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Condensation at the outside of highly insulating glazings: Results from theoretical and practical studies

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SUMMARY

One of the important advantages of ordinary double glazing in comparison with single glazing is the avoidance of condensation at the inner surface during normal household activities. The reason being the higher internal surface temperature when using double glazing.
However, highly insulating glazings will have lower external surface temperatures due to the good thermal insulation. During periods of clear sky during the night, the outside surface temperature may drop below the external air temperature. This may cause condensation at the outer surface if the outdoor relative humidity is sufficiently high. This phenomenon is rather frequently observed on improved glazing applications in a country as Belgium.
The following issues are described in the paper :

- theoretical description of the process with emphasis on the sky radiation;
- theoretical example applied to single glazing, ordinary double glazing and improved insulating glazing;
- results of monitoring on the PASSYS Test Cells;
- guidelines for future product development.

1. INTRODUCTION

Condensation at the inner surface of glazings is a very common problem in many occupied buildings. Normally condensation is the result of low inner surface temperatures (especially on single glazing) in combination with a relatively high internal air humidity. These problems can be solved by increasing the surface temperature (eg. by replacing the glazing by better insulating glazing elements) and/or by reducing the internal humidity level (eg. by increasing the ventilation rates).
This problem is sufficiently well known.

Another type of condensation is found at the external surface of the glazing. However, instead of being found on poorly insulating glazings, it is mostly found on well insulating glazings but only during specific weather conditions. This type of condensation phenomena is the subject of this article.

First, the physical process describing the problem is given. Then, results concerning measured sky radiation are shown in order to give the reader an idea of the importance of the undercooling effect. Based on theoretical calculations, the effect of the type of glazing, of its inclination and of the wind speed are shown.
The effect of the edge effects due to the metal spacer on the condensation pattern is also discussed. Finally, some conclusions and recommendations are given.

2. BRIEF DESCRIPTION OF THE PHYSICAL PROCESS

The surface temperature at the external surface of a building component is determined by 6 types of heat exchange (see figure 1) :

- heat exchange between the outer and inner surfaces of the component;
- convective heat exchange with the outside air;
- short wave radiation from the sun;
- longwave radiation heat exchange with the sky/clouds and surrounding obstacles;
- condensation/evaporation at the surface;
- rain, snow,... on the surface

An essential element for understanding the problem is the longwave radiation exchange. This is described in the next paragraph.

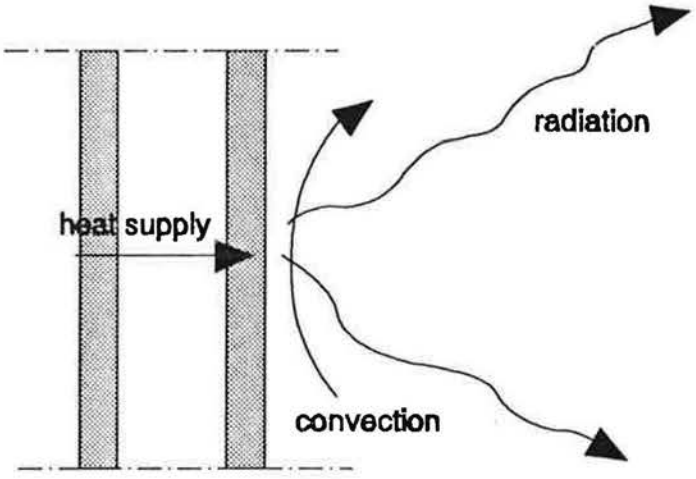

Figure 1: Heat exchange of the double glazing during a clear night

3. THE IMPORTANCE OF UNDERCOOLING : MEASUREMENTS IN PASSYS

At the Belgian PASSYS test site at C.S.T.C./W.T.C.B. (1), 2 pyrgeometers measure the long wave radiation coming from the sky and the environment on both the horizontal plane and the vertical south facing plane.

This long wave (infrared) radiation I_{ir} (W/m²) can be translated into an equivalent black body temperature T_{ir} by using the following formula :

$$I_{ir} = \sigma \left(\frac{T_{ir}}{100} \right)^4$$

Figure 2 shows the measured equivalent temperature of the sky (horizontal surface) and of the environment in front of the south wall of the test cells (vertical surface) for the period 26 December 1992 to 6 January 1993. Also the outdoor air temperature (mechanically ventilated air sensor) is given.
As one can observe, during periods of clear sky, the sky temperature may be up to 25 °C lower than the outdoor air temperature. The equivalent black body temperature, when measured in a vertical plane, is almost the average of the air and sky temperatures.

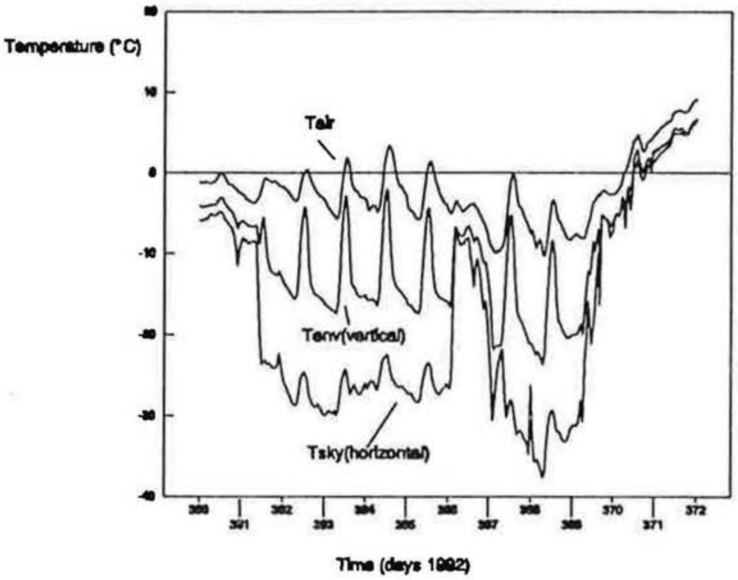

Figure 2: Comparison of sky, environment and air temperatures

hows for the same period :

surface temperatures on a very well insulated flat roof;

ne net radiation exchange (W/m²) between this well insulated flat roof and the sky (assumption : $\varepsilon_L = 0.85$);

- the net radiation exchange between a surface at the same temperature as the outdoor air and the sky (assumption : $\varepsilon_L = 0.85$)

This radiation is calculated by using the following formula :

$$I_{net} = \varepsilon_L \cdot \sigma \cdot (T_{sky}^4 - T_2^4)$$

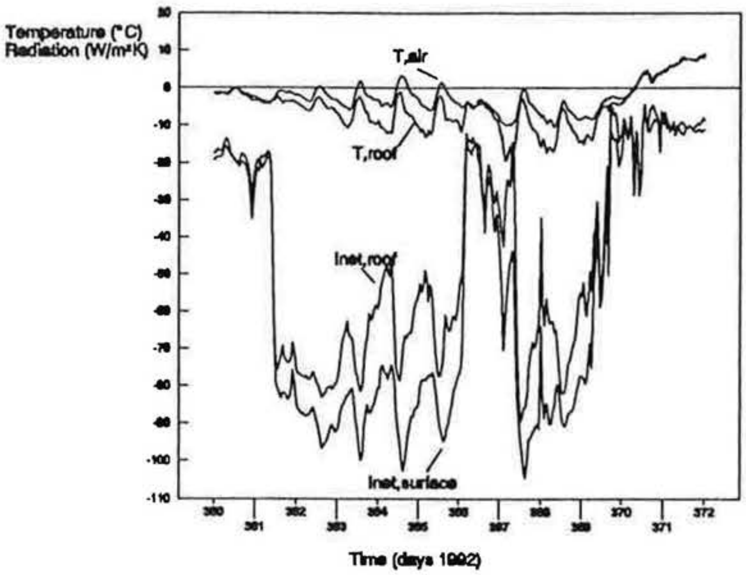

Figure 3 : Longwave radiation exchange of a flat roof

4. THEORETICAL RESULTS

The effect of longwave radiation losses is in this paragraph calculated in a simplified manner. This allows to draw some conclusions.

The following assumptions are made :

- the heat losses to the sky I_{sky} can be described in a simplified way by using the following formulae :
  - horizontal surface : $80+4.(T_{eo}-T_e)$ (W/m²)
  - vertical surface : $40+4.(T_{eo}-T_e)$ (W/m²)

  These formulae assume that the net radiation for a surface at air temperature equals 80 W/m² for a horizontal surface and 40 W/m² for a vertical surface.

- The relation between wind speed v and heat exchange by convection q_{conv} is described by the formula :

$$q_{conv} = (4 + 4 \, . \, v)*(T_{eo} - T_e)$$

The calculations in table 1 give for 3 types of glazing (single glazing, ordinary double glazing and improved double glazing), for 2 inclinations (horizontal and vertical) and for 3 wind velocities the outside surface temperature on these glazings. The assumption is made that there are no obstacles (buildings, trees,...) in the surroundings.
Also the relative humidity of the outside air above which condensation will occur is given in table 1.

Wind (m/s)	T_e (°C)	Inclination	Single glazing (U=5.8 W/m²K)	Double glazing (U=2.86 W/m²K)	Improved double glazing (U= 1.3 W/m²K)
0	10	Vertical	12.4 °C / -	9.3 °C /95 %	7.2 °C / 83 %
	0	Vertical	7.3 °C / -	2.2 °C / -	-1.3 °C / 90 %
	-10	Vertical	2.2 °C / -	-4.9 °C / -	-9.9 °C / 99 %
	10	Horizontal	9.8 °C / 99 %	5.8 °C / 75 %	2.9 °C / 61 %
	0	Horizontal	4.7 °C / -	-1.3 °C / 90	-5.6 °C / 63 %
	-10	Horizontal	-0.3 °C / -	-8.4 °C / -	-14.1 °C / 69 %
4	10	Vertical	11.2 °C / -	9.7 °C / 99 %	9.0 °C / 93 %
	10	Horizontal	9.9 °C / 99 %	8.3 °C / 89 %	7.4 °C / 84 %
10	-10	Vertical	10.7 °C / -	9.9 °C / 99 %	9.5 °C / 97 %

Table 1 : Calculated outside surface temperatures of the glazing and corresponding outside relative humidity above which condensation will occur during clear sky conditions (room temperature of 20 °C)

Interpretation :

- external condensation on a single glazing is quasi impossible if used in a well heated room;
- improving the thermal insulation of the glazing reduces the heat flow to the external surface and results in lower external surface temperatures;
- higher wind velocities will reduce the difference between air and surface temperatures. This means lower temperatures for poorly insulated glazings but higher temperatures for well insulated glazings. During clear sky conditions the effect of the wind increases the heat losses for poorly insulated glazings but reduces the heat losses for well insulated glazings;
- high relative humidity levels (eg. 95...99%) are not compatible with clear sky conditions. Indeed, during clear sky conditions, there are no clouds and normally the outside air will have a relative humidity significantly below 100%.

'S OF INTERNAL AND EXTERNAL CONDENSATION

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the s' :hange coefficient in the corners is often lower.
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. .ısation at the external surface, the metal spacer also leads the heat losses. However, it will lead to INCREASED external peratures at the edges. Therefore, external condensation will start ntral part of the glazing and will only in extreme situations occur at the s. A typical pattern in shown in figure 4.b.

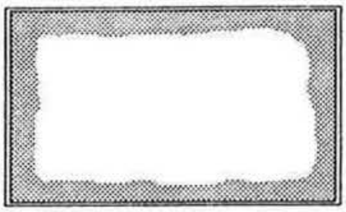

Figure 4.a: Internal condensation

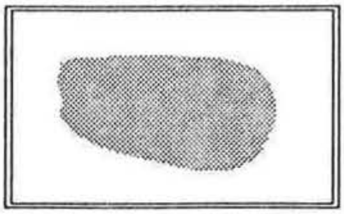

Figure 4.b : External condensation

6. CONCLUSIONS

Condensation at the outer leaf of well insulated glazings can be rather easily explained. It is essentially related to clear sky conditions, low wind velocities and a large view factor to the sky (especially horizontal surfaces).
This type of condensation should not be seen as a product failure but an indication of a good thermal insulation level.
One possibility to avoid this type of condensation in the future might be the application of low emissivity coatings at the external surface.

7. REFERENCES

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