The World Leader in Vibrating Wire Technology

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Instruction Manual

Model 4435

VW Soil Strainmeter

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 Model 4435 Vibrating Wire Soil Strainmeter is designed to measure axial deformations in soil as might occur in dam embankments, levees, and highway fills, etc.

The basic sensing element is a vibrating wire strain gage in series with a precision music wire spring. As the two end flanges of the Soil Strainmeter are pulled apart the tension in the spring and also in the vibrating wire element increases. This change in tension alters the vibrational frequency of the vibrating wire element and this is measure by a readout box or datalogger and converted, by means of a calibration constant supplied, into an equivalent soil strain.

The Geokon Model 4435 Vibrating Wire Soil Strainmeters can be installed linked together in series to provide incremental deformation measurements over any length. Base lengths of the gage can vary from a minimum of 1 meter to over 25 meters.

The internal spring and sensor are covered by an outer PVC tube which is sealed by O-rings at the two flange ends and in the middle by a telescoping section of PVC tubing. The readout cable issues from the side of one of the end flanges. A thermistor is included for the measurement of temperatures.

Different combinations of gage length and sensor range provide for optimum sensitivity. For maximum strain resolution, a long base gage with a short range transducer will give best results. For maximum deformation: short base length, longer transducer range. The flexibility of the system allows the user to choose the most useful combination of range and sensitivity according to predicted movements.

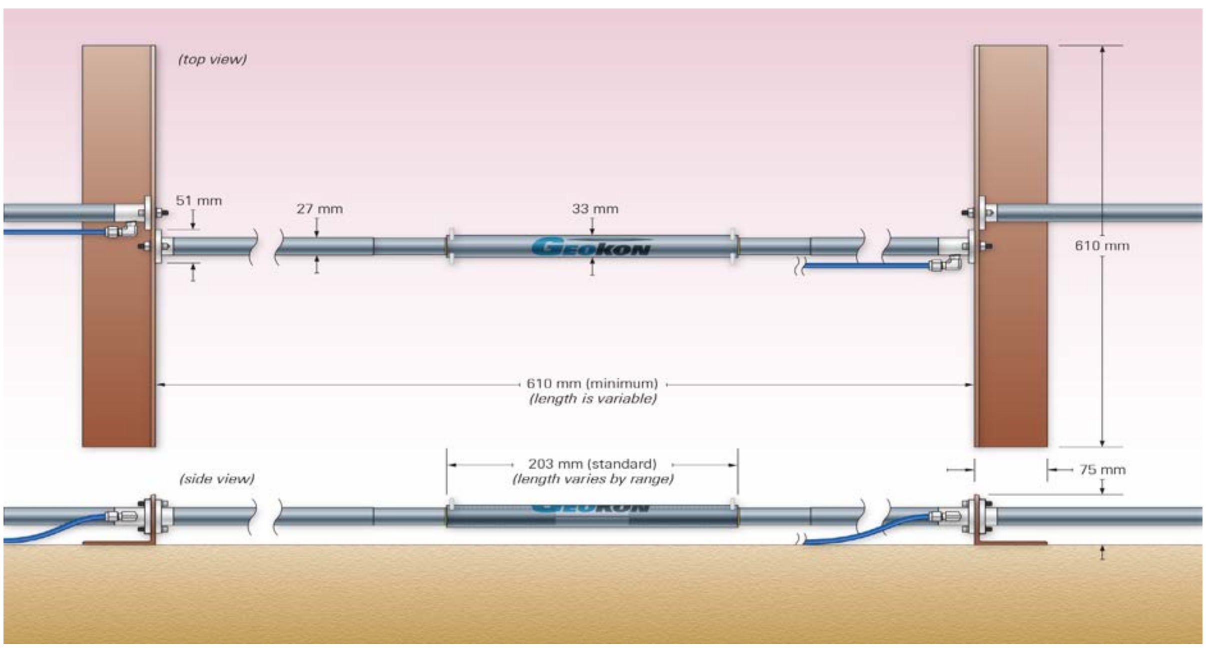

Figure 1 - Model 4435 Soil Strainmeter

Readouts available from Geokon, used in conjunction with the Vibrating Wire Soil Srainmeter, will provide the necessary voltage pulses to pluck the wire and convert the measured frequencies to a displayed reading.

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. In position "B" the gage will read between 2000 and 8000 digits. Pull slightly on the end flanges (Figure 1), the reading should increase.

Checks of electrical continuity can also be made using an ohmmeter. Resistance between the gage leads should be approximately 180Ω, ±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. Installation in Fills and Embankments

The Model 4435 Soil Strainmeter is installed in fills and embankments by placing the straimeter sections in shallow, horizontal trenches in the fill. Multiple sensors can be installed in series to give a total deformation profile along a particular axis as in a dam or highway embankment.

A one meter wide, flat bottomed trench should be excavated in previously compacted fill. The sensors are first assembled: longer sensors may need to be assembled by connecting the inner rods together and cementing together the sections of PVC pipe. telescoping couplings will be required if the selected range of soil deformation exceeds 75mm(3 inch). Very long sensor assemblies (in excess of 5 meters) may require more than one telescoping coupling.
To preserve the telescopning coupligs in a closed positon while assembly is going on they are held in a closed position by means of two nylon screws. These screws should be slackened when the assembled sensors are in there final locations.

Multiple sensors are linked together by means of the (75mm x 75mm) flanges provided. The sensors are bolted to the flanges and the coiled readout cables laid alongside the tubing. When all the sensor sections are in place the cables are strung out in the trench the trench is then backfilled with material which has had any large (>10 mm, 0.5") aggregate removed. Backfill and hand tamp the first 15 cm (≈6") and then proceed with the compaction of the fill in the normal way.

2.3. Cable Protection and Termination

Terminal boxes with sealed cable entries and covers are available allowing many gages to be terminated at one location with complete protection of the lead wires. The panel can have built-in jacks or a single connection with a rotary position selector switch. Lightning protection components can also be installed in the terminal boxes.

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. When making splices, use solder connections wherever feasible or crimp connectors if not.

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.

2.5. Initial Readings

All readings are referred to an initial reading so it is important that this initial reading be carefully taken. Conditions should be noted at the time of all readings, especially during curing, i.e., temperature, time after placement, local conditions, etc.

2.6. Lightning Protection

The Model 4435 Vibrating Wire Soil Strainmeter, 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 deformation meter 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 5. 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.

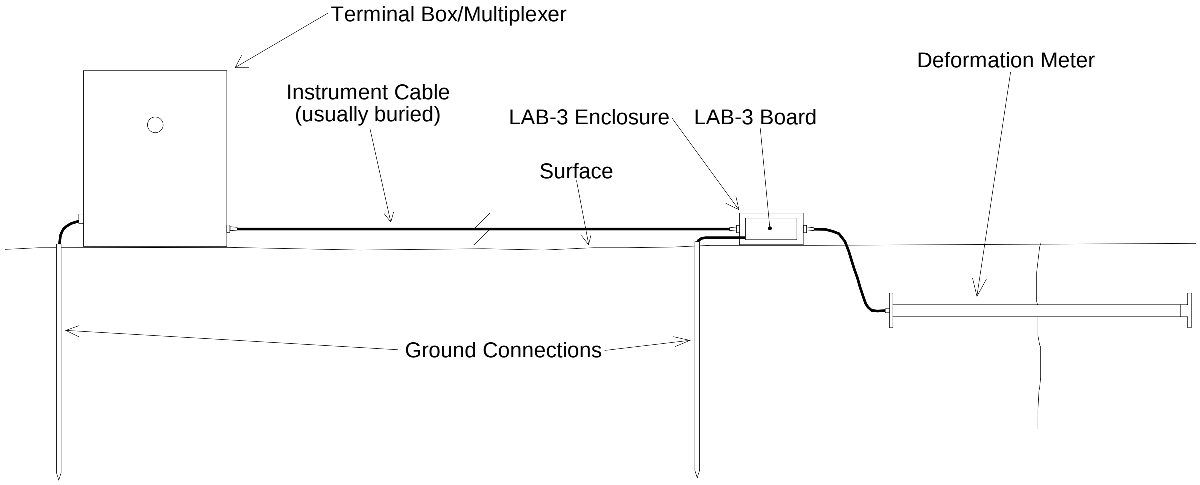

Figure 2 - Lightning Protection Scheme

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 gage, 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 6 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 GK405 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 3) or, if more convenient, can be removed and operated up to 20 meters from the Remote Module

Figure 3 GK405 Readout Unit

For further details consult the GK405 Instruction Manual.

3.4. Measuring Temperatures

Each Vibrating Wire Soil Strainmeter 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 - a digital ohmmeter is required.

1. Connect the ohmmeter to the two thermistor leads coming from the deformation meter. (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 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, GK-404 and GK 405 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 Deformation Meters are "digits". The units displayed by all the Readout Boxes in position "B" are digits. 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

To convert digits to deformation the following equation applies;

Deformation = (Current Reading - Initial Reading) × Calibration Factor × Conversion Factor

or

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

Equation 2 - Deformation Calculation

Where; 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 in terms of millimeters or inches per digit.
(A typical Calibration Sheet is shown in figure 3 Page 10)
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 soils strainmeter with a 25 mm transducer range is 4250 digits. The Current Reading (R_1) is 6785. The Calibration Factor is 0.004457 mm/digit. The deformation change is;

$$D = (6785 - 4250) \times 0.004457 = +11.4 \text{ mm}$$

Note that increasing readings (digits) indicate increasing extension.

4.2. Temperature Correction

The Model 4435 Soil Strainmeter 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. The following equation applies;

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

Equation 3 - Thermally Corrected Deformation Calculation

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.
L_C is the correction for the gage length.

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;

$$\text{Thermal Coefficient} = ((\text{Reading in Digits} \times \text{Multiplier}) + \text{Constant}) \times \text{Calibration Factor}$$

or

$$K = ((R_1 \times M) + B) \times C$$

Equation 4 - Thermal Coefficient Calculation

See Table 2 for the Multiplier and Constant values used in Equation 4. The Multiplier (M) and Constant (B) values vary for the stroke of the transducer used in the Deformation Meter.

Model:	4435-6 mm 4434-0.25”	4435-12 mm 4435-0.5"	4435-25 mm 4435-1"	4435-50 mm 4435-2"	4435-100mm 4435-4”	4435-150mm 4435-6”	4435-300mm 4435-12”
Multiplier (M):	0.00073	0.000295	0.000301	0.000330	0.000192	0.000216	0.000250*
Constant (B):	0.583	1.724	0.911	0.415	0.669	0.491	0.450*
Transducer Length (L):	267mm 10.5”	267 mm 10.5"	267 mm 10.5"	292 mm 11.5"	393mm 15.49”	510.5mm 20.1”	715.2mm 28.2”

* Calculated

Table 2 - Thermal Coefficient Calculation Constants

The gage length correction (L_C) is calculated using Equation 5.

$$L_C = 17.3 \times 10^{-6} \times L \times (T_1 - T_0)$$

Equation 5 - Gage Length Correction

Where L is the length of soil strainmeter in millimeters or inches, minus the transducer length (see Table 2) in millimeters or inches, respectively.

Consider the following example using a Model 4435 Soil Strainmeter with a 1 meter gage length and 25 mm transducer. From the calibration sheet of Figure 4

$R_0 = 4250$ *digits*

$R_1 = 6785$ *digits*

$T_0 = 10° C$

$T_1 = 20° C$

$G = 0.004457$ *mm/digit*

$K = ((6785 \times 0.0003) + 0.911) \times 0.004457 = 0.0131$

$L = 1000 - 267 = 733$

$L_C = 17.3 \times 10^{-6} \times 733 \times (20 - 10) = 0.1268$

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

$D_{corrected} = ((6785 - 4250) \times 0.004457) + ((20 - 10) \times 0.0131) + 0.1268$

$D_{corrected} = (2535 \times 0.004457) + (10 \times 0.0131) + 0.1268$

$D_{corrected} = 11.298 + 0.131 + 0.1268$

$D_{corrected} = +11.56$ *mm*

As can be seen from the above example, the corrections for temperature change are small and can often be ignored.

4.3. Environmental Factors

Since the purpose of the Soil Strainmeter 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

Maintenance and troubleshooting of Vibrating Wire Soil Strainmeters is confined to periodic checks of cable connections. Once installed, the cells 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: 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 deformation meter on a different readout position. For instance, channel A of any of the readout boxes might be able to read the deformation meter. 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 If using the GK-403, Gk-404 or GK-405 readout, connect the clip with the blue boot to the shield drain wire.
- ✓ Does the readout work with another soil strainmeter? If not, the readout may have a low battery or be malfunctioning. Consult the appropriate readout manual for charging or troubleshooting directions.

Symptom: No Reading

- ✓ 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 180Ω, ±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 strainmeter? If not, the readout or datalogger may be malfunctioning. Consult the readout or datalogger manual for further direction.

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

Vibrating Wire Displacement Transducer Calibration Report

Range: 25 mm

Calibration Date: September 01, 2005

Serial Number: 05-8389

Temperature: 23.6 °C

Cal. Std. Control Numbers: 529, 406, 344, 057

Calibration Instruction: CI-4400 Rev: C

Technician: Elice

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	2230	2228	2229	-0.055	-0.22	-0.008	-0.03
5.0	3369	3368	3369	5.024	0.10	5.014	0.06
10.0	4494	4492	4493	10.04	0.14	9.999	0.00
15.0	5615	5613	5614	15.03	0.13	15.00	-0.02
20.0	6729	6729	6729	20.00	0.01	19.99	-0.03
25.0	7841	7841	7841	24.96	-0.17	25.01	0.02

(mm) Linear Gage Factor (G): 0.004457 (mm/ digit) **Regression Zero: 2241**

Polynomial Gage Factors: A: 1.11026E-08 B: 0.004345 C: -9.7486

(inches) Linear Gage Factor (G): 0.0001755 (inches/ digit)

Polynomial Gage Factors: A: 4.37111E-10 B: 0.0001711 C: -0.38380

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 : 4795 Temp(T_0): 23.7 °C Date: September 19, 2005

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 4 - Typical Soil Strainmeterr Calibration Sheet

APPENDIX A - SPECIFICATIONS

A.1. Model 4435 Deformation Meter

Strainmeter Length:[1]	Variable, (1 meter (40 inches) standard).
Ranges Available:[1]	12, 25, 50, 100, 150, 300 mm 0.5, 1, 2, 4, 6, 12"
Overrange:	115%
Accuracy:	0.1% (with polynomial expression)
Resolution:	0.025% FSR
Linearity:	0.25% FSR
Thermal Zero Shift:	< 0.05% FSR/°C
Stability:	< 0.2%/yr (under static conditions)
Temperature Range:	-40 to +60°C -40 to 120° F
Frequency Range:	1200 - 2800 Hz
Coil Resistance:	180 Ω, ±10 Ω
Cable Type:[2]	2 twisted pair (4 conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250")
Diameter:	26.7 mm, 1.050" (body), 33mm (telescoping section) 51 mm, 2" (flange)
Flange:	610 x 75 x 75 mm (3 x 3 x 24 inch)
Weight:	1 kg., 2.2 lbs.(Standard 1 meter length)

Table A-1 Model 4435 Specifications

Notes:
1 Consult the factory for other lengths and ranges available.
2 Consult the factory for alternate cable types.

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:

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

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