

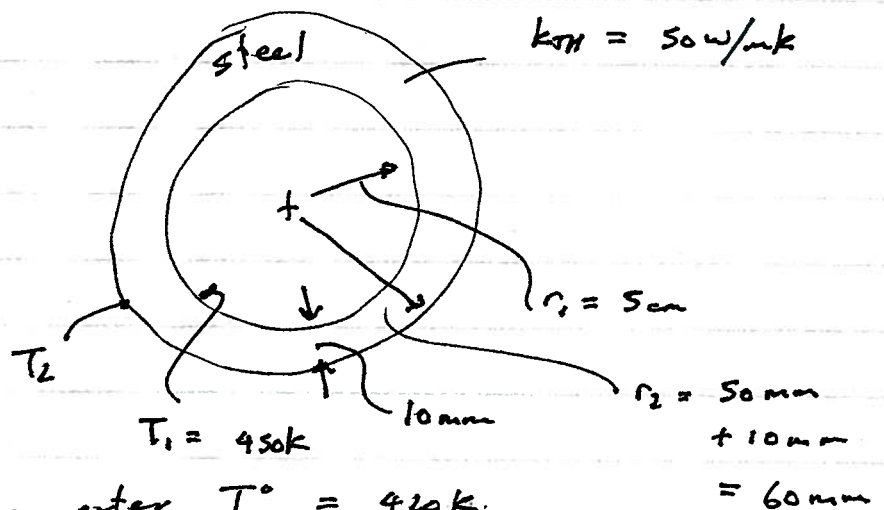
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steel pipe

$L = 20 \text{ m}$

$T_{\text{in pipe}} = 450 \text{ K}$



- no insulation, outer  $T^\circ = 420 \text{ K}$

- with insulation, outer  $T^\circ = 320 \text{ K}$

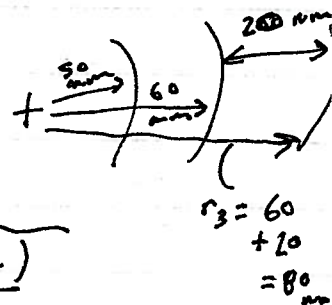
(a) no insulation:

$$\Phi = \frac{-2\pi k_{TH} L (T_2 - T_1)}{\ln(r_2/r_1)}$$

$$= \frac{-2\pi (50) (20) [420 - 450]}{\ln\left(\frac{60}{50}\right)} = 1034000 \frac{\text{J}}{\text{s}} = 1.034 \text{ MW}$$

(b) with insulation:

$$\Phi = \frac{-2\pi L (T_2 - T_1)}{\frac{\ln(r_2/r_1)}{k_{TH1}} + \frac{\ln(r_3/r_2)}{k_{TH2}}}$$



$$= \frac{-2\pi (20) [320 - 450]}{\frac{\ln(60/50)}{50} + \frac{\ln(80/60)}{0.25}} = \frac{16336.3}{1.154} = 14156 \frac{\text{J}}{\text{s}} = 14.1 \text{ kW}$$

$$(c) \quad \dot{Q}_{\text{desired}} = \frac{1}{2} [ \dot{Q}_{(u)} ] = 7078 \text{ J/s}$$

so

$$7078 = \frac{-2\pi(20)[320-450]}{\frac{\ln(60/50)}{50} + \frac{\ln(r_3/60)}{0.25}}$$

$$\frac{\ln(60/50)}{50} + \frac{\ln(r_3/60)}{0.25} = 2.308$$

$$\text{get } r_3 = 106.74 \text{ mm}$$

$$\text{so Ken thickness} = r_3 - r_2$$

$$= 106.74 - 60$$

$$= 46.74 \text{ mm}$$