**42.6 A $75KVA$ transformer with 99% efficiency is located in an electrical room at $70°F$. The transformer's enclosure is a floor standing box with dimensions of $3ft$ height, $2ft$ width, $3ft$ depth. The exposed surfaces have an average temperature of $85°F$. The load is resistive and uses 60% of the transformer's capacity. What is the overall heat transfer coefficient?**

A. $1.9\frac{Btu}{hr\cdot ft^2\cdot°F}$

B. $2.4\frac{Btu}{hr\cdot ft^2\cdot°F}$

C. $2.8\frac{Btu}{hr\cdot ft^2\cdot°F}$

D. $4.7\frac{Btu}{hr\cdot ft^2\cdot°F}$

The Overall Heat Transfer Coefficient is given by:

$$\dot{Q} = UA\Delta T \rightarrow U = \frac{\dot{Q}}{A\Delta T}$$

The surface area for the floor standing enclosure includes 5 faces: the top and 4 sides. Note there is no base area to include in the surface area:

$$A = (2)\left[(3ft)(3ft)\right] + (3)\left[(2ft)(3ft)\right] = 36ft^2$$

The temperature differential is the difference between the exposed surfaces of the enclosure and the ambient temperature in the electrical room:

$$\Delta T = 85°F - 70°F = 15°F$$

The heat produced by the transformer depends on the demand, efficiency, and power factor. The load is purely resistive; therefore the power factor should be taken as unity:

$$PF = \frac{KW}{KVA} = 1$$

The *real* power draw i.e. the heat load in $KW$ is then:

$$P = (75KVA)(.6)\left(\frac{1KW}{1KVA}\right) = 45KW$$

Calculate the losses associated with a 99% efficient transformer, converted to $Btu$:

$$\dot{Q} = (45KW)(.01)\left(3412\frac{Btu}{hr\cdot KW}\right) = 1535\frac{Btu}{hr}$$

Calculate $U$:

$$U = \frac{\dot{Q}}{A\Delta T} = \frac{\left(1535\frac{Btu}{hr}\right)}{(36ft^2)(15°F)} = 2.84\frac{Btu}{hr\cdot ft^2\cdot °F}$$

**Answer C**

**42.7 48°F chilled water flows in a $200ft$ long $8in$ steel pipe with $2in$ of insulation through a room maintained at $73°F$. The insulation has a thermal conductivity of $1.8\frac{Btu \cdot in}{hr \cdot ft^2 \cdot °F}$. The overall coefficient of heat transfer for the outside of the insulation to the surrounding room including convection and radiation is $2\frac{Btu}{hr \cdot ft^2 \cdot °F}$. What is the surface temperature of the outside of the insulation?**

A. $55.8°F$

B. $59.8°F$

C. $61.2°F$

D. $66.3°F$

Heat is gained from the ambient space and enters the insulation according to an overall heat transfer coefficient for the insulation (which includes both convection and radiation). The same quantity of heat then propagates through the insulation by conduction based on the thickness and thermal conductivity of the insulation. Heat travels through the thickness of the pipe by conduction, and finally, into the flowing water by convection.

Neglect the heat transfer by conduction through the thickness of the pipe because the steel is highly conductive in comparison to the insulation, and no thermal conductivity was given for the pipe.

Neglect the heat transfer by convection into the water as the flow is likely to be turbulent and the chilled water temperature will quickly reach equilibrium with the pipe.

Therefore, consider only the heat gain by the insulation from the room by convection, and the heat gain by conduction through the insulation. These quantities must be equal.

Write an expression for the heat gain by the insulation from the room as though it were a composite plane wall:

$$Q_{conv,rad} = U_o A \Delta T = U_o A \left(T_{room} - T_{surface}\right)$$

Write an expression for the heat gain by conduction through the insulation based on the formula for conduction through a cylindrical wall:

$$Q_{cond} = 2\pi L \frac{k}{ln\left(\frac{r_2}{r_1}\right)} \left(T_{surface} - T_{water}\right)$$

Set these two expressions equal. Recognize area is the surface area of the outside of the insulation where the conduction and radiation are acting on the insulation, which is given by $2\pi r_2 L$, where $2\pi L$ cancels from both sides leaving $r_2$on the left.

$$Q_{conv,rad} = Q_{cond}$$

$$U_o A \left(T_{room} - T_{surface}\right) = 2\pi L \frac{k}{ln\left(\frac{r_2}{r_1}\right)} \left(T_{surface} - T_{water}\right)$$