DEW ON WINDOW PANES

Statement

Find if dew on window panes is avoided by having a double-glazed frame, instead of a single glass. Assume two 4 mm glass sheets, separated by a 6 mm dry-air gap, with convective coefficient of 20 W/(m^2·K) for outside air, which is at 0 ºC, and 10 W/(m^2·K) for indoor air, at 22 ºC, and 50% RH everywhere.

Estimar si una ventana de vidrio doble evitaría el empañamiento, en comparación con una de vidrio simple. Tómese láminas de vidrio de 4 mm de espesor, 6 mm de aire seco atrapado en el caso doble, coeficientes convectivos de 20 W/(m^2·K) para el aire exterior, a 0 ºC, y 10 W/(m^2·K) para el aire interior, que está a 22 ºC, y 50% HR en ambos casos.

Solution

This is a typical composite-wall problem, sketched in Fig. 1, with a heat flux given by:

$$\dot{q} = K\Delta T = h_0\left(T_1 - T_0\right) = k_{12}\frac{T_2 - T_1}{L_{12}} = k_{23}\frac{T_3 - T_2}{L_{23}} = k_{34}\frac{T_4 - T_3}{L_{34}} = h_5\left(T_5 - T_4\right) =$$

$$= \frac{T_5 - T_0}{\frac{1}{h_0} + \frac{L_{12}}{k_{12}} + \frac{L_{23}}{k_{23}} + \frac{L_{34}}{k_{34}} + \frac{1}{h_5}} = \frac{22 - 0}{\frac{1}{20} + \frac{0.004}{1} + \frac{0.006}{0.024} + \frac{0.004}{1} + \frac{1}{10}} = 54\ \frac{\text{W}}{\text{m}^2}$$

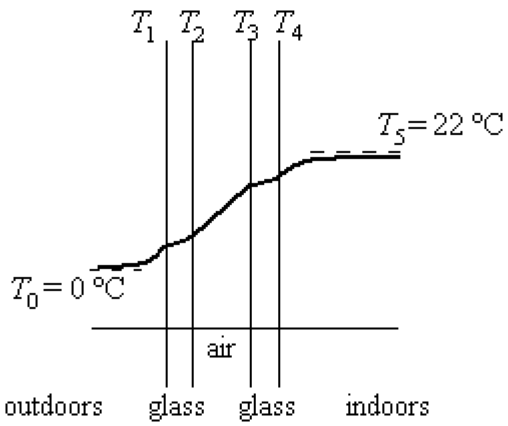

Fig. 1. Temperature profile in a double glass window.

where a thermal conductivity value of k=1 W/(m·K) for glass and k=0.024 W/(m·K) for air have been considered.

Condensation will take place when the indoor interface T_4 falls below the dew-point temperature in the room, T_{dew}, which is a function of indoor temperature T_5 and relative humidity ϕ_5. The dew point is reached when cooling the humid air until saturation, at constant pressure and composition, i.e. when the vapour pressure at T_{dew}, $p^*(T_{dew})$, equals $\phi p^*(T)$, what yields:

$$p^*(T_{dew}) = \phi\, p^*(T) \quad \Rightarrow \quad \frac{T_{dew}}{T_u} = \frac{1}{\dfrac{1}{\dfrac{T}{T_u}+C} - \dfrac{\ln\phi}{B}} - C$$

where Antoine equation for vapour pressure is substituted (T_u=1 K is used to make the equation dimensionless). Antoine's coefficients *A, B* and *C* can be found in Table A3.5 in Martínez-1992, and thence:

$$T_{dew} = \frac{1}{\dfrac{1}{(22+273)-39} - \dfrac{\ln 0.5}{3985}} + 39 = 284.2 \text{ K } (11.1\ ^\circ\text{C})$$

On the other hand, the glass temperature T_4 is obtained by one of the first equations:

$$\dot{q} = h_5\left(T_5 - T_4\right) = 54 = 10\left(22 - T_4\right) \quad \Rightarrow \quad T_4 = 16.6\ ^\circ\text{C}$$

showing that there is no-condensation problem ($T_4 > T_{dew}$). Notice that, if a single glazing is considered:

$$\dot{q} = \frac{T_5 - T_0}{\dfrac{1}{h_0} + \dfrac{L_{15}}{k_{15}} + \dfrac{1}{h_5}} = \frac{22-0}{\dfrac{1}{20} + \dfrac{0.004}{1} + \dfrac{1}{10}} = 143\ \frac{\text{W}}{\text{m}^2} \quad \Rightarrow \quad T_4 = T_5 - \frac{\dot{q}}{h_5} = 22 - \frac{143}{10} = 7.7\ ^\circ\text{C}$$

condensation would take place.

Comments

Condensation must be avoided not just to have a clear view, but because it damages window frames, sills, the surrounding paint, wallpaper, plasterboard, etc. When condensation cannot be avoided (as in bath rooms and kitchens) supplementary ventilation (e.g. exhaust fans) and water-proof walls should be used.

We have just considered water condensation (dew, or sweating) at the indoor interface; condensation might occur within the double pane if the seal around is broken, since the cavity inside double-pane windows is filled with a dry gas (dry air, carbon dioxide, sulfur hexafluoride, argon or even kripton) and sealed when manufactured. Recently, evacuated double-glazing panes are in the market too, with a vacuum gap of some 0.5 mm (the separation in vacuum is thermally irrelevant), and minute spacers (e.g. pillars some 0.5 mm in diameter and 20 mm apart) to support atmospheric pressure. Condensation might also take place in the outdoors interface, like in car windows, but this requires the panes to be colder than the air around (by sky radiation at dawn in cool nights following a warm day), what is more difficult to happen on living spaces.

Besides double glazing, condensation can be avoided by heating the pane (as in the rear windows of cars and airplane windshields, by blowing heated air over the pane, or by blowing dry (refrigerated) air. There are also some double-pane set-ups where condensation is avoided by heating the glass, as in some supermarket freezer doors.

A final comment is that we have only considered a one-dimensional heat transfer problem (by combined conduction and convection) with fixed convective coefficients, without regarding the effect of radiation, convection within the gas space, the influence of the surrounding window frame, or airflows, both wanted (ventilation) and unwanted (infiltration).

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