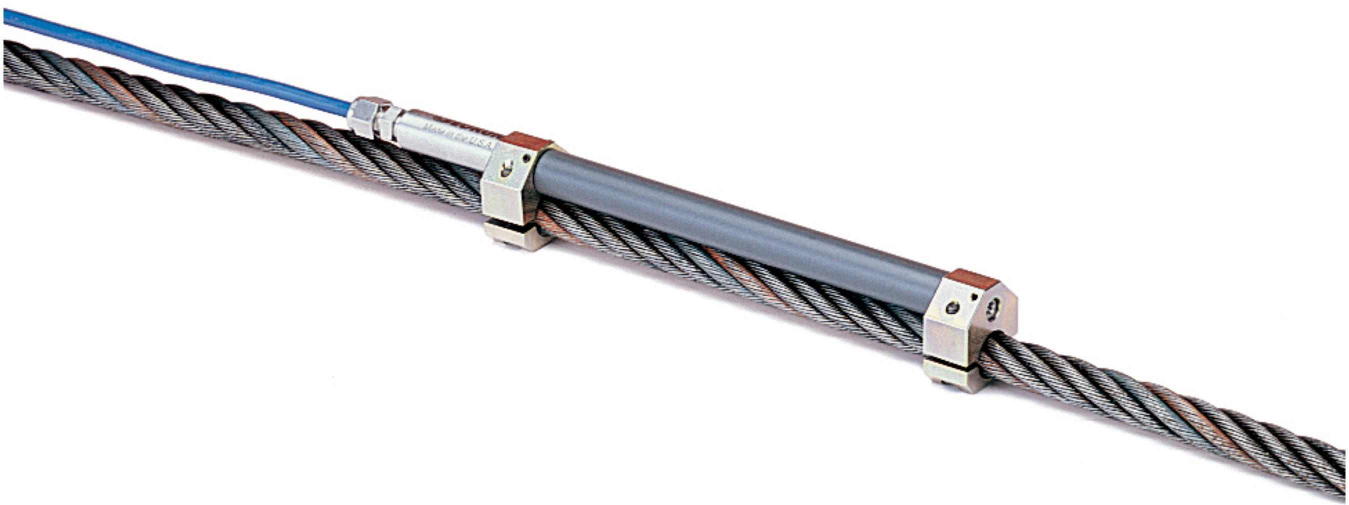
Model 4410

Vibrating Wire Strandmeter

Instruction Manual



GEOKON®

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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 that wear or are damaged by misuse are not warranted. This includes fuses and batteries.

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1. INTRODUCTION

The GEOKON 4410 Vibrating Wire Strandmeter is designed to measure change in deformation in wire strands such as those that are commonly used in tiebacks and earth anchors.

The sensor consists of a vibrating wire sensing element in series with a heat treated, stress relieved spring which is connected to the wire at one end and a connecting rod at the other. The unit is fully sealed and operates at pressures of up to 250 psi. As the connecting rod is pulled out from the sensor body, the spring is elongated causing an increase in tension, which is sensed by the vibrating wire element. The tension in the wire is directly proportional to the extension; hence, the change in deformation can be determined very accurately by measuring the strain change with the vibrating wire readout box.

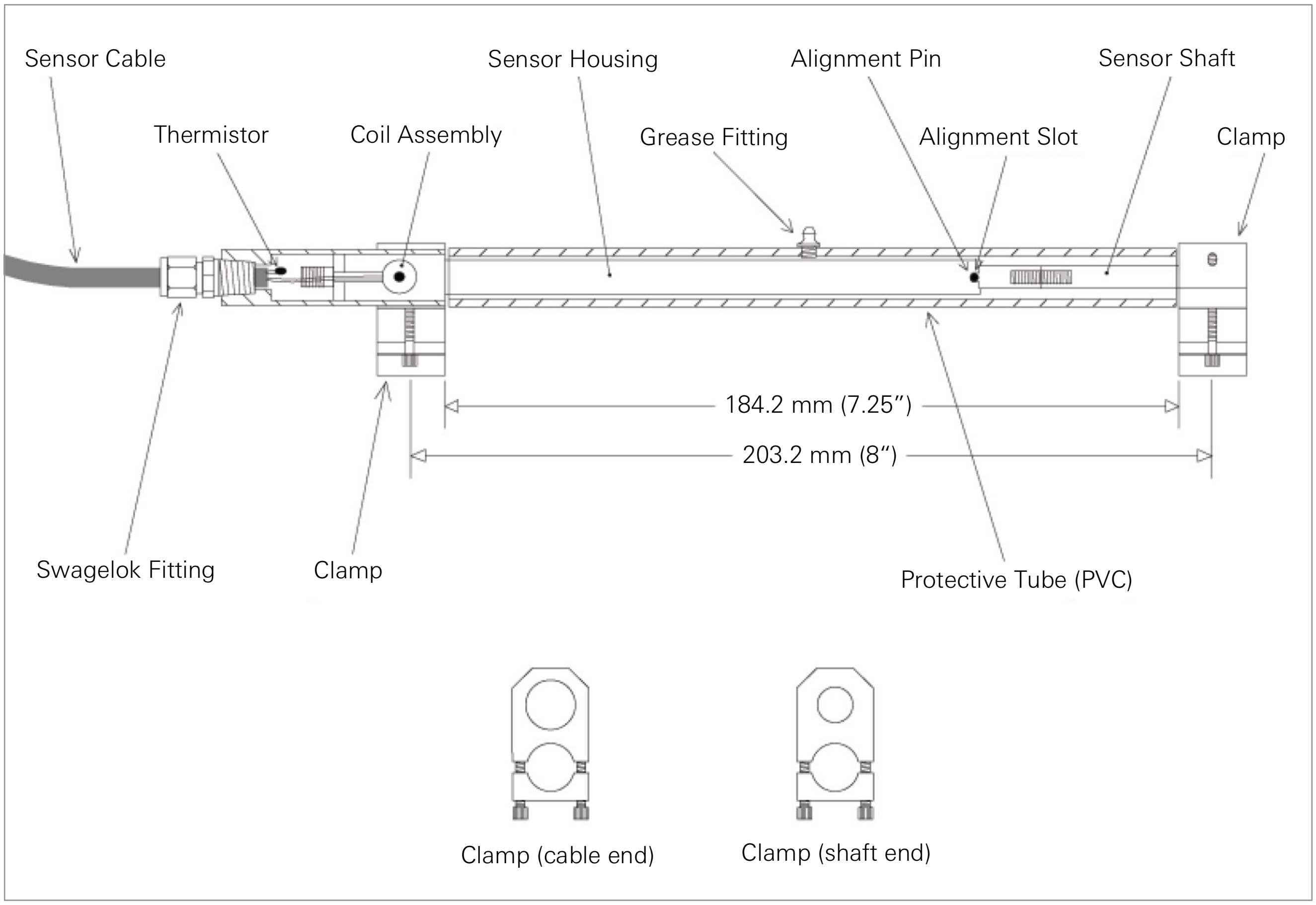

FIGURE 1: *Model 4410 Vibrating Wire Strandmeter*

2. PRIOR TO INSTALLATION

2.1 PRELIMINARY TESTS

GEOKON recommends that each sensor is function tested before installing in the field. To perform this preliminary check complete the following steps:

1. Connect the sensor to a readout. This could be a portable, handheld readout or the system that will be used in the final installation.
2. The sensor should have a strong, stable signal. When the shaft of the sensor is pulled, the frequency or digits should increase. When retracted into the sensor housing, the readings should decrease. The temperature reading should match the ambient temperature.

Important! Do not extend the shaft so that the full range of the sensor as indicted in the supplied calibration sheet is exceeded.

3. Check electrical continuity using an ohmmeter. Resistance between the sensor leads (usually red and black) should be approximately 150 ohms. Remember to add cable resistance, which is approximately 48.5Ω per km (14.7Ω per 1000 feet) of 22 AWG stranded copper leads at 20 °C. Multiply this factor by two to account for both directions. Resistance between thermistor leads (usually green and white) will vary based on temperature (see Appendix B). Resistance between any conductor and the shield should exceed two megaohms.

Should any of these preliminary tests fail, see Section 6 for troubleshooting tips.

3. INSTALLATION

3.1 SENSOR INSTALLATION

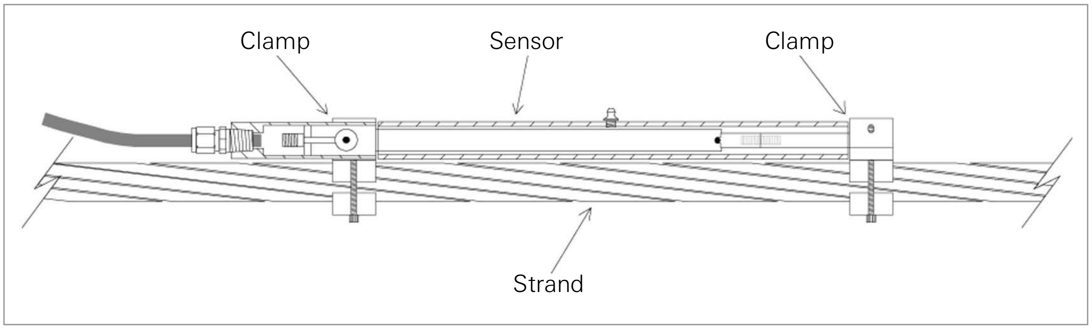

FIGURE 2: *Model 4410 Strandmeter Installation*

Note: References to the PVC grease tube in the following instructions are for strandmeters used on strands that are to be embedded in concrete. For strands out in the open, the grease tube may be omitted.

Sensor installation is as follows:

1. Unbolt and separate the two halves of the clamps.
2. Slide the upper half of the clamp with the large hole around the strand meter so that the coil housing sits up against the shoulder in the clamp recess.
3. Slide the PVC grease tube over the strandmeter and then the upper half of the clamp with the small hole over the shaft end of the strandmeter.
4. Place the assembly down so that the bottoms of the two clamps sit on a flat surface.
5. Take the spacer bar and position it between the clamps. Make sure that the coil housing is against the shoulder in the clamp, snug the two clamps up to the spacer bar.
6. Tighten the four 6-32 set screws holding the strandmeter to the two clamps.

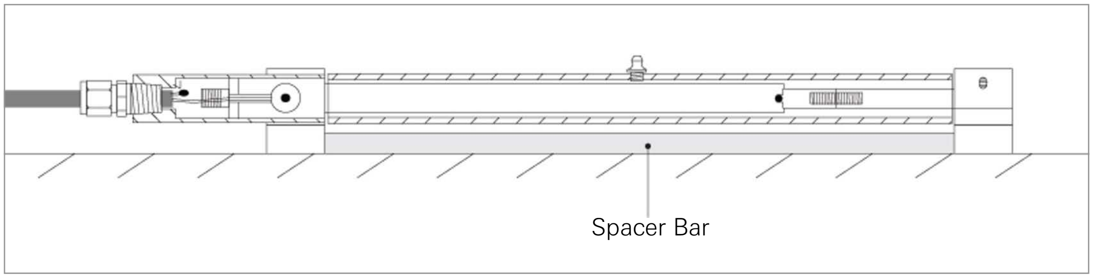

FIGURE 3: *Spacer Bar Position*

7. Remove the spacer bar and place the assembly in the correct location over the strand.
8. Tighten the lower half of the clamps onto the strand using the four cap screws.
9. Set the zero reading of the sensor by completing the following:
   a. Loosen the two 6-32 set screws that hold the clamp to the strandmeter shaft.
   b. Insert a 10-32 screw (supplied) into the end of the shaft that comes through the clamp.
   c. Connect the sensor leads to the readout box and switch to position 'B'.
   d. While watching the reading on the readout, gently pull on the 10-32 screw until an increasing reading is seen. Do not allow the reading to reach 8000.

e. While holding the reading between 2500-4000 (3000 is recommended), tighten the two 6-32 set screws using the Allen wrench provided. Tighten them down hard, so that the sensor will not move.

f. Tighten the 6-32 set screws on the other clamp as well.

10. For strands that are to be embedded in concrete, fill the PVC tube with grease. A 1/4-28 threaded hole (Figure 1) is provided which will accept a standard grease fitting. Screw the fitting into the hole, fill with grease, and then remove the fitting.
11. For embedded strandmeters, it is necessary to provide the clamps with a bond breaker. Using the Aqua-Seal provided, place a layer over the clamp areas on both ends followed by an overall layer of electrical tape. The purpose of this is to isolate the sensor from stresses other than those imposed by the tendon.
12. Initial readings must be taken and carefully recorded along with the temperature at the time of installation. These readings serve as a reference for subsequent deformation calculations.

3.2 CABLE SPLICING AND TERMINATION

Because the vibrating wire output signal is a frequency rather than a current or voltage, cable splicing has no ill effects. The cable used for making splices should be a high-quality twisted pair type, with 100% shielding and an integral shield drain wire. **It is very important that the shield drain wires be spliced together.** Always maintain polarity when possible 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.

3.3 PROTECTION FROM ELECTRICAL NOISE

Install sensor cables as far away as possible from sources of electrical interference such as power lines, generators, motors, transformers, arc welders, etc. Cables should never be buried or run with AC power lines. Doing so will cause the sensor cables to pick up the frequency noise from the power cable, and this will likely make obtaining a stable reading difficult.

3.4 LIGHTNING PROTECTION

In settings where lightning strikes are a concern, GEOKON offers the Model 4999-12L/LE Surge Protection Module:

FIGURE 4: *Model 4999-12L/LE*

Model 4999-12L/LE Manual

The module features replaceable surge protection circuitry in the event that it is damaged by a lightning strike. The Module is installed between a sensor and the datalogger or terminal box it is connected to. Consult GEOKON and the Model 4999-12L/LE Instruction Manual for additional information.

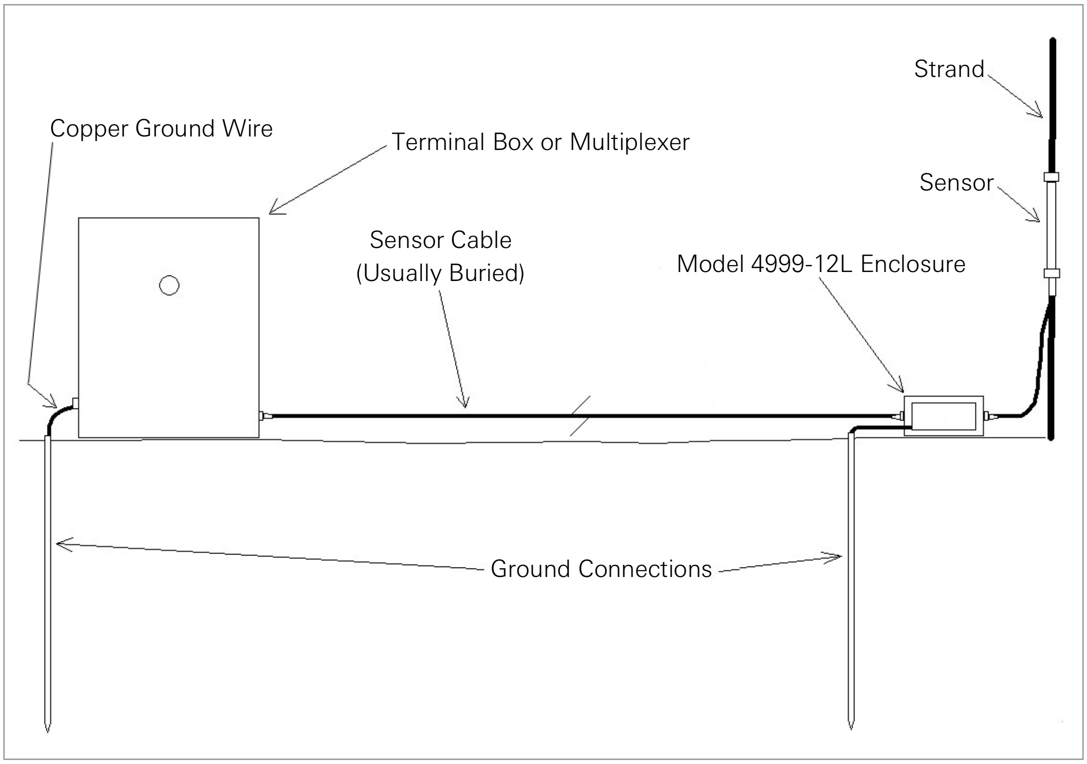

FIGURE 5: *Lightning Protection Scheme*

4. TAKING READINGS

4.1 COMPATIBLE READOUTS AND DATALOGGERS

The most important reading is the first reading; it is the base reading to which all subsequent readings will be compared. Conditions should be noted at the time of all readings, especially during curing, e.g., temperature, time after placement, local conditions, etc.

GEOKON can provide several readout and datalogger options. Devices compatible with this product are listed below. For further details and instruction consult the corresponding Manual(s) at geokon.com/Readouts and geokon.com/Dataloggers.

Readouts

DIGITAL READOUTS:

■ **GK-404**

The Model GK-404 VW Readout is a portable, low-power, hand-held unit capable of running for more than 20 hours continuously on two AA batteries. It is designed for the readout of all GEOKON Vibrating Wire (VW) instruments, and is capable of displaying the reading in digits, frequency (Hz), period (µs), or microstrain (µε). The GK-404 displays the temperature of the transducer (embedded thermistor) with a resolution of 0.1 °C.

■ **GK-406**

The Model GK-406 is a field-ready device able to quickly measure a sensor, save data, and communicate results with custom PDF reports and spreadsheet output. Measurements are geo-located with the integrated GPS allowing the GK-406 to verify locations and lead the user to the sensor locations. The large color display and VSPECT™ technology create confidence of getting the best measurement possible both in the field and in the office.

Dataloggers

DATALOGGERS:

■ **8600 Series**

The MICRO-6000 Datalogger is designed to support the reading of a large number of GEOKON instruments for various unattended data collection applications through the use of GEOKON Model 8032 Multiplexers. Weatherproof packaging allows the unit to be installed in field environments where inhospitable conditions prevail. The Nema 4X enclosure also has a provision for locking to limit access to responsible field personnel.

■ **GeoNet Series**

The GeoNet series is designed to collect and transfer data from vibrating wire, RS-485, and analog instruments. GeoNet offers a wide range of telemetry options, including LoRa, cellular, Wi-fi, satellite, and local. Loggers can work together to operate in a network configuration, or be used separately as standalone units. GeoNet devices arrive from the factory ready for deployment and may commence with data acquisition in minutes.

Data is transferred to a secure cloud-based storage platform where it can be accessed through the GEOKON OpenAPI. Industry leading data visualization software, such as the free GEOKON Agent Software, can be used with the OpenAPI for data viewing and reporting. Dataloggers without network capabilities are also available.

4.2 MODEL 4999 TERMINAL BOXES

Terminal boxes with sealed cable entries are available from GEOKON. These allow many sensors 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.

Terminal Boxes make it easy to manually connect a Readout Box (GK-404 or GK-406). The rotary switch is used to select which “channel” or sensor is being read by the Readout Box.

Model 4999 Manual

For further details and instruction consult the Model 4999 Instruction Manual.

4.3 MEASURING TEMPERATURES

All GEOKON vibrating wire sensors are equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. The white and green leads of the sensor cable are normally connected to the internal thermistor. The GK-404 and GK-406 readouts will read the thermistor and display the temperature in degrees Celsius.

USING AN OHMMETER TO READ TEMPERATURES:

Connect an ohmmeter to the green and white thermistor leads coming from the sensor. Since the resistance changes with temperature are large, the effect of cable resistance is usually insignificant. For long cables a correction can be applied equal to approximately 48.5Ω per km (14.7Ω per 1000') at 20 °C. Multiply these factors by two to account for both directions.

Look up the temperature for the measured resistance in Appendix B.

5. DATA REDUCTION

5.1 DATA CALCULATION

The basic units utilized by GEOKON for measurement and reduction of data from this sensor are digits. The calculation of digits is based on the following equation:

$$\text{digits} = \left(\frac{1}{\text{Period}}\right)^2 \times 10^{-3} \quad \text{or} \quad \text{digits} = \frac{\text{Hz}^2}{1000}$$

EQUATION 1: *Digits Calculation*

In typical installations the linear calculation is more than sufficient. However, if utmost accuracy is desired, the polynomial calculation can be used. Refer to the applicable section below.

5.1.1 LINEAR CALCULATION

To convert digits to deformation the following equation applies:

$$D = G(R_1 - R_0)$$

EQUATION 2: *Linear Deformation Calculation*

Where:
G = The gauge factor found on the calibration report, usually in terms of millimeters or inches per digit.

R_1 = The current reading in digits.
R_0 = The initial field zero reading in digits.

EXAMPLE:

The initial reading (R_0) at installation of a sensor is 4200 digits. The current reading (R_1) is 5000 digits. The calibration factor (G) is 0.0008495 mm/digit. The displacement change is:

$$D = (5000 - 4200) \times 0.0008495$$

$$D = 0.6796 \text{ mm}$$

Note that increasing (positive) readings indicate increasing extension.

5.1.2 POLYNOMIAL CALCULATION

To convert digits to deformation using the polynomial expression the following equation applies:

$$D = AR_1^{\,2} + BR_1 + C$$

EQUATION 3: *Polynomial Deformation Calculation*

Where:
R_1 = The current reading in digits.
A, B = The polynomial gauge factors found on the calibration report.
C = The polynomial gauge factor that needs to be calculated (see below).

To perform the polynomial calculation, gauge factor “C” must be calculated first. This is done by using the equation above, but replacing “D” with a value of zero, and “R_1” with the value of “R_0”.

$$0 = AR_0^2 + BR_0 + C$$

EQUATION 4: *Calculation for Polynomial Gauge Factor “C”*

Where:
R_0 = The initial field zero reading in digits.
A, B = The polynomial gauge factors found on the calibration report.

The calculated “C” can then be used in Equation 3 to find the precise value of displacement (D).

EXAMPLE:

The given polynomial gauge factors on the calibration are:

A = 8.9722E^{-10}

B = 0.0008409

The initial reading (R_0) at installation of a sensor is 4200 digits. The current reading (R_1) is 5000 digits.

First, the gauge factor “C” must be calculated:

$$0 = AR_0^2 + BR_0 + C$$

$$0 = 8.9722\times10^{-10} \times 4200^2 + 0.0008409 \times 4200 + C$$

$$0 = 3.5476 + C$$

$$C = -3.5476$$

The displacement change is:

$$D = AR_1^2 + BR_1 + C$$

$$D = 8.9722\times10^{-10} \times 5000^2 + 0.0008409 \times 5000 + (-3.5476)$$

$$D = 0.6793 \text{ mm}$$

Note that increasing (positive) readings indicate increasing extension.

5.2 USING THE DATA TO CALCULATE STRAIN

The gauge length of the standard strand meter is 203.2 mm, (eight inches). The strain in microstrain μ is given by the equations below. These equations use the calculated deformation (D) from Equation 2 or Equation 3.

Where deformation is in mm:

$$\mu = \left(\frac{D}{203.2}\right) \times 10^6 \text{ microstrain}$$

EQUATION 5: *Strand Calculation in Millimeters*

Where deformation is in inches:

$$\mu = \left(\frac{D}{8}\right) \times 10^6 \text{ microstrain}$$

EQUATION 6: *Strand Calculation in Inches*

5.3 OPTIONAL CALCULATIONS

5.3.1 TEMPERATURE CORRECTION

The sensor has a very small coefficient of thermal expansion so in most cases correction is not necessary. However, if maximum accuracy is desired or the temperature changes are extreme (>10° C) corrections may be applied. By correcting the sensor for temperature changes the deformation of the mass may be distinguished. The following thermal correction equation is performed, then afterwards is added to the deformation calculation (Equation 2 or Equation 3):

$$T_{Correction} = K(T_1 - T_0)$$

EQUATION 7: *Thermal Correction for Displacement*

Where:
K = The thermal factor that needs to be calculated (see below).

T_1 = The current temperature reading in °C.
T_0 = The initial field temperature reading in °C.

Tests have determined that the thermal coefficient "K" changes with the position of the sensor shaft. Hence, the first step in the temperature correction process is determination of the proper thermal coefficient based on the following equation:

$$K = ((R_1 \times 0.000520) + 3.567) \times G$$

EQUATION 8: *Calculation for Thermal Factor "K"*

Where:
R_1 = The current readings in digits.
G = The gauge factor found on the calibration report, usually in terms of millimeters or inches per digit.

EXAMPLE:

T_0 = 20.3 °C.

T_1 = 32.9 °C.

R_1 = 5000 digits

G = 0.0008495 mm/digit

First, calculate the thermal coefficient (K):

$$K = ((R_1 \times 0.000520) + 3.567) \times G$$

$$K = ((5000 \times 0.000520) + 3.567) \times 0.0008495 = 0.0052$$

Calculate the thermal correction:

$$T_{Correction} = K(T_1 - T_0)$$

$$T_{Correction} = 0.0052(32.9 - 20.3) = 0.0655$$

Add this value to the displacement calculated using Equation 2 or Equation 3 to find the thermal corrected displacement.

The temperature coefficient of the strand to which the sensor is attached should also be taken into account. Use the temperature coefficient of the strand, combined with the changes in temperature from initial to current readings, to determine thermal effects of the strand.

5.3.2 ENGINEERING UNITS CONVERSION

To convert to a different engineering unit, take the result from data calculation (after other optional calculations have been completed, if applicable) and multiply it by the appropriate conversion multiplier from Table 1.

		CONVERT FROM				
		Inches	**Feet**	**Millimeters**	**Centimeters**	**Meters**
CONVERT TO	**Inches**	1	12	0.03937	0.3937	39.37
	Feet	0.0833	1	0.003281	0.03281	3.281
	Millimeters	25.4	304.8	1	10	1000
	Centimeters	2.54	30.48	0.10	1	100
	Meters	0.0254	0.3048	0.001	0.01	1

TABLE 1: *Engineering Units Conversion Multipliers*

5.4 ENVIRONMENTAL FACTORS

Since the purpose of the installation is to monitor site conditions, factors which may affect these conditions should always 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 levels, excavation and fill levels and sequences, traffic, temperature and barometric changes, changes in personnel, nearby construction activities, seasonal changes, etc.

6. TROUBLESHOOTING

Technical Support

Maintenance and troubleshooting is confined to periodic checks of cable connections and maintenance of terminals. Once installed, the sensor is usually inaccessible and remedial action is limited.

Should difficulties arise, consult the following list of problems and possible solutions. For additional troubleshooting and support visit geokon.com/Technical-Support.

SYMPTOM: THERMISTOR RESISTANCE IS TOO HIGH

- ☐ Check for an open circuit. Check all connections, terminals, and plugs. If a cut is in the cable, splice according to instructions in Section 3.2.

SYMPTOM: THERMISTOR RESISTANCE IS TOO LOW

- ☐ Check for a short circuit. Check all connections, terminals, and plugs. If a short is in the cable, splice according to instructions in Section 3.2.
- ☐ Water may have penetrated the interior of the sensor. There is no remedial action.

SYMPTOM: SENSOR READING UNSTABLE

- ☐ Make sure the shield drain wire is connected to the blue clip on the flying leads.
- ☐ Isolate the readout from the ground by placing it on a piece of wood or another insulator.
- ☐ Check for sources of nearby electrical noise such as motors, generators, antennas, or electrical cables. Move the sensor cable away from these sources if possible. Contact the factory for available filtering and shielding equipment.
- ☐ The sensor may have been damaged by over-ranging or shock. Inspect for damage.
- ☐ The body of the sensor may be shorted to the shield. Check the resistance between the shield drain wire and the sensor housing. If the resistance is very low, the sensor conductors may be shorted.
- ☐ Is the readout box position set correctly? If using a datalogger to record readings automatically, are the swept frequency excitation settings correct?
- ☐ The sensor shaft may be positioned outside the specified range (either extension or retraction). When the shaft is fully retracted with the alignment pin inside the alignment slot, the readings will likely be unstable because the vibrating wire is under-tensioned.
- ☐ Check the readout with another sensor to ensure it is functioning properly.

SYMPTOM: SENSOR FAILS TO GIVE A READING

- ☐ Check the readout with another sensor to ensure it is functioning properly.
- ☐ The sensor may have been damaged by over-ranging or shock. Inspect for damage.
- ☐ Check the resistance of the cable by connecting an ohmmeter to the sensor leads. Cable resistance is about 48.5Ω per km (14.7Ω per 1000'). If the resistance is very high or infinite, the cable is probably broken. If the resistance is very low, the sensor conductors may be shorted. If a break or a short is present, splice according to the instructions in Section 4.1. Refer to the expected resistance for the various wire combinations below.

  Vibrating Wire Sensor Lead Resistance Levels

  Red/Black Coil Resistance: ≅150Ω

  Green/White 3000Ω at 25 °C

  Any other wire combination will result in a measurement of infinite resistance.

Note: Tests should be performed with a quality multimeter to accurately show possibilities of shorts. Sensors should be disconnected from other equipment while performing resistance tests, this includes surge modules, terminals, multiplexers and dataloggers. Fingers cannot be touching the multimeter leads or sensor wires while testing.

Table 2 shows the expected resistance for the various wire combinations.

Table 3 is provided for the customer to fill in the actual resistance found.

Vibrating Wire Sensor Lead Grid - SAMPLE VALUES					
	Red	**Black**	**White**	**Green**	**Shield**
Red					
Black	≅150Ω				
White	Infinite	Infinite			
Green	Infinite	Infinite	3000Ω at 25°C		
Shield	Infinite	Infinite	Infinite	Infinite	

TABLE 2: *Sample Resistance*

Vibrating Wire Sensor Lead Grid - SENSOR NAME/##					
	Red	**Black**	**White**	**Green**	**Shield**
Red					
Black					
White					
Green					
Shield					

TABLE 3: *Resistance Worksheet*

APPENDIX A. SPECIFICATIONS

A.1 MODEL 4410 SPECIFICATIONS

Range[1]	3 mm (0.125", 15,000 $\mu\varepsilon$)
Resolution[2]	< 5 $\mu\varepsilon$
Linearity	±0.5% F.S.
Accuracy[3]	0.1% F.S.
Thermal Zero Shift	< 0.05% F.S./°C
Stability	< 0.2%/yr (under static conditions)
Overrange	115% F.S.
Temperature Range	Standard: -20 to +80 °C
Frequency Range	1400 - 3500 Hz
Coil Resistance	Standard: 150 Ω, ±10Ω
Cable Type[4]	Two twisted pair (four conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250")
Length	Sensor: 203 mm (8") Clamp Width: 45 mm (1.8")
Weight (With Clamps)	0.5 kg (1.1 lb)

TABLE 4: *Model 4410 Vibrating Wire Strandmeter Specifications*

Note:

[1] Other ranges available.

[2] Minimum, greater resolution possible depending on readout.

[3] Accuracy established under lab conditions.

[4] Polyurethane jacket cable available.

A.2 THERMISTOR

See Appendix B for more information.

Range: -80 to +150 °C

Accuracy: ±0.5 °C

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

B.1 3KΩ THERMISTOR RESISTANCE

Thermistor Types include YSI 44005, Dale #1C3001–B3, Alpha #13A3001–B3, and Honeywell 192–302LET–A01.

Resistance to Temperature Equation:

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

EQUATION 9: *3KΩ Thermistor Resistance*

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	15.72K	-9	2221	32	474.7	73	137.2	114
187.3K	-49	14.90K	-8	2130	33	459.0	74	133.6	115
174.5K	-48	14.12K	-7	2042	34	444.0	75	130.0	116
162.7K	-47	13.39K	-6	1959	35	429.5	76	126.5	117
151.7K	-46	12.70K	-5	1880	36	415.6	77	123.2	118
141.6K	-45	12.05K	-4	1805	37	402.2	78	119.9	119
132.2K	-44	11.44K	-3	1733	38	389.3	79	116.8	120
123.5K	-43	10.86K	-2	1664	39	376.9	80	113.8	121
115.4K	-42	10.31K	-1	1598	40	364.9	81	110.8	122
107.9K	-41	9796	0	1535	41	353.4	82	107.9	123
101.0K	-40	9310	1	1475	42	342.2	83	105.2	124
94.48K	-39	8851	2	1418	43	331.5	84	102.5	125
88.46K	-38	8417	3	1363	44	321.2	85	99.9	126
82.87K	-37	8006	4	1310	45	311.3	86	97.3	127
77.66K	-36	7618	5	1260	46	301.7	87	94.9	128
72.81K	-35	7252	6	1212	47	292.4	88	92.5	129
68.30K	-34	6905	7	1167	48	283.5	89	90.2	130
64.09K	-33	6576	8	1123	49	274.9	90	87.9	131
60.17K	-32	6265	9	1081	50	266.6	91	85.7	132
56.51K	-31	5971	10	1040	51	258.6	92	83.6	133
53.10K	-30	5692	11	1002	52	250.9	93	81.6	134
49.91K	-29	5427	12	965.0	53	243.4	94	79.6	135
46.94K	-28	5177	13	929.6	54	236.2	95	77.6	136
44.16K	-27	4939	14	895.8	55	229.3	96	75.8	137
41.56K	-26	4714	15	863.3	56	222.6	97	73.9	138
39.13K	-25	4500	16	832.2	57	216.1	98	72.2	139
36.86K	-24	4297	17	802.3	58	209.8	99	70.4	140
34.73K	-23	4105	18	773.7	59	203.8	100	68.8	141
32.74K	-22	3922	19	746.3	60	197.9	101	67.1	142
30.87K	-21	3748	20	719.9	61	192.2	102	65.5	143
29.13K	-20	3583	21	694.7	62	186.8	103	64.0	144
27.49K	-19	3426	22	670.4	63	181.5	104	62.5	145
25.95K	-18	3277	23	647.1	64	176.4	105	61.1	146
24.51K	-17	3135	24	624.7	65	171.4	106	59.6	147
23.16K	-16	3000	25	603.3	66	166.7	107	58.3	148
21.89K	-15	2872	26	582.6	67	162.0	108	56.8	149
20.70K	-14	2750	27	562.8	68	157.6	109	55.6	150
19.58K	-13	2633	28	543.7	69	153.2	110		
18.52K	-12	2523	29	525.4	70	149.0	111		
17.53K	-11	2417	30	507.8	71	145.0	112		
16.60K	-10	2317	31	490.9	72	141.1	113		

TABLE 5: *3KΩ Thermistor Resistance*

GEOKON®

Vibrating Wire Displacement Transducer Calibration Report

Model: 4410-1-3MM

Serial Number: 2271760

Calibration Instruction: CI-4400

Cable Length: 3 meters

Calibration Date: April 04, 2023

This calibration has been verified/validated as of 10/04/2024

Temperature: 23.6 °C

Technician: Dean O. Cowdery

GK-401 Reading Position B

Actual Displacement (mm)	Gauge Reading 1st Cycle	Gauge Reading 2nd Cycle	Average Gauge Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2981	2981	2981	0.00	-0.03	0.00	0.02
0.6	3687	3688	3688	0.60	-0.02	0.60	-0.04
1.2	439	4397	4397	1.20	0.05	1.20	0.01
1.8	5102	5103	5103	1.80	0.04	1.80	0.00
2.4	5808	5809	5809	2.40	0.03	2.40	0.02
3.0	6511	6512	6512	3.00	-0.06	3.00	-0.01

(mm) Linear Gauge Factor (G): 0.0008495 **(mm/ digit)** **Regression Zero:** 2982

Polynomial Gauge Factors: **A:** 8.9722E-10 **B:** 0.0008409 **C:** ______

Calculate C by setting D = 0 and R_1 = initial field zero reading into the polynomial equation

(inches) Linear Gauge Factor (G): 0.00003344 **(inches/digit)**

Polynomial Gauge Factors: **A:** 3.5324E-11 **B:** 0.00003311 **C:** ______

Calculate C by setting D = 0 and R_1 = initial field zero reading into the polynomial equation

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

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.

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FIGURE 6: *Typical Calibration Report*

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