GEOKON
The World Leader in Vibrating Wire Technology

48 Spencer Street
Lebanon, NH 03766, USA
Tel: 603•448•1562
Fax: 603•448•3216
E-mail: geokon@geokon.com
http://www.geokon.com

Instruction Manual

Model 4410

Vibrating Wire Strandmeter

(Doc Rev L, 2/15)

Warranty Statement

Geokon, Inc. 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.

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1. INTRODUCTION

1.1. Theory of Operation

The Geokon 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 instrument 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 gage 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.

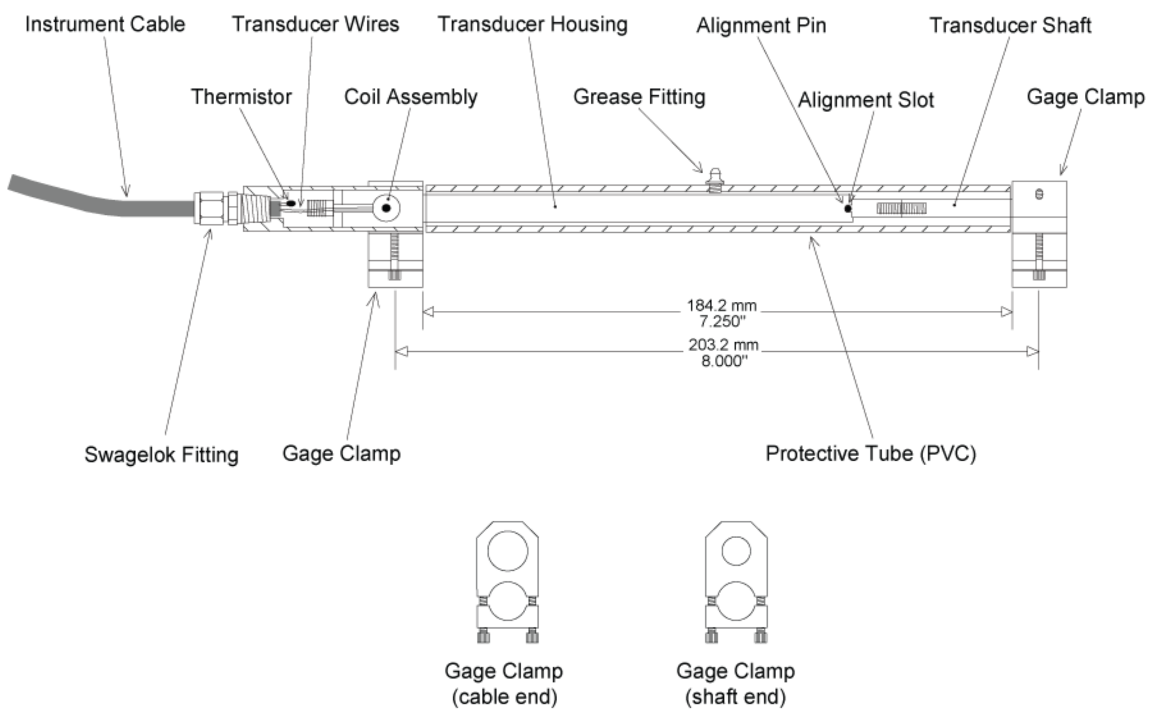


Figure 1 - Model 4410 Vibrating Wire Strandmeter

2. INSTALLATION

2.1. Preliminary Tests

Upon receipt of the instrument, the gage should be checked for proper operation (including the thermistor). See Section 3 for readout instructions. When the shaft is fully retracted the vibrating wire is slack and may give an erratic reading. This is normal. Extending the shaft very slightly the vibrating wire is put in tension and, in position "B" the gage will read around 1500-2000. **Do not extend the connector more than the range of the gage.** (A reading of about 8000 digits)

Checks of electrical continuity can also be made using an ohmmeter. Resistance between the gage leads should be approximately 150Ω, ±10Ω. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 14.7Ω/1000' or 48.5Ω/km, multiply by 2 for both directions). Between the green and white should be approximately 3000 ohms at 25° (see Table B-1), and between any conductor and the shield should exceed 2 megohms.

2.2. Strandmeter Installation

See Figure 2 and the following instructions.

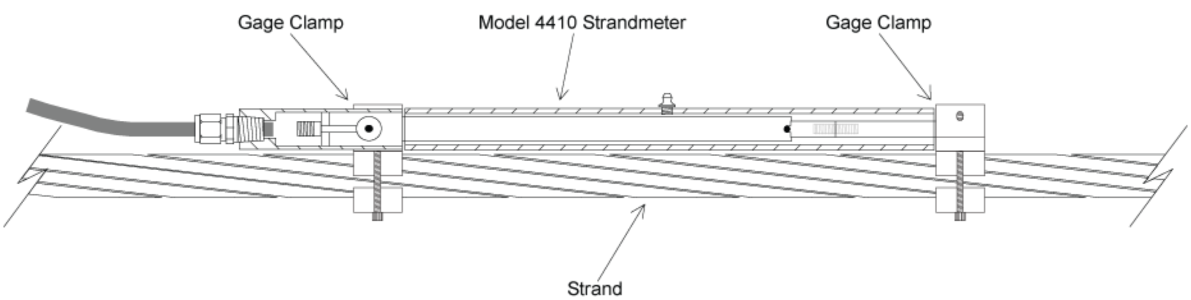


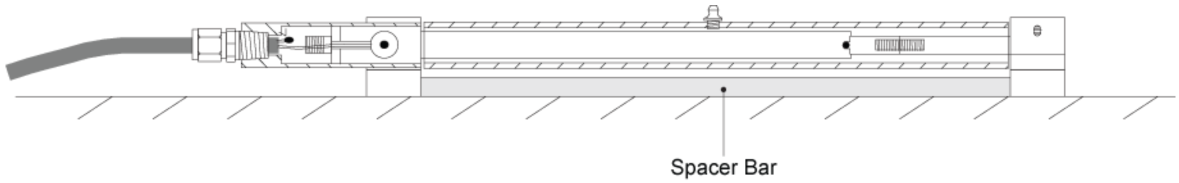
Figure 2 - Model 4410 Strandmeter Installation

Strandmeter installation instructions;

Note: references to the PVC grease tube 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.

1. Unbolt and separate the two halves of the clamps. 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. 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..

2. Place this assembly down so that the bottoms of the two clamps sit on a flat surface. 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 and then tighten the four 6-32 set screws holding the strandmeter to the two clamps.



3. Remove the spacer bar and place the assembly over the strand, locate it correctly then tighten the lower half of the clamps onto the strand using the 4 cap screws.

4. The next step is to set the zero reading on the gage. Slacken off the two 6-32 set screws holding the clamp to the strandmeter shaft. Insert a 10-32 screw (supplied) into the end of the shaft that comes through the clamp. Connect the gage leads to the readout box (see section 3) and switch to position 'B'. 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. Now, while holding the reading so that it is between 2500-4000, (3000 is good), tighten the two 6-32 set screws using the Allen wrench provided. Tighten these screws hard, and the 6-32 set screws at the other clamp

5. For strands that are to be embedded in concrete, fill the PVC tube with grease. A ¼-28 threaded hole (see 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.

6. 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.

2.3. Cable Installation

The cable should be routed in such a way so as to minimize the possibility of damage due to moving equipment, debris or other causes.

Cables may be spliced to lengthen them, without affecting gage readings. Always waterproof the splice completely, preferably using an epoxy based splice kit such the 3M Scotchcast™, model 82-A1. These kits are available from the factory.

2.4. Electrical Noise

Care should be exercised when installing instrument cables to keep them 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. The instrument cables will pick up the 50 or 60 Hz (or other frequency) noise from the power cable and this will likely cause a problem obtaining a stable reading. Contact the factory concerning filtering options available for use with the Geokon dataloggers and readouts should difficulties arise.

2.5. Initial Readings

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.

2.6. Lightning Protection

The Model 4410 Vibrating Wire Strandmeter, unlike numerous other types of instrumentation available from Geokon, do not have any integral lightning protection components, i.e. transzorbs or plasma surge arrestors. Usually this is not a problem however, if the instrument cable is exposed, it may be appropriate to install lightning protection components, as the transient could travel down the cable to the gage and possibly destroy it.

Note the following suggestions;

- If the gage is connected to a terminal box or multiplexer components such as plasma surge arrestors (spark gaps) may be installed in the terminal box/multiplexer to provide a measure of transient protection. Terminal boxes and multiplexers available from Geokon provide locations for installation of these components.
- Lighting arrestor boards and enclosures are available from Geokon that install near the instrument. The enclosure has a removable top so, in the event the protection board (LAB-3) is damaged, the user may service the components (or replace the board). A connection is made between this enclosure and earth ground to facilitate the passing of transients away from the gage. See Figure 3. Consult the factory for additional information on these or alternate lightning protection schemes.
- Plasma surge arrestors can be epoxy potted into the gage cable close to the sensor. A ground strap would connect the surge arrestor to earth ground, either a grounding stake or other suitable earth ground such as perhaps the strand to which the transducer is attached.

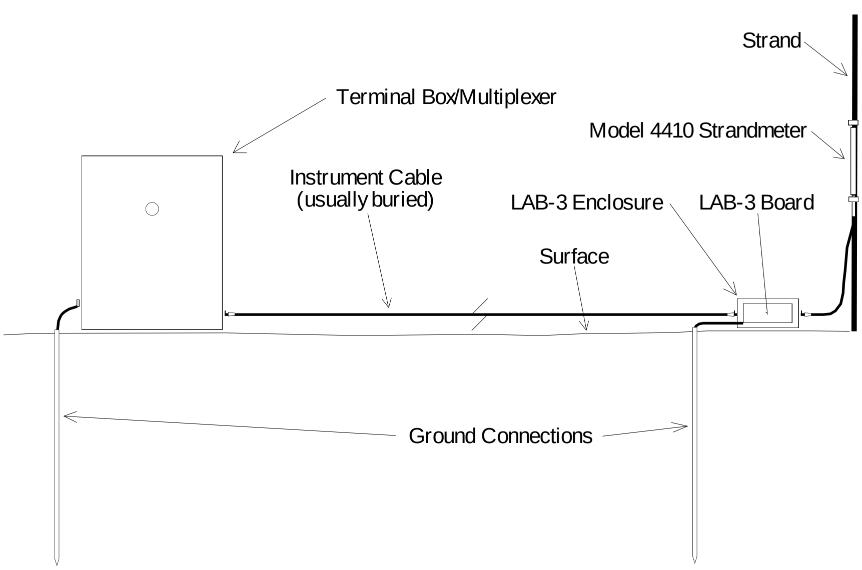


Figure 3 - Lightning Protection Scheme

3. TAKING READINGS

3.1. Operation of the GK-403 Readout Box

The GK-403 can store gage readings and also apply calibration factors to convert readings to engineering units. Consult the GK-403 Instruction Manual for additional information on Mode "G" of the Readout. The following instructions will explain taking gage measurements using Mode "B".

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire transducer, the white and green clips are for the thermistor and the blue for the shield drain wire.

1. Turn on the Readout. Turn the display selector to position "B". Readout is in digits (see Equation 1).

2. Turn the unit on and a reading will appear in the front display window. The last digit may change one or two digits while reading. Press the "Store" button to record the value displayed. If the no reading displays or the reading is unstable see section 5 for troubleshooting suggestions. The thermistor will be read and output directly in degrees centigrade.

3. The unit will automatically turn itself off after approximately 2 minutes to conserve power.

3.2 Operation of the GK404 Readout Box

The GK404 is a palm sized readout box which displays the Vibrating wire value and the temperature in degrees centigrade.
The GK-404 Vibrating Wire Readout arrives with a patch cord for connecting to the vibrating wire gages. One end will consist of a 5-pin plug for connecting to the respective socket on the bottom of the GK-404 enclosure. The other end will consist of 5 leads terminated with alligator clips. Note the colors of the alligator clips are red, black, green, white and blue. The colors represent the positive vibrating wire gage lead (red), negative vibrating wire gage lead (black), positive thermistor lead (green), negative thermistor lead (white) and transducer cable drain wire (blue). The clips should be connected to their respectively colored leads from the vibrating wire gage cable.

Use the **POS** (Position) button to select position **B** and the MODE button to select **Dg** (digits).
Other functions can be selected as described in the GK404 Manual.

The GK-404 will continue to take measurements and display the readings until the OFF button is pushed, or if enabled, when the automatic Power-Off timer shuts the GK-404 off.

The GK-404 continuously monitors the status of the (2) 1.5V AA cells, and when their combined voltage drops to 2V, the message **Batteries Low** is displayed on the screen. A fresh set of 1.5V AA batteries should be installed at this point

3.3 Operation of the GK-405 Readout Box

The GK-405 Vibrating Wire Readout is made up of two components:

- the Readout Unit, consisting of a Windows Mobile handheld PC running the GK-405 Vibrating Wire Readout Application
- the GK-405 Remote Module which is housed in a weather-proof enclosure and connects to the vibrating wire sensor by means of:

1) Flying leads with alligator type clips when the sensor cable terminates in bare wires or,
2) by means of a 10 pin connector..

The two components communicate wirelessly using Bluetooth®, a reliable digital communications protocol. The Readout Unit can operate from the cradle of the Remote Module (see Figure 4) or, if more convenient, can be removed and operated up to 20 meters from the Remote Module

Figure 4 GK405 Readout Unit

For further details consult the GK405 Instruction Manual.

3.3. Measuring Temperatures

Each Vibrating Wire Strandmeter is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Usually the white and green leads are connected to the internal thermistor.
The GK 401 readout box will not read temperatures directly – an ohmmeter is required.

1. Connect the ohmmeter to the two thermistor leads coming from the strandmeter. (Since the resistance changes with temperature are so large, the effect of cable resistance is usually insignificant.)

2. Look up the temperature for the measured resistance in Table B-1 (Appendix B). Alternately the temperature could be calculated using Equation B-1 (Appendix B). For example, a resistance of 3400 ohms is equivalent to 22° C. When long cables are used

the cable resistance may need to be taken into account. Standard 22 AWG stranded copper lead cable is approximately 14.7Ω/1000' or 48.5Ω/km, multiply by 2 for both directions.

Note: The GK-403 and GK-404 readout boxes will read the thermistor and display temperature in °C automatically.

4. DATA REDUCTION

4.1. Deformation Calculation

The basic units utilized by Geokon for measurement and reduction of data from Vibrating Wire Strandmeters are "digits". To convert digits to deformation the following equation applies;

$$D = (R_1 - R_0) \times G \times F$$

Equation 1 - Deformation Calculation

Where; D is the Deformation in millimeters or inches
R_1 is the Current Reading.
R_0 is the Initial Reading usually obtained at installation (see section 2.4).
G is the Calibration Factor, usually millimeters or inches per digit.
F is an engineering units conversion factor (optional), see Table 1.

From→ To↓	Inches	Feet	Millimeters	Centimeters	Meters
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

For example, the Initial Reading (R_0) at installation of a strandmeter is 4783 digits. The Current Reading (R_1) is 5228. The Calibration Factor is 0.0006194 mm/digit. The deformation change is ***$D = (5228 - 4783) \times 0.0006194 = +0.2756$ mm***

Note that increasing readings (digits) indicate increasing extension.

A typical Calibration Sheet for a 3mm range strand meter is shown on the next page.

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

Vibrating Wire Displacement Transducer Calibration Report

Range: 3 mm

Serial Number: 08-29153

Calibration Date: January 12, 2009

Temperature: 23.1 °C

Calibration Instruction: CI-4400

Technician:

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2321	2317	2319	-0.01	-0.22	0.00	0.00
0.6	3300	3301	3301	0.60	0.04	0.60	0.00
1.2	4277	4275	4276	1.21	0.19	1.20	0.01
1.8	5244	5242	5243	1.80	0.15	1.80	-0.02
2.4	6208	6206	6207	2.40	0.06	2.40	0.02
3.0	7162	7162	7162	2.99	-0.23	3.00	0.00

(mm) Linear Gage Factor (G): 0.0006194 (mm/ digit) **Regression Zero: 2330**

Polynomial Gage Factors: A: 2.10436E-09 B: 0.0005995 C: -1.4015

(inches) Linear Gage Factor (G): 0.00002439 (inches/ digit)

Polynomial Gage Factors: A: 8.28489E-11 B: 0.00002360 C: -0.05518

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

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B: ________ Temp(T_0): _____ °C Date: ________

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.

4.2. Strain Calculation

The gage length of the standard strand meter is 203.2mm, (8 inches) so the strain in **microstrains μ** is given by the equations:

μ = (D/203.2) x 10^6 microstrain where D is in mm or

μ = (D/8) x 10^6 microstrain where D is in inches

4.3. Temperature Correction

The Model 4410 Vibrating Wire Strandmeters have a small coefficient of thermal expansion so in many cases correction is not necessary. However, if maximum accuracy is desired or the temperature changes are large corrections may be applied. The temperature coefficient of the strand to which the Strandmeter is attached should also be taken into account. By correcting the transducer readings for temperature changes the temperature effect on the strand can be isolated and quantified.
The following equation applies;

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

<u>Equation 2 - Thermally Corrected Deformation Calculation</u>

Where; R_1 is the Current Reading.
R_0 is the Initial Reading.
G is the Calibration Factor.
T_1 is the Current Temperature.
T_0 is the Initial Temperature.
K is the Thermal Coefficient for the Transducer, (see Equation 3).

Tests have determined that the Thermal Coefficient, K, changes with the position of the transducer shaft. Hence, the first step in the temperature correction process is determination of the proper Thermal Coefficient based on the following equation;

Thermal Coefficient = (Reading in Digits × 0.000295) + 1.724) × Calibration Factor

or

$$\mathbf{K = ((R_1 \times 0.000295) + 1.724) \times G}$$

<u>Equation 3 - Thermal Coefficient Calculation</u>

Where; R_1 is the Current Reading.
G is the Calibration Factor supplied with the instrument.

Consider the following example using a Model 4410-5 mm Strandmeter;

$R_0 = 4783$ *digits*

$R_1 = 5228$ *digits*

$T_0 = 15.8°\ C$

$T_1 = 27.2°\ C$

$G = 0.0006194$ *mm/digit*

$K = ((5228 \times 0.000295) + 1.724) \times 0.0006194 = 0.00202$

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

$D_{corrected} = ((5228 - 4783) \times 0.0006194) + ((27.2 - 15.8) \times 0.00202)$

$D_{corrected} = (445 \times 0.0006194) + 0.02303$

$D_{corrected} = 0.2756 + 0.02303$

$D_{corrected} = +0.2986$ *mm*

4.3. Environmental Factors

Since the purpose of the strandmeter 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.

5. TROUBLESHOOTING

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

Symptom: Strandmeter Readings are Unstable

- ✓ Is the readout box position set correctly? If using a datalogger to record readings automatically are the swept frequency excitation settings correct? Try reading the strandmeter on a different readout position. For instance, channel A of the GK-401 and GK-403 might be able to read the strandmeter. To convert the Channel A period display to digits use Equation 1.
- ✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, transformers, arc welders and antennas. Make sure the shield drain wire is connected to ground whether using a portable readout or datalogger. If using the GK-401 Readout connect the clip with the green boot to the bare shield drain wire of the pressure cell cable. If using the GK-403 connect the clip with the blue boot to the shield drain wire.
- ✓ Does the readout work with another strandmeter? If not, the readout may have a low battery or be malfunctioning. Consult the appropriate readout manual for charging or troubleshooting directions.
- ✓ Has the strandmeter gone outside its range? If so, the strandmeter can be reset using the instructions in section 2.

Symptom: Strandmeter Fails to Read

- ✓ Is the cable cut or crushed? This can be checked with an ohmmeter. Nominal resistance between the two gage leads (usually red and black leads) is 150Ω, ±10Ω. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 14.7Ω/1000' or 48.5Ω/km, multiply by 2 for both directions). If the resistance reads infinite, or very high (megohms), a cut wire must be suspected. If the resistance reads very low (<100Ω) a short in the cable is likely.
- ✓ Does the readout or datalogger work with another strandmeter? If not, the readout or datalogger may be malfunctioning. Consult the readout or datalogger manual for further direction.

APPENDIX A - SPECIFICATIONS

A.1. Model 4410 Vibrating Wire Strandmeter

Range:[1]	3 mm 0.125 inches
Resolution:[2]	0.025% FSR
Linearity:	0.25% FSR
Thermal Zero Shift:	< 0.05% FSR/°C
Stability:	< 0.2%/yr (under static conditions)
Overrange:	115%
Temperature Range:	-20 to +80°C -4 to 176° F
Frequency Range:	1200 - 2800 Hz
Coil Resistance:	150 Ω, ±10 Ω
Cable Type:[3]	2 twisted pair (4 conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250")
Weight: **(with gage clamps)**	0.5 kg. 1.1 lb.

Table A-1 Model 4410 Strandmeter Specifications

Notes:
[1] Other ranges available, consult factory.
[2] Minimum, greater resolution possible depending on readout.
[3] Polyurethane jacket cable available.

A.2 Thermistor (see Appendix B also)

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

APPENDIX B - THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3

Resistance to Temperature Equation:

$$T = \frac{1}{A + B(\mathrm{LnR}) + C(\mathrm{LnR})^3} - 273.2$$

Equation B-1 Convert Thermistor Resistance to Temperature

where: T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance
$A = 1.4051 \times 10^{-3}$ (coefficients calculated over the –50 to +150° C. span)
$B = 2.369 \times 10^{-4}$
$C = 1.019 \times 10^{-7}$

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 B-1 Thermistor Resistance versus Temperature