RST INSTRUMENTS LTD.

VW Liquid Settlement System Instruction Manual

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VW Liquid Settlement System Instruction Manual

Product: VW Liquid Settlement System Instruction Manual

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1 INTRODUCTION

Liquid Settlement Systems are used in many situations, such as:

- preload consolidation monitoring
- construction control of embankments, and tills
- subsidence monitoring

The RST VW Liquid Settlement System monitors settlement or heave, by measuring any changes in elevation between a reservoir and a settlement plate as shown in Figure 1. The liquid reservoir is mounted, ideally in a stable location (i.e. not subjected to any settlement), at a higher elevation relative to the settlement plate. As the plate settles, the liquid pressure at the settlement plate increases and is measured by the vibrating wire sensor.

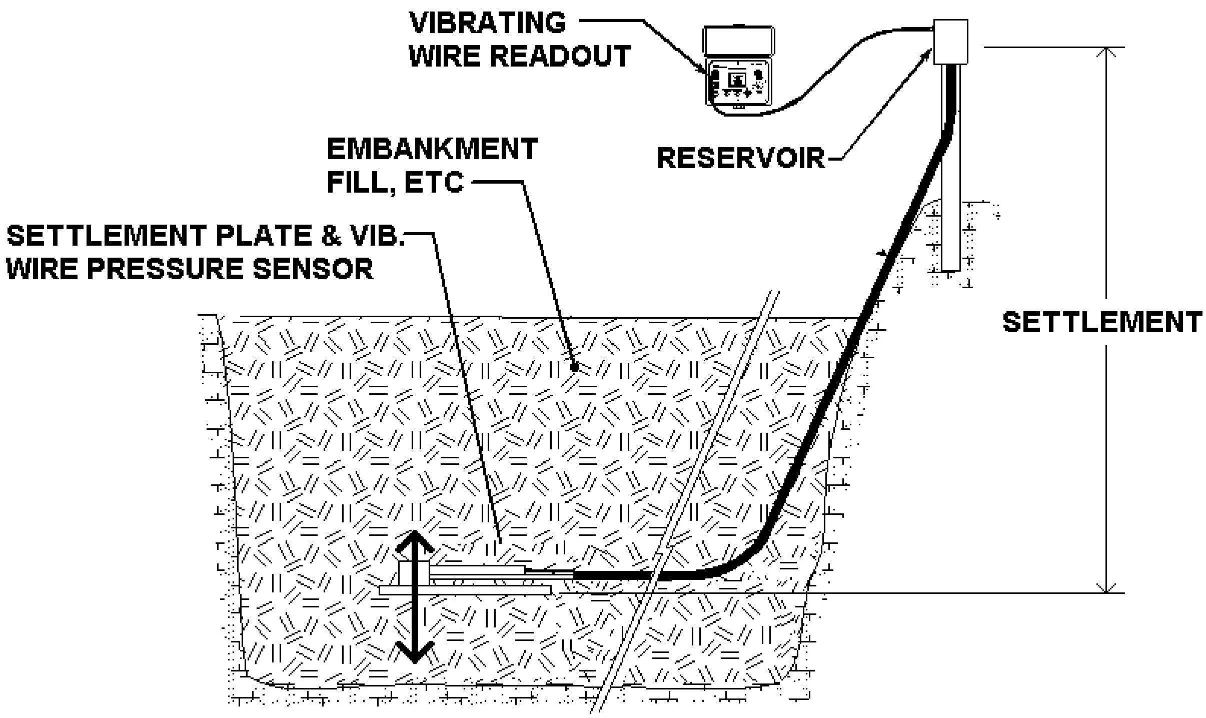

Figure 1: Typical installation of VW Settlement System

Typical VW Liquid Settlement System consists of an array of vibrating wire sensors connected to fluid-filled tubes branching from the manifold. Each branch contains a sensor that is installed at a specific location. Each sensor contains a thermistor for temperature measurement, and gas discharge tubes for lightning protection. The system uses de-aired antifreeze solution to prevent algae growth and freezing. Furthermore, the system uses two liquid lines so that it may be flushed in order to remove air bubbles from the system. Settlement is measured relative to the initial readings taken during installation. Changes in atmospheric conditions and fluid level evaporation are compensated for by an additional vibrating wire sensor located at the manifold. Settlement of the reservoir can be corrected from manual survey data.

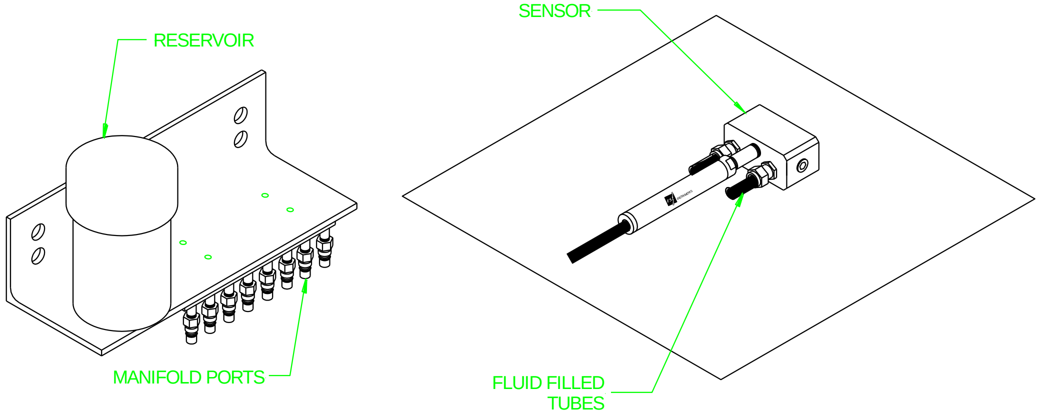

Figure 2: Typical layout of Reservoir and VW Transducer

Different system options are shown in the figure below. The system may have any number of positions, and different types of tubing.

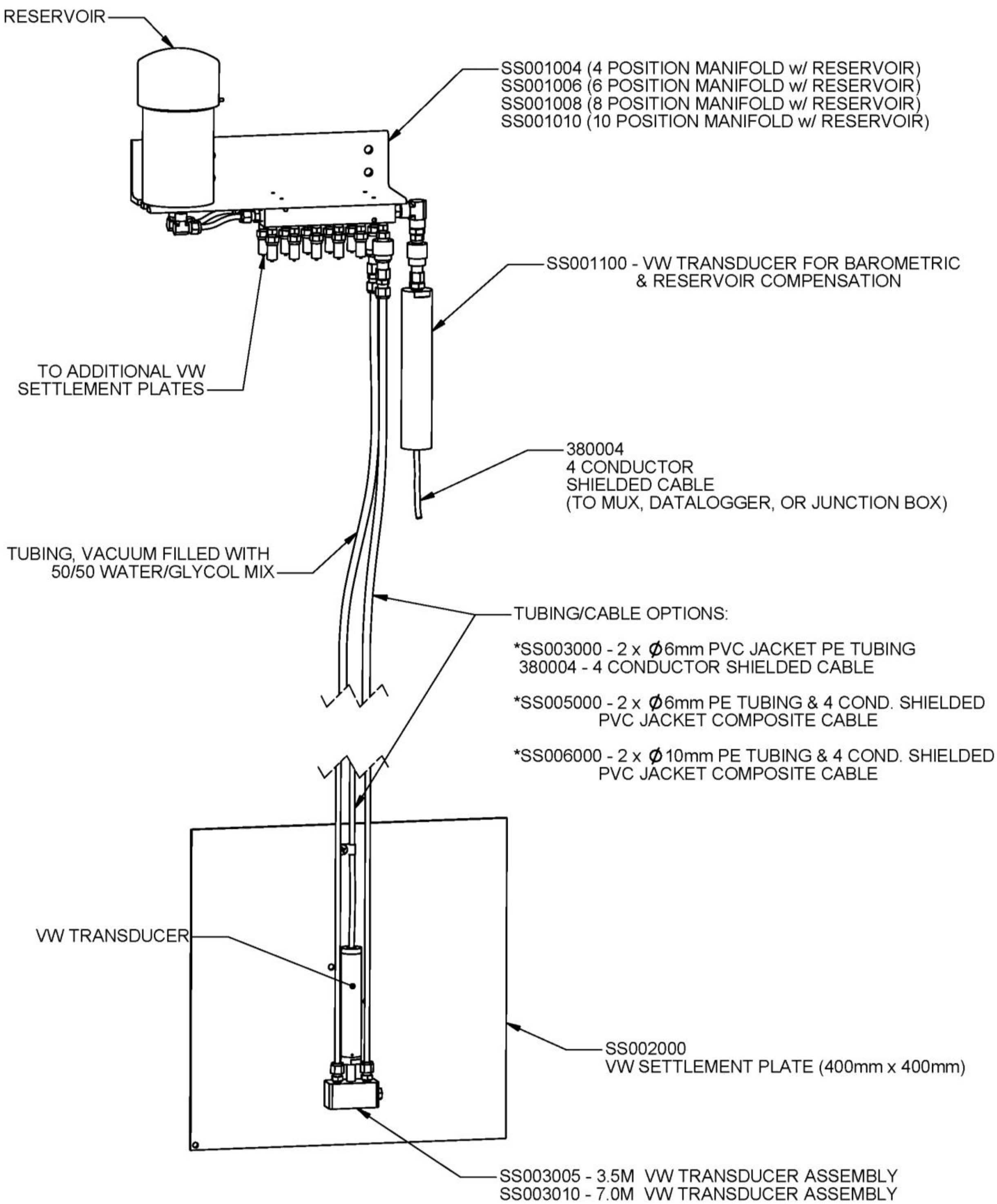

Figure 3: Various configurations of Reservoir and VW Transducer

2 INSTALLATION

Liquid settlement systems are shipped pre-filled, tested, calibrated, and ready to install. Generally, 5% additional tubing should be used to accommodate settlement.

It is critical that the settlement as shown in Figure 1 be within the anticipated range of the sensor. This system uses the 10psi sensor and thus the maximum settlement is 6.57m. For example, if the site conditions require that the initial installation height be 2.57m, the anchor plate can settle a maximum of 4m before the sensor is over pressurized and possibly becomes permanently damaged.

Typical installations in fill entail:

1. Embedding the settlement plate and sensor at the point to be monitored:

   A smooth, flat-bottomed excavation should be made in the fill for placement of the plate. This should be about 6 to 12 inches deep. The sensor and plate assembly should be placed in the excavation and surrounded by fine sand to a level at least 6 inches above the sensor and tamped in place.

2. Running the cable and tubing in a trench up to the reservoir:

   As the relative density of the fluid in the liquid lines changes with temperature, the interconnecting tubing should be buried and the system maintained at a constant temperature. Any additional tube at the reservoir end should be coiled and buried, with only the minimum length of tubing required above ground leading to the reservoir. If the cables are not buried, they should be adequately supported to prevent undulations and protected from sunlight and rapid temperature fluctuations with insulation.

   When running the cable and tubing to the readout location, localized high areas should be avoided and in no case should any part of the tubing be above the reservoir elevation. The cable and tubing should be placed in a trench (6 to 12 inches deep) that runs to the readout location, and surrounded with fine grain material which should be subsequently compacted. Prior to back filling the trench, it is recommend that the system be tested by making the necessary connections (see subsequent steps) and progressively raising the reservoir upwards, to simulate settlement in the system, while verifying with a vibrating wire readout that the system is operating correctly. Large angular rocks must not rest directly on the cables. Furthermore, the migration of water along the trench may be prevented by filling with bentonite at intervals. Compaction of succeeding lifts over the sensor and tubing can now proceed in the normal manner.

3. Installing the reservoir:

   The reservoir should be installed in a location that is on stable ground away from the area of anticipated settlement or one that can be periodically checked by survey so that it can provide a fixed reference level. The computations for settlement are based on the difference in elevation between the reservoir and the sensor, and therefore the reservoir fluid elevation must be known. The reservoir should be filled up to the overflow fitting (use de-aired solution of 50% distilled water and 50% ethylene glycol antifreeze) before the instrument is attached and should be topped up if necessary before taking readings. A few drops of light oil added through the top of the reservoir will slow down evaporation from the liquid surface.

4. Connecting the tubes and cable from the sensor to the junction box:

   There are two tubes so that the system may be flushed if any air bubbles ever contaminate the system. The female quick connects should be topped up with liquid in order to avoid introducing air bubbles into the system before simultaneously snapping them into the reservoir connections.

   The cable runs through the cable gland and the wires are connected to the terminal block as per the wiring diagram on the inner enclosure panel (generally, the black and red colors represent the vibrating wire element, the green and white colors represent the thermistor, and the last color represents the cable shield).

5. Acquiring initial readings:

   The reservoir should be filled up to the overflow point to serve as a quick visual check on any future fluctuations due to temperature, pressure, evaporation or leakage. Also, the ambient temperature should be recorded.

   Connect a vibrating wire readout to the junction box by matching the colors of the connectors and record the initial reading. Also, record the initial sensor temperature (if the readout does not display the sensor temperature, then the temperature may be obtained by measuring the resistance between the green and white banana jacks and using the conversion formula in the appendix). These measurements will serve as the reference or zero measurements for the future, and thus it is necessary to double check that they are stable.

3 RESERVOIR Assembly Instructions

1. Mount Reservoir Assembly. Make sure the Assembly is level using a spirit level.

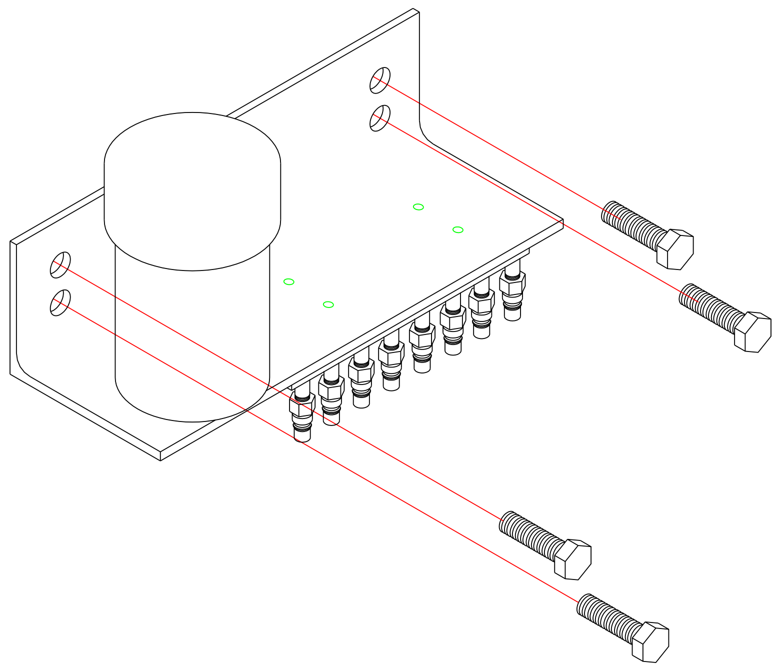

Figure 4: Reservoir mounting

2. Ensure the site is ready for installation as per the site engineer's instructions. This includes:
    1. An inclined, evenly graded, surveyed trench for laying the sensor leads back to the manifold. (**Trench depth must accommodate a 12"(300mm) bed of, packed, Select Backfill**).
    2. Enough sand to provide a 1"(25mm) thick leveling base for each cell.
    3. Enough **Select Backfill** to provide a 12"(300mm) protective barrier for the Cell and its leads, from the Regular Backfill.
3. Survey in each sensor at its site specific Reference location and level.
4. Survey in the Reference Level at the manifold location.
5. Fill the reservoir to the level indicated by the red line on the outer surface of the reservoir with the de-aired solution provided.
6. Remove both 6" extension pipes and caps in the reservoir. (Liquid is pre-filled in the manifold to ensure no air is trapped in the system.)

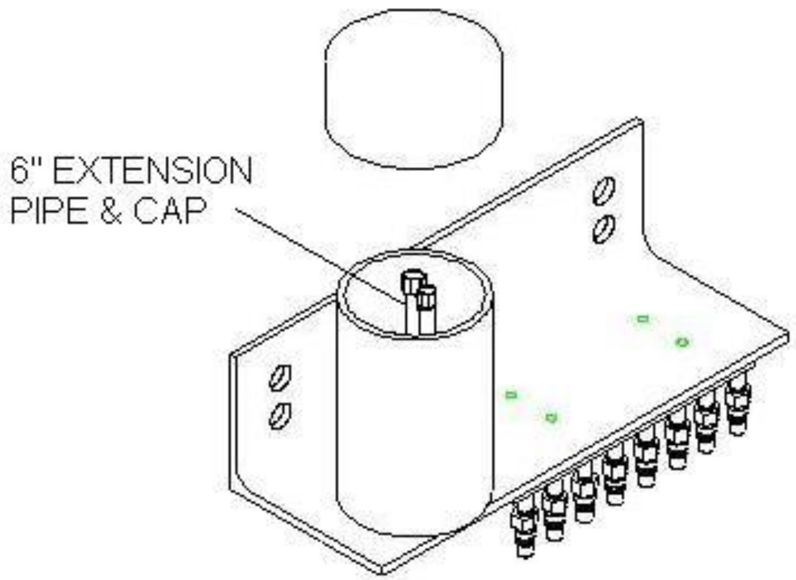

Figure 5: Removing the 6” extension pipes & caps

7. Fill each of the female quick connects with de-aired solution. Attach both tubes of each sensor to the manifold at the same time.

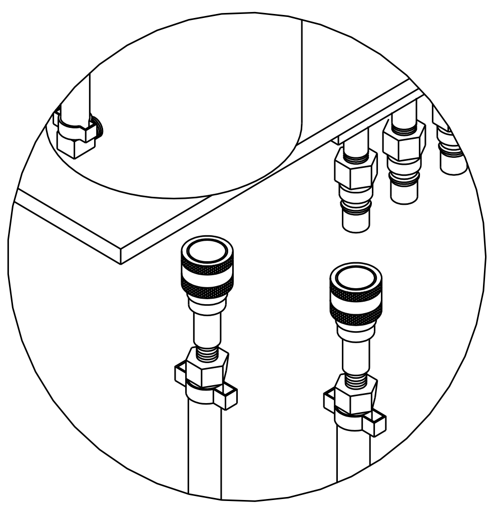

Figure 6: Filling the female quick connects with de-sired solution

8. Fill the end of the female Quick Connect, on the Barometric VW Transducer, if installed, with fluid and then connect it to the Manifold.
9. Top up the reservoir level if required and add a couple drops of mineral oil to the reservoir to prevent evaporation.
10. Make electrical connections to a readout/datalogger (RST VW-2106) and take the initial readings.

Note: If air is suspected in the lines then contact RST Instruments for further instructions.

4 OPERATION

After the installation, the measurements may be obtained by using the RST Vibrating Wire Readouts. Connect the readout to the junction box by matching the colors of the connectors. The black and red colors carry the frequency signal that is proportional to the pressure. The green and white colors are connected to the thermistor.

Having recorded the initial reading and temperature after installation, the zero reading is now established and all subsequent data can be referred to these numbers. Use the initial count reading as R_0 and the initial temperature recorded as T_0. Refer to the calibration sheets for the appropriate calibration and thermal factors for each system. Use the following formula to determine settlement.

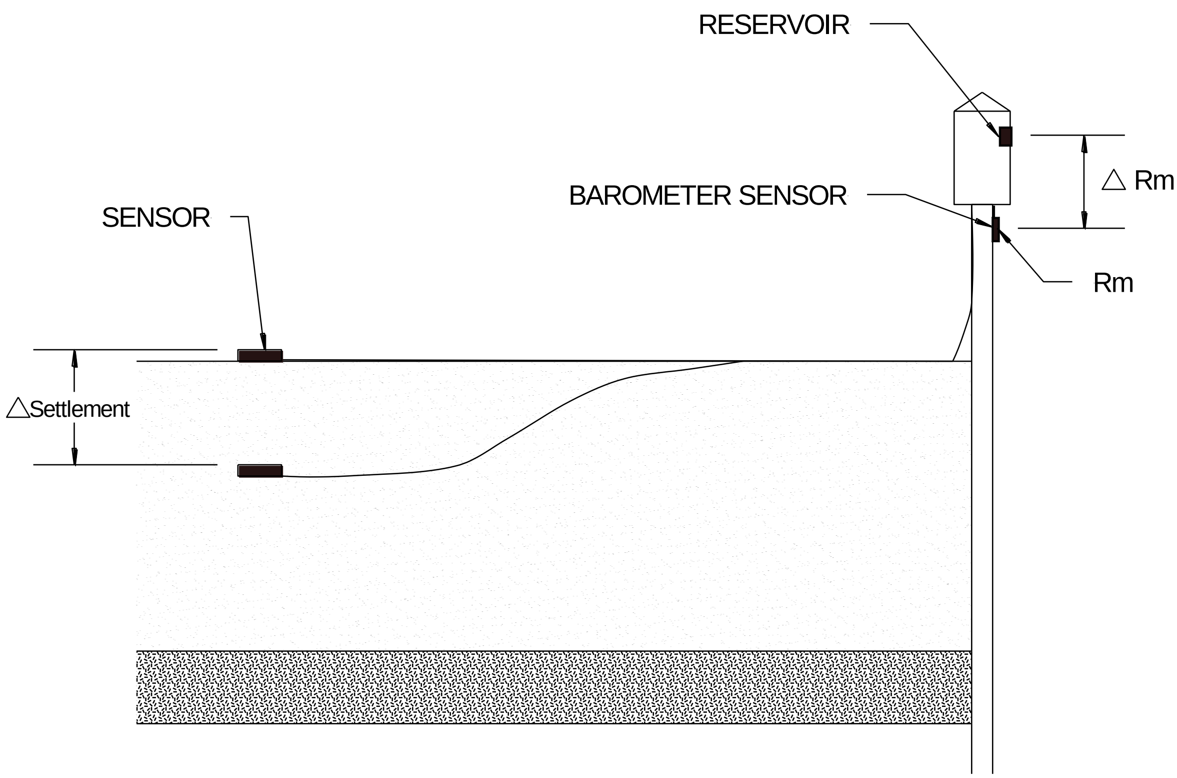

Figure 7: Monitoring settlement or heave

4.1 CALCULATION OF DATA WITHOUT BAROMETER

$$Settlement\,,\ \Delta z = CF*(L_i - L_c) - Tk*(T_i - T_c)$$

Where:

CF = Calibration Factor (from Calibration Sheet)
L_I = Initial Readout Box reading
L_c = Current Readout Box reading
T_k = Thermal Factor (from Calibration Sheet)
T_i =Initial Temperature.
T_c =Current Temperature

For example, if the initial readings at installation were 7905 Hz^2/1000 and 17°C, and the current readings are 7530 Hz^2/1000 and 15°C (and the calibration sheet shows -0.0015936 m/B for CF and -0.0043 m/(°C) for T_k, a sample calibration sheet is included in the appendix), then the plate has settled a distance of 0.589m:

$$\Delta z = (-0.0015936 m/b)*(7905-7530) - (-0.0043 m/^{o}C)*(17-15)^{\circ}C = -0.598m + 0.009m = -0.589m$$

From the above sample calculation, it can be seen that generally the temperature effects are small, which is especially true for buried cable.

4.2 CALCULATION OF DATA WITH BAROMETER

$$Settlement\,,\ \Delta z = CF*(L_i - L_c) - Tk*(T_i - T_c) - 0.0953*(B_i - B_c)$$

Where:

CF = Calibration Factor (from Calibration Sheet)
L_I = Initial Readout Box reading
L_c = Current Readout Box reading
T_k = Thermal Factor (from Calibration Sheet)
T_i =Initial Temperature.
T_c =Current Temperature
B_i= Initial Barometric pressure (at installation)
B_c = Current Barometric pressure in kPa (at time of reading)

5 TROUBLESHOOTING & MAINTENANCE

If the readings appear faulty (i.e. unstable, fluctuating, or simply unrelated to physical phenomena), then several checks should be made. First, check that the readout is functioning correctly. A continuity check of the sensor should also be performed. The resistance between the gauge leads (Red and Black wires) should be approximately 180Ω. The resistance between the thermistor leads (Green and White wires) should be approximately 3kΩ at room temperature. It may be important to add the cable resistance to these numbers (note that 22 AWG stranded copper leads have resistance of approximately 48.5Ω/km).

Second, check that the liquid level in the reservoir is at the overflow point. If the liquid level dropped significantly, then there is most likely a leak in the system. Also, visually check for air bubbles or plugged lines in the system, in which case it will be necessary to flush the system (contact RST Instruments for assistance).

Unstable readings may also result from electrical noise such as nearby power lines or electrical equipment because the vibrating wire signal is very susceptible to frequency noise. If possible, the readings should be taken when the equipment is not operating; otherwise, it may be necessary to move away from the noise.

The vibrating wire sensor is completely sealed and does not require maintenance. In fact, only the junction box and the connecting tubing and cable require minimal attention. Approximately every three months, visually examine the reservoir level and add liquid if necessary up to the overflow tube. Also, check that there are no leaks and air bubbles in the tubing, and that the tubing is not plugged. Furthermore, check that the electrical connections are not corroded.

APPENDIX A

The following equation may be used to convert the measured thermistor resistance R (Ω) to 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

APPENDIX B

RST INSTRUMENTS
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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

VW-105 LIQUID SETTLEMENT SENSOR

Customer:	RST Instruments Ltd.	**Cable Length (m):**	1000
Calibration Date:	16-Jan-15	**Tubing Length (m):**	1000
Model Number:	SSVW105	**Fluid Type:**	Water/EthyleneGlycol 50/50
Customer ID:	**N/A**	**Specific Gravity:**	1.070
Serial Number:	**VS1234**	**Calibration Readout:**	VR0097
Mfg Number:	12345	**Barometric Pressure (kPa):**	102.35
Order Number:	206032	**Temperature (°C):**	16.2
Thermistor Type:	3 Kohms	**Range (m):**	7
Cable Colour Code:	Red / Black (coil)	Green / White (thermistor)	

Displacement (Meters)	Indicated B Units	Calculated * Settlement Meters
0.00	8599	0.00
0.29	8447	0.29
0.59	8295	0.58
0.88	8144	0.88
1.17	7992	1.17
1.47	7840	1.46
1.76	7688	1.76
2.05	7537	2.05
2.35	7385	2.34
2.64	7233	2.64
2.93	7081	2.93
3.23	6929	3.23
3.52	6777	3.52
3.81	6626	3.81
4.11	6473	4.11
4.40	6322	4.40
4.11	6473	4.11
3.81	6624	3.81
3.52	6775	3.52
3.23	6927	3.23
2.93	7079	2.94
2.64	7230	2.64
2.35	7382	2.35
2.05	7534	2.06
1.76	7685	1.76
1.47	7838	1.47
1.17	7989	1.18
0.88	8142	0.88
0.59	8293	0.59
0.29	8444	0.30
0.00	8596	0.00

Linear Gage Factor (**CFm**):	**-0.0019330**	Meters Displacement / B Unit
Regression Zero:	**8597.5**	B units
Sensor Temperature Correction Factor **Tkm**:	**-0.0022**	meters/ °C rise

*At calibration the zero position of the reservoir level was 1.00 meters above the transducer.

Settlement $\Delta z = CF*(Li-Lc) - Tk*(Ti-Tc) - 0.0953*(Bi-Bc)$

	Date (dd/mm/yy)	VW2106 Pos. B	Temp °C (Ti)	Baro (Bi)
Shipped Zero Readings:	16-Jan-15	8623	19.2	100.93

L_i, L_c = initial (at installation) and current readings B units
T_i, T_c = initial (at installation) and current temperature, in °C
B_i, B_c = initial (at installation) and current barometric pressure readings, in kPa

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

Calibrated By: Z. Soos ZS Date: 16-Jan-15

Applied Science Technologists and Technicians of British Columbia — 22724 — AL CULLEY — AScT

Doc Number: SS0007K