INSTRUCTION MANUAL

SPOT WELDABLE VIBRATING WIRE STRAIN GAUGE

Model SM-2W

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1 PRODUCT

1.1 INTRODUCTION

The SM-2W weldable vibrating wire strain gauge is designed to measure strain and allows calculation of stress when deformation modulus is known.

It can be installed by a technician without the assistance of a skilled welder. The SM-2W gauge construction is unique amongst vibrating wire strain gauges in that the wire tension in the installed gauge is largely balanced by the compression in a spring built into the gauge and, thus, the forces on the welded flanges are minimal. The gauge is intended for long-term, precise strain measurements in situations where the SM-A/SM-B gauges are impractical because of their greater bulk; for example, for measurements on rebar, bolts and pipe work. The SM-2W can be used in any other circumstance where problems could be encountered with the need for electric arc welding associated with SM-A/SM-B strain gauges.

1.2 DESCRIPTION

The SM-2W is a spot weldable gauge. As shown in Figure 1, the gauge essentially consists of two end blocks between which a length of high tensile steel wire is clamped. The wire is protected by a stainless steel tube engaging the end blocks and sealed against dust and moisture by o-rings. A small stainless steel compression spring mounted on the tube presses against one of the end blocks and holds the wire under tension. The initial wire tension is set by adjusting the position of a gripping-type retaining ring which is mounted on the tube and determines the amount of spring compression. Stainless steel flanges are welded to each end block. The flanges are used to spot-weld the gauge in place.

The electromagnet housing, or cover, used to pluck the wire and measure wire vibrations, also acts as a mechanical protection for the gauge. It fits over the gauge and is kept in position by spot welding the two flanged u-shaped brackets to the structure surface. The bracket is held in place by the two parallel bosses on the cover. A thermistor cast into the electromagnet housing is a standard feature of the SM-2W gauge.

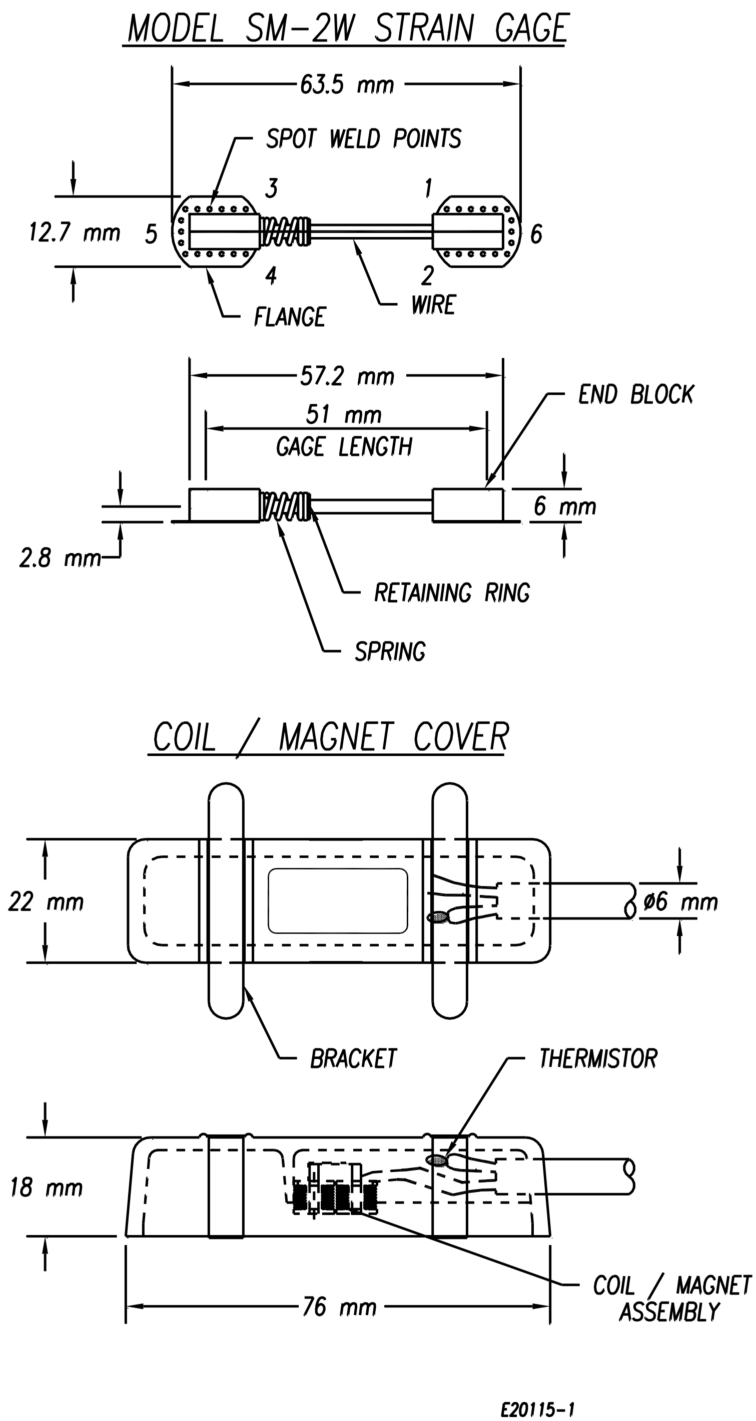

Figure 1 SM-2W schematic diagram and dimensions

1.3 STRAIN RANGE

The nominal strain range of the SM-2W vibrating wire strain gauge is 3000 microstrains. Unless specified otherwise when ordering, SM-2W strain gauges are normally supplied with the wire tension set near the mid-range point, providing a range of 1500 μstrains in compression and in tension. The mid-range reading taken with the readout unit is about 400 μsec.

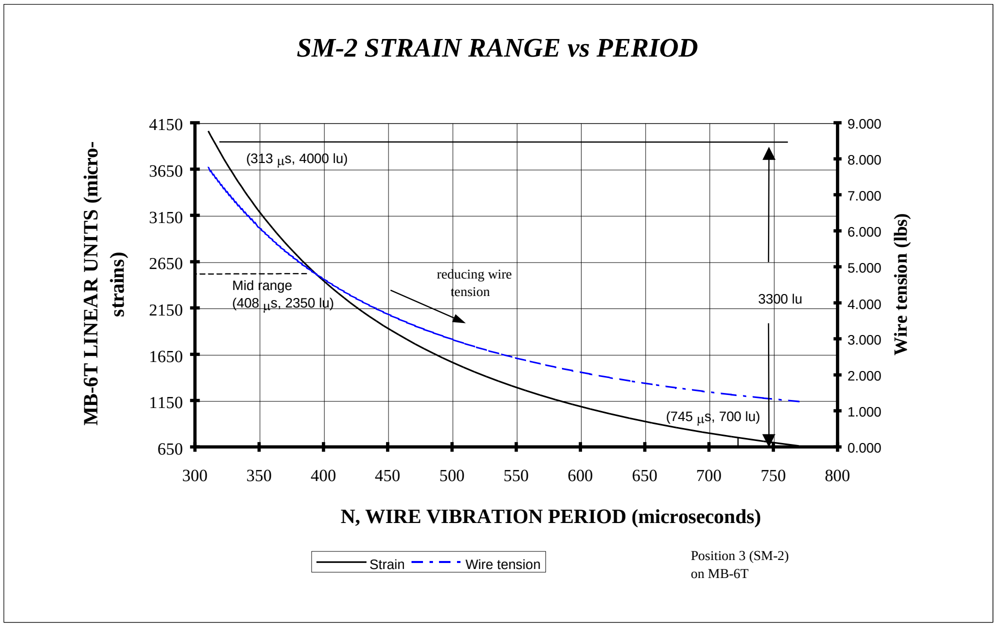

Figure 2 Graph of the SM-2 strain range vs. period

2 INSTALLATION

The SM-2W is designed to be installed onto steel structures, especially on flat surfaces. However, it can also be used on curved surfaces provided that the circular plane is normal to the gauge axis.

2.1 CHANGING THE INITIAL WIRE TENSION

It is recommended that adjustments be made to the initial wire tension **only when they are absolutely necessary**. The initial wire tension is adjusted by changing the position of the retaining ring, and thus the spring compression, and this requires the use of a small vice and a set of retaining ring pliers.

Note: It is very important not to overstrain the retaining ring when moving it; otherwise, the set reading cannot be held.

The pliers normally supplied for this purpose are permanently set to limit their expansion, so the retaining ring cannot be accidentally overstrained. The outside dimension across the plier's tips, when actuated, should not exceed 2.67 mm ± 0.13 mm.

If only compressive strains are anticipated, the initial reading should be adjusted by further compressing the spring to around 350.0 μsec. Similarly, if only tensile strains are anticipated, the initial reading should be set to around 700.0 μsec. Refer to Figure 2 for the strain range *vs.* period graph.

To make adjustments, clamp the end of the gauge nearest to the spring in the jaws of a small vice with the uppermost foil to prevent damage (see Figure 3). Increase the spring compression (to increase the compressive strain range), by opening the retaining ring slightly using the special pliers provided for this purpose, and forcing the retaining ring against the end block. A force of roughly 4.5 kg is required to move the retaining ring without opening it, and 2 kg when the retaining ring is sprung slightly.

Decrease the spring compression (to increase the tensile strain range), by opening the retaining ring slightly using the pliers and allowing it to move away from the end block.

Warning: Do not overstrain the retaining ring while opening it, otherwise it will not grip the tube and hold spring compression. Should this accidentally occur, squeeze the end tabs of the retaining ring together with an ordinary pair of pliers. Do not set the initial gauge readings outside the recommended range.

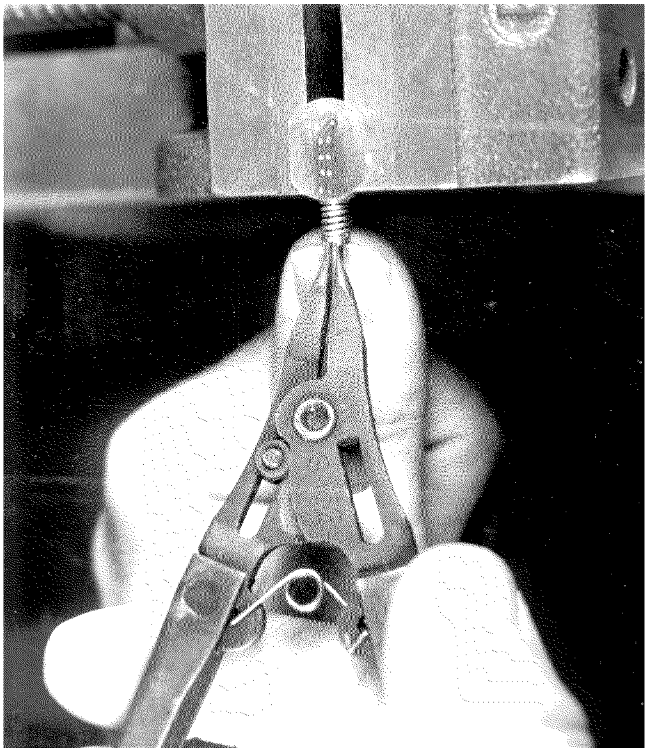

Figure 3 Photograph showing wire tension change

2.2 SURFACE PREPARATION

For efficient welds, the surface to which the gauge is to be spot-welded must be free of grease, rust, scale oxides and surface irregularities.

Steps for cleaning the surfaces are:

(1) Clean the metal surface with an appropriate solvent such as trichloroethylene.

(2) Using a fine file or silicone carbide paper, remove rust and scale oxide to leave smooth bright surfaces where the end flanges are to be welded.

(3) Thoroughly wash off dusts using the solvent.

(4) Surface, if ground or filed, should be as flat as possible.

2.3 GAUGE SPOT WELDING PROCEDURES

Before actually attempting to install the SM-2W gauge for the first time, it is advisable to first practice. Follow the instructions supplied with the welding set, make one spot-weld and then pull the extra metal strip from the test surface; a small slug of metal should be pulled out of the test strip for a correct weld. On the spot-welder, the weld energy should be set to approximately 25 for most applications.

Common welding problems include:

(a) Sputtering of the metal around the spot weld: this is due to excessive weld energy or electrode force.

(b) Weak weld; test strip pulls off without tearing out a slug: this is due to insufficient weld energy or electrode pressure.

(c) Sparking; this is usually due to insufficient electrode force, a dirty welding electrode or high contact resistance between the gauge flange and metal surface (poor surface preparation).

In all cases, it is essential to have a good electrical connection through the welding electrode to the welder "common" cable.

Gauge setting procedures are as follows:

(a) Align the SM-2W gauge on the metal surface: 1) checking that the gauge flanges sit flat on the surface, and 2) using the setting jig (see FIGURE 4) to hold the gauge in aligned position. Read the gauge to make sure it is functioning properly. Next, tack it down with four spot welds at the four inside corner points marked on the flange and numbered 1, 2, 3 and 4 in Figure 1. Complete the initial welding stage by welding at the end of each flange, points 5 and 6 in Figure 1.

(b) Continue to spot weld at the marked positions to complete the installation. Roughly fifteen (15) spot welds are recommended for each flange.

(c) Use the template to mark four corners for positioning the SM-2W gauge cover. Check that the electromagnet housing face is free of dirt or chips. The coil magnet tends to pick up magnet chips. **Cleaning of the magnet face is essential.** Position the plucking coil assembly over the gauge and make an initial reading. Hold the assembly firmly while taking the reading. If care has been taken during installation, the reading should be within ± 200 μstrains of the pre-installation reading on the MB-3T readout unit.

(d) Tack weld the plucking coil housing over the gauge using the four metal tags protruding from the sides, first taking care that the housing is not touching the gauge. For extra protection against corrosion, the weld points can be covered by a soft curing elastomer such as Dow Corning Silicone Rubber Sealant No. 732 prior to welding the plucking coil housing in place.

Figure 4 Photograph showing gauge installation

2.4 MOUNTING THE SM-2W ON CYLINDRICAL SURFACES

Mount the SM-2W gauge in the usual procedure as described above. Use the hose clamps to mount the SM-2W electromagnet on a round object.

Locate the electromagnet over the gauge and take a reading to ensure the placement accuracy. Loosen the two hose clamps completely and place one at either end, approximately over the mounting tabs. Tighten the hose clamps but do not overtighten, as the electromagnet may be damaged.

If these gauges are to be covered with grout, a bead of silicone should be placed around the bottom of the electromagnet to protect the gauge from ingress of grout.

2.5 CORROSION PROTECTION

With the gage now installed, it is imperative that the gage weld point be protected from corrosion. The gage itself will not corrode since it is made of stainless steel but the substrate can corrode, especially at the weld points, unless they are covered by water-proofing layer. The recommended procedure is as follow:

1. Apply several drops of cyano-acrylate adhesive to the edge of all the spot-welded mounting tabs. The glue will wick into the gap between the mounting tabs and the substrate and provide the first line of defense.

2. Mask off the areas where the spot welds will be required to hold the plucking coil housing of the Model SM-2W.

3. Spray a coat of Self Etching Primer, (available at any auto-parts store), over the mounting tab areas and all exposed bare metal areas. Again, the idea is to protect the substrate weld points, so be careful to get complete coverage of the mounting tab edges, paying particular attention to the point where the tab is under the gage tube. Don't worry if the primer coats the gage.

3 DATA READING AND ANALYSIS (WITH MB-3T)

3.1 GENERALITIES

Readings can be taken manually with a portable readout unit model MB-3TL or automatically when connected to a SENSLOG data acquisition system.

A 3kΩ thermistor (temperature sensor) is integrated to the sensor. Temperature can then be read using a MB-3TL, a SENSLOG data acquisition system or an ohmmeter as well.

Manual readings can be taken either directly on the cable end or through a switching panel using a readout unit.

To facilitate reading a cluster of gages, the lead wires from each individual gage can be connected to a switching panel. The wiring instructions for connecting the gages to the wiring block with the junction box are included in the junction/switchbox manual.

3.2 TAKING MEASUREMENTS

The readout unit MB-3TL with the four-pin, male, panel-mounted electrical connector is supplied with one multi-core cable fitted with a mating female connector at one end and a set of four color coded alligator clips at the other. The conductor's insulation is color coded to match that of the alligator clips and the instrument cable conductors' insulation jacket. Connect the alligator clips to the gage lead wire according to the table below.

	Connections				
Cable	Wire High	Wire Low	Temp. High	Temp. Low / Shield	
IRC-41A(P)	red	black	white	green	shield

Table 1: Wiring code for electrical cables

Vibrating wire gages and thermistors are not usually affected by polarity changes (High and Low reversal). However, if problems occur during gage readings, check the polarity.

Switch on the MB-3TL and press Enter.

At the Type prompt, choose the appropriate frequency and temperature settings. Press Change to display a different combination. Press Enter to select the option that is displayed.

Select Type: VWSG: uStrain + THRM for spotweld SM-2

The MB-3TL displays readings converted into microstrains (equivalent to Linear Units or L) and Celsius degrees for 3 kohms thermistor.

Choose frequency sweep B or C.

Record these numbers as they appear on the display.

Please consult the MB-3TL instruction manual for more details. The jumper cables should never be short-circuited when they are connected to the readout unit front panel.

3.3 READING CONVERSION

Conversion from gross readings (Hz or microseconds) to L is done with the following formulae:

$$L = \frac{K \times F^2}{1000}$$

Where L = Linear units (LU)

K = Gage factor (0.3911)

F = Frequency (Hertz)

$$F = \frac{10^6}{N}$$

Where F = Frequency (Hertz)

N = Normal reading (micro seconds)

To determine the strain change in the instrumented structure from linear reading, the following equation is applied:

$$\Delta\varepsilon = (L_1 - L_0)$$

where $\Delta\varepsilon$ = Strain change in microstrains in the structure.

L_0 = Initial reading in the MB-3TL linear units

L_1 = Current reading in the MB-3TL linear units

Example:

L_0 = 2200 linear units

L_1 = 1650 linear units

$\Delta\varepsilon$ = (1650 - 2200)

$\Delta\varepsilon$ = - 550 microstrains (compression)

4 MISCELLANEOUS

4.1 PRESSURE VESSELS AND PIPE LINES

When adequately supported, pressure vessels are partially strained by internal pressures with the strain being always tensile in nature. In cases where the wall thickness is small compared to the vessel dimensions, the strain can usually be assumed to be uniformly distributed throughout the cross sections. In these cases, a vibrating wire gauge which normally stands above the structural surface (by roughly 2.5 mm with the SM-2W gauge), can safely be assumed to be measuring the actual structure strain change and correction for bending strains are not required.

4.2 CONVERSION FACTORS

	To Convert From	To	Multiply By
LENGTH	Microns	Inches	3.94E-05
	Millimeters	Inches	0.0394
	Meters	Feet	3.2808
AREA	Square millimeters	Square inches	0.0016
	Square meters	Square feet	10.7643
VOLUME	Cubic centimeters	Cubic inches	0.06101
	Cubic meters	Cubic feet	35.3357
	Liters	U.S. gallon	0.26420
	Liters	Can–Br gallon	0.21997
MASS	Kilograms	Pounds	2.20459
	Kilograms	Short tons	0.00110
	Kilograms	Long tons	0.00098
FORCE	Newtons	Pounds-force	0.22482
	Newtons	Kilograms-force	0.10197
	Newtons	Kips	0.00023
PRESSURE AND STRESS	Kilopascals	Psi	0.14503
	Bars	Psi	14.4928
	Inches head of water*	Psi	0.03606
	Inches head of Hg	Psi	0.49116
	Pascal	Newton / square meter	1
	Kilopascals	Atmospheres	0.00987
	Kilopascals	Bars	0.01
	Kilopascals	Meters head of water*	0.10199
TEMPERATURE	Temp. in °F = (1.8 x Temp. in °C) + 32 Temp. in °C = (Temp. in °F – 32) / 1.8		

* at 4 °C

E6TabConv-990505

Table 2 Conversion Factors

4.3 THERMISTOR: TEMPERATURE READING

Temp. °C	Reading in Ohms			Temp. °C	Reading in Ohms		
	With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor		With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor
-50		201100	670500	1	6208	9310	31030
-49		187300	670500	2	5900	8851	29500
-48		174500	624300	3	5612	8417	28060
-47		162700	581700	4	5336	8006	26690
-46		151700	542200	5	5080	7618	25400
-45		141600	440800	6	4836	7252	24170
-44		132200	472000	7	4604	6905	23020
-43		123500	411700	8	4384	6576	21920
-42		115400	384800	9	4176	6265	20880
-41		107900	359800	10	3980	5971	19900
-40	67320	101000	336500	11	3794	5692	18970
-39	63000	94480	315000	12	3618	5427	18090
-38	59000	88460	294900	13	3452	5177	17260
-37	55280	82870	276200	14	3292	4939	16470
-36	51800	77660	258900	15	3142	4714	15710
-35	48560	72810	242700	16	3000	4500	15000
-34	45560	68300	227700	17	2864	4297	14330
-33	42760	64090	213600	18	2736	4105	13680
-32	40120	60170	200600	19	2614	3922	13070
-31	37680	56510	188400	20	2498	3748	12500
-30	35400	53100	177000	21	2388	3583	11940
-29	33280	49910	166400	22	2284	3426	11420
-28	31300	46940	156500	23	2184	3277	10920
-27	29440	44160	147200	24	2090	3135	10450
-26	27700	41560	138500	25	2000	3000	10000
-25	26080	39130	130500	26	1915	2872	9574
-24	24580	36860	122900	27	1833	2750	9165
-23	23160	34730	115800	28	1756	2633	8779
-22	21820	32740	109100	29	1682	2523	8410
-21	20580	30870	102900	30	1612	2417	8060
-20	19424	29130	97110	31	1544	2317	7722
-19	18332	27490	91650	32	1481	2221	7402
-18	17308	25950	86500	33	1420	2130	7100
-17	16344	24510	81710	34	1362	2042	6807
-16	15444	23160	77220	35	1306	1959	6532
-15	14596	21890	72960	36	1254	1880	6270
-14	13800	20700	69010	37	1203	1805	6017
-13	13052	19580	65280	38	1155	1733	5777
-12	12352	18520	61770	39	1109	1664	5546
-11	11692	17530	58440	40	1065	1598	5329
-10	11068	16600	55330	41	1024	1535	5116
-9	10484	15720	52440	42	984	1475	4916
-8	9932	14900	49690	43	945	1418	4725
-7	9416	14120	47070	44	909	1363	4543
-6	8928	13390	44630	45	874	1310	4369
-5	8468	12700	42340	46	840	1260	4202
-4	8032	12050	40170	47	808	1212	4042
-3	7624	11440	38130	48	778	1167	3889
-2	7240	10860	36190	49	748	1123	3743
-1	6876	10310	34370	50	720	1081	3603
0	6532	9796	32660	51	694	1040	3469

TABLE 3: Conversion Table (Continued)

Temp. °C	Reading in Ohms			Temp. °C	Reading in Ohms		
	With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor		With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor
52	668	1002	3340	102	128	192.2	640.3
53	643	965.0	3217	103	125	186.8	622.1
54	620	929.6	3099	104	121	181.5	604.4
55	597	895.8	2986	105	118	176.4	587.5
56	576	863.3	2878	106	114	171.4	571.0
57	555	832.2	2774	107	111	166.7	555.1
58	535	802.3	2675	108	108	162.0	540.0
59	516	773.7	2580	109	105	157.6	524.9
60	498	746.3	2488	110	102	153.2	510.7
61	480	719.9	2400	111	99	149.0	496.4
62	463	694.7	2316	112	97	145.0	483.1
63	447	670.4	2235	113	94	141.1	469.8
64	432	647.1	2157	114	91	137.2	457.4
65	416	624.7	2083	115	89	133.6	444.9
66	402	603.3	2011	116	87	130.0	433.4
67	388	582.6	1942	117	84	126.5	421.8
68	375	562.8	1876	118	82	123.2	410.7
69	363	543.7	1813	119	80	119.9	399.6
70	350	525.4	1752	120	78	116.8	389.4
71	339	507.8	1693	121	76	113.8	379.2
72	327	490.9	1636	122	74	110.8	369.4
73	316	474.7	1582	123	72	107.9	360.1
74	306	459.0	1530	124	70	105.2	350.8
75	296	444.0	1479	125	68	102.5	341.9
76	286	429.5	1431	126	67	99.9	333.0
77	277	415.6	1385	127	65	97.3	324.6
78	268	402.2	1340	128	63	94.9	316.6
79	260	389.3	1297	129	62	92.5	308.6
80	251	376.9	1255	130	60	90.2	301.1
81	243	364.9	1215	131	59	87.9	293.5
82	236	353.4	1177	132	57	85.7	286.0
83	228	342.2	1140	133	56	83.6	279.3
84	221	331.5	1104	134	54	81.6	272.2
85	214	321.2	1070	135	53	79.6	265.5
86	208	311.3	1036	136	52	77.6	259.3
87	201	301.7	1004	137	51	75.8	253.1
88	195	292.4	973.8	138	49	73.9	246.9
89	189	283.5	944.1	139	48	72.2	241.1
90	183	274.9	915.2	140	47	70.4	235.3
91	178	266.6	887.7	141	46	68.8	229.6
92	172	258.6	861.0	142	45	67.1	224.2
93	167	250.9	835.3	143	44	65.5	218.9
94	162	243.4	810.4	144	43	64.0	214.0
95	157	236.2	786.4	145	42	62.5	208.7
96	153	229.3	763.3	146	41	61.1	203.8
97	148	222.6	741.1	147	40	59.6	199.4
98	144	216.1	719.4	148	39	58.3	194.5
99	140	209.8	698.5	149	38	56.8	190.1
100	136	203.8	678.5	150	37	55.6	185.9
101	132	197.9	659.0				

Table 3 Thermistor temperature derivation