5S.1
Graphical Representation of One-Dimensional, Transient Conduction in the Plane Wall, Long Cylinder, and Sphere

In Sections 5.5 and 5.6, one-term approximations have been developed for transient, one-dimensional conduction in a plane wall (with symmetrical convection conditions) and radial systems (long cylinder and sphere). The results apply for $Fo > 0.2$ and can conveniently be represented in graphical forms that illustrate the functional dependence of the transient temperature distribution on the Biot and Fourier numbers.

Results for the plane wall (Figure 5.6*a*) are presented in Figures 5S.1 through 5S.3. Figure 5S.1 may be used to obtain the *midplane* temperature of the wall, $T(0, t) \equiv T_o(t)$, at any time during the transient process. If T_o is known for particular values of *Fo* and *Bi*, Figure 5S.2 may be used to determine the corresponding temperature at any location *off the midplane.* Hence Figure 5S.2 must be used in conjunction with Figure 5S.1. For example, if one wishes to determine the surface temperature ($x^* = \pm 1$) at some time *t*, Figure 5S.1 would first be used to determine T_o at *t*. Figure 5S.2 would then be used to determine the surface temperature from knowledge of T_o. The

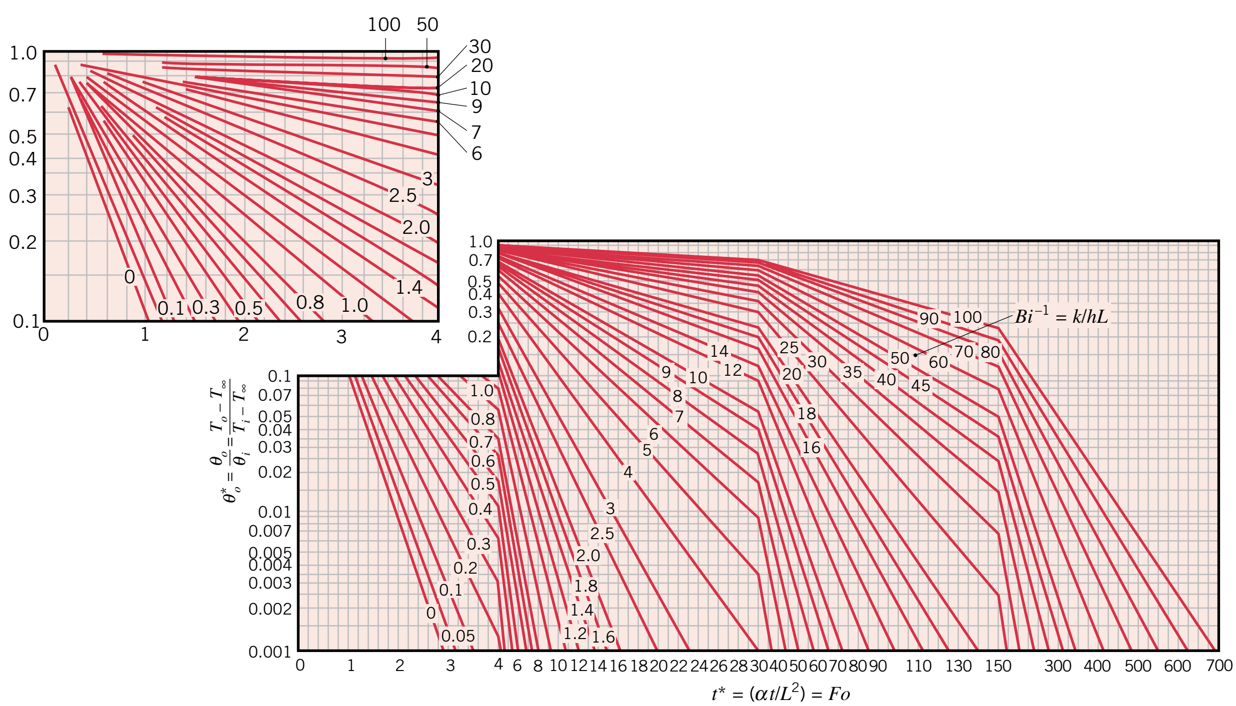

FIGURE 5S.1 Midplane temperature as a function of time for a plane wall of thickness 2*L* [1]. Used with permission.

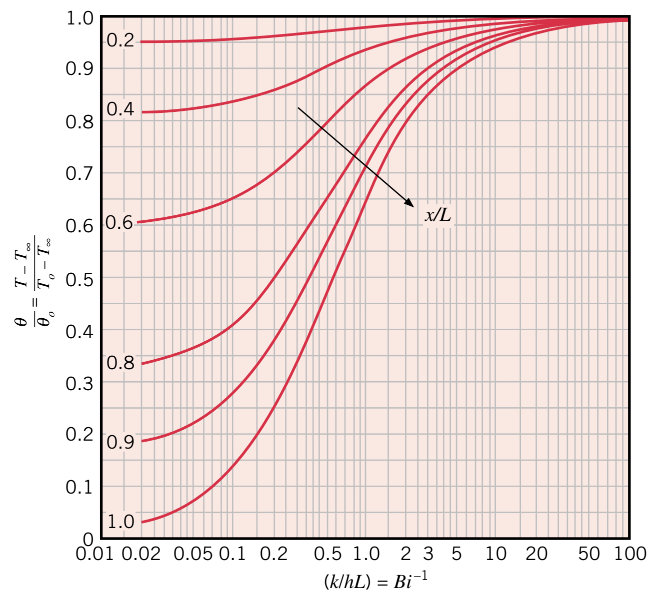

FIGURE 5S.2 Temperature distribution in a plane wall of thickness 2L [1]. Used with permission.

procedure would be inverted if the problem were one of determining the time required for the surface to reach a prescribed temperature.

Graphical results for the energy transferred from a plane wall over the time interval t are presented in Figure 5S.3. These results were generated from Equation 5.46. The dimensionless energy transfer Q/Q_o is expressed exclusively in terms of Fo and Bi.

Results for the infinite cylinder are presented in Figures 5S.4 through 5S.6, and those for the sphere are presented in Figures 5S.7 through 5S.9, where the Biot number is defined in terms of the radius r_o.

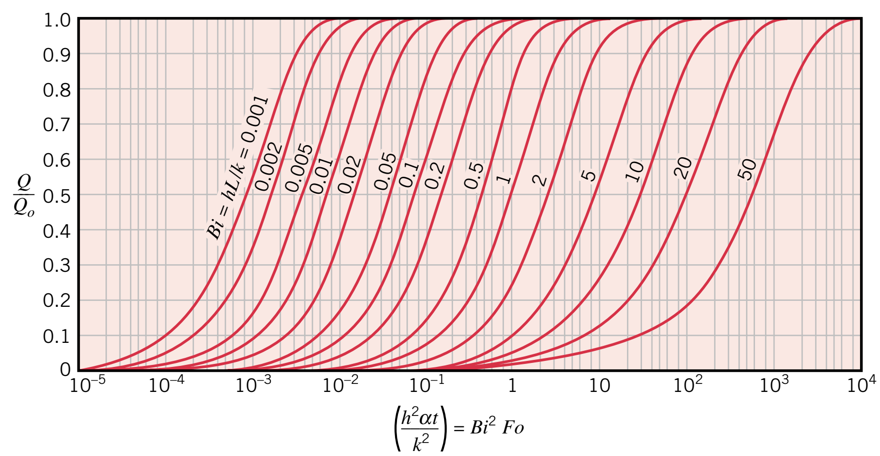

FIGURE 5S.3 Internal energy change as a function of time for a plane wall of thickness 2L [2]. Adapted with permission.

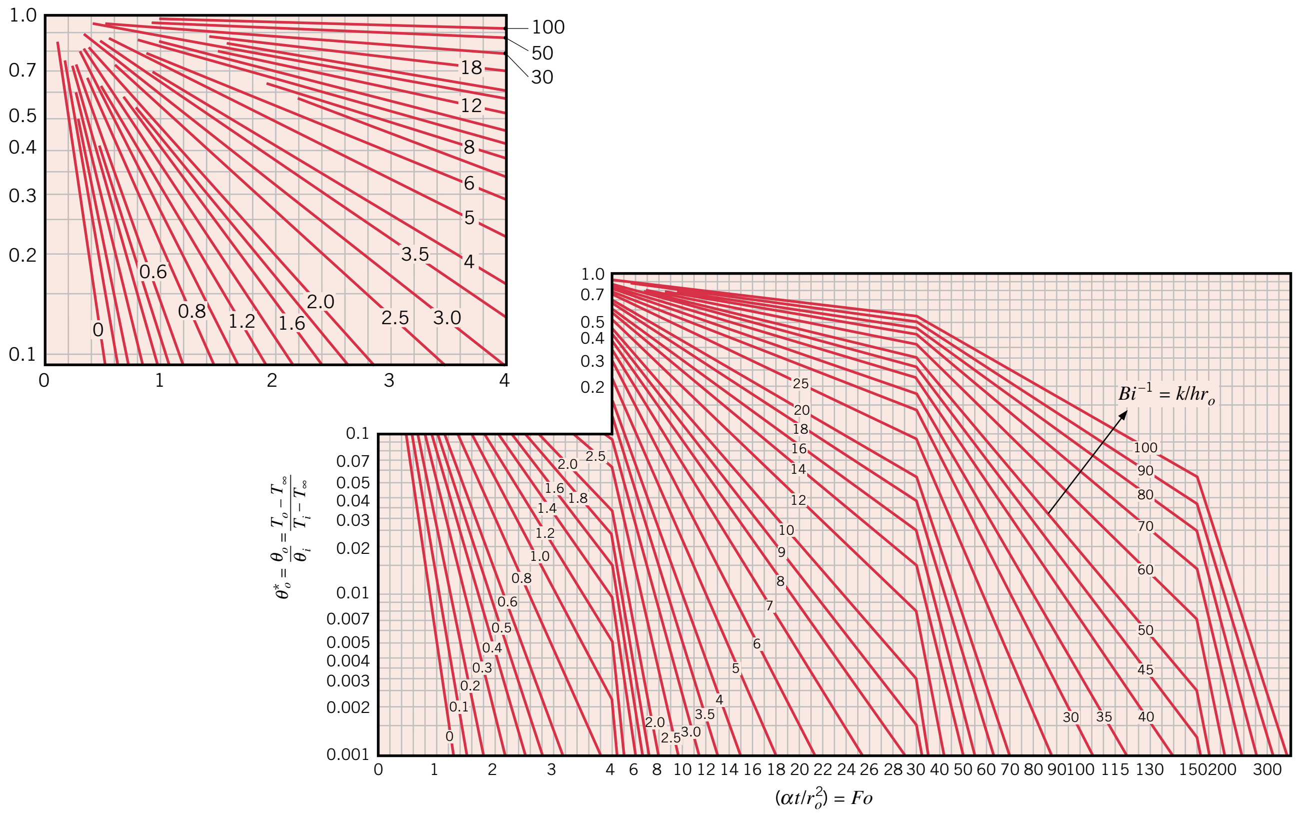

FIGURE 5S.4 Centerline temperature as a function of time for an infinite cylinder of radius r_o [1]. Used with permission.

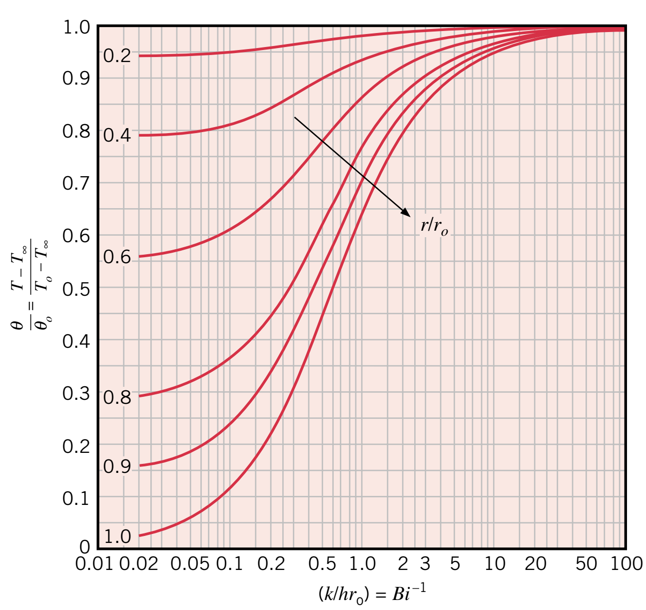

FIGURE 5S.5 Temperature distribution in an infinite cylinder of radius r_o [1]. Used with permission.

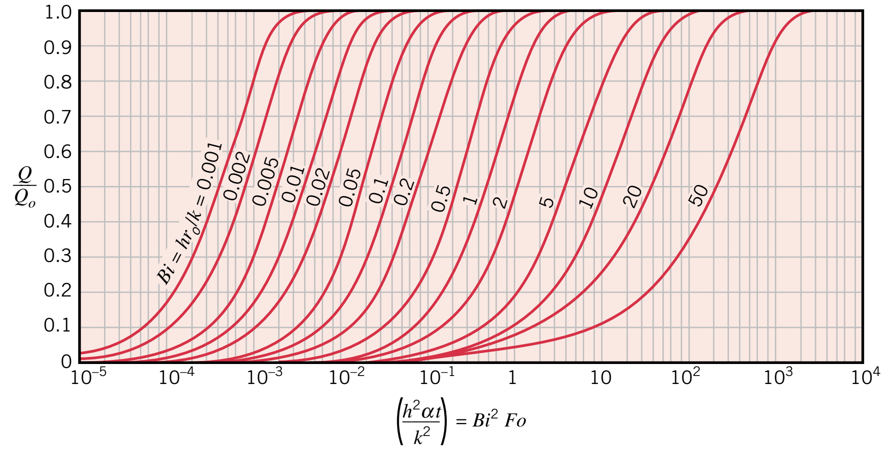

FIGURE 5S.6 Internal energy change as a function of time for an infinite cylinder of radius r_o [2]. Adapted with permission.

The foregoing charts may also be used to determine the transient response of a plane wall, an infinite cylinder, or sphere subjected to a *sudden change in surface temperature*. For such a condition it is only necessary to replace T_∞ by the prescribed surface temperature T_s and to set Bi^{-1} equal to zero. In so doing, the convection coefficient is tacitly assumed to be infinite, in which case $T_\infty = T_s$.

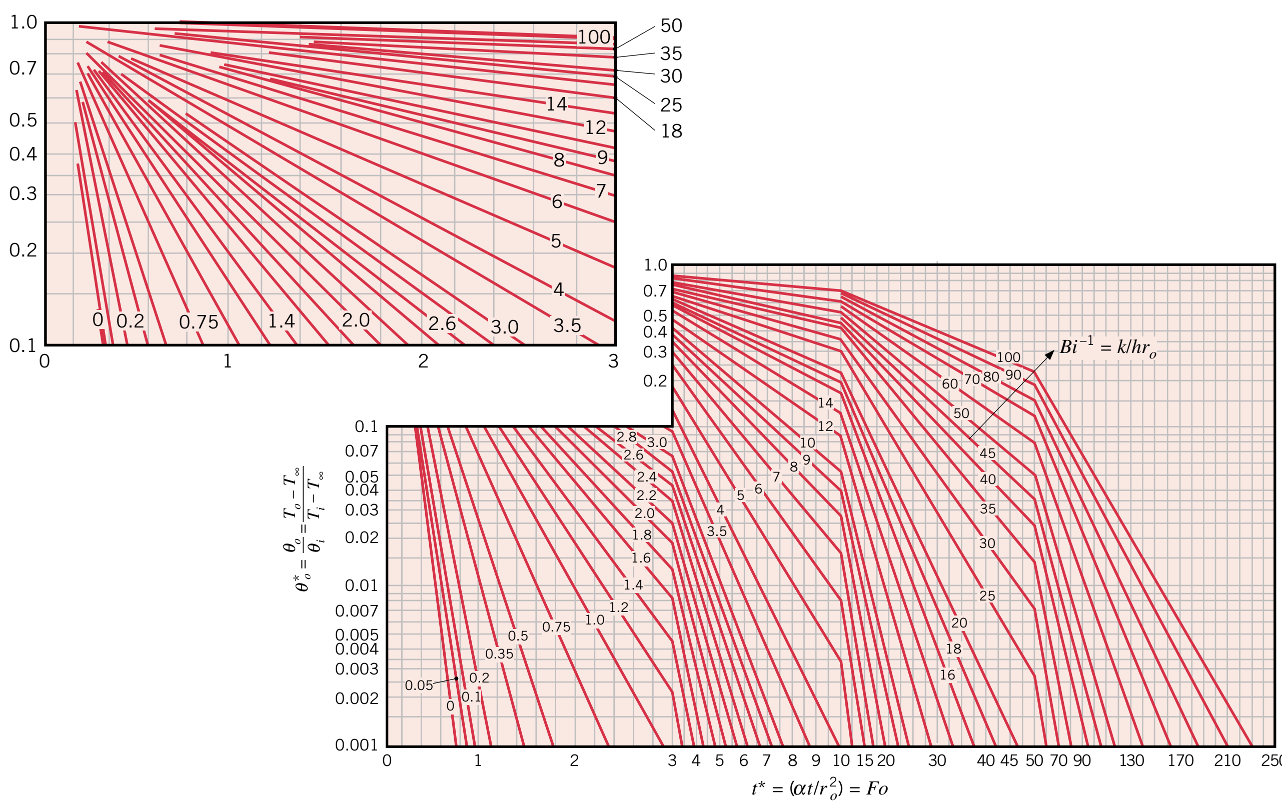

FIGURE 5S.7 Center temperature as a function of time in a sphere of radius r_o [1]. Used with permission.

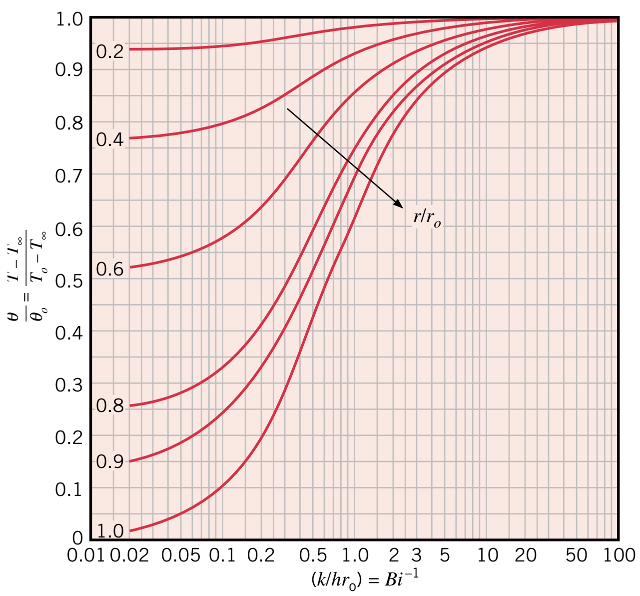

FIGURE 5S.8 Temperature distribution in a sphere of radius r_o [1]. Used with permission.

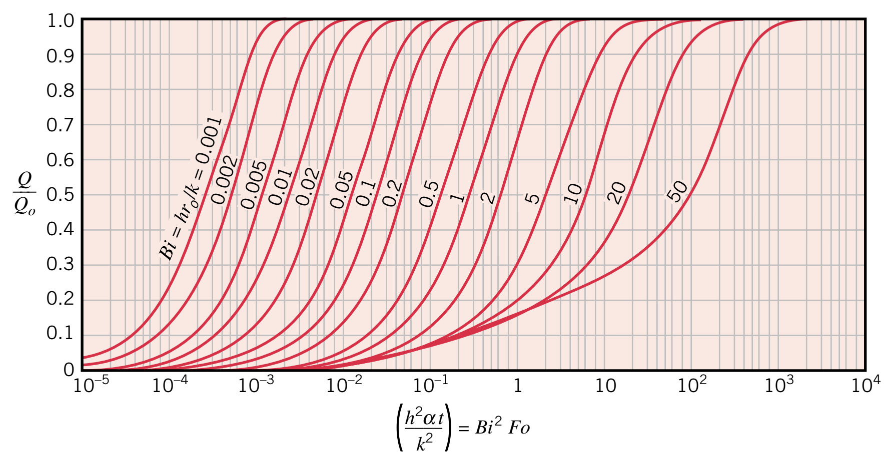

FIGURE 5S.9 Internal energy change as a function of time for a sphere of radius r_o [2]. Adapted with permission.

References

1. Heisler, M. P., *Trans. ASME,* **69,** 227–236, 1947.
2. Gröber, H., S. Erk, and U. Grigull, *Fundamentals of Heat Transfer,* McGraw-Hill, New York, 1961.