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Vibrating Wire Soil Extensometer Manual

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Revision History

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I	Operation and Temperature Correction section updates: Rc and Ri changed to Lc and Li to match calibration sheets, units of linear calibration factor changed to [mm/B-unit], typo in corrected linear displacement example removed. Revision Table added. List of Equations added.	2019-Sep-16	MP	QR
J	Figure 3-1 corrected.	2019-Nov-22	MP	CJ

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1 INTRODUCTION

The RST Vibrating Wire Soil Extensometer measures axial movement in soil, rocks, or concrete. Typical applications include earth dams (see Figure 1-2), preload consolidation, highway fills, and embankments. The instrument consists of two customizable End Flanges and a telescopic section (see Figure 1-1). The flexible design allows for a multitude of configurations with various stroke and gauge lengths, and can be chained together in series to monitor the incremental deformation across a structure or medium.

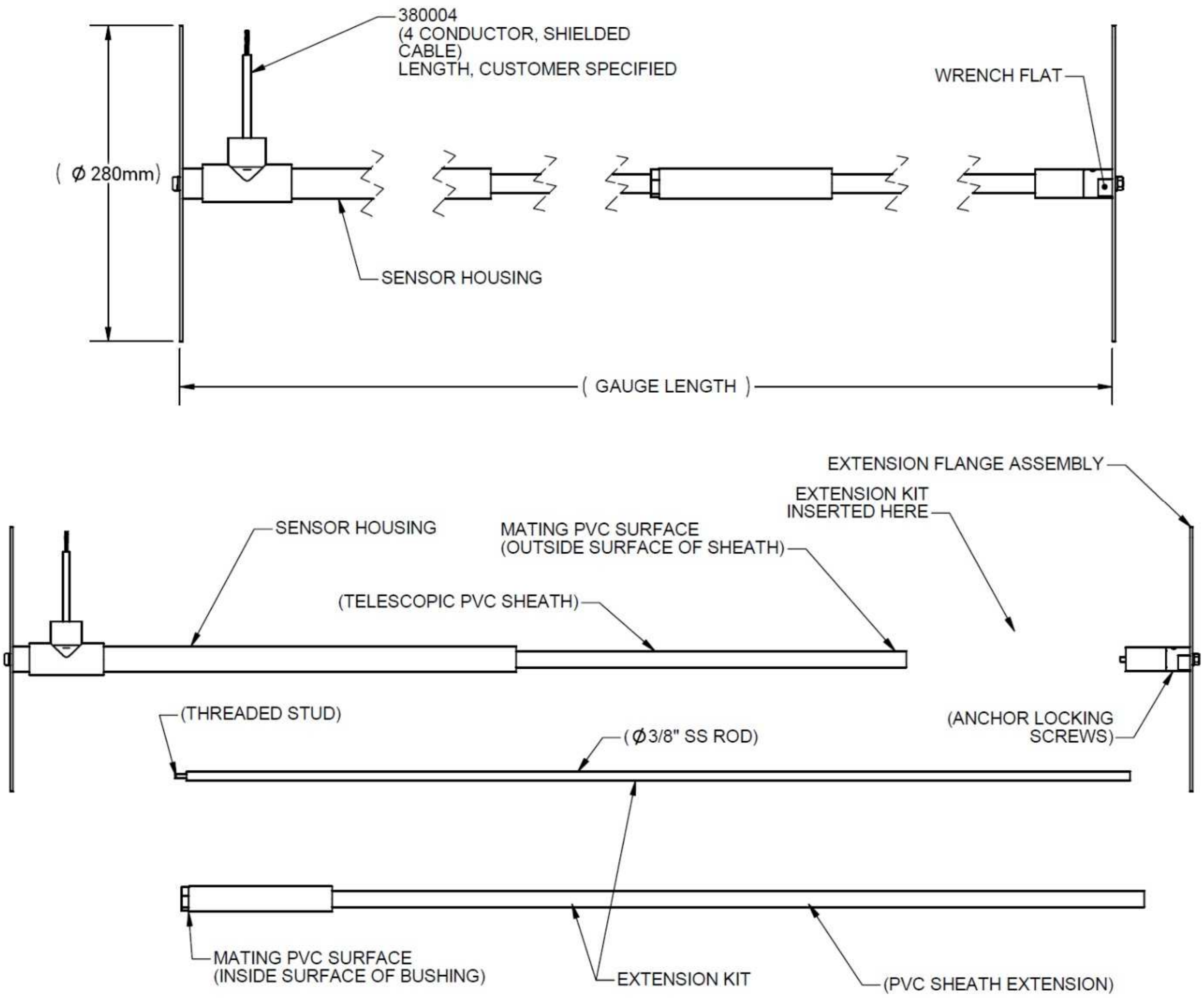

FIGURE 1-1 VIBRATING WIRE SOIL EXTENSOMETER

1.1 PRINCIPLE OF OPERATION

A Vibrating Wire Readout is used to excite the Vibrating Wire sensing element, within the Soil Extensometer, which is very sensitive to strain changes. As the End Flanges move apart the Vibrating Wire Sensing Element emits different frequencies at different strains upon excitation. A Vibrating Wire Readout is used to read the frequency, and a formula on the Calibration Sheet converts the frequency into temperature compensated linear units.

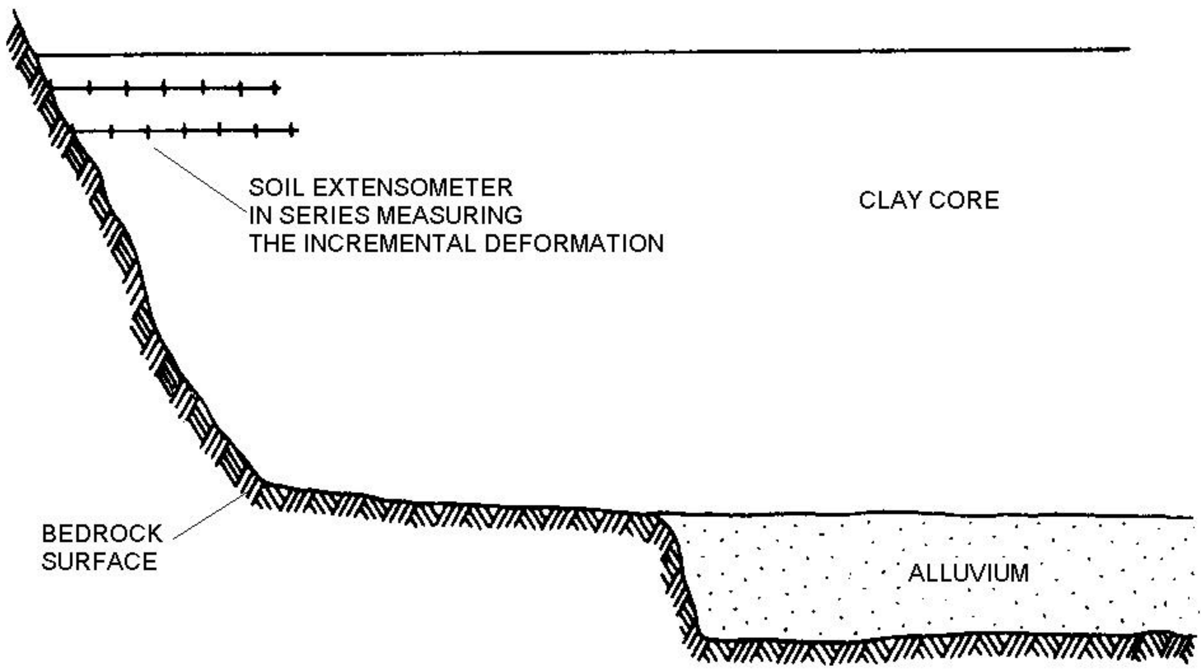

FIGURE 1-2 TYPICAL EMBEDMENT OF THE SOIL EXTENSOMETER IN A DAM

2 SAFETY

WARNING: DO NOT ROTATE THE SHAFT OF THE SENSOR ASSEMBLY AT ANY TIME AS THIS WILL DAMAGE THE VW SENSOR. WHEN THREADING THE RODS TOGETHER, ONLY ROTATE THE ROD THAT IS BEING COUPLED TO THE INSTRUMENT.

3 INSTALLATION

Upon receiving the instrument, verify the instrument is functioning properly. The instrument is shipped fully retracted, thus connecting a readout box should show a stable reading of approximately 2,500-3,000 B units Hz2x10-3 (Full Extended is 7,000 - 9,000). It is recommended to carefully stroke the instrument and verify that the readings change accordingly.

A quick continuity check should also be performed. The resistance between the gauge leads (Red and Black wires) should be approximately 185Ω. The resistance between the thermistor leads (Green and White wires) should be approximately 3kΩ at room temperature, and it should decrease with increasing temperature, i.e. when someone squeezes the instrument. Finally, there should be infinite resistance between the shield and the other leads.

The Soil Extensometer cable should be routed away from sources of electrical interference such as power lines, motors, transformers, etc. The cable cannot run with AC power lines because it will pick up the 50 or 60Hz noise. The cable may be lengthened, and the frequency of the signals will not be affected.

3.1 EXTENSOMETER ASSEMBLY

WARNING: DO NOT ROTATE THE SHAFT OF THE SENSOR ASSEMBLY AT ANY TIME AS THIS WILL DAMAGE THE VW SENSOR. WHEN THREADING THE RODS TOGETHER, ONLY ROTATE THE ROD THAT IS BEING COUPLED TO THE INSTRUMENT.

If the Extensometers Gauge Length is too long to be shipped assembled, follow the procedure below (refer to Figure 1-1);

1 Organize Sensor Bodies and Extension Kits (SS Rods and Extension Sheaths) into per location groups.

2 Clean the Mating surfaces of the Telescopic PVC Sheath, Extension Sheath, and Extension Flange with a PVC Cleaner.

3 Slide the Extension PVC Sheath over the SS Rod.

4 Apply a Thread Locker to the Threaded Stud protruding from the SS Rod.

5 Thread the SS Rod into the rod protruding from the Sensor Body.

WARNING: DO NOT ROTATE THE SHAFT OF THE SENSOR ASSEMBLY AT ANY TIME AS THIS WILL DAMAGE THE VW SENSOR. WHEN THREADING THE RODS TOGETHER, ONLY ROTATE THE ROD THAT IS BEING COUPLED TO THE INSTRUMENT.

6 Apply PVC Solvent to the outer mating surface of the Telescopic Sheath and inner surface of the Extension Sheath (inner surface of Bushing).

7 Slide the Extension Sheath into the Telescopic Sheath rotating back and forth during insertion.

8 Repeat steps 2-7 until gauge length is achieved.

9 Thread the Extension Flange Assembly onto the Extensometer Assembly.

10 Apply PVC Solvent to the inner mating surface of the Extension Flange Assembly and outer surface of the Extension Sheath.

11 Slide the Extension Sheath into the Extension Flange Assembly rotating back and forth during insertion.

3.2 INSTALLATION IN FILLS AND EMBEDMENTS

Compact the fill until the target elevation, for installing the Soil Extensometers, has been reached. Determine the amount of pre-stroke desired based on site specifications (to allow the instrument to measure some shrinkage or compression). Skim away the compacted fill so that the entire length of the Extensometer is fully supported with compacted fill. Be sure to provide adequate recesses for the flanges (at the desired pre-stoked distance) and for the cable. Lay the instrument in the recess and make electrical connections to confirm the instrument is at the desired pre-stroke. Completely cover the instrument with hand compacted fill, and make sure to remove any large rocks that could damage the instrument or the cable. Proceed with the typical fill and compaction method.

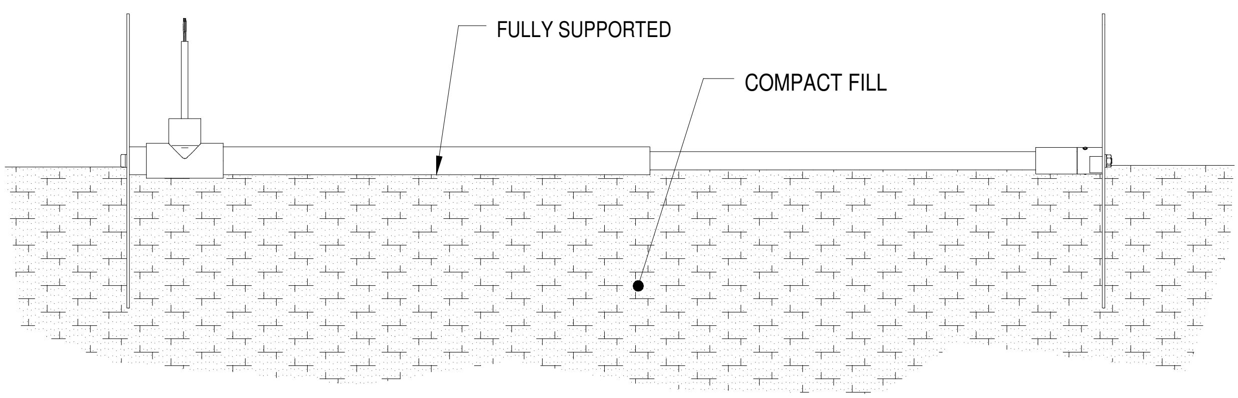

FIGURE 3-1 INSTRUMENT PLACEMENT DETAILS

3.3 INSTALLATION IN CONCRETE

Place the instrument directly into the freshly poured concrete.

3.4 EXTENSOMETERS IN SERIES

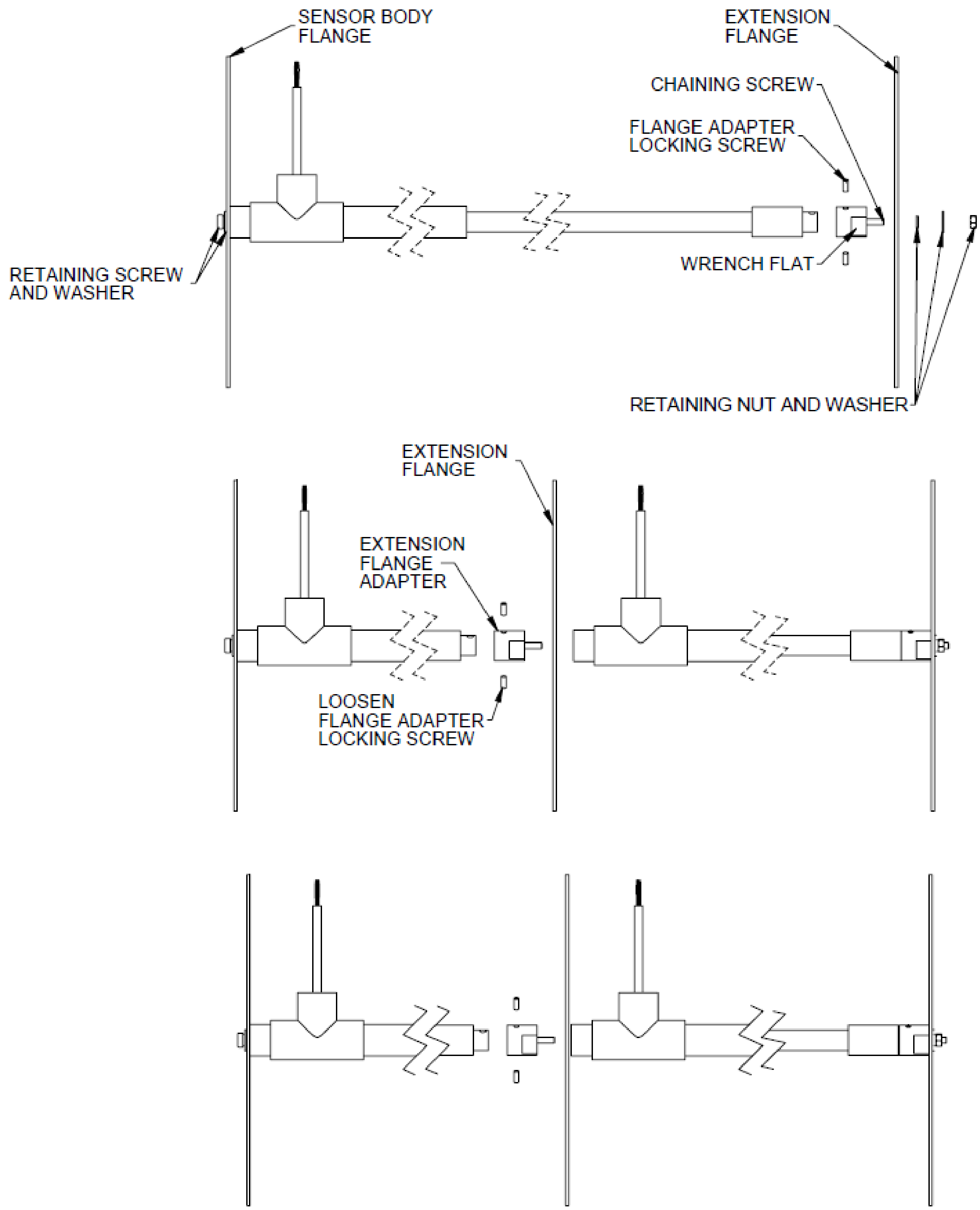

FIGURE 3-2 CHAINING EXTENSOMETER IN SERIES

To chain the extensometers together in series;

1 Remove the Retaining Nut and Washer from Extension Flange.

2 Remove the Retaining Screw, Washer from the Sensor Body Flange (if applicable). The Extension Flange should be loosened.

3 Loosen the Flange Locking Screw from the Extension Flange Adapter.

4 Thread the Extension Flange Adapter and Extension Flange into the Sensor Body.

5 Tighten the Flange Adapter Locking Screw.

4 OPERATION

After the installation is complete, initial readings can be recorded by using an RST Vibrating Wire Readout or Data Logger. Make the electrical connections according to the instructions supplied with the readout and be sure to record relative site information to provide a unique identifier for the data. When referenced with the instrument's initial readings, subsequent readings will provide actual deformation, according to Equation 1:

$$Subsequent\ reading - Initial\ reading = Deformation$$

EQUATION 1 ACTUAL DEFORMATION

The readouts will output the displacement in B-units (Hz^2x10^{-3}) and the calibration factor, supplied with each calibration sheet, may be used to convert to linear displacement units. The readouts also output the temperature in °C. If an Ohmmeter is used directly on the green and white wires, then Appendix B may be used to convert to °C.

4.1 TEMPERATURE CORRECTION

Temperature correction may not be necessary in many cases as the Vibrating Wire crack meter has a small coefficient of thermal expansion. Temperature corrections may be applied for maximum accuracy or when temperature fluctuations are greater than 10°C.

$$Corrected\ Linear\ Displacement = CF(L_c - L_i) + K(T_c - T_i)$$

EQUATION 2 LINEAR DISPLACEMENT

Enter the appropriate values into Equation 2 to calculate the displacement and convert the readings into linear units. All subsequent readings should be subtracted from the initial reading to calculate the distance the crack has opened, where:

L_c	Current reading	[B-unit]
L_i	Initial reading	[B-unit]
CF	Linear Calibration Factor, provided on the calibration sheet	[mm/B-unit]

T_c	Current temperature	[°C]
T_i	Initial temperature	[°C]
K	Temperature Factor, see Equation 3	[mm/°C]

Use Equation 3 to calculate K, the temperature correction factor:

$$K = CF[(L_c * M) + B]$$

EQUATION 3 TEMPERATURE CORRECTION FACTOR

L_c	Current reading	[B-unit]
M	Slope, see Table 4-1	[1/°C]
B	Constant, see Table 4-1	[B-unit/°C]
CF	Linear Calibration Factor, provided on the calibration sheet	[mm/B-unit]

TABLE 4-1 TEMPERATURE CORRECTION FACTOR

Stroke (mm)	25	50	100	150	200	300
Slope (M)	0.000310	0.000311	0.000399	0.000359	0.000306	0.000277
Constant (B)	-0.3186	-0.2758	-0.8128	-0.5579	-0.4498	-0.2495

Sample calculation:

Assuming the following measurements from a 150mm sensor:

L_c	3762	[B-unit]
L_i	4791	[B-unit]
CF	0.0291788	[mm/B-unit]
T_c	22.5	[°C]
T_i	13.3	[°C]
M	0.000359	[1/°C]
B	-0.5579	[B-unit/°C]

First, calculate the Temperature Correction Factor (Equation 3):

$$K = CF[(L_c * M) + B]$$

$$K = (0.0291788) * [(3762 * 0.000359) + (-0.579)]$$

$$K = (0.0291788) * (0.792658)$$

$$K = 0.023129$$

Next, apply the Temperature Correction Factor to Equation 2 to find the Linear Displacement:

$$Corrected\ Linear\ Displacement = CF(L_c - L_i) + K(T_c - T_i)$$

$$Corrected\ Linear\ Displacement = [(0.291788) * (3762 - 4791)] + [(0.023129) * (22.5 - 13.3)]$$

$$Corrected\ Linear\ Displacement = (-1029 * 0.291788) + (0.023129 * 9.2)$$

$$Corrected\ Linear\ Displacement = (-30.02499) + (0.212785)$$

$$Corrected\ Linear\ Displacment = -29.8122mm$$

5 TROUBLESHOOTING & MAINTENANCE

If the readings appear faulty (i.e. unstable, fluctuating, or simply unrelated to physical phenomena), then several checks can 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 185Ω. 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 53.1Ω/km).

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, readings should be taken when equipment is not in operation; otherwise, it may be necessary to reroute the instrument cable.

Check for corrosion at all electrical connections (except at sensor end) and clean if necessary. This check should be performed approximately every three months.

6 SPECIFICATIONS

The instrument specifications are shown in Table 6-1. Please note that the length, extension range, and flange diameter can be customized to the customer's requirements.

TABLE 6-1 VIBRATING WIRE SOIL EXTENSOMETER SPECIFICATIONS

Gauge Length	1m -3m (in 1/2m increments)
Sensor Stoke	25mm, 50mm, 100mm, 150mm, 200mm, 300mm
Over Extension Limit	Sensor Stoke + 20%
Accuracy	0.5% FSR
Resolution	0.025% FSR
Linearity	0.25% FSR
Thermal Zero Shift	<0.05% FSR/°C
Temperature Range	-20°C … 100°C
Frequency Range	1600Hz … 3000Hz
Coil Resistance	125W+/-10W
Body Diameter	1.1"
Thermistor Range	-80°…150°C
Thermistor Accuracy	+/-0.2°C

7 ORDERING DETAILS

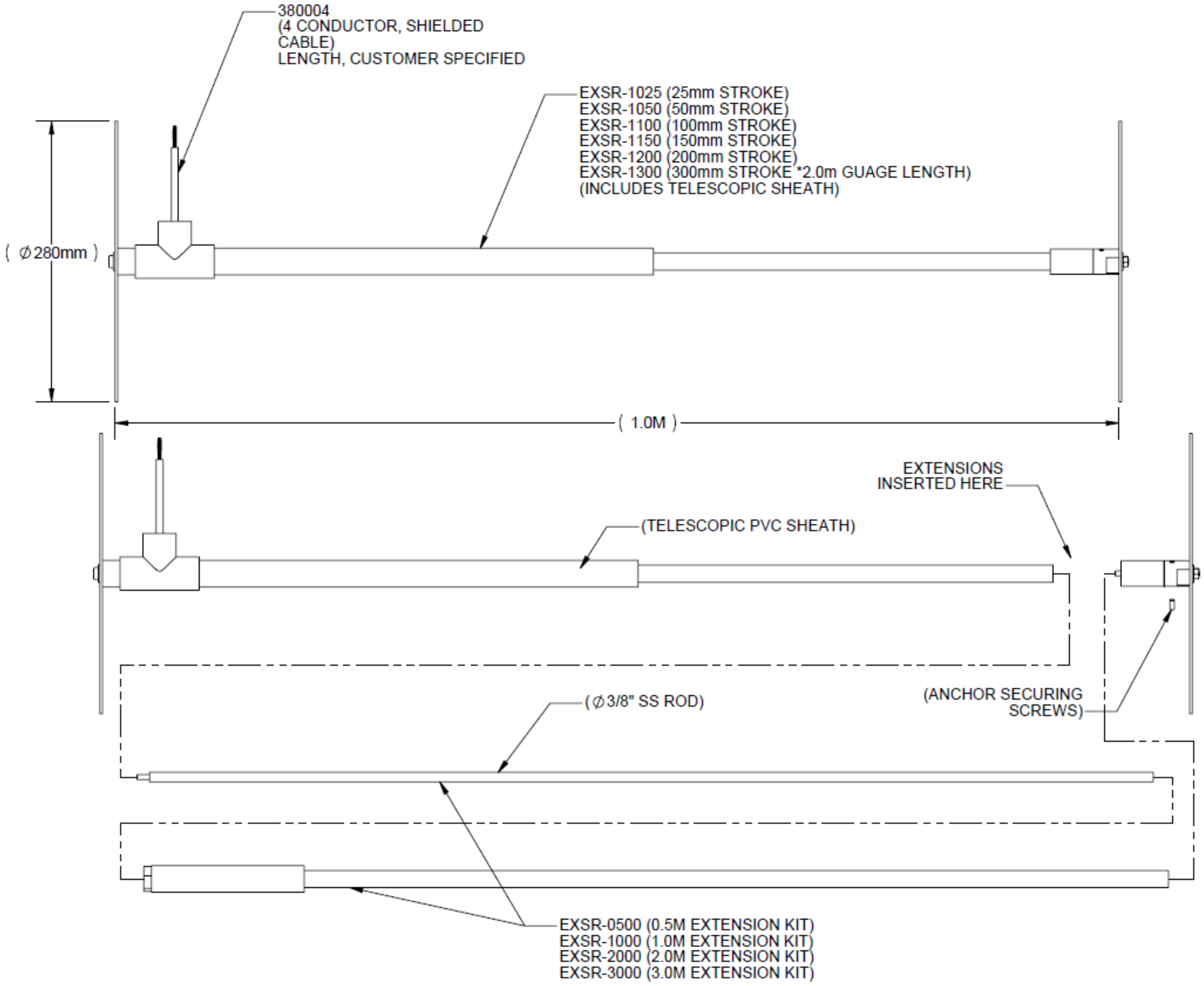

FIGURE 7-1 ORDERING DETAILS

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

EQUATION 4 CONVERTING THERMISTOR RESISTANCE TO TEMPERATURE

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

TABLE 7-1 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