Conservation Matters in Wales
Challenging Buildings: the Search for Solutions

Post prints of a one-day conference held on Thursday 15 June 2006, at The Oakdale Institute, Museum of National History, St. Fagans, Cardiff.

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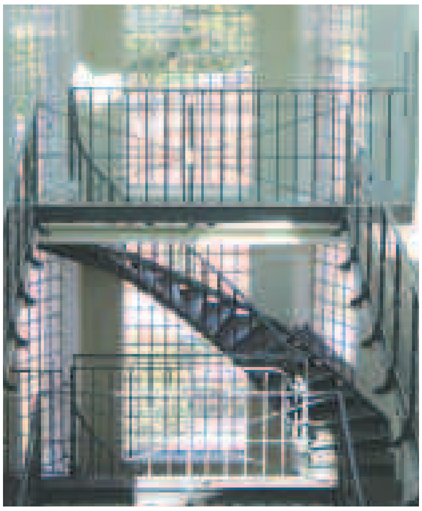

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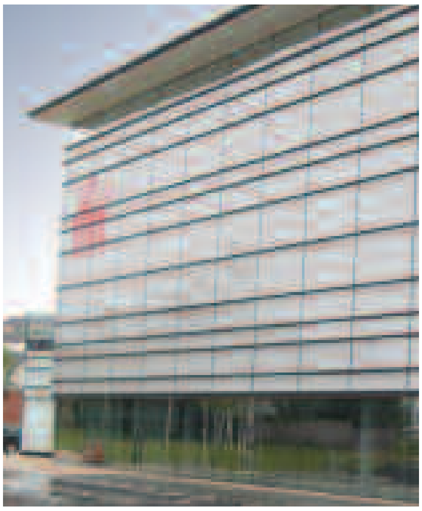

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How to design a museum building that protects the collection without destroying itself

Tim Padfield

Mechanical air conditioning has become so standard a component in modern public and commercial buildings that its unglamorous components are now becoming design icons. Sometimes these components are sneaked into the facade with understated wit, as in Venturi's extension to the National Gallery London *(Figure 1)* or, with bravado, as dominant features, as in Richard Rogers Lloyds building *(Figure 2)*.

Air conditioning, defined as the combination of heating, cooling, humidification and de-humidification, uses a lot of energy, compared with just warming a building *(Figure 3)*. It also uses a lot of the building. Humidity can only be controlled by piping air around the building. Up to a quarter of the volume of the building can be consumed by this pipework and its associated machinery. Air conditioning lasts about twenty years, after which it is either worn out or inefficient compared with current technology. Air conditioning in a museum presents further particular disadvantages. Because air is being moved about, air conditioning is noisy, particularly when it is fitted into old buildings, so that the pipes have to be narrow and tortuous. Air conditioning requires continuous oversight, being capable of filling an exhibition room with steam within minutes if a control fails. The burden of maintaining a technical skill far from the core expertise of the museum staff strains the budget and generates competition for funding between the core jobs, research and exhibition curating, and the mundane necessity of fuelling and staffing the climate control.

The extreme separation between the career paths of the scholar of art and the microclimate technician has not been satisfactorily bridged by the museum conservator. Conservators are mostly trained on top of a non-scientific basic education. Even those well versed in basic science are hampered by the surprising absence from the syllabus, even at university level, of the science of microclimate. Architects suffer the same limitations in their education. The conscientious curator, faced with specifying for the architect the technical requirements for a new building, or a major rebuilding, will consult her conservator, who in turn will turn to a national or international standard to define a climate, relying on the authority of a prestigious institution rather than on an informed critical analysis of the nature of the building, the artefact collection, and the local climate.

Standards for museum and archive climate are unusually hard to formulate because the specification has to optimise the durability of all materials ever used by man. There are some specialist stores, photographic archives for example, that have standards based on research on specific materials. The general purpose standards, however, are timid documents, assuming that conditions comfortable for mankind cannot be too bad for the products of human ingenuity that were made to share the human environment. They furthermore assume that the more constant the better. Knowing of the existence of air conditioning capable of maintaining a constant interior climate regardless of the outside weather, the standards committee specifies a constancy that can only easily be obtained by air conditioning. It is a safe choice for which they will not be criticised. The blame for failing to comply with the standards falls on the design engineer, who protects his reputation by conservative design with ample reserve capacity, whose running costs are borne by the institution.

It is undeniable that perfect climatic stability can only prolong the survival of artefacts. But a climate that is controlled by a sensor discretely placed in an air conditioned room

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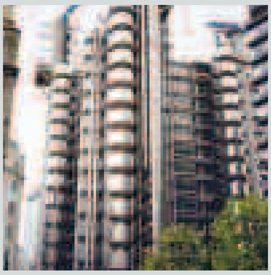

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Figure 1: The back entrance of the 1991 extension to the National Gallery, London.
Architects: Venturi, Rauch and Scott Brown.

Figure 2: The Lloyds building in London, 1984.
Architect Richard Rogers.

Figure 3: Air conditioning is major drain on the resources of a museum. It takes up space, makes a noise, uses more fuel than heating and requires trained technicians to maintain it. And it doesn't last nearly as long as the exhibits.

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Figure 4: The Arts and Industries Building in Washington D.C. Architect Adolf Cluss. Opened 1881. The exhibition area is all on one floor. It was originally ventilated by the stack effect: warm air rose through the spires, drawing fresh air in through the doors. The roof was replaced in 1975 but has now deteriorated so much that the building is now (2006) closed. According to the US National Trust for Historic Preservation this is one of the 11 most endangered historic structures in the United States.

Figure 5: Shortly after re-opening to the public in 1976, eye witnesses reported rain from clouds forming within the central rotunda of the Arts and Industries Building.

cannot prevent the insult of direct sunlight warming a glazed picture 40 degrees over the temperature so carefully controlled by the sensor mounted out of the sun's glare. Even restrained exhibition lighting subjects exhibits to a 6% variation in relative humidity, according to whether the light is on or off. In practice, the stability promised by electronically controlled air conditioning is very seldom realised in the microclimate around individual objects.

To say that the promise is not always achieved is not the same as to accuse air conditioning of causing harm. Yet it does cause harm, even when it functions correctly. The congenial winter temperature we expect as visitors, combined with the moderate relative humidity thought necessary for the art, combine to stress the building, often itself a valued item of solid history. This assertion is best illustrated by a case history, which describes how the renovation of an old building to conserve its ancient appearance while conforming to modern standards of collection care, human comfort and fire resistance, proved incompatible with a faithful restoration of a historic building.

The Arts and Industries Building in Washington DC *(Figure 4)* was designed as a museum and opened in 1881. The spires provided ventilation by the stack effect: warm air rises through the spire, being replaced by cooler air rushing in through the door. Much later, air conditioning was installed.

In preparation for the centenary of the building, it was restored within by clearing out the functionaries who had carved out offices from the immense single exhibition floor of the building. It was restored without, including a new roof, designed to imitate the old roof in appearance while satisfying modern standards for thermal insulation and fire resistance.

The new roof became famous shortly after the re-opening of the building in 1976. It rained inside during fine sunny spring weather *(Figure 5)*. A year long investigation proved that the rain originated as condensation from the humidified indoor air. The process is described in *Figures 6-12*.


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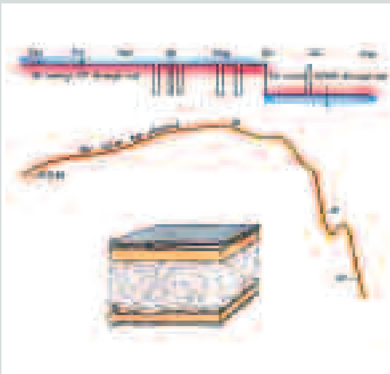
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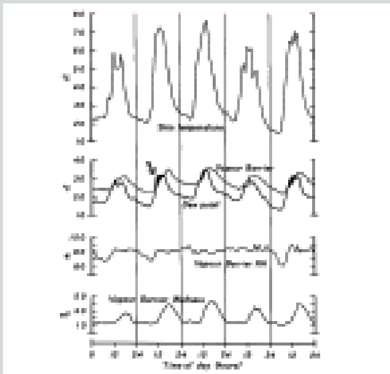
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*Figure 6: The rain proved on analysis to be a solution of fireproofing salts originating in the plywood panels supporting the roof. *Koktaite is a hydrated calcium ammonium sulphate.*

Figure 7: The stack effect is the architectural expression of the hot air balloon. In winter, warm humidified air rises within the high single room of the building, finding its way out through imperfections in the roof construction. Cool air enters through the doors.

Figure 8: The roof is made from many prefabricated boxes. Top and bottom are of plywood. The insulation is fibreglass. There is polyester sheet laid on the lower plywood to act as an air barrier. The outer cover is lead coated copper strips with crimped joints. There are abundant cracks through this construction for warm air to penetrate. During the winter, water condenses on the lower surface of the upper plywood, aided by the hygroscopic fireproofing salts.

Figure 9: In early summer, the sun warms the dark grey lead roof surface to about 80°C. Water vapour distills down to the relatively cool surface of the polyester foil where it condenses and eventually runs down to escape through cracks in the ceiling panels.

Figure 10: This diagram shows quantitatively the annual cycle of winter condensation followed by summer distillation. The top line shows the direction of air movement. There is a steady upward movement during the winter which quite suddenly reverses with the onset of summer. The second line shows the relative humidity (RH) just below the upper plywood panel. It increases steadily during the winter, never reaching 100%, because the fireproofing salts absorb water at a lower RH and thus buffer the RH to about 80%.The roof gains about 30 tons of water during the winter and early spring. This water is evaporated rapidly in summer, so that by August the roof is dry again.

Figure 11: A detailed examination of a week of data from sensors disposed through the thickness of the roof shows that condensation only occurs during brief periods of intense solar heating, shown by the black areas marking the overlap of temperature and dew point. The stability of the roof is finely balanced. Summer rain within can probably be prevented by reducing the winter temperature and relative humidity in the building.

Figure 12: Here is a summary diagram of the winter charging of the roof followed by summer discharge of water into the interior of the building. The roof is now, after 30 years of this stressful cycle, in such poor condition that the building has been closed to the public.

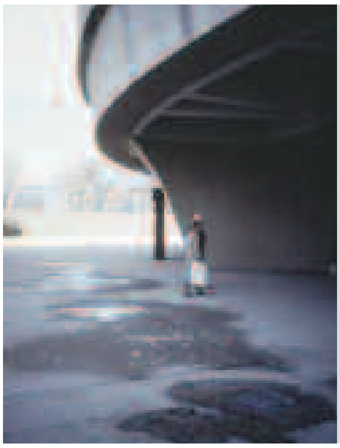

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Figure 13: Office workers passing under the raised bulk of the Hirshhorn Museum in Washington DC are unaware of the danger from falling ice.

Figure 14: How the Hirshhorn makes ice. Warm, humidified air from the pressurised interior leaks out. Its water content freezes on the cold outer skin of the wall. The rising sun warms the concrete and melts the ice, which escapes through drain holes to the outside of the wall where it re-freezes because of evaporative cooling in the brisk wind of air of low relative humidity. Later, the growing solar radiation melts the ice where it touches the wall, sending slabs of ice to smash on the pavement below.

A similar process, but on a vertical plane, bombarded people passing under the Hirshhorn Art Gallery. The process is displayed in *Figure 13* and explained in *Figure 14*. The warm air leaks out of this building not because of the stack effect but because the inside air is under pressure. This is to ensure that outside air does not enter by unauthorised routes to disturb the operation of the air conditioning.

These buildings, or restorations, date from the middle of the twentieth century.

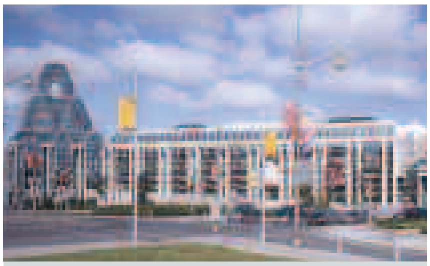

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Figure 15: The National Gallery of Canada in Ottawa, opened in 1988. The architect is Moshe Safdie. Light is channelled through wells from the roof into the lower galleries. The elaborate sealing of the complicated skylights has not been entirely adequate to prevent condensation of water from escaping air.

Figure 16: A group of delegates from the 1994 IIC conference on preventive conservation is listening to the guide, one of the architectural team who designed the National Gallery of Canada. In the gloom to the right, a bucket collects drips of condensate.

Architects and their engineers now understand these threats to the building structure. Buildings are now much more carefully designed, even with the help of conservation scientists. *Figure 15* shows the National Gallery of Canada in Ottawa, opened in 1988. The winter climate is severely cold so extreme precautions were taken to prevent condensation in the elaborately designed light wells bringing daylight down to the lower floors. Unfortunately they also bring the condensation down, as shown by the bucket behind the group listening to the architect extolling the merits of his building *(Figure 16)*.

Can we do better in the twenty first century? Success is far from certain. There are two factors working against establishing a good museum climate which is also safe for the building. The first is the architectural fashion for lightweight buildings and the second is the natural desire of architects, and their sponsors, to make the building itself a novel and surprising work of art. *Figure 17* shows the 'Black Diamond', the 1999 extension of the Danish Royal Library. It appears to be of massive granite, but in reality the walls have to be lightweight to lean outwards. The outward leaning wall has rapidly become a standard architectural idiom, most recently exemplified in Cardiff's Millennium Centre *(Figure 18)* with its copper wall surface.

However, the advantages of massive walls in stabilising both the temperature and the relative humidity in buildings cannot be denied. Much of the RH variation outdoors is attributable to the daily temperature cycle, typically bringing the RH down to 60% during the day and up to 100% during the dew fall of the night. The actual water content of the air does not vary much at all. Keeping the temperature stable by having walls with sufficient thermal inertia to buffer the daily cycle will automatically stabilise the RH, without help from mechanical devices. If the walls are porous so that they can absorb and desorb water vapour and pollutants the climate is further stabilised and its long term stability can be maintained by ventilating only when the outside air is of suitable water content to push the interior RH to the desired value.

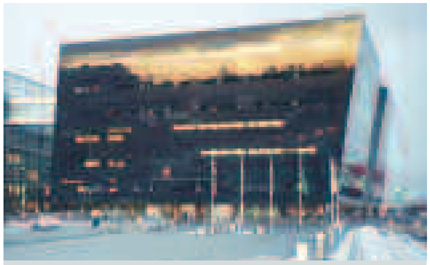

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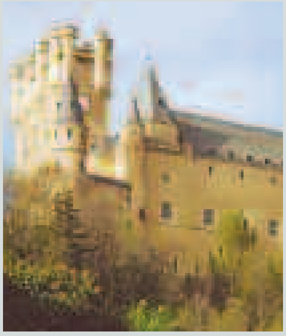
Figure 17: The Royal Library in Copenhagen, opened in 1999. Architects Schmidt, Hammer & Lassen. The outward sloping walls are covered with black Zimbabwe granite veneer and with large areas of glass.

Figure 18: The Millennium Centre, Cardiff, Wales, 2004. Percy Thomas Architects.

To appreciate the potential of these building techniques one has, for most examples, to turn to more sober architecture, designed for purpose rather than for pomp. However, I start with a notably pompous building, the castle of Segovia in Spain *(Figure 19)*. This comes from a vanished age when prestige was expressed through weighty construction, so the cellar of this



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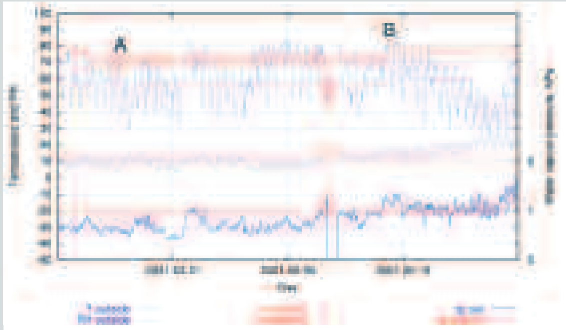

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Figure 19: The castle of Segovia. Mainly 16th century with extensive rebuilding after a fire in 1862. The military archive lies behind the lowest row of windows.

Figure 20: The military archive in the castle of Segovia. The room has massive temperature buffering from the approximately 13 metre thick limestone wall on the left. The room is lit by small windows in the thinner, but still massive wall on the right. (Photo by Victoria Smith).

Figure 21: The climate in the archive over a three month period. Notice the daily dips in RH at point A, caused by the archivist opening the windows during the day. At point B, later in the year, the outside air contains more water vapour, so opening the windows now increases the interior RH. If a combination of sensors and computer could calculate exactly when to open the windows, a more even RH would be obtained, and also a lower average RH.

building *(Figure 20)* has a good natural environment for preservation *(Figure 21)*. The climate in the archive is very steady but the RH is a bit too high for most archivists to accept.

An archive in Copenhagen (*Figures 22-24*) illustrates one strategy for reducing the RH without using air conditioning. In this archive heat is borrowed from the surrounding office areas and balanced against heat loss to the outside, so that the interior temperature lies about half way between inside and outside temperature.

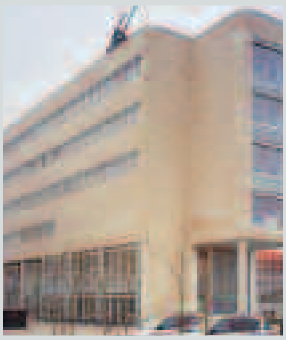
This will give an annual average RH around 50% while keeping the average annual temperature below that comfortable for humans, but which gives slower chemical decay of the archived materials.

At this stage in the slow progress to low, or zero energy consumption climate control for historic collections, there is still much scope for progress. Calculation shows that it should be possible to lower the temperature of the archive to the annual average temperature, which is about 7°C in Copenhagen, while keeping the interior RH well below the 85% average RH outdoors. This means ventilating only in winter and relying on RH buffering by absorbent materials to tide the archive over the summer.

In public exhibition spaces, the ventilation rate has to be sufficient for breathing and removal of smelly chemicals. This will strain the buffer capacity of simple heat and moisture absorbers, so labyrinthine heat and humidity buffers will have to be developed.

Building physicists are just beginning to make the framework of standards and computer programs that will give architects and engineers the confidence to design passive climate control, by way of an intermediate stage of mechanically assisted climate control.

A further advantage of this design approach is that buildings designed to eliminate the need for air conditioning will also protect themselves against structural damage through condensation.



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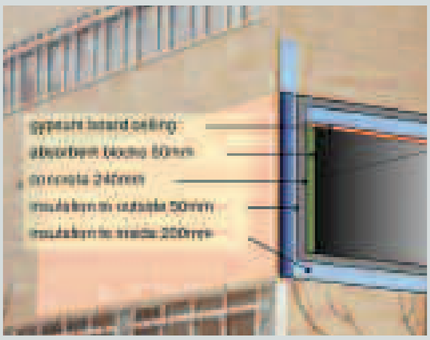

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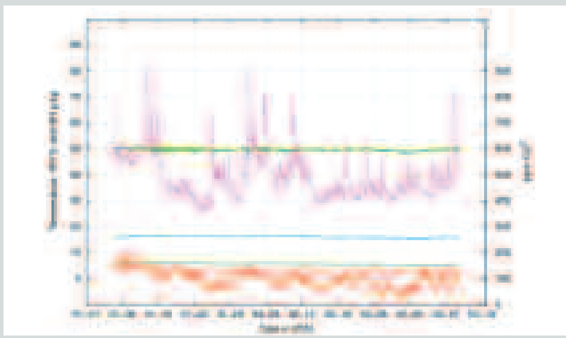

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Figure 22: The Arnemagnaean archive of early Scandinavian manuscripts occupies the windowless volume behind the facade of this building in Copenhagen University. KHRAS Architects 2004.

Figure 23: A cross section of the archive. On the inside there is a 50mm layer of moisture absorbing expanded cement covered with a single coat of porous silicate paint. The massive reinforced concrete box, designed to withstand a fall to the ground, functions as a temperature buffer. The insulation outside the concrete shell is, unusually, thicker towards the interior of the building and thinner towards the outside. This results in a temperature in the room which hovers midway between the nearly constant temperature of the inhabited parts of the building and the annual cycle of outside temperature.

Figure 24: The climate in the archive is very stable. The saw tooth trace of the carbon dioxide concentration can be used to check that the air exchange rate of the archive remains at the planned value, about one air change per day. Sensors outdoors and within the archive allow the controlling computer to pump air into the room only when it will move the RH to the programmed value, which varies slightly from winter to summer.

Denbighshire Record Office: an essay in pragmatism

Jane Brunning

There has been a gaol on this site in Ruthin since at least the sixteenth century; the earliest surviving building dates from 1775, and the archives are mainly stored in the most recent part of the gaol site, the block built in 1866, modelled on Pentonville, which at that time incorporated the latest thinking in prison design. There is also a smaller wing which formerly housed the women's prison, which is now used to shelve outsize items. After the prison closed in 1916 it was used for a variety of purposes, – as police flats, as a munitions factory during the 2nd World War and as County Council offices and stores.

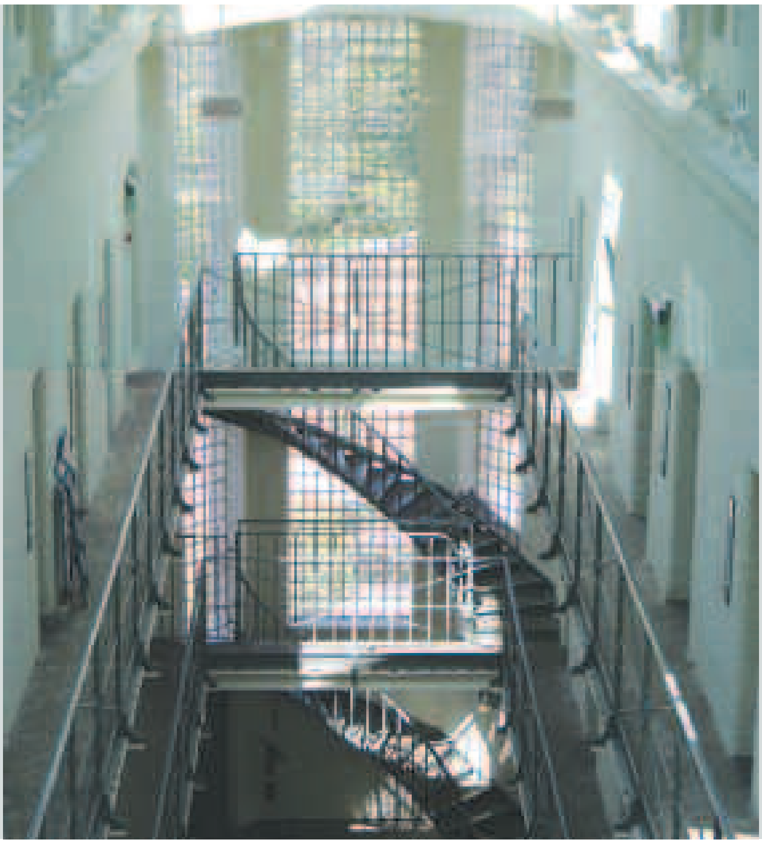
The Denbighshire Record Office was established on the site in 1972, became part of the Clwyd Record Office in 1974, and once again reverted to Denbighshire after local government reorganisation in 1996, although 'new' Denbighshire covers a rather different area from the pre 1974 county.

New Denbighshire inherited a rather large debt from one of its predecessor authorities, which imposed considerable financial constraints on the county for the first three years of its existence. There was no capital funding available, so there was no prospect of obtaining match-funding for any large HLF grant, which made any thought of alterations and improvements impossible. Luckily, the capital funding was restored in 1998, in time to make the Ruthin Gaol project application viable.

The project's assets were considered to be:

- The extensive archive collections which covered the entire county of 'old' Denbighshire.
- The buildings and the site itself. The site had been defaced by ad-hoc additions to the entrances and exterior walls, and by the partial demolition of the gateway. There had been a pre-fabricated branch library building in the centre of the courtyard, which although demolished, had left noticeable scars on the landscape. The intention was to remove all extraneous structures, and to restore the site to its nineteenth century state as far as possible.
- The 1866 block in particular had great potential, it was a large and very striking building from the outside. In addition to removal of various unsightly excrescences, the interior needed extensive work to remove the floors which had been added in the munitions factory period, which would open up the central atrium, and to restore the walkways with their distinctive iron railings.

It was also decided to remove the original attic floor, which was unsafe, and which would also allow the roof to be fitted with skylights which would increase the light levels in the building, and also allow for venting of smoke in case of fire.



- The building's thermal mass, the fact that the cells had thick walls and small windows, which helped to minimise heat exchange, and the original ducting, which could be used to house the pipes for environmental control, meant that the architects and heating engineers involved had a way to achieve BS5454 compliance without having to deface either the central atrium or the cells. There was also room for all the plant to be housed in the side attics, which were hidden from view from the ground.

The lottery bid was submitted in 1998, and was successful in March 1999, with a grant of £1.3 million. Match funding was found from a variety of sources, which covered the total cost of £3 million.

The main requirements for the improvements to the building which the proposal had to meet were:

- BS5454 compliance, which was to be achieved using an airflow system through the old ducting in and out of each cell, with monitoring sensors in two cells on each floor, connected to computer software which would take readings at regular intervals. Temperature and humidity could also be adjusted if necessary by using the software.
- CCTV monitors, two externally, to cover both entrances and two internally, one in reception and one in the public searchroom.
- Automatic fire extinguishing system, with sensors in all cells and areas where documents were stored, to sense both particulates and heat, with an inergen gas system, with gas cylinders and plant stored in the roof space.
- An improved security system, with outside monitoring at all times.
- The development of a heritage trail in the basement and part of the ground floor, to reflect the history of the gaol, and provide an interactive space for school groups and others.

As was inevitable in the reuse of an existing structure, there were some problems which were going to be insurmountable, mainly access, efficient use of restricted space and shared use of the building.

Disabled access was always going to cause difficulties, particularly when wheelchair access was needed. The gaol is on several levels, which necessitated the installation of a lift between reception and the public searchroom. Microfilm readers had been housed in several cells on the ground floor; the door frames are very narrow, and encased in metal, so there was no possibility of widening them. In order to provide disabled access to microfilm readers, a few machines have been moved out into the central area, something which the architects had discouraged on the grounds of spoiling the look of the space.

Twenty-two small cells on each floor meant that maintaining constant temperature and humidity in all rooms was always more problematic than controlling a large space. The size of the cells also meant that shelving was restricted, and could never be as efficient as in a larger space.

Another concern was that there were now two quite separate areas for staff to manage, the public searchroom and the reception. It was calculated that in order to maintain the same levels of staffing, almost double the number of people would have been needed, and of course there was no budget for additional posts.

The separation between the heritage trail and archives caused a few problems in ensuring the segregation of the two types of visitor, but this has been achieved by locking two access doors, and having some rather complicated keypad programming of the lift which travels between the basement and the second floor.

Although not, by any means, a perfect solution, the HLF grant did enable us to make significant improvements to the Record Office, and to develop the Heritage trail to exploit the historically interesting features of the only example of this kind of gaol which is not still in use as a prison.

To conclude

- As a result of the HLF grant, the building now has a much more up-to-date environmental control system, though the teething problems have still not been eliminated, and there is an unacceptable range of fluctuation in both temperature and humidity at times.
- CCTV, security and fire detection systems are all working well, and are a great improvement on previous installations.
- The new shelving, although somewhat cramped, has given expansion room for a several years at the present rate of intake.
- The heritage trail has opened the building to people who would never have considered visiting the archives.
- The reception area, while causing staffing problems, does provide a distinct waiting area for those visiting the record office.
- The new document processing area has provided a space for segregating, cleaning and sorting new accessions.

Current thinking on environmental standards

○ Jonathan Ashley-Smith

Introduction

When it comes to standards for environmental conditions in museums, libraries and archives, current thinking does not appear to be greatly different to past thinking. All of the relevant information has been around for decades. Recent work has refined understanding rather than revolutionising it. All of the possible attitudes to this information have been published at various times during the thirty-something years that I have had an interest in the subject. The thing that does change with time is fashion. What changes is the selection of information and the emphasis on a particular attitude. This specific emphasis can be the deliberate choice of the author, or result from unconscious filtering in the mind of the reader.

The reason it is possible to have changes in fashion, without any substantive change in the context or the relevant data, is that standards present a fundamental dichotomy. There are two distinct groups of people. People like you who need standards because you need to be told exactly what to do and how to do it. Then there are people like me, who are intelligent and sensitive. We can work things out for ourselves and don't need to be tied down by petty regulations that stand in the way of progress. The pendulum appears to swing, sometimes favouring liberalisation, sometimes favouring control. But any sense of a long-term trend is illusory.

A paradigm shift?

For the most recent published thinking in the conservation arena we can go to the pre-prints of the 14th Triennial meeting of ICOM-CC in The Hague in September 2005. In the oral presentation of their paper, authors Rob Waller and Stefan Michalski[1] claimed that attitudes to preventive conservation are undergoing a paradigm shift. Preventive conservation is in danger of becoming nothing more than the mindless adherence to ritualistic procedures. The proposed saviour of the situation is 'predictive conservation'.

Applying this new attitude to environmental parameters, we can move on from defining the tightly specified rectangle of conditions (eg 20 ±1°C, 50 ± 5% RH) as the only allowable place to be, or to strive to be. We can now take time to look at the environmental conditions we have at the moment, and then predict what the consequences for our collections will be in the long term. We may feel able to accept the outcome. But if we are not happy, we can choose another environment that gives a more acceptable predicted outcome. We then work out whether we can afford the cost to our purses, and to the collection, of making the transition.

This system replaces mindless procedure with intelligent procedure, but is not an attack on standards. It's another type of standard.

Types of standard

During the late 1960s my parents and my colleagues considered me to be some kind of hippie. On several occasions I was refused service in pubs because of my long hair or because I was not wearing shoes and socks. The reason given was always that "we have to preserve standards". This is the Type I standard that says "we want you to be like people like us."

This was not a universal standard and I could always find a pub where I would be served. In these places I became the setter of standards. I needed to know that when I asked for a pint of beer I would be served exactly one English pint of beer with a specified alcohol content. I would have none of this glass half-full of foam that they seem to allow in foreign parts. This is the Type 2 standard that says "I want to know that what I ask for is what I get."

Type I standards are the basis of benchmarking. Forms of observed or possible behaviour are classified and ranked. People in the lower ranks are encouraged to upgrade.

Type 2 standards facilitate trade and communication. They do this by trying to ensure that words and numbers relating to different activities can unambiguously be understood and acted on by different groups. So that when I use one tape measure to assess my waist size, someone in the Philippines can use another tape measure to gauge how much denim to cut. When I go to a shop and ask for my size in jeans, I get a pair that fits.

Type 2 standards are useful for people who want reusable specifications. They can however become the currency of mindless regulation.

In theory standards do not impose the will of the few on the many. Everyone is supposed to feel the benefit. BSI, the British Standards Institute, defines standardization as:

"Establishing and applying an agreed set of solutions, intended for repeated application, directed at benefits for stakeholders and balancing their diverse interests."

In theory standards need consensus before they can be applied. ISO, the International Organization for Standardization, defines a standard as:

"A document established by consensus, and approved by a recognized body, that provides for common and repeated use, guidelines or characteristics for activities or their results aimed at the achievement of the optimum degree of order in a given context."[2]

There needs to be a document, something that anyone can read. Its content must be the result of agreement between relevant professionals. The bit about a "recognized body" is probably where some environmental standards come unstuck for conservators. No international, or large national, conservation body has ever prepared or endorsed any relevant standards, even though a number of such institutions claim that one of their priority interests is 'standards'.

Even if you believe that standards come from consensus and represent agreement, you still have a dilemma. Does agreement signal the start of uncontested regulation, or is it merely an agreed starting point for continuing discussion?

Fashions in standards

Below are seven pairs of words, each word is related to an attitude to what a standard should contain and how it might be implemented.

universal	*local*
general	*specific*
coercion	*guidance*
performance	*need*
evangelism	*cost awareness*
certainty	*risk*
fixed numbers	*general directions*

A standard can be universally applicable, or it might reflect that there are local differences that must be accommodated, such as geography and climate. It might give general guidance on a range of object types, or relate to just one specific type, such as archives or photographs. The wording of the standard may imply a degree of coercion to comply, or it may suggest guidance that can be ignored or modified in some circumstances.

The basis for the standard may be the best performance of the best available technology, or the basis may be the needs of the collection, modified by the limitations of the building. Some standards appear evangelical, yet others may accept that not everyone can afford redemption. The certainty that non-standard conditions will cause damage may appeal to some people more than the risk concept that suggests that only probabilities can be predicted, and then only with some uncertainty. Fixed numbers can be useful for setting controls but, given the complexity of the interactions between collections and environment, an indication of general direction for the environment might be safer.

All of these different approaches have been expressed at various times in discussions about the control of the museum environment. It is tempting to see the left-hand column as descriptive of the bad old days and the right-hand column expressing the new and enlightened era. However there have been ineffectual discussions about risk and cost-benefit for at least ten years, while further fixed numbers were published less than three years ago.

If you are looking for fixed numbers you will not find them in the publications of authorities such as MLA, the Museums Libraries and Archives Council, or its previous incarnation Re:source. Publications such as "Benchmarks in Collections Care"[3] and the MLA "Accreditation Standard"[4] imply that environmental control is important, but stop well short of suggesting even loose or flexible specifications. This might be considered a good indication of the enlightened trend in standards.

The primary purpose of these documents is to promote and assess levels of institutional competence. It is not their role to give reasoned guidance. Instead they offer set procedures, and procedures for showing that procedures are being followed.

The environment

The factors that most people would want to see included in an environmental standard are pests, particulates, pollution, light, temperature and humidity. As a first step towards defining appropriate standards, these can be divided into three groups. Different types of standard may be needed for the different groups.

pests *particulates* *pollution*	*zero a reasonable target*
light	*zero not always reasonable*
temperature *relative humidity*	*zero irrelevant and impossible*

For the first three, zero is a reasonable target. No-one would object if you said that your ambition was to eradicate pests, dust and pollutants. Total eradication may not be possible, but the ideal is not stupid. In the case of light, zero ultra-violet content may be reasonable, and zero light when there is no-one to see the objects may be reasonable. But if someone wants to see the objects there must be light. Standards must reflect the needs of the viewer and the vulnerability of the collection.

The principle damage caused by light is due to chemical change. Humidity and temperature are implicated in both physical and chemical change. You cannot remove temperature from the environment. All you can do is define temperatures that are too high or too low for the physical well-being of the object and the comfort of the visitor. As far as chemical reaction is concerned, absolute zero might seem an ideal target, but unlike a target of zero bugs or zero dust, the cost and consequences of heading in that direction make it unfeasible.

For the majority of objects where levels of humidity are a concern, water molecules form an integral part of the structure of the object.

To head for zero humidity would be to radically change, if not destroy, the object. Standards must indicate levels that keep chemical reactions slow, while maintaining the physical integrity of the object.

Pests

Standards for pests in museums do not discuss permissible levels of population in the way that allowable levels of pollutants might be proposed. Nor do standards for pests suggest that a certain level of damage is unavoidable and so must be acceptable, as has happened with lighting guidelines.

The regulation of chemical means to reduce pest populations means that is more difficult to aim for zero tolerance. The guidelines that are available to museums concentrate on procedures to improve monitoring and to ensure hygiene.[5]

Particulates

What are sometimes taken as standards for levels of particulates are specifications for the efficiency of the filters within air handling equipment. Although frequently requested by conservators, specifications such as Eurovent 4/5 do not directly relate to the particle concentrations and size distributions you might expect in a gallery.

At best such a specification gives assurance that, if it were tested in a properly equipped laboratory, this filter would stop a certain percentage of particles of a certain size. The standard takes no account of the real-life installation, or of levels of maintenance and replacement, or of activities within the gallery space. And of course it can only be applied when there is mechanical air-handling.

The increased level of building works in museums in the last few years of the 20th century, resulting from millennium fervour and funding, brought a renewed interest in dust. Particulates can be considered in two classes: those that are very small and so stay in the air for a long time, and those that are larger and tend to fall and cause visible dust coverings on the horizontal surfaces of objects. In the UK, conservation science has largely ignored the first group. Concentrations of the second group can be measured using a fairly cheap low-tech method, the change in gloss of a microscope slide.[6]

Current thinking about dust levels comes from the results of widespread fashion for this method. Although not uncontested as an appropriate unit of measurement, a number of papers propose measuring dust concentrations in terms of soiling units. Building work causes high levels greater than 30 soiling units a week, general human activity causes levels below 10 soiling units a week.[7] A standard might be set by declaring what level of activity is tolerable, and so what soiling level is acceptable. A different approach has been to compare the rate of soiling with the economic demands of cleaning and maintenance and the probable damage caused by these activities.[8]

Pollutants

For a long time the major concern was about levels of pollutants brought in from the outside. Standards for levels of sulphur dioxide, ozone and nitrogen oxides were determined by the best that air-conditioning with activated carbon filters could achieve. More recent thinking has been concerned with levels of internally generated pollutants such as formic and acetic acids emitted by timber products and adhesives. Much of current thinking has been published by Jean Tétreault from the Canadian Conservation Institute.[9] His is a risk-based approach where the allowable levels of pollutants are determined by the decision on how long you want your collections to last. He proposes a dose relationship allowing you to juggle concentration and time of exposure, in a manner that has become familiar with intensity and time of exposure for light dose. He also talks about the NOAEL, the No Observable Adverse Effects Level, a concentration of pollutant in the environment below which no damage appears to occur. The idea that such a level exists is seductive and is supported by anecdotal evidence. However it is not supported by critics of Tétreault's experimental technique.[10]

Light

The conservation department at the V&A is responsible for the most recent practical thinking about allowable lighting levels,[11] although these 'new' developments are based on earlier, less accessible, work from the Canadian Conservation Institute. The V&A approach is essentially risk-based, not surprising given my involvement. It relies on determining what a perceptible change (PC) in colour is, and then asking what rate of change is acceptable. The conclusion that one PC in 50 years is acceptable will not greatly alter the way light-sensitive objects are treated in a well-run museum. It does however openly recognise that the viewer has both limitations and rights, and that the custodian must accept that the decision to display is a conscious decision to damage.

Temperature and Relative Humidity

To find out the latest thinking on standards for RH and T you could try going to the Environmental Monitoring and Control section of Conservation on-line.[12] What you will find is a number of animated essays, most of which date from 1995-96. The cause of this flurry of animation was a press release from the Smithsonian Institute in 1994. It stated that research at the Smithsonian had shown that the current allowable range for relative humidity, of ± 5% (or less), was unnecessarily rigid. Moreover the trend towards tighter specification would lead to unnecessary expenditure on fitting and maintaining air-conditioning plant. Since this was a charter to avoid unnecessary worry it was not popular with conservators. The fact that it was couched in economic terms, rather than valiant defence of the collections, was even more annoying.

What the Smithsonian scientists had shown was that for a large number of samples the internal stress that was large enough to take the internal strain beyond the elastic limit was not reached with fluctuations much larger than the accepted specification.[13] Although Stefan Michalski chose to criticise the experiments that supported these results, he had published similar conclusions at around the same time.[14]

The Smithsonian work dealt with the physical effects of temperature and humidity. At around the same time the standards relating to the effect of temperature and humidity on chemical degradation were also being questioned. At a conference on photographic conservation held in Copenhagen in 1995, Tim Padfield and Jesper Stub Johnsen demonstrated the limitations of the existing standards for photographic archives.[15] They maintained that " Standards have an authority that encourages acquiescence without deeper consideration, particularly by administrators who have little knowledge of the experimental or experiential basis for the standard." One point made in their paper was that for the climate of Copenhagen a flattish line for RH, at levels well within accepted guidelines, can be achieved simply by raising the temperature. Unfortunately this increases the rate of degradation by a factor of at least two, and so they propose dehumidification as a better solution. This was shortly after the National Trust had won a Conservation Award for the concept of 'conservation heating' where the air inside historic houses is heated to 5 degrees above the outside temperature. This prevents humidities from staying too long in the mould region, but has consequences for the preservation of the collections which are at odds with stated aim of conservation.

It should however be noted that conservation heating does give lower degradation rates, and saves more energy, than heating to the 19 or 20 degrees centigrade required by other 'conservation' standards.

ASHRAE

In North America the bible for environmental standards is the ASHRAE Heating Ventilation and Air-conditioning Applications Handbook,[16] which has a chapter on Museums, Libraries and Archives. ASHRAE is the American Society of Heating Refrigerating and Air-conditioning Engineers. Its mission is "advancing HVAC&R to serve humanity and promote a sustainable world". So its aim is to promote the installation of energy-consuming equipment while stopping global warming? The proposed specifications do not save the planet, sustainability is not yet one of the criteria for museum environment standards, but ASHRAE is right to draw the problem to our attention.

The Handbook is a set of specifications for use by engineers. Conservators seem to like it because it is written with engineers in mind, so it makes the difficult task of communication with engineers more easy. As a set of specifications for use by engineers it works quite well, but as a set of standards it lacks something because it starts with the presumption of active mechanical control. The other reason conservators like the "ASHRAE chapter", as it is called, is because the lead writer for the 1999 and 2003 editions is Stefan Michalski. Most people have some respect for what he says, which almost makes what he says the consensus view.

The Handbook specifies five types of environment, starting with one where the only constraint is that is 'reliably below 75% RH', and moving up to a tight specification of precision control, with no seasonal variation, of ±5% RH and ± 4°F (this is America!). Intermediate specifications allow for some difference in set point between summer and winter. Each set of conditions is accompanied by a description of the risk to the collection. It is interesting to note that the tightest specification, which leads to "no risk of mechanical damage", is ±5% and not the previously fashionable ±3% or the totally ludicrous ±1% once called for by the Royal Collection.

You could think of the five sets of conditions, not as specifications for equipment, but as descriptions of types of building with different possibilities for control. Such a classification has recently been developed within the MASTER EU research project.[17] This work, recently presented at the final workshop for the project in January, has yet to be published.

BS 5454

To return to the ICOM-CC conference in the Hague and to the idea of prevention of chemical degradation as the focus of a standard, let us consider some more work from the V&A.[18] We have to refer to the most referred-to standard in the UK, BS 5454, 'Recommendations for storage and exhibition of archival documents', updated in 2000. In the foreword to the document it is stated that this standard "takes the form of guidance and recommendations. It should not be quoted as if it were a specification...". However providers of grants for building work such as the Heritage Lottery Fund often stipulate compliance with BS 5454 as a condition of the grant. Unfortunately it is difficult to comply with the standard without installing air-conditioning plant. Apart from the criticism of its global-environmental unsustainability, air-conditioning also takes up space, abuses historic architecture and costs a lot to keep it running. Yet the HLF insists, and MLA uses the standard as the definition of 'best practice' in its bench-marking scheme.

In his paper Boris Pretzel describes the environmental needs of the RIBA Archive, the collection whose housing the HLF was being asked to fund. He argues that, for individual sheets of paper, environmentally induced stresses are not a major problem, and that at the perennially dry V&A neither is mould. This leaves chemical degradation caused by oxidation and hydrolysis as the major factor to be controlled. Permanence is the key issue.

The concept of the isoperm, originated by Donald Sebera in the 1980s, has recently been given new life by Stefan Michalski.[19] If a graph is created with temperature and humidity as its two axes, lines can be drawn which join points of identical rates of degradation. Isoperms are lines which join points of equal permanence, which is another way of saying the same thing. Where temperature and humidity are high, in the top right corner of the graph, the rate of degradation will be high. Where temperature and humidity are low, down in the bottom left, the rate of degradation will be low, that is the permanence will be much greater. BS5454 allows a small rectangle of values for RH and T. Every possible point to the left of an isoperm that passes through the BS5454 permitted space will have as great or greater permanence than that specified. Yet nearly all of these better sets of conditions fall outside the standard! Boris argues ad absurdum that conditions in an outdoor location, exposed to external conditions but sheltered from rain and direct sunlight, give a greater permanence than BS 5454.

CEN

CEN – the European Committee for Standardization[20] is the sort of organisation that will standardize anything that moves, or that sits still for too long. In response to an Italian initiative it has set up a Technical Committee, TC346, to look at all aspects of conservation work. One Working Group ,CEN TC 346 WG4, convenor Jesper Stub Johnsen, is looking at Environment. This is work in progress and I have been unable to find out the direction the working group is taking.

In a promotional presentation that can be down-loaded from the web, CEN describes the justification of standardization: "harmonization diminishes trade barriers, promotes safety, allows interoperability of products, systems and services, and promotes common technical understanding." Which is reasonable enough.

The presentation also contains the line that CEN's objectives "may be attained by all means", which gives a hint of Europe 1939 rather than liberal 21st century explanatory guidelines. I predict more fixed and inflexible numbers.

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The New Waterfront Museum Swansea: Teething problems and solutions

R. E. Child

The Waterfront Museum Swansea is the phoenix rising from the ashes of the, now demolished, Industrial and Maritime Museum in Cardiff and that of Swansea Museum. The building, which opened in October 2005, comprises the listed 19th century dockside building which formed the original Swansea Museum industrial and Maritime Museum, and a brand new building connecting to it. The architect's brief was to blend the old with the new and to provide a 21st century museum in which to display a wide variety of collections.

The conservation problems envisaged were:

- *time to prepare the collections for display*
- *correct conservation grade mounts and exhibition cases*
- *correct environmental conditions*

As is normal with such a large scale undertaking, the plans were subject to constant change. Objects chosen for exhibition would be exchanged for others and often an excess of objects would be picked out in order that a later choice could be made. This made the planned programme of conservation difficult, owing to the sheer number of objects required. The changing date of the opening also made hard and fast planning difficult.

The mounting of the objects was carried out by an external contractor who made the original mounts from pictures and dimensions. They then spent time on site with the collections doing the final fittings. Entertainingly, some of the mounts fitted so well that they stuck to the objects, while one or two objects fell through the mounts and then dried out and shrank.

The exhibition cases were both bespoke to our specifications and commercially available ones from a good established company. After some initial problems with poor sealing of gaps, misalignment of glass sides, non-sealing of the wooden surfaces against off-gassing, etc., these were resolved. However, we have had ongoing problems with the case lights heating up the interiors

and causing daily fluctuations of temperature and relative humidity. The problems were connected to the heat output of the fibre-optic projectors which are located under the exhibition cases. Various tactics were tried to limit the heat transfer including adding additional insulation, ventilation fans and lowering the wattage of the lamps. These actions have, in the main, reduced the fluctuations to within our original design parameters. Where there are still isolated problems, we proposed to change the lighting system to cold LED's.

The building itself has had the usual teething problems. We wanted a period of at least a month to allow all the systems such as air-conditioning, case lighting, etc., to be evaluated. In the end, we were denied this and objects were put in – in some cases to be taken out again until the subsequent snagging could be undertaken.

The museum has now been open for nine months and is very popular with the public. We are already preparing for the first 'refreshing' of the exhibitions and to evaluate the condition of the objects. This will allow us to develop realistic cleaning and maintenance schedules and to change exhibits. No longer can we lock something in a case for 20 years and ignore it.

Introducing heating into re-erected traditional buildings

Gerallt D. Nash

A coal fire - the traditional method of heating a 19th century terraced house at Rhyd-y-Car, Merthyr Tydfil (now re-built at St Fagans)

Introduction

Changing lifestyles, the development of more efficient insulation materials, combined with the rising cost of fossil fuels, has led to a growing awareness of the potential benefits of using the building itself, and in particular the floor slab, (acting as a heat reservoir), as a potentially efficient and cost-effective means of heating houses. The purpose of this paper is to investigate the potential benefits of introducing under-floor heating into re-erected traditional buildings within a museum context, and more specifically at St Fagans: National History Museum.

Background

The purpose of any building is to provide accommodation and shelter for its occupants, livestock, belongings, machinery or crops. In the case of human occupants it is important to provide not just shelter (from wind and rain), but also, if possible, a degree of comfort. Traditionally, this generally took the form of a fire, which not only heated the room, but could also be used for cooking, preserving meat and fish (by smoking), for keeping valuable commodities (such as salt) dry, or for drying out the dog if he'd just fallen into the mill pond!

The adoption of the chimney, during and after Middle Ages, meant not only the more efficient removal of smoke from rooms, but also enabled the insertion of a second floor, something that was not possible with earlier open-hall arrangements.

The heat from the fire could now be used to heat not only the room in which the fire was located, but also the room above. If the chimney stack was built of brick or stone, it also served as a means of holding and transferring heat, or at least warmth, into the rooms above. Where there was a central stack, heat could be distributed through even more of the building.

Fuel for fires came from whatever was available locally – wood, peat, coal or culm (a mixture of coal dust and clay). Traditionally, the fire was never allowed to go out. Last thing at night the coal, peat or culm would be built up into a mound and then covered with a thin layer of clay. Using a poker, one or two holes would be made in the top – to act as smoke vents. A kettle of cold water was then hung above the fire. By daybreak, when the first occupants woke up, heat from the enclosed fire had boiled the water. The clay covering was cracked open and the fire was built up once again.

The Museum context

Moving a traditional building into an open-air Museum setting such as St Fagans provides the opportunity to show how it would have looked in the past, how it was furnished, and decorated, and how people lived and worked there. Wherever possible, fires are lit in the houses, in order to show not only how people heated their homes and cooked in the past, but also as a means of keeping warding staff warm and to try and achieve the best environmental conditions for both the building structure and display items such as furniture.

However, being a Museum, recreating the past can give rise to certain problems. For instance, it is not usually possible to keep fires lit for 24 hrs a day as would have been done originally, because of security and health & safety considerations. Consequently, fires are lit just before the Museum opens to the public at 10am, and are allowed to go out by the time it closes at 5pm.

Not keeping a building warm can create its own problems when, for instance, it comes to lighting a fire. It has been found that in some of the cottages, when fires are lit in the morning, when the buildings are cold, the rooms fill with smoke. This situation can remain for several hours in wintertime, until, that is, the chimney has warmed up and smoke begins to be drawn up it more efficiently.

If a graph were to be drawn showing the temperature and humidity levels in one of these houses, we would find that they would fluctuate quite considerably during the course of 24 hours. When the fires are lit in the mornings, the inside temperature gradually builds up and the humidity levels gradually drop. By the afternoon, the buildings are comfortably warm. Then, from about 3pm, by which time the houses have reached their optimum in terms of warmth and RH, the fires are allowed to go out. Our graph would show temperatures falling and humidity levels creeping up again. These pendulum-like fluctuations mean that it can be difficult to control moulds, rot and dampness in some buildings.

It is therefore important to try and achieve the best balance. Too high a level of RH can result in mould growth and rot; too dry, and there is a danger of the buildings, and especially timbers, drying out too quickly, resulting in shrinkage, cracking, twisting and splitting. Keeping a fire in the house overnight would serve to maintain more balanced conditions inside.

However, even if it were possible to keep the fire alight after the Museum closed to the public, one would still be faced with another problem. Whereas, traditionally, the fire was prepared last thing at night, and could be kept going until the family woke at daybreak, this represents a maximum period of about 10 hours. The Museum scenario of leaving the fire unattended from 5pm-10am would mean keeping it alive for 16-17 hrs, which would be virtually impossible.

Case Study 1: St Fagans Castle (Elizabethan gentry house)

One possible solution that has been explored at St Fagans, is the introduction of some form of under-floor heating into some of the buildings.

This was first tried in 1991 when major refurbishment works were carried being out at St Fagans Castle and in particular the kitchen, which was to be re-displayed to its late Victorian appearance. There had long been a problem with this room. The floor level is lower than the remainder of the ground floor, and the flagstone floor was always cold and damp, with moisture condensing on the surface.

This had obvious implications as far as furniture was concerned, as it gave rise to a situation where contact with the moist floor surface created ideal conditions for moulds.

The decision was taken to install electric cables under the floor, with the flagstones serving as a heat store. This was controlled by a thermostat located about 3m above floor level.

The results were encouraging. The problem of condensation was removed and, as long as the thermostat was not interfered with, it maintained a reasonable temperature inside and much improved levels of RH.

Case Study 2: Fron Haul (slate-workers' houses)

In 1998 the Museum was asked to supervise the removal and re-erection of a small terrace of four houses from Tanygrisiau, near Blaenau Ffestiniog, Gwynedd, to the National Slate Museum, Llanberis. As with St Fagans Castle, it was decided to install under-floor heating. Once again, an electrical system was chosen, the objective being to provide low-level background heat, effectively to keep the interiors from 'chilling', especially at nights and in winter.

The cables were laid in zig-zag lines across the floor, with several circuits in each room, arranged in such a way that two circuits occupied each area or zone. Thus, if one circuit failed, there was always a second circuit to maintain warmth. Had all the circuits been kept separate, if one failed, unheated 'cold spots' would have resulted within the room.

The installation has worked successfully for the past seven years, and, even though it is known that one section of wiring has failed, the second circuit has enabled the room in question to stay warm. The fact that the floors were covered with slate flags obviously helped, as these were able to act as 'storage heaters'.

Case Study 3: The 'Green' House

In 2001, the Museum hosted an architectural competition to design a 'House for the Future'. The winning design, the 'Green' House, by architects Jesticoe & Whiles, was conceived as an energy-efficient, sustainable building. It incorporates many elements that hark back to traditional constructional techniques, – the use of oak-framing, slate roofing and clay block walls for instance. All windows are double-glazed and there is a strong emphasis on high insulation specification.

The building can be heated in several ways. Large areas of glazing on the south side mean that the interior can quickly be warmed by direct sunlight. A ground source heat pump linked to a 35m deep borehole circulates heated water via a compressor unit. A constant temperature of 10°C underground is raised three-fold in the heat pump and this is then fed under the floor, which acts as a giant heat reservoir.

There is also a small stove in the main living space downstairs which burns pellets made from recycled sawdust. However, the building is so efficient that the stove has only been used on very rare occasions.

Exterior view of St Fagans Castle (built circa 1590). Electric under-floor heating was introduced into the kitchen in 1991.

St Fagans Castle. Electric under-floor heating was introduced into the kitchen, the flagstone floor acting as a heat reservoir.

Fron Haul: a terrace of four houses moved from Tanygrisiau, Gwynedd, and re-erected at the National Slate Museum, Llanberis in 1998. Electric under-floor heating was incorporated in the houses, the slate-flag floors acting as heat reservoirs, enabling a constant background temperature to be maintained even at nights and in winter.

Y Tŷ Gwyrdd (a 'House for the Future') designed by Jesticoe & Whiles and built at the Museum in 2001. A ground source heat pump is one of four different systems available for heating the interior.

Aluminium prefab: moved to the Museum in 1998. An electric under-floor heating system was installed in order to maintain even temperatures throughout the building.

St Teilo's church: rebuilt at the Museum to its appearance circa 1520. A ground source heat pump has been incorporated to improve inside temperatures and humidity levels.

St Teilo's church: Under-floor pipework being laid inside the church on top of a limecrete base. The flagstone floor acts as a heat reservoir and the system is controlled by hydrostrats located in the roof-space.

Case Study 4: Aluminium Prefab

Post-war prefabs were notorious for their poor insulation qualities. Former residents often spoke about how they would bake in summer and freeze in winter. When the Museum was offered such a building in 1998 the decision was taken to see whether matters could be improved somewhat. Although there was a coal fire in the living room, with a primitive form of central heating where cold air drawn from the hallway was heated and fed through ceiling grilles into the two bedrooms, this was never a particularly successful design. So the Museum opted for an under-floor solution again. Sheets of wired 'foils' – similar to like large toaster elements, – were stapled to the underside of the timber joists under the floors. Extra insulation was added in order to improve performance.

The system has not been a total success. This is partly due to the fact that the outside doors are kept open most of the time when the building is open to the public, resulting in considerable loss of any heat that has built up. It has also resulted in the floor boards drying out and shrinking, so that gaps have started to appear between the boards. That said, at least at night it is now possible to maintain a degree of low-level background heating.

Case Study 5: St Teilo's Church

The major rebuilding project currently under way at St Fagans is the re-erection of St Teilo's church and its refurbishment to its possible appearance about 1520.

The building is built using masonry and lime mortar. It incorporates a lot of original timberwork in the roofs of the porch, south aisle and north chapel and a substantial amount of new (green) oak in the nave and chancel as well as the carved Rood screen which would have separated the congregation from the high altar in the chancel.

It was realised quite early on that there could be advantages in incorporating under-floor heating within the building, not only to maintain comfortable working conditions during winter, but also as a means of controlling RH levels.

Using the experience gained of the various systems already tried out at Museum sites, it was decided to use a ground source heat pump (GSHP). This time, instead of drilling down 35m as had been done at the 'Green' House, coils of pipework (slinkies) were laid 2m down in six trenches extending some 50m each. Water pumped through these coils was then fed back through the heat pump (which effectively acts like a fridge in reverse) and into the church, then via a set of manifolds through pipework laid under the floor.

The floor itself was specially constructed with a geotextile membrane laid first, then 150mm of insulation, another layer of geotextile, followed by 150mm of limecrete. The pipes were then laid out and fixed onto the limecrete base before being covered by 50-75mm of lime screed and finally flagstones.

The system here is controlled not by thermostats, but rather by humidistats which measure the RH. Again, the intention is not so much to heat the building, but rather to provide a degree of low-level background warmth and to enable a RH level of around 70% to be maintained. The system is still being monitored and refined, but results to-date appear very promising.

For instance, data collected during the period 27 November to 12 December 2005, shows that the outside temperature fluctuated around freezing point for about 5 days, then hovered around 7ºC for about 4 days before fluctuating again above and below freezing point. Such temperatures would normally have meant that no building work, especially plastering, using lime, would have been possible for most of that time, as 7ºC is considered the critical point, below which fresh lime plaster would probably fail.

However, thanks to the use of the GSHP, the inside temperature actually remained above this level for most of the time, enabling work to continue and our deadlines to be met. The plasterwork did not suffer from any of the shrinkage or crazing that would normally have been expected when working at that time of year.

Equally critically, the new timberwork has not suffered from having heating in the building, because the system is controlled by a humidistat rather than a thermostat (and RH levels did not fall below 60%). The system installed in the church is not intended as a means of heating the building, though it can be increased above its present level, and will certainly take the chill off the temperatures on a bleak January morning.

Summary

Is under-floor heating therefore the answer for maintaining levels of background warmth and RH levels in re-erected traditional buildings in Museums? In some cases, as we have seen, the answer will almost certainly be yes.

However, one must err on the side of caution, and recognise that, as with the aluminium prefab, there may be better or more appropriate methods available for some buildings. Buildings with beaten earth floors, for instance, may also be a problem, as introducing heat into such floors may well cause them to dry out, become brittle and break up. But where floors are of solid mass-construction and where greater control of RH is important, then the use of some form of under-floor heating may well be the answer.

Hot, hot, hot in the summer

Heather Perry

Cynon Valley Museum and Gallery, Aberdare, is housed in a late nineteenth century Grade 2 listed building. The venue opened to the public in 2000 and from 2006 onwards will also act as the collections centre for the museum service.

There are a number of factors that make the internal environment difficult to control:

- *Gallery and main stores open to the roof nine metres above*
- *Roof is single skin with no insulation and valley guttering, windows, doors and wall to roof joints are poorly sealed, all glazing single, non security and non filtered*
- *Air conditioning system is ineffective, providing little more than low level heating during the winter*
- *Brickwork not treated to prevent dust and salts*
- *Blast furnaces at the rear are a breeding ground for rats, pigeons and other pests*

Without a major refurbishment there is a limit to the amount that can be done to improve overall conditions. Consequently the focus is on trying to implement smaller changes to improve the existing environment.

The introduction of an extensive environmental monitoring system means that future decisions will be based on hard evidence. Results have shown that the environment in the galleries and stores is very unstable – temperatures are very high in the summer and very low in the winter. Whilst relative humidity fluctuates widely it is generally too low.

There has been a move away from placing artefacts on open display, with preference given to creating microclimates in cases. Through monitoring the performance of cases we have confirmed that they significantly buffer temperature and relative humidity. Those most stable will be used to house the most sensitive items. Further assessment will be used to determine whether active control measures will be necessary for the most delicate artefacts.

Flooding, caused by blockages to the valley guttering and internal drainpipes, is a recurring problem during the winter. The cost of access to this area prohibits regular maintenance. Thus early detection is essential and flood bugs (which produce an audible alarm upon contact with water) have been placed in known trouble spots to raise the alarm.

Dust and dirt is a problem within the stores. An enhanced programme of house-keeping and ensuring all items are boxed and protected by dust covers will minimise damage. Meanwhile the most sensitive artefacts are kept in the most environmentally stable part of the museum.

Pigeon netting has been installed over the furnace mouths to discourage birds from roosting and nesting. The area between the museum and furnaces is also kept clear of rubbish and vegetation in order to deter animal pests from entering the museum.

Opportunities were missed to prevent many of these problems because specialist advice was not available from the beginning of the conversion project – work had started before the decision was made to use the building as a museum. In addition, the building was incorrectly listed as part of an early nineteenth century ironworks – something that impacted on the original renovation work and continues to cause problems. However, this case study shows some of the solutions available to a small museum with limited resources.

Newtown Textile Museum: You will need to wear a woolly??

○ Jane Henderson

Introduction

Newtown Textile Museum is a museum set in typical 19thC weaving factory in Newtown, Powys and is managed by Eva Bredsdorff, senior museum curator (Montgomeryshire). The building is Grade 2* listed by Cadw so all works require their approval. Prior to recent improvements the museum had major problems with poor condition of the building fabric. There were also complications due to the occupation of the cottages associated with the factory by three tenants. Between 1995 and 2003 Powys County Council with the support of The Heritage Lottery Fund (HLF) refurbished the building and took ownership of the cottages. The whole site was then developed into a museum. The museum now comprises a row of three two storey cottages with two floors of weaving shops above.

Environmental assessment

In 2003 I was asked to recommend an environmental control strategy. At this point the major external works had been completed but the internal works had not begun. The problems for environmental management were as follows:

- *Environmental conditions for the refurbished building were not known*
- *The budget for environmental monitoring and control must be allocated at one time*
- *The site will only be open and staffed for part of the year*
- *The curator is based at another site, a 20 minute drive away*
- *The building retained many period features that must be preserved*
- *The only route around the building involved going out of one door, crossing a courtyard and entering another*
- *The museum planned to borrow collections from the National Museum Wales (NMW) and had to meet the necessary indemnity requirements*
- *The workshop galleries has four looms for open display*
- *The museum has a low revenue budget*

Passive measures

Prior to the refurbishment, environmental conditions had been mainly damp and cold. Insect infestations had occurred and objects showed signs of damage. We were starting with an 'unsuitable' building so the first steps were to try to stabilise environmental conditions by:

- *improving insulation*
- *reducing air leaks*
- *providing additional barriers such as internal doors or lobbies*

This activity was limited by the listed building status and display requirements. The main successes were lobbies at the stairwells leading up to the weaving shops, brush seals on external doors and some very basic curtains.

Environmental control

The aim for environmental control was to try to reduce excess rather than battle with the natural conditions. Equipment fitted must provide minimum disruption to the fabric and be simple to operate. The principles of conservation heating[1] were used, and a hierarchy of target conditions was established.

Equipment selected

Oil filled electric radiators fitted with timer controls and frost protection switches were specified. The project architects were concerned whether electric heaters would be sufficient but agreed not to install radiators because of the impact on the building, the lack of occupation all year round and the threat of disasters.

To assist the conservation heating de-humidifiers were plumbed in to reduce Relative Humidity (RH) in summer. Fortunately, because of the previous residential occupation the building has several drain points. A small number of humidifiers were also purchased in case it ever got dry.

Over specification?

When planning to control an as yet unknown environment it is very tempting to buy more powerful equipment than is needed. This would create more confidence that the equipment will perform as required and you would have the ability to control the environment if conditions worsen. The biggest temptation to over specify was that the money is available now but once it is gone, it is gone. However, spending too much on the equipment will reduce another budget and powerful equipment is larger and more intrusive. It may also provide too strong a response to conditions causing rapid environmental change. In the end, we resisted the urge to over specify and aimed for what we thought was required.

In order to target our efforts where they were most needed we agreed a hierarchy of environmental conditions:

1. *Best conditions:*
   Set for the collections
2. *Second level conditions:*
   Set for human comfort
3. *Third level conditions:*
   Set for the workshop displays.

Best conditions were set for stores and rooms with loan collections. The aim was for 50-60% RH all year round. Conservation heating tends to heat to approximately 6°C above external conditions so these spaces will be cool during the winter.

To accommodate this and conform to security requirements all of the loan collections would be displayed in closed rooms with a viewing window. Other displays had the same equipment in open rooms. This would not achieve such precise conditions but in these rooms most of the collections were inside cases and had additional buffering.

Second level conditions were set for human comfort with least impact on the collections. Conditions were to be maintained in areas such as the reception and the study room only when people are in the building. The heaters were set to gently raise temperature before staff arrive. Frost protection settings and supplementary portable humidification equipment are available to protect from extremes.

The third level conditions were set for the workshop displays. Year round tight environmental control would be costly, intrusive and maybe impossible. For the third floor weaving display we were quite ambitious with targets of 5-19°C and dehumidification year round to avoid extremes. The top floor was more problematic so the fall back plan was to pack up all the smaller sensitive collections into storage over winter.

Monitoring equipment

A telemetric monitoring system was set up that connected via a modem to the computer in the office of the county curator. Staff in the museum also have a real time display of conditions at the reception desk.

How did it work?

As with most projects some things went well and some went wrong. On the positive side the county architects signed up to what was for them a very unusual system and agreed in the end that it was sound. HLF released the money and the National Museum allowed their loans. The temperature has not caused any complaints.

There were continuous problems with collecting data from the monitoring system. Problems with the modem, compatibility of IT systems and the staff's lack of confidence to use the system all led to a loss of data. When the remote monitoring failed problems went un-noticed including spent batteries in the loggers and electricians switching off all the equipment. Staff did not feel confident to interpret the results and make small modifications as the system became established. Most irritating to staff was the dehumidifier on the third floor which is large and quite noisy.

The future

There are many good points about the set up, the main drawback being that it has taken a long time to bed down, especially as consistent data is not forthcoming. There is a temptation to move equipment or settings without a clear picture of what is happening. I am optimistic that this will soon be resolved and we can re-instigate a period of informed decision making.

Thanks as always to Eva Bredsdorf Senior Museum Curator for her willingness to work to the best practice in difficult circumstances and her truly amazing ability to get everyone to do what she asks them.

[1]*Bullock, L. Hayes, B. Staniforth, S and Singleton, A., (1997) Conservation Heating by Cable and Radio, National Trust Houses Museum Practice 4 Museums Association, London 71-74.*

Conservation Matters in Wales

Challenging Buildings: the Search for Solutions