GEOKON The World Leader in Vibrating Wire Technology

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Instruction Manual

Model 4420

VW Crackmeter

(Doc Rev Q, 6/13)

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1. INTRODUCTION

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

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 gage body, the spring is elongated causing an increase in tension which is sensed by the vibrating wire element. The tension in the wire is directly proportional to the extension, hence, the opening of the joint can be determined very accurately by measuring the strain change with the vibrating wire readout box.

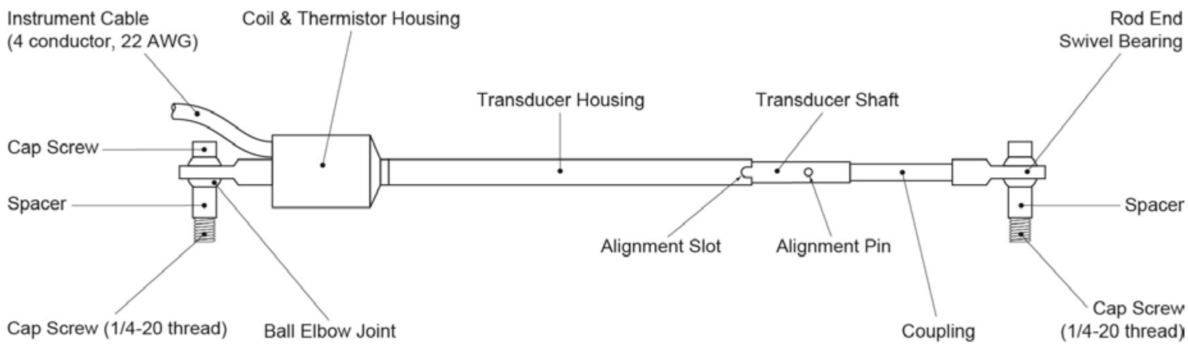

Figure 1: Model 4420-1-50/100/150/200/300 Vibrating Wire Crackmeter

The Model's 4420-12 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.

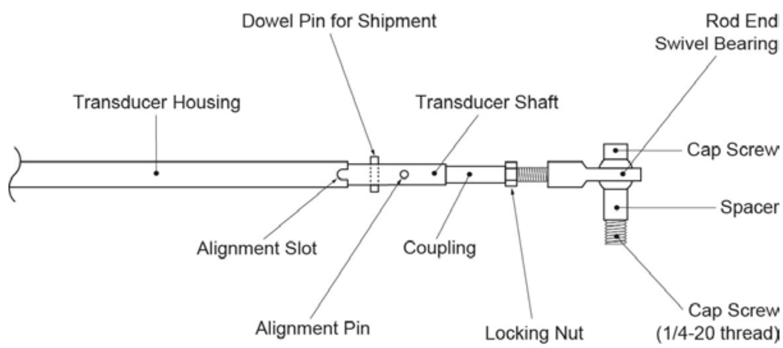

Figure 2 - Model 4420-1-12/25 Detail

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. Do not, under any circumstamces, extend the crackmeter beyond its working range

2. INSTALLATION

2.1. Preliminary Tests

Upon receipt of the instrument, the gage should be checked for proper operation (including the thermistor). **The Crackmeter normally arrives with it's shaft secured at approximately 50% of it's range, by either a split PVC sleeve, (for crackmeters over 100mm (4 inch) range), or a dowel pin held in place by a piece of tape, (see Figure 2).** These devices hold the crackmeter in tension thereby helping to protect it during shipping. **Remove this PVC split sleeve or dowel pin before proceeding**. Connect the gage to the Readout to take a reading (see section 3). The reading should be stable and in the range of 4000 to 5000.

Checks of electrical continuity can also be made using an ohmmeter. Resistance between the gage leads should be approximately 180 ohms, ±10 ohms. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 14.7Ω/1000' or 48.5Ω/km, multiply by 2 for both directions). Between the green and white should be approximately 3000 ohms at 25° (see Table B-1), and between any conductor and the shield should exceed 2 megohms.

2.2. Crackmeter Installation

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

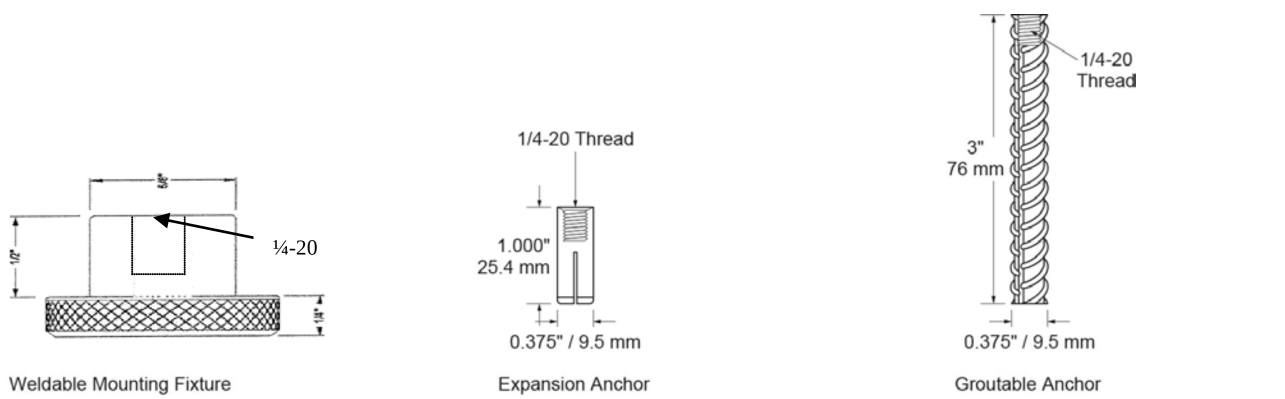

Figure 3 - Anchor Types with Dimensions

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 (see Table 1) depending on the anticipated direction of movement, (extensions or compressions). The following three sections detail instructions for each of the above three anchors.

Model & Range	**Mid-Range**	**To Monitor Extensions**	**To Monitor Compressions**
4420-12 mm 4420-.5"	325 mm 12.8"	319 mm 12.6"	331 mm 13.0"
4420-25 mm 4420-1"	333 mm 13.1"	321 mm 12.6"	345 mm 13.6"
4420-50 mm 4420-2"	406 mm 16”	381 mm 15”	432 mm 17"
4420-100 mm 4420-4"	543 mm 21.4"	493 mm 19.4"	593 mm 23.3"
4420-150 mm 4420-6"	686 mm 27.0"	611 mm 24.1"	761 mm 30.0"
4420-200 mm 4420-8”	740 mm 29.1”	640 mm 25.2”	840 mm 33.1”
4420-300 mm 4420-12	967 mm 38.1"	817 mm 32.2"	1117 mm 44"

Table 1 - Crackmeter Anchor Spacing Distances

When setting the gage position using a portable readout (see section 3) use the reading ranges in Table 2 to determine the proper position.

Approx Mid-Range Reading	**Approx Reading to Monitor Extensions**	**Approx Reading to Monitor Compressions**
4500-5000	2500-3000	6500-7000

Table 2 - Crackmeter Reading Ranges

Note also that the calibration sheet (Figure 8) 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 it's range, either in anticipation of closure or opening of the crack. The Crackmeter can be extended until the desired reading (see Section 3 for readout instructions) is obtained and then held in this position while the distance between the anchor points (threaded cap screws inside the swivel bearings), see Figure 1) is measured. This measurement can then serve as a spacing guide for drilling or welding the anchor points.

Caution: ***Do not rotate the shaft of the Crackmeter. 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.***

Special note regarding installation of the Model's 4420-1-12 or 4420-1-25: If the reading is not in the proper range after installation additional adjustment is provided for by the inclusion of a threaded extension and locking nut as depicted in Figure 2. In order to use this feature the transducer needs to be attached, at the coil assembly end, to the anchor. Position (but do not attach) the opposite end of the Crackmeter over the threaded hole of the anchor. If the reading is not in the proper range (see Table 2) loosen the locking nut (Figure 2) and rotate the threaded rod which carries the rod end swivel bearing, in or out of the end of the Transducer Shaft until the desired spacing and initial reading has been achieved. The transducer shaft itself must not be rotated. It should be gripped while rotating the rod end swivel bearing. After adjusting, align the hole in the rod end swivel bearing over the anchor, place the

cap screw through the hole and through the ½ inch spacer and then tighten the cap screw into the anchor.

2.2.1. Installation using Weldable Fixtures

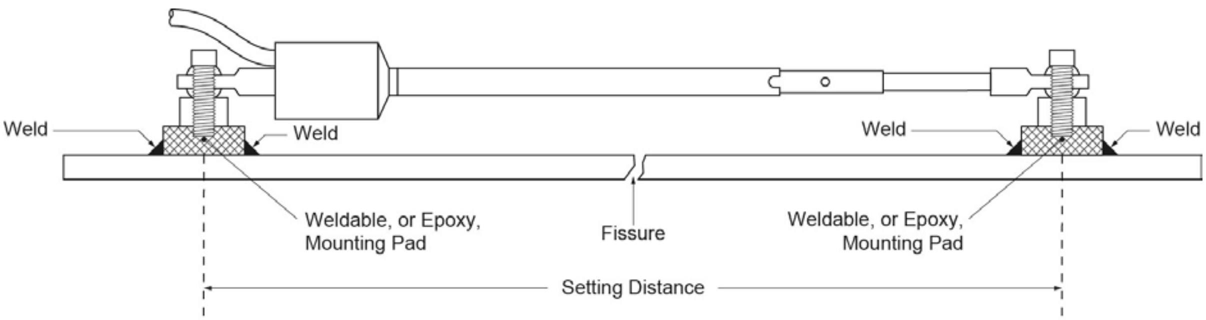

Figure 4 - Installation using Weldable Fixtures

Installation instructions;

(See section 2.2 for special instructions re Models 4420-1-12 and 4420-1-25)

1. Determine proper setting distance using figures in Table 1 or the readings on the calibration sheet. Prepare the surface (grinding, sanding, etc.) of the steel around the area of each weldable fixture.
2. Locate the welding fixtures on prepared surfaces, check spacing again and tack weld to the member.
3. Remove the nylon tie securing the transducer shaft. Thread the cap screw through the swivel bearing and through the ½ inch spacer on each end. Then tighten the cap screws into the welding fixtures.
4. Check the reading with a portable readout. Use Table 2 or the readings on the calibration sheet to check the position. The installation is now complete.

2.2.2. Installation using Groutable Anchors

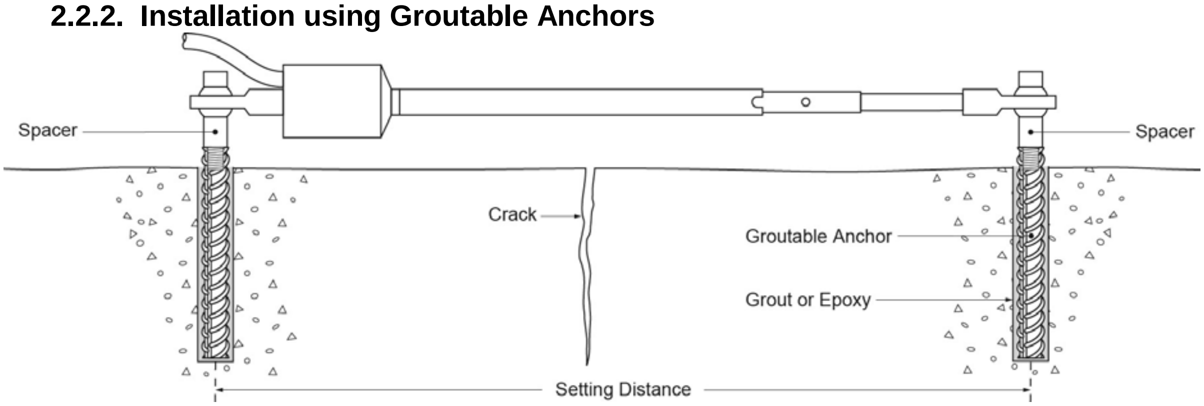

Figure 5 - Installation using Groutable Anchors

Installation instructions;

(See section 2.2 for special instructions re Models 4420-1-12 and 4420-1-25)

1. Determine proper setting distance using figures from Table 1 or the readings on the calibration sheet. Using a hammer drill or other suitable equipment, drill two ½" holes approximately 3" deep at the proper locations. Shorter holes may be drilled if the anchors are cut down accordingly.

2. Assemble the Crackmeter with cap screws threaded through the swivel bearings and the spacers and threaded loosely into the groutable anchors. If installing the instrument at the mid-range position, leave the nylon tie installed (see Figure 1) that secures the transducer shaft. Fill the holes with grout or epoxy and push the anchors in until the tops are flush with the surface. For holes drilled overhead use a quick setting grout or epoxy.

3. Tighten the set screws after the grout or epoxy has set. Remove the nylon tie.

4. Check the reading with a portable readout. Use Table 2 or the readings on the calibration sheet to check the position. Installation complete.

2.2.3. Installation using Expansion Anchors

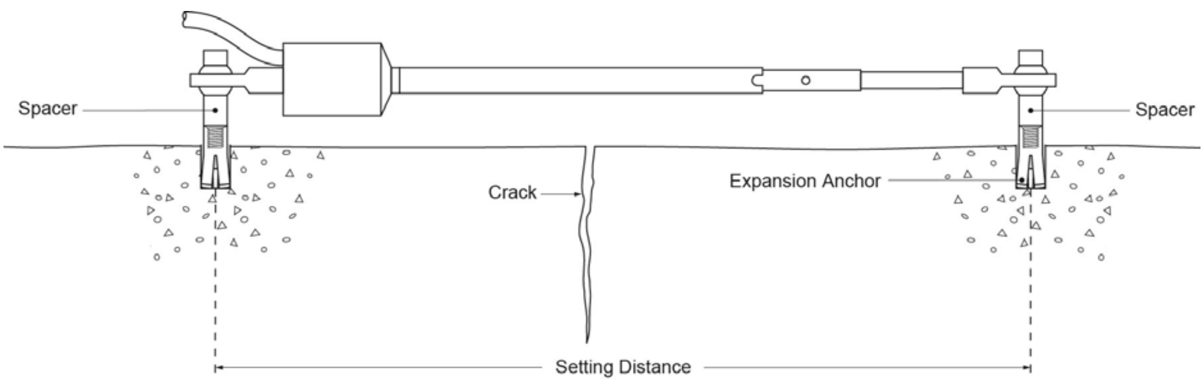

Figure 6 - Installation using Expansion Anchors

Installation instructions;

(See section 2.2 for special instructions re Models 4420-1-12 and 4420-1-25)

1. Determine proper setting distance using figures from Table 1 or the readings on the calibration sheet. Using a masonry drill or other suitable equipment, drill two 3/8 inch, (or 10mm), diameter holes 1¼", (32mm), deep at the proper locations.

2. Insert the expansion anchors into the holes, with the slotted end down and then, insert the setting tool provided, small end first, into the anchor and expand the anchor by hitting the large end of the setting tool with several sharp hammer blows.

3. Remove the nylon tie securing the transducer shaft. Push the cap screws through the swivel bearings and spacers on each end of the crackmeter then tighten the cap screws into the anchors.

4. Check the reading with a portable readout. Use Table 2 or the readings on the calibration sheet to check the position. Installation complete.

2.3 Protection from mechanical damage

can be had by using the cover plates made by Geokon. (See Figure 7). Two 3/8 x 2 inch long hex-head bolts which will hold the cover plates should be anchored in place using either groutable or expansion anchors. The special cover plates are made from sheet steel formed into a channel shape. To get the correct spacing for the bolts a spacer jig is available or the cover plate can be flipped over on its back and the holes in the cover plate used to mark the bolt locations. The holes are spaced at a nominal 21 inches (530mm) apart: one hole is slotted so that the spacing is not critical.

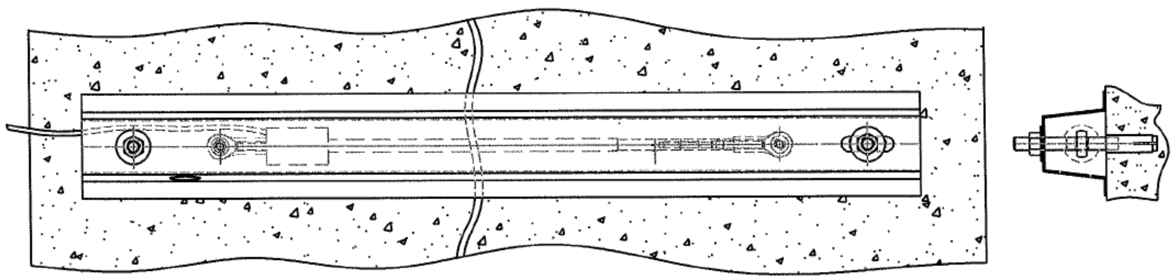

Figure 7 - Typical Cover Plate Installation

The standard cover plate is long enough to cover the two inch range crackmeter – longer range crackmeters must use two overlapping cover plates bolted together.

2.4. Cable Installation

The cable should be routed in such a way so as to minimize the possibility of damage due to moving equipment, debris or other causes.

Cables may be spliced to lengthen them, without affecting gage readings. Always waterproof the splice completely, preferably using an epoxy based splice kit such the 3M Scotchcast™, model 82-A1. These kits are available from the factory.

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, do not have any integral lightning protection components, i.e. transzorbs or plasma surge arrestors. Usually this is not a problem however, if the instrument cable is exposed, it may be appropriate to install lightning protection components, as the transient could travel down the cable to the gage and possibly destroy it.

Note the following suggestions;

- If the gage is connected to a terminal box or multiplexer components such as plasma surge arrestors (spark gaps) may be installed in the terminal box/multiplexer to provide a measure of transient protection. Terminal boxes and multiplexers available from Geokon provide locations for installation of these components.
- Lighting arrestor boards and enclosures are available from Geokon that install near the instrument. The enclosure has a removable top so, in the event the protection board (LAB-3) is damaged, the user may service the components (or replace the board). A connection is made between this enclosure and earth ground to facilitate the passing of transients away from the gage. See Figure 8. Consult the factory for additional information on these or alternate lightning protection schemes.
- Plasma surge arrestors can be epoxy potted into the gage cable close to the sensor. A ground strap would connect the surge arrestor to earth ground, either a grounding stake or other suitable earth ground.

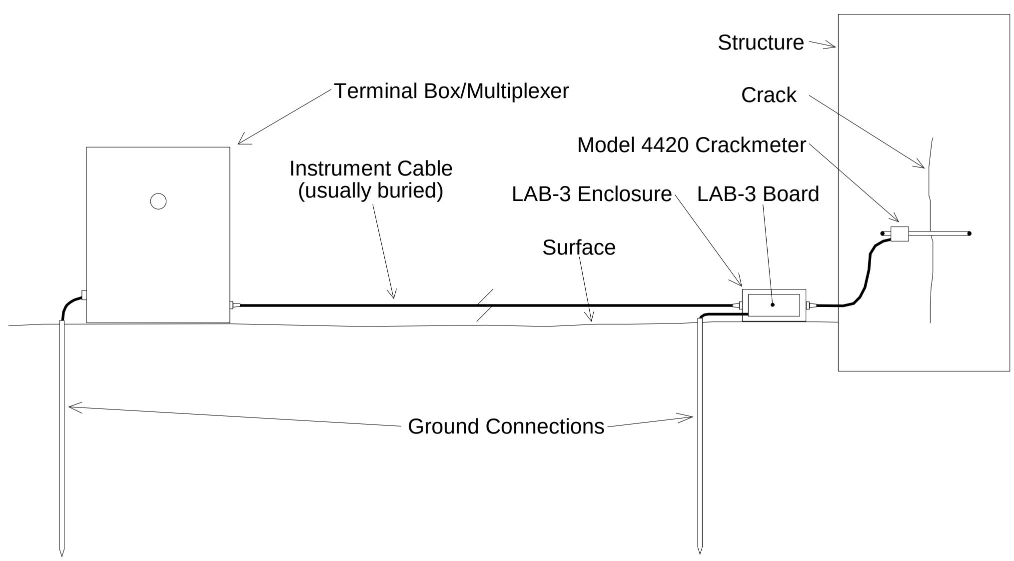

Figure 8 - Lightning Protection Scheme

3. TAKING READINGS

3.1. Operation of the GK-403 Readout Box

The GK-403 can store gage readings and also apply calibration factors to convert readings to engineering units. Consult the GK-403 Instruction Manual for additional information on Mode "G" of the Readout. The following instructions will explain taking gage measurements using Modes "B" and "F" (similar to the GK-401 switch positions "B" and "F").

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the white and green clips are for the thermistor and the blue for the shield drain wire.

1. Turn the display selector to position "B" (or "F"). Readout is in digits (Equation 4-1).

2. Turn the unit on and a reading will appear in the front display window. The last digit may change one or two digits while reading. Press the "Store" button to record the value displayed. If the no reading displays or the reading is unstable see section 5 for troubleshooting suggestions. The thermistor will be read and output directly in degrees centigrade.

3. The unit will automatically turn itself off after approximately 2 minutes to conserve power.

3.2 Operation of the GK404 Readout Box

The GK404 is a palm sized readout box which displays the Vibrating wire value and the temperature in degrees centigrade.
The GK-404 Vibrating Wire Readout arrives with a patch cord for connecting to the vibrating wire gages. One end will consist of a 5-pin plug for connecting to the respective socket on the bottom of the GK-404 enclosure. The other end will consist of 5 leads terminated with alligator clips. Note the colors of the alligator clips are red, black, green, white and blue. The colors represent the positive vibrating wire gage lead (red), negative vibrating wire gage lead (black), positive thermistor lead (green), negative thermistor lead (white) and transducer cable drain wire (blue). The clips should be connected to their respectively colored leads from the vibrating wire gage cable.

Use the **POS** (Position) button to select position **B** and the MODE button to select **Dg** (digits).
Other functions can be selected as described in the GK404 Manual.

The GK-404 will continue to take measurements and display the readings until the OFF button is pushed, or if enabled, when the automatic Power-Off timer shuts the GK-404 off.

The GK-404 continuously monitors the status of the (2) 1.5V AA cells, and when their combined voltage drops to 2V, the message **Batteries Low** is displayed on the screen. A fresh set of 1.5V AA batteries should be installed at this point

3.3 Operation of the 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
- the GK-405 Remote Module which is housed in a weather-proof enclosure and connects to the vibrating wire sensor by means of:

1) Flying leads with alligator type clips when the sensor cable terminates in bare wires or,
2) by means of a 10 pin connector..

The two components communicate wirelessly using Bluetooth®, a reliable digital communications protocol. The Readout Unit can operate from the cradle of the Remote Module (see Figure 9) or, if more convenient, can be removed and operated up to 20 meters from the Remote Module

Figure 9 GK405 Readout Unit

For further details consult the GK405 Instruction Manual.

3.4. Measuring Temperatures

Each Vibrating Wire Crackmeter is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Usually the white and green leads are connected to the internal thermistor.

The GK 401 readout box will not read temperatures – an ohmmeter is required

1. Connect the ohmmeter to the two thermistor leads coming from the Crackmeter. (Since the resistance changes with temperature are so large, the effect of cable resistance is usually insignificant.)

2. Look up the temperature for the measured resistance in Table B-1. Alternately the temperature could be calculated using Equation B-1.

   Note: The GK-403, GK-404 and GK-405 readout boxes will all read the thermistor and display temperature in °C automatically.

4. DATA REDUCTION

4.1. Deformation Calculation

The basic units utilized by Geokon for measurement and reduction of data from Vibrating Wire Crackmeters are "digits". Calculation of digits is based on the following equation;

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

Equation 1 - Digits Calculation

To convert digits to deformation the following equation applies;

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

Equation 2 - Deformation Calculation

Where; R_1 is the current reading.
R_0 is the initial reading, usually obtained at installation (see section 2.4).
G is thegage factor, usually millimeters or inches per digit (see Figure 10).
F is an optional engineering units conversion factor, see Table 3.

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 3 - 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 gage factor is 0.004457 mm/digit. The deformation change is;

$$D_{uncorrected} = (6000 - 2500) \times 0.004457 = +15.60 \text{ mm}$$

Note that increasing readings (digits) indicate increasing extension.

To use the Polynomial Gage factors given on the Calibration Sheet, use the value of R_0 and Gage 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, N.H. 03766 USA

Vibrating Wire Displacement Transducer Calibration Report

Range: 25 mm

Calibration Date: September 01, 2005

Serial Number: 05-8389

Temperature: 23.6 °C

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

Calibration Instruction: CI-4400 Rev: C

Technician: Erica

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2230	2228	2229	-0.055	-0.22	-0.008	-0.03
5.0	3369	3368	3369	5.024	0.10	5.014	0.06
10.0	4494	4492	4493	10.04	0.14	9.999	0.00
15.0	5615	5613	5614	15.03	0.13	15.00	-0.02
20.0	6729	6729	6729	20.00	0.01	19.99	-0.03
25.0	7841	7841	7841	24.96	-0.17	25.01	0.02

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

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

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

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

Calculated Displacement: **Linear,** $D = G(R_1 - R_0)$

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B: 4795 Temp(T_0): 23.7 °C Date: September 19, 2005

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.
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Figure 10 - Typical Crackmeter Calibration Sheet

4.2. Temperature Correction

The Model 4420 Vibrating Wire Crackmeters have a small coefficient of thermal expansion so in many 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 gage factor.
T_1 is the current temperature.
T_0 is the initial temperature.
K is the thermal coefficient (see Equation 4).

Tests have determined that the thermal coefficient, K, changes with the position of the transducer shaft. Hence, the first step in the temperature correction process is 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 4.
B is the constant from Table 4.
G is the linear gage factor from the supplied calibration sheet.

Model:	4420-6 mm 4420-0.25''	4420-12 mm 4420-0.5"	4420-25 mm 4420-1"	4420-50 mm 4420-2"	4420-100 mm 4420-4"	4420-150 mm 4420-6"
Multiplier (M):	0.00073	0.000295	0.000301	0.000330	0.000192	0.000216
Constant (B):	0.583	1.724	0.911	0.415	0.669	0.491

Model:	4420-200 mm 4420-8”	4420-300 mm 4420-12”				
Multiplier (M):	0.000305	0.000245				
Constant (B):	0.240	0.564				

Table 4 - Thermal Coefficient Calculation Constants

Consider the following example using a Model 4420-25 mm Crackmeter;

R_0 = 4773 digits

R_1 = 4589 digits

T_0 = 20.3° C

T_1 = 32.9° C

G = 0.00555 mm/digit

$K = (((4589 \times 0.000301) + 0.911) \times 0.00555) = 0.0127$

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

$D_{corrected} = ((4589 - 4773) \times 0.00555) + (((32.9 - 20.3) \times 0.0127)$

$D_{corrected} = (-184 \times 0.00555) + 0.160$

$D_{corrected} = -1.021 + 0.160$

$D_{corrected} = -0.861$ 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 Geokon Vibrating Wire Crackmeters is confined to periodic checks of cable connections and maintenance of terminals. The transducers themselves are sealed and cannot be opened for inspection. However, note the following problems and possible solutions should difficulties arise. Consult the factory for additional troubleshooting help.

Symptom: Crackmeter Readings are Unstable

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

✓ Is the transducer shaft positioned outside the specified range (either extension or retraction) of the instrument? Note that when the transducer shaft is fully retracted with the alignment pin inside the alignment slot (Figure 1) the readings will likely be unstable because the vibrating wire is now under-tensioned.

✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators and antennas.

Symptom: Crackmeter Fails to Read

- ✓ Is the cable cut or crushed? This can be checked with an ohmmeter. Nominal resistance between the two transducer leads (usually red and black leads) is 180Ω, ±10 Ω. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 14.7Ω/1000' or 48.5Ω/km). If the resistance reads infinite, or very high (>1 megohm), a cut wire must be suspected. If the resistance reads very low (<100 Ω) a short in the cable is likely. Splicing kits and instructions are available from the factory to repair broken or shorted cables. Consult the factory for additional information.

- ✓ Does the readout or datalogger work with another transducer? If not the readout or datalogger may be malfunctioning.

APPENDIX A - SPECIFICATIONS

A.1 Model 4420 Crackmeter

Range:	12 mm 0.50 "	25 mm 1"	50 mm 2"	100 mm 4 "	150 mm 6 "	200mm 8"	300mm 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:	1200 - 2800 Hz							
Coil Resistance:	180 Ω, ± 10 Ω							
Cable Type:[3]	2 twisted pair (4 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: (mid-range, end to end)	325 mm 12.8"	333mm 13.1"	406mm 16"	543 mm 21.4"	686 mm 27.0"	740 mm 29.2"	967mm38.1 "	
Coil Assembly Dimensions: (length × OD)	31.75 × 25.4 mm 1.25 × 1"							
Weight:	180 g 5.75 oz.	175 g 5.6 oz.	197 g 6.3 oz.	297 g 9.5 oz.	355 g 11.4 oz.			

Table A-1 Crackmeter Specifications

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

A.2 Thermistor

Range: -80 to +150° C   Accuracy: ±0.5° C

APPENDIX B - THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3

Resistance to Temperature Equation:

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

Equation B-1 Convert Thermistor Resistance to Temperature

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

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

Table B-1 Thermistor Resistance versus Temperature

APPENDIX C – 3D Arrays

Monitoring crack movements in three dimensions requires an array of three crack meters. One such array is shown in Figure 11

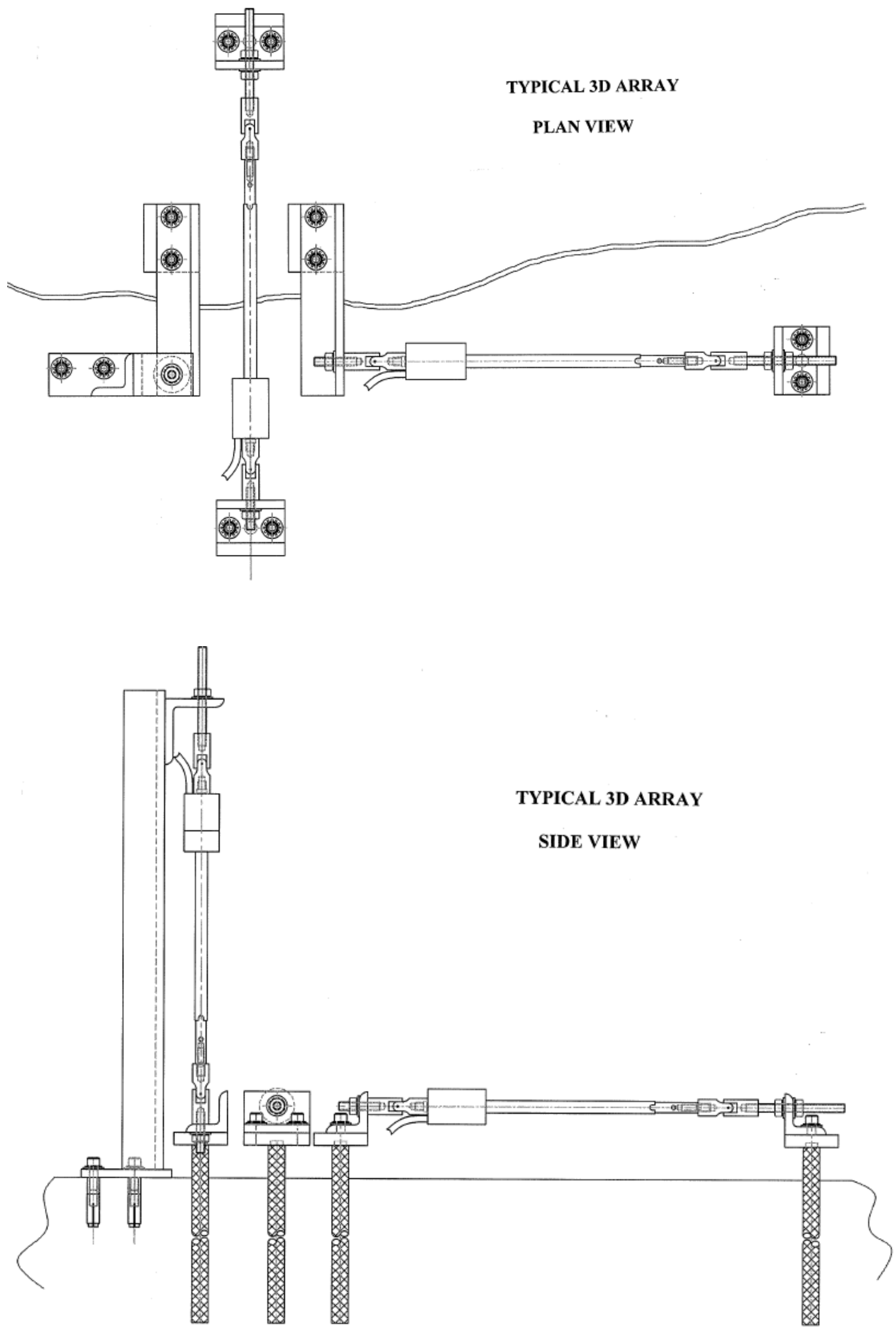

Figure 11 Typical 3D Array

The ends of the crack meters are fixed to brackets and these brackets are bolted to anchor pads made from a small stainless steel welded to a short length of #3 rebar. The rebars are grouted into short boreholes 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. The actual height of the crackmeters above the surface should be chosen with regard to the clearance necessary to accommodate the anticipated movements. . Refer to the instructions in Sections 2.2.2 for groutable anchors and Section 2.2.3 for drop-in expansion anchors.

An alternative version is available where the vertical element is replaced by a cantilever arrangement, the cantilever having a Model 4150 strain gage attached to measure shear movements

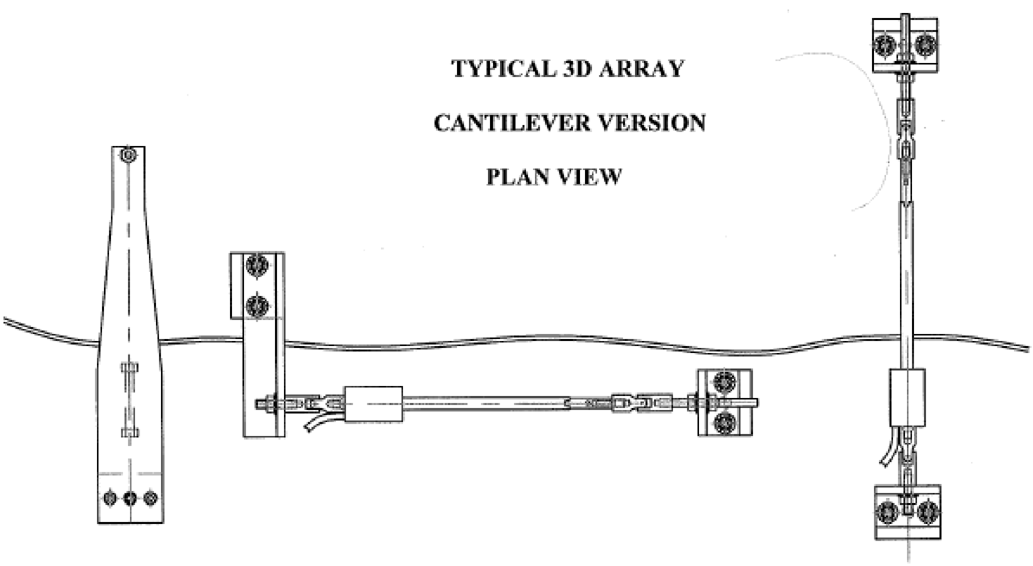

Figure 12 3D Array, Cantilever Version

Instruction for Installing the Cantilever

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" (267mm)

Clean out the drill cuttings and place the drop-in anchor in the hole.

Place the anchor setting tool into the anchor and strike the drive pin with several sharp hammer blows.

Now screw the target plate into one of the threaded drop-in anchor holes [using loctite cement on the threads] until it is tight in the anchor.

Next place the crackmeter over the other hole and screw the supplied cap screw into the drop-in anchor while aligning it with the target and while also 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.

Tighten the clamping cap screw.

Now connect the readout box to the cable and observe the transducer output in pos B. With no contact with the target the output will be between 1800 and 2500 digits.
This will be your rough zero point.

If all the anticipated displacement is seen as the cantilever moving down with reference to the target, set the zero position at 3000 digits by turning the threaded rod on the cantilever tip until the reading is achieved; afterwhich the locknut may be tightened. If all the movement is seen as moving up set at 10,000 digits. For mid-range set at 7000 digits.

The cable is tied to the sensor with tywraps but should be secured near the carckmeter to prevent any strain on the small gage leadwires.

I areas of high traffic the gage should be protected by a cover plate.