CLIMATE MANAGEMENT AND CONTROL

American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). Chapter 21: Museums, libraries and archives. In *ASHRAE Handbook: Applications.* ASHRAE, Atlanta (2003), pp. 21.1–21.16.

Bordass, W.; Bemrose, Colin *Heating your church* Church House Publishing, London (1996).

Brown, Dennis. Alternatives to Modern Air-Conditioning Systems: Using Natural Ventilation and Other Techniques. *APT Bulletin* 27, 3, Museums in Historic Buildings (1996), pp. 46–49.

In a historic building with inadequate or no air conditioning or where it is not possible to install modern systems fitted with air filters, humidification, and controls, it is possible to mitigate the effects of temperature and humidity extremes on a building and its contents by controlling air-flow. When used in conjunction with mechanical air conditioning, this method can also save a little money. Effective control of airflow requires understanding the existing climatic conditions in and around the building; measuring and keeping records of current environmental behaviour; and using various techniques to improve airflow within the building. (Author's introduction)

Camuffo, D.; Leissner, J.; Schellen, H.; Van Grieken. R.; Kozlowski, R.; Rissanen, S.; Busà, A.; Consonni, E. G.; Zajaczkowska - Kloda, J. and Kozarzewski, M. Friendly heating: Both comfortable for people and compatible with conservation of artworks in churches (Contract No : EVK4-CT-2001-00067). (2002-2005)
http://www.heritage.xtd.pl/conference_report/camuffo.html

A significant number of historic churches are heated in the cold period sporadically when used. The artificial climate produced by air heating episodes is usually uncomfortable for the congregation and has a negative impact on the works of art preserved in churches. The rapid warming of the air causes a drop in the relative humidity and a subsequent release of moisture and shrinkage of artworks with little thermal inertia, such as paintings on canvas or delicate objects of wood. On the other hand, the increased moisture content of the air generated by those using the church causes condensation on surfaces that remain cold, such as walls, ceilings or stained glass.
FRIENDLY HEATING - a research project within the European Commission 5th Framework Programme was launched in 2002. Its aim is to develop a novel heating system which will contain heat just in the area where people sit and will minimise leakage of heat, dust and moisture to works of art. The system will be set up and studied in a church in Rocca Pietore, in the Dolomites in Italy, because of the extreme climatic conditions found there.
The system will emit warm air at low temperature and at a very low velocity from diffusers situated at the base of the pews. In order to reach satisfactory levels of comfort, additional heating will be provided by means of heating foils. The system will be designed with the help of simulation models that will reproduce the indoor conditions and the air leakage

from the sitting area. The prototype of the heating system will be set up and tested in a laboratory, then on site. In order to verify the efficiency of this system and reduce the leakage, surveys with tracers will check that the warm air remains mostly confined to the sitting area. Also, the perturbation to the local microclimate and the internal air movements will be controlled, to be sure that warm air and moisture do not reach walls and damage artworks. The risk of environmental factors potentially damaging artworks will be evaluated before and after the installation of the heating prototype in the church to test the system. A particular focus will be on the disappearance of dimensional changes in wooden artworks and wall condensation. Field monitoring will be used as feedback to modify the system until the desired performance is reached. Field monitoring will ensure that the new environment has improved the conservation standards, is more comfortable for people and does not cause acoustic noise. (From report)

Camuffo, D.; Pagan, E.; Schellen, H.; Limpens-Neilen, D.; Kozlowski, R.; Bratasz, L.; Rissanen, S. and et al. *Church heating and preservation of the cultural heritage: A practical guide to the pros and cons of the various heating systems* Electa Mondadori, Milan (2006).

Camuffo, D.; Sturaro, G. Church heating: A challenge looking for solutions. In *Research for Protection, Conservation and Enhancement of Cultural Heritage: Opportunities for European Enterprises.* Brandt-Grau, Astrid, ed. European Commission, Luxembourg (2002), pp. 128-136. ftp://ftp.cordis.europa.eu/pub/eesd/docs/ka4_protection_conservation_enhancement.pdf

Camuffo D.; Sturaro G.; Bernardi A.; Pagan E. and Becherini F. Microclimate: A difficult variable in museums (presentation at 4th meeting of the Indoor Air Pollution Working Group. IAP Copenhagen. (2001) http://iaq.dk/iap/iap2001/2001_01.htm

While the external climate has strongly influenced planning in the past, today modern technology creates the desired microclimate inside buildings with powerful systems to heating, ventilating, air conditioning (HVAC), and lighting. While in many cases highly satisfactory levels of comfort for people have been reached, the situation is rather more complex and problematical for the conservation of works of art. In some cases, the microclimate in museums is controlled for human welfare during opening times, and is left to evolve freely during the night. When the HVAC is switched on/off, the room environment undergoes abrupt changes, and also in the following it is continually perturbed by many factors. Field surveys show that the weak point of HVAC is not the production or absorption of heat or vapour, but rather the redistribution inside the rooms in order to obtain a climate which is homogeneous throughout the space and which is constant in time. Field surveys performed to do a sound environmental diagnostic in a number of European museums have found some weak point that are particularly common and that have been removed, or mitigated, after having been recognised. (From website)

Camuffo, Dario; Pagan, Emanuela. Heating churches: An innovative solution to preserve cultural heritage and to provide comfort. In *Influences of the environment and defense of the territory on recovery of cultural heritage: Lectures and proceedings of the 6th International Symposium on the Conservation of Monuments in the Mediterranean Basin, Lisbon, Portugal, 7-10 April 2004.* International Group for the Protection and Conservation of the Cultural Heritage, Lisbon (2004), pp. 103-106. http://www.fh-comfort.it/pdf/lisbon3.pdf

Church heating is mainly operated at broken times and the consequent heat peaks and relative humidity drops constitute a tremendous challenge for conservation. The dynamic regime established with weekly heating cycles associated with release of moisture from people
generates condensation on cold structures. The damage is cumulative and, in the long run, it reaches macroscopic levels. The European project FRIENDLY-HEATING constitutes a change in heating strategy: instead of heating the entire church, only people are heated by containing heat just in the area where people stay. The system is based on low-temperature radiant elements displaced according the physiological needs of the body. At the same time, part of the dangerous excess moisture emitted by people breathing will be removed. Due to the combined effect of moderate pew heating, and moisture removal, smoke particles and moisture will not be able to reach walls and ceiling. Artworks will remain in safe conditions. The comfort was proven first measuring the globe thermometer temperature profile between pews and then the actual churchgoer skin temperature when the system was operating. (Author's abstract)

Camuffo, Dario; Pagan, Emanuela and Maraner, Antonella Friendly Heating: A holistic study of synergism between microclimate, air pollution and cultural heritage (presentation at 6th Indoor Air Quality 2004 Meeting (IAQ2004) Padova, Italy, 10-12 November 2004. (2004) www.isac.cnr.it/iaq2004/pdfabstract/Camuffo_1abstract.pdf

Cultural heritage is preserved in many places, at different levels of environmental safety. Air pollution, microclimate and human impact are determined by the location and the use and their synergisms increase the deterioration rate. The consequences are even worse in the case of periodic microclimate unbalances. Museums and archives are in a fortunate situation, being used under the supervision of specialists in conservation. In most cases, however, temperature and relative humidity undergo dangerous daily synergistic cycles whose consequences are still
quantitatively unknown. The consequences are even more dramatic in the case of more enhanced weekly cycles, as it happens in churches that are at the same time place of worship and exhibition rooms for many artworks. In many cases, especially in the Art Cities, people pay to visit a Church, which is transformed into a museum in business days, and in worship place in holidays. (Author's abstract)

Camuffo, Dario; Sturaro, Giovanni; Pagan, Emanuela; Bernardi, Adriana and Becherini, Francesca. Heating in historical buildings: A manifold problem. In *Art 2002: 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage: 2-6 June 2002, Congress Centre Elzenveld, Antwerp, Belgium: Proceedings.* Grieken, R. van; Janssens, K.; Van't dack, L. and Meersman, G., University of Antwerp, Antwerp (2002), pp. 1-11.

An immense cultural heritage is conserved in historic buildings open to the public--e.g., museums, churches, theaters. Problems connected with the most common heating methods are discussed, especially the cases in which the main objectives for the heating system are limited to human comfort and economy. The most difficult situation is found for rooms heated only once a week or for occasional concerts or services. A key problem arises when the excess moisture released by people condenses on cold walls in buildings not permanently heated. The situation is complex, and the effect depends upon the thermal inertia of the artwork. The rapid heating causes a drop in relative humidity with the consequence of dehydrating canvas paintings and other low-inertia artworks; on the other hand, frescoes, walls, and massive statues remain cold, and the moisture released by people may condense on them. Lamps, especially incandescent ones, may contribute significantly to local heating and air convection, enhancing pollutant deposition and thermal stresses. When only the main room is heated, opening a door connecting the room with colder environments constitutes a source of perturbation that is hard to mitigate. Some mitigating measures are discussed. (A.A.- AATA)

Camuffo, Dario; Sturaro, Giovanni; Valentino, Antonio and Camuffo, Marco. The conservation of artworks and hot air heating systems in churches: are they compatible? The case of Rocca Pietore, Italian Alps. *Studies in conservation* 44, 3 (1999), pp. 209-216.

Most works of art require a stable microclimate, and a field study has been undertaken to understand the environmental risks in a mountain church that is heated once a week. The church was selected on the basis of the artworks present and the existing heating system: a hot-air system which is popular due to its low cost and rapid response. The heating system is switched on only during the liturgical services and generates rapid temperature and humidity changes which, in the long run, are very damaging. The temperature stratification leaves people with cold feet, whereas the air at higher levels is too hot and dry. Moisture condenses on the cold walls. Deliquescent salts in masonry and frescoes undergo dangerous crystallization cycles. Wooden artifacts contract and expand in line with humidity cycles. Deposition of candle and incense smoke is increased, darkening the artworks. The essay discusses these problems, some common errors, and possible methods to mitigate the risk factors. (A.A.- AATA)

Conrad, Ernest *A table for classification of climatic control potential in buildings* Landmark Facilities Group, Inc., Norwalk, CT (1995).

Kerschner, K. Richard Providing safe and practical environments for cultural properties in historic buildings...and beyond. (Presented at 20th Annual National Archives Preservation Conference. Beyond the Numbers: Specifying and Achieving an Efficient Preservation Environment. March 16, 2006). (2006) http://www.archives.gov/preservation/conferences/2006/kerschner.pdf

Kerschner, L. Richard; Baker, Jennifer Practical climate control: A selected, annotated bibliography. http://palimpsest.stanford.edu/byauth/kerschner/ccbiblio.html

For the purpose of this bibliography, practical climate control is described as alternative strategies to standard heating, venting, and air conditioning, or a modification in the design or use of standard HVAC systems to improve museum environments. Until the early 1980's, there was limited discussion of methods to improve environmental conditions other than complete climate control, since complete systems were required to achieve the recommended conditions of 48%-52% RH and 65-68°F. Since such systems were expensive and difficult to install in historic buildings and expensive to operate, few small and mid-sized museums were able to improve environmental conditions for their collections. In addition, maintenance of the recommended conditions could cause serious damage to historic buildings in temperate climates.

During the mid 1980's, several U.S. conservators and engineers initiated a different approach to environmental control. They began to investigate simpler, low cost methods for improving collection environments. Adopting methods developed in Canada and the United Kingdom during the 1970's, their goal was not to achieve a "perfect" climate, but rather to improve existing conditions by allowing temperature and relative humidity levels to float seasonally within broader limits while limiting temperature and RH extremes. This holistic approach led to the investigation of practical climate control measures such as minimal heating during winter months to avoid drying out artifacts and buildings, humidistatically-controlled heating to prevent high humidity levels during cool rainy periods, and humidistatically-controlled ventilation to decrease humidity and heat buildup in collection buildings during hot and humid weather. In addition, efforts were made to control problems at the source: direct water away from buildings by improving building and ground drainage systems, control dust on paths and roadways throughout the site, change programming so that historic buildings would not have to be heated and desiccated during the coldest winter months. For a more complete explanation of practical climate control measures, read Kerschner's article referenced in the bibliography.

In the early 1990's, the development of practical climate control methods was aided by two actions. (1) The National Endowment for the Humanities established the Division of Preservation and Access and began awarding grants of up to $1 million to improve collection environments. The NEH recognized that practical climate control methods were

cost effective and had a potential to significantly improve environmental conditions for material culture artifacts. (2) The Smithsonian's Conservation Analytical Laboratory published research that indicated that relative humidity standards broader than 48%-52% were safe for many materials. Although broader standards had been proposed by other conservators as early as 1964, CAL's often-challenged claim that museum's could save significant amounts of money by designing environmental improvement systems to the "new" standards caught the attention of large and small museums throughout the U.S and heightened interest in practical climate control methods. (Author's introduction)

Kerschner, Richard L. Implementation of practical climate control strategies at the Shelburne Museum. In *The conservation of heritage interiors: Preprints of a conference symposium 2000, Ottawa, Canada May 17 to 20, 2000 .* Canadian Conservation Institute , Ottawa, Canada (2000), pp. 161-166.

From 1992 to 1998, the Shelburne Museum implemented a variety of practical climate control strategies to mitigate relative humidity (RH) extremes in 15 historic buildings and five new or reproduction structures containing approximately 80 000 collections artifacts. The purpose of this paper is to evaluate the success of these strategies and to share the lessons learned. Recent modification of RH guidelines for museums favours the use of practical climate control strategies. However, conservators employing these strategies must be thoroughly familiar with their collections so that artifacts that cannot tolerate wider humidity standards can be identified and protected. The Getty Conservation Institute quantified the success of these practical climate control methods in a study of environmental conditions in three selected buildings before and after improvements. Humidistatically controlled conservation heating was very successful, but the requirement to keep buildings cold during the winter can affect public programming and exhibit preparation and maintenance. Environmental improvements from humidistatically controlled conservation ventilation were positive but less dramatic. Use of conventional HVAC systems was modified to maintain safe environmental conditions for the historic structures and the objects they contain. Direct digital controls essential to operate HVAC systems and fans must be monitored and maintained, and good service from the vendor of the controls is crucial. (BCIN)

Kerschner, Richard L. A practical approach to environmental requirements for collections in historic buildings. *Journal of the American Institute for Conservation* 31, 1 (1992), pp. 65-76.

Ideal environmental conditions for the preservation of artifacts housed in a historic structure often differ from the ideal conditions for the preservation of the structure itself. It is important to consider carefully the preservation requirements of both the collection and the building when setting specific temperature and humidity standards and designating

climate control systems. For historic house museums in the northeastern United States, a compromise acceptable relative humidity (RH) range of 35% in the winter to 60% in the summer with gradual seasonal changes is proposed. Seven specific climate control actions to improve environmental conditions in historic structures are discussed. They include reducing environmental problems at the source, reducing heat to maintain reasonable RH levels during the winter, humidistatically controlled heating and ventilating, and modified use of conventional climate control systems. (A.A.)

Kozlowski, Roman Novel heating strategy of historic churches - the friendly heating project. http://www.ucl.ac.uk/sustainableheritage/conference-proceedings/pdf/2B.9_kozlowski.pdf

It is generally recognised that heating of historic churches as adverse effects on their structure and contents due to fluctuations of temperature and relative humidity, enhanced deposition of particulates and condensation of moisture on cold surfaces. The Friendly Heating project has developed a novel strategy of a localised heating of people in the seating area while keeping the natural climate elsewhere in the church. The heating system is based on low-temperature sources installed in the pews and emitting radiant heat reaching directly feet, legs and hands of people. The system is modular - each pew can be heated independently, and fast - the operation temperature is reached in ten minutes. The proposed solution brings also a considerable saving of energy, and thus protects the environment. It is an important step towards better adaptation of historic buildings containing artworks for the use by citizens (abstract from UCL-website)

Maekawa, S.; Toledo, F. Sustainable climate control for historic buildings in subtropical climates. *Management of environmental quality: An international journal* 14, 3 (2003), pp. 369-382.

To preserve both cultural collections and historic buildings that house them, a technologically simple, yet robust climate control system was installed in the Historic Archive of the Canary Islands. The archive is located in a municipal building, a late-19th-century massive masonry building in the city of La Laguna, on Tenerife Island, Spain. The system was designed to maintain the RH level necessary for preventing microbial activities on collections in cultural institutions by operating residential-type ventilators and a convective heater under a humidistatic control. The authors have confirmed that the system not only successfully eliminated events of high RH but also stabilized the climate. The annual temperature variation was significantly reduced, although daily variations increased. The room's moisture content was reduced to less than that of the outside, and microbial activities were reduced in the environment. The system was simple to install and inexpensive to operate. (A.A. - AATA)

Maekawa, Shin; Beltran, Vincent. Climate controls for historic buildings: a new strategy. *GCI Newsletter* 19, 1 (2004). http://www.getty.edu/conservation/publications/newsletters/19_1/news_in_cons2.html

Many museums, libraries, and archives housed in hot and humid regions have sought to reduce the threat posed by biological infestation by controlling relative humidity through the use of air-conditioning systems. But use of these systems can result in other problems. For this reason, the GCI has been conducting research to identify and test alternative systems that are robust, sustainable, and simple to operate. (Author's abstract)

Maekawa, Shin; Beltran, Vincent and Toledo, Franciza. Testing alternatives to conventional air-conditioning in coastal Georgia. *APT Bulletin* 38, 2-3 (2007), pp. 3-12.

Maekawa, Shin; Toledo, Franciza. A climate control system for Hollybourne Cottage, Jekyll Island Historic District, Georgia. In *IAQ 2001: Moisture, Microbes, and Health Effects: Indoor Air Quality and Moisture in Buildings in San Francisco, CA, November 4-7, 2001.* American Society of Heating Refrigeration Air-conditioning Engineers (ASHRAE), (2001). http://www.getty.edu/conservation/publications/pdf_publications/iaq453.pdf

The efficacy of a humidistat-controlled mechanical ventilation and space heating system was studied for creating a preservation environment for both objects and historic buildings (such as museums, libraries, and archives) that are located in warm, humid climate regions. The goal was to reduce and stabilize the level of relative humidity to avoid deterioration of collections by fungi and bacteria. A low-cost, robust, and technically simple climate control system was designed and tested at Hollybourne Cottage, a 100-year-old, two-and-one-half story faux tabby building. The cottage is located in the Jekyll Island Historic District on the Atlantic coast of the state of Georgia in the United States, within the ASHRAE-defined warm, humid cooling climate region. The efficacy of the control scheme was evaluated through monitoring climates, dust depositions, and microbial activities in the building before and after the installation of the system. (A.A. - AATA)

Maekawa, Shin; Toledo, Franciza. Controlled ventilation and heating to preserve collections in historic buildings in hot and humid regions. In *13th triennial meeting, Rio de Janeiro, 22-27 September 2002: Preprints.* ICOM Committee for Conservation and Roy Vontobel, eds. James & James, London (2002), pp. 58-65. http://getty.edu/conservation/publications/pdf_publications/icomcc1.pdf

Ventilator-heater-based climate control systems, designed to provide preservation environments for both buildings and their collections, were installed in two historic buildings in hot and humid regions. Relative humidity (RH) sensors located both inside and outside the buildings controlled the operation of the systems. Their environments were

monitored before and after the installation and operation of the climate systems to evaluate their effectiveness. An RH of less than 75% was maintained. Dust depositions increased slightly, only as a result of air movement, since the supply air had been filtered. In one case, microbial activity was reduced significantly. The installation of the systems and the modifications to the buildings were very simple. The operation and costs of running the ventilators and heaters were documented during the study. (A.A. - AATA)

Maekawa, Shin; Valentin, Nieves. Ventilation and heating-based microbial controls for cultural institutions. *Moulds, health and heritage: September 4-5, Braunschweig 2003.* Braunschweigisches Landesmuseum, Braunschweig (2003).

Historic buildings have been adapted to house cultural objects and records. However, especially in hot and humid regions of the world, these collections often suffer from fungal and bacterial attacks, primarily due to poor environmental conditions. These cultural institutions have attempted installing air-conditioning systems both to improve the collection environment and to increase the comfort level of visitors and staff members. However, the results of these installations have yielded less than desired environmental improvement. Therefore, there is a great need for a viable alternative solution to air-conditioning systems. To meet that need, the use of humidistatically controlled mechanical ventilation and space heating is being investigated as a means to control microbial activities in historic buildings. Initially, a series of laboratory experiments were conducted to identify the efficacy of using ventilation to control microbial activities on paper surfaces and the surrounding environment. These experiments were repeated using an old book in a small room located in a historic building to simulate more realistic conditions found in archives in historic buildings. Based on the above principles and results, an experimental climate control system was installed in two historic buildings in hot and humid climatic regions--Jekyll Island, Georgia, USA, and Tenerife Island, Spain. The efficacy evaluation study of the climate systems was carried out by monitoring of environmental parameters and activities of fungi and bacteria before and after the installation of the systems. A concept of humidistatic control of an environment for reducing microbial activities and its application in historic buildings is presented. (A.A.)

Michalski, Stefan. Climate control priorities and solutions for collections in historic buildings. *Historic Preservation Forum* 12, 4 (1998), pp. 8-14.

The control of RH continues to be an expensive and difficult challenge. In many situations, an attractive option is to control the RH within display cases instead of controlling the entire space. Stefan Michalski, Paul Marcon, and Tom Strang from the Canadian Conservation Institute are working on a centralized module supplying filtered and humidity-controlled air to each case through small tubes (typically 6-mm diameter) without return air, relying on compensating leakage from the case. The possibility of using an Internet application to provide remote control of the module and remote monitoring of the

units is being investigated.

Padfield, Tim; Larsen, Poul Klenz; Jensen, Lars Aasbjerg and Ryhl-Svendsen, Morten The potential and limits for passive air conditioning of museums, stores and archives. (2007)

The climate in unventilated stores and archives can be entirely passively controlled in temperate regions. Two actual and one simulated archive demonstrate the potential of various forms of conservation heating. The heat and humidity buffering of the building and its content must be sufficient to allow the building to cruise through both summer and winter extremes on inertial guidance. This brings the passive climate quite close to the strict limits imposed by standards and guidelines. The potential for increased chemical decay caused by lack of ventilation cannot be quantified because of a lack of research on the kinetics of gas-solid reactions in stores with multiple levels of enclosures. Extension of passive climate control to exhibition spaces cannot provide a constant climate but is certainly capable of reducing variation in temperature and relative humidity to a useful degree and within the safe limits according to current scientific knowledge. (Authors' abstract)

Park, Sharon C. Heating, ventilating, and cooling historic buildings. http://www.oldhouseweb.com/stories/Detailed/255.shtml

The need for modern mechanical systems is one of the most common reasons to undertake work on historic buildings. Such work includes upgrading older mechanical systems, improving the energy efficiency of existing buildings, installing new heating, ventilation, or air conditioning (HVAC) systems, or--particularly for museums--installing a climate control system with humidification and dehumidification capabilities. Decisions to install new HVAC or climate control systems often result from concern for occupant health and comfort, the desire to make older buildings marketable, or the need to provide specialized environments for operating computers, storing artifacts, or displaying museum collections. Unfortunately, occupant comfort and concerns for the objects within the building are sometimes given greater consideration than the building itself. In too many cases, applying modern standards of interior climate comfort to historic buildings has proven detrimental to historic materials and decorative finishes. This Preservation Brief underscores the importance of careful planning in order to balance the preservation objectives with interior climate needs of the building. It identifies some of the problems associated with installing mechanical systems in historic buildings and recommends approaches to minimizing the physical and visual damage associated with installing and maintaining these new or upgraded systems. (Author's introduction)

Ryhl-Svendsen, Morten; Padfield, Tim; Smith, Victoria A. and De Santis, Franco The indoor climate in historic buildings without mechanical ventilation systems. http://www.padfield.org/tim/cfys/ppubs/indclim.pdf

A study of the microclimate in four rooms in historic buildings reveals the different priorities, and, therefore, the different climatic data, needed by museum conservators, compared with people studying human welfare. In particular, it is important for conservators to know if a low pollutant concentration indoors is due to a clean outdoor climate, a low air exchange rate or pollutant absorbent artwork on the interior walls of the building. Relative humidity is a quality of the indoor climate that the conservator will try to hold within narrower bounds than those considered important to human health. A study of a historic archive shows how the structure of the room, the nature of the stored materials and the custodian's decisions combine to influence the indoor climate. An important result of this study is that the data cannot be usefully interpreted without continuous measurement of the air exchange rate in comparable detail to the measurements we routinely make of temperature, relative humidity and pollution concentration. (http://www.padfield.org/tim/cfys/ppubs/indclim.pdf)

Schellen, Henk *Heating monumental churches indoor climate and preservation of cultural heritage.* Technische Universiteit Eindhoven, Eindhoven (2002).

Schellen, Henk L.; Neilen, Dionne; Schijndel, Jos A. W. M. van and Aarle, Marcel A. P. van Indoor air humidity of monuments and hygrothermal surface conditions (presented at 6th Indoor Air Quality 2004 Meeting (IAQ2004) Padova, Italy, 10-12 November 2004). http://www.isac.cnr.it/iaq2004/pdfabstract/schellen_abstract.pdf

Schellen, Henricus Lambertus *Heating monumental churches: Indoor climate and preservation of cultural heritage* Technische Universiteit Eindhoven, Eindhoven (2002).

Schijndel, A. W. M. van; Schellen, H. L.; Neilen, D. and Aarle, M. A. P. van. Optimal setpoint operation of the climate control of a monumental church. In *Research in building physics: Proceedings of the 2nd International Conference on Building Physics, 14-18 September 2003, Antwerpen, Belgium.* Carmeliet, J; Hens, H and Vermeir, G, eds. A.A. Balkema, Lisse; Exton, PA (2003), pp. 777-784.

Staniforth, Sarah; Bullock, Linda; Hayes, Robert and Singleton, Andy. Conservation heating by cable and radio. *Museum Practice* 2, 1 (1997), pp. 71-74.

Staniforth, Sarah; Hayes, Bob and Bullock, Linda. Appropriate technologies for relative humidity control for museum collections housed in historic buildings. In *Preventive conservation: Practice, theory and research: Preprints of the contributions to the Ottawa Congress, 12-16 September 1994.* Roy, Ashok; Smith, Perry, eds. International Institute for Conservation of Historic and Artistic Works, London (1994), pp. 123-128.

The care of artifacts sensitive to relative humidity (RH) in historic buildings requires a different approach to that of collections housed in buildings which have been designed as museums. Consideration of the welfare of the building is as important as the care of the collection. The National Trust is also concerned about the effects of its properties on the wider environment, and works with limited financial resources. These many factors have resulted in the National Trust adapting standard museum practice for relative humidity control to the needs of historic buildings. Heating systems are operated on RH-priority, and dehumidification is used in storage areas. Electronic monitoring and control systems have been introduced. Good management and staff training procedures are essential if environmental control is to be successful. (A.A. - AATA)

Taylor, Joel. Negotiating the climate: a plan for the appraisal of control options in historic houses. *The conservator* 26, (2002), pp. 85-92.

A decision-making tool for assessing priorities for climate control in historic houses has been piloted at two English Heritage (EH) historic houses. The tool, an environmental management plan (EMP), had been designed by EH to help decision making regarding control strategy by bringing together all the relevant information and expertise at the same time. The focal point of the EMP is a facilitated meeting between various stakeholders and experts about the importance of the climate issues and the effectiveness of different control options, using a framework based on cost-benefit analysis. This article reports trials of such meetings to reach agreed broad solutions about climate control at Kenwood House and Chiswick House. It is shown that by careful planning, use of a prepared decision matrix, and an external facilitator, agreed solutions can be achieved in one day. Attention is drawn to the need for the issues affecting the decision to be extremely well defined, and to the importance of negotiation. (AATA, BCIN)