Precision Liquid Settlement Array Manual

Document Number: SSM0034B

Release Date: 02 March 2020

RST INSTRUMENTS LTD.
11545 Kingston St.,
Maple Ridge, BC
CANADA V2X 0Z5

SALES + SERVICE + MANUFACTURING:
604 540 1100 | info@rstinstruments.com
TOLL FREE (USA & Canada) | 1-800-665-5599

www.rstinstruments.com

REVISION HISTORY

Rev.	Revision History	Date	Prepared By	Approved By
A	Initial release.	2018-Nov-20	MP	TW
B	Added revision history, added information about measuring up/down deflection of ceilings in underground structures, restructured introduction, added “Scope” section.	2020-Mar-02	MP	JT, AV

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The Precision Liquid Settlement Array (Figure 1-1) provides reliable, real-time monitoring of relative settlement and heave which may occur at excavation sites, tunnelling projects, underground openings and related applications. It is ideal for monitoring structures near underfills, preloads, embankments, and grouting. It can also be used to measure vertical deflection of ceilings on underground structures.

The system is comprised of a sensor connected to liquid pressure and air compensation tubes and an electrical cable. Three settlement-measuring ranges (0.6, 1.8, and 3 m) are available for ordering and are chosen based on site conditions and anticipated settlement by the site engineer.

Settlement is measured by comparing the changes in liquid pressure between the sensor at the zone of interest and to the reference sensor. All measured data is received digitally and can be temperature compensated.

The Precision Liquid Settlement Array can be monitored by a wired connection to a computer or wirelessly from a remote location. Users have real-time access through an internet connection on a computer and can also receive updates via email at chosen intervals.

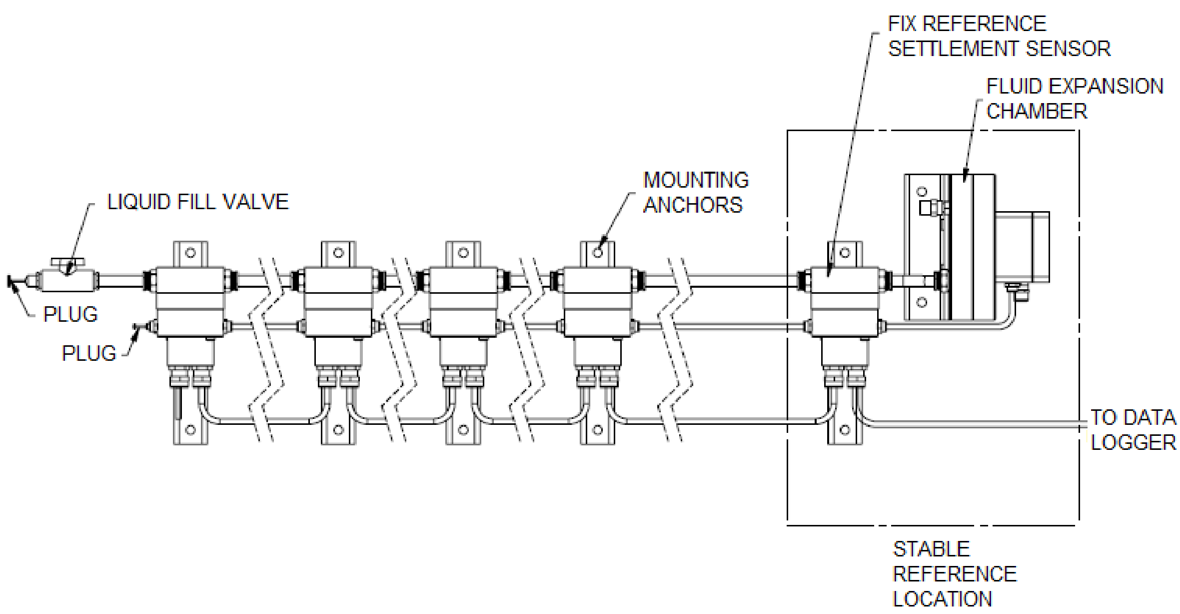


FIGURE 1-1 PRECISION LIQUID SETTLEMENT SYSTEM

2 SCOPE

The Precision Liquid Settlement Array system is designed for real-time monitoring of differential vertical deflection between multiple monitoring points. Monitoring applications include: building structures (above and underground), bridges and tunnels, pipelines and tanks, power lines, hydraulic facilities and structures, as well as railway tracks.

3 PRACTICAL THEORY

The Precision Liquid Settlement Array is a liquid-levelling system. This type of system consists of a series of settlement sensors installed at different measurement locations that are hydraulically connected to a reference sensor and reservoir. All settlement data are obtained by subtracting the values of this reference sensor from the data collected by the settlement sensors.

The system records data in mm H_2O. To ensure accurate settlement readings, a network of air tubes is used to equalize the air pressure at the location of each sensor.

Since temperature affects liquid density, changes in ambient temperature can influence the readings of the settlement. To minimize the effect of temperature changes, temperature is measured at each sensor location together with pressure. The fluid level change measurements are then compensated for temperature changes.

4 SAFETY

Normal safety precautions should be followed and proper personal protective equipment (PPE) should be worn when working in the field with this equipment, including safety glasses and nitrile gloves.

The system uses a 50%-by-volume solution of de-aired water and ethylene glycol with a small amount of a disinfectant added to inhibit biological activity (Figure 4-1). Take care to ensure there is no direct contact with skin, eyes or mouth. Refer to the MSDS for further information.

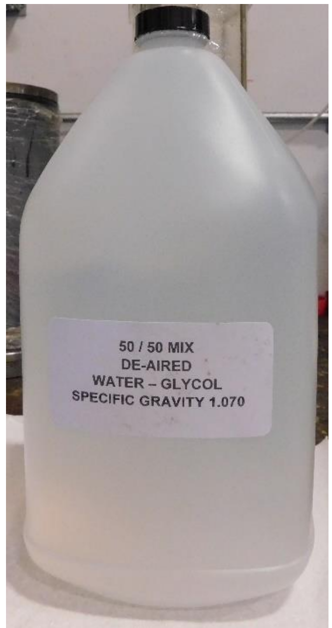


FIGURE 4-1 50% BY VOLUME GLYCOL AND WATER SOLUTION

50/50 Mix De-Aired Water-Glycol Mix

WARNING

May cause eye irritation.
May cause skin irritation.
Corrosive to metals.

Precautions:
Wear protective gloves.
Wash hands thoroughly after handling.
Do not eat, drink or smoke when using this product.

Keep container tightly closed in a dry, well-ventilated area.
Dispose of waste in accordance with local regulations.

IF IN EYES: Rinse eyes with running water immediately for at least 15 minutes. If irritation persists, get medical advice.
IF ON SKIN: Wash with plenty of water. If skin irritation persists, get medical advice.
IF SWALLOWED: Immediately contact POISON CENTRE, emergency treatment centre or physician. Aspiration hazard – DO NOT induce vomiting.

Refer to the Material Safety Data Sheet for further information.

RST Instruments, 11545 Kingston St., Maple Ridge, BC V2X 0Z5

5 INSTALLATION

5.1 INSTALLATION TOOLS AND COMPONENTS

Ensure all tools and components required for the installation are present prior to installing the Precision Liquid Settlement Array.

Tools and equipment required for a typical installation include:

- Precision Liquid Settlement sensors, reference sensor, and fluid expansion chamber.
- ½” push-in ball valve (referred to in this document as the “liquid fill valve”).
- Campbell Logger or RST DT2485 data logger.
- EL380004 digital cable.
- ½" O.D. HDPE liquid tube.
- ¼" O.D. Nylon 11 air tubing.
- Anchor kit with 25 mm M8 anchors. Hilti Flush anchor HKD M8x25 or equivalent.
- Anchor setting tool (carbon steel).
- Hex wrench.
- Two 20 mm open wrenches or small crescent wrenches.
- Level.
- Hammer drill and 10mm hammer drill bit.
- 50%-by-volume de-aired water and ethylene glycol solution.
- Additional length of ½" O.D. HDPE liquid tube for siphon.

5.2 INSTALLATION PREPARATION

Determine the installation location for the Precision Liquid Settlement System. The location must allow sensor connections after the system has been mounted.

CAUTION: AVOID CHOOSING AN INSTALLATION LOCATION IN AREAS OF RAPID OR EXTREME CHANGES IN TEMPERATURE, SUCH AS IN DIRECT SUNLIGHT OR NEAR HEATING OR COOLING EQUIPMENT. THE USE OF SUN SHADES AND/OR EXTERNAL INSULATION IS RECOMMENDED FOR EXPOSED UNITS. TUBING SHOULD NOT BE INSTALLED IN AREAS WHERE TEMPERATURES DROP BELOW -10°C.

General guidelines for installation planning include:

- Securely attach the mounting angles with the supplied hardware to a rigid structure that is free of vibration. The brackets are designed to be bolted to a wall or a pedestal and should be firmly attached with either anchor bolts or epoxy-grouted studs.
- Minimize the height difference between the sensors. Remove unnecessary liquid tubing to minimize the total height of the liquid column.
- The total span of the entire system MUST be less than 150 m. The spacing between sensors does not matter.
- The final sensor in the array (i.e. farthest from the reference sensor) should also be the lowest.
- Install the reference sensor in a location where little to no settlement is expected.
- Connect the precision liquid sensor electronics one by one, or section by section. Run the accompanying software after each connection to ensure the connected sensors are functioning properly. This step-by-step approach will facilitate troubleshooting.
- The installation of the sensors must be well within the measuring range (0.6, 1.8, and 3.0 m, as defined when placing an order) of the system to allow for precise settlement measuring without the risk of overloading the sensors.
- Use a siphon to fill the system.

5.3 INSTALLATION PROCEDURE

5.3.1 Mounting the Precision Liquid Sensors

Figure 5-1 illustrates a Precision Liquid Sensor and important components.

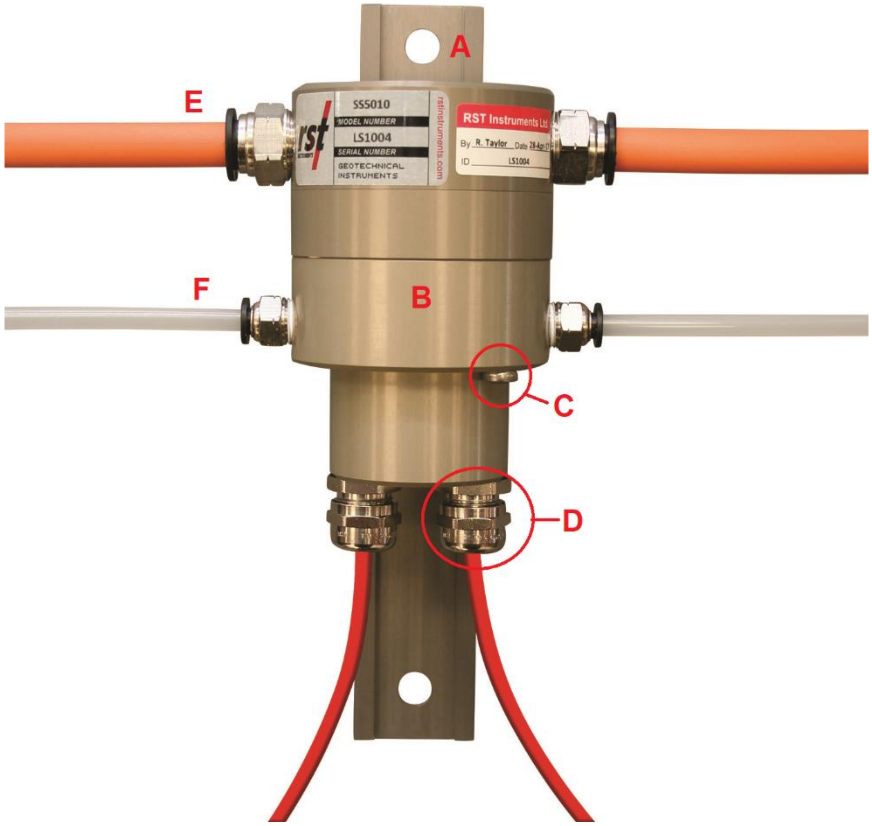


FIGURE 5-1 PRECISION LIQUID SENSOR

> **NOTE: ALWAYS MOUNT THE SENSORS ON A FLAT, VERTICAL SURFACE.**

1. On a flat, vertical surface, mark the locations of where the precision liquid sensors will be mounted. Set the initial level of all points to be the same +/- 3 mm.

2. Place the 25 mm M8 concrete anchors for the sensors (Figure 5-1, A). Sensors should be vertical +/- 1.5 degrees.

3. Mount the sensors onto the anchors and tighten the nuts.

4. On the lower portion of the sensor enclosure (Figure 5-1, B), loosen all screws (Figure 5-1, C).

5. Carefully lower the bottom of the sensor enclosure. This will expose the terminal.

6. Slide the cable through the cable gland (Figure 5-1, D) and insert the wires into the terminal according to Table 5-1.

TABLE 5-1 PIN LAYOUT FOR TERMINAL

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

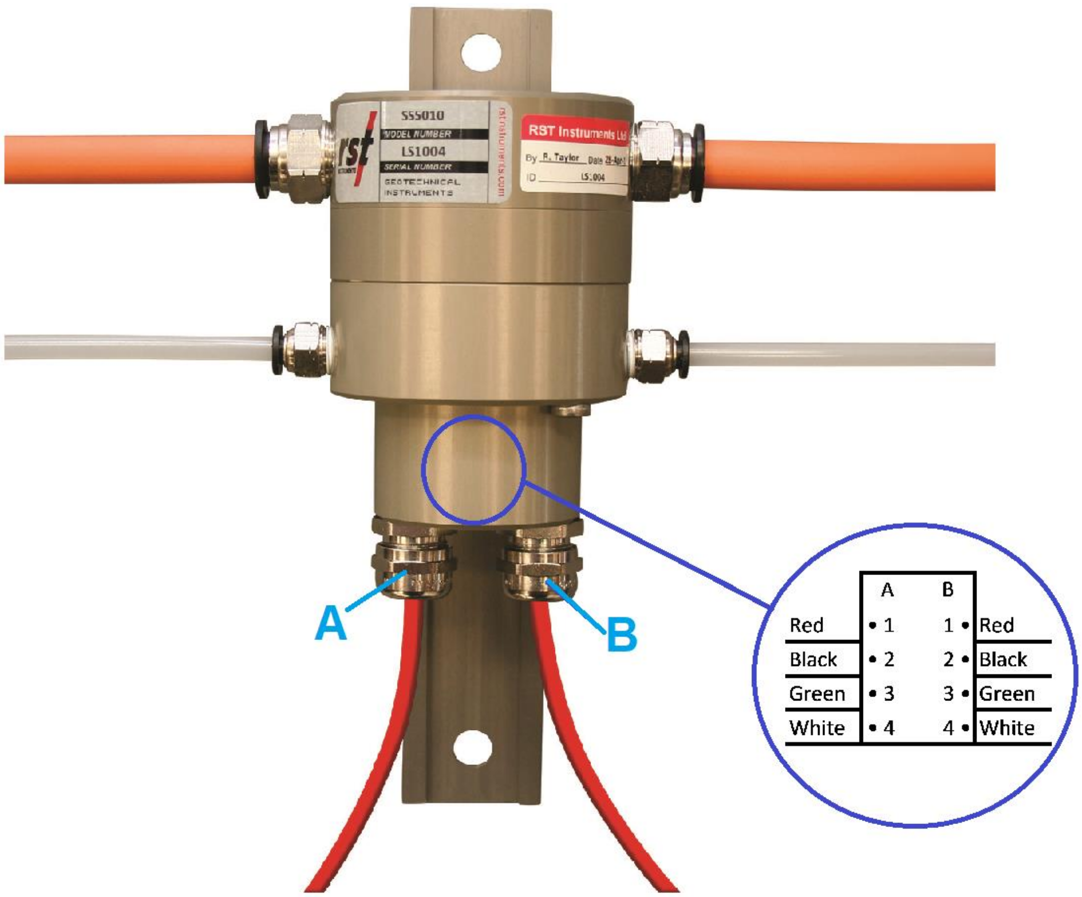


FIGURE 5-2 SENSORS AND CABLE GLANDS

7 Slide the bottom of the enclosure back into place and replace the screws removed in step 4. Tighten the cable glands using two wrenches.

CAUTION: THE CABLE GLANDS ARE CRITICAL TO PROTECTING EACH SENSOR FROM WATER INGRESS. THEY SHOULD BE TIGHTENED USING TWO WRENCHES.

8 Connect the liquid tubing (Figure 5-1, E) and air tubing (Figure 5-1, F) by inserting the tubes into their respective fittings. The tubing should be cleanly cut at 90º and inserted as far as possible into the fitting.

CAUTION: FAILURE TO FOLLOW THESE STEPS CORRECTLY MAY RESULT IN DAMAGE TO THE SYSTEM.

5.3.2 Mounting the Precision Liquid Reference Sensor

The reference sensor acts as a reference for all the other sensors in the system. It is mounted, wired and tested in the same way as the other sensors, but preferably in a fixed location that does not allow for movement, or in a location that is frequently surveyed. See Appendix A for a detailed diagram.

NOTE: MOUNT THE REFERENCE SENSOR ON A FLAT, VERTICAL SURFACE. TO ENSURE THE ACCURACY OF THE DATA, MAKE SURE THE REFERENCE SENSOR IS MOUNTED IN A LOCATION THAT DOES NOT MOVE OR IN A LOCATION THAT IS FREQUENTLY SURVEYED.

5.3.3 Mounting the Fluid Expansion Chamber

The fluid expansion chamber (Figure 5-3) is typically installed near the reference sensor, as illustrated in Figure 1-1. The following instructions outline the correct procedure for installing the fluid expansion chamber.

1 Attach the mounting bracket to a flat, vertical surface using 25 mm M8 cement anchors.

2 Place the sensor onto the mounting bracket and secure it by tightening the nuts.

3 Connect the liquid tube and air tube from the final sensor in the array to the reference sensor by firmly inserting each tube into the appropriate fitting on the reference sensor (Figure 5-3).

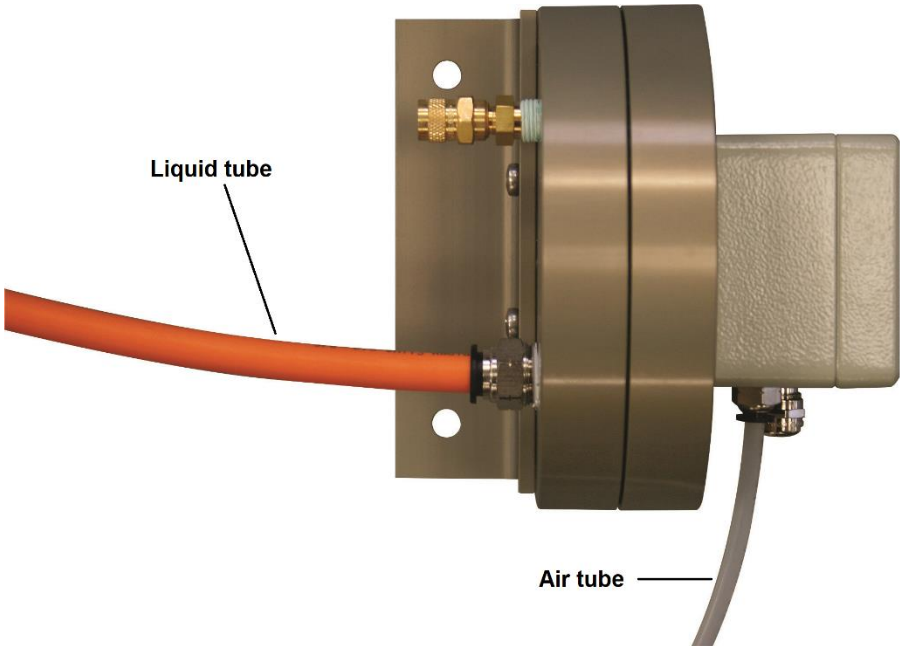


FIGURE 5-3 PRECISION LIQUID SETTLEMENT FLUID EXPANSION CHAMBER, WITH LIQUID TUBE AND AIR TUBE

5.3.4 Filling the Array with Liquid

Filling the array should be done very carefully to prevent air bubbles from entering the lines. To reduce the introduction of air bubbles into the system, RST recommends using a siphon to complete the filling procedure. During the process, the pressure of the liquid must be monitored to ensure it does not exceed 10 kPa. This operation requires two technicians.

NOTE: DUE TO THE HORIZONTAL SPAN OF THE ARRAY, TWO TECHNICIANS ARE REQUIRED TO SIMULTANEOUS FILL THE SYSTEM AND MONITOR THE LIQUID PRESSURE.

CAUTION: THE PRESENCE OF AIR BUBBLES MAY COMPROMISE THE ACCURACY OF READINGS.

1. Connect the system to the Field PC or a laptop. Run the accompanying software.
2. Insert one end of the siphon into the ball valve (also called the liquid fill valve).
3. With the liquid fill valve (Figure 5-4) closed and detached from the array, coil the tail of the siphon into the source container of the 50%-by-volume ethylene glycol and water solution.

> **NOTE: WHEN THE VALVE IS OPEN, THE HANDLE WILL BE IN LINE WITH THE VALVE. WHEN THE VALVE IS CLOSED, THE HANDLE WILL BE PERPENDICULAR FROM THE VALVE.**

4 With the valve still closed, lower the liquid fill valve below the fluid source.

5 Open the valve to initiate the flow of the liquid.

6 Close the liquid fill valve temporarily once the liquid begins flowing smoothly and without interruption.

7 Attach the liquid fill valve to the liquid tubes on the lowest end of the settlement array (i.e. to the sensor located farthest away from the reference sensor, see Figure 5-4).

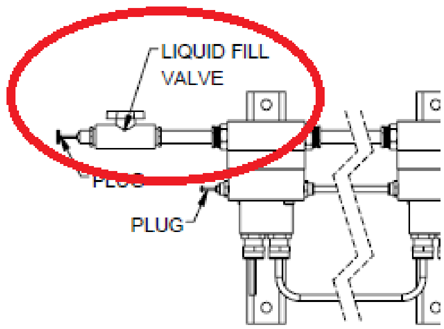


FIGURE 5-4 LIQUID FILL VALVE

8 Open the purge valve on the fluid expansion chamber (Figure 5-5).

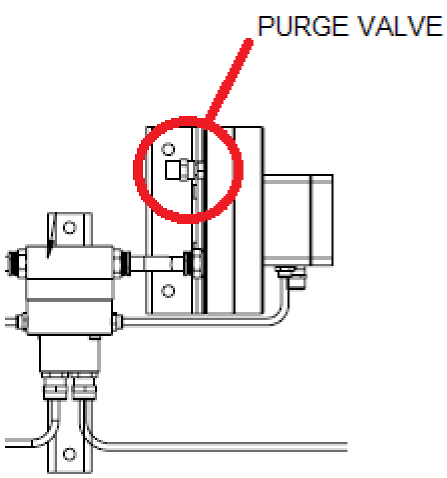


FIGURE 5-5 PURGE VALVE ON REFERENCE SENSOR

9 Open the valve to begin filling the array, ensuring the fluid source container remains higher than the liquid fill valve.

10 Fill the array carefully and slowly to prevent the formation of air bubbles and push the existing column of air out of the purge valve.

11 Monitor the fluid pressure on the Field PC or laptop. Do not exceed 10 kPa.

NOTE: THE FLOW OF THE SOLUTION CAN BE ADJUSTED BY RAISING THE LEVEL OF THE FLUID SOURCE.

12 Continue to siphon the solution into the array until the discharge from the purge valve is completely liquid.

CAUTION: DO NOT EXCEED 10 KPA WATER PRESSURE.

13 Allow the system to stabilize.

14 Close the purge valve (Figure 5-5) on the fluid expansion chamber.

15 Close the liquid fill valve, leave it on the array and replace the plug.

16 Remove the siphon tubing from the array.

6 OPERATION

6.1 CONNECTING THE ARRAY TO A DATA LOGGER

The Precision Liquid Settlement Array must be connected by cable to an installed data logger, such as the RST DT2485. The data logger will read data from the array at user-specified intervals and provides the user with wired or wireless remote monitoring. Users have real-time access to data through an internet connection on a computer and can also receive updates via email at chosen intervals. Please refer to the manual specific to your data logger for further information.

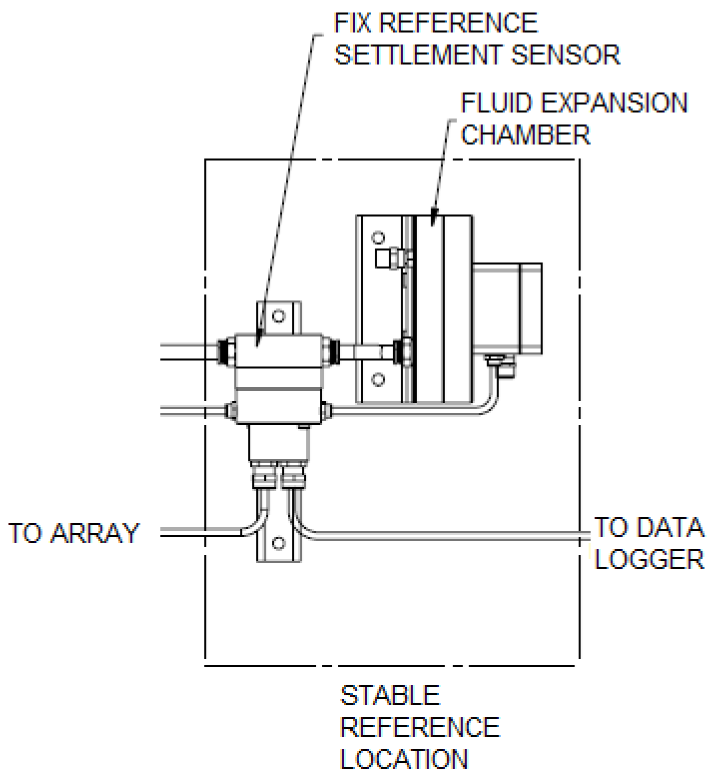


FIGURE 6-1 REFERENCE SENSOR AND CONNECTION TO DATA LOGGER

6.2 POWER

The Precision Liquid Settlement sensors receive power from a wired connection to an installed data logger. Data loggers are battery powered and can be programmed to take readings from the entire array at specified intervals. Please refer to the manual specific to your data logger for further information.

6.3 SURVEYING THE REFERENCE CELL

Ensure that the reference cell readings are stable and have not changed since installation by comparing them to the calibration record.

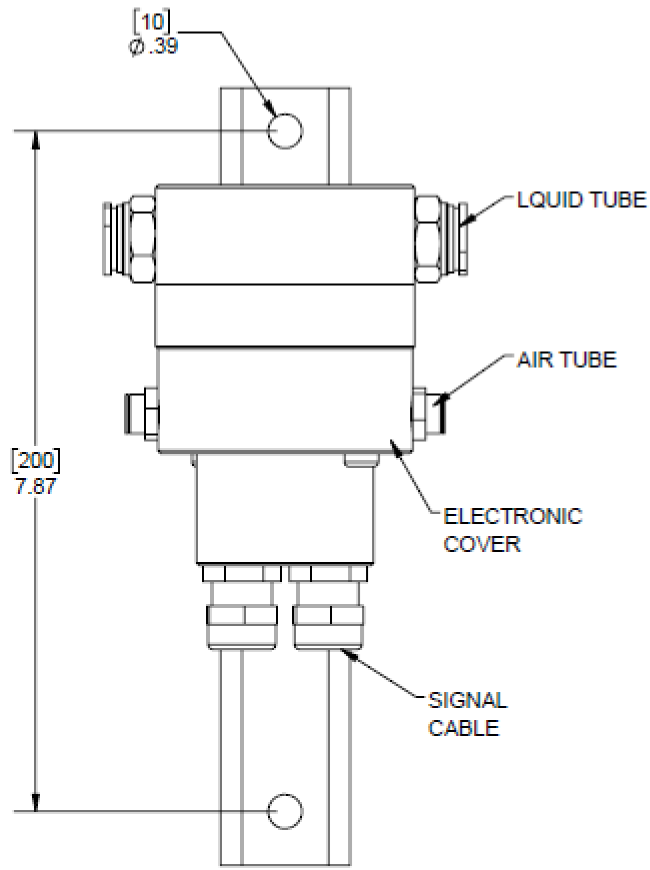
6.4 COLLECTING READINGS

Readings are recorded by the data logger and transmitted to a computer either wirelessly or through a physical connection. Settlement is measured by comparing the changes in liquid pressure between a given sensor and the reference sensor. Data are recorded in mm H_20 and are corrected for temperature. Please refer to the manual specific to your data logger for further information about collecting data.

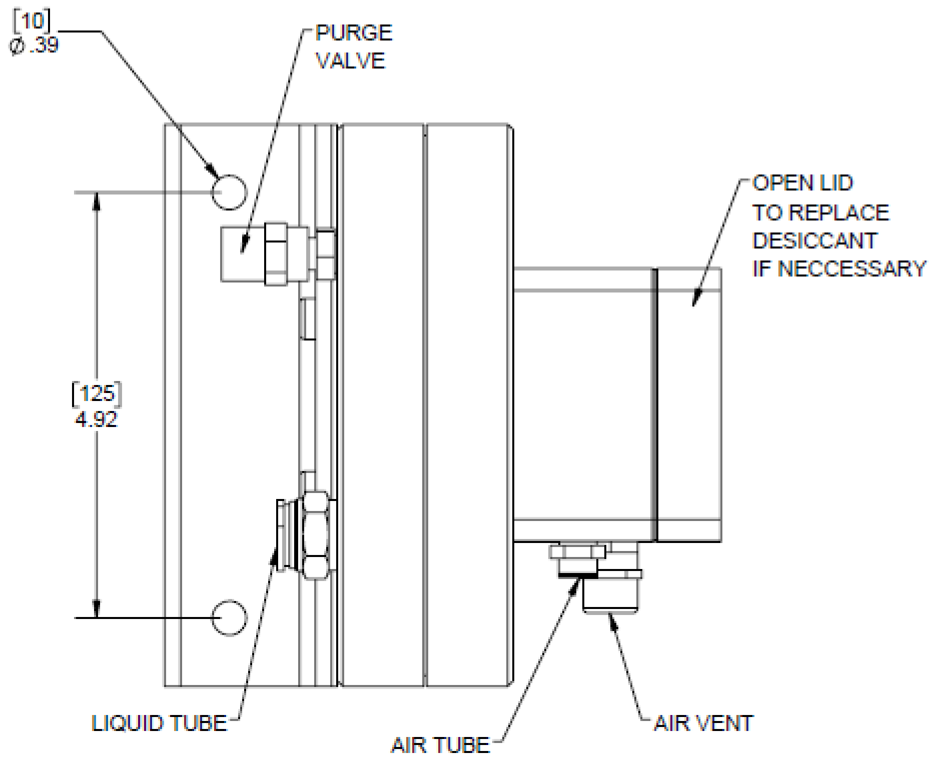
7 SERVICE AND REPAIR

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

Appendix A PRECISION SENSOR DETAILS



Appendix B FLUID EXPANSION CHAMBER DETAILS



Appendix C SAMPLE CALIBRATION CERTIFICATE

rst INSTRUMENTS Monitor with Confidence

Calibration Record
RST Instruments Ltd., 11545 Kingston St., Maple Ridge, British Columbia, Canada V2X 0Z5
Tel: 604 540 1100 · Fax: 604 540 1005 · Toll Free: 1 800 665 5599 (North America only)
e-mail: info@rstinstruments.com · Website: www.rstinstruments.com

Precision Liquid Settlement Array Sensor

Calibration Record

Customer:	RST Instruments Ltd
Order Number:	123456
Model Number:	SS5010
Serial Number:	**18**
Range:	600 mm
Calibration Date:	30-Oct-18
Cable Type:	EL380004

Wiring:

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

References: Pressure Controller CPM6050: 41000EJJ
Referenced to National Standards Annually

Applied Displacement mm	-15.4 °C Output mV	9.1 °C Output mV	38.6 °C Output mV
0	584.98	586.69	602.99
100	1145.65	1150.01	1168.26
200	1707.36	1714.38	1735.24
300	2269.02	2278.91	2303.13
400	2830.87	2843.69	2870.34
500	3393.06	3408.31	3438.06
600	3954.92	3973.68	4005.11
Max Error %	0.02	0.03	0.04

Cal Factor (mm/mV):	0.17802	0.17714	0.17631
Regression Zero (mm):	-104.01	-103.77	-106.10

Calculated Displacement = (Cal Factor * Output) + Regression Zero

Calibrated By: ______________________________