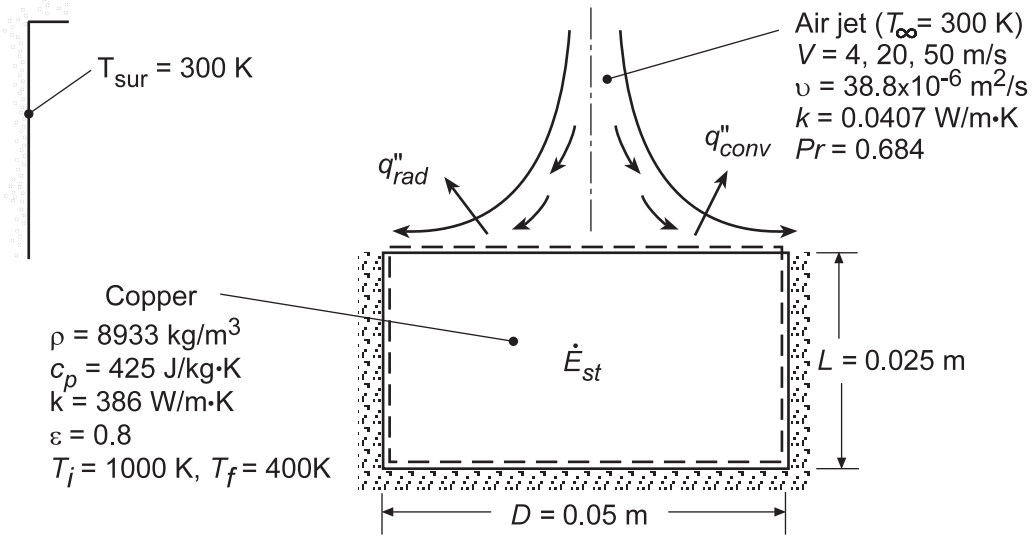
PROBLEM 6.15

KNOWN: Convection correlation and temperature of an impinging air jet. Dimensions and initial temperature of a heated copper disk. Properties of the air and copper.

FIND: Effect of jet velocity on temperature decay of disk following jet impingement.

SCHEMATIC:



ASSUMPTIONS: (1) Validity of lumped capacitance analysis, (2) Negligible heat transfer from sides and bottom of disk, (3) Constant properties.

ANALYSIS: Performing an energy balance on the disk, it follows that $\dot{E}_{st} = \rho V c\, dT/dt = -A_s\left(q''_{conv} + q''_{rad}\right)$. Hence, with V = A_sL,

$$\frac{dT}{dt} = -\frac{\bar{h}\left(T - T_\infty\right) + h_r\left(T - T_{sur}\right)}{\rho cL}$$

where, $h_r = \varepsilon\sigma\left(T + T_{sur}\right)\left(T^2 + T_{sur}^2\right)$ and, from the solution to Problem 6.14,

$$\bar{h} = \frac{k}{D}\overline{Nu}_D = \frac{k}{D}\left(1 + \frac{2a}{n+2}\right)0.814\,Re_D^{1/2}\,Pr^{0.36}$$

With a = 0.30 and n = 2, it follows that

$$\bar{h} = \left(k/D\right)0.936\,Re_D^{1/2}\,Pr^{0.36}$$

where Re_D = VD/ν. Using the *Lumped Capacitance Model* of IHT, the following temperature histories were determined.

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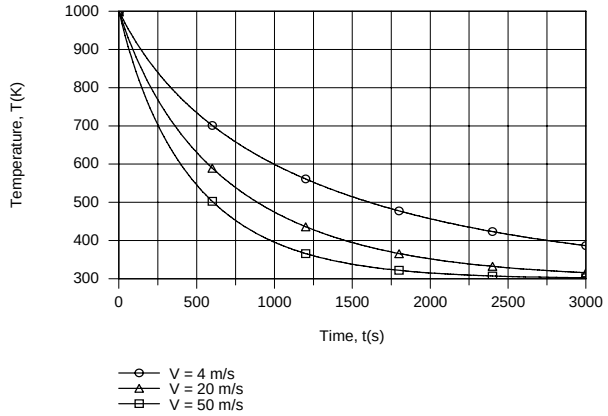
PROBLEM 6.15 (Cont.)



The temperature decay becomes more pronounced with increasing V, and a final temperature of 400 K is reached at t = 2760, 1455 and 976s for V = 4, 20 and 50 m/s, respectively.

COMMENTS: The maximum Biot number, Bi = $\left(\bar{h} + h_r\right) L \Big/ k_{Cu}$, is associated with V = 50 m/s (maximum $\bar{h}$ of 169 W/m^2·K) and t = 0 (maximum h_r of 64 W/m^2·K), in which case the maximum Biot number is Bi = (233 W/m^2·K)(0.025 m)/(386 W/m·K) = 0.015 < 0.1. Hence, the lumped capacitance approximation is valid.