European Sealing Association e.V.

Elastomeric & Polymeric Seals Division

A Statement on Low Temperature Sealing

As an elastomer is cooled it will be become steadily stiffer and more brittle as the polymer chains move closer together and the energy in the system reduces. Once the polymer chains no longer have sufficient energy to move past one another the material undergoes a phase change called the glass transition (T_g), as in this state the material is glassy and brittle. As effective sealing often relies, at least in part, on the reaction force generated by an applied squeeze or pressure, this means that sealing at or around the glass transition needs to be approached with care. It is perhaps worth noting that in contrast to the irreversible degradation that occurs at elevated temperature, the changes that occur on cooling are completely reversible.

Several standards are used to attempt to quantify the performance of elastomeric materials at low temperatures by measurement of a variety of physical properties. Techniques include Dynamic Mechanical Thermal Analysis (DMTA or DMA), Differential Scanning Calorimetry (DSC), Temperature Retraction, Torsional Modulus, Bending and Impact Testing.

Although these tests can provide useful comparison, the major drawback is meaningful application to real world situations. Some members of the ESA Elastomeric and Polymeric Seals Division (E&PSD) have carried out testing in which a pressure was applied to a system in which a seal had already been established and then cooling until failure. At lower pressures sealing just below T_g is achievable and at higher pressures sealing integrity is maintained at well below $T_{g.,}$ Although interesting this regime is applicable to only very few sealing situations. The members of the ESA therefore worked on a new method, in which a seal is cooled before applying any pressure. The full method is outlined in one of several papers produced by the ESA , one of which can be found on the E&PSD section of the ESA website. In short, temperature is reduced to a point just above T_g at which a seal can be formed, temperature is then dropped in 5°C increments until a seal cannot be formed; then increased in 1°C increments until a seal is formed once more; this temperature is reported as the Minimum Sealing Temperature.

This method produced results that were very close to T_g however it was found that rate at which cooling took place had a large influence on results, this is discussed in more detail in the paper found on the ESA website. The slower the cooling rate the lower the sealing temperature and this is reflected in the real world experience of the E&PSD members. Additionally the testing does not consider previous excursion to high temperatures, differing design considerations, and chemical exposure.

Therefore the original objective of deriving a definitive test for low temperature operating limit guidance has not as yet been achieved, primarily due to the significant effect of cooling/heating rate on the end result. To attempt to set tight limits on this parameter was felt to be impractical, and indeed counter-productive as in real applications these rates can vary widely.
However the basic test methodology has been shown to be effective and could be used to qualify materials for specific applications. It is strongly recommended that such testing is carried out in specific cases where low temperature performance is of importance.

The E&PSD would encourage end-users to discuss low temperature sealing requirements with their seal suppliers and test houses to allow realistic test regimes to be developed for applications where materials are intended to be used at the limits of their capabilities.