TECHNICAL PAPER

"Low Temperature Sealing in High Pressure Applications"

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There are many choices in elastomer materials based on criteria such as chemical and heat resistance. Often the low temperature performance of an elastomer is overlooked or the data describing the performance may not be understood fully by the end user. Complicating elastomer material selection is the pressure of the application. High pressures are known to increase an elastomer's glass transition temperature which decreases the low temperature sealing performance.

First let us describe some of the low temperature tests for elastomers that may commonly be found on a materials datasheet or a specification for a seal or O-ring.

- Temperature of Retraction, ASTM Test Method D1329 measures the temperature at which a stretched elastomer specimen will retract a given percentage. Typically 10% retraction is noted and called the TR10.
- Brittleness point, ASTM Test Method D2137 measures the lowest temperature an elastomer sample will not break or fracture when struck.
- Glass Transition or Tg via DSC, ASTM Test Method D7426 uses a precise analytical instrument called a differential scanning calorimeter or DSC. This instrument measures the specific heat capacity of a material and can indicate the transition of an elastomer from a glass-like material to a material with flexible properties. Most often the inflection point of the transition region is reported as the Tg. The midpoint and onset of the transition region may also be reported depending on sealing situation.
- Brittleness point is a temperature that is often reported on material datasheets for seals but this reported temperature does not really indicate low temperature sealing performance. Brittleness point is not the same as the glass transition but rather a measure of resistance to a striker at a given temperature. Both temperature of retraction and Tg are better indicators of low temperature sealing as they indicate a level of elasticity of the material which is required to maintain a robust seal in application.

The ASTM tests are conducted at ambient atmospheric pressure and the effect of pressure on a sealing material should be considered if low temperature sealing integrity is critical. Higher pressures will increase the glass transition temperature. It is generally thought that pressure decreases the free volume of a polymer thereby reducing molecular mobility. Direct laboratory measurements may not be possible but there are a few published papers that may be consulted which are beyond the scope of this technical report (Dlubek & et al, 2004) (McKenna, 1989).

As a rule of thumb, for every 5 MPa (725 psi) increase in pressure the Tg increases by 1°C.

The table below shows how high pressure may change an elastomer's ability to seal at various temperatures.

Pressure	Glass Transition °C, TFE/P	Glass Transition °C, Standard FFKM	Glass Transition °C, Low Temp FFKM
Atmospheric	+2	+5	-30
5. 1 MPa (750 psi)	+3	+6	-29
68.9 MPa (10,000 psi)	+15	+17	-17
137.8 MPa (20,000 psi)	+29	+32	-3
206.8 MPa (30,000 psi)	+43	+46	+11

Table 1 shows the theoretical effect of pressure on the glass transition of an elastomer at the "rule of thumb" relationship of 5 MPa to 1°C". As the pressure increases the Tg increases. This means that an elastomer's ability to seal in low temperature decreases with pressure. In high pressure applications, it is advisable to consider the change in glass transition and use a material that will seal the entire range of the specified temperature and pressure range.

There are many real world applications where high pressure can create sealing problems at low temperatures. Deep-water subsea oil and gas equipment is often in seawater temperatures between 0°C and 3°C requiring sealing materials that have elastic properties below this temperature. Compounding the problem of the low temperature of the seawater are the high pressures from deep wells which requires careful consideration of the polymer's ambient and glass transition temperatures when a seal is fully pressurized.

Precision Polymer Engineering (PPE) offers several low temperature materials for high pressure Oil and gas applications. EnDura® V91A is a very low temperature fluoroelastomer (FKM) with an ambient glass transition of -40°C and Perlast® Ice G90LT is a perfluoroelastomer (FFKM) with a glass transition of -30°C. Both EnDura V91A and Perlast Ice G90LT resist rapid gas decompression, oils, fuels, seawater, hydraulic control fluids, and a variety of fluids found in oil and gas environments. Both materials and engineering sealing experts at PPE are able to assist with specific sealing designs for low temperature high pressure applications.

References

Dlubek, G., & et al. (2004, November 17). Temperature and Pressure Dependence of the Free Volume in Fluoroelastomers from PALS and PVT Experiments. *Macromolecules, 107*(37), pp. 6606-6618.

McKenna, G. B. (1989). Glass Formation and Glassy Behavior. In C. Booth, & C. Price, *Comprehensive Polymer Science* (Vol. 2, pp. 311-362). Oxford: Pergamon.