# HDT *versus* Tg - Don't be misled

## What is the difference between the HDT and the Tg of a material?

Over many years I have noticed that many manufacturers and suppliers of resin systems confuse these two properties and usually quote whichever is the higher to give a better impression of the material's properties.

This may be lack of knowledge on their part but may also be in the hope that customers will not know the difference, and will think that the material has more useful properties than it actually has.

This Technical Bulletin explains what these terms mean, the difference between them, and why one is so much more useful than the other.

### 1. HDT - Heat Distortion Temperature

The Heat Distortion Temperature is the temperature at which a sample of the cured material bends by a fixed distance under a fixed load. It gives an indication of how the material behaves when stressed at elevated temperatures. A material can have only "one" HDT.

A useful way of thinking about the HDT is as a measure of the "stiffness" of the material as the temperature increases. All polymeric materials soften as the temperature increases and the Heat Distortion Temperature puts a single figure on this for a given material.

Harder materials generally have higher HDT's than soft materials because harder materials are stiffer at higher temperatures.

The reason for this stiffness is because hardness is a function (mainly) of the polymer chains to move when a load is applied. In hard materials the polymer chains are more tightly crosslinked and so more restricted than in soft materials, where they can move more easily. Heat increases the mobility of all polymer chains and so even a hard material with highly restricted polymer chains will deform if heated enough.

The HDT puts a standard, single value on this property because it is measured under fixed and controlled conditions.

It obvious, therefore, that any ingredients in the formulation that contribute to the stiffness of the material will increase the HDT. Likewise any additive that increases the ease with which the polymer chains can move will decrease the HDT.

The HDT can therefore can be greatly affected by the judicious use of reinforcements, fillers and plasticisers, the first two of which usually increase the HDT (by making it harder and stiffer under heat), the latter usually decreases it by making the material softer and more flexible.

This Newsletter is written by Dr Graham Hunt as a discussion document for the topic mentioned.
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## 2. Tg - Glass Transition Temperature

The Glass Transition Temperature, or Tg, of a material is entirely different. The Tg is the temperature at which a crystalline or semi-crystalline portion of the material melts and changes from an ordered structure to an amorphous structure.

This is analogous to water changing from the "crystalline" structure of ice to the "amorphous" structure of liquid water at 0°C. In this example the Tg of water would be 0°C.

However the structures of polymer systems are much more complicated than water. The polymer chains that form the solid product align and orientate themselves to give a number of different structures, from highly crystalline and well-ordered areas analogous to crystalline domains in metals, to highly random amorphous areas with no regular structure at all. The amount of each of these structures and the degree of crystallinity or randomness in the morphology of a given product depends hugely on the chemical make-up of the material and the processing conditions that have produced it.

It is not difficult to appreciate, therefore, that some materials could easily have more than one crystalline phase, depending on the chemical make-up. Therefore it is possible for a material to have more than one Tg, one for each structurally distinct crystalline phase.

It is also clear, from the definition of Tg in the first paragraph, that the Tg of a given material is *primarily* dependant upon the polymer structure, or morphology, and not on any other ingredients in the formulation such as fillers, reinforcements, plasticizers and so on. Consequently Glass Transition Temperature (or Temperatures) for a material are little affected by the overall formulation.

## 3. Conclusion

Clearly these two properties measure very different features of a material and are not interchangeable. Of course the crystalline domains of a material (if present) can contribute to the HDT by being areas of restricted movement, but that is all.

Nor are they comparable. The HDT of one material CANNOT be compared with the Tg of another. Yet, despite this, many datasheets will quote whichever figure gives the best impression of the material and users frequently regard these properties as interchangeable.

As far as most applications are concerned the property that is important is the HDT. A user wants to know how the material will withstand elevated temperatures, how much will it soften, will it be usable at elevated temperatures? HDT gives an indication of this feature, Tg alone does not.

Ask yourself "Do I need to know the temperature at which a small portion of the polymer structure turns from crystalline to amorphous?" Surely a far more useful question is "How will this material deform as the temperature increases?"

So, now you know the difference between these two properties, you can better assess whether or not the information provided to you on datasheets meets your need, or whether the manufacturer is trying to mislead you with inappropriate data.

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