Week 8

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 thickenss to be 13 mm)

Ans

$$U_{window} = \frac{U_{center}A_{center} + U_{edge}A_{edge} + U_{fram}A_{fram}}{A_{window}},$$

$If\ it\ is\ a\ double-pane\ window, disregard\ the\ thermal\ resistances\ of\ \ glass\ layers,$

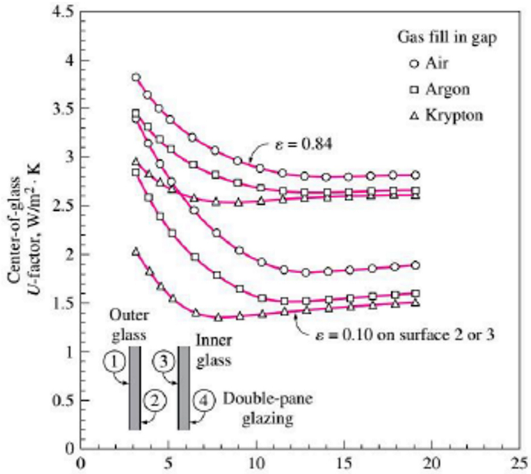
$$\frac{1}{U_{double\ -pane\ (center\ region)}} \approx \frac{1}{h_i} + \frac{1}{h_{space}} + \frac{1}{h_0},\ h_{space} = h_{rad,\,space} + h_{conv,\,space}$$

$The\ U_{center}, i.e. the\ h_{space}\ changes\ by\ changing\ the\ gas\ that\ fills\ the\ gap.$

When the gap thickenss is 13 mm,

By changing the gas that fills the gap from air to argon, the U-value of the center of the glass decreases from $2.8\frac{W}{m^2K}$ *to* $2.65\frac{W}{m^2K}$*, which means the U-value decreases about 6.43%;*

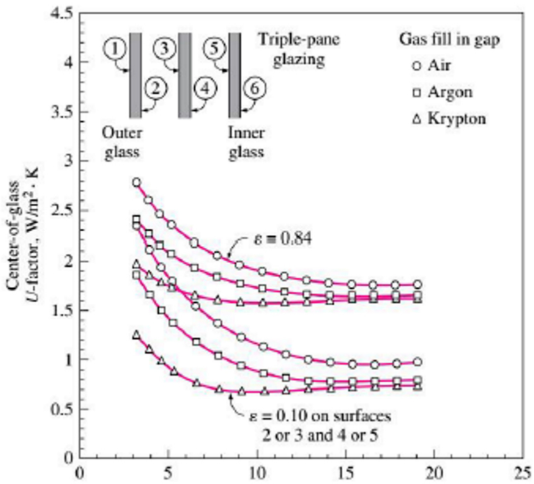
By changing the gas that fills the gap from air to krypton, the U-value of the center of the glass decrease from $2.8\frac{W}{m^2K}$ *to* $2.6\frac{W}{m^2K}$*, which means the U-value decreases abouth 7.14%.*



$The\ U_{center}, i.e. the\ h_{space}\ changes\ by\ adding\ an\ extra\ pane.$

When the gap thickenss is 13 mm, and the gas that fills the gap is air,

By adding an extra pane, the U-value of the center of the glass decreases from $2.8\frac{W}{m^2K}$ *to* $1.8\frac{W}{m^2K}$*, which means the U-value decreases about 55.6%.*



Another way to change the U_{center}*, is to coat the glass surfaces with a film that has a low emissivity.*

When the gap thickenss is 13 mm, and the gas fills the gap is air,

By coating the glass surfaces with a film that has the emissivity of 0.1, the U-value of the center of the glass decreases from $2.8\frac{W}{m^2K}$ *to* $1.8\frac{W}{m^2K}$*, which means the U-value decreases about 55.6%.*

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 m^2 on the west, fixed 3.6 m^2 on the south and an operable 3.6 m^2 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 ?

1. The net area of walls (excluding doors and windows) of a building located in Piacenza is 105.8 m^2, the calculated U value is 0.438 W/m^2K for the winter and 0.435 W/m^2K for the summer. Find the corresponding heating and cooling load.

2. A fixed heat absorbing double layer glass (with a wooden frame) window at the east side of a building located in Piacenza has a surface of 14.4 m^2. In case there are no internal and external shading factors. Calculate the heating and cooling load of the corresponding to that window.

PIACENZA, Italy WMO#: **160840**

Lat: **44.92N** Long: **9.73E** Elev: **138** StdP: **99.68** Time Zone: **1.00 (EUW)** Period: **89-10** WBAN: **99999**

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		
			99.6%			99%			0.4%		1%				
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	
1	-6.2	-4.8	-11.6	1.4	3.1	-8.8	1.8	1.8	8.8	5.6	7.7	6.2	2.1	250	(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB		
		0.4%		1%		2%		0.4%		1%		2%				
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
8	11.9	33.1	22.7	31.9	22.4	30.3	21.8	24.6	30.2	23.7	29.2	22.9	28.3	2.4	90	(2)

Ans

$\boldsymbol{First\ of\ all, define\ the\ cooling\ design\ temperature\ T_{cooling} = 24\ °C,}$
$\boldsymbol{and\ heating\ design\ temperature\ T_{heating} = 20\ °C, thus}$

$\Delta\, T_{cooling} = 31.9\ °C\ - 24\ °C = 7.9\ °C = 7.9K$

$\Delta\, T_{heating} = 20°C\ - (-4.8°C) = 24.8\ °C = 24.8K$

From the table above, $DR = 11.9\ °C = 11.9K$

Calculating the cooling load of the fixed window on the west:

$q_{window_{west}} = A \times CF_{window\,west}$

$A = 14.4m^2,$

$CF_{window_{west}(Heat\ Trasnfer\ Part)} = U_{window_{west}}(\Delta T_{cooling}\ - 0.46\ DR)$

$\therefore U_{window_{west}} = 2.84\,\frac{W}{m^2K}$

$i.e.,\ CF_{window_{west}(Heat\ Trasnfer\ Part)} = 2.84\,\frac{W}{m^2K} \times (7.9\ K\ - 0.46{\times}11.9\ K) \approx 6.89\ \frac{W}{m^2}$

$PXI_{window_{west}} = E_D + E_d = 559 + 188\ = 747$

$SHGC = 0.54$

No internal shading, so $IAC = 1$

$FF_s = 0.56$

$CF_{window_{west}(Irradiation\ Part)} = PXI \times SHGC \times IAC \times FF_s$

$q_{window_{west}} = A \times CF_{window_{west}} = A \times (CF_{window_{west}(Heat\ Trasnfer\ Part)} + CF_{window_{west}(Irradiation\ Part)})$

$$\approx 14.4\ m^2 \times (6.89 + 747 \times 0.54 \times 1 \times 0.56) \frac{W}{m^2} \approx 3352.07\ W$$

Calculating the heating load of the fixed window on the west:

$q_{window_{west}} = A \times HF_{window_{west}} = A \times U_{window_{west}}\ \Delta T_{heating}$

$$= 14.4\ m^2 \times 2.84 \frac{W}{m^2 K} \times 24.8K \approx 1014.22\ W$$

When the frame were to be aluminium, $U_{window_{west}} = 3.61 \frac{W}{m^2 K},\ HSGC = 0.56$

$CF'_{window_{west}(Heat\ Trasnfer\ Part)} = U'_{window_{west}} (\Delta T_{cooling} - 0.46\ DR)$

$$= 3.61 \frac{W}{m^2 K} \times (7.9\ K - 0.46 \times 11.9\ K) \approx 8.76 \frac{W}{m^2}$$

Cooling load $q'_{window_{west}} = A \times CF'_{window_{west}}$

$$= A \times (CF'_{window_{west}(Heat\ Trasnfer\ Part)} + CF'_{window_{west}(Irradiation\ Part)})$$

$$\approx 14.4\ m^2 \times (8.76 + 747 \times 0.56 \times 1 \times 0.56) \frac{W}{m^2} \approx 3499.48\ W$$

Heating load $q'_{window_{west}} = A \times HF'_{window_{west}} = A \times U'_{window_{west}}\ \Delta T_{heating}$

$$= 14.4\ m^2 \times 3.61 \frac{W}{m^2 K} \times 24.8\ K \approx 1289.20\ W$$

Calculating the cooling load of the fixed window on the south:

$q_{window_{south}} = A \times CF_{window_{south}}$

$A = 3.6\ m^2$,

$CF_{window_{south}(Heat\ Trasnfer\ Part)} = U_{window_{south}} (\Delta T_{cooling} - 0.46\ DR)$

$\because$ *The window has a fixed heat absorbing double layer glass with a wooden frame,*

$\therefore U_{window_{south}} = 2.84 \frac{W}{m^2 K}$

i.e., $CF_{window_{south}(Heat\ Trasnfer\ Part)} = 2.84 \frac{W}{m^2 K} \times (7.9\ K - 0.46 \times 11.9\ K) \approx 6.89 \frac{W}{m^2}$

$PXI_{window_{south}} = E_D + E_d = 348 + 209 = 557$

$SHGC = 0.54$

No internal shading, so IAC =1

$FF_s = 0.47$

$CF_{window_{south}(Irradiation\ Part)} = PXI \times SHGC \times IAC \times FF_s$

$q_{window_{south}} = A \times CF_{window_{south}} = A \times (CF_{window_{south}(Heat\ Trasnfer\ Part)} + CF_{window_{south}(Irradiation\ Part)})$

$$\approx 3.6\ m^2 \times (6.89 + 557 \times 0.54 \times 1 \times 0.47) \frac{W}{m^2} \approx 553.72\ W$$

Calculating the heating load of the fixed window on the south:

$q_{window_{south}} = A \times HF_{window_{south}} = A \times U_{window_{south}}\, \Delta T_{heating}$

$$= 3.6\, m^2 \times 2.84 \frac{W}{m^2K} \times 24.8K \approx 253.56\, W$$

When the frame were to be aluminium, $U_{window_{south}} = 3.61 \frac{W}{m^2K},\ HSGC = 0.56$

$CF'_{window_{south}(Heat\ Trasnfer\ Part)} = U'_{window_{south}} \left(\Delta T_{cooling} - 0.46\, DR\right)$

$$=3.61 \frac{W}{m^2K} \times (7.9\, K - 0.46 \times 11.9\, K) \approx 8.76 \frac{W}{m^2}$$

Cooling load $q'_{window_{south}} = A \times CF'_{window_{south}}$

$$= A \times \left(CF'_{window_{south}(Heat\ Trasnfer\ Part)} + CF'_{window_{south}(Irradiation\ Part)}\right)$$

$$\approx 3.6\, m^2 \times (8.76 + 557 \times 0.56 \times 1 \times 0.47) \frac{W}{m^2} \approx 559.30\, W$$

Heating load $q'_{window_{south}} = A \times HF'_{window_{south}} = A \times U'_{window_{south}}\, \Delta T_{heating}$

$$= 3.6\, m^2 \times 3.61 \frac{W}{m^2K} \times 24.8\, K \approx 322.30\, W$$

Calculating the cooling load of the operable window on the south:

$q_{window_{south}} = A \times CF_{window_{south}}$

$A = 3.6\, m^2$,

$CF_{window_{south}(Heat\ Trasnfer\ Part)} = U_{window_{south}} \left(\Delta T_{cooling} - 0.46\, DR\right)$

$\because$*The window has an operable heat absorbing double layer glass with a wooden frame,*

$\therefore U_{window_{south}} = 2.87 \frac{W}{m^2K}$

$i.e.,\ CF_{window_{south}(Heat\ Trasnfer\ Part)} = 2.87 \frac{W}{m^2K} \times (7.9\, K - 0.46 \times 11.9\, K) \approx 6.96 \frac{W}{m^2}$

$PXI_{window_{south}} = E_D + E_d = 348 + 209 = 557$

$SHGC = 0.46$

No internal shading, so IAC =1

$FF_s = 0.47$

$CF_{window_{south}(Irradiation\ Part)} = PXI \times SHGC \times IAC \times FF_s$

$q_{window_{south}} = A \times CF_{window_{south}} = A \times (CF_{window_{south}(Heat\ Trasnfer\ Part)} + CF_{window_{south}(Irradiation\ Part)})$

$$\approx 3.6\, m^2 \times (6.96 + 557 \times 0.46 \times 1 \times 0.47) \frac{W}{m^2} \approx 458.58\, W$$

Calculating the heating load of the operable window on the south:

$q_{window_{south}} = A \times HF_{window_{south}} = A \times U_{window_{south}}\, \Delta T_{heating}$

$$= 3.6\, m^2 \times 2.87 \frac{W}{m^2K} \times 24.8K \approx 256.23\, W$$

When the frame were to be aluminium, $U_{window_{south}} = 4.62 \frac{W}{m^2K},\ HSGC = 0.55$

$CF'_{window_{south}(Heat\ Trasnfer\ Part)} = U'_{window_{south}} \left(\Delta T_{cooling} - 0.46\, DR\right)$

$$=4.62\ \frac{W}{m^2K} \times (7.9\ K\ - 0.46 \times 11.9\ K) \approx 11.21\ \frac{W}{m^2}$$

$Cooling\ load\ q'_{window_{south}} = A \times CF'_{window_{south}}$

$$= A \times \left(CF'_{window_{south}(Heat\ Trasnfer\ Part)} + CF'_{window_{south}(Irradiation\ Part)}\right)$$

$$\approx 3.6\ m^2 \times (11.21 + 557 \times 0.55 \times 1 \times 0.47)\frac{W}{m^2} \approx 558.70\ W$$

$Heating\ load\ q'_{window_{south}} = A \times HF'_{window_{south}} = A \times U'_{window_{south}}\ \Delta T_{heating}$

$$= 3.6\ m^2\ \times 4.62\frac{W}{m^2K}\ \times 24.8\ K \approx 412.47\ W$$