GEOKON

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Instruction Manual

Model 4400

V W Embedment Jointmeter

(Doc Rev H, 4/09)

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1. INTRODUCTION

Geokon Model 4400 Vibrating Wire Embedment Jointmeters are intended primarily for the measurement of joint openings between lifts or sections in mass concrete or across fracture zones in fully grouted boreholes.

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. As the connecting rod is pulled out from the gage body, the spring is elongated causing an increase in tension and a resulting change in frequency of the vibrating wire sensing 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 frequency change with the vibrating wire readout box. The unit is fully sealed and operates at pressures of up to 250 psi.

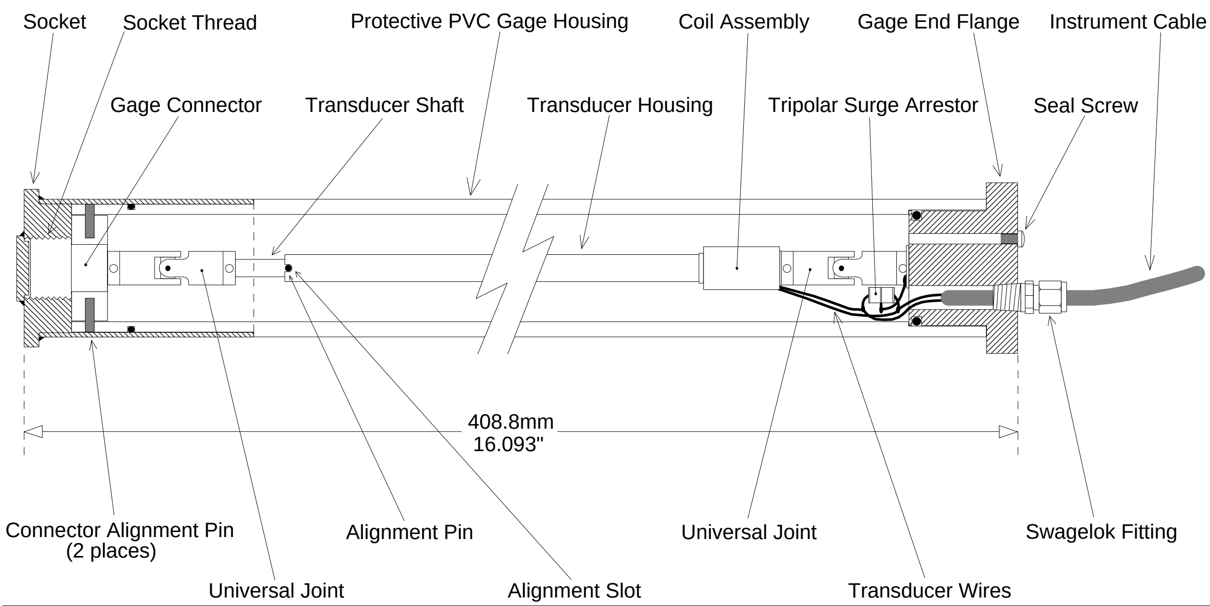

Figure 1 - Model 4400 Vibrating Wire Embedment Jointmeter

In use, a socket is placed in the first lift of concrete and, when the forms are removed, a protective plug is pulled from the socket. The gage is then screwed into the socket, extended slightly and then concreted into the next lift. Any opening of the joint is then measured by the gage which is firmly anchored in each lift. The sensing gage itself, is smaller than the protective housing, and a degree of shearing motion is allowed for by the use of universal ball-joint connections on the gage.

A thermistor is also located inside the vibrating wire transducer housing for the measurement of temperature at the jointmeter location. In addition, a tripolar plasma surge arrestor inside the housing provides protection for the sensor coils from electrical transients such as may be induced by direct or indirect lightning strikes.

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 around 2000 when the threaded connector is pulled out approximately 3 mm (0.125"). **Do not extend the connector more than the range of the gage.** The threaded connector on the end of the gage should not be turned independently of the gage body.

Checks of electrical continuity can also be made using an ohmmeter. Resistance between the gage leads should be approximately 180 Ω, ±10 Ω. 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. Embedment Jointmeter Installation

The installation of the Vibrating Wire Embedment Jointmeter consists of two stages; first, installing the socket and, second, installing the gage.

2.2.1. Installing the Socket

The socket of the gage is meant to be installed in the first lift of concrete. The socket comes with a PVC plug held in place by two O'rings. This plug is designed to keep concrete from entering the inside of the socket and to hold the socket in place while the concrete is poured. After installation the face of the socket must coincide with the finished face of the concrete if it is to be accessible. If the socket plug is removed and needs to be replaced it will be necessary to temporarily remove the socket plug bolt so that the air inside the socket can escape when the plug is forced back into the socket..

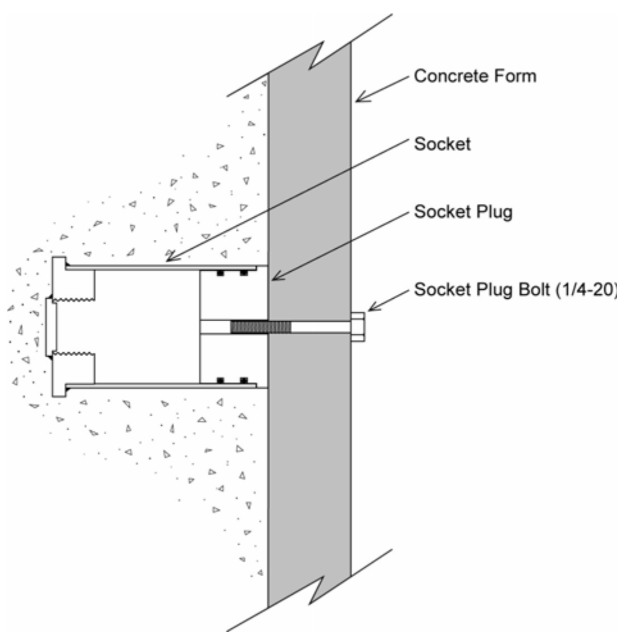

Figure 2 - Socket Installation

The protective socket plug is supplied with a ¼-20 x 1 inch bolt which can be used to bolt the socket to the forms. See Figure 2.

2.2.2. Installing the Jointmeter.

1. After the forms have been stripped and socket exposed, the socket plug should be removed using the socket plug bolt or, if necessary, one of the eyebolt supplied. The bore of the socket is supplied covered with O'lube to facilitate the assembly. Make sure that the inside of the socket is clean and greased before proceeding.

2. Before pushing the jointmeter into the socket, **make sure that the pins in the connector engage the slots in the plastic housing. (See Figure 3). This is very important.**

Figure 3 Showing Pin Engaged in Slot

3. Remove the seal screw from the cable end flange. See Figure 1. This allows air to enter the inside of the jointmeter while it is being adjusted.

4. Push the gage into the socket until it stops. While applying an inward pressure, rotate the gage in a clockwise direction, for approximately 4 revolutions until the connection is snug in the socket thread. Note: If the stiff direct burial cable is being used, the cable bundle or reel should also be rotated to avoid crimping the cable. **Again, it is very important that the pins in the connector are inside the slots of the PVC housing. If the pins are not in the slots and the jointmeter is twisted the jointmeter will be broken**.

5. The next step is to secure the gage body and cable in position for placing concrete. Readings should be taken on the gage (and thermistor) at this time (see Section 3).

2.2.3 Setting the Initial Rreading

2.2.3.1 Models 4400 –25, 4400-50, 4400-100, 4400-150

To allow for slight compression of the gage, it is recommended that the gage be pulled out until a reading of **3000-3500 in position 'B'** is obtained. This will set the gage at approximately 25% of its range in tension. It should be remembered that the gage should not be rotated after pulling it from the socket. After extending the gage, wrap 2-3 layers of electrical tape around the gage tube immediately adjacent to the socket to hold the gage at this reading while the concrete is being placed. If the gage has to be removed from the socket, it **MUST** be pushed back in until the pins catch and then rotated counter-clockwise until it comes loose.

2.2.3.2 Model 4400-12

The above procedure for the longer range models is not recommended for the 4400-12 model. Here the danger of over-ranging the sensor due to the sudden release, when pulling the gage out, is too great. So leave the transducer as is. The natural compression of the gage a will be enough to allow for any small amount of joint closure.

6. **Don't forget to re-install the 10-32 × 3/8" seal screw into the gage end flange**.

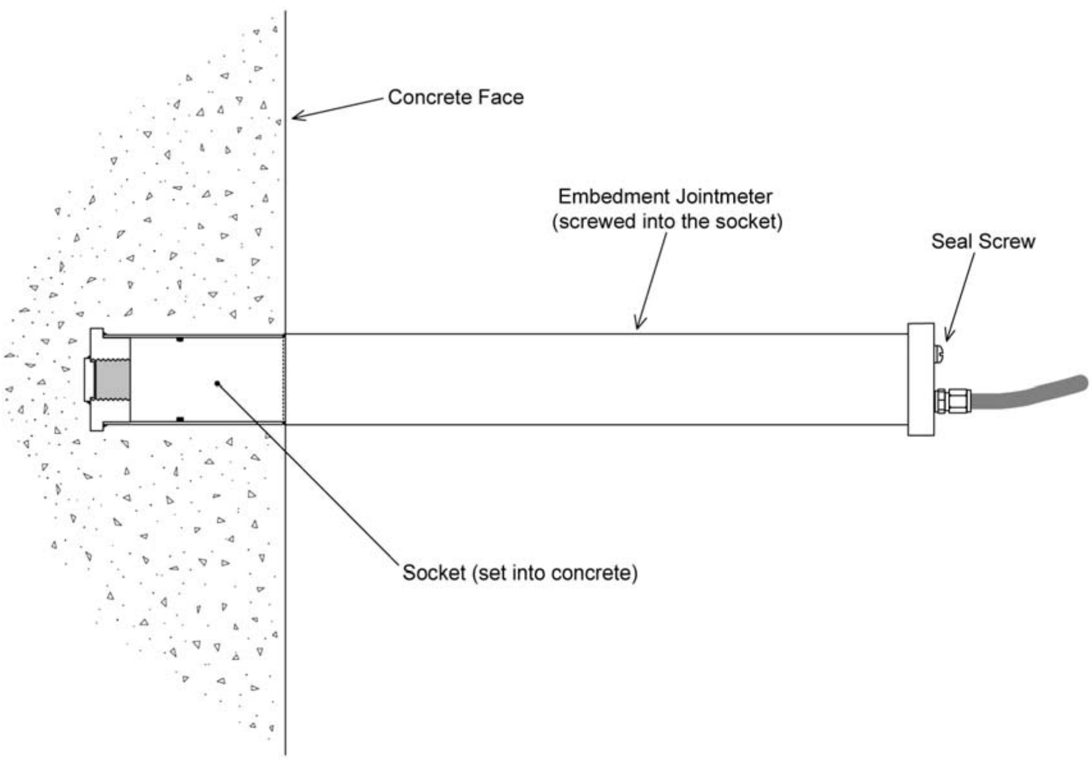

Figure 4 – Completed Embedment Jointmeter Installation

2.3. 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.

2.4. 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.

2.5. Initial Readings

Initial readings must be taken and carefully recorded along with the temperature at the time of installation. Take the initial readings while the gage is in position, just prior to placing the second lift of concrete. Take readings again after the second lift of concrete has cured.

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, ie. inches or millimeters. 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 transducer, 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 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 GK-404 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. Measuring Temperatures

Each Vibrating Wire Embedment Jointmeter 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.

1. Connect an ohmmeter to the two thermistor leads coming from the jointmeter. (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 Jointmeters 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;

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

Equation 1 - Digits Calculation

To convert digits to deformation the following equation applies;

Deformation = (Current Reading - Initial Reading) × Calibration Factor × Conversion Factor
or

$$\mathbf{D = (R_1 - R_0) \times G \times F}$$

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 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 jointmeter with a 12 mm transducer range is 3150 digits. The Current Reading (R_1) is 6000. The Calibration Factor is 0.00356 mm/digit. The deformation change is;

$$D = (6000 - 3150) \times 0.00356 = +10.146 \text{ mm}$$

Note that increasing readings (digits) indicate increasing extension.

4.2. Temperature Correction

The Model 4400 Vibrating Wire Jointmeter 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. The temperature coefficient of the mass in which the Jointmeter is embedded should also be taken into account. By correcting the transducer for temperature changes the deformation of the mass may be distinguished. The following equation applies;

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

Equation 3 - Thermally Corrected Deformation Calculation

Where; R_1 is the Current Reading.
R_0 is the Initial Reading.
G 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 expansion/contraction of the universal joints and flanges, (see figure1).

.

Tests have determined that the Thermal Ceofficient, 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;

Thermal Coefficient = ((Reading in Digits × Multiplier) + Constant) × Calibration Factor

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

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 Jointmeter.

Model:	**4400-6mm 4400-0.25”**	**4400-12 mm 4400-0.5"**	**4400-25 mm 4400-1"**	**4400-50 mm 4400-2"**	**4400-100mm 4400-4”**	**4400-150mm 4400-6”**
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
Length of joints and flanges, (L):	226mm 13.3”	226 mm 13.3"	221 mm 13.1"	162 mm 10.8"	146mm 5.75”	146mm 5.75”

Table 2 - Thermal Coefficient Calculation Constants

The correction for expansion/contraction of the universal joints and flanges, (L_C), is calculated using Equation 5.

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

Equation 5 - Gage Length Correction

Where L is from Table 2 in millimeters or inches, to match the Calibration Factor units.

Consider the following example using a Jointmeter with a 25 mm range transducer.

R_0 = 3150 digits

R_1 = 6000 digits

T_0 = 15.3° C

T_1 = 20.8° C

$G = 0.00356$ mm/digit

$K = ((6000 \times 0.000295) + 0.911) \times 0.00356 = 0.0095$

$L_C = 17.3 \times 10^{-6} \times 221 \times (20.8 - 15.3) = 0.021$

$D = (6000 - 3150) \times 0.00356 = 10.146$ mm

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

$D_{corrected} = ((6000 - 3150) \times 0.00356) + (20.8 - 15.3) \times 0.0095) + 0.021$

$D_{corrected} = (2850 \times 0.00356) + (5.5 \times 0.0095) + 0.021$

$D_{corrected} = 10.146 + 0.052 + 0.021$

$D_{corrected} = +10.219$ mm

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

4.3. Environmental Factors

Since the purpose of the jointmeter 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 Embedment Jointmeters is confined to periodic checks of cable connections and maintenance of terminals. Once installed, the Jointmeters 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: Jointmeter 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 of the Jointmeter positioned outside the specified range 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 out of range.

- ✓ 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.

Symptom: Jointmeter 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, ±10Ω. 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 (<100Ω) 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 Jointmeter? If not the readout or datalogger may be malfunctioning.

APPENDIX A - SPECIFICATIONS

A.1 Model 4400 Embedment Jointmeter

Range:[1]	12 mm 0.50 inches	25 mm 1 inch	50 mm 2 inches
Resolution:	0.025% FSR		
Linearity:	0.25% FSR		
Accuracy:	0.5% FSR (0.1% FSR with a polynomial expression)		
Thermal Zero Shift:	< 0.05% FSR/°C		
Stability:	< 0.2%/yr (under static conditions)		
Overrange:	115%		
Temperature Range:	-40 to +60°C -40 to 120° F		
Frequency Range:	1200 - 2800 Hz		
Coil Resistance:	180 Ω, ±10 Ω		
Cable Type:[2]	2 twisted pair (4 conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250")		
Length: (compressed)	408.8 mm 16.093"		
Maximum Diameter: (flange)	63.5 mm 2.5"		
Tube Diameter:	50.8 mm 2.0"		
Weight:	1.5 kg 3.3 lb.		

Table A-1 Embedment Jointmeter Specifications

Notes:
[1] Consult the factory for other ranges available.
[2] Consult the factory for alternate cable types.

A.2 Thermistor (see Appendix B also)

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 = 1.4051×10^{-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