Low energy free-running paper stores: moisture buffering model and monitored data

Alan Clarke, Nick Grant
Woodlands, Lydney, UK
alan@arclarke.co.uk, nick@elementalsolutions.co.uk

Summary

The passive paper archive for Imperial War Museum (IWM) completed in 2019 is unheated and relies on pressurisation with air supplied at a fixed dew point to control relative humidity (RH) [Grant, Clarke 2020]. For a new archive project we developed a monthly moisture balance model in conjunction with PHPP to model temperature. This model has been compared with measured data from the IWM archive over two years.

Key findings are:

- A monthly model is sufficient for a passive archive since conditions are very stable
- Seasonal relatively humidity variation in reality (±2%) compares well with model
- Paper mass in the archive is key in balancing humidity
- Evaporation from masonry estimated at 0.2-0.4 kg/m^2/year here increases RH by 3-5%

The model

The IWM paper archive is very airtight, n_{50} = 0.03 h^{-1} so water vapour movement to and from outside can be largely controlled using the mechanical ventilation. The paper contents of the archive form a very large moisture buffer and our model aims to quantify the impact of this on conditions in the building.

PHPP is used to estimate monthly temperatures in the store, using the summer sheet to predict temperatures without heating.

Moisture in materials such as paper has a relationship with the relative humidity of surrounding air. Increasing the RH will lead to moisture being absorbed and reducing the RH will lead to moisture desorbing from the paper (the relationship also depends on temperature to a lesser extent).

We assume the paper in the store attains moisture content equilibrium with the water vapour in the air over the month, and this gives a mass of water evaporated or absorbed to reach the new equilibrium, and hence a new mass of water in the air. Diffusion of water vapour into a book is slow compared with into a single sheet so we compared different percentages of the paper assumed to be absorbing and desorbing moisture from the air.

Mechanical ventilation supplies air at a known flowrate (200 m3/h) and this displaces the same quantity of air from the building (due to pressurisation of the building infiltration is calculated to be negligible). The moisture content of the supply air is controlled by a cooling coil so is known (and monitored) so the net flow of moisture in or out of the building can be calculated.

Results

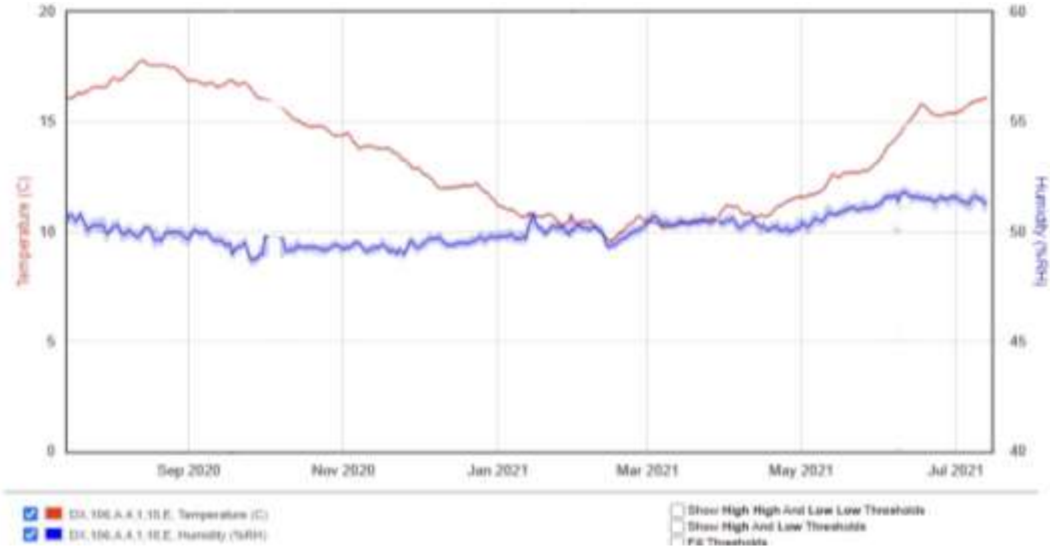

Figure 1: Measured data from IWM paper archive

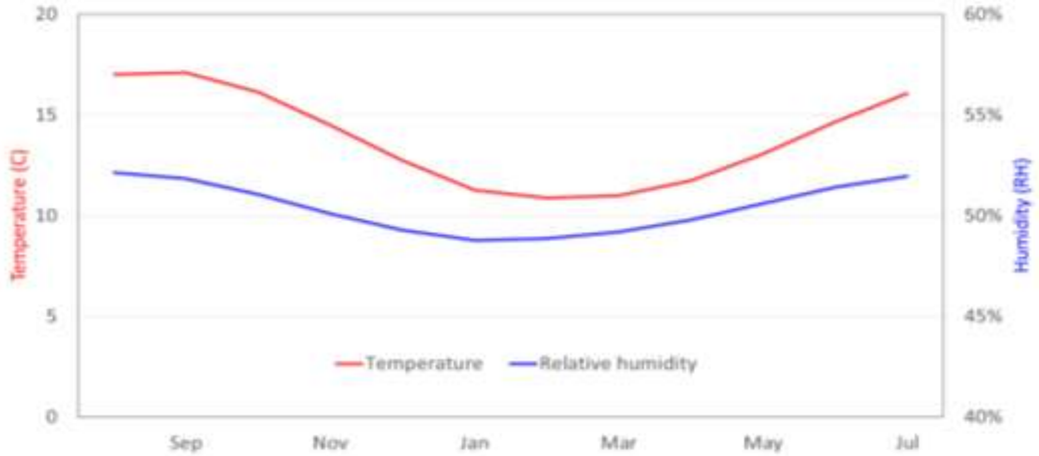

Figure 2: Model results for IWM paper archive

For the model to predict the real life range of the annual variation in RH we had to include most of the paper in the moisture balance. This suggests that on a monthly timescale water vapour from the air reaches most of the paper fibres.

We know there is some construction moisture evaporating from concrete components, and by introducing this into the balance to match predicted average annual RH with measured the model suggests this is around 1000 kg/year or 0.2-0.4 kg/m^2/year of masonry surface.

The model is now being used in the design of a large automated book store which will also operate with free running temperature. The store will use reduced oxygen levels of 15% for fire protection. The process of removing the oxygen also removes moisture and this has eliminated the need for any other humidity control, reducing capital and energy costs.

References

[Grant 2020] Grant, N.; Clarke, A.: *Applying Passivhaus Experience to Archive Buldings* In: Proceedings of the 24th International Passive House Conference 2020. Passive House Institute, Darmstadt, 2020