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Instruction Manual

Model 4370

Concrete Stressmeter

(Doc Rev A, 6/08)

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1. INTRODUCTION

The Geokon Model 4370 Concrete Stressmeter is designed to measure stresses in concrete. Conventional ways of doing this suffer from some drawbacks: for instance, strain gages can measure strains but the conversion of strains to stress is made difficult because of changing modulus with time, shrinking and swelling due to varying moisture content, and creep under sustained loads. Most of these problems can be overcome by the use of hydraulic flatjack type stress cells; however, these cells are subject to a strong temperature dependence, which can also cause de-coupling of the cell from the surrounding concrete requiring a means of re- inflating the cells after the initial concrete curing period.

The Model 4370 Concrete Stressmeter is designed to overcome these problems by, in effect, making a stressmeter out of concrete so that it will have the same properties of shrinkage/swelling, modulus variation, temperature dependence, and creep potential, as the surrounding concrete.

2. DESIGN, CONSTRUCTION AND OPERATING PRINCIPLE

The Model 4370 Concrete Stressmeter is shown in figure1.

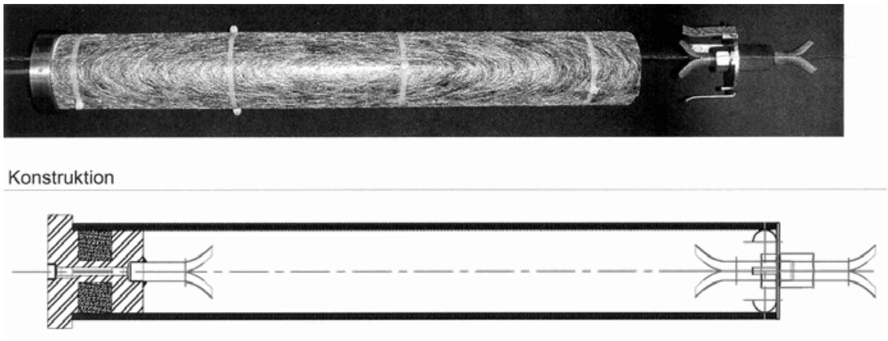


Figure 1 The Model 4370 Concrete Stressmeter.

In essence, the stressmeter comprises a short vibrating wire load cell, in series with a cylinder of concrete. This concrete cylinder has the same properties as the surrounding concrete but is de-bonded from it by means of a smooth-walled, porous plastic tube and is coupled at its ends to the surrounding concrete by means of two flanges equipped with sections of split rebar to provide a better grip. The vibrating wire load cell measures the load imposed on the inner concrete cylinder by stresses in the surrounding concrete. This load, when divided by the cross sectional area of the inner cylinder, gives the stress in the surrounding concrete. Variations of moisture content in the surrounding concrete are felt also by the inner concrete so that shrinkage and swelling are the same both inside and out, leading to no net change in the load cell readout. (This is not strictly true due to the short length of the metal load cell portion, which behaves differently, but the effect is kept small by the large difference in the relative lengths of the concrete cylinder versus the length of the load cell).

A thermistor is included inside the cell for the measurement of temperatures.

3. INSTALLATION

The Stressmeter is first wrapped in A Tyvec type material for additional de-bonding power. The stressmeter is then positioned in line with the direction in which the stress is to be measured and is tied off to the rebar cage or a small size supplemental rebar cage, using iron wire, or nylon tie-wraps. A typical installation is shown in figure 2. Be sure to leave enough slack in the cable so that the stressmeter can be un-tied and positioned vertically for filling.

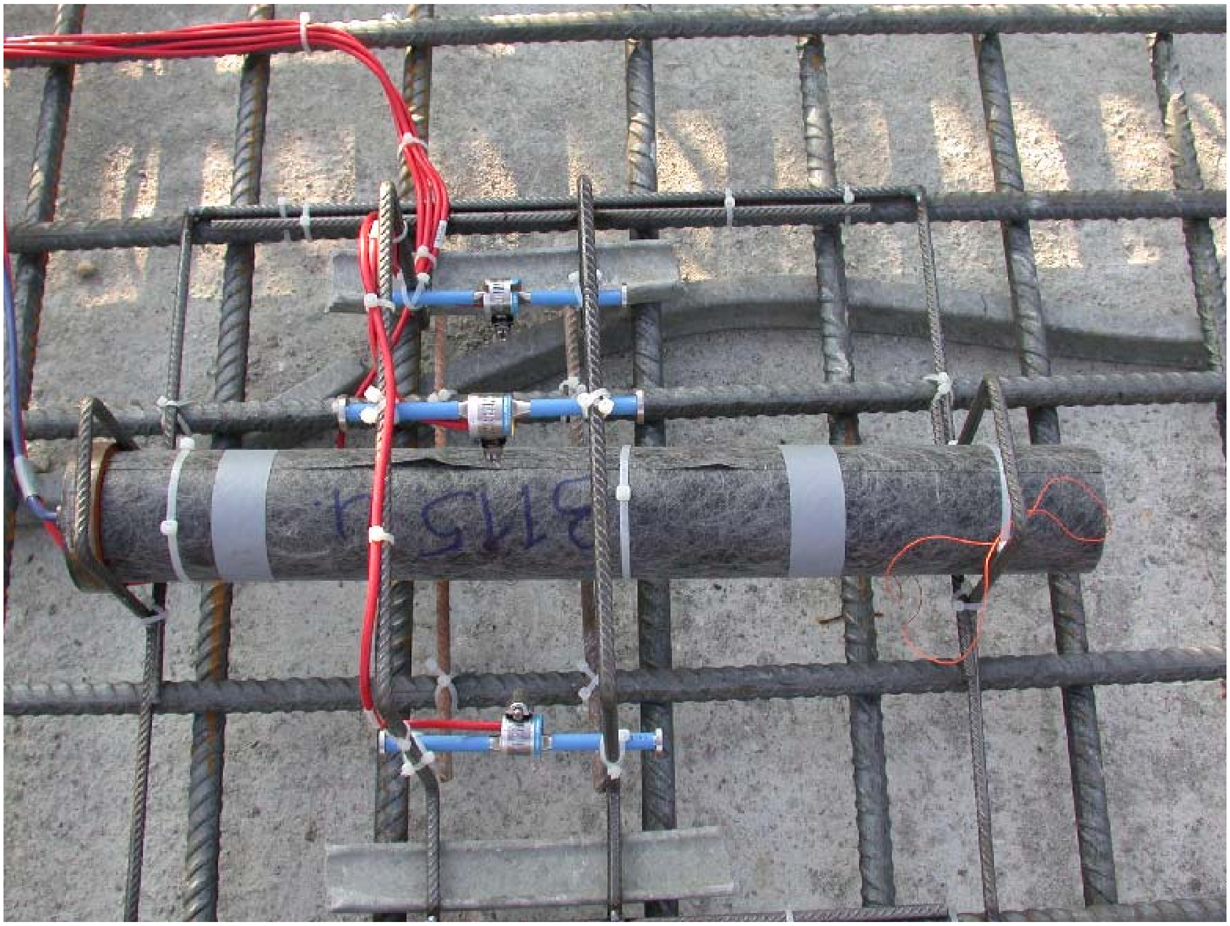


Figure 2. A Model 4370 Stressmeter installed, ready for the concrete pour.

Also shown in the picture are three Model 4200 vibrating wire strain gages. These were installed for experimental purposes to compare the stresses measured by the stressmeter with the strains measured externally.

As the figure 2 shows the far end of the stress meter is left open so that when the concrete is poured around the stressmeter the cell can be untied from the rebar and held vertical so that the same concrete can be packed inside the cell, and then the end flange is pushed inside the end of the tube and securely taped in place. <u>It is of the utmost importance that there be no spaces left inside the cell so the concrete must be very carefully packed, vibrated and rodded to get rid of all traces of air.</u> Another typical installation is shown in figure 3.

Figure 3. Another typical stress meter installation.

Figure 4 shows the Flanged end secured in place as the concrete is poured around the gage

Figure 4. Concrete being poured around the stressmeter

Cables from the stressmeter should be routed carefully so that they are protected from the concrete placement and from traffic.

4. LIGHTNING PROTECTION

The Model 4370 Stressmeter, 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 as the stressmeters are installed within concrete or grout and somewhat isolated from potentially damaging electrical transients. However, there may be occasions where some sort of lightning protection is desirable, for example where the stressmeter is in contact with rebar that may be exposed to direct or indirect lightning strikes. Also, 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 stressmeter and possibly destroy it.

Note the following suggestions:

- If the stressmeter 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 at the exit point of the instrument cable from the structure being monitored. 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 the rebar itself.

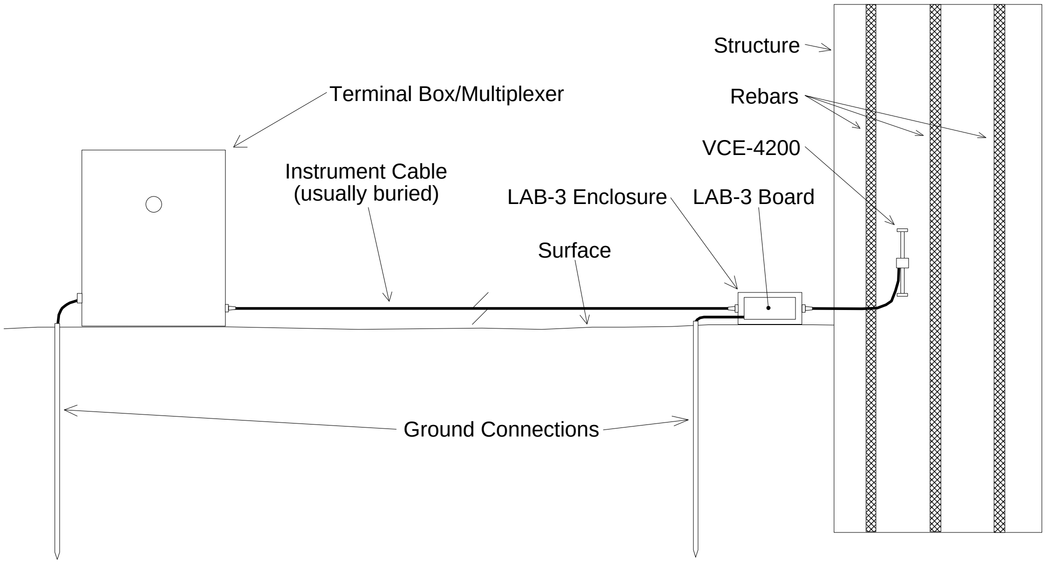


Figure 5 - Lightning Protection Scheme

5. TAKING READINGS

5.1. Operation of the GK-401 Readout Box

The GK-401 is a basic readout for all Vibrating Wire Sensors.
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 green or blue clip for the shield drain wire. The GK-401 cannot read the thermistor. To read temperatures connect an Ohmeter between the green and white wires read the resistance in ohms and then use the Table A1 in Appendix a to convert ohms to degrees Centigrade.

1. Turn on the Readout. Turn the display selector to position "B". Readout is in "digits"
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 5 for troubleshooting suggestions.
3. The unit will automatically turn itself off after approximately 4 minutes to conserve power.

5.2. 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 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.

5.3. Measuring Temperatures

Each Model 4370 Concrete Stressmeter 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 transducer. (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 readout box will read the thermistor and display temperature in °C automatically.

6. DATA REDUCTION

6.1 Stress Calculation

The basic units utilized by Geokon for measurement and reduction of data from Model 4370 Concrete Stressmeters are "digits". Calculation of digits is based on the following equation;

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

To convert digits to concrete stress the following equation applies;

$$\textbf{Concrete Stress} = (R_0 - R_1) \times G / A$$

Where; R_1 is the current reading.

R_0 is the initial reading, usually obtained at installation just before the concrete is poured.

G is the calibration factor, lbs or Kgm per digit. Taken from the calibration chart supplied.

A is the cross sectional area of the Stressmeter. Equal to 5.31sq ins, For example, the initial reading, R_0, at installation of a stressmeter is 7207 digits. The current reading, R_1, is 6050. The calibration factor is 5.384 lbs/digit. The calculated concrete stress is

$$\textbf{Concrete Stress} = (7207 - 6050) \times 5.384/5.31 = 1173 \text{ psi}$$

Note that decreasing readings (digits) indicate increasing compression. A typical Calibration Chart is shown in Figure 6

6.2. Temperature Correction

The Model 4370 Concrete Stressmeter has a coefficient of thermal expansion very similar to the concrete surrounding it so in most cases correction is not necessary.

7. TROUBLESHOOTING

Maintenance and troubleshooting of embedment strain gages are confined to periodic checks of cable connections and maintenance of terminals. Once installed, the gages are usually inaccessible and remedial action is limited.

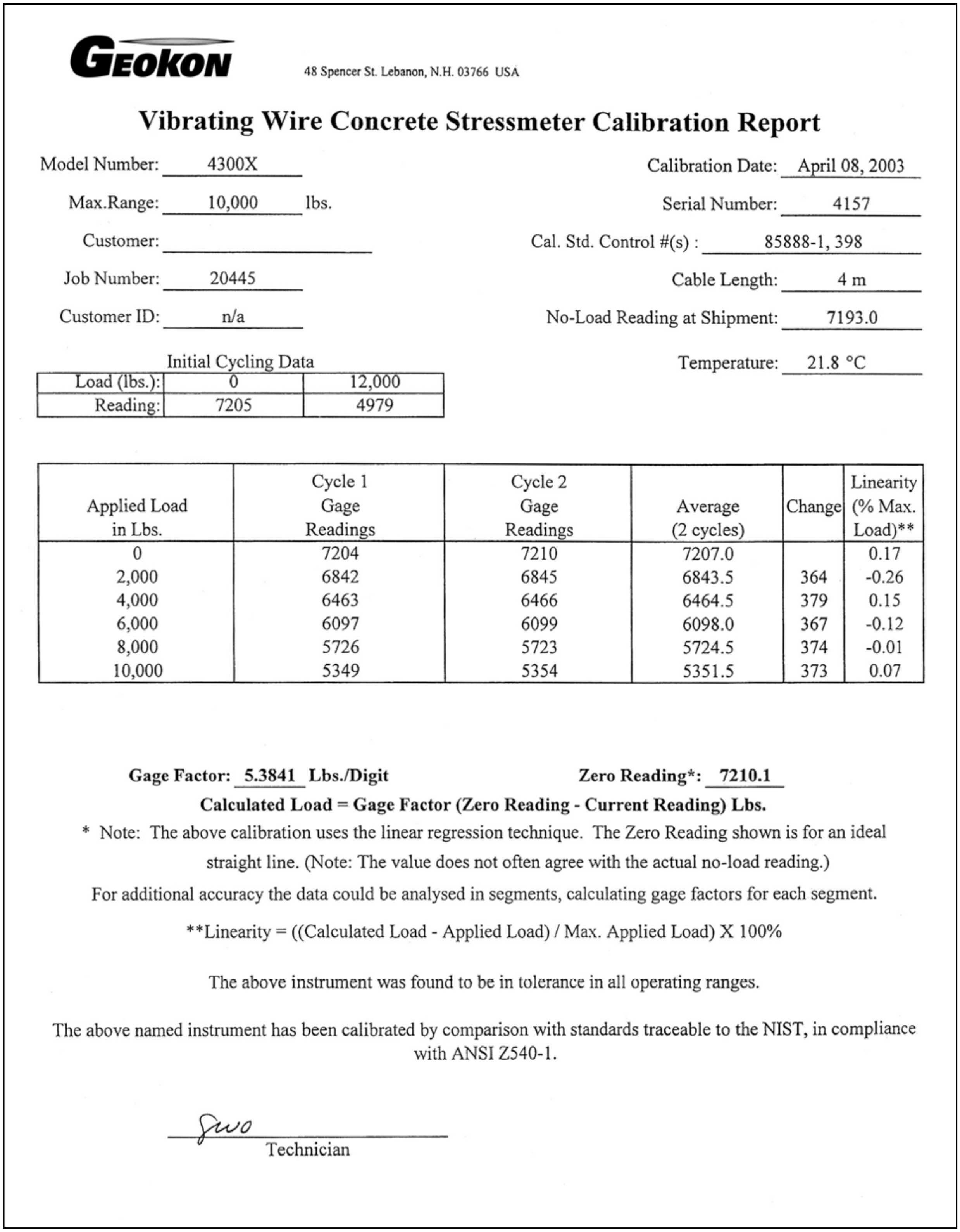
Consult the following list of problems and possible solutions should difficulties arise. Consult the factory for additional troubleshooting help.

Symptom: Strain Gage 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 strain reading outside the specified range (either compressive or tensile) of the instrument?
- ✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators and antennas. Move the equipment away from the installation or install electronic filtering. Make sure the shield drain wire is connected to ground whether using a portable readout or datalogger.
- ✓ Does the readout work with another gage? If not, the readout may have a low battery or be malfunctioning.

Symptom: Strain Gage 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 50Ω, ±10Ω. 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). If the resistance reads infinite, or very high (megohms), 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 strain gage? If not, the readout or datalogger may be malfunctioning.



GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Vibrating Wire Concrete Stressmeter Calibration Report

Model Number: 4300X

Max.Range: 10,000 lbs.

Customer:

Job Number: 20445

Customer ID: n/a

Calibration Date: April 08, 2003

Serial Number: 4157

Cal. Std. Control #(s) : 85888-1, 398

Cable Length: 4 m

No-Load Reading at Shipment: 7193.0

Temperature: 21.8 °C

Initial Cycling Data

Load (lbs.):	0	12,000
Reading:	7205	4979

Applied Load in Lbs.	Cycle 1 Gage Readings	Cycle 2 Gage Readings	Average (2 cycles)	Change	Linearity (% Max. Load)**
0	7204	7210	7207.0		0.17
2,000	6842	6845	6843.5	364	-0.26
4,000	6463	6466	6464.5	379	0.15
6,000	6097	6099	6098.0	367	-0.12
8,000	5726	5723	5724.5	374	-0.01
10,000	5349	5354	5351.5	373	0.07

Gage Factor: 5.3841 Lbs./Digit **Zero Reading*: 7210.1**

Calculated Load = Gage Factor (Zero Reading - Current Reading) Lbs.

* Note: The above calibration uses the linear regression technique. The Zero Reading shown is for an ideal straight line. (Note: The value does not often agree with the actual no-load reading.)

For additional accuracy the data could be analysed in segments, calculating gage factors for each segment.

**Linearity = ((Calculated Load - Applied Load) / Max. Applied Load) X 100%

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.

Technician

Figure 6 A Typical Calibration Chart

APPENDIX A - 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 C-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 A-1 Thermistor Resistance versus Temperature