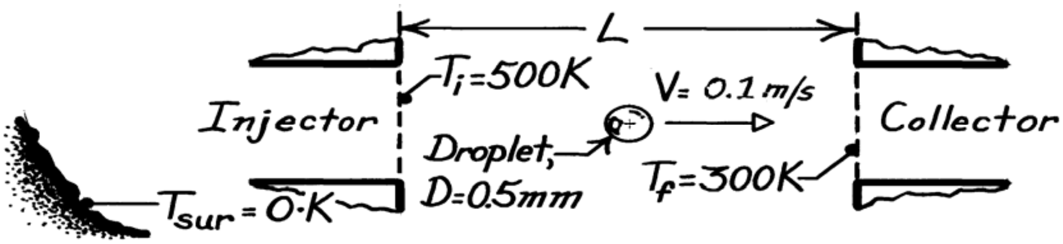
PROBLEM 5.23

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): ρ = 885 kg/m^3, c = 1900 J/kg·K, k = 0.145 W/m·K, ε = 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 $T = T_i$.

$$h_r = \varepsilon\sigma T_i^3 = 0.95\times 5.67\times 10^{-8}\,\text{W/m}^2\cdot\text{K}^4\,(500\text{ K})^3 = 6.73\text{ W/m}^2\cdot\text{K}.$$

Hence

$$\text{Bi}_r = \frac{h_r(r_o/3)}{k} = \frac{\left(6.73\text{ W/m}^2\cdot\text{K}\right)\left(0.25\times 10^{-3}\text{ m/3}\right)}{0.145\text{ W/m}\cdot\text{K}} = 0.0039$$

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

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

$$L = \frac{(0.1\text{ m/s})885\text{ kg/m}^3(1900\text{ J/kg}\cdot\text{K})0.5\times 10^{-3}\text{ m}}{18\times 0.95\times 5.67\times 10^{-8}\text{ W/m}^2\cdot\text{K}^4}\left(\frac{1}{300^3} - \frac{1}{500^3}\right)\frac{1}{\text{K}^3}$$

$$L = 2.52\text{ m.}$$ <

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

$$E_i - E_f = \rho V c\left(T_i - T_f\right) = 885\text{ kg/m}^3\pi\frac{\left(5\times 10^{-4}\text{m}\right)^3}{6}1900\text{ J/kg}\cdot\text{K}(200\text{ K})$$

$$E_i - E_f = 0.022\text{ J.}$$ <

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.