ZOTEFOAMS

Technical Information Sheet TIS 08

THERMAL STABILITY AND ELEVATED TEMPERATURE PERFORMANCE

The ability of a foam to perform at elevated temperatures is application dependent. Factors such as the exposure time and whether the foam is under a load are very important.

If used at elevated temperatures, three main impacts on the material should be considered:

1. Dimension changes can occur, both temporary and permanent. Temporary dimension changes can occur when the temperature of a foam is increased below the softening point, due to thermal expansion of the polymer and the gas in its cells. Permanent shrinkage can occur when foam materials are exposed to temperatures above the softening point for long periods, then cooled back to ambient.
2. Mechanical properties will change with temperature, and for thermoplastic polymers usually results in softening with increasing temperature. Changes to mechanical properties can be both a gradual and a step change (a transition temperature).
3. Chemical degradation of polymer - the amount of degradation for a polymer is dependent on the temperature and environment to which it is exposed, and the length of time in those conditions. One effect of this is a reduction in strength.

This document focuses on the dimensional changes that can occur at different temperatures.

Permanent dimension changes

In common with other foam materials, Zotefoams closed cell, cross-linked materials shrink at elevated temperatures. This is due to diffusion of gas from the cells and is not just dependent on the time and temperature, but also on the thickness of the part and whether the foam is under any load. Overall, the degree of shrinkage experienced by a foam material depends on the type of polymer, temperature, time, density, dimensions (thickness) and cell size. This section explores the shrinkage effects that may occur upon exposure to elevated temperatures.

IMPACT OF TIME AND THICKNESS

Total shrinkage usually comprises a rapid shrinkage phase followed by a slower shrinkage phase:

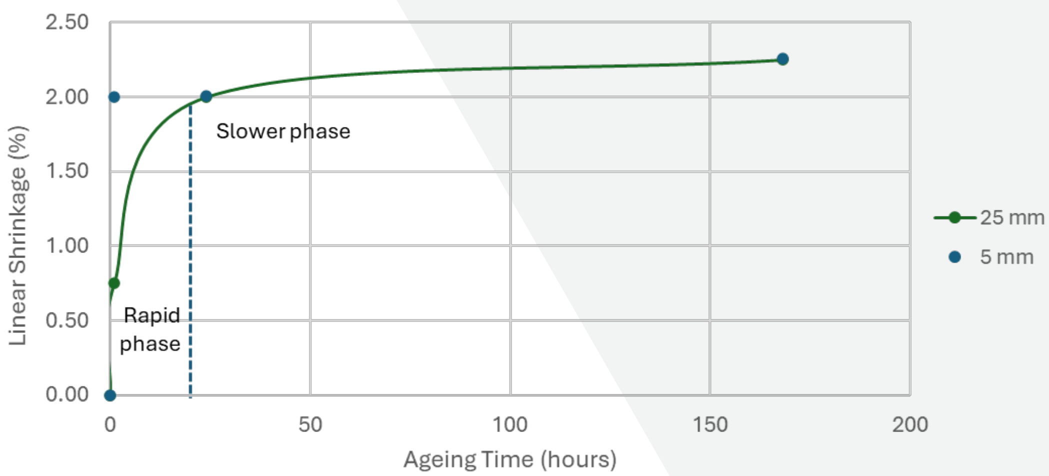

Figure 1: Graph showing the percentage linear shrinkage over time measured for Plastazote LD33 material in 5 mm and 25 mm thick aged at 80°C.

Thicker sheets will shrink more slowly, so for short exposure times - within the ‘rapid phase’ of shrinkage – thin sections of foam will shrink much more noticeably than thicker sections. Over longer time periods, the overall percentage shrinkage expected for different thicknesses of material will converge. Effectively, for thinner materials the rapid phase is shortened.

Around the softening point of the material, shrinkage is relatively low, and the thickness of the part has lower impact. As you near the melting point of the material, much larger differences between thicknesses are noticed for short heating times.

Higher temperatures will result in more rapid initial shrinkage and higher overall levels of shrinkage. The worst case would be total loss of gas from the foam and the polymer shrinking back to its pre-expansion dimension.

This relationship is exhibited in the graphs below, comparing Plastazote LD33 product aged at 80°C and 100°C.

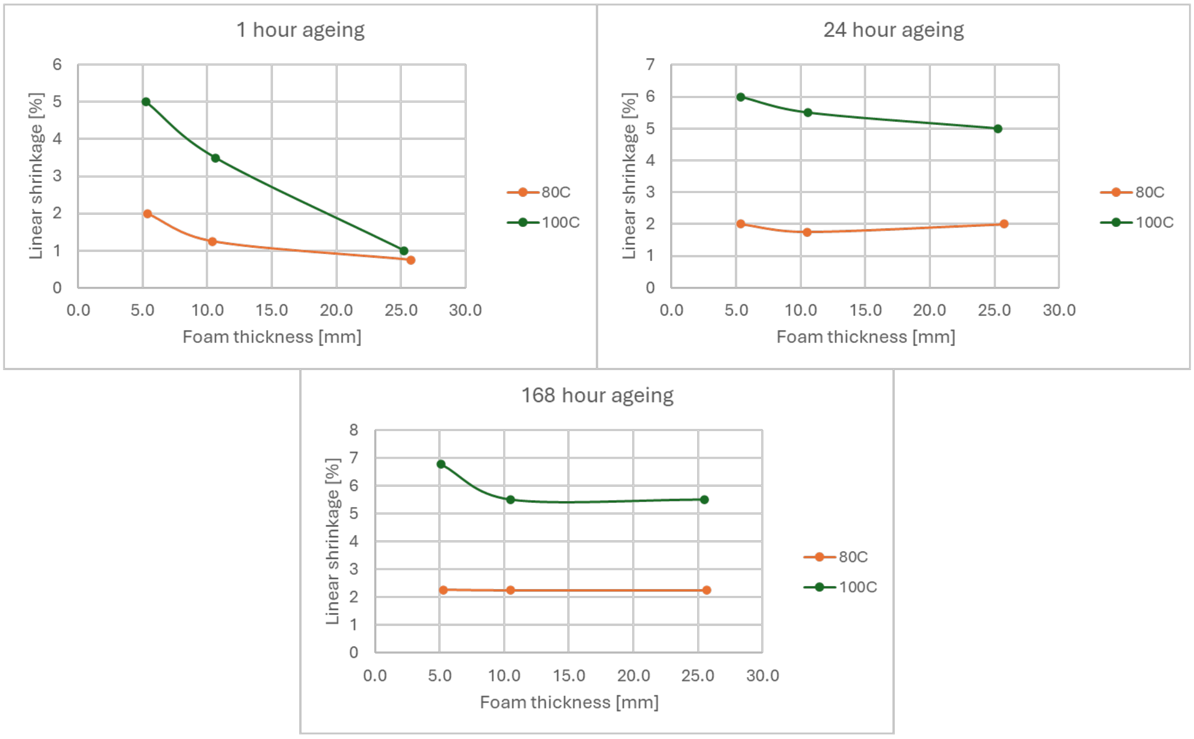

Figure 2: Graphs showing the relationship between foam thickness and percentage linear shrinkage of Plastazote LD33 aged at 80°C and 100°C for 1, 24 or 168 hours.

IMPACT OF DENSITY

Heavier density foams shrink slower and by less overall at the same temperature compared to lower density materials. The following graphs show the typical relationship between foam density and extent of shrinkage for Plastazote LD and ZOTEK F HT products.

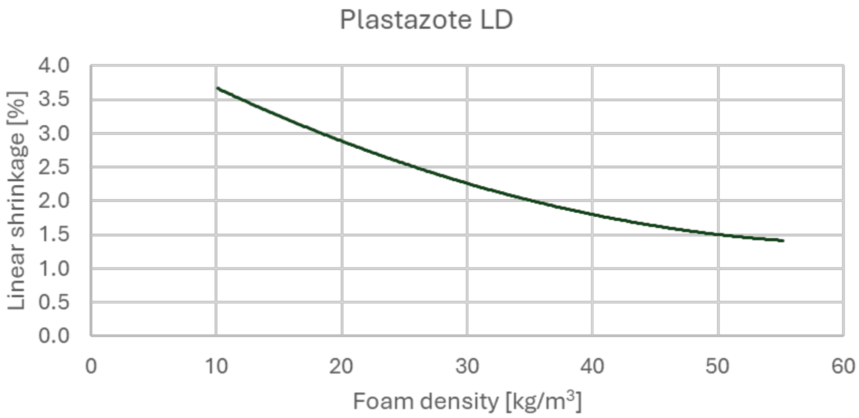

Figure 3: Typical relationship between percentage linear shrinkage and foam density measured for Plastazote LD products, aged at 80°C for 168 hours.

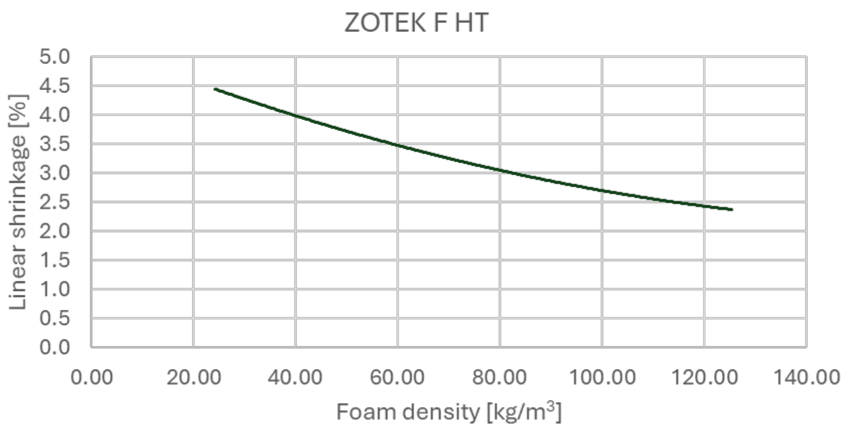

Figure 4: Typical relationship between percentage linear shrinkage and foam density measured for Zotek F HT products, aged at 145°C for 168 hours.

Impact of temperature

Within most Zotefoams product information sheets, you will find a recommended maximum operating temperature stated. This is the temperature at which a sample sized 100 x 100 x 25 mm will be expected to shrink by a maximum of 5% in length after heating in a hot air oven for 24h. In many applications, this level of shrinkage in this time period will not be acceptable - the maximum operating temperature does not represent a temperature which the product should be exposed to for a long period of time.

- For Plastazote LD products the shrinkage below 60°C is negligible.
- Evazote products shrink at lower temperatures compared to LD, and this can be noticeable from as low as 40°C for EV products, with significant densification above 80°C.
- Plastazote HD products are the most temperature stable in the AZOTE range, exhibiting low levels of shrinkage even at 100°C.
- For Zotek F HT products, shrinkage below 100°C is negligible.
- Shrinkage between 70 to 90°C is noticeable but stable for Plastazote LD products. For Zotek F HT products, the same is true for temperatures between 100 to 145°C.
- Within 10-15°C of the melting point of the base polymer of each foam, shrinkage becomes more varied, rapid and less predictable.

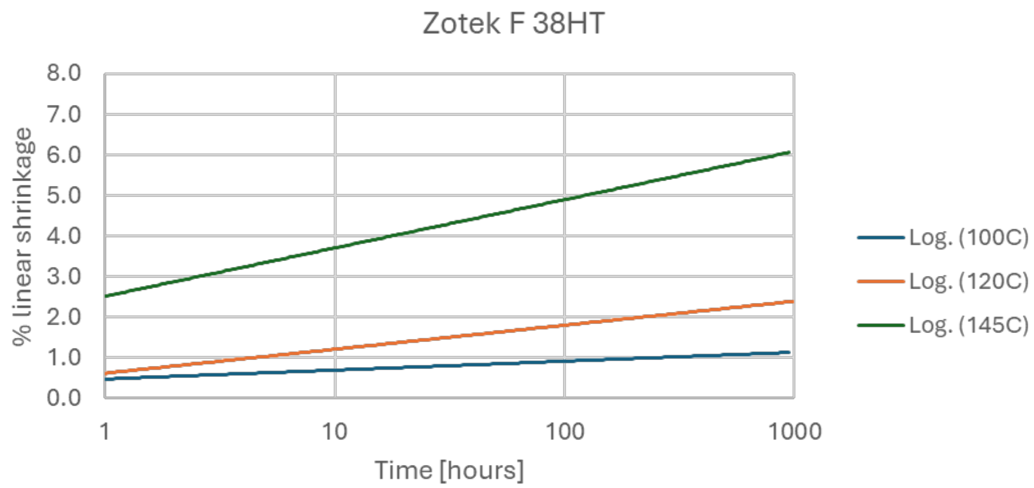

Figure 5: The above chart is based upon linear shrinkage measurements made on 25 mm thick samples of F38HT heated in a hot air oven for various time periods up to 750 hours. Test temperatures 100, 120 and 145°C.

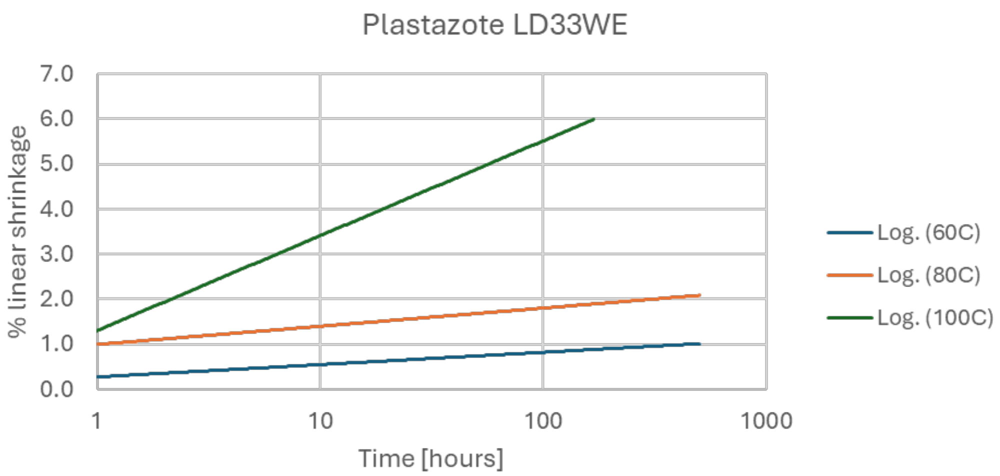

Figure 6: The above chart is based upon linear shrinkage measurements made on 25 mm thick samples of LD33WE heated in a hot air oven for various time periods up to 500 hours. Test temperatures 60, 80 and 100°C.

IMPACT OF HEATING MECHANISM

Degree of shrinkage will also depend on whether the material is heated from one side (for example, when the foam is used to insulate a heated object), or if the material is exposed to heat in all directions (placing the foam in an oven). In each scenario, the driving forces for diffusion of gas out of the foam structure will be different.

For example, foam heated from one side by a hot surface will exhibit the most shrinkage in the foam's thickness (direction of heat flow) – the shrinkage seen along the length of the foam (perpendicular to the heat flow) will be less. Foam heated from all directions (foam placed in a hot environment) will tend to shrink by a similar percentage in all dimensions, so change in dimensions will be more noticeable (the overall volume shrinkage will be higher).

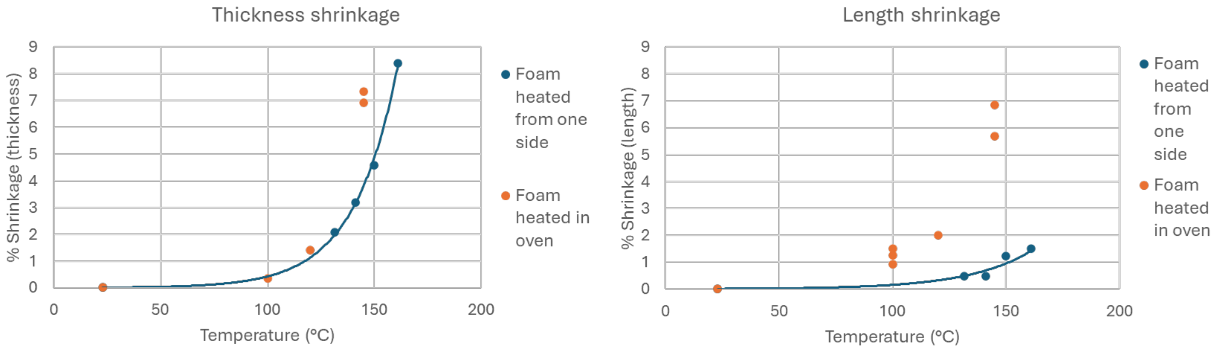

Figure 7: Thickness shrinkage (left) and Length Shrinkage (right) measured for F43HT material aged for 1000 hours at a variety of temperatures up to 160°C.

IMPACT OF SHRINKAGE ON MATERIAL PROPERTIES

Where foam dimensions shrink after exposure to elevated temperatures, the density of the materials will increase. As foam stiffness increases with foam density, if material shrinks significantly then foam properties will also change noticeably.

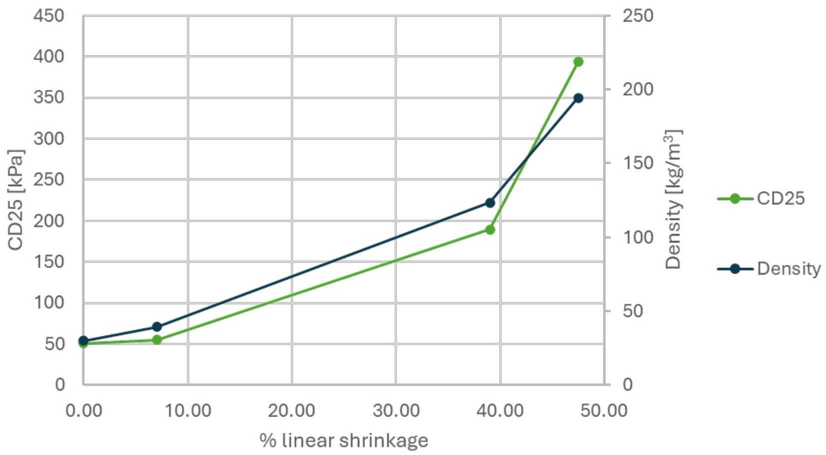

Figure 8: Graph showing the relationship between compressive stress at 25% compression strain and percentage linear shrinkage, and density of material compared to percentage linear shrinkage. Measured using Evazote VA35 material aged for 1, 24, and 168 hours at 100°C.

Please continue to the next page for information about *<u>temporary dimension changes</u>*.

Temporary dimension changes

Temporary dimension changes can occur when the temperature of a foam is increased or decreased, due to thermal expansion of the polymer and the gas in the foam cells. The material will tend to expand at elevated temperatures and shrink at lower temperatures, before returning to its original dimensions when heated or cooled back to ambient temperature. These dimension changes can be noticeable when material is stored and processed in different temperature environments.

Thermal expansion coefficients for foam will depend on the polymer that the foam is made from, and the density of the foam:

Material family	Relative thermal expansion coefficient	Density dependence	Temperature dependence
Plastazote LD	High	High	High
Plastazote HD	Low	Low	Medium
Plastazote EV	Very High	High	High
ZOTEK F	Medium	n/a	Medium
ZOTEK F HT	Low	Low	Medium
ZOTEK N	Very low	-	Low
ZOTEK T	Medium	n/a	Low

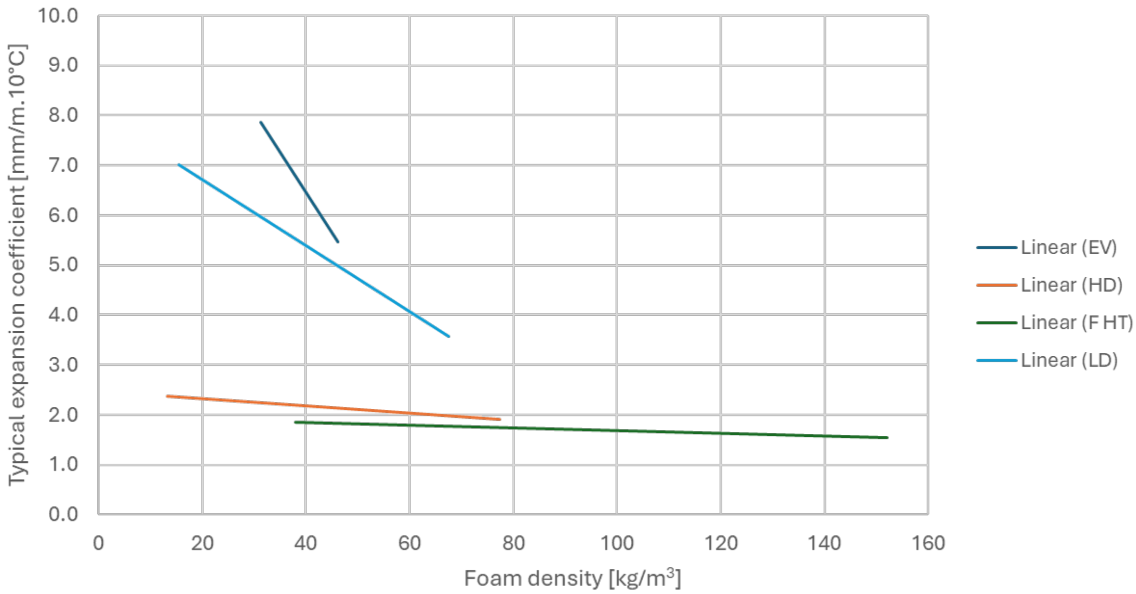

Figure 9: Relationship between density and thermal expansion coefficient for different polymer foams. The thermal expansion coefficients are taken from measurements between 0°C and below the softening point of the foams. In this graph, thermal expansion coefficients are represented in units of mm/m.10°C, so show the expected change in dimension in mm per metre original length of material per 10°C change in temperature.

Thermal expansion coefficients for foams and polymers will vary with temperature. At sub-zero temperatures, especially below the material's glass transition temperature, thermal expansion coefficients for the same material will tend to be lower compared to thermal expansion coefficients above ambient temperatures. Closer to the material's melting temperature, the foam will begin to shrink.

An example of the change in expansion coefficient with temperature is presented below for Plastazote LD15FM:

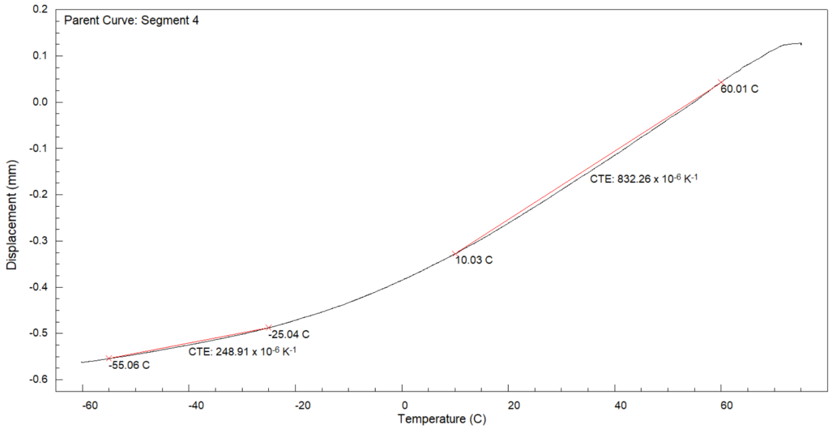

Figure 10: Thermomechanical Analysis of Plastazote LD15FM foam measured between -60°C and +75°C, using a heating rate of 5°C/min in accordance with ISO 11359-2:2021.

For certain materials, such as our ZOTEK T foam, the thermal expansion coefficient does not change very much with temperature over the range investigated, so changes in dimension are easier to predict:

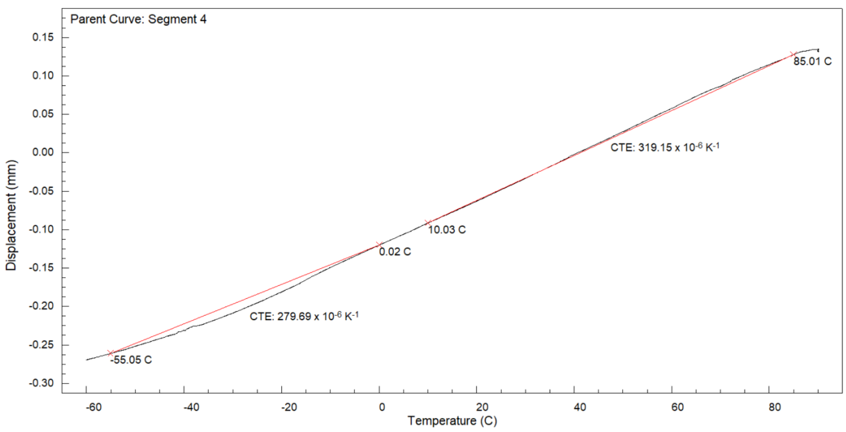

Figure 11: Thermomechanical Analysis of ZOTEK T 75 foam measured between -60°C and +90°C, using a heating rate of 5°C/min in accordance with ISO 11359-2:2021.

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