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MICROCLIMATE MODELLING IN OLD MUSEUM BUILDINGS

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INTRODUCTION

It is important when considering the environment in which an exhibition or museum objects are to be displayed, to consider the way in which the building itself responds to the external parameters of relative humidity and temperature. This paper will be concerned with measurements recorded by thermohygrograph units, placed inside display galleries at the Western Australian Museum in Francis Street in Perth, and also at the Freemantle Museum and the Maritime Museum in Fremantle. The data for external values of temperature and relative humidity were obtained from the Bureau of Meteorology in Perth.

BEAUFORT STREET BUILDING, WA MUSEUM, PERTH

The Beaufort Street wing consists of a two-storey double-brick building which originally comprised the Art Gallery section of the combined Musuem and Art Gallery (Fig. 1). It is an Edwardian red brick strudture with the lower floor having a ceiling height of 6.75m while the upper gallery height is 7 metres. The upper gallery also has a large central lantern running the length of the gallery, reaching a height of 12.5 m. The internal decoration includes a replica of the Parthenon frieze below the lantern windows (Fig. 2). During the Bicentennial "Shipwreck" exhibition it was realised that there were major problems in housing an exhibition in the lower section of the Beaufort Street gallery, in that the ambient temperatures recorded during the month of February were typically in the area of 28-32°C, which caused a large amount of discomfort to visitors. There were no ceiling-fans, but air circulation was provided by half-a-dozen oscillating domestic fans at a height of about 4.5m above the ground. In an attenpt to overcome the problems of the low humidity that would be anticipated during the exhibition, the designers of the display cases had been specifically asked to produce cases to provide an effective seal from the external environment and thereby create an internal micro-environment when could be buffered by suitable agents, so that the conflicting requirements of the diverse range of materials in the exhibition could be accommodated.

The buffering capacity of a building to withstand changes in relative humidity can be defined for the purpose of these discussions as δRH, where

$$\delta RH = \frac{\Delta RH\ ext}{\Delta RH\ int}$$

and $\Delta RH\ ext$ is the change in the external relative humidity (over a given time period), and $\Delta RH\ int$ is the change in RH inside the building or showcase. Owing to variable time-lags between a change in internal RH from external values, the time interval is normally of the same relative value, but only occassionally does it cover the same absolute interval.

Fig. 1 - Western Australian Museum, Perth along Beaufort Street frontage. The Jubilee Wing housing the Dinosaur gallery is in the left-hand building while the Beaufort Street galleries are on the right-hand side. (Photo: D. Gilroy)

An example of the diverse requirements of objects in a mixed-media exhibition can be seen in the materials viewed during "Shipwreck". The polyethyleneglycol-stabilised archaeological timber from the "Batavia" required relative humidity of 55% (which could have been obtained using saturated magnesium nitrate sale solution), while the iron armour and material such as a composite cannon, (a mixture of iron, a tin-lead solder, copper and brass), was best suited to a relative humidity of approximately 30-40%. There was also a wide range of very delicate textiles recovered from the "Batavia" site, and leather shoes recovered from the "Sydney Cove", which also had their own specific humidity requirements. In an exhibition such as "Shipwreck" it is impossible to have the ideal environment for each category in the actual gallery itself and hence the importance of our request for display cases that were capable of maintaining substantial differential in humidity between external and internal conditions. Unfortunately the display cases failed to meet these criteria, since they had 2-3mm gaps between some panels.

During a review of the gallery environment during "Shipwreck" it was noted that the lower gallery had humidity buffering values of the order 4.2 ± 1.5 (see Table 1); while the upper gallery showed two distinct domains: namely one when the values were similar to the lower gallery with δ values of 2.6 ± 1.0, and another, with much the better δ value of 10.2 ± 2.3. The root cause of the differences in the ability of the building to withstand humidity changes lay in the varied work-patterns in the far end of the building. When printing is in full swing and the days are hot, a door is opened onto Beaufort Street, and the rushing winds cool the printers and provide fresh air. However, the back stairs take the hot dry winds up to a curtained archway and into the gallery. Hence, the building functions much better with all the doors shut!

Table 1: Relative Humidity Buffering Capacity of Beaufort Street Galleries

Location	δ Shipwreck Jan-Feb 88	δ First Impressions Feb-Mar 89	δ Winter Aug 89
Beaufort Street			
- lower gallery	4.2 ± 1.5	9.5 ± 1.7	-
- upper gallery (closed)	10.2 ± 2.3	8.3 ± 0.3	7.7 ± 1.2
- upper gallery (open)	2.6 ± 1.0	3.0 ± 1.2	3.4 ± 1.7

In 1989 the Museum hosted the final Bicentennial exhibition of "First Impressions". This collection comprised a series of carefully-framed prints and drawings and a range of other paraphernalia, including prized stuffed faunal speciments associated with the early impressions of Australia by white settlers. Measurements of the conditions showed that the closely-framed pictures with good mounts were largely buffered from changes in relative humidity but the large display cases that were open and had large gaps in the proscenium above the area viewed by the public had essentially no buffering capacity. This was corrected by placing heavy foam rubber over the air gaps, which helped control the micro-climate inside the cases.

A typical set of measurements is seen in Fig. 2 which is the thermohygrograph chart for the period of 9-16 March 1989. In the last four days of that week running from the Saturday through to the Wednesday we see the typical variation of external humidity, shown as the dotted line, with data provided by the Perth Weather Bureau. Between 3am - 6am the east winds blow in from the desert and the

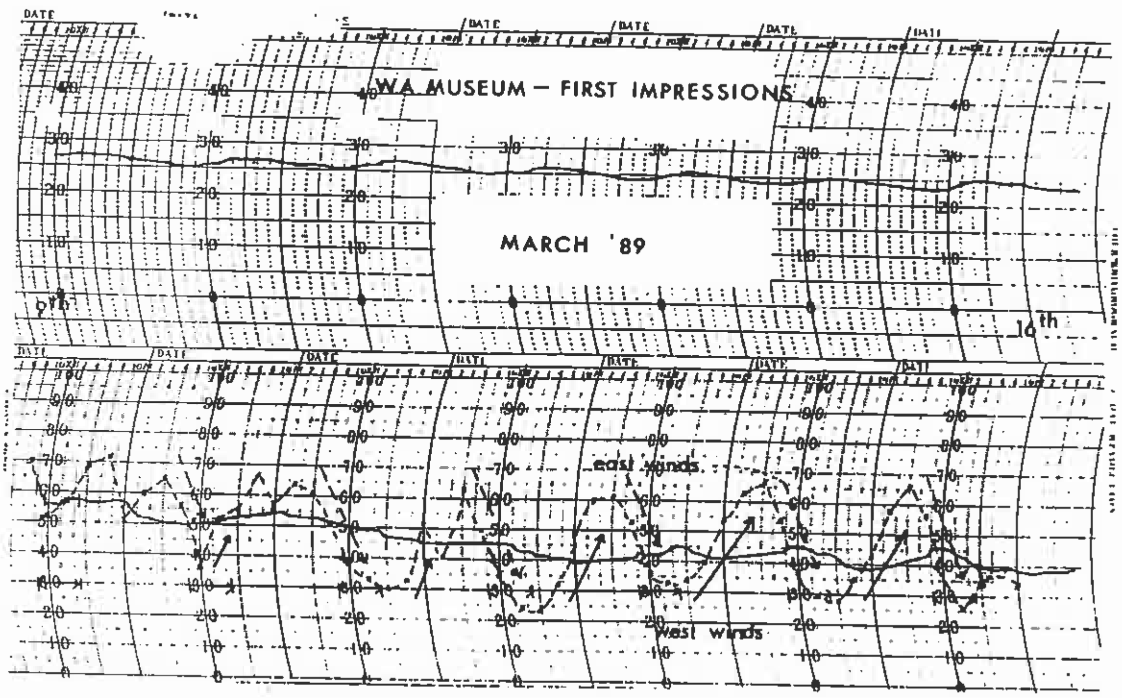

Fig. 2 - Thermohygrograph chart for lower Beaufort Street gallery 9-16 March 1989. Dotted line represents RH readings from Bureau of Meteorology.

humidity falls quite rapidly. In the afternoon the sea breeze, the weterly moisture-laden winds that come in from the sea, the so-called "Fremantle Doctor", brings about a rise in relative humidity. The external humidity falls over a period of 6 to 9 hours at the rate of approximately 4.3 ± 0.14% RH per hour during the flow of the easterly winds, and the westerly winds rehumidify the external environment and bring humidity in at the rate of 3.7 ± 0.3% per hour, whilst inside the humidity changes by 0.7 ± 0.5% per hour. When we look at the response of the building to the external humidity we find that there is a lag of between 5 to 7 hours in the response to the external environmental conditions.

The main difference to note betwen "First Impressions" and the experience we had had the year before with "Shipwreck" was that the main door leading from the foyer to the street frontage had been shut during the second exhibition. This was because we realised very shortly after the opening of "First Impressions" that as soon as the huge glass doors from the Beaufort Street frontage were opened, the winds blowing-in from the street were causing too large a humidity change. It was necessary to have the visitation route changed to one coming from the double doors via the museum courtyard, which create an air lock from the inner courtyard of the museum into the foyer of the exhibition area, and then through doors into the exhibition area proper. By adopting this technique we are able to damp-out much of the worst of the variations in relative humidity. This is most readily seen in the fact that the δ values for the lower gallery had increased from 4.2 to 9.5 ± 1.7 by adopting the simple method of air movement described above. Both exhibitions occured during the hot summer months but we were able to double the ability of the gallery to resist changes in RH without recourse to traditional airconditioning. Two domestic-sized evaporative air-coolers in the foyer gave psychological rather than real relief to the exhibition an the public visitors. The changes in air-flow also reduced the rate of change of the internal RH from values of 1.02 ± 0.48% RH/hr during "Shipwreck" to 0.69 ± 0.49% RH/hr during "First Impressions".

Inspection of the thermohygrographs during the exhibition provides a wealth of information about the way the gallery responds in the "closed" conditions. If the gallery was functioning as a totally-closed system, we would have expected a fall in humidity as the temperature rose, but the internal RH of the gallery increased with temperature. The increase was apparently due to the moisture coming from the visitors in the gallery; for example on 17 March 1989 a relative humidity increase of 4% occurred within the space of 4 hours with a 1.5°C rise in temperature. The increase temperature is partly due to the exhibition lighting being turned on at 10am, and also due to heat from light coming into the gallery from the windows just below the ceiling level, and from delayed heat transfer owing to the mass of the building itself. It should also be noted that the effect of the humidity from the visitors was more noticeable when the average relative humidity in the gallery was approximately 40%. Once the humidity in the gallery was in the region of 55% the extra moisture contribution from the visitors was not as noticeable. It should be noted that the "humps" in the relative humidity downstairs due to visitor activity on Friday, Saturday and Sunday occurred well into the afternoon rather than at noon on the other days, and this was simply due to the different opening hours. This gives further credence to the belief that the humps seen in Fig. 2 are due to moisture transpired from the visitors in the gallery.

With the gallery essentially shut-up like a cocoon, the temperature varied in one week between 23 to 27°C but the maximum diurnal variation in temperature was closer to 2°C. The environments of the upper and lower galleries are shown in the thermohygrographs charts for the week of 16-23 March 1989 as seen in Figs. 5 & 6. The first thing we notice is that the upstairs gallery has a larger total variation in temperature than the lower gallery downstairs. Although the highest maximum temperature recorded was 28°C downstairs the upper gallery maximum was 29°C but this difference is hardly significant. However, downstairs the minimum temperature was 24° and the minimum upstairs was 21° so the total temperature variation is larger in the upper than the lower gallery. Of more significance is looking at the way in which the galleries responded to the massive change in external humidity, for example on 21 March there was a change of 76% in relative humidity over the space of 18 hours. In the lower gallery the relative humidity changed at a rate of 3.2% per hour compared with the maximum corresponding rate in external conditions at the same time of 7.7% per hour, and the total internal change of RH was 8.5%. The slightly higher rate of 3.8% RH per hour occurred in the upper gallery and the total change was of the order 16% RH. The total air space in the upper gallery is approximately 3500m^3 compared with 2700m^3 in the lower area and these difference must be considered when looking at the varied responses. The temperatures in the upper gallery show a normal diurnal variation expected from solar heating and cooling, whereas the temperatures in the lower part of the gallery during the same period show that the variation in temperature has been partly damped-out as a result of the incorporation of the airlocks and the buffering that the upstairs provides.

The charts to this point relate to the exhibition periods in February and March typical of our summer weather conditions. When we look at the building behaviour during the winter months we also observe massive changes in the external relative humidity, for example a change of 65% over a period of 12 hours as the weather changed from a bright sunny winter's day to a wet evening. Analysis of the thermohygrographs show that there is no statistically significant difference in the way the building can buffer RH changes in the winter compared with the summer months since the δ values (see Table 1) are essentially the same for the "open" and "closed" forms of air flow in the upper display gallery regardless of the season.

JUBILEE WING - DINOSAUR GALLERY - WA MUSEUM, PERTH

By the way of comparison, we can look at the behaviour of the Dinosaur Gallery which runs east-west compared with the Beaufort Street wing which runs north-south. A typical thermohygrograph for the gallery is shown in Fig. 3 for the week of 14-21 August 1989. The windows of the upper gallery were permanently nailed open, and we see that on 17 August the worst scenario was a change of relative humidity of 25% per hour! This is totally unacceptable to all types of museum objects and since the data was recorded, procedures have been instituted to nail the windows shut. The temperature within the gallery had a typical winter value of about 16°C with diurnal variation of 1-2°C. The worst buffering value is found with a δ value of only 1.25 whereas the mean buffering value for the gallery is 4.3 ± 1.3.

Comparing this δ value with those listed in Table 1 shows that the upstairs gallery of Beuafort Street has an "open" δ value of 3.4 ± 1.7, which is essentially the same as the "open" Dinosaur gallery. In other words, you can expect the same buffering capacity for basically the same type of building when you have air roaring through it. The worst situation occurred when the δ value fell to 1.25, which corresponded to a 70% change in external humidity with a 56% change inside. This occurred at a time when there was increased activity in the associated and interconnected galleries. The main doorways were open in the Beaufort Street foyer, and so there was a roaring wind going up the stairs as well as through the open windows of the building during some painting activities, and so the air residence-times were very short.

THE OLD GAOL - WA MUSEUM, PERTH

The Old Gaol lies in a courtyard with three sides composed of the Jubilee wing, the Beafort Street building and the five-storied Francis Street Wing. The doors of the gaol are open during visitor periods, but one set of double doors swing shut, and only a single domestic-sized door facilitates the other point of egress. The building is quite solid, having sandstone walls approximately 0.5m thick, and there appears to be two types of buffering capacity. One response is characterised with high δ values which represent a buffering capacity of 12.0 ± 0.9 when the relative humidity is swinging between 20-60%. The high δ value for the old gaol is at the upper limit of the Beaufort Street galleries when they are kept "closed". However the buffering capacity is much lower with δ values of round about 3.5 ± 1.4 when the relative humidity varies between 65-85%.

As seen in Table 1, the buffering values of the upstairs Jubilee Wing, the Dinosaur Gallery and the Beaufort Street gallery, and the Old Gaol are essentially identical when the doors are open and there is reasonable circulation of air. However, the Old Gaol does have the ability to damp-out a lot of the variation in humidity when it is going from extremely-dry to just moderately-moist conditions. These different responses may relate to the amount of moisture that is able to be absorbed and released by the stone which is also dependent on its porosity. Once the stone has become "saturated" with mositure the building loses a lot of its ability to damp-out the variations in relative humidity. Since RH vlaues in Perth tend to be closer to the 20-60% range for most of the year than the 65-85% domain, the Old Gaol provides a generally-acceptable environment.

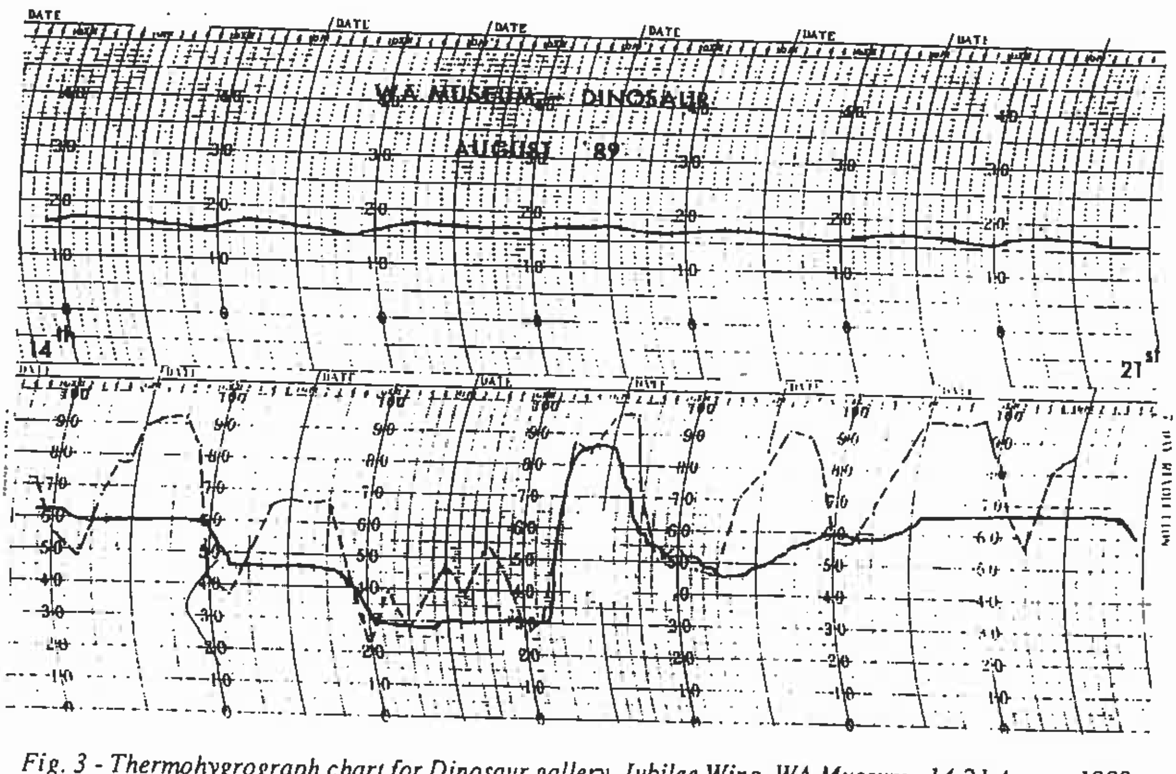

Fig. 3 - Thermohygrograph chart for Dinosaur gallery, Jubilee Wing, WA Museum. 14-21 August 1989. Dotted line represents RH readings from Bureau of Meteorology.

DISPLAY CASE MICROENVIRONMENT

Having observed the problems of ill-fitting show-cases during the "Shipwreck" and to a lesser extent with "First Impressions", we decided to run thermohygrographs inside the custom-built display cases down in the "uncontrolled" airspace of the Maritime Museum in Fremantle to see what effect a good seal has on withstanding RH changes. The display cases were constructed of a high quality plywood base and a perspex of plexiglass cover. The aluminium top-to-base frame is a snug fit, and when used with a mohair strip it provides a reasonable seal. The form of the metal and the deep fit (50mm) also minimises air exchange. There was essentially no damping of temperature between conditions inside the gallery and inside the display case. This is entirely consistent with the fact the infarred radiation as the primary source of heat transfer is able to move easily through the perspex material. However, the relative humidity is almost invariant inside the display case, whereas outside we are getting variations up to 10% humidity. The relatively-small changes in RH in the gallery are due to a combination of little air movement, thick limestone walls and some leakage of climate-controlled air from the adjacent gallery housing the "Batavia" reconstruction. Over any 24-hour period a change of less than 1.5% RH occurs inside the case, and this is as good as the best conditioned galleries provide. The display case in question had a base 0.9 x 0.9m. This ability to create a stable microenvironment was used to good effect in an upstairs gallery at the Fremantle Museum. The giant 1876 "Stars and Stripes" flag measured 14' x 10' and had been used in a bold escape plan that resured eleven Fenian prisoners via the American whaler "Catalpa". The gallery windows were protected from direct sunlight by a series of internal wooden shutters. The wooden display case was glass-fronted and well-fitting, with measurements 16' x 8' x 3' depth. The conditions during July (the middle of winter) were quite suitable for the display of the flag with the temperature ranging between 17-19°C and we were able to control the relative humidity inside the display case to within 52-57% humidity over a total period of some 60 days. The rate of humidity change inside the case was normally 0.25% per hour compared with typical values in the exhibition areas of 2.8% per hour. Well-constructed and sealed display case provide improved control over the rate of change of relative humidity by a factor of approximately 10, compared with the ambient gallery conditions.

In the conservation laboratory at the WA Maritime Museum where the airconditioning has no humidity control, the mean weekly RH in the lab during the week 21-28 August 1989 was 45.68 ± 5.00%, whilst the humidity inside a drawer of a laminated wood-veneer particle-board desk had a mean value of 46.47 ± 0.44% RH. Thus the simple microenvironment of a wooden drawer reduced the variablity of RH by a factor of 11.5.