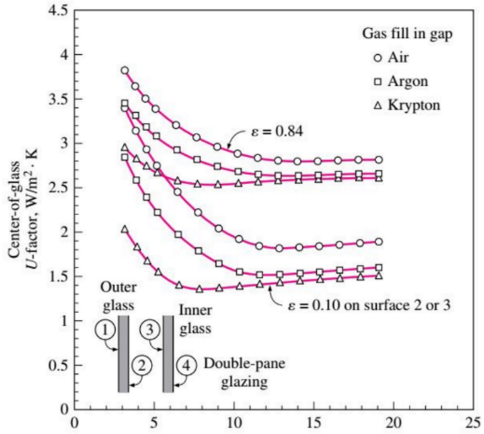
Subission 8 - Technical Environmental Systems

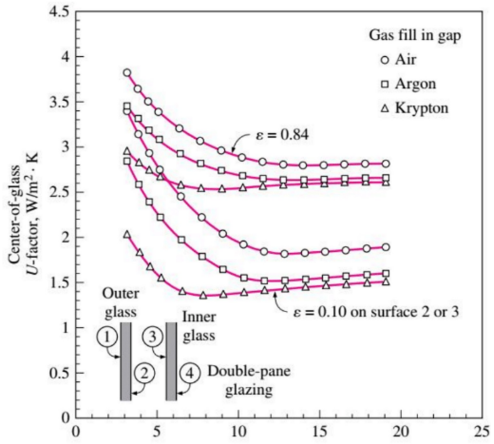
1. **Using the diagrams given in the presentation, calculate how much (%) is the effect of applying different modifications (changing the gas, adding an extra pane, using a low emissivity coating) on the U value with respect to a benchmark case of double layer with air and no coating ? (Keep the gap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

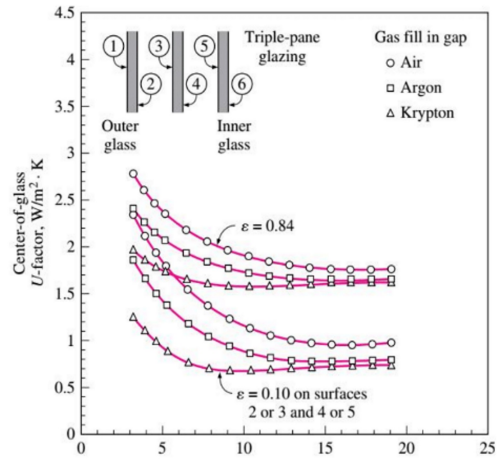
-Changing the gas:



Changing the gas fill in the gap to Argon/Krypton reduces the U-value of the Centre-of-glass by 3.6% and 7.2% respectively.

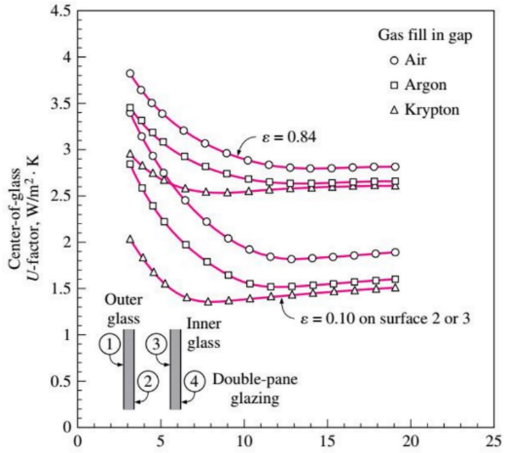
-Adding an extra pane:





Adding an extra pane reduces the U-value by ~35.7% (1/3rd)

-Using a low emissivity coating:



Using a low-emissivity coating on surface 2 or 3 also reduces the U-value by ~35.7% (1/3rd)

2. **Consider the house that we analyzed in the last 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?**

Defining the cooling design temperature, $T_{cooling} = 24\ °C$ and the heating design temperature, $T_{heating} = 20\ °C$,
$\Delta T_{cooling} = 31.9 - 24 = 7.9\ °C = 7.9K$
$\Delta T_{heating} = 20 - (-4.8) = 24.8\ °C = 24.8K$
$DR{=}11.9\ K$ (from table)

Fixed window on the west:

- ***Cooling Load:***

$Q_{window_{west}} = A\ * CF_{window_{west}}$

$A = 14.4\ m^2$
$CF_{window_{west}}(Heat\ transfer) = U_{window_{west}}(\Delta T_{cooling} - 0.46\ DR)$

For a fixed, heat absorbing double layer glass window with wooden frame, $U_{window_{west}} = 2.84\ W/m^2K$
$SHGC = 0.54$

$Therefore,$
$CF_{window_{west}}(Heat\ transfer) = 2.84\ *7(9 - 0.46\ (11.9)) = 6.8898\ W/m^2$

$$PXI_{window_{west}} = E_d + E_D = 188 + 559 = 747\frac{W}{m^2}\ (from\ table)$$

$IAC{=}1$
$FF_s = 0.56\ (from\ table)$

$CF_{window_{west}}(Irradiation) = PXI * SHGC * IAC * FF_S = 747 * 0.54 * 1 * 0.56$
$= 225.8928\ W/m^2$

$Q_{window_{west}}(Cooling) = A * CF_{window_{west}} = A * (CF_{window_{west}}(Heat\ Transfer) + CF_{window_{west}}(Irradiation))$
$= 14.4\ (6.8898 + 225.8928) = 3352.07\ W$

- ***Heating Load:***

$A = 14.4\ m^2$

$Q_{window_{west}}(Heating) = A * HF_{window_{west}} = A * U_{window_{west}} * \Delta T_{heating}$
$= 14.4 * 2.84 * 24.8 = 1014.22\ W$

- ***If the frame is changed to aluminium:***

$U'_{window_{west}} = 3.61\ W/m^2K$
$SHGC = 0.56$

$CF'_{window_{west}}(Heat\ transfer) = U'_{window_{west}}(\Delta T_{cooling} - 0.46\ DR)$
$= 3.61 * 7(9 - 0.46\ (11.9)) = 8.7578\ W/m^2$
$CF_{window_{west}}(Irradiation) = PXI * SHGC * IAC * FF_S = 747 * 0.56 * 1 * 0.56$
$= 234.2592\ W/m^2$

Thus, Cooling Load = $Q'_{window_{west}}(Cooling) = A * CF'_{window_{west}} = A * (CF'_{window_{west}}(Heat\ Transfer) + CF_{window_{west}}(Irradiation)) = 14.4\ (8.7578 + 234.2592) = 3499.445\ \frac{W}{m^2}$

Heating Load = $Q'_{window_{west}}(Heating) = A * HF'_{window_{west}} = A * U'_{window_{west}} * \Delta T_{heating} = 14.4 * 3.61 * 24.8 = 1289.2\ W$

Fixed window on the south:

- ***Cooling Load:***

$Q_{window_{west}} = A * CF_{window_{west}}$

$A = 3.6\ m^2$
$CF_{window_{west}}(Heat\ transfer) = U_{window_{west}}(\Delta T_{cooling} - 0.46\ DR)$

For a fixed, heat absorbing double layer glass window with wooden frame, $U_{window_{west}} = 2.84\ W/m^2K$
$SHGC = 0.54$

$Therefore,$
$CF_{window_{west}}(Heat\ transfer) = 2.84 * 7(9 - 0.46\ (11.9)) = 6.8898\ W/m^2$

$PXI_{window_{west}} = E_d + E_D = 209 + 348 = 557\ \frac{W}{m^2}\ (from\ table)$

$IAC=1$
$FF_S = 0.47\ (from\ table)$
$CF_{window_{west}}(Irradiation) = PXI\ * SHGC\ * IAC\ * FF_S = 557 * 0.54 * 1 * 0.47$
$= 141.3666\ W/m^2$

$Q_{window_{west}}(Cooling) = A * CF_{window_{west}} = A * (CF_{window_{west}}(Heat\ Transfer) + CF_{window_{west}}(Irradiation))$
$= 3.6\ (6.8898 + 141.3666) = 533.723\ W$

- ***Heating Load:***

$A = 3.6\ m^2$

$Q_{window_{west}}(Heating) = A * HF_{window_{west}} = A * U_{window_{west}} * \Delta T_{heating}$
$= 3.6\ * 2.84 * 24.8 = 253.5552\ W$

- ***If the frame is changed to aluminium:***

$U'_{window_{west}} = 3.61\ W/m^2K$
$SHGC = 0.56$

$CF'_{window_{west}}\ (Heat\ transfer) = U'_{window_{west}}(\Delta T_{cooling} - 0.46\ DR)$
$= 3.61\ *7(9 - 0.46\ (11.9)) = 8.7578\ W/m^2$
$CF_{window_{west}}(Irradiation) = PXI\ * SHGC\ * IAC\ * FF_S = 557 * 0.56 * 1 * 0.47$
$= 146.6024\ W/m^2$

Thus, Cooling Load = $Q'_{window_{west}}(Cooling) = A * CF'_{window_{west}} = A * (CF'_{window_{west}}(Heat\ Transfer) + CF_{window_{west}}(Irradiation)) = 3.6\ (8.7578 + 146.6024) = 559.2967\ \frac{W}{m^2}$

Heating Load = $Q'_{window_{west}}(Heating) = A * HF'_{window_{west}} = A * U'_{window_{west}} * \Delta T_{heating} = 3.6\ * 3.61\ * 24.8 = 322.3\ W$

Operable window on the south:

- ***Cooling Load:***

$Q_{window_{west}} = A\ * CF_{window_{west}}$

$A = 3.6\ m^2$
$CF_{window_{west}}(Heat\ transfer) = U_{window_{west}}(\Delta T_{cooling} - 0.46\ DR)$

For an operable, heat absorbing double layer glass window with wooden frame, $U_{window_{west}} = 2.87\ W/m^2K$
$SHGC = 0.46$

$Therefore,$
$CF_{window_{west}}(Heat\ transfer) = 2.87\ *7(9 - 0.46\ (11.9)) = 6.9626\ W/m^2$

$$PXI_{window_{west}} = E_d + E_D = 209 + 348 = 557 \frac{W}{m^2} \ (from\ table)$$

$IAC=1$
$FF_s = 0.47\ (from\ table)$
$CF_{window_{west}}(Irradiation) = PXI\ * SHGC\ * IAC\ * FF_S = 557 * 0.46 * 1 * 0.47$
$= 120.4234\ W/m^2$

$Q_{window_{west}}(Cooling) = \ A * CF_{window_{west}} = \ A * (CF_{window_{west}}(Heat\ Transfer) +$
$CF_{window_{west}}(Irradiation))$
$= 3.6\ (6.9626 + 120.4234) = 458.5896\ W$

- ***Heating Load:***

$A = 3.6\ m^2$

$Q_{window_{west}}(Heating) = \ A * HF_{window_{west}} = \ A * U_{window_{west}} * \Delta T_{heating}$
$= 3.6\ * 2.87 * 24.8 = 256.2336\ W$

- ***If the frame is changed to aluminium:***

$U'_{window_{west}} = 4.62\ W/m^2K$
$SHGC = 0.55$

$CF'_{window_{west}}\ (Heat\ transfer) = U'_{window_{west}}(\Delta T_{cooling} - 0.46\ DR)$
$= 4.62\ * 7(9 - 0.46\ (11.9)) = 11.2081\ W/m^2$
$CF_{window_{west}}(Irradiation) = PXI\ * SHGC\ * IAC\ * FF_S = 557 * 0.55 * 1 * 0.47$
$= 143.9845\ W/m^2$

Thus, Cooling Load = $Q'_{window_{west}}(Cooling) = \ A * CF'_{window_{west}} = \ A *$
$(CF'_{window_{west}}(Heat\ Transfer) +$
$CF_{window_{west}}(Irradiation)) = 3.6\ (11.2081 + 143.9845) = 558.69 \frac{W}{m^2}$

Heating Load = $Q'_{window_{west}}(Heating) = \ A * HF'_{window_{west}} = \ A * U'_{window_{west}} *$
$\Delta T_{heating} = 3.6\ * 4.62\ * 24.8 = 412.47W$