SEMI-PASSIVE AIR CONDITIONING OF AN ARCHIVE

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Abstract. The archive of the Arnemagnæan Institute in Copenhagen University has a climate controlled by the balance of heat flow through two exterior walls and the heat flow from the interior of the building. The temperature is between ten and four degrees above the outside temperature, according to the time of year. This gives a relative humidity in the archive with a yearly cycle between 40% and 50%. The good insulation, massive construction and moisture absorbing walls smooth out the variations that would be caused by irregular changes in the outside climate.

1. The climate control principle

An archive should be cool and dry. A reasonable quantitative interpretation of this imprecise specification is 12 - 20 degrees and 40% - 50% relative humidity (RF). The low average temperature reduces chemical degradation; the RH is below the 50% RH limit for biological growth and above the level at which organic materials such as paper and film become brittle. Brief excursions of the temperature outside this range are not serious but a rise in RH over 60% would allow mould germination within a few weeks.

There is a convenient way to get an approximation to this climate almost free, if the archive is in an occupied building in a cool climate. One can take heat from the building, which holds a temperature within the narrow band that is acceptable to human office workers, and mix it in the archive with heat flowing from the outside (usually negative). Both flows are moderated by carefully calculated thicknesses of thermal insulation so that the annual temperature cycle within the archive is smoother than that outside and follows a path about half way between the fairly constant indoor temperature and the seasonally varying outdoor temperature. If the archive has a slow air exchange with the outside, the RH will be lower than the outside RH, which has an annual average around 70% in much of northern Europe. Humidity buffering by absorbent walls, and by the archived materials themselves, will ensure an even RH throughout the year.

2. The Arnemagnæan Institute's archive

We have a chance to test this theory in the small archive that has just been built for the Arnemagnæan Institute of Copenhagen University. This institute holds manuscripts from Iceland and the Nordic countries, dating back to the 12th century.

The archive plan is shown in Figure 1. The room is entirely enclosed by dense reinforced concrete, for physical security. It is this massive construction, together with limited access to people, that makes the semi-passive climate control possible. The archive is on the second floor, with a corridor and lobby on two sides and the outer wall of the building on two sides.

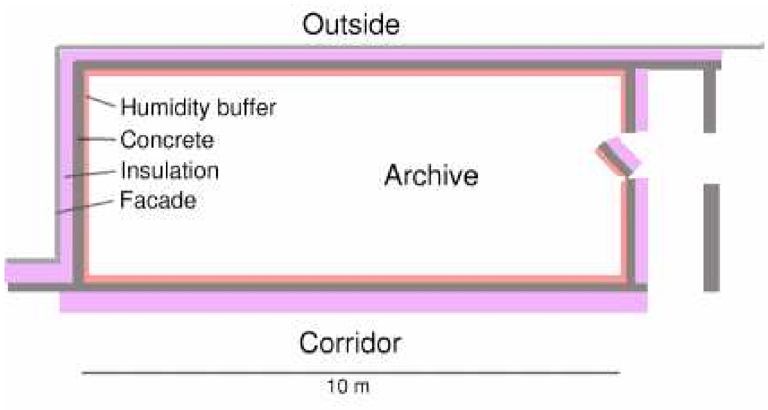

FIGURE 1. Plan of the archive in the Arnemagnæan Institute, Copenhagen University. The room has two sides exposed to the outside. Thin insulation on these two walls, combined with thicker insulation on the interior walls, gives the archive a temperature roughly half way between the building temperature and the outside temperature.

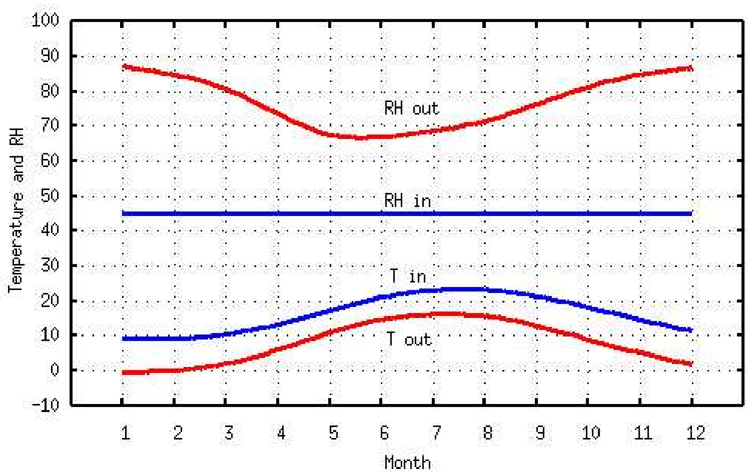

FIGURE 2. The monthly average temperature and relative humidity in Copenhagen (top and bottom curves). The curve marked 'T in' is the temperature to which this air must raised for the relative humidity to fall to 45%.

3. Modelling the climate in the archive

Let us now build up a picture of the climate in the archive. We will approach the matter obliquely by starting with a different method of temperature control: deliberately heating a room exactly enough to ensure a constant RH, a practice known as 'Conservation Heating'. Figure 2 shows the monthly average outside temperature and RH for a year (top and bottom curves). The second curve from the bottom shows the room temperature required to reduce to 45% the RH of outside air that moves into the room.

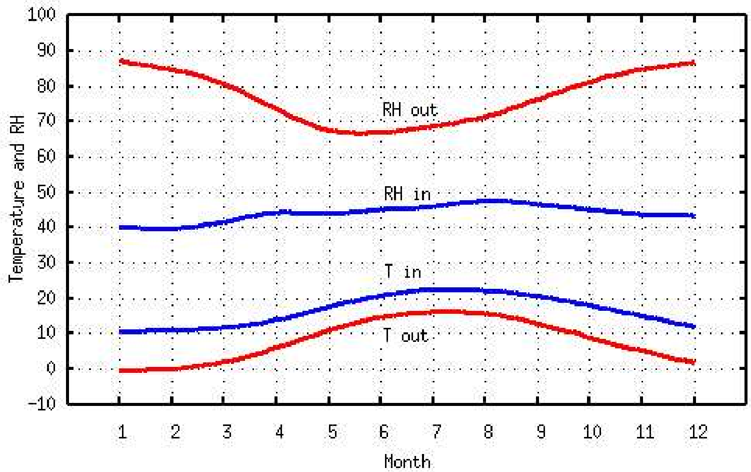

FIGURE 3. The monthly average temperature and relative humidity in Copenhagen (top and bottom curves), modified by the expected temperature within the archive (marked 'T in'). The relative humidity varies between 40% and 48% in an annual cycle.

The air temperature must be raised about 8 degrees to reduce the typical outside RH, about 70%, to the desired 45% RH. The temperature difference is less in summer than in winter, because the outdoor relative humidity is lower in summer.

3.1. **The temperature.** The next step is to model the temperature in the archive, with various thicknesses of insulation on both inside and outside walls (and floor and ceiling) so that the temperature varies through the year in a way that comes closest to ensuring the desired 45% RH. The best fit to the desired archive climate is shown in figure 3. The insulation is 100 mm of mineral fibre to the outside and 200 mm towards the interior of the building.

The RH is not quite constant, but near enough. The temperature varies on an annual cycle but that is not a significant threat, according to present knowledge of the durability of materials.

3.2. **Thermal inertia.** The real weather does not stick very closely to the monthly average, as idealised in these two diagrams. Indeed the weather can deviate from the average for weeks at a time. How well will the walls and the insulation suppress short excursions to extreme temperatures and how well will the water absorbent wall covering, and the archive itself, buffer the extremes of outside water vapour content?

The archive temperature can be modelled reliably by computer programs. It is shown in figure 4, against the background of the test reference year for Copenhagen. This is an imaginary but typical year. The model archive started out at too high a temperature but after April the graph gives a reliable impression of the considerable stabilisation afforded by massive walls and good insulation.

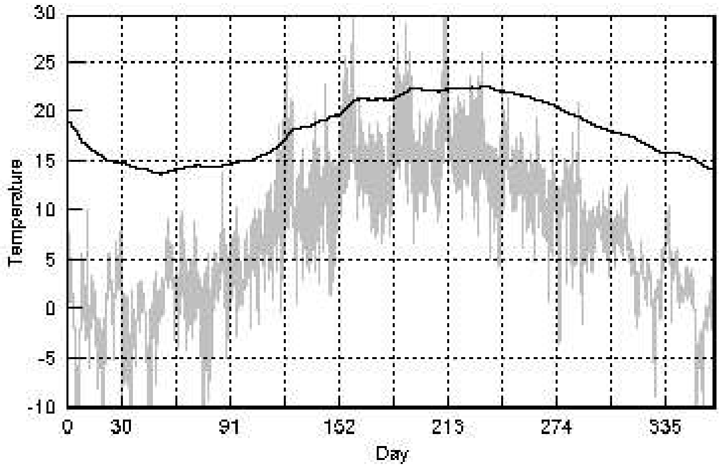

FIGURE 4. The expected course of the temperature in the archive through a typical year. The grey background is the temperature of the 'test reference year' for Copenhagen. The modelling started with the archive at room temperature, so the curve is first correct from some time in April.

It is surprising to see a room better insulated against the inside climate than the outside, but that is the key to the climate control.

3.3. **The relative humidity.** The RH is more difficult to predict. Computer models for moisture movement are not nearly so well tested as those for temperature. Also, the buffer capacity of the archive depends on the unspecified amount of absorbent material within it. Only the wall surface, which is of cellular concrete, has a defined moisture capacity and permeability. The archive must have sufficient moisture buffer capacity to ensure that the relative humidity does not ever climb into the danger region for mould growth, which is above 60%RH.

There are other complicating factors. There is the water mixed into the concrete when it was cast. This will diffuse out slowly during the first five years. We don't really know how often the door will be opened. This will let in moist air from the building.

3.4. **Mechanical fine tuning of the relative humidity.** To ensure a safe start to the archive, there is a backup system for steering the relative humidity towards a moderate value. The water content of the outside air is measured continuously. If the outside air has, by chance, a water content that would bring the inside air closer to the set point, 45% RH, air will be pumped slowly into the room, through filters.

To find out how often the air will be of the right water content to correct deviations from the set point, we have extracted three seasons' measured climate data and calculated the excess, or deficit of water vapour, in relation to the water vapour content of the archive air. These calculations are shown in figure 5.

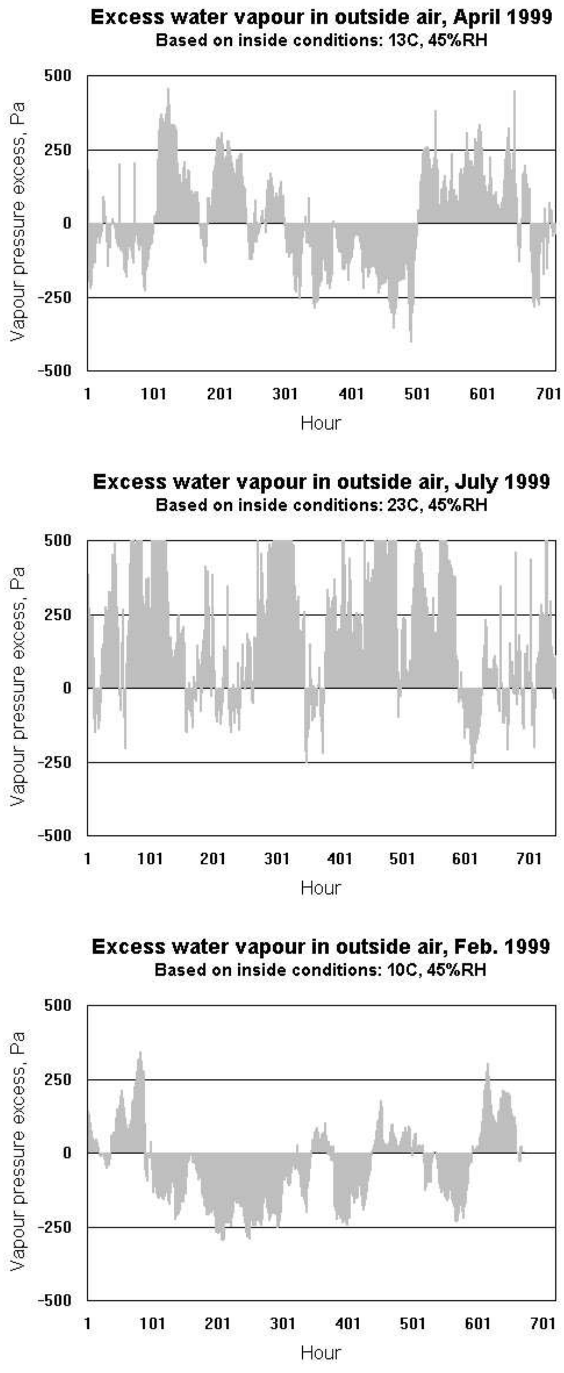

FIGURE 5. The difference in water content between outside air and archive air at the ideal 45% RH, calculated from climate data for 1999. The top graph, for April, shows an even distribution of the difference about zero. In midsummer (middle graph) the inside temperature is lower than ideal, so the archive air will drift upwards in RH, with only short periods available for pumping in air to correct this tendency. In winter (bottom graph) the temperature is too high for a balanced difference, so the RH will tend to drift down. This is unlikely to happen, however, because occasional opening of the door will allow humid air to enter from the building.

The grey areas in these graphs show when the outside air has more, or less, water vapour than the air that the archive should contain, at 45% RH. One can see that there can be periods of two hundred hours - over a week - when the grey area is continuously over, or under, the zero line. During these periods, a correction that requires air of the opposite moisture content difference is impossible. We don't, however, expect a serious drift from the humidity set point during these periods, because of the enormous buffer capacity of the archive.

4. Conclusion

We will update this article as the data accumulate and the theory is tested against reality. At this time, 2002-11-17, the climate is quite satisfactory, but the archive is not yet in use.

5. Acknowledgements

We thank Jens Eg Rahbek of COWI Consulting Engineers for the prediction of the temperature cycle in the archive. The archive, and the enclosing building, was designed by KHRAS Architects. We are particularly grateful for support and encouragement from Peter Springbord, Leader of the Arnemagnæan Institute of Copenhagen University.

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