HEAT TRANSFER

[CH21204]

March 18, 2023

TURBULENT FLOW IN TUBES

$$f = (0.790 \ln \mathrm{Re} - 1.64)^{-2} \qquad 10^4 < \mathrm{Re} < 10^6$$

$$\mathrm{Nu} = 0.125 f \mathrm{Re}\mathrm{Pr}^{1/3}$$

$$f = 0.184\ \mathrm{Re}^{-0.2}$$

$$\mathrm{Nu} = 0.023\ \mathrm{Re}^{0.8}\ \mathrm{Pr}^{1/3} \qquad \begin{pmatrix} 0.7 \le \mathrm{Pr} \le 160 \\ \mathrm{Re} > 10{,}000 \end{pmatrix}$$ **Colburn equation**

$$\mathrm{Nu} = 0.023\ \mathrm{Re}^{0.8}\ \mathrm{Pr}^{n}$$

$n = 0.4$ for *heating* and 0.3 for *cooling*

Dittus–Boelter equation

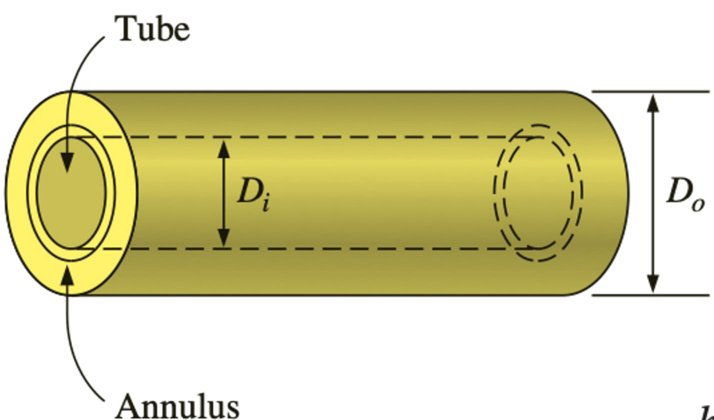
Liquid metals, T_s = constant: $\quad \text{Nu} = 4.8 + 0.0156\,\text{Re}^{0.85}\,\text{Pr}_s^{0.93}$

Liquid metals, $\dot{q}_s$ = constant: $\quad \text{Nu} = 6.3 + 0.0167\,\text{Re}^{0.85}\,\text{Pr}_s^{0.93}$

$0.004 < \text{Pr} < 0.01$

Colebrook equation:

$$\frac{1}{\sqrt{f}} = -2.0 \log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\text{Re}\sqrt{f}}\right) \qquad \text{(turbulent flow)}$$



$$D_h = \frac{4A_c}{p} = \frac{4\pi(D_o^2 - D_i^2)/4}{\pi(D_o + D_i)} = D_o - D_i$$

$$\text{Nu}_i = \frac{h_i D_h}{k} \quad \text{and} \quad \text{Nu}_o = \frac{h_o D_h}{k}$$

D_i/D_o	Nu_i	Nu_o
0	—	3.66
0.05	17.46	4.06
0.10	11.56	4.11
0.25	7.37	4.23
0.50	5.74	4.43
1.00	4.86	4.86

Cooling water available at 10°C is used to condense steam at 30°C in the condenser of a power plant at a rate of 0.15 kg/s by circulating the cooling water through a bank of 5-m-long 1.2-cm-internal-diameter thin copper tubes. Water enters the tubes at a mean velocity of 4 m/s, and leaves at a temperature of 24°C. The tubes are nearly isothermal at 30°C. Determine the average heat transfer coefficient between the water and the tubes, and the number of tubes needed to achieve the indicated heat transfer rate in the condenser.

$$\rho = 998.7\ \mathrm{kg/m^3}$$

$$C_p = 4184.5\ \mathrm{J/kg.°C}$$

$$h_{fg} = 2431\ \mathrm{kJ/kg}$$

Water is to be heated from 10°C to 80°C as it flows through a 2-cm-internal-diameter, 7-m-long tube. The tube is equipped with an electric resistance heater, which provides uniform heating throughout the surface of the tube. The outer surface of the heater is well insulated, so that in steady operation all the heat generated in the heater is transferred to the water in the tube. If the system is to provide hot water at a rate of 8 L/min, determine the power rating of the resistance heater. Also, estimate the inner surface temperature of the pipe at the exit.

$$\rho = 990.1 \text{ kg/m}^3$$

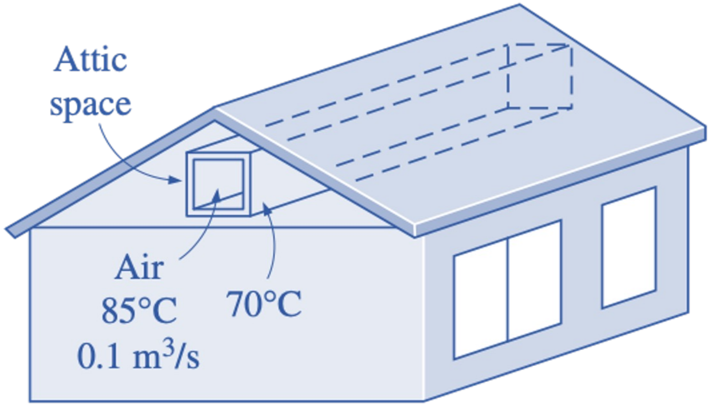
$$k = 0.637 \text{ W/m.°C}$$

$$\upsilon = \mu / \rho = 0.602 \times 10^{-6} \text{ m}^2/\text{s}$$

$$C_p = 4180 \text{ J/kg.°C}$$

$$\Pr = 3.91$$

Hot air at atmospheric pressure and 85°C enters a 10-m-long uninsulated square duct of cross section 0.15 m X 0.15 m that passes through the attic of a house at a rate of 0.10 m³/s. The duct is observed to be nearly isothermal at 70°C. Determine the exit temperature of the air and the rate of heat loss from the duct to the air space in the attic.



$$\rho = 0.9994 \text{ kg/m}^3$$
$$k = 0.02953 \text{ W/m.°C}$$
$$\upsilon = 2.097 \times 10^{-5} \text{ m}^2\text{/s}$$
$$C_p = 1008 \text{ J/kg.°C}$$
$$\Pr = 0.7154$$

Consider the flow of oil at 10°C in a 40-cm-diameter pipeline at an average velocity of 0.5 m/s. A 300-m-long section of the pipeline passes through icy waters of a lake at 0°C. Measurements indicate that the surface temperature of the pipe is very nearly 0°C. Disregarding the thermal resistance of the pipe material, determine (a) the temperature of the oil when the pipe leaves the lake, (b) the rate of heat transfer from the oil, and (c) the pumping power required to overcome the pressure losses and to maintain the flow oil in the pipe.

$$\rho = 893.5\ \text{kg/m}^3, \qquad k = 0.146\ \text{W/m.°C}$$

$$\mu = 2.325\ \text{kg/m.s}, \qquad \upsilon = 2591\times10^{-6}\ \text{m}^2/\text{s}$$

$$C_p = 1838\ \text{J/kg.°C}, \qquad \text{Pr} = 28750$$