CHAPTER 7
Thermal Behavior

Refractories are high-temperature resistant ceramics used in applications such as metal casting. The most effective refractories have low values of thermal expansion and thermal conductivity. (Courtesy of R. T. Vanderbilt Company, Inc.)

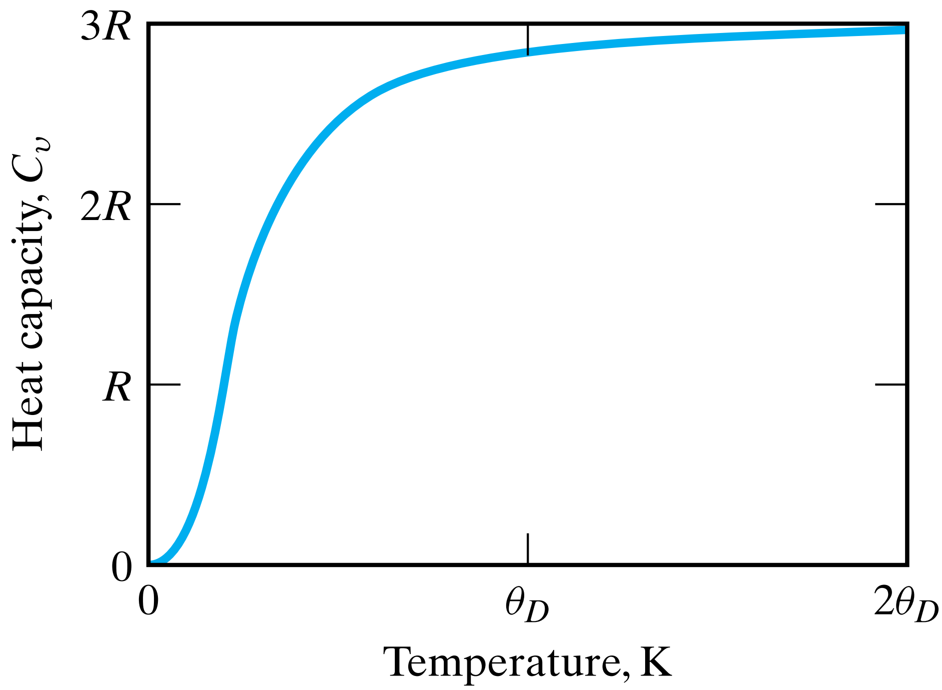


Figure 7-1 *The temperature dependence of the heat capacity at constant volume, C_v. The magnitude of C_v rises sharply with temperature near 0 K and, above the Debye temperature (θ_D), levels off at a value of approximately 3R.*

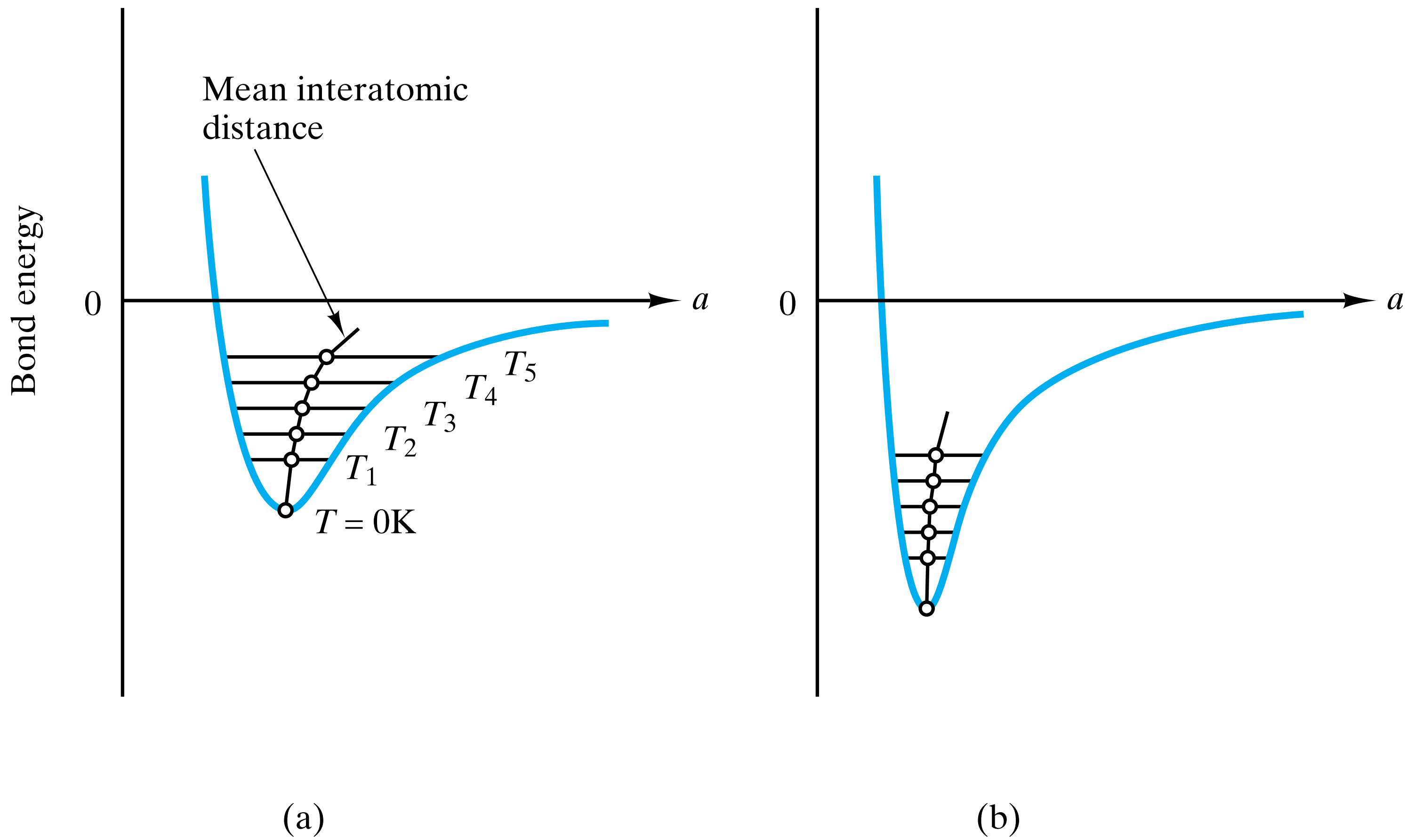


Figure 7-2 *Plot of atomic bonding energy versus interatomic distance for (a) weakly bonded solid and (b) a strongly bonded solid. Thermal expansion is the result of a greater interatomic distance with increasing temperature. The effect (represented by the coefficient of thermal expansion in Equation 7.4) is greater for the more asymmetrical energy well of the weakly bonded solid. As shown in Table 7.3, melting point and elastic modulus increase with increasing bond strength.*

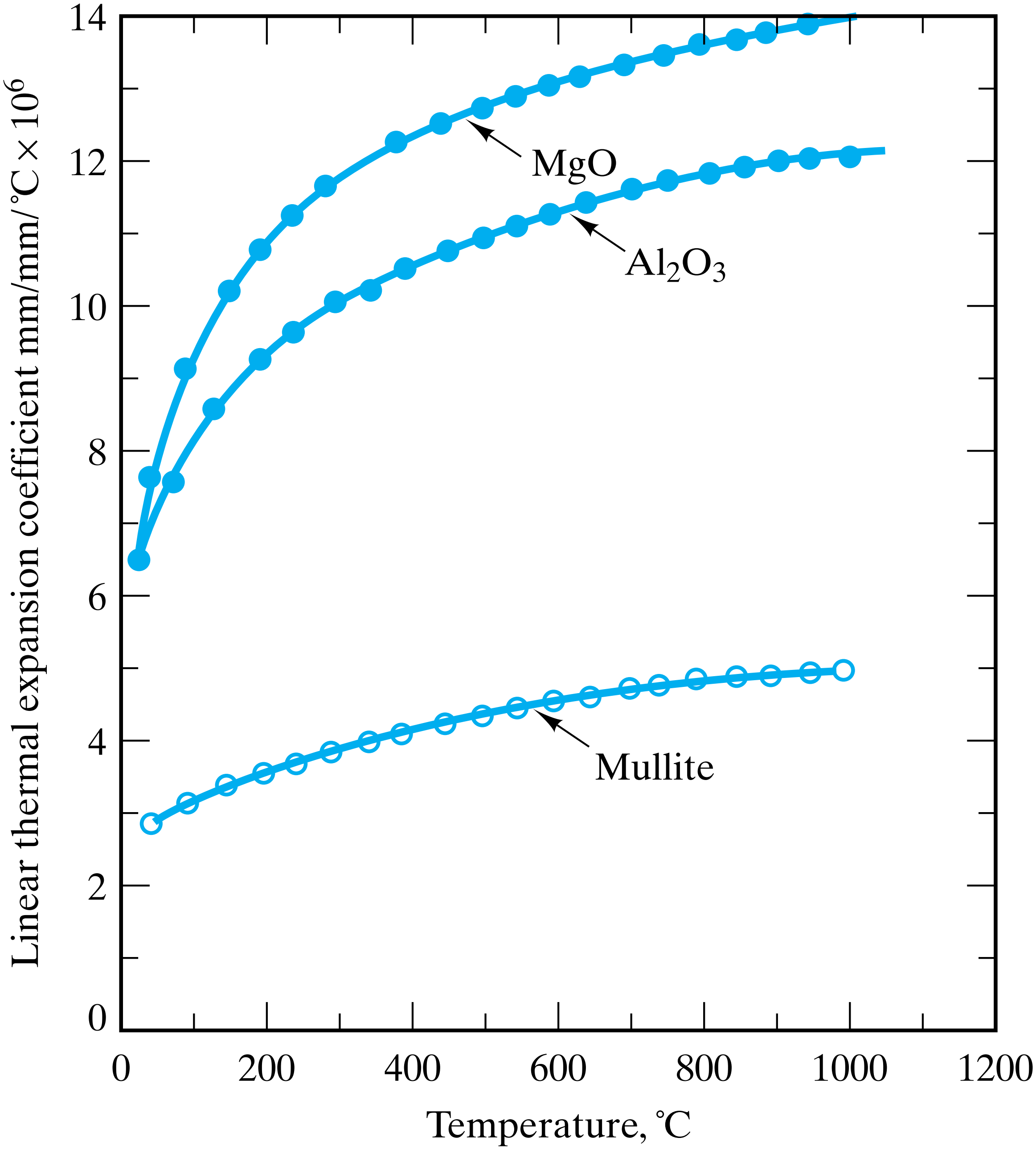
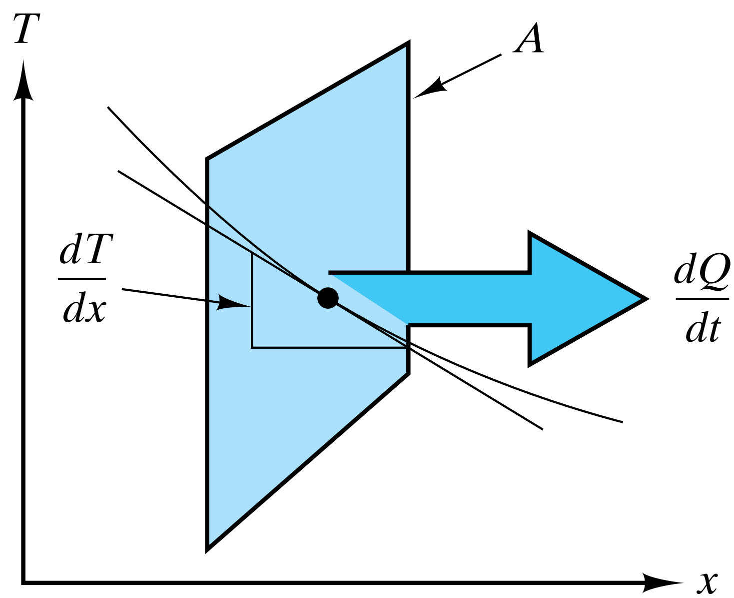


Figure 7-3 *Linear thermal expansion coefficient as a function of temperature for three ceramic oxides (mullite* $= 3Al_2O_3 \cdot 2SiO_2$*). (From W. D. Kingery, H. K. Bowen, and D. R. Uhlmann,* Introduction to Ceramics, *2nd Ed., John Wiley & Sons, Inc., New York, 1976.)*



$$k = -\frac{(dQ/dt)}{A(dT/dx)}$$

Figure 7-4 *Heat transfer is defined by Fourier's law (Equation 7.5).*

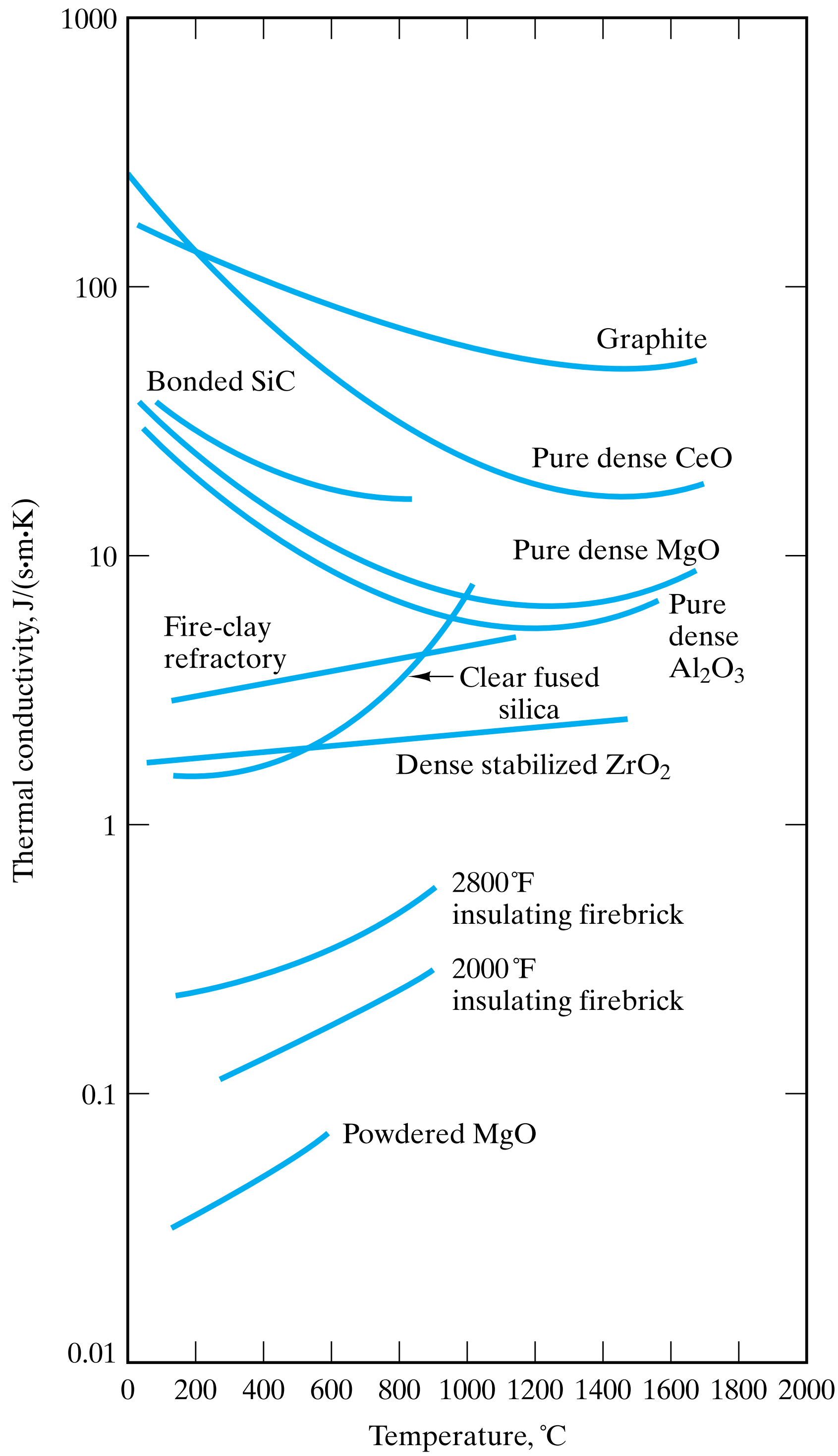


Figure 7-5 *Thermal conductivity of several ceramics over a range of temperatures. (From W. D. Kingery, H. K. Bowen, and D. R. Uhlmann,* Introduction to Ceramics, *2nd Ed., John Wiley & Sons, Inc., New York, 1976.)*

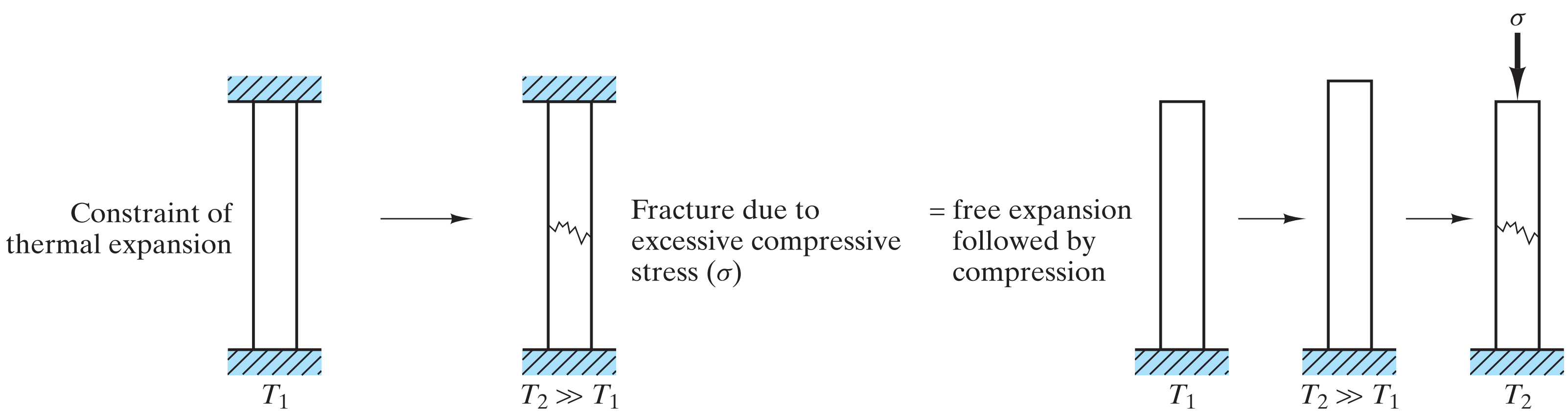


Figure 7-6 *Thermal shock resulting from constraint of uniform thermal expansion. This process is equivalent to free expansion followed by mechanical compression back to the original length.*

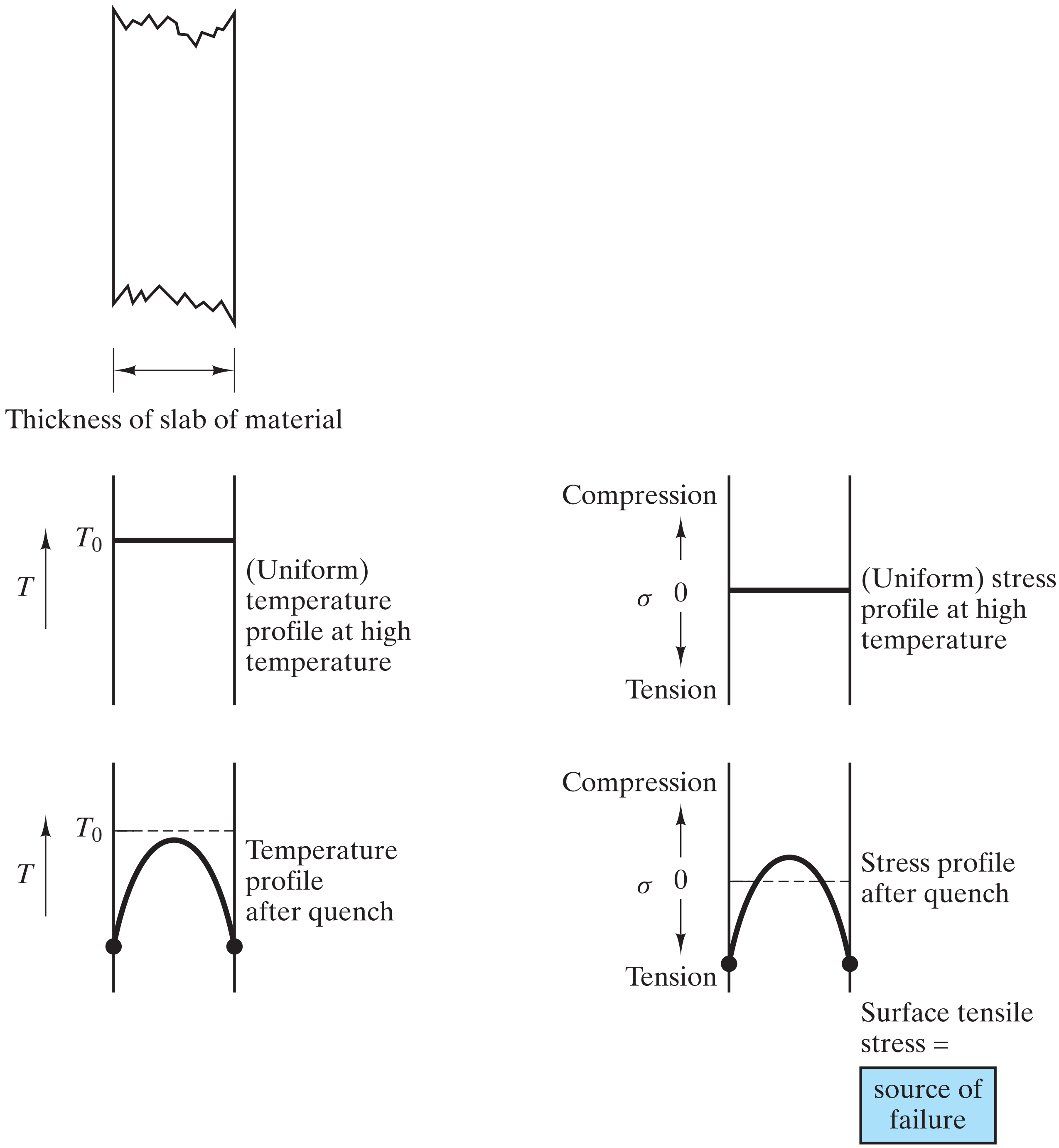


Figure 7-7 *Thermal shock resulting from temperature gradients created by a finite thermal conductivity. Rapid cooling produces surface tensile stresses.*

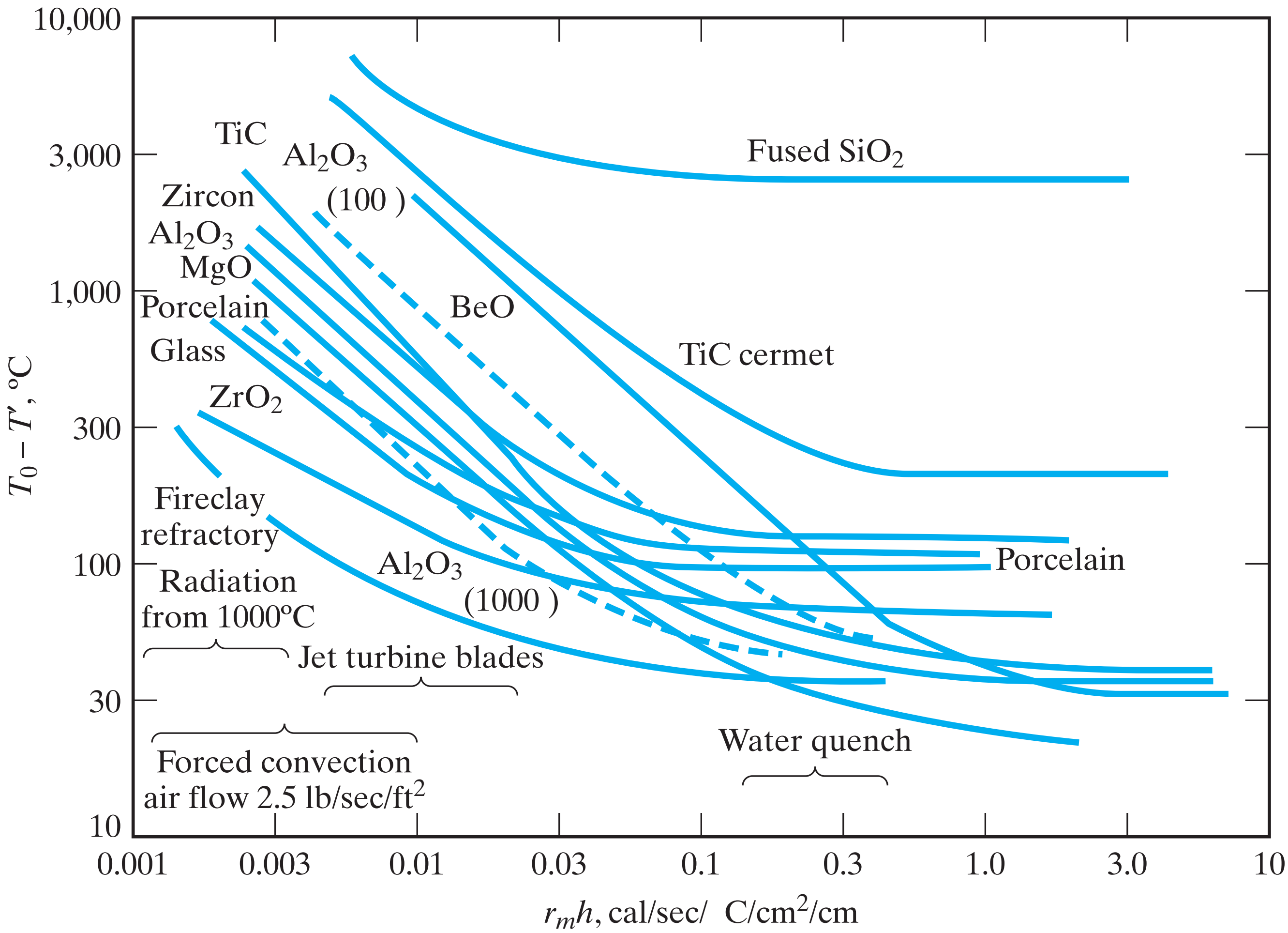


Figure 7-8 *Thermal quenches that produce failure by thermal shock are illustrated. The temperature drop necessary to produce fracture ($T_0 - T'$) is plotted against a heat transfer parameter ($r_m h$). More important than the values of $r_m h$ are the regions corresponding to given types of quench (e.g., "water quench" corresponds to an $r_m h$ around 0.2 to 0.3). (From W. D. Kingery, H. K. Bowen, and D. R. Uhlmann,* Introduction to Ceramics, *2nd Ed., John Wiley & Sons, Inc., New York, 1976.)*