

## Usage Temperatures of Piezoceramic Materials

### Usage Temperature

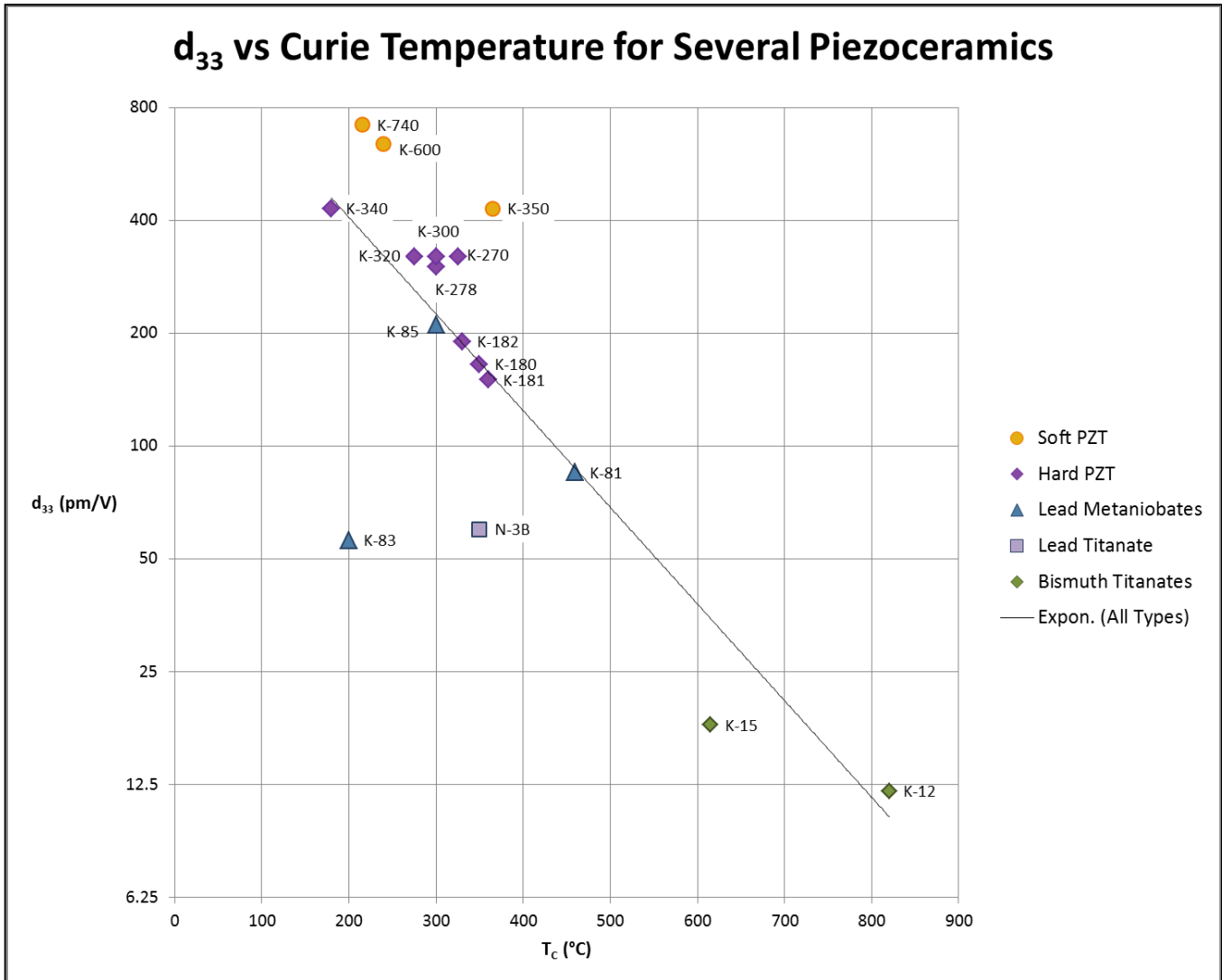
The temperature at which a piezoceramic is to be used is often the most important consideration for what material is the best choice for the application. As a rule of thumb, the usage temperature should not exceed about one half of the Curie temperature (as measured in °F or °C,) of the piezoceramic.

The Curie temperature can be thought of as the “melting” temperature of the piezoelectric properties, because the material cannot sustain polarization at a temperature above the Curie temperature. Polarization, a critical property of a piezoceramic, is possible because the ceramic has a very asymmetric crystal lattice. When piezoelectric materials are warmed above their Curie temperature, the lattice structure becomes more symmetric and the net polarization disappears.

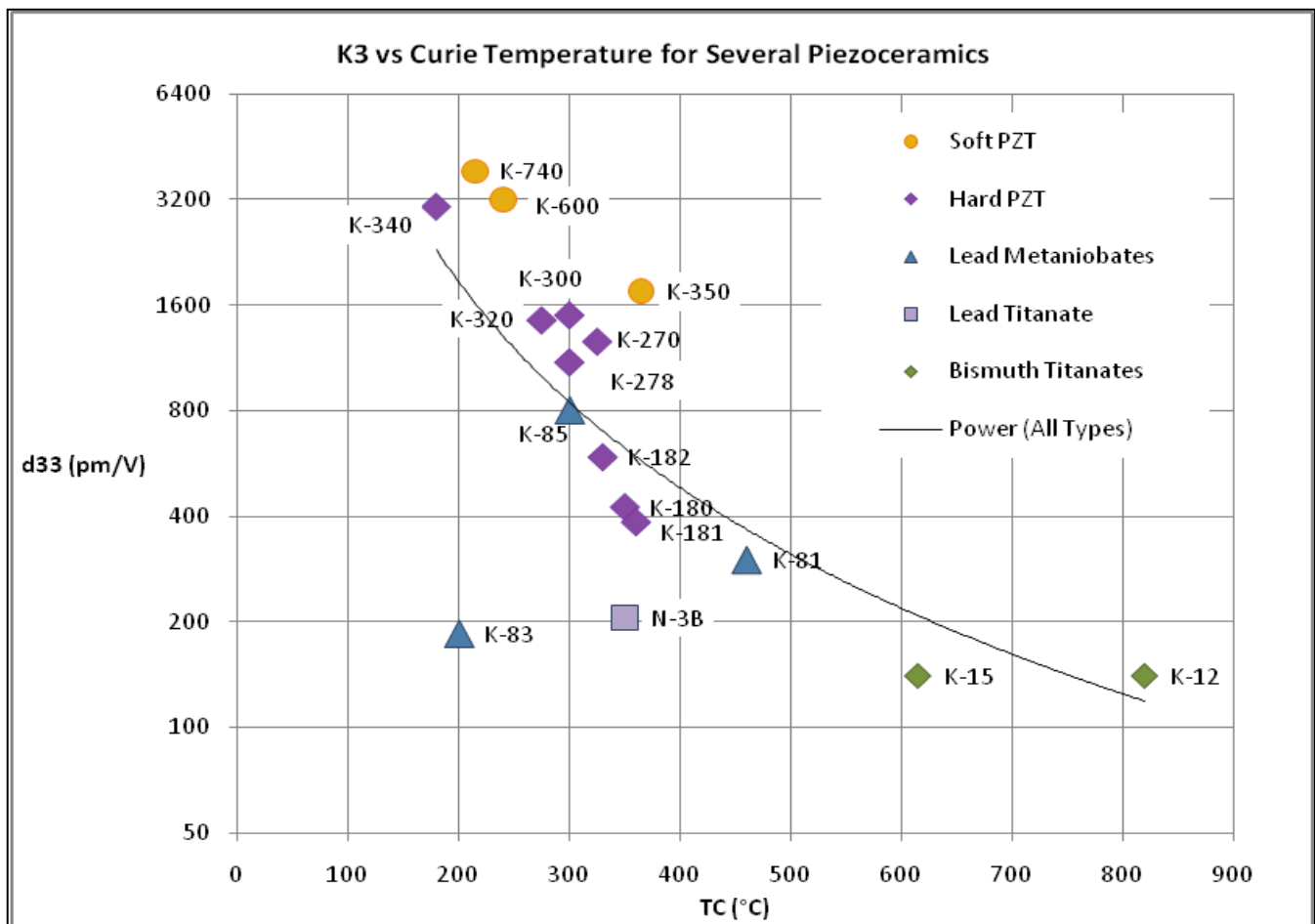
When a piezoceramic is polarized, its entropy is decreased. Thermal variations increase the entropy of systems, thus causing the part to depolarize over time. The rate of this depolarization increases with temperature. If a polarized part is like a clean house, then increasing the temperature is like having kids in the house... the more the kids, the faster the cleanliness decays.

The usage temperature is a function of the ambient temperature for the application and the amount of energy that will be dissipated in the ceramic. For many low-power applications, the application temperature is essentially the same as the ambient application. For some high-power applications, the temperatures in the ceramic may be tens or even hundreds of degrees above the ambient temperature. In general, as the application temperature decreases, the properties of the piezoceramic that can be used for the application improve.

There is a trade-off between the piezoelectric properties and Curie temperatures. To demonstrate this, the room temperature coupling coefficient  $d_{33}$  (Figure 1) and the room temperature dielectric constant  $K_3$  (Figure 2) of several Piezo Technologies' piezoceramics are plotted versus their Curie temperatures. Note:  $d_{33}$  is a measure of the response of piezoelectric materials to applied voltage.  $K_3$  is the ratio of the capacitance of a piezoceramic to an equivalent structure formed with vacuum between the electrodes.



**Figure 1: Coupling Coefficient  $d_{33}$  vs Curie Temperature.** Note the logarithmic scale of the vertical axis. Plotted here are many of the piezoceramics in Piezo Technologies' materials product line.



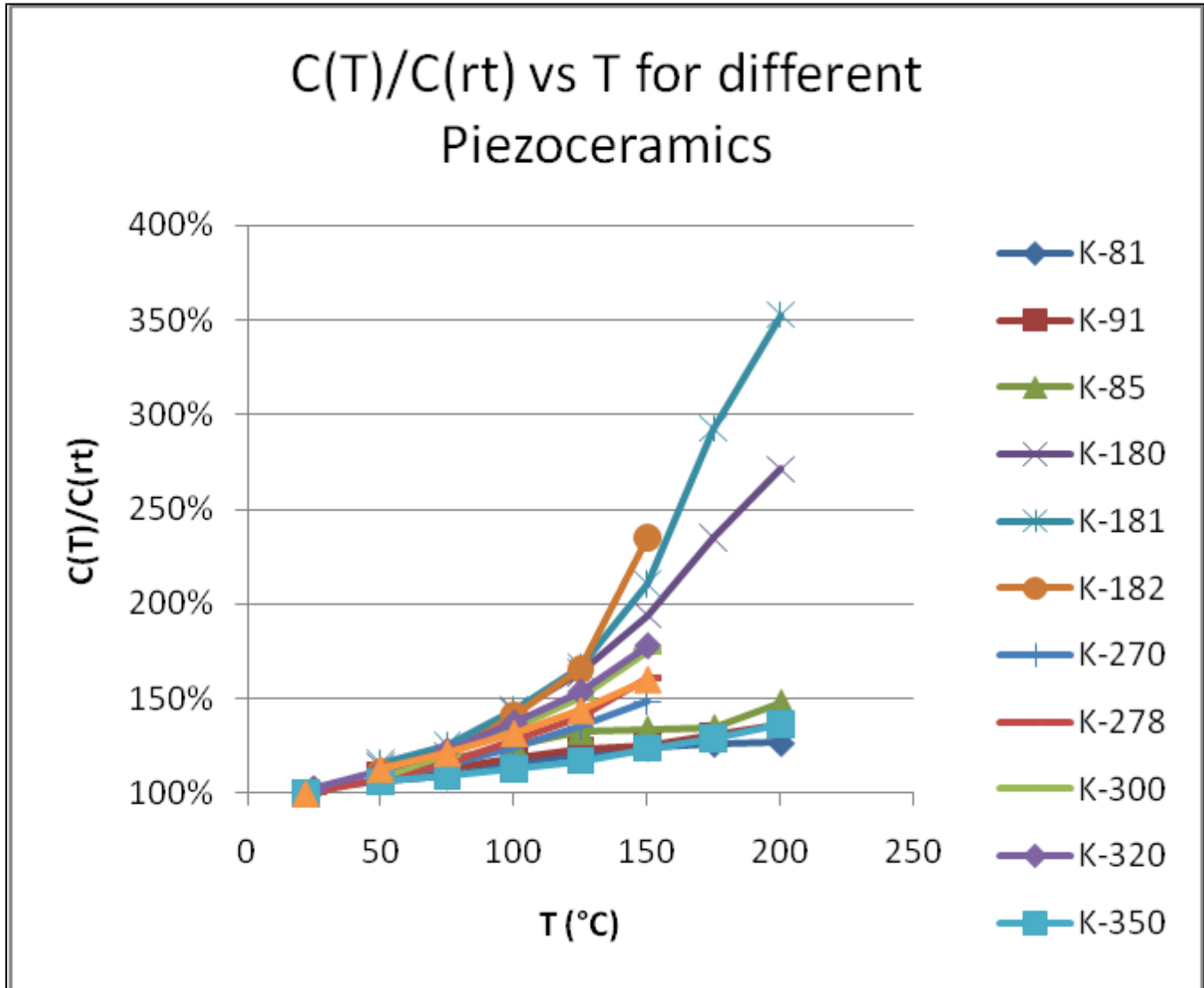
**Chart 2: Free Dielectric Constant  $K_3$  versus Curie Temperature.** Note the logarithmic scale of the vertical axis. Plotted here are many of the piezoceramics in Piezo Technologies' materials product line.

### Temperature Dependence of some Key Properties

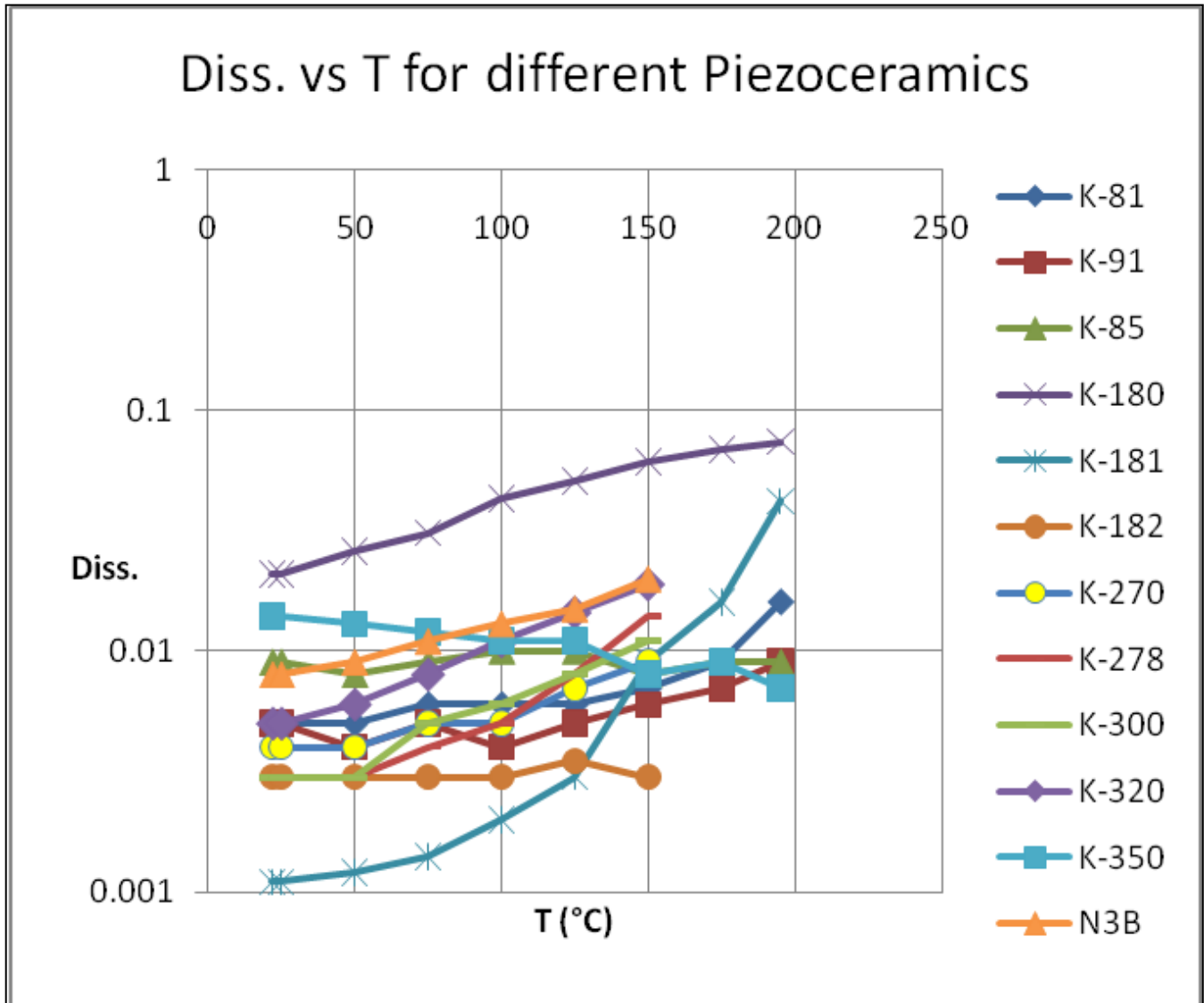
Many of the properties of piezoceramics change significantly as the material is heated. For example, the capacitance of piezoceramics rises to a maximum at the Curie temperature (this is how  $T_c$  is measured) and values can be 50% or more higher at the top of its workable temperature range than at room temperature. Figure 3 shows a curve of the normalized capacitance (capacitance at temperature / capacitance at room temperature) for several Piezo Technologies' piezoceramics. Figure 4 shows how the dissipation changes with temperature. While the dissipation increases for many materials, the soft

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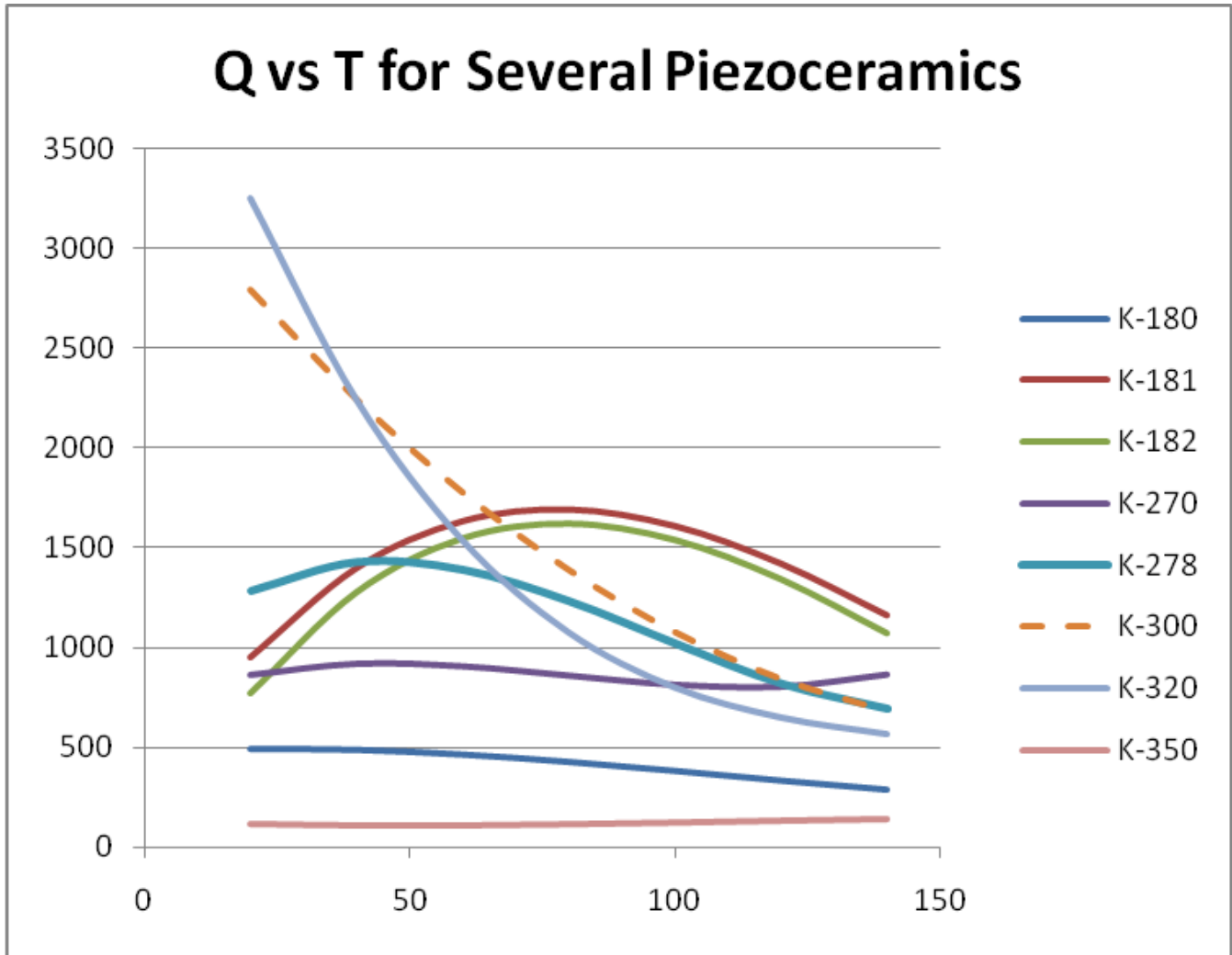
PZT K-350 shows a decrease as temperatures go up. Figure 5 shows a comparison of the quality factor Q versus temperature for several piezoceramic materials (again, using Piezo Technologies materials for comparison purposes). Some materials have Q values which decrease with temperature and others show a peak, while the soft PZT K-350 has a Q which continues to rise across the measurement range.



**Figure 3: Normalized Capacitance versus Temperature for Several Piezoceramics.**  
Plotted here are many of the piezoceramics in Piezo Technologies' materials product line.



**Figure 4: Dissipation versus Temperature for Several Piezoceramics.** Dissipation values are measured at 1 kHz. For some materials (especially Piezo Technologies' K-180), the dissipation drops rapidly as frequency is increased. Plotted here are many of the piezoceramics in Piezo Technologies' materials product line.



**Figure 5: Quality Factor versus Temperature for Several Piezoceramics.** Plotted here are many of the piezoceramics in Piezo Technologies' materials product line.

### **About Piezo Technologies**

Piezo Technologies is a world leader in providing custom-engineered Medical Ultrasonic Transducers for Air-In-Line / AIL (also referred to as Bubble Detectors or Air Sensors), as well as Diagnostic, Treatment and Therapeutic Medical Devices. We handle every aspect of our ultrasonic transducer development in-house, from piezoceramic materials formulations to fully integrated medical transducer assemblies - meeting the exact requirements of your next generation medical device. Learn more at [www.PiezoTechnologies.com](http://www.PiezoTechnologies.com).