What Historic Timber Needs

Live monitoring and forecast at the Rotunda, Woolwich

TECHNICAL NOTE · ROTUNDA TRUST · NOVEMBER 2026

The Rotunda's roof is twenty-four laminated timber trusses, held together by iron straps, bolts and pegs, under a lead covering. Nine of the trusses are propped. Whether that timber survives another two centuries depends less on any single repair than on the air it lives in, day after day. This note sets out what the timber needs, what three months of measurement show it has been getting, and how a live record with a two-day forecast lets the people caring for it act before conditions arrive rather than after. It accompanies the live record at https://www.rotundatrust.org.uk/rotunda-monitoring.html.



The Rotunda from the north-east: the brick drum of 1818–1820 and the lead roof over Nash's timber structure. FennecMedia, CC BY 4.0.

1. What historic timber needs

Timber is hygroscopic. Its moisture content moves toward equilibrium with the relative humidity of the air around it, and it changes size as it does so, mostly across the grain. At 50 per cent relative humidity softwood settles near 9 to 10 per cent moisture content; at 65 per cent, near 12 per cent. Iron does not move with moisture at all, only with temperature. Every joint in this roof where iron meets timber therefore feels two different rhythms at once. From that, four needs follow.

Not too wet

Surfaces held above about 80 per cent relative humidity for days allow mould to germinate. Moisture contents above roughly 20 per cent admit decay fungi. Both begin at the surface and at the bearings, where air is stillest.

Not too dry

Dried hard, timber shrinks, checks along the grain and works loose at its iron fastenings and laminations. The roof reached 31 per cent in August 2026, an inferred moisture content near 6 per cent.

Not changing fast

Between those limits aged timber tolerates the level it has reached but not the rate of change. Each swing is a cycle of strain at the connections, and the cycles accumulate. Movement between wet and dry is the harm.

No water standing on it

A surface colder than the dew point of the air beside it wets, whatever the room humidity. What matters is the temperature of the timber, not the reading on a wall.

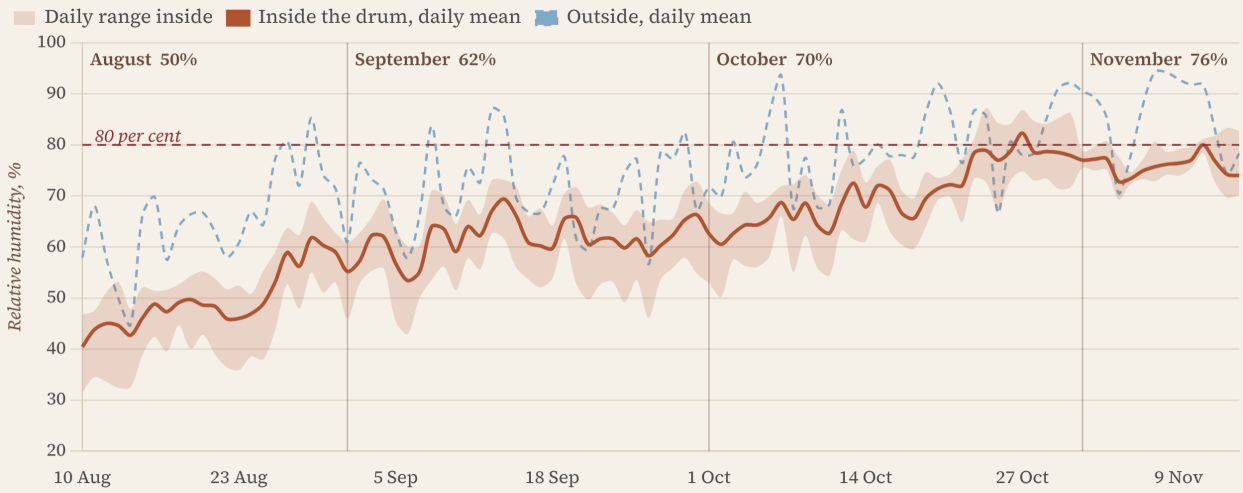
Two things follow for measurement. The condition has to be read at the timber, which means surface temperature as well as air, at the heights and aspects where risk concentrates. And because the harm is in the movement, the record has to be continuous and it has to look ahead: a reading from yesterday tells you what went wrong, while a forecast for tomorrow tells you what to do about it.



An iron strap and timber pegs at a rafter joint, where iron and timber move to different rhythms. FennecMedia, CC BY 4.0.

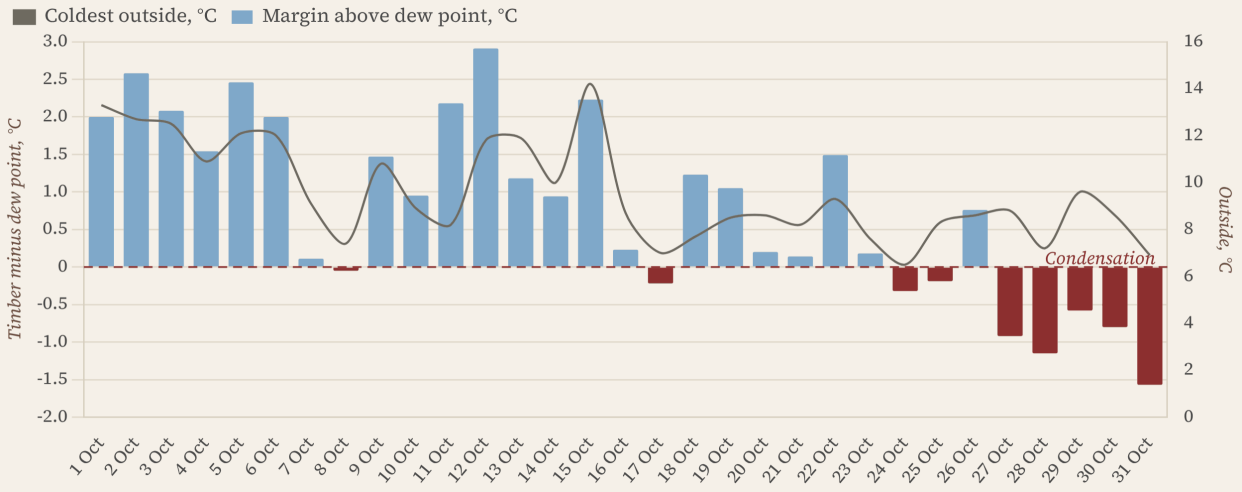
2. What three months have shown

Eight sensors have been reporting from inside the drum since 10 August 2026. The record so far covers the end of a hot summer and the turn into a wet autumn, and it already answers the question the building set: not whether it is damp or dry, but how far and how fast it moves between the two.



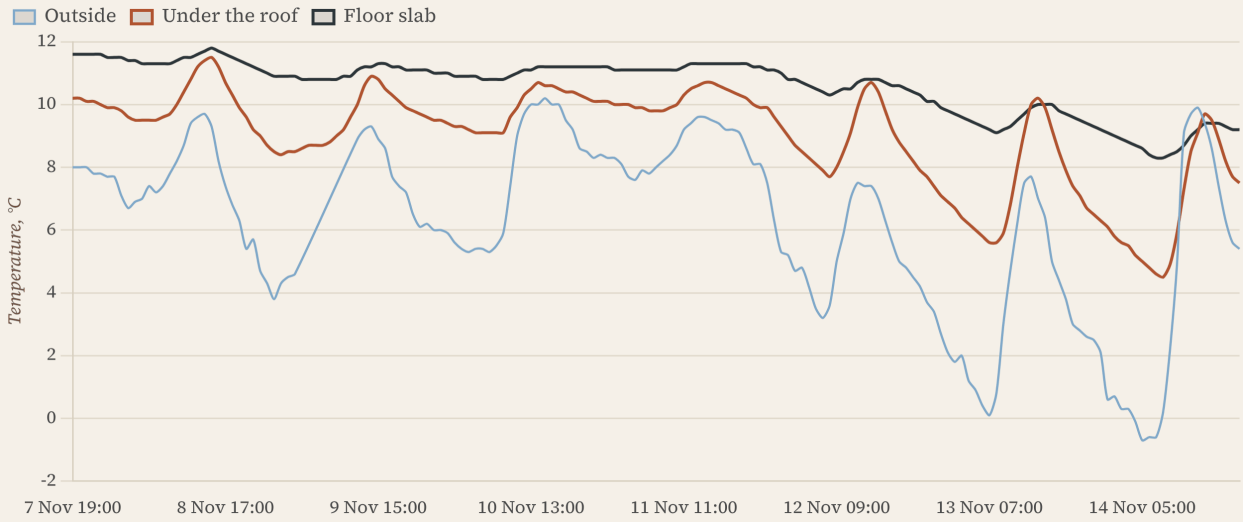
From a dry summer to a damp autumn. *Relative humidity in the drum each day since 10 August 2026: the daily mean, with a band from each day's driest to dampest reading, against the outside air. The drum averaged 50 per cent in August, 62 in September, 70 in October and 76 in November to 14 November. In October 7 per cent of readings were above 80 per cent.*

The swing is the finding. In August the upper roof fell to 31 per cent relative humidity; by late October the drum was touching 80. That is a seasonal journey from the dry limit almost to the wet one in under three months, in an empty building with every opening fixed. The day-to-day band is narrower than the outside air's, so the brick and timber are buffering the short swings. They cannot buffer the season.



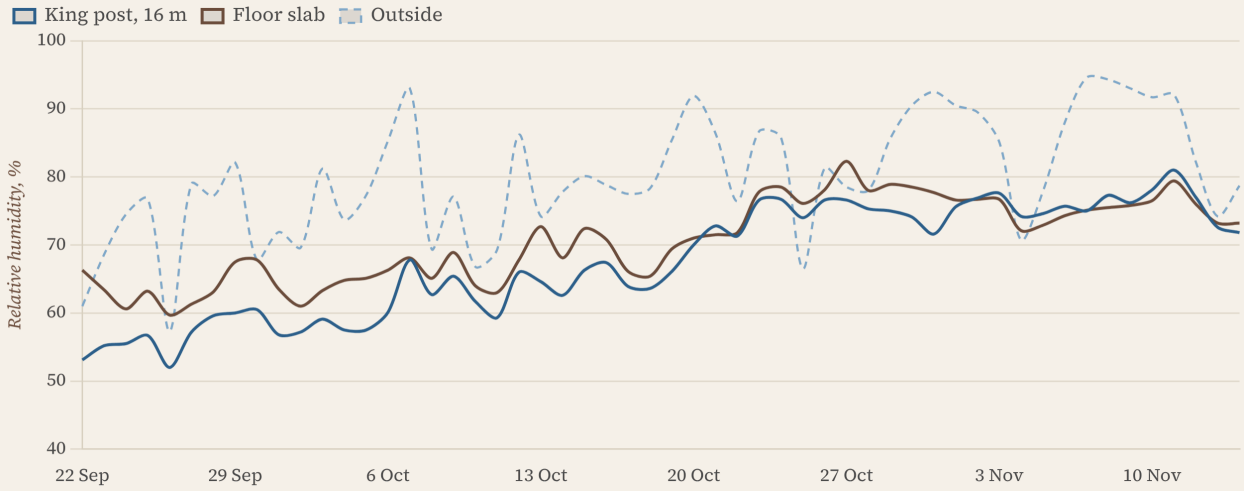
October: the roof timber reaches dew point. *Each day's closest approach of the timber beneath the lead to the dew point of the air beside it, from probes in contact with the sarking at five positions, against the coldest outside temperature. On 9 of October's 31 days the margin reached zero or below, most of them in the last week.*

Condensation arrives with the cold nights. The sarking boards sit directly under the lead, which radiates to a clear night sky and falls below the air temperature. Through most of October the timber stayed a degree or two clear of dew point; in the last week it crossed it on most nights. Condensation at the sarking is recorded, not controlled. It forms on the cold underside of the lead, and heating the room cannot remove it, since warmer air carries more vapour to the same cold surface. It is a matter for the roof repair, not for the room environment.



The roof follows the weather, the floor stays steady. *Hourly air temperature outside and under the roof, and the surface of the floor slab, for the seven days to 14 November 2026. Outside swung through 11 °C, the air under the lead through 7 °C, the floor slab through 3.5 °C.*

The building has two speeds. The air under the lead follows the outside within hours; the lead and boards have little mass and the sun and sky act on them directly. The floor slab and the brick drum move slowly and late. The trusses span between the two, so the roof timbers live in the fast part of the building and their bearings in the slow part.



Top and bottom of the Rotunda. *Daily mean relative humidity at the king post, 16 m above the floor, and at the floor slab, since 22 September 2026, against outside. The top has averaged 68 per cent and the floor 71.*

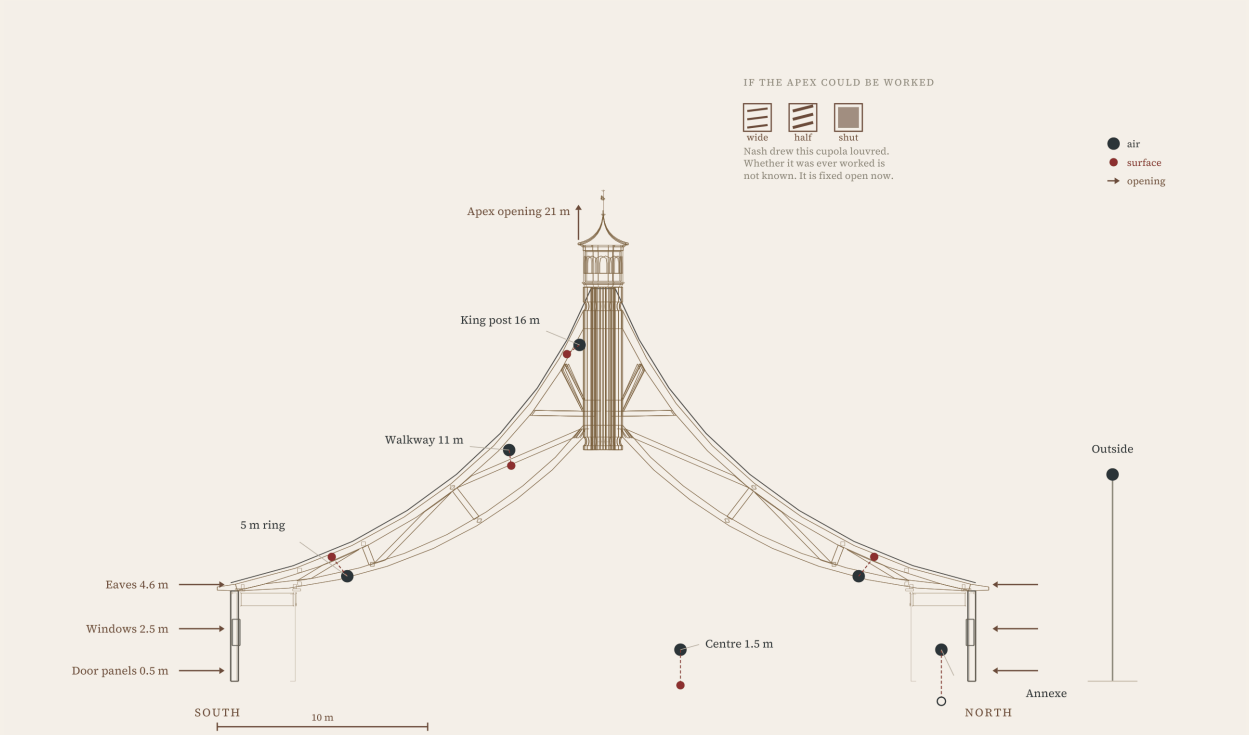
Warm air gathers at the top. The roof is stratified, approximately 1.1 K per metre between 1.5 and 5 m and 0.5 K per metre between 5 and 11 m. Warmer air reads drier for the same moisture, so the king post runs drier than the floor, and drier still in summer. A single sensor at standing height would have missed both the summer drying at the apex and the autumn wetting at the eaves.

3. Live monitoring

Eight multi-sensor units (Dragino LHT65S-E3) measure air temperature, relative humidity and, by an external probe, the temperature of a solid surface beside them. A weather station (SenseCAP S2120) records outside conditions. All report every 5–20 minutes over a low-power radio network to a gateway on site, and every reading is kept in an append-only record. The units are battery powered, need no mains supply and are fixed without adhesive to unpainted surfaces, so the array leaves no mark.

At the timber. Roof probes sit between the sarking boards in contact with the timber under the lead. Each unit pairs the air beside a surface with the surface itself, because condensation is governed by surface temperature against the dew point of the adjacent air. The probe at the centre of the drum rests on the floor slab; one, in the annexe, is suspended in subfloor air and is treated as an air reading.

At the heights and aspects that matter. Sensors stand at floor level, on a ring 5 m up, at walkway level at 11 m and beside the king post at 16 m. The ring carries four aspects, south, east, west and south-west, so a condition across the whole building can be told from a local one. The south position is on truss 21, the member with the recorded bottom chord failure, and the walkway sensor is on the same truss, giving a vertical pair on the element of greatest structural concern.



Section through the Rotunda showing the array. Dark markers are the sensor bodies, reading air; red markers the probes, reading the fabric they rest against. Arrows mark the ventilation openings: in at three low levels, out at the apex. Nash drew the cupola louvred; it is fixed open now, as is every other opening.

Outside, twice. The weather station stands on a post about 8 m above ground in the lee of the building, so its wind reads the site's shelter. A second stream comes from London City Airport, 2.5 km north at standard exposure, half-hourly: wind, temperature, dew point, pressure and cloud. Over the paired record the mast reads about 0.13 of the airport wind, and dew point at the two sites agrees within 0.7 K, a running check on the humidity sensing.

Published live. The record is published as it arrives, at four fixed views: an outlook of the past day and the next two; the past two days at every reading; the past week, where the daily cycle and the lag behind the weather are legible together; and the whole record as daily means with their range. Derived quantities sit alongside measured ones throughout, since vapour concentration and the condensation margin carry the conservation meaning, while relative humidity alone misleads when compared between places at different temperatures.

4. The forecast: two days ahead

The record tells the Trust what the building has done. The forecast tells it what the building is about to do. Outside conditions for the next two days come from the Norwegian Meteorological Institute's Locationforecast service, retrieved every six hours. The interior is projected from the building's own measured response to them. Each interior quantity S is treated as a first-order lag on an outside driver D, with further driving terms X:

$$dS/dt = k(D - S) + \Sigma\, b_i X_i + c$$

> The couplings are fitted by least squares on the trailing seven days and refitted on every page load, so the model follows the building through the seasons. Interior temperature is driven by outside temperature with a lagged solar term. Fabric temperature carries a further term for radiative loss to a clear night sky, with cloud from the airport behind the present and from the forecast ahead of it; this is the term that

> anticipates the cold-night condensation of section 2. Interior humidity is carried as the slow variable, drawn toward the level the outside air's daily-mean vapour would set at the interior temperature. Each level is carried from the floor by its own fitted stratification. The solar lag is chosen by day-ahead skill rather than by residual fit: the residual prefers about an hour, the day-ahead test a lag near twelve hours, of the order of the roof covering's own conduction time. A projection is read a day or two ahead, so it is fitted on that horizon.

How well it verifies. Archived forecasts for 30 July to 9 August 2026 were compared with the station over 194 overlapping hours. Forecast air temperature showed a bias of +0.48 K and a mean absolute error of 1.86 K; forecast humidity a bias of −5.0 points and an error of 6.0. The temperature figures are good enough to drive a two-day projection. The humidity figures are weaker and biased dry, which matters because the sign of the moisture difference between inside and outside decides whether an exchange of air would dry the building or wet it.

What drives the interior. Regression of the record ranks the outside influences. Interior relative humidity follows first the moisture content of the outside air, which alone carries about two thirds of its variance, then outside temperature acting through the building's slow thermal response. Interior vapour has two channels of similar size: exchange with outside air with no appreciable lag, and release from the fabric about six hours after sunshine. Wind explains under one per cent of any interior quantity.

Limits. The model describes the building in its present fixed state, empty and unheated. Any change to the openings, heating or occupancy invalidates the fitted couplings until they are refitted, which the daily refit then does. The king post, with the shortest record, is the least well constrained level. The projection is indicative.

5. From record to care

The monitoring exists to change what happens to the timber. Four uses follow from it.

Humidity, not temperature, is the thing to govern. Moisture content in timber follows relative humidity, not temperature, so the interior temperature can float. Heat is used only to bring humidity down when it rises, and is switched off when it falls, rather than holding the building at a set temperature. That is far less energy and far less intervention. The building was heated continuously from the boiler house of the 1860s until the museum left in 2001, so humidity-led heating reinstates historical practice rather than introducing something new. The Trust's working range is 45 to 75 per cent relative humidity, held mostly between 55 and 65 per cent across the year: an engineering position, to be refined once a full measured year allows targets to be set from the building's own climate, following BS EN 15757:2010.

Act on the forecast, not the reading. A rise in humidity follows a change in the outside air by hours, and the fabric by longer. Read two days ahead, the forecast shows a damp airmass or a run of clear cold nights before it arrives, so heat can be brought on early and gently, at lower power and with less swing, rather than late and hard after the drum has already wetted.



Timber perimeter ties at the eaves, where the roof meets the drum. FennecMedia, CC BY 4.0.

Know what heating cannot do. The margin at the sarking is governed by radiation from the lead to the night sky. It is reported and alarmed, not used to call for heat. Protecting the sarking is a matter for the roof repair.

Size the repair from evidence. Every decision about the roof covering, the floor and the ventilation of the finished building will be taken against this record rather than against an assumed climate. The record is also the means of checking afterwards that a repair has done what it was meant to do.

6. Calibration and derived quantities

The instruments were co-located before installation and their offsets computed against the group mean over settled night hours. The spread is 0.47 °C in air temperature, 2.1 points of relative humidity and 0.26 °C on the probes, within the manufacturer's specification. Propagated through the relations below, this corresponds to about ±0.5 K in derived dew point and so in the condensation margin; differences between positions smaller than that are not significant. Offsets are applied in analysis, not to the published series. The gap between sarking boards varies from place to place, so a probe in a wider opening reads partly air; each probe's behaviour over time is unaffected.

Each unit reports air temperature T, relative humidity RH and surface temperature T_s. Everything else is derived, with the Magnus form and the coefficients of Sonntag:

$$e_s(T) = 6.112 \cdot \exp[17.62T / (243.12 + T)] \text{ hPa}$$

$$AH = 216.7 \cdot e_s(T) \cdot RH / 100 / (273.15 + T) \text{ g m}^{-3}$$

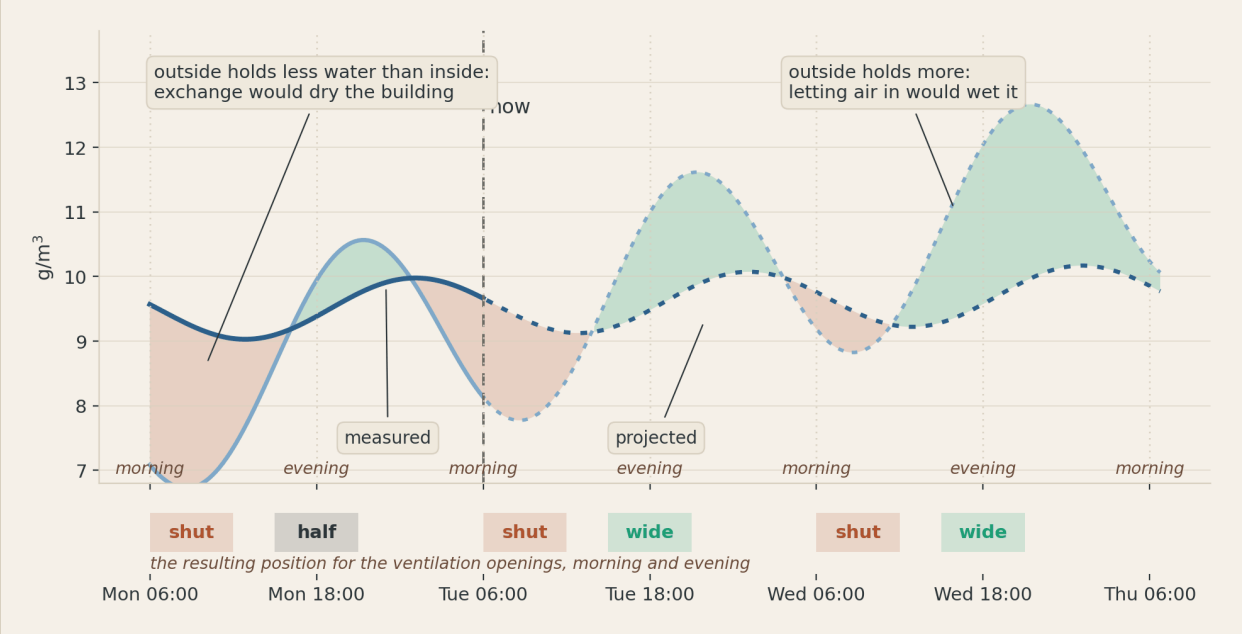
$$\gamma = \ln(RH / 100) + 17.62T / (243.12 + T), \; T_d = 243.12\gamma / (17.62 - \gamma) \text{ °C}$$

$$\Delta T_{cond} = T_s - T_d(T, RH) \text{ K}$$

> A margin of zero means the surface is at the dew point of the adjacent air and begins to wet. Because humidity at a surface rises as the surface cools, mould thresholds are reached before the margin reaches zero, so a positive margin alone is not enough over sustained periods.

The moisture chart shows the sign of the difference in vapour concentration between outside and inside: the direction in which any exchange of air would move the interior. Seasonal trend is the 30-day central moving average of the daily mean, in accordance with BS EN 15757.

Code implementing these relations, the forecast model and the control strategy for conservation heating are published with the record at https://github.com/mjbt/timber-monitoring, the code under the MIT licence and the text and data under Creative Commons Attribution 4.0.



Reading the charts, on an illustrative week in which a dry airmass gives way to a wet one. Solid lines are measurement; broken lines, ahead of the present, are projection or forecast. Green marks periods when the outside air holds more water than the inside, russet when it holds less.

7. Sources

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Standards. BS EN 15757:2010, Specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic materials · BS EN 15758:2010, Procedures and instruments for measuring temperatures of the air and the surfaces of objects · BS EN 16242:2012, Procedures and instruments for measuring humidity in the air and moisture exchanges between air and cultural property · BS EN 15759-1:2011, Indoor climate: guidelines for heating churches, chapels and other places of worship · PAS 198:2012, Specification for managing environmental conditions for cultural collections.

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Code and data. The formulas, model, control strategy and record are at https://github.com/mjbt/timber-monitoring. Cite as Rotunda Trust, Woolwich Rotunda monitoring record, https://doi.org/10.5281/zenodo.24247030.