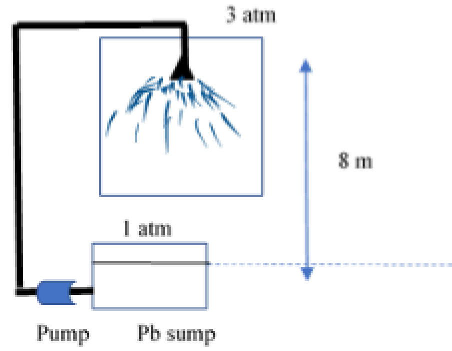
1. \What HP rating is needed to pump 100 metric tons (100,000 kg) of liquid Pb per hour to a Zn shock cooler shown in the sketch. The sprayer requires a 2.026×10^5 Pa (2 atm) pressure drop to operate as designed. There are no e_f data for the sprayer. The pipe is has a 2-cm ID smooth wall



$h := 8 \cdot m \qquad P_2 := 3 \cdot atm \qquad f := 0.005$

$L := 22 \cdot m \qquad P_1 := 1 \cdot atm \qquad \eta := 2.5 \cdot 10^{-3} \cdot \frac{kg}{m \cdot s}$

$d := 2 \cdot cm \qquad LD_{El} := 20 \quad \beta := 1$

$w := \frac{100000}{3600} \cdot \frac{kg}{s} \qquad \rho := 10500 \cdot \frac{kg}{m^3} \quad Q := \frac{w}{\rho} = ?$

$v := \frac{Q}{\pi \cdot \left(\frac{d}{2}\right)^2} = ? \qquad Re := \frac{d \cdot v \cdot \rho}{\eta} = 7.074 \cdot 10^5 \qquad ef_{Sump} := 0.4$

$F := 2 \cdot f \cdot \left(\frac{L}{d} + 3 \cdot LD_{El}\right) + \frac{1}{2}\, ef_{Sump} \qquad Ef := F \cdot v^2$

$M := -\left(\left(\frac{(P_2 - P_1)}{\rho} + g \cdot h + Ef\right) \cdot w\right) = -34.811\ hp$

3. Determine the heat loss rate for a 2-mm diameter Pb sphere as it is undergoing liquid-to-solid transformation as it falls at its approximate terminal velocity of 0.8 m/s in air at 100 °C.

$k_f := 0.032 \cdot \frac{W}{m \cdot K} \qquad R := 0.08205 \cdot \frac{m^3 \cdot atm}{K \cdot mol} \qquad Pr := 0.7 \qquad \eta_f := 2.4 \cdot 10^{-5} \cdot \frac{kg}{m \cdot s}$

$D := 2 \cdot mm \qquad \rho_f := \frac{28.600\ \frac{kg}{mol} \cdot 1\ atm}{R \cdot 350 \cdot K} = 0.996\ \frac{kg}{m^3} \qquad V := 0.8 \cdot \frac{m}{s}$

$Re := \frac{D \cdot V \cdot \rho_f}{\eta_f} = 66.394 \qquad A := \pi \cdot \left(\frac{D}{2}\right)^2 \qquad \rho_{Pb} := 10560 \cdot \frac{kg}{m^3}$

Ranz-Marshall Correlation

$Nu := 2.0 + 0.6 \cdot Re^{0.5} \cdot Pr^{0.333} = 6.341 \qquad h := \frac{Nu \cdot k_f}{D} = 101.463\ \frac{W}{m^2 \cdot K}$

$Q := A \cdot h \cdot (600 \cdot K - 300 \cdot K) = 0.096\ W$

$H_{fusion} := 24100 \cdot \frac{J}{kg} \qquad t_s := \frac{1.333}{Q} \cdot \pi \cdot \left(\frac{D}{2}\right)^3 \cdot \rho_{Pb} \cdot H_{fusion} = 11.145\ s$

4 A 4-cm radius cylindrical tube furnace has an inner liner of material A from r = 4 cm to r = 8 cm and a second layer of material B from r = 8 cm to 24 cm. What is the

1) the heat loss per meter of furnace length and
2) what is the temperature at the interface between A and B?

Data: $k_A = 0.5$ W*m^{-1}*K^{-1}

Data: $k_B = 0.05$ W*m^{-1}*K^{-1}

$T_i = 1100$ °C $h_i = 5$ W*m^{-2}*k^{-1}

$T_o = 100$ °C $h_o = 8$ W*m^{-2}*k^{-1}

$$k_A := 0.5 \cdot \frac{W}{m \cdot K} \qquad k_B := 0.05 \cdot \frac{W}{m \cdot K} \qquad h_o := 8 \cdot \frac{W}{m^2 \cdot K} \qquad h_i := 5 \cdot \frac{W}{m^2 \cdot K}$$

$$R_t := \frac{1}{2 \cdot \pi \cdot L} \cdot \left(\frac{\ln\left(\frac{8}{4}\right)}{k_A} + \frac{\ln\left(\frac{24}{8}\right)}{k_B} + \frac{1}{h_i \cdot 4 \cdot cm} + \frac{1}{h_o \cdot 24 \cdot cm} \right) = 0.209 \ \frac{K}{W}$$

$$Q := \frac{(1100 - 100) \cdot K}{R_t} = \left(4.786 \cdot 10^3\right) \ W$$

$$R_{iA} := \frac{1}{2 \cdot \pi \cdot L} \cdot \left(\frac{1}{h_i \cdot 4 \cdot cm} \right) = 0.036 \ \frac{K}{W}$$

$$T_{iA} := 1100 \cdot K - Q \cdot R_{iA} = 926.866 \ K$$

$$R_{AB} := \frac{1}{2 \cdot \pi \cdot L} \cdot \left(\frac{\ln\left(\frac{8}{4}\right)}{k_A} + \frac{1}{h_i \cdot 4 \cdot cm} \right) = 0.046 \ \frac{K}{W}$$

$$T_{AB} := 1100 \cdot K - Q \cdot R_{AB} = 878.863 \ K$$

$$R_{Bo} := \frac{1}{2 \cdot \pi \cdot L} \cdot \left(\frac{1}{h_i \cdot 4 \cdot cm} + \frac{\ln\left(\frac{8}{4}\right)}{k_A} + \frac{\ln\left(\frac{24}{8}\right)}{k_B} \right) = 0.205 \ \frac{K}{W}$$

$$T_{Bo} := 1100 \cdot K - Q \cdot R_{Bo} = 118.035 \ K$$

$$R_t := \frac{1}{2 \cdot \pi \cdot L} \cdot \left(\frac{\ln\left(\frac{8}{4}\right)}{k_A} + \frac{\ln\left(\frac{24}{8}\right)}{k_B} + \frac{1}{h_i \cdot 4 \cdot cm} + \frac{1}{h_o \cdot 24 \cdot cm} \right) = 0.209 \ \frac{K}{W}$$

$$T_o := 1100 \cdot K - Q \cdot R_t = 100 \ K$$