46.35 A variable frequnecy drive producing $100W$of waste heat during continuous operation is housed in an insulated sheet matal enclosure mounted in a machine room. The insulation is $\frac{1}{8}in$ thick with a thermal conductivity of $0.2\frac{Btu}{hr \cdot ft \cdot {}^\circ F}$. The thermal resistance of the sheet metal is negligible. The surface area of the enclosure is $8ft^2$. The machine room is maintained at $76^\circ F$. The film coefficients both inside and outside the enclosure are $4\frac{Btu}{hr \cdot ft^2 \cdot {}^\circ F}$. What is the steady state temperature inside the enclosure?

A. $52^\circ F$

B. $88^\circ F$

C. $100^\circ F$

D. $112^\circ F$

Model the enclosure as a Composite Wall with 3 layers: 2 films and the insulation. Negligible thermal resistance is provided by the sheet metal. The total heat transfer through the composite wall may be described by the equation $\dot{Q} = UA\Delta T$, where the overall coefficient of heat transfer, $U = \frac{1}{R_T}$, and where R_T is the total thermal resistance. Determine the total thermal resistance by adding the individual thermal resistenaces in series.

$$R_T = \frac{1}{h_i} + \frac{L_{ins}}{k_{ins}} + \frac{1}{h_o}$$

$$R_T = \frac{1}{\left(4\frac{Btu}{hr \cdot ft^2 \cdot {}^\circ F}\right)} + \frac{\left(\frac{1}{8}in\right)\left(\frac{1ft}{12in}\right)}{0.2\frac{Btu}{hr \cdot ft \cdot {}^\circ F}} + \frac{1}{\left(4\frac{Btu}{hr \cdot ft^2 \cdot {}^\circ F}\right)} = 0.55\frac{hr \cdot ft^2 \cdot {}^\circ F}{Btu}$$

Calculate the overall heat transfer coefficient from the total thermal resistance.

$$U = \frac{1}{R_T} = \frac{1}{0.55\frac{hr \cdot ft^2 \cdot {}^\circ F}{Btu}} = 1.8\frac{Btu}{hr \cdot ft^2 \cdot {}^\circ F}$$

Calculate the temperature differential using the total heat transfer, the overall heat transfer coefficient, and the surface area.

$$\Delta T = \frac{\dot{Q}}{UA} = \frac{(100W)\left(3.412\frac{Btu}{hr \cdot W}\right)}{\left(1.8\frac{Btu}{hr \cdot ft^2 \cdot {}^\circ F}\right)(8ft^2)} = 23.7^\circ F$$

Use the temperature differential to calculate the temperature inside the encolsure based on the room temperature.

$$\Delta T = T_{enclosure} - T_{room}$$

$$T_{enclosure} = \Delta T + T_{room} = 23.7^\circ F + 76^\circ F = 99.7^\circ F$$

Answer C

46.36 In a counterflow heat exchanger, the cold fluid increases in temperature from $50°F$ to $100°F$ and the warm fluid is cooled from $180°F$ to $145°F$. What is the logarithmic mean temperature difference?

A. $45°F$

B. $87°F$

C. $115°F$

D. $119°F$

It is valid to use the Reference Handbook formula for Log Mean Temperature Difference. There is also a generalized version of the LMTD equation not provided in the reference handbook which is easier to remember and applies to both Counterflow and Parallel Flow heat exchangers, provided the flow directions are drawn out first. Note the opposite direction for the arrows for a counterflow heat exchanger.

$$Cold\,Fluid:\ 50°F \longrightarrow 100°F$$

$$Hot\,Fluid:\ 145°F \longleftarrow 180°F$$

Define one *physical* side of the heat exchanger as 'A' and the other side as 'B' and determine the respective temperature differences. Conveniently, the assignment of labels A and B turns out to be arbitrary. However, the *direction* of the flows is critical.

$$\Delta T_A = 145°F - 50°F = 95°F$$

$$\Delta T_B = 180°F - 100°F = 80°F$$

Use the formula below to calculate the log mean temperature difference.

$$LMTD = \frac{\Delta T_A - \Delta T_B}{ln\left(\frac{\Delta T_A}{\Delta T_B}\right)}$$

$$LMTD = \frac{95°F - 80°F}{ln\left(\frac{95°F}{80°F}\right)} = 87.3°F$$

Answer B