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VWCM-4000 CRACK METER

INSTRUCTION MANUAL

GEOSENSE

CONTENTS

1.0 INTRODUCTION

This manual is intended for all users of **VWCM-4000 Crack Meters** 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 VW Crack Meter READ and UNDERSTAND the manual, prior to working with the equipment.

1.1 General Description

A Vibrating Wire Crack Meter can be installed singly or included in many types of monitoring regime and can be linked to various types of readout equipment.

The primary uses for **Geosense**® **VWCM-4000 Cracks Meters** are :-

Measure movement of Joints and behaviour of Cracks in Structures.
Measure Joint and Crack movement in Rock Faces

With applications such as, but not limited to, the following :-

Bridges
Dams
Tunnels
Buildings
Rock Faces
Mines

Particular features of the **Geosense**® **VWCM-4000 Cracks Meters** are:-

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

The Frequency signals generated by Vibrating Wire instruments are particularly suitable for the demanding environment of civil engineering applications. 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 **VWCM-4000 Cracks Meters** can be supplied in various configurations to suit varying installation environments and techniques.

1.1 General Description contd

1.2 Theory of Operation

The **Geosense® VWCM-4000 Crack Meter** is an stainless steel instrument that contains a VW transducer that is connected to a Calibrated Spring which is in turn connected to an extending shaft. The ends of the instrument are connected to either side of a crack or joint so that, as structural movement occurs, the shaft is moved within the housing. The shaft movement changes the tensions the spring which, in turn, changes the tension in the vibrating wire. When interrogated, the vibrating wire in the transducer measures its tension which can be converted to a linear displacement measurement in engineering units, commonly millimetres.

The internal parts of all **Geosense® VWCM-4000 Crack Meters** are identical, only the ’Spring Rate’ of the spring and the length changes.

Within the Vibrating Wire transducer coil housing, two coils are located close to the axis of the wire. When a voltage, or swept frequency excitation is briefly applied to the coils, a magnetic field is created momentarily, causing the wire to oscillate at its’ resonant frequency. The wire continues to oscillate for a short time through the ‘field’ of the permanent magnet, thus generating an alternating current (sinusoidal) output. The frequency of this current output is detected and processed by a vibrating wire readout unit or by a data logger equipped with a vibrating wire interface. Readings can be converted, by calculation, into ‘Engineering’ units.

2.0 CONFORMITY

Geosense Limited
Nova House
Rougham Industrial Estate
Rougham, Bury St Edmunds
Email: info@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,

Low Voltage Directive 73/23/EEC (as amended by 93/68/EEC)
The Electromagnetic Compatibility Directive 2004/108/EC
The Construction Products Directive 89/106/EEC

Equipment description	**VW Crack Meter**
Make/Brand	**Geosense**
Model Numbers	**VWCM-4000 Crack Meter Range**

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

EN 61326-1:2006 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

June 2014

3.0 MARKINGS

Geosense VW Crack Meter are labelled with the following information:-

Manufacturers name & contact details

Product name

Product Type

Operating Range

Serial number

Electrical Input & Output details

CE mark

4.0 DELIVERY

This section should be read by all users of **VWCM-4000 Crack Meters** manufactured by **Geosense**® .

4.1 Packaging

VWCM-4000 Crack Meters 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, as soon as possible, to both the transportation company and Geosense.

4.2 Handling

Whilst they are a robust devices, **VWCM-4000 Crack Meters** are precision measuring instruments. They and their associated equipment should always be handled with care during transportation, storage and installation.

Once a shipment has been inspected, it is recommended that **VWCM-4000 Crack Meters** remain in their original packaging for storage or further transportation.

Cable should also be handled with care. Do not allow it to be damaged by sharp edges and do not exert force on the cable as this my damage the internal conductors and could render an 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**® **VWCM-4000 Crack Meters** carry a **unique** identification serial number and are supplied with individual calibration sheets.

Calibration Sheets contain VITAL information about the VW Crack Meter. They MUST be stored in a safe place.
It is suggested that only copies should be taken to site.

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 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 **VWCM-4000 Crack Meters** manufactured by **Geosense**® 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 VWCM-4000 Crack Meters 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 in good time before installation is to be carried out. Check that all components that are detailed on the shipping documents are included.

5.1 Getting started - Preparation for Installation

Prior to installation of a **VWCM-4000 Crack Meters** 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 location and subsequent Protection
2. Expected Movement of the Crack or Joint (see setting range)
3. Anchoring Method
4. Cable routing and marking

The end of the cables connected to **VWCM-4000 Crack Meters** is marked with the unique serial number of the sensor to which it is attached.

All instrument cables should be marked with unique identification (e.g. colour codes). 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 correctly. 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 separation is commonly applied (marking materials available on request from Geosense).

Cable routing must be carefully considered so as to ensure that it is not vulnerable from intentional or accidental damage. Vibrating Wire signals can be affected by electrical interference (EMI), so cable routing should AVOID close proximity to possible sources.

5.1 Getting started - Preparation for Installation contd...

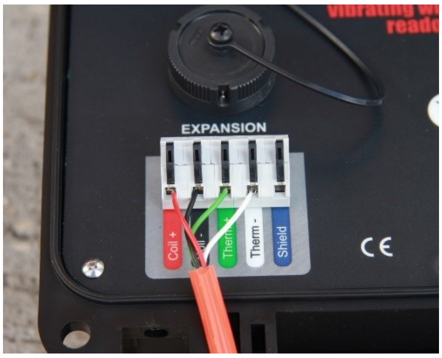
Tools

Obtain any tools necessary to carry out the installation. The following is a brief list of tools typically used during the installation of **VWCM-4000 Crack Meters.**

- **Wire cutters and strippers**
- **Vibrating Wire Readout unit** for setting the Crack Meter
- **Cable Marking** system / equipment (e.g. coloured PVC Tapes)
- **Marker Pen**
- **Hammer Drill** (mains for battery powered)
- **Drill Bit** suitable for the materials into which the fixings will be fixed
- **Power Supply** for the drill (if required)
- **Clean Cloth**
- **Suitable resin** bonding material
- **4mm & 5mm 'Allen' (hexagonal) keys.**
- **Adjustable spanner**

5.2 Preliminary tests

Before installing the **VWCM-4000 Crack Meter**, it should be checked for proper operation.



Using a manual readout, such as a VW2106 (see readout manual), select the B sweep range (1200 - 3550 Hz) and connect the signal wires as shown on the right. **Gently** pull the shaft out to its, mechanical, full extension stop. **DO NOT TWIST THE ROD.**

The readout should display an increasing reading up to 6700-7200 Digits. This value should be checked against the Full Range reading on the individual calibration certificate.

Gently allow the shaft to return into the housing making sure that the pins on the shaft are aligned into the slot on the housing.

Check the operation of the thermistor by holding the red coil housing in your hand; the temperature reading on the readout should slowly increase.

NB   If the readout display is in 'Period' units a calculation must be performed to convert from Hertz²/1000 (Linear Digits) units, since the calibration sheet is presented in Hertz²/1000 units. The Geosense Readout model* ***VW200* *displays the readings in 'Period'. The RST readout / logger unit Model Number* **VW2106** *displays the readings in Linear Digits. See Section 6 of this manual for more information about units and conversion routines.*

DO NOT TWIST THE SHAFT OF THE CRACK METER

5.3 Anchor spacing distance

The positioning of the fixing anchors (spacing distance) will depend on the range of the crack meter and whether extension or compression is to be monitored. If this is unknown gauges are typically set to mid-range.

The Table below shows the suggested anchor spacing distances for various operating ranges and measurement configurations. If, for example, a crack meter is to be used to measure only opening of a crack, we suggest that a 10% allowance for closing (compression) is built into the spacing so that un-expected closing does not damage the gauge. A similar principle is recommended for the spacing of anchors for crack closing applications.

These are only recommendations and the user should decide what positions the anchors are required to be set.

A portable readout and the individual calibration certificate must be used in conjunction with the table below to determine/confirm the required anchor spacing.

RANGE (mm)	MID RANGE 50% of range (mm)	MONITOR COMPRESSION 90% of range (mm)	MONITOR EXTENSION 10% of range (mm)
5	248.3	250.5	246.0
12.5	266.6	272.3	261.0
25	320.3	331.5	309.0
50	363.5	386.0	341.0
75	467.8	501.5	434.0
100	512.0	557.0	467.0
150	660.5	728.0	593.0
200	815.0	905.0	725.0
300	1117.0	1252.0	982.0
500	1724.0	1949.0	1499.0

All of the above are approximate dimensions and the setting, ‘centre to centre’ distance on the crack meter may need to be adjusted using the Rose joint on the end of the shaft.

5.4 Installation - using Re-bar anchors

INSTALLATION TEMPLATE

It is recommended to make and use a 'site specific' spacing template for the following reasons:-

- Maintains a consistent setting distance between the anchors
- Makes marking of drill holes easier
- Helps keep anchors in place during the curing of the fixing resin

Typical materials that can be used to make the template are wood, steel or plastic. Obviously if the material is soft (wood / plastic) it will wear more with use.

1. Cut a suitable piece of bar for use as a template. Carefully mark the centres of the holes that correspond to the position of the fixing holes.

   Drill one 5mm and one 6mm hole in the template.

   Clear the intended location of debris or dust.

2. Using the template, mark the hole centres to be drilled. Using a suitable masonry drill bit, drill a pilot hole in the locations marked.

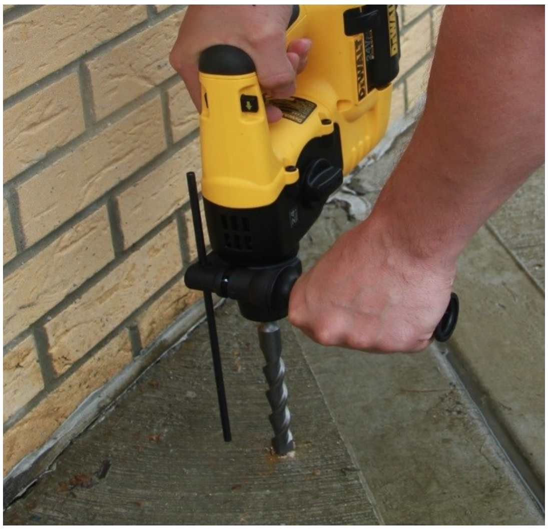
3. Select a suitable masonry drill bit for the groutable anchors that are to be used.

   12mm rebar use 18mm drill bit
   16mm rebar use 20mm drill bit

4. Measure the required depth to be drilled and set a stop on drill so that hole is drilled to the required depth.

5.4 Installation - using Re-bar anchors contd...

5. Drill both holes to the required depth.



BE SURE NO ELECTRICAL CABLES OR OTHER SERVICES ARE DIRECTLY BELOW SURFACE TO BE DRILLED

6. **Cleaning out the drill holes before inserting bonding resin is essential .** A small brush is a good tool for cleaning out the loose debris and the bicycle pump is good for blowing out the dust so that the resin can adhere well to the inner walls of the hole.

7. To install the groutable anchors will require a gauge template plus suitable fixing resin* and applicator gun (if necessary).

8. Attach the anchors to the template with the M5 and M6 screws supplied, as shown.

5.4 Installation - using Re-bar anchors contd...

SELECT A <u>NON-SHRINKING</u> RIGID RESIN SUITABLE FOR THE MATERIAL INTO WHICH ANCHORS ARE BEING PLACED

9. Thoroughly mix an adequate amount of resin and fill the anchor holes.

Where a resin cartridge is being used, insert the cartridge nozzle into the base of the holes and fill from the base upwards.

10. Insert the groutable anchors to the required depth, rotating them to ensure a good bond. Leave the resin to cure for the time stated in the product manufacturer's instructions.

5.4 Installation - using Re-bar anchors contd...

11. Once the resin has hardened remove the securing screws.

12. Fix the M6 bolt through the Rose joint on the transducer end of the crack meter and into the rebar anchor.

13. Fit the M5 bolt through the Rose joint on the **shaft** end of the gauge and carefully extend the shaft. Fix the screw into the anchor but do not tighten it. A reading of the gauge should be taken to ascertain correct setting before the bolts are fully tightened.

14. Check the reading on the readout to ensure that it is at approximately the value that corresponds to the extension required.

    This should be checked against the individual calibration sheet for the Crack meter being installed.

5.4 Installation - using Re-bar anchors contd...

15. If the reading/setting distance is not in the correct range then adjustments can be made to the threaded Rose joint on the shaft of the crack meter. To adjust, undo M5 bolt and carefully remove Rose joint from the anchor. Ensure that the Rose joint locking nut is loose and turn the Rose joint **clockwise** to lower the crack meter readings and **anticlockwise** to raise the readings.

    DO NOT ROTATE THE SHAFT

16. When the reading is correct remove the fixing and carefully allow the crack meter to close, ensuring the alignment pins engage with the slots on the housing tube.

    Tighten the locking nut to ensure that the rose joint is tight.

17. Re-fix the crack meter to the anchor and tighten the screw using the Allen key.

The crack meter is now installed. Its readout cable can be routed to a convenient location for termination or to a data logger location.

It is strongly recommended that the crack meter is fitted with a lined protective cover to reduce the risk of damage and reduce the effects of temperature changes.

ONCE INSTALLED AND THE CRACK METER'S TEMPERATURE HAS STABILISED, IT IS IMPORTANT TO ESTABLISH <u>INITIAL READINGS</u>.
ALL SUBSEQUENT READINGS WILL BE REFERENCED TO THESE INITIAL READINGS

5.5 Installation - using mechanical type anchors

INSTALLATION TEMPLATE

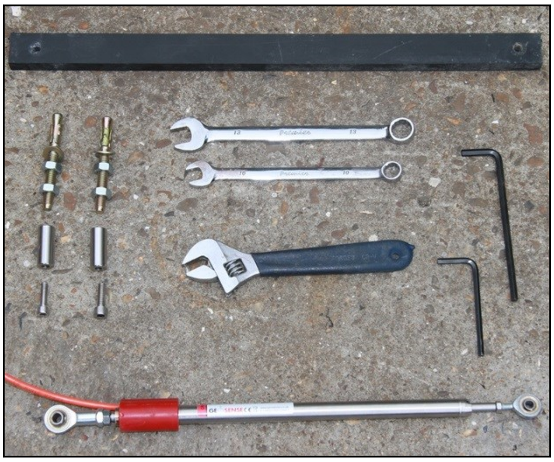
It is recommended to make and use a 'site specific' spacing template for the following reasons:-

- Maintains a consistent setting distance between the anchors
- Makes marking of drill holes easier

Typical materials that can be used to make the template are wood, steel or plastic. Obviously if the material is soft (wood / plastic) it will wear more with use.

1. First gather all the components and tools together. For this type of installation, this will include:

   Template
   Hammer Drill
   Suitable Drill Bit(s)
   10 and 13mm spanners
   Hammer
   Adjustable spanner
   4mm and 5mm Allen Keys
   Anchors
   Mounting blocks
   Gauge with Rose joint ends

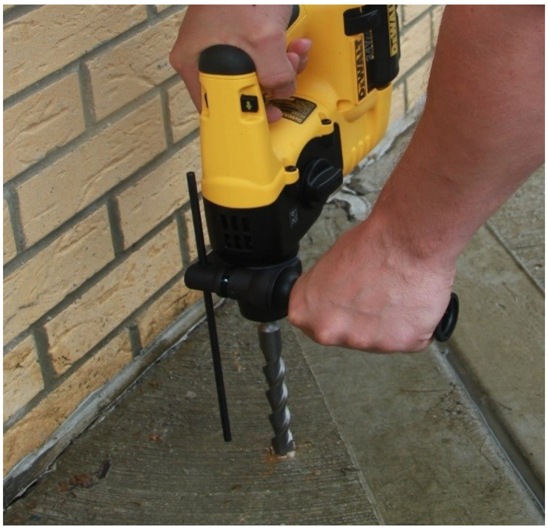


1. Clear the installation area and mark the position of the fixings using the template.

2. Set the depth gauge on the drill to the required depth.

5.5 Installation - using mechanical type anchors - cont...

3. Drill the holes for the anchors



BE SURE NO ELECTRICAL CABLES OR OTHER SERVICES ARE DIRECTLY BELOW SURFACE TO BE DRILLED

4. Clean out the drill hole to ensure it is free from dust. A bicycle pump is useful here.

5. Install the anchors - as anchor types differ, the fixing of the anchors will vary.

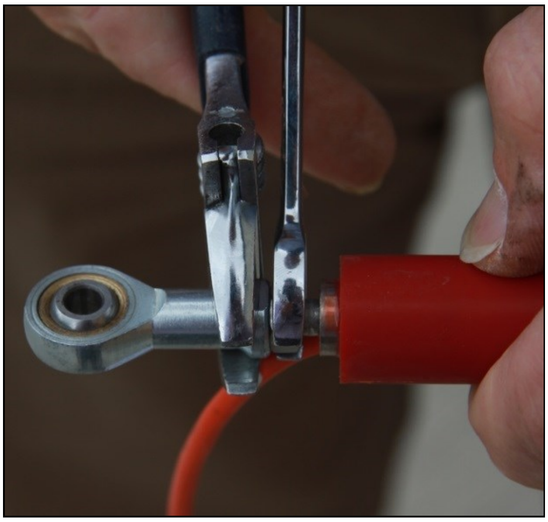
5.5 Installation - using mechanical type anchors - cont...

6. Tighten any securing nuts / bolts to ensure that the fixing does not move

7. Fit both the mounting blocks to the anchors. Remember that one end has a larger and one a smaller threaded crack meter mounting.

   Use the second nut on the fixing to ‘lock’ the mounting block onto the anchor.

8. Ensure that the larger Rose joint end is firmly attached to the Crack meter by checking that it fully tightened up to its locking nut.



5.5 Installation - using mechanical type anchors - cont...

9. Fit the larger end of the crack meter (sensor end) to its mounting using the M6 bolt.

10. Tighten the bolt using the 5mm Allen key (use a spanner on the locking nut as a tightening reaction)

11. Check that smaller Rose joint is screwed into the other end of the Crack meter. (it is best to screw it fully into Crack meter and then un-screw it by 4 turns, leaving the locking nut loose, at this stage.

    Carefully draw the end of the transducer out and fit it the mounting block, using the M5 screw.

12. Check the reading on the readout to ensure that it is at approximately the value that corresponds to the extension required.

    This should be checked against the individual calibration sheet for the Crack meter being installed.

5.5 Installation - using mechanical type anchors - cont...

13. If the reading/setting distance is not in the correct range then adjustments can be made to the threaded Rose joint on the shaft of the crack meter. To adjust, undo M5 bolt and carefully remove Rose joint from the anchor. Ensure that the Rose joint locking nut is loose and turn the Rose joint **clockwise** to lower the crack meter readings and **anticlockwise** to raise the readings.

    DO NOT ROTATE THE SHAFT

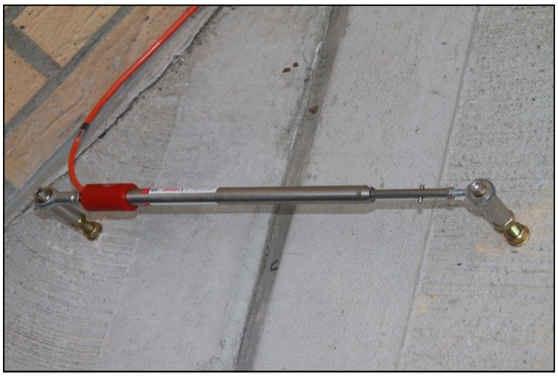
14. When the reading is correct remove the fixing and carefully allow the gauge to close, ensuring the alignment pins engage with the slots on the housing tube.

    Tighten the locking nut to ensure that the rose joint is tight.

15. Re-fix the gauge to the anchor and tighten the screw using the Allen key and a spanner on the anchor locking nut.

    The crack meter is now installed. Its readout cable can be routed to a convenient location for termination or to a data logger location.

    It is strongly recommended that the crack meter is fitted with a lined protective cover to reduce the risk of damage and reduce the effects of temperature changes.



ONCE INSTALLED AND THE CRACK METER'S TEMPERATURE HAS STABILISED, IT IS IMPORTANT TO ESTABLISH INITIAL READINGS. ALL SUBSEQUENT READINGS WILL BE REFERENCED TO THESE INITIAL READINGS

5.6 Installation - using Welded anchors

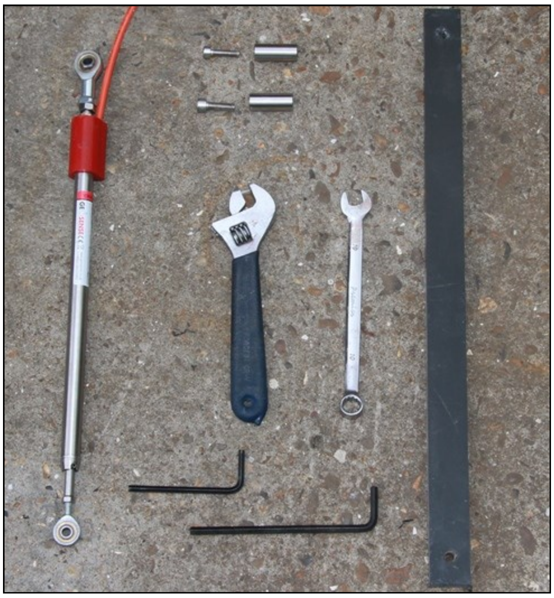
INSTALLATION TEMPLATE

It is recommended to make and use a ‘site specific’ spacing template for the following reasons:-

- Makes marking of mounting positions easier
- Can be used to support the anchor blocks during welding

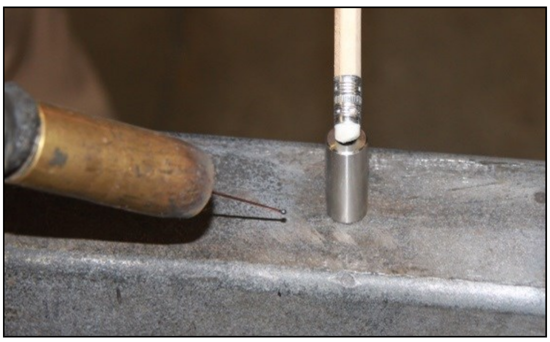
Typical materials that can be used to make the template are wood, steel or plastic. Obviously if the material is soft (wood / plastic) it will wear / melt with use.

1. First gather all the components and tools together. For this type of installation, this will include:
   Template
   10 mm spanner
   Adjustable spanner
   4mm and 5mm Allen Keys
   Mounting blocks
   Gauge with Rose joint ends
   Welding Equipment



2. Clear the installation area and mark the position of the fixings using the template.

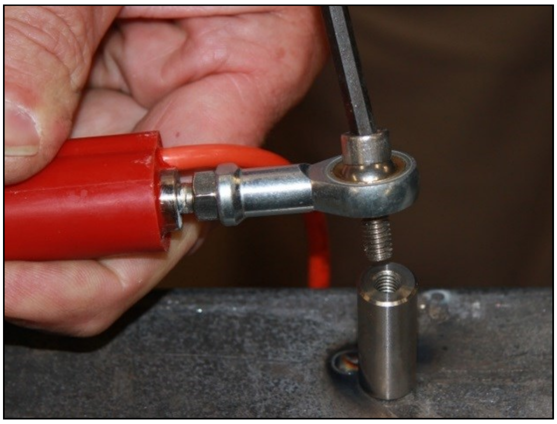
3. Weld the mounting blocks in the required position.



5.6 Installation - using Welded anchors - cont….

4. Ensure that the larger Rose Joint end is firmly attached to the Crack meter by checking that it fully tightened to its locking nut.

5. Fit the **larger** end of the crack meter (sensor end) to its mounting, using the M6 bolt through the Rose joint, and tighten the Allen screw.



6. Slide the M5 bolt through the mounting hole on the Rose joint on the shaft end of the crack meter. Carefully draw the shaft out and fix it to the other anchor, but do not tighten reading of the gauge should be taken to ascertain correct setting before the bolts are fully tightened.

7. Check the reading on the readout to ensure that it is at approximately the value that corresponds to the extension required.

   This should be checked against the individual calibration sheet for the Crack meter being installed.

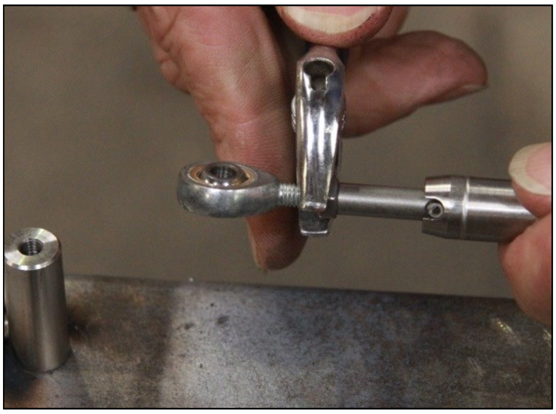
5.6 Installation - using Welded anchors - cont….

8. If the reading/setting distance is not in the correct range then adjustments can be made to the threaded Rose joint on the shaft of the crack meter. To adjust, undo M5 bolt and carefully remove Rose joint from the anchor. Ensure that the Rose joint locking nut is loose and turn the Rose joint **clockwise** to lower the crack meter readings and **anticlockwise** to raise the readings.

   DO NOT ROTATE THE SHAFT

9. When the reading is correct remove the fixing and carefully allow the gauge to close, ensuring the alignment pins engage with the slots on the housing tube.

   Tighten the locking nut to ensure that the rose joint is tight.



10. Re-fix the gauge to the anchor and tighten the screw using the Allen key and a spanner on the anchor locking nut.

The crack meter is now installed. Its readout cable can be routed to a convenient location for termination or to a data logger location.

It is strongly recommended that the crack meter is fitted with a lined protective cover to reduce the risk of damage and reduce the effects of temperature changes.

ONCE INSTALLED AND IT'S TEMPERATURE STABILISED, IT IS IMPORTANT TO ESTABLISH INITIAL READINGS.
ALL SUBSEQUENT READINGS WILL BE REFERENCED TO THESE INITIAL READINGS

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 Taking 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 **VW2106** 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. Switch on the unit and, where necessary, select range B

3. The readout displays the Vibrating Wire reading (in $Hz^2/1000$ - Linear Digits) and a temperature reading in degrees C.

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 the reading from Vibrating Wire instruments. These include devices manufactured and supplied by Geosense in both single and multi-channel configurations, as well as equipment manufactured by other suppliers.

Geosense configures and supply's equipment manufactured by both Campbell Scientific Ltd and DataTaker Ltd. These are the most commonly adopted third party manufacturers of data loggers that can be used with Vibrating Wire Instruments. Specific configuration and programming advice can be obtained from Geosense and/ or the manufacturers documentation.

6.2 Data Reduction

Overview

Readings from a crack meter are in a form that is a function of frequency, rather than in units of distance. Commonly the units would be either **Frequency** - Hertz (Hz), **Linear** - $Hz^2/1000$ or $Hz^2/1000000$ or **Period** - Time - (Seconds $x10^{-2}$ or $x10^{-7}$).

To convert the readings to units of distance, calibration factors must be applied to the recorded values. For most Vibrating Wire sensors, these factors are unique and are detailed on the sensor calibration sheet. A unique calibration sheet is supplied with each Geosense VW crack Meter. An example of the calibration sheet is shown on page 39.

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 readings 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
(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'.

$$\text{Linear Digits } (Hz^2/1000) = (2768.5)^2 / 1000 = 7664.6$$

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 1000 to maintain the standard Linear Digits ($Hz^2/1000$) format for the standard calculations.

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 straight forward calculation to convert 'raw' data to engineering units. It requires that the readings are in Linear Digits ($Hz^2/1000$) and it can be easily carried out using a simple calculator. Where this is not the case, the readings must be converted to Linear Digits prior to computation.
For most applications this equation is perfectly adequate and is carried out as follows:

Displacement (mm) = Linear Factor (K for mm) x (Current Reading - Initial Reading)

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.

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

Once the Site "C" Constant is established the polynomial formula can be used to convert Raw Data to Engineering Units.

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

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

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

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

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

The instrument calibration sheet similar to the example on page 31 of this manual includes the following information:

Model	This refers to the Geosense model number.
Serial	This is a unique sensor identification number that can be found on the body of the crack meter and, for long cables, at the end of the cable.
Works ID	Unique works code
Cable m	Length of cable fitted
Readout No.	Serial Number of the readout used to display the crack meter output
R/O Cal Date	The date on which the Readout was calibrated to a traceable standard
Cal Date	Date the calibration of the crack meter was performed
Master	Serial number of the Master Transducer used for the calibration
Temp ^{o}C	Temperature at which the unit was calibrated
Batch	Works batch number
Range mm	Operating range of the crack meter

(Continued from page 28)

Ap. Displacement	Displacement applied to the transducer as part of the calibration cycle in mm
$Hz^2 * 10^{-3}$	Readings from the crack meter as movement is applied and reduced, in steps. The average is calculated.
Ind. Displacement	Calculation of the displacement using the calculated Linear and Polynomial equations.
Lin. Error % FSO	Non Linearity expressed as a percentage of the crack meters Full Scale.
Poly. Error % FSO	Non Linearity expressed as a percentage of the crack meters Full Scale.
Deviation	Non Linearity expressed in Digits (Hz^2/1000)
Hysteresis	Difference between increasing and decreasing readings as a percentage of the crack meters Full Scale.
Calibration Factors	'Linear' and 'Polynomial' factors are provided for a selection of

Engineering units (other units can be calculated directly from the mm values).

Examples of calculated values are detailed below.

The following are examples of data reduction calculations and are based upon the crack meter to which the attached example calibration sheet refers. The results are displayed as 'change in distance' in millimetres

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

Site Initial Reading (period units) = 5142
Initial Converted to Linear Digits = 3782
Calibration Factor for mm (K) = 0.012218561

Current Reading (period units) = 4282
Current Converted to Linear Digits = 5454.8

Equation

Displacement in mm = K x (Current Reading - Initial Reading)
Displacement in mm = 0.012218561x (5454.8 - 3782.0)
Displacement in mm = 20.44 mm

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

Calibration Factors for mm A = 3.9746^{-8}
B = 0.011820338
C = - 35.375

Current Reading in Linear Digits = 5454.8

Equation

$$\text{Displacement in mm} = [A \times (\text{Reading})^2] + [B \times \text{Reading}] + C$$
$$= [3.9746^{-8} \times (5454.8)^2] + [0.011820338 \times 5454.8] - 35.375$$

(Continued on page 30)

= 1.183 + 64.477 - 35.375
= 30.29 mm

'Linear' calculations require the establishment of an Initial reading on site after the crack meter has been installed and its temperature stabilised.

This is often considered the most representative approach since the value is established on site and in its operating environment.

'Polynomial' calculations produce a displacement value related to the 'Zero' displacement established in the factory during the calibration process.

6.3 Temperature Considerations

Geosense® VWCM-4000 Crack Meters include temperature sensors. Where a crack meter are installed in a zone where its temperature is likely to fluctuate significantly, records of temperature data should be recorded. This can then be used to assess any temperature effects on the crack meter readings and on the structure being monitored . Readings from readouts can be in either Engineering units or resistance (see thermistor linearization on page 32).

The Thermal influences on crack meter readings are often complex. Therefore, in order to apply any correction for temperature changes it is first necessary to establish the effects of temperature changes on a particular crack meter and, more importantly, on the structure to which it is attached.

To establish the true affects of temperature changes, it is necessary to observe the readings from a particular crack meter over a period of thermal change, when little or no structural changes are taking place. This helps to identify the overall effects on the crack meter, the material on which it is mounted and the structure as a whole.

To minimise the effects of rapid temperature changes (thermal shock) it is advisable to fit a protective thermal cover over the installation. This will reduce the risk of thermal gradients over the crack meter itself when the temperature changes rapidly (e.g. sun strike).

The below table provides empirically derived corrections for temperature variations on the sensor engineering output (mm/C°)

Size of Gauge	Recommended Thermal Factor (mm/°C)
5	NA
12.5	-0.0005
25	-0.0025
50	-0.0086
75	-0.0100
100	-0.0150
150	-0.0219
200	-0.0330
300	-0.0530

6.3.1Thermistor Linearization

USING STEINHART & HART LOG

Thermistor Type. YSI 44005, Dale 1C 3001 B3, Alpha 13A3001-B3

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

7.0 MAINTENANCE

The **VWCM-4000 Crack Meter** is a maintenance free device for most applications. This is because it is intended for installation in areas that may normally be inaccessible. Where accessible, the primary maintenance issue would be to ensure that it is free from the build up of debris and dust that may affect its performance.

In addition, where the units can be safely removed from their mountings and a need arises, these instruments can be re-calibrated by Geosense.

Maintenance of wiring connections between the **VWCM-4000 Crack Meter** 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.

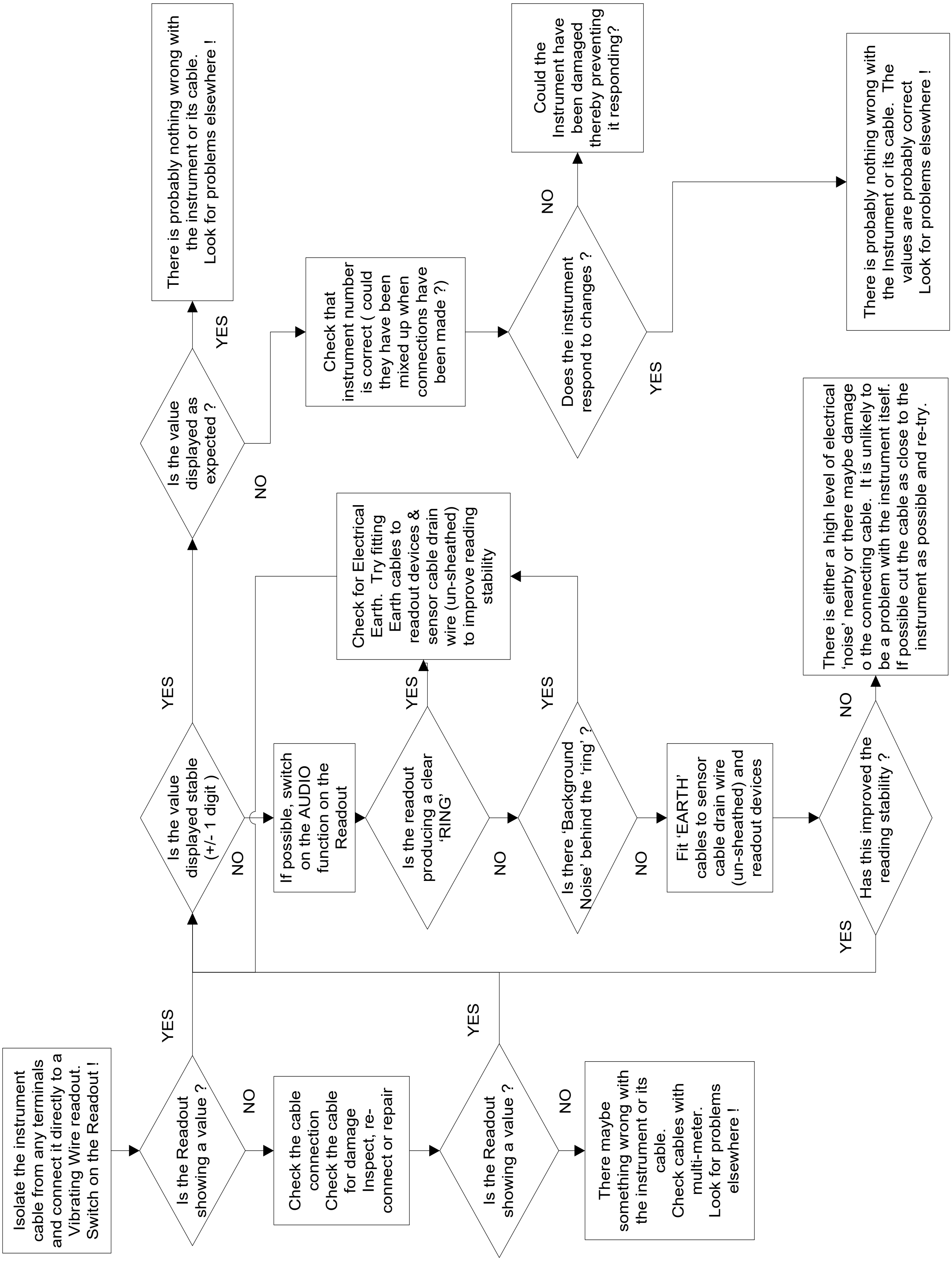
8.0 TROUBLESHOOTING

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. However, 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 as close to the sensor as is possible.

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

8.0 TROUBLESHOOTING - cont.



9.0 SPECIFICATION

VWCM-4000 Crack Meter

Range	5, 12.5, 25, 50, 100, 150, 200, 300, 500mm
Resolution	<0.025% FS
Accuracy	±0.1 to ±0.5% FS
Non-linearity	<0.5% FS
Frequency range	1650-2700 Hz
Nominal zero value	1850 Hz
Body material	Stainless steel
Inner rod	Stainless steel
O-ring	Viton
Anchor material	Mild steel, BZP
Anchor types	Grout, bond, bolt, arc weld, expandable
Waterproof rating	16 bar
Cable	2 pair PUR sheath

CHEMICAL METAL*

PRODUCT DESCRIPTION
Universal fix-it product, which joins, fills, seals and replaces metal, wood, stone etc.
Sets hard in 10 minutes.

Performance of cured material

Electrical conductivity (Ω/cm)	10^{14}
Hardness (Shore D)	85-90
Tensile strength (N/mm^2)	~16
Compressive strength (N/mm^2)	~90
Adhesion Mild steel	< +160 °C

Chemical resistance
Cured material is resistant to water, salt solutions, organic solvents, diluted acids and alkalis

OTHER SIMILAR BONDING MATERIALS HAVING SIMILAR PROPERTIES WILL BE SUITABLE FOR THIS APPLICATION

* Chemical Metal is a Loctite product

10.0 SPARE PARTS

As a VWCM-4000 Crack Meter 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.
- Replacement anchors and ‘Rose joints’

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 Ltd for a **Returns Authorisation Number,** request a **Returned Equipment Report Form QF034** and, 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 and a copy of the form should be faxed or emailed in advance to the factory.

11.2 Chargeable Service or Repairs

Inspection & estimate

It is the policy of Geosense Ltd 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.

11.3 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 **VWCM-4000 Cracks Meters** 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 Ltd 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.

11.4 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, MGS Geosense should be contacted for advice. Geosense Ltd will not be responsible for damage resulting from inadequate returns packaging or contamination under any circumstances.

11.5 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 **VWCM-4000 Cracks Meters** 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 Ltd** by the purchaser as regards the nature of the installation to allow **Geosense Ltd** to select the correct type and range of **VWCM-4000 Cracks Meters** and other component parts.

The **VWCM-4000 Cracks Meters** 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 (insert product type) 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 **VWCM-4000 Cracks Meters** equipment from the time of delivery to Purchaser.

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