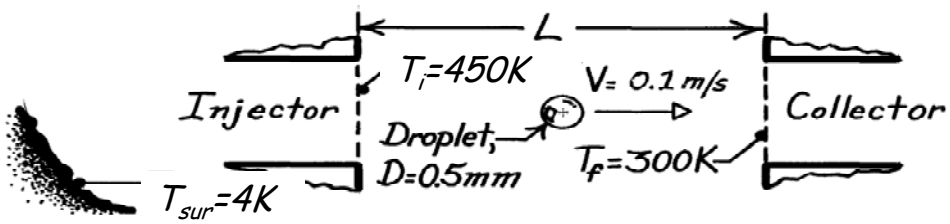
PROBLEM 5.36

KNOWN: Droplet properties, diameter, velocity and initial and final temperatures.

FIND: Travel distance and rejected thermal energy.

SCHEMATIC:



ASSUMPTIONS: (1) Constant properties, (2) Negligible radiation from space.

PROPERTIES: Droplet (given): $\rho = 885$ kg/m^3, $c = 1900$ J/kg·K, $k = 0.145$ W/m·K, $\varepsilon = 0.95$.

ANALYSIS: To assess the suitability of applying the lumped capacitance method, use Equation 1.9 to obtain the maximum radiation coefficient, which corresponds to $T = T_i$.

$$h_r = \varepsilon\sigma T_i^3 = 0.95\times 5.67\times 10^{-8}\,\text{W/m}^2\cdot\text{K}^4(450\text{K})^3 = 4.91\ \text{W/m}^2\cdot\text{K}.$$

Hence

$$\text{Bi}_r = \frac{h_r\left(r_o/3\right)}{k} = \frac{\left(4.91\ \text{W/m}^2\cdot\text{K}\right)\left(0.25\times 10^{-3}\ \text{m}/3\right)}{0.145\ \text{W/m}\cdot\text{K}} = 0.0028$$

and the lumped capacitance method can be used. From Equation 5.19,

$$t = \frac{L}{V} = \frac{\rho c\left(\pi\ D^3/6\right)}{3\varepsilon\left(\pi\ D^2\right)\sigma}\left(\frac{1}{T_f^3}-\frac{1}{T_i^3}\right)$$

$$L = \frac{\left(0.1\ \text{m/s}\right)885\ \text{kg/m}^3\left(1900\ \text{J/kg}\cdot\text{K}\right)0.5\times 10^{-3}\ \text{m}}{18\times 0.95\times 5.67\times 10^{-8}\ \text{W/m}^2\cdot\text{K}^4}\left(\frac{1}{300^3}-\frac{1}{450^3}\right)\frac{1}{\text{K}^3}$$

$$L = 2.26\ \text{m}. \qquad <$$

The amount of energy rejected by each droplet is equal to the change in its internal energy.

$$E_i - E_f = \rho V c\left(T_i - T_f\right) = 885\ \text{kg/m}^3\pi\frac{\left(5\times 10^{-4}\text{m}\right)^3}{6}1900\ \text{J/kg}\cdot\text{K}\left(150\ \text{K}\right)$$

$$E_i - E_f = 0.017\ \text{J}. \qquad <$$

COMMENTS: Because some of the radiation emitted by a droplet will be intercepted by other droplets in the stream, the foregoing analysis overestimates the amount of heat dissipated by radiation to space.