# IWM Duxford

Energy Strategy for proposed Large Object Store and Conservation Workshop

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## Initial Feasibility

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## Introduction

These proposals are informed by our experience designing and monitoring the Hereford Archive and Records Centre (HARC). The approach at HARC was heavily inspired by the work of Tim Padfield and his colleagues at the Technical University Denmark combined with our experience designing very airtight, well insulated buildings to the Passivhaus Standard. Whilst HARC is a fully certified Passivhaus building, it owes more to the genuinely passive approach of Padfield and his colleagues.

This passive approach forms the basis of recommendation in PD 5454 and the current draft BS EN 16893. However the energy strategy for HARC was conceived to meet the then current British Standard which was based around a higher fixed temperature without seasonal variation. This resulted in a number of design decisions that would have been made differently in light of PD 5454.

The proposed design will allow an environment in the range 13°C to 18°C and 40-60% RH to be met with minimal energy use and a high level of stability.

The building comprises a large object store, a large conservation workshop and smaller rooms within the workshop area where temperatures can be controlled. An initial energy balance for the proposed building envelope has been carried out using the Passivhaus design software PHPP 9.6

The proposed approach relies on an extremely airtight insulated envelope with an uninsulated ground-bearing floor slab. Temperature in the store can vary seasonally but will be moderated by the ground temperature. A minimum winter temperature can be maintained with a simple heating system if this is considered necessary. It is proposed that the Conservation Workshop (CW) would be maintained at a comfortable working operative temperature with little daily fluctuation. Experience suggests that minimum of 13°C without drafts or lower radiant temperatures is likely to be acceptable but this needs to be agreed with those who will be working in the spaces. Localised radiant heaters could be used if required and separate rooms within the workshop space can be heated to a higher temperature to suit sedentary work.

### Building Fabric

The building comprises 3 key environments:

1. Large object store (LOS) – temperatures allowed to vary by season with the minimum temperature dictated by average ground temperature or with additional heat input to a maximum of 13°C if required. Supply air dehumidification throughout the year with heat gains retained within the building as much as possible.

2. Conservation Workshop (CW), large open area maintained at a minimum of 13°C (TBC) with dehumidified supply air in addition to that escaping from the Large Object Store doors. Additional gains from people, lighting, equipment and roof lights will mean that the temperature will rise in summer but should remain well under 18°C.

3. Smaller insulated offices and workshop rooms within the envelope of the conservation workshop with easily controlled heaters to allow temperatures to be controlled to suit desk work.

The proposed building is single storey and rectangular in plan with open mezzanine storage structures. An insulated fire resistant wall and large doors separates the Large Object Store from the Conservation Workshop. Smaller workshop and office spaces would be insulated from the surrounding space to allow them to be easily heated to 18-20°C. The floors of these rooms would be insulated to improve comfort. Machine shops could have solid concrete flooring with localised insulated mats for comfort.

Super-airtight construction is key to the proposed strategy. The more airtight the building, the less air flow we need to create a slight positive pressure to prevent infiltration of outside air with associated moisture load and pollutants. This considerably reduces the size of plant and results in very stable conditions with minimal variation despite very simple controls.
Our assumed air permeability for the proposed store is 0.15 $m^3/(m^2.hour)$. This is over sixty times less air leakage than current building regulations but only slightly better than is regularly achieved for Passivhaus homes with complex fenestration and intermediate floors.

Construction is assumed to be a steel frame with 150mm core, insulated steel sandwich panels for walls and roof. This should allow very airtight construction but this will require a carefully thought out strategy that avoids any structural penetration of the envelope. Normally best practice for such a construction system might achieve a permeability around $1m^3/(m^2.h)$ but we need to do much better than this. Whilst the panels themselves are completely impermeable, the joints would need to be taped. The challenge is in creating a simple detail and method of taping joints where they pass over purlins and other structural elements. Keeping the structure simple will be crucial to cost effectiveness. Typically such buildings are difficult to make airtight simply because the airtight layer cannot be easily accessed.

*Figure 1. Examples of very difficult and expensive airtightness details when attempting to improve the airtightness of an archive using the proposed construction method*

The proposed levels of insulation are modest for a low energy building due to the acceptable low winter operating temperature and the excellent volumetric form factor (volume divided by heat loss area).

**Provisional insulation proposal:**

| Element | Insulation mm | U value |
|---|---|---|
| Walls | 150mm ‘Kingspan panels’ | 0.12 W/m$^2$.K |
| Floor | None | n/a |
| Roof | 150mm | 0.12 W/m$^2$.K |

Whilst an uninsulated ground floor is proposed, care must be taken to avoid mould risk at the floor wall junction. Because we can predict the internal temperature and humidity at the coldest time of year we can determine the minimum acceptable surface temperature to avoid risk of mould growth. This is above the dew point temperature and corresponds to the temperature that will result in a localised rise in RH to 80% (aw80). See figure 3.

Figure 2 shows the sort of detail that can be used to reduce the wall/floor thermal bridge and so eliminate mould risk whilst reducing heat loss at the perimeter. The exact detail will depend on the construction method chosen but projecting pile caps should be avoided.

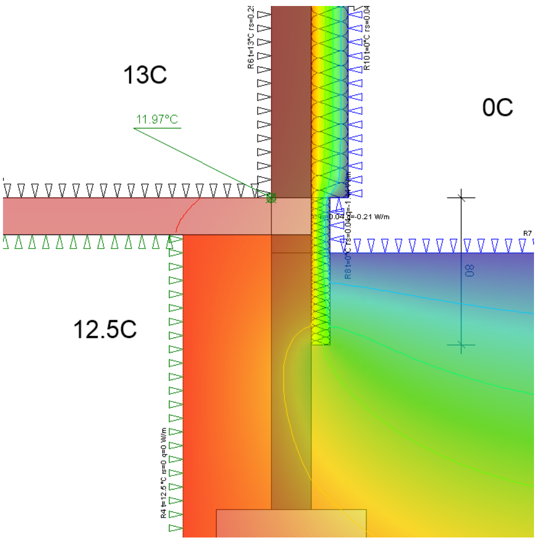


*Figure 2. Improved edge detail 13°C air temperature and 12.5°C winter ground.*

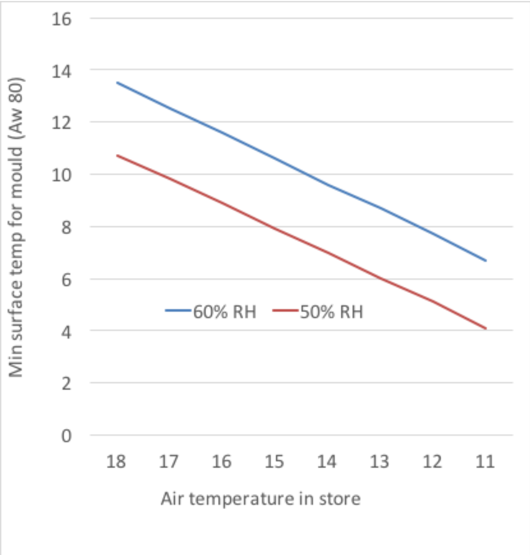

*Figure 3. Minimum surface temperature to avoid mould risk.*

The plant room should be located within the thermal envelope of the building but within a fire resistant enclosure (4 hour assumed). This simplifies structural and airtightness details and allows the gains from plant to usefully contribute to the building's energy balance.

## Doors

Whilst an area-based permeability has been assumed to estimate required airflow rates and dehumidifier capacity, we expect most of the leakage to occur around the door openings. This slight pressurisation should also reduce infiltration of un-conditioned air when staff come and go through the regular doors.

By ensuring access is from one end of the building we can avoid the risk of un-wanted cross ventilation through leaking or open doors. Without this cross flow we expect conditions in the store and workshop to be only slightly impacted by normal door opening.

The large doors to allow aircraft access will only be opened very infrequently and so can be sealed with tape if required. A separate tail-fin door reduces the height of the door panels required.

## Energy and Power

The proposed building has been modelled crudely in PHPP to inform, among other things, design U values. A nominal amount of roof light area has been included in the CW model.

Whilst the current model shows the building achieving the Passivhaus 15kWh/($m^2$.a) target, this is purely coincidental. The target relates to dwellings with domestic ceiling heights heated to 20°C and has no real basis in terms of a building such as this. However we would be confident in arguing for Passivhaus certification on the basis of the proposed approach.

The results of the modelling are sensitive to assumptions about internal heat gains such as lighting and machinery but several scenarios have been modelled to get a feel for how the building is likely to perform. As the design develops and assumptions are confirmed we can provide more confident predications of energy use.

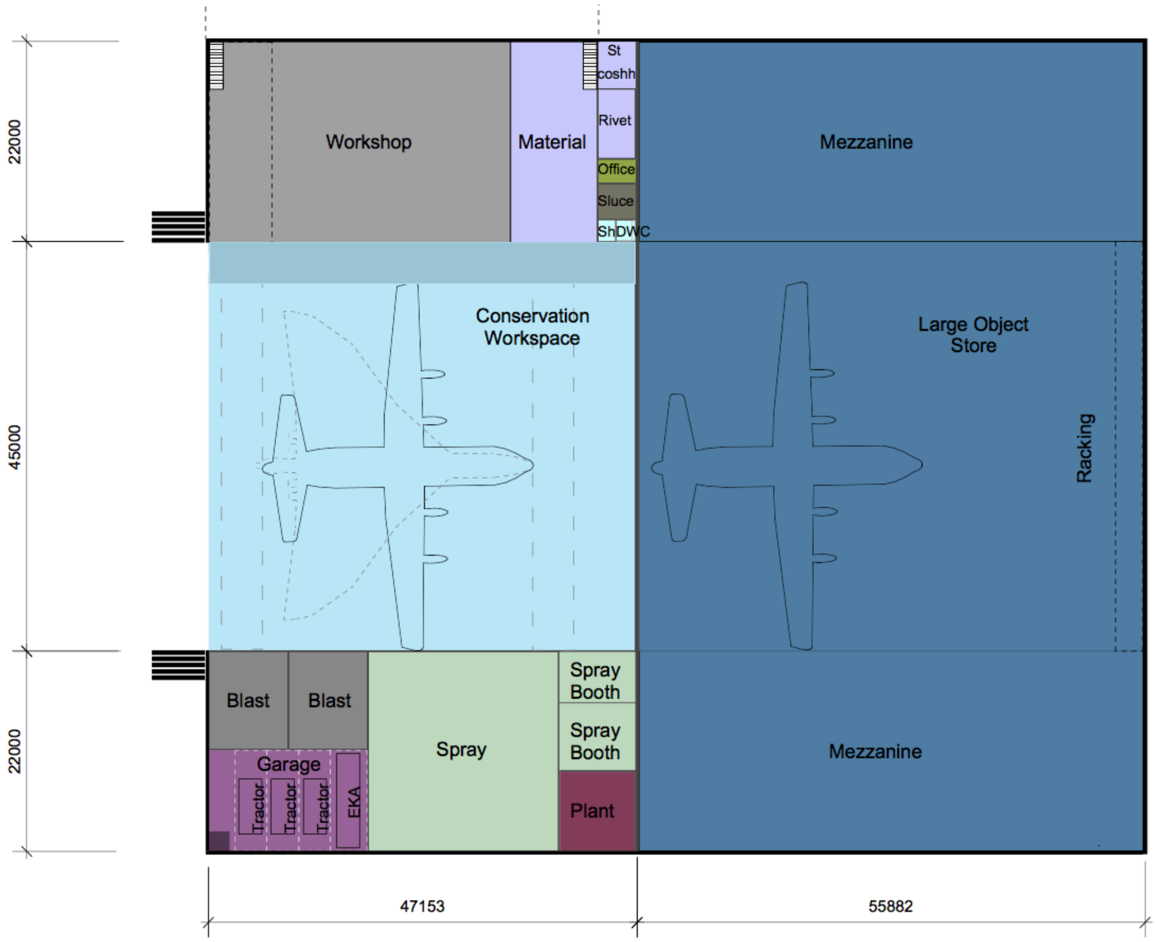


*Figure 4. Design as modelled. The building is considered as 2 zones.*

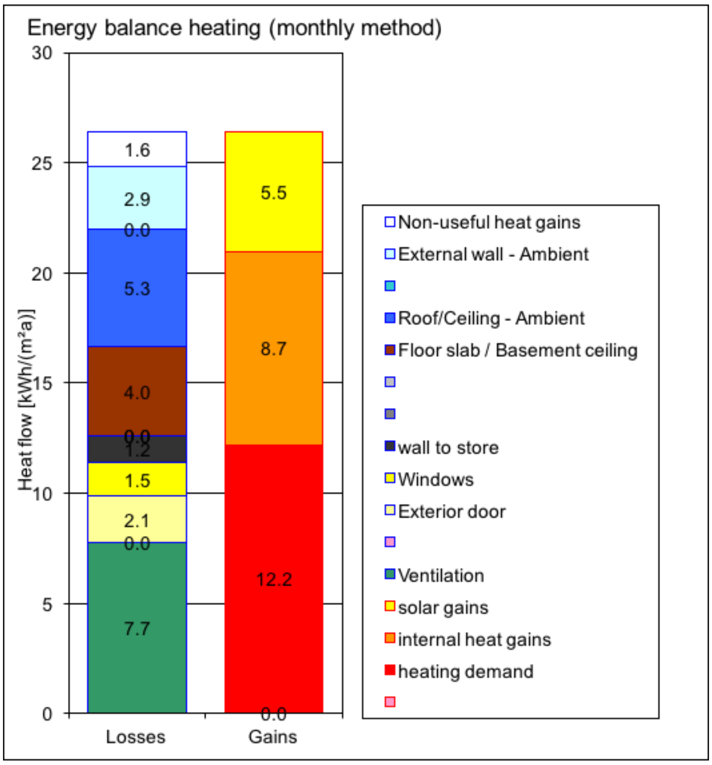


*Figure 5. Provisional heating energy balance for workshop assuming 14°C winter temperature.*

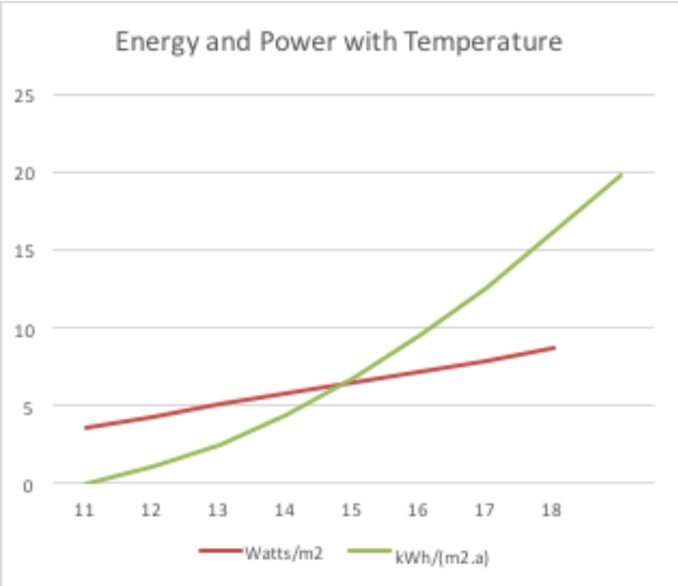


*Figure 6. Peak heating load and annual energy use with varying winter temperature set point for CW, both per $m^2$.*

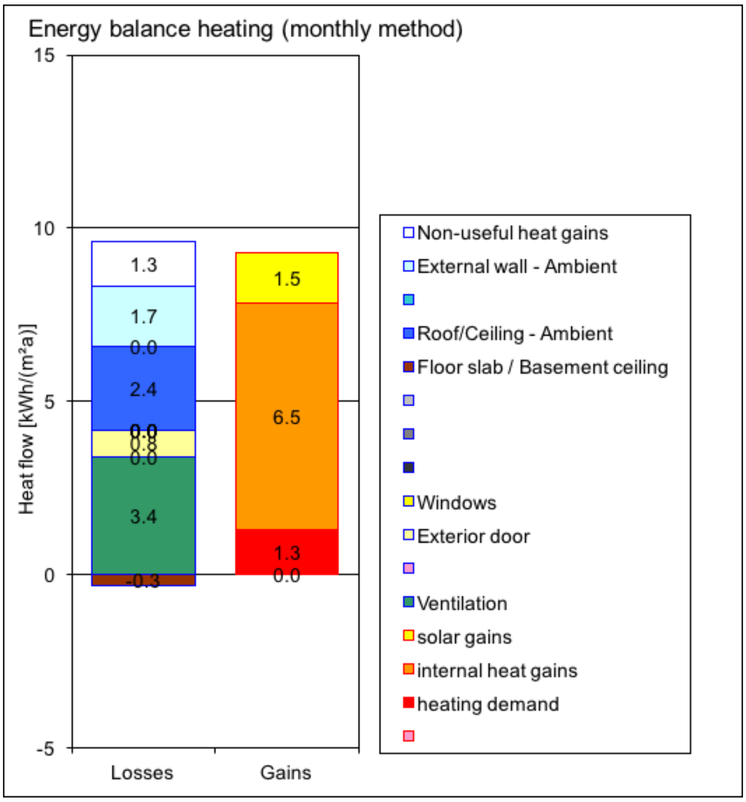


*Figure 7. Initial heating energy balance for LOS assuming 10°C winter set point. Solar gains are through walls and roof.*

The results are sensitive to internal heat gains (IHG) assumptions which will be largely due to lighting and the desiccant dehumidifier.

## Conditioning the Space

### Heating

The details for heating will be developed post planning but several options are possible and can be compared for capital and running costs once the building design is finalised. The lack of mains gas limits the main options to an LPG boiler or air source heat pumps such as split units.

The peak heat load for the CW is likely to be under 50kW and zero for the LOS if it is acceptable for temperatures to fall below 13°C in winter.

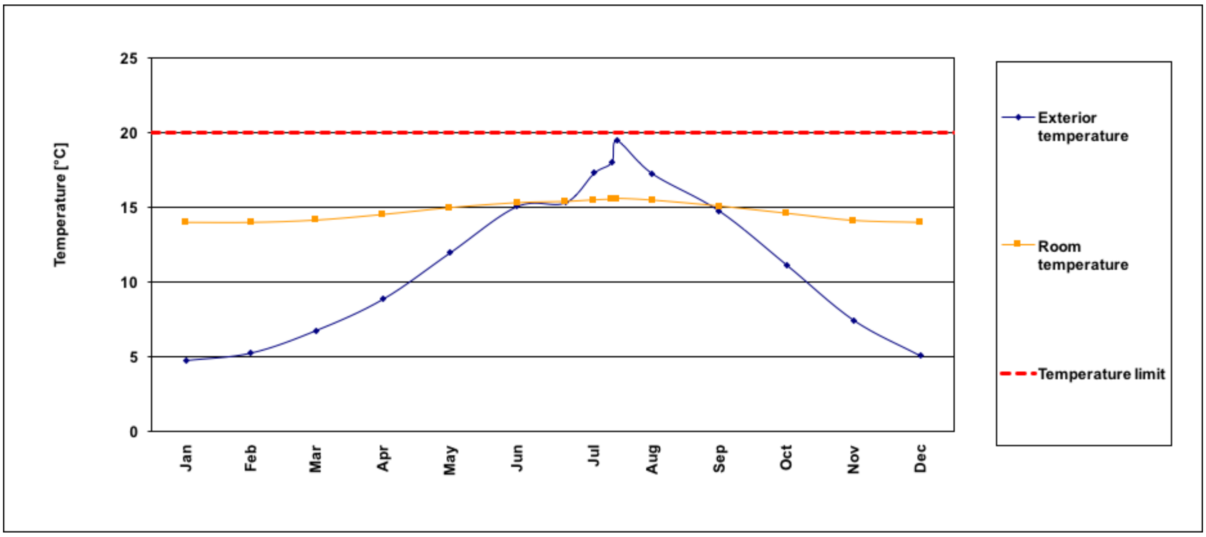


*Figure 8. The yellow line shows predicted internal temperature of the workshop zone assuming a 14°C winter heating set-point.*

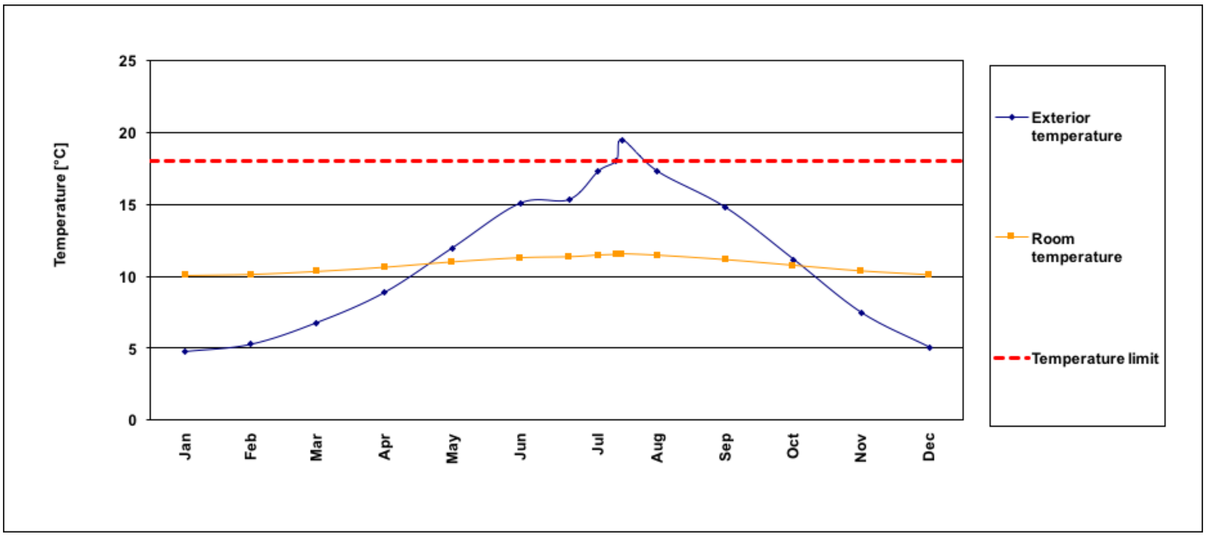


*Figure 9. Calculated internal temperatures for the LOS assuming 10°C winter set point.*

If the CW can be run cool in winter this considerably reduces heating demand but also reduces the risk of high temperatures in summer.

## Dehumidification

The low internal gains and proposal to avoid under-slab insulation (to reduce cost and simplify the structure) guides us towards running the store at a lower temperature but with supply air dehumidification. For HARC, heat gains from the desiccant dehumidifier had to be removed by a cooling coil but for this building the gains are beneficial.

The provisional proposal is to use a Munters MLT30 dehumidifier to supply outdoor air at a flow rate of about 2,500m$^3$/h to the Large Object Store and Workshop.

Total power is about 22kW.

The MLT30requires a 3 phase supply and can be modulated to deliver air at a given absolute humidity.

### Control

The dehumidification can be controlled on the basis of the conditions in the space, or on the basis of the condition of the supply air. For the system proposed here, where the dehumidifier is running on supply air and not recirculating within the space we propose to control the condition of the supply air without reference to the internal conditions.

This is the approach taken for the main repositories at HARC, and has proved effective at control. This is not surprising given that with the airtightness and low occupancy of the building the main source of moisture is the incoming fresh air.

We also benefit from the humidity buffering of the building fabric and contents when the services are not designed to directly control internal humidity. Figure 10 shows the result of turning off the supply air dehumidification at HARC. The result is very slow and subtle despite a step change in the supply air condition.

This stability is the result of relying on the building and contents to maintain stable conditions through airtightness, insulation, thermal mass and moisture capacity. This limits the influence of the very variable outside conditions.

The LOS with have considerably less buffering capacity than the paper store but the supply air absolute humidity can be controlled to ensure very stable conditions.

The excellent airtightness allows a controlled supply air volume of about one air change per day. This is more than enough to provide fresh air for people working in the store but low enough to limit the impact of changes in outdoor conditions.

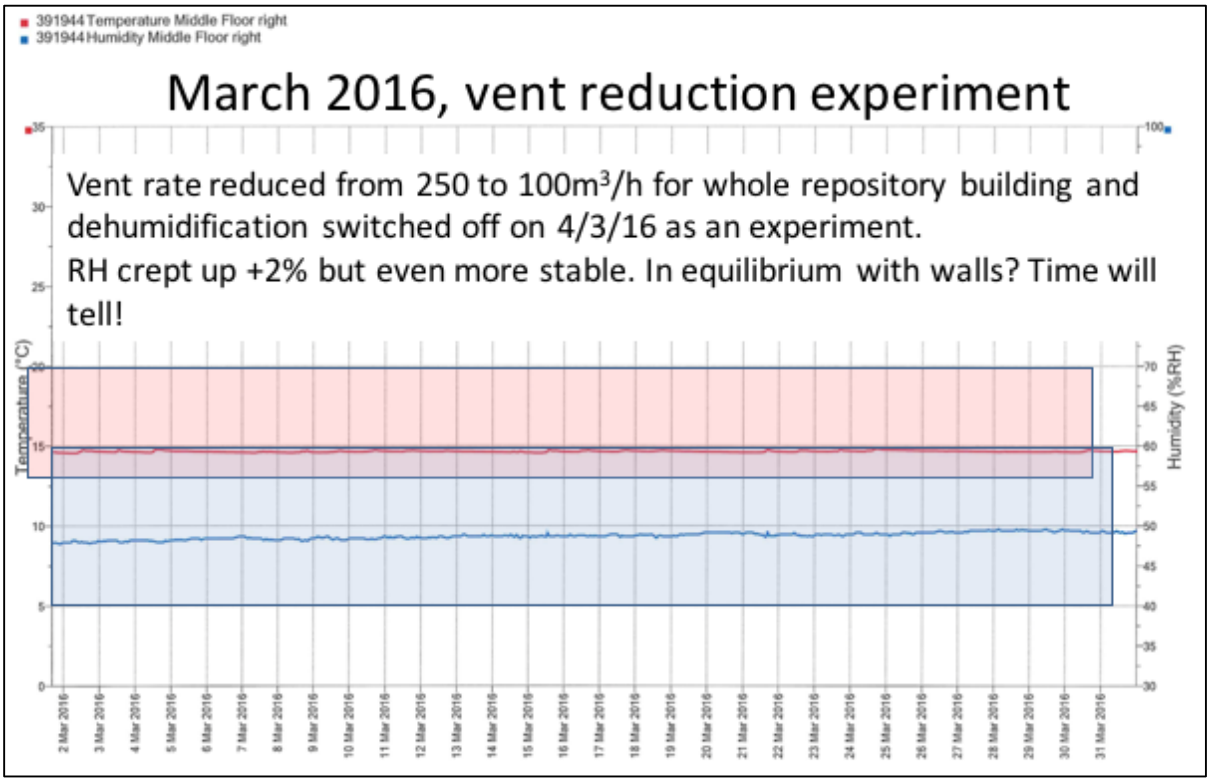

*Figure 10. The slow and subtle impact of turning off the supply air dehumidification at HARC. Dehumidification was turned back on again.*

The very slow response of the building combined with very limited capacity for heating and dehumidification result in a very stable environment with only the simplest of controls. No attempt is made to control the RH in the space directly using sensors as this will not work because of the buffering. Instead the trend can be observed and dehumidification can be turned on or off on a seasonal basis. Unlike recirculating conditioning, the system cannot accidentally over–dry the air, for example if a sensor fails.

Similarly with a limited heating capacity there is no risk of the building accidentally overheating.

This extreme damping of RH and temperature should allow a simplified control strategy without resorting to a BMS. The larger 3Phase dehumidifiers include a modulating control and dew point sensor.

## Electrical Load Limit

Heating load, assuming 14°C winter set point for CW, is estimated at about 25-50kW. This could be provided by an LPG boiler or an air source heat pump.

**Summary of main electrical loads for CW and LOS combined:**

| | |
|---|---|
| Dehumidifier | 20kW |
| Lighting, 12.5kW CW, 2.5kW for LOS | 15kW |
| Heat (heat pump) | 10kW approx |

Fire suppression, e.g. pump for mist system TBC.

Lighting assumes about $3W/m^2$ for CW and $1W/m^2$ for LOS although this assumes the whole area is lit at the same time. The height of the building and high efficiency of modern LED fittings indicates a very energy efficient scheme is feasible at low cost:

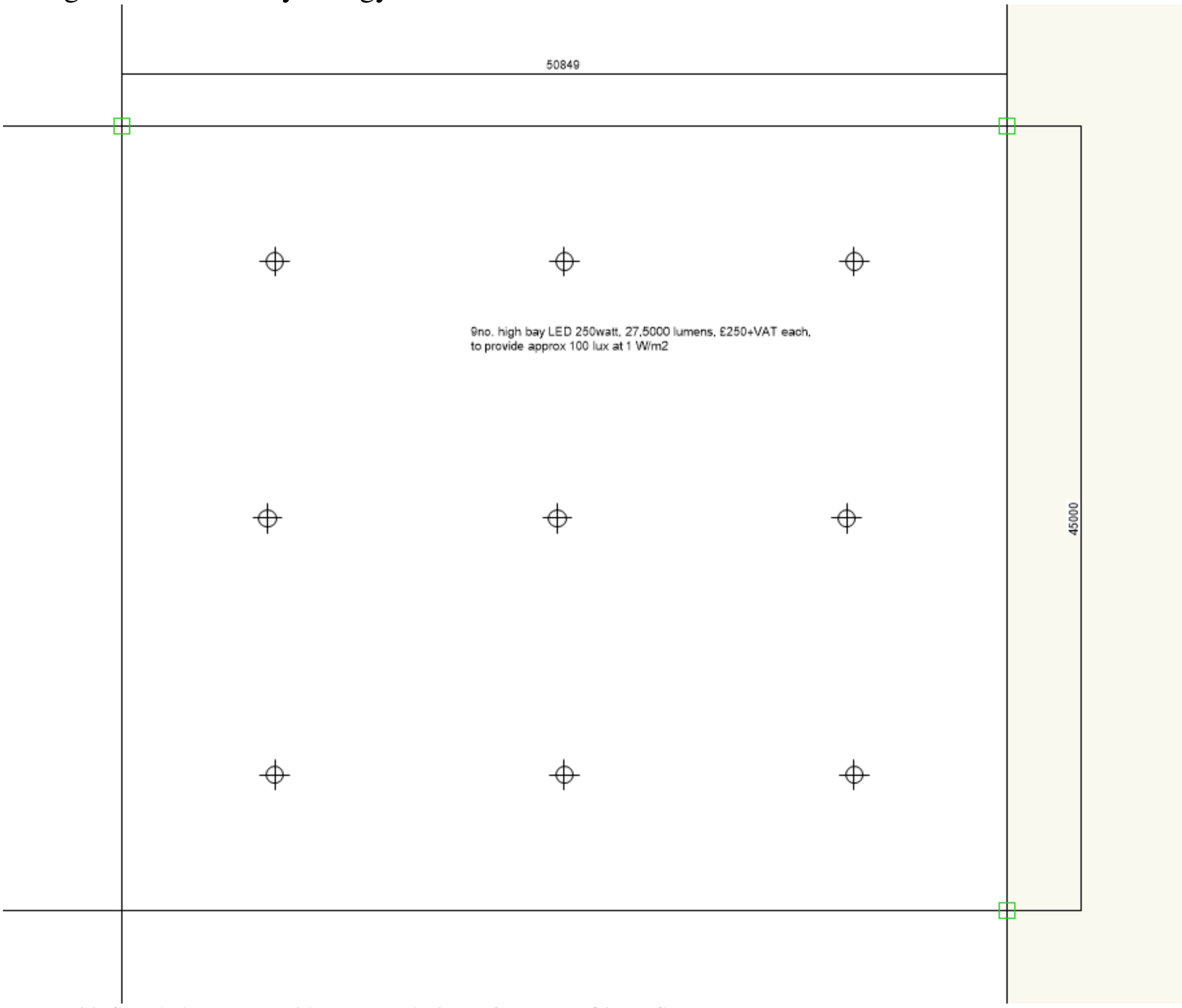


*Figure 11. Simple low cost and low power lighting for Large Object Store.*

## Fire suppression

This is outside our brief and expertise but all aspects of the design should be considered by all disciplines because of the potential synergies or unintended consequences of decisions. Our main concern would be to avoid any electrical frost heating of water pipes and storage should a mist system be used. Also any standby electrical consumption would be of interest to us.

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