Stress Relaxation:

A Conversation Between Our Chief Chemist (Bruce Anderson) and Our Vice President of Sales, (Mike Cordek) and a customer of Ashtabula Rubber

Customer: "What types of things can cause rubber seals to fail?"

Bruce: "We have seen examples of field failures occurring due to improper choice of materials. When a particular polymer type has a history of working in a known environment, it is often called out strictly with polymer type and durometer hardness.

If the part needs to provide long-term sealing, it needs to be designed to do so. Within a given family of polymer, a wide range of compression stress relaxation (CSR) properties can be observed. If not properly specified, one nitrile (for example) may not work nearly as well as another for CSR in a particular environment.

In one case, a neoprene compound was used for years, but with changing environments and part designs, the poor CSR characteristic of the compound posed serious problems after several months in the field due to the seal leaking (water). When a rubber with better CSR resistance was specified, it solved the problem. In another series of parts, we went from a sulfur-cured compound to a more heat stable compound, which provided significantly better CSR properties, and solved a leak problem. In another application, parts that were being dynamically stressed (in extension), were improved by going to a tighter cure system, which improved the dynamic stress relaxation, and maintained the required load over time.

However, your particular seal failed because compression stress relaxation properties were ignored in the initial specifications."

Customer: "Will you shed some more light on 'compression stress relaxation'?"

Bruce: "Sure. Rubber has the unique ability to store elastic energy. This property is why rubber is often used in compression as a seal or gasket.

Stress relaxation is the reduction of force the rubber exerts over time, when subjected to constant strain (compression or extension). The process of stress relaxation takes place due to both physical and chemical changes in the rubber matrix. The initial (reversible) change is caused by relaxation of the polymer chains and fillers. Long-term (irreversible) changes occur due to chemical reactions over time. Each polymer type, and specific formula used within a given family of polymer, will react differently to the environment in which it is used. The formula used for a specific application will have a significant affect on how the part works. The design of the part will also have a significant affect on how the part works.

ASTM D-6147 and GMNA 3922 TP are examples of tests used to perform compression stress relaxation (CSR) measurements. These tests provide CSR measurements (over time) in a variety of environments, which enables direct comparisons of various formulations, and test sample geometries. The information is a significant tool for design engineers who need to know how much force a given rubber sample exerts on the surfaces it is sealing under the given test conditions over time. With this information, Arrhenius plots can be used to provide service life predictions, where a minimum "load to seal" is needed for a particular design. Material designers can also use this as a tool for continuous improvement of compound designs."

Mike: "How does CSR fit in with other specifications?"

Bruce: "You can pick the right polymer, hardness (durometer), tensile strength, elongation and compression set, but if you have not factored in the CSR, you have a variable in your equation that needs to be given as much weight as all the other factors. The wrong CSR spec may, eventually, rear its ugly head and cause field failures that cost way more to replace than initial design, development and testing would have cost."

Mike: "In what other types of applications should an engineer consider CSR?"

Bruce: "Anywhere the rubber part is a compression seal that needs long-term durability in extreme field conditions."