# CONSIDERATIONS OF THERMAL EXPANSION IN ENCAPSULANTS

All encapsulating resins, as well as all other electrical grade materials, have their own unique rate of expansion and contraction over a range of temperatures. This is referred to as the Coefficient of Thermal Expansion (CTE).

Most frequently it is measured as the coefficient of *linear* thermal expansion. A few manufacturers will report their products in terms of the coefficient of *volumetric* thermal expansion. Fortunately, there is a rough correlation between the volumetric and linear coefficients of thermal expansion which helps to simplify the confusion. Generally, the volumetric coefficient is approximately three times that of the linear coefficient.

The importance of an encapsulating resin's CTE is that it usually differs to some degree with the CTE of the materials it encapsulates. If the differential between the CTEs is sufficiently large enough, then stress can result between the encapsulating resin and the other components.

When this problem occurs, it can show up as one or more of the following:

1. Loss of adhesion to a case wall which leaves a void space and, therefore, an avenue for moisture penetration.
2. A shear stress to a substrate surface or compressive forces which fracture a component. Parts can be ripped or torn free from their proper positioning.
3. A fracture of the encapsulant itself. In the instance of rigid encapsulants, this is most likely to occur where resin is in a thick section or at points or corners of the encapsulant.

Listed below is a selection of the CTEs of a variety of encapsulating resins and electrical/electronic construction materials. Notice the broad range over which they fall.

<u>Selecting an Encapsulant</u>

Since many electrical/electronic materials are of particularly low CTEs, or at least lower than the CTEs of encapsulating resins, it would appear that selecting a rigid, highly filled epoxy would be the best solution for all encapsulating applications. In many instances, this is the correct selection. With their low CTE, rigid, highly filled epoxies thermal cycle similarly enough to the other materials in the electrical/electronic unit that insufficient stress develops to cause harm. However, often the encapsulant must provide more stress relief. In these instances, a more flexible encapsulant, even though it has a higher CTE, may be the solution.

**CTEs OF COMMON ENCAPSUATION RESINS AND OTHER ASSEMBLY MATERIALS**

(*expressed in* **x $10^{-6}$ in/in/C** *or commonly as* **ppm**)

| | |
|---|---|
| Steel | 10-12 |
| Gold | 14 |
| Copper | 16-18 |
| Silver | 19 |
| Aluminum | 24-27 |
| Silicon | 3 |
| Glass | 2-12 |
| Polystyrene | 60-80 |
| ABS | 75-90 |
| Nylon | 80-120 |
| Polypropylene | 110-120 |
| | |
| Rigid, 66% mineral filled epoxy | 25-30 |
| Rigid, 50% mineral filled epoxy | 30-40 |
| Rigid, unfilled epoxy | 45-60 |
| Semi-rigid, filled epoxy | 100-125 |
| Semi-rigid, unfilled epoxy or polyurethane | 100-150 |
| Flexible, filled silicone | 175-200 |
| Flexible, unfilled silicone or polyurethane | 200-250 |
| Unfilled silicone gel | 250-350 |
| | |

It should not be assumed that a material which is flexible at room temperature will remain just as flexible at a low temperature. Many flexible epoxies, and a few polyurethanes, become surprisingly rigid at low temperatures. For instance, a Shore A-50 epoxy encapsulant is quite flexible at room temperature, but becomes a Shore D-50 at -20°F. If so, it may not provide a sufficient stress relief when operating at low temperatures.

In its place, another encapsulant which maintains its flexibility at lower temperatures might be a better selection. Certain polyurethanes and most of the silicone encapsulants have particularly low glass transition temperatures. (See below.) Polymark has specifically formulated them to be appropriate for low temperature flexibility and stress relief.

There are also applications where the selection of an encapsulant with an intermediate CTE is appropriate. A filled, semi-rigid epoxy encapsulant would be an example of such a resin. This type of encapsulant provides intermediate levels of CTE with a degree of flexibility to provide some stress relief. This sort of encapsulant is also appropriate in packages where a more durable outer surface is required than a soft silicone or polyurethane can offer.

Case Wall Adhesion

While the cause of case wall adhesion problems may be due to a CTE which is too high, occasionally the solution is to improve the opportunity to get a good bond. Making sure the material to which the epoxy must adhere is clean and making use of encapsulants with improved adhesive strengths will help to obtain a better bond to the material. Epoxies, or course, are traditionally the strongest adhesives. While most silicones have lower cohesive strength, with a heat cure, can produce a quite strong bond as well. Similarly, polyurethanes can be formulated to produce very strong bonds to many surfaces.

Glass Transition Temperature

The glass transition temperature (Tg) of the encapsulating  resin is that temperature at which the resin changes from a rigid to more flexible condition. At this temperature, the resin’s CTE also changes. As would be expected, the CTE below the Tg is lower than the CTE about it.

Rigid, heat resistant epoxies have high Tgs. Flexible urethanes and silicones actually have Tgs below room temperature. The “heat distortion point” often coincides with the Tg. Similar to the correlation between the linear and volumetric expansion mentioned earlier in this article, the CTE also will essentially triple in value once a material is heated above the Tg.

In applications where the encapsulated unit will operate at temperatures on both sides of the Tg, it may be necessary to understand the dual CTEs and that the resin is stressing the unit at different rates on either side of the Tg.