

Meng 263 – Fluids and Heat Transfer

Tutorial: Convective Heat Transfer Coefficient

Do the question in the follow example problem in two different ways:

- Using the formula for Nu that is included as part of the 'Part 1' Convective Heat Transfer class hand out (different than the one below).
- Assume the flow over the pipe is in still air (a calm day). That means ... Natural Convection.
- Compare the example results with yours.

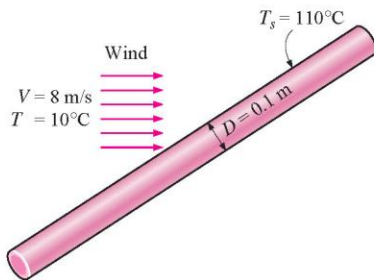


FIGURE 12-42
Schematic for Example 12-5.

EXAMPLE 12-5 Heat Loss from a Steam Pipe in Windy Air

A long 10-cm-diameter steam pipe whose external surface temperature is 110°C passes through some open area that is not protected against the winds (Fig. 12-42). Determine the rate of heat loss from the pipe per unit of its length when the air is at 1 atm pressure and 10°C and the wind is blowing across the pipe at a velocity of 8 m/s.

Solution A steam pipe is exposed to windy air. The rate of heat loss from the steam is to be determined.

Assumptions 1 Steady operating conditions exist. 2 Radiation effects are negligible. 3 Air is an ideal gas.

Properties The properties of air at the average film temperature of $T_f = (T_s + T_\infty)/2 = (110 + 10)/2 = 60^\circ\text{C}$ and 1 atm pressure are (Table A-22)

$$k = 0.02808 \text{ W/m} \cdot ^\circ\text{C} \quad \text{Pr} = 0.7202$$

$$\nu = 1.896 \times 10^{-5} \text{ m}^2/\text{s}$$

Analysis The Reynolds number is

$$\text{Re} = \frac{VD}{\nu} = \frac{(8 \text{ m/s})(0.1 \text{ m})}{1.896 \times 10^{-5} \text{ m}^2/\text{s}} = 4.219 \times 10^4$$

The Nusselt number can be determined from

$$\begin{aligned} \text{Nu} &= \frac{hD}{k} = 0.3 + \frac{0.62 \text{Re}^{1/2} \text{Pr}^{1/3}}{[1 + (0.4/\text{Pr})^{2/3}]^{1/4}} \left[1 + \left(\frac{\text{Re}}{282,000} \right)^{5/8} \right]^{4/5} \\ &= 0.3 + \frac{0.62(4.219 \times 10^4)^{1/2} (0.7202)^{1/3}}{[1 + (0.4/0.7202)^{2/3}]^{1/4}} \left[1 + \left(\frac{4.219 \times 10^4}{282,000} \right)^{5/8} \right]^{4/5} \\ &= 124 \end{aligned}$$

and

$$h = \frac{k}{D} \text{Nu} = \frac{0.02808 \text{ W/m} \cdot ^\circ\text{C}}{0.1 \text{ m}} (124) = 34.8 \text{ W/m}^2 \cdot ^\circ\text{C}$$

Then the rate of heat transfer from the pipe per unit of its length becomes

$$A_s = pL = \pi DL = \pi(0.1 \text{ m})(1 \text{ m}) = 0.314 \text{ m}^2$$

$$\dot{Q} = hA_s(T_s - T_\infty) = (34.8 \text{ W/m}^2 \cdot ^\circ\text{C})(0.314 \text{ m}^2)(110 - 10)^\circ\text{C} = \mathbf{1093 \text{ W}}$$

The rate of heat loss from the entire pipe can be obtained by multiplying the value above by the length of the pipe in m.

Discussion The simpler Nusselt number relation in Table 12-1 in this case would give $\text{Nu} = 128$, which is 3 percent higher than the value obtained above using Eq. 12-47.