Measurement and Prediction of Creep

To quantitatively design for creep deformation, *creep curve* information is desired. This is a measurement of plastic strain versus time for a particular loading, such as a tensile test. However, this information is not always easy to obtain. We often wish materials that are subject to creep conditions to be in service for long periods of time – 20 years, for example. It is not practical to test under exact service conditions. Prediction of creep deformation often involves extrapolation of shorter time-measured data, with associated uncertainties. With glasses and polymers, it is sometimes possible to accelerate deformation with increased stresses, and then to piece together several shorter time measurements into a master curve through a procedure of *time-temperature superposition*.

Creep curves are usually divided into three regions. The initial data show strain hardening in a region labeled primary creep. The final data show a rapidly increasing strain rate leading to fracture in a region labeled, appropriately, tertiary creep. It is the middle region that is of most interest, where we often observe an extended time with a constant steady-state creep rate. The numerical value of this steady-state creep rate depends on both the experimental temperature T and the level of applied stress σ. Steady-state creep has successfully been fitted with an equation of the form:

$$\dot{\varepsilon}_{SS} = A\left[\sigma^{n}\right]\left[e^{-Q/RT}\right]$$

The parameters {*A, n, Q*} collectively specify the steady-state creep rate for a particular material.

If you are a student of chemistry, you will recognize the temperature-dependent bracket as an example of the *Arrhenius law*. This law also describes the rates of chemical reactions, including oxidation and corrosion. Q is called the *activation energy* of the process, and R is the ideal gas constant (8.314 J/mol•K). The temperature T is in degrees kelvin. It is important to note that, as an exponential relationship, this is a rapidly varying function. It is not unusual for a change of 20 ºC to double (or halve) the rate. The first bracket of a power law dependence on stress is also rapidly varying. The *creep exponent n* is typically between 3 and 8 numerically.