How to Check the Presence of Dew on Windows

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Abstract

The issue of external water condensation on well-insulated windows in cold climates has been studied with a new, unique experimental test facility in Uppsala, Sweden. The characteristics of the outer surface of the window affects the occurrence, amount and type of external water condensation. Specifically, it influences how good the visibility is through the water layer.

In this article, measurements with this new equipment of the occurrence of dew on glass samples with different coatings are presented and discussed.

These initial results both show that the test facility gives reliable results and give an indication of what surfaces can be used to prevent either dew from occurring or the view through the window from being distorted by dew.

Key words: External water condensation, Thin film coatings, Hydrophilic glazing, Low-e glazing, Dew, Functional coatings on glass

1 Introduction

In cold climates, where the heat transfer is predominantly from the inside to the outside, well-insulated windows are considered high priority to minimize the (heating) energy use of buildings. Dew sometimes forms on these windows on the surface facing the exterior. It typically happens during still, clear and humid nights. Sometimes the dew remains till the morning and obstructs the view to the outside.

Today, the best insulated windows - a U-value of the glazing of $0.4\ W/(m^2, K)$ is offered by several window companies - are not chosen because customers are afraid external water condensation will obstruct the outward view through the windows in the morning after a clear night. The dew is formed since the temperature of the outer surface of the glazing is below that of the ambient air and of the dew point. The surface is not sufficiently heated by the heat transfer from the interior to eliminate the formation of condensation.

Although not many studies have been published on how different surfaces influence the dew formation on glass, it has been indicated that the changes in visibility through a window due to external condensation depend on the outer surface of the outer pane [1–4]. Specifically, it has been shown that different coatings give condensation with different characteristics [2]. Furthermore, it has been pointed out that a low-emissivity (here referred to as low-e) coating could be efficient to reduce the external water condensation and that a self-cleaning coating could smear out the water so that the visibility through the window is not destroyed.

The materials of interest for the coatings are limited. Owing to the required aging stability only hard coatings are possible to use. Fluorine doped tin oxide is one of the most durable transparent conducting oxides known today and it is widely used as a low-e coating. Tin oxide is deposited by atmospheric chemical vapour deposition, commonly referred to as pyrolitic deposition. It has been extensively studied regarding growth mechanism, electrical, optical and mechanical properties [5,6]. Tin oxide is thus expected to be sufficiently durable for the application of condensation suppression coating on windows and was chosen for this project.

Another concept to deal with the problem is to use a hydrophilic coating. The idea is that even though condensation is formed, it is reduced to a water film on the glass surface rather than light scattering drops of water. For this application titanium oxide was chosen also for its hardness and excellent durability, and for the fact that this coating is already marketed as self-cleaning glass. The optical and hydrophilic properties of titanium oxide have also been extensively studied and a number of papers have been published [7–9].

In this article, we use the test box described in [10] and photographed in figure 1 to test different coatings as to how easily they get condensation on the external surface. Up to three sample panes can be tested simultaneously and under identical conditions.

A laser beam is directed through the glass sample. The transmitted beam hits a detector on the other side. When there is water on the surface, the beam is deviated and does not hit the detector. The detector signal thus decreases. It is also possible to see when the dew disappears since the detector signal then increases again.

These initial measurements were made both to see how the measurement method was working and to get some preliminary results on different

Fig. 1. The test equipment used for the measurements presented in this article. Up to three sample panes can be tested simultaneously under similar circumstances.

coatings.

The U-values of the tested panes, marginally affected by the surface emissivity, lie between 5.7 and 5.9 $W/(m^2, K)$. These are U-values calculated under standard conditions for a window assuming an interior temperature of $T_i = 20\ °C$ [11]. Under these conditions condensation never appears on the outside of a single glazed window, but by reducing the temperature inside the test box, the power P being conducted through the pane can be reduced. From $P = U \cdot \Delta T = U \cdot (T_i - T_o)$, where T_o is the air temperature outside the box, it can be seen that reducing T_i is equivalent to reducing the U-value. Thus different U-values can be simulated using only single panes. This feature of the test equipment has not been specifically evaluated in this paper.

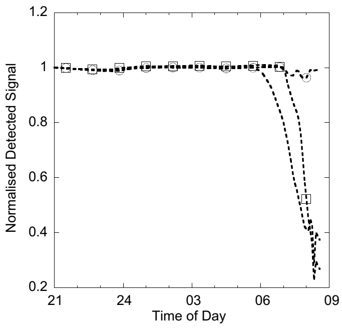
2 Experimental

The tests have been chosen among many series of measurements because they illustrate different features of the various coatings. The experimental set-ups are described here.

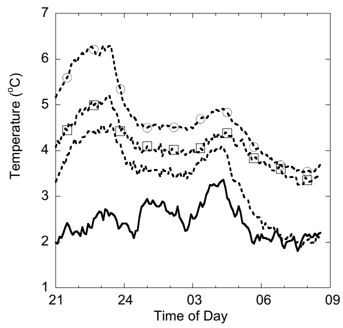
Three low-e coated samples were tested with emissivity values of $\epsilon = 0.15$, $\epsilon = 0.35$ and $\epsilon = 0.60$, respectively. A self-cleaning pane ($\epsilon = 0.84$) and an uncoated pane ($\epsilon = 0.84$) were also tested.

Throughout the night the box was in some tests heated with a power of 8 W. To make sure that there was no moisture on the panes at the beginning of the test affecting the measurement results, the box was heated with an additional power of 11 W until approximately midnight.

According to our calculations and knowledge of the wall material and geometry of the test box, around half of the dissipated power in the box,



(a) Intensity of the detection signal versus time.



(b) Pane temperature versus time. Solid curve shows outdoor air temperature.

Fig. 2. Three parallel samples with $\epsilon = 0.15$ (circles), 0.35 (squares) and 0.60 (no markers), respectively. Internal heating of 8 W applied throughout the night. Until approximately midnight an extra 11 W was applied to make sure that the surfaces were dry during the experiment.

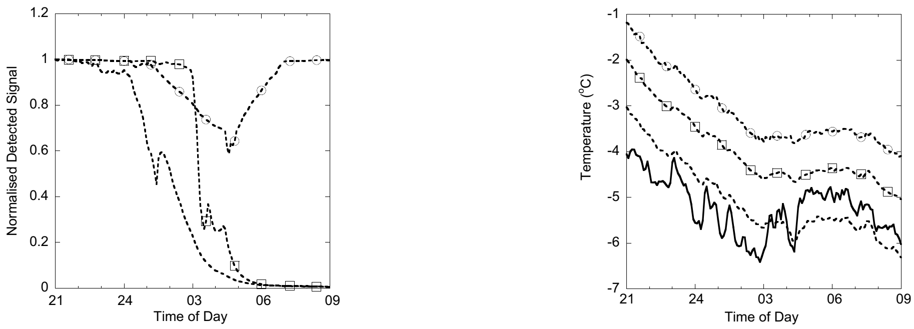
$\approx 4\ W$, escapes through the glazed part. Since the temperature difference was around $4\ ^{\circ}C$, this test situation was approximately equivalent to testing panes in windows with glazing U-values of $U = 1\ W/(m^2, K)$. Nevertheless, as stated in the introduction, U-value simulations were not the prime object of this investigation. The heating power was low enough to ensure that condensation would occur on some panes during our tests.

It can be seen in figures 2 and 3 that the lower the emissivity the later the formation of condensation starts. The surface with the lowest emissivity is kept free from condensation throughout the night in figure 2 and only shows a dip in detector signal in figure 3.

Due to the internal heating the panes stay warmer than the outside air throughout the night, see figure 2(b). As expected the pane with the lowest emissivity has the highest temperature.

Condensation appears when there is a drop in outside temperature early in the morning.

The night for the test in figure 3 was substantially colder than the night shown in figure 2. Frost instead of water drops formed on the sample panes.



(a) Intensity of the detection signal versus time.

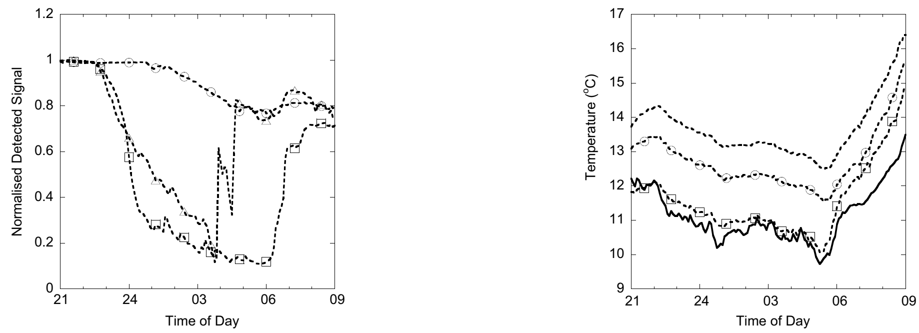
(b) Pane temperature versus time. Solid curve shows outdoor air temperature.

Fig. 3. Three parallel samples with $\epsilon = 0.15$ (circles), 0.35 (squares) and 0.60 (no markers), respectively. Internal heating of 8 W applied throughout the night. No preheating applied.

The measurement results in figure 3 show that the test equipment works even during these circumstances, but we did notice something unexpected in our measurement results: The detection signal started to decrease earlier for the pane with $\epsilon = 0.15$ than for the pane with $\epsilon = 0.35$. It could have something to do with the heating inside the box being uneavenly distributed. Condensation formed on all three panes, but on the pane with the lowest emissivity it had disappeared in the morning.

Next, three different kinds of samples were tested as indicated in figure 4. The measurement results show that it is possible to see a tendency for the water to form a film on the self-cleaning sample. This makes the visibility through the pane increase at approximately four o'clock in the morning, see figure 4(a), and go back to its initial value. This is probably due to the coalescence of water drops into a film which reduces the scattering.

The slow drop in signal for the low-e coated surfafce is due to a temperature drift in the detection system. No condensation could be seen on this surface.



(a) Intensity of the detection signal versus time.

(b) Pane temperature versus time. Dotted curve with no markers show temperature inside the box and solid curve shows outdoor air temperature.

Fig. 4. Three parallel samples; a low-e sample with $\epsilon = 0.15$ (circles), a self-cleaning sample with $\epsilon = 0.84$ (triangles) and an uncoated sample with $\epsilon = 0.84$ (squares). Internal heating of 8 W applied.

3 Conclusion and Future Outlook

The test facility was used to test different glass surfaces as to how prone they were to get condensation. These first tests indicate that condensation occurs when there is a drop in the outdoor air (and pane) temperature(s). This is consistent with theory. When the air temperature drops the difference between the air temperature and the dew point is reduced. The lower the emissivity of the surface, the later the pane temperature drops and the later the formation of condensation starts.

The concept of using light scattering as an indication of condensation works well, even during frost nights.

Different window U-values can be simulated by changing the heating power in the box so that full size windows do not need to be installed. In the present study the power of the internal heater was not adjustable. Therefore the simulated U-value could not be fully controlled. To perform more precise U-value simulations a flexible internal heater should be installed, the power of which can be regulated to maintain a constant temperature difference between the inside and the surrounding air.

It could also be of interest to separate the box into three chambers with different temperatures. This way, the same surface could be tested with three different temperatures as if mounted in windows with three different U-values.

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