature **above zero degrees Celsius.** If the water freezes, damage could be caused to the diaphragm.

5.0 INSTALLATION

Installation will be dependent on the actual application and therefore should be installed in accordance with the project specification. Installation methods typically include attachment to grout pipes or special installation rods together with other items being installed simultaneously within the borehole.

It is VITAL that personnel responsible for the installation and use of the piezometers READ and UNDERSTAND the 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 documents are included.

5.1 ZERO PRESSURE Reading

Vibrating wire transducers differ from most other pressure sensors in that they indicate a positive value at zero applied pressure. They will never read ZERO. Their readings at **ZERO PRESSURE** can vary significantly between sensors.

IT IS ESSENTIAL TO TAKE ZERO PRESSURE READINGS
BEFORE
INSTALLATION IS CARRIED OUT

As with most transducers, do not directly handle the Pressure Transducer when recording the **ZERO PRESSURE** readings, as this will cause local temperature gradients across the body that will distort the readings.

The Pressure Transducer is supplied with a filter inside its threaded bulkhead. The bulkhead has a threaded socket (1/4” BSPF) that is used for connection to liquid (or gas) pressure sources. The treaded bulkhead should be removed prior to establishing **ZERO PRESSURE** values.

5.1 ZERO PRESSURE Reading contd...

The ‘on-site’ **ZERO PRESSURE** readings for Vibrating Wire Piezometers and Transducers are obtained as follows:

1. Fill a large bucket with clean, potable water, ideally at a temperature close to 20° C. Ensure that the bucket is away from any heat sources in an air temperature close to 20°C. (+/- 3°C is acceptable). Remove any fitted filters and place the sensor(s) in the bucket.

   Leave the sensor bodies covered with water for a minimum of 4 hours - preferably over night.

2. At the free end of the cable, connect the leads to a vibrating wire readout unit and occasionally monitor the sensor output by turning on the readout and observing the display (see the readout user manual for assistance).

   Be sure to turn off the readout between periods of readings so as to avoid ‘heating’ the Vibrating Wire element.

3. Turn on the readout and, **holding only the cable**, lift the sensor out of the bucket, allowing it to hang vertically downwards and immediately record 2 or 3 readings. Replace the sensor in the water as before.

   After approximately two minutes of re-immersion, repeat and record another set of readings. Repeat three times, checking that the readings displayed are within +/- 1 digits of each other.

4. On the calibration sheet, note these readings together with the sensor temperature, local barometric pressure, approximate elevation above sea level, date and time.

5. Return the sensor to the water and ensure that no air is trapped inside the body.

6. Still **all underwater**, refit the filter, taking care not to trap air inside the sensor. Either leave the sensor in the bucket of water or transfer it to another water filled container, for transport to site for installation. If, for any reason the water escapes from the sensor body, repeat the water filling exercise, just prior to installation. (the Site Zero need not be repeated)

5.2 Preparation for Installation

Prior to installation of a piezometer / transducer, it is essential to establish and confirm details of the installation to be carried out. Some of the main considerations are listed below :-

1. **Intended elevation and depth for the Sensor**

   This can be calculated as either the depth below a known level (ground level for example) or as the elevation with respect to a remote datum. For borehole installations, the final depth should be determined from the intended installation elevation and then marked on the cable to show the intended installed position.

   Which ever positioning system is adopted, it is very important to determine and record the final elevation of the piezometer diaphragm and its orientation.

2. **Borehole Installation type / specification**

   Where a piezometer is to be installed in a borehole, is it to be pushed into the base of the borehole using the appropriate technique of the project specification. In softer material, the push-in piezometer can be pushed from ground level to its intended elevation, using hydraulic equipment such as a Cone Penetrometer machine. This removes the need for a borehole.

3. **Surface Installation type / specification**

   Where a piezometer is to be installed at surface level (for example: as embankment fill is placed), is it to be pushed into a pre-formed cylindrical void or installed in a small excavated pocket? Piezometers in these installations would normally be covered by fill material which would be compacted manually to a certain depth and then mechanically, thereafter.

   In a location where high permeability material is present, a sand filter pocket type installation is preferred but the sand has to be enclosed within a permeable 'Geo-fabric' pocket to prevent it being 'lost' into the surrounding materials.

   Where a piezometer is to be installed in a material with a low permeability, it is normally better pushed into a pre-formed void so as to maintain intimate contact with the surrounding material. (Sand pockets should be avoided in low permeability surface installations).

4. **Filter zone**

   A specially graded sand (commonly 600 - 1200 µm) is the most common material used to provide a filter zone within a borehole and support the borehole around the piezometer tip. The volume of material required will depend upon the diameter of the borehole and the length of the filter zone to be formed. Typically a 0.5 metre long filter zone is recommended but it should be in accordance with specific project requirements and specifications.

   In some cases piezometers can be fitted inside small geotextile bags that are then filled with filter sand. This creates a small pre-formed filter pocket but also

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adds weight to the assembly to help with borehole installations. The filter bag should be fitted in advance of installation, filled with sand and allowed to soak in a bucket of water prior to placing.

5. **Bentonite seal**

Where a sealed piezometer filter zone is to be formed in a borehole, highly compressed and dehydrated Bentonite in the form of either pellets, balls or chips is commonly used to form the seal and is commercially available in bagged form. Balls can also be created on site using Bentonite powder and manual labour, However, small man-made bentonite balls are only suitable for shallow boreholes with a diameter ≥ 100mm. This is because they are more difficult to use as they can break-up before reaching their intended elevation in deeper boreholes.

Once in place, the Bentonite expands by absorbing water to form a highly impermeable borehole plug. Consequently, in dry boreholes, water must be added to allow the Bentonite to swell. Normally a plug is only required above any filter zone but a plug may also be used below a filter zone, for example, where the borehole extends beyond a piezometer filter base elevation.

6. **Cable marking**.

Cables should be marked with a unique identification system. Where multiple cables are to be grouped together along one route, markings should be repeated at regular intervals along the cable, 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 ends of the cables. The spacing of markings can vary according to specific site requirements. As a guide, 5m to 10m is commonly applied, but closer spacing nearer the ends.

7. **Tools.**

Obtain any tools necessary to carry out the installation. The following is a brief list of tools typically used during the installation of Vibrating Wire Piezometers. Some variation and addition may be necessary for different types of application.

- **Fibre measuring tape** with a weight added to the end for borehole depth measurement and cable length measurement.
- **Wire cutters and strippers**
- **Vibrating Wire Readout unit** for checking the piezometer function
- **Cable Marking** system / equipment (eg coloured PVC Tapes)
- **Grout mixing and placing equipment**
- **PVC tape**

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 Piezometer Readings

Geosense® Vibrating Wire Piezometers and Transducers include both pressure and temperature sensors. Where a piezometer is installed in a zone where its temperature is likely to fluctuate significantly, records of both pressure and temperature data should be recorded. This data can then be used to compensate for 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 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. Press the 'On/Off' button to switch the unit on. Press it again to acquire a reading from the connected instrument.

3. The readout displays the Vibrating Wire readings in both 'Frequency' (in Hz) and Linear 'B' Digits (in $Hz^2/1000$). Temperature reading in both resistance (Ohms) and degrees C.

   For more details see the readout manual.

4. Press and hold down the On/Off' button to switch the unit off.

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 adopted. Since the temperature sensor is a Thermistor, its connection polarity is **not** important.

6.1.2 Data Loggers

A number of data loggers are available to automatically excite, interrogate and record

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the reading from Vibrating Wire instruments including GeoLogger, CR & Linx Series.

6.2 Data Reduction

Overview

Readings from a Vibrating Wire Readout or Logger are in a form that is a function of frequency, rather than in units of pressure. Commonly the units would be either **Frequency** - Hz, **Linear 'Digits' ('B' Units)** - $Hz^2/1000$ or $Hz^2/1000000$ or, less commonly, **Period** - Time - (Seconds $x10^{-2}$ or $x10^{-7}$).

Linear Digits are required for all pressure conversion calculations so to convert the readings to units of pressure, some calculation is required.

For most Vibrating Wire sensors, unique calibration factors are detailed on individual sensor calibration sheets. A unique calibration sheet is supplied with every **Geosense®** Vibrating Wire Piezometer / Transducer.

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 their Vibrating Wire data in Linear Digits but further divided by 1000. In this case the data would have to be multiplied by a further 1000 to maintain the standard Linear Digits ($Hz^2/1000$) format for standard calculations.

If the readout display is in the less common, 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 on the next page. The first (1) where the readout includes a decimal point and displays the Period in ***Seconds x*** 10^{-2} and the second (2) where the readout displays the Period in ***Seconds x*** 10^{-7}

(1) Readout 'Period' Display = 0.03612
Linear Digits ($Hz^2/1000$) = $(1 / 0.03612 \times 10^{-2})^2 / 1000$
= 7664.8

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

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

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GEOSENSE

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Calibration

As part of the routine calibration of the '**High Temperature**' variant of the Vibrating Wire transducer / piezometer, Geosense subject each unit to a full range of thermal environments. The sensor is calibrated over its pressure range to establish a 'Calibration Factor' and sensor 'Zero' at a number of thermal stages. Full calibration information is provided on the calibration sheet supplied with each sensor.

Both the Factor and the Zero for an individual sensor will vary slightly as the temperature changes, meaning that to compute the pressure accurately, the Factor and Zero must be calculated using the **actual** sensor temperature. The temperature is measured using the Thermistor housed within the sensor.

Since the effects of temperature changes on the Zero are almost linear, a simple Linear equation is used to compute the Zero at a particular sensor temperature. The effects of temperature change on the Calibration Factor are more complex so a 3rd order Polynomial equation is used to compute the appropriate Factor. These equations are also provided on the calibration sheet.

Examples from the attached Calibration Sheet are given below:-

Calculated Zero Reading (Digits) = M*t + C + (20°C Site Zero - 20°C Factory Zero)

Calculated Calibration K factor = $A{*}t^3 + B{*}t^2 + C{*}t + D$

Where: M = -1.84474 C = 8407.01 Where 't' is the temperature at which the readings are taken in degrees C.

A	B	C	D	
2.27232E-09	-2.00568E-06	1.98746E-04	-1.80619	**Linear**

Calculation

Once the Zero and Factor values have been computed for the temperature at which a reading is taken, a simple linear calculation is used to convert the 'raw' sensor data to engineering units. It can be easily carried out using a calculator and assumes that the sensor readings are in Linear Digits ($Hz^2/1000$). Where this is not the case, the reading should be converted to these units prior to using the equation. For most applications the equation is carried out as follows:

Pressure (kPa) = Calculated Factor (k) for kPa x (Current Reading - Calculated Zero Reading)

…...all at a particular temperature. Where the temperature changes by more than +/- 10°C, a new Zero and Calibration Factor should be calculated.

Where the Pressure is required in an alternative format, mH_2O or psi for example, a simple conversion using standard conversion factors can be applied at the end of the equation. (1 psi = 0.7031 mH_2O for example).

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An instrument calibration sheet similar to the example in the Section 9 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 sensor body and, for long cables, at the end of the cable.
Works ID	Unique works batch and range code
Calibration Date	Date the calibration was performed
Baro	Barometric Pressure at the time of calibration
Temp °C	Temperature at which the sensor was calibrated
DPI SN	Serial number of the Digital Pressure Indicator used in conjunction with the pressure generator
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.
Error % fso	Non Linearity expressed as a percentage of the transducers Full Scale.
Calibration Factors	‘Linear’ calibration factors are provided for ‘kPa’ and ‘psi’ over a number of thermal steps (other units can be calculated directly from the kPa or psi values).
Zero Equation	A linear equation to obtain the correct ‘Zero’ at a particular temperature.
Constant Equation	A 3rd order polynomial equation to calculate the correct ‘Constant’ at a particular temperature.
Factory Zero	Zero Pressure sensor reading at 20°C

Examples of calculated values are detailed below.

The following are examples of data reduction calculations and are based upon the sensor to which the attached example calibration sheet refers.

A. An example of the calculation from Frequency units (Hz) to pressure, in metres of water (mH_2O) is given below:-

Site Zero Reading in Hz @ 21°C	= 2896
Site Zero Reading in Linear Digits	= **8386.8** (calculated from above)
Sensor Temperature	= 195°C (from readout)
Calculated Zero @ 195°C (equation from Cal Sheet)	= -1.84474*195 + 8407.0 + (8386.8 - 8359.0) = **8052.1**

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Calibration Factor for kPa @ 195^o (equation from Cal Sheet) = (2.27232E-09*195^3) + (-2.00568E-06*195^2) + (1.98746E-04*195) - 1.80619
= **- 1.82685**

Current Reading in Hz = 7657.3 Hz
Current Reading in Linear Digits = **5863.4** (calculated from Hz)

Pressure Equation

Water Pressure kPa = Calculated Factor x (Current Reading - Calculated Zero)
Water Pressure kPa = **- 1.82685** x (**5863.4 - 8052.1**)

Water Pressure = **3998.4 kPa**

Water Pressure mH_2O = 3998.4 / 10.1972

= **392.1 m mH_2O**

Barometric Pressure Considerations

In some locations, barometric pressure varies only a little, except when there are storms. In other locations, normal weather may bring barometric pressure changes as large as 35 mb (0.35 mH_2O) during a day, and 70 mb (0.70 mH_2O) during a year.

However, as most of the High Temperature variants of the Vibrating Wire sensors are used to detect higher pressures and in sealed systems, these effects will have no, or insignificant, effect on their data, so can be ignored.

For example, a 40mb change in pressure is equivalent to 4 kPa (0.6psi)

Temperature Considerations

Thermal influences on Piezometer / Transducer readings and its surroundings are complex. The Thermal effects presented on the Calibration sheet relate purely to the 'sensor'.

7.0 MAINTENANCE

The Vibrating Wire piezometer is a maintenance free device for most applications. This is because it is intended for sub-surface installation and would normally be irretrievably sealed into boreholes.

However, when the piezometer is installed in a location where a flow of water moves past it and it can be recovered, a check should be made to determine the condition of the filter. If any crystalline chemical deposits or algae are present on or in the filter, it

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could affect the performance of the filter and, therefore, the piezometer.

It may be necessary to determine the nature of any build up, so that a suitable chemical compound can be sourced to dissolve the build up, without damaging the stainless steel of the body, filter and diaphragm. The body and sintered filter are made from Grade 316 stainless steel.

It would only be necessary to resort to dissolving any build-up if it either blocked the filter or there was any sign of build up on the surface of the diaphragm.

Maintenance of wiring connections between the piezometer and any terminal panels / or loggers should involve occasional tightening of any screw terminals to prevent loose connections or cleaning to prevent the build up of corrosion.

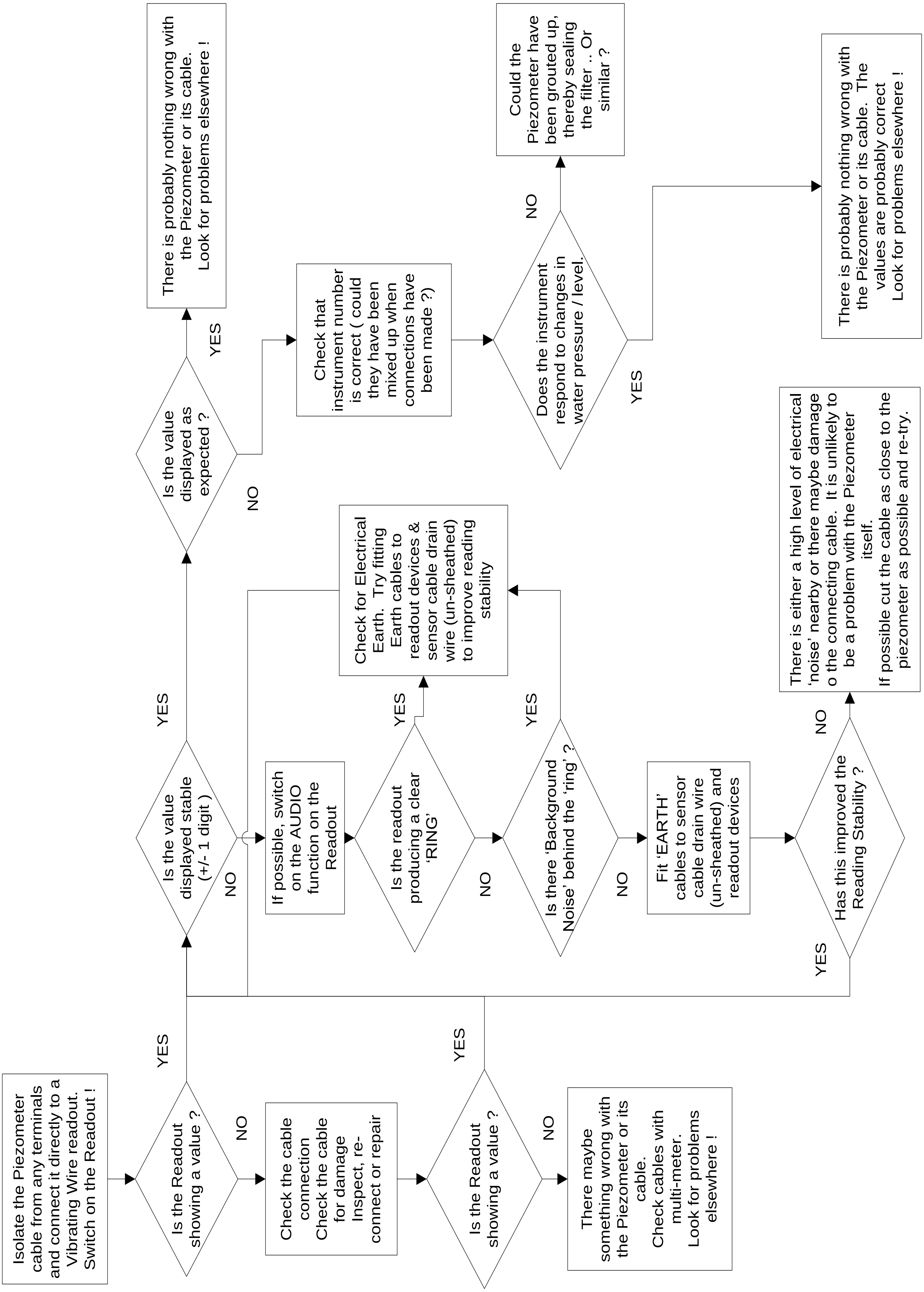
8.0 TROUBLESHOOTING

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 best way to fault find an instrument is to isolate it from all other instruments and connections. Where possible begin fault finding from the sensor itself.

A fault finding flow diagram is included on the next page, to help with troubleshooting.

A diagnostic resistance check routine is also included to help identify problems with cables.

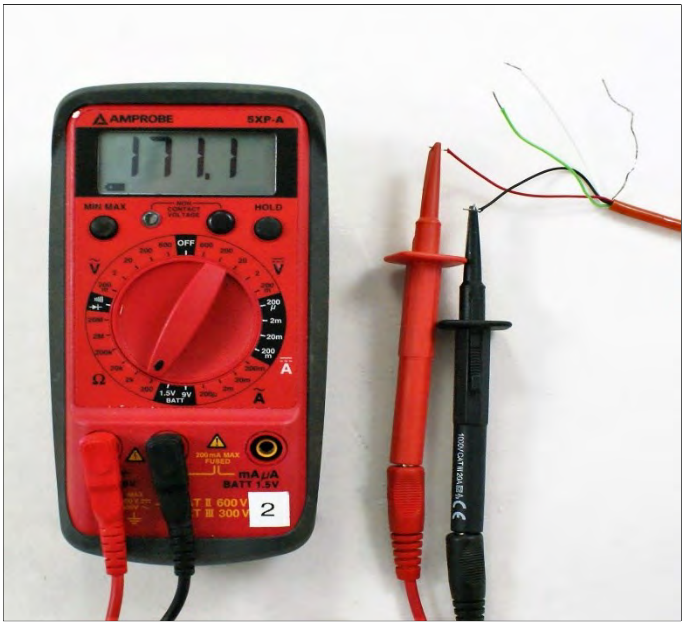

Isolate the Piezometer cable from any terminals and connect it directly to a Vibrating Wire readout. Switch on the Readout !
Is the Readout showing a value ?
YES
NO
Check the cable connection Check the cable for damage Inspect, re-connect or repair
Is the Readout showing a value ?
YES
NO
There maybe 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.

8.0 TROUBLESHOOTING contd…

RESISTANCE DIAGNOSTICS

Where damage to a sensor or cable is suspected this guide illustrates the way in which simple resistance checks can be taken to identify the possible cause of the problem.

Resistance checks can be made with most types of multi-meter which are readily available in the market.



RESISTANCE OF THE COILS

STEP 1

Set the range to 200Ω (or Ω if using a multi-meter which has automatic ranging).

STEP 2

Connect the VW+ (red) conductor to the red lead on the multi-meter and the VW- (black) to the black lead on the multi-meter.

The correct readings should be as follows ±10%

Pressure Transducer	~ 160Ω
Strain gauge	~ 180Ω
Load Cell / Sister Bar / Miniature Strain gauge	~ 50Ω

IF THE VALUES ARE OUT OF THESE RANGES THEN THERE IS A FAULT IN THE CABLE OR (Less Likely) THE COILS

8.0 TROUBLESHOOTING contd…

RESISTANCE OF THE THERMISTOR

STEP 1

Set the range to 20kΩ (or Ω if using a multi-meter which has automatic ranging).

STEP 2

Connect the T+ (green) conductor to the red lead on the multi-meter and the T- (white) to the black lead on the multi-meter.

The readings will be dependent on the temperature as below:-

10°C ~ 5.971kΩ (5971Ω)
15°C ~ 4.714kΩ (4714Ω)
20°C ~ 3.478kΩ (3478Ω)
25°C ~ 3.000kΩ (3000Ω)

PLEASE REFER TO THE THERMISTOR LOOK UP TABLE ON THE NEXT PAGE

IF THESE VALUES DIFFER THEN THERE IS A PROBLEM WITH THE THERMISTOR OR IT'S CONNECTING CABLE

8.0 TROUBLESHOOTING contd…

Thermistor Linearization for VWPHT-3600

USING STEINHART & HART LOG

Thermistor Type: 3K @25°C

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.
$A = 1.4051 * 10^{-3}$
$B = 2.369 * 10^{-4}$
$C = 1.019 * 10^{-7}$

Resistance versus temperature table

Temperature	Resistance	Temperature	Resistance	Temperature	Resistance
(°C)	(kΩ)	(°C)	(kΩ)	(kΩ)	(°C)
-40	128.75	41	1.509	122	0.117
-39	119.81	42	1.449	123	0.114
-38	111.54	43	1.392	124	0.111
-37	103.89	44	1.338	125	0.108
-36	96.822	45	1.286	126	0.106
-35	90.276	46	1.236	127	0.1032
-34	84.213	47	1.189	128	0.1008
-33	78.596	48	1.144	129	0.0984
-32	73.389	49	1.100	130	0.0961
-31	68.560	50	1.059	131	0.0939
-30	64.079	51	1.019	132	0.0917
-29	59.920	52	0.982	133	0.0896
-28	56.057	53	0.946	134	0.0875
-27	52.468	54	0.911	135	0.0856
-26	49.132	55	0.878	136	0.0836
-25	46.029	56	0.846	137	0.0817
-24	43.142	57	0.816	138	0.0799
-23	40.455	58	0.787	139	0.0781
-22	37.953	59	0.759	140	0.0764
-21	35.621	60	0.732	141	0.0747
-20	33.448	61	0.707	142	0.0730
-19	31.422	62	0.682	143	0.0714
-18	29.531	63	0.659	144	0.0699
-17	27.767	64	0.636	145	0.0684
-16	26.119	65	0.614	146	0.0669
-15	24.580	66	0.594	147	0.0655
-14	23.142	67	0.574	148	0.0641
-13	21.797	68	0.554	149	0.0627
-12	20.539	69	0.536	150	0.0614
-11	19.362	70	0.518	151	0.0601
-10	18.260	71	0.501	152	0.0588
-9	17.229	72	0.485	153	0.0576
-8	16.262	73	0.469	154	0.0564
-7	15.356	74	0.454	155	0.0552
-6	14.506	75	0.440	156	0.0541
-5	13.709	76	0.426	157	0.0530
-4	12.961	77	0.412	158	0.0519
-3	12.259	78	0.399	159	0.0509
-2	11.599	79	0.387	160	0.0498
-1	10.979	80	0.375	161	0.0488
0	10.397	81	0.363	162	0.0479
1	9.849	82	0.352	163	0.0469
2	9.334	83	0.341	164	0.0460

8.0 TROUBLESHOOTING contd…

Thermistor Linearization for VWPHT-3600

Thermistor Type: 3K @25°C

Resistance versus temperature table

3	8.849	84	0.331	165	0.0451
4	8.392	85	0.321	166	0.0442
5	7.963	86	0.312	167	0.0434
6	7.557	87	0.302	168	0.0425
7	7.176	88	0.293	169	0.0417
8	6.816	89	0.285	170	0.0409
9	6.476	90	0.276	171	0.0401
10	6.156	91	0.268	172	0.0393
11	5.854	92	0.261	173	0.0386
12	5.568	93	0.253	174	0.0379
13	5.299	94	0.246	175	0.0372
14	5.044	95	0.239	176	0.0365
15	4.803	96	0.232	177	0.0358
16	4.575	97	0.226	178	0.0351
17	4.360	98	0.219	179	0.0345
18	4.156	99	0.213	180	0.0339
19	3.963	100	0.207	181	0.0332
20	3.780	101	0.202	182	0.0326
21	3.607	102	0.196	183	0.0320
22	3.443	103	0.191	184	0.0315
23	3.287	104	0.186	185	0.0309
24	3.140	105	0.181	186	0.0304
25	3.000	106	0.176	187	0.0298
26	2.867	107	0.171	188	0.0293
27	2.741	108	0.167	189	0.0288
28	2.622	109	0.163	190	0.0283
29	2.508	110	0.158	191	0.0278
30	2.400	111	0.154	192	0.0273
31	2.298	112	0.150	193	0.0268
32	2.200	113	0.146	194	0.0264
33	2.107	114	0.143	195	0.0259
34	2.019	115	0.139	196	0.0255
35	1.935	116	0.136	197	0.0250
36	1.855	117	0.132	198	0.0246
37	1.779	118	0.129	199	0.0242
38	1.707	119	0.126	200	0.0238
39	1.638	120	0.123		
40	1.572	121	0.120		

8.0 TROUBLESHOOTING contd…

Thermistor Linearization for VWPHT-3610

Thermistor Type: 10K @25°C

Resistance versus temperature table

Temperature (°C)	Resistance (kΩ)
0	28.44
1	27.19
2	26.01
3	24.89
4	23.82
5	22.80
6	21.84
7	20.92
8	20.05
9	19.22
10	18.43
11	17.67
12	16.95
13	16.26
14	15.61
15	14.99
16	14.39
17	13.82
18	13.28
19	12.77
20	12.27
21	11.80
22	11.35
23	10.91
24	10.50
25	10.10
26	9.729
27	9.374
28	9.034
29	8.708
30	8.396
31	8.096
32	7.809
33	7.534
34	7.269
35	7.016
36	6.774
37	6.541
38	6.317

Temperature (°C)	Resistance (kΩ)
39	6.103
40	5.897
41	5.698
42	5.507
43	5.323
44	5.147
45	4.977
46	4.814
47	4.658
48	4.507
49	4.362
50	4.223
51	4.088
52	3.958
53	3.833
54	3.713
55	3.597
56	3.486
57	3.378
58	3.275
59	3.175
60	3.079
61	2.985
62	2.896
63	2.809
64	2.725
65	2.644
66	2.567
67	2.491
68	2.419
69	2.349
70	2.281
71	2.216
72	2.152
73	2.091
74	2.031
75	1.974
76	1.919

Temperature (°C)	Resistance (kΩ)
77	1.865
78	1.814
79	1.764
80	1.715
81	1.668
82	1.623
83	1.579
84	1.536
85	1.495
86	1.455
87	1.416
88	1.337
89	1.342
90	1.307
91	1.273
92	1.240
93	1.208
94	1.177
95	1.146
96	1.117
97	1.089
98	1.061
99	1.035
100	1.009
101	0.9831
102	0.9585
103	0.9347
104	0.9116
105	0.8892
106	0.8674
107	0.8463
108	0.8258
109	0.8059
110	0.7866
111	0.7671
112	0.7481
113	0.7297
114	0.7119

8.0 TROUBLESHOOTING contd…

Thermistor Linearization for VWPHT-3610

Thermistor Type: 10K @25°C

Resistance versus temperature table

Temperature (°C)	Resistance (kΩ)
115	0.6945
116	0.6777
117	0.6614
118	0.6455
119	0.6301
120	0.6152
121	0.6003
122	0.5859
123	0.5719
124	0.5583
125	0.5451
126	0.5322
127	0.5197
128	0.5076
129	0.4958
130	0.4844
131	0.4730
132	0.4620
133	0.4513
134	0.4409
135	0.4307
136	0.4209
137	0.4113
138	0.4020
139	0.3929
140	0.3841
141	0.3754
142	0.3670
143	0.3588
144	0.3509
145	0.3431
146	0.3356
147	0.3282
148	0.3211
149	0.3141
150	0.3073
151	0.3007
152	0.2942
153	0.2879

Temperature (°C)	Resistance (kΩ)
154	0.2817
155	0.2758
156	0.2699
157	0.2642
158	0.2587
159	0.2533
160	0.2481
161	0.2429
162	0.2378
163	0.2329
164	0.2281
165	0.2234
166	0.2189
167	0.2144
168	0.2101
169	0.2058
170	0.2017
171	0.1976
172	0.1936
173	0.1898
174	0.1860
175	0.1823
176	0.1787
177	0.1752
178	0.1717
179	0.1684
180	0.1651
181	0.1619
182	0.1587
183	0.1557
184	0.1527
185	0.1497
186	0.1469
187	0.1441
188	0.1414
189	0.1387
190	0.1361
191	0.1335

Temperature (°C)	Resistance (kΩ)
192	0.1310
193	0.1286
194	0.1262
195	0.1238
196	0.1216
197	0.1193
198	0.1171
199	0.1150
200	0.1129
201	0.1109
202	0.1089
203	0.1069
204	0.1050
205	0.1031
206	0.1013
207	0.09942
208	0.09766
209	0.09594
210	0.09426
211	0.09260
212	0.09098
213	0.08940
214	0.08785
215	0.08633
216	0.08484
217	0.08339
218	0.08196
219	0.08057
220	0.07921
221	0.07786
222	0.07654
223	0.07525
224	0.07399
225	0.07276
226	0.07154
227	0.07036
228	0.06920
229	0.06806

8.0 TROUBLESHOOTING contd…

Thermistor Linearization for VWPHT-3610

Thermistor Type: 10K @25°C

Resistance versus temperature table

Temperature (°C)	Resistance (kΩ)
230	0.06694
231	0.06584
232	0.06476
233	0.06371
234	0.06267
235	0.06166
236	0.06067
237	0.05969
238	0.05874
239	0.05780
240	0.05689
241	0.05598
242	0.05510
243	0.05423
244	0.05337
245	0.05254
246	0.05172
247	0.05091
248	0.05013
249	0.04935
250	0.04860

8.0 TROUBLESHOOTING contd…

RESISTANCE OF ALL INDIVIDUAL CONDUCTORS

STEP 1

Set the range to 20kΩ or Ω if using a multi-meter which has automatic ranging.

STEP 2

Both pairs of conductors should be checked by connecting them to the red and black leads on the multi-meter as follows:-

Red to Red / Black to Black

Red to Green / Black to White

A value of approximately 0.2 kΩ is expected for the Red / Black pair

A value of between 1 and 10 kΩ is expected for the Green / White pair

A value of O.L (open loop) means that there is a high / infinite resistance and therefore it is likely that the cable or a joint has been cut / disconnected / damaged.

A value of close to 0 (short circuit) means that there is a very low resistance and therefore it is likely that the cable or a joint has been shorted / damaged.

If one of the above pairs is OK, check each individual conductor against the earth drain wire (as shown above)

9.0 SPECIFICATION

SENSOR

Pressure range MPa	2.1, 3.5, 5.2, 6.9, 10.4, 13.8, 20.7, 34.5
Calibration range VWPHT-3600	+ 20 to + 200°C,
Calibration range VWPHT-3610	+20 to + 250°C
Operating range VWPHT-3600	0 to + 200°C
Operating temperature VWPHT-3610	0 to + 250°C
Thermistor type VWPHT-3600	3K
Thermistor type VWPHT-3610	10K
Pressure over range [1]	1.5 x pressure
Accuracy[2]	±0.1% FS
Resolution	0.025% FS
Linearity	<0.5% FS
Thermal effect	0.02% FS/°C
Frequency range	1400 - 3500 Hz
Piezometer filter	LAE (Low resistance to air entry) 50µ 316 sintered stainless steel
Transducer connection	¼" BSPF
Dimension L x Ø	177 x 25mm
Weight	480g

[1] The maximum pressure that may be applied continuously without causing damage and maintaining set point repeatability

[2] Based on polynomial regression

CABLE

Jacket	Incoloy 825*
Conductors	4 x 24 AWG stranded, tinned copper
Insulation	PFA
Diameter	4mm

* FEP jacket available on request

10.0 CALIBRATION

GEOSENSE QUALITY PROCEDURE	
FORM No G/QF/131 A	
ISS.	5
DATE :	Feb-21
SIG.	GC

VW HIGH TEMPERATURE PIEZOMETER LAE

Model	VWPHT-3600	Cal date	21-Nov-15	DPI No.	8233
Serial	315891	Baro.	1000.0	Readout No.	2108
Works ID	56 6 19	Temp °C MAX	200	R/O Cal. date	21/05/2015
		Factory Zero at Room Temp	8359.0		

		APPLIED PRESSURE							
		0 Psi	200.1	400.3	600.4	800.6	1000.7		
TEMP °C	SERIAL NO	0 kPa	1380.0	2760.0	4140.0	5520.0	6900.0	LINEAR	POLY
20	315891	8359.0	7599.7	6834.3	6070.8	5303.1	4530.4	0.13%	0.04%
50	315891	8320.0	7560.7	6797.8	6031.6	5262.1	4491.5	0.14%	0.02%
80	315891	8264.3	7505.8	6740.6	5976.1	5205.7	4437.8	0.13%	0.04%
110	315891	8210.2	7450.1	6682.7	5918.6	5153.6	4390.2	0.07%	0.07%
140	315891	8151.3	7390.1	6624.8	5863.4	5100.3	4335.2	0.03%	0.04%
170	315891	8091.1	7338.2	6585.2	5834.4	5073.2	4301.6	0.26%	0.08%
200	315891	8032.7	7277.7	6520.8	5765.3	5013.5	4255.6	0.06%	0.06%

THE EQUIPMENT USED IN THE CALIBRATION OF THE PRODUCT DETAILED ABOVE IS TRACEABLE TO NATIONAL/INTERNATIONAL STANDARDS

CALIBRATION FACTORS

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

Calculated Zero Reading (Digits) = MT + C + (20°C Site Zero - 20°C Factory Zero)

Where: M = -1.84474167 C = 8407.01144

Calculated Calibration K factor = $AT^3 + BT^2 + CT + D$

A	B	C	D
2.27232E-09	-2.00568E-06	1.98746E-04	-1.80619

Linear Pressure Calculation [kPa] = Calculated K (kPa) * (Current Reading - Calculated Zero Reading)

THIS IS AN ELECTRONIC CERTIFICATE AND IS VALID WITHOUT A SIGNATURE

11.0 SPARE PARTS

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

Replacement filter units are available as follows:-

Part number	**Description**
G1025	LAE (Low Air Entry) Stainless Steel filter assembly

Geosense can provide the following parts that may be required to effect repairs to instrument cables:

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

Please contact Geosense for prices and availability of the above components.

12.0 RETURN OF GOODS

12.1 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.

12.2 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.

12.3 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 Piezometer 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.

12.4 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.

12.5 Transport & Storage

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

12.0 LIMITED WARRANTY

The manufacturer, (**Geosense Ltd)**, warrants the **VWPHT-3600 Vibrating Wire Piezometers** 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 **VWPHT-3600 Vibrating Wire Piezometer** and other component parts.

The **VWPHT-3600 Vibrating Wire Piezometer** equipment shall be installed in accordance with the manufacturer’s recommendations.

The equipment is warranted for 2 years 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 VWPHT-3600 High Temperature Piezometer 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 Piezometer equipment from the time of delivery to Purchaser.

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

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