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Instruction Manual

Model 4422

Monument Crackmeter

(Rev D, 9/15)

Warranty Statement

Geokon, Inc. warrants its products to be free of defects in materials and workmanship, under normal use and service for a period of 13 months from date of purchase. If the unit should malfunction, it must be returned to the factory for evaluation, freight prepaid. Upon examination by Geokon, if the unit is found to be defective, it will be repaired or replaced at no charge. However, the WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion or current, heat, moisture or vibration, improper specification, misapplication, misuse or other operating conditions outside of Geokon's control. Components which wear or which are damaged by misuse are not warranted. This includes fuses and batteries.

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1. INTRODUCTION

Geokon Model 4422 Monument Crackmeters are designed to measure movement across joints and cracks in monuments. The small size is designed to render the crackmeter as unobtrusive as possible.

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 4422-1 Monument Crackmeter

The shaft of the Monument Crackmeter has three small holes drilled in it. A metal pin is supplied for insertion inside one of these holes. These holes and the metal pin are designed to assist the user in selecting the range of the crackmeter so that it can be set to measure mainly tensions, mainly compressions, or both depending on which hole the metal pin is inserted. The maximum range is 4mm.

Approx Mid-Range Reading	Approx Reading to Measure Extensions	Approx Reading to Measure Compression
4500-5000	2500-3000	6500-7000

Crackmeter Reading Ranges

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 the metal pin placed inside the middle of the three holes, (see Figure 2). This holds the instrument in tension in its mid-range position. (This also helps protect it during shipping). Connect the gage to the readout box and take a reading (see section 3). The mid range position should give a reading of about 4500 on Channel B. Gently pull on the ends of the gage and the readings should be stable and in the range of 2000 to 7000 on Channel B. ***CAUTION: Do not rotate the shaft of the Crackmeter, or pull too hard on it. This may cause irreparable damage to the instrument.***

Checks of electrical continuity can also be made using an ohmmeter. Resistance between the gage leads should be approximately 50 ohms, ±5 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

The Monument Crackmeter is provided with threaded rods that can be either grouted in short drill holes or epoxied to the surface. It will normally be found more convenient to fix the cable in place before the crackmeter is attached.

Drill Hole Type

For the standard range crackmeter, (4mm), **two 9mm (3/8 inch) diameter holes 25mm(1 inch) deep should be drilled at a spacing of 110mm (4 3/8 inches).** A drill hole spacer bar is provided to make this easier. Drill one hole then place a slightly smaller drill in the hole and use the spacer bar to locate the second hole.

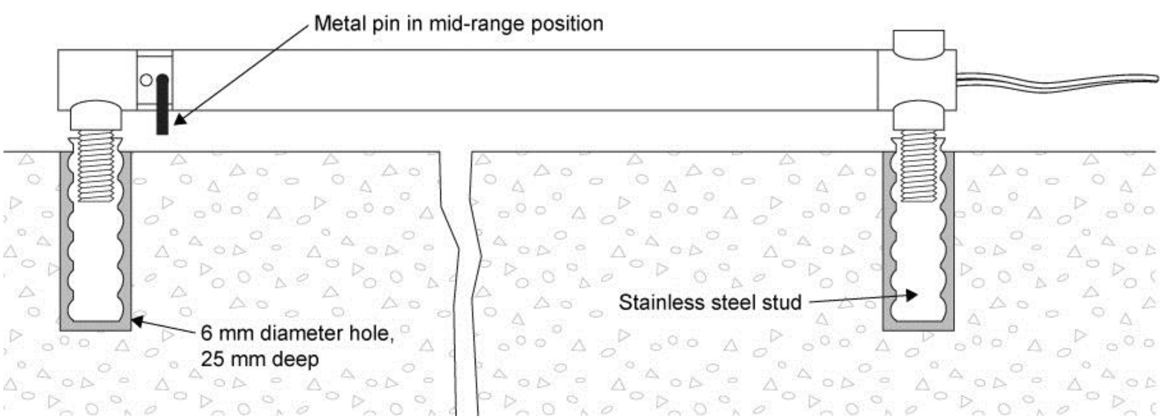

Figure 2: Model 4422-1 Monument Crackmeter, Groutable Anchor Type

Screw the two stainless steel studs onto the threaded rods, fill the drill holes with epoxy or quick setting cement and push the studs into the grout or epoxy with the metal pin holding the crackmeter at the mid range position still in place. When the grout or epoxy has hardened then the metal pin can be removed.

Surface Mounting

For surface mounting two stainless steel feet are supplied that can be screwed on to the threaded rods. Prepare some quick setting epoxy and apply to both the surface of the monument and to the surface of the stainless steel feet. With the metal pin holding the crackmeter inits mid range position still in place, press the feet down on to the monument surface and hold in place until the epoxy sets up. Now remove the metal pin.

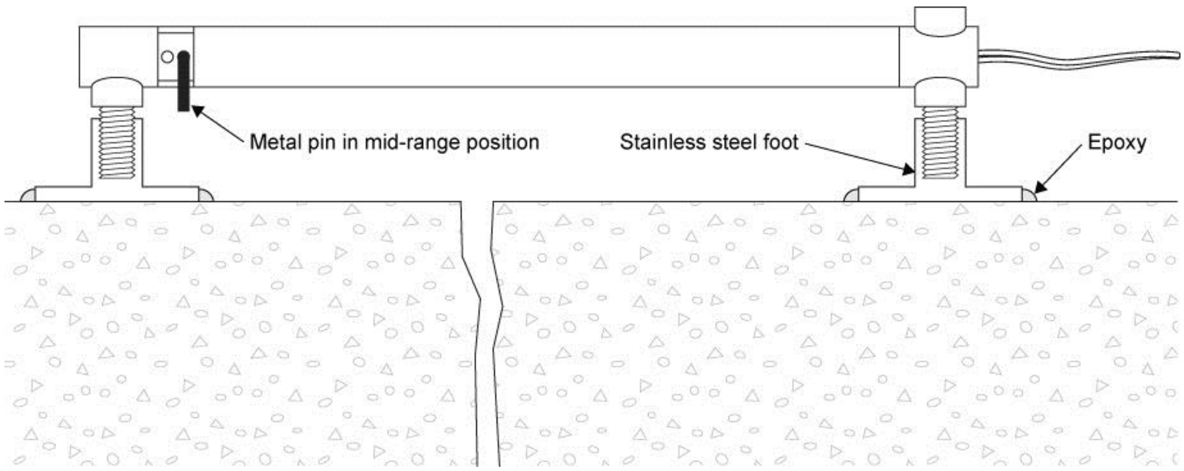

Figure 3: Model 4422-2 Monument Crackmeter, Surface Mounting Type

2.3. Cable Installation

The cable should be routed in such a way so as to minimize the possibility of damage due to traffic or vandalism. It should be held firmly in place by tying off to studs attached to the wall. 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. Lightning Protection

The Model 4422 Monument 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 7. 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.

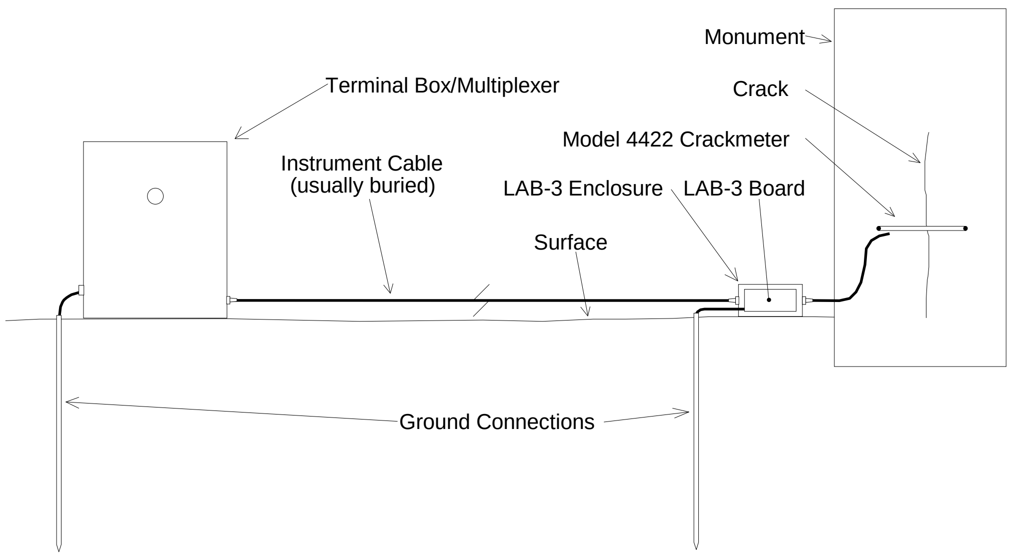

Figure 4 - Lightning Protection Scheme

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 GK405 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 5) or, if more convenient, can be removed and operated up to 20 meters from the Remote Module

Figure 5 GK405 Readout Unit

For further details consult the GK405 Instruction Manual.

3.4. Measuring Temperatures

Each Monument 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. Note: The GK-403, GK-404 and GK-405 readout boxes will read the thermistor and display temperature in °C automatically. If an ohmmeter is used:

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.

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;

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

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 6).
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

Engineering Units Conversion Multipliers

For example, the initial reading R_0, at installation of a crackmeter is 4000 digits. The current reading, R_1, is 5000. The gage factor is 0.001077 mm/digit. The deformation change is;

$$D_{uncorrected} = (5000 - 4000) \times 0.001077 = +1.077mm$$

Note that increasing readings (digits) indicate that the crack is widening.

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: 3 mm

Calibration Date: July 14, 2008

Serial Number: 08-14823

Temperature: 24.1 °C

Calibration Instruction: CI-4400

Technician:

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	2547	2548	2548	-0.01	-0.38	0.00	-0.07
0.6	3119	3120	3120	0.60	0.15	0.60	0.09
1.2	3683	3680	3682	1.21	0.32	1.20	0.08
1.8	4234	4234	4234	1.80	0.15	1.80	-0.08
2.4	4787	4785	4786	2.40	-0.03	2.40	-0.09
3.0	5337	5338	5338	2.99	-0.24	3.00	0.07

(mm) Linear Gage Factor (G): 0.001077 **(mm/ digit)** **Regression Zero:** 2558

Polynomial Gage Factors: **A:** 8.82487E-09 **B:** 0.001007 **C:** -2.625

(inches) Linear Gage Factor (G): 0.00004239 **(inches/ digit)**

Polynomial Gage Factors: **A:** 3.47436E-10 **B:** 0.00003965 **C:** -0.10335

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 : Passed Temp(T_0): 25.8 °C Date: July 15, 2008

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 6 - Typical 4422 Monument Crackmeter Calibration Sheet

4.2. Temperature Correction

The Model 4422 Monument Crackmeter has 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:	4422
Multiplier (M):	0.000471
Constant (B):	0.3562

Table 4 - Thermal Coefficient Calculation Constants

Consider the following example using a Model 4422 Crackmeter;

R_0 = 4773 digits

R_1 = 4589 digits

T_0 = 20.3° C

T_1 = 32.9° C

G = 0.001077 mm/digit

$K = (((4589 \times 0.00073) + 0.583) \times 0.001077) = 0.00424$

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

$D_{corrected} = ((4589 - 4773) \times 0.001077) + (((32.9 - 20.3) \times 0.000424)$

$D_{corrected} = (-184 \times 0.001077) + 0.00534$

$D_{corrected} = -0.198 + 0.00534$

$D_{corrected} = -0.193$ 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 Monument Crackmeter 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 50Ω, ±5Ω. 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 (<10Ω) 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 4422 Crackmeter

Range:	**4 mm** **0.16inches**
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:	-40 to +60°C -40 to 120° F
Frequency Range:	1200 - 2800 Hz
Coil Resistance:	50 Ω, ±5 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)**	120mm (4 ¾ inch"

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