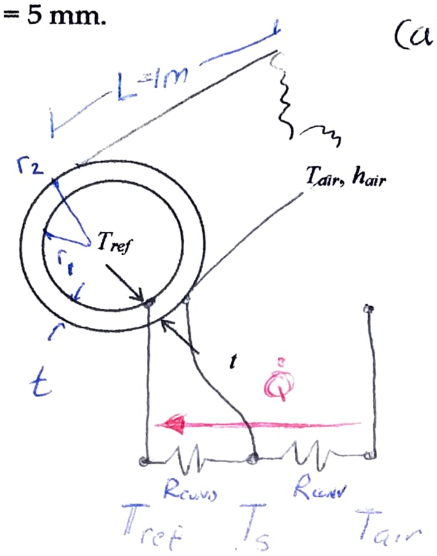
Example

A 10-mm diameter pipe containing a condensing refrigerant is to be insulated with a material that has a conductivity of $k_{insul} = 0.055$ W/m-°C. For the air surrounding the pipe, $T_{air} = 20$°C and $h_{air} = 5$ W/m²-°C. The temperature of the refrigerant is –10°C. Assuming that the inside wall temperature is the same as the refrigerant temperature

(a) calculate the rate of heat transfer per unit pipe length for an insulation thickness of t = 2 mm, and

(b) t = 5 mm.



(a) Conduction resistance

$$R_{COND} = \frac{\ln(r_2/r_1)}{2\pi k_{insul} L} = \frac{\ln\left[\frac{D/2 + t}{D/2}\right]}{2\pi k_{INSUL} L} = \frac{\ln\left[\left(\frac{10\,mm}{2} + 2\,mm\right)/(10\,mm/2)\right]}{2\pi \cdot 0.055 \frac{W}{m\text{-}°C} \cdot 1\,m} = 0.9737\ °C/W$$

Convection resistance

$$R_{CONV} = \frac{1}{h_{air} A_s}$$

$$= \frac{1}{h_{air} \cdot 2\pi r_2 \cdot L} = \frac{1}{h_{air} \cdot 2\pi \left[D/2 + t\right] L}$$

$$= \frac{1}{5 \frac{W}{m^2 °C} \cdot 2\pi \cdot \left[\frac{0.010\,m}{2} + 0.002\,m\right] 1\,m} = 4.547\ °C/W$$

$$\dot{Q} = \frac{T_{air} - T_{REF}}{R_{COND} + R_{CONV}} = \frac{20°C - (-10°C)}{[0.9737 + 4.547]\ °C/W} = 5.43\ W$$ ← ANS

(b) Same process.

Results: $R_{COND} = 2.006$ °C/W $\quad R_{CONV} = 3.183$ °C/W

$\dot{Q} = 5.78$ W ← ANS

WHAT?!!