Indoor Climate and Tourism Effects - a UK perspective

Alan Young

The Bartlett School of Graduate Studies, University College London

May Cassar

UCL Centre for Sustainable Heritage, University College London

This paper, written jointly by May Cassar and myself, is a position statement setting out our view of the current state of UK knowledge and experience in the control of indoor climate in buildings and how tourism effects might be mitigated. It deals specifically with buildings which display our cultural heritage, or are themselves part of that heritage, and which welcome visitors to educate and enrich their lives in a relaxed and comfortable environment. As such it is wide ranging and necessarily deals with generic issues at a strategic level, not with specific problems. It does, however, where we think it appropriate, use examples from the UK heritage, commercial and university sectors to clarify our thoughts. I hope by the end of the paper that gaps in our knowledge will have been identified and important and pressing research areas highlighted.

1. INTRODUCTION

In the context of indoor climate and tourism, the absolutely key issue is how we arrive at a responsible balance between the need for access to the interested public (who are after all the true owners of the heritage) and the need to preserve the cultural heritage itself, whether it be a collection of artefacts in a new purpose-built building, or the fabric of an historic building. This balance, or the strategy adopted, which will inevitably involve some level of degradation over time, must be defendable to the stakeholders, both present and future. It is easy to take what might be considered the moral high ground and stipulate that the heritage is of paramount importance, and must be preserved in perpetuity at all costs. The outcome of this, clearly, would be such strict protective measures that only a “heritage elite” would have access to it. We believe it is impossible, nowadays, to defend such an argument, and controlled degradation over time is the best that can be achieved. We believe, as do most interested parties in the UK, that access to all but the most fragile and vulnerable heritage items should be available wherever possible. Clearly there is a pressing need to provide guidance to the heritage sector on appropriate protective measures - how to arrive at an acceptable balance[1]. For this, research still needs to be carried out, specifically on the rate of degradation as the result of visitors, who can cause damaging variations in relative humidity and temperature, be a source of damaging particles and gaseous pollutants in museums and historic buildings, and cause structural damage simply by the weight of numbers.

While on display (or in open access storage) a critical factor in the protection of objects, other than physical damage through bad handling, is the indoor climate. This, in the context of the changing pattern of tourism, is the main subject of our paper.

---

[1] Such guidance, on achieving a balance between access and protection from people, would probably involve weighing up the following issues: whether the object is of local or international importance, its uniqueness and vulnerability, the ability to make facsimiles, the acceptability and cost of displaying a facsimile, the rate of degradation from rapid environmental conditions and air-borne pollutants, the quality of the protective environment and so on. We feel this is so important that it is a research priority at the UCL Centre for Sustainable Heritage. Details of the Centre can be found at http://www.ucl.ac.uk/sustainableheritage.

2. OPTIONS FOR ENVIRONMENTAL CONTROL

First, I would like to deal with some options for the control of indoor climate. In the UK, at the strategic level, this is dealt with in one of three ways, first by providing a building-wide solution, next by providing microclimates locally within the building and lastly by a mixture of the two. Each of these can, broadly speaking, be achieved by active, passive or hybrid means: each with its own advantages and disadvantages. We believe that there is no single answer for all situations (indeed that there never will be) and that each case must be dealt with on its own terms. The solution adopted will in most cases, necessarily, be a mixture of these techniques. We believe that the broad balance between active and passive and between microclimates and building-wide solutions, will depend on the following:

- the size, sensitivity and/or vulnerability of the objects and/or the historic building
- number of occupants
- occupant needs, such as comfort and health and safety
- the character and significance of the collection, and/or the historic building
- how much intervention there can be in the historic building
- financial resources available
- legal and planning constraints

It is worth stressing that the first two of these points are closer than is often thought. The needs of objects/buildings, and the needs of occupants/visitors fortunately are not that dissimilar and, in fact, overlap to a large extent. However, it must be remembered that acceptable rates of change of conditions may be different for objects and people. (See figure 1: *The overlap of temperature and humidity conditions required for conservation of museum exhibits and for comfort of visitors*.) Notwithstanding, this means that the problem is often not so much to reconcile the needs of the collection with those of the visitors, but the needs of the collection with what is realistically achievable in an historic building, or even purpose built museum, at prices that can be afforded.

3. ACHIEVING AN APPROPRIATE INDOOR CLIMATE

I would now like to look at these options, ie, passive/active/hybrid and local/central, in more detail and define what we mean by each. In doing so, we hope to highlight the opportunities and constraints of each.

3.1 Passive versus Active versus Hybrid control

The words “passive environmental control” in this context mean the use of the structure and fabric of the building to control the indoor climate. Purely passive control would mean letting the building fabric itself control the environment, through moisture absorption and desorption and thermal buffering[1], without any intervention at all to heat, cool, ventilate or light. This is clearly not possible in most buildings. All usable buildings in northern, central and eastern Europe will at least need an active heating and lighting system. Except in the most exceptional circumstances, winter temperatures and natural light levels, are too low to allow internal heat gains and daylight to maintain acceptable temperatures, humidities and light levels, either for the building or occupant well-being. So in passive control we include

[1] The prime building example of thermal buffering is the stone church. Here the thermal capacity of the structure is so great that it is cool in summer and warm in winter - it could almost be considered to provide inter-seasonal heat storage - and painted panels have been known to survive for hundreds of years in such environments.

heating, with natural ventilation to control overheating and to maintain air quality. Buildings, other than closed stores, will also need an “active” or electric lighting system.

By active systems, in the present context, we mean ones which provide mechanical cooling and humidity control, or air conditioning, again whether locally or centrally provided and controlled. And a hybrid system, or hybrid control, is one which combines elements of passive and active systems, and would normally be thought of as one with heating and lighting systems, but with mechanical ventilation, and/or local free-standing humidification and de-humidification. There are many variations, and the distinctions between passive/hybrid/active and indeed local/central often become blurred. As I have said before, for most real buildings there will be a range of permutations.

3.2 Local versus Building-wide Control

There are many ways of producing microclimates within buildings, ranging from display cases, with or without humidity control using a passive buffer or full air conditioning, to locally situated humidifiers and de-humidifiers and split-system cassette air conditioners. Similarly for building-wide control, there are a whole range of options from a central air conditioning plant, to individual systems in each climatic zone of the building. Normally, ease of installation and cost will determine the preferred option. What is clear, however, is that local control of microclimates goes naturally with passive and hybrid systems. It makes sense to achieve rough control of the environment passively, then to fine tune the local environment using display cases[1], or for a larger volume, or a more critical situation, the use of cassette air conditioners and humidifiers, and so on. In any real building, a mixture of local and central and active, hybrid and passive systems will be used. The important decision is the appropriateness of each solution for each problem[2].

3.3 The Opportunities and Constraints of Passive, Active and Hybrid Systems

So just what are the advantages and disadvantages of each? Tables 1 and 2 list these for passive and active systems. Hybrid systems will fall somewhere in-between.

What we are trying to say here is that the traditional and easy answer of blanket full air conditioning is often not appropriate today, particularly if as frequently happens it is badly designed and maintained, and if there are running cost constraints, and that the heritage sector must start to investigate the applicability of other environmental control strategies. In this, hybrid systems would appear to have the greatest change of success.

4. THE STATE-OF-THE-ART IN THE UK IN THE PASSIVE AND HYBRID CONTROL OF BUILDINGS

So just where do we stand in implementing passive and hybrid technologies in the UK? We believe that in order to understand the application of passive and hybrid control to heritage buildings, we must use, as reference points, commercial buildings where the technology has been most widely used. There has been considerable development recently, and there now appears to be a substantial knowledge base in the commercial sector, but we still need to see how far they would be appropriate for cultural heritage applications. An example of a successful passively controlled building in the UK is Short Ford’s Queen’s Building[3] at de Montfort University, Leicester, figure 2. A building engineered in the UK, but

---

[1] However, the current UK trend seems to be away from display cases towards more open display for better “access”, for example the British Art and Design Galleries at the Victoria and Albert Museum, London, opening later this year.

[2] The usual classification of active/hybrid/passive, used for commercial buildings, may be inappropriate in the heritage sector. Really all we mean by passive control is whether the fabric of the building is involved in controlling the internal environment. In a heritage building or a museum, passive control will almost certainly be assisted by active systems and be a hybrid solution!

[3] Energy Efficiency Office, Best Practice Programme: New Practice Report 102 - The Queen’s

built in a much more hostile climate, is Peake Short's Brewery in Malta[1], figure 3. Successful hybrid ones are Miller's Elizabeth Fry Building[2] at the University of East Anglia, Norwich, one of the lowest energy consuming buildings in the UK and one which uses mechanical ventilation through hollow core slabs to maintain thermal stability, figure 4, Rab Bennetts's PowerGen Headquarters, Coventry[3], figure 5, which largely uses cross and stack ventilation through an atrium for control of overheating and Feilden Clegg's Environmental Office of the Future[4] for the Building Research Establishment, Watford, figure 6, which uses a series of solar chimneys to ventilate and pull cool air through the building at night-time to pre-cool it for the next day.

The most recent and perhaps the most spectacular, certainly the highest profile, of this clutch of hybrid buildings, is Hopkins's Portcullis House[5], the new Parliamentary Building, built to house our Members of Parliament, figure 7. Sadly, and despite the huge cost of this building, the government has decided that it will not be monitored and the results made public. This building uses fans to draw air through the building and over heat-exchange-coils at very low velocities, to reduce pressure losses, and the energy consumed to distribute air around the building. Ground water cooling, another hybrid technology which is becoming popular in the UK[6], is used without further mechanical cooling to reduce peak summertime temperatures. Here water at around 10^{o}C is pumped from aquifers under London. This same technique has also been implemented at the Building Research Establishment's Environmental Office of the Future, as mentioned above.

It would, however, be wrong to claim that our knowledge is complete or that mistakes have not been made. For example, Hopkins's Inland Revenue Offices[7], figure 8, universally praised for its architecture, is only partially successful, in its hybrid strategy. Here, the top floors, because they are of light-weight construction overheat in summer, and the glass stair towers, which make such a strong architectural statement and which were designed to increase the natural ventilation flow in the open-plan lower-floors through the stack effect, in reality, only add marginally to the rate of air change.

It is time for the cultural heritage field "to grasp the nettle" and take this experience and expertise on board to develop its own appropriate solutions. But it would be unfair to claim that there has been no activity in this area in the UK. The environmental conditions in Great Court at the British Museum, by Foster Associates, figure 9, are controlled by a mixture of passive and hybrid systems[8]. Furthermore, the Jersey Archive Centre, figure 10, has attempted to control the relative humidity inside its repository to $\pm$ 5% by passive means. Ove Arup and Partners[9] have engineered this building to use the passive absorption and

---

Building, de Montfort University - feedback for designers and clients, Department of the Environment, June 1997, and A Ashbridge and R Cohen, Probe 4: Queen's Building, Building Services, The Chartered Institution of Building Services Engineers Journal, London, April 1996.

[1] Architects' Journal, London, 10th February 1993 and Architecture Today, London, January 1991.

[2] Energy Efficiency Office, Best Practice Programme, New Practice Final Report 106: The Elizabeth Fry Building, University of East Anglia - feedback for designers and clients, The Department of the Environment, Transport and the Regions, March 1998.

[3] A Brister, The New Generation, Building Services, The Chartered Institution of Building Services Engineers Journal, London, March 1995 and The Choice of a New Generation, Architects Journal, 2nd March 1995.

[4] Energy Efficiency Office, Best Practice Programme: Future Practice R&D 59 - The Energy Efficient Office of the Future, Her Majesty's Stationary Office, January 1995.

[5] R Bunn, Lord of the Files, Building Services Journal, The Chartered Institution of Building Services Engineers, London, September 2000.

[6] In London, this technology is being considered more and more as the water table is rising, due to the reduction in extraction by industry, making access to cool sources of water easier and less expensive.

[7] Energy Efficiency Office, Best Practice Programme: New Practice Case Study 114 - The Inland Revenue Headquarters - feedback for designers and clients, Her Majesty's Stationery Office, March 2000.

[8] A Blyth, British Museum's Comfort Factor, Architects' Journal, 23rd September 1999, page 30.

[9] C D A Twinn, Passive Control of Relative Humidity to $\pm$ 5%, CIBSE National Conference, Alexandra

release of moisture from the concrete structure, combined with controlled natural ventilation and heating to maintain the relative humidity within tight limits. The fabric, with its contents, act like a moisture and thermal flywheel[1].

The success of these buildings has been enhanced by, if not totally dependent on, the major developments which have occurred in the prediction by computer of environmental conditions and air flow within buildings. Failure, it must be added, has most often been due to resource issues, such as reducing time for commissioning and fine-tuning of the system, sometimes the removal of control items, or even whole Building Management Systems (BMS).

Simulation techniques are now highly sophisticated, and allow designers to ask "what if" questions relating to the performance under a set of real or likely conditions. They can be used, for example, to investigate the response of buildings and their systems to large step-changes in internal casual gains - an influx of visitors - or to the outdoor climate - a cold dry spell followed by a warm humid one. A major recent development in building simulation programs is that they can now integrate many features that used to be stand-alone. Previously, software was produced in separate units. For example, one package would deal with thermal performance, one with natural and artificial lighting, one air movement (cfd, or computational fluid dynamics) and another moisture movement and ab- and de-sorption, and so on. The really exciting recent developments have been in the integration of these packages. ENERGY +, an American program, in the public domain models the interaction between the fabric, including ad- and de-sorption of moisture, and the mechanical services systems, in an iterative way, and allows air movement to be modelled simultaneously[2]. There are pitfalls too, of course, in using these modes if mistakes are made in input data or inappropriate default values are selected or unrealistic assumptions are made to reduce data input.

But what does this mean for the heritage sector? The successes in passive and hybrid control, I have described, have been largely in commercial, domestic and university buildings, where the over-riding factor is the dry-bulb temperature, and where occupant thermal comfort is the aim of the system. In historic buildings, and in museums with sensitive collections, the issues are different and more difficult: relative humidity becomes the variable to be controlled, and objects and historic building fabric are much more sensitive than people to rapid changes in environmental conditions. We may know much about the way concrete responds to thermal and moisture cycles in new constructions, but we still have a lot to learn about the way historic structures, their fabric and their materials respond over the short and indeed the longer term.

Nevertheless, we feel that much of the necessary predictive "technology" is in place, and becoming more and more reliable every day. With micro-processor control the necessary innovative control strategies are becoming easier to visualise, design and implement. The heritage sector needs to take what we already know, and with strength and imagination, develop and extend it to its own needs.

I'd now like to leave these matters and look at issues surrounding visitors to historic buildings and museums.

Palace, London, 5-7 October 1997, Volume 2, page 77.

[1] It should be noted that this is an extremely airtight building with an air change rate of 0.05 air changes per hour (equivalent to 1 air change per day). Natural ventilation is only employed when the outdoor air is at the appropriate temperature and moisture content.

[2] The big disadvantage of Energy + is that there is no friendly front end to help the user, and no default values are suggested - the user must research and input every single value.

5. MITIGATING THE EFFECTS OF TOURISM

Tourism patterns are changing. Tourists in general, but specifically visitors to museums and historic buildings on heritage trails, come in waves, in coaches, and often have only limited time before they are whisked off to the next destination. The duration of the visit means that they have a quick and sudden impact on environmental conditions, and a cycling of these impacts may occur throughout the day, as successive waves of tourists enter the building. Special exhibitions may have very high visitor numbers. In addition, as well as being informed, they nowadays expect to be entertained in a comfortable environment, and the younger visitors may expect interactive displays, with their attendant heat gains. The additional lighting to display the "heritage" will also increase heat gains. All these place an enormous burden on the environmental control systems, and if these are unable to cope, on the building fabric and the collection itself. It is difficult enough to design air conditioning and attendant controls to cope with these sudden stresses, let alone passive or hybrid systems which respond much more slowly. There appears to be conflict between the slow responsiveness of benign systems and the unsustainable energy-intensive manner of organising our tourism.

There are, however, some common sense measures which can mitigate the worst effects of large crowds. For example, by the provision of

- air locks at the entrance to prevent ingress of outdoor air as large numbers of visitors enter the building
- a buffer space to receive a coach of visitors
- well-ventilated cloakrooms at the entrance for wet clothing and umbrellas
- an appropriate exhibition layout which places the less sensitive items near the entrance, where visitor numbers are greatest, with the more sensitive objects sited further away where visitor numbers are fewer
- display cases for the most vulnerable objects

These measures are not without problems, especially for historic buildings. For example, expecting an historic building to act as a sponge may be detrimental to the fabric, and the addition of ventilated cloakrooms, air locks, even doors separating different climatic zones, may compromise the historic character of the building. It may also be difficult to place the less sensitive objects near the entrance, as the exhibition will have its own "story-line" or specific theme, requiring certain objects to be placed in the most problematic spaces. Nevertheless, the first strategy in tackling any problem should be to reduce the size and complexity of the problem in the first place.

Waves of tourists, who now arrive in short bursts, place historic buildings and their collections under shorter, and in many cases, more extreme cycles of stress and as yet we do not know how they are coping. There is a need to develop diagnostic techniques which will allow us to understand how our heritage is standing up to these new stresses. Only then can be develop appropriate strategies for preventive conservation.

6. THE FUTURE

Before finishing, I'd like to step back for a moment, take stock of our position, be a little provocative, and ask what all the fuss is about.

We have a fairly extensive and robust knowledge-base, for example, we know what conditions are needed - more or less - for the long term preservation of artefacts and historic fabrics, we have reasonably sensitive predictive tools to determine expected conditions in our heritage, even when under stress of large numbers of tourists, and we have mechanical services systems which, if designed properly (a big if) and they are looked after by the right pair of hands (another big if) can control conditions to the required level, admittedly at a cost.

But overall our current state of knowledge is sound, so why is the heritage sector in such a confused state over the control of indoor environment: what are the constraining and confounding factors? It seems to us that the main reasons are the following:

- lack of resources
- lack of awareness
- lack of understanding of the wider technical issues (leading to the need for technology transfer)
- uncertainty over the use of new technologies and their long term effects on the heritage - how to marry these new technologies to old materials and systems
- lack of commitment, perhaps due to a feeling of helplessness in the face of large and demanding problems, with few resources and little guidance

The first of these will not go away, and will be an ever present problem, not, thankfully, under examination in this workshop. But the others indicate that there is great and pressing need for education, as well as research. Both clients and their consulting engineers need training in what is possible, its cost, and what the consequences are of not getting it right in a sustainable way. The UCL Centre of Sustainable Heritage is attempting to remedy this with a new masters course, planned to come on line for the 2003/4 academic year.

But there is a greater need, we need to do it sustainably, not just for cost reasons, although this is a major benefit and may eventually be an over-riding one, but for global environmental or moral reasons, and as yet we do not know what this entails. Nor do we yet know if we do do it sustainably, whether it will place further stresses on already fragile objects and buildings.

Perhaps I should explain what we mean by sustainability in the present context, and give some indicators of how we might proceed down the sustainability road. An idealised definition could be something like *the control of the environmental conditions for our cultural heritage which minimises its degradation over time, without reducing user access, at least cost to the global environment*. Clearly, like all definitions of sustainability, this is a tall order, but we feel, it should be the watchword of heritage professionals.

In the context of indoor climate, sustainability probably means the following:

- the use of as few active systems as possible
- the avoidance of over-sizing of any active systems
- the use of energy recovery systems where possible, and
- the use of innovative control strategies

Total passive control, using only heating and natural ventilation, plus the enhancement of the buffering capacity of the building without compromising its character, is the most sustainable option. The problem is that sufficiently tight control of relative humidity is probably not yet possible in complex heritage buildings with large numbers of visitors. Research into innovative control strategies and techniques is therefore a pressing need.

Over the last 10 year or so in the UK, environmental managers in the heritage sector, following research carried out at the Bartlett and elsewhere[1], have been moving away from using air conditioning as a panacea for all environmental problems. There has grown up a feeling that natural ventilation is sufficiently good for all but the most stringent applications. We feel that this assumption should be challenged: natural ventilation in this context does not

---

[1] T Oreszczyn, M Cassar and K Fernandez, Comparative Study of Air-Conditioned and Non-Air-Conditioned Museums; IIC Preventive Conservation Congress, Ottawa; 1994.

mean opening windows, rather it means tightly controlled natural ventilation, probably filtered and mechanically distributed, basically another hybrid solution.

7. IMMEDIATE RESEARCH AREAS

So what are the areas in which research needs to be carried out? In the present context, we feel the most important and urgent are:

- rates of deterioration of objects and building fabric over the long term, to see if we can relax conditions for some materials
- diagnostic techniques for determining historic building condition over the long term
- sustainable technologies
- innovative strategies for the passive and hybrid control of relative humidity and temperature
- further important research gaps can be found in: *Technological Requirements for Solutions in the Conservation and Protection of Historic Monuments and Archaeological Remains*, for the European Parliament, Directorate A, Scientific and Technological Options Unit (STOA Project 2000/13-CULT/04), Luxembourg, October 2001; edited by M Cassar; Section 2, page 20, which can be downloaded from the web as a .pdf file from http://www.europarl.eu.int/stoa/publi/pdf/00-13-04_en.pdf

There is also a pressing need for education, awareness raising and training. It is hoped that our UCL Centre for Sustainable Heritage, will not only contribute to the sector through research but also through its learning and teaching programme.

8. FINAL SUMMARY

Let me end by briefly summarising what we feel are the major issues currently facing the heritage sector in indoor climate control and the effects of tourism. We feel that we need to

- get the balance between access and conservation right
- consider passive and hybrid options before air conditioning
- mitigate the effects of large numbers of tourists at source
- engage in discussions with the tourism industry to reduce tourist impact
- learn from other sectors in the building industry how to control the indoor climate with minimum impact on the global environment
- use the new predictive tools to investigate innovative systems and control strategies
- carry out research, and develop diagnostic techniques, into long term degradation of historic buildings and their collections
- raise awareness of the issues, and provide education and guidance
- seek funding from public and other sources

Not a bad list of actions for completion before breakfast - just a small challenge for us all in the 21st century!

Table 1: The Opportunities and Constraints of Passive Control

PASSIVE SYSTEMS	
Advantages	**Disadvantages**
• no capital cost • no running cost • no maintenance cost • non-intrusive • non-polluting	• requires heavy-weight building (may be an advantage in an historic building) • uncertainty over environmental performance with climate and casual heat inputs • unable to cope with large step changes in heat input

Table 2: The Opportunities and Constraints of Active Control

ACTIVE SYSTEMS	
Advantages	**Disadvantages**
• close control of environmental conditions • can cope with most environmental stresses, however severe, if properly designed, maintained, and at a cost	• difficult for non-technical staff to brief consultant • needs constant maintenance to perform as designed • needs knowledgeable and committed operating staff • difficult, or impossible, to integrate into historic buildings • high capital cost • high running cost * • high maintenance cost • uses otherwise useful space • can be unsightly • usually runs on electricity, so is polluting (with high CO_2 emissions)
* Research carried out at the Bartlett shows that the running costs of an air conditioned museum is around twice that of a naturally ventilated one in the UK (T Oreszczyn, T Mullany and C Ni Riain, A Survey of Energy Use in Museums and Galleries in "Museums Environment Energy", edited by M Caaasr; HMSO, London, 1994, page 17)	