Next Generation Passivhaus Archives

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1 Introduction

Lessons from HARC, The first Passivhaus Archive in the UK

The Hereford Archive and Record Centre (HARC) was the first Passivhaus Archive in the UK [Grant 2016]. Whilst the repository and records building are certified to the Passivhaus Standard, the repository owes more to the passive conservation storage approach of Tim Padfield and his colleagues in Denmark [Padfield 2017]. Contributions from the Passivhaus approach include excellent airtightness detailing and thermal continuity of the envelope.

Two years of operation at HARC has shown that close control of the supply air condition is not necessary: monitoring demonstrates excellent temperature and RH stability with simplified operation can be achieved by simply cooling the supply air to reduce the absolute moisture level close to that required in the store.

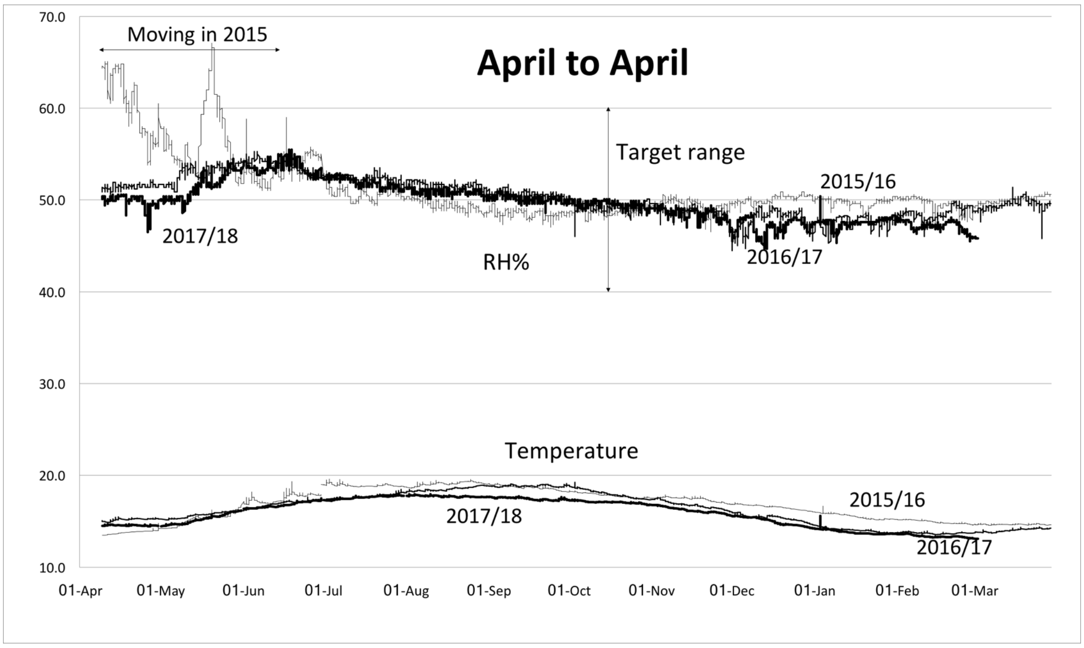

Figure 1. Temperature and RH monitoring of the middle floor of HARC since practical completion.

The supply air flow rate is set very low, at less than one air change per day and is intended to slightly pressurise the building to effectively eliminate infiltration of unconditioned air. The repository air tightness via external walls is around 0.05 m/h so most overflow is via internal doors to the occupied part of the building.

We have now designed a new archive for paper storage, under construction in 2018, which builds on the lessons learnt from HARC.

No heating

HARC was designed to be heated to maintain a minimum temperature of 14°C. In fact the heating has not operated at all. This is partly due to higher than expected heat gains from lighting, but also we discovered that the archivists didn't need this minimum temperature to be maintained. Provided that conditions are such that condensation doesn't occur when material is removed from the archive for viewing elsewhere then lower temperatures are better for preserving paper.

The client for the new archive was consulted and we are planning for a minimum temperature as low as 10°C which will avoid the need to install any heating plant.

No floor insulation

We debated whether to insulate under the slab at HARC but decided to do this after the PHPP model showed lower heating energy consumption with insulation. Now we can let the archive temperature drop we don't need insulation, and in fact the thermal mass of the ground will transfer heat into the archive in cold weather.

In summer the heat loss to the ground is beneficial. Although HARC has stayed below the target 20°C, since chemical degradation increases with temperature, lower is better and with ground-coupling we expect to stay below 15°C.

Thermal modelling shows that simple edge insulation will ensure that surface temperatures in the repository are high enough to avoid risk of mould, given the low absolute humidity we will maintain inside. So this change will improve conditions and reduce construction cost.

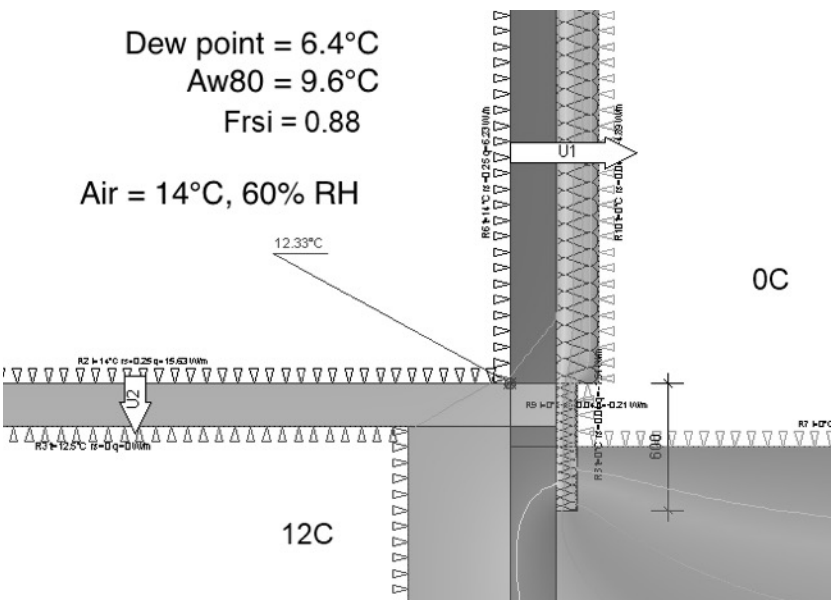

Figure 2. Ground coupled slab with edge insulation to avoid mould risk (repository temperature 12°C).

Simple supply-air conditioning

A cold water cooling system has to run several degrees above freezing so the dew point of the fresh air supply is typically 8-10 °C. This is equivalent to 60% RH around 16 °C, so this is too high a moisture level for a repository expected to be at 10-15 °C.

Following design modelling, the HARC supply air system used both cooling coils and a desiccant dehumidifier to ensure the moisture content could be reduced sufficiently. Since the desiccant dehumidifier adds heat an additional cooling coil was added for post cooling. With water in the coils, a frost heater was added to the intake.

We have now designed future archive systems to use a single means of dehumidification, and developed a bespoke spreadsheet to analyse the implications of this.

2 Modelling

Monthly moisture balance

With a highly sealed building and very low ventilation rate the quantity of moisture absorbed into the building fabric and the archive contents becomes the main factor determining relative humidity in the building. The moisture content of the materials tends to equilibrium with the relative humidity in the air when the environment is sealed.

With conventional air conditioning, the much higher air flow negates this moisture buffering effect and so relative humidity in the space is modified by adjusting the properties of the air using air conditioning plant. With our airtight passive archive we have a very small air flow so the relative humidity is largely dependent on this moisture balance with the archive materials.

We developed a spreadsheet based moisture balance model with a monthly time step. This accounts for the moisture contained in the building contents and calculates the corresponding equilibrium relative humidity and air temperature. This allows an estimation of net moisture change through ventilation for the month and hence estimation of total moisture mass within the building the following month.

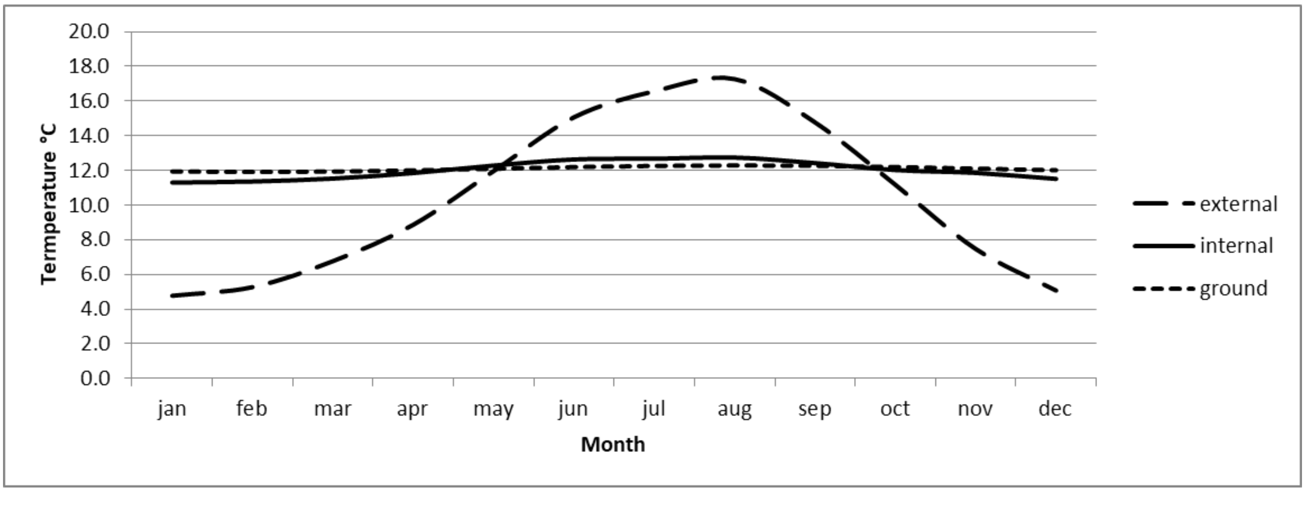

Figure 3. Modelled repository temperatures.

To provide detailed input of fabric solar gains and ground temperature to the model we used a modified version of PHPP: we added a monthly internal heat gain sheet to allow for gains and losses from dehumidification plant, and then used the summer sheet for the monthly energy balance.

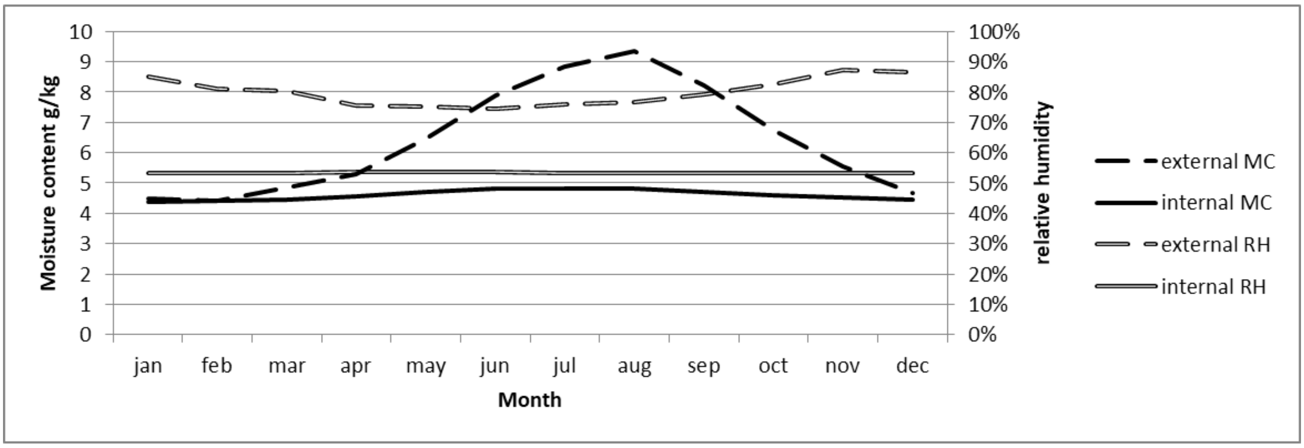

Figure 4. Modelled air absolute moisture content and relative humidity.

Two dehumidification options were modelled, firstly a desiccant dehumidifier, which tends to add heat to the building, and a chiller coil, which tends to cool the building.

Modelling conclusions

- minimum temperature with no heating and no floor insulation = 11-12°C
- internal air moisture content required for 40%-60% RH at this temperature = 4.5 g/kg
- chiller dehumidification has to cool air supply to 2-4 °C
- most dehumidification of supply air is required during summer

In practice desiccant dehumidification works least well during warmer conditions with low relative humidity but high absolute humidity, and would not be able to meet the supply air moisture content required at peak times, whereas a suitable sized chiller and cooling coil will always be able to do this.

The down side is that during summer the chiller would be providing a large amount of sensible cooling which is unnecessary. (“Sensible” cooling reduces the temperature of the air, “latent” cooling reduces the moisture content of the air.) We can avoid this by using cold off-coil air to precool incoming air. We explored the use of a counter-flow air-air heat exchanger – now available at high efficiency for use in passive house ventilation systems.

3 System design

The diagram below shows example summer conditions. The incoming air enters the MVHR in the normal place of extract air, and the chiller is “outside”. The incoming is cooled and starts to condense, and arrives at the chiller at close to 100% RH and relatively cool. It is chilled further to 3 °C and 100% RH, and then takes the place of incoming fresh air in the MVHR and is warmed to a temperature close to that of the original intake air, though at very low humidity.

Basically the heat recovery unit recovers the sensible heat in the process so that the duty of the chiller is restricted to latent heat only.

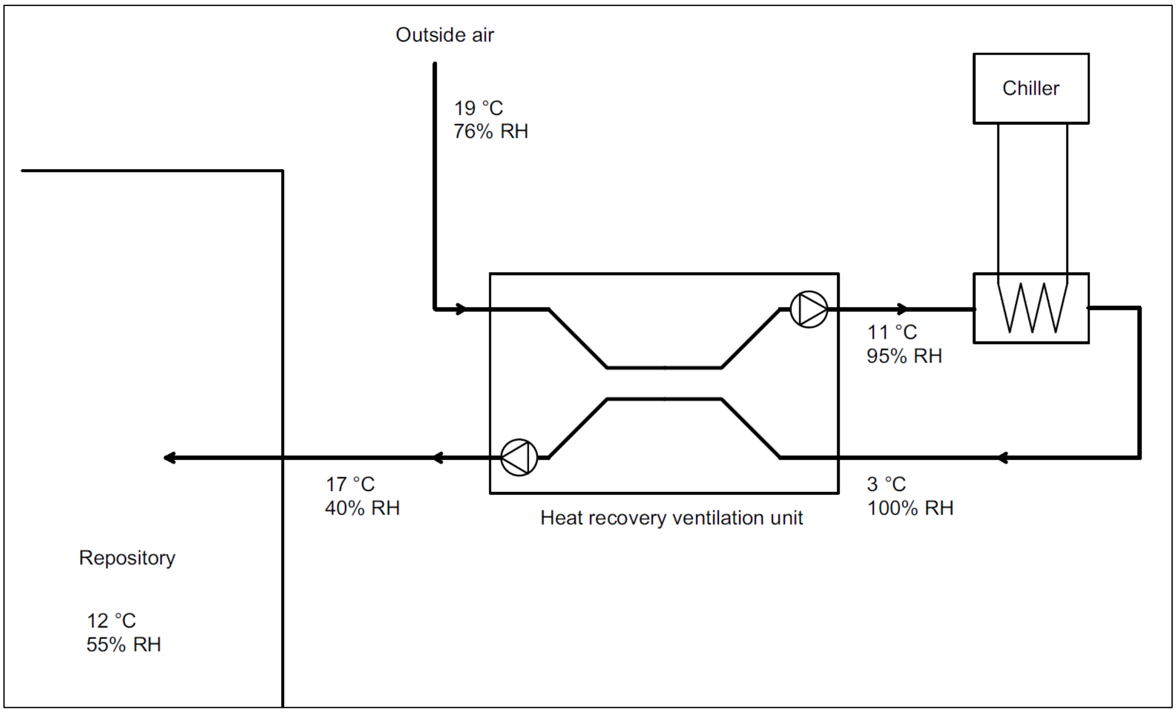

Figure 5. Supply air dehumidification with energy recovery.

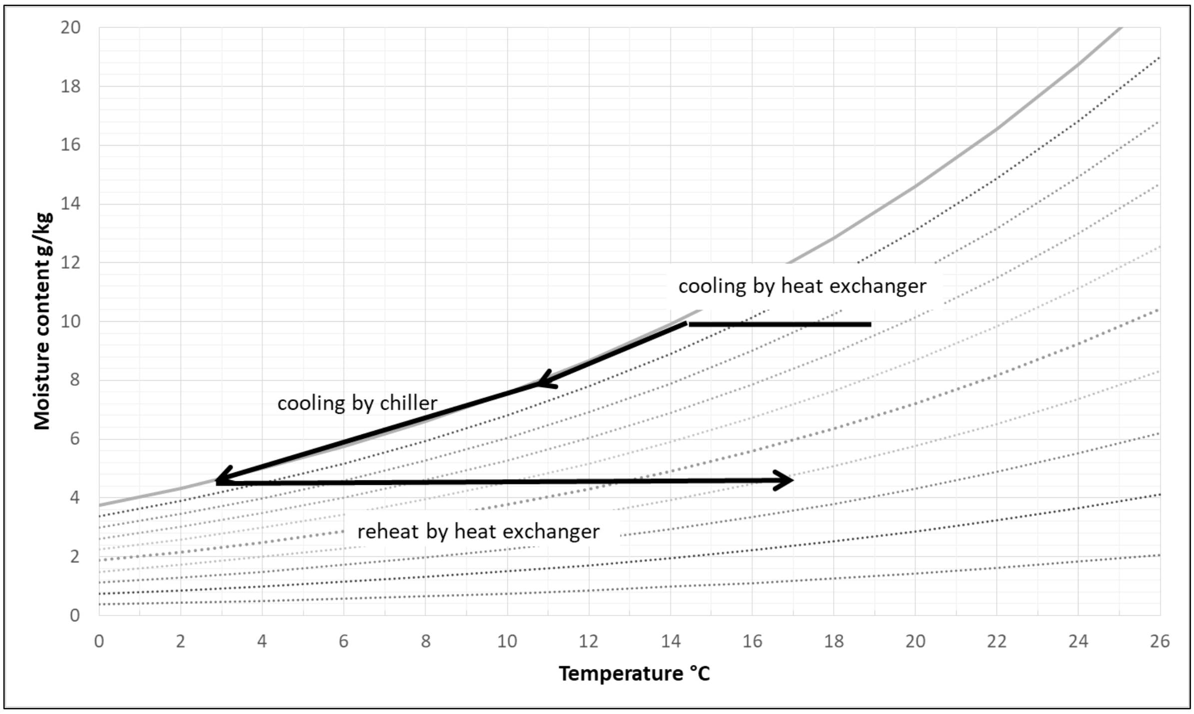

Figure 6. Psychrometric diagram of process.

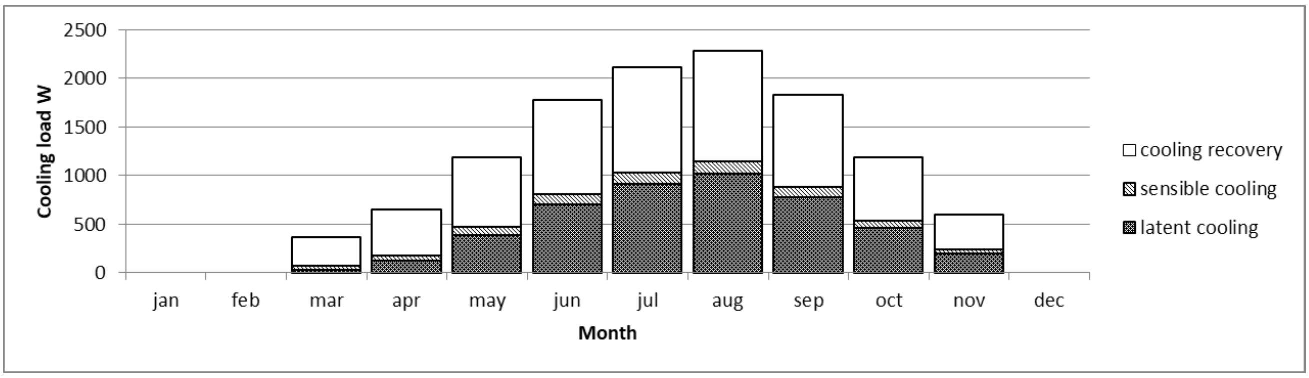

Figure 7. Average monthly chiller load including effect of heat recovery.

4 Conclusions

Monitoring of the HARC Passivhaus archive shows that an airtight passive envelope with minimal building services inputs provides a very stable storage environment at the desired conditions.

For archive storage of documents at “cool” temperatures (down to 10 °C) our experience at HARC shows that such an archive can be built with no heating and no floor insulation in the UK climate. Such ground-coupling will add to thermal stability and minimise summer temperatures.

Conditioning is still needed to control humidity to the required conditions of 40%-60% with minimal variation. To achieve this with the lowest energy cost a very airtight construction is needed so that infiltration is prevented by slight pressurisation with a low ventilation rate.

The supply air requires dehumidification to meet the moisture level of the cool internal air. Using a chiller for dehumidification provides unnecessary sensible cooling as well as the latent cooling required. By using an air to air heat exchanger to cool the incoming fresh air with the chilled air reduces the load on the chiller by around 50%.

References

[Grant 2016] Clarke, A.: Grant, G.: *The First Passivhaus Archive in the UK.* In: Feist, W. (ed.): Proceedings of the 20th International Passive House Conference 2016 in Darmstadt. Passive House Institute, Darmstadt, 2016.

[Padfield 2017] Padfield, T.:Ryhl-Svendsen, M.:Klenz Larsen, P.: Aasbjerg Jensen, L.: *Drifting temperature air conditioning*. Download: www.conservationphysics.org