The mitigating effects of packaging on temperature and humidity fluctuations

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Abstract

Monitoring sensors in storage spaces are generally located out in the open and thus are checking conditions in the general air space of the storage area. In cases where a collection is packaged or boxed however, collection items are entirely within a secondary climate system which whilst related to the ambient conditions, is also modified by a number of factors: the buffering effects of the packaging or boxing materials, the construction of the storage enclosure and the thermostatic and humidistatic properties of the collection material itself. It is felt that since these are the actual conditions collection items are stored in, then it is these which conservators should be most concerned with.

Research has been carried out at the National Archives of Australia to examine the variations between ambient storage conditions and those within storage containers. This has revealed that there is a significant difference between the two sets of conditions; inside a storage container is always less variable than outside.

Background

The National Archives of Australia (NAA) is currently in the throes of specifying a new storage building in Canberra, the National Archives Preservation Centre, to hold a large portion of its holdings.

As a result we have been carefully looking over current trends in prescribed storage conditions to ensure that our specifications are not out of step with current thinking and practices. As a result we have looked at research conducted in Canada by Stephan Michalski of the Canadian Conservation Institute (Michalski 1993), and David Erhardt and Marion Mecklenburg of the Conservation Analytical Laboratory at the Smithsonian (Erhardt & Mecklenburg 1994). Their work has been reflected in the specifications set for the environment in the NAA's new building.

Another pressure on specification for the new building is the strong and of course justified push for new buildings to be as 'green' as possible. This means that the new building will need to reduce its energy usage and thus achieve a high 'green' rating. This will be done by looking carefully at the siting of the building, its construction and how it draws its power.

A relaxation of the parameters specified for storage may also help here – we do not want to specify environmental parameters which necessitate unwarranted expenditure and energy usage, on heating, cooling, humidification and dehumidification.

Part of our thinking on this subject related to how we monitor environmental conditions. Since it is a feature of the archive that everything is boxed, it occurred to us that when considering questions of environmental control, measuring ambient conditions in storage spaces was not really the most appropriate way of knowing what was happening to the actual records in storage. Each item was in a microclimate within its box and we thought it would be quite likely that the box could have a mitigating effect on environmental fluctuation experienced by the item.

Some history

The Commonwealth Archive Office was established independently in 1961 after starting life as a section of the National Library of Australia. It was renamed the Australian Archives in 1975 and then the National Archives of Australia (NAA) in 1998.

The box that we at the NAA call the 'Type 1' is actually our own invention – it was developed by Ian MacLean, the Chief Archives Officer back in 1962. We have long been happy with the folded design which avoids adhesives and fasteners and is tough and sturdy. The bulk of the archive is stored in Type 1 boxes, of which there are roughly 1.5 million. Records that do not fit in Type 1 boxes are stored either in a range of other standard sized boxes based on the Type 1 theme or in tailor-made boxes that are generally based on the Type 1 design avoiding adhesives and fasteners.

Initially the Type 1 box (Figure 1) was made from a common grade of brown acidic corrugated paperboard. In more recent times the boxes have been produced from buffered archival paperboard and we have been moving toward getting everything transferred from the acidic brown boxes to the lovely pristine archival boxes before the move to the new building.

Figure 1: Type 1 boxes made from acidic brown paperboard in the 1960s (left) and buffered archival paperboard currently used (right) at the NAA

Also of interest to us is the fact that other box-making materials are currently available; one prominent alternative is a box made from polypropylene to the basic Type 1 dimensions.

Other modes of storage are used at the NAA for large format flat items such as maps and plans. These items are either placed in plan cabinets inside secondary protective folders, or for particularly large items, on open shelving using sturdy tailor made folders. Items which are simply too big are rolled and placed in protective tubes. This current study considers only Type 1 boxes.

The Experiments

To explore these issues we decided to embark on a series of experiments that would tell us exactly how well our Type 1 boxes acted as buffers to environmental fluctuations. We also decided it would be worthwhile to compare these results to those for boxes constructed with polypropylene which currently provide the other major alternative to the use of corrugated paperboard. For the experiments carried out so far we have utilised 'real-life' conditions in the NAA's storage spaces.

Experiments were carried out in two of the NAA's ACT buildings:

1. A storage repository in our Mitchell building. The room we used is on the top floor of two floors and has 24 hour air conditioning aimed at maintaining conditions of 20 ± 2°C and 50 ± 5% RH.
2. The Greenway repository, a large open-plan 'warehouse' style building with no air conditioning. As expected, this Greenway building provided a greater variation in ambient conditions than the Mitchell building.

Standard NAA Type 1 boxes in archival corrugated paperboard were used, along with polypropylene boxes of the same dimensions. Conditions (temperature and relative humidity) inside and outside the boxes were monitored using ACR Smart Reader 2 data loggers, each with a pair of probes, termed 'Internal' and 'External'. For each data set one of the pair of probes was positioned inside the box and one outside. In each case the external probe was placed on top of the box.

Three configurations inside the box were tested:

A. In a box full of standard paper files, with the internal probe sitting in a cut out space in the middle of a file, in the middle of the box (Figure 2).

B. In a box full of standard paper files, with the internal probe sitting in an air space within the box (Figure 3).

C. In an empty box.

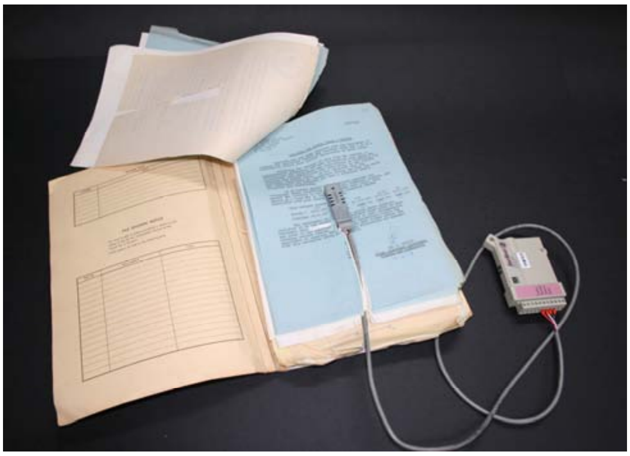

Figure 2: Internal probe in file before being placed in box

Figure 3: Internal probe in air space in a filled box

The boxes were placed on standard NAA shelving which is constructed with powder coated metal. The shelves are open-fronted and five Type 1 boxes fit on a single shelf. The boxes were placed in the middle of a row of shelves with boxes of actual archives on either side (Figure 4).

Given the possibility for environmental variation within a storage space, in both locations two different shelf locations were used: a central shelf (fifth from the bottom of eight shelves) and a top shelf (eighth of eight).

Boxes with the loggers included were placed in location for periods of seven days at a time. At the end of each seven-day period the data was downloaded and printed in graphical form.

Figure 4: Boxes in place on shelf in Mitchell

Experimental results

Spatial variations

The first thing we noticed was that ambient conditions in both storage spaces vary much more at the higher shelf level than on the middle shelf. In Mitchell the repository we utilised for testing is on the top floor of the building and clearly outdoor conditions have an effect on indoor conditions closer to the roof. A good example is seen in the graph from 11-19 May (Figure 5). On the top shelf there was a maximum daily humidity fluctuation of approximately 7% (49-56%) and a temperature fluctuation of 3°C (18-21°C). For the same period on a middle shelf the maximum RH variation was only 3% (42-45%), whilst temperature varied only by 1°C (18-19°C). These variations were not present every day, with some days showing much less variation. It can therefore be seen that we are almost meeting our necessary parameters, albeit with a fairly high daily fluctuation in some areas. Similar spatial variations were observed in the Greenway building.

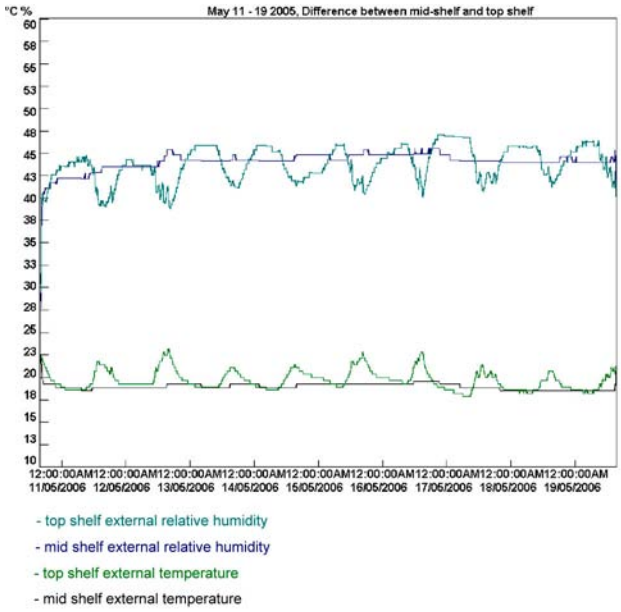

Figure 5: Difference in conditions between mid-shelf and top shelf in the Mitchell building from 11-19 May 2006

Empty boxes

When considering the effects of boxes on their internal environments we first looked at the boxes alone, with nothing inside. Figures 6 and 7 show the results for empty examples of both corrugated paperboard and polypropylene boxes.

These graphs reveal a considerable difference in performance between the two empty box types. To take an extreme day, on 18 August 2006 conditions in the repository fluctuated by 10% (from 27 to 37%); this fluctuation transferred into the polypropylene box without any reduction whereas inside the corrugated paperboard box conditions only fluctuated by 3% (32-35%). As for temperature, both box types had a similar effect on temperature fluctuations, reducing maxima and minima by about 1°C. The other interesting thing to note from these graphs is that for the corrugated paperboard box there is a delay between the humidity rise outside the box and inside the box; this is presumably due to the humidistatic effect of the boxing material – there is no similar delay for the polypropylene box.

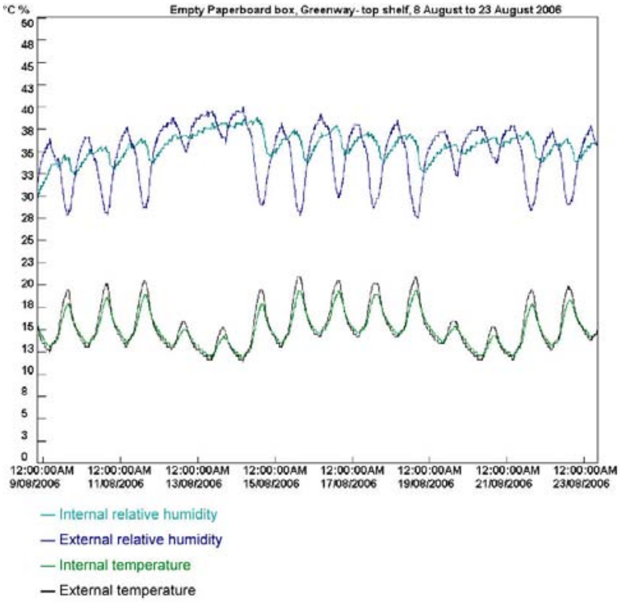

Figure 6: Empty corrugated paperboard box results for Greenway, top shelf, 8-23 August 2006

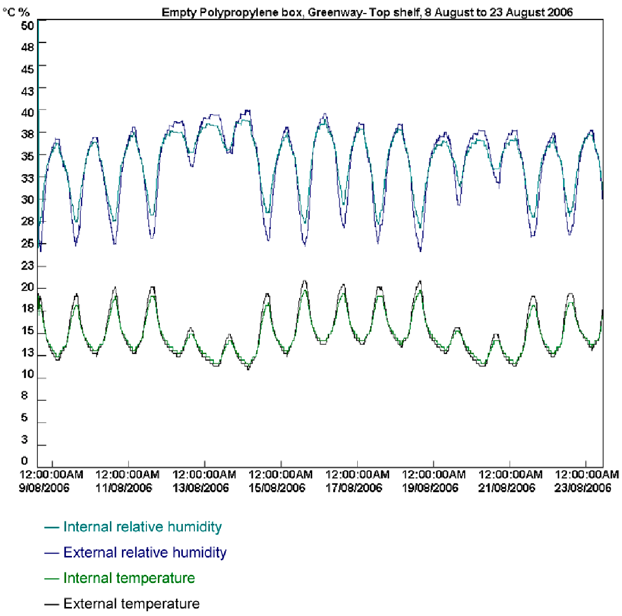

Figure 7: Empty polypropylene box results for Greenway, top shelf, 8-23 August 2006

Although more experimentation is required, these results seem to suggest that, at least in the area of humidity control, the corrugated paperboard box insulates against fluctuations better than the polypropylene box. As will be seen however, these effects appear fairly inconsequential when the box is filled with hygroscopic material such as paper. The effect would be more significant when a box contains only a small amount of hygroscopic material or when it contains non-hygroscopic materials such as metals. In such cases the use of a box which has a controlling effect on humidity fluctuations may be of some benefit.

Filled boxes

In an archival collection, boxes are generally filled with paper-based materials such as files and volumes. To determine the 'real life' conditions within boxes it was necessary to examine the effects of boxing material in concert with the effects of the box contents. As previously stated, these tests were carried out using two probe locations; in the heart of a file in the middle of a full box and in an air pocket in a full box (see Figures 2 and 3).

The recorded data reveal a great deal and also raise several questions. The first thing to note is that for both boxes the conditions in the heart of the box contents were much less variable than those outside the box. This applies to temperature and humidity fluctuations, both of which are considerably reduced by the box and its contents.

The second point to note is that there is very little difference between the results for the two box manufacturing materials. This strongly suggests that, when a box is full of hygroscopic material, the effect of the box construction material on internal conditions is fairly negligible. This is most likely because the contents of the box constitute a significant temperature and humidity 'sink' and will buffer external changes. It seems that such 'sinking' effects practically dwarf any effects that might be due to the box itself. This is not surprising when considering the mass of the contents when compared to the mass of the box.

The third point that stands out is that, with the humidity results, there is not only a reduction inside the box but the two traces – inside and outside the box – are significantly offset from each other. For example, for the polypropylene box the average humidity outside the box is approximately 33% whilst within the box the average is about 44%. Furthermore there is an inverse relationship between the two humidity traces; when the humidity falls outside the box as a result of a temperature increase, the humidity inside the box increases. We are not able to give an explanation for this but suggest that the box contents may be releasing moisture in reaction to the temperature rise and driving the humidity up slightly. Unfortunately, as our graphs are for fairly short periods, we do no know whether or not, over time, the two humidity traces would come into better alignment. These features are visible in all graphs where the probe is within the file (Figures 8 and 9).

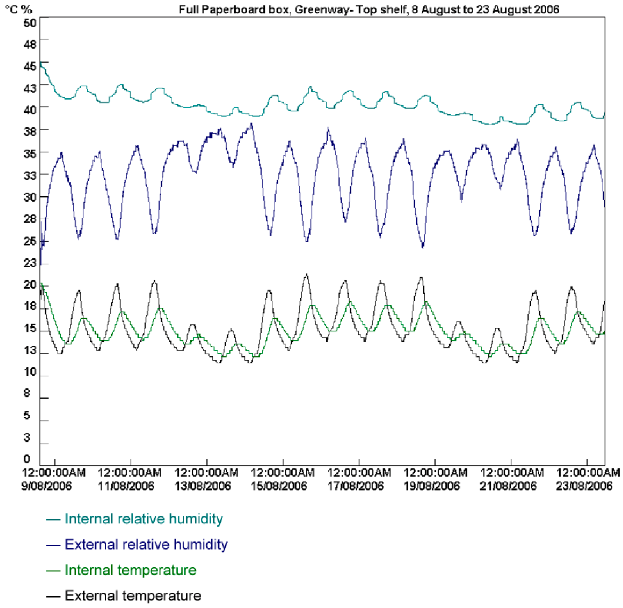

Figure 8: Full corrugated paperboard box results, probe within a file, Greenway, top shelf, 8-23 August 2006

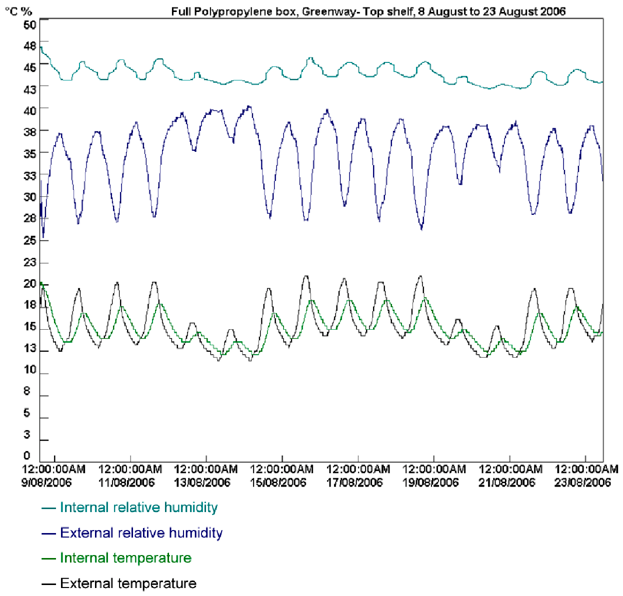

Figure 9: Full polypropylene box results, probe within a file, Greenway, top shelf, 8-23 August 2006

The graph in Figure 10 is from a box on the top shelf at Mitchell and is for a period with fairly minor temperature and humidity fluctuations. However, the same unusual features can be seen: the offsetting of the traces for inside and outside the boxes and the inverse relationship between external and internal humidity levels.

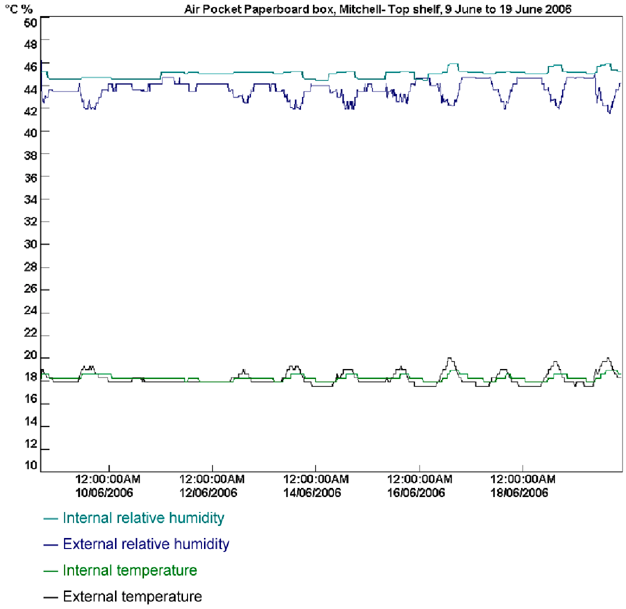

Figure 10: Corrugated paperboard box results, probe in air pocket, Mitchell, top shelf, 9-19 June 2006

To possibly confuse things further, we can look at results for the air pocket within the box. Figure 11 shows a set of such results, for the top shelf at Greenway. As can be seen in this graph, the offset between the internal and external conditions is present, albeit greatly reduced, but the puzzling inverse relationship remains.

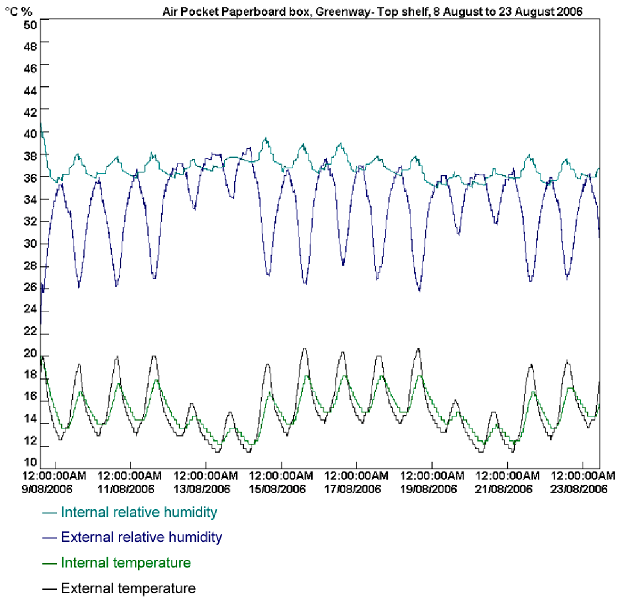

Figure 11: Corrugated paperboard box results, probe in air pocket, Greenway, top shelf, 8-23 August 2006

Conclusions

This is an ongoing study and this report can only be considered preliminary; however, the following conclusions can be made based on the information gathered so far:

- When empty, a box made of corrugated paperboard has a significant reductive effect on the transference of external humidity fluctuations to the inside of the box. Boxes constructed from polypropylene do not have this facility.
- Dense groups of paper files in a semi-sealed micro-environment act as an effective humidistat and thermostat, levelling out fluctuations in the humidity level and temperature of the air around them.

Given these conclusions, the following questions present themselves:

- For fully boxed collections, if we wish to know the actual conditions experienced by collection items, where should we be monitoring temperature and humidity? This study suggests that perhaps our monitoring device should be within a storage box.
- Again, for fully boxed collections, what environmental parameters should we be prescribing for the storage area? If we know that fluctuations will be reduced within the boxes can we relax our allowable variation?
- What is the cause of the unusual offset and inverse relationship in humidity levels inside and outside boxes? Would this offset decrease over time? And would it be present when external conditions are markedly different from those prevailing for these experiments?
- What box-making materials should we be using for different types of collections?

As stated, this study is part of an ongoing examination of boxes and their effectiveness in protecting collection items. We will soon be in possession of an environmental chamber that will allow us to simulate variations in environment across a range of parameters. This should provide us with a much better set of data from which to make conclusions.

There are also further questions we wish to address later in this project:

- How effective are plan cabinets in buffering environmental fluctuations?
- Are conditions better maintained within closed compactus shelving?
- How do different box-making materials behave in a flood?
- How do different box-making materials behave in a fire?

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AUTHOR BIOGRAPHIES

Ian Batterham was in the first intake of students for the (then) Canberra College of Advanced Education (CCAE) Materials Conservation course in 1978. On graduation he went to work for the National Archives of Australia (NAA) where he remains to this day. He achieved his Masters Degree in Conservation at the University of Canberra (UC) in 2000. Over the years, at different times, he has worked as a lecturer in paper conservation at UC. He has had numerous papers published including one in the journal *Restaurator* on conservation work he carried out on the Walter Burley Griffin Canberra Designs. His first book *The Office Copying Revolution* is to be launched at the AICCM Book and Paper Symposium in July 2008. He is currently in the position of Assistant Director, Operations Development at the NAA where he writes preservation policy and carries out preservation-related research.

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Jessica Wignell has worked in the Paper Conservation Laboratory at the National Archives of Australia for four years. Currently a Paper Conservator, she began working as a Conservation and Preventive Conservation Assistant. In 2005 she completed an Insect Science course unit at the University of Queensland, by correspondence. In 2007 she worked as a Paper Conservator at the National Library of Australia for six months.

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