

The walls of a refrigerator are typically constructed by sandwiching a layer of insulation between sheet metal panels. Consider a wall made from fiberglass insulation of thermal conductivity $k_i = 0.046 \text{ W/m}\cdot\text{K}$ and thickness $L_i = 50 \text{ mm}$ and steel panels, each of thermal conductivity $k_p = 60 \text{ W/m}\cdot\text{K}$ and thickness $L_p = 3 \text{ mm}$. If the wall separates refrigerated air at $T_{\infty,i} = 4^\circ\text{C}$ from ambient air at $T_{\infty,o} = 25^\circ\text{C}$, what is the heat gain per unit surface area? Coefficients associated with natural convection at the inner and outer surfaces may be approximated as $h_i = h_o = 5 \text{ W/m}^2\cdot\text{K}$.

Steel (2 layers)

$K_{\text{steel}} = 60 \text{ W/mK}$, $L_{\text{steel}} = 3 \text{ mm}$.

Fiberglass

$K_f = 0.046 \text{ W/mK}$, $L_f = 50 \text{ mm}$.

Air (inner)

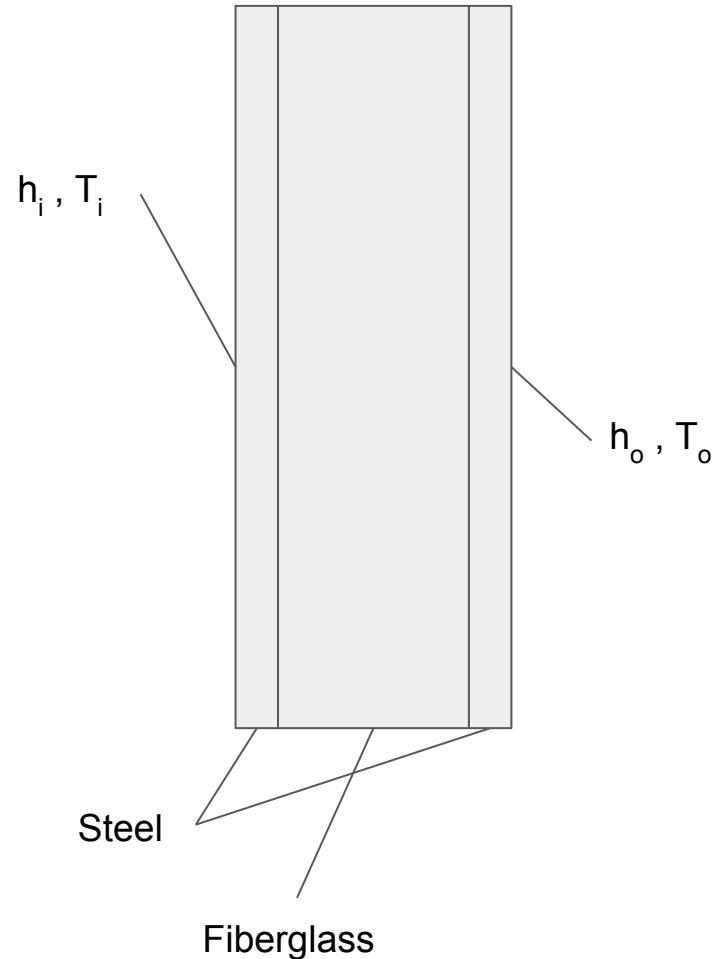
$h_i = 5 \text{ W/m}^2\text{K}$

$T_i = 4^\circ\text{C}$

Air (outer)

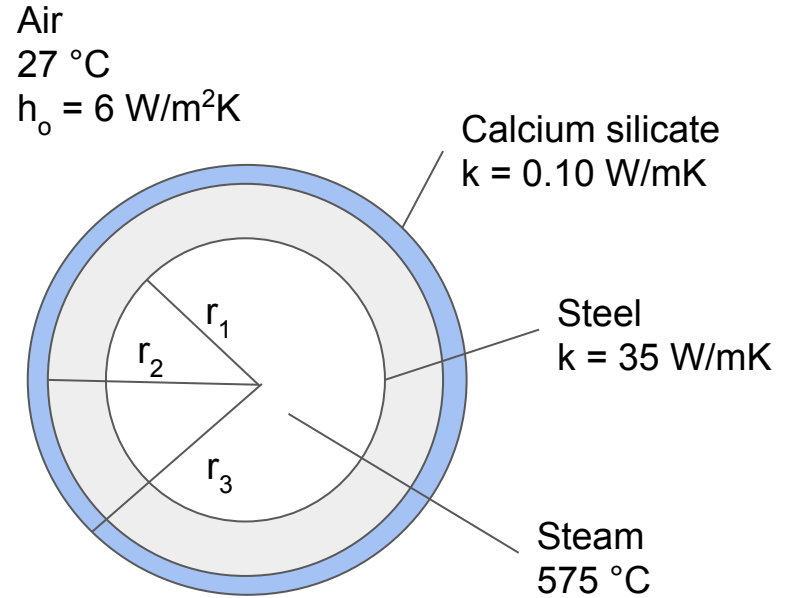
$h_o = 5 \text{ W/m}^2\text{K}$

$T_o = 20^\circ\text{C}$



Superheated steam at 575°C is routed from a boiler to the turbine of an electric power plant through steel tubes ($k = 35 \text{ W/m}\cdot\text{K}$) of 300-mm inner diameter and 30-mm wall thickness. To reduce heat loss to the surroundings and to maintain a *safe-to-touch* outer surface temperature, a layer of calcium silicate insulation ($k = 0.10 \text{ W/m}\cdot\text{K}$) is applied to the tubes, while degradation of the insulation is reduced by wrapping it in a thin sheet of aluminum having an emissivity of $\varepsilon = 0.20$. The air and wall temperatures of the power plant are 27°C .

- (a) Assuming that the inner surface temperature of a steel tube corresponds to that of the steam and the convection coefficient outside the aluminum sheet is $6 \text{ W/m}^2\cdot\text{K}$, what is the minimum insulation thickness needed to ensure that the temperature of the aluminum does not exceed 50°C ? What is the corresponding heat loss per meter of tube length?



The thin sheet of aluminum can be neglected for the calculation of the conduction thermal resistance, but it can't be neglected for the radiation resistance.