

The Humidity at Which a Window Starts to Fog Is Set by the Window, Not the Room

— the same room at relative humidity **0.5** fogs a single pane but not a double one — the separator is whether one asks how damp the air is or how cold the surface is — [Paper 853]

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Abstract

Winter condensation on windows is blamed on “too much moisture in the room”. This paper counts where the humidity at which condensation begins is actually set. No new theorem or law is claimed. First, the inner glass temperature is set by thermal resistances in series: at 20 °C inside and 0 °C outside: **5.0575 °C** single, **12.3529 °C** double, **15.4386 °C** triple (Section 2). Second, and this is the core. The onset humidity differs by window: **0.375006** single, **0.614094** double, **0.750225** triple (Section 3). Third, the same air in the same room fogs one window and not another: a room at relative humidity 0.5 fogs single glazing and not double (Section 3). Fourth, colder outdoors lowers the threshold: at −10 °C: **0.219391** single, **0.475909** double, **0.647323** triple (Section 3). Fifth, the room’s dew point alone gives no answer: at relative humidity 0.5 it is **9.2611 °C**, and what it must be compared with is the glass (Section 3). Sixth, the separator is whether one asks how damp the air is or how cold the surface is: condensation is decided where a property of the air meets a property of the surface (Section 4). **Keywords:** condensation, dew point, surface temperature, thermal resistance, saturation vapour pressure, model.

Scope of this paper (scope note): No new theorem or law is claimed: that saturation vapour pressure is set by temperature (the Magnus formula), the dew point, that surface temperature follows from thermal resistances in series, and that condensation occurs when a surface falls below the dew point, are all known. No design advice is given, which window to choose and how to ventilate are not stated. No real window is claimed: glazing resistances of 0.004, 0.17 and 0.40 m²K/W and surface resistances of 0.13 and 0.04 m²K/W are model values. Frames and thermal bridges are not included: only the centre of the glass is considered; cold edges and frames are not treated. What follows is not treated: mould and health are not entered. Relation to earlier papers: Paper 451 showed that what insulates is not the snow but the air it holds, and its scope note left open “buildings are not designed: choice of insulation, construction and measures against condensation are not the subject”. This paper sits in that seat; there is no earlier occupant. Paper 399 showed that humidity rises from 53.80 to 100 per cent without adding a drop of water. This paper stands beside it: there air is lifted and cooled, here air meets a cold surface. What is added is laying out surface temperatures and onset humidities for three windows at two outdoor temperatures, counting a case where the same room fogs one window and not another, and placing the separator on damp air versus cold surface.

1. Notation and the Question

Setting: let T_{in} be room temperature and T_{out} outdoor temperature, and model the window as inner surface, glass and outer surface in series. The inner surface temperature T_s and the relative humidity at which condensation begins there are as follows.

$$T_s = T_{\text{in}} - (T_{\text{in}} - T_{\text{out}}) \frac{R_{si}}{R_{si} + R_g + R_{se}}, \quad \phi_{\text{max}} = \frac{e_s(T_s)}{e_s(T_{\text{in}})}$$

The saturation vapour pressure e_s follows the Magnus formula. When room humidity exceeds ϕ_{max} , the inner glass fogs.

Question: what sets the humidity at which condensation begins?

2. The Inner Glass Temperature

Computation 2.1: with the room at 20 °C, the inner surface temperatures of three windows were computed.

window	outdoors 0 °C	outdoors –10 °C
single glazing	5.0575 °C	–2.4138 °C
double glazing	12.3529 °C	8.5294 °C
triple glazing	15.4386 °C	13.1579 °C

Observation 2.2

in the same room, the inner glass temperature varies widely by window. At 0 °C outdoors, single and triple differ by more than 10 °C: the lower the glazing resistance, the further the surface is pulled toward the outdoor side.

3. The Onset Humidity

Computation 3.1: dividing the saturation pressure at the surface by that at room temperature gave the onset relative humidity.

window	outdoors 0 °C	outdoors –10 °C
single glazing	0.375006	0.219391
double glazing	0.614094	0.475909
triple glazing	0.750225	0.647323

Observation 3.2

this is the core. The threshold is set by the window, not the room. In the same room at 0 °C outdoors, single glazing fogs above 0.375006 and double above 0.614094: the room air is the same; only the coldness of the inner glass differs.

Computation 3.3: a room at relative humidity 0.5 was placed. Its dew point is 9.2611 °C.

window (outdoors 0 °C)	surface temperature	fogs?
single glazing	5.0575 °C	yes (below the dew point)
double glazing	12.3529 °C	no (above the dew point)

Observation 3.4

the same air fogs one window and not another. The dew point 9.2611 °C is a property of the room, but whether it is crossed is a property of the window: “too much moisture” names only one of the two quantities.

Observation 3.5

colder outdoors lowers the threshold. For single glazing it falls from 0.375006 to 0.219391. This is why the same room with the same moisture fogs more readily on colder nights.

4. The Separator

Observation 4.1

the separator is whether one asks how damp the air is or how cold the surface is. The first fixes the dew point; the second decides whether it is crossed: condensation happens where a property of the air meets a property of the surface.

Observation 4.2

sitting in Paper 451's seat and standing beside Paper 399.451 showed that the air held by snow, not the snow, insulates, and left condensation open. Here too thermal resistances in series do the work, and condensation is counted as one of their consequences. 399 showed that humidity reaches 100 per cent without adding water. There air is lifted and cooled; here air meets a cold surface. The same dew point, approached from the air's side or from the surface's side.

Observation 4.3

what is not said. Which window to choose, frames and thermal bridges, ventilation and mould are not treated. What is shown is that the onset humidity is set by the window.

5. Census and Closing

1. single glazing inner surface **5.0575 °C** (Computation 2.1): **0 °C outdoors**.
2. double glazing **12.3529 °C** (Computation 2.1): **same room**.
3. single fogs at **0.375006** (Computation 3.1): **the core**.
4. double holds to **0.614094** (Computation 3.1): **the window decides**.
5. triple **0.750225** (Computation 3.1): **higher still**.
6. dew point **9.2611 °C** (Computation 3.3): **a room property**.
7. same air fogs only the single pane (Observation 3.4): **a window property**.
8. at **−10 °C** single falls to **0.219391** (Computation 3.1): **threshold drops**.
9. colder nights fog more (Observation 3.5): **same moisture**.
10. damp air, or cold surface (Observation 4.1): **the separator; Papers 451, 399**.

Closing: The humidity at which a window starts to fog is set by the window, not the room. With 20 °C inside and 0 °C outside, the inner glass is 5.0575 °C single, 12.3529 °C double and 15.4386 °C triple, and condensation begins at 0.375006, 0.614094 and 0.750225, because each window pulls its surface toward the outdoor side to a different degree through its series resistances. A room at relative humidity 0.5 fogs a single pane, whose 5.0575 °C lies below the dew point 9.2611 °C, and not a double one at 12.3529 °C: the dew point belongs to the room, but whether it is crossed belongs to the window. At −10 °C outdoors the single-pane threshold falls to 0.219391, which is why the same room fogs more readily on colder nights. Placed among the earlier papers: sitting in the condensation seat Paper 451 left open, and placing “air meets a cold surface” beside Paper 399’s “air lifted and cooled”. To be honest: the resistances are model values, and only the centre of the glass is treated, not frames or cold edges.

References

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