Passive environmental control: the use of insulated archival boxes to control fluctuations in relative humidity and temperature

by

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Submitted to the School of Information Management Victoria University of Wellington

in partial fulfilment of the requirements for the degree

of Master of Library and Information Studies

October 2009

Acknowledgements

This research project was completed with the assistance of many people. I would like to thank all my Victoria University lecturers and tutors, in particular Lynley Stone, who has helped me bite through the ‘elephant’ of MLIS study by always being available and endlessly patient. Thanks also to my fellow classmates (now called the old girls network) who have been there for discussion and encouragement in challenging times. The support of my manager, Sarah Padey at the Auckland City Council Archives is much appreciated and I am grateful to her for the loan of the HOBO LCD Temp/RH data loggers used in this project. Lastly, I would like to thank Gillian Oliver, my supervisor for this project, for her guidance and constructive criticism.

Abstract

Key Words*: archival boxes, passive environmental control, temperature, humidity, Archives New Zealand Storage Standard*

Four archival boxes made from different materials, were tested to see how effective they were at stabilizing fluctuations in temperature (T) and relative humidity (RH) and if this method of passive environmental control could meet the environmental requirements of the *Archives New Zealand Storage Standard* (ANZSS), instead of using heating, ventilation and air conditioning (HVAC)systems. The boxes were placed in an un-insulated attic space in Auckland, New Zealand, during the winter for twelve weeks from June 7, to August 29, 2009. Twenty-four hour samples of T and RH of each box were taken by a Hobo LCD data-logger placed inside the boxes. Another Hobo LCD data-logger was placed in the ambient environment to determine the difference. The main results were; RH fluctuations inside all the boxes met part of Requirement 28, of the ANZSS, during the twelve weeks of the study, by not fluctuating more than 10% over a twenty-four hour period, even though the ambient RH fluctuated by as much 22%. However, although the T inside the boxes mostly fluctuated less than in the ambient environment it did not consistently reach the 4 degree centigrade or below fluctuation level of requirement, 29 of the ANZSS. The conclusion reached from the study is all the archival boxes used in study are effective in controlling fluctuations in RH and T; however, institutions needing to meet the ANZSS will require other methods to control environmental conditions.

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1.0 Introduction

The aim of this study is to investigate the potential of insulated archival boxes to meet the environmental requirements of the *Archives New Zealand Storage Standard* (ANZSS). This standard, under the *Public Records Act, 2005* is mandatory for central and local government archives, including community archives approved to hold government records. Heating, ventilation and air-conditioning (HVAC) systems are usually required to fulfil the levels of relative humidity (RH) and temperature (T) specified. However, HVAC systems can be costly to install and run and an alternative option of insulated archival boxes could be of benefit to institutions, with limited budgets needing to meet the ANZSS.

There have been previous studies done which confirm that archival boxes made of cardboard and wood, do level out fluctuations in RH and T in the ambient environment (including Kamba, 1994, Shenton, 1999, Harold, 2003, and Wignell and Batterham, 2008). This study addresses the gap of testing insulated archival boxes to find out if they could further reduce RH and T levels. To achieve this, four archival board boxes were constructed using different types of insulating materials; Ethafoam®, Plastazote®, 6mm board and 3mm board. These were tested over a twelve week period, in an Auckland attic space, during the winter months of June, July and August. Each box was placed in the attic one day per week, with one data-logger inside it and another outside it, each recording twenty-four hour RH and T samples, so a comparison could be made. Limitations of the study were; it could not be carried out for a year due to Victoria University's requirement that this project be completed in two semesters and that all the boxes could not be tested at the same time because of the cost of data-loggers.

Section one of this report outlines the background to environmental control for archives storage and how standards have been developed. Archives New Zealand Storage Standard environmental requirements are listed fully. How the environment paper is stored in affects its longevity, is explained with RH and T examined in more depth, including the relationship between them and how they can contribute to the deterioration of paper. The disadvantages of HVAC systems are then discussed alongside passive environmental control alternatives. The benefits that this research on insulated archival boxes, could have to those who care for archival materials are given.

Section two describes the theoretical framework that this project fits into. Section three examines literature on housing practices for paper based archival collections, storage standards and previous experiments on testing RH and T within archival boxes. Section four describes the methodology used to carry out the experiment from the initial research questions to the method used and data collection details. Section five, discusses the results, with tables showing the T and RH information collected from the data-loggers for each. These show the differences the boxes made to RH and T fluctuations in the ambient environment over the twelve week period of testing. These results are then interpreted and analysed to answer the research questions. Conclusions from the study and recommendations for future research are given in section six. The appendix lists specifications of materials and equipment used in this study and the glossary defines technical terms used in the research project.

1.1 Background

The aging effects of the environment objects are stored in, has been studied for some time now, beginning in the nineteenth century with scientists employed in European museums. In Berlin, the first scientific book on conservation was published, *Die Konservierung Von Altertumsfunden* (The conservation of antiquities) by Friedrich Rathgen in 1898. Some of the objects from British Museum collections, after being stored in underground tunnels, during World War 1, were found to have deteriorated. This resulted in the British Museum establishing a permanent scientific research laboratory to investigate the causes of decay, with Harold Plenderleith appointed as a conservation scientist in 1926. In the United States of America, the first journal for conservation and technological research, *Technical studies in the field of the fine arts* was published in 1932, by the Fogg Art Museum (Oddy, Andrew, 1992, p. 13-15).
In 1950 the International Institute for Conservation of Historic and Artistic Works (IIC) was founded in London with the aim of improving "the state of knowledge and standards of practice" (International Institute of Conservation, no date).

How the environment in a museum affects the aging processes of objects came to be called 'Museum Climatology' (Bromelle, 1968, preface). From the late 1940s Plenderleith recommended certain levels of temperature, relative humidity and light. During the early 1960s articles began to use the words 'standards' in relation to preventive conservation measures (Alcantara, 2002, p. 7). In 1973, the USSR's Ministry of Culture published *Recommendations on projecting artificial light in museums*. These recommendations were based on scientific research and observations by museum personnel. In the 1980s, standards were developed in English speaking countries. An early example of environmental standards set by an institution is the United Kingdoms Institute for Conservation's (UKIC), 1984 *Environmental Standards* *for the Permanent Storage of Excavated Material from Archaeological Sites* (Alcantara, 2002, p. 9). As a result of continued scientific study there are now codes of ethics for conservators to follow and environmental standards which archival institutions throughout European countries are required to meet for storage and display of objects. These are "a set of core principles or a statement of best practice arrived at by a consensus among appropriately qualified individuals or groups" (Alcantara, 2002, p. 11).

An example of current environmental storage standards are the *British Standards BS 5454:2000, Recommendations for the storage and exhibition of archival documents.* Recommendations are given for the site of buildings, building construction and protection, fire precautions, the storage environment for paper and parchment, lighting, storage and production equipment, packaging for storage, modern media, other materials and exhibition (British Standards Committee, 2000, p. i). Another is the *Standard for the physical storage of commonwealth records* (Commonwealth of Australia, 2002), which gives similar guidelines.

1.2 Archives New Zealand Storage Standard, 2007

In New Zealand under the Public Records Act 2005*, the Storage standard: standard for the storage of records and archives 2007,* public offices, local authorities and community archives approved to hold government records need to meet certain obligations for the storage of physical records and archives. One of these is having environmentally controlled storage areas with the following requirements listed:

"Requirement 26: Inactive records of archival value must be stored in conditions where the relative humidity is never above 60% or below 30%.
(Applies to inactive records of archival value, and archives)

Requirement 27: Inactive records of archival value must be stored in conditions where the temperature is never above 25 degrees centigrade. (Applies to inactive records of archival value and archives)

Requirement 28: Inactive records of archival value must be stored in conditions where the relative humidity does not fluctuate by more than 10% in a 24 hour period, or by 20% in a year. (Applies to archives)

Requirement 29: Archives must be stored in conditions where the temperature does not fluctuate by more than 4 degrees centigrade over a 24 hour period, or 10 degrees centigrade a year. (Applies to archives)

Requirement 30: Environmental conditions for records of archival value must be regularly monitored and records of monitoring must be kept. (Applies to inactive records of archival value, and archives)" (Archives New Zealand, 2007, p. 18)

The purpose of the standard is to make sure government records are maintained, for as long as they are required. Compliance for these standards by government record holders is expected to be 2010.

1.3 Rationale for study

It is important to control the environmental conditions in the archives storage areas as unfavourable conditions will accelerate deterioration of paper based materials. A controlled environment will stabilise items and ideally prevent the need for intervention by conservators. Capel defines environmental control as, "all procedures to place the object in a secure location surrounded by a benign environment, which includes using stable materials to confer physical support and protection to the object" with the aim of preserving "the object in its present chemical and physical form" (Capel, 2000, p. 152).

1.3.1 Environmental causes of deterioration of paper

These environmental guidelines of Temperature (T) and relative humidity (RH) in ANZSS are among five main factors, which cause deterioration of paper-based objects in storage. These are:

1. Temperature and relative humidity
2. Light and lighting
3. Air quality
4. Mould and pests
5. Physical damage (breakage)

(Appelbaum, 1992, pp.25-145).

"It is important to control, or at least reduce, the affects of these agents in order to ensure the long term preservation of cultural collections" (Consortium for Heritage Collections and their Environment, 2002, p. 10).

1.3.2 The relationship between temperature and relative humidity

'Relative humidity is a measure of the amount of moisture in the air relative to the amount the air is capable of holding, expressed as a percentage' (Appelbaum, 1991, p. 25). If the RH is 50% at a given temperature, the air contains half the water vapour it is capable of holding. When the RH is 100%, this means the air is saturated and cannot hold additional moisture as vapour. This extra water becomes rain or condensation. In an enclosed space such as a building, room or display case an increase in T will produce a decrease in RH because warmed air is able to hold more moisture. When the air temperature goes down, the air holds less moisture so the RH goes up.

1.3.3 Effects of temperature and relative humidity levels on paper

When air has less moisture than it is capable of holding, it begins to take up moisture from hydroscopic materials (those, which absorb, retain and give up moisture) such as paper. This can make paper materials dry out and become vulnerable to mechanical stress. The opposite of this happens, when at a higher RH there is too much moisture in the air, which paper absorbs, making it softer and easier to tear. Surface textures can change and coated papers may bond. Rises in T and RH will speed up chemical reactions which lead to paper deterioration, especially paper that is acidic due to the manufacturing process (e.g. made of wood-pulp), or has corrosive pigments on it such as iron-gall ink. Foxing (brownish spots) damage to paper, which may be caused by mould or metallic impurities, can increase in a high RH environment (Appelbaum, 1991, p. 189).

There is the likelihood of condensation during periods of higher RH. This can cause water damage, by water stains or by fugitive media on becoming fluid (Balloffet & Hille, 2005, pp. 2-5). Mould can also result in staining. At an RH of above 70%, there is the probability of fungal growth, causing paper to disintegrate in time. Fungi reproduce by means of spores, which are always present in the atmosphere and require a high RH for a certain period of time to propagate plus food such as paper to feed on. The right environmental conditions and paper are ideal for fungal growth (Consortium for Heritage Collections and their Environment, 2002, pp. 10-12).

Insects, which eat paper & products associated with it (for example glue), are affected by T and RH. Insects are active between 5-45 degrees Celsius with eating and reproduction at optimal levels at 30 degrees Celsius and an RH of about 70% (Consortium for Heritage Collections and their Environment, 2002, p. 14). Fluctuations of RH can be extreme if the T is raised and lowered daily. A change in T causes the RH of the air to change every time. As the temperature goes down, the RH goes up and vice versa. Moisture moves in and out of paper materials causing expansion and contraction. If the paper is restrained in some way it can rip. This may cause flaking of thick pigment layers. Distortions of book structures can be caused by large RH fluctuations, and may make it difficult to remove books difficult from tightly packed shelves (Appelbaum, 1992, p. 191).

1.3.4 New Zealand's climate

New Zealand's climate varies from being warm and subtropical in the far north to cool and temperate in the far south. Three major factors influence New Zealand's climate: its global position, being surrounded by ocean and its topography.

New Zealand is over 1000 km from the nearest landmass of Australia, so the sea affects all weather systems reaching New Zealand. The wind picks up moisture creating humidity, and the temperatures are moderated by the sea.

New Zealand's location in the mid-latitude westerly belt gives it a general maritime humid climate. The mountains that run down the length of the country create a wide range of climates between the west coasts and eastern areas, with microclimates in between. Western regions are more exposed to rainfall brought by prevailing winds, while eastern areas are usually drier, with greater temperature variability (Kirkpatrick, 1999, p. 7).

How these changeable weather conditions affect indoor temperatures was recorded in a study sampling 400 houses throughout New Zealand from 1999 to 2005. The mean daily T fluctuation during summer months (December, January and February) inside houses was 3.9 degrees Celsius (19.2 to 23.1) compared with the 5.6 degree T range (14.5 to 20.1) outside the house. (Camiller, M French, L., Issacs, N. & Pollard, A., 2007, p.1-12) The RH levels were not recorded in this study but as the T and RH are linked RH levels would also have fluctuated.

1.3.5 Problems with heating, ventilation and air-conditioning systems

To meet the standards listed in ANZSS with the extremes of the New Zealand climate usually requires the installation of HVAC equipment to deliver air at a specific T and RH via ducts to reach all parts of a building. Although, it is common for buildings to be air-conditioned not many require the strict standards specified for cultural material preservation. Air conditioning in buildings for the comfort of people is mostly concerned with temperature control whereas object preservation also requires an exacting an RH which air conditioning engineers can lack experience in achieving (Cassar, Fernandez and Oreszcyn, 1994, p. 146). HVAC systems can also have other disadvantages. Building staff may not be prepared for the large amount of maintenance required to balance and adjust air volumes, humidistat and thermostat levels. If there is a malfunction of an HVAC system, emergency procedures need to be implemented to avoid possible damage to items by condensation and mould. Sometimes microclimates form between objects and outside walls, with differing levels of T and RH. Environmental control in an historic building can also be complicated. For example it may not be possible to take down walls in order to install vapour barriers, or break holes through ceilings for ducts (Appelbaum, 1992, p. 62). With it being difficult to accommodate HVAC systems in these buildings, it may not be easy to maintain them either. Older buildings can be large and not suited for air-conditioning which works best in well insulated, sealed buildings. The construction materials of some historic buildings may not be suited to the high moisture content of humidified air (Cassar, Fernandez and Oreszczyn, 1994, p.146). Although there are developments in creating solar powered air conditioning systems (CSIRO, 2009, p. 8), and the use of wind energy (Kilkis, 1999, pp. 147-153), HVAC systems are usually powered by large amounts of electricity or gas. This is not only detrimental to the global environment but also uses money that could be better utilized.

1.3.6 Passive environmental control

One way to eliminate the need for HVAC systems is by passive climate control by creating microclimates inside containers. Examples of containers are buildings, rooms, exhibition cases, picture frames, storage cabinets and boxes. The air exchange with the outside is slow enough so that the inside air is protected from the highs and lows of the ambient environment.

Because of the high energy costs and maintenance problems with air-conditioned buildings, architects are looking at the ways that design and construction materials can play in the control of the internal environment. Buildings can offer passive climate control by having a design that minimises extremes of temperature and humidity. "By appropriate planning, choice of materials, and especially the management of ventilation, one can achieve free heating in cool climates and even free cooling in over heated climates" (Consortium for heritage collections and their environment, 2002, p. 25). Buildings can be sustainable by being designed for example to reduce heat gained during the day and increase heat loss at night. This may require open lightweight structures in humid tropical areas and having thick walls in arid tropical climates. Buildings can be located on favourable sites to take advantage of microclimates, the sun and wind directions and placed away from areas likely to flood (Dean, 2002, p. 3).

There are archives which don't use HVAC systems and have RH and T levels close to the BS5454:2000 recommendations. In temperate zones there are two basic ways of controlling the storage environment according to Padfield. The first is to heat the storage area to maintain a 50% RH and the T is then approximately 7 degrees Celsius above the ambient temperature. In the summer selective pumping of outside air can reduce the temperature along with humidity buffering by walls and a rooms contents (Padfield, 2008, p. 3). An example of this the Arnamagneau archive in Copenhagen,

> "The winter temperature is held up above ambient by heat leaking from the inhabited part of the building. Relatively thin insulation to the outside ensures that the archives temperature is about half way between the building temperature and the outside. This combined with the humidity buffering by the room walls and by its contents, ensures a steady RH, even though the vapour concentration is different from that on the outside over long periods. Fine tuning of the RH is achieved through pumping in outside air when by chance, it has the right water vapour concentration to correct the inside RH" (Jensen, Larsen, Padfield and Ryhl-Svendsen, 2009, p. 1).

A second way to control the environment is by dehumidifying the storage area to 50% RH and the T left to follow the ambient range. An example of this is the Vejle storage building, in, Vejle County, Denmark; a shared storage facility for sixteen museums and archives, built in 2003 using passive climate control with concrete walls, thick isolation and floors which use the ground's natural heat, with minimal running costs (Knudsen and Rasmussen, 2005, p.468). It has a T cycle from 8 degrees Celsius to 18 degrees Celsius. The RH has an annual range between 50 to 65%RH. In some climates, though it may not be necessary to heat or humidify as in St Catherine's Monastery library in Sinai, Egypt where there is a yearly temperature cycle from 8 to 30 degrees Celsius and a very low RH from 15 to 35%. Although these figures do not fall within the range of BS5454:2000 environmental requirements, the books inside this library have been stored in a similar environment to this for hundreds of years (Padfield, 2008, pp. 2-5).

While buildings that function this way are ideal they can be costly and many institutions have to make do with the buildings they are given. It is possible to improve the environment of collections by using the natural properties of a building's space. Interior spaces can have more stable levels of RH and T than exterior walls with windows. Large rooms with high ceilings have better air movement (Appelbaum, 1992, p. 41).

Smaller enclosures such as exhibition cases and boxes can be used on their own to help protect contents from environmental extremes or dry silica gel can be used to increase the buffering capacity of a container. This was originally developed in the early 1900s as an inert desiccant to prevent condensation in packing containers for moisture sensitive materials. Silica gel has a capacity to both retain and easily release moisture. Shiner explains, "This application uses a very small range of its moisture holding capacity, and regular silica gel is not very efficient as a buffering material." Varying the microscopic attributes to form different grades can provide more effective buffering for museum storage but sometimes silica gel buffering is ineffective For example "air leakage through the case, and inadequate quantities of the buffering materials can overwhelm the buffering capacity and monitoring and maintaining the buffers can be overlooked" (Shiner, 2007, pp. 267-270).

There have been passive environmental control studies done of levels of RH and T inside wooden and cardboard archival boxes by Shenton (1999), Kamba (1994, pp. 181-184), Harold (2003, pp. 38-48) and Batterham & Wignell (2008, pp. 1-6). Conclusions from these studies were that archival boxes did create a microclimate and fluctuations of RH and T were reduced inside the boxes. Insulation inside archival boxes may further reduce these fluctuations.

1.3.7 Potential benefits of research

The resulting relative humidity and temperature data from this study could be useful for managers of smaller archival collections, who find the cost and maintenance of air-conditioning systems prohibitive. Also larger archival collections often require off-site storage which may have inefficient air-conditioning.

Caretakers of small collections of archives, for example historical societies not required to meet storage standards but would like to store materials in favourable conditions for longevity could be interested in the low tech, minimal financial outlay of insulated archival boxes. Collectors of family history and genealogical materials may also like a portable long-term storage solution.

Preventive conservation has become more ‘green’ and many institutions have moved to passive means of modifying collection environments. Apart from being more cost effective passive environmental control leaves less of an ecological footprint. (Staniforth, 2000, p. 7). The environmental impact of preserving archival material needs to be evaluated. There is a paradox in having a high energy approach of using HVAC equipment to preserve archival material, when this is not sustainable on an environmental level. The most widely used definition of sustainable development is that of Norwegian prime minister, Brundtland in 1987, “development that meets the needs of the present without compromising the ability of future generations to meet their own needs’’ (World Commission on Environment and Development, 1987, p. 43). Climate change is one of the most critical aspects of sustainability and reducing energy consumption helps to address this (Museums Association, 2008, p. 9). Passive environmental control is linked with sustainable buildings which regulate heat and humidity by ventilation control and insulation, creating microclimates inside buildings as previously discussed in 1.3.6, Passive environmental control, p. 11.

Insulated boxes could provide another layer of insulation within the building envelope. They fit into the concept of 'phased conservation', a term first coined in the 1970s by the Conservation Office of the Library of Congress. The main idea behind it is to limit conservation treatments of individual items and preserve collections by non-invasive measures such as protective housing enclosures (Waters, 1998). This is where the term 'phase box' originated and different institutions around the world have taken up this approach. In this present era, of digital capture, where information can be seen in an electronic format and the original is not accessed often, an effective simple storage solution is a box. The practice of boxing books has not been as common as the boxing of loose archives but has had a longer history in Asian countries. In many Asian countries, wooden boxes are traditionally used for the storage of scrolls, art objects and books. The construction of boxes from paulownia wood (kiri-bako) has been developed over centuries by box makers (Fleury, 2001). As Kamba states, "In Japan, objects have been kept in traditional storage cases and chests for a long time. It seems obvious that these cases have contributed to the preservation of our cultural property" (Kamba, 1994, p. 181).

2.0 Theoretical framework

The theoretical framework for this study is the premise that risks for the deterioration of objects are created by unsuitable environmental conditions. This framework has been developed over several decades by researchers and scientists. Risk based management emphasizes scientific assessment with a reduction of exposure or probabilities according to risks and benefits (Hovden, 2004, p. 4). Preventive conservation requires an understanding of the particular hazards that affect cultural materials.

Waller developed a conceptual framework called the 'Cultural Property Risk Analysis Model'. He has identified ten risks, which are agents of deterioration: physical forces, fire, water, criminals, pests, contaminants, light and UV, incorrect temperature, incorrect relative humidity and custodial neglect (Waller, 2003, p. 50). A crucial factor in the calculation of these risks is the quantification of the loss of value of the collection materials as a consequence of specific damage connected with the various risk factors. Waller's approach enables comparison of different risk types (Bruin, Porck, Ligterink and Scolten, 2006, p. 87). The framework "was developed to guide priorities for resource allocation to preventive conservation under conditions of uncertainty" (Waller, 2003, p. iii), and restrict the rate of value lost from cultural property to a low level (Waller, 2003, p. 110).

The goal of preservation management is to slow down the rate of deterioration of materials in it, by controlling the risks listed by Waller. Doing this contributes to the cost of maintaining a collection. Achieving the lowest levels of deterioration can mean the highest cost. Some changes in deterioration can be prevented such as damage by insects, moulds, physical forces and floods while others only slowed down as in the case of chemical reactions, which cause natural aging in objects.

Mishalski's theory of enclosures is explained in *Leakage prediction for buildings, cases, bags and bottles,* (1994). The basis of this theory is that the more enclosures placed around an object creating microenvironments, the better protected it will be from agents of deterioration such as light, contaminants and fluctuating levels of relative humidity and temperature; "According to the theory of enclosures, each container that encloses an element (an element in a box, the box in a drawer, the drawer inside a cabinet, which is inside a room, inside a building) forms a protective barrier around the specimen" (Munoz-Saba, and Simmons, 2003, p. 46).

3.0 Review of literature

This literature review looks at broad range of literature on the storage of paper based collections; including different methods to provide suitable storage environments, storage standards, studies on testing RH and T within archival boxes and suitable materials to use for insulated boxes.

There is much literature and advice about the most suitable environmental conditions to store archives in from conservation institutions, including the Canadian Conservation Institute (CCI) and the National Library's Preservation Office, Te Tari Tohu Taonga to monographs such as 'Preservation and conservation for libraries and archives' (Balloffert & Hille, 2005). All offer similar information about RH & T levels to house paper based collections in, i.e. a stable environment without large fluctuations and temperatures around 16-22 degrees Celsius and a relative humidity of 50-55%.

Conservation standards were developed during the 1970s and 1980s in Europe and the US, to provide ethical frameworks for conservation treatments and to justify the use of public funds. Examples of these were *Recommendations for the Storage and Display of Archival Documents* (BS 5454) and the *Standard on Active Conservation* (BS 4971) developed in the 1980s by the British Standards Institute (Alcantara, 2002, p. 9).
The International Organisation for Standardisation (ISO) defines an ISO standard as "a documented agreement containing technical specifications or other precise criteria to be used consistently as rules, guidelines or definitions of characteristics to ensure that materials, products, processes and services are fit for their purpose" (ISO, no date).

As the science of conservation is relatively, young it is to be expected there will be continued questioning and research into what are the best levels of RH and T are to store paper-based collections. “In 1987, the practice of setting fixed standards for temperature and humidity was criticised on the grounds that insufficient research on physical deterioration mechanisms had been done” (Alcantara, 2002, p.16). When scientists at the Smithsonian Institution’s Conservation Analytical Laboratory found in 1994, “that wide fluctuations in temperature and relative humidity would not cause permanent physical damage to museum collections, the predominant response was one of caution” (Alcantara, 2002, p. 16).

In 2008, Padfield queried the RH and T guidelines laid down in the BS 5454:2000, as they are not attainable without air conditioning. “One has to question whether air conditioning to BS5454, with the associated expense of constant surveillance by skilled engineers, is justified by the greater durability of the stored items” (Padfield, 2008, p. 5). He thinks paper and parchment, have been stored in rooms with usual T and RH fluctuations until HVAC systems were developed and do not require the strict environmental levels set by the BS5454. If more experimentation was done with humidity buffering, archive design would progress and make storage facilities resistant to inevitable periods of power failure and negligence (Padfield, 2008 p. 5). Brokerhof, thinks that we need to keep in mind that in the future standards will be redefined as more research is done. Environmental storage standards could become more stringent or more relaxed (Brokerhof, 2007, p. 116).

High humidity and high temperatures do create though, the ideal conditions for the establishment of moulds and insect infestations, which can create permanent damage to paper objects. As Dean says, moisture whether in the form of condensation, direct wetting or high humidity forms the right conditions for mould germination and it makes sense to store paper based records elsewhere (Dean, 2002, p. 5).

However, this project is not concerned whether ANZSS requirements for RH and T are correct or the most suitable, what concerns this study is that these standards have been set and if it is possible to meet these using insulated boxes instead of HVAC systems.

The literature on temperature and relative humidity control by microclimates created inside boxes has findings that support the hypothesis that insulated boxes could be enough to control the levels to meet the requirements set by the ANZSS. Dean has written that boxes as protective enclosures can add an insulating layer to reduce the effects of varying levels of temperature and humidity (Dean, 1999, p. 12).

In trying to achieve the environmental specifications for photographic storage at the British Library boxes were tested by placing separate data loggers inside an empty box, another in a box which stored photographs and one in the storage environment. Less fluctuation in T & RH was found inside the box (Shenton, 1999).

Kamba, conducted a study of RH in eleven different types of traditional Japanese storage boxes, to examine their buffering effects against fluctuations of the ambient relative humidity. The cases were placed in a humidity chamber, in which the humidity was increased and decreased to observe how the relative humidity changed inside the boxes. He used data-loggers to measure this. The result was that all the cases performed well in buffering daily humidity changes but only one box that he studied could also buffer seasonal changes as well. This particular box was made from Zelkova wood coated with lacquer. He concluded that the thick walls of the box combined with the lacquer coating improved “relative humidity regulation by interfering with the diffusion of moisture through the case wall” (Kamba, 1994, p. 184).

Kenjo describes preservation storage boxes which protect documents from climatic conditions in Japan. They are made from Japanese cedar and cypress as these woods absorb moisture. The boxes have legs for air circulation underneath. Objects inside the boxes are wrapped in traditional Japanese paper. He reports on an experiment where the changes in T and RH inside these preservation boxes were measured; “Results show that temperature and humidity hardly change within preservation boxes.” He predicts, “if double preservation boxes were used, changes would be even less” (Kenjo, 1997). From what he has written, it seems he conducted this experiment, once for one hour only and does not specify the equipment used or what the RH and T readings were inside and outside the boxes.

Harold, conducted an experiment for a year in Dunedin, New Zealand to find out if a box could provide, an improved climate to an open stack in an a controlled environment. He also placed a box in an uncontrolled environment in a garage for twenty-four hours to test the diurnal range of RH and T. His data- logger measurements in both tests found that “a building envelope can buffer the terrestrial [outdoor] T range and RH to half, and boxing items can halve the building’s climate range” (Harold, 2003, p. 46).

In a study similar to Harold’s, Batterham and Wignell also found that “dense groups of paper files in a semi-sealed micro-environment [a box] act as an effective humidistat and thermostat, leveling out fluctuations in the humidity level and temperature of the air around them"(Batterham & Wignell, 2008, p. 16).

In another study Gourley, Granowski and Wise conducted an experiment to detect levels of volatile organic compounds (VOC's) in four Solander boxes (storage boxes made of coated wood and lined with paper). At the same time, a data logger was placed inside one of the boxes and outside the boxes for four weeks. The environment they were in was 'stable'. The results from inside the Solander box indicated that there was a 10% change in RH (38% to 48%) and a 4 degree Celsius change in temperature (18-22 degrees Celsius) over the testing period. However, how these results compared with the outside temperature and relative humidity has not been reported.

The reason for Gourley, Granowski and Wise's experiment was to test for VOC's and these need to be considered when using boxes as microclimates. Even if the enclosure materials do not emit VOC's, the paper inside them may degrade faster because acidic compounds produced as paper ages can be trapped. Hengemihle, Shahani & Weberg conducted a study of this. As the "concentration [of acidic compounds] increases, the rate of acid hydrolysis of cellulose accelerates." This can be slowed down with paper that is made with an alkaline buffer. Acidic paper can be neutralized also by coming into contact with alkaline paper. They mention that buffered boxes can work in the same way but the life of the sheets of paper decreases the further away they are from the buffered board. They concluded, "micro-environments can insulate paper from sharp environmental fluctuations, and thus provide a more stable environment" (Hengemihle, Shahani & Weberg, 1993, pp. 65-67).

This was also mentioned in relation to the microenvironment created by museum showcases. "The potential major drawback of tightly sealing showcases, besides cost and time, is the concentration of off-gassed products from objects, dressing or construction materials" (Calver, Fletcher, Lambarth and Thickett, 2007, p. 245).They recommended air-exchange by having a fan drawing air into the compartment. In their experiment to help stabilize fluctuations in RH, they used silica gel as a buffer to absorb moisture.

Plastazote® (manufactured by Zotefoams Incorporated) and Ethafoam® (manufactured by the Dow Chemical Company) as storage materials have been looked at by Tetreault and Williams. They are both made of polyethylene and are thought to be "stable for conservation/museum applications" (Williams, 1998). Both these foams have passed the Photographic Activity Test (PAT), (National Archives of Australia, 2007).

Padfield and Larsen describe how passive environmental control can be done by using archives themselves as "humidity buffering materials". They say that although ventilation in archives is "often cited as an important inhibitor of fungal growth this is irrelevant in most archives where the collection is boxed" (Larsen & Padfield 2006, pp. 1-2) and the low air exchange can be helpful to control RH. As the RH rises, cotton in the paper absorbs water, which is released again when the RH falls. They have illustrated their article with diagrams which are predictions based on physics.

The advantage that insulated boxes can offer institutions required to meet ANZSS is that, they fit in with a 'phased conservation' approach of preserving collections by improved storage rather than by individual item conservation treatments as discussed by Waters (1998). Insulated boxes also belong with sustainable, passive environmental control methods such as purpose built buildings written about by Padfield (2008, pp.2-

5), and Dean, (2002, p. 3) which are becoming more widespread as the high energy usage and costs associated with HVAC systems are becoming unsustainable.

In conclusion, although there may be some disagreement by experts on correct storage standards there is evidence from the literature from previous studies of archival boxes made of cardboard and wood, that insulated boxes could control RH and T to the levels required by ANZSS. This study addresses the gap in the literature of the testing relative humidity and temperature levels inside boxes insulated with materials such as Plastazote® and Ethafoam®.

4.0 Methodology

The methodology for this research project is quantitative, as the approach is one of experimentation and hypothesis testing. 'Quantitative' refers to research based on concrete measures such as numbers or time. The two main reasons for using quantitative measures are being "concerned with developments over time, or trends, and the other is concerned with making comparisons" (Mann, 1990, p. 46). As this research project measures levels of RH and T inside insulated boxes and comparing this to the ambient RH and T in the area where the boxes are placed, quantitative research is appropriate.

4.1 Research questions

The following research questions were identified for this study:

Question 1: Can insulated archival boxes keep records housed in acceptable environmental conditions that meet requirements, 26, 27, 28 and 29 of ANZSS?

Question 2: Which type of insulation would work best and also meet requirements for archival storage? i.e. not off-gas harmful chemicals which could damage archival items stored within them. Materials need to meet international storage standards such as those which have passed the Photographic Activity Test (PAT), (National Archives of Australia, 2007).

4.2 Hypothesis

The aim of this research was to test an experimental hypothesis which is:

The insulation of archival boxes will have an impact on controlling fluctuations in RH and T in the ambient environment. This hypothesis is based on:

(a) Kamba's study of fluctuations of RH in the ambient environment compared to that inside traditional Japanese wooden storage boxes, which found they had a buffering effect (Kamba, 1994, pp. 181-184). See, 3.0 Review of literature, pp. 20-21

(b) Testing done for RH & T done at the British Library inside boxes where boxes moderated the ambient environment in a storage area (Shenton, 1999). See 3.0, Review of literature, p. 20

(c) In an experiment using data-loggers carried out by Harold placing a paper filled archive box in a garage in Dunedin, over one, twenty-four hour period found that the fluctuation of T & RH inside the box was less than the ambient environment of the garage (Harold, 2003, pp. 41-43). See 3.0, Review of literature, p. 21

(d) An experiment carried out by Batterham & Wignell using data loggers in archival boxes in a large open warehouse with no air conditioning concluded that "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" (Batterham & Wignell, 2008, pp. 1-6). See 3.0, Review of literature, pp. 21-22

The independent variable was the insulated box (and the construction material). The dependant variables were the relative humidity and temperature in the environment inside the box. The intervening variables were the climate and weather at the time of testing which cannot be controlled. The controlled variables were the boxes placed in a controlled HVAC environment. This had have a mean T of 22 degrees Celsius and mean RH of 55%.

4.3 Method

In order to establish whether insulation would have an effect on the RH and T inside insulated boxes the experiment was for twelve weeks, starting on June 7, 2009 and finishing on August 30, 2009.

The boxes were placed in an un-insulated attic space that has a corrugated iron roof in Auckland, New Zealand. The reason this space was chosen is that attic spaces are specifically recommended not to store archival material in, because of wide fluctuations in RH and T, therefore a good place test the effectiveness of insulated archival boxes (National Library of New Zealand, 2008).

Sampling of RH and T inside and outside the four boxes was carried out over the twelve week period. Each box was placed in the attic space for a period of 24 hours, each week. During this time, one data logger was inside the box and data logger was in the ambient environment recording levels of RH and T for comparison.

Each box was also placed in an HVAC controlled environment for a period of 24 hours. The controlled environment is a general storage area for archives and records and has average RH of 52% and T average of 21 degrees Celsius. The chart below illustrates the experiment design. The relative humidity and temperature measurements were recorded for 24 hour periods over twelve weeks. The diagram below illustrates how the highest and lowest RH and T readings will be compared over twelve weeks. RH = relative humidity T = temperature in degrees Celsius

	Attic Space 12 weeks –June7 to August 30 24 hour data - logger recording of ambient attic environment RH & T at the same time a box is placed inside it.	**HVAC Environment** 1 week - September 20-26 hour 24 data - logger recording of ambient HVAC environment RH & T at the same time a box is placed inside it.
Box A (with Ethafoam lining) Placed in attic for one, 24 hour period each week, for 12 weeks between June 7 to August 30	Highest RH? Lowest RH? Highest T? Lowest T?	Highest RH Lowest RH ? Highest T Lowest T?
Box B (with Plastazote lining) Placed in attic for one, 24 hour period each week, for 12 weeks between June 7 to August 30	Highest RH? Lowest RH? Highest T? Lowest T?	Highest RH Lowest RH ? Highest T Lowest T?
Box C (made from 6 mm card) Placed in attic for one, 24 hour period each week, for 12 weeks between June 7 to August 30.	Highest RH? Lowest RH? Highest T? Lowest T?	Highest RH Lowest RH? Highest T Lowest T?
Box D (made from 3 mm card) Placed in attic for one, 24 hour period each week, for 12 weeks between 7 June 7 to August 30	Highest RH? Lowest RH? Highest T? Lowest T?	Highest RH Lowest RH? Highest T Lowest T?

4.4 Limitations of the study

To test the requirements of the ANZSS, the experiment should be conducted for both a twenty-four hour period and over a year. Some limitations of this experiment are:

- It was carried over a period of twelve weeks – to meet VUW requirements that the Research Project INFO 580 be completed in two semesters.
- Not all of the boxes could be placed in the same environment at exactly the same time due to the cost of data loggers (approximately $400-$600 each).
- Results were taken from twenty–four hour samples of environmental conditions over the twelve week period.

4.5 Test Materials

The first stage involved constructing four different types of boxes with different types of insulation materials. All materials used in this experiment meet the appropriate standards to house paper based archives long term. These materials do not emit chemicals, which could damage items housed in them and pass the Photographic Activity Test (PAT) (National Archives of Australia, 2007).

Box A: Made from 3mm Klug corrugated archival board with 10mm Platazote® foam lining. The Platazote® was attached with Evosol adhesive (an archival, neutral synthetic adhesive).

Box B: Made from 3mm Klug corrugated archival board lined with 10mm Ethafoam® lining. The Ethafoam® was attached with Evasol adhesive.

Box C: Made from 6mm double thickness Klug corrugated archival board and no lining or adhesive.

Box D: Made from 3mm Klug corrugated archival board with no lining or adhesive.

All interior dimensions were 380mm length x 250mm width x 75mm depth, as this is an average size used to house loose sheets of paper. The exterior dimensions varied slightly depending on the thickness of the different types of insulation.

The tests were done with paper inside the boxes to replicate boxes in use. Fifty A4 sheets of 80gsm photocopy paper were placed inside each box.

4.6 Equipment

Onset Computer Corporation HOBO LCD data loggers were used to measure both RH and T. These are small and portable, can fit inside boxes and be placed in the ambient environment next to the boxes. They can also be read at any time. When the testing period was completed the data stored on them was downloaded and graphs printed out of the RH and T over the testing period.

4.7 Pilot study

A small pilot study was conducted over a period of a week to observe the effectiveness of the data loggers recording and downloading data. One box (Box D with 50 sheets of A4 paper) was placed in the test environment for 5 test periods of twenty-four hours. One data logger was inside the box plus another outside it, in the test environment. The information on the data loggers was downloaded after each twenty-four hour period. The same test was carried out in the control environment. The data loggers were found to be working effectively and consistently at both recording and downloading data on RH & T.

4.8 Data collection

After each box was placed in the environment for 1 day each week (for a twelve week period), the data logger that was inside the box and the data logger outside the box had the information on them downloaded and saved in Microsoft Word format. The boxes in the control environment had the information stored on them, downloaded and saved in the same way.

5.5 Data analysis

After this data was gathered it was formulated into sums to determine the level of fluctuations in temperature and relative humidity inside the boxes compared to the ambient environment and whether these levels meet the requirements of ANZSS.

For example the highest level of RH for the interior recorded over a 24 hour period for Box A may have been 60% and the lowest level 50%:

Interior measurement of RH fluctuation: 60% - 50% = 10%.

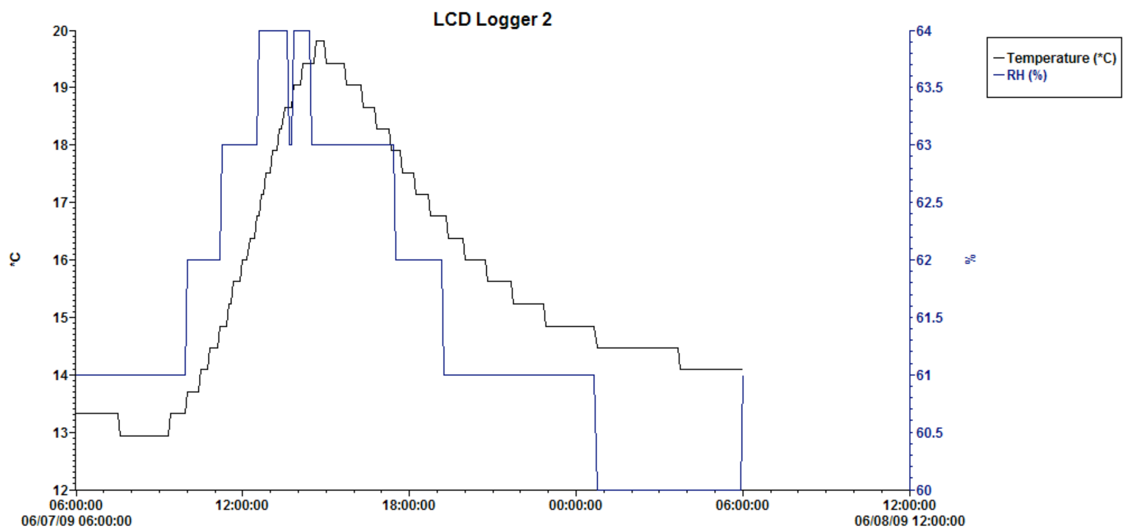
This was also done for the ambient measurement of RH in the attic space.

The resulting information is in table format to be analysed and to compare the differing types of insulation used in the boxes. The results show whether the measurements for RH and T are different for the interior of the boxes compared to the exterior measurements, which boxes performed best and if insulated boxes in themselves meet ANZSS requirements.

5.0 Results

5.1 Collection of data

The data-loggers were downloaded and printed out in Microsoft Word format as in the example below of the interior RH and T of Box A.



Then the high and low points of the RH and T over the twenty-four hour periods and the fluctuations between them were placed in tables. Calculations were done of the fluctuation between the high and low points. Using the above example, the high point of the RH was 64% and the lowest point was 60%. The difference between them is 4%, so this is the amount of fluctuation over the twenty four hour period. The ambient environment in the attic was also recorded in the same way. For this particular date, the ambient environment had a fluctuation of 16%. To calculate the difference the box made to the RH fluctuations, the 4% fluctuation of the box environment was subtracted from the 16% fluctuation of the ambient environment. Therefore, the difference the box has made is 12%. The same calculations were done for all the twenty-four hour samples taken over the twelve-week period for both RH and T. Then all the differences were all added up and divided by twelve to find the average difference. The readings and calculations were put into tables for each box as seen below for RH and T.

Table 1: Difference in the highest and lowest levels of RH% for Box A, interior and ambient environments over twenty-four hour periods, for twelve weeks (June 7 to August 30, 2009)

	Box A			**Ambient Environment**			
Week	**High RH%**	**Low RH%**	**Fluctuation RH%**	**High RH%**	**Low RH%**	**Fluctuation RH%**	**Difference RH%**
1 (June 7)	64	60	4	64	48	16	12
2 (June 14)	70	69	3	73	63	10	7
3 (June 21)	62	60	2	58	51	7	5
4 (June 28)	72	69	3	83	70	13	10
5 (July 5)	70	67	3	79	63	16	13
6 (July 13)	66	61	5	66	56	10	5
7 (July 19)	72	70	2	74	66	8	6
8 (July 26)	68	64	4	63	53	10	6
9 (August 2)	69	65	4	74	54	10	6
10 (August 9)	57	56	1	59	53	4	3
11 (August 16)	67	66	1	75	70	5	4
12 (August 25)	63	61	2	72	57	15	13

7.5% Ave.

These RH figures demonstrate that for Box A (made from 3mm board and lined with 10mm Ethafoam®) in every twenty-four hour sampling, carried out over the twelve week experiment the RH fluctuation recorded inside the box is less than that of the ambient environment. The largest difference was 13% recorded in weeks, five (July 5) and twelve (August 25). Mostly the maximum RH recorded inside the box was also lower than that of the ambient environment, however, two 24 hour samples in weeks 3(June 21) and 8(July 36) show that the maximum RH% inside the box was higher than the maximum RH in the ambient environment. In week three (June 21), the RH recorded inside the box was 62% compared with 58% in the ambient environment and in week 8 (July 26), the RH maximum was 68% compared with a 63% maximum in the ambient environment. The average RH fluctuation difference of the interior of the box, over the twelve weeks compared to the ambient environment was 7.5% which was highest RH fluctuation difference of all the four boxes.

Table 2: Difference in the highest and lowest levels of RH % for Box B, interior and ambient environments over twenty-four hour periods, for twelve weeks (June 7 to August 30, 2009)

	Box B			Ambient Environment			
Week	**High RH%**	**Low RH%**	**Fluctuation RH%**	**High RH%**	**Low RH%**	**Fluctuation RH%**	**Difference RH%**
1 (June 8)	63	60	3	71	59	12	9
2 (June 15)	71	68	3	73	67	6	3
3 (June 25)	64	60	4	66	54	12	8
4 (June 29)	74	68	6	77	69	8	2
5 (July 6)	71	66	5	72	63	9	4
6 (July 14)	68	62	6	79	57	22	16
7 (July 20)	71	67	4	71	64	7	3
8 (July 27)	66	61	5	60	53	7	2
9 (August 3)	66	61	5	62	55	7	2
10 (August 10)	58	56	2	60	54	6	4
11 (August 17)	68	66	2	73	64	9	7
12 (August 30)	71	65	6	82	64	18	12

6.0%Ave.

These RH figures demonstrate that for Box B (made from 3mm board and lined with 10mm Plastazote®) in every twenty-four hour sampling, carried out over the twelve week experiment the RH fluctuation recorded inside the box is less than that of the ambient environment. The largest difference was recorded in week six (July 14) was 16%. Mostly the maximum RH recorded inside the box was also lower than that of the ambient environment, however, once it recorded the same maximum RH as ambient environment, 71% in week seven (July 20). There were two 24 hour samples in weeks eight (July 27) and nine (August 3) which show that the maximum RH% inside the box was higher than the maximum RH in the ambient environment. In weeks eight (July 27), and nine (August 3) the maximum RH recorded inside the box was 66% compared with 60% in the ambient environment in week eight and 62% in week nine. The average RH fluctuation difference of the interior of the box, over the twelve weeks compared to the ambient environment was 6.0%

Table 3: Difference in the highest and lowest levels of RH % for Box C, interior and ambient environment over twenty-four hour periods, for twelve weeks (June 7 to August 30, 2009)

	Box C			**Ambient Environment**			
Week	**High RH%**	**Low RH%**	**Fluctuation RH%**	**High RH%**	**Low RH%**	**Fluctuation RH%**	**Difference RH%**
1 (June 9)	72	63	9	83	68	15	6
2 (June 16)	71	64	7	71	62	9	2
3 (June 26)	70	61	9	79	67	12	3
4 (June 30)	70	68	2	72	66	6	4
5 (July 7)	70	64	6	70	60	10	4
6 (July 15)	76	70	6	79	63	16	10
7 (July 21)	71	67	3	74	65	9	6
8 (July 28)	71	61	10	78	56	22	12
9 (August 4)	66	56	10	63	42	21	11
10 (August 11)	63	56	7	66	53	13	6
11 (August 18)	70	65	5	70	63	7	2
12 (August 25)	74%	65%	9%	84%	69%	15%	8%

6.1% Ave.

These RH figures demonstrate that for Box C (made from 6mm board) in every twenty-four hour sampling, carried out over the twelve week experiment the RH fluctuation recorded inside the box is less than that of the ambient environment. The largest difference was recorded in week, eight (July 28), was 12%. Mostly the maximum RH recorded inside the box was also lower than that of the ambient environment, however, two 24 hour samples in weeks two (June 16) and eleven (August 18) show that the maximum RH% was the same as the maximum RH in the ambient environment. In week two, it was 71% and in week eleven was 70%. In week nine the maximum RH at 66% was higher inside the box compared with a 63% maximum in the ambient environment. The average RH fluctuation difference of the interior of the box, over the twelve weeks compared to the ambient environment was 6.1%.

Table 4: Difference in the highest and lowest levels of RH% for Box D, interior and ambient environment over twenty-four hour periods, for twelve weeks (June 7 to August 30, 2009)

	Box D			**Ambient Environment**			
Week	**High RH%**	**Low RH%**	**Fluctuation RH%**	**High RH%**	**Low RH%**	**Fluctuation RH%**	**Difference RH%**
1 (June 10)	77	70	7	83	70	13	6
2 (June 17)	67	60	7	62	56	6	-1
3 (June 27)	73	69	4	77	70	7	3
4 (July 1)	70	66	4	70	64	6	2
5 (July 8)	70	65	5	73	65	8	3
6 (July 16)	77	70	7	83	68	15	8
7 (July 22)	73	67	6	77	65	12	6
8 (July 29)	72	66	6	77	65	12	6
9 (August 5)	60	54	6	63	51	12	6
10 (August 12)	66	58	8	72	52	20	12
11 (August 19)	70	64	6	71	59	12	6
12 (August 26)	77	67	10	83	61	22	12

5.75 % Ave

These RH figures demonstrate that for Box D (made from 3mm board) in every twenty-four hour sampling, carried out over the twelve week experiment the RH fluctuation recorded inside the box is mostly less than that of the ambient environment. The largest difference was 12%, recorded in weeks, ten (August 12) and twelve (August 26). In week 2 (June 17) the RH difference was higher in the ambient environment than inside the box by 1%. Mostly the maximum RH recorded inside the box was also lower than that of the ambient environment, however, in week four (July 1) the RH maximum in the box was the same as the ambient environment at 70% The average RH difference of the interior of the box, over the twelve weeks compared to the ambient environment was 5.75%. This was the lowest RH fluctuation difference of all the four boxes tested.

Table 5: Difference in the highest and lowest levels of T°C for Box A, interior and ambient environments over twenty-four hour periods, for twelve weeks (June 7 to August 30, 2009)

	Box A			Ambient Environment			
Week	**High T°C**	**Low T°C**	**Fluctuation T°C**	**High T°C**	**Low T°C**	**Fluctuation T°C**	**Difference T°C**
1 (June 7)	19.8	12.9	6.9	21.0	12.6	8.4	1.5
2 (June 14)	16.4	14.5	1.9	16.8	14.1	2.7	0.8
3 (June 21)	14.5	9.4	5.1	15.7	9.0	6.7	1.6
4 (June 28)	17.1	15.6	1.5	16.8	15.2	1.6	0.1
5 (July 5)	17.9	13.7	4.2	17.9	13.3	4.6	0.4
6 (July 13)	14.6	8.6	6.0	15.6	8.2	7.4	1.4
7 (July 19)	16.4	12.5	3.9	17.1	12.1	5.0	1.1
8 (July 26)	17.0	8.5	8.5	18.3	8.2	10.1	1.6
9 (August 2)	19.8	13.3	6.5	21.0	12.9	8.1	1.6
10 (August 9)	15.6	12.1	3.5	15.6	11.7	3.9	0.4
11 (August 16)	17.9	15.2	2.7	18.3	14.8	3.5	0.8
12 (August 23)	17.9	14.8	3.1	17.5	14.4	3.1	0.0

0.94°C Ave.

These T figures demonstrate that for Box A (made from 3mm board and lined with 10mm Ethafoam®) in every twenty-four hour sampling, carried out over the twelve week experiment the T fluctuation recorded inside the box is less than that of the ambient environment. The largest difference was 1.6 degrees Celsius recorded in weeks, three (June 21), eight (July 26) and nine (August 2). Mostly the maximum T recorded inside the box was also lower than that of the ambient environment. There were two twenty-four hour samples in weeks four(June 28) and twelve(August 23), when it was higher; 17.1 degrees Celsius in week four compared to 16.8 degrees Celsius in the ambient environment, and 17.9 in week twelve compared to 17.5 in the ambient environment. There were also two twenty-four hour samples when the maximum T inside the box was the same as that of the ambient environment; in week five (July 5) the maximum T for both the interior of the box and the ambient environment was 17.9 degrees Celsius and in week ten (August 9), the box interior and ambient environment recorded a maximum of 15.6 degrees Celsius. The average T difference of the interior of the box, over the twelve weeks compared to the ambient environment was 0.94 degrees Celsius which was highest T fluctuation difference of all the four boxes.

Table 6: Difference in the highest and lowest levels of T°C for Box B interior and ambient environments over twenty-four hour periods for twelve weeks (June 7 to August 30, 2009)

	Box B			Ambient Environment			
Week	**High T°C**	**Low T°C**	**Fluctuation T°C**	**High T°C**	**Low T°C**	**Fluctuation T°C**	**Difference T°C**
1 (June 8)	14.5	13.3	1.2	14.1	13.3	0.8	-0.4
2 (June 15)	16.4	13.7	2.7	16.8	13.3	3.5	0.8
3 (June 25)	15.7	11.3	4.4	16.3	11.3	5.0	0.6
4 (June 29)	16.8	12.2	4.6	16.4	11.8	4.6	0.0
5 (July 6)	17.0	12.2	4.8	17.5	11.8	5.7	0.9
6 (July 14)	14.1	8.2	5.9	14.1	7.8	6.3	0.4
7 (July 20)	16.8	12.2	4.6	17.6	11.8	5.8	1.2
8 (July 27)	17.0	9.4	7.6	18.8	9.0	9.8	2.2
9 (August 3)	17.6	12.9	4.7	18.3	12.2	6.1	1.4
10 (August 10)	16.0	13.3	2.7	16.7	12.9	3.8	1.1
11 (August 17)	17.9	14.8	3.1	18.3	14.4	3.9	0.8
12 (August 30)	22.1	14.9	7.3	23.1	14.2	8.9	1.6

0.88°C Ave.

These T figures demonstrate that for Box B (made from 3mm board and lined with 10mm Plastazote®) in the twenty-four hour samples, carried out over the twelve week experiment the T fluctuation recorded inside the box is mostly less than that of the ambient environment. In week one (June 8), though the fluctuation is greater in the ambient environment than inside the box, by 0.4 degrees Celsius. The largest fluctuation difference was recorded in week, eight (July 27), at 2.2 degrees Celsius. Mostly the maximum T recorded inside the box was also lower than that of the ambient environment. There was one exception in week four (June 29), when it was higher; 16.8 degrees Celsius in week four compared to 16.4 degrees Celsius in the ambient environment. There was also one twenty-four hour sample, in week six (July 14) when the maximum T inside the box was the same as that of the ambient environment, at 14.1 degrees Celsius. The average T fluctuation difference of the interior of the box, over the twelve weeks, compared to the ambient environment was 0.88 degrees Celsius.

Table 7: Difference in the highest and lowest levels of T °C for Box C, interior and ambient environments, over twenty-four hour periods, for twelve weeks (June 7 to August 30, 2009)

T°C	**Box C**			**Ambient Environment**			
Week	**High T°C**	**Low T°C**	**Fluctuation T°C**	**High T°C**	**Low T°C**	**Fluctuation T°C**	**Difference T°C**
1 (June 9)	16.0	14.1	1.9	15.6	13.7	1.9	0.0
2 (June 16)	16.0	10.8	5.2	16.4	10.2	6.2	1.0
3 (June 26)	15.6	12.9	2.7	15.7	12.5	3.2	0.5
4 (June 30)	13.3	11.7	1.6	13.3	11.4	1.9	0.3
5 (July 7)	17.5	11.8	5.7	17.9	11.8	6.1	0.4
6 (July 15)	17.2	14.1	3.1	17.5	13.7	3.8	0.7
7 (July 21)	16.0	11.8	4.2	16.0	11.4	4.6	0.4
8 (July 28)	15.2	9.8	5.4	16.3	9.4	6.9	1.5
9 (August 4)	21.8	12.1	9.7	23.1	11.8	11.3	1.6
10 (August 11)	18.3	13.3	5.0	18.7	12.9	5.8	0.8
11 (August 18)	19.4	14.4	5.0	19.4	14.1	5.3	0.3
12 (August 25)	17.2	13.7	3.5	17.2	13.3	3.9	0.4

0.6°C Ave.

These T figures demonstrate for Box C (made from 6mm board) that the twenty-four hour samples, carried out over the twelve week experiment the T fluctuation recorded inside the box is mostly less than that of the ambient environment. In week one (June 9), though the fluctuation is the same as the ambient environment at 1.9 degrees Celsius. The largest fluctuation difference was recorded in week, nine (August 4), at 1.6 degrees Celsius. Mostly the maximum T recorded inside the box was also lower than that of the ambient environment. There was one exception in week one (June 9), when it was higher; 16.0 degrees Celsius compared to 15.6 degrees Celsius in the ambient environment. There were also four twenty-four hour samples when the maximum T inside the box was the same as that of the ambient environment; in week four (June 30) at 13.3 degrees Celsius, week seven (July 21), at 16.0 degrees Celsius, week eleven (August 18), at 19.4 degrees Celsius and week twelve (August 25) at 17.2 degrees Celsius. The average T fluctuation difference of the interior of the box, over the twelve weeks, compared to the ambient environment was 0.6 degrees Celsius. This was the lowest fluctuation difference in T in all the four boxes tested.

Table 8: Difference in the highest and lowest levels of T °C for Box D interior and ambient environment over twenty-four hour periods, for twelve weeks (June 7 to August 30, 2009)

	Box D (3mm card)			Ambient Environment			
Week	**High T°C**	**Low T°C**	**Fluctuation T°C**	**High T°C**	**Low T°C**	**Fluctuation T°C**	**Difference T°C**
1 (June 10)	19.8	16.0	3.8	20.2	16.0	4.2	0.4
2 (June 17)	14.9	9.4	5.5	15.2	9.4	5.8	0.3
3 (June 27)	17.2	15.6	1.6	17.2	15.2	2.0	0.4
4 (July 1)	13.7	11.0	2.7	14.1	10.2	3.9	1.2
5 (July 8)	14.9	11.4	3.5	15.2	10.9	4.3	0.8
6 (July 16)	18.7	13.7	5.0	19.1	13.3	5.8	0.8
7 (July 22)	18.3	12.9	5.4	18.7	12.5	6.2	0.8
8 (July 29)	16.0	12.9	3.1	16.4	12.6	3.8	0.7
9 (August 5)	17.9	12.2	5.7	18.7	11.4	7.3	1.6
10 (August 12)	19.8	14.4	5.4	20.6	13.7	6.9	1.5
11 (August 19)	19.8	14.5	5.3	20.6	14.1	6.5	1.2
12 (August 26)	20.9	15.2	5.7	21.4	14.8	6.6	0.9

0.8°C Ave.

These T figures demonstrate for Box D (made from 3mm board) that the twenty-four hour samples, carried out over the twelve week experiment the T fluctuation recorded inside the box is less than that of the ambient environment. The largest fluctuation difference was recorded in week, nine (August 5), at 1.6 degrees Celsius. Mostly the maximum T recorded inside the box was also lower than that of the ambient environment. There was one exception in week three (June 27), when it was the same as the ambient environment at 17.2 degrees Celsius. The average T fluctuation difference of the interior of the box, over the twelve weeks compared to the ambient environment was 0.8 degrees Celsius.

Table 9: Difference in the highest and lowest levels of RH% for boxes A, B, C & D interior and ambient environments over one, twenty-four hour period in an HVAC Controlled Environment (Week, September 20-26, 2009)

	Box Environment			**Ambient Environment**			
	High RH%	**Low RH%**	**Fluctuation RH%**	**High RH%**	**Low RH%**	**Fluctuation RH%**	**Difference RH%**
Box A (September 26)	52	52	0.0	53	52	1.0	1.0
Box B (September 26)	51	51	0.0	53	52	1.0	1.0
Box C (September 27)	52	52	0.0	53	51	2.0	2.0
Box D (September 27)	52	51	1.0	53	51	2.0	1.0

These figures in demonstrate the differences in RH between all four boxes compared to the ambient environment (which is the HVAC environment in the Auckland City Council Archives storage area) over one twenty-four hour testing period. All the boxes show a greater reduction in RH fluctuation from that of the ambient environment. Box C shows the greatest difference at 2.0%. All the other boxes are the same at 1.0%. All the boxes have a maximum RH level which is less than that of the ambient environment. Box B has the lowest maximum RH level at 51%. The other boxes (A, C and D) have the same maximum level at 52%.

Table 10: Difference in the highest and lowest levels of T°C for Box A, B, C &D interior and the ambient environment over one, twenty-four hour period in an HVAC controlled environment (1Week, September 20-26, 2009)

	Box Environment			**Ambient Environment**			
	High T°C	**Low T°C**	**Fluctuation T°C**	**High T°C**	**Low T°C**	**Fluctuation T°C**	**Difference T°C**
Box A (September 26)	21.3	21.3	0.0	21.3	21.3	0.0	0.0
Box B (September 26)	21.3	21.3	0.0	21.3	21.3	0.0	0.0
Box C (September 27)	21.3	21.3	0.0	21.7	21.3	0.4	0.4
Box D (September 27)	21.7	21.3	0.4	21.7	21.3	0.4	0.0

These figures in Table 10, demonstrate the differences in T between all four boxes compared to the ambient environment (which is the HVAC environment in the Auckland City Council Archives storage area) over one twenty-four hour testing period. Only Box C shows a greater reduction in T fluctuation from that of the ambient environment. All the other boxes show no difference from the interior measurement of T to that of the ambient environment. The highest maximum T recorded in a box is in Box D, at 21.7 but this is the same as in the ambient environment

5.2 Interpretation of data

The results in the graphs show that the interior environment of all the boxes in the attic space, during the twelve weeks of this study, had an impact on the ambient environment around them. The answers from the results to the two research questions are as follows:

Question 2: Can insulated archival boxes keep records housed in acceptable environmental conditions that meet requirements, 26, 27, 28 and 29 of the ANZSS?

Although none of the boxes met all of these requirements consistently, they did minimise the highs and lows and fluctuations of RH and T in the ambient environment. How they met individual requirements is discussed below.

Requirement 26: Inactive records of archival value must be stored in conditions where the relative humidity is never above 60% or below 30%.

Three of the four boxes tested met this requirement once, during the twelve weeks of the experiment.

Box A met this requirement in week ten. The RH high was 57%, however the ambient environment was 59%, so also not above 60%.

Box B also met this requirement in week ten. The RH high was 58%. The ambient environment RH high reached was 60%.

Box D met this requirement in week nine. The RH high was 60%. The ambient environment RH high was 63%

Box C, did not meet this requirement during the testing period. The closest it came was in week 10 (August 11), when the box interior RH high was 63% and the low was 56%. The ambient environment RH high was 66% and low was 53%.

Requirement 27: Inactive records of archival value must be stored in conditions where the temperature is never above 25 degrees centigrade.

Throughout the testing period the highest ambient T reached was 23.1 degrees Celsius in week 9, (on August 4) and in week 12, (on August 30). None of the boxes recorded a higher T than this. The highest T recorded inside a box was Box B, in week 12, (August 30), with 22.1 degrees Celsius. The ambient T high was 23.1.

Requirement 28: Inactive records of archival value must be stored in conditions where the relative humidity does not fluctuate by more than 10% in a 24 hour period, or by 20% in a year.

Every box tested during the period of this study met the first part of this requirement. There was no RH fluctuation measured inside a box that was higher than 10% even though the ambient RH fluctuation was as high as 22% during three twenty four hour periods in week 6, (July 14), week 8, (July 28) and week 12, (August 26).

Requirement 29: Archives must be stored in conditions where the temperature does not fluctuate by more than 4 degrees centigrade over a 24 hour period, or 10 degrees centigrade a year.

Although this requirement was not met consistently, there were 24 hour periods over the time of this study where boxes met the first part of this requirement but during the times they did, the ambient environment also didn't have fluctuations above this requirement.

Box A met this requirement six times, in weeks 2, 4, 7, 10, 11 and 12.

Box B, met this requirement four times in weeks 1, 2, 10 and 11.

Box C, met this requirement five times during weeks 1, 3, 4, 6 and 12.

Box D, met this requirement four times during weeks 1, 3, 4, and 5.

Question 2: Which type of insulation would work best and meet requirements for archival storage? i.e. not off-gas harmful chemicals which could damage archival items stored within them. Materials used would need to meet international storage standards such as those recommended in the Photographic Activity Test (Pat) (National Archives of Australia, 2007).

The experiment did not have a clear answer to this question with one of the limitations of the experiment, being that the boxes were not be tested at the same time in the same ambient environment. The interior environments of all the boxes during the study mostly had fewer fluctuations in both T and RH compared with the ambient environment. There were two exceptions. In week 2 (June 17), Box D had an RH fluctuation of 7% and the ambient environment fluctuated by only 6%. In week 1 (on June 1), Box B had a T fluctuation of 1.2 degrees Celsius and the ambient environment fluctuated by 0.8 degrees Celsius.

The averages done of the difference between the fluctuation inside the boxes and the fluctuation in the ambient environment during the twelve weeks of testing showed the following results:

- Box A had the greatest difference in RH fluctuations between the interior and ambient environments at 7.5% compared to 6% for Box B, 6.1% for Box C and 5.75% for Box D.

- Box A also showed the greatest average T fluctuation difference between the interior to the ambient environment. This was 0.94 degrees Celsius difference compared to 0.88 degrees Celsius difference for Box B, 0.6 degrees Celsius difference for Box C and 0.88 degrees difference for Box D.

- In the HVAC controlled environment, the T was the same in the interior of the boxes, as that of the ambient environment, expect for Box C. When the ambient environment had a high of 21.7 degrees Celsius, the interior of Box C was 21.3 degrees Celsius. Box D, which was tested at the same time had the same interior T as the ambient environment.

- There was a difference in RH fluctuations in all the boxes, compared to that of the HVAC controlled environment. Boxes A, B, D all had a 1% fluctuation difference. Box C, had a 2.0% fluctuation difference.

The results for this study agree with results found by Harold (2003), Batterham & Wignell (2008) & Shenton (1999) & Kamba (1994). Harold conducted a similar experiment over one twenty-four period in his un-insulated garage in Dunedin, New Zealand in August 2000. He used a paper filled archive box, which recorded RH fluctuations of 3.4% and 3.2 degrees Celsius and the garage ambient environment fluctuated by 10% RH and 4 degrees Celsius (Harold, 2003, pp.41-43).Although, the same measurements were not recorded during the twelve week period, with any of the four boxes, the results were similar in that the boxed environment had less of a fluctuation range than the ambient environment.

Shenton didn't provide RH and T measurements of gathered by data-loggers in placed in the drop-back boxes but found 'the environment within the boxes was stable compared to the cycling pattern outside' (Shenton, 1999). This was also found with all of the four boxes, used in this experiment.

Batterham and Wignell's study found that on one occasion during their study, that the un-insulated ambient environment where they placed an empty corrugated box the RH fluctuated by 10% whereas the box environment only fluctuated by 3%. They did not give the T measurement but said the temperature fluctuation was reduced by 1 degree Celsius in the box compared to the ambient temperature (Batterham & Wignell, 2008, pp. 1-6). This result was similar in all of the four boxes tested in this study.

Kamba's study of RH fluctuations in traditional wooden storage boxes using an humidification chamber had similar results to this study in that the containers buffered RH fluctuations in the ambient environment (Kamba, 1994, pp. 181-184).

The experiment has confirmed the hypothesis that the insulation of archival boxes would have an impact on controlling fluctuations in RH and T inside the boxes. During the twelve weeks of the study there was only one example of the T fluctuation difference between the interior of the box being greater than the ambient T. (This was Box B in week 1, with an T fluctuation of 1.2 degrees Celsius compared with 0.8 degrees Celsius in the ambient environment) and only one example in Week 2, of the RH fluctuation being greater inside a box than the ambient environment (Box D had a fluctuation of 7% compared to 6% in the ambient environment).

However, although the environment was stabilised within the boxes none of the boxes used in the test, met all the requirements of the ANZSS so could not be used in institutions legally required to fulfil them. The study has shown that archival boxes, of any of type used in the study could be used to better protect archival items, whether they are family history materials stored at home, part of library collections or gathered by institutions such as historical societies.

One of the limitations of the study of not having five data-loggers due to the expense meant that it was not possible to study all four types of boxes and the ambient environment at the same time. In retrospect, a clearer result may have been achieved as to whether insulation made a difference by choosing 2 boxes only; one with insulation such as Box A, lined with Ethafoam® and the other a clamshell phase Box, as in Box D made of 3mm archival card and testing these at the same time.

Another limitation of the study was the time limit between May and September to meet the requirements of completing the research project by October. This meant that testing could not be carried out over a whole year, when the ambient temperature and humidity may have reached higher levels with which to test the differences inside the boxes. Also, it could be seen if the RH fluctuated by more than 20% and the T by 10 degrees Celsius in a year inside the boxes, as these are the limits set by the ANZSS.

6.0 Conclusions and recommendations

6.1 Conclusions

These are conclusions reached from the results of this study:

- Archival boxes of all of the four types used in the experiment stabilize both the RH and T with less fluctuation inside the boxes compared to the ambient environment around the boxes.
- All the archival box types used in the experiment met part of the RH fluctuation conditions of the ANZSS, Requirement 28, being 10% or under over a twenty-four hour period when the ambient environment sometimes fluctuated by as much as 22%.
- Archival boxes used in the experiment did not meet ANZSS, Requirement 26 that the RH is never above 60%, consistently.
- During the study, all the boxes met ANZSS, Requirement 27 that the T is never above 25 degrees Celsius, although the ambient environment did not go above this T either.
- None of the boxes in the study consistently met ANZSS, Requirement 29 that the T must not fluctuate by more than 4 degrees centigrade over a twenty-four hour period, although all the boxes did level out fluctuations in T in the ambient environment.
- The box lined with Ethafoam® recorded a greater average difference in fluctuations of RH and T, from the ambient environment than the other boxes.

From these conclusions, if there were a need to store archival material in a location that does not have an HVAC system, perhaps as an interim measure, boxing up items in any of the boxes used in this study would be advantageous. This would not only help prevent extremes in RH and T fluctuations but also protect items from dust, light, water and physical damage.

6.2 Recommendations for future research

- To find out whether the yearly environmental requirements of the ANZSS could be met it would make it necessary to carry this study out for a year. If all four boxes were tested in an experiment it would be preferable to test them all at the same time in the same ambient environment.

- It would be advantageous to have the study in different locations throughout New Zealand to see how effective the boxes are in different climate zones.

- Other forms of insulation could be experimented with too, such as double insulation of either Ethafoam® or Plastazote®, or lacquered wood as in Kamba's experiment with traditional Japanese boxes. (Kamba, 1994, pp. 181-184)

- From the twenty-four hour RH and T samples from this study Ethafoam®, seems to the most effective at insulating boxes from RH and T fluctuations in the ambient environment. This could be tested more vigorously by having at least one other type of box tested with it at the same time, in the same ambient environment for comparison.

Word Count: 13,640

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Appendices

Appendix I: Glossary

Archival

In book conservation, this term often refers to materials such as paper, board or other items that are acid-free or inert and therefore not harmful when used with archived objects such as documents, photographs, etc., that are being stored for preservation. (Balloffet and Hille, 2005, p. 199)

Archives

1. *archive* records, also referred to as archive materials. They may include written or printed documents or photographs, maps, audio and visual recordings, computer disks etc.
2. the building or place that houses the *archives***.** This is often called the archive repository and may include archives, libraries and museums.
3. the *Archives* institution or agency responsible for the material. (The National Preservation Office, 2005, p. 26)

Conservation

The management of resources, especially cultural material to enhance usability, to prolong life and to clarify contained messages. (Waller, 2003, p. 149)

Data loggers

A small computer which 'logs' temperature and humidity readings over a designated period. This information is then downloaded onto a computer with software. (Archives New Zealand, 2007, p. 19).

Environmental Control

"all procedures to place the object in a secure location surrounded by a benign environment, which includes using stable materials to confer physical support and protection to the object" with the aim of preserving "the object in its present chemical and physical form" (Capel, 2000, p.152).

Macroenvironment

Atmospheric conditions (temperature, humidity, air quality) prevailing in a large space where documents are preserved. (Forde, 2007, Glossary)

Microenvironment

Atmospheric conditions (temperature, humidity, air quality) in a small enclosure where documents are preserved. (Forde, 2007, Glossary)

Passive environmental control

Using materials (of a building or smaller enclosure within a building) to create a variation in temperature and relative humidity rather than use an air-conditioning system.

Phase box

A simple economical box designed to provide a good degree of protection to its contents without undertaking full conservation treatment. Initially developed to provide intermediate protection to materials awaiting further treatment. (National Library of Australia, no date)

Photographic Activity Test (PAT)

The photographic activity test was developed by the Image Permanence Institute of the USA to test the quality of photographic storage materials. It is the subject of International Standards Organization ISO 18916: 2007 Imaging materials-Processed imaging materials-Photographic activity test for enclosure materials. It indicates whether storage materials are likely to damage photographic material. If a product fails, it shouldn't be near photographic material (National Archives of Australia, 2007). Materials that pass this test are also suitable to store other archival materials such as books and files.

Preservation

This includes all of the steps that can be taken to minimize the deterioration of the archives. This can be in the form of preventive conservation and conservation treatment. (The National Preservation Office, 2005, p. 27)

Public Records Act

The legislation governing records governing records, record keeping and archives in the New Zealand public sector and local government. Replaced the Archives Act 1957. (Archives New Zealand, 2006, p.25)

Relative Humidity

The amount of water vapour in the air, expressed as a percentage of the maximum amount of water that the air could hold at a given temperature. (Balloffet and Hille, 2005, p. 202)

Appendix II: Box construction materials

All four boxes were made in this clamshell box style:

Below is Box A, made with 3mm board lined with Ethafoam®

Box B, made with 3mm board lined with Plastazote®

Below is Box C made with 6mm board

Below is Box D made with 6mm board

All the boxes were made with Klug-conservation board. The specifications for this are below, taken from their website

Specifications:

- 100 % bleached alpha cellulose
- without usage of recycled fibres
- lignin-free (free from wooden fibres)
- acid-free - pH-value 8,0 - 9,5; and in accordance with ISO 6588-1-2005 cold extract
- buffered with more than 2 - 3 % natural calcium carbonate (GCC)
- neutral/synthetic sizing (without alum additive).

“We guarantee that all our board and paper qualities correspond to the technological basis of the ISO 9706 standard as well as to the DIN 6738 LDK 12-80 standard, which is the highest level of permanency’” (Klug Conservation, no date). Retrieved October 10, 2009 from http://www.klug-conservation.com)

Box A was lined with Ethafoam®. This information is taken from an information sheet by the manufacturer of it, the Dow Chemical Company. Further technical information can be found from the website given in the bibliography.

Ethafoam® 220 polyethylene foam is a strong, resilient, medium density foam which is non-abrasive and performs over a wide range of temperatures. It is produced using a patented CFC- and HCFC-free blowing agent system. It is made of non-crosslinked polyethylene.

Ethafoam Specifications:

- Meets U.S. Federal standard PPP-C-1752D,Type I and CID A-A 59136-Type I-Class 1-Grade A
- Passed FMVSS 302 flammability testing, conducted according to the Code of Federal Regulations, CFR 49
- Density 35kg/M^3
- Applications: Suited for shock absorbency, wrapping and protecting objects, packaging applications for impacts or loadings up to 17kPa (Dow Chemical Company, 2001)

Box B was lined with Plastazote®LD29. The following information about it was taken from an information sheet by the manufacturer of it, Zotefoams. Further technical information can be found from the website given in the bibliography.

"Plastazote® is a closed cell, cross-linked polyethylene foam manufactured using Zotefoams unique production process…Plastazote® foam LD29 is available in sheet form and is fabricated by modern techniques and can be thermoformed into shapes" (Zotefoams, 2004).

Plastazote® Specifications

- Meets UK military specification DEF STAN 81-116. This standard states that the water-soluble sulphatecontent, calculated as Na_2SO_4 to the requirements of BS2782 method 452E, shall be less than 0.1%mm.
- Tolerance: for all dims to comply with DIN 7715
- Density: 40/50 Kg/M^3
- Applications: Boxmaking, storage and packaging, backing and support panels (Conservation-by-design, no date)

The Ethafoam® and Plastazote® were attached to the board with Evasol adhesive. The information about it below is by Conservation Resources a company who supply conservation materials.

“Evasol has been specially formulated to give good bonding to paper and paper board products. It has a medium open time, and this controlled drying permits a reduction in the warping or buckling of water-sensitive substrates. It may be diluted with water, or mixed with other adhesives such as starch paste or methyl cellulose, to the proportion of 10-15%, without significant loss to the initial EVA tack. Higher dilution or mix proportions may be used where other criteria, such as heavier weights of paper, or concerns of warping, are present.”

Evasol Specifications:

Basic Resin Ethylene vinyl acetate co-polymer (VAE*)

Viscosity 2000 – 3000 cps #3/6/25°C

Appearance White; creamy and soft texture

Solids Approximately 58 – 60%

Initial Tack Medium

Setting Speed Medium, in temperate climate conditions

Film-forming temperature Approximately 5°C

Film Appearance Very slight haze; flexible film

Water sensitivity Dry film will reconstitute to emulsion form

pH 7 – 8

Shelf Life Indefinite. Do not refrigerate. May need occasional stirring

Passed PAT (Conservation Resources, 2006)

Appendix III: Data loggers

Onset Computer Corporation Hobo LCD Temp/RH Data loggers were used in this study. The Hobo LCD logger records and displays temperature and humidity conditions in manufacturing, processing, and storage environments where reliable monitoring and documentation of specific temp/RH conditions are critical (Onset Computer Corporation, 2002, p. 39).

Temperature Humidity Logger Specifications (Microdaq, no date)

Data Storage Capacity	65,136 Samples/Readings
Sampling Rate	1 Second to 9 Hours
Measurement Range	Temperature: -20°C to 50°C (-4°F to 122°F) Humidity: 15% to 95% at 25°C (77°F)
Accuracy	Temperature: ±0.7°C at 20°C (±1.3°F at 68°F) Humidity: ±3% over range of 20% to 80%
Resolution	0.4°C at 20°C (0.7°F at 68°F)
Drift	Temperature: Negligible Humidity: < 2% over 5 Years (typical)
Response Time (to 90%)	Temperature: < 15 Minutes in Airflow of 1 m/s Humidity: < 2 Minutes in Airflow of 1 m/s
Time Accuracy	1 Minute per week at 20C (68F)
LCD	Size: 33mm x 50.8mm (1.3" x 2.0") Display: temperature, humidity, C or F, battery level, flashing alerts and remaining storage
Alarms	Flashing Visual
Recording Mode	Stop When Full or Wrap Around When Full
Contact Relay Output	Selectable: Normally Closed (NC) or Normally Open (NO) Contact Rating: 48 Volts DC, 1A Max Contact Resistance: < 1 Ohm
Operating Range	Temperature: -20°C to 50°C (-4°F to 1228°F) Humidity: 0 to 95%, non-condensing
Battery Life	Typically 1 Year
Battery	3 AAA Alkaline Batteries (User Replaceable)
Standards Compliance	CE
Weight	170 g (6.0 oz) with batteries
Dimensions	125mm x 92mm x 31mm (4.9" x 3.6" x 1.2")