RST INSTRUMENTS LTD.

MULTI-POINT COMBO EXTENSOMETER

Installation Manual

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Multi-Point Combo Extensometer Installation Manual

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1 INSTALLATION TOOLS

The following tools are required for the installation of a Multi-Point Combo Extensometer System:

1. Hacksaw – Fine Tooth	2. Loctite© 222 Thread Lock
3. Cable Saw	4. Allen keys – Metric & Imperial.
5. Wrenches – Small Sizes, Metric & Imperial	6. PVC Solvent Cleaner
7. Adjustable Crescent Wrenches – 2 - Small	8. PVC Cement
9. Tape Measure	10. Vise Grips® Pliers – 3 Pairs - Medium Size
11. Screwdrivers – Flat and Phillips	12. Gear Hose Clamps – 10 - Medium Size
13. Flat Metal File – Small, Fine Toothed	14. Grease Gun - with Grease
15. Round Metal File – Small, Fine Toothed	16. Sharpie Felt Marker Pens – Fine & Medium
17. PVC Electrical Tape – Several Rolls	18. Snap Blade Knife – with Spare Blades
19. Several Dry Cleaning Rags	20. Spare Parts – As Required

2 INSTALLATION OF THE MULTI-POINT COMBO EXTENSOMETER SYSTEM

These installation instructions are general and may require alteration to suit specific site conditions and the required configuration of the instrument. The User is encouraged to read these general installation instructions carefully prior to the installation and to anticipate any steps or procedures which may require modifications.

It is noted that flat hole installations are the easiest because the extensometer assembly will rest on the drillhole invert during the installation and can be easily pushed into the drillhole, as it is assembled. Upward or downward inclined drillholes will require somewhat different procedures to ensure that the installation does not either fall down the drillhole or fall out of the drillhole collar. In addition, the grouting of upward inclined drillholes is also much more difficult and subject to technical issues.

In general, for inclined drillholes, the extensometer assembly must be secured at the drillhole collar by using a pair of Vise Grip® pliers to hold the lead extensometer rod. In a downward inclined drillhole, the Vise Grip® pliers can be set to rest on the top edge of the grouted-in Aluminum Grout Collar.

In an upward inclined drillhole, the Vise Grip® pliers will also hold the lead extensometer rod, but must be suspended from a secure anchor point located adjacent to the Aluminum Grout Collar. This is usually accomplished with an anchor bolt into the surrounding rock and a steel cable or rope sling arrangement.

CAUTION: It is noted that Vise Grip® pliers have a spring loaded locking mechanism within the handle. An unintended blow or knock to the handle has been known to unintentionally release a set of Vise Grip® pliers, which would allow the extensometer installation to either fall in to or out of the drillhole. It is therefore recommended that PVC electrical tape be used to secure the Vise Grip® plier handles whenever the extensometer installation is being held at rest at the drillhole collar.

3 INSTALLATION PREPARATIONS

1. Based on the intended instrument downhole design, compile a reference table containing the calculated lengths between each Anchor, starting from the deepest anchor and proceeding to the borehole collar. This tabulated information will determine the length of Extensometer Rods and PVC Sheaths to be installed before adding the next anchor. For example; if each Anchor was spaced 10m apart, then 10m worth of Extensometer Rods and PVC Sheaths would be installed onto the first Anchor, before proceeding with the installation of the second Anchor.

2. Organize the Extensometer Rods and PVC Sheaths into anchor groups, starting with the deepest Extensometer Anchor. Verify that all lengths of Extensometer Rod and PVC Sheaths are present for each anchor to reach its target depth. The use of a long table or saw horses is recommended to ensure that all of the instrumentation segments can be laid out and clearly organized prior to the installation. **Noted that the stainless steel Extensometer Rods and PVC Sheaths are provided in 1m, 2m and 3m lengths, as require for the installation.**

3. Number each Extensometer Rod at both ends, with its sequence in the installation order, using a Sharpie Felt Marker Pen. Recommend to use letters to designate which extensometer the Extensometer Rod belongs to and a number designating the Rod location from the bottom upwards. For example: The first Rod threaded to the deepest anchor extension would have a "A1" label at both ends. And the next Rod would be labeled "A2" at both ends, etc.. (The second anchors' rods would be labeled as "B1", "B2", etc.).

4. VERY IMPORTANT: To ensure that the required backfill grouting can be effectively carried out in the drillhole, once the extensometer instrumentation is installed, it is strongly recommended that downhole water pressure testing be carried out prior to the instrument installation. With a single stage grouting line usually used for an extensometer installation, it is very important to establish that the hole will be able to hold grout and that proper 100% backfill grouting will be able to occur. If water loss problems are encountered during water testing, it will be necessary to either pressure grout the hole and re-drill it to establish an acceptable lower permeability or abandon the leaky hole in favor of a new hole without permeability issues. This issue is very important to establish before the downhole installation of the extensometer instrument is commenced.

4 INSTALLATION INSTRUCTIONS

4.1 USING RE-BAR TYPE GROUT-IN ANCHORS

Preparations:

1. Ensure that the permeability of the drillhole will be acceptable to allow proper backfill grouting to be carried out, as detailed in Section 3, Note 4.

2. For clarity purposes, the instructions provided in this section are for flat or downward oriented drillholes which will have a grout delivery line installed to the hole bottom and a vent line or opening installed at the hole collar. Upward oriented drillholes will be the opposite, with grout delivery occurring at the hole collar and venting occurring by way of a vent line installed to the hole bottom (higher than the hole collar). Refer to Section 4.5 for further details on installations in upward oriented drillholes.

3. The grout delivery line will have to pass though the annulus between the drillhole ID and the Grout Collar OD. This should be checked for adequate clearance prior to the installation of the grout delivery line. If adequate space is not available, an axial passage slot will have to be chipped in the drillhole ID, to the depth of the Grout Collar, to provide clearance.

4. Insert the grout delivery line to the hole bottom. The delivery line will have to be semi-rigid in order to successfully navigate irregularities in the drillhole wall. Noted that ¾" Class 200 PVC plastic tubing will work well, but other tubing products made from ABS or Polyethylene plastics may also be acceptable. The tubing ID should be between 12 and 25 mm to ensure low line friction and good grout delivery. Downhole installations of a grout delivery line should be easier due to gravity assistance. Noted that a weight can be attached to the bottom of the delivery line to assist with the downhole placement. Steel products should not be used for downhole grout delivery lines due to the tensile strength of the steel which could act as reinforcement in the grout backfill and could impact the function of the installed instrument anchors. Noted that upholes will definitely require the use of the more rigid PVC tubing.

5. Insert the aluminum Grout Collar into the borehole collar with the Large Vent Hole and three retaining bolt holes oriented to the outside of the hole. The Grout Collar should be located at about 75mm (3") above the nominal Borehole Collar (Figure 1). Generally, the Large Vent Hole should be oriented upward, to ensure that complete grouting of the Grout Collar interior space will occur.

6. The Grout Collar needs to be firmly attached into bedrock at the drillhole collar so that a reliable fixed measurement reference point is established. The Grout Collar must be firmly wedged in place using wooden wedges and grout soaked rags. Noted that the installed downhole grout delivery line and a short collar vent line will pass up the annulus between drillhole ID and the Grout Collar OD. The annular space is then sealed in-place using a quantity of quick-setting cement hand pack and left to cure.

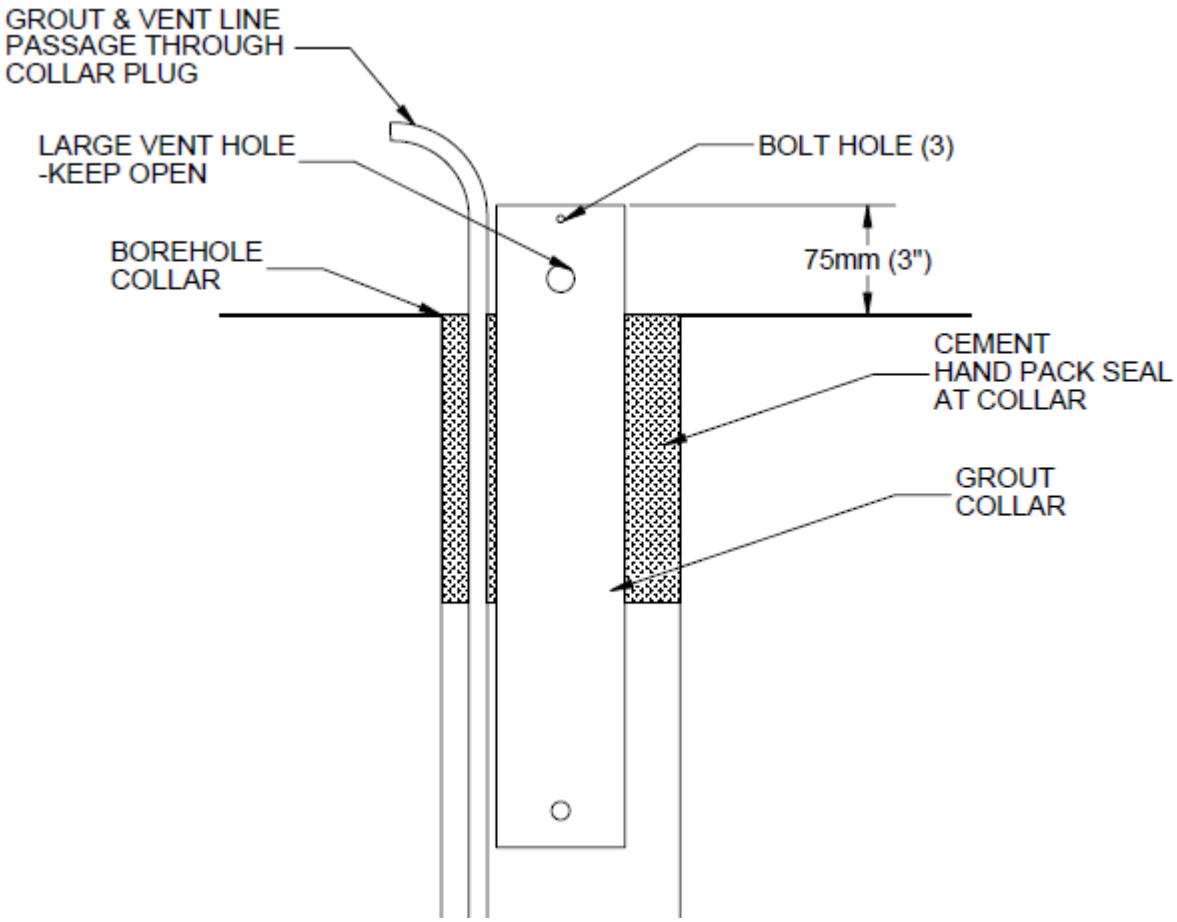

Figure 1: Grout Collar Installation

First Anchor:

7. Locate the Re-Bar Anchor for the deepest Extensometer (Figure 2). This anchor segment will have a short starter rod attached to the re-bar segment, which is intended to provide a 0.50 m offset length between the stainless extensometer rods joints and the PVC Sheath joints. The threaded connection between the starter rod and the Re-Bar Anchor will have been made during manufacture with Loctite© 222, so there is no need to disassemble this connection in the field. Noted that the center point of the Re-Bar length is considered to be the extensometer anchor point for technical purposes.

8. Select the next PVC Sheath to be installed and clean both ends with PVC Solvent Cleaner (male and female ends). On surface, slide the newly cleaned PVC Sheath length over the next SS Extensometer

Rod to be installed. Check the reference labeling on each Extensometer Rod to confirm that the correct Rod has been selected for installation. Hold the PVC Sheath back to allow the threaded rod connection to be prepared (Figure 3).

9. Apply Loctite© 222 to the male screw threads at the bottom end of the SS Extensometer Rod and thread it into the top of the Starter Rod. Tighten with the medium Vise Grip ® pliers.

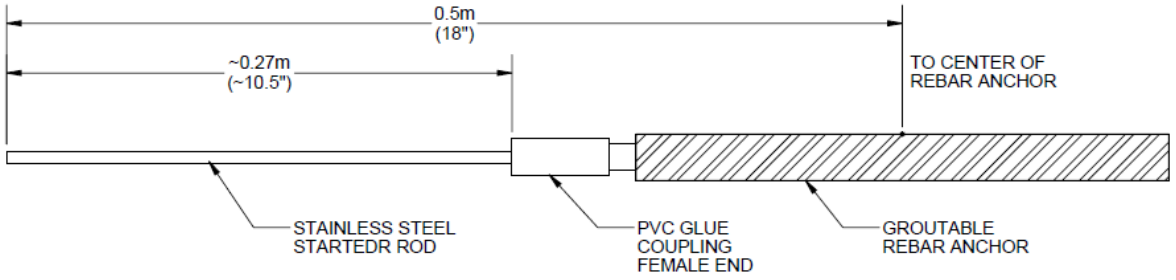

Figure 2: Re-Bar Type Anchor

10. Apply a liberal coating of PVC Cement to the outer diameter (male end) of the clean PVC Sheath. For obvious reasons, it is not possible to apply PVC Cement to the female coupling end.

11. Insert the PVC Sheathing, into the Coupling, rotating slightly during insertion. **Must allow the PVC glue to set until sufficient strength has been developed to allow the weight of the instrument string to be safely suspended in the drillhole by clamping onto the top of the PVC Sheath OD. The amount of time required will be dependent on the plastic temperature. Noted that PVC gluing should not be carried out at sub-freezing temperatures. At low temperatures, up to 20 minutes could be required. Therefore, keeping the PVC plastic and PVC glue warm would be a preferred solution. Field testing of the glued joint strength could be carried out to use to establish the appropriate set time.**

12. Place the lead section of the Extensometer Rod Assembly into the borehole Grout Housing and lock it off with a pair of medium Vise Grips® pliers by gripping onto the PVC Sheath. **As noted above in Section 2, the Vise Grip® plier handles must always be secured with PVC electrical tape to ensure that the pliers cannot be inadvertently released.**

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13. Repeat Steps 8 to 12, as required to add additional rod lengths to the Extensometer until the bottom Anchor has reached the depth where the next (second) Anchor lead section is required to be added, as calculated in Section 3, Note 1.

Second Anchor:

14. Prepare the lead section for the second anchor for attachment onto the PVC Sheath of the first anchor by following Steps 7 to 11.

    Place the second anchor lead section beside the PVC Sheath of the first anchor and adjust into the correct relative depth position. The two anchors are then taped together at several points with PVC electrical tape. For details of the attachment, refer to Step 16 below.

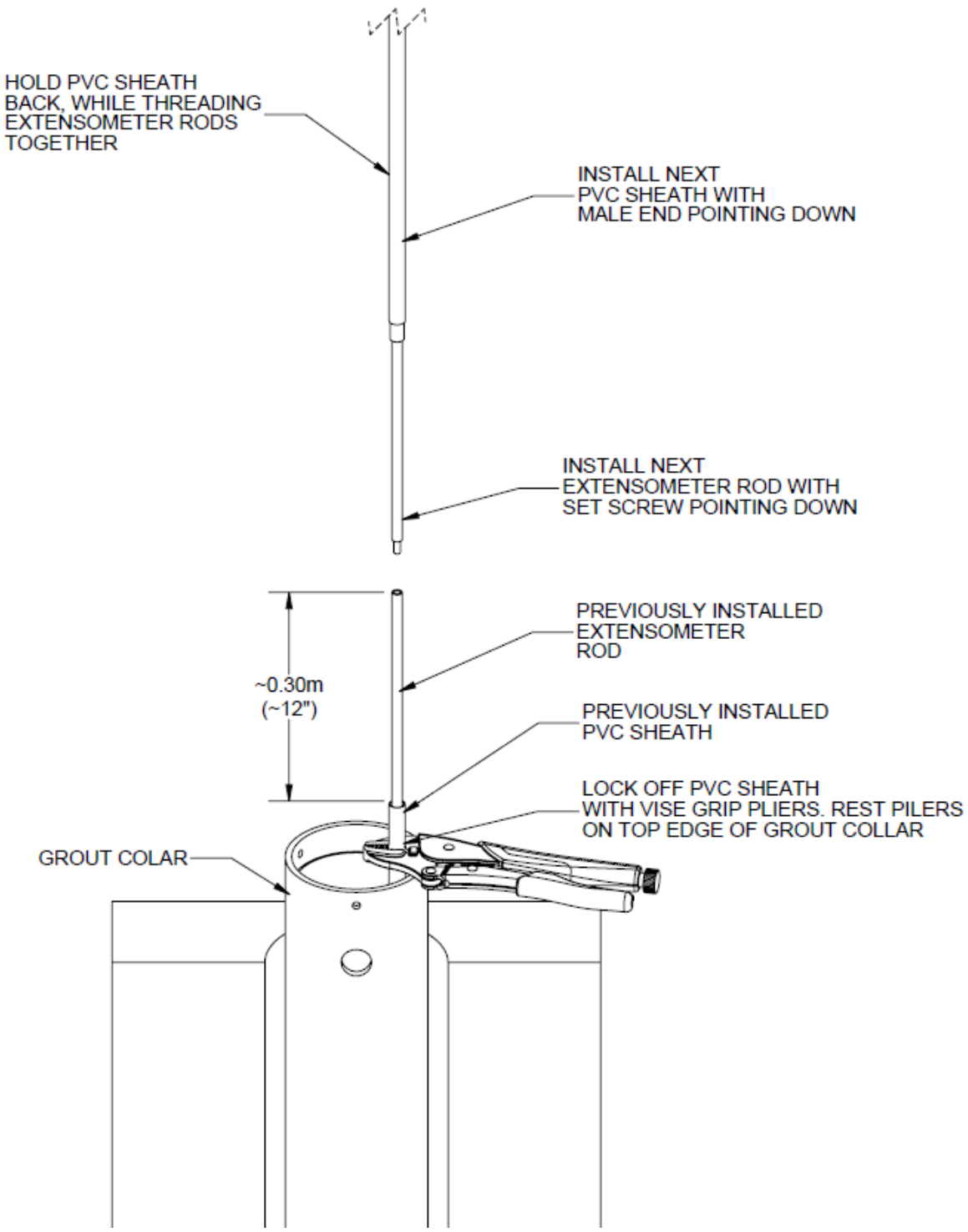

Figure 3: Installing Additional Extensometer Rod and PVC Sheathing

15. The two anchors need to be taped together so that there will be an approximate 20mm space between the first anchor's PVC Sheath and the second anchor's re-bar anchor. The taping should be started approximately 1 meter above the re-bar anchor. At this lowest taping location, build-up a layer of PVC electrical tape to separate the two PVC Sheaths so that an approximate 20mm separation is formed adjacent to the re-bar anchor when the subsequent taping higher-up, pulls the two PVC Sheaths together. **This may require some effort to get the re-bar anchor separation correct, but it is a very**

important to ensure that the re-bar anchor will be fully encapsulated in grout, and connect to the drillhole ID, when the backfill grouting is carried out.

16. Lower the assembly into the borehole using only the PVC Sheath for the first anchor to take the load. Lock off the first anchor PVC Sheath using the medium Vise Grip® pliers. **Note that the Vise Grip® plier handles must always be secured with PVC tape when holding a load.**

17. Add the next extension rods for both anchors.

18. At the first extension rod above a new anchor, tape the PVC Sheaths together securely at two locations with PVC electrical tape and install one gear drive hose clamp over top of each taped location. For all subsequent extension rods above the first one, use only one wrap of PVC electrical tape.

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19. Repeat Steps 13 to 19, as required to add additional rod lengths to the two Extensometers until the bottom Anchor has reached the depth where the next (third) Anchor lead section is required to be added, as calculated in Section 3, Note 1.

Third Anchor:

20. Prepare the lead section for the third anchor for attachment onto the PVC Sheath of the first anchor by following Steps 7 to 11.

21. Place the third anchor lead section beside the PVC Sheath of the first anchor and adjust into the correct relative depth position. **Noted that the third Anchor PVC Sheath needs to be added so that the three rods are arranged in Clock-Wise order 1 to 3, when looking downward from the drillhole collar. This Clock-Wise arrangement will match the Clock-Wise order of the number stampings on the Collar Reference Head.** The three anchors are then taped together at several points with PVC electrical tape. For details, refer to Step 23 below.

22. The three anchors need to be taped together so that there will be an approximate 20mm space between the first and second anchor's PVC Sheath and the third anchor's re-bar anchor. The taping should be started approximately 1 meter above the re-bar anchor. At this lowest taping location, build-up a layer of PVC electrical tape to separate the three PVC Sheaths so that an approximate 20mm separation is formed adjacent to the re-bar anchor when the subsequent taping higher-up, pulls the three PVC Sheaths together. **This may require some effort to get the re-bar anchor separation correct, but it is a very important to ensure that the re-bar anchor will be fully encapsulated in grout, and connected to the drillhole ID, when the backfill grouting is carried out.**

23. Lower the assembly into the borehole using only the PVC Sheath for the first anchor to take the load. Lock off the first anchor PVC Sheath using the medium Vise Grip® pliers. **Note that the Vise Grip® plier handles must always be secured with PVC tape when holding a load.**

24. Add the next extension rods for all three anchors. **Ensure that the Clock-Wise arrangement of the three anchors sheaths is maintained at all times. Do not allow the anchor PVC Sheaths to cross over.**

25. At the first extension rod above the new anchor, tape the three PVC Sheaths together securely at two locations with PVC electrical tape and install one gear drive hose clamp over top of each taped location. For all subsequent extension rods above the first one, use only one wrap of PVC electrical tape.

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26. Repeat Steps 24 to 26, as required to add additional rod lengths to the three Extensometers, until the installation is located exactly 1.00m above the Final Downhole Installation Position. Secure at this location using the Vise Grip® pliers on the first anchor PVC Sheath. **Note that the Vise Grip® plier handles must always be secured with PVC tape when holding a load.**

4.2 READING HEAD INSTALLATION

The Multi-Point Combo Extensometer Reading Head is designed to be attached to the Aluminum Grout Collar, which must be securely attached into the drillhole collar. All downhole displacements are measured relative to the Extensometer Reading Head. It is therefore very important for the accuracy of the instrument, that the Extensometer Reading Head is correctly and securely installed.

Refer to Figures 4 and 5 which illustrates the general arrangement and functional components of the Extensometer Reading Head.

The Extensometer Reading Head must be installed prior to the backfill grouting to ensure that the SS Extensometer Rods are properly aligned within the Reading Head. To accomplish this, the SS Extensometer Rods and the PVC Sheathing have to be trimmed to length, in a very precise manner, which will place the Re-Bar Anchors at their intended downhole depth locations, when the reading Head is at it`s final location on top of the aluminum Grout Collar.

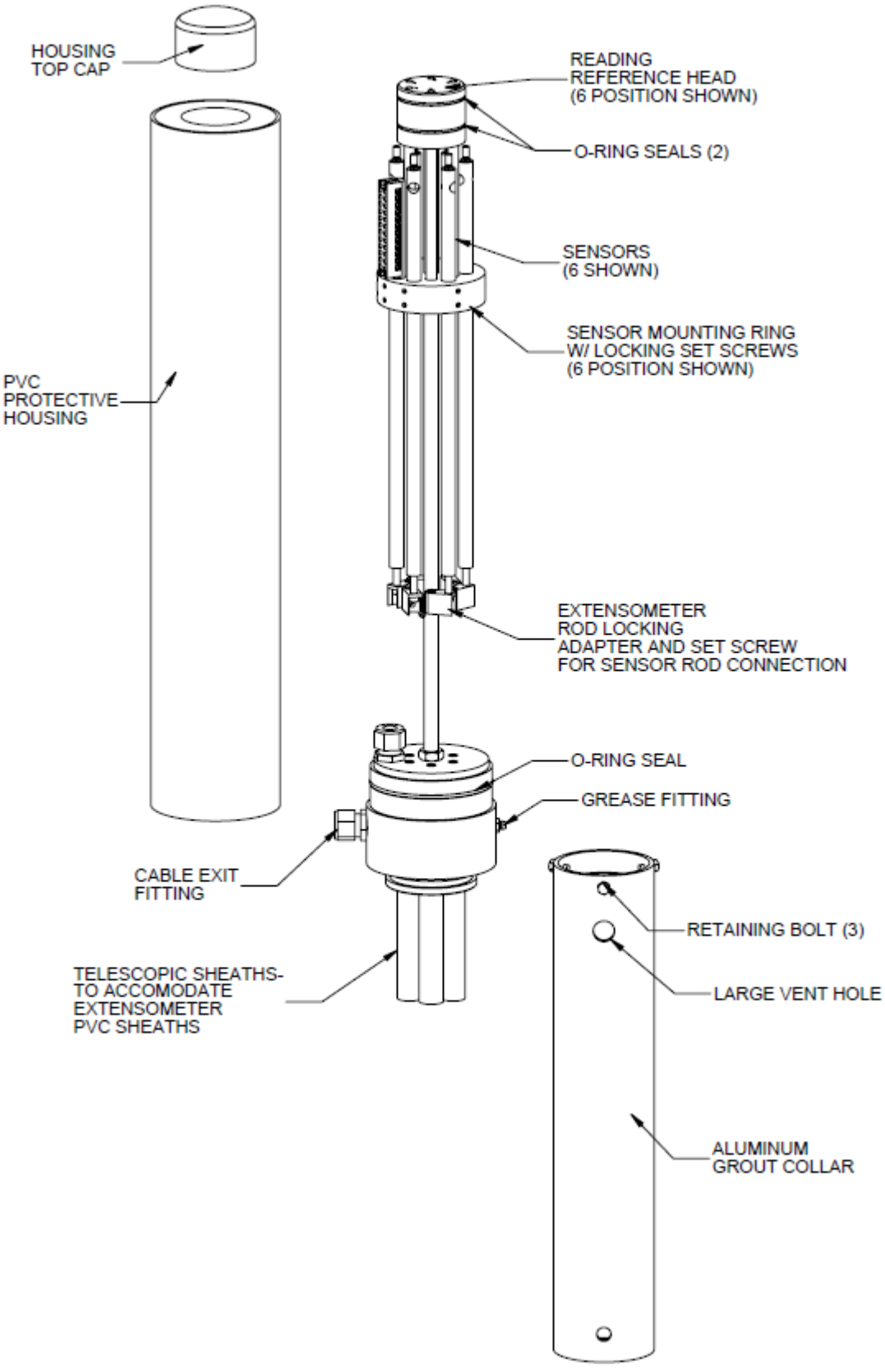

Figure 4: Extensometer Reading Head - General Arrangement

Because these cuts must be precise and are irreversible, it is recommended that the installer prepare a sketch diagram to graphically represent the working stick-ups and the final collar arrangement. It is also recommended that the calculations and lay-out be checked several times, prior to the final cutting.

A hacksaw will be required for the SS rod cutting work. However, it is noted that a small electric angle grinder, with an abrasive cut-off wheel, would be a useful addition to the tool list, if available.

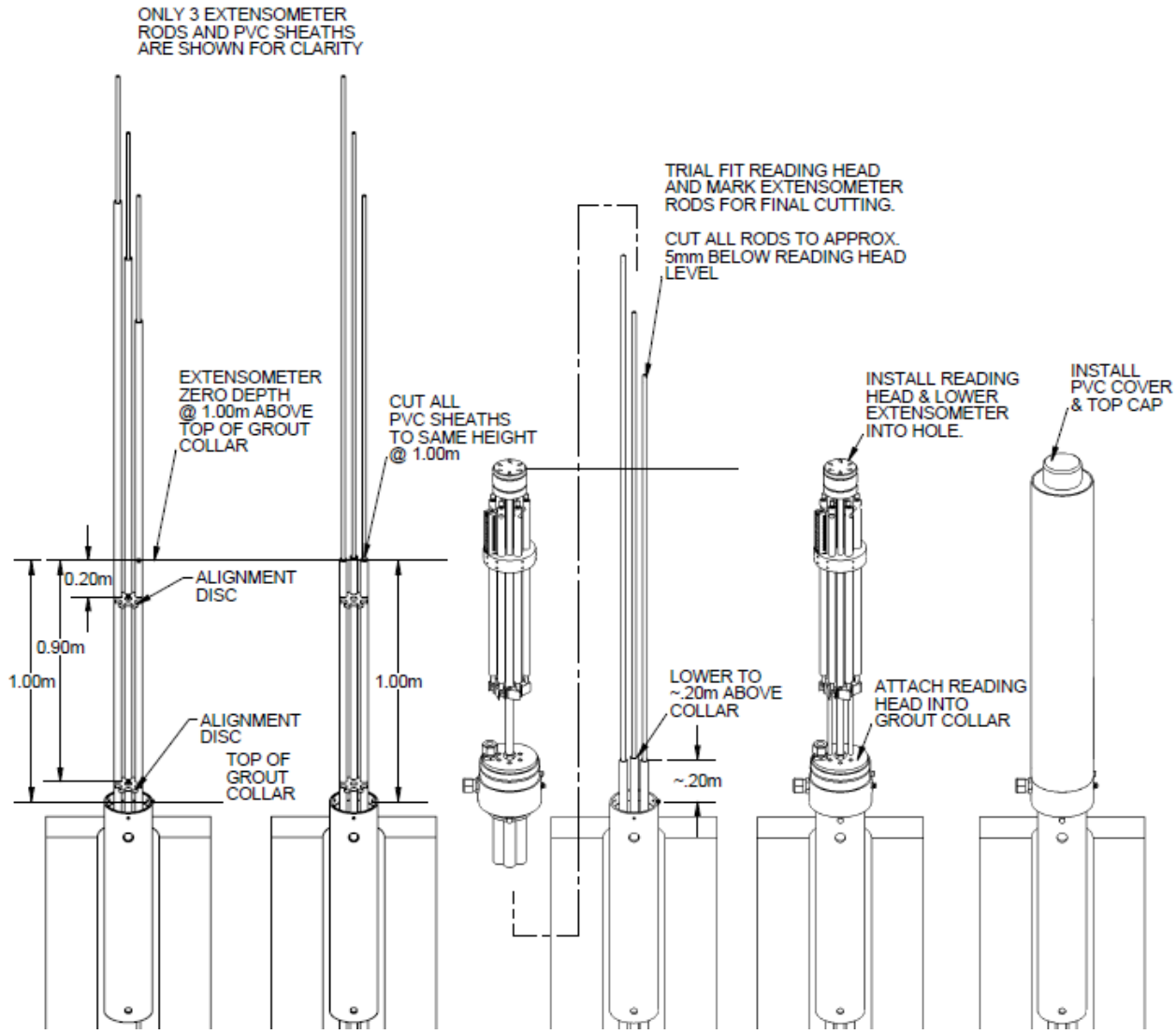

Figure 5: Extensometer Reading Head Installation

1. Noted that as per Section 4.1, Step 27, the Extensometer installation is now located exactly 1.00m above the Final Downhole Installation Position. This needs to be kept in mind as the final installation steps are carried out by the installer.

2. **Separate the three extensometer PVC Sheaths and arrange in the correct Clock Wise relative order, Anchor 1 to Anchor 3.** Install two PVC Sheath Alignment Disks at the locations that will eventually be 0.20m and 0.90m below the top of the installed aluminum Grout Collar, when the Anchors reach their target depths. Secure the PVC Sheath Alignment Disks in place with a few wraps of PVC electrical tape.

3. The next steps will involve the cutting of the PVC Sheaths and the SS Extensometer Rods to final length. Need to be absolutely sure that the installation will be where it is intended to be when lowered

into the hole, the last 1.00m. Double check all calculations and installation records to confirm all is correct. **Once the PVC Sheaths and the SS Extensometer Rods are cut to final length, there is no way to make a correction. The installer must be absolutely sure before cutting.**

4. Mark each PVC Sheath at the Zero Depth Location (Final Downhole Position), which should be located exactly 1.00m above the top of the aluminum Grout Collar. Label each PVC Sheath with the extensometer number, just below the mark.

5. Proceed to trim the PVC Sheaths off at the marks which are located at the Zero Depth Location (Final Downhole Position). The hack saw or cable saw may be used. Once the cut is made, remove the excess PVC Sheathing.

6. Using a file, create a slight chamfer around the outer edge, of the top of each PVC Sheath. These chamfers are required to assist the installation of the Extensometer Reading Head, which has Telescopic Sheaths with O-ring seals at the bottom, which must slide over the PVC Sheaths.

7. Trim the SS Extensometer Rods to be about 0.80m above the Zero Depth Location (Final Downhole Position) and the top of the trimmed PVC Sheaths. This length is interim and will be trimmed to final, after the Reading Head is fitted, and final measurements are made. A file should be used on the cut tops of the SS Extensometer Rods to remove any sharps edges.

8. Mark the top end of each cut-off SS Extensometer Rod with the Extensometer number for reference.

9. Remove the PVC Housing Top Cap and PVC Protective Housing from the Extensometer Reading Head, as shown in **Error! Reference source not found.**.

10. Place the Extensometer Head over the three SS Extensometer Rods and slide it down toward the tops of the three PVC Sheaths. Take care to align the three rods into the correct passage holes through the Reading Reference Head. (Noted that the Extensometer numbers are stamped onto the surface of the Reference Head beside each passage hole).

11. Must also ensure that the three PVC Sheaths for the SS Extensometer Rods are fully inserted into the Telescopic Sheaths at the bottom of the Extensometer Head. Noted that these Telescopic Sheaths have internal O-ring seals which may require some pressure to seat.

12. Mark the point at which the three SS Extensometer Rods emerge from the top of the Reading Reference Head.

13. Remove the Extensometer Reading Head. Cut each of the three SS Extensometer Rods approximately 5mm shorter than the mark which was made. These cuts should be made as perpendicular as possible to the extensometer rod and then, using a file, dressed up to be dead flat and perpendicular. Mark the number of each rod on the finished top surface so that it can be seen when the Extensometer Reading Head is installed.

14. Re-install the Extensometer Reading Head over the tops of the PVC Sheaths. Ensure that each SS Extensometer Rod is installed into the correct passage hole and matches the stamped number on the Reading Reference Head surface. Ensure that the top ends of the SS Extensometer Rods are sitting at the correct depth positions inside the passage holes. Ensure that the Telescopic Sheaths, located at the bottom of the Extensometer Reading Head, are correctly seated onto the Extensometer PCV Sheaths.

15. Lock-off the SS Extensometer Rods in the Extensometer Reading Head using the three set screw holes which are located adjacent to each of the three rod passage holes, around the bottom of the Extensometer Reading Head body.

16. Lift up the Extensometer Reading Head by hand and ensure that the three extensometer rods are securely attached to the Reading Head. Once satisfied with the extensometer rod attachment, remove the Vise Grip® pliers from the first anchor PVC Sheath, that has been resting on the Grout Collar and holding everything in place. Lower the Reading Head the remaining 1.00m into the hole and install it into

the top of the aluminum Grout Collar. Secure the Reading Head onto the Grout Collar with the three provided retaining bolts.

17. Using the Grease Fitting in the bottom of the Extensometer Reading Head, fill the grease trap until grease is seen exiting up through the extensometer rod holes.

18. Replace the PVC Protective Housing and Housing Top Cap to protect the Extensometer Reading Head.

19. Ready to proceed with the downhole grouting.

20. Noted that once the grouting is complete, and the grout is fully set, the three set screws, which are located adjacent to each of the three rod passage holes, around the bottom of the Extensometer Reading Head, need to be completely loosened to allow free movement of the extensometer rods.

4.3 GROUTING

1. Check the installed grout delivery tube to ensure that all is clear and functional. Might have to pump some water down, to confirm open condition and function.

2. Set-up the grout plant and prepare the required backfill grout volume, plus about 20 percent.

3. Proceed with grouting the borehole. Watch for grout return at the Large Vent Hole in the Grout Collar. Pumping can stop when good quality grout return is noted at the hole collar. Allow it to set undisturbed for a few minutes to see if the grout level holds in the hole. If the level is noted to be receding quickly, grouting will have to resume through the grout delivery line. If the volume loss is small, it can be topped up from the surface using the Large Vent Hole in the Grout Collar or the top vent line or hole.

4. Allow the grout to set for a minimum of 12 hours before doing any work on the work collar.

4.4 USING SPRING TYPE GROUT-IN ANCHORS

Spring Type Anchors are recommended for use in drillholes in soft rock or consolidated soil where a grouted-in re-bar anchor may not be able to provide a secure attachment to the drillhole wall. A Spring Type Anchor will provide a positive mechanical attachment for the extensometer end point to the drillhole wall and should ensure that anchor slippage will not occur. Refer to Figure 6 which illustrates the configuration of the three spring anchor arrangement, which when deployed, will contact the hole wall at six locations.

Backfill grouting must still be carried out when spring anchors are employed to ensure that the anchors are securely attached to the adjacent drillhole walls. In addition, the backfill grouting fixes the extensometer sheaths and rods in the hole so that lateral movements, which will result in reading inaccuracies, cannot occur. The backfill grouting also ensures that downhole caving or deterioration will not affect the extensometer long-term operation.

When carrying out an Extensometer installation with Spring Anchors, great care must be taken to ensure that the Pull Lines to the Trigger Pins of the Spring Anchors are not accidently pulled and activated during the installation. An unintended or accidental occurrence would immobilize the installation within the drillhole, at mid task. Movement in either direction would be impossible and there would be no corrective action available that would not severely damage the installation. For this reason, Spring Type Grout-In Anchors should only be used when there is no other option available.

General practice to avoid an accidental anchor deployment, is to leave a little slack in the Pull Lines near the Trigger Pins, and then tape the lines securely to the PVC Sheathing to avoid an accidental activation. When the entire extensometer installation is in position and the anchors are ready to be deployed, a very

strong and deliberate pull must be used. Small size braided steel cables may be a better choice for this task, than string or cord.

Noted that the Pull Lines should be well marked, as to which Anchor they belong to, so that the anchor deployment can be done in sequence from the hole bottom toward the top. This will help prevent unequal strain from occurring in the Extensometer Rods and PVC Sheaths between the anchor locations.

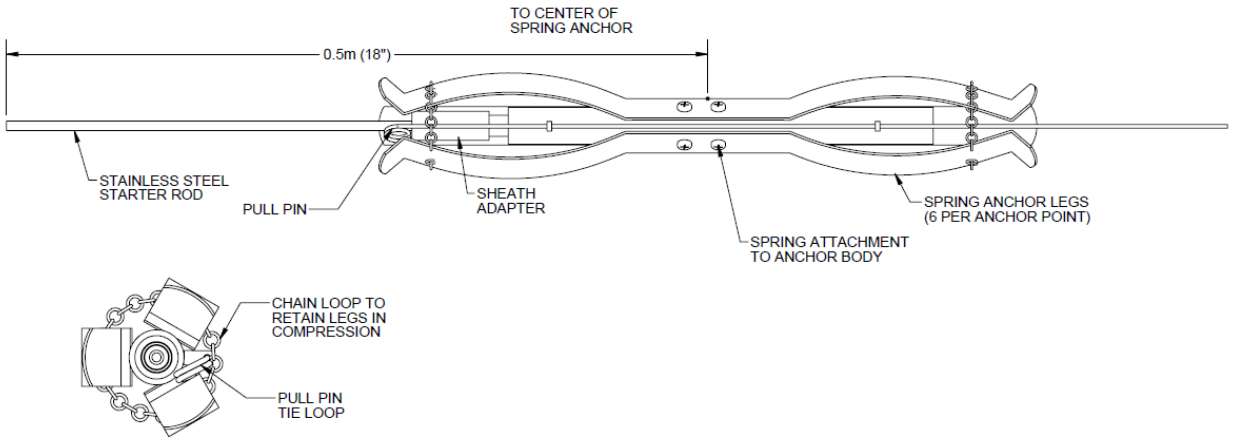

Figure 6: Spring Type Anchor General Arrangement

4.5 UP HOLE INSTALLATIONS

Up hole installations are much more difficult to carry out than downhole installations. When planning the installation of an extensometer instrument in an up hole, the following considerations need to be taken into account:

- As stated in Section 4.1, Item 2; The backfill grouting of upward oriented drillholes will be the opposite to downward hole. The grout delivery will occur at the hole collar, through a short tube, and the venting will occur by way of a long return line to the end of the hole.

- Due to the hole orientation, the hole collar can experience high pressures and loads during grouting. This is due to the static weight of the confined grout column, plus the applied pumping pressure. As a result, special attention is required when grouting up holes to ensure that the drillhole collar plug can effectively hold the expected loads. Collar plug failure could be catastrophic, with the plug materials and the entire grout volume being ejected. As a result, a plug failure could cause severe damage to the installed instrument and have safety implications to nearby workers.

- To prevent potential equipment damage and worker injury due the unexpected failure of a up-hole collar plug, it is highly recommended that the collar plug be reinforced with steel bars or plates anchored securely into the surround rock mass.

- The work is always being done overhead and against gravity. This means that all loads must be lifted into place and often need to be held in place, while being secured. The work will be slower and require more manpower.

- The work is usually being done from an elevated work platform or staging. This makes access difficult and time consuming. Special effort and extra manpower will be required to move equipment and materials into place.

- Noted that an extensometer installation into an up hole will require that the instrument be pushed up into the drillhole from the collar, against gravity. If the instrument is too long and/or if the hole walls are too

rough, the instrument might not be able to be pushed to the full design depth. The extensometer instrument may require modifications to reduce up hole friction. Another solution is to install a cable and pulley system at the hole top end, so that the extensometer instrument can be pulled into the drillhole from the hole collar. This can be a difficult operation.

- Up holes may have water flowing from their collars. This will make for a wet working environment which will further complicate the execution of the work.

5 LINEAR POTENTIOMETER ELECTRICAL CONNECTIONS

1 Remove the PVC Top Cap and PVC Protective Housing from the Extensometer Reading Head.

2 Make electrical connections from the Linear Potentiometers in the Extensometer Head to the Datalogger input board, as indicated on the Wiring Diagram which was provided with the instrumentation equipment. Refer to Figure 7 for an example of a Linear Potentiometer Extensometer Wiring Diagram.

3 Adjust the Linear Potentiometer stoke to be at approximately 10% of the full range in the direction opposite to where the movement is expected to occur.

4 To test the function of a Linear Potentiometer, simply apply a known excitation voltage (**10 VDC maximum - Do not apply a current**) take the output value reading and divide it by the applied excitation voltage. This will provide a decimal number, which can be multiplied by the total range of the Linear Potentiometer, and will then give the linear offset measurement for the instrument. A quick check with a measuring tape should confirm the validity of this number.

5 For example, if 5 VDC was applied to a 100mm stroke Linear Potentiometer, and a reading of 2.5 VDC was taken, then;

$$Measurement = \frac{Voltage\ \mathrm{Re}ad}{Excitation\ Voltage} * Potetiometer Range$$

$$Measurement = \frac{2.5V}{5.0V} * 100mm = .5 * 100mm = 50mm$$

6 Lock the Rod Adapter onto the Extensometer Rod by tightening the Locking Set Screws. This effectively connects the Linear Potentiometer onto the Extensometer Rod, so that all rod movements will be measured by the electrical instrument.

7 Record the Serial Number of the Reference Head, the Extensometer Rod Number, the Potentiometer Serial Number and the Potentiometer initial manual reading. Refer to the relevant Datalogger Operating Manual for instructions on how view the electronic reading for the same Extensometer Rod. Record this electronic reading and compare it to the manual readings. The two readings should agree closely. If a reading problem is discovered, it is important to resolve this issue before leaving the site.

8 Repeat steps 3-6 for all the Linear Potentiometer sensors.

9 Re-install the PVC Protective Housing and PVC Top Cap.

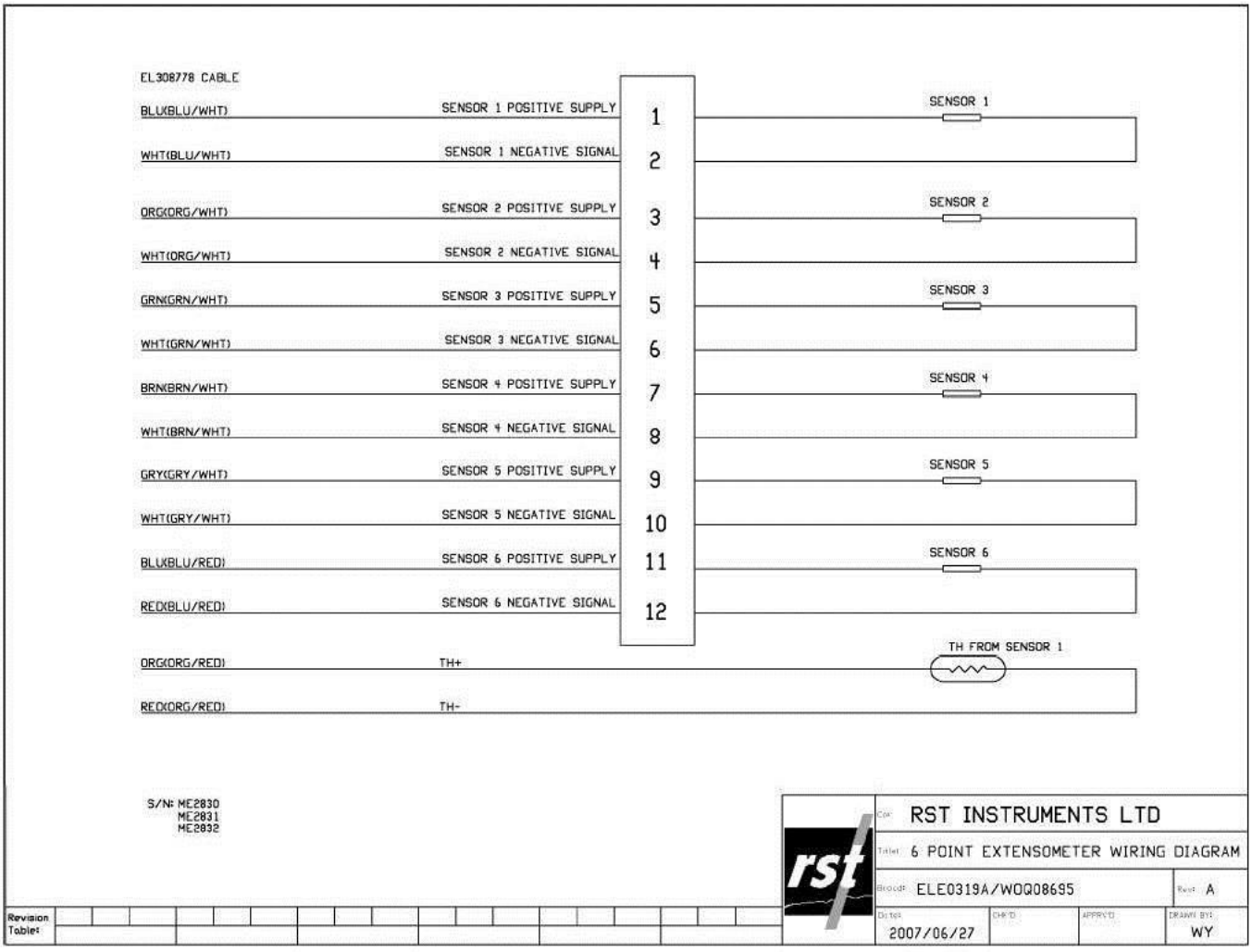

Figure 7: Linear Potentiometer Wiring Diagram -Typical Example

6 VIBRATING WIRE ELECTRICAL CONNECTIONS

After the installation, the measurements may be obtained by using an RST VW2106 Vibrating Wire Readout. Connect the wires as per the Figure 8 below.

If it is necessary to check the wire connections inside the Extensometer Reading Head, then it can be expected that the wires coming out of the Vibrating Wire sensor generally have the following color coding. Black and red wires connect to the Vibrating Wire coil and carry the frequency signal that is proportional to the vibrating wire strain. The green and white wires are connected to the thermistor. The shield is the bare wire.

Figure 8: VW Wiring Diagram

The VW Readout Unit will show displacement output data in Digits called B Units (Frequency Hz^2 / 1000). The Calibration Factor, found on the Calibration Sheet for that particular sensor, is typically used to convert the B Unit reading into engineering units (i.e. mm). Refer to **Error! Reference source not found.**sample calibration sheet.

The VW Rreadout Unit will output the temperature in °C. If an Ohmmeter is used directly on the green and white wires, the equation and/or table in Appendix A can be used to calculate/derive the temperature in °C.

Vibrating Wire Multi-Point Extensometer

Customer:	CLIENT	
Model:	EXMPBX001	
Serial Number:	**ME02869**	
Mfg Number	505642	
Sensor Number:	2	
Range:	50	mm
Date of Calibration:	18-Jan-13	
Master:	20162	
Temperature:	19.0	°C
Work Order Number:	Q012345	
Cable Length:	50	m
Cable Colour Code:	White/Orange (Coil)	Red/Orange (Thermistor)
Cable Type :	EL380012	
Thermistor Type:	3	Kohms

Applied Displacement	**$Hz^2 *10^{-3}$**		**Average**	**Indicated Displacement**	**Error Linear**	**Indicated Displacement**	**Error Polynomial**
mm	1 up	2 up	Digit	Linear (mm)	% FSO	Polynomial (mm)	% FSO
0.0	2558	2565	2562	-0.11	-0.22%	-0.02	-0.04%
10.0	3416	3410	3413	10.06	0.12%	10.04	0.08%
20.0	4255	4248	4252	20.07	0.14%	20.00	0.00%
30.0	5089	5085	5087	30.05	0.09%	29.98	-0.05%
40.0	5925	5918	5922	40.01	0.02%	39.99	-0.01%
50.0	6753	6751	6752	49.92	-0.15%	50.01	0.02%

CALIBRATION FACTORS

Linear Calibration Factor: **C.F.= 0.011940** mm/B unit

Polynomial Gage Factors : (mm) **A: 3.6801E-08** **B: 0.011597** **C: -29.969**

Displacement is calculated with the following equations:

Linear: $D(mm) = C.F. \times (Lc - Li)$

Polynomial: $D(mm) = A(Lc)^2+BLc+C$

Li, Lc = initial (at installation) and current readings

B units = B scale output of VW 2102, VW 2104, VW 2106 and DT 2011 readouts

B units = $Hz^2 / 1000$ ie: 1700Hz = 2890 B units

Users must establish site zero base readings for calculation purposes

Note: Readings are taken in frequency squared units.

Please refer to User Manuals if reading in period or frequency units

Figure 9: VW Displacement Transducer Calibration Sheet

7 TAKING A MANUAL READING WITH A DEPTH MICROMETER

1. Remove the Extensometer Protective Housing PVC Top Cap to expose the manual reading Reference Head. Figure 10.

2. Record the Serial Number marked on the top of the Reference Head which will identify the extensometer instrument.

3. Identify the anchor numbers marked beside each Extensometer Passage Hole coming through the top of the Reference Head.

4. Proceed with the manual readings starting with Anchor #1, and proceeding to Anchors #2 and #3.

5. To take a manual reading, set the Depth Micrometer directly over each Extensometer Passage Hole, with the micrometer rod extending down into the Passage Hole. Noted that the Depth Micrometer only has a certain amount of travel available in the mechanism. Therefore, a series of different length extension rods are used to span the full range of potential measurements. The depth measurement will therefore be the depth shown on the Depth Micrometer plus the length of the installed extension rod.

6. With the correct extension rod installed, the top ratchet knob on the Depth Micrometer is used to lower the rod into the Passage Hole until it touches the top of the extensometer rod to be measured. The reading is taken when the ratchet knob clicks indicating that the Depth Micrometer rod is in contact with the top of the extensometer rod.

7. For a correct depth reading, must ensure that the Depth Micrometer base is in firm flat contact with the Reference Head surface.

8. Replace the PVC Top Cap when all reading are completed at the Extensometer.

9. Repeat Steps 1 to 8 for each Extensometer installation.

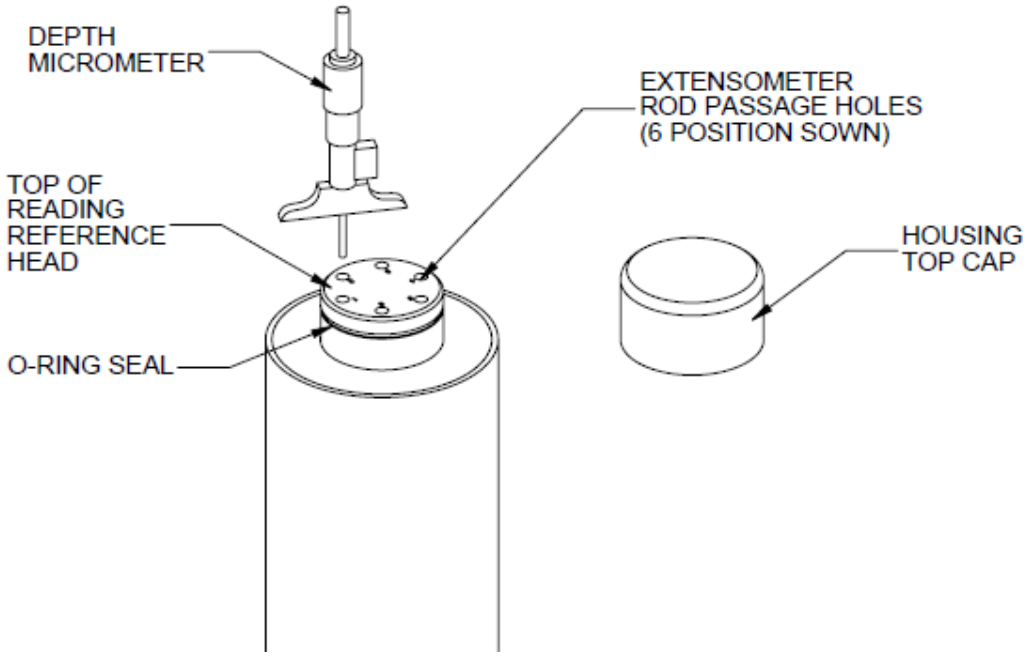

Figure 10: Taking an Extensometer Reading with a Depth Micrometer

8 APPENDIX A

The following equation may be used to convert the measured thermistor resistance R (Ω) into temperature T (°C).

$$T = \frac{1}{1.4051*10^{-3} + 2.369*10^{-4}*\ln(R) + 1.019*10^{-7}*(\ln(R))^3} - 273.2$$

Alternatively, the values may be looked up directly in Table 1.

Table 1: Thermistor Resistance (Ω) versus Temperature (°C)

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	141.11	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
77.99K	-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	-35	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	282.4	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	56.92	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.	53	250.9	93	83.6	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
								55.6	150