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Instruction Manual

Model 4425

VW Convergence Meter

(Doc Rev P.1, 05/01/23)

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1. INTRODUCTION

The Model 4425 Vibrating Wire Convergence Meter is designed to detect the deformation of rock or soil masses by measuring the contraction (or elongation) between two fixed anchor points. Anchor points are established in the mass and connecting rods from one anchor lead back to transducer assembly located at the second anchor point. Changes in distance between the two anchors are conveyed by the connecting rods and measured by the transducer.

The Model 4425 Convergence Meter consists of three basic components: the two anchor points, 6 mm (1/4") diameter connecting rods, and the spring-tensioned vibrating wire transducer assembly. (See Figure 1.) Essential accessories include: A vibrating wire readout and an installation tool kit (supplied).

The transducer 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 gauge 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, so the convergence can be determined very accurately by measuring the strain change with the vibrating wire readout box.

The convergence meter can operate in horizontal, inclined, or vertical orientations. In areas where construction traffic is expected or where the instrument may be left in an exposed location, some form of protective housing should be considered.

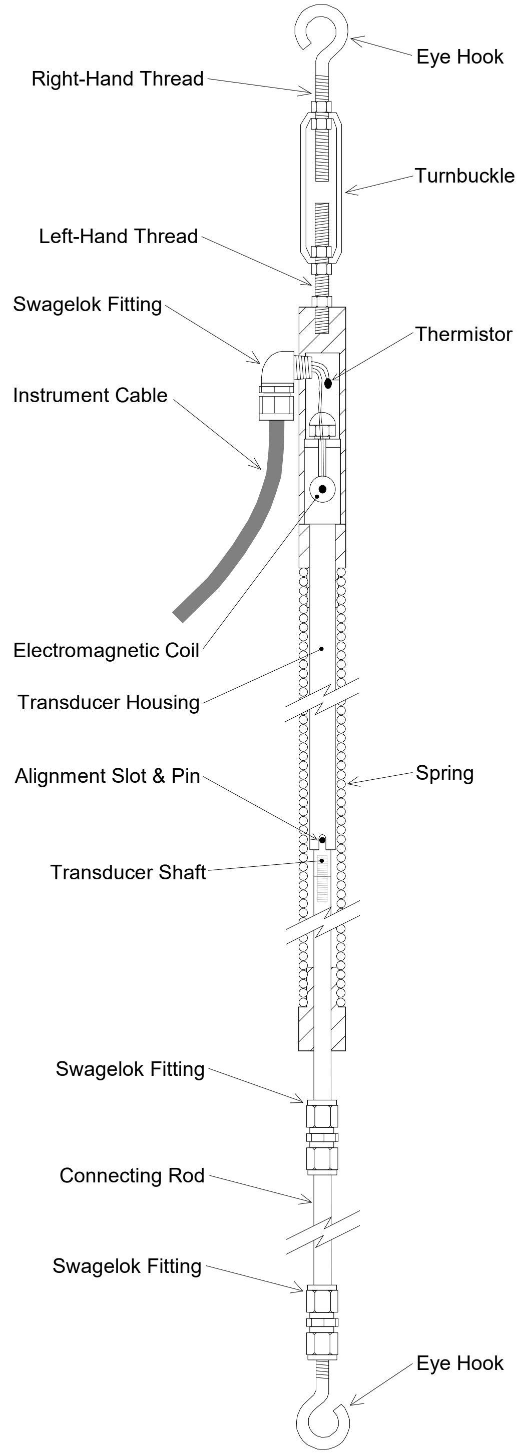

Figure 1 - Model 4425 Convergence Meter

2. INSTALLATION

2.1 Preliminary Tests

Upon receipt of the instrument, the gauge should be checked for proper operation (including the thermistor). See Section 3 for readout instructions. In position "B" the gauge will read around 2000 when the threaded connector is pulled out approximately 3 mm (0.125").

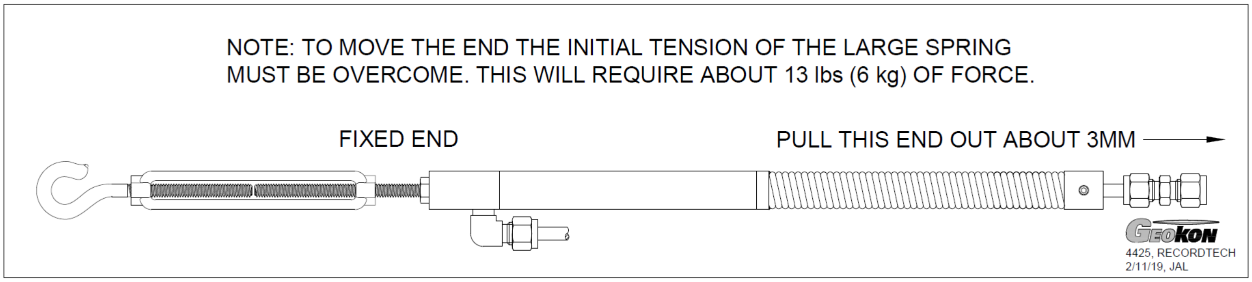

Figure 2 - Operation Check

CAUTION! Do not extend the connector more than the range of the gauge. Do not turn the threaded shaft at the end of the gauge more than 180 degrees or gauge failure may occur!

Checks of electrical continuity can also be made using an ohmmeter. Resistance between the gauge leads (red and black) should be approximately 180 Ω, ±10 Ω. Resistance between the thermistor leads (white and green) varies with temperature; see Appendix B. Resistance between any conductor and the shield should exceed two megohms. (For long cables a correction can be applied, equal to approximately 14.7 Ω per one thousand feet [48.5Ω per km] of 22 AWG stranded copper leads. Multiply this factor by two to account for both directions.)

2.2 Convergence Meter Installation

1) The first step is to unpack all the various components and lay them on a flat surface in their relative positions. (Refer to Figure 1 in Section 1.)

2) Next, the two anchor points must be installed. When the locations have been decided, drill holes to accommodate the anchors. Cement the eyebolt anchors in place using quick-set (hydraulic) cement or epoxy. Allow the cement or epoxy to set completely before attempting the installation of the convergence meter.

3) Attach the turnbuckle assembly to the convergence meter by screwing in the left-hand threaded portion. Use thread locking cement and tighten the lock nut. Set the turnbuckle such that about 10-12 mm (0.5") of thread is inside from each end
.

4) Measure the total distance from anchor eyebolt to anchor eyebolt, inside to inside at the points where they will touch the convergence meter eyehooks.

5) Check and confirm the convergence meter length against the length shown in Table 1. The measurement is made from inside the eyehooks (at the point where they touch the anchor eyebolts), to the end of the Swagelok fitting. To calculate the rod length that will be needed, subtract the convergence meter length from the anchor eyebolt to anchor eyebolt distance,

add 30 mm (1.2") to account for the distance the rod penetrates the Swagelok fittings. This is the nominal rod length that will be required.

Range:	12 mm 0.50 inches	25 mm 1 inch	50 mm 2 inches	100 mm 4 inches	150 mm 6 inches
Convergence Meter Length (Including Swagelok eyehook assembly):	710 mm 28"	710 mm 28"	865 mm 34"	1195 mm 47"	1615 mm 63.5"

Table 1 - Convergence Meter Length

6) Next, the connecting rods must be assembled. Connect the first length of connecting rod to the sensor using the Swagelok fitting. Push the rod into the fitting until it hits the stop. Tighten the Swagelok connector according to the instructions in Appendix C. Connect the second and successive rods using the Swagelok fittings as described above.

7) Connect the Swagelok eyehook to one end of the rods and the convergence meter to the other.

8) Hook the eyehook end into the installed eyebolt <u>first</u>.

9) Hook the convergence meter into the other eyebolt. It should go in without having to extend the convergence meter spring. **Remember that if the spring is extended beyond the range of the transducer the transducer could be damaged.**

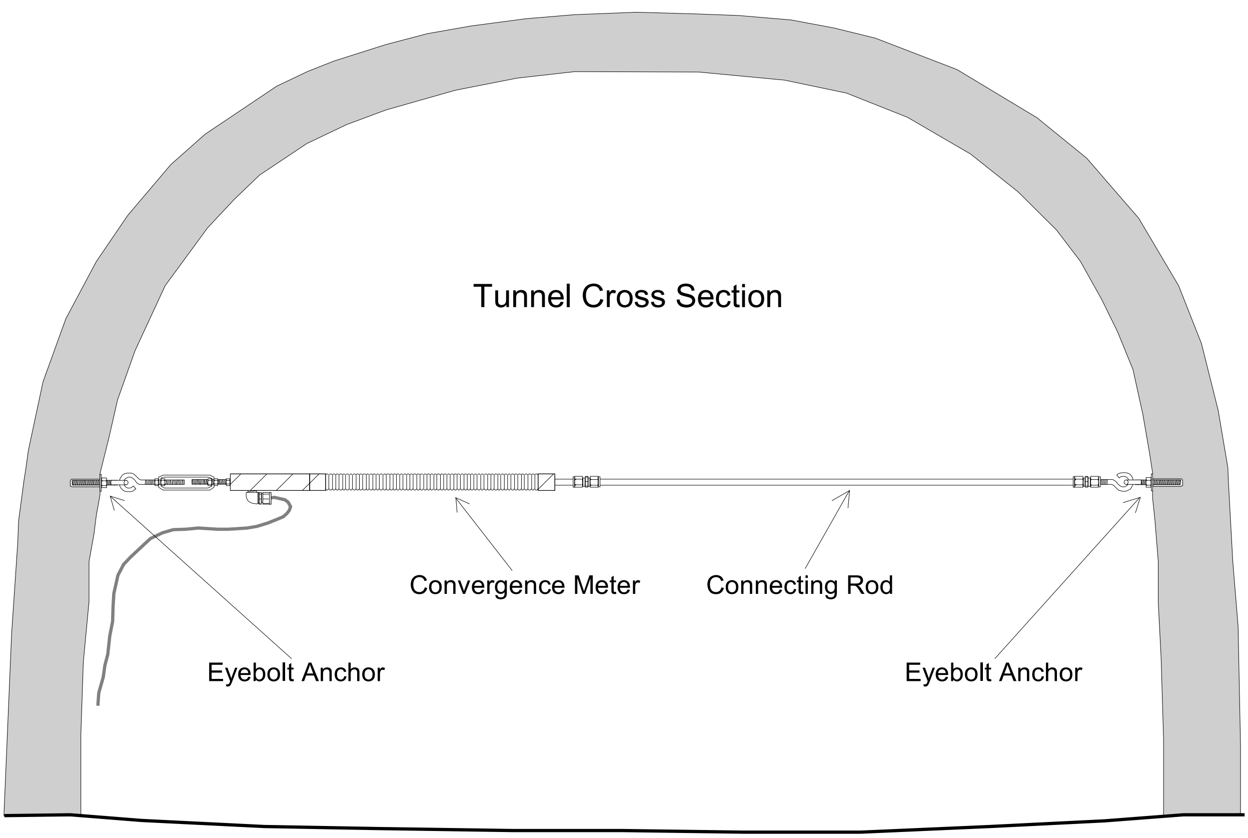

Figure 3 - Model 4425 Convergence Meter Installation

10) Connect the readout box. To set the transducer to midrange, rotate the turnbuckle until a reading of approximately 5500 digits is obtained. To use the total range in convergence, set the meter at 8000. To use the total range in extension, set the meter at 2500.

11) Tighten the locknuts on the turnbuckle. (See Figure 4 below.)

12) Initial readings must be taken and carefully recorded along with the temperature at the time of installation.

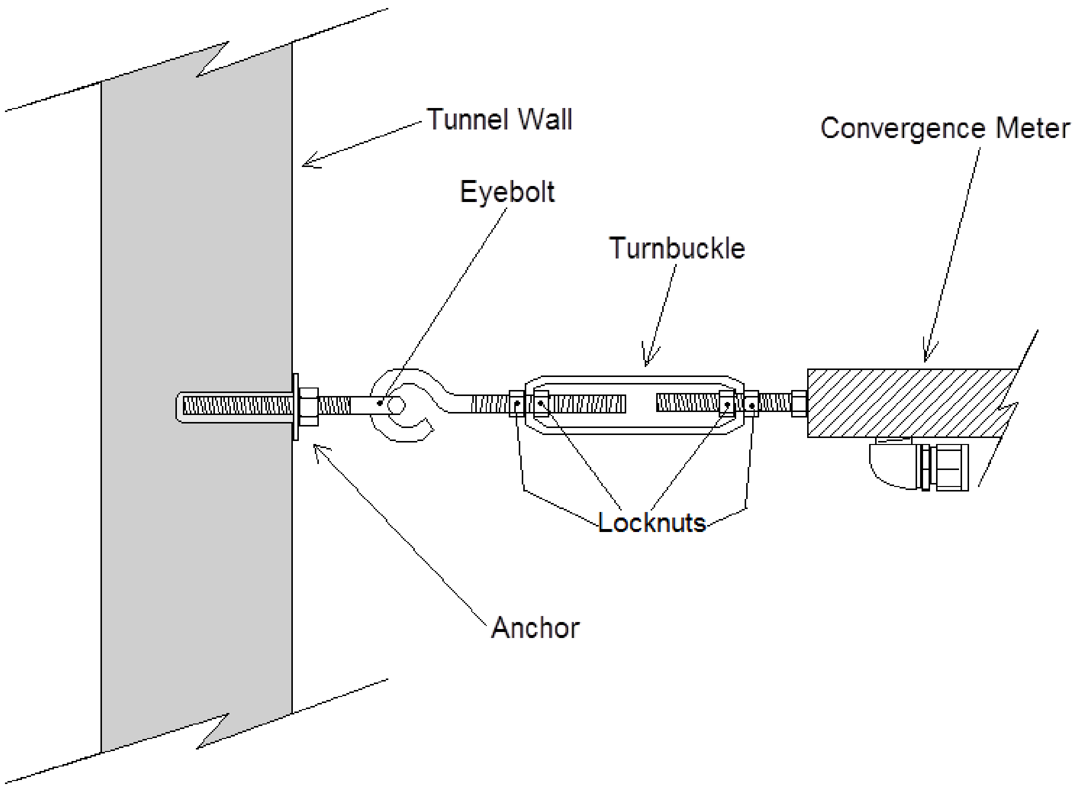

Figure 4 - Convergence Meter Installation Detail - Turnbuckle End

2.3 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.

2.4 Removal

To remove the system, loosen the turnbuckle all the way and then remove the convergence meter. Disconnect the Swagelok fittings on the rods and disassemble the rods to a manageable length. If the rod string needs to be lengthened (or shortened) for the next installation, cut off the ferrules and reinstall new ferrules for the next installation.

2.5 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 using 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 gauges to be terminated at one location with complete protection of the lead wires. The interior panel of the terminal box can have built-in jacks or a single connection with a rotary position selector switch. Contact GEOKON for specific application information.

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

Splice kits recommended by GEOKON incorporate casts, 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 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.

3. TAKING READINGS

3.1 GK-404 Readout Box

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

3.1.1 Operating the GK-404

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 5). Insert the Lemo connector into the GK-404 until it locks into place.

Figure 5 - 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 be displayed. 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 gauge 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, please refer to 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 gauge to be measured. The two components communicate wirelessly. 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 senor 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 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).

3.2.3 Operating the GK-405

Press the button labeled "POWER ON". 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 6 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.

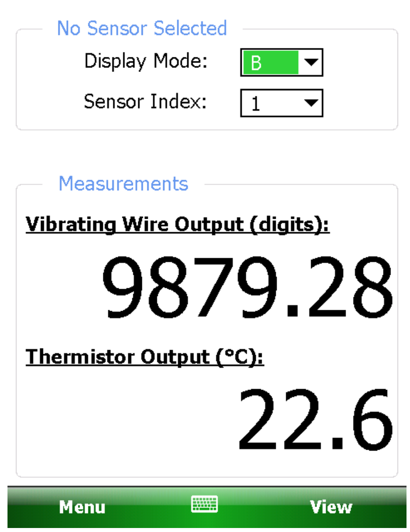

Figure 6 - Live Readings – Raw Readings

3.3 GK-403 Readout Box (Obsolete Model)

The GK-403 can store gauge readings and apply calibration factors to convert readings to engineering units. The following instructions explain taking gauge 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 senor 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 gauge 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

Each Vibrating Wire Convergence Meter 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-403, GK-404, and GK-405 readout boxes will read the thermistor and display temperature in °C automatically

If an Ohmmeter is used, connect the ohmmeter to the two thermistor leads coming from the convergence meter. (Since the resistance changes with temperature are so large, the effect of cable resistance is usually insignificant.) Look up the temperature for the measured resistance using Table 9 in Appendix B. Alternately, the temperature could be calculated using Equation 10, also found in Appendix B. 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 per 1000 ft. or 48.5Ω per km. Multiply these factors by two to account for both directions.

4. DATA REDUCTION

4.1 Digits

The basic units utilized by GEOKON for measurement and reduction of data from vibrating wire Convergence Meters are "digits". The units displayed by the GK-403, GK-404, and GK-405 in position "B" are digits. Calculation of digits is based on the following equation:

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

Equation 1 - Digits Calculation

To convert digits to deformation the following equation applies:

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

Equation 2 - Deformation Calculation

Where;
D is the calculated deformation.
R_1 is the current reading.
R_0 is the initial reading usually obtained at installation.
G is the calibration factor, usually in terms of millimeters or inches per digit taken from the calibration report, an example of which is shown in Appendix D.
F is an engineering units conversion factor (optional), 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, the initial reading, R_0, at installation of a convergence meter with a 12 mm transducer range is 4919 digits. The current reading, R_1, is 6820. The Calibration Factor is 0.00258 mm/digit. The deformation change is:

$$D_{uncorrected} = (6820 - 4919) \times 0.002402 = +4.566 \text{ mm}$$

Note that increasing readings (digits) indicate increasing extension.

4.2 Temperature Correction

In most cases, temperature correction is not necessary, since the Model 4425 Vibrating Wire Convergence Meter has a very small coefficient of thermal expansion. However, if maximum accuracy is desired or the temperature changes are extreme (>10° C) corrections may be applied. The following equation applies:

$$D_{temperature} = (T_1 - T_0)(K + LK_R + K_T)$$

Equation 3 - Temperature Correction

Where;
$D_{temperature}$ is the deformation due to temperature change.
T_1 is the current temperature in degrees C.
T_0 is the initial temperature in degrees C.
K is the thermal coefficient of transducer, see Equation 4.
K_R is the thermal coefficient of the connecting rod, see Table 4.
L is the length of the connecting rod, in millimeters or inches.
K_T is the thermal coefficient of the turnbuckle/spring, 0.0007" or 0.0178 mm/°C.

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

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

Equation 4 - Transducer Thermal Coefficient Calculation

Where;
K is the transducer thermal coefficient.
R_1 is the current reading in digits.
M is the multiplier from Table 3.
B is the constant from Table 3.
G is the calibration factor from the supplied calibration report.

Model	Multiplier	Constant
4425-12 mm / 4425-0.5"	0.000375	1.08
4425-25 mm / 4425-1"	0.000369	0.572
4425-50 mm / 4425-2"	0.000376	0.328
4425-100 mm / 4425-4"	0.000398	0.0864
4425-150 mm / 4425-6"	0.000384	-0.3482
4425-200 mm / 4425-8.0"	0.000396	-0.4428
4425-300 mm / 4425-12"	0.000424	-0.6778

Table 3 - Transducer Thermal Coefficient Calculation Constants

All of the above thermal corrections describe an expansion of components with an increase in temperature. Hence, the calculated thermal corrections must be *added* to the deformation calculated using Equation 2.

$$D_{tcorrected} = D_{uncorrected} + D_{temperature}$$

Equation 5 - Thermally Corrected Deformation Calculation

Experience has shown that the most stable readings are obtained when the system is at a stable temperature. Taking readings late at night or early in the morning will eliminate the transient effects of sunlight and rapid warming of sensor components. If a datalogger is used, readings will show the trends associated with thermal effects during the day and through the seasons and allow corrections for these effects to be accurately made.

4.3 Rod Stretch Correction

$$\text{Rod Stretch} = \frac{PL}{aE}$$

Equation 6 - Rod Stretch

Where;
P is the rod tension (lb. or Newtons).
L is the rod length (inches or mm).
a is the rod area of cross section (sq. inches or square mm).
E is the Young's modulus (lb./sq. inch or MPa).

P depends on the spring rate, **S**, of the large exterior tension spring and the amount of deformation ($D_{tcorrected}$), i.e. P = S $D_{corrected}$ so that:

$$D_{rodstretch} = \frac{SDL}{aE}$$

Equation 7 - Rod Stretch correction

Values for K_R and E are as follows:

Rod Material	**E, Young's Modulus**		**K_R Thermal Coefficient**
	Lb./sq. in.	MPa	**Per ºC**
Stainless Steel	28.5×10^6	0.196×10^6	17.3×10^{-6}
Graphite	17×10^6	0.117×10^6	0.2×10^{-6}
Invar	21×10^6	0.145×10^6	1.1×10^{-6}
Fiberglass	6×10^6	0.041×10^6	6.0×10^{-6}

Table 4 - Young's Modulus and Thermal Coefficients

Increasing tensions cause the rod to elongate so that the required correction would be positive, when $D_{tcorrected}$ is positive.

Values for S are as follows:

Model Number	Range		Spring Rate	
	Inches	mm	Lb./in.	Newtons/mm
4425-12	½	12	34	5.95
4425-25	1	25	34	5.95
4425-50	2	50	17	2.98
4425-100	4	100	17	2.98
4425-150	6	150	8.5	1.49

Table 5 - Spring Rates

4.4 Correction for Sag

$$\text{Correction for sag} = -LW^2/24P^2 \text{ or } -L^3\omega^2/24P^2$$

Equation 8 - Sag Correction

Where;
L = length of rods (The distance over which the measurement is made).
W = weight of rods
P = tension. The springs used have an initial tension of 13 lb. (57.8N), and this must be added to the force caused by the displacement = SD
ω = weight of rods per unit length (see Table 6)

For convergence the correction is negative, for extensions the correction is positive.

Rod Material	Weight per unit length	
	Lb./inches	Kgm/mm
Stainless Steel	0.0139	248×10^{-6}
Graphite	0.00275	49.1×10^{-6}
Invar	0.0139	248×10^{-6}
Fiberglass	0.0035	62.4×10^{-6}

Table 6 - Densities

For example:

Consider a horizontal convergence meter consisting of 60 ft. of graphite rods with spring constant of 17 lb. per inch.

L = length of rods = 60 ft. (The distance over which the measurement is being made.)
W = weight of 60 ft. of graphite rods = 2 lb.
P_0 = 47 lb. and P_1 = 30 lb. (These values are obtained from a knowledge of the spring tension at various extensions, and that an apparent measured convergence of 1.000 inch has taken place.)

The correction to L for sag initially is -60 x 4 / 24 x 47 x 47 = - 0.0045 ft. = - 0.054 inches

The correction for sag at T_1 is - 60 x 4 / 24 x 30 x 30 = - 0.0111 f.t = - 0.133 inches

After correction for sag the true convergence is 1 – (0.133 – 0.054) = 0.921 inches

Summing all the various effects:

$$D_{corrected} = D_{uncorrected} + D_{temperature} + D_{rodstretch} + D_{sag}$$

Equation 9 - Corrected Deformation

Again, consider the following example from a Model 4425-12 Convergence Meter attached to 30 meters of 1/4 inch diameter graphite rod.

R_0 = 4919 digits
R_1 = 6820 digits
T_0 = 15.3° C
T_1 = 32.8° C
$(T_1 - T_0)$ = + 17.5 °C
G = 0.002402 mm/digit
L = 30 meters = 30,000 mm
S = 5.95 N/mm
a = 31.67 sq. mm
E = 0.117×10^6 MPa
ω = 0.049 Kgm/m = 0.481 N/m (0.033 lb./ft.)
P_0 = 133 N
P_1 = 163 N

From Equation 4:

K = ((6820 × 0.000375) + 1.08) × 0.002402 = 0.0087 mm

From Equation 2:

$D_{uncorrected}$ = (6820 - 4919) × 0.002402 = + 4.566 mm
(The plus sign indicates an extension.)

From Equation 3:

$D_{temperature} = + 17.5(0.0087 + 0.2\times10^{-6} \times 30{,}000 + 0.0178) = + 0.568$ mm

From Equation 5:
$D_{corrected} = + 4.566 + 0.568 = + 5.134$ mm

From Equation 7:
$D_{rodstretch} = 5.95 \times 5.045 \times 30{,}000 / 31.67 \times 0.117 \times 10^6 = +0.243$ mm

From Equation 8: (Not required if the convergence meter is vertical)
$D_{sag} = [30^3 \text{ x } 0.481^2 /24 \text{ x } 133 \text{ x } 133] - [30^3 \text{ x } 0{,}481^2/24 \text{ x } 163 \text{ x } 163] = + 4.918$ mm

From Equation 9:
The true extension:

$D_{corrected} = + 4.566 + 0.568 +0.243 + 4.918 \qquad = + 10.29$ mm

4.5 Environmental Factors

Since the purpose of the convergence meter 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, 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 GEOKON Vibrating Wire Convergence Meters are confined to periodic checks of cable connections and maintenance of terminals. The Convergence Meters contain no user serviceable components. However, consult the following list of problems and possible solutions should difficulties arise. Consult the factory for additional troubleshooting help.

Symptom: Thermistor resistance is too high:

✓ Is there an open circuit? Check all connections, terminals, and plugs. If a cut is located in the cable, splice according to instructions in Section 2.5.

Symptom: Thermistor resistance is too low:

✓ Is there a short? Check all connections, terminals, and plugs. If a short is located in the cable, splice according to instructions in Section 2.5.
✓ Water may have penetrated the interior of the Convergence Meter. 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 of the Convergence Meter positioned outside the specified range 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 transducer is now out of range.
✓ 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-403, GK-404, or GK-405 connect the clip with the blue boot to the shield drain wire. (Green for the GK-401.)

Symptom: Instrument Fails to Read:

✓ Is the cable cut or crushed? Check the resistance of the cable by connecting an ohmmeter to the gauge leads. Table 7 on the following page shows the expected resistance for the various wire combinations; Table 8 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 (<20Ω), the gauge conductors may be shorted. If a cut or a short is located in the cable, splice according to the instructions in Section 2.5.

✓ Does the readout or datalogger work with another gauge? 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	≅180Ω	infinite	infinite	infinite
Black	≅180Ω	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 7 - Sample Resistance

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

Table 8 - Resistance Work Sheet

APPENDIX A. SPECIFICATIONS

A.1 Model 4425 Convergence Meter

Range:	12 mm 0.50 inches	25 mm 1 inch	50 mm 2 inches	100 mm 4 inches	150 mm 6 inches
Resolution:[1]	0.025% FSR				
Linearity:	0.25% FSR				
Accuracy:	0.1% FSR (with polynomial expression)				
Thermal Zero Shift:[2]	< 0.05% FSR/°C				
Stability:	< 0.2%/yr (under static conditions)				
Overrange:	115% FSR				
Temperature Range:	-40 to +60 °C -40 to 120 °F				
Frequency Range:	1400 - 3500 Hz				
Coil Resistance:	180 Ω, ±10 Ω				
Cable Type:[3]	Two twisted pair (four conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250")				
Convergence Meter Length including Swagelok eyehook assembly:	710 mm 28"	710 mm 28"	865 mm 34"	1195 mm 47"	1615 mm 63.5"

Notes:
[1] Minimum; greater resolution possible depending on readout.
[2] Depends on application.
[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:

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

Equation 10 - Resistance to Temperature

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

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	**3000**	**25**	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Table 9 - Thermistor Resistance Versus Temperature

APPENDIX C. SWAGELOK TUBE FITTING INSTRUCTIONS

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

C.1 Installation

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

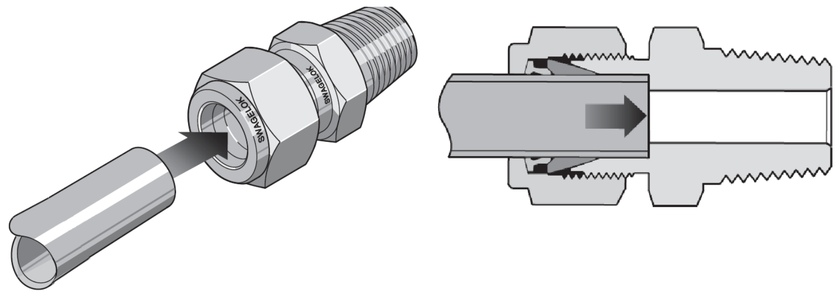

Figure 7 - Tube Insertion

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.

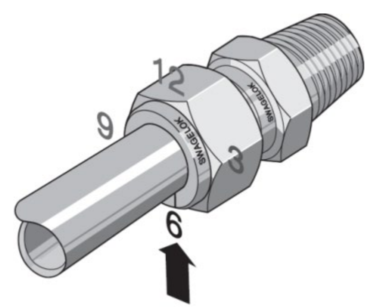

Figure 8 - Make a Mark at Six O'clock

4) While holding the fitting body steady, tighten the nut one and one-quarter turns until the mark is at the nine 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 three o'clock position.)

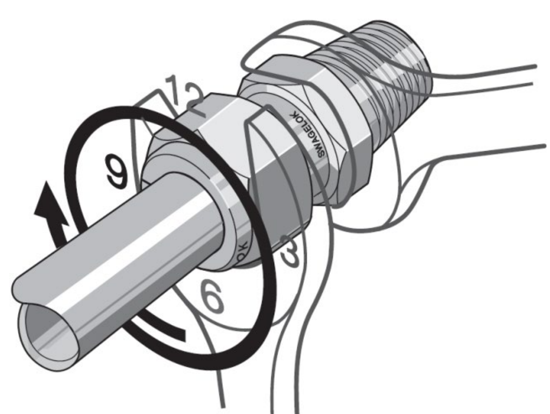

Figure 9 - Tighten One and One-Quarter Turns

C.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.*

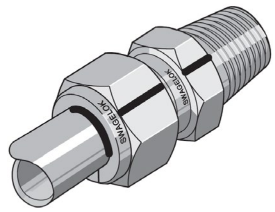

Figure 10 - Marks for Reassembly

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.

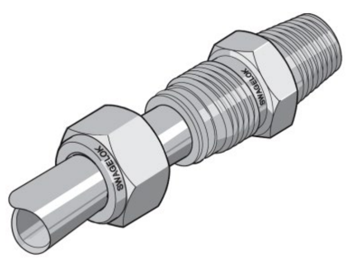

Figure 11 - Ferrules Seated Against Fitting Body

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.

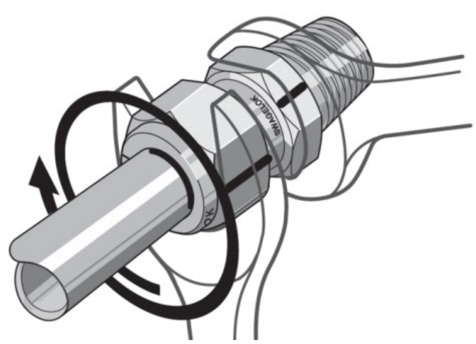

Figure 12 - Tighten Nut Slightly

APPENDIX D. EXAMPLE CALIBRATION REPORT

GEOKON 48 Spencer St. Lebanon, NH 03766 USA

Vibrating Wire Displacement Transducer Calibration Report

Range: 12.5 mm

Calibration Date: August 23, 2012

Serial Number: 1224097

Temperature: 23.9 °C

Calibration Instruction: CI-4400

Technician: [signature]

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	2333	2331	2332	-0.02	-0.15	0.00	0.00
2.5	3383	3382	3383	2.50	0.04	2.50	0.00
5.0	4429	4427	4428	5.02	0.13	5.00	0.00
7.5	5469	5467	5468	7.51	0.12	7.50	-0.01
10.0	6505	6504	6505	10.00	0.04	10.00	0.01
12.5	7535	7535	7535	12.48	-0.15	12.50	0.00

(mm) Linear Gage Factor (G): 0.002402 (mm/ digit) **Regression Zero: 2340**

Polynomial Gage Factors: A: 5.388E-09 B: 0.002349 C: ________

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

(inches) Linear Gage Factor (G): 0.00009458 (inches/digit)

Polynomial Gage Factors: A: 2.1213E-10 B: 0.00009249 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.

Figure 13 - Typical 4425 Calibration Report