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*Instruction Manual*

# Model 3900

## Embedment Strain Gage


(Doc REV D 05/16/17)

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# FIGURES, TABLES and EQUATIONS

# 1. INTRODUCTION

The Model 3900 Embedment Strain Gage is designed for the measurement of dynamic strains in concrete structures and soils. It comprises a full-bridge strain gage proving ring element coupled in series with a tension spring which is stretched between two end flanges. An outer PVC tube sealed with O-rings provides a waterproof housing. The end flanges are embedded and move in accordance with the surrounding material. The voltage signals from the strain gage are transmitted via cable to the readout location.

**Figure 1 - The Model 3900 Embedment Strain Gage.**

The strain gage can be read out by means of the Geokon Model 502 Readout Box or by a applying a 2 to 12 Volt excitation to the input leads, and reading the corresponding millivolt output. The output at full range is approximately 3 mV/V. The standard wiring for use with the GK-502 readout box is configured to compensate for the use of long cables by the remote sensing of the input voltage at the sensor. A Thermistor is included inside the sensor to measure temperatures. This requires a cable with four shielded pairs of conductors.

## 2. INSTALLATION

The embedment gage is delivered with the sensor set at an approximately midrange position ready for installment. The standard range is ± 2500 microstrains. (Other ranges are available). An initial test can be conducted by connecting the strain gage to the GK-502 Readout Box or to a regulated voltage supply. Movement of the end flanges should produce a corresponding change in the gage output. At no time should the end flanges be twisted or pulled beyond the range of the sensor as this could permanently damage the gage.

The gage should be installed directly in the concrete or soil by hand. Large aggregate should be removed from the area immediately surrounding the sensor. The use of vibrators immediately next to the gage should be avoided. The standard cable has a thick PVC jacket and can be placed directly in the concrete.

## 3. TAKING READINGS

Connect the ten pin connector to the GK-502 readout box or connect the bare wires to a voltage supply and millivoltmeter as follows:

### 3.1 Input Connections

| Bendix Pin | Circuit Label | Description | Geokon Purple Cable |
|---|---|---|---|
| A | S- | Bridge Output - | White's Black |
| B | P+ | Bridge Excitation + | Red |
| C | P- | Bridge Excitation - | Red's Black |
| D | S+ | Bridge Output + | White |
| E | NC | No Connection | NC |
| F | G | Ground for shield | Shield |
| G | T | Thermistor | Blue |
| H | T | Thermistor | Blue’s Black |
| J | RS+ | Remote Sense + | Green |
| K | RS- | Remote Sense - | Green's Black |

**Table 1 - Input Connections**

Notes:
[1] Blue and Blue’s Black (thermistor) wires must be connected to an ohmmeter to measure temperature.

## 3.2 Circuit Diagram

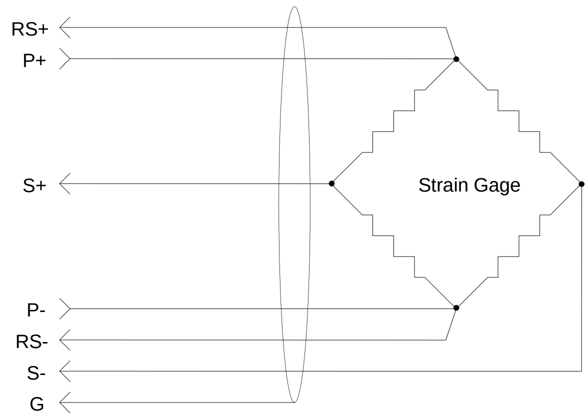


**Figure 2 - Circuit Diagram**

## 3.3 Using the Geokon GK-502 Readout Box

The user is referred to the GK-502 Instruction Manual for additional information on the following instructions:

1. Connect the embedment gage to the readout box by means of the 10 pin input connector.
2. Press the ‘ON/OFF’ button power switch to the "ON" position.
3. Press the ‘UNITS’ button until the UNITS displayed are mV/V.
4. Read the display and record.
5. See the GK-502 Instruction Manual for further instructions.

# 4. DATA REDUCTION

## 4.1 Displacement Calculation

The basic units utilized by Geokon for measurement and reduction of data from Model 3900 Embedment Strain Gages are mV/V

If a GK-502 readout box is in use **mV/V** can be displayed directly.

The displacement **D** is given by the equation

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

**Equation 1 - Displacement**

Where; **D** is the displacement in the units given on the calibration sheet.
$\mathbf{R_0}$ is the initial GK-502 reading in mV/V.
$\mathbf{R_1}$ is the current GK-502 reading in mV/V.
**C** is the calibration factor in **millimeters/mV/V, or inches/mV/V** as supplied on the Cal Sheet (Figure 3).

If a regulated power supply and a millivoltmeter are used, then calculate the mV/V by dividing the displayed millivolt output by the voltage input measured at the sensor using the remote signal leads, (Green and Green’ Black).

## 4.2 Strain Calculation

To calculate the **strain ε,** divide the measured displacement **D** by the gage length **L.**
The standard length for **L** is 203 mm (Eight inches)

**Example:** Using a GK-502, $R_0$ = -0.8640 and $R_1$ = -0.5563, C = 0.05193inches/mV/V.
Strain **ε = ((-0.5563-(-0.8640) x 0.05193/8 = +2000 microstrain (tension)**

**Note that an increasing reading denotes a tensile strain.**

## 4.3 Temperature Correction Factor

Tests have shown that the temperature effect is such that the embedment gage reading goes down (compression) as the temperature goes up and the required temperature correction factor is plus six microstrains per °C.

So, for example, using the GK-502 (displaying mV/V) to take the readings, and a standard eight inch long gage, where **C** is given in inches/mV/V, the calculation for strain **S**, corrected for temperature change **($T_1$ - $T_0$)** measured in degrees Centigrade, is:

$$S = (R_1 - R_0) \times C/8 + 6(T_1 - T_0) \text{ microstrain}$$

**Equation 2 - Stain Calculation with Temperature Correction**

Where **C** is given in mm/mv/v the equivalent equation is

$$\mathbf{S = ((R_1 - R_0) \times C/203 + 6(T_1 - T_0) \text{ microstrain}}$$

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## Resistance Strain Gage

This Calibration has been Verified/ Validated as of: January 24, 2017

Model Number: 3900 Range: 5000 με

Serial Number: 1704760 Temperature: 22.4 °C

Date of Calibration: January 19, 2017

Technician:

| | Displacement (volts) | Displacement (inches) | Gage Reading (mV/V) | Change | Linearity % FS |
|---|---|---|---|---|---|
| **First Cycle** | 0.0000 | 0.00000 | 0.3320 | | -0.09 |
| | 0.4001 | 0.00800 | 0.4830 | 0.1510 | -0.01 |
| | 0.8004 | 0.01601 | 0.6338 | 0.1508 | 0.08 |
| | 1.2004 | 0.02401 | 0.7840 | 0.1503 | 0.09 |
| | 1.6004 | 0.03201 | 0.9338 | 0.1498 | 0.03 |
| | 2.0005 | 0.04001 | 1.0840 | 0.1503 | -0.11 |
| **Second Cycle** | 0.0000 | 0.00000 | 0.3323 | | -0.09 |
| | 0.4002 | 0.00800 | 0.4830 | 0.1508 | -0.01 |
| | 0.8001 | 0.01600 | 0.6343 | 0.1513 | 0.09 |
| | 1.2001 | 0.02400 | 0.7848 | 0.1505 | 0.11 |
| | 1.6005 | 0.03201 | 0.9345 | 0.1498 | 0.02 |
| | 2.0000 | 0.04000 | 1.0828 | 0.1483 | -0.09 |

**Calibration Factor (C): 0.05324 (inches/ mV/ Volt)**

**Function Test at Shipment**

**0.7540 (mV/ V)**

**Temperature: 22.0 °C** **Date: January 24, 2017**

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.



**Figure 3 - Typical Calibration Sheet**

# APPENDIX A. SPECIFICATIONS

## A.1 Model 3900 Embedment Strain Gage Specifications

| | |
|---|---|
| **Standard Range[1]:** | 5000 microstrain |
| **Accuracy:** | ± 0.1% FS |
| **Linearity:** | <0.5% FSR |
| **Resolution:** | ± 0.025% FSR |
| **Repeatability:** | 0.1% FSR |
| **Temperature Effect:** | 0.12% FSR/°C |
| **Temperature Range:** | –20 to +80° C<br>0 to 110° F |
| **Active Gage Length[2]** | 203 mm |
| **Input Resistance:** | 350Ω |
| **Output Resistance:** | 350 Ω |
| **Excitation Voltage:** | 2 to 15 V DC |
| **Maximum Excitation Voltage:** | 30 V |
| **Cable Type:** | Four twisted pair (eight conductor) 22 AWG<br>Foil shield, PVC jacket, nominal OD=9.5 mm (0.375") |

**Table 2 - Specifications**

Notes
[1] Other ranges are available on request.
[2] Other gage lengths available on request.

# APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

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

**Resistance to Temperature Equation:**

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

**Equation 3 - 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 3 - Thermistor Resistance versus Temperature**