

- 1.21 A new design of an electric water heater for a house is being analyzed. The heater is to consist of a length of tubing wrapped with an electrical-conducting tape, which in turn is well insulated. When electric current passes through the tape, it heats the tube, which heats the water inside. The system is set up such that heating occurs only when water flows through the tube. The inside diameter of the tube is 20 mm, and the tube length is 3 m. The convection coefficient between the tube and water is $1000 \text{ W/(m}^2\cdot\text{K)}$, which is an average over the 3-m length, based on an effective temperature difference of 340 K (assumed constant).

(a) Determine the heat transferred to the water, and the downstream temperature of the water if the average water velocity is 1.2 m/s and its density is 1000 kg/m^3 .
 (b) If the voltage applied to the heater is 120 V, will a 15-A fuse be sufficient in the electrical line? Take the initial water temperature to be 20°C , and the specific heat of water to be $4.2 \text{ kJ/(kg}\cdot\text{K)}$.

Solution:

$$D = 20 \text{ mm} = 0.02 \text{ m}; \quad L = 3 \text{ m}; \quad h_c = 1000 \text{ W/(m}^2\cdot\text{K)}; \quad \Delta T = 340 \text{ K}; \\ V = 1.2 \text{ m/s}; \quad \rho = 1000 \text{ kg/m}^3; \quad c_p = 4200 \text{ J/(kg}\cdot\text{K)}$$

$$q = h_c A (T_w - T_i) = h_c \pi D L \Delta T = 1000 \pi (0.02)(3)(340) = 6.4 \times 10^4 \text{ W} = 64 \text{ kW}$$

$q = \dot{m} c_p (T_f - T_i)$, where T_f = final water temperature downstream, and $T_i = 20^\circ\text{C}$ = the initial water temperature.

$\dot{m} = \rho A V$ where A = cross sectional area = $\pi D^2/4$; and

$$\dot{m} = 1000 \pi (0.02)^2/4 (1.2) = 0.377 \text{ kg/s. Substituting,}$$

$$6.4 \times 10^4 = 0.377 (4200) (T_f - 20); \text{ solving,}$$

$$\boxed{T_f = 60.3^\circ\text{C}} \quad 120 \text{ V} \times 15 \text{ A} = 1800 \text{ W; } 15 \text{ A is too small.}$$

- 1.22 One way of using stove-burner heat to heat a kitchen effectively (but costly) is to utilize a hot plate. Consider a lighted gas burner. Heat is transferred from the flame to the surroundings by what mode(s) of heat transfer? Suppose a hot plate consisting of cast iron with a 6-in diameter is placed over the burner. The plate absorbs a significant fraction of the energy from the flame and, in turn, the plate radiates heat in all directions. It is observed that use of the hot plate heats the surrounding room (kitchen) very well compared to the burner alone.

Consider a hot plate over a burner. The flame temperature is 1800°F . The convection heat transfer coefficient between the rising exhaust gases and the plate is $15 \text{ Btu/(hr}\cdot\text{ft}^2\cdot^\circ\text{R)}$. The plate transfers heat to the surroundings primarily by radiation. Determine the equilibrium temperature of the plate, assuming the surroundings to be at 61°F and to behave as a black body. The plate surface has $\epsilon = 0.8$.

Engineering Heat Transfer Rathore Solution Manual

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