Model 4420

Vibrating Wire Crackmeter

Instruction Manual

GEOKON®

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Note: The Model 4420HT High Temperature Series is not CE approved.

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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 that wear or 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 tension cracks in soils, joints in rock and concrete, construction joints in buildings, bridges, pipelines, dams, and more.

The sensor 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 to a connecting rod at the other. The standard units are fully sealed and operates at pressures of up to 1 MPa (145 psi). The Model 4420WP series can be used for pressures over 1 MPa (145 psi) and are recommended in applications where the sensor will be submerged.

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.

The ends of the sensor are attached to anchors that are grouted, bolted, welded, or bonded on opposite sides of the crack or fissure to be monitored. 3D Mounting brackets allow for measurement of displacements in two or three orthogonal directions. Special clamps (Model 4420-8) for attachment to a variety of earth reinforcements and geogrids are available.

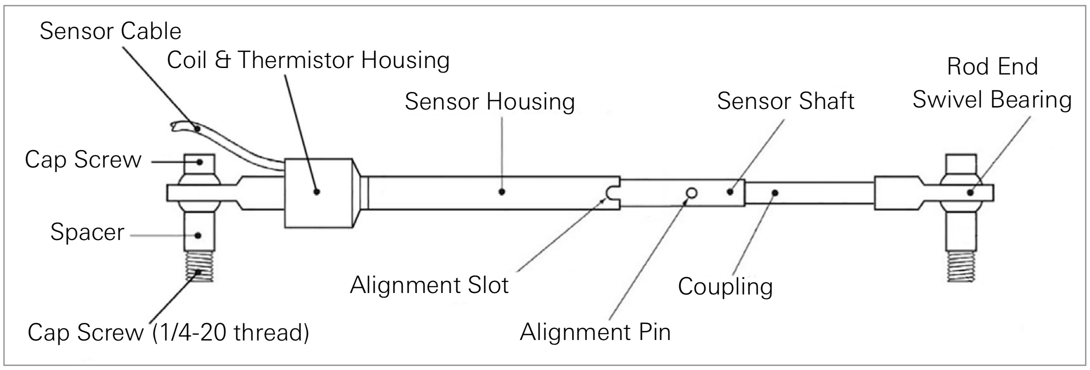

***FIGURE 1:** Model 4420 Vibrating Wire Crackmeter*

Models 4420-1-3, 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.

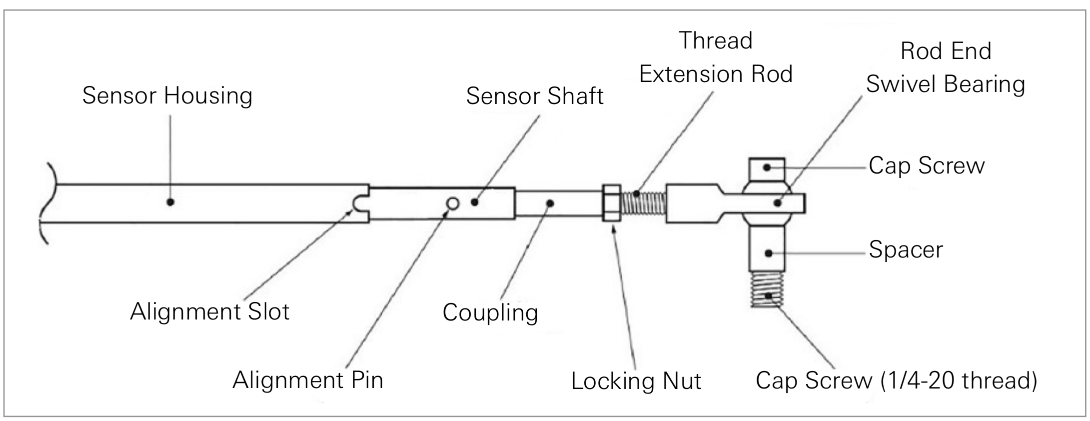

***FIGURE 2:** Models 4420-1-3, 4420-12.5, and 4420-25 Detailed View*

Model 4420HT High Temperature Crackmeters are rated to 200 °C. This model is supplied with 316 stainless steel U-joints on the ends, as opposed to the 303 stainless steel rod end bearings installed on standard crackmeters.

Caution! Never extend the sensor beyond its working range or rotate the shaft more than 180 degrees. (The sensor shaft may be rotated 90 degrees in either direction to align the mounting points.)

2. PRIOR TO INSTALLATION

2.1 PRELIMINARY TESTS

Most sensors are shipped with shipping spacer(s) installed that maintain tension to prevent damage during transportation. Installed spacers are different depending on the range of the sensor:

- **Range of 3 mm (0.125"):** Sensors are shipped with the push rod fully retracted and have no shipping spacer to remove.
- **Ranges 12.5 mm (0.50”) through 50 mm (2"):** Sensors are secured using a shipping wire inserted into a machined hole and coiled around the shaft.
- **Ranges of 100 mm (4") or More:** Sensors are secured using stackable slotted sleeves around the shaft.

GEOKON recommends that each sensor is function tested before installing in the field. To perform this preliminary check complete the following steps:

1. Carefully remove the shipping spacer(s) or wire.

Important! Care should be taken to not rotate the push rod in relation to the sensor housing or to let the push rod snap back uncontrolled into the housing.

2. Connect the sensor to a readout. This could be a portable, handheld readout or the system that will be used in the final installation.
3. The sensor should have a strong, stable signal. When the push rod of the sensor is pulled, the frequency or digits should increase. When retracted into the sensor housing, the readings should decrease. The temperature reading should match the ambient temperature.

Important! Do not extend the push rod so that the full range of the sensor as indicted in the supplied calibration sheet is exceeded.

4. Check electrical continuity using an ohmmeter. Resistance between the gauge leads (usually red and black) should be approximately 180 ohms (128 ohms for Model 4420HT). Remember to add cable resistance, which is approximately 48.5Ω per km (14.7Ω per 1000 feet) of 22 AWG stranded copper leads at 20 °C. Multiply this factor by two to account for both directions. Resistance between thermistor leads (usually green and white) will vary based on temperature (see Appendix B). Resistance between any conductor and the shield should exceed two megaohms.

Should any of these preliminary tests fail, see Section 7 for troubleshooting tips.

3. INSTALLATION

For Model 4420-3 Low Profile Crackmeters refer to Appendix D.

For Model 4420-6, 2D & 3D Crackmeter Arrays, refer to Appendix E.

3.1 ANCHORS AND SETTING DISTANCE

Three types of anchors are available:

- **Weldable Mounting Fixture:** Designed to aid in mounting the sensor on steel members.
- **Rawl Drop-In Anchors:** Used to install the sensor on concrete or rock. This anchor requires a competent mounting surface.
- **Groutable Anchor:** Used to install the sensor on concrete or rock.

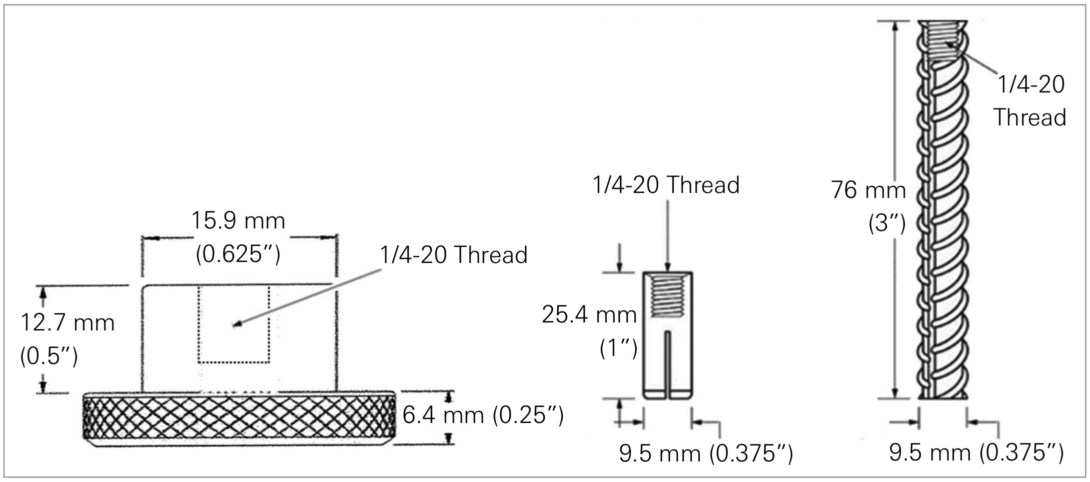

***FIGURE 3:** Anchor Types with Dimensions, Weldable (Left), Drop-In (Middle), Groutable (Right)*

The anchors are installed at the appropriate spacing distance, depending on the anticipated direction of movement (extension or compression). Refer to the table below as a guide.

Model & Range	Midrange	To Monitor Extension	To Monitor Compression
4420-1-3 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")
4420WP-12.5 mm (.5")	414 mm (16.3")	406 mm (16")	419 mm (16.5")
4420WP-25 mm (1")	439 mm (17.3")	427 mm (16.8")	452 mm (17.8")
4420WP-50 mm (2")	516 mm (20.3")	490 mm (19.3")	541 mm (21.3")
4420WP-100 mm (4")	612 mm (24.1")	561 mm (22.1")	663 mm (26.1")
4420WP-150 mm (6")	704 mm (27.7")	627 mm (24.7")	780 mm (30.7")
4420WP-200 mm (8")	927 mm (36.5")	826 mm (32.5")	1029 mm (40.5")
4420WP-300 mm (12")	1245 mm (49")	1092 mm (43")	1397 mm (55")
Note: For Model 4420HT Hight Temperature only, 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:** Anchor Spacing Distances*

When installing the sensor, the individual calibration report for that serial number should be consulted to ensure the sensor is installed at the desired point within its range, either in anticipation of closure or opening of the crack. The calibration report shows factory readings at zero, 20%, 40%, 60%, 80%, and 100% of the range of extension.

Be sure to consider the following:

- Extend the sensor until the desired reading is obtained.
- Hold the sensor in this position while the distance between the cap screws is measured (set inside the swivel bearings, see Figure 1). This measurement can serve as a spacing guide for drilling or welding the anchor points.
- Use the alignment pin on the sensor shaft and slot on the body as a guide for alignment. The sensor shaft may be rotated 90 degrees in either direction to align the mounting points.

Important! Never rotate the shaft more than 180 degrees.

Section 3.2 contains detailed installation instructions on each type of anchor.

Section 3.3 contains additional post-installation instructions only applicable for sensors with ranges of 3 mm (0.125"), 12.5 mm (.5"), or 25 mm (1").

3.2 SENSOR INSTALLATION

The installation procedure will be different depending on the anchor type.

3.2.1 INSTALLATION USING WELDABLE FIXTURES

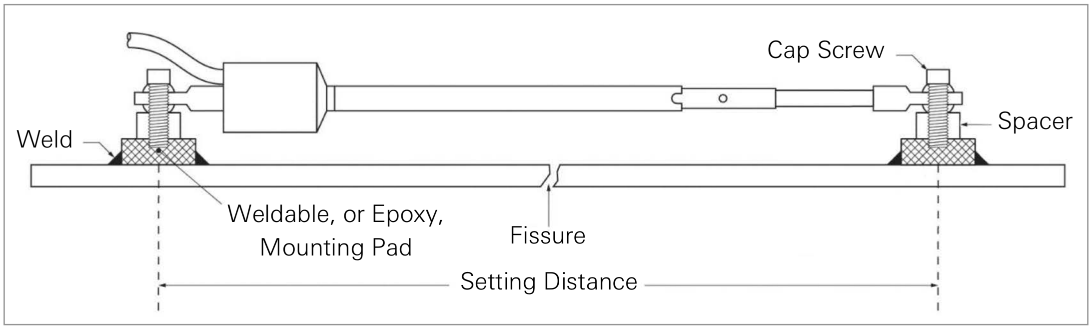

FIGURE 4: *Installation Using Weldable Fixtures*

1. Determine the proper setting distance, refer to Section 3.1.
2. Grind, sand, or otherwise prepare the surface of the steel around the area of each weldable fixture.
3. Position the welding fixtures on prepared surfaces.
4. Verify the placement again, then tack weld to the member.
5. With the shipping spacer(s) removed from the sensor, thread the cap screw through the swivel bearing and through a spacer on each end.
6. Tighten the cap screws into the welding fixtures.
7. Check and record the reading with a portable readout. Refer to the readings on the calibration sheet to check the position.

3.2.2 INSTALLATION USING GROUTABLE ANCHORS

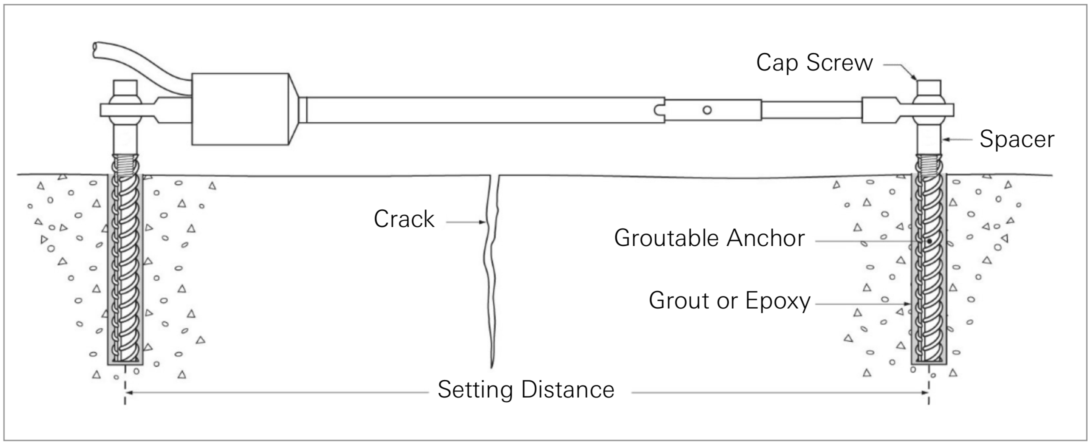

FIGURE 5: *Installation Using Groutable Anchors*

1. Determine the proper setting distance, refer to Section 3.1.
2. Using a hammer drill (or other suitable equipment), drill two 12.7 mm (1/2”) diameter holes approximately 76.2 mm (3”) deep at the proper locations. Shorter holes may be drilled if the anchors are cut down accordingly.
3. With the shipping spacer(s) removed from the sensor, thread the cap screw through the swivel bearing and through a spacer on each end.
4. Loosely thread the cap screws into the groutable anchors.

Note: High temperature (HT) models have a wider diameter coil housing. To prevent housing contact with the mounting surface use the longer shipping spacers provided.

5. Fill the holes three quarters full with grout or epoxy. For holes drilled overhead use a quick setting grout or epoxy.
6. Push and twist the anchors in until the tops are flush with the surface. Wipe any excess epoxy clear of the tops of the anchors.
7. After the grout or epoxy has set, tighten the set screws.
8. Check and record the reading with a portable readout. Refer to the readings on the calibration sheet to check and adjust the position as needed.

3.2.3 INSTALLATION USING RAWL DROP-IN ANCHORS

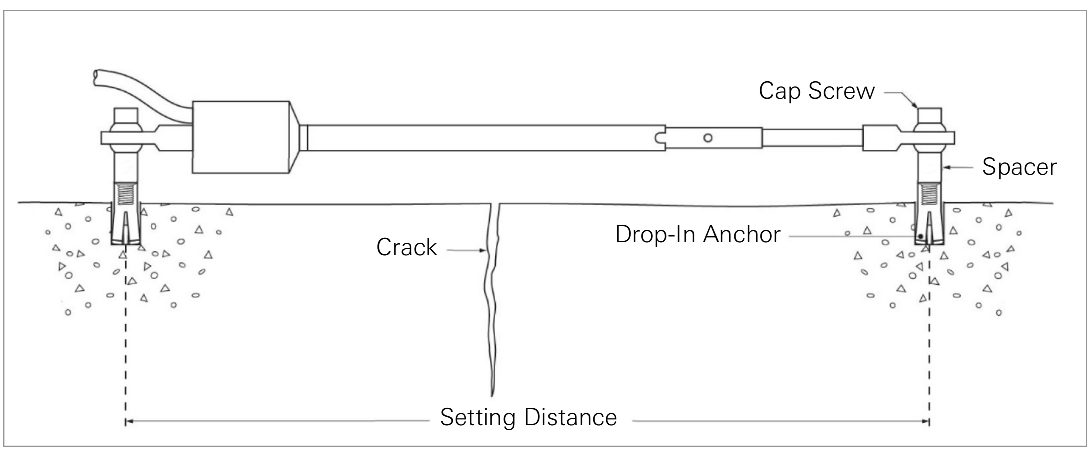

FIGURE 6: *Installation Using Rawl Drop-In Anchors*

1. Determine the proper setting distance, refer to Section 3.1.

2. Using a masonry drill (or other suitable equipment), drill two 10 mm (3/8") diameter holes, 32 mm (1.25") deep at the proper locations.
3. Insert the drop-in anchors, threaded side up, into the holes. Insert the Model TLS-208 Setting Tool into the anchors and strike with a hammer until the lip of the anchor touches the lip of the setting tool.
4. With the shipping spacer(s) removed from the sensor, thread the cap screw through the swivel bearing and through a spacer on each end.

Note: High temperature (HT) models have a wider diameter coil housing. To prevent housing contact with the mounting surface use the longer shipping spacers provided.

5. Tighten the cap screws into the drop-in anchors.
6. Check and record the reading with a portable readout. Refer to the readings on the calibration sheet to check and adjust the position as needed.

3.3 SPECIAL INSTALLATION NOTE

Regarding Models 4420-1-3 mm (.125"), 4420-1-12.5 mm (.5"), and 4420-1-25 mm (1") only, please keep the following in mind:

- If the reading is not in the proper range after installation, make adjustments using the threaded extension at the end of the sensor shaft.
- To make accurate adjustments, attach the sensor to the anchor at the cable end, and temporarily remove it from the opposite anchor.

TO MAKE AN ADJUSTMENT, DO THE FOLLOWING:

1. Loosen the locking nut and then rotate the threaded rod into or out of the end of the sensor shaft.

Important! Grip the sensor shaft while rotating the threaded rod. Never rotate the sensor shaft beyond 180 degrees, or gauge failure may result.

2. After making an adjustment, align the hole in the swivel bearing over the anchor and check the reading.
3. Make adjustments until the desired reading displays on the readout.
4. Push the cap screw through the swivel bearing and spacer.
5. Tighten into the anchor.
6. Re-tighten the locking nut.

4. SENSOR PROTECTION

4.1 CABLE SPLICING AND TERMINATION

Because the vibrating wire output signal is a frequency rather than a current or voltage, cable splicing has no ill effects. The cable used for making splices should be a high-quality twisted pair type, with 100% shielding and an integral shield drain wire. **It is very important that the shield drain wires be spliced together.** Always maintain polarity when possible by connecting color to color.

Splice kits recommended by GEOKON incorporate casts that 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.

4.2 MECHANICAL PROTECTION

4.2.1 COVER PLATES (MODEL 4000-6, 4000-13 AND EXTENDED)

Model 4000-6 and 4000-13 Cover Plates are easy-to-install and are designed for light-impact situations or to obscure the sensor from view. Model 4000-6 is designed for steel installations, while 4000-13 is designed for concrete installations. These standard cover plates are long enough to cover sensors up to 500 mm (2”) range.

Sensor with ranges of 100 mm (4”) or more use custom extended cover plates made from anodized aluminum U-channel. These cover plates are available in two configurations that depend on variables such as space limitation and the amount of protection the sensors require. The cover mounting options are:

- Single mount, where the cover and sensor are mounted on/with the same hardware.
- Double mount, the traditional method with separate mounting for the sensor and cover.

Contact GEOKON for further information on extended covers.

The installation varies slightly depending on the installation surface.

1. Mark two areas centered on either side of the sensor location (see Figure 7 for reference) using Model 4000-10 Installation Template (for singular covers), or flip the cover plate onto its back and mark using the holes of the plate.
2. Secure the hex bolts/threaded rods:
   - **Steel:** Weld the head of the provided hex bolts at the marked locations.

Note: Avoid welding near the sensor location as this will cause local distortions in the metal that may affect gauge readings.

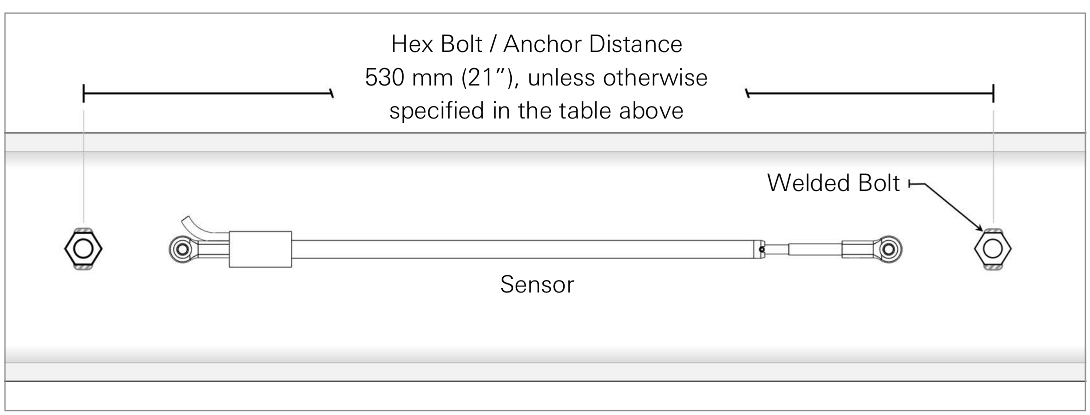

***FIGURE 7:** Hex Bolt / Threaded Rod Locations, (Model 4000-6) Steel Installation Shown*

- **Concrete:**
    a. Drill two 13 mm x 45mm (1/2 x 1 3/4 inch) holes in the concrete.
    b. Insert the drop-in anchors, threaded side up, into the holes. Insert the Model TLS-209 Setting Tool into the anchors and strike with a hammer until the lip of the anchor touches the lip of the setting tool.
    c. Install the threaded rods into the anchors.

3. Apply corrosion protection on/around the sensor and any weld points according to Section 4.4.
4. Place the cover plate over the bolts/threaded rods.
5. Secure the cover plate by installing washers and then nuts onto each hex bolt. Avoid excessive force while tightening, as this will cause local distortions in the metal that may affect sensor readings.
6. Apply additional corrosion protection as needed.

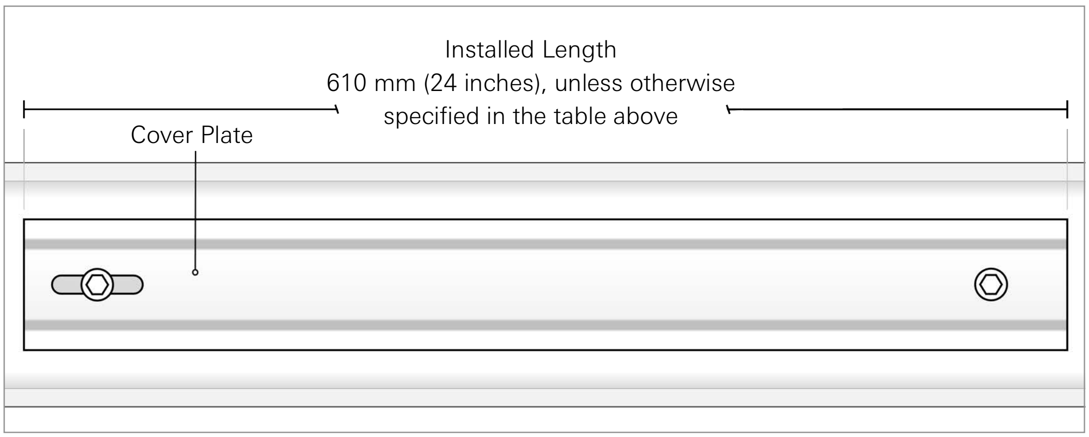

FIGURE 8: *Cover Plate (Model 4000-6) Installation, Top View, Steel Installation Shown*

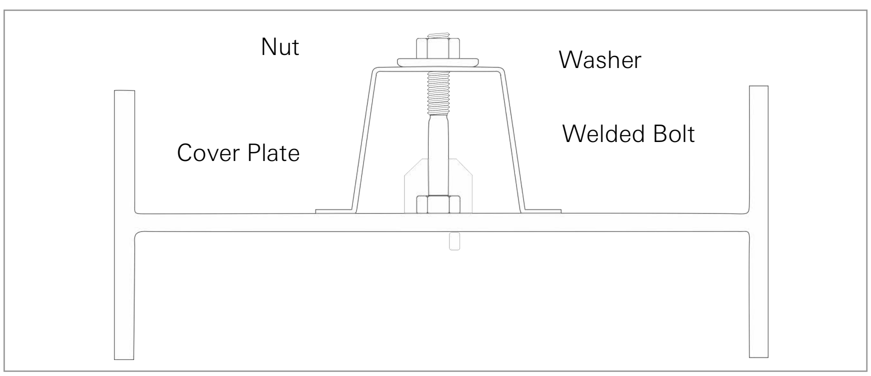

FIGURE 9: *Cover Plate (Model 4000-6) Installation, Side View, Steel Installation Shown*

4.3 CABLE AND CONNECTOR PROTECTION

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. The conduit can be connected via conduit bulkhead connectors to the cover plates. The GEOKON cover plate has a stamped knockout which provides a hole for connecting the conduit connector.

4.4 CORROSION PROTECTION

It is imperative that any installation welds be protected from corrosion. The sensors are made of stainless steel and will not corrode, but the surrounding substrate (especially at weld points) can become compromised unless it is covered by a waterproofing layer.

GEOKON recommends the following procedure:

1. Mask off the locations where covers or coil housing will need to be spot-welded or arc-welded.
2. Apply self-etching primer (obtained locally) on the gauge and surrounding bare metal areas. Do not worry if the primer also coats the sensor.
3. Once primed, cover the sensor and any nearby bare metal surfaces with a durable spray-paint (obtained locally).

4.5 PROTECTION FROM ELECTRICAL NOISE

Install sensor cables 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. Doing so will cause the sensor cables to pick up the frequency noise from the power cable, and this will likely make obtaining a stable reading difficult.

4.6 SUNLIGHT-INDUCED TEMPERATURE CHANGES

Sensors have the same thermal coefficient of expansion as steel and do not require temperature correction if the sensor and its steel substrate are at the same temperature. To achieve the highest accuracy, protect the sensor from direct exposure to sunlight or other heat sources that may cause it to be at a different temperature than the steel structure. Protection from thermal effects is best provided by covering the gauges with a layer of insulating material such as Polystyrene foam or fiberglass.

4.7 LIGHTNING PROTECTION

In settings where lightning strikes are a concern, GEOKON offers the Model 4999-12L/LE Surge Protection Module:

FIGURE 10: *Model 4999-12L/LE*

Model 4999-12L/LE Manual

The module features replaceable surge protection circuitry in the event that it is damaged by a lightning strike. The Module is installed between a sensor and the datalogger or terminal box it is connected to. Consult GEOKON and the [Model 4999-12L/LE Instruction Manual]() for additional information.

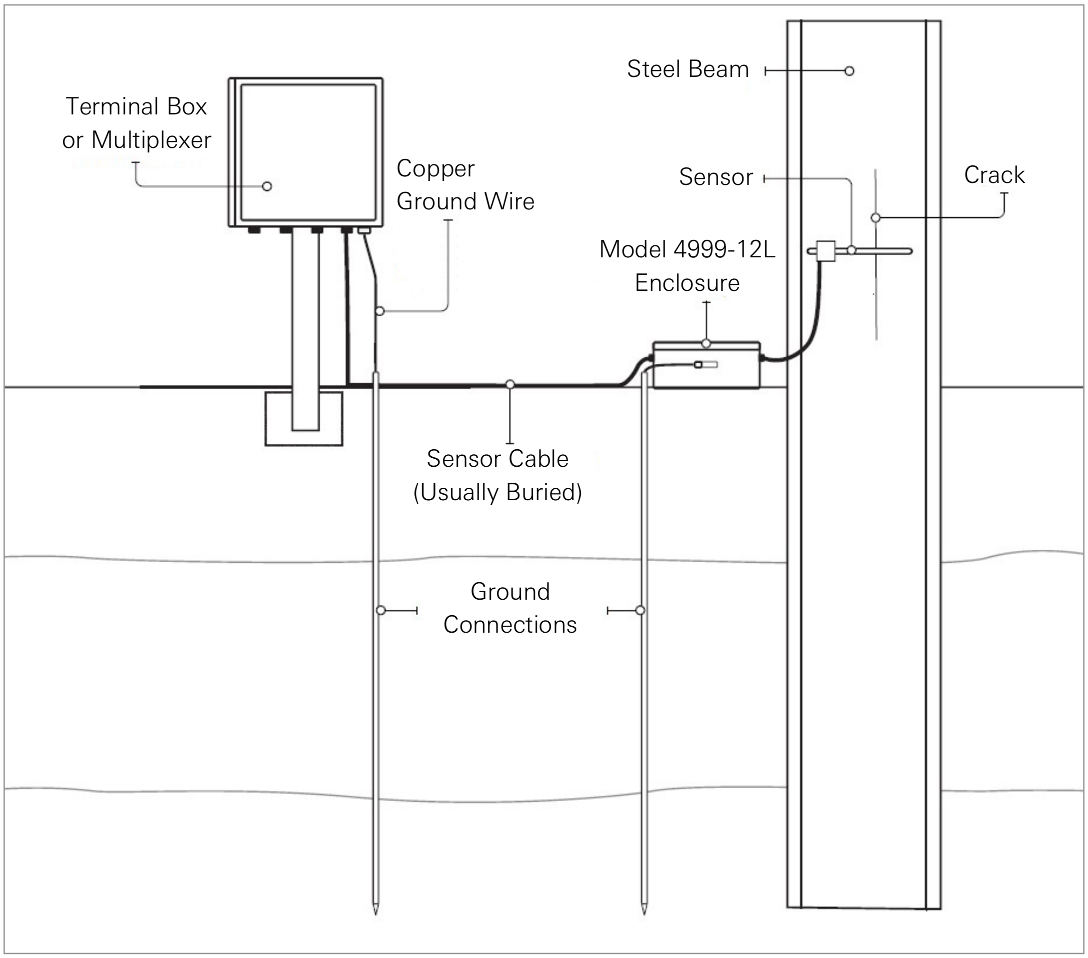

FIGURE 11: *Lightning Protection Scheme*

5. TAKING READINGS

5.1 COMPATIBLE READOUTS AND DATALOGGERS

The most important reading is the first reading; it is the base reading to which all subsequent readings will be compared. Conditions should be noted at the time of all readings, especially during curing, e.g., temperature, time after placement, local conditions, etc.

GEOKON can provide several readout and datalogger options. Devices compatible with this product are listed below. For further details and instruction consult the corresponding Manual(s) at geokon.com/Readouts and geokon.com/Dataloggers.

Readouts

DIGITAL READOUTS:

- **GK-404**

  The Model GK-404 VW Readout is a portable, low-power, hand-held unit capable of running for more than 20 hours continuously on two AA batteries. It is designed for the readout of all GEOKON Vibrating Wire (VW) instruments, and is capable of displaying the reading in digits, frequency (Hz), period (µs), or microstrain (µε). The GK-404 displays the temperature of the transducer (embedded thermistor) with a resolution of 0.1 °C.

- **GK-406**

  The Model GK-406 is a field-ready device able to quickly measure a sensor, save data, and communicate results with custom PDF reports and spreadsheet output. Measurements are geo-located with the integrated GPS allowing the GK-406 to verify locations and lead the user to the sensor locations. The large color display and VSPECT^{TM} technology create confidence of getting the best measurement possible both in the field and in the office.

Dataloggers

DATALOGGERS:

- **8600 Series**

  The MICRO-6000 Datalogger is designed to support the reading of a large number of GEOKON instruments for various unattended data collection applications through the use of GEOKON Model 8032 Multiplexers. Weatherproof packaging allows the unit to be installed in field environments where inhospitable conditions prevail. The Nema 4X enclosure also has a provision for locking to limit access to responsible field personnel.

- **GeoNet Series**

  The GeoNet series is designed to collect and transfer data from vibrating wire, RS-485, and analog instruments. GeoNet offers a wide range of telemetry options, including LoRa, cellular, Wi-fi, satellite, and local. Loggers can work together to operate in a network configuration, or be used separately as standalone units. GeoNet devices arrive from the factory ready for deployment and may commence with data acquisition in minutes.

  Data is transferred to a secure cloud-based storage platform where it can be accessed through the GEOKON OpenAPI. Industry leading data visualization software, such as the free GEOKON Agent Software, can be used with the OpenAPI for data viewing and reporting. Dataloggers without network capabilities are also available.

5.2 MODEL 4999 TERMINAL BOXES

Terminal boxes with sealed cable entries are available from GEOKON. 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.

Terminal Boxes make it easy to manually connect a Readout Box (GK-404 or GK-406). The rotary switch is used to select which "channel" or sensor is being read by the Readout Box.

Model 4999 Manual

For further details and instruction consult the Model 4999 Instruction Manual.

5.3 MEASURING TEMPERATURES

All GEOKON vibrating wire sensors are equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. The white and green leads of the sensor cable are normally connected to the internal thermistor. The GK-404 and GK-406 readouts will read the thermistor and display the temperature in degrees Celsius.

USING AN OHMMETER TO READ TEMPERATURES:

Connect an ohmmeter to the green and white thermistor leads coming from the sensor. 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 48.5Ω per km (14.7Ω per 1000') at 20 °C. Multiply these factors by two to account for both directions.

Look up the temperature for the measured resistance in Appendix B. For high temperature models, see Appendix B, Section B.2.

6. DATA REDUCTION

6.1 DATA CALCULATION

The basic units utilized by GEOKON for measurement and reduction of data from this sensor are digits. The calculation of digits is based on the following equation:

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

EQUATION 1: *Digits Calculation*

In typical installations the linear calculation is more than sufficient. However, if utmost accuracy is desired, the polynomial calculation can be used. Refer to the applicable section below.

6.1.1 LINEAR CALCULATION

To convert digits to displacement the following equation applies:

$$D = G(R_1 - R_0)$$

EQUATION 2: *Linear Displacement Calculation*

Where:
G = The gauge factor found on the calibration report, usually in terms of millimeters or inches per digit.

R_1 = The current readings in digits.
R_0 = The initial field zero reading in digits.

EXAMPLE:

The initial reading (R_0) at installation of a sensor is 4200 digits. The current reading (R_1) is 6000 digits. The calibration factor (G) is 0.01211 mm/digit. The displacement change is:

$$D = (6000 - 4200) \times 0.01211$$

$$D = 21.79 \text{ mm}$$

Note that increasing (positive) readings indicate increasing extension.

6.1.2 POLYNOMIAL CALCULATION

To convert digits to displacement using the polynomial expression the following equation applies:

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

EQUATION 3: *Polynomial Displacement Calculation*

Where:
R_1 = The current readings in digits.
A, B = The polynomial gauge factors found on the calibration report.
C = The polynomial gauge factor that needs to be calculated (see below).

To perform the polynomial calculation, gauge factor “C” must be calculated first. This is done by using the equation above, but replacing “D” with a value of zero, and “R_1” with the value of “R_0”.

$$0 = AR_0^{\ 2} + BR_0 + C$$

EQUATION 4: *Calculation for Polynomial Gauge Factor “C”*

Where:
R_0 = The initial field zero reading in digits.
A, B = The polynomial gauge factors found on the calibration report.

The calculated “C” can then be used in Equation 3 to find the precise value of displacement (D).

EXAMPLE:

The given polynomial gauge factors on the calibration are:

A = 4.1548E^{-08}

B = 0.01173

The initial reading (R_0) at installation of a sensor is 4200 digits. The current reading (R_1) is 6000 digits.

First, the gauge factor “C” must be calculated:

$$0 = AR_0^{\ 2} + BR_0 + C$$

$$0 = 4.1548 \times 10^{-8} \times 4200^2 + 0.01173 \times 4200 + C$$

$$0 = 49.999 + C$$

$$C = -49.999$$

The displacement change is:

$$D = AR_1^{\ 2} + BR_1 + C$$

$$D = 4.1548 \times 10^{-8} \times 6000^2 + 0.01173 \times 6000 + (-49.999)$$

$$D = 21.88 \text{ mm}$$

Note that increasing (positive) readings indicate increasing extension.

6.2 OPTIONAL CALCULATIONS

6.2.1 TEMPERATURE CORRECTION

The sensor has a very small coefficient of thermal expansion so in most cases correction is not necessary. However, if maximum accuracy is desired or the temperature changes are extreme (>10° C) corrections may be applied. By correcting the sensor for temperature changes the deformation of the mass may be distinguished. The following thermal correction equation is performed, then afterwards is added to the displacement calculation (Equation 2 or Equation 3):

$$T_{Correction} = K(T_1 - T_0)$$

EQUATION 5: *Thermal Correction for Displacement*

Where:
K = The thermal factor that needs to be calculated (see below).
T_1 = The current temperature reading in °C.
T_0 = The initial field temperature reading in °C.

Tests have determined that the thermal coefficient “K” changes with the position of the sensor shaft. Hence, 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 6: *Calculation for Thermal Factor "K"*

Where:
R_1 = The current readings in digits.
M = The multiplier, from the table below.
B = The constant, from the table below.
G = The gauge factor found on the calibration report, usually in terms of millimeters or inches per digit.

Table 2 gives the multiplier and constant values used in Equation 6. The multiplier (M) and constant (B) values vary for the stroke of the sensor used.

Model	Multiplier (M)	Constant (B)
4420-1-3 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 2: *Thermal Coefficient Constant Values*

EXAMPLE:

The given multiplier and constant values for a Model 4420-50 mm (2") crackmeter are:

M = 0.000376

B = 0.328

T_0 = 20.3 °C.

T_1 = 32.9 °C.

R_1 = 6000 digits

G = 0.01211 mm/digit

First, calculate the thermal coefficient (K):

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

$$K = ((6000 \times 0.000376) + 0.328) \times 0.01211 = 0.031292$$

Calculate the thermal correction:

$$T_{Correction} = K(T_1 - T_0)$$

$$T_{Correction} = 0.031292(32.9 - 20.3) = 0.394$$

Add this value to the displacement calculated using Equation 2 or Equation 3 to find the thermal corrected displacement.

The temperature coefficient of the mass or member to which the sensor is attached should also be taken into account. Use the temperature coefficient of the mass or member, combined with the changes in temperature from initial to current readings, to determine thermal effects of the mass or member.

6.2.2 ENGINEERING UNITS CONVERSION

To convert to a different engineering unit, take the result from data calculation (after other optional calculations have been completed, if applicable) and multiply it by the appropriate conversion multiplier from Table 3.

		CONVERT FROM				
		Inches	**Feet**	**Millimeters**	**Centimeters**	**Meters**
CONVERT TO	**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 3: *Engineering Units Conversion Multipliers*

6.3 ENVIRONMENTAL FACTORS

Since the purpose of the 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.

Technical Support

7. TROUBLESHOOTING

Maintenance and troubleshooting is confined to periodic checks of cable connections and maintenance of terminals. Once installed, the sensor is usually inaccessible and remedial action is limited.

Should difficulties arise, consult the following list of problems and possible solutions. For additional troubleshooting and support visit geokon.com/Technical-Support.

SYMPTOM: THERMISTOR RESISTANCE IS TOO HIGH

☐ Check for an open circuit. Check all connections, terminals, and plugs. If a cut is in the cable, splice according to instructions in Section 4.1.

SYMPTOM: THERMISTOR RESISTANCE IS TOO LOW

☐ Check for a short circuit. Check all connections, terminals, and plugs. If a short is in the cable, splice according to instructions in Section 4.1.

☐ Water may have penetrated the interior of the sensor. There is no remedial action.

SYMPTOM: SENSOR READING UNSTABLE

☐ Make sure the shield drain wire is connected to the blue clip on the flying leads.

☐ Isolate the readout from the ground by placing it on a piece of wood or another insulator.

☐ Check for sources of nearby electrical noise such as motors, generators, antennas, or electrical cables. Move the sensor cable away from these sources if possible. Contact the factory for available filtering and shielding equipment.

☐ The sensor may have been damaged by over-ranging or shock. Inspect for damage.

☐ The body of the sensor may be shorted to the shield. Check the resistance between the shield drain wire and the sensor housing. If the resistance is very low, the gauge conductors may be shorted.

☐ Is the readout box position set correctly? If using a datalogger to record readings automatically, are the swept frequency excitation settings correct?

☐ The sensor shaft may be positioned outside the specified range (either extension or retraction). When the 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.

☐ Check the readout with another sensor to ensure it is functioning properly.

SYMPTOM: SENSOR FAILS TO GIVE A READING

☐ Check the readout with another sensor to ensure it is functioning properly.

☐ The sensor may have been damaged by over-ranging or shock. Inspect for damage.

☐ Check the resistance of the cable by connecting an ohmmeter to the sensor leads. Cable resistance is about 48.5Ω per km (14.7Ω per 1000'). If the resistance is very high or infinite, the cable is probably broken. If the resistance is very low, the gauge conductors may be shorted. If a break or a short is present, splice according to the instructions in Section 4.1. Refer to the expected resistance for the various wire combinations below.

Vibrating Wire Sensor Lead Resistance Levels

Red/Black Coil Resistance values may vary for different models:

- Standard: ≅180Ω
- High Temp (HT): ≅128Ω
- Model 4420-3: ≅50Ω

Green/White 3000Ω at 25 °C

Any other wire combination will result in a measurement of infinite resistance.

Note: Tests should be performed with a quality multimeter to accurately show possibilities of shorts. Sensors should be disconnected from other equipment while performing resistance tests, this includes surge modules, terminals, multiplexers and dataloggers. Fingers cannot be touching the multimeter leads or sensor wires while testing.

Table 4 shows the expected resistance for the various wire combinations.

Table 5 is provided for the customer to fill in the actual resistance found.

Vibrating Wire Sensor Lead Grid - SAMPLE VALUES					
	Red	**Black**	**White**	**Green**	**Shield**
Red					
Black	≅180Ω				
White	Infinite	Infinite			
Green	Infinite	Infinite	3000Ω at 25°C		
Shield	Infinite	Infinite	Infinite	Infinite	

TABLE 4: *Sample Resistance*

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

TABLE 5: *Resistance Worksheet*

APPENDIX A. SPECIFICATIONS

A.1 MODEL 4420 SPECIFICATIONS

The table below lists the specifications for all models except for the Model 4420-3 Low Profile Crackmeter. For information on that model, refer to Appendix D.

Range	**3 mm (0.125″)**	**12.5 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% F.S.							
Linearity	±0.5% F.S.							
Accuracy	0.5% F.S. (0.1% F.S. with a polynomial expression)							
Thermal Zero Shift[2]	< 0.5% F.S./°C							
Stability	< 0.2%/yr (under static conditions)							
Overrange	115% F.S.							
Temperature Range	Standard: -20 to +80 °C							
Frequency Range	1400 - 3500 Hz							
Coil Resistance	Standard: 180 Ω, ±10Ω High Temperature (HT): 128 Ω, ±10Ω							
Cable Type[3]	Two twisted pair (four conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250")							
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 Housing Dimensions (Length x OD)	Standard: 31.75 x 25.4 mm (1.25 x 1″)							

TABLE 6: *Model 4420 Vibrating Wire Crackmeter Specifications*

Note:

[1] Minimum, greater resolution possible depending on readout.

[2] Depends on application.

[3] Polyurethane jacket cable available.

A.2 THERMISTOR

See Appendix B for more information.

Standard Thermistor Range: -80 to +150 °C

High Temperature Thermistor Range: -55 to +300 °C

Accuracy: ±0.5 °C

A.3 PARTS LIST

4420-2	Groutable Anchors
4420-6X/Y-#	2D Mounting assembly, X and Y axis. Supplied spacers based on maximum anticipated movement in the Z-axis.
4420-6-#	3D Mounting assembly. Requires TLS-208 Rawl Setting Tool (sold separately)
4420-8	Geogrid clamps (one pair)
4420-9	Weldable or epoxy anchors
4420-5	Rawl drop-in anchors. Requires TLS-208 Rawl Setting Tool (sold separately)
4000-6	Galvanized steel cover plate, 0.6 m (2’) long, with mounting hardware for steel installation
4000-13	Galvanized steel cover plate, 0.6 m (2’) long, with mounting hardware for concrete installation. Requires TLS-209 Rawl Setting Tool (sold separately)
TLS-208	Setting tool for 1/4" Rawl drop-in anchors
TLS-209	Setting tool for 3/8" Rawl drop-in anchors

TABLE 7: *Model 6650 Parts List*

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

B.1 3KΩ THERMISTOR RESISTANCE (STANDARD)

Thermistor Types include YSI 44005, Dale #1C3001–B3, Alpha #13A3001–B3, and Honeywell 192–302LET–A01.

Resistance to Temperature Equation:

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

EQUATION 7: *3KΩ Thermistor Resistance*

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

TABLE 8: *3KΩ Thermistor Resistance*

B.2 10KΩ THERMISTOR RESISTANCE (HIGH TEMP)

Thermistor Type: US Sensor 103JL1A

Resistance to Temperature Equation:

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

***EQUATION 8:** 10KΩ Thermistor Resistance*

Where:
T = Temperature in °C
LnR = Natural Log of Thermistor Resistance
A = 1.127670×10^{-3}
B = 2.344442×10^{-4}
C = 8.476921×10^{-8}
D = 1.175122×10^{-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 9:** 10KΩ Thermistor Resistance*

APPENDIX C. TYPICAL CALIBRATION REPORT

GEOKON®

Vibrating Wire Displacement Transducer Calibration Report

Model: 4420-1-50MM

Serial Number: 2414181

Calibration Instruction: CI-4400

Cable Length: 30 feet

Calibration Date: March 29, 2024

This calibration has been verified/validated as of 09/20/2024

Temperature: 22.2 °C

Technician:

GK-401 Reading Position B

Actual Displacement (mm)	Gauge Reading 1st Cycle	Gauge Reading 2nd Cycle	Average Gauge Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2541	2540	2541	-0.10	-0.21	-0.01	-0.02
10.0	3378	3377	3378	10.03	0.07	10.01	0.03
20.0	4207	4207	4207	20.08	0.16	20.00	0.01
30.0	5031	5031	5031	30.06	0.11	29.98	-0.03
40.0	5854	5854	5854	40.02	0.05	40.01	0.01
50.0	6670	6670	6670	49.91	-0.19	50.00	0.00

(mm) Linear Gauge Factor (G): 0.01211 **(mm/ digit)** **Regression Zero:** 2549

Polynomial Gauge Factors: **A:** 4.1548E-08 **B:** 0.01173 **C:**

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

(inches) Linear Gauge Factor (G): 0.0004768 **(inches/digit)**

Polynomial Gauge Factors: **A:** 1.6358E-09 **B:** 0.0004617 **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.

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FIGURE 12: *Typical Calibration Report*

APPENDIX D. MODEL 4420-3 LOW PROFILE CRACKMETER

GEOKON Model 4420-3 Low Profile Vibrating Wire Crackmeters use a Model 4150 strain gauge mounted to the underside of a stainless steel plate, an adjustable oval point set screw, and an sensor cable, which is secured and weatherproofed by a Swagelok connector.

The sensor is mounted as a cantilever, with the cable end of the sensor fixed to the mounting surface by a cap screw installed into a drop-in anchor, with the opposite end left free. This free end allows the cone point set screw to maintain contact with the mounting surface (or reference disc) as it moves.

Strains are measured using the vibrating wire principle. As the mounting surface rises or falls, it increases or decreases the strain in the vibrating wire inside the 4150 gauge. This change in tension is measured as a change in the resonant frequency of vibration of the wire.

The threaded rod and accompanying jam nuts allow the zero reading to be adjusted as needed.

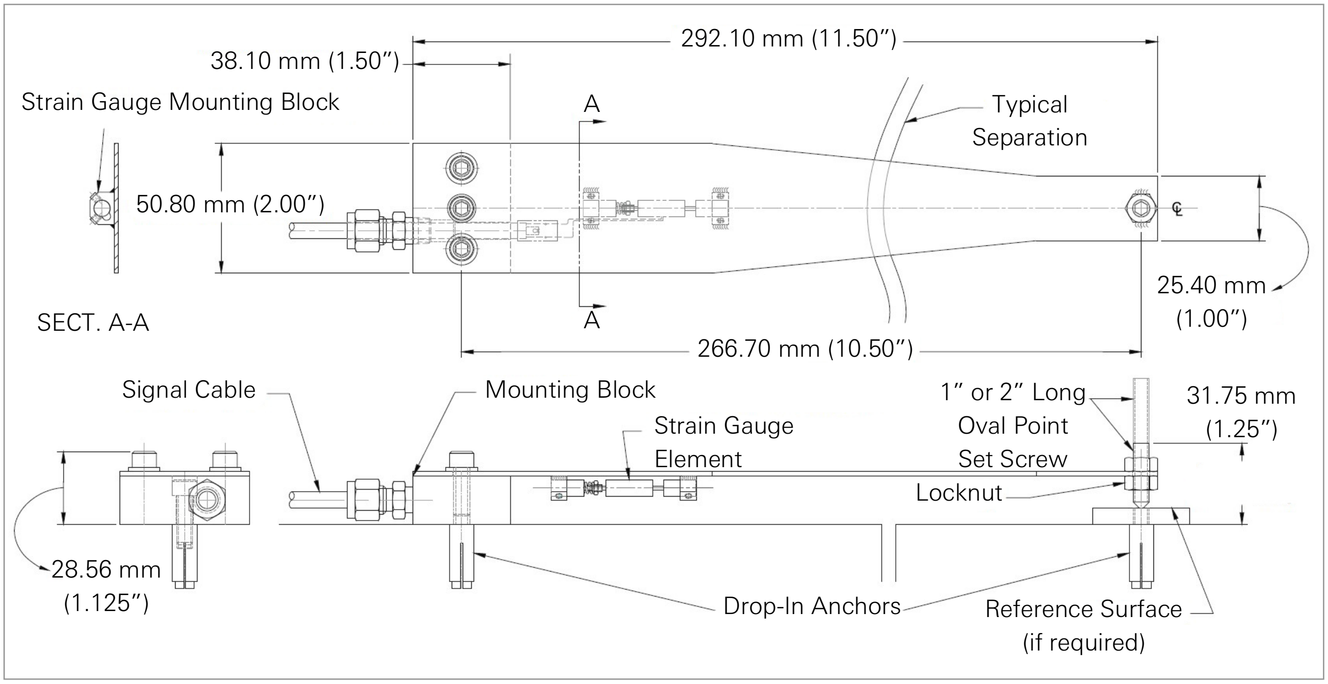

FIGURE 13: *Model 4420-3 Vibrating Wire Low Profile Crackmeter Layout*

D.1 INSTALLATION

1. Using a masonry drill (or other suitable equipment), drill a 9.5 mm (3/8") diameter by 32 mm (1.25") deep hole on each side of the crack, at a spacing of 267 mm (10.5").

Note: For mounting surfaces that are smooth in texture, the reference disc may be omitted. For installations without the reference disc only one hole and one expansion anchor is required. The completed assembly without a reference disc is shown in Figure 14.

2. Insert the drop-in anchors, threaded side up, into the holes. Insert the Model TLS-208 Setting Tool into the anchors and strike with a hammer until the lip of the anchor touches the lip of the setting tool.
3. Using Loctite cement on the threads, screw the reference disc into one of the threaded drop-in anchor holes until it is tight in the anchor.
4. Loosen the jam nuts on the oval point set screw. Using the wrench provided, back off the set screw so that it will not make contact with the reference surface when the gauge is mounted.

Note: A one-inch set screw is provided for installations where 75% or more of the displacement is anticipated to move the reference surface up in relationship to the sensor. When using the one-inch set screw, the jam nuts should be placed on the underside of the gauge, space permitting.

5. Align the threaded hole on the cable side of the sensor over the other anchor.
6. Slide a washer over the supplied cap screw and tighten it into the drop-in anchor.

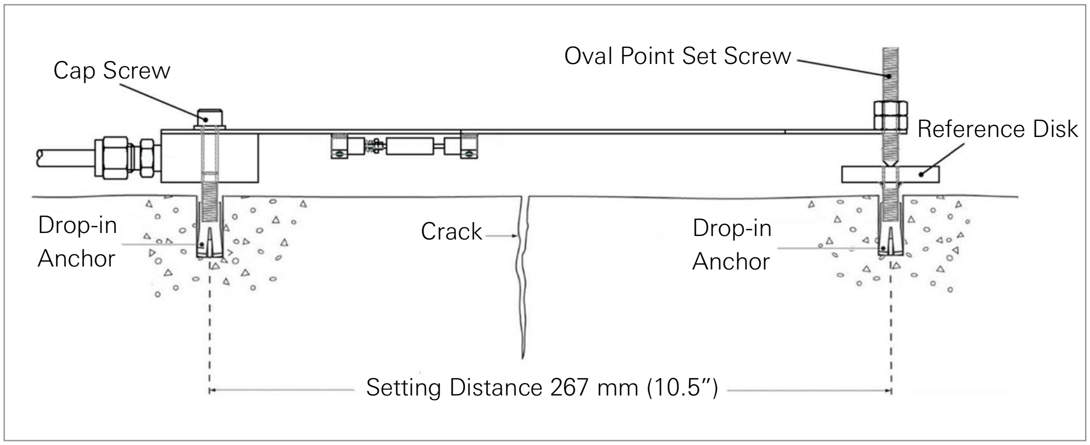

FIGURE 14: *Assembly Using Reference Disk and Two Anchors*

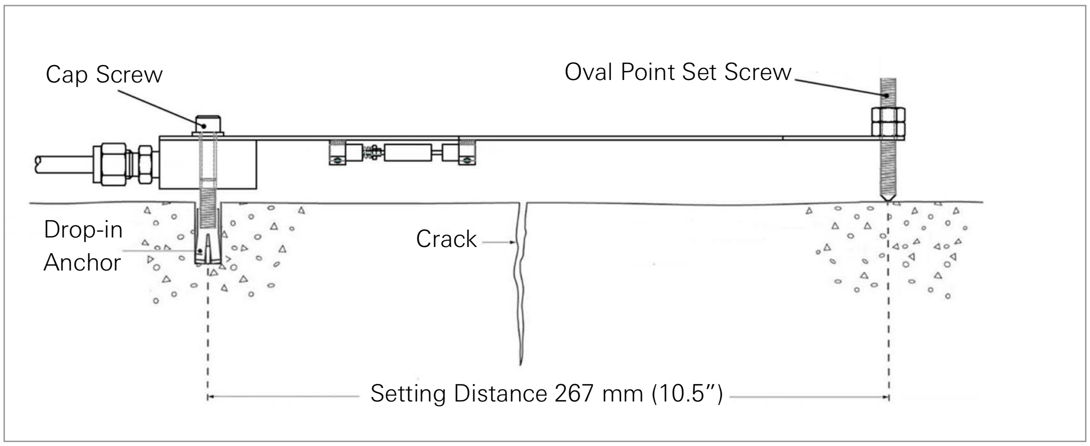

FIGURE 15: *Assembly with Only One Anchor and Without a Reference Disk*

7. Connect the cable to the readout box. Use the POS button to choose position E and the MODE button to select microstrain ($\mu\varepsilon$). The calibration sheet indicates the minimum and maximum readings recommended based on the set points utilized during the calibration process.
8. Set the zero position by turning the oval point set screw until the desired reading is achieved. The correct zero reading can be determined by the following:
   - If the set screw end of the gauge is anticipated to move up only in relationship to the 4150 gauge, set the zero reading near the 0.0 mm displacement according to the calibration sheet.
   - If the set screw end of the gauge is anticipated to only move down in relationship to the 4150 gauge, set the zero reading near the 25.4 mm displacement according to the calibration sheet.
   - For unknown movement or to set the gauge at midrange, set the zero reading between the 10.2 mm and 15.2 mm displacement according to the calibration sheet.

Note: The above zero reading suggestions are given assuming the two sides of the joint are on the same plane when the sensor is installed. If there is a major discrepancy between the two sides, contact GEOKON to determine if a custom solution is required.

9. Once the reading is set, tighten the locknuts to secure the set screw.

10. In areas of high traffic, the gauge should be protected by a cover plate. For more information, see Section 4.2.

D.2 MODEL 4420-3 SPECIFICATIONS

Range[1]	25 mm (1")
Resolution	0.01% F.S.
Linearity	<0.5% F.S.
Accuracy[2]	±1.5% F.S. (< ±25% F.S.)
Temperature Range	-20 to +80 °C
Frequency Range	1400 - 3600 Hz
Coil Resistance	Standard: 50 Ω, ±5Ω
Cable Type	Two twisted pair (four conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250")
Dimensions (LxWxH)	292 x 50 x 38 mm (11.5 x 2 x 1.5")

TABLE 10: *Model 4420-3 Vibrating Wire Low Profile Crackmeter Specifications*

Note:

[1] Other ranges (<25 mm) available on request.

[2] Accuracy using polynomial equation.

D.3 TEMPERATURE CORRECTION FACTOR

A small correction can be made for change in temperature. As the temperature goes up the average reading of the sensor will go down approximately one digit per °C. To calculate the displacement, corrected for temperature, use the equation below.

$$D_{Corrected} = G[(R_1 - R_0) + (T_1 - T_0)]$$

EQUATION 9: *Displacement, Thermal Correction Applied*

Where:
G = The gauge factor found on the calibration report, usually in terms of millimeters or inches per digit.

R_1 = The current readings in digits.
R_0 = The initial field zero reading in digits

T_1 = The current temperature reading in °C.
T_0 = The initial field temperature reading in °C.

The temperature effect shown above is for a low profile crackmeter that has not been installed yet and is very minor. The actual temperature effect of the installed sensor can be arrived at empirically only by simultaneous measurements of deformation and temperature over a short period of time.

APPENDIX E. MODEL 4420-6 2D & 3D CRACKMETER ARRAYS

The following instruction shows the standard array/install of an X, Y, and Z (3D) mounting assembly. For Model 4420-6-X/Y (2D), omit the Z axis from the instructions that follow. Also see Section E.3 for a Model 4420-3 Cantilever 3D array alternative.

These arrays allow for measurement of displacements in two or three orthogonal directions. The ends of the sensors are fixed on each side of a fissure by means of a bracket or by direct mounting using expansion anchors.

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

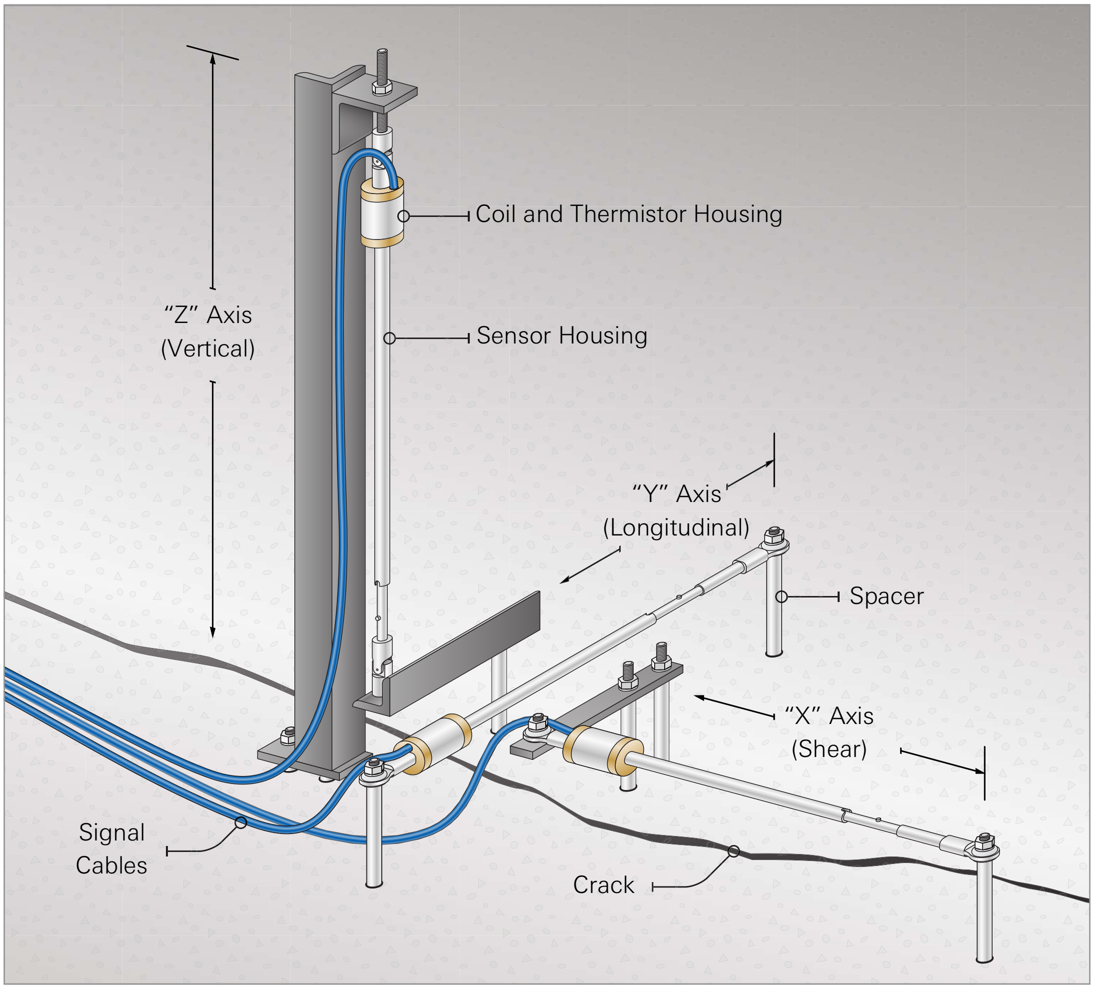

FIGURE 16: *Typical 3D Array, Top View*

E.1 ARRAY OF X, Y AND Z CRACKMETERS

Monitoring crack movements in three dimensions requires an array of three Model 4420 Crackmeters, one each for monitoring the X, Y, and Z dimensions.

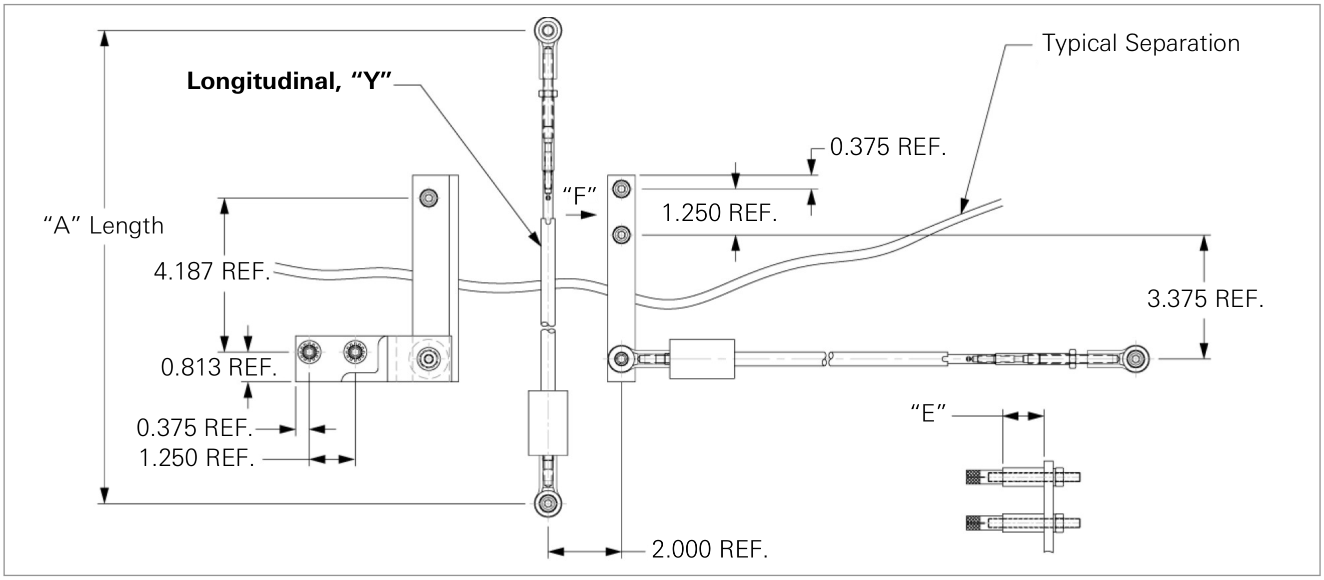

***FIGURE 17:** Typical 3D Array, Top View*

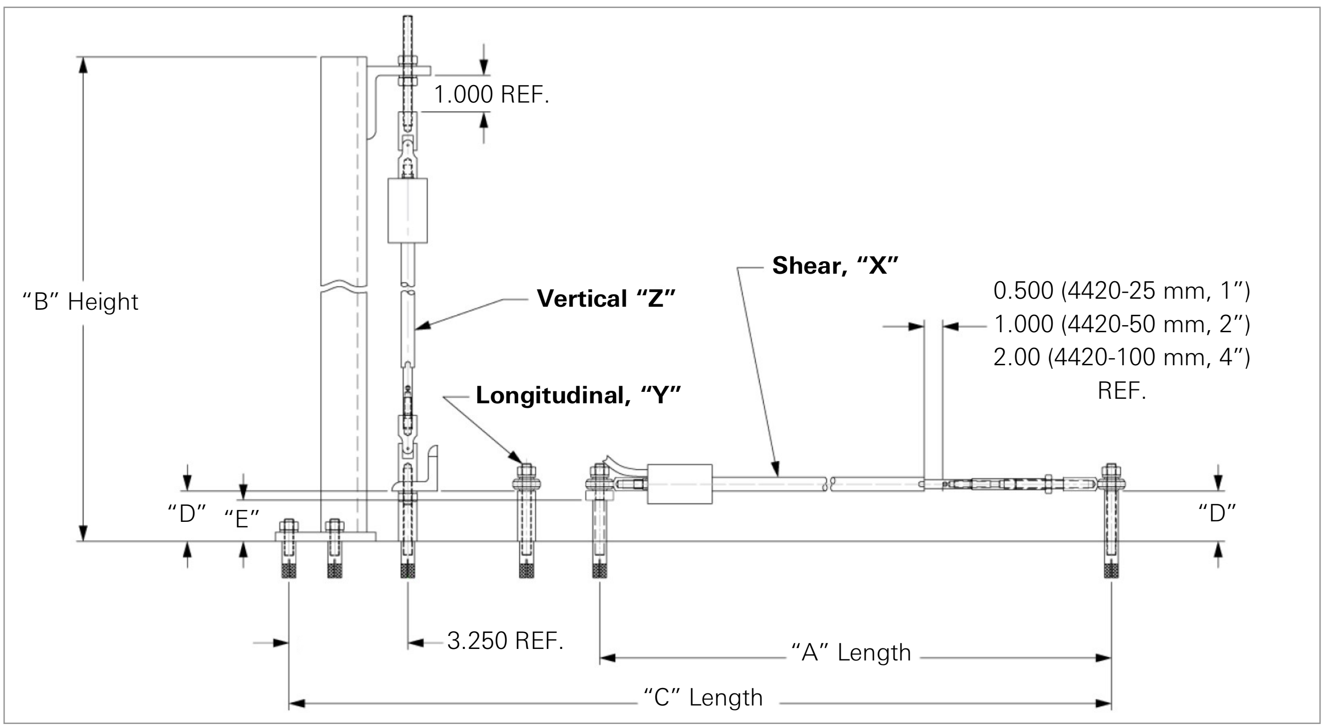

***FIGURE 18:** Typical 3D Array, Front View*

Range	"A" Length @ Midrange	"B" Height	"C" Lenght	"D" Dimension	"E" Dimension
25 mm (1")	342.90 mm (13.50")	384.56 mm (15.14")	558.80 mm (22")	34.93 mm (1.375")	28.58 mm (1.125")
50 mm (2")	396 mm (15.625")	489.28 mm (19.263")	612.78 mm (24.125")	60.33 mm (2.375")	53.98 mm (2.125")
100 mm (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")

***TABLE 11:** Typical 3D Array*

E.2 INSTALLING THE X, Y AND Z CRACKMETERS

For spacing distances, refer to Section 3.1. When setting the gauge position using a portable readout, refer to the calibration sheet to determine the proper position.

The instructions below show the installation method using drop-in anchors. If groutable anchors are used, refer to Section 3.2.2 for the grouting method.

E.2.1 X-AXIS

The X-axis uses a 1/4" x 3/4" stainless steel bar to transfer **parallel** motion along the axis of the crack to an sensor.

Perform the following installation steps:

1. Using a masonry drill (or other suitable equipment), drill two 10mm (3/8”) diameter holes, 32 mm (1.25") deep, 32 mm (1.25") apart. The holes should be positioned **perpendicular** to, and 25-50 mm (1-2”) in away from, the crack.
2. Insert the drop-in anchors, threaded side up, into the holes. Insert the Model TLS-208 Setting Tool into the anchors and strike with a hammer until the lip of the anchor touches the lip of the setting tool.
3. Place the shorter spacers on top of the anchors and attach the 143 mm (5.625") long stainless steel bar to the anchors using the provided threaded rods, lock washers, and nuts.

Note: The spacers used here are 1/8" (3.2 mm) shorter than the others to accommodate the width of the bar.

4. Drill another 10mm (3/8”) diameter hole, directly below the tapped hole in the stainless steel bar, to use as a guide.
5. Using the spacing from Section 3.1, make another 10mm (3/8”) diameter, 32 mm (1.25") deep hole **perpendicular** from the guide hole (parallel to the crack).
6. Insert the drop-in anchor, threaded side up, into the hole made in the previous step. Insert the Model TLS-208 Setting Tool into the anchor and strike with a hammer until the lip of the anchor touches the lip of the setting tool.
7. Place the spacer on top of the anchor and attach the sensor with rod end bearings, with the shipping spacer(s) removed, to the anchor using the threaded rod, lock washer, and nut provided.
8. Secure the other end of the sensor to the stainless steel bar with the short threaded rod, lock washer, and nut provided.
9. Check and record the reading with a portable readout. Refer to the readings on the calibration sheet to check and adjust the position as needed. A percentage of the sensor’s range can be established by tightening or loosening the nuts on the long threaded rod.

E.2.2 Y-AXIS

The Y-axis monitors any movement **perpendicular** to the crack. It is mounted the same way in as the standard sensor installation, referenced in Section 3.2.3, on either side of the crack.

Perform the following installation steps:

1. Determine the proper setting distance using Table 1 in Section 3.1.
2. Using a masonry drill (or other suitable equipment), drill two 10 mm (3/8") diameter holes, 32 mm (1.25") deep at the proper locations.
3. Insert the drop-in anchors, threaded side up, into the holes. Insert the Model TLS-208 Setting Tool into the anchors and strike with a hammer until the lip of the anchor touches the lip of the setting tool.

4. Place the spacers on top of the anchors and attach the sensor with rod end bearings, with the shipping spacer(s) removed, to the anchors using the threaded rod, lock washer, and nuts provided.
5. Check and record the reading with a portable readout. Refer to the readings on the calibration sheet to check and adjust the position as needed. A percentage of the sensor's range can be established by tightening or loosening the nuts on the long threaded rod.

E.2.3 Z-AXIS

The Z-axis measures vertical movement along the crack utilizing two brackets: one to transfer movement across the crack, and one to mount the sensor vertically.

1. Using a masonry drill (or other suitable equipment), drill two 10mm (3/8") diameter holes, 32 mm (1.25") deep, 32 mm (1.25") apart. The holes should be positioned **perpendicular** to, and 25-50 mm (1-2") in away from, the crack.
2. Insert the drop-in anchors, threaded side up, into the holes. Insert the Model TLS-208 Setting Tool into the anchors and strike with a hammer until the lip of the anchor touches the lip of the setting tool.
3. Attach the 143 mm (5.625") long stainless steel bar to the anchors using the provided threaded rods, lock washers, and nuts. No spacers are used.
4. Attach the sensor with threaded rod ends, with the shipping spacer(s) removed, to the steel bar using the lock washers, and nuts provided.
5. Secure the other end of the sensor to the stainless steel bar with the lock washer and nut provided. The bar should be **perpendicular** with the crack.
6. Drill another 10mm (3/8") diameter, 32 mm (1.25") deep hole, directly below the machined hole in the stainless steel bar.
7. Insert the drop-in anchor, threaded side up, into the hole. Insert the Model TLS-208 Setting Tool into the anchor and strike with a hammer until the lip of the anchor touches the lip of the setting tool.
8. Place the spacer on top of the anchor and attach the bar using the threaded rod, lock washer, and nut provided.
9. Check and record the reading with a portable readout. Refer to the readings on the calibration sheet to check and adjust the position as needed. A percentage of the sensor's range can be established by tightening or loosening the nuts on the long threaded rod.

E.3 MODEL 4420-3 CANTILEVER 3D ARRAY ALTERNATIVE

You can use the Model 4420-3 Cantilever Crackmeter to construct an alternative version of this 3D array, where the 4420-3 monitors the vertical Z-axis in a cantilever arrangement.

The 4420-3 employs a Model 4150 strain gauge to measure vertical movements. This version, shown below, is available in a one-inch range only.

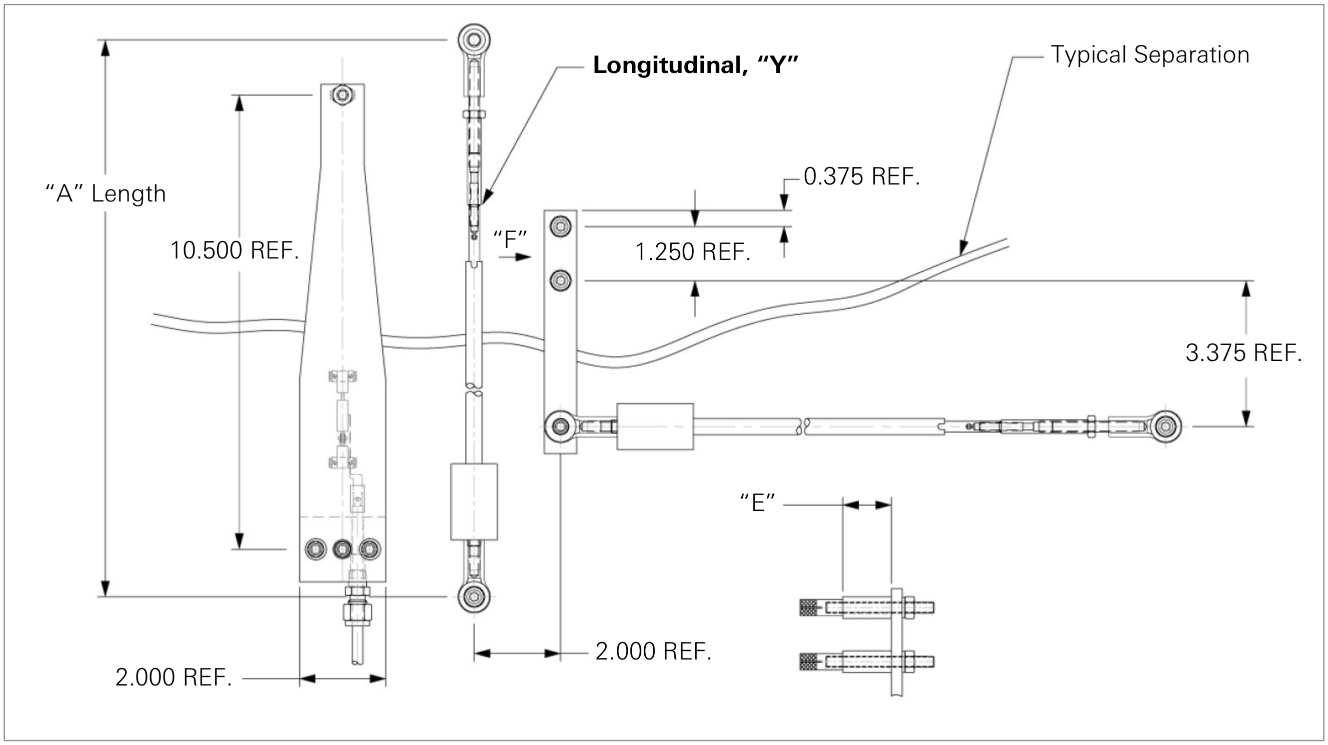

FIGURE 19: *Cantilever 3D Array, Top View*

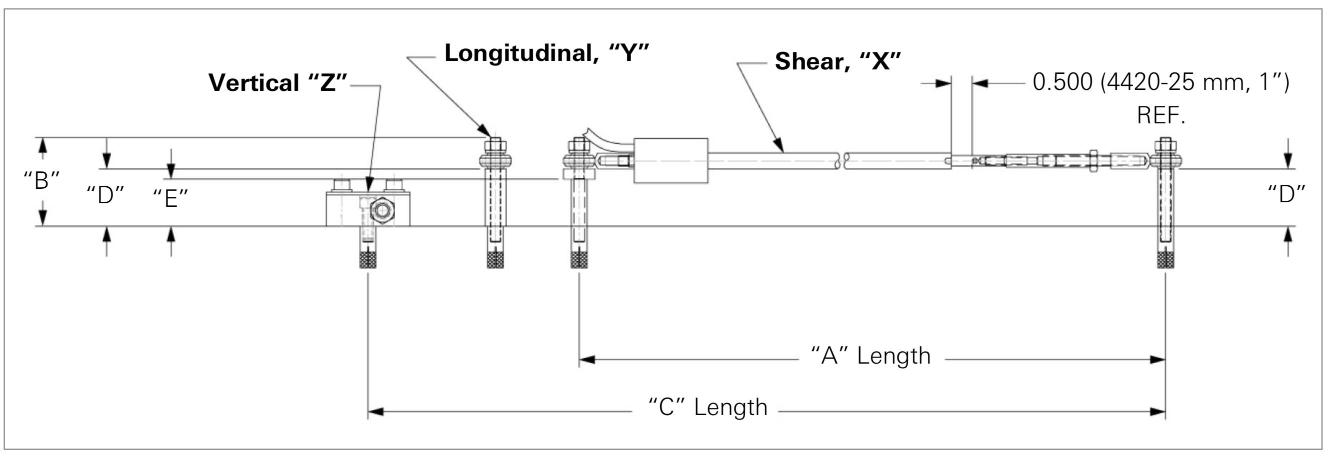

FIGURE 20: *Cantilever 3D Array, Front View*

Range	"A" Length @ Midrange	"B" Height	"C" Lenght	"D" Dimension	"E" Dimension
25 mm (1")	342.90 mm (13.50")	53.98 mm (2.125")	558.80 mm (22")	34.93 mm (1.375")	28.58 mm (1.125")

TABLE 12: *Cantilever 3D Array*

For detailed information about the Model 4420-3 Low Profile Crackmeter, refer to Appendix D.

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