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Tunnel Profile Monitoring System Installation Manual

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1 INTRODUCTION

The Tunnel Profile Monitoring System (TPMS) is used to monitor changes to a planer cross section of a tunnel. The TPMS consists of an array of low profile instruments that are mounted to anchors, which are installed in the tunnel lining. As the tunnel lining shifts, the anchors will shift accordingly and the instruments will measure the relative change and provide a new cross sectional profile. Each instrument consists of a tilt sensor and a displacement sensor, which reports data to a data logger. The data is then processed by GeoViewer software and will display the tunnel profile in real time.

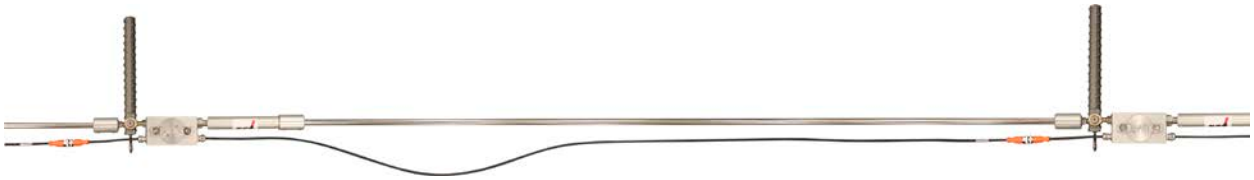

FIGURE 1-1 TUNNEL PROFILE MONITORING SYSTEM

The TPMS is commonly installed in tunnel locations where integrity may be in question. Concerns may arise due to nearby construction or a predisposition to naturally occurring phenomena. The TPMS is robust and practical, enabling it to be installed during or post construction of the tunnel. It is also tolerant of electromagnetic fields, temperature changes, and vibrations.

There are two configurations of a TPMS: Closed Loop and Open Ended. An Open Ended system monitors the circumference of the tunnel but is open at either end where the floor meets the walls. An Open Ended system will initially have to be surveyed and may need subsequent surveys unless one of the ends can be established as a stable reference point. The Closed Loop system completely traverses the circumference of the tunnel and needs an initial survey to provide a reference. Refer to Figure 1-2 for cross section diagrams of the two tunnel profile monitoring system configurations. Associated Products

Describe separate RST or third-party products that may be used in combination with the subject of this manual. This could be software, or a related mechanical or electrical device.

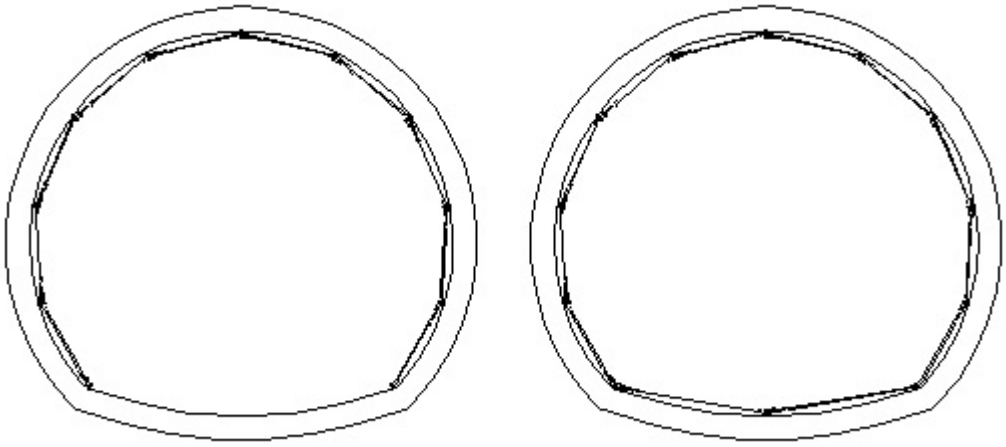

FIGURE 1-2 OPEN ENDED AND CLOSED LOOP TUNNEL PROFILE MONITORING SYSTEMS

2 COMPONENTS

Ensure that all components of the TPMS are accounted for and are functioning correctly upon receiving the instrumentation. Verify that damage has not occurred during shipping. Store the instruments in a dry and secure area prior to installation. Refer to Figure 2-1 for a diagram of the TPMS components.

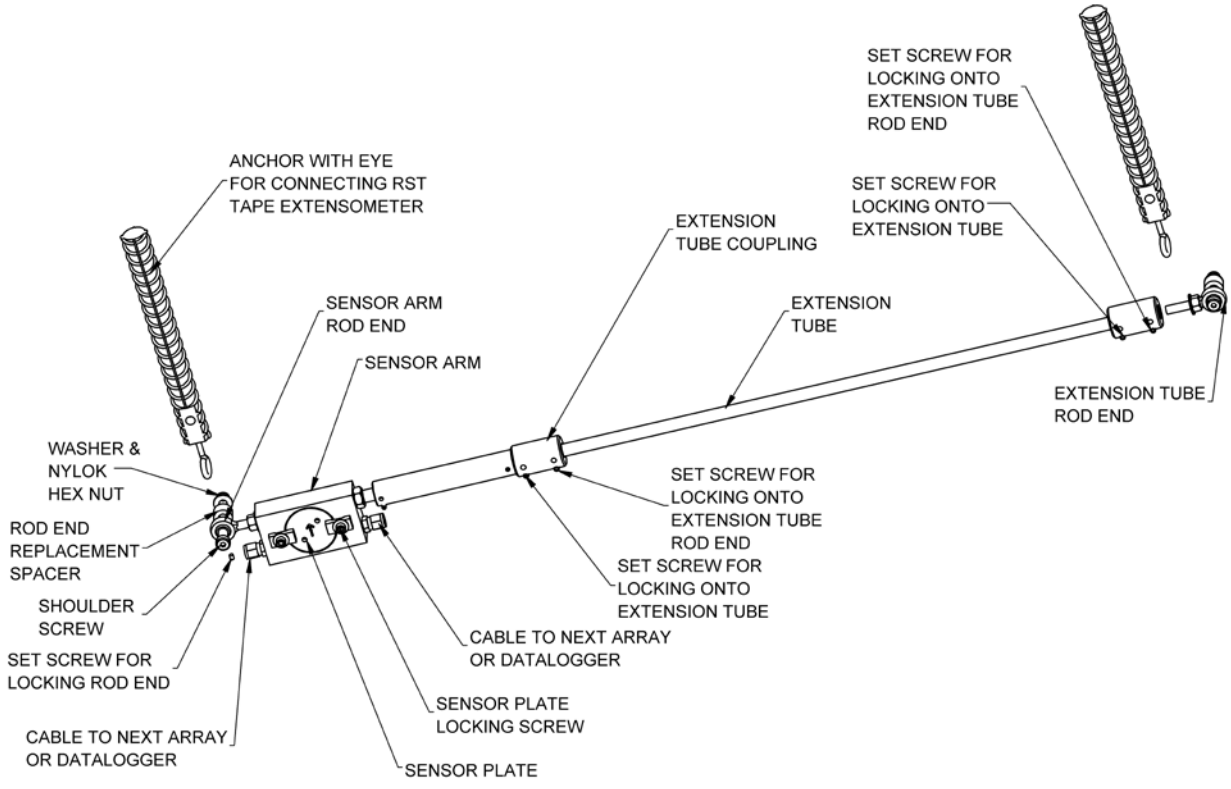

FIGURE 2-1 TUNNEL PROFILE MONITORING SYSTEM COMPONENTS

- Sensor Arms (quantity of the sensor arms will be site specific);
- Anchors (quantity of the anchors will be equal to the number of sensor arms plus 1);
- Extension Tubes (length is site specific and will vary according to the size of the tunnel);
- Extension Tube Couplings (equal to double the number of sensor arms);
- Extension Tube Rod Ends (equal to the number of sensor arms);
- Rod End Replacement Spacers (2);
- Data Loggers (quantity dependent on the number of instrumentation arrays);
- GeoViewer software and manual;
- Allen Keys in the sizes of: $^{1}/_{8}$", $^{3}/_{16}$", $^{3}/_{32}$", and $^{5}/_{32}$";
- Wrenches in the sizes of: $^{1}/_{2}$" and $^{9}/_{16}$";
- Installation kit (consisting of the installation tool and threaded rod with attached hardware).

2.1 INSTALLATION TOOLS AND MATERIALS

The following is a list of tools and supplies required to install a TPMS.

- ø½" (12 mm) Tube Bender;
- ø½" (12 mm) Tube Cutter;
- ø½" (12 mm) Tube Deburring Tools (for O.D. and I.D.);
- Tube Gripper Pad;
- Concrete Fasteners (not a stud - such as a M10 HKD Series Hilti Anchor) or similar product;
  - Quantity to be equal to the number of Sensor Arms.
- Drill for drilling the concrete fastener holes and 30 mm anchor holes;
- Quick Set Rock Bolt Resin Pack to grout the anchors in place;
- Tape Measure;
- Level.

2.2 INSTALLATION ORIENTATION STANDARD

NOTE: A LOCATION FOR THE INSTALLATION OF THE SENSOR ARRAY MUST BE PREDETERMINED. A CROSS SECTION PLANE PERPENDICULAR TO THE LONGITUDINAL AXIS OF THE TUNNEL MUST BE SURVEYED AND CLEARLY

MARKED ON THE CIRCUMFERENCE OF THE TUNNEL LINING. THIS PROVIDES A REFERENCE FOR THE INSTALLATION OF THE ANCHORS.

It is necessary to establish a standard computer screen rendering of the tunnel cross section with respect to the real world, to prevent any confusion when viewing the data. The GeoViewer software assigns sensor designation starting from the bottom left continuing clockwise, around the circumference, and finishing at the bottom right. The direction of view must be determined and recorded (i.e., looking north, south, east, west, or any combination thereof) to maintain the same orientation when interpreting the data. This standard should be followed for each instrument array.

2.3 ANCHOR INSTALLATION

The following steps outline the procedure to install the anchor.

NOTE: IF ANCHOR HOLES HAVE TO BE RELOCATED DUE TO EXTENUATING CIRCUMSTANCES THEN IT CRUCIAL THAT RST INSTRUMENTS BE NOTIFIED IMMEDIATELY.

1. Survey and drill 30 mm anchor holes as outlined in Figure 3-1 (the anchor holes should be drilled perpendicular to the tunnel lining and lie in the same cross sectional plane).

2. Install M10 concrete fasteners, on the scribed straight line, at the intervals shown in Figure 2-2 and outlined in Table 3-1. This allows the installation tool to use only one bolt anchor hole for two anchors because the installation tool can be spun around 180 degrees and then used to install the other anchor (e.g., Bolt Anchor B can be used to install Surveyed Anchors 2 and 3).

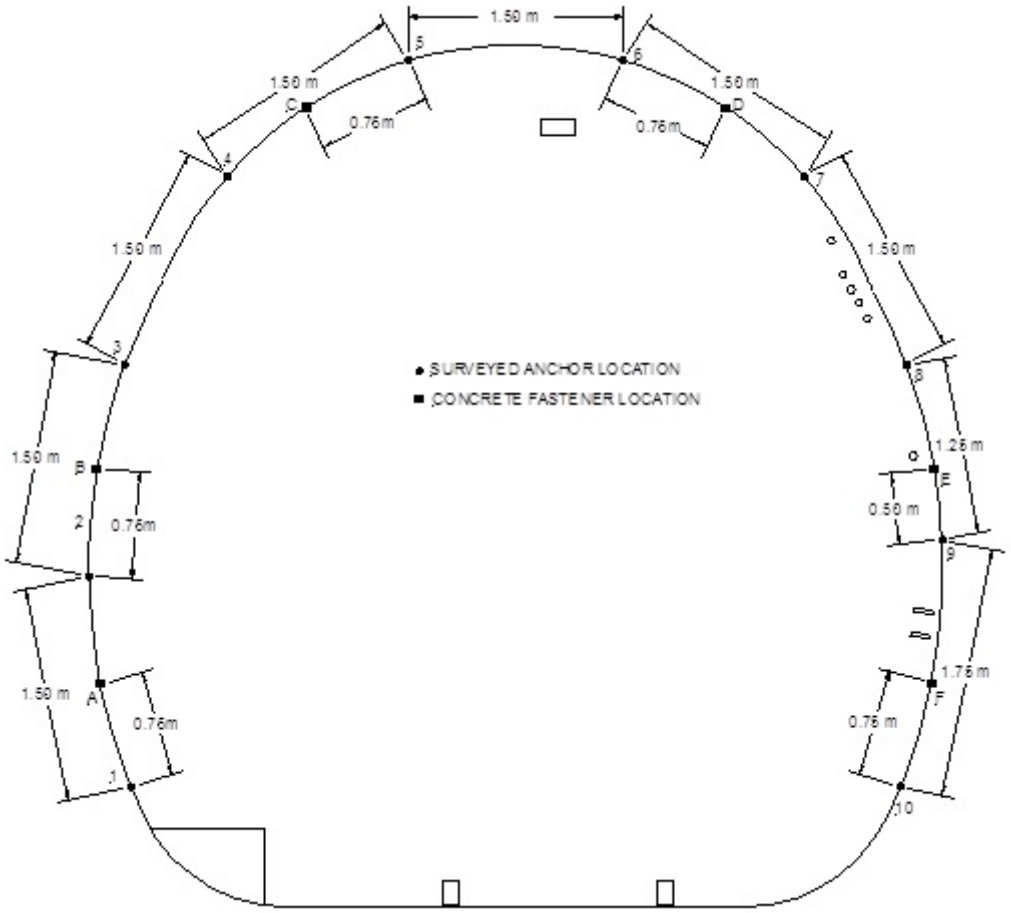

FIGURE 2-2 ANCHOR AND CONCRETE FASTENER HOLE LAYOUT

NOTE: THE DISTANCES BETWEEN THE ANCHOR HOLES MAY DIFFER PER TUNNEL. ANCHOR LENGTHS ARE BUILT TO SUIT.

TABLE 2-1 ANCHOR CONFIGURATION

Concrete Fastener	Surveyed Anchor
A	1
B	2, 3
C	4, 5
D	6, 7
E	8, 9
F	10

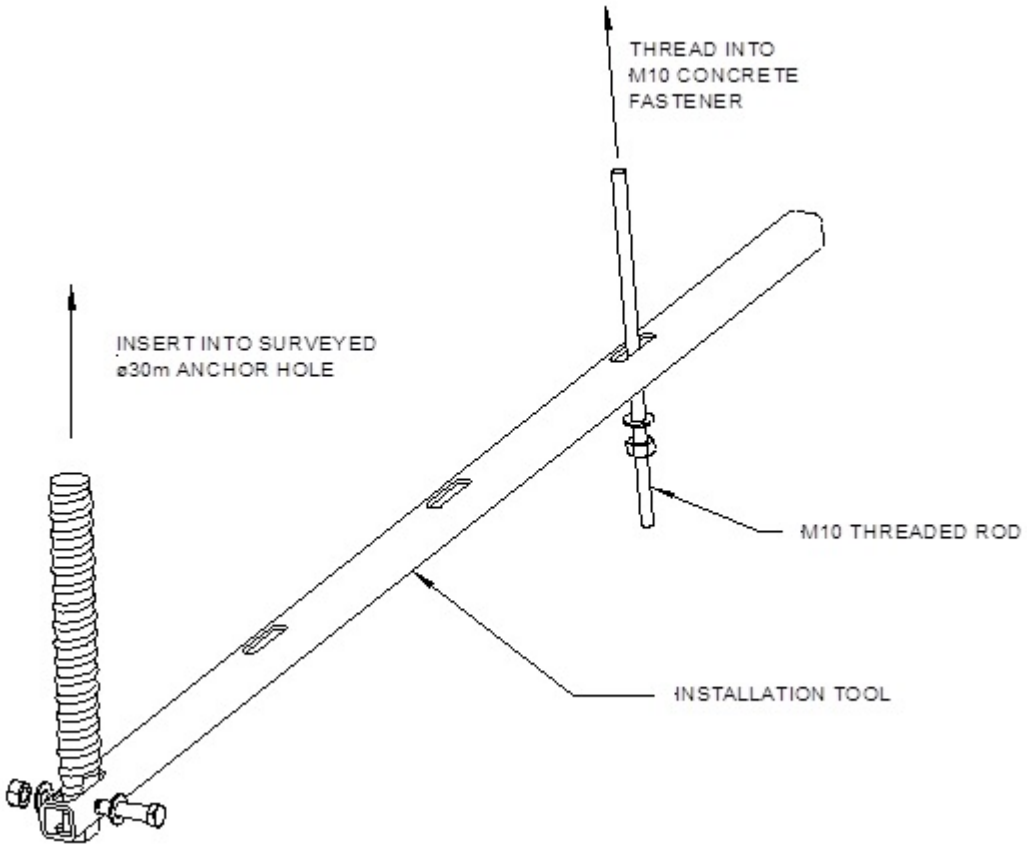

FIGURE 2-3 SURVEYED ANCHOR SECURED IN PLACE USING THE INSTALLATION TOOL

3 Bolt the installation tool to an anchor, and slide the supplied threaded rod, with a washer and nut, into the appropriate slot. The slot will be determined by inserting the anchor into a surveyed anchor hole and then noticing which slot of the installation tool is in-line with the installed concrete fastener.

4 Insert the anchor into its hole and then thread the Ready Rod into the concrete fastener. 5 or 6 turns should be sufficient. Tighten the hex nut on the Ready Rod until the end of the milled flat on the anchor is even with the tunnel lining. Ensure the free end of the installation tool lies on the arc marked on the tunnel lining. The anchor and installation tool are now pre-set for grouting.

5 Remove the anchor from the hole by reversing the hex nut a few turns and removing the Ready Rod.

6 Load the anchor hole with Quick Setting Rock Bolt Resin.

7 Insert the anchor into the loaded hole and thread the Ready Rod into the concrete fastener. Wipe off any resin spill over.

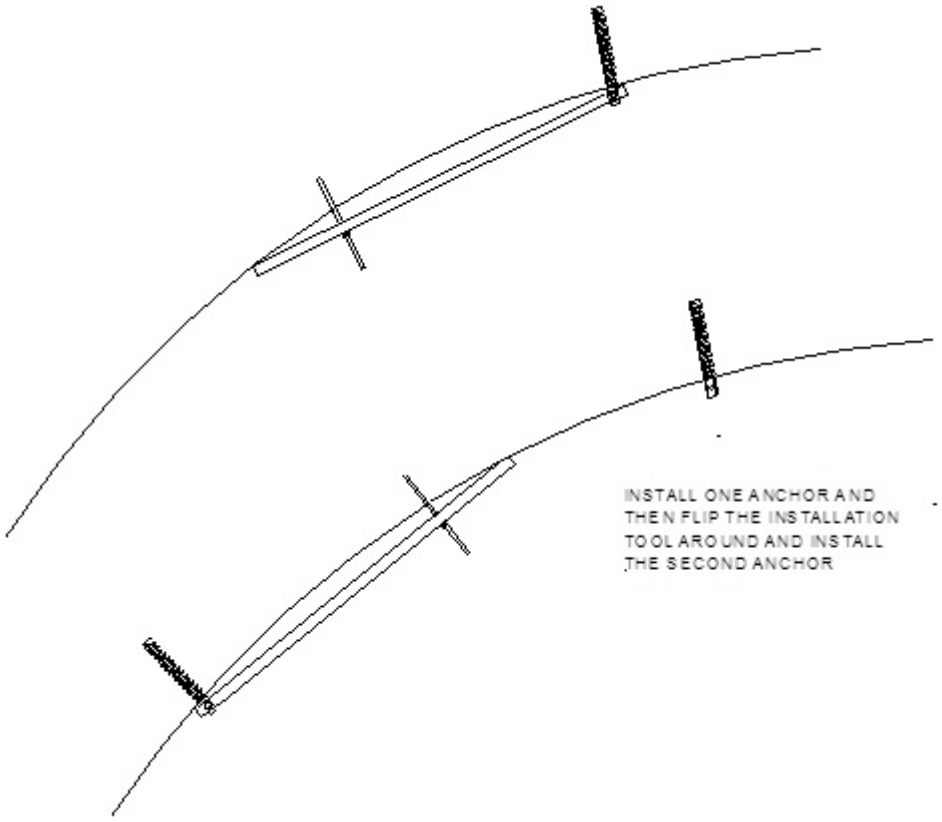

FIGURE 2-4 INSTALL TWO ANCHORS WITH ONE CONCRETE FASTENER

8 Ensure the anchor is centered in the hole and then tighten the hex nut until the anchors' milled flat is flush with the tunnel lining. Remove any excess resin.

9 Allow the resin to set and remove the installation tool from the surveyed anchor.

10 Repeat steps 3-9 until all of the anchors are installed.

2.4 INSTALL INSTRUMENTATION ARRAY

1 Loosen the locking set screw located in the outer face of the rod end of the sensor arm.

2 Locate the sensor to be installed and fasten it to the installed surveyed anchor with the supplied shoulder bolt, rod end replacement spacer, and Nylok hex nut.

3 Fasten a tube extension rod end to the next anchor with the supplied shoulder bolt, rod end replacement spacer, and Nylok hex nut. Ensure that both rod ends are mated to the same side of their respective surveyed anchor.

4 Loosen the locking set screw located at the outer face of the rod end.

5 Rotate the sensor arm and extension tube rod end so they are pointing towards each other and then measure the distance between them.

6 Trim a piece of extension tube to the length determined in step 5 and remove any burrs.

- Should bending the tube be required to avoid in-place services in the tunnel, bend the tube first using a tube bender, then trim the ends using a tube cutter and remove any burrs. At least 200 mm of each end should be kept straight post bending and trimming.

7 Slide an extension tube coupling over each end of the extension tube.

8 Place the piece of extension tube in between the sensor arm and extension tube rod end and then slide the extension tube couplings onto the sensor arm and extension tube rod end.

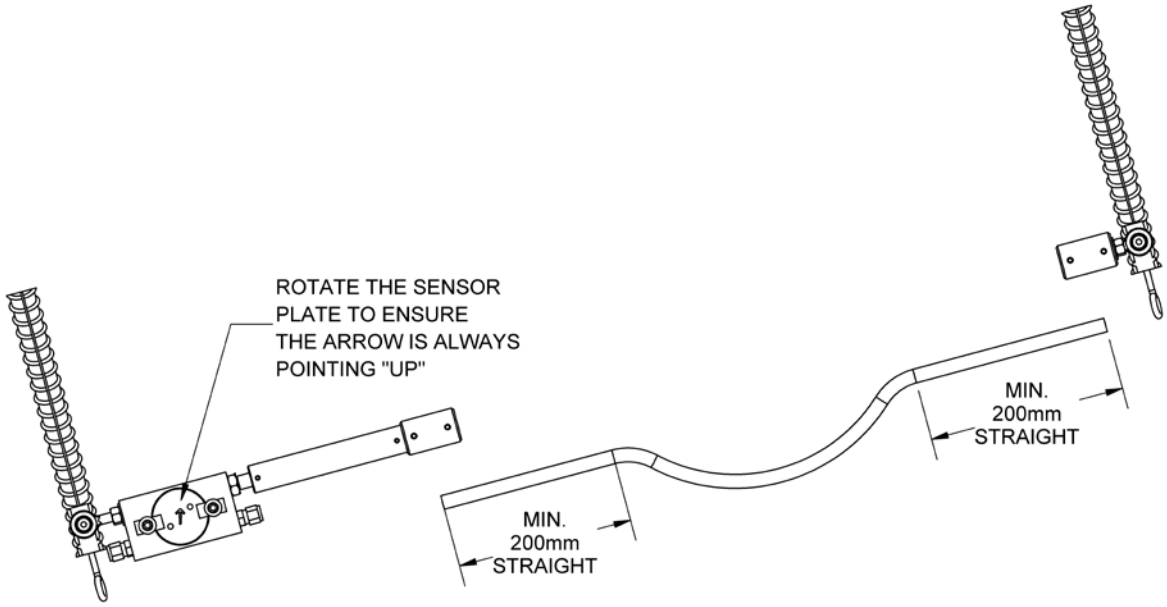

FIGURE 2-5 TUBE EXTENSION INSTALLATION

9 Lock the extension tube couplings onto the extension tube and the extension tube rod end by tightening the set crews with a $^{1}/_{8}$" Allen Key. Do not secure onto the sensor arm.

10 Use a level to ensure that the sensor arm face is vertical and tighten the set screws in the remaining extension tube coupling using a $^{1}/_{8}$" Allen Key.

11 Tighten the locking set screws in both of the rod ends using a $^{3}/_{32}$" Allen Key. Ensure the sensor arm face is still vertical.

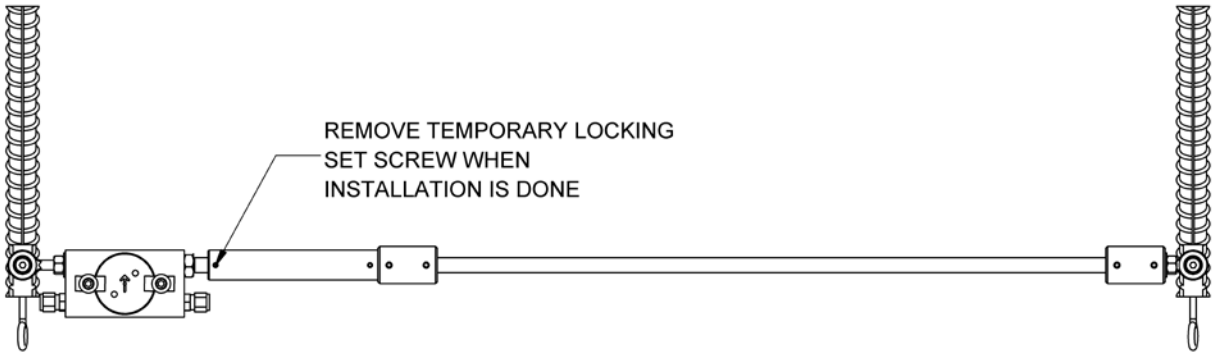

FIGURE 2-6 REMOVE LOCKING SET SCREW

12 Remove the nylon locking set screw to unlock the displacement sensor. Refer to Figure 2-6.

13 Repeat steps 1-12 for the next sensor arm. Replace the rod end replacement spacer with the rod end of the next Sensor Arm. Continue until the instrumentation array is complete.

NOTE: THE SPACER CAN BE USED AS THE SPACER FOR THE NEXT EXTENSION TUBE ROD END AS THE NEXT SENSOR ARM REPLACES THE ROD END REPLACEMENT SPACER. THE ROAMING ROD END REPLACEMENT SPACER WILL EVENTUALLY BE INSTALLED AS THE SPACER FOR THE LAST EXTENSION TUBE ROD END WHERE IT WILL REMAIN.

14 Run the sensor cables to the side of the tunnel where the data logger will be installed. Use the sensors to hold the cables in place and out of the way by incrementally taping the cables to the sensor over the length of the sensor array. Refer to Figure 2-7.

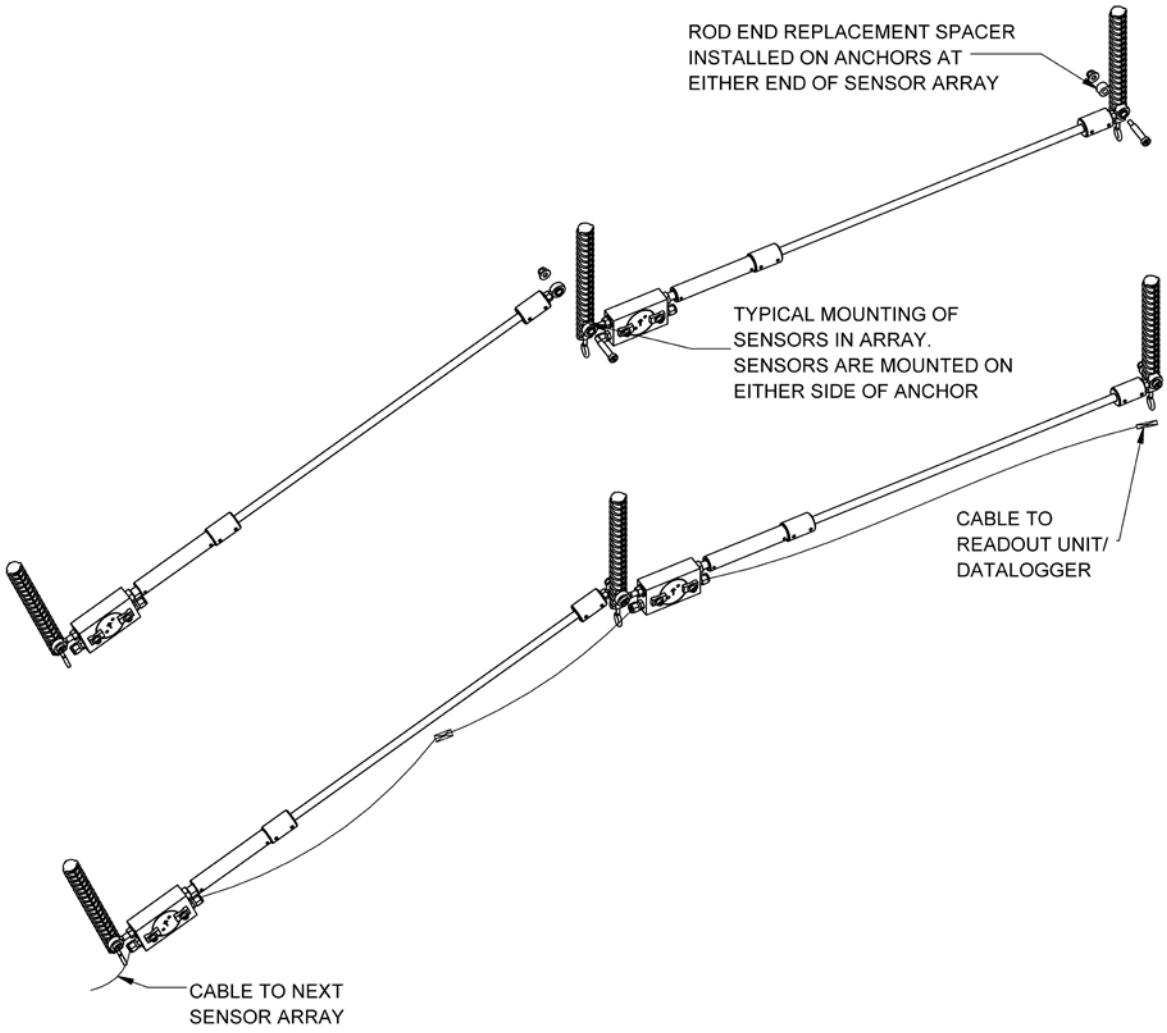

FIGURE 2-7 SENSOR ARRANGEMENT IN SENSOR ARRAY

2.5 DATA LOGGER INSTALLATION

The data loggers should be installed at an easily accessible location and elevation. The top of the data logger should be at eye level. Refer to the wiring diagram in Section 4 for details on wiring the instrumentation array to the data logger.

2.6 INITIALIZE THE INSTRUMENTATION ARRAY

1. Connect a laptop computer to the data logger and open LoggerNet to download the data to the Laptop. Refer to the LoggerNet operating manual for operating instructions.

2. Loosen the sensor plate locking screw of a sensor arm. Use the GeoViewer software to zero the sensor by monitoring the output while rotating the tilt sensor

plate using a flat head screwdriver. When the ↑ on the tilt sensor plate is vertical, the output should be 0 (zero). The units will be the sin of the angle.

3 Record the Tilt Sensor Designation and its corresponding output.

4 Record the Potentiometer Designation and its corresponding output.

5 Repeat step 2-4 for the remaining sensors.

2.7 ANCHOR COORDINATES

It is necessary to acquire the initial position of the anchors as the TPMS will only show relative movement. The initial position can be achieved by 2 methods as listed below.

1 Obtain an optical survey of all the anchors in the TPMS array.

2 Measure the distance between each anchor. The distances “x” and “y” must also be obtained for every anchor relative to the first anchor measured to achieve the Anchor coordinates. Anchor Position “1” is (0,0). Refer to Figure 2-8.

Use the COS Law $\{c^2=a^2 + b^2 – ab(COS\ \alpha)\}$ to calculate α. Use the formula $\{(x+b)= c(cos\ \alpha)\}$ to obtain the “x” coordinate. Use the formula $\{c^2=y^2 + (b+x)^{2}\}$ to obtain the “y” coordinate.

It is highly recommended that baseline measurements be recorded using a RST Tape Extensometer following the same procedure as illustrated above and in Figure 2-8. Any movement occurrence may be verified by taking additional readings with the RST Tape Extensometer and compared to the baseline readings.

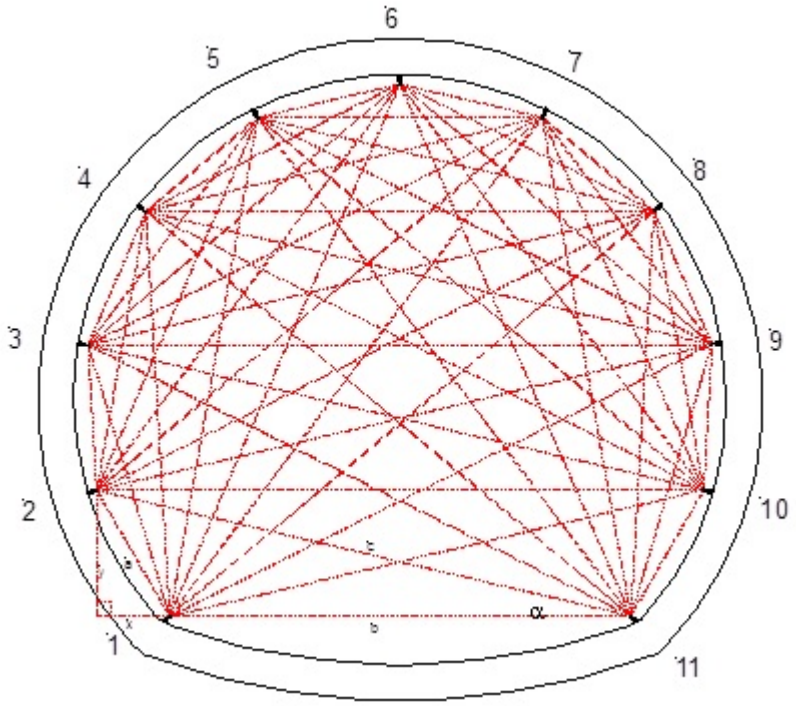

FIGURE 2-8 ACQUIRING ANCHOR COORDINATES

3 WIRING DIAGRAM

TABLE 3-1 WIRING DIAGRAM

Colour	Function	Pin
Brown	Voltage +	1
White	Ground	2
Blue	RS485 A +	3
Black	RS485 B -	4

4 SERVICE AND REPAIR

The product contains no user-serviceable parts. Contact RST for product service or repair not covered in this manual.

Appendix A CALIBRATION RECORD

Calibration Record

200 - 2050 Hartley Ave., Coquitlam, British Columbia, Canada V3K 6W5
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e-mail: info@rstinstruments.com • Website: www.rstinstruments.com

MEMS Tunnel Profile Monitoring System

Customer:	XYZ
Order Number:	12345
Model Number:	ICTPMS015
Serial Number:	ET1234
Calibration Date:	01-Dec-17
Bay Length:	1.5 m
Cable Length:	1.5 m
Cable Type:	M12

Wiring:

Colour	Function	Pin
Brown	Voltage +	1
White	Ground	2
Blue	RS485 A +	3
Black	RS485 B -	4

References:

Inclinometer Frame	RST-07
Gauge Block Set	50073

Referenced to National Standards Annually

Tilt Sensor

Applied Degrees ⊖	Applied Sin ⊖	Displayed Sin ⊖	Error Sin ⊖
5	0.08716	0.08715	0.00000
4	0.06976	0.06973	0.00002
3	0.05234	0.05233	0.00000
2	0.03490	0.03491	-0.00001
1	0.01745	0.01745	0.00000
0	0.00000	0.00000	0.00000
-1	-0.01745	-0.01744	-0.00001
-2	-0.03490	-0.03490	0.00000
-3	-0.05234	-0.05234	0.00000
-4	-0.06976	-0.06975	-0.00001
-5	-0.08716	-0.08714	-0.00001

For A axis : Positive angle = Right side tilts down

Displacment Sensor

Applied Displacement (mm)	Output Displacement (mm)
10.00	10.00

Calibrated By: W. Mok

Document Number: ICL0047C