

**Rod Extensometers  
With Displacement Transducers**  
User Manual



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## Section 1 : Foreword

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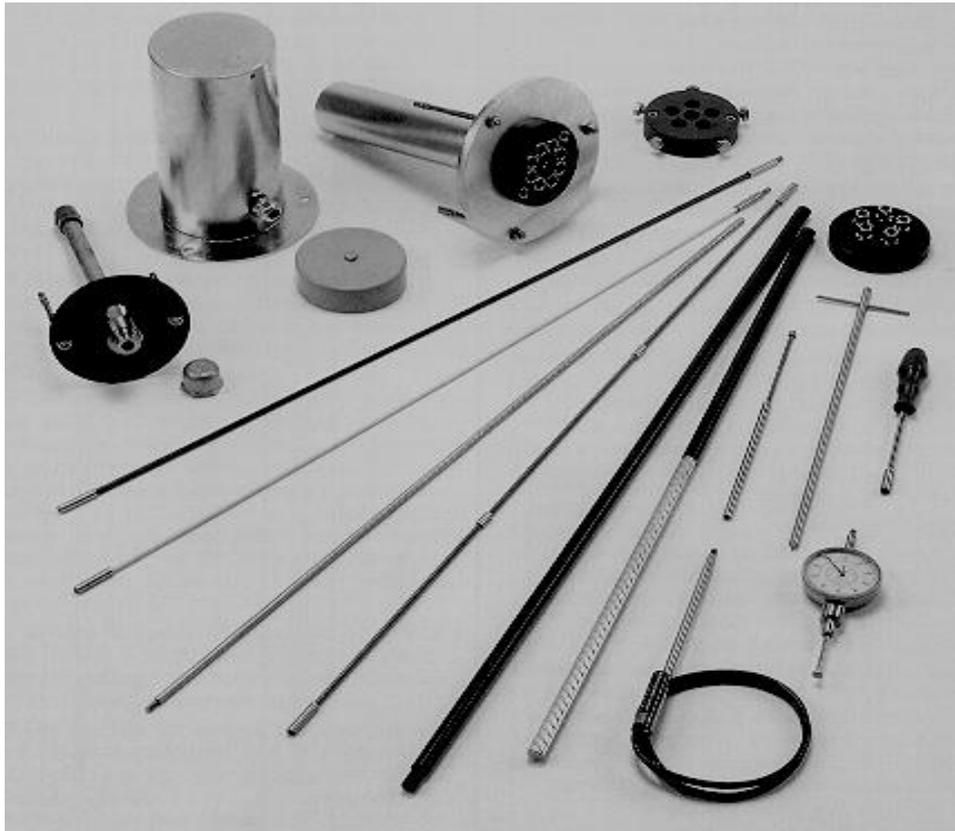
- The installation, operation and data interpretation of Rod Extensometers should be carried out by suitably competent and qualified personnel. They must **READ AND UNDERSTAND** the procedures outlined in this manual before attempting installation or operation of the equipment on site.
- This user's manual describes the general techniques required for the installation and reading of single and multiple rod extensometers with grouted anchors in boreholes at any orientation used in conjunction with vibrating wire displacement transducers.
- The techniques described are intended to serve as a general guide and will vary to suit individual site conditions and criteria.
- Soil Instruments will not accept for repair under guarantee, instruments that have been neglected or mishandled in any way.

## Section 2 : Introduction

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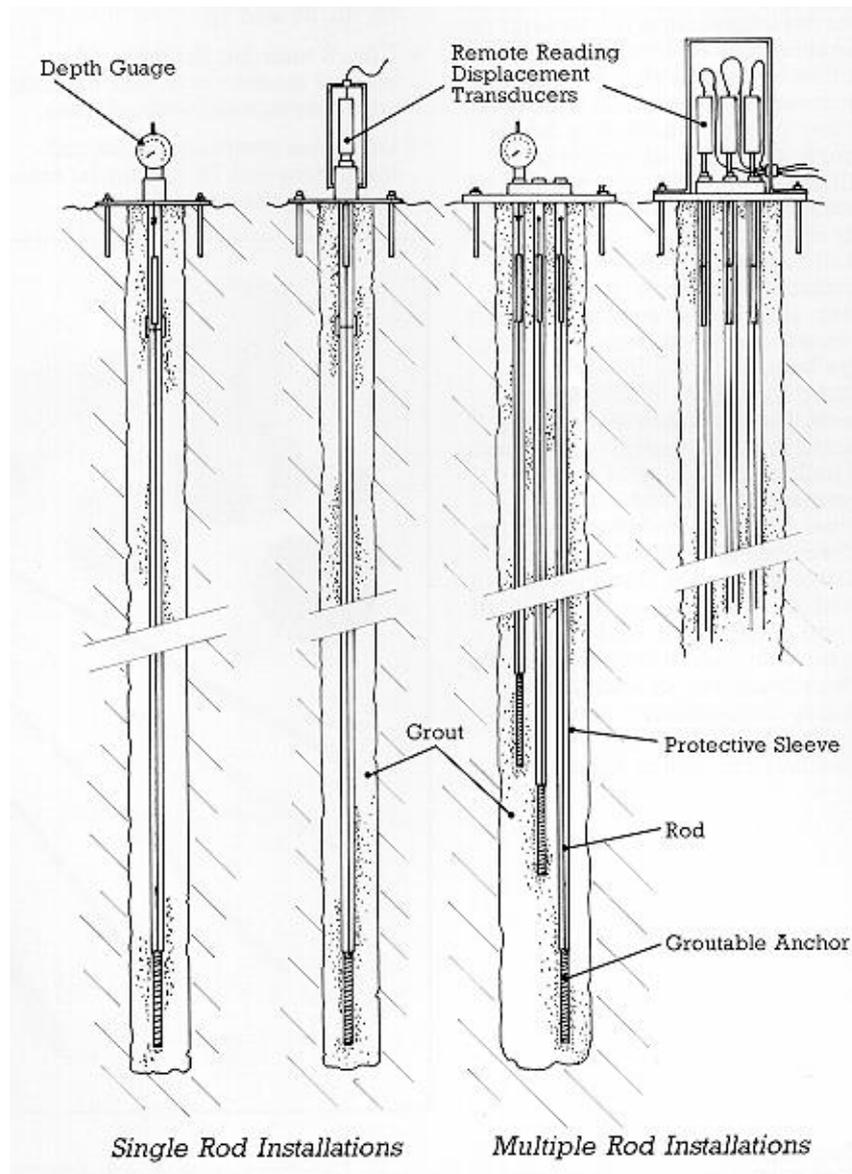
- Figures 1 and 2 show typical single and multiple rod extensometers.
- A single rod extensometer measures relative movement between two fixed points, the anchor and the reference plate. Accordingly a multiple rod extensometer will measure relative movements between the multiple anchors and the reference plate.
- These relative movements can be measured using either a dial depth gauge, digital depth gauge or a vibrating wire displacement transducer (VWDT). This manual only covers the use of VWDT.
- The extensometer anchor is located within a borehole. A rod is attached to the anchor and passes through a reference head that is fixed to the face of the borehole. The complete assembly is grouted in place. Each rod is individually isolated and protected from grout contamination by a close fitting protective sleeve, thus allowing free movement of each rod whilst securing the anchor to its neighbouring material. Relative movement between the anchor and reference plate can then be measured.
- The rod extensometer system is reliable, accurate and relatively simple to install and read. The system is adaptable and has a proven "track record". It can be installed in boreholes of all orientations with measuring lengths in excess of 100m, depending on the number of rods, in hole diameters of 38 - 101mm.

## 2.01 Figure 1. Rod Extensometer Equipment



- Single Rod Reference Head
- Cover for Remote Reading Reference Head, Cover for Manual Reading Reference Head
- Multiple Rod Reference Head
- Sleeve Support Clamp
- Glass Fibre Extensometer Rod
- Stainless Steel Extensometer Rod
- Carbon Fibre Extensometer Rod
- Protective Sleeve
- Groutable Anchor Unit
- Datum Plate
- Installation Tool
- Range Adjustment Tool
- Dial Depth Gauge
- Vibrating Wire Displacement Transducer

## 2.02 Fig.2 Rod Extensometer Installations



## **Section 3 : Preparation and Checks of Equipment Prior To Installation**

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### **3.01 Receipt of Equipment on Site**

Upon receipt of the instrument on site, the following duties should be carried out:

- a) The equipment should be checked to ensure all necessary parts are present and that no damage has occurred during transit.
- b) The VWDT should be subjected to a simple operational test. Having held the transducer at a roughly stable temperature for no less than 4 hours and whilst supporting the transducer by the cable, observe the period reading via the portable vibrating wire readout unit and verify that a consistent, toned, audio signal is obtainable. A change in measurement of less than  $\pm 2$  units indicates correct operation of the VWDT.
- c) Although the VWDT is fully checked after fabrication, the transducer should be monitored for as long as possible prior to installation to confirm operational stability and obtain "at rest" readings.
- d) Sleeves, rods and anchors should be kept away from direct sunlight and fully supported whilst being stored to prevent warping.

### **3.02 Pre-Installation**

Prior to installation the following duties should be carried out:

- a) A practice assembly undercover away from the site is always advisable for any instrument. If space does not permit, check that all the parts are present and fit together. It will also save time and reduce on-site confusion if a few minutes explanation on the installation procedure is given to technicians and labourers.
- b) A degreasing agent should be used to clean sleeve and rod connections prior to assembly.
- c) The bore of the sleeves and anchors should be checked to ensure no blockages exist.
- d) Grout mix trials may be necessary to ensure the strength of the grout is weaker than the parent material. Ideally an anti shrink admixture should be included to ensure good bonding between rock, grout and anchor interfaces.

## Section 4 : Installation

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Extensometer installation will require the use of solvents and glues, **the use of these materials should only be used in well ventilated areas and the manufacturer's safety precautions should be adhered to.**

The installation procedures outlined in this text are intended as a general guide and flexibility in the interpretation is required to suit local site conditions.

For clarity only grouted multiple anchors are discussed however single rod installations are merely simpler versions of the following procedures.

The technique used is dependent upon the orientation of the borehole and the effect of gravity on grouting operations i.e. for downhole and downward inclined holes, gravity assists grouting, for upward inclined and uphole, sealing of the reference head and the provision of grout return/air bleed pipes are necessary.

**Note:** Horizontal installations are not recommended because of the difficulties of ensuring pockets of air do not occur. In these instances it is advisable to produce a borehole with a +5° or -5° inclination from the horizontal.

### 4.01 Borehole Preparation

- a) The borehole should be bored to a length exceeding 0.5 metres past the final proposed anchor position.
- b) Once excavated the hole is water flushed to ensure it is free from debris and loose material.
- c) The borehole should then be checked to ensure the integrity of the hole. If there is water ingress, grout around the extensometer body could be diluted or flushed away. Additionally, especially in uphole installations, if there are sufficient fissures in the surrounding rock, grout loss could mean anchor/grout interfaces are compromised. If the borehole integrity is intact go to stage e).
- d) If the borehole is fissured it may be necessary to conduct a water pressure test on the drillhole to the same pressures as expected during grouting. If the results indicate substantial water losses the borehole will have to be pressure grouted over the fissured length and stages a) to c) inclusive should be repeated.
- e) Once the hole is clean and watertight the reference head is securely attached to the borehole face using the three anchors. A seal between the rock interface and reference head is made using either a thick grout mix or a suitable resin.

### 4.02 Downhole Installations

There are two accepted methods for downhole installations both with their own merits:

- Completed assembly prior to installation (section 3.2.1).
- Step by step installation (section 3.2.2).

### 4.02.1 Completed Assembly prior to Installation

This method is only possible if space and neighbouring activities are favourable but has the advantage of being able to inspect the completed extensometer body prior to installation, check that glued and threaded joints are adequate, and check on the completed length. The completed rod/sleeve assembly is highly flexible and can be curved at radii of approximately 4 metres whilst being inserted into the hole; therefore the completed assembly can be passed over a drill rig immediately before the hole.

The procedure is as follows:

- a) The anchor and sleeves for the longest rod assembly are cleaned and glued together using the PVC adhesive.
- b) The spacer plate is slid over the sleeve and positioned 250mm below the final design length. The temporary support plate is positioned and attached to the sleeve at the final design length. Ensure a nominal sleeving length protrudes above the support plate, therefore contamination of the sleeve bores is prevented during the grouting stage.
- c) Repeat stages a) & b) for all remaining anchor assemblies. At this point it should be noted which anchor orientations are designated to their respective depths i.e. longest at position "1" reducing in length in a clockwise direction.
- d) A grout pipe is fixed loosely along the length of the longest rod and positioned 400mm past the tip of the anchor, past the pipe through the temporary support plate. Ensure the tube is free from blockage and unlikely to kink on installation.
- e) For the purposes of moving the extensometer body to the borehole, temporarily strap anchor assemblies together. Carefully insert the extensometer body into the borehole removing the straps as the instrument is pushed in. The instrument should not be allowed to excessively flex during handling (a radius of approximately 4 metres is a safe minimum).
- f) The temporary support plate is then located against the reference head and screwed together.
- g) The design grout is then pumped through the grout pipe and the pipe gradually withdrawn ensuring the pipe remains within the placed grout. Finish grouting when pure grout returns to the face of the borehole.
- h) The grout is then left to cure.
- i) Once the grout has cured, remove the temporary support plate and cut the sleeves flush with the reference head.
- j) Insert the rod, female end first, into the deepest anchor sleeve, attach mole grips to the top of the rod and apply thread adhesive to the exposed male end connection. Screw the second rod tightly to the first rod. Unclamp the mole grips and carefully insert the rod assembly. Repeat the procedure until the full length of rod has been installed. Rotate the rod assembly to screw into the anchor. Mark the reference head level on the rod assembly.
- k) Repeat stage j) for all remaining anchor assemblies.
- l) The precise and final lengths of the completed rod assemblies are dependent on the anticipated direction and magnitude of movement and the size of the VWDT used. Once the cutting position has been decided, rotate the rod assembly to unscrew the rod from the deepest anchor. Withdraw from the protective sleeve to a convenient height and clamp tightly with mole grips.

- m) If glass or carbon fibre rods are used, use a hacksaw to cut the rod length using the marked reference head level as a datum. The cut must be clean and square, a file may be necessary. A threaded end adaptor is then glued on using an epoxy resin and a steel pin may be inserted through the adaptor and rod to ensure a secure attachment. If stainless steel rods are used, remove the final length of rod and replace with the rod adjustment stud. Cut to length and screw on the threaded end adaptor ensuring that all threads are glued.
- n) When the glue has dried, use a long shaft screwdriver and screw the rod assembly back into the anchor unit.
- o) Repeat stages l) to n) inclusive for the remaining rod assemblies.
- p) Attach the permanent mounting plate to the reference head using the screws supplied.
- q) The VWDT's are now ready for installation.

**Important Note: The VWDT has a non-twist locator pin to maintain the orientation of the telescopic shaft during transit. If the orientation of the shaft is not maintained during extension, accuracy, repeatability and overall operation of the instrument will be compromised.**

Slacken the locator bushes on the permanent mounting plate. Insert the VWDT through the mounting plate to connect with the rod of the deepest anchor. **Ensure a pushing pressure** whilst screwing the VWDT into the rod.

- r) Connect the vibrating wire readout unit to the transducer and zero the readout unit using the VWDT calibration constant and the "at rest" period reading.
- s) **Ensuring no rotation occurs**, pull the VWDT to the predetermined setting and tighten the locator bushes. Record the setting.
- t) Repeat stages q) to s) inclusive for each anchor assembly.
- u) Thread main multicore cabling through the supplied protective cover and connect the cable to the VWDT cables.
- v) Attach the protective cover.
- w) Connect the vibrating wire readout unit to the multicore cabling and check correct operation. Record the readings.
- x) Zero readings should be taken after a predetermined interval from installation to allow time for instrument operation to recover from tensioning and handling and equalise within its local environment (generally between 24 and 48 hrs is sufficient).  
Record the transducer readings and ensure readings are constant.

#### **4.02.2 Step by Step Installation**

If space is limited or site conditions are not conducive to the above method this method can be used.

The procedure is as follows:-

- a) The anchors are attached to the temporary support plate using the support screws to lightly grip them. The grout tube is passed through the support plate and loosely attached to the deepest anchor 400mm past the tip of the anchor.
- b) The temporary support plate is then screwed to the reference head. At this point it should be noted which anchor orientations are designated to their respective depths i.e. longest at position "1" reducing in length in a clockwise direction.
- c) Screw a rod onto the allocated deepest anchor, do not apply any thread adhesive to this first connection, however all subsequent rod connections on the same anchor assembly will require thread adhesive.
- d) Pass a sleeve over the rod and use the PVC adhesive to secure this first sleeve to the anchor.
- e) Repeat stages c) and d) for all anchor assemblies.
- f) Once the PVC adhesive has cured on the first anchor connection, attach mole grips to the top of the rod, release the temporary support plate screw and gently lower the deepest anchor together with the grout pipe.
- g) Once the top of the sleeve is at the support plate level gently and tighten support screws. For security leave the mole grips attached.
- h) Repeat stages f) and g) for all anchor assemblies.
- i) Repeat stages c) to h) inclusive until design depths have been achieved. Ensure a nominal sleeving length protrudes above the support plate; therefore contamination of the sleeve bores is prevented during the grouting stage.
- j) Refer to section 3.2.1., stages l) to x) inclusive.

### **4.03 Uphole Installations**

- a) Refer to section 3.2.1., stages a) to c) inclusive.
- b) A PVC grout return/air bleed tube is fixed along the longest rod and positioned 400mm past the tip of the anchor, pass the pipe through the temporary support plate. Ensure the tube is free from blockage and unlikely to kink on installation as the hole will hydraulically lock if air cannot escape.
- c) Pass approximately 1.0 metre of grout pipe through the temporary support plate and attach to the anchor assemblies.
- d) For the purposes of moving the extensometer body to the borehole, temporarily strap anchor assemblies together. Carefully insert the extensometer body into the borehole removing the straps as the instrument is pushed in. The instrument should not be allowed to excessively flex during handling (a radius of approximately 4 metres is a safe minimum).
- e) The temporary support plate is then located against the reference head and screwed together. To prevent the grout plug escaping use a temporary seal around the support plate i.e. clay. Ensure the grout return/air bleed tube is clear by blowing air through the tube and checking the return through the grout pipe.

- f) Connect the grout pipe to the pump and pump sufficient grout to cover the top of the grout tube i.e. 1.0 metre column. Release the pump from the pipe and allow any excess grout to drain back through the pipe. Blow air through the pipe to ensure pipe is clean. Allow grout plug to cure.
- g) The design grout is then pumped through the grout pipe and continued until grout of identical consistency to that entering the borehole exits the grout return/air bleed pipe. Disconnect the grout pump and seal the grout pipe and grout return/air bleed pipe by kinking the tubes. Allow the grout to cure.
- h) Refer to section 3.2.1., stages h) to x) inclusive, to complete installation.

## Section 5 : Taking Readings and Monitoring

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### 5.01 Taking Readings

Vibrating Wire Rod Extensometer transducers can be read with the Soil Instruments data loggers and portable loggers or any other readout capable of reading a vibrating wire transducer. The wire of the sensor is "plucked" by means of a magnetic field. Either the period or the frequency of oscillation of the wire can be measured. The reading on the portable logger is displayed in units of  $\text{Period} \times 10^7$  or as "linear" units ( $f^2/1000$ ) or as engineering units.

One channel on the portable or data logger can be reserved for each VWDT. Details such as zero reading, gauge factor and required units of measurement for each transducer are stored in the logger as a "channel table". The information in this channel table enables readings in units of displacement to be taken and stored in the logger's memory.

It is extremely important to establish the zero reading in the chosen units at the time of installation. The logger will display positive displacement for extension and negative displacement for compression once a negative factor given in the calibration certificate is stored in its table at a dedicated channel.

### 5.02 Monitoring

Throughout the construction of and operating life of the structure within which it is installed, the Vibrating Wire Rod Extensometer may be monitored in the following fashion:

- a) During construction it may be the case that only the naked ends of the conductors in the cable are available for reading the instrument. The instrument can be read at this stage using a lead from the portable logger with two crocodile clips which connect to the conductors.
- b) The cables may be connected to a terminal box from which many transducers can be read using the portable logger.
- c) The cables may be connected to a data logger either separately or more conveniently for longer cable runs, via multicore cables.

The data logger can be programmed to take a series of pre-programmed readings over time of any Vibrating Wire instruments connected to it. The data from these readings can be downloaded to computer and presented using Soil Instruments Data Management Software Package.

### **5.03 Frequency of readings**

The frequency with which readings of the Vibrating Wire Rod Extensometer are taken will depend on the stage of construction and the behaviour of the structure after completion.

The following points are relevant:

- a) Immediately after installation it is a good idea to take frequent readings for a number of days to ensure that the instruments are behaving correctly and ensure a good zero reading.
- b) During the general construction phase of the project, a normal reading frequency for the Extensometer would be once a week. If any construction activities are expected to effect the instrument readings it is advisable to obtain readings prior to and after the activity.
- c) After completion of the structure, the frequency with which readings are taken should be related to observed movements and engineering judgement.

## Section 6 : Data Interpretation

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As with any monitoring system it is essential that all the factors that could possibly affect the readings are recorded and taken into account such as atmospheric conditions and construction activities. Because of the nature of the instrument, monitoring during periods of excessive vibration will cause erroneous readings and should be avoided.

Temperature changes have a measurable effect on extensometer systems and therefore ambient and differential temperatures should be recorded. Electronic systems such as readout units are known to be affected by temperature variations.

It should be remembered that rod extensometers are designed to measure relative movements between head and anchor assemblies. Absolute displacements can be obtained if alternative movement monitoring techniques are used in conjunction with rod extensometers.

### 6.01 What does the data mean?

An outward movement of the Extensometer piston will lead to increased tension in the vibrating wire within the transducer in turn, when plucked, will exhibit a higher frequency of vibration. It can then be seen that any increase in the measured frequency of vibration would mean that the distance between anchor point and the reference head is increasing.

### 6.02 How is the data converted to Engineering Units (mm)?

The calibration certificate has a selection of Gauge Constants enabling the operator to read and log data directly in the **ENGINEERING** units if desired.

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

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

From 'Period' units and from 'Linear'(f<sup>2</sup>/1000) units using two methods: a simple Linear equation or a Polynomial equation.

#### Calculation using 'Period' units.

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

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

Where,

E is the Pressure in resultant Engineering units,

K is the Period Gauge Factor for units of calibration (from the calibration sheet),

P0 is the Period 'base' or 'zero' reading,

P1 is the current Period reading.

This method of calculation is used by the Soil Instruments Vibrating Wire loggers' (models RO-1-VW-1 or 2 and with serial numbers starting VL or TVL) internal processors', for calculating and displaying directly on the loggers' LCD screen, the required Engineering based units.

The loggers' require 'Period' base or zero reading units for entering into their channel tables, to calculate and display correctly the required engineering units.

If an alternative Engineering-based unit is required other than the units of calibration, then the correct K factor will have to be calculated using the standard relationship between engineering units.

For example, if the units of calculation required were in inches and the calibration units were mm, we can find out that 1 inch is equal to 25.4mm, so we would derive the K factor for inches by dividing the K factor for mm by 25.4.

### **Calculation using Linear units.**

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

$$E = G (R0 - R1)$$

Where,

E is the resultant Engineering unit,

G the linear Gauge factor for the units of calibration (from the calibration sheet),

R0 is the Linear 'base' or 'zero' reading,

R1 is the current Linear reading.

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

### **Linear unit calculation using a Polynomial equation.**

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

$$E = AR1^2 + BR1 + C$$

Where,

E is the resultant Engineering unit,

A, B and C the Polynomial Gauge factors A, B and C, from the instrument's calibration sheet,

R1 is the current Linear reading.

The value C is an offset value and relates to the zero position experienced by the transducer at the time of calibration. If the transducer is required to read zero engineering units when in its installed position then C should be re-calculated at the installation time as follows:

$$C = - (AR0^2 + BR0)$$

Where,

A and B are as above,

R0 is the Linear 'base' or 'zero' reading.

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

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

## **6.03 Sign of the Engineering Units**

Vibrating Wire Rod Extensometer Transducers are supplied with negative calibration factors ("K" and "G" values). This ensures that when the above vibrating wire equations are used to analyse subsequent period or linear readings obtained from the Extensometers that:

PISTON OUT = + change in reading in mm.

PISTON IN = - change in reading in mm.

More practically, a + change in reading for the Extensometer will imply that the distance between anchor and reference head is increasing.

## Section 7 : Temperature Corrections and Coefficients

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The Transducers working elements are made primarily of steel and stainless steel and are affected by changing temperature to a certain predictable degree. In case of large temperature changes application of temperature correction will improve the accuracy of the measurements. The approximate temperature effect on the gauge is -0.02mm per degree Celsius. Hence for a temperature increase of 10°C a transducer will indicate (-0.02 x 10) 0.2mm to the result indicated by the transducer reading. A fall in temperature will result in a positive change in linear measurement which can be corrected accordingly. Physical dimensional changes due to temperature in the transducer and the structure on which it is mounted are of the order of 10-6m/m/°C and can be neglected.

If you are using the stainless steel rods the formula is:

Length (meters) x E-6 x 17.5 x °C change  
Temperature coefficient 17.5ppm

If you are using fibreglass rods formula is:

Length (meters) x E-6 x 3 x °C change  
Temperature coefficient of 3ppm

## Section 8 : Troubleshooting Guide

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If a failure of any vibrating wire transducer or the electrical cable is suspected, the following steps can be followed. The transducers themselves are sealed and cannot be opened for inspection. The "Troubleshooting Flowchart" should also be followed if any instrument failures are suspected.

The steps below and the Troubleshooting Flowchart are applicable generally to any vibrating wire instrument.

### STEP 1

Before any of the following steps are followed, the readout unit should be used to verify the stability of the reading and the audio signal from the portable logger should be heard. Unstable (wildly fluctuating) readings from a transducer or an unsteady audio signal are either indications of possible problems with instruments or their related electrical cables.

If a portable data logger is giving faulty readings or audio signals from all transducers, a faulty readout unit must be suspected. Another readout unit should be used to check the readings from the transducers and Soil Instruments should be consulted about the faulty readout unit.

### STEP 2

The resistance across the two conductors of the electrical cable should be checked. This can be done using a multimeter device across the two exposed conductors if the cable has not been connected to a terminal cabinet, or can be done just as easily across the two conductors if the instrument has been connected to such a terminal (or datalogger).

The resistance across the two conductors should be approximately of the order of  $120\Omega$  to  $180\Omega$ . The majority of this resistance will come from the transducer (say approximately  $130\Omega$ ) and the remainder from the electrical cable connected to the transducer.

Before proceeding to Steps 3 and 4, the continuity should be checked between conductors and earthing screen of the electrical cable. If continuity exists, a damaged cable is confirmed.

### STEP 3

If the resistance across the two conductors is much higher than the values quoted in "STEP 1" (or is infinite), a severed cable must be suspected.

### STEP 4

If the resistance across the two conductors is much lower than the values quoted in "STEP 1" (say  $80\Omega$  or less) it is likely that cable damage has occurred causing a short in the circuit.

### STEP 5

If the resistance is within the values quoted in "STEP 1" (i.e.  $120\Omega$  to  $180\Omega$ ), AND no continuity exists between conductor and earth screen and on checking the reading from the transducer, it proves to be still unstable or wildly fluctuating, it must be assumed that the integrity of the circuit is good. A faulty transducer could be suspected if neighbouring construction activities do not account for the anomaly Soil Instruments should be consulted. If the point at which the cable is damaged is found, the cable can then be spliced in accordance with recommended procedures.

## TROUBLE SHOOTING FLOWCHART

