Summary:

Convective heat conduction occurs only in the liquid, and it occurs because the relative movement between the various parts of the fluid occurs, thereby infiltrating each other to transfer thermal energy. There are two reasons for the convection of a fluid: one is natural convection, which refers to a fluid of the same temperature, because a part of it is affected by temperature changes to produce a temperature difference, forming a convective motion. The second is forced convection, which means that the fluid is forced to convect because of the external force.

The extent of natural convection depends mainly on the temperature difference between the various parts of the fluid. The greater the temperature difference, the stronger the convection. The extent of forced convection depends on the magnitude of the external force. The greater the external force, the stronger the convection.

The heat transfer process in the air layer is different from the process in the solid material. The solid material layer transfers heat in a thermally conductive manner. In the air layer, heat conduction / convection and radiation exist.

Therefore, the air layer is not like the solid material layer. When the thermal conductivity of the material reaches a certain value, the thermal resistance of the material layer is proportional to the thickness. In the air layer, the thermal resistance is mainly determined by the thickness of the air boundary layer at the two interfaces and the radiation intensity between the interfaces. Therefore, there is no proportional relationship between the thermal resistance and the thickness of the void layer.

$$A = 0.8m \cdot 1.5m = 1.2m^2$$

$$R_{conv,1} = \frac{1}{h_1 A} = \frac{1}{\frac{10W}{m^2 \cdot ℃} \cdot 1.2m^2} \approx 0.0833℃/W$$

$$R_{glass,1} = \frac{L_1}{k_1 A} = \frac{0.006m}{\frac{0.78W}{m \cdot ℃} \cdot 1.2m^2} \approx 0.0064℃/W$$

$$R_{air} = \frac{L_2}{k_2 A} = \frac{0.013m}{\frac{0.026W}{m \cdot ℃} \cdot 1.2m^2} \approx 0.4167℃/W$$

$$R_{glass,2} = \frac{L_3}{k_3 A} = \frac{0.006m}{\frac{0.78W}{m \cdot ℃} \cdot 1.2m^2} \approx 0.0064℃/W$$

$$R_{conv,2} = \frac{1}{h_2 A} = \frac{1}{\frac{40W}{m^2 \cdot ℃} \cdot 1.2m^2} \approx 0.0208℃/W$$

$$R_{total} = R_{conv,1} + R_{glass,1} + R_{air} + R_{glass,2} + R_{conv,2} \approx 0.5333℃/W$$

$$Q = \frac{T_{\infty 1} - T_{\infty 2}}{R_{total}} = \frac{20℃ - (-10℃)}{0.5333℃/W} \approx 56.2535W$$

$$\because \dot{Q} = \frac{T_{\infty 1} - T_1}{R_{conv,1}} = \frac{T_{\infty 1} - T_1}{1/h_1 A}$$

$$\therefore T_1 = T_{\infty 1} - \dot{Q} R_{conv,1} \approx 20℃ - 56.2535W \cdot 0.0833\frac{℃}{W} \approx 15.3℃$$