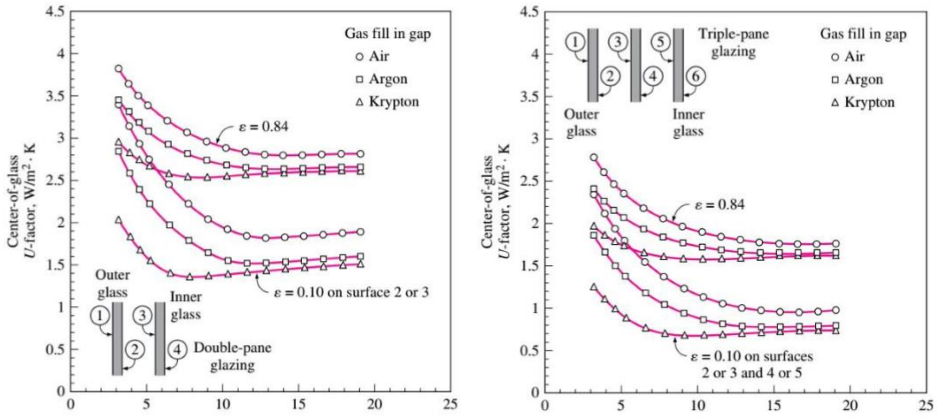
Task 1 Using the diagrams given in the presentation calculate how much (%) is the effect of applying different modifications (changing the gas, adding an extra pane, using a low emissivity coating) on the U value with respect to a benchmark case of double layer with air and no coating? (keep the gap thickness to be 13 mm)



Solution:

(1) Changing the gas:

By changing the gas filled in the gap from air to argon, the U of the center of the glass decreases from 2.8$\frac{W}{m^2 K}$ to 2.65$\frac{W}{m^2 K}$, which means the U decreases 5.4%.

By changing the gas filled in the gap from air to krypton, the U of the center of the glass decreases from 2.8$\frac{W}{m^2 K}$ to 2.6$\frac{W}{m^2 K}$, which means the U decreases 7.1%.

(2) Adding an extra pane:

The U of the center of the glass decreases from 2.8$\frac{W}{m^2 K}$to 1.8$\frac{W}{m^2 K}$, which means the U decreases 35.7%.

(3) Using a low emissivity coating:

The U of the center of the glass decreases from 2.8$\frac{W}{m^2 K}$ to 1.8$\frac{W}{m^2 K}$, which means the U decreases 35.7%.

Task 2 Consider the house that we analysed in the alst two examples, calculate the heating and cooling load of the other windows which are fixed 14.4 m2 on the west, fixed 3.6 m2 on the south and an operable 3.6 m2 on the south (the same window and frame type). How much does the total value change if I change the frame of the window from wooden one to aluminium ?

Task 2

Answer：

$\Delta T_{cooling} = 31.9 - 24 = 7.9℃$

$\Delta T_{heating} = 20 - (-4.8) = 24.8℃$

DR=11.9℃

Wood Frames

Window1 (east, wood frame, fixed)

$$A_{window1} = 14.4\ m^2$$

Heating:

$$U_{window1} = 2.84 \frac{w}{m^2} \cdot K$$

$$HF_{window1} = U_{window1} * \Delta T_{cooling} = 2.84 * 24.8 = 70.44\ w/m^2$$

$$Q_{window1} = HF_{window1} * A_{window} = 70.44 * 14.4 = 1014.2w$$

Cooling:

Heat transfer:

$$CF_{window1} = U_{window1(\Delta T_{cooling} - 0.46 * DR)} = 2.84(7.9 - 0.46 * 11.9) = 6.9w/m^2$$

Irradiation：

$$E_D = 559,\ E_d = 188,\ FF_{seast} = 0.31$$

$$PXI_{window1} = E_D + E_d = 559 + 188 = 747$$

$$CF_{window1} = PXI * SHGC * IAC * FF_{Seast} = 747 * 0.54 * 1 * 0.31 = 125.1$$

$$CF_{fenestration1} = U_{window1}(\Delta Tcooling - 0.46 * DR) + PXI * SHGC * IAC * FF_{Seast}$$
$$= 6.9 + 125.1 = 132\ W/m^2$$

$$\dot{Q}_{window1} = CF_{fenestration1} * A_{window1} = 132 * 14.4 = 1900.8w$$

Window2 (west, wood frame, fixed)

$$\mathrm{A_{window2}} = 14.4\ \mathrm{m^2}$$

Heating:

U_window2=2.84 w/㎡·K

$$HF_{window2} = U_{window2} * \Delta T_{cooling} = 2.84 * 24.8 = 70.44\ w/m^2$$

$$Q_{window2} = HF_{window2} * A_{window} = 70.44 * 14.4 = 1014.2w$$

Cooling:

Heat transfer:

$$CF_{window}2 = U_{window}2(\Delta T\_cooling - 0.46 * DR) = 2.84(7.9 - 0.46 * 11.9) = 6.9w/m^2$$

Irradiation:

$$E_D = 559,\ E_d = 188,\ FF_{swest} = 0.56$$

$$PXI_{window1} = E_D + E_d = 559 + 188 = 747$$

$$CF\_window2 = PXI * SHGC * IAC * FF\_Swest = 747 * 0.54 * 1 * 0.56 = 225.9$$

$$CF\_fenestration2 = U\_window2\ (\Delta Tcooling - 0.46 * DR) + PXI * SHGC * IAC * FF\_Swest$$
$$= 6.9 + 225.9 = 232.8\ W/m^2$$

$$\dot{Q}_{window2} = CF_{fenestration2} * A_{window2} = 232.8 * 14.4 = 3352.32w$$

Window3 (south, wood frame, fixed)

$$\mathrm{A_{window3}} = 3.6\ \mathrm{m^2}$$

Heating:

$$U_{window3} = 2.84\ w/m^2 \cdot K$$

$$HF_{window3} = U_{window3} * \Delta T_{cooling} = 2.84 * 24.8 = 70.44\ w/m^2$$

$$Q_{window3} = HF_{window3} * A_{window} = 70.44 * 3.6 = 253.6w$$

Cooling:

Heat transfer:

$$CF_{window3} = U_{window3}(\Delta T\_cooling - 0.46 * DR) = 2.84(7.9 - 0.46 * 11.9) = 6.9w/m^2$$

Irradiation:

$$E_D = 348, \quad E_d = 209, \quad FF_{ssouth} = 0.47$$

$$PXI_{window3} = E_D + E_d = 348 + 209 = 557$$

$$CF_{window3} = PXI * SHGC * IAC * FF\_ssouth = 557 * 0.54 * 1 * 0.47 = 141.4$$

$$CF_{fenestration3} = U_{window3}\ (\Delta T cooling - 0.46 * DR) + PXI * SHGC * IAC * FF_{ssouth}$$

$$= 6.9 + 141.4 = 148.3\ W/m^2$$

$$\dot{Q}_{window3} = CF_{fenestration3} * A_{window3} = 148.3 * 3.6 = 533.88w$$

Window4 (south, wood frame, openable)

$$\mathrm{A_{window3}} = 3.6\ \mathrm{m^2}$$

Heating:

$$U_{window4} = 2.87\ w/m^2 \cdot K$$

$$HF_{window4} = U_{window4} * \Delta T_{cooling} = 2.87 * 24.8 = 71.17\ w/m^2$$

$$Q_{window4} = HF_{window4} * A_{window} = 71.17 * 3.6 = 256.2w$$

Cooling:

Heat transfer:

$$CF_{window4} = U_{window4}(\Delta T_{cooling} - 0.46 * DR) = 2.87(7.9 - 0.46 * 11.9) = 6.96w/m^2$$

Irradiation:

$$E_D = 348, \quad E_d = 209, \quad SHGC = 0.46, \quad FF_{ssouth} = 0.47$$

$$PXI_{window4} = E_D + E_d = 348 + 209 = 557$$

$$CF_{window4} = PXI * SHGC * IAC * FF_{ssouth} = 557 * 0.46 * 1 * 0.47 = 120.4$$

$$CF_{fenestration4} = U_{window4}\ (\Delta T cooling - 0.46 * DR) + PXI * SHGC * IAC * FF_{ssouth}$$

$$= 6.9 + 120.4 = 127.3\ W/m^2$$

$$\dot{Q}_{window4} = CF_{fenestration4} * A_{window4} = 127.3 * 3.6 = 458.28w$$

$$\dot{Q}_{totalcoolingwood} = 1900.8 + 3352.32 + 533.88 + 458.28 = 6245.3w$$

$$\dot{Q}_{totalheatingwood} = 1014.2 + 1014.2 + 253.6 + 256.2 = 2538.2w$$

Aluminum Frames

Window1 (south, aluminum frame, fixed)

Heating:

$$U_{window1} = 3.61\ w/m^2 \cdot K$$

$$HF_{window1} = U_{window1} * \Delta T_{cooling} = 3.61 * 24.8 = 89.52\ w/m^2$$

$$Q_{window1} = HF_{window1} * A_{window} = 89.52 * 14.4 = 1289.1w$$

Cooling:

Heat transfer:

$$CF_{window1} = U_{window1}(\Delta T_{cooling} - 0.46 * DR) \ = 3.61(7.9 - 0.46 * 11.9) = 8.7 w/㎡$$

Irradiation:

$$E_D = 559, \quad E_d = 188, \quad SHGC = 0.56, \quad FF_{seast} = 0.31$$

$$PXI_{window1} = E_D + E_d = 559 + 188 = 747$$

$$CF_{window1} = PXI * SHGC * IAC * FF_{seast} = 747 * 0.56 * 1 * 0.31 = 129.6$$

$$CF_{fenestration1} = U_{window1}\ (\Delta T cooling - 0.46 * DR) + PXI * SHGC * IAC * FF_{seast}$$

$$= 8.7 + 129.6 = 138.3\ W/㎡$$

$$\dot{Q}_{window1} = CF_{fenestration1} * A_{window1} = 138.3 * 14.4 = 1991.5w$$

<u>Window2 (west, aluminum frame, fixed)</u>

$$\mathrm{A_{window2}} = 14.4\ ㎡$$

Heating:

$$U_{window2} = 3.61\ w/㎡ \cdot K$$

$$HF_{window2} = U_{window2} * \Delta T_{cooling} = 3.61 * 24.8 = 89.52\ w/㎡$$

$$Q_{window2} = HF_{window2} * A_{window} = 59.52 * 14.4 = 1289.1w$$

Cooling:

Heat transfer:

$$CF_{window}2 = U_{window}2(\Delta T\_cooling - 0.46 * DR) \ = 3.61(7.9 - 0.46 * 11.9) = 8.7 w/㎡$$

Irradiation:

$$E_D = 559, \quad E_d = 188, \quad FF_{swest} = 0.56$$

$$PXI_{window1} = E_D + E_d = 559 + 188 = 747$$

$$CF\_window2 = PXI * SHGC * IAC * FF\_Swest = 747 * 0.56 * 1 * 0.56 = 234.26$$

$$CF\_fenestration2 = U\_window2\ (\Delta T cooling - 0.46 * DR) + PXI * SHGC * IAC * FF\_Swest$$

$$= 8.7 + 234.26 = 242.96\ W/㎡$$

$$\dot{Q}_{window2} = CF_{fenestration2} * A_{window2} = 242.96 * 14.4 = 3498.6w$$

<u>Window3 (south, aluminum frame, fixed)</u>

$$\mathrm{A_{window3}} = 3.6\ ㎡$$

Heating:

$$U_{window3} = 3.61\ w/㎡ \cdot K$$

$$HF_{window3} = U_{window3} * \Delta T_{cooling} = 3.61 * 24.8 = 89.52\ w/㎡$$

$$Q_{window3} = HF_{window3} * A_{window} = 89.52 * 3.6 = 322.2w$$

Cooling:

Heat transfer:

$$CF_{window3} = U_{window3}(\Delta T\_cooling - 0.46 * DR) \ = 3.61(7.9 - 0.46 * 11.9) = 8.7 w/㎡$$

Irradiation:

$$E_D = 348, \quad E_d = 209, \quad FF_{ssouth} = 0.47$$

$$PXI_{window3} = E_D + E_d = 348 + 209 = 557$$

$$CF_{window3} = PXI * SHGC * IAC * FF\_ssouth = 557 * 0.56 * 1 * 0.47 = 146.6$$

$$CF_{fenestration3} = U_{window3}\ (\Delta Tcooling - 0.46 * DR) + PXI * SHGC * IAC * FF_{ssouth}$$
$$= 8.7 + 146.6 = 155.3\ W/㎡$$
$$\dot{Q}_{window3} = CF_{fenestration3} * A_{window3} = 155.3 * 3.6 = 559.08w$$

Window4 (south, aluminum frame, openable)

$$\mathrm{A_{window3}} = 3.6\ ㎡$$

Heating:

$$U_{window4} = 4.62\ w/㎡ \cdot K$$

$$HF_{window4} = U_{window4} * \Delta T_{cooling} = 4.62 * 24.8 = 114.57\ w/㎡$$

$$Q_{window4} = HF_{window4} * A_{window} = 114.57 * 3.6 = 412.4w$$

Cooling:

Heat transfer:

$$CF_{window4} = U_{window4}(\Delta T_{cooling} - 0.46 * DR)\ = 4.62(7.9 - 0.46 * 11.9) = 11.2w/㎡$$

Irradiation:

$$E_D = 348,\quad E_d = 209,\ \ SHGC = 0.55,\ \ FF_{ssouth} = 0.47$$
$$PXI_{window4} = E_D + E_d = 348 + 209 = 557$$
$$CF_{window4} = PXI * SHGC * IAC * FF_{ssouth} = 557 * 0.55 * 1 * 0.47 = 143.98$$
$$CF_{fenestration4} = U_{window4}\ (\Delta Tcooling - 0.46 * DR) + PXI * SHGC * IAC * FF_{ssouth}$$
$$= 11.2 + 143.98 = 155.18W/㎡$$
$$\dot{Q}_{window4} = CF_{fenestration4} * A_{window4} = 155.18 * 3.6 = 558.65w$$

$$\dot{Q}_{totalcoolingaluminum} = 1991.5 + 3498.6 + 559.08 + 558.65 = 6607.8w$$
$$\dot{Q}_{totalheatingaluminum} = 1289.1 + 1289.1 + 322.2 + 412.4 = 3312.8w$$

$$\frac{\dot{Q}_{totalcoolingwood}}{\dot{Q}_{totalcoolingaluminum}} = \frac{6245.3}{6607.8} = 94.5\%$$
$$\frac{\dot{Q}_{totalheatingwood}}{\dot{Q}_{totalheatingaluminum}} = \frac{2538.2}{3312.8} = 76.6\%$$