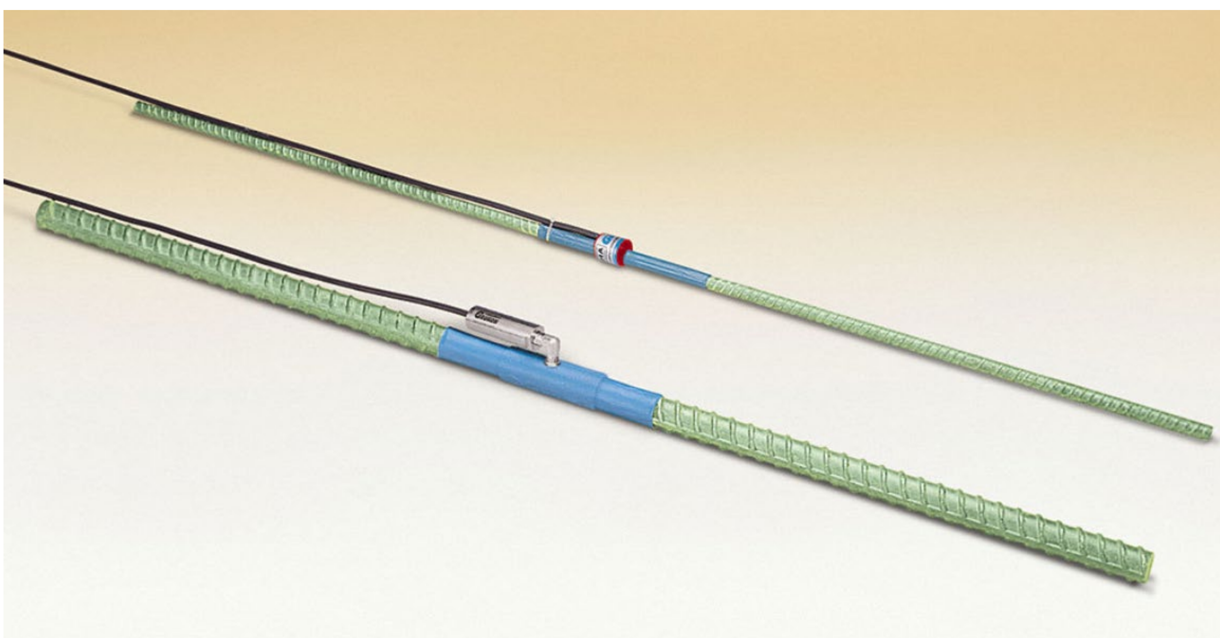
48 Spencer Street
Lebanon, NH 03766, USA
Tel: 603·448·1562
Fax: 603·448·3216
Email: geokon@geokon.com
http://www.geokon.com

Installation Manual

Models 3911/3911A

Resistance Type Rebar Strain Meters



(Doc Rev G, 04/30/2019)

Warranty Statement

Geokon warrants its products to be free of defects in materials and workmanship, under normal use and service for a period of 13 months from date of purchase. If the unit should malfunction, it must be returned to the factory for evaluation, freight prepaid. Upon examination by Geokon, if the unit is found to be defective, it will be repaired or replaced at no charge. However, the WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion or current, heat, moisture or vibration, improper specification, misapplication, misuse or other operating conditions outside of Geokon's control. Components which wear or which are damaged by misuse are not warranted. This includes fuses and batteries.

Geokon manufactures scientific instruments whose misuse is potentially dangerous. The instruments are intended to be installed and used only by qualified personnel. There are no warranties except as stated herein. There are no other warranties, expressed or implied, including but not limited to the implied warranties of merchantability and of fitness for a particular purpose. Geokon is not responsible for any damages or losses caused to other equipment, whether direct, indirect, incidental, special or consequential which the purchaser may experience as a result of the installation or use of the product. The buyer's sole remedy for any breach of this agreement by Geokon or any breach of any warranty by Geokon shall not exceed the purchase price paid by the purchaser to Geokon for the unit or units, or equipment directly affected by such breach. Under no circumstances will Geokon reimburse the claimant for loss incurred in removing and/or reinstalling equipment.

Every precaution for accuracy has been taken in the preparation of manuals and/or software, however, Geokon neither assumes responsibility for any omissions or errors that may appear nor assumes liability for any damages or losses that result from the use of the products in accordance with the information contained in the manual or software.

TABLE of CONTENTS

FIGURES

TABLES

EQUATIONS

1. INTRODUCTION

Geokon Resistance Rebar Strain Meters are designed primarily for monitoring the stresses in reinforcing steel in concrete structures, such as bridges, concrete piles, and diaphragm walls. The strain meter comprises a length of high strength steel on which electrical resistance strain gauges are bonded. Readout of load or stress is achieved remotely using a portable readout or datalogging system available from Geokon.

The Model 3911 (Figure 1) comprises lengths of Grade 60 rebar welded to a central section of high-strength steel to which four electrical resistance strain gauges are attached in a full Wheatstone Bridge circuit (two axial, two Poisson). It is designed to be wire tied in parallel with the structural rebar. The small diameter of the bar minimizes its affect on the sectional modulus of the concrete. The cable exits from the strain meter through a small gland of protective epoxy.

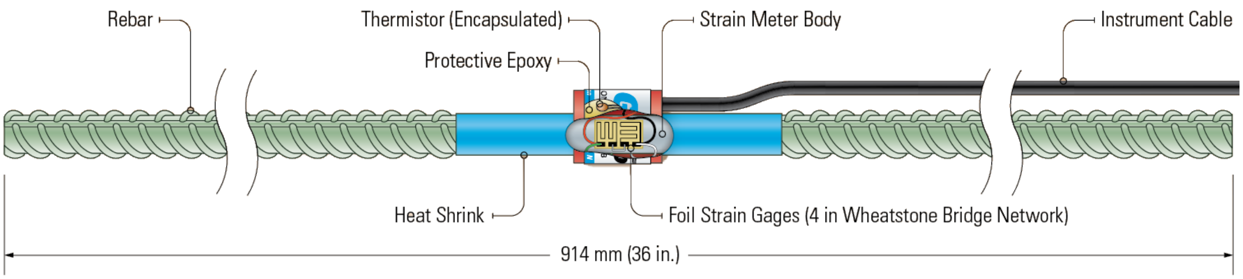


Figure 1 - Model 3911 Resistance Rebar Strain Meter

The Model 3911A (Figure 2) comprises of two lengths of Grade 60 rebar welded to a central section of high-strength steel to which four electrical resistance strain gauges are attached in a full Wheatstone Bridge circuit (two axial, two Poisson). It is designed to be welded between sections of structural concrete reinforcing bar. The cable exits from the strain meter through a small gland of protective epoxy.

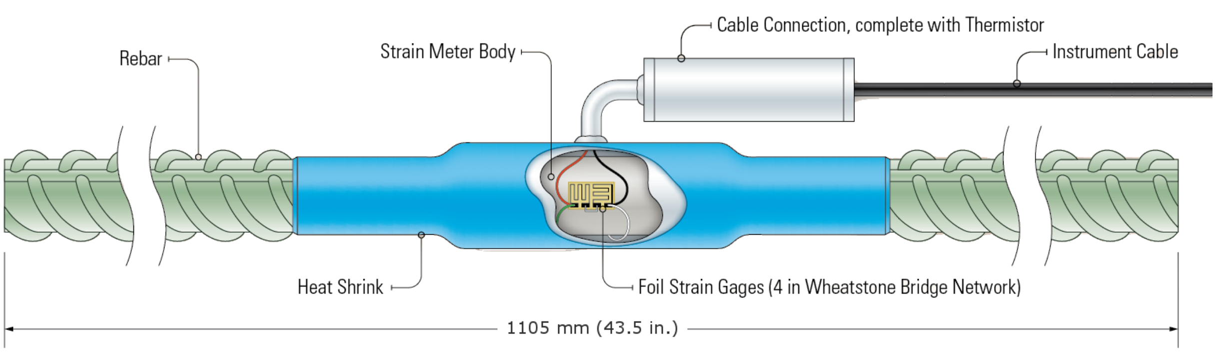


Figure 2 - Model 3911A Rebar Strain Meter

Both models of strain meters are robust, reliable, and easy to install and read, and are sealed against moisture. They can measure dynamic strain changes. Long cables (>100 m) may introduce cable effects and remote sense technologies may be advisable.

2. INSTALLATION

2.1 Preliminary Tests

A preliminary check should be performed before installing gauges in the field. To perform the preliminary check, complete the steps below.

Warning! Do not lift the strain meter by the cable.

1) Connect the gauge to a readout box. (See readout instructions in Section 3.) Observe the displayed readout.

2) Compare the zero reading given on the calibration report to the current zero reading. Under normal circumstances the two readings should not differ by more than 25 digits (10 microstrains), however, shocks incurred during shipping may cause larger shifts. If the reading is within 100 digits (40 microstrains) of the factory zero, and is stable, it is safe to proceed with the installation.

3) Pull on the strain meter ends; confirm that digits on the readout rise as the tension increases.

Checks of electrical continuity can be made using an ohmmeter. For the 3911A and 3911, resistance should be approximately 350 Ω between red and black and 350Ω between green and white plus the resistance of any cables attached. The resistance of 22 AWG stranded copper leads is approximately 14.7Ω per 1,000 feet (48.5Ω per km), multiply this factor by two to account for both directions.

Resistance between the blue and the black of blue leads varies with temperature. Using Table 4 in Appendix C, convert the resistance to temperature and compare the result to the ambient temperature.

Resistance between any conductor and the shield should exceed 10 megohms.

If the strain meter fails any of the preliminary tests, see Section 5 for troubleshooting.

2.2 Model 3911 "Sister Bar" Installation

The "Sister Bar" is usually installed using standard iron tie wire. Normally, ties near the ends and at the one-third points are enough if the gauge is being wired to a larger section of rebar or to horizontal bars. Wiring at the one-third points alone is enough if the gauge is being wired in parallel to the structural rebar. See Figure 3 and Figure 4 on the following page. Route the instrument cable along the rebar system and tie it off every three to four feet (one-meter) using nylon cable ties. Avoid using the tie wire on the instrument cable as it could cut the cable.

Be sure when installing the strain meters to note the location and serial numbers of all instruments. This is necessary for applying the proper calibration factors and determining load characteristics when reducing data.

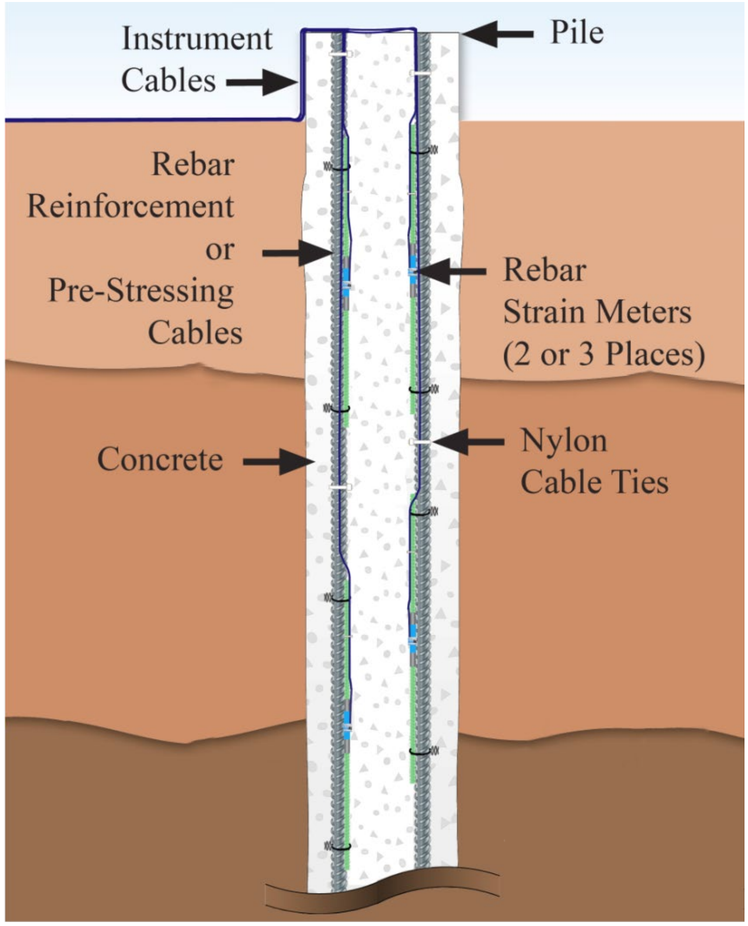


Figure 3 - Model 3911 Resistance "Sister Bar" Installation

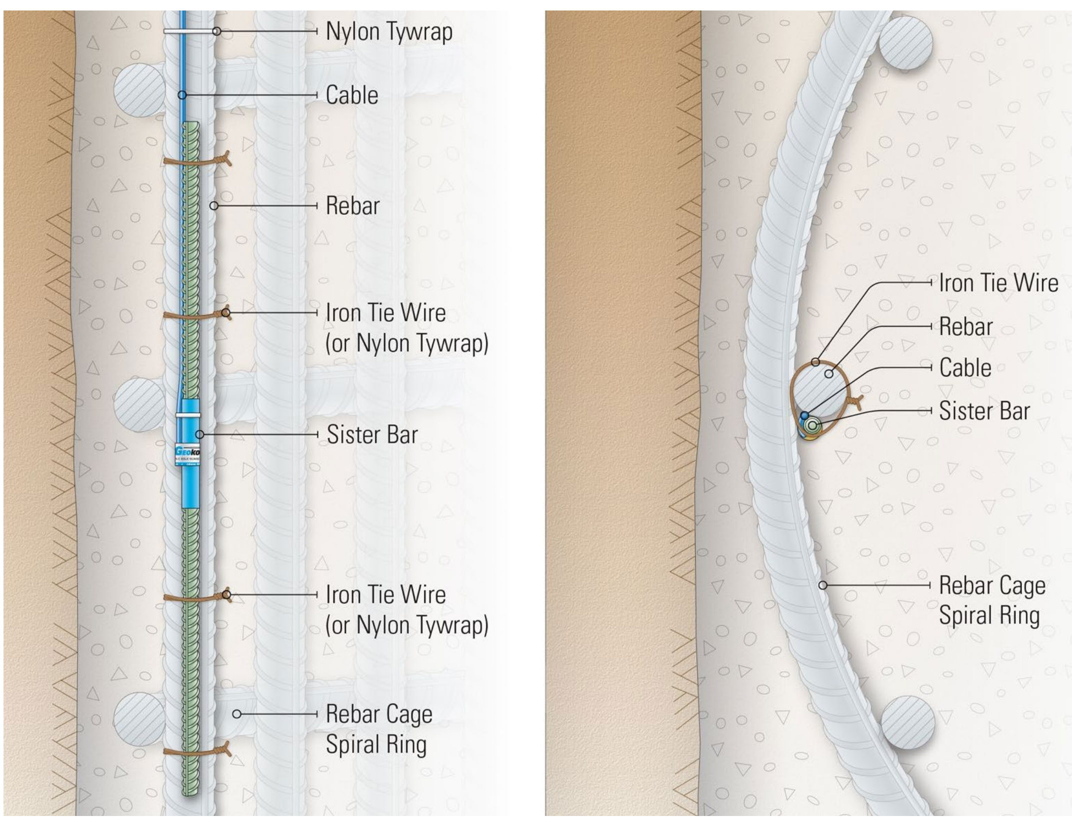


Figure 4 - Model 3911 Resistance "Sister Bar Installation Detail"

2.3 Model 3911A Installation

The normal procedure is to weld the strain meter in series with the reinforcing steel that is to be instrumented on the site. For a typical installation, see Figure 5 below. The strain meter is long enough that it may be welded in place without damaging the internal strain gauge element. However, care should still be taken to ensure that the central portion of the strain meter does not become too hot as the plucking coil and protective epoxy could melt. To prevent this, it may be necessary to place wet rags between the weld area and the coil housing. Also, take care not to damage or burn the instrument cable when welding. After welding, route the instrument cable along the rebar system and tie it off every three to four feet (one-meter) using nylon cable ties. Avoid using iron tie wire to secure the cable as the cable could be cut.

Be sure when installing the strain meters to note the location and serial numbers of all instruments. This is necessary for applying the proper calibration factors and determining strain characteristics when reducing data.

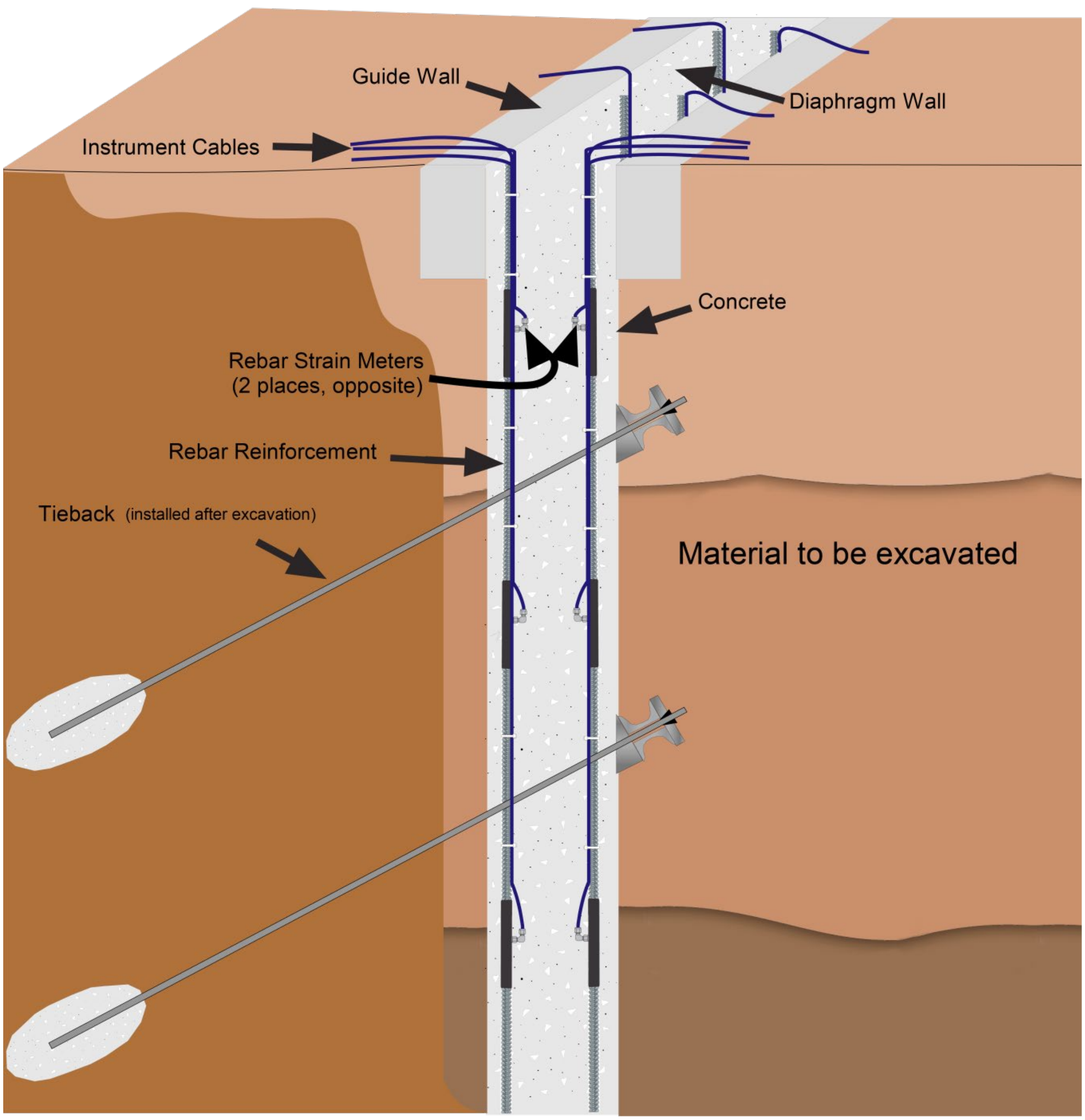


Figure 5 - Model 3911A Installation

2.4 Cable Splicing and Termination

Terminal boxes with sealed cable entries are available from Geokon for all types of applications. These allow many gauges to be terminated at one location with complete protection of the lead wires. The interior panel of the terminal box can have built-in jacks or a single connection with a rotary position selector switch. Contact Geokon for specific application information.

Because the vibrating wire output signal is a frequency rather than a current or voltage, variations in cable resistance have little effect on gauge readings; therefore, splicing of cables has no ill effects, and in some cases may in fact be beneficial. The cable used for making splices should be a high-quality twisted pair type, with 100% shielding and an integral shield drain wire. **When splicing, it is very important that the shield drain wires be spliced together.** Always maintain polarity by connecting color to color.

Splice kits recommended by Geokon incorporate casts that are placed around the splice and are then filled with epoxy to waterproof the connections. When properly made, this type of splice is equal or superior to the cable in strength and electrical properties. Contact Geokon for splicing materials and additional cable splicing instructions.

Cables may be terminated by stripping and tinning the individual conductors and then connecting them to the patch cord of a readout box. Alternatively, a connector may be used which will plug directly into the readout box or to a receptacle on a special patch cord.

The cable from the strain meters can also be protected using flexible conduit, which can be supplied by Geokon.

3. TAKING READINGS

3.1 Using the GK-502 Readout Box

The user is referred to the GK-502 Instruction Manual for additional information on the following instructions:

1. Connect the strain meter to the readout box by means of the 10-pin input connector.
2. Press the ON/OFF button to the "ON" position.
3. Press the UNITS button and select mV/V.
4. Read the display and record.
5. See the GK-502 Instruction Manual for further instructions.

3.2 Using the Micro-Measurements P3 Readout Box

Connect the strain meter to the readout using either the 10-pin input connector or by connecting the bare leads to the connector marked S+, S-, P+, P-, using the tags on the cable leads as a guide or the color code Red to P+, Black to P-, Green to S+, White to S-. Connect the cable shield to the connector marked "ground" on the readout box.

Switch the P3 Readout Box to the following settings:

a) Switch "Bridg Type" to "FB v opp".
b) Set "Gauge Factor/Scaling" units to mV/V.
c) Disable the balance control.
d) Press the "Run" button and read the display reading.

3.3 Using a Millivoltmeter and DC Power Supply

If the gauge is excited by a regulated DC power supply (12-30 VDC) and the output measured by a voltmeter then readings obtained with the voltmeter are used in conjunction with the gauge factor given in microstrain/mv/v. **Wiring is Red to P+, Black to P-, Green to S+, White to S-.**

If a regulated power supply and a millivoltmeter are used, then calculate the mV/V by dividing the displayed millivolt output by the input voltage input measured.

3.4 Wiring Diagram for Remote Sense and Thermistor

For added accuracy, it is advisable to use a 'remote' sensing technique, which measures the voltage output of the Wheatstone bridge at the bridge, rather than at the readout location. This eliminates any errors caused by voltage drops in the cable; it does require another pair of conductors. If also the thermal effects need to be accounted for, then use a thermistor, encapsulated inside the sensor and connected to another pair of conductors. The wiring diagram for this configuration is shown in Table 1 on the following page.

GEOKON CABLE	INTERNAL WIRING	FUNCTION	10-PIN DESIGNATION
BLACK OF WHITE	WHITE	S-	A
RED	RED	P+	B
BLACK OF RED	BLACK	P-	C
WHITE	GREEN	S+	D
N/C	N/C	N/C	E
SHIELDS (5)	N/C	GROUND	F
BLUE	N/C	THERM	G
BLACK OF BLUE	N/C	THERM	H
GREEN	RED	RS+	J
BLACK OF GREEN	BLACK	RS-	K

Table 1 - Wiring Diagram for Remote Sense with Thermistor

4. DATA REDUCTION

4.1 Strain Calculation

The basic units utilized by Geokon for measurement and reduction of data from resistance Type Rebar Strain Meters are "mV/V".
To convert digits to strain the following equation applies:

$$\varepsilon_{uncorrected} = (R_1 - R_0) \times C$$

Equation 1 - Strain Calculation

Where;
R_0 is the initial reading in mV/V, usually obtained at installation.
R_1 is the current reading in mV/V.
C is the Gauge factor from the supplied calibration report (see Appendix D for a sample calibration report).

For example, using the GK-502 readout box set to read mV/V and assuming an initial reading, R_0, of 0.693 mV/V, a current reading, R_1, of 0.830 mV/V, and a calibration factor, G, of 755.44 microstrains per mV/V.

$$\varepsilon_{uncorrected} = (0.693 - 0.830) \times -755.44 = -103.5\ \mu\varepsilon \text{ (compression)}$$

Using a 12-volt excitation supply, if the initial output (R_0) is 8.307 mV and R_1 = 9.960 mV, then microstrain = (9.960 – 8.316) x –755.44/12 = -103.5 με (compression)

4.2 Temperature Correction

Rebar strain meters are usually embedded in concrete and strained by the concrete, the assumption being that the strain in the meter is equal to the strain in the concrete. When the temperature changes the concrete expands and contracts at a rate slightly less than the rate of the steel of the vibrating wire. The coefficients of expansion are:

Steel:	12.2 ppm/°C	6.7 ppm/°F
Concrete:	≈10 ppm/°C	≈5.5 ppm/°F
Difference (K):	2.2 ppm/°C	1.2 ppm/°F

Table 2 - Thermal Coefficients

A correction is required to the observed strains equal to the difference of these two coefficients, shown in Equation 2.

$$\varepsilon_{corrected} = ((R_1 - R_0) \times G) + ((T_1 - T_0) \times K)$$

Equation 2 - Thermally Corrected Strain Calculation

Where;
T_0 is the initial temperature recorded at the time of installation.

T_1 is the current temperature.
K is the thermal coefficient from Table 2.

4.3 Environmental Factors

Since the purpose of the strain meter installation is to monitor site conditions, factors which may affect these conditions should be observed and recorded. Seemingly minor effects may have a real influence on the behavior of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to, blasting, rainfall, tidal or reservoir levels, excavation and fill levels and sequences, traffic, temperature and barometric changes, changes in personnel, nearby construction activities, seasonal changes, etc.

5. TROUBLESHOOTING

Maintenance and troubleshooting of Resistance Type Rebar Strain Meters are confined to periodic checks of cable connections. Once installed, the meters are usually inaccessible and remedial action is limited.

Consult the following list of problems and possible solutions should difficulties arise. Consult the factory for additional troubleshooting help.

Symptom: Thermistor resistance is too high:

- ✓ Is there an open circuit? Check all connections, terminals, and plugs. If a cut is located in the cable, splice according to instructions in Section 2.4.

Symptom: Thermistor resistance is too low:

- ✓ Is there a short? Check all connections, terminals, and plugs. If a short is located in the cable, splice according to instructions in Section 2.4.

- ✓ Water may have penetrated the interior of the tilt sensor. There is no remedial action.

Symptom: Strain Meter Readings are Unstable

- ✓ Is the readout box position set correctly?

- ✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, and antennas. Make sure the shield drain wire is connected to ground whether using a portable readout or datalogger.

- ✓ Does the readout work with another strain meter? If not, the readout may have a low battery or be malfunctioning.

Symptom: Strain Meter Fails to Read

- ✓ Is the cable cut or crushed? This can be checked with an ohmmeter. For the 3911A and 3911, nominal resistance between the red and black or green and white leads is 350Ω. Remember to add cable resistance when checking. Cable resistance is approximately 14.7Ω per 1000 feet (48.5Ω per km) of 22 AWG wire. Multiply this factor by two to account for both directions. If the resistance reads infinite or very high (megohms), a cut wire must be suspected. If the resistance reads very low, a short in the cable is likely.

- ✓ Does the readout or datalogger work with another strain meter? If not, the readout or datalogger may be malfunctioning.

APPENDIX A. SPECIFICATIONS

A.1 Resistance Type Rebar Strain Meters

Model:	3911 "Sister Bar"	3911A
Range:	3000 με	
Rebar Sizes Available:	#4	#5, #6, #7, #8, #9, #10, #11
Sensitivity:	0.025% FSR	
Accuracy:	0.25% FSR	
Linearity:	0.25% FSR	
Operating Temperature:	-20 to +80° C -4 to 175° F	
Young's Modulus:	207 GPa (30 x 10^6 psi)	
Circuit Resistance:	350 Ω	
Length:	914 mm (36")	1105 mm (43.5")
Materials:	Grade 60 Rebar and High Strength Steel	
Electrical Cable:	Two twisted pair (four conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250")	

Table 3 - Model 3911A/3911 Strain Meter Specifications

Notes:
[1] The number, N, designates the size, i.e., the diameter = N/8 inches. For example: #6 rebar = 6/8 inches = ¾ inch diameter.

A.2 Thermistor
(See Appendix C also.)

Range: -80 to +150° C
Accuracy: ±0.5° C

APPENDIX B. LOAD CALCULATIONS

To calculate loads in the rebar: Multiply the strain by the Young's Modulus, and by the cross-sectional area of the rebar. Loads in the surrounding concrete will depend on the modulus and cross-sectional area of the concrete. The strain in the concrete is the same as the strain in the rebar.

APPENDIX C. THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3
Resistance to Temperature Equation:

$$T=\frac{1}{A+B(\mathrm{LnR})+C(\mathrm{LnR})^3}-273.15\ °C$$

Equation 3 - Resistance to Temperature

Where;
T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance
$A = 1.4051 \times 10^{-3}$
$B = 2.369 \times 10^{-4}$
$C = 1.019 \times 10^{-7}$
Note: Coefficients calculated over the −50 to +150° C. span.

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	141.1	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
77.66K	-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	-34	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	292.4	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	5692	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	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	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

Table 4 - Thermistor Resistance Versus Temperature

APPENDIX D. SAMPLE CALIBRATION REPORT

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report (resistance element)

Model Number : 3911-4

Date of Calibration: January 10, 2018

Serial Number: 1748745

Cable Length: 8 meters

Temperature: 23.2 °C

Regression Zero: 1508

Calibration Instruction: CI-VW Rebar

Technician:

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	1407.4	1402.1	1404.8		
1500	83.865	83.865	83.9	-1321	-0.11
3000	-1341.8	-1341.8	-1341.8	-1426	-0.19
4500	-2783.3	-2785.9	-2784.6	-1443	0.03
6000	-4216.8	-4216.8	-4216.8	-1432	0.06
100	1402.1				

Gage Factor: -0.1779 με / digit (GK-501) **-711.49 με /mV / V**

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

Figure 6 - Sample Model 3911 Calibration Report