Temperature Record Users Guide

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Introduction

The *Temperature Record* utility allows the user to create a record file of one or more measured temperatures and to compensate for known thermometer errors based on three data points. The correction is based on a curve touching the three calibration temperature points that may or may not be linear resulting in a more natural shape as compared to a straight-line approximation between any two of the three points. Utilities are included to assist in evaluation and estimation of measurement uncertainty. Calibration data can be setup for more than one thermometer. No support for imperial (Fahrenheit) temperatures is provided with this utility.

Overview

The *Temperature Record* utility main window is shown in Illustration 1.

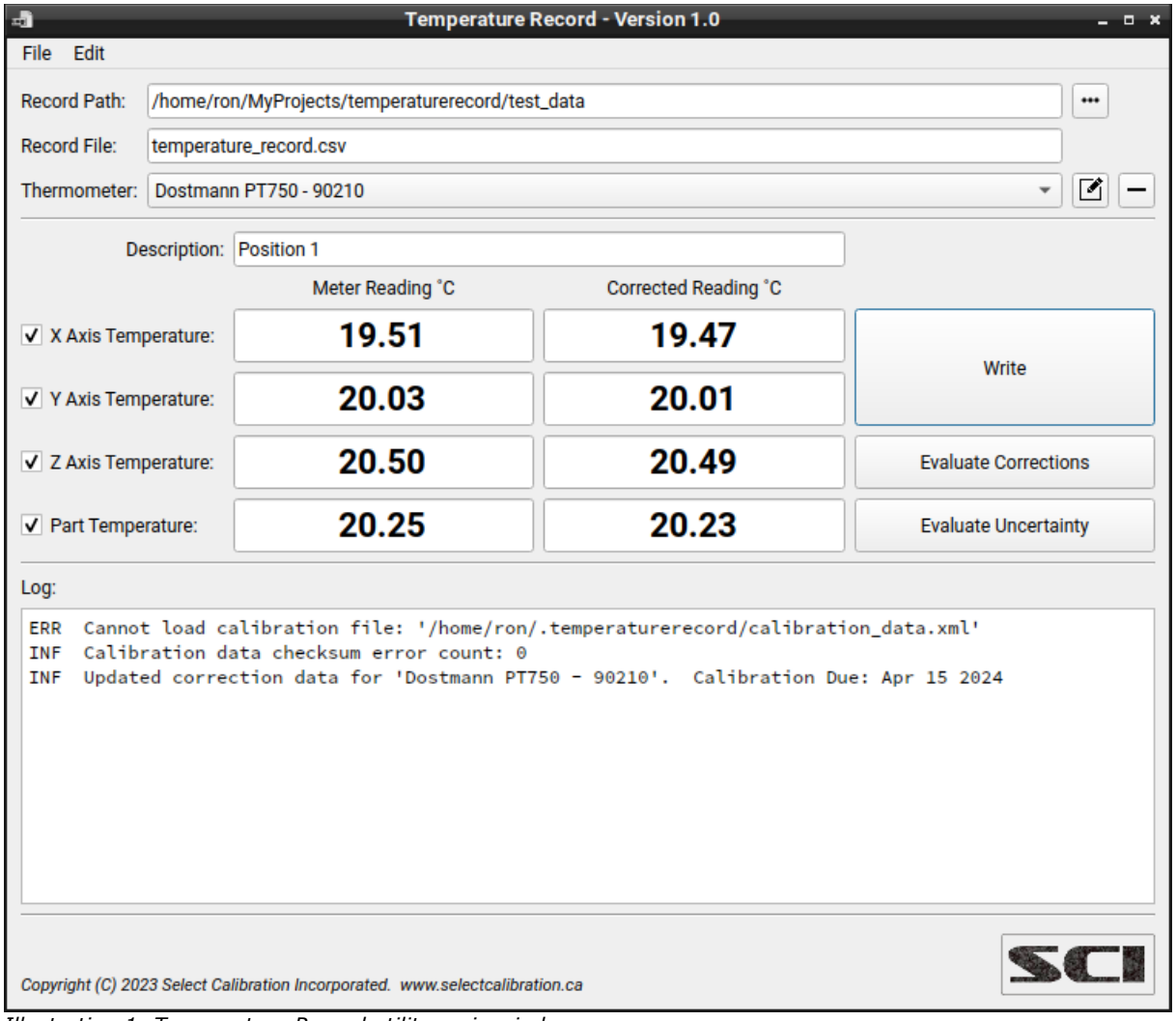

Illustration 1: Temperature Record utility main window.

Data displayed by the selected thermometer is entered into the *Meter Reading* column resulting in updated values in the *Corrected Reading* column. The input temperature is not required to be within the calibration range defined by the three data points although the error is expected to increase the further outside of the calibration range the measurement is.

Four fields are provided to allow recording of the temperature for each axis of the CMM and the part. The fields for each axis and part can be selected using the check-box on the left side of the display. Fields that are unselected will not be written to the record file.

Options:

Option	*Description*
Record Path	Location where the record file is created or updated.
Record File	Name of the file that will be created or appended which contains the temperature measurements.
Thermometer	Selection of the active thermometer.
Description	Name of the position attached to the temperature measurement.
X, Y, Z, Part Temperature	Checkbox indicating the data for the entry will be written to the record file. If unchecked, the entry is not written.
Write	Create or update the record file with the currently selected temperatures.
Evaluate Corrections	Generate a data file containing results from a series of temperature test points using the current correction values.
Evaluate Uncertainty	Generate a data file containing results from a series of temperature test points based on the current correction values. The correction values are the current corrections offset by the calibration uncertainty with all possible input combinations.
Log	Information related to specific events as they occur.
	Browse button for the record path.
	Edit button for the thermometer correction data. New calibration data will be created if the description does not exist.
	Remove selected thermometer calibration data.

The edit function allows both creation of calibration data for a thermometer or modification of an existing thermometer. The difference between adding or editing the calibration data is based on the uniqueness of the description. Existing thermometers can be removed by clicking on the remove button.

When the calibration due date has past, no thermometer is selected, or the calibration data point range is less than 1˚C, then no results are shown in the corrected reading column. Illustration 2 shows the *Corrected Reading* values when one or more of the above problems exist.

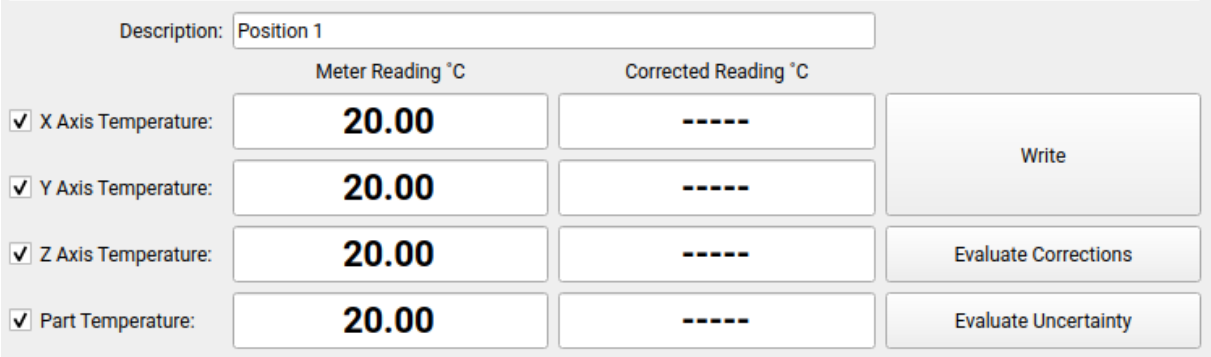

Illustration 2: Temperature Record display when no thermometer is selected, the selected thermometer calibration due date has passed, or the calibration data range is less than 1˚C.

Correction Editor

The correction editor allows manipulation of the thermometer data which includes the description, the calibration due date, and the three calibration data points. Illustration 3 shows the correction editor dialog.

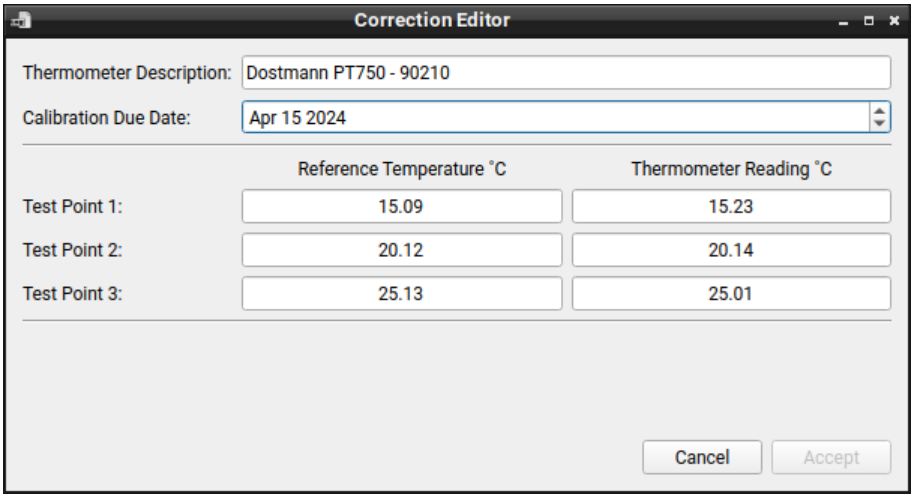

Illustration 3: Correction editor dialog.

The *Reference Temperature* column is the real or known temperature of some sample and the *Thermometer Reading* is what the thermometer reported when measuring that same sample. The three calibration test points should cover the expected range that would be encountered when using the thermometer for best results.

The minimum temperature range required between the three tests points is 1˚C.

For any thermometer the ideal correction is linear but this may not be the case so a curve correction is used to make sure that all test points fit perfectly which is not possible with only a linear correction.

If the thermometer description is changed to something that is unique a new thermometer entry is automatically created using the current data when the *Accept* button is clicked. The new thermometer description must be unique otherwise the *Accept* button will be disabled.

Options:

Option	*Description*
Thermometer Description	Unique description of the thermometer.
Calibration Due Date	The thermometer can be used prior to this date.
Test Point <n>	Entries used for the basis of the correction function. The reference temperature is the known temperature of some sample where the thermometer reading is what is shown by the thermometer measuring the same sample.
Cancel	Close the correction editor. All changes are lost.
Accept	Close the correction editor and save all changes. If the description is unique a new entry is created.

Temperature Record

The temperature record contains the corrected temperature measurements along with other information such as the selected thermometer and measurement description. Table 1 shows and example of the temperature record log file with various options enabled.

Table 1: Temperature record example file.

Measurement Description	Thermometer	X Temp. C	Y Temp. C	Z Temp. C	Part Temp. C
Position 1	Dostmann PT750 - 90210	19.47	20.01	20.49	
Only X and Part	Dostmann PT750 - 90210	19.47			20.23
All axis and Part	Dostmann PT750 - 90210	19.47	20.01	20.49	20.23

The temperature record file is always appended and never replaced. If the record file does not exist a new file is created and initialized with the proper column labels otherwise the new data is simply appended to the end of the file.

No validation is performed to ensure an existing file is actually a temperature record file.

Correction Evaluation

The evaluate corrections option creates a CSV text file containing corrected temperatures extending over the range of the calibration points. The purpose of this output is to allow evaluation of the error correction based on the three calibration test points.

Illustration 4 shows calibration data used for the evaluation test and illustration 5 shows a graphical analysis of the resulting data. The range of the test temperatures extends beyond the range of the calibration points to the nearest integer value and separated by 0.1 °C within that range.

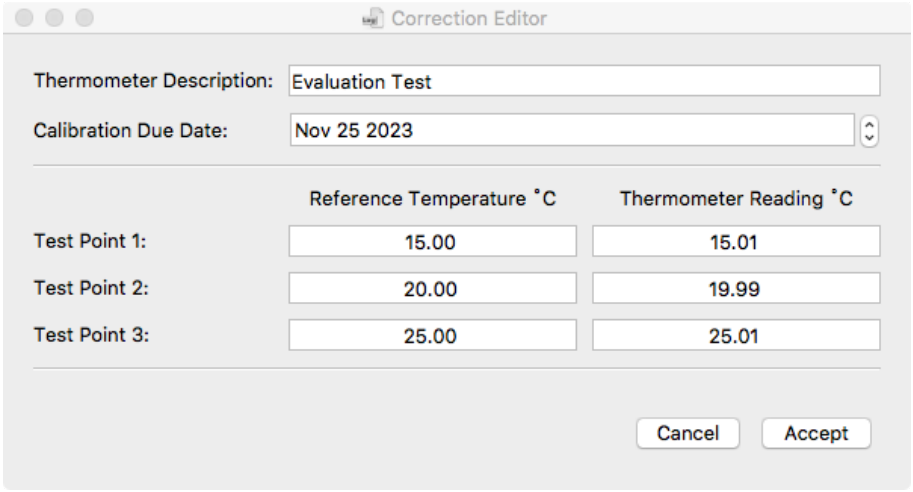

Illustration 4: Evaluation test data.

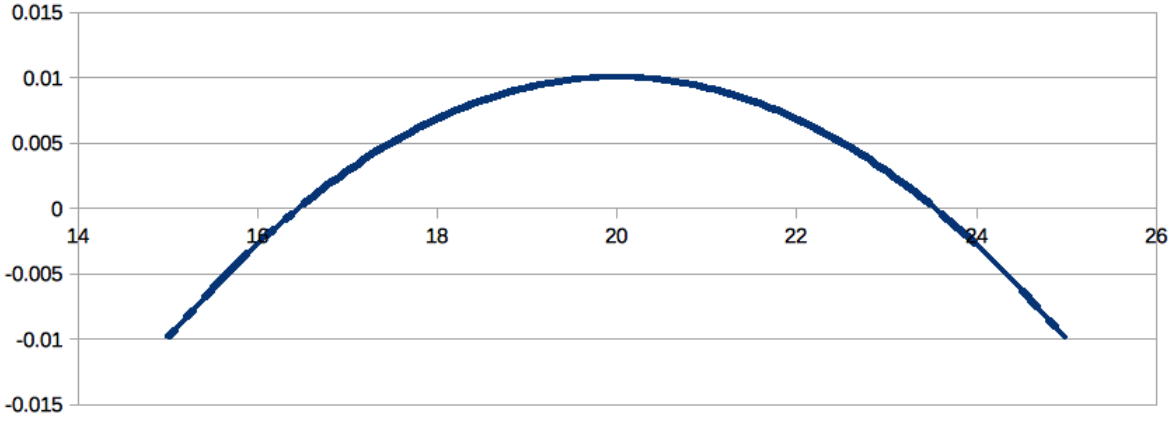

Illustration 5: Analysis of evaluation test data.

It is unknown what the real shape between the calibration points should be. Using a straight-line interpolation has problems where there is an abrupt change in direction where a curve has a more natural shape. A curve fit seems to be a more logical choice for this reason.

Uncertainty Evaluation

The evaluate uncertainty option creates a CSV text file containing corrected temperatures extending over the range of the calibration points at an increment of 1 °C. The calibration points are uniquely manipulated based on the user provided calibration measurement uncertainty resulting in a unique result. For the three data points there are 57 unique combinations of points

used for the simulation. The uncertainty evaluation does not produce a final result but only the raw data necessary to calculate a final value.

The uncertainty entered by the user is assumed to be a +/- value. For example, if the calibration uncertainty provided by the user is 0.04°C then the range in the output data would theoretically be 0.08°C. The range in the uncertainty data should be divided by 2 in order to return the calculated result to a proper +/- expression.

Illustration 6 shows the input dialog for the calibration uncertainty of the lab performing the temperature measurement.

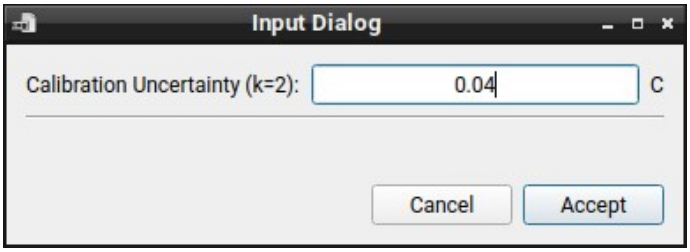

Illustration 6: Input dialog for the calibration uncertainty.

Table 2: Uncertainty table data sample.

	Calibration Point Offsets			Evaluation Temperature				
Set	Offset 1	Offset 2	Offset 3	15	16	17	18	19
0	0.00	0.00	0.00	14.858	15.880	16.903	17.927	18.952
1	0.04	0.00	0.00	14.817	15.850	16.883	17.915	18.946
2	0.00	0.04	0.00	14.860	15.867	16.879	17.894	18.914
3	0.04	0.04	0.00	14.818	15.837	16.858	17.882	18.908
4	0.00	0.00	0.04	14.858	15.883	16.908	17.932	18.955
...								
60	0.00	0.00	-0.04	14.858	15.877	16.898	17.922	18.948
61	-0.04	0.00	-0.04	14.900	15.907	16.919	17.934	18.954
62	0.00	-0.04	-0.04	14.857	15.890	16.923	17.955	18.986
63	-0.04	-0.04	-0.04	14.898	15.920	16.943	17.967	18.992
Min:				14.815	15.834	16.854	17.877	18.905
Max:				14.901	15.926	16.953	17.977	18.999
Range				0.086	0.092	0.099	0.100	0.094
Range/2:				0.043	0.046	0.049	0.050	0.047
Standard Uc:		Mean:	0.028	0.025	0.027	0.029	0.029	0.027

The set number ranges from 0 to 63 with duplicate entries removed resulting in 57 samples (not 64 samples as implied from only from the set number). Samples 8, 16, 24, 32, 48, 56, and 64 are duplicates of set 0 and not included.

The evaluation section at the bottom of the data as shown in 2 does not exist in the file generated by the Temperature Record utility.

The range of error increases between the calibration sample points resulting in a non-linear uncertainty as more weight is placed on pairs of samples. Illustration 7 shows the estimated standard uncertainty across a range of temperatures. The smallest uncertainty is at the temperature of the calibration points where the largest is in between the calibration points.

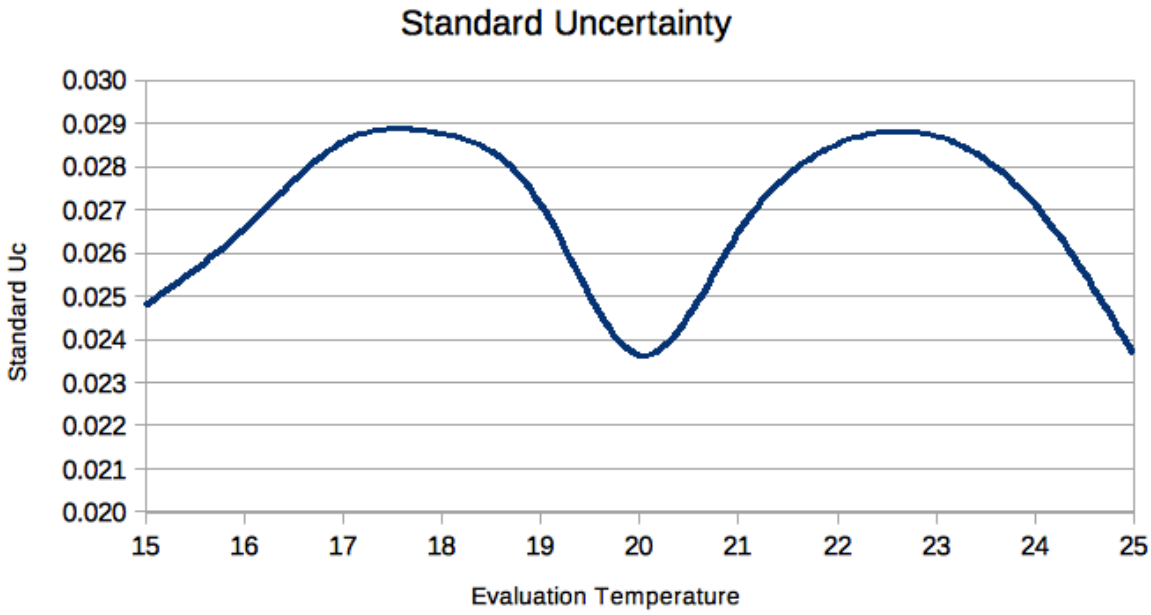

Illustration 7: Uncertainty evaluation between 15 and 25 C.

Revision History

Date	*Version*	*Changes*
Nov 1, 2023	1.0	New Program
Nov 8, 2023	1.1	Added description of the measurement in the log when written