32.10 $80gpm$ **of** $70°F$ **water flowing in a** $200ft$ **long** $3in$ **diameter standard weight steel pipe is cooled by** $10°F$ **over the entire the length. The flow is turbulent and fully developed. The thermal conductivity of water is** $0.34\frac{Btu}{hr \cdot ft °F}$**. The Nusselt number for this application is given by:**

$$Nu = \frac{hD}{k} = 0.023 Re_D^{0.8} Pr^{0.3}$$

What is the rate of convective heat loss from the fluid?

A. $240\frac{Btu}{hr}$

B. $38,000\frac{Btu}{hr}$

C. $765,000\frac{Btu}{hr}$

D. $1,150,000\frac{Btu}{hr}$

Calculate the Reynolds Number. Use the Propeties of Water table to look up the kinematic viscosity. Use the Schedule 40 Steel Pipe table to look up the inside diameter for $3in$ nominal standard weight steel pipe. Find the velocity by using the volume flow rate and area.

$$\nu_{@70°F} = 1.059 \times 10^{-5} \frac{ft^2}{s}$$

$$Q = vA$$

$$v = \frac{Q}{A} = \frac{\left(80\frac{gal}{min}\right)\left(\frac{1ft^3}{7.48gal}\right)\left(\frac{1min}{60s}\right)}{\frac{\pi}{4}\left(\frac{3.068in}{12\frac{in}{ft}}\right)^2} = 3.47\frac{ft}{s}$$

$$Re = \frac{vD}{\nu} = \frac{\left(3.47\frac{ft}{s}\right)\left(\frac{3.068in}{12\frac{in}{ft}}\right)}{1.059 \times 10^{-5}\frac{ft^2}{s}} = 83,826$$

Calculate the Prandtl Number by using the specific heat capcity, absolute viscosity, and thermal conductivity. Multiplying by the gravitational constant, g_c, is necessary to make the units work.

$$Pr = \frac{c_p \mu}{k}$$

$$Pr = \frac{\left(1\frac{Btu}{lb_m °F}\right)\left(2.05 \times 10^{-5}\frac{lb_f \cdot s}{ft^2}\right)\left(32.2\frac{lb_m \cdot ft}{lb_f \cdot s^2}\right)}{\left(0.34\frac{Btu}{hr \cdot ft °F}\right)\left(\frac{1hr}{3600s}\right)} \approx 7$$

Calculate the Nusselt Number from the equation provided.

$$Nu = 0.023 Re_D^{0.8} Pr^{0.3} = 0.023\left(83,826\right)^{0.8}\left(7\right)^{0.3} = 358$$

Rearrange to find the convection heat transfer coefficient, h.

$$Nu = \frac{hD}{k} = 358$$

$$h = (358)\frac{k}{D} = (358)\frac{\left(0.34\frac{Btu}{hr \cdot ft^{\circ}F}\right)}{\left(\frac{3.068in}{12\frac{in}{ft}}\right)} = 476.2\frac{Btu}{hr \cdot ft^{2\circ}F}$$

Calculate the heat transfer by Convection. The area needed is the *surface area* for the length of pipe under consideration.

$$\dot{Q} = hA\Delta T$$

$$A_s = \pi DL = \pi\left(\frac{3.068in}{12\frac{in}{ft}}\right)(200ft) = 160.6ft^2$$

$$\dot{Q} = \left(476.2\frac{Btu}{hr \cdot ft^{2\circ}F}\right)\left(160.6ft^2\right)\left(10^{\circ}F\right) = 765,000\frac{Btu}{hr}$$

Answer C