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# CTE Tester Accuracy vs Repeatability
# Application Note: 1240130

## Data Accuracy

WinCTE provides the estimated accuracy tolerance with each test. CTE is determined as:

$$CTE = \Delta x / (\Delta T * L)$$

where the parameters are:

1) change in sample length ($\Delta x$),
2) change in sample temperature ($\Delta T$), and
3) nominal sample length (L).

CTE accuracy depends on the combination of the accuracies of each measured parameter. Given that $\Delta T$ is accurate to ±0.2C. Temperature-related accuracy ratio depends on the size of $\Delta T$. For example, testing with $\Delta T$=10 is yields ±2% for the temperature accuracy. Testing with $\Delta T$=100 is yields ±0.2% accuracy for the temperature accuracy. Generally, the larger the temperature change ($\Delta T$), the tighter the temperature-accuracy tolerance.

Sample length, L, is measured with lab calipers prior to testing and is generally accurate to about ± 25 to ± 50 microns typically for most operators. Sample lengths can range from 50mm to 10mm which generally yields insignificant accuracy-ratio impact.

$\Delta x$ is measured in steps of 0.10 microns, with typical accuracy tolerance of ±1 to 1.5 steps. $\Delta x$ magnitude controls the dimensional accuracy ratio and depends on the CTE and $\Delta T$. The more expansive the material, the better the accuracy tolerance associated with dimensional measurement.

Combining these accuracies for CTE measurement, here are some examples.

a. For low expansion materials with CTE less than 10E-6/C, over a 100C $\Delta T$ in 50mm length, total accuracy will exceed ±10%.
b. For a sample with CTE of 20E-6 over 100C $\Delta T$, accuracy is about ±5%; at 50C $\Delta T$, accuracy is about ±10%.

## Repeatability

There is no specification or estimate of repeatability since this depends on many variables associated with the operator's use of "best practice". Tests that are properly executed will have repeatability tolerances much smaller than the accuracy tolerance. Alternatively, poor test execution can yield unlimited repeatability variation. Therefore,

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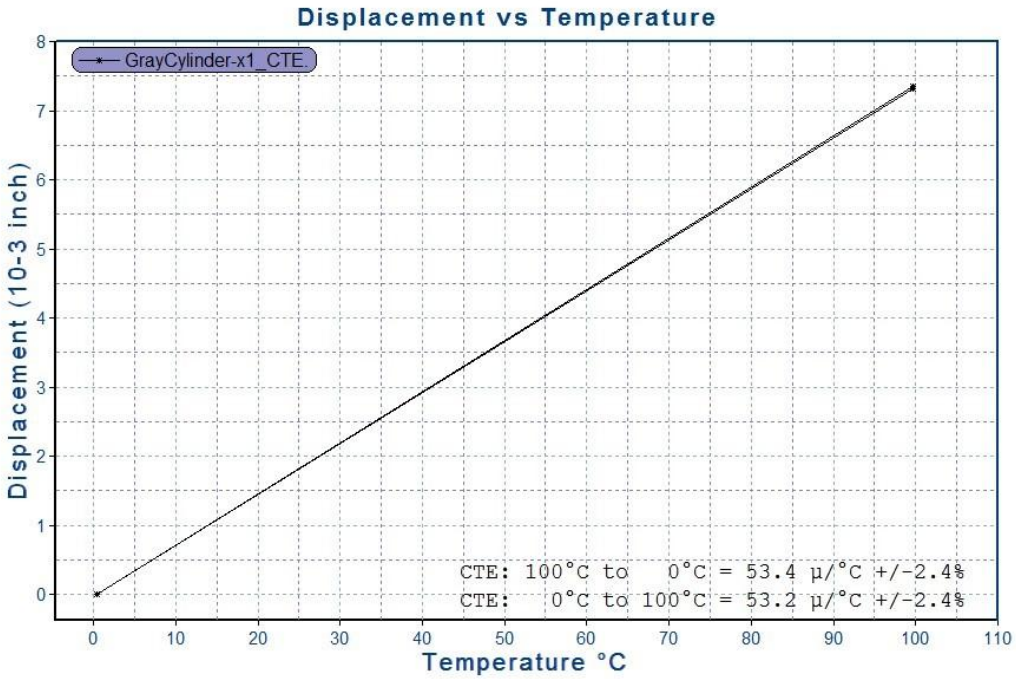
the measurement of repeatability is a necessary step to ensure that the test procedure is correct. The following operational techniques will help to ensure high quality CTE test data by evaluation of test repeatability:

a) **Round-trip tests** The initial temperature point and final temperature point should be the same to ensure that the sample returns to the original dimension. If not, issues such as stress-relaxation, dimensional creep, or phase-change may be occurring. The following example, using three temperatures (100C, 0C, 100C), shows typical repeatability. If the sample fails to substantially return to the original length, annealing the sample to relieve internal stresses (oven-soaking at or above the maximum CTE temperature) for an hour or more can be beneficial.




When testing a new material, general best-practice is to perform a few temperature cycles to accurately assess inelastic/plastic behavior associated with stress relaxation and dimensional creep. These issues generally become more severe for materials that closer to their melting or softening temperature. Cyclic testing is shown in the following plots.

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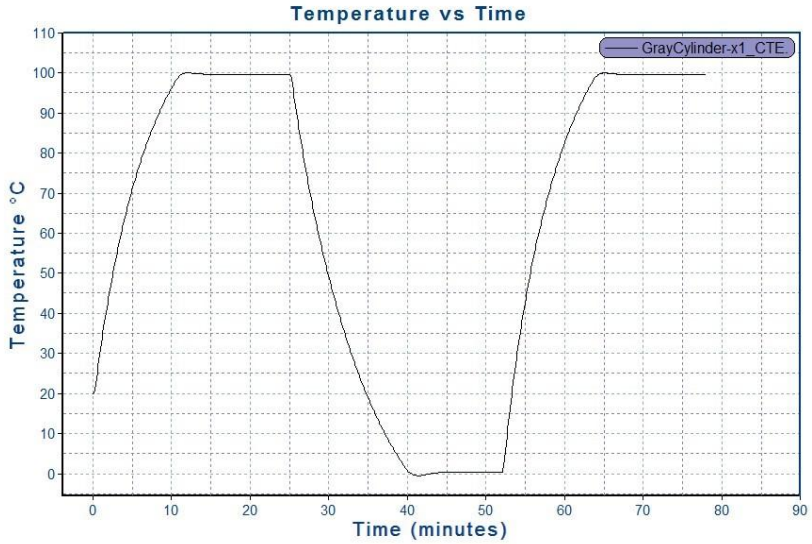


The issues that can affect repeatability are:

1. sample creep/stress relaxation (overcome by pre-annealing/T-soaking)
2. laboratory temperature variations greater than about 5 degrees C
3. a vibrating/shaky work bench
4. various neglect to follow the operating instructions

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I have also included a couple of additional plots that show the variation of accuracy with CTE. If proper procedures are followed, repeatability will be substantially smaller tolerance than the estimated test accuracy.