



The World Leader in Vibrating Wire Technology

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Instruction Manual
Model 4430
VW Deformation Meter



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1. INTRODUCTION

1.1. Theory of Operation

The Geokon Model 4430 Vibrating Wire Deformation Meter is designed to measure axial deformations in boreholes in rock, concrete or soil. It can also be embedded in soils in embankments such as earth dams and highway fills. The units can be installed in series providing incremental deformation measurements over any length. Base lengths of the gage can vary from a minimum of 1 meter to over 25 meters.

The basic sensing element is a vibrating wire strain gage in series with a precision music wire spring which is coupled to a movable shaft. As the shaft moves in or out of the sensor body, the tension in the spring, and also in the vibrating wire element, change. This change in tension is directly proportional to the amount of extension and, through calibration, a calibration factor that relates the frequency of vibration to the amount of extension is determined. The unit is stress relieved after manufacture providing for excellent stability over long periods of time.

The gage sensor is attached to a flange at one end and by a connecting rod of some length to a flange at the other end. The sensor and the rod are covered by a plastic (PVC) tube which holds the end flanges apart at a predetermined distance (gage length), and insures that the rod is free to move. As the flanges move apart the movement is conveyed by the connecting rod to the sensor and measured by the readout system. Different combinations of gage length and sensor range provide for optimum sensitivity. For maximum strain resolution, a long base gage with a short range transducer will give best results. For maximum deformation: short base length, longer transducer range. The flexibility of the system allows the user to choose the most useful combination of range and sensitivity according to predicted movements.

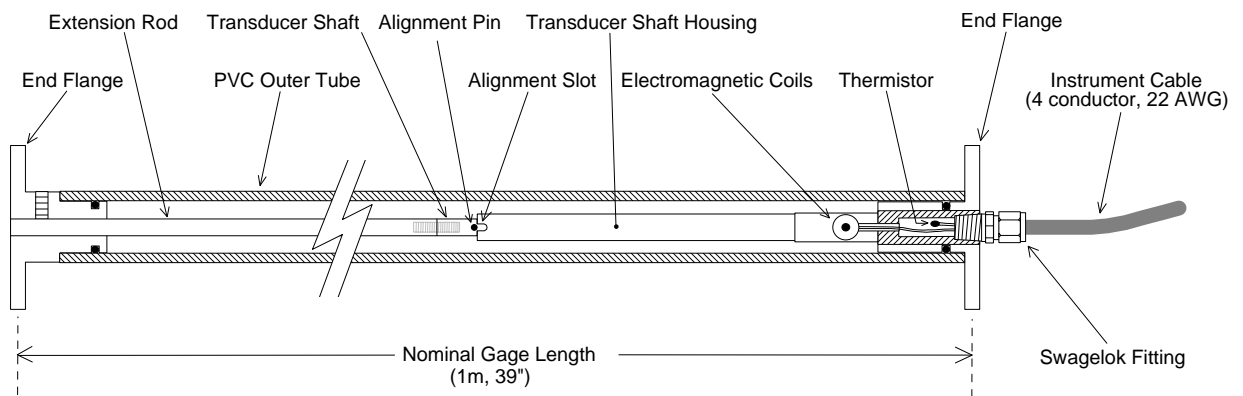


Figure 1 - Model 4430 Deformation Meter

Readouts available from Geokon, used in conjunction with the Vibrating Wire Deformation Meter, will provide the necessary voltage pulses to pluck the wire and convert the measured frequencies so as to display the reading.

2. INSTALLATION

2.1. Preliminary Tests

Upon receipt of the instrument, the gage should be checked for proper operation (including the thermistor). See Section 3 for readout instructions. In position "B" the gage will read between 2000 and 8000 digits. Pull slightly on the end flanges (Figure 1), the reading should increase.

Checks of electrical continuity can also be made using an ohmmeter. Resistance between the gage leads should be approximately 180Ω , $\pm 10\Omega$. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately $14.7\Omega/1000'$ or $48.5\Omega/\text{km}$, 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. Deformation Meter Installation

2.2.1. Installation in Boreholes

The primary use of the Model 4430 is for the measurement of axial strains or deformations in boreholes. The most common method of installation is by grouting. Horizontal holes should be inclined slightly downward to make for easy grouting and to avoid air pockets. Vertical up holes require special grouting apparatus and snap-ring or hydraulic anchors on the gage itself to hold it in place while grouting the hole. Horizontal and vertical down holes are instrumented as follows:

Drill the borehole at least 0.5 m (≈ 2 ft) beyond the location of the deepest flange. The borehole must be a minimum of 60 mm (2.25") in diameter. Fill the hole with grout mixture of 1 part Portland cement to 1-2 parts water by volume. An expansive mix is helpful particularly in horizontal holes. Lower or push the sensor(s) down the hole to the proper location as noted by a mark on the cable. If more than one sensor is to be placed in a hole, be sure to maintain the position of the lower sensor while installing shallower ones.

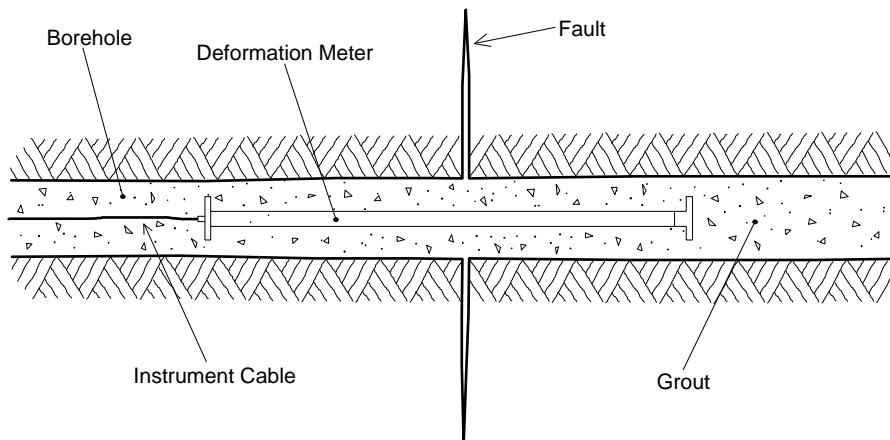


Figure 2 - Borehole Installation

For situations such as soft ground or when the hole is cased and casing must be withdrawn, it may be advisable to use a sensor with a hydraulic anchor for permanent positioning. This should be discussed with the application engineers at the factory.

2.2.2. Installation in Mass Concrete

The Model 4430 can be placed directly into concrete or prewired into the rebar cage or network prior to concrete placement. Tiewires should be connected to the tube rather than the end blocks and should be perpendicular to the tube and not excessively tight to allow for shifting during placement of the concrete. The unit has a compressive modulus of approximately 200,000 psi, and should follow the concrete at very early stages of curing.

2.2.3. Installation in Fills and Embankments – Soil Strain Gages (For more details see the Model 4435 Soil Strainmeter Manual)

The Model 4435, which is a variation of the Model 4430, is used as a soil deformation meter in fills and embankments by placing the unit in shallow, horizontal trenches in the fill. Multiple sensors can be installed in series to give a total deformation profile along a particular axis as in a dam or highway embankment. Cables issue out of the side of the device so that the flanges can be linked together easily.

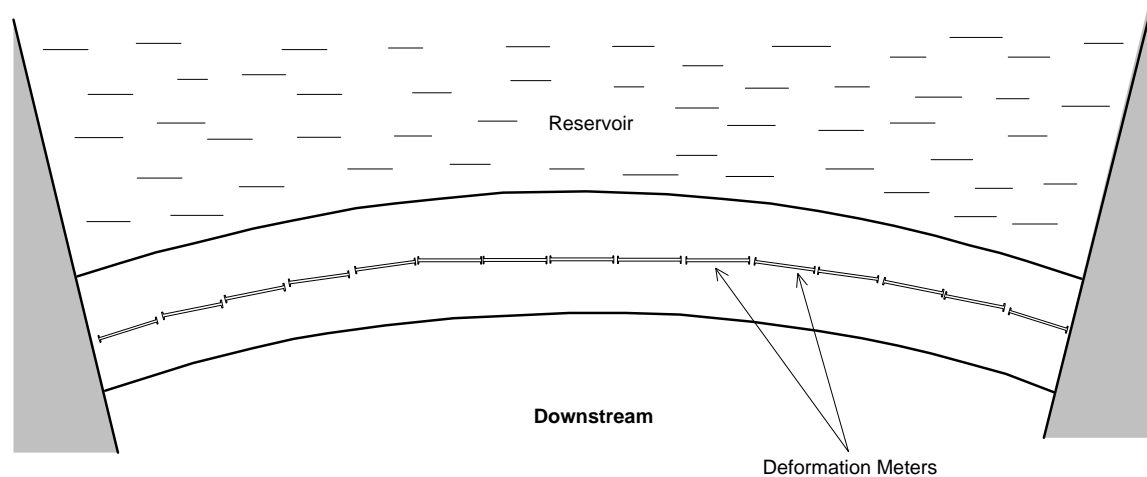


Figure 3 - Installation Along Crest of Dam

A narrow flat bottom trench should be excavated in previously compacted fill. The sensor is laid in the trench and backfilled with material which has had any large (>10 mm, 0.5") aggregate removed. Backfill and hand tamp the first 15 cm (≈ 6 ") and then proceed with the compaction of the fill in the normal way. Cables should also be run in trenches and backfilled in the same manner as above. For more details consult the Model 4435 Soil Strainmeter manual.

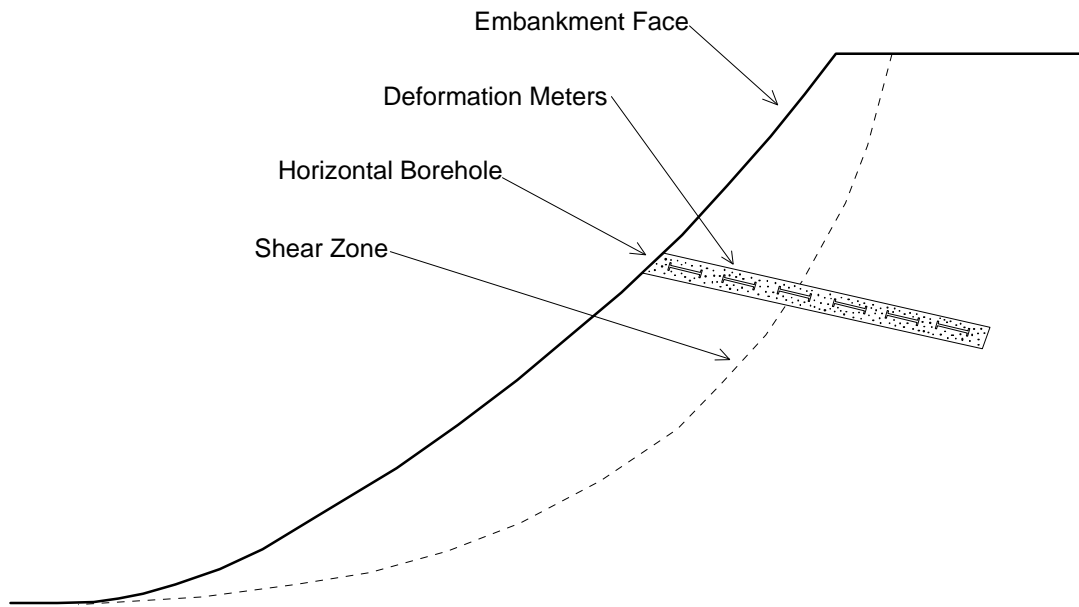


Figure 4 - Borehole Installation in Embankment

2.3. Cable Protection and Termination

As noted above, the cable from the gages can be protected by the use of flexible conduit, which can be supplied by Geokon.

Terminal boxes with sealed cable entries and covers are also available, allowing many gages to be terminated at one location with complete protection of the lead wires. The panel can have built-in jacks or a single connection with a rotary position selector switch. Lightning protection components can also be installed in the terminal boxes.

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. When making splices, use solder connections wherever feasible or crimp connectors if not.

2.4. Initial Readings

All readings are referred to an initial reading so it is important that this initial reading be carefully taken. Conditions should be noted at the time of all readings, especially during curing, i.e., temperature, time after placement, local conditions, etc.

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.

2.6. Lightning Protection

The Model 4430 Vibrating Wire Deformation Meter, unlike numerous other types of instrumentation available from Geokon, do not have any integral lightning protection components, i.e. transzorb 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 deformation meter 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.
- Lightning 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 5. 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.

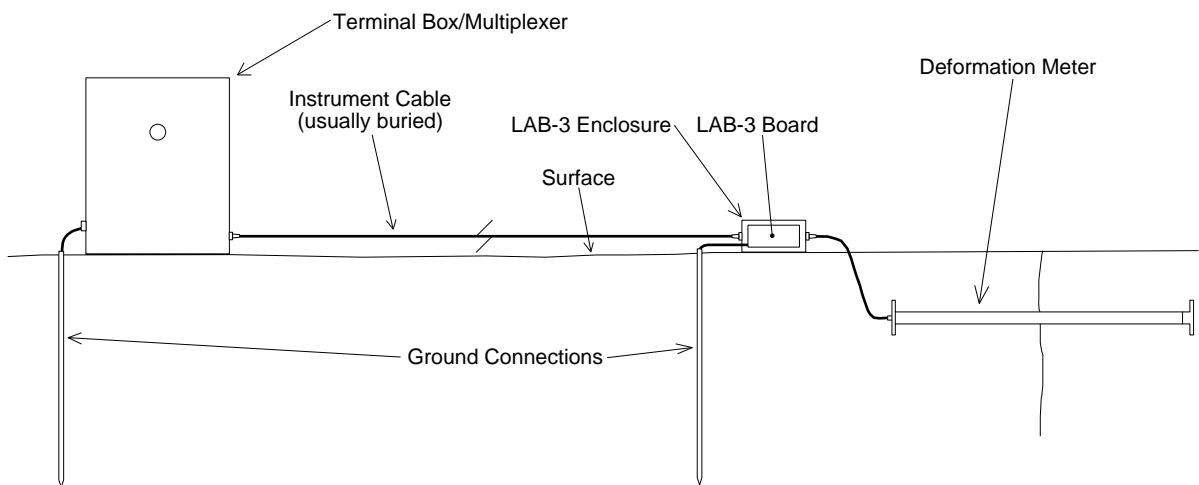


Figure 5 - Lightning Protection Scheme

3. TAKING READINGS

3.1. Operation of the GK-401 Readout Box

The GK-401 is a basic readout for all Vibrating Wire Deformation Meters.

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 green or blue clip for the shield drain wire. The GK-401 cannot read the thermistor (see Section 3.4).

1. Turn on the Readout. Turn the display selector to position "B". Readout is in "digits" (see Equation 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. Record the value displayed. If zeros are displayed or the reading is unstable see section 6 for troubleshooting suggestions.
3. The unit will automatically turn itself off after approximately 4 minutes to conserve power.

3.2. 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 Mode "B".

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 on the Readout. Turn the display selector to position "B". Readout is in digits (see Equation 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 6 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.

3.3 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

3.4. Measuring Temperatures

Each Vibrating Wire Deformation Meter is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Usually the white and green leads are connected to the internal thermistor. The GK-401 readout box will not read temperatures - a digital ohmmeter is required.

1. Connect the ohmmeter to the two thermistor leads coming from the deformation meter. (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 (Appendix B). Alternately the temperature could be calculated using Equation B-1 (Appendix B). For example, a resistance of 3400 ohms equivalent to 22° C. When long cables are used the cable resistance may need to be taken into account. Standard 22 AWG stranded copper lead cable is approximately 14.7Ω/1000' or 48.5Ω/km, multiply by 2 for both directions.

Note: The GK-403 and GK 404 readout boxes will 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 Deformation Meters are "digits". The units displayed by the GK-401, GK-402, and GK-403 in position "B" 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;

$$\text{Deformation} = (\text{Current Reading} - \text{Initial Reading}) \times \text{Calibration Factor} \times \text{Conversion Factor}$$

or

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

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).

C is the Calibration Factor, usually in terms of millimeters or inches per digit.

F is an engineering units conversion factor (optional), see Table 1.

| 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 1 - Engineering Units Conversion Multipliers

For example, the Initial Reading (R_0) at installation of a deformation meter with a 25 mm transducer range is 4250 digits. The Current Reading (R_1) is 6785. The Calibration Factor is 0.00619 mm/digit. The deformation change is;

$$D = (6785 - 4250) \times 0.00619 = +15.692 \text{ mm}$$

Note that increasing readings (digits) indicate increasing extension.

4.2. Temperature Correction

The Model 4430 Deformation Meter 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 ($>10^{\circ}\text{C}$) corrections may be applied. The following equation applies;

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

Equation 3 - Thermally Corrected Deformation Calculation

Where; R_1 is the Current Reading.
 R_0 is the Initial Reading.
 C is the Calibration Factor.
 T_1 is the Current Temperature.
 T_0 is the Initial Temperature.
 K is the Thermal Coefficient.
 L_C is the correction for the gage length.

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;

$$\text{Thermal Coefficient} = ((\text{Reading in Digits} \times \text{Multiplier}) + \text{Constant}) \times \text{Calibration Factor}$$

or

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

Equation 4 - Thermal Coefficient Calculation

See Table 2 for the Multiplier and Constant values used in Equation 4. The Multiplier (M) and Constant (B) values vary for the stroke of the transducer used in the Deformation Meter.

| | | | | | | | |
|---------------------------|----------------------------|----------------------------|--------------------------|--------------------------|---------------------------|---------------------------|----------------------------|
| Model: | 4430-6 mm 4430-0.25" | 4430-12 mm 4430-0.5" | 4430-25 mm 4430-1" | 4430-50 mm 4430-2" | 4430- 100mm 4430-4" | 4430- 150mm 4430-6" | 4430- 300mm 4430-12" |
| Multiplier (M): | 0.00073 | 0.000295 | 0.000301 | 0.000330 | 0.000192 | 0.000216 | 0.000250* |
| Constant (B): | 0.583 | 1.724 | 0.911 | 0.415 | 0.669 | 0.491 | 0.450* |
| Transducer Length (L): | 267mm 10.5" | 267 mm 10.5" | 267 mm 10.5" | 292 mm 11.5" | 393mm 15.49" | 510.5mm 20.1" | 715.2mm 28.2" |

* Calculated

Table 2 - Thermal Coefficient Calculation Constants

The gage length correction (L_C) is calculated using Equation 5.

$$L_C = 17.3 \times 10^{-6} \times L \times (T_1 - T_0)$$

Equation 5 - Gage Length Correction

Where L is the length of deformation meter in millimeters or inches, minus the transducer length (see Table 2) in millimeters or inches, respectively.

Consider the following example using a Model 4430 Deformation Meter with a 1 meter gage length and 25 mm transducer.

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

$$R_1 = 6785 \text{ digits}$$

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

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

$$C = 0.00619 \text{ mm/digit}$$

$$K = ((6785 \times 0.0003) + 0.911) \times 0.00619 = 0.01824$$

$$L = 1000 - 267 = 733$$

$$L_C = 17.3 \times 10^{-6} \times 733 \times (20 - 10) = 0.1268$$

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

$$D_{corrected} = ((6785 - 4250) \times 0.00619) + ((20 - 10) \times 0.01824) + 0.1268$$

$$D_{corrected} = (2535 \times 0.00619) + (10 \times 0.01824) + 0.1268$$

$$D_{corrected} = 15.692 + 0.1824 + 0.1268$$

$$D_{corrected} = 16.001 \text{ mm}$$

As can be seen from the above example, the corrections for temperature change are small and can often be ignored.

4.3. Environmental Factors

Since the purpose of the Deformation Meter 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 Vibrating Wire Deformation Meters is confined to periodic checks of cable connections. Once installed, the cells are usually inaccessible and remedial action is limited. Consult the following list of problems and possible solutions should difficulties arise. Consult the factory for additional troubleshooting help.

Symptom: Deformation Meter 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? Try reading the deformation meter on a different readout position. For instance, channel A of the GK-401 and GK-403 might be able to read the deformation meter. To convert the Channel A period display to digits use Equation 1.
- ✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, transformers, arc welders and antennas. Make sure the shield drain wire is connected to ground whether using a portable readout or datalogger. If using the GK-401 Readout connect the clip with the green boot to the bare shield drain wire of the pressure cell cable. If using the GK-403 connect the clip with the blue boot to the shield drain wire.
- ✓ Does the readout work with another deformation meter? If not, the readout may have a low battery or be malfunctioning. Consult the appropriate readout manual for charging or troubleshooting directions.

Symptom: Deformation Meter Fails to Read

- ✓ Is the cable cut or crushed? This can be checked with an ohmmeter. Nominal resistance between the two gage leads (usually red and black leads) is $180\Omega, \pm 10\Omega$. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately $14.7\Omega/1000'$ or $48.5\Omega/\text{km}$, multiply by 2 for both directions). If the resistance reads infinite, or very high (megohms), a cut wire must be suspected. If the resistance reads very low ($<100\Omega$) a short in the cable is likely.
- ✓ Does the readout or datalogger work with another deformation meter? If not, the readout or datalogger may be malfunctioning. Consult the readout or datalogger manual for further direction.

APPENDIX A - SPECIFICATIONS

A.1. Model 4430 Deformation Meter

| | |
|--------------------------------------|--|
| Gage Length:¹ | 1 meter (40 inches) |
| Ranges Available:¹ | 12, 25, 50 mm 0.5, 1, 2" |
| Overrange: | 115% |
| Accuracy: | 0.1% (with polynomial expression) |
| Resolution: | 0.025% FSR |
| Linearity: | 0.25% FSR |
| Thermal Zero Shift: | < 0.05% FSR/°C |
| Stability: | < 0.2%/yr (under static conditions) |
| Temperature Range: | -40 to +60°C -40 to 120° F |
| Frequency Range: | 1200 - 2800 Hz |
| Coil Resistance: | 180 Ω , $\pm 10 \Omega$ |
| Cable Type:² | 2 twisted pair (4 conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250") |
| Length: (end to end) | 1 meter, 40 inches |
| Diameter: | 26.7 mm, 1.050" (body) 51 mm, 2" (flange) |
| Weight: | 1 kg., 2.2 lbs. |

Table A-1 Model 4430 Specifications

Notes:

¹ Consult the factory for other lengths and ranges available.

² Consult the factory for alternate cable types.

A.2 Thermistor (see Appendix B also)

Range: -80 to +150° C

Accuracy: $\pm 0.5^\circ$ C

APPENDIX B - THERMISTOR TEMPERATURE DERIVATION

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

Resistance to Temperature Equation:

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

Equation B-1 Convert Thermistor Resistance to Temperature

Where; T = Temperature in °C.

LnR = Natural Log of Thermistor Resistance

A = 1.4051×10^{-3} (coefficients calculated over the -50 to +150° C. span)

B = 2.369×10^{-4}

C = 1.019×10^{-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