GEC Instruments
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Calibration Report – January 14, 2010
Precision Thermocouple Thermometer, Model S4TC, Serial No. FK02

This instrument is a very high accuracy, high resolution electronic thermometer manufactured by GEC Instruments. It includes 4 type T thermocouple inputs. The instrument connects to a Windows computer via a standard RS-232 serial port and is accompanied by a versatile and powerful program for display, plotting, logging and retrieval of temperature data. This program is called PinPoint Monitor (PPM).

The 4 thermocouples supplied with this unit were made from the same roll of 24 gage type T SLE solid wire. The EMF vs. temperature relationship for this thermocouple wire was determined by recording the voltage generated by the 4 thermocouples at multiple temperatures in a stable liquid bath containing water and glycol at approximately 5 °C intervals over the range -10 to 60 °C, while simultaneously recording the temperature of the reference junction internal to the instrument (which varied between 24 °C and 27 °C). A precision thermistor thermometer, SBE Model 38, SN 131, with a resolution of 0.0002 °C and an accuracy of 0.003°C, was used to measure the bath temperature. Additional data were obtained from a thermocouple circuit with the reference junction in a distilled water ice bath, and with the measuring junction at multiple stable temperatures between 24 and 28 °C. These data were used to adjust each reading from the original data set, to obtain a new data set for EMF vs. temperature with a reference junction at 0 °C. These data were then fitted to a polynomial to generate coefficients for a reference function for this wire that can be used to calculate EMF of a thermocouple circuit in microvolts as a function of measuring junction temperature when the reference junction is at 0 °C. The same EMF vs. temperature data were used to generate coefficients for an inverse function used to calculate measuring junction temperature as a function of EMF in microvolts, when the reference junction is at 0 °C. The coefficients for the reference function and those for the inverse function were placed in the configuration file for this instrument: FK02.ppc. These coefficients are used by the PPM software to calculate thermocouple measuring junction temperatures as function of measured EMF and reference junction temperature.

The Calibration Wizard in the PPM software was used to perform a 2 point calibration on the instrument and attached thermocouples with the 4 thermocouples submerged to a depth of 8” in the stable liquid bath. The calibration points were -10.000 °C and 59.999 °C. The observed readings were compared against the bath readings, the temperatures were converted to Kelvin units, and a slope and offset correction was calculated for each thermocouple channel. These slopes and offsets were placed in the configuration file for this instrument: FK02.ppc

The accuracy of the thermocouple calibration was verified on January 11, 2010 by recording the readings from the GEC Model S4TC, Serial No. FK02 instrument against the SBE 38, Serial No. 131 reference thermometer at multiple stable temperatures at approximately 5 °C intervals over the range -10 to 60 °C. A total of 5 readings at each stable temperature were recorded. The stability criterion at each stable temperature was based on attaining 15 successive readings at 5 second intervals where the difference between the maximum and minimum temperature of all readings during the previous 75 seconds was no more than 0.002 °C as measured by the SBE 38. The bath was controlled in such a manner that the thermocouples were very close to the stable temperature for several minutes prior to reaching the stability criterion. Then the reading errors for each thermocouple at each stable bath temperature were calculated by subtracting the bath temperature reading from the thermocouple temperature reading at each point. Results of this verification are shown in the following table:

Elapsed Time Minutes	TC REF (°C)	Bath (°C)	TC1 (°C)	TC2 (°C)	TC3 (°C)	TC4 (°C)	Error TC1 (°C)	Error TC2 (°C)	Error TC3 (°C)	Error TC4 (°C)
0.00	25.7451	-10.0303	-10.026	-10.030	-10.034	-10.025	0.004	0.000	-0.003	0.005
2.16	25.7430	-10.0363	-10.041	-10.048	-10.043	-10.044	-0.005	-0.011	-0.007	-0.008
2.66	25.7426	-10.0392	-10.036	-10.043	-10.049	-10.042	0.004	-0.004	-0.009	-0.003
4.08	25.7413	-10.0431	-10.043	-10.046	-10.043	-10.038	0.000	-0.003	0.000	0.005
4.18	25.7410	-10.0396	-10.038	-10.045	-10.043	-10.038	0.001	-0.005	-0.003	0.002
27.89	25.5654	-5.0518	-5.051	-5.052	-5.049	-5.050	0.001	0.000	0.003	0.001
27.94	25.5652	-5.0508	-5.052	-5.059	-5.052	-5.054	-0.001	-0.008	-0.001	-0.003
28.04	25.5643	-5.0499	-5.051	-5.054	-5.049	-5.049	-0.001	-0.004	0.001	0.001
28.13	25.5631	-5.0493	-5.050	-5.053	-5.046	-5.050	-0.001	-0.004	0.003	0.000
32.02	25.5209	-4.9965	-4.996	-5.002	-4.999	-5.001	0.001	-0.006	-0.002	-0.004
43.04	25.3750	-0.0677	-0.069	-0.073	-0.069	-0.074	-0.001	-0.005	-0.002	-0.006
43.14	25.3738	-0.0676	-0.069	-0.075	-0.061	-0.070	-0.001	-0.008	0.007	-0.002
43.23	25.3723	-0.0680	-0.072	-0.076	-0.070	-0.073	-0.005	-0.008	-0.002	-0.005
54.45	25.2174	-0.0231	-0.020	-0.028	-0.021	-0.026	0.003	-0.005	0.002	-0.003
54.55	25.2164	-0.0230	-0.029	-0.035	-0.028	-0.032	-0.006	-0.012	-0.005	-0.009
78.64	24.9197	5.0032	4.999	4.990	4.998	4.992	-0.004	-0.013	-0.005	-0.011
78.74	24.9189	5.0036	5.001	4.995	4.999	4.995	-0.003	-0.009	-0.005	-0.009
78.79	24.9183	5.0043	4.997	4.992	5.001	4.996	-0.007	-0.013	-0.003	-0.008
78.89	24.9175	5.0050	4.997	4.992	5.000	4.994	-0.008	-0.013	-0.005	-0.011
78.99	24.9164	5.0055	5.004	4.995	5.004	5.004	-0.001	-0.011	-0.002	-0.002
94.68	24.7465	9.9930	9.988	9.982	9.984	9.983	-0.005	-0.011	-0.009	-0.010
94.73	24.7459	9.9937	9.987	9.980	9.985	9.981	-0.006	-0.014	-0.008	-0.013
94.83	24.7449	9.9937	9.985	9.983	9.985	9.980	-0.008	-0.011	-0.009	-0.014
96.50	24.7279	9.9960	9.988	9.983	9.986	9.982	-0.008	-0.013	-0.010	-0.014
96.60	24.7267	9.9964	9.988	9.984	9.992	9.983	-0.008	-0.012	-0.005	-0.014
113.27	24.5717	14.9394	14.933	14.929	14.931	14.931	-0.007	-0.011	-0.008	-0.008
119.08	24.5297	14.9755	14.968	14.967	14.969	14.969	-0.008	-0.008	-0.006	-0.007
119.17	24.5289	14.9759	14.971	14.963	14.971	14.966	-0.005	-0.012	-0.005	-0.010
121.78	24.5111	14.9825	14.985	14.975	14.981	14.975	0.002	-0.008	-0.001	-0.007
121.83	24.5110	14.9825	14.979	14.969	14.977	14.975	-0.003	-0.013	-0.006	-0.008
151.29	24.2785	19.8503	19.845	19.841	19.847	19.844	-0.006	-0.010	-0.003	-0.006
151.44	24.2775	19.8501	19.849	19.843	19.847	19.844	-0.001	-0.007	-0.004	-0.006
151.53	24.2770	19.8504	19.845	19.838	19.845	19.844	-0.005	-0.012	-0.005	-0.006
158.81	24.2388	19.8911	19.887	19.879	19.884	19.881	-0.004	-0.012	-0.007	-0.010
158.86	24.2386	19.8905	19.896	19.880	19.885	19.885	0.006	-0.011	-0.005	-0.006
178.83	24.0907	24.9540	24.949	24.945	24.950	24.948	-0.005	-0.009	-0.004	-0.006
178.88	24.0907	24.9545	24.949	24.945	24.950	24.948	-0.006	-0.009	-0.004	-0.007
178.98	24.0907	24.9552	24.949	24.945	24.950	24.948	-0.006	-0.010	-0.005	-0.007
179.08	24.0907	24.9555	24.949	24.945	24.950	24.948	-0.007	-0.010	-0.005	-0.008
179.17	24.0907	24.9561	24.949	24.945	24.950	24.948	-0.007	-0.011	-0.006	-0.008
188.57	24.0170	29.9974	29.996	29.995	29.997	29.996	-0.001	-0.003	0.000	-0.002
188.67	24.0163	29.9971	29.997	29.992	29.996	29.994	0.000	-0.005	-0.001	-0.003
189.06	24.0134	29.9950	29.992	29.987	29.992	29.994	-0.003	-0.008	-0.003	-0.001
213.60	23.9897	29.9814	29.980	29.977	29.977	29.980	-0.001	-0.005	-0.004	-0.002
213.75	23.9901	29.9814	29.983	29.977	29.978	29.978	0.002	-0.004	-0.003	-0.003
226.69	23.9888	34.9810	34.983	34.980	34.984	34.979	0.002	-0.001	0.003	-0.002

Elapsed Time Minutes	TC REF (°C)	Bath (°C)	TC1 (°C)	TC2 (°C)	TC3 (°C)	TC4 (°C)	Error TC1 (°C)	Error TC2 (°C)	Error TC3 (°C)	Error TC4 (°C)
226.88	23.9879	34.9807	34.982	34.976	34.981	34.977	0.001	-0.005	0.000	-0.004
226.93	23.9877	34.9807	34.979	34.976	34.981	34.975	-0.002	-0.005	0.000	-0.006
227.03	23.9873	34.9807	34.977	34.975	34.982	34.981	-0.004	-0.005	0.001	0.000
227.13	23.9871	34.9806	34.978	34.976	34.979	34.973	-0.002	-0.005	-0.001	-0.008
240.21	23.9103	39.9799	39.977	39.969	39.977	39.970	-0.003	-0.011	-0.003	-0.010
240.31	23.9095	39.9804	39.979	39.978	39.978	39.977	-0.001	-0.003	-0.002	-0.003
240.36	23.9092	39.9800	39.977	39.973	39.975	39.974	-0.003	-0.007	-0.005	-0.006
240.46	23.9088	39.9801	39.974	39.971	39.971	39.973	-0.006	-0.009	-0.009	-0.007
240.56	23.9081	39.9803	39.980	39.972	39.978	39.976	0.000	-0.008	-0.002	-0.005
254.87	23.8183	44.9421	44.935	44.933	44.932	44.932	-0.007	-0.009	-0.010	-0.010
254.97	23.8171	44.9418	44.944	44.939	44.947	44.938	0.003	-0.003	0.005	-0.004
255.07	23.8164	44.9427	44.941	44.937	44.939	44.938	-0.001	-0.006	-0.004	-0.005
255.16	23.8157	44.9419	44.945	44.939	44.943	44.940	0.003	-0.003	0.001	-0.002
255.21	23.8147	44.9424	44.945	44.938	44.942	44.942	0.003	-0.004	0.000	-0.001
255.31	23.8142	44.9427	44.947	44.940	44.945	44.940	0.004	-0.003	0.002	-0.003
270.51	23.6684	49.9187	49.919	49.913	49.919	49.912	0.001	-0.006	0.000	-0.006
270.56	23.6675	49.9189	49.918	49.912	49.916	49.913	-0.001	-0.006	-0.003	-0.006
270.66	23.6667	49.9192	49.916	49.914	49.917	49.914	-0.003	-0.006	-0.002	-0.006
270.75	23.6655	49.9186	49.919	49.914	49.920	49.917	0.001	-0.005	0.001	-0.002
270.80	23.6649	49.9191	49.922	49.917	49.920	49.914	0.003	-0.002	0.001	-0.005
270.90	23.6640	49.9191	49.922	49.917	49.921	49.916	0.002	-0.002	0.002	-0.003
285.90	23.5018	54.8941	54.895	54.894	54.897	54.889	0.001	0.000	0.003	-0.005
286.00	23.5006	54.8939	54.891	54.886	54.890	54.885	-0.003	-0.008	-0.004	-0.009
286.10	23.4996	54.8940	54.893	54.890	54.890	54.885	-0.001	-0.004	-0.004	-0.009
286.15	23.4991	54.8940	54.895	54.893	54.897	54.888	0.001	-0.001	0.003	-0.006
286.25	23.4982	54.8939	54.889	54.885	54.890	54.888	-0.005	-0.009	-0.004	-0.006
286.35	23.4969	54.8941	54.894	54.894	54.894	54.889	0.000	0.000	-0.001	-0.005
301.59	23.3394	59.8602	59.865	59.864	59.868	59.863	0.005	0.004	0.008	0.003
301.69	23.3387	59.8603	59.864	59.862	59.864	59.857	0.004	0.001	0.003	-0.003
301.79	23.3378	59.8600	59.864	59.859	59.867	59.863	0.005	-0.001	0.007	0.003
301.84	23.3373	59.8606	59.861	59.856	59.863	59.857	0.000	-0.004	0.002	-0.004
301.94	23.3365	59.8615	59.861	59.859	59.862	59.861	0.000	-0.002	0.000	-0.001
302.04	23.3354	59.8613	59.868	59.860	59.866	59.860	0.007	-0.002	0.005	-0.002

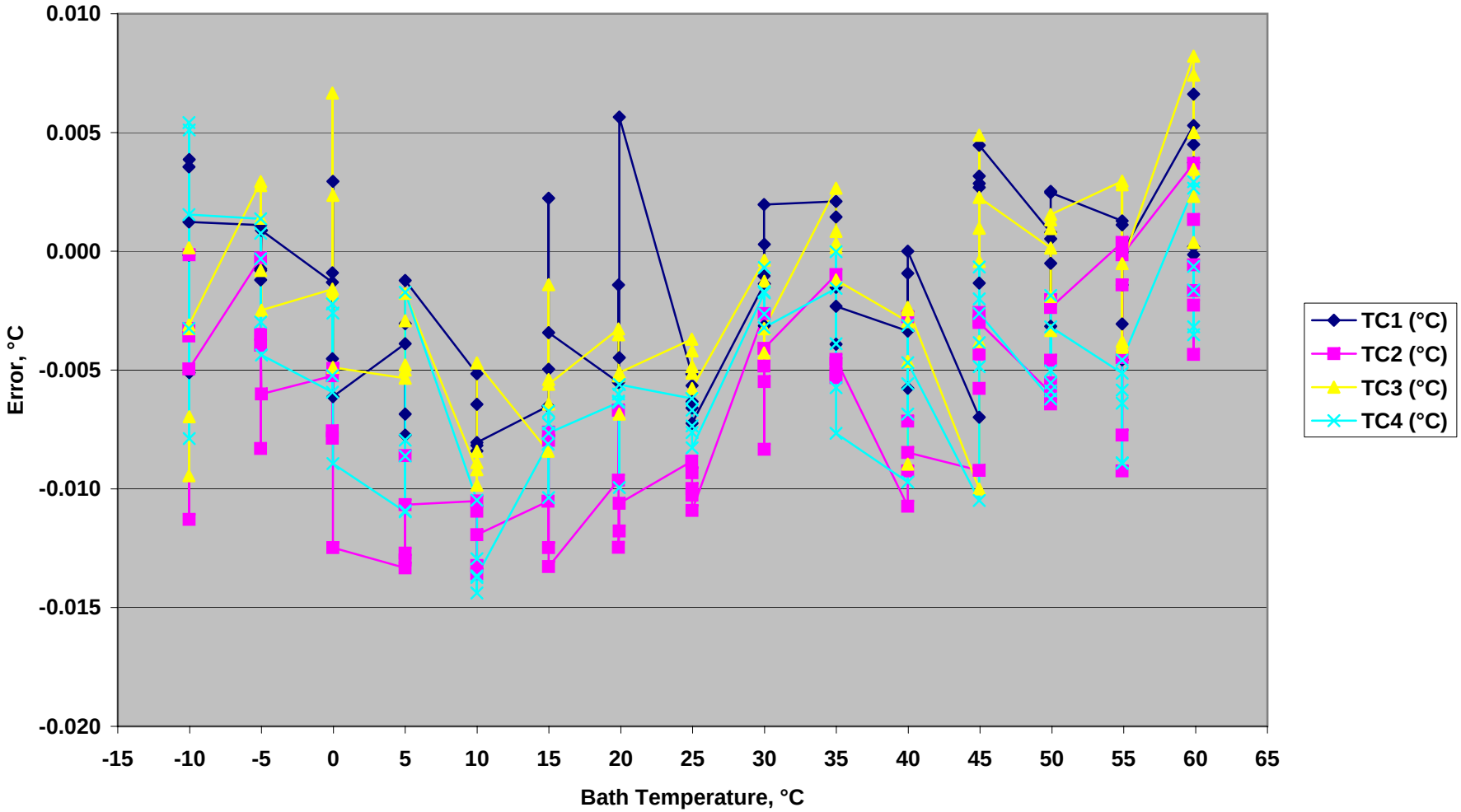
A plot of the thermocouple reading errors from the above table is on page 4 of this report.

On January 14, 2010 the accuracy of the thermocouple readings was verified at the melting point of Gallium by placing the 4 thermocouples in a Gallium cell at a nominal 29.7646 °C and recording temperatures for 50 minutes. Data are shown in the plot on page 5.

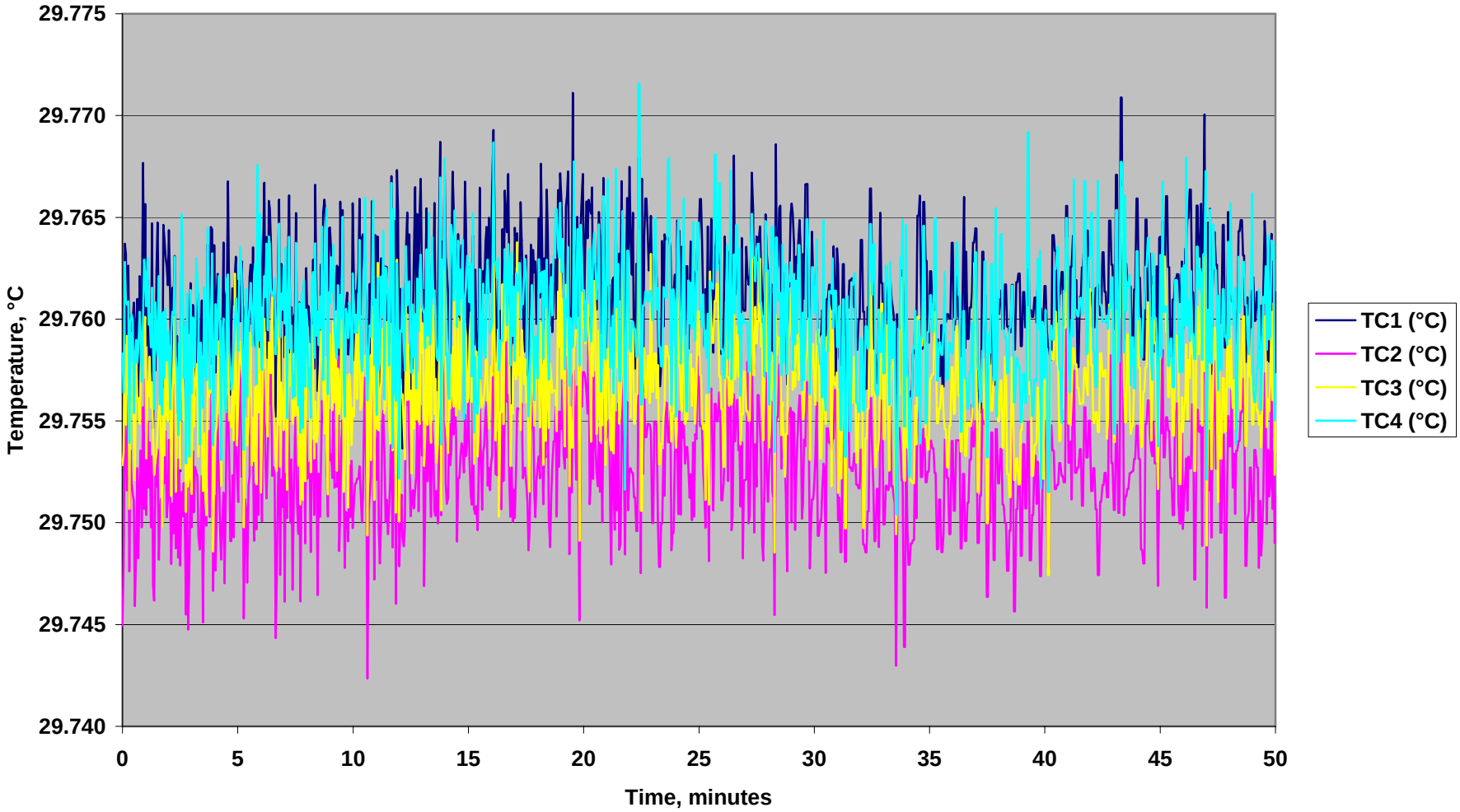
Then the male connector on each thermocouple was shifted by one channel at the instrument, and data were recorded for 60 minutes to get an indication of the uniformity between individual thermocouples. Data are shown in the plot on page 6. Results indicated that the 4 thermocouples are matched to each other within about 0.003 °C at this temperature. The average temperatures recorded with the thermocouples in the Gallium apparatus were:

TC1 = 29.7612 °C TC4 in Channel 1 = 29.7637 °C
TC2 = 29.7522 °C TC1 in Channel 2 = 29.7554 °C
TC3 = 28.7565 °C TC2 in Channel 3 = 29.7568 °C
TC4 = 29.7600 °C TC3 in Channel 4 = 29.7582 °C

GEC Instruments Thermocouple Scanner Model S4TC, Serial FK02
24 AWG Type T Thermocouples - SLE Solid Wire
Reading Errors After 2 Point Calibration at -10.000 °C and 59.999 °C



GEC Instruments Thermocouple Scanner Model S4TC, Serial FK02
24 AWG Type T Thermocouples - SLE Solid Wire
Readings with 4 thermocouples in Gallium Cell at 29.7646 °C



GEC Instruments Thermocouple Scanner Model S4TC, Serial FK02
24 AWG Type T Thermocouples - SLE Solid Wire
Readings with 4 thermocouples (shifted at input connectors) in Gallium Cell at 29.7646 °C