Using Fluke Calibration readouts with tungsten-rhenium

and other thermocouples

Fluke Calibration readouts, including Models 1529 and 1560, will display temperature for many of the common letter–designated types of thermocouples using standard algorithms. There are other types of thermocouples for which the readouts do not have the algorithms built in. These include tungsten–rhenium thermocouples (type C). The readouts can still calculate temperature for these thermocouples using the polynomial conversion option, but it requires the user to enter polynomial coefficients. This document provides polynomial coefficients that allow the Fluke Calibration readouts to directly display temperature for some of these special types of thermocouples.

Model 1529

Model 1529, when using the TC–POLY conversion option, accepts coefficients for a sixth order polynomial, described by

$$t(E[\mathrm{mV}])[°\mathrm{C}] = \sum_{i=0}^{6} C_i E^i$$

Temperature, in degrees Celsius, is calculated from EMF, in millivolts. This polynomial is used because it requires minimal processing time to calculate temperature. Thermocouples are typically defined by an equation where EMF is a polynomial function of temperature. Thus the above polynomial can only approximate the defined temperature–EMF relationship. However, with properly chosen coefficients given the temperature range of interest, the approximation can be adequate.

   In order to perform automatic reference junction compensation, the 1529 requires an additional parameter, labeled as mV (25 C), which gives the EMF in millivolts at a temperature of 25 °C. The 1529 uses this value to calculate, with close approximation, the EMF contributed by the reference junction at its temperature.

   It is recommended that after the coefficients are entered the conversion be tested with the TEST PROBE menu function to ensure the coefficients have been entered correctly. A millivolts value may be entered, and the corresponding temperature will be displayed. Check the temperature value against the expected value shown in the test points table and compare the error with the typical error depending on the set of coefficients used.

Model 1560

Model 1560 (with model 2565 or 2566 module attached), using the TC–POLY conversion option, accepts coefficients for a fifteenth order polynomial described by

$$E(t[°\mathrm{C}])[\mu\mathrm{V}] = \sum_{i=0}^{15} C_i t^i$$

EMF, in microvolts, is calculated from temperature, in degrees Celsius. In some cases this equation is the same as the one that defines the thermocouple, though the order might be higher than necessary. In other cases the definition can consist of more than one equation for different ranges, and the above polynomial can be used to approximate the definition over a larger range.

   The 1560 uses the above equation for two purposes. One is to calculate the EMF contribution of the reference junction, given its measured or specified temperature. The second is to calculate the temperature of the measuring junction from its EMF, which requires iterative inversion of the polynomial equation.

   It is recommended that after the coefficients are entered the conversion be tested with the TEST

CONV menu function to ensure that the coefficients have been entered correctly. This requires that the CJC setting in EDIT PROBE temporarily be set to EXTERNAL and the CJC TEMP setting be set to 0.0. A volts value may be entered, and the corresponding temperature will be displayed. Check the temperature value against the expected value shown in the test points table and compare the error with the typical error depending on the set of coefficients used. Once the test is complete be sure to set CJC and CJC TEMP back to the appropriate settings depending on what type of reference junction compensation is to be used.

Tungsten–Rhenium thermocouple

Tungsten–Rhenium thermocouples can be used at very high temperatures, up to 2315 °C. The more common type comprises 95% tungsten, 5 % rhenium versus 74% tungsten, 26% rhenium. This is sometimes referred to as W5Re/W26Re or letter-designated type C. ASTM standard E 988–96 gives defining equations and tables for this thermocouple.

Below is a table of coefficients that can be used in Fluke Calibration readouts, with the TC–POLY conversion option, to closely approximate the defined characterization for the W5Re/W26Re thermocouple. Sets of coefficients are optimized for different temperature ranges. Typical accuracies, in terms of standard deviation of the errors relative to the definition over the range, are given. The errors for any of the approximations are less than the defined initial calibration tolerances, which are no less than 4.4 °C.

W5Re/W26Re thermocouple coefficients for Fluke Calibration 1529

Min Max Std err	0 °C 631 °C 0.04 °C	631 °C 2315 °C 0.30 °C	0 °C 1700 °C 0.31 °C	0 °C 2315 °C 1.9 °C
mV(25C)	0.3420	0.3420	0.3420	0.3420
C0	0.0000000E+00	4.1102500E+02	0.0000000E+00	0.0000000E+00
C1	7.4411468E+01	–6.1463789E+01	7.3060966E+01	7.0964994E+01
C2	–4.5680255E+00	1.4651879E+01	–3.3864687E+00	–2.4641971E+00
C3	6.0972079E–01	–9.9683382E–01	2.7131105E–01	1.3498093E–01
C4	–5.5888380E–02	3.7141869E–02	–1.2136110E–02	–3.2237400E–03
C5	2.9645590E–03	–7.0836000E–04	2.9489100E–04	2.9184600E–05
C6	–6.5745000E–05	5.5012700E–06	–2.8596000E–06	9.1213000E–08

W5Re/W26Re thermocouple coefficients for Fluke Calibration 1560

Min Max Std err	0 °C 631 °C 0.02 °C	0 °C 2315 °C 0.11 °C
C0	0.0	0.0
C1	13.40632	13.384971
C2	0.011924992	0.012324776
C3	–7.9806354E–06	–1.0745E–05
C4	–5.0787515E–09	3.96948E–9
C5	1.3164197E–11	–7.4652E–13
C6	–7.9197332E–15	8.21553E–17
C7	0.0	–1.0318E–20
C8	0.0	0.0
C9	0.0	0.0
C10	0.0	0.0
C11	0.0	0.0
C12	0.0	0.0
C13	0.0	0.0
C14	0.0	0.0
C15	0.0	0.0

W5Re/W26Re thermocouple test points

mV (Model 1529)	V (Model 1560)	Temperature, °C	Temperature, °F
0.00000	0.0	0.0	32.0
2.25100	0.002251	150.0	302.0
3.96300	0.003963	250.0	482.0
6.73200	0.006732	400.0	752.0
11.19500	0.011195	630.0	1166.0
18.26000	0.01826	1000.0	1832.0
23.52000	0.02352	1300.0	2372.0
29.69600	0.029696	1700.0	3092.0
33.66900	0.033669	2000.0	3632.0
37.07000	0.03707	2315.0	4199.0

Type L thermocouple

The type L thermocouple is similar to type J; the materials being iron versus copper–nickel alloy. It is defined by the DIN 43710–1985 standard for the range –200 °C to 900 °C.

Below is a table of coefficients that can be used in Fluke Calibration readouts, with the TC–POLY conversion option, to closely approximate the defined characterization for the type L thermocouple. Sets of coefficients are optimized for different temperature ranges. Typical accuracies, in terms of standard deviation of the errors relative to the definition over the range, are given.

Type L thermocouple coefficients for Fluke Calibration 1529

Min Max Std err	–200 °C 0 °C 0.19 °C	0 °C 900 °C 0.17 °C
Mv(25C)	1.3120	1.3120
C0	0.0000000E+00	0.0000000E+00
C1	1.9411006E+01	1.9215707E+01
C2	–2.7947245E–01	–1.4775967E–01
C3	–1.4394260E–02	7.3511090E–03
C4	7.3235700E–03	–1.7138000E–04
C5	4.1765060E–03	1.5196200E–06
C6	2.9726300E–04	–3.7520000E–09

Type L thermocouple coefficients for Fluke Calibration 1560

Min Max Std err	–200 °C 0 °C 0.26 °C	0 °C 900 °C 0.15 °C
C0	0.0	0.0
C1	51.71695298	51.15498827
C2	0.027996778	0.040273933
C3	–1.1062E–04	–1.8216E–04
C4	2.79121E–07	4.75668E–07
C5	–2.0213E–10	–7.1249E–10
C6	1.27534E–11	5.74996E–13
C7	9.0306E–14	–1.8749E–16
C8	0.0	0.0
C9	0.0	0.0
C10	0.0	0.0
C11	0.0	0.0
C12	0.0	0.0
C13	0.0	0.0
C14	0.0	0.0
C15	0.0	0.0

Type L thermocouple test points

mV (Model 1529)	V (Model 1560)	Temperature, °C	Temperature, °F
–8.15000	–0.00815	–200.0	–328.0
–4.75000	–0.00475	–100.0	–148.0
0.00000	0.0	0.0	32.0
8.15000	0.00815	150.0	302.0
13.75000	0.01375	250.0	482.0
22.16000	0.02216	400.0	752.0
36.64000	0.03664	650.0	1202.0
53.14000	0.05314	900.0	1652.0

Type U thermocouple

The type U thermocouple is similar to type T, the materials being copper versus copper–nickel alloy. It is defined by the DIN 43710–1985 standard for the range –200 °C to 600 °C.

Below is a table of coefficients that can be used in Fluke Calibration readouts, with the TC–POLY conversion option, to closely approximate the defined characterization for the type U thermocouple. Sets of coefficients are optimized for different temperature ranges. Typical accuracies, in terms of standard deviation of the errors relative to the definition over the range, are given.

Type U thermocouple coeffcients for Fluke Calibration 1529

Min Max Std err	–200 °C 0 °C 0.17 °C	0 °C 600 °C 0.09 °C
Mv(25C)	0.9990	0.9990
C0	0.0000000E+00	0.0000000E+00
C1	2.5576443E+01	2.5193282E+01
C2	–6.3435822E-01	–3.6079726E-01
C3	1.0924012E-01	–1.1353050E-02
C4	–1.9119260E-02	1.3863040E-03
C5	–5.6560400E-03	–4.1675000E-05
C6	–8.0136000E-04	4.1640300E-07

Type U thermocouple coefficients for Fluke Calibration 1560

Min Max Std err	−200 °C 0 °C 0.23 °C	0 °C 600 °C 0.09 °C
C0	0.0	0.0
C1	39.01425961	39.05050554
C2	0.040617893	0.04491193
C3	−7.6773E−05	−2.257E−04
C4	2.81054E−07	1.67431E−06
C5	−2.0134E−10	−5.3127E−09
C6	−2.736E−11	7.44299E−12
C7	−8.6619E−14	−3.8464E−15
C8	0.0	0.0
C9	0.0	0.0
C10	0.0	0.0
C11	0.0	0.0
C12	0.0	0.0
C13	0.0	0.0
C14	0.0	0.0
C15	0.0	0.0

Type U thermocouple test points

mV (Model 1529)	V (Model 1560)	Temperature, °C	Temperature, °F
−5.70000	−0.0057	−200.0	−328.0
−3.40000	−0.0034	−100.0	−148.0
0.00000	0.0	0.0	32.0
6.62000	0.00662	150.0	302.0
11.98000	0.01198	250.0	482.0
21.00000	0.021	400.0	752.0
34.31000	0.03431	600.0	1112.0

NiMo/NiCo thermocouple

The 82 % nickel–18 % molybdenum versus 99.2 % nickel–0.8 % cobalt thermocouple is sometimes letter-designated type M. It is defined by the ASTM E1751 standard for the range -50 °C to 1410 °C.

Below is a table of coefficients that can be used in Fluke Calibration readouts, with the TC–POLY conversion option, to closely approximate the defined characterization for the NiMo/NiCo thermocouple. Sets of coefficients are optimized for different temperature ranges. Typical accuracies, in terms of standard deviation of the errors relative to the definition over the range, are given.

NiMo/NiCo thermocouple coefficients for Fluke Calibration 1529

Min Max Std err	-50 °C 370 °C 0.04 °C	370 °C 1410 °C 0.11 °C
Mv(25C)	0.9500	0.9500
C0	0.0000000E+00	–8.9820000E+01
C1	2.7097759E+01	3.1309960E+01
C2	–8.8245100E–01	–2.3011215E–01
C3	7.3472441E–02	–2.1945200E–03
C4	–4.7669200E–03	1.1591800E–04
C5	1.9506200E–04	–1.3916000E–06
C6	–3.0205000E–06	5.7411300E–09

NiMo/NiCo thermocouple coefficients for Fluke Calibration 1560

Min Max Std err	-50 °C 370 °C 0.02 °C	0 °C 1400 °C 0.46 °C
C0	0.0	0.0
C1	36.90092	38.45158
C2	0.04408523	–0.02297417
C3	–3.1429E–05	7.8830703E–04
C4	–1.02522E–07	–4.44569E–06
C5	1.84698E–10	1.2018821E–08
C6	–9.7381E–14	–1.8540871E–11
C7	–3.3944E–16	1.7265052E–14
C8	0.0	–9.632948E–18
C9	0.0	2.972083E–21
C10	0.0	–3.905592E–25
C11	0.0	0.0
C12	0.0	0.0
C13	0.0	0.0
C14	0.0	0.0
C15	0.0	0.0

NiMo/NiCo thermocouple test points

mV (Model 1529)	V (Model 1560)	Temperature, °C	Temperature, °F
–1.73200	–0.001732	–50.0	–58.0
–0.72000	–0.00072	–20.0	–4.0
0.00000	0.0	0.0	32.0
6.38100	0.006381	150.0	302.0
11.22500	0.011225	250.0	482.0
16.88400	0.016884	370.0	698.0
29.10100	0.029101	630.0	1166.0
49.68000	0.04968	1000.0	1832.0
73.50300	0.073503	1400.0	2552.0
74.10400	—	1410.0	2570.0

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