



The World Leader in Vibrating Wire Technology

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Instruction Manual
Model 4450
VW Displacement Transducer



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1. INTRODUCTION

1.1 Theory of Operation

Geokon Model 4450 Vibrating Wire Displacement Transducers consist of a vibrating wire sensing element, in series with a heat treated, stress relieved spring. One end of the spring is connected to a vibrating wire, the other end to the transducer shaft. As the transducer shaft is pulled out from the gage body, the spring is elongated, causing an increase in tension in the vibrating wire. The increase in tension (strain) of the wire is directly proportional to the extension of the shaft. This change in strain allows the Model 4450 to measure displacement very accurately.

Model 4450 Displacement Transducers are fully sealed and can operate at pressures of up to 250 psi. They are designed to be read by one of the various readout boxes available from Geokon.

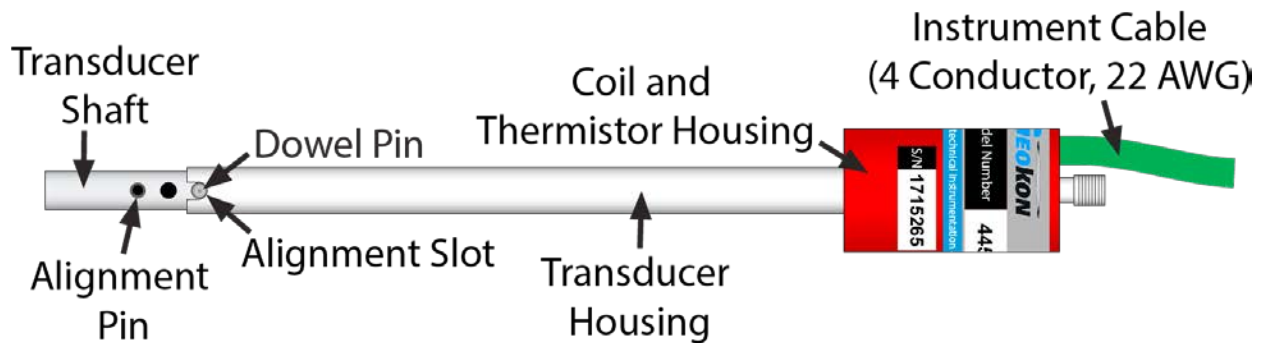


Figure 1 - Model 4450 Displacement Transducer

2. INSTALLATION

2.1 Preliminary Tests

CAUTION! Do not rotate the transducer shaft of the crackmeter more than 180 degrees. This may cause irreparable damage to the instrument. The alignment pin on the transducer shaft and slot on the body serve as a guide for alignment. Never extend the crackmeter beyond its working range.

Before installing the gages in the field, perform a preliminary check by completing the following

- 1) Connect the gage to a readout box. (See Section 3 for information on using readout boxes.)
- 2) Take a reading. The reading should be stable and in the range of 4000 to 5000 digits.
- 3) To prevent damage during shipping, the transducer arrives with either a split PVC sleeve taped to the body, or a metal dowel pin inserted into the shaft. Remove the PVC split sleeve or dowel pin. When the shipping spacer is removed and the alignment pin is resting in the alignment slot the reading should be in the range of 2000 to 3000.

- 4) A check of electrical continuity can be made using an ohmmeter. The resistance between the two lead wires (usually red and black) should be around 180 ohms. Remember to add the cable resistance at approximately $14.7\Omega/1000'$ or $48.5\Omega/km$ at 20 °C. Multiply this factor by two to account for both directions.
- 5) Using an ohmmeter check the resistance between the two thermistor wires (usually white and green). Using Table 6 in Appendix A, convert the resistance to temperature. Compare the result to the current ambient temperature.
- 6) Resistance between any conductor and the shield should exceed two megohms.

2.2 Displacement Transducer Installation

- 1) Be sure to place the alignment pin of the transducer shaft into the alignment slot during installation. This will prevent the internal wire from twisting.
- 2) With the #10-32 thread of the transducer shaft pressed against the shaft-mounting device, rotate the transducer approximately 16 turns to tighten the transducer shaft onto the mounting device.
- 3) Attach the red and black gage leads to the readout box. Select position B. (See Section 3 for readout instructions.)
- 4) Gently pull on the transducer housing until the desired reading is obtained, see Table 1. **Do not extend the shaft further than the range of the gage! The transducer also may be damaged if it is allowed to free fall through its stroke.**
- 5) Hold the desired reading and secure the cable side of the gage against or inside the mounting device. The transducer can be secured by using a Swagelok male connector with nylon front and back ferrules. Tighten the Swagelok connector per the instructions in Section 2.3. **Do not rotate the gage tube relative to the shaft while securing!**
- 6) 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.

Transducer	Digit Change	Minimum Reading	Maximum Reading	Midrange	1/3 Compression 1/3 Extension	1/3 Extension 1/3 Compression
Standard 12, 25, and 50 mm	5,000	2000	7000	5000	6500	4000
Standard 100 and 150 mm	5,000	2000	7000	5000	6500	4000
Slim 12, 25, and 50 mm	10,000	3000	13000	8000	6000	9000

Table 1 - Model 4450 Reading versus Position in the Range

2.3 Swagelok Tube Fitting Instructions

These instructions apply to one inch (25 mm) and smaller fittings.

2.3.1 Installation

- 1) Fully insert the tube into the fitting until it bumps against the shoulder.

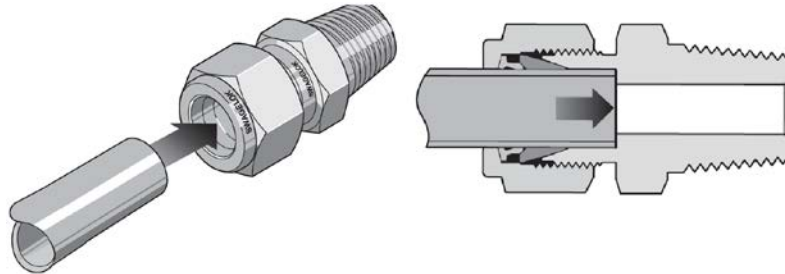


Figure 2 - Tube Insertion

- 2) Rotate the nut until it is finger-tight. (For high-pressure applications as well as high-safety-factor systems, further tighten the nut until the tube will not turn by hand or move axially in the fitting.)
- 3) Mark the nut at the six o'clock position.

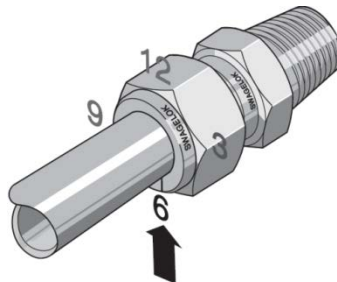


Figure 3 - Make a Mark at Six O'clock

- 4) While holding the fitting body steady, tighten the nut one and one-quarter turns until the mark is at the 9 o'clock position. (Note: For 1/16", 1/8", 3/16", and 2, 3, and 4 mm fittings, tighten the nut three-quarters of a turn until the mark is at the 3 o'clock position.)

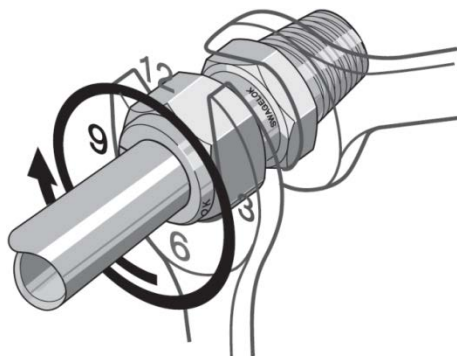


Figure 4 - Tighten One and One-Quarter Turns

2.3.2 Reassembly Instructions

Swagelok tube fittings may be disassembled and reassembled many times.

Warning: Always depressurize the system before disassembling a Swagelok tube fitting.

- 1) Prior to disassembly, mark the tube at the back of the nut, then make a line along the nut and fitting body flats. *These marks will be used during reassembly to ensure the nut is returned to its current position.*



Figure 5 - Marks for Reassembly

- 2) Disassemble the fitting.
- 3) Inspect the ferrules for damage and replace if necessary. **If the ferrules are replaced the connector should be treated as a new assembly. Refer to the section above for installation instructions.**
- 4) Reassemble the fitting by inserting the tube with preswaged ferrules into the fitting until the front ferrule seats against the fitting body.

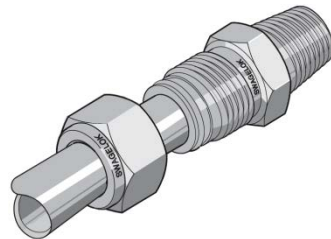


Figure 6 - Ferrules Seated Against Fitting Body

- 5) While holding the fitting body steady, rotate the nut with a wrench to the previous position as indicated by the marks on the tube and the connector. At this point, there will be a significant increase in resistance.
- 6) Tighten the nut slightly.



Figure 7 - Tighten Nut Slightly

2.4 Cable Installation and Splicing

The cable should be routed to minimize the possibility of damage due to moving equipment, debris or other causes. The cable can be protected by the use of flexible conduit, which can be supplied by Geokon.

Terminal boxes with sealed cable entries are available from Geokon for all types of applications. These allow many gages 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 gage 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, which 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 itself 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.

2.5 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 alongside AC power lines; they will pick up the noise from the power cable, which will likely cause unstable readings. Contact the factory concerning filtering options available for use with the Geokon dataloggers and readouts.

2.6 Lightning Protection

Unlike numerous other types of instrumentation available from Geokon, displacement transducers do not have any integral lightning protection components, such as transorbs 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.

Suggested Lightning Protection Options:

- If the instrument 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 the installation of these components.
- Lightning arrestor boards and enclosures are also available from Geokon. These units install where the instrument cable exits the structure being monitored. The enclosure has a removable top to allow the customer to service the components or replace the board in the event that the unit is damaged by a lightning strike. A connection is made between the enclosure and earth ground to facilitate the passing of transients away from the displacement transducer. See Figure 8.
- Plasma surge arrestors can be epoxied into the instrument cable, close to the transducer. A ground strap then connects the surge arrestor to an earth ground, such as a grounding stake or the rebar itself.

Consult the factory for additional information on available lightning protection.

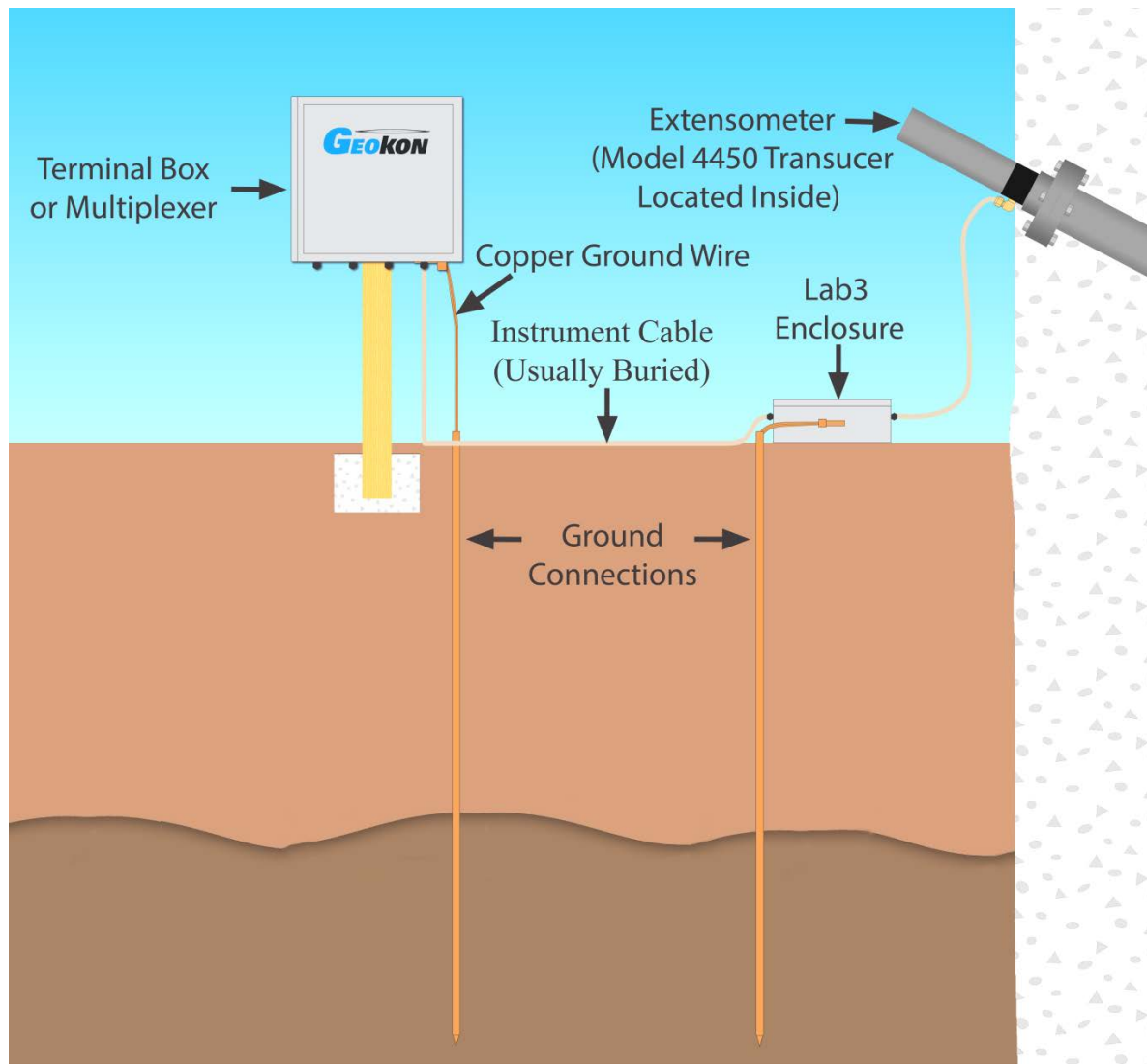


Figure 8 - Lightning Protection Scheme

3. TAKING READINGS

3.1 GK-404 Readout Box

The Model GK-404 Vibrating Wire Readout is a portable, low-power, handheld unit that is capable of running for more than 20 hours continuously on two AA batteries. It is designed for the readout of all Geokon vibrating wire gages and transducers, and is capable of displaying the reading in either digits, frequency (Hz), period (μs), or microstrain ($\mu\epsilon$). The GK-404 also displays the temperature of the transducer (embedded thermistor) with a resolution of 0.1 °C.

Before use, attach the flying leads to the GK-404 by aligning the red circle on the silver “Lemo” connector of the flying leads with the red line on the top of the GK-404 (Figure 9). Insert the Lemo connector into the GK-404 until it locks into place.



Figure 9 - Lemo Connector to GK-404

Connect each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

To turn the GK-404 on, press the “ON/OFF” button on the front panel of the unit. The initial startup screen will display:

Geokon Inc.
GK-404 verX.XX

After approximately one second, the GK-404 will start taking readings and display them based on the settings of the POS and MODE buttons.

The unit display (from left to right) is as follows:

- The current Position: Set by the **POS** button, displayed as a letter A through F.
- The current Reading: Set by the **MODE** button, displayed as a numeric value followed by the unit of measure.
- Temperature reading of the attached gage in degrees Celsius.

Use the **POS** button to select position **B** and the **MODE** button to select **Dg** (digits). (Other functions can be selected as described in the GK-404 Manual.)

The GK-404 will continue to take measurements and display readings until the unit is turned off, either manually, or if enabled, by the Auto-Off timer. If no reading displays or the reading is unstable, consult Section 5 for troubleshooting suggestions. For further information, consult the GK-404 manual.

3.2 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; and the GK-405 Remote Module, which is housed in a weatherproof enclosure and connects via a cable to the vibrating wire gage to be measured. The two components communicate wirelessly using Bluetooth[®], a reliable digital communications protocol. The Readout Unit can operate from the cradle of the Remote Module, or, if more convenient, can be removed and operated up to 20 meters from the Remote Module.

3.2.1 Connecting Sensors with 10-pin Bulkhead Connectors Attached

Align the grooves on the sensor connector (male), with the appropriate connector on the readout (female connector labeled sensor or load cell). Push the connector into place, and then twist the outer ring of the male connector until it locks into place.

3.2.2 Sensors with Bare Leads

Attach the GK-403-2 flying leads to the bare leads of a Geokon vibrating wire sensor by connecting each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

3.2.3 Operating the GK-405

Press the button labeled “POWER ON (BLUETOOTH)”. A blue light will begin blinking, signifying that the Remote Module is waiting to connect to the handheld unit. Launch the GK-405 VWRA program by tapping on “Start” from the handheld PC’s main window, then “Programs” then the GK-405 VWRA icon. After a few seconds, the blue light on the Remote Module should stop flashing and remain lit. The Live Readings Window will be displayed on the handheld PC. Choose display mode “B”. Figure 10 shows a typical vibrating wire output in digits and thermistor output in degrees Celsius. If no reading displays or the reading is unstable, see Section 5 for troubleshooting suggestions. For further information, consult the GK-405 Instruction Manual.

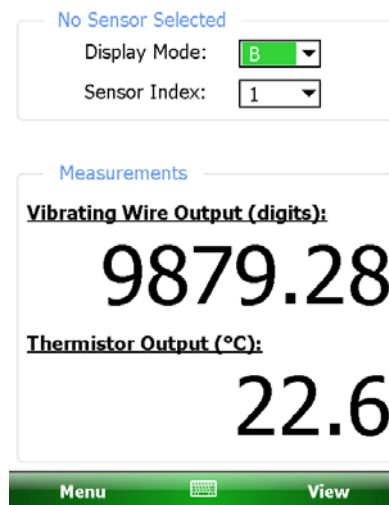


Figure 10 - Live Readings – Raw Readings

3.3 GK-403 Readout Box (Obsolete Model)

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

3.3.1 Connecting Sensors with 10-pin Bulkhead Connectors Attached

Align the grooves on the sensor connector (male), with the appropriate connector on the readout (female connector labeled sensor or load cell). Push the connector into place, and then twist the outer ring of the male connector until it locks into place.

3.3.2 Connecting Sensors with Bare Leads

Attach the GK-403-2 flying leads to the bare leads of a Geokon vibrating wire sensor by connecting each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

3.3.3 Operating the GK-403

- 1) Turn the display selector to position "B".
- 2) Turn the unit on.
- 3) The readout will display the vibrating wire output in digits. The last digit may change one or two digits while reading.
- 4) The thermistor reading will be displayed above the gage reading in degrees centigrade.
- 5) 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 unit will automatically turn off after approximately two minutes to conserve power.

3.4 Measuring Temperatures

All vibrating wire transducers are equipped with a thermistor, which gives a varying resistance output as the temperature changes. The white and green leads of the instrument cable are normally connected to the internal thermistor.

The GK-403, GK-404, and GK-405 readout boxes will read the thermistor and display the temperature in degrees C.

To read temperatures using an ohmmeter: Connect an ohmmeter to the green and white thermistor leads coming from the displacement transducer. (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 14.7Ω for every 1000 ft., or 48.5Ω per km at 20°C . Multiply these factors by two to account for both directions.) Look up the temperature for the measured resistance in Appendix A, Table 6.

4. DATA REDUCTION

4.1 Deformation Calculation

The basic unit utilized by Geokon for measurement and reduction of data from Vibrating Wire Displacement Transducers is "digits". Calculation of digits is based on the following equation:

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

Equation 1 - Digits Calculation

To convert digits to deformation use Equation 2.

$$D_{\text{uncorrected}} = (R_1 - R_0) \times G \times F$$

Equation 2 - Displacement Calculation

Where;

R_1 is the current reading.

R_0 is the initial reading, usually obtained during installation (see Section 2.2).

G is the calibration factor, usually millimeters or inches per digit.

F is an optional engineering units conversion factor, see Table 2.

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 2 - Engineering Units Conversion Multipliers

For example, if the initial reading (R_0) is 6783 digits, the current reading (R_1) is 7228, and the calibration factor (G) is 0.011906 mm/digit, then the deformation change is calculated as follows: $D = (7228 - 6783) \times 0.011906 = +5.3 \text{ mm}$
(Note that increasing readings [digits] indicate increasing extension.)

4.2 Temperature Correction

Geokon's Vibrating Wire Displacement Transducers have a small coefficient of thermal expansion; therefore, in most cases correction may not be necessary. However, if maximum accuracy is desired, or the temperature changes are extreme ($>10^{\circ}\text{C}$), a correction may be applied based on the following equation:

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

Equation 3 - Thermally Corrected Displacement 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 (see Equation 4).

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 to determine the proper thermal coefficient based on the following equation:

$$K = ((R_1 \times TM) + TB) \times G$$

Equation 4 - Thermal Coefficient Calculation

Where;

R_1 is the current reading.

TM is the multiplier from Table 3.

TB is the constant from Table 3.

G is the calibration factor, usually millimeters or inches per digit.

Model	Multiplier (TM)	Constant (TB)
4450-3 mm / 4450-0.125"	0.000520	3.567
4450-12 mm / 4450-0.5"	0.000375	1.08
4450-25 mm / 4450-1"	0.000369	0.572
4450-50 mm / 4450-2"	0.000376	0.328
4450-100 mm / 4450-4"	0.000398	0.0864
4450-150 mm / 4450-6"	0.000384	-0.3482
4450-200 mm / 4450-8"	0.000396	-0.4428
4450-300 mm / 4450-12"	0.000424	-0.6778

Table 3 - Thermal Coefficient Calculation Constants

Consider the following example, which uses the calibration factor from Figure 11, a sample calibration sheet for Model 4450-25 mm. As can be seen from the obtained correction, corrections for temperature change are small and can often be ignored.

$$R_0 = 4250 \text{ digits}$$

$$R_1 = 5875 \text{ digits}$$

$$T_0 = 10^\circ \text{ C}$$

$$T_1 = 20^\circ \text{ C}$$

$$G = 0.006152 \text{ mm/digit}$$

$$K = ((5875 \times 0.000369) + 0.572) \times 0.006152 = 0.0168.$$

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


$$D_{\text{corrected}} = ((5875 - 4250) \times 0.006152) + ((20 - 10) \times 0.0168)$$

$$D_{\text{corrected}} = 9.997 + .168$$

$$D_{\text{corrected}} = +10.165 \text{ mm}$$

4.3 Environmental Factors

Since the purpose of the displacement transducer installation is to monitor site conditions, factors that 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, traffic, temperature and barometric changes, weather conditions, changes in personnel, nearby construction activities, excavation and fill level sequences, seasonal changes, etc.



48 Spencer St. Lebanon, NH 03766 USA

Vibrating Wire Displacement Transducer Calibration Report

Range: 25 mm

Serial Number: 1720191


Calibration Instruction: CI-4400

Cable Length: 11.6 meters

Calibration Date: June 15, 2017

This calibration has been verified/validated as of 07/17/2017

Temperature: 22.7 °C

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	2672	2672	2672	-0.04	-0.15	0.00	0.00
5.0	3492	3491	3492	5.00	0.02	5.00	0.00
10.0	4308	4308	4308	10.03	0.11	10.00	0.01
15.0	5120	5120	5120	15.02	0.10	15.00	0.00
20.0	5929	5929	5929	20.00	0.00	20.00	-0.01
25.0	6736	6736	6736	24.97	-0.14	25.00	0.01

(mm) Linear Gage Factor (G): 0.006152 (mm/digit) Regression Zero: 2678

Polynomial Gage Factors: A: 1.5386E-08 B: 0.006008 C: _____

Calculate C by setting D = 0 and R₁ = initial field zero reading into the polynomial equation

(inches) Linear Gage Factor (G): 0.0002422 (inches/digit)

Polynomial Gage Factors: A: 6.0574E-10 B: 0.0002365 C: _____

Calculate C by setting D = 0 and R₁ = initial field zero reading into the polynomial equation

Calculated Displacement: Linear, D = G (R₁ - R₀)

Polynomial, D = AR₁² + BR₁ + 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 11 - A Typical Calibration Sheet.

5. TROUBLESHOOTING

Maintenance and troubleshooting of displacement transducers is confined to periodic checks of cable connections and maintenance of terminals. Once installed, the gages are usually inaccessible and remedial action is limited. Should difficulties arise, consult the following list of problems and possible solutions. Return any faulty gages to the factory. **Gages should not be opened in the field.** For additional troubleshooting and support, contact Geokon.

Symptom: Thermistor resistance is too high:

- ✓ There may be 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:

- ✓ There may be 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 transducer. There is no remedial action.

Symptom: Instrument 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?
- ✓ Is the transducer shaft positioned outside the specified range (either extension or retraction) of the instrument? Note that when the transducer shaft is fully retracted with the alignment pin inside the alignment slot (as shown in Figure 1) the readings will likely be unstable because the vibrating wire is out of its specified range.
- ✓ Is there a source of electrical noise nearby? Likely candidates are generators, motors, arc welding equipment, high voltage lines, etc. If possible, move the instrument cable away from power lines and electrical equipment or install electronic filtering.
- ✓ Make sure the shield drain wire is connected to ground. Connect the shield drain wire to the readout using the blue clip. (Green for the GK-401.)
- ✓ Does the readout work with another gage? If not, it may have a low battery or possibly be malfunctioning.

Symptom: Instrument Fails to Read:

- ✓ Is the cable cut or crushed? Check the resistance of the cable by connecting an ohmmeter to the gage leads. Table 4 on the following page shows the expected resistance for the various wire combinations; Table 5 is provided to fill in the actual resistance found. Cable resistance is approximately 14.7 Ω per 1000' of 22 AWG wire. (Multiply this factor by two to account for both directions.)

If the resistance is very high or infinite (megohms), the cable is probably broken or cut. If the resistance is very low ($<20\Omega$), the gage conductors may be shorted. If a cut or a short is located in the cable, splice according to the instructions in Section 2.4.

- ✓ Does the readout or datalogger work with another gage? If not, it may have a low battery or possibly be malfunctioning.

Vibrating Wire Sensor Lead Grid - SAMPLE VALUES					
	Red	Black	White	Green	Shield
Red	N/A	$\cong 180\Omega$	infinite	infinite	infinite
Black	$\cong 180\Omega$	N/A	infinite	infinite	infinite
White	infinite	infinite	N/A	3000Ω at 25°C	infinite
Green	infinite	infinite	3000Ω at 25°C	N/A	infinite
Shield	infinite	infinite	infinite	infinite	N/A

Table 4 - Sample Resistance

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

Table 5 - Resistance Work Sheet

APPENDIX A. THERMISTOR TEMPERATURE DERIVATION

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

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

Equation 5 - Resistance to Temperature

Where;

T = Temperature in °C.

LnR = Natural Log of Thermistor Resistance.

A = 1.4051×10^{-3}

B = 2.369×10^{-4}

C = 1.019×10^{-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 6 - Thermistor Resistance versus Temperature

APPENDIX B. SPECIFICATIONS

B.1 Model 4450 Displacement Transducer

Range:	12 mm 0.50 inches	25 mm 1 inch	50 mm 2 inches	100 mm 4 inches	150 mm 6 inches
Resolution¹:	0.025% FSR				
Linearity:	0.25% FSR				
Thermal Zero Shift²:	< 0.05% FSR/°C				
Stability:	< 0.2%/yr (under static conditions)				
Overrange:	115%				
Temperature Range:	-40 to +80 °C -40 to 180 °F				
Frequency Range (standard model):	1200 - 2800 Hz				
Frequency Range (slim stick model):	1700 - 3600 Hz				
Coil Resistance:	180 Ω, ±10 Ω				
Cable Type³:	Two twisted pair (four conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250")				
Dimensions:	See Sections A.3 and A.4 for dimensions				

Table 7 - Model 4450 Displacement Transducer Specifications

Notes:

¹ Minimum; greater resolution possible depending on readout.

² Depends on application.

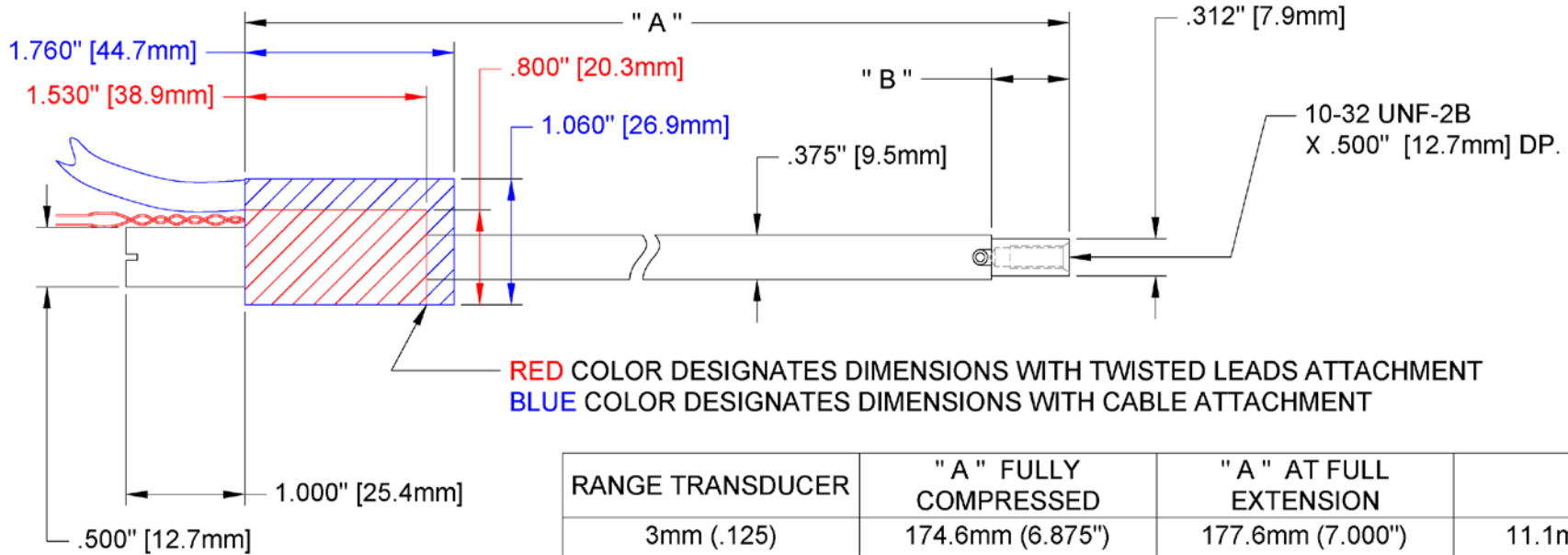
³ Polyurethane jacket cable available.

B.2 Thermistor (see Appendix A also)

Range: -80 to +150° C

Accuracy: ±0.5° C

B.3 Dimensions Drawing for Ranges of 50 mm (2") and Below

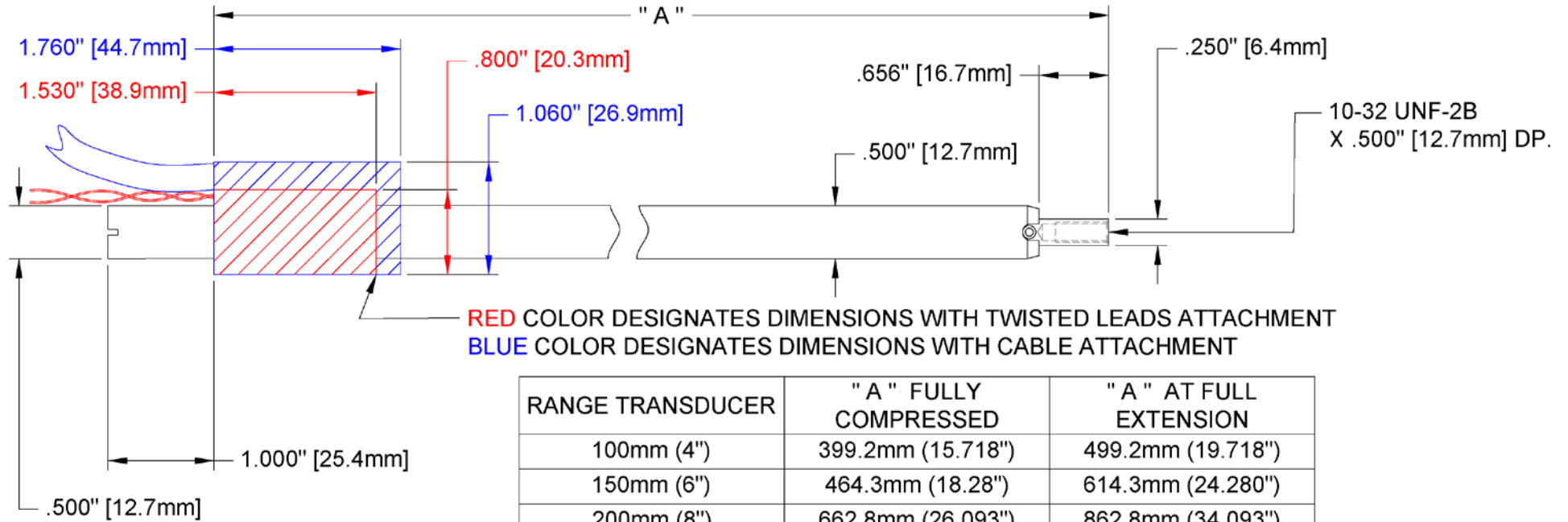


NOTE: DIMENSIONS ARE FOR REFERENCE ONLY

RANGE TRANSDUCER	" A " FULLY COMPRESSED	" A " AT FULL EXTENSION	" B "
3mm (.125)	174.6mm (6.875")	177.6mm (7.000")	11.1mm (0.438")
12.5mm (.5")	177.1mm (6.971")	189.6mm (7.471")	16.7mm (0.656")
25mm (1")	196.2mm (7.726")	221.2mm (8.726")	16.7mm (0.656")
50mm (2")	262.8mm (10.348")	312.8mm (12.348")	16.7mm (0.656")

Figure 12 - Dimensions: Ranges of 50 mm (2") and Below

B.4 Dimensions Drawing for Ranges of 100 mm (4") and Above



RED COLOR DESIGNATES DIMENSIONS WITH TWISTED LEADS ATTACHMENT
 BLUE COLOR DESIGNATES DIMENSIONS WITH CABLE ATTACHMENT

RANGE TRANSDUCER	" A " FULLY COMPRESSED	" A " AT FULL EXTENSION
100mm (4")	399.2mm (15.718")	499.2mm (19.718")
150mm (6")	464.3mm (18.28")	614.3mm (24.280")
200mm (8")	662.8mm (26.093")	862.8mm (34.093")
230mm (9")	688.2mm (27.093")	918.2mm (36.093")
300mm (12)	929.5mm (36.593")	1229.5mm (48.593")

NOTE: DIMENSIONS ARE FOR REFERENCE ONLY

Figure 13 - Dimensions: Ranges of 100 mm (4") and Above