GEOKON®

48 Spencer Street
Lebanon, NH 03766, USA
Tel: 603·448·1562
Fax: 603·448·3216
Email: geokon@geokon.com
http://www.geokon.com

Instruction Manual

Model 4420

VW Crackmeter

Doc Rev V, 04/30/2019

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Geokon warrants its products to be free of defects in materials and workmanship, under normal use and service for a period of 13 months from date of purchase. If the unit should malfunction, it must be returned to the factory for evaluation, freight prepaid. Upon examination by Geokon, if the unit is found to be defective, it will be repaired or replaced at no charge. However, the WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion or current, heat, moisture or vibration, improper specification, misapplication, misuse or other operating conditions outside of Geokon's control. Components which wear or which are damaged by misuse are not warranted. This includes fuses and batteries.

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1. INTRODUCTION

Geokon Model 4420 Vibrating Wire Crackmeters are designed to measure movement across joints such as tension cracks in soils, joints in rock and concrete, and the construction joints in buildings, bridges, pipelines, dams, etc.

The instrument consists of a vibrating wire sensing element in series with a heat treated, stress relieved spring which is connected to the wire at one end and a connecting rod at the other. The unit is fully sealed and operates at pressures of up to 250 psi. As the connecting rod is pulled out from the gauge body, the spring is elongated causing an increase in tension, which is sensed by the vibrating wire element. The increase in tension (strain) of the wire is directly proportional to the extension of the shaft. This change in strain allows the Model 4420 to measure the opening of the joint very accurately.

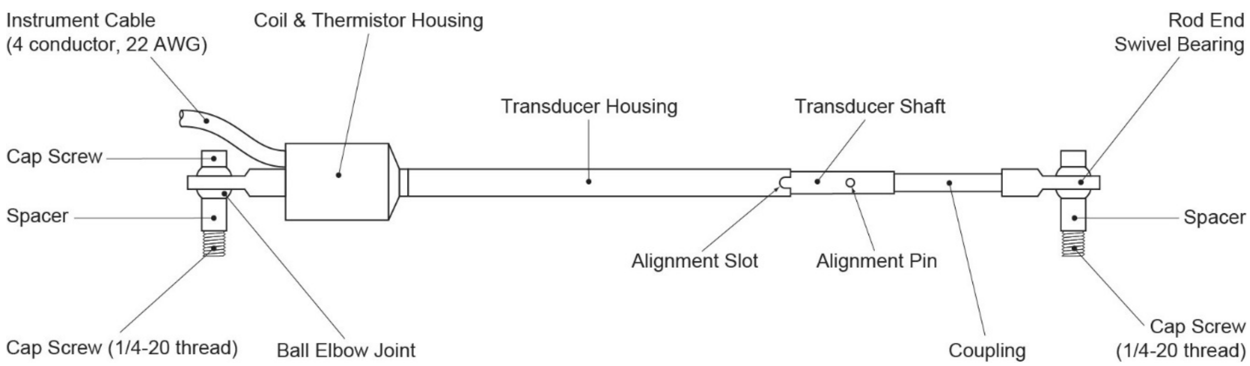


Figure 1 - Model 4420-1-50/100/150/200/300 Vibrating Wire Crackmeter

Models 4420-3, 4420-12.5 and 4420-25 differ slightly from the standard Crackmeter in that they provide for adjustment of the setting distance with a threaded extension rod and locking nut.

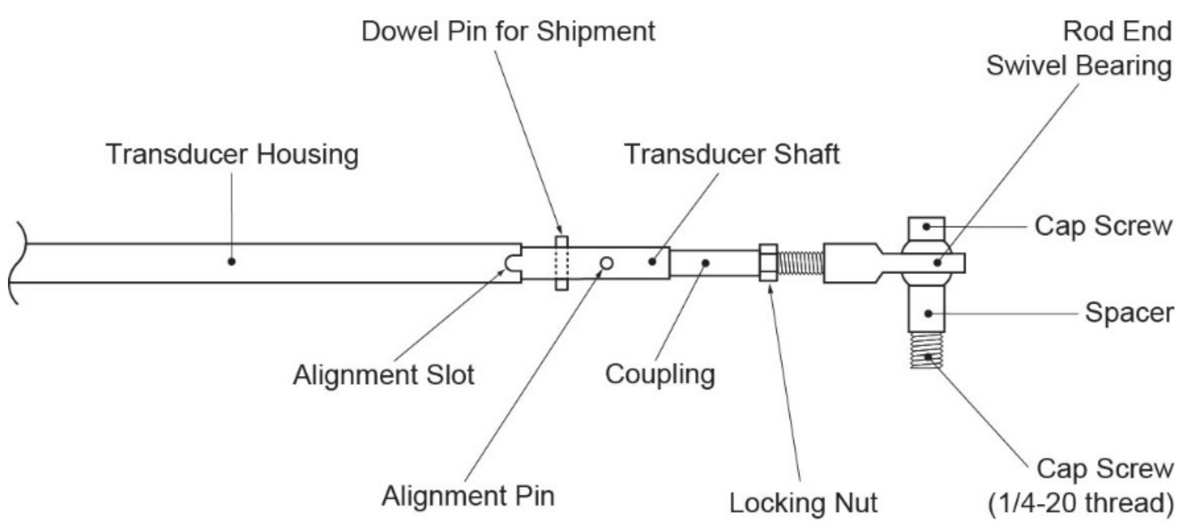


Figure 2 - Model 4420-1-12/25 Detail

CAUTION! Do not rotate the 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.

2. INSTALLATION

2.1 Preliminary Tests

Upon receipt of the instrument, the gauge should be checked for proper operation (including the thermistor). The crackmeter normally arrives with its shaft secured at approximately 50% of its range. This is accomplished by a dowel pin held in place with a piece of tape for crackmeters with a range of 100 mm (four inches) or smaller (see Figure 2). For crackmeters with a range greater than 100 mm, a slotted sleeve made of PVC is used. These devices hold the crackmeter in tension to protect it during shipping. With the shipping spacers still in place, connect the gauge to a readout box and take a reading. (See Section 3 for readout instructions.) The reading should be stable and in the range of 4000 to 5000 digits. Please note that crackmeters with a 3 mm (.125 inch) range are shipped with the push rod fully retracted and have no shipping spacer to remove. These gauges should read between 2000 to 3000 digits.

Remove the PVC slotted sleeve or dowel pin before proceeding further.

Checks of electrical continuity can be made using an ohmmeter. Resistance between the gauge leads should be approximately 180 ohms, ±10 ohms. Remember to add the cable resistance, which is approximately 14.7Ω per 1000 ft. (48.5Ω per km) of 22 AWG stranded copper leads at 20 °C. Multiply this factor by two to account for both directions. Resistance between the green and white conductors will vary based on temperature; see Table 9 in Appendix B for standard crackmeters, Appendix D, Table 10 for model 4420HT. Resistance between any conductor and the shield should exceed two megohms.

2.2 Crackmeter Installation

For additional instructions regarding 3D Arrays and Model 4420HT see Appendix C and Appendix D respectively.

2.2.1 Anchors

Three types of anchors are available from the factory for installing the Model 4420 Vibrating Wire Crackmeter:

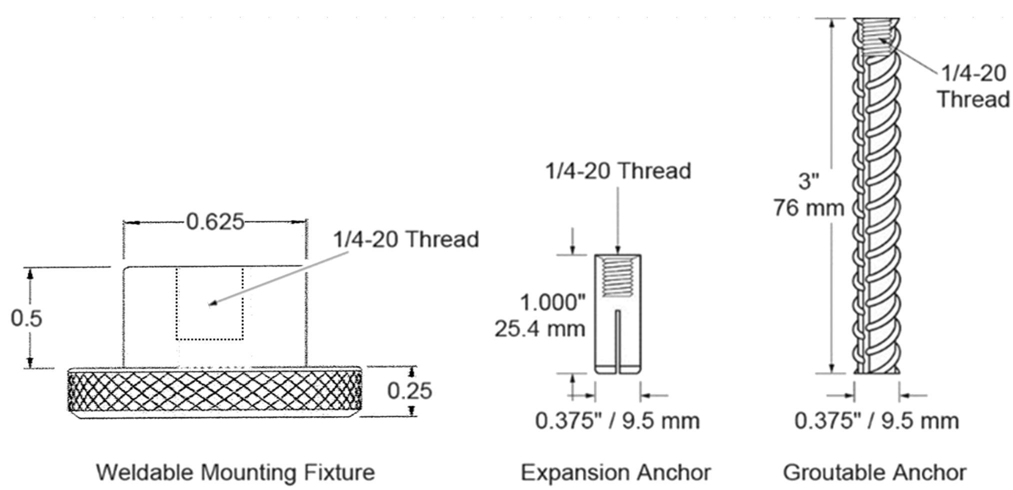


Figure 3 - Anchor Types with Dimensions

The weldable fixture is designed to install the Crackmeter on steel members. The machine bolt expansion anchors and groutable anchors are used to install the Crackmeter on concrete or rock. The anchors are installed at the appropriate spacing distance (Table 1) depending on the anticipated direction of movement (extension or compression). Sections 2.2.2 through 2.2.4 give detailed instructions for each type of anchor. See Section 2.2.5 for special instructions for Models 4420-1-3MM (.125”), 4420-1-12.5MM (.5”), and 4420-1-25MM (1”).

Model & Range	Midrange	To Monitor Extension	To Monitor Compression
4420-3 mm (.125")	292.6 mm (11.52")	291.1 mm (11.46")	294.1 mm (11.58")
4420-12.5 mm (.5")	317 mm (12.5")	310 mm (12.2")	325 mm (12.8")
4420-25 mm (1")	343 mm (13.5")	330 mm (13")	356 mm (14")
4420-50 mm (2")	396 mm (15.6”)	371 mm (14.6”)	422 mm (16.6")
4420-100 mm (4")	554 mm (21.8")	503 mm (19.8")	605 mm (23.8")
4420-150 mm (6")	645 mm (25.4")	569 mm (22.4")	721 mm (28.4")
4420-200 mm (8”)	869 mm (34.2”)	767 mm (30.2”)	970 mm (38.2”)
4420-300 mm (12”)	1186 mm (46.7")	1034 mm (40.7")	1339 mm (52.7")
Note for model 4420HT: Due to the U-joint configuration of 4420HT, the overall gauge assembly length is increased by 35 mm (1.375”). This length should be added to the anchor spacing distance shown above.			

Table 1 - Crackmeter Anchor Spacing Distances

When setting the gauge position using a portable readout, use the reading ranges in Table 2 to determine the proper position.

Approximate Midrange Reading	Approximate Reading to Monitor Extensions	Approximate Reading to Monitor Compressions
4500-5000	2500-3000	6500-7000

Table 2 - Crackmeter Reading Ranges

Note that the calibration sheet (Figure 11) supplied with the Crackmeter shows actual readings at zero, 25%, 50%, 75%, and 100% of the range of extension. These readings can be used as a guide to set the Crackmeter in any part of its range, either in anticipation of closure or opening of the crack. Extend the crackmeter until the desired reading is obtained. Hold the crackmeter in this position while the distance between the cap screws (set inside the swivel bearings, see Figure 1) is measured. This measurement can serve as a spacing guide for drilling or welding the anchor points. The alignment pin on the transducer shaft and slot on the body serve as a guide for alignment. **Do not rotate the shaft of the Crackmeter more than 180 degrees. This may cause irreparable damage to the instrument.**

2.2.2 Installation using Weldable Fixtures

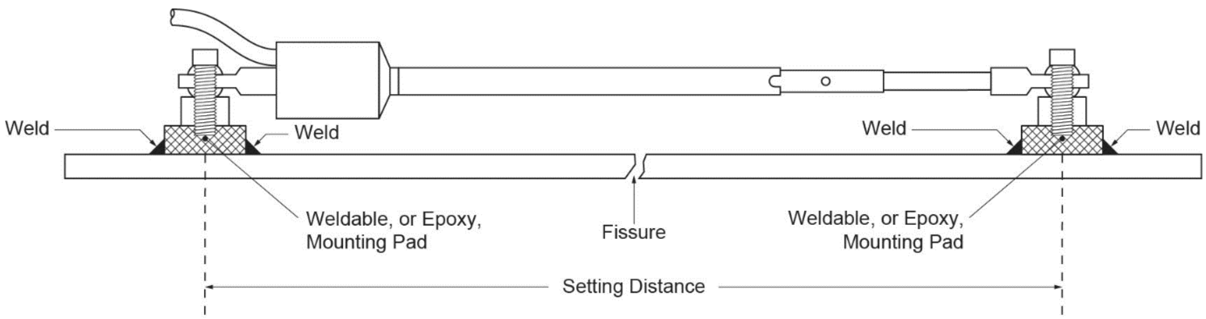


Figure 4 - Installation using Weldable Fixtures

Installation instructions:

1) Determine the proper setting distance using the figures in Table 1, or the readings on the calibration sheet.

2) Prepare the surface of the steel (grinding, sanding, etc.) around the area of each weldable fixture.

3) Locate the welding fixtures on prepared surfaces.

4) Check the spacing again and tack weld to the member.

5) Remove the PVC slotted sleeve or dowel pin securing the transducer shaft.

6) Thread the cap screw through the swivel bearing and through the half-inch spacer on each end.

7) Tighten the cap screws into the welding fixtures.

8) Check and record the reading with a portable readout. Use Table 2 or the readings on the calibration sheet to check the position.

2.2.3 Installation using Groutable Anchors

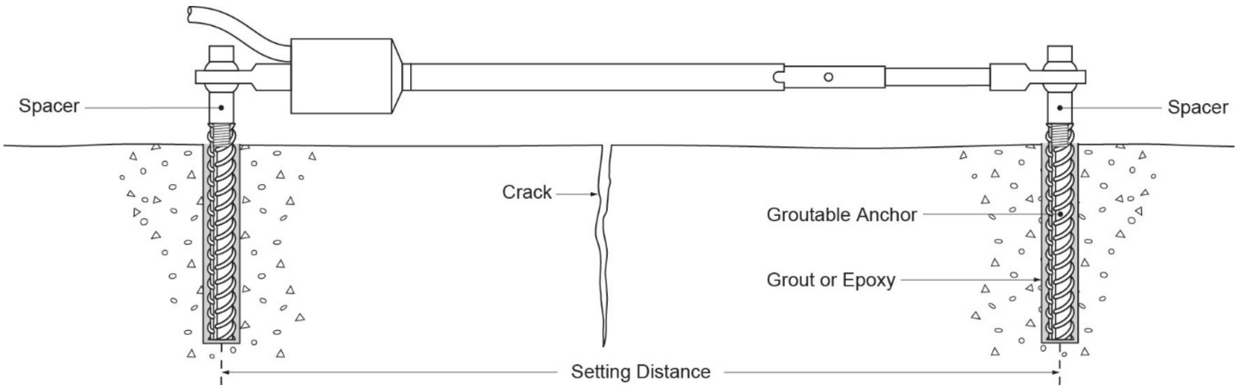


Figure 5 - Installation using Groutable Anchors

Installation instructions:

1) Determine the proper setting distance using the figures from Table 1 or the readings on the calibration sheet.

2) Using a hammer drill (or other suitable equipment), drill two half-inch holes approximately three inches deep at the proper locations. Shorter holes may be drilled if the anchors are cut down accordingly.

3) Push the cap screws through the swivel bearings and spacers on each end of the crackmeter and then loosely thread them into the groutable anchors.

4) If installing the instrument at the midrange position, leave the PVC slotted sleeve or dowel pin that secures the transducer shaft in the midrange position installed.

5) Fill the holes with grout or epoxy. For holes drilled overhead use a quick setting grout or epoxy.

6) Push the anchors in until the tops are flush with the surface.

7) After the grout or epoxy has set, tighten the set screws.

8) Remove the PVC slotted sleeve or dowel pin if it was not removed earlier.

9) Check and record the reading with a portable readout. Use Table 2 or the readings on the calibration sheet to check the position.

2.2.4 Installation using Expansion Anchors

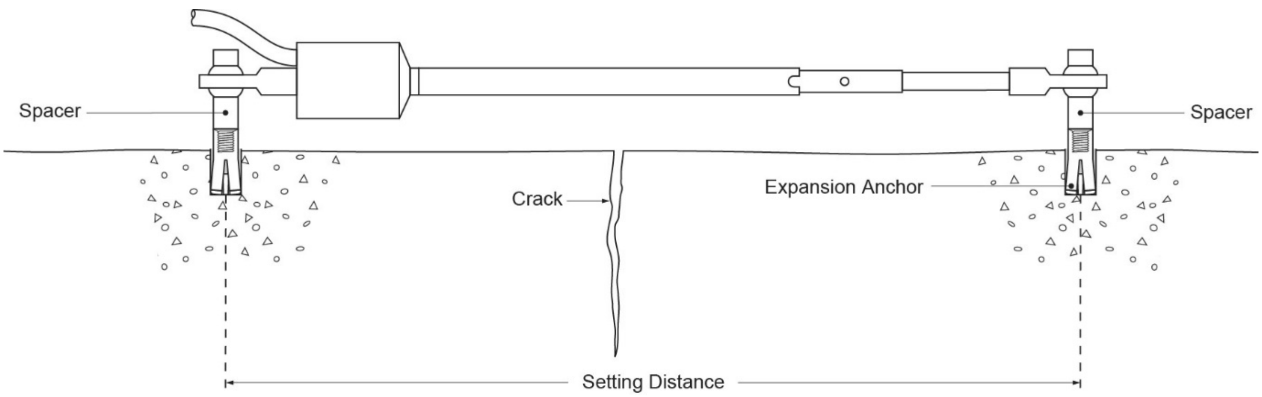


Figure 6 - Installation using Expansion Anchors

Installation instructions:

1) Determine the proper setting distance using the figures from Table 1 or the readings on the calibration sheet.

2) Using a masonry drill (or other suitable equipment), drill two 3/8-inch (10 mm) diameter holes, 1.25" (32 mm) deep at the proper locations.

3) Insert the expansion anchors into the holes, with the slotted end down.

4) Insert the provided setting tool, small end first, into the anchor. Expand the anchor by hitting the large end of the setting tool with several sharp hammer blows.

5) Remove the PVC slotted sleeve or dowel pin securing the transducer shaft.

6) Push the cap screws through the swivel bearings and spacers on each end of the crackmeter and then tighten the cap screws into the anchors.

7) Check and record the reading with a portable readout. Use Table 2 or the readings on the calibration sheet to check the position.

2.2.5 Special note regarding installation of Models 4420-1-3MM (.125"), 4420-1-12.5MM (.5"), and 4420-1-25MM (1")

If the reading is not in the proper range after installation, additional adjustment may be made using the threaded extension at the end of the transducer shaft. In order for adjustments to be accurately made, the transducer needs to be attached to the anchor at the cable end, and free at the opposite end.

To make an adjustment, loosen the locking nut then rotate the threaded rod in or out of the end of the transducer shaft. **The transducer shaft should be gripped while rotating the threaded rod. The transducer shaft must never be rotated beyond 180 degrees or gauge failure may result!** After making an adjustment, align the hole in the swivel bearing over the anchor and check the reading. Continue to adjust until the desired reading is shown on the readout. Once the desired reading is obtained, push the cap screw through the swivel bearing and spacer and then tighten into the anchor.

2.3 Protection from mechanical damage

Protecting the crackmeter from damage can be accomplished by using cover plates available from Geokon, which are made from sheet steel formed into a channel shape (Model 4420-7). The standard cover plate is long enough to cover the two-inch range crackmeter; longer range crackmeters utilize multiple cover plates tack welded together.

Use the mounting hardware provided to install the cover plates as follows:

1) Anchor the two 3/8 x 2" long threaded rods in place head down using either groutable or expansion anchors. The bolts should be spaced at a nominal 21 inches (530 mm) apart. A spacer jig is available from Geokon, or the cover plate can be flipped onto its back and the holes in the cover plate can be used to mark the bolt locations. One hole in the cover plate is slotted, so the spacing is not critical.

2) Place the cover plate over the welded bolts.

3) Install washers, then nuts. Avoid excessive force while tightening the cover retaining nuts. See Figure 7 for a diagram of the completed assembly.

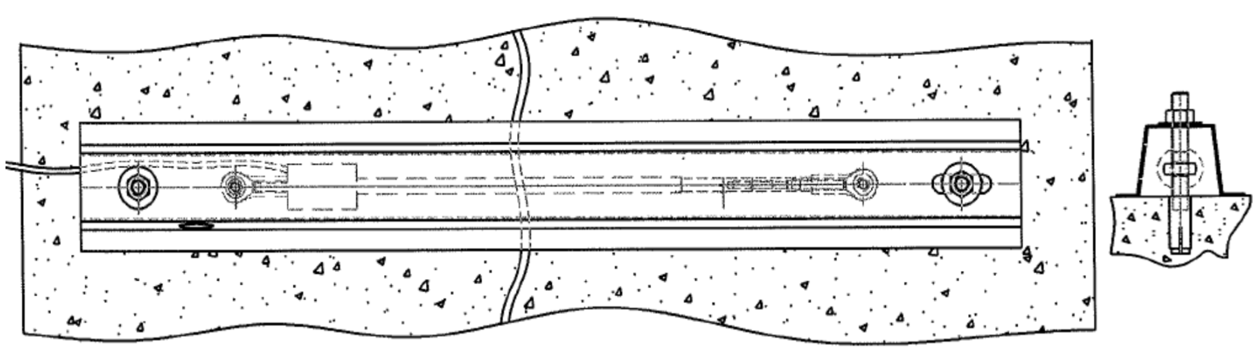


Figure 7 - Typical Cover Plate Installation

For crackmeters with a range greater than two inches, tack weld multiple cover plates together. They should be positioned so that the extended slots are on both sides to accommodate the range of motion. The mounting nut and washer should only be loosely tightened to enable the cover to slide on the 3/8-16 threaded rods. An extra nut is provided as a locknut. Critical dimensions of the extended range covers are shown in Table 3.

Range	Total Length	Hole Spacing	Slot Lengths
100 mm (4")	36"	32.5"	2"
150 mm (6")	36"	31.5"	3"
200 mm (8")	48"	42.5"	4"
300 mm (12")	60"	52.5"	6"

Table 3 – Dimensions of Extended Range Covers

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 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.

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 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.

2.6 Lightning Protection

The Model 4420 Vibrating Wire Crackmeter, unlike numerous other types of instrumentation available from Geokon, does 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 gauge and possibly destroy it.

Note the following suggestions:

- If the gauge 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, allowing access to the protection board. In the event that the (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 gauge. See Figure 8. Consult the factory for additional information on these or alternate lightning protection schemes.

- Plasma surge arrestors can be epoxy potted into the gauge 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.

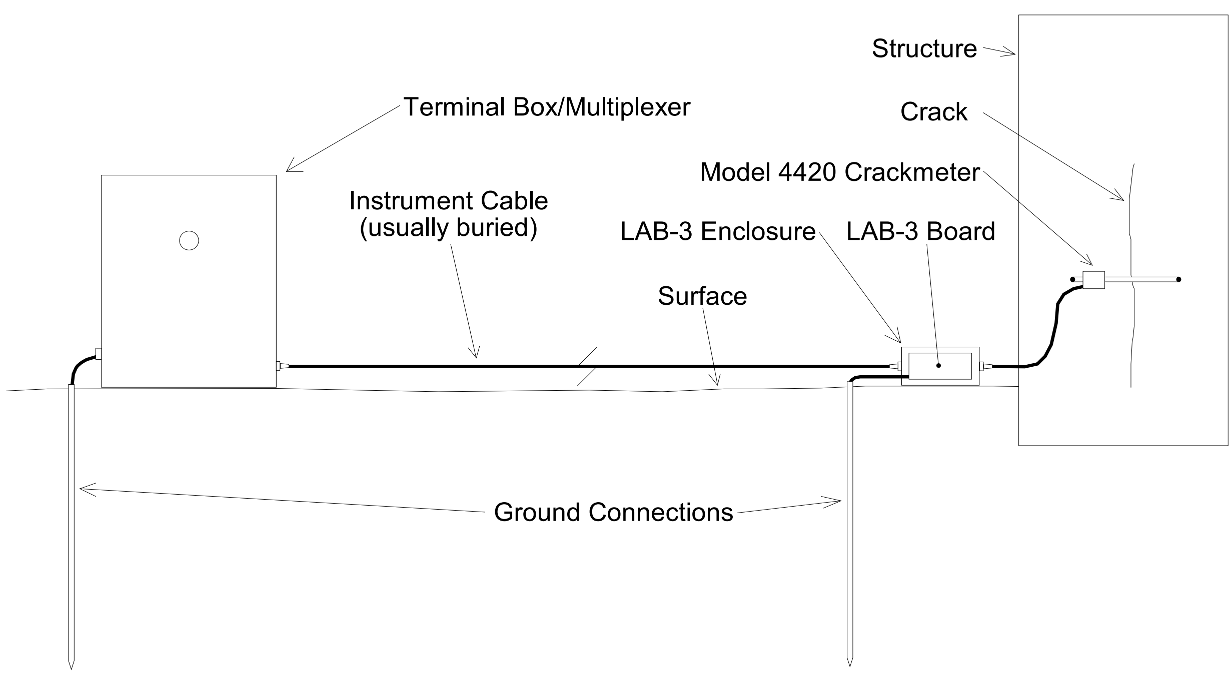


Figure 8 - Lightning Protection Scheme

3. TAKING READINGS

3.1 GK-404 Readout Box

The Model GK-404 Vibrating Wire Readout is a portable, low-power, handheld unit that 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 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. 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) of the GK-404 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). The GK-404 will continue to take measurements and display readings until the unit turned off, either manually, or if enabled, by the Auto-Off timer. 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 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

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.

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).

3.2.2 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 10 shows a typical vibrating wire output in digits and thermistor output in degrees Celsius.

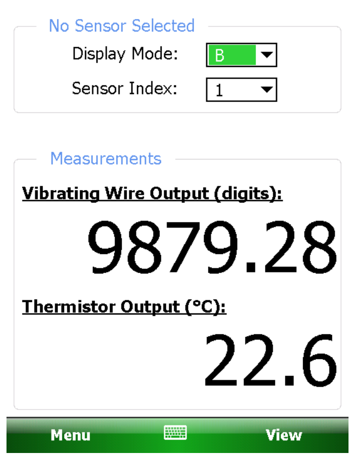


Figure 10 - Live Readings – Raw Readings

For further information, consult the GK-405 Instruction Manual.

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”.

3.3.1 Connecting Sensors to the GK-403

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.

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).

3.3.2 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.

The unit will automatically turn off after approximately two minutes to conserve power. Consult the GK-403 Instruction Manual for additional information.

3.4 Measuring Temperatures

All vibrating wire crackmeters 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. Geokon 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 crackmeter. (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 14.7 Ω 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 B, Table 9 for standard crackmeters; Appendix D, Table 10 for model 4420HT.

4. DATA REDUCTION

4.1 Deformation Calculation

The basic units utilized by Geokon for measurement and reduction of data from Vibrating Wire Crackmeters 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:

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

Equation 2 - Deformation Calculation

Where;
R_1 is the current reading.
R_0 is the initial reading, usually obtained at installation.
G is the gauge factor, usually millimeters or inches per digit (see Figure 11).
F is an optional engineering units conversion factor, see Table 4.

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 4 - Engineering Units Conversion Multipliers

For example, the initial reading R_0, at installation of a crackmeter is 2500 digits. The current reading, R_1, is 6000. The gauge factor is 0.006223 mm/digit. The deformation change is:

$$D_{\text{uncorrected}} = (6000 - 2500) \times 0.006223 = +21.78 \text{ mm}$$

Note that increasing readings (digits) indicate increasing extension.

To use the Polynomial Gauge factors given on the Calibration Sheet, use the value of R_0 and Gauge Factors A and B with D set to zero to calculate the new value of C. then substitute the new value of R_1 and use A, B and the new value of C to calculate the displacement D.

GEOKON 48 Spencer St. Lebanon, NH 03766 USA

Vibrating Wire Displacement Transducer Calibration Report

Range: 25 mm

Serial Number: 1617772

Calibration Instruction: CI-4400

Cable Length: 10 feet

Calibration Date: June 15, 2016

This calibration has been verified/validated as of 09/15/2016

Temperature: 23.3 °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	2659	2658	2659	-0.03	-0.11	0.00	0.00
5.0	3468	3467	3468	5.01	0.02	5.00	-0.01
10.0	4275	4274	4275	10.03	0.11	10.00	0.01
15.0	5079	5077	5078	15.03	0.11	15.00	0.01
20.0	5879	5877	5878	20.01	0.02	20.00	-0.01
25.0	6676	6676	6676	24.97	-0.11	25.00	0.00

(mm) Linear Gage Factor (G): 0.006223 (mm/ digit) **Regression Zero: 2663**

Polynomial Gage Factors: A: 1.4286E-08 B: 0.006089 C: ______

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

(inches) Linear Gage Factor (G): 0.0002450 (inches/digit)

Polynomial Gage Factors: A: 5.6242E-10 B: 0.0002397 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 11 - Typical Crackmeter Calibration Sheet

4.2 Temperature Correction

Geokon's Vibrating Wire crackmeters 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 °C) corrections may be applied. The temperature coefficient of the mass or member to which the Crackmeter is attached should also be taken into account. By correcting the transducer for temperature changes the temperature coefficient of the mass or member may be distinguished. The following equation applies:

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

Equation 3 - Thermally Corrected Deformation Calculation

Where;
R_1 is the current reading.
R_0 is the initial reading.
G is the linear gauge 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. The first step in the temperature correction process is determination of the proper thermal coefficient based on the following equation:

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

Equation 4 - Thermal Coefficient Calculation

Where;
R_1 is the current reading.
M is the multiplier from Table 5.
B is the constant from Table 5.
G is the linear gauge factor from the supplied calibration sheet.

Model:	Multiplier (M):	Constant (B):
4420-3 mm (0.125")	0.000520	3.567
4420-12 mm (0.5")	0.000375	1.08
4420-25 mm (1")	0.000369	0.572
4420-50 mm (2")	0.000376	0.328
4420-100 mm (4")	0.000398	0.0864
4420-150 mm (6")	0.000384	-0.3482
4420-200 mm (8")	0.000396	-0.4428
4420-300 mm (12")	0.000424	-0.6778

Table 5 Thermal Coefficient Calculation Constants

Consider the following example using a Model 4420-200 mm Crackmeter:
R_0 = 4773 digits
R_1 = 4589 digits
T_0 = 20.3 °C
T_1 = 32.9 °C
G = 0.04730 mm/digit
K = (((4589 × 0.000396) - 0.4428) × 0.04730) = 0.065011
$D_{corrected} = ((R_1 - R_0) \times G) + (((T_1 - T_0) \times K)$
$D_{corrected} = ((4589 - 4773) \times 0.04730) + ((32.9 - 20.3) \times 0.065011)$
$D_{corrected} = (-184 \times 0.04730) + 0.819$
$D_{corrected} = -8.7032 + 0.819$
$D_{corrected} = -7.8842$ mm

4.3 Environmental Factors

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

Symptom: Thermistor resistance is too high

- ✓ It is likely that there is 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

- ✓ It is likely that there is 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 crackmeter. 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 crackmeter 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 the readings will likely be unstable because the vibrating wire is under-tensioned.
- ✓ 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 whether using a portable readout or datalogger. Connect the shield drain wire to the readout using the blue clip. (Green for the GK-401.)

- ✓ Does the readout work with another gauge? 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 gauge leads. Table 6 shows the expected resistance for the various wire combinations; Table 7 is provided for the user to fill in the actual resistance found. Cable resistance is approximately 14.74Ω 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 2.4.

- ✓ 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 6 - Sample Resistance

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

Table 7 - Resistance Work Sheet

APPENDIX A. SPECIFICATIONS

A.1 Model 4420 Crackmeter

Range:	3 mm/ .125"	12 mm/ 0.50"	25 mm/ 1"	50 mm/ 2"	100 mm/ 4"	150 mm/ 6"	200 mm/ 8"	300 mm/ 12"
Resolution:[1]	0.025% FSR							
Linearity:	0.25% FSR							
Thermal Zero Shift:[2]	< 0.05% FSR/°C							
Stability:	< 0.2%/yr (under static conditions)							
Overrange:	115% FSR							
Temperature Range:	-20 to +80 °C -5 to +175 °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")							
Cable Wiring Code:	Red and Black are the VW Sensor, White, and Green the Thermistor.							
Length: (midrange, end to end)	312 mm/ 12.3"	337 mm/ 13.3"	362 mm/ 14.3"	415 mm/ 16.4"	573 mm/ 22.6"	664 mm/ 26.2"	889 mm/ 35"	1205 mm/ 47.5"
Coil Assembly Dimensions: (length × OD)	31.75 × 25.4 mm 1.25 × 1"							

Table 8 - Crackmeter Specifications

Notes:
[1] Minimum, greater resolution possible depending on readout.
[2] Depends on application.
[3] Polyurethane jacket cable available.

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

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

$$T = \frac{1}{A + B(\mathrm{Ln}R) + C(\mathrm{Ln}R)^3} - 273.15\ ^\circ\mathrm{C}$$

Equation 5 - Resistance to Temperature

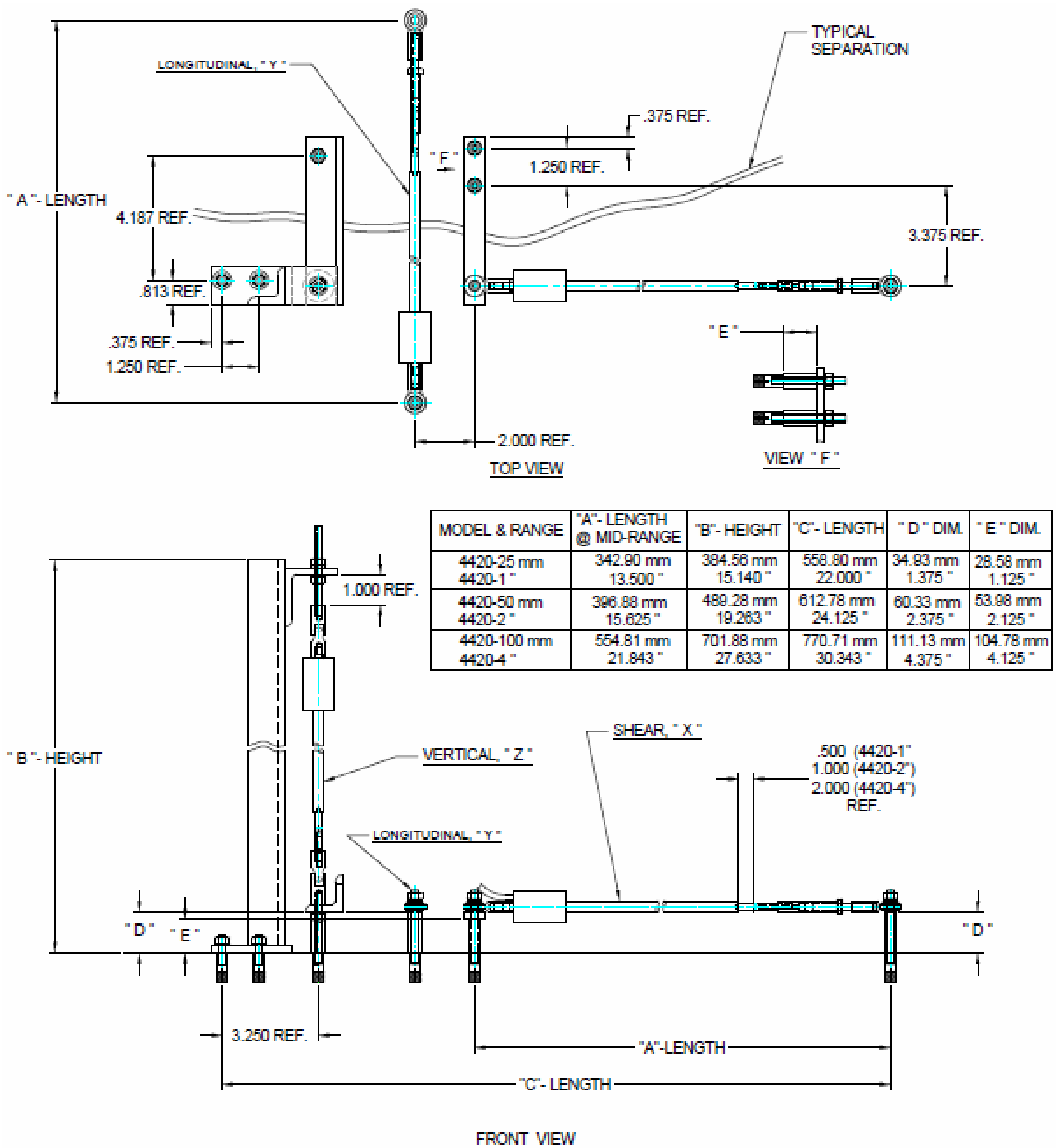
Where;
T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance.
$A = 1.4051 \times 10^{-3}$
$B = 2.369 \times 10^{-4}$
$C = 1.019 \times 10^{-7}$
Note: Coefficients calculated over the −50 to +150° C. span.

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. 3D ARRAYS

Monitoring crack movements in three dimensions requires an array of three crack meters. One such array is shown in Figure 12.



MODEL & RANGE	"A"- LENGTH @ MID-RANGE	"B"- HEIGHT	"C"- LENGTH	" D " DIM.	" E " DIM.
4420-25 mm 4420-1 "	342.90 mm 13.500 "	384.56 mm 15.140 "	558.80 mm 22.000 "	34.93 mm 1.375 "	28.58 mm 1.125 "
4420-50 mm 4420-2 "	396.88 mm 15.625 "	489.28 mm 19.263 "	612.78 mm 24.125 "	60.33 mm 2.375 "	53.98 mm 2.125 "
4420-100 mm 4420-4 "	554.81 mm 21.843 "	701.88 mm 27.633 "	770.71 mm 30.343 "	111.13 mm 4.375 "	104.78 mm 4.125 "

Figure 12 - Typical 3D Array

The ends of the crack meters are fixed on each side of a fissure by means of a bracket or by direct mounting using expansion anchors.

The X-axis, as shown in Figure 12, utilizes a 1/4” x 3/4” stainless steel bar to transfer parallel motion along the axis of the crack. For this sensor, two 3/8" diameter x 1 1/4" deep holes are made 1-1/4” apart, perpendicular to and one to two inches in from the crack in question. Once the anchors are installed with the spacers on top, the 5-5/8” long stainless steel bar is attached with the provided threaded rods, lock washers, and nuts. Note: The spacers used here are 1/8” shorter to accommodate the width of the bar. The spacing, chosen from Table 1 in Section 2.2.1, is then measured perpendicular from the 1/4-20 tapped hole located on the stainless steel bar. Install another expansion anchor and spacer at this location, and then attach the crackmeter with rod end bearings using the threaded rod, lock washer, and nuts provided.

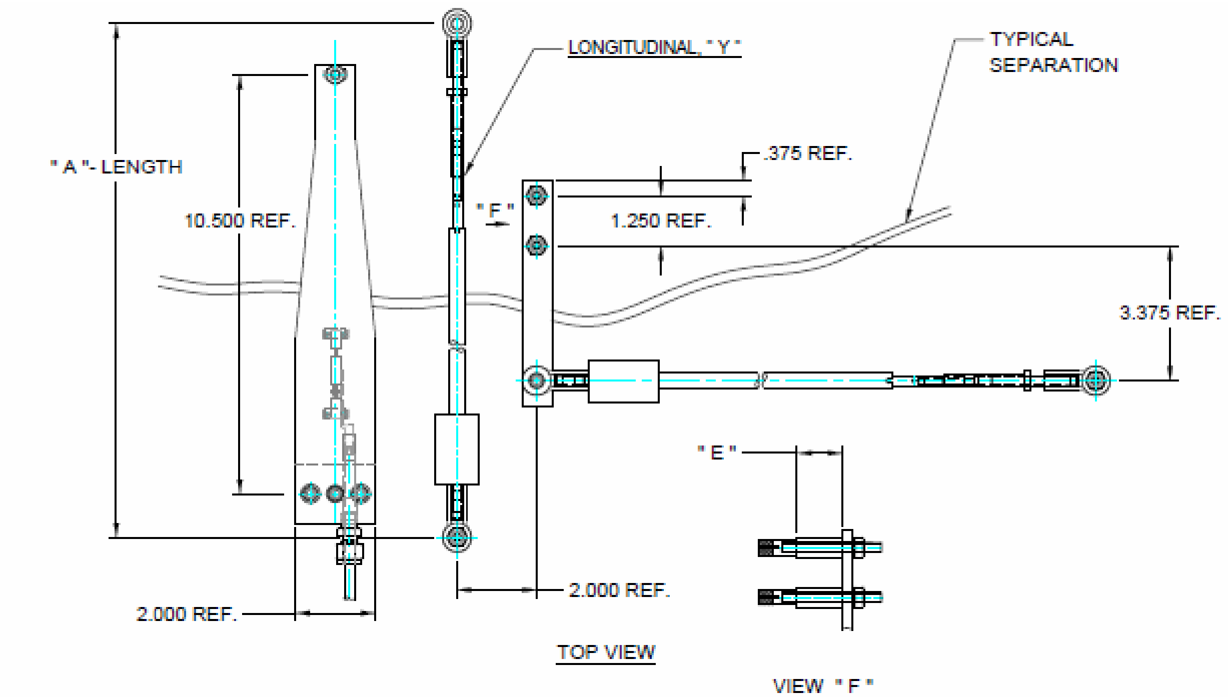
The Y-axis, as shown in Figure 12, monitors any movement perpendicular to the break. It is mounted the same as the standard crackmeter installation, referenced in Section 2.2.4, with 3/8" diameter x 1 1/4" deep hole on each side of the crack to be measured, and at a spacing chosen from Table 1 in Section 2.2.1. Custom spacers are provided to be installed between the expansion anchors and the rod end bearings.

The Z-axis, as shown in Figure 12, measures vertical movement along the crack utilizing two brackets: one installed to transfer movement across the crack and one to mount the sensor vertically. The 5-5/8” long stainless steel angle iron is mounted across the crack by installing an expansion anchor with a spacer approximately two inches in from the break. The vertical element is then aligned so that a crackmeter with U-joints on both ends will be upright in relation to the break. There are two expansion anchors supplied with this part located 1-1/4” apart, no spacers are required. A percentage of the transducer’s range can be established by tightening or loosening the nuts on the long-threaded rod.

The actual height of the crackmeters above the surface is determined by the spacers provided and is proportional to the range of the sensor to accommodate the maximum amount of movement.

The 3D hardware comes standard with expansion anchors but is designed to be interchangeable with groutable anchors. Refer to the instructions in Sections 2.2.3 for groutable anchors and Section 2.2.4 for drop-in expansion anchors.

An alternative version is available, where the vertical element Z-axis is replaced by a cantilever arrangement. The cantilever has a Model 4150 strain gauge attached to measure vertical movements. This version is shown in Figure 13 and is available in a one-inch range only.



MODEL & RANGE	"A"- LENGTH @ MID-RANGE	"B"- HEIGHT	"C"- LENGTH	" D " DIM.	" E " DIM.
4420-25 mm 4420-1 " & 4420-3	342.90 mm 13.500 "	53.98 mm 2.125 "	558.80 mm 22.000 "	34.93 mm 1.375 "	28.58 mm 1.125 "

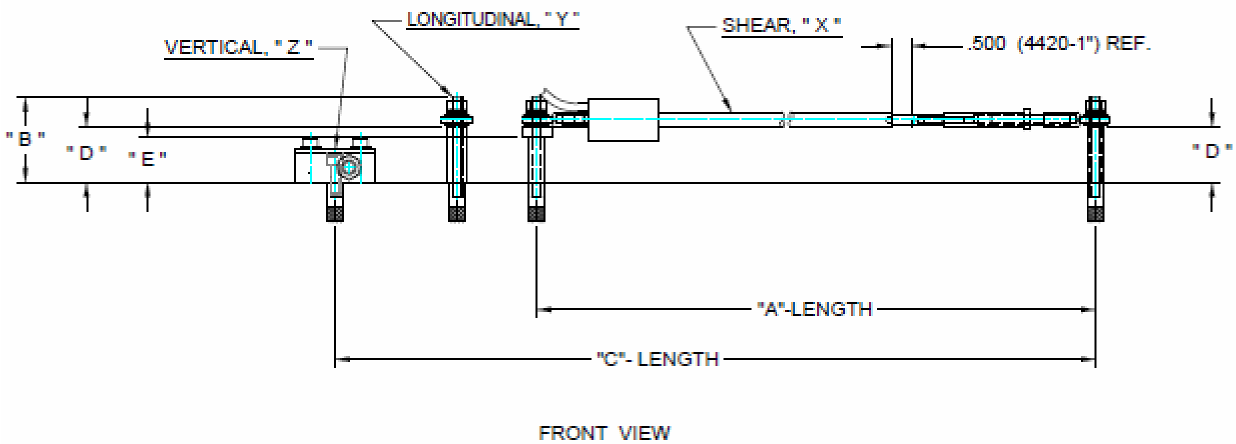


Figure 13 - 3D Array, Cantilever Version

Instruction for Installing the Cantilever

1) Drill a 3/8" diameter x 1 1/4" deep hole on each side of the crack to be measured at a spacing of 10.5" (267 mm)

2) Clean out the drill cuttings and insert the anchors into the holes, with the slotted end down.

3) Insert the provided setting tool, small end first, into each anchor. Expand the anchors by hitting the large end of the setting tool with several sharp hammer blows.

4) Using Loctite cement on the threads, screw the target plate into one of the threaded drop-in anchor holes until it is tight in the anchor.

5) While aligning the crackmeter with the target and making sure that the cantilever does not become overstressed (this can be avoided by backing off the jam nut and unscrewing the pointed threaded rod), place the crackmeter over the other hole and screw the supplied cap screw into the drop-in anchor.

6) Tighten the clamping cap screw.

7) Connect the readout box to the cable and observe the transducer output in position B. With no contact with the target, the output will be between 1800 and 2500 digits.

8) Set the zero position by turning the threaded rod on the cantilever tip until the reading is achieved. Once the reading is set, tighten the locknut. If all the anticipated displacement is seen as the cantilever moving down with reference to the target, set the zero position at 3000 digits. If all the movement is seen as moving up, set it at 10,000 digits. For midrange set at the zero position at 7000 digits.

9) In areas of high traffic, the gauge should be protected by a cover plate.

APPENDIX D. MODEL 4420HT – HIGH TEMPERATURE VERSION

A high temperature version (Model 4420-HT) is offered which is rated to 200 degrees Celsius. These models are supplied with 316 stainless steel U-joints on the ends, as opposed to the rod end bearings installed on standard crackmeters. Due to the U-joint configuration, the overall gauge assembly length is increased by 35 mm (1.375") which would have to be added to the anchor spacing distance found in Table 1 in Section 2.2.1.

The epoxied diameter is slightly larger with the HT version due to added waterproofing and strain relief for the Teflon cable. This results in a space between the U-joint and the OD of the epoxy at the largest part of about 14.5 mm (0.569"). The standard spacer supplied with anchors as shown in Figure 5 and Figure 6, is about 12.7 mm (.500"); therefore, interference between the epoxied area and the mounted surface may occur. In this case the assembly can be rotated 180 degrees on its axis or the larger spacers supplied can be used.

4420HT Crackmeters are supplied with a high temperature thermistor that has a range of -80 to +200 °C, and an accuracy of ±0.5 °C. To convert Ohms to temperature use Equation 6 or Table 10 below.

Resistance to Temperature Equation for *US Sensor 103JL1A*:

$$T=\frac{1}{A+B(LnR)+C(LnR)^3+D(LnR)^5}-273.15$$

Equation 6 - High Temperature Resistance to Temperature

Where;
T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance.
$A = 1.127670 \times 10^{-3}$
$B = 2.344442 \times 10^{-4}$
$C = 8.476921 \times 10^{-8}$
$D = 1.175122 \times 10^{-11}$

Note: Coefficients optimized for a curve "J" Thermistor over the temperature range of 0 °C to +250 °C.

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
32,650	0	7,402	32	2,157	64	763.5	96	316.6	128	148.4	160	76.5	192	42.8	224
31,029	1	7,098	33	2,083	65	741.2	97	308.7	129	145.1	161	75.0	193	42.1	225
29,498	2	6,808	34	2,011	66	719.6	98	301.0	130	142.0	162	73.6	194	41.4	226
28,052	3	6,531	35	1,942	67	698.7	99	293.5	131	138.9	163	72.2	195	40.7	227
26,685	4	6,267	36	1,876	68	678.6	100	286.3	132	135.9	164	70.8	196	40.0	228
25,392	5	6,015	37	1,813	69	659.1	101	279.2	133	133.0	165	69.5	197	39.3	229
24,170	6	5,775	38	1,752	70	640.3	102	272.4	134	130.1	166	68.2	198	38.7	230
23,013	7	5,545	39	1,693	71	622.2	103	265.8	135	127.3	167	66.9	199	38.0	231
21,918	8	5,326	40	1,637	72	604.6	104	259.3	136	124.6	168	65.7	200	37.4	232
20,882	9	5,117	41	1,582	73	587.6	105	253.1	137	122.0	169	64.4	201	36.8	233
19,901	10	4,917	42	1,530	74	571.2	106	247.0	138	119.4	170	63.3	202	36.2	234
18,971	11	4,725	43	1,480	75	555.3	107	241.1	139	116.9	171	62.1	203	35.6	235
18,090	12	4,543	44	1,432	76	539.9	108	235.3	140	114.5	172	61.0	204	35.1	236
17,255	13	4,368	45	1,385	77	525.0	109	229.7	141	112.1	173	59.9	205	34.5	237
16,463	14	4,201	46	1,340	78	510.6	110	224.3	142	109.8	174	58.8	206	33.9	238
15,712	15	4,041	47	1,297	79	496.7	111	219.0	143	107.5	175	57.7	207	33.4	239
14,999	16	3,888	48	1,255	80	483.2	112	213.9	144	105.3	176	56.7	208	32.9	240
14,323	17	3,742	49	1,215	81	470.1	113	208.9	145	103.2	177	55.7	209	32.3	241
13,681	18	3,602	50	1,177	82	457.5	114	204.1	146	101.1	178	54.7	210	31.8	242
13,072	19	3,468	51	1,140	83	445.3	115	199.4	147	99.0	179	53.7	211	31.3	243
12,493	20	3,340	52	1,104	84	433.4	116	194.8	148	97.0	180	52.7	212	30.8	244
11,942	21	3,217	53	1,070	85	421.9	117	190.3	149	95.1	181	51.8	213	30.4	245
11,419	22	3,099	54	1,037	86	410.8	118	186.1	150	93.2	182	50.9	214	29.9	246
10,922	23	2,986	55	1,005	87	400.0	119	181.9	151	91.3	183	50.0	215	29.4	247
10,450	24	2,878	56	973.8	88	389.6	120	177.7	152	89.5	184	49.1	216	29.0	248
10,000	**25**	2,774	57	944.1	89	379.4	121	173.7	153	87.7	185	48.3	217	28.5	249
9,572	26	2,675	58	915.5	90	369.6	122	169.8	154	86.0	186	47.4	218	28.1	250
9,165	27	2,579	59	887.8	91	360.1	123	166.0	155	84.3	187	46.6	219		
8,777	28	2,488	60	861.2	92	350.9	124	162.3	156	82.7	188	45.8	220		
8,408	29	2,400	61	835.4	93	341.9	125	158.6	157	81.1	189	45.0	221		
8,057	30	2,316	62	810.6	94	333.2	126	155.1	158	79.5	190	44.3	222		
7,722	31	2,235	63	786.6	95	324.8	127	151.7	159	78.0	191	43.5	223		

Table 10 - Thermistor Resistance versus Temperature for Model 4420HT