INSTRUCTION MANUAL

TEMPERATURE SENSOR

Model TH-T

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1 APPLICATIONS

The model TH-T temperature sensor unit is a rugged sealed thermistor device for long-term temperature monitoring of any location primarily in conjunction with other geotechnical equipment.

2 PRODUCT

2.1 GENERAL DESCRIPTION

The external housing is made of an extruded stainless steel shellbuilt to withstand long-term use without corrosion. It encapsulates a highly sensitive and reliable thermistor.

The two leads of the thermistor are soldered to the sensor cable lead wires. In order to prevent moisture, the whole assembly is potted with a high-density epoxy, specially selected for improved thermal conductivity and increased resistance to impact and thermal shocks.

The unit is read directly in degrees Celsius or Fahrenheit with the MB-6T(L) portable readout unit. An ohmmeter in conjunction with the conversion table at the end of this manual can also be used to determine sensor temperature.

Figure 1: TH-T temperature sensor

2.2 OPERATION PRINCIPLE

The heart of the TH-T is a miniature thermistor. Temperature changes affect the resistance of the device, following a law described later in the manual.

Note: The standard thermistor used in the TH-T sensor is a 3 kΩ thermistor.

3 READING PROCEDURE

Different readout procedures can be used to get the temperature from the sensor resistance.

3.1 MB-6T READOUT UNIT

The MB-6T(L) readout unit reads the thermistor integrated in the gage, then converts the resistance value into temperature and displays the temperature in °C and °F.

Connect the jumper cable into the sockets on the front panel of the MB-6T(L). Connect the alligator clips on the jumper cable to the TH-T cable as follows:

	Connections		
Cable	Temp. High (white)	Temp. Low (green)	Shield (blue)
IRC-41A(P)	white	green	shield

Table 1: Wiring code for TH-T gage

Connect the shield socket on the MB-6T(L) front to the cable shield using the single lead jumper cable.

The jumper cable should never be short-circuited when it is connected to the readout unit front panel.

Depending of the type of thermistor used in the gage, switch the thermistor selector on the MB-6T(L) to the correct position, using the following table. Otherwise, position the selector on D and record the resistance value. The latter is to be converted subsequently, using conversion tables or polynomial equation appropriate to the thermistor type.

Selector position	Function
A	2 kΩ thermistor
B	3 kΩ thermistor
C	10 kΩ thermistor
D	Ohmmeter mode

Table 2: Thermistor type or function vs. Selector position

For complete details about the MB-6T(L) readout, please refer to its instruction manual.

3.2 OHMMETER

An ohmmeter may also be used to monitor the TH-T gage. Zero the ohmmeter by connecting together its two connecting wires.

Measure the resistance between the green and white wires of the gage. Convert the reading in ohms to temperature using conversion tables or polynomial equation appropriate to the thermistor type.

3.3 SENSLOG DATA ACQUISITION SYSTEM

The TH-T can also be read using a SENSLOG data acquisition system. The latter reads a V_{out} output, then converts it in ohms according to the following relation:

$$R_T = R_{25} \cdot \left(\frac{A}{V_{out}} - B \right)$$

where R_T = resistance in ohms

R_{25} = resistance in ohms at 25°C depending of the type of thermistor used (2 000, 3 000 or 10 000 Ω)

A, B = conversion factors depending on the type of thermistor

V_{out} = voltage output in volts

	Thermistor type		
	2 kΩ	**3 kΩ**	**10 kΩ**
A	6.25	4.17	1.25
B	3.0	2.0	0.6

Table 3: Conversion factors vs. Thermistor types

Example:

With V_{out} = 1.00 V

R_{25} = 3 000 Ω (3 kΩ thermistor)

We get $R_T = 3000 \cdot \left(\frac{4.17}{1.00} - 2.0 \right) = 6\,510\ \Omega$

3.4 QUICK VERIFICATION OF MEASUREMENTS

On site, even before converting raw readings into engineering values, several checks can be done to prevent a bad measurement.

- Compare readings to previous ones. Are they in the same range? Are they changing slowly or abruptly? Consider external factors that can affect the measurements like construction activities, excavations or fills…

- In any case, it is advised to take several readings to confirm the measurement. Then, repeatability can be appreciated and dummy readings erased.

4 CONVERSION OF RESISTANCE READINGS

A temperature reading is obtained from a resistance reading using one of the following relations.

4.1 POLYNOMIAL APPROXIMATION

The following polynomial approximation can be use:

$$T = C_0 + C_1 X + C_2 X^2 + C_3 X^3 + C_4 X^4 \text{ with } X = \ln \frac{R_T}{R_{25}}$$

where T = temperature in degrees Celsius

R_T = resistance in ohms

R_{25} = resistance in ohms at 25°C depending of the type of thermistor used (2 000, 3 000 or 10 000 Ω)

C_0 = 25.032

C_1 = -22.756

C_2 = 1.4997

C_3 = -0.1196

C_4 = 0.0114

Example:

With R_T = 5 500 Ω

R_{25} = 3 000 Ω (3 kΩ thermistor)

We get X = 0.6061 and T = 11.8°C

4.2 ANOTHER RELATION

Please note that many formulae can be used to transform ohm readings in temperature readings. One of the most accurate one is:

$$T = \frac{1}{A + B \cdot \ln R_T + C \cdot \ln^3 R_T} - 273.15$$

where T = temperature in degrees Celsius

$\ln R_T$ = natural logarithm of the resistance in ohms

A, B, C = constant factors

A, B, C have been determined following empirical measurements. These factors will vary according to the type of thermistor (refer to table below).

The accuracy of this formula is ± 0.15 °C with a range of -50°C to +150°C.

	Thermistor type (from Dale Electronics)		
	2 kΩ	**3 kΩ**	**10 kΩ**
A	$1{,}49896.10^{-3}$	$1{,}4051.10^{-3}$	$1{,}1303.10^{-3}$
B	$2{,}3781.10^{-4}$	$2{,}369.10^{-4}$	$2{,}339.10^{-4}$
C	$1{,}0668.10^{-7}$	$1{,}019.10^{-7}$	$8{,}863.10^{-8}$

Table 4: Conversion factors

5 TROUBLESHOOTING

Periodically check cable connections and terminals. The transducers themselves are sealed and cannot be opened for inspection.

5.1 UNSTABLE READING

- Check if the same troubles occur with other gages. If so, compare cable routes or check the readout unit.

- Is the shield drain wire correctly connected to the readout unit?

- Check the battery of the readout unit.

- The sensor body may be shorted to the shield. Check the resistance between the shield drain and the sensor housing.

- Check the integrity of the cable.

5.2 NO READING

- Check the battery of the readout unit.

- Check if the same troubles occur with other instruments. If so, the readout unit may be suspected and the factory should be consulted.

- The sensor body may be shorted to the shield. Check the resistance between the shield drain and the sensor housing.

- Check the cable resistance. An estimation of its resistance can be calculated: the resistance of a 22 gage copper cable is approximately 0.07Ω/m. Having an idea of the temperature, convert it into ohms (using chart below for example) and add the cable resistance twice.
    - If the resistance is high or infinite, a cut cable must be suspected.
    - If the resistance is close to zero, a short must be suspected.

- Cuts or shorts are located, the cable may be spliced in accordance with recommended procedures.

6 MISCELLANEOUS

	To Convert From	To	Multiply By
LENGTH	Microns	Inches	3.94E-05
	Millimetres	Inches	0.0394
	Meters	Feet	3.2808
AREA	Square millimetres	Square inches	0.0016
	Square meters	Square feet	10.7643
VOLUME	Cubic centimetres	Cubic inches	0.06101
	Cubic meters	Cubic feet	35.3357
	Litres	U.S. gallon	0.26420
	Litres	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*	0.10197
TEMPERATURE	Temp. in °F = (1.8 x Temp. in °C) + 32 Temp. in °C = (Temp. in °F – 32) / 1.8		

* at 4 °C

Table 5: Conversion factors E6TabConv-990505

APPENDIX 1

CONVERSION TABLE: THERMISTOR RESISTANCE vs. TEMPERATURE

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 6: 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 6: Conversion table