Report on Thermal Contraction of Some Materials Including Stycast 2850FT*

TS-SSC 90-060
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September 9, 1990
(Revised September 28, 1990)

Measurements of the thermal contraction curves of several materials have been performed at the Fermilab Materials Development Lab (MDL) using a dilatometer. This is a report of some preliminary results.

A parallelopiped of the material to be tested with nominal measurements 1/2" x 1/2" x 1" is inserted in a hollow pyrex tube. (Some of the samples are actually 1/2" diameter cylinders 1" in length.) The sample is instrumented with a thermocouple (type E), inserted in a hole drilled into the bottom of the sample. A pyrex pushrod rests against the top of the sample. The relative vertical position of the pushrod is measured with an LVDT. The LVDT output range of +10V to -10V corresponds to 50mils.

The sample is immersed in liquid nitrogen, until the temperature stabilizes. When the temperature has stabilized, the sample is removed and allowed to return to room temperature[1], while data are recorded by a Hewlett-Packard computer every 5 seconds. The plots shown in this report are abstracted from the large data files written to the Hewlett Packard.

I am ignoring for now any systematic errors in the temperature measurement, due to either thermocouple calibration uncertainty (no calibration was attempted) and the thermal gradient between the inside and the outside of the sample[2].

I am also taking the LVDT readings straight from the raw data file. They are given to four decimal places, the least significant digit corresponding to .0005 mils, a small variation probably not to be believed. However, the smoothness and monotonicity of the LVDT vs temperature data from the raw data files is degraded somewhat if the LVDT values are rounded to three decimal places, indicating that the stability of the LVDT is good to less than one one-thousandth of a mil.

The sample pieces have ends which are "flat" to several mils. A systematic error could occur if the pushrod happens to rest against a locally high part of the sample end, so that the data (reported as L(293K) - L(T) / L(293)) are normalized to the wrong length.

The maximal contraction shown on the plots in this report is 8 mils per inch, or 8 mils for the nominal 1" sample size. Each major division on the vertical graph axis corresponds to a change in length of about 1 mil.

* These data were taken at the Fermilab Materials Research Laboratory, under the direction of Jay Hoffmann. Barb Sizemore prepared and operated the dilatometer apparatus, and was responsible for data acquisition. Dave Muniz prepared the material samples. I would like to thank all of these people for their work, as well as Finlay Markley for his guidance and suggestions in these studies and in the preparation of this report.

Figure 1 shows the reults of a dilatometer run for aluminum. The data from MDL are compared with tabulated values from Altman, Rubin, and Johnston, 1954. In this run, data wree unfortunately taken all the way down to liquid nitrogen temperature. However, the agreement with the Altman et al. data is good.

The fairly good agreement of the two sets of data gives some indication of the accuracy of our measurements. (The maximum deviation between our data and Altman et al. corresponds to an absolute length difference of .2 mils for our sample.)

Figure 2 shows results for a run with a sample of Stycast 2850FT, cured with 24LV (see TS-SSC 90-053.) Also plotted are data from Mackowski et al. (The full reference is given in TS-SSC 90-053.) The data are in fairly good agreement at higher temperature values, but seem to diverge at lower temperatures.

Our simple measurement[3] in Lab 2 gave 478 x 10^{-5} at 77K, closer to the Mackowski value than to our MDL result. If anything, we would have expected the Lab 2 sample to have given an artificially small contraction value because of the heating that occured between removal from the liquid nitrogen bath and the micrometer measurement. The Lab 2 measurement is shown on the graph for comparison, as are the Lab 2 measurements for 304 stainless steel and G-10 in the plane of the fiber layers.

Figure 3 shows results for a glass-filled epoxy, US Polymeric EM-7302. It seems to contract less than the Stycast 2850FT sample and more than aluminum metal.

Figure 4 shows the results of a run using a sample of G10 material with the fiber planes parallel to the direction in which the contraction was measured. The contraction at liquid nitrogen temperature is greater than that shown in our Lab 2 test (see Figure 1), but greater than that of 304 stainless steel.

Finally, Figure 5 shows the contraction for "green putty" material, a highly filled epoxy. It shows less thermal contraction than any of the other materials tested.

Notes

1. In early tests, the temperature of the apparatus was allowed to return to room temperature quickly, over a period of several hours. In later testing, the apparatus was insulated so that the temperature increase was much more gradual.

2. It was later found that at liquid nitrogen temperature (77K), the thermocouple reads 80K.

3. These measurements are reported in TS-SSC 90-053. We measured the lengths of stainless steel, G10, and Stycast samples before and after plunging in liquid nitrogen.

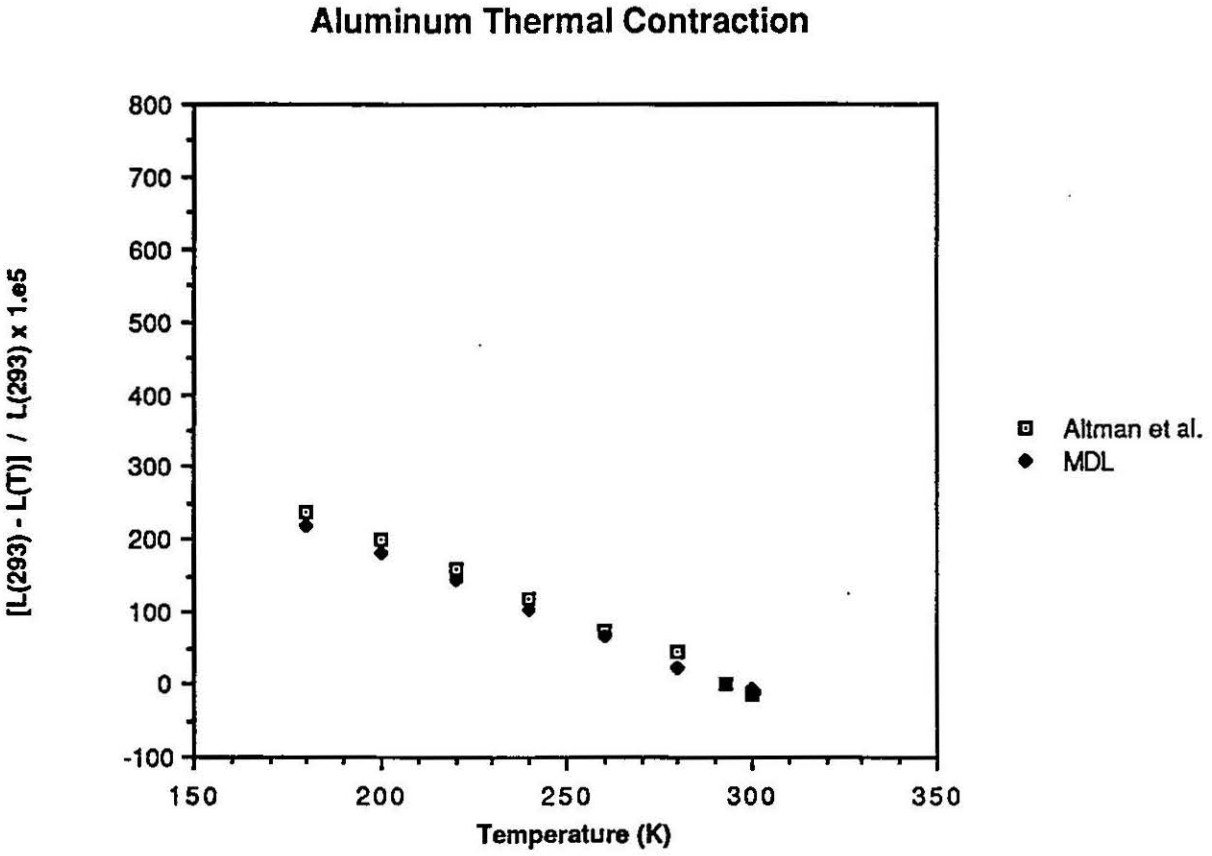
Aluminum Thermal Contraction
[L(293) - L(T)] / L(293) x 1.e5
800
700
600
500
400
300
200
100
0
-100
150
200
250
300
350
Temperature (K)
Altman et al.
MDL

Figure 1

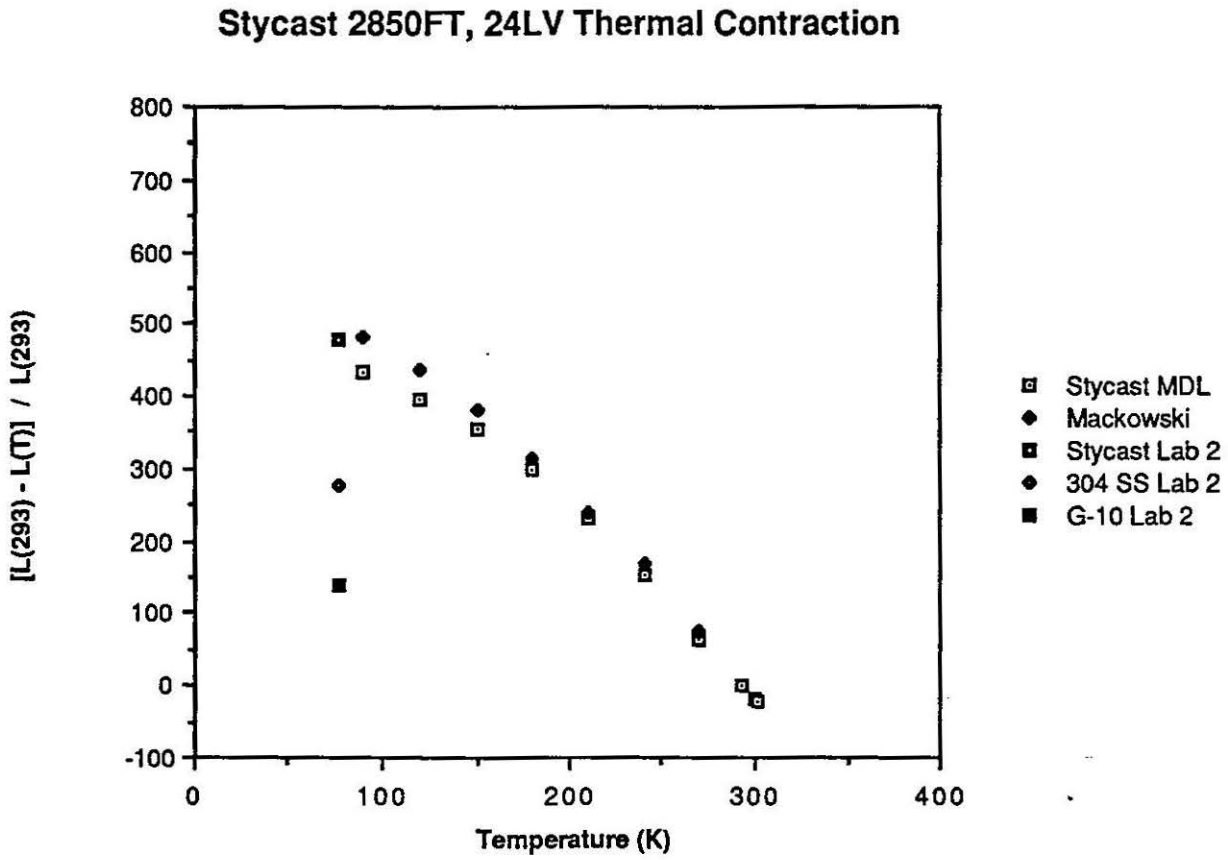
Stycast 2850FT, 24LV Thermal Contraction
[L(293) - L(T)] / L(293)
800
700
600
500
400
300
200
100
0
-100
0
100
200
300
400
Temperature (K)
Stycast MDL
Mackowski
Stycast Lab 2
304 SS Lab 2
G-10 Lab 2

Figure 2

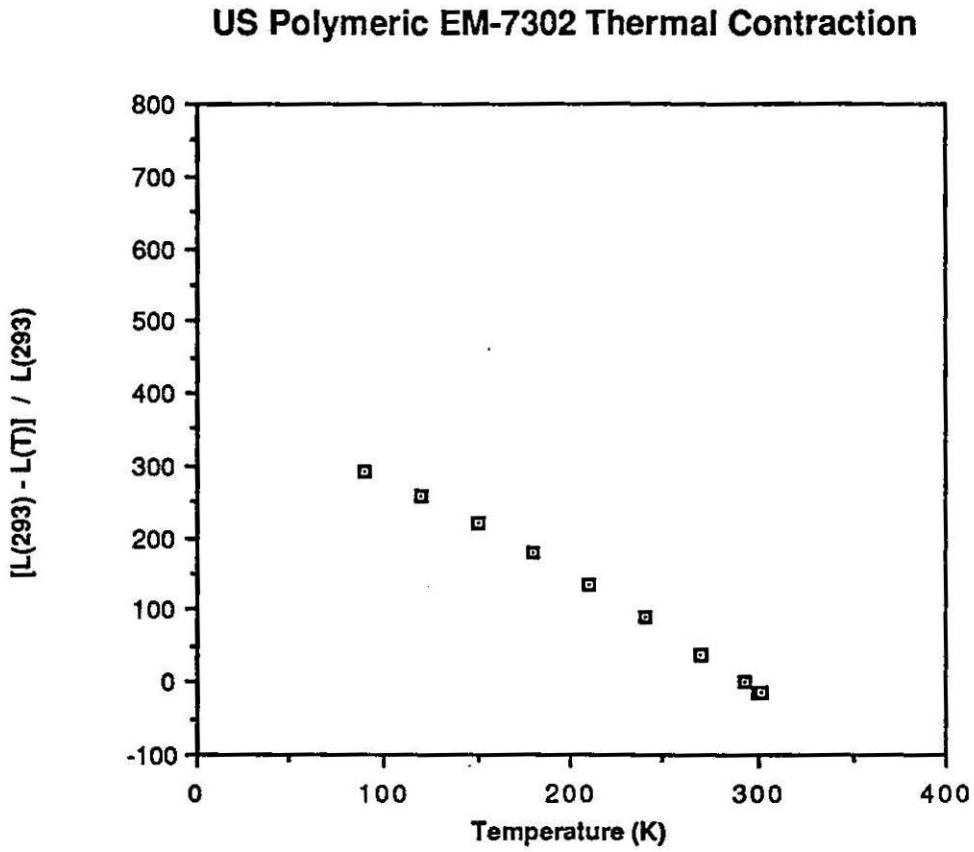
US Polymeric EM-7302 Thermal Contraction
[L(293) - L(T)] / L(293)
800
700
600
500
400
300
200
100
0
-100
0
100
200
300
400
Temperature (K)

Figure 3

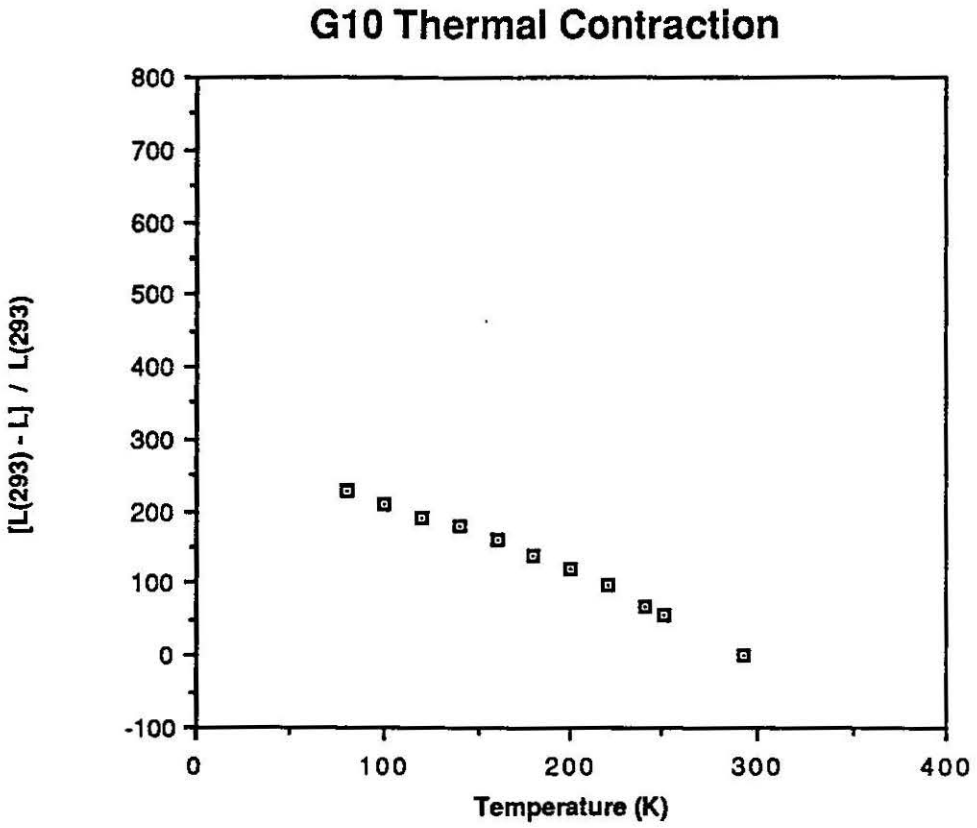
G10 Thermal Contraction
[L(293) - L] / L(293)
800
700
600
500
400
300
200
100
0
-100
0
100
200
300
400
Temperature (K)

Figure 4

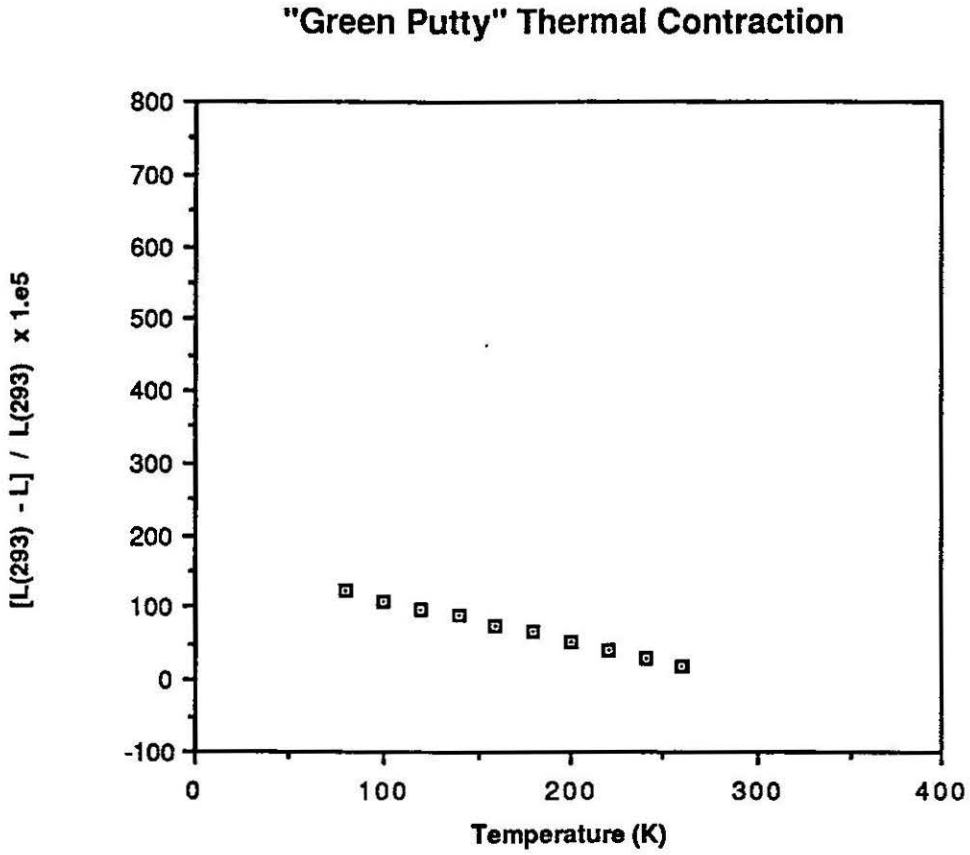
"Green Putty" Thermal Contraction
[L(293) - L] / L(293) x 1.e5
800
700
600
500
400
300
200
100
0
-100
0
100
200
300
400
Temperature (K)

Figure 5