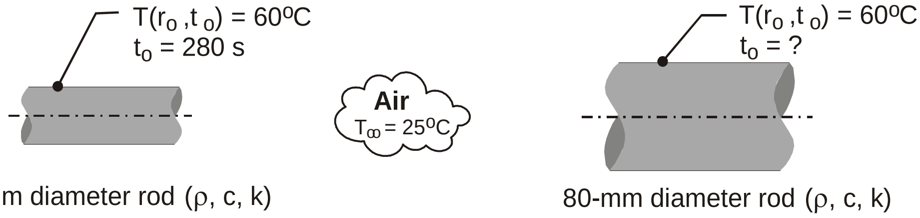
PROBLEM 5.68

KNOWN: Long rods of 40 mm- and 80-mm diameter at a uniform temperature of 400°C in a curing oven, are removed and cooled by forced convection with air at 25°C. The 40-mm diameter rod takes 280 s to reach a *safe-to-handle* temperature of 60°C.

FIND: Time it takes for a 80-mm diameter rod to cool to the same safe-to-handle temperature. Comment on the result? Did you anticipate this outcome?

SCHEMATIC:



ASSUMPTIONS: (1) One-dimensional radial (cylindrical) conduction in the rods, (2) Constant properties, and (3) Convection coefficient same value for both rods.

PROPERTIES: Rod (*given*): $\rho = 2500$ kg/m^3, c = 900 J/kg·K, k = 15 W/m·K.

ANALYSIS: Not knowing the convection coefficient, the Biot number cannot be calculated to determine whether the rods behave as spacewise isothermal objects. Using the relations from Section 5.6, Radial Systems with Convection, for the infinite cylinder, Eq. 5.52, evaluate $Fo = \alpha t / r_o^2$, and knowing $T(r_o, t_o)$, a trial-and-error solution is required to find $Bi = h r_o/k$ and hence, h. Using the *IHT Transient Conduction* model for the *Cylinder*, the following results are readily calculated for the 40-mm rod. With $t_o = 280$ s,

$$Fo = 4.667 \qquad Bi = 0.264 \qquad h = 197.7\ W/m^2 \cdot K$$

For the 80-mm rod, with the foregoing value for h, with $T(r_o, t_o) = 60$°C, find

$$Bi = 0.528 \qquad Fo = 2.413 \qquad t_o = 579\ s$$ <

COMMENTS: (1) The time-to-cool, t_o, for the 80-mm rod is slightly more than twice that for the 40-mm rod. Did you anticipate this result? Did you believe the times would be proportional to the diameter squared?

(2) The simplest approach to explaining the relationship between t_o and the diameter follows from the lumped capacitance analysis, Eq. 5.13, where for the same θ/θ_i, we expect $Bi \cdot Fo_o$ to be a constant. That is,

$$\frac{h \cdot r_o}{k} \times \frac{\alpha t_o}{r_o^2} = C$$

yielding $t_o \sim r_o$ (not r_o^2).