Environmental Management Performance Standards

Guidelines for historic buildings
Introduction to Environmental Performance Standards

These Environmental Performance Standards are essential reading for anyone responsible for managing collections within historic buildings.

These Standards have been developed from six high-level guiding principles on environmental management and are underpinned by real-world advice based on the wealth of knowledge and experience of English Heritage staff managing some of the most renowned historic properties in England.

These guiding principles are:

1. Involve all relevant disciplines in environmental decision-making – when in doubt, it is better to include rather than to exclude others’ contributions. Until the recent past, it was considered the responsibility of the conservators to care for the buildings around a collection. Now it is widely accepted that buildings and structures influence the indoor environment, and that in turn, the external environment affects the condition and behaviour of buildings and structures. The interdependence of the work of conservators, curators, conservation scientists, architects, engineers and facilities managers is illustrated by case study 3: Secret Wartime Tunnels at Dover Castle. Kent, which demonstrates the multidisciplinary nature of decision making for environmental control.

2. Whatever standards you choose to use, think about their relevance and apply them to your circumstances – do not accept them in their entirety without question.

3. Remember that, while we are responsible for the historic environment, we are also stewards of the whole of our heritage, both natural and cultural.

4. Antoine de Saint Exupéry remarked: ‘We have not inherited the earth from our parents, we have borrowed it from our children’. While we may not be able to change the external environment, case study 5 on Chiswick House, London demonstrates the kind of responsible and considerate attitude needed when a historic property is used for private events.

5. These principles distil the recommendations on environmental management contained in these guidelines. The guidelines expand upon these principles and illustrate their application in a number of case studies, which focus on important English Heritage assets – its historic properties.

6. Purpose-built museum buildings are designed to protect collections as well as to provide for the comfort of visitors and staff. In contrast, a historic building itself may be the first and most important object, as illustrated in case study 1: Chapel of St Leonard, Farleigh Hungerford Castle, Somerset. Here, preventive and passive measures were evaluated in order to understand better how to control the effects of the environment on a historically sensitive building fabric.

7. Historic buildings may be vulnerable because of their location, construction and condition; threats to a building’s fabric are increased when the climate, weather and the seasons are changed. Buildings are vulnerable not only to climate change but also to the effects of pollution, which can be particularly damaging. Historic places should be the first choice for historic properties.

8. Historic buildings are part of the landscape and the human environment. Buildings and streets are part of the outdoor environment, and in that turn, the external environment affects the condition and behaviour of buildings and structures. The interdependence of the work of conservators, curators, conservation scientists, architects, engineers and facilities managers is illustrated by case study 3: Secret Wartime Tunnels at Dover Castle. Kent, which demonstrates the multidisciplinary nature of decision making for environmental control.

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A building maintenance programme must therefore not only be planned, it must also be executed in order to reduce the risk of water penetration, higher levels of indoor relative humidity and an increase in the incidence of mould growth. For these reasons, the Environmental Performance Standards in the following six case studies are specific to the conditions in each case, rather than prescriptive. They follow objectively based standards tailored to individual historic properties, whose distinctiveness in each example is defined by the institutional aims and statement of management for the building.

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Project outline
To further English Heritage’s policy, which emphasizes the importance of maintenance, the site usefully illustrates the significance of preventive as opposed to corrective maintenance in mitigating deterioration factors, and in sustaining the best possible conditions within the chapel through passive means of environmental control.

Performance requirements
Site description: The chapel comprises two main spaces: a large single rectangular space incorporating the nave and chancel under an open-trussed, stone-tiled roof and a smaller north chapel with lead roof over a vaulted crypt. Later additions include a small western porch (15th century) and a small wash building abutting the north-east corner (now incorporating public toilets on the ground floor; and the ticket office and shop above).

Encircled on its north and west by a modern perimeter wall, the chapel is partially embedded into the sloping crest of land, with the main nave some 1.2m below ground at the west end, while at the east end, the floor of the chancel is almost 2m above external ground level.

Presentation and interpretation: Before a solution concept and control strategy can be developed, activities that can affect the interpretation of the chapel need to be assessed because sound environmental management must be based on quantitative or qualitative evidence and data. These datasets must inform the original objective or purpose of the display and interpretation of the chapel, and the development of performance standards. Useful datasets include:

- actual and planned number of visitors and events
- available surveys and environmental monitoring data
- opening hours and use patterns
- diagnostic environmental monitoring to assess the suitability of a space for the intended use

It should be noted that such evidence can be gathered through non-invasive and non-destructive methods, which should always take priority.

The objectives for the presentation of St Leonard Chapel could be described as follows:

- To communicate the complex and cumulative history of the chapel within the context of Farleigh Hungerford Castle and its grounds, highlighting its architectural and artistic beauty.
- Understanding the inherent features that promote environmental stability in a historic building; these are given, but they must be understood if they are to be used to their full potential.

Aim
To understand the inherent environmental performance of the building the condition of the fabric and the impact of subsequent alterations in its use, as a means of determining strategies for improving the internal environment for the benefit of both the building and its contents. By breaking the cycle of reactive repair to initiate a programme of informed building maintenance and management.

Statement of significance
The Chapel of St Leonard is nestled among the ruins of Farleigh Hungerford Castle, an extensive fortified building dating from the late 14th century. Originally the local parish church, the Hungerford family converted it into their private family chapel in the 1440s. Despite numerous periods of neglect and dereliction, and extensive alterations to the fabric, the chapel stands virtually intact and contains a series of important medieval wall paintings, numerous family tombs, and a small collection of late Jacobean wooden furniture. The crypt contains arguably the finest collection of 16th- and 17th-century anthropomorphic lead coffins in England.

Conservation and care issues: In reality, the capacity for preservation of historic buildings is frequently compromised by previous restorations and invidious use of added materials. Furthermore, the need to balance preservation of the fabric with the capacity of the building for visitor access is a relatively recent challenge. This means that any conservation intervention must consider that the building no longer functions as it was originally designed.

Solution concept: Typical of many medieval structures, the chapel was not designed with any deliberate means of environmental control, but rather has relied on the passive buffering of the structure. Equally common, the chapel has been subject to numerous physical alterations, not least the blocking of the nave windows, the loss of external render, and modern re-painting with cementitious mortar. The chapel interior retains sensitive historic wall paintings, which are integral to the fabric, so the nature of the building envelope and its limitations need to be considered before designing the right control strategy.

The introduction of fixed mechanical environmental control is neither feasible, nor desirable for this site. Previous interventions have been limited to the introduction of a few basic storage heaters; whose heat output, compared to the air volume of the chapel does not have a significant impact on internal stability. There has never been any agreed operational regime for the heaters but the custodian could have nominal control by switching them on and off. The development of an environmental control strategy can offer passive remodelling, and in combination with targeted repairs and maintenance can assist in reducing the rates of deterioration to the chapel and its interior.

Control strategy: An environmental control strategy must be based on an in-depth understanding of the changes that have occurred to the building in the past. The following three measures summarise the process of developing a control strategy:

- Understanding the inherent features that promote environmental stability in a historic building; these are given, but they must be understood if they are to be used to their full potential.
- Taking further action to enhance passive control; this involves capital expenditure. Works improved the capability of the building to resist the weather, such as enhancing the rainwater goods and improving the stability of internal conditions with a new insulated roof in 2001.
- Taking additional routine measures to maintain control for which an additional expenditure will be required. This requires an effective building maintenance programme to sustain the condition of the chapel. However, the maintenance budget for the chapel is part of the maintenance budget of a larger site, its needs have to be compared with other urgent issues, such as collapsing walls, which have health and safety consequences, and priorities decided.

English Heritage carried out a number of key technical studies to characterise the environment in and around the building before deciding on the control strategy appropriate to the chapel. These studies comprised:

- research on the physical history of the site and its buildings;
- a condition survey of both the building and key significant features;
- a survey of microbiological factors; and the initiation of a monitoring programme.

They demonstrate the complexity of the environmental issues surrounding the chapel and that the whole building was intended to benefit from any adaptation to avoid condensation risks.

Achieving and maintaining an acceptable solution
Ground drainage: Where problems above ground (such as damp lower portions of walls)
are evident, drainage may need to be characterized in order to isolate any problem caused by underground conditions. In the case of St Leonard Chapel this should not have huge resource implications.

Maintenance in context. Maintenance of the chapel cannot be restricted to just the visible structure when the condition of the land around it and the underground drainage are so critical to its well-being. The chapel is situated in a hollow surrounded by a battlemented retaining wall. This creates a local contest for the building. Vegetation and silt of the drains are critical issues for the chapel’s maintenance. A regular programme of preventive maintenance is necessary to reduce water ingress into the walls. Gulles must be kept clear and free from vegetation if they are not to retain liquid moisture and cause damp penetration. This building has a gully along the west wall.

Maintenance of the fabric. As early as 1839 a trust was set up to maintain the chapel and which may have been associated with one of the roof repairs in 1840. Nevertheless, in 1844 a plaster fall occurred and revealed the medieval wall paintings. Extensive and intrusive repairs following long periods of neglect can create extreme cycles that may not stabilize the building or benefit the integrity of the structure. The principle of little and often should ideally be applied to historic buildings to keep them physically sound and weatherproof. Keeping a building in good condition ensures that it is able to resist the weather for its own survival and contributes towards stabilizing internal conditions for the decorative wall finishes, fixtures and fittings.

Unfortunately this was not something that happened to the chapel in the past, although since being taken under the care of English Heritage, more detailed evaluation of the more vulnerable points in the chapel that require regular and routine inspection have taken place.

Evaluation through monitoring. It is important in the complex circumstances of the chapel to consider various solutions as responses to understood causes rather than to rush to a conclusion on the basis of slim or misleading evidence.

Monitoring had established that the building had little thermal buffering, especially through the open-tiled roof, which led to almost immediate air exchange between the interior and the exterior of the building.

Diagnostics monitoring is continuing at St Leonard Chapel with the purpose of understanding the effectiveness of the new insulated roof of the chapel. Vertical profiles of conditions are being recorded at intervals from the roof to the ground in the south-east corner of the chapel in which the St George and the Dragon wall painting is located. Depending on the results of these records, monitoring decisions will be made on the need and design of any permanent system of monitoring.

Ventilation: Ventilation is often challenging in the context of historic structures. At one extreme, sealing a historic building is both practically impossible, and can actually accelerate damage through raising internal relative humidity. At the other extreme, draughts created by open doors and windows can be equally deleterious, as they provide for almost uncontrolled air exchange.

At St Leonard Chapel the diagnostic investigations identified that rapid exchange of moisture-laden external air through gaps in the roof exacerbated through the west door open throughout the day resulted in periods of prolonged condensation as the air came in contact with cold internal surfaces. Immediate improvements were achieved through the installation of an automatic door closure device.

Re-roofing to improve environmental stability. Previous historic roof repairs had never been deliberately designed to attempt to improve environmental conditions inside the chapel. Rather, since the late 17th century in six programmes of repair (1610, 1782, 1840, 1900, 1930 and 1950) responded to specific damage and disruption; largely due to periods of neglect, which included replaced partial collapse. The extent of repair ranged from nearly a complete re-roofing, to localised repair of holes in the roof. It is often the most recent, and more collaborative, building repair programme, derived from a comprehensive building condition survey in 1994 that identified the potential synergy of repairs that would provide opportunities for environmental improvement and demonstrate the importance of routine maintenance.

Reduced air infiltration was achieved through complete re-tile and the design of internal timber boarding, which also offered a potential insulating layer to improve thermal buffering. All details were carefully considered from an aesthetic and historical perspective, and agreed with the Historic Building Inspector. The resulting stability in conditions, and the reduction in levels of high humidity entering the chapel, were designed to reduce substantially the risk of surface condensation on the wall paintings, marble tombs and other stone tombs.

Lessons learned from the Chapel of St Leonard

Integration of building, site and landscape. The two reports that were prepared in 2000 and 2003 focused separately on the castle ruins and context, and on the chapel, respectively. These reports have been important in understanding the physical history of the individual components of the site, but not of the site as a whole. It can be difficult to make connections between parts of the heritage that ought to belong together and to analyse how problems with one might affect the other as well as whether solving the problems in one might improve the other also.

An integrated Conservation Management Plan for the whole site would ensure that environmental management addresses the relevant issues throughout the site.

Understanding cause and effect of building alterations. The need for substantive roof re-roofing was identified following the condition survey of the fabric, and was originally considered as part of general building maintenance. In parallel, concerns over the condition of the wall paintings, as well as other internal features, highlighted the need to address environmental issues. The relative significance of the wall paintings, and the efforts made to evaluate their condition, provided the driver for improving the environment of the chapel as a whole. Most important in the development and design of the building works, these overlapping concerns prompted the need to gain an in-depth understanding of the interaction between the exterior and internal environments and the behaviour of the fabric of the building. A range of specialists from English Heritage, both regional and central, and external consultants became involved. They included architects, building managers, building services engineers, building scientists, conservation scientists and conservators. Through persistent collaborative working among these specialists, an integrated approach to the environmental improvements and management of the chapel gradually developed.

The project not only demonstrates the need to understand the condition of the building and the environmental impacts on it through in-depth study of what is actually going on, but also the importance of a post-works review to check the efficacy and success of any intervention.

Points to consider

In summary, the following were points or steps in St Leonard Chapel project plan:

1. Understanding through in-depth interdisciplinary study the interactions between the exterior and interior environment across the different elements of the building roof, walls and floors.

2. Implementing diagnostic monitoring in order to ensure that the causes of problems were understood before solutions are devised.

3. Ensuring that the correct range of advisers, specialists and consultants were engaged in the project and to provide the means by which they could be encouraged to collaborate effectively.

4. Identifying the potential synergy of repairs that would provide opportunities for environmental improvement.

5. Utilising the opportunity provided by intervention to demonstrate the value of routine maintenance, applying the principle of little and often, in order to keep historic buildings physically sound and weatherproof.

6. Maintaining the site beyond the footprint of the building in order to divert moisture problems away from the structure.

7. Undertaking a post-works review to check the efficacy and success of any intervention.

References


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Fig 3 Enclosure around Chapel of St Leonard showing ground sloping towards the chapel.

Fig 4 Relative humidity (RH) and temperature at low and high level at the wall-painting surface.
Case study 2 Brodsworth Hall, South Yorkshire  
Demonstrating environmental management as an integral part of a refurbishment project

Aim
‘a gentle approach’ (English Heritage Commissioners and Executive Board) To conserve and present to the public the history of Brodsworth Hall, including the effect on materials of the passage of time, by arresting years of progressive decay without destroying its special character.

The real significance of Brodsworth Hall is that it represents the evolution of a country house, not just one period, but a palimpsest, with evidence of changes from time to time. Because it gradually fell into disuse, Brodsworth Hall contains not only fine furnishings and fittings, but also many of the more mundane items essential to any country house.

Project outline
To further its policy of educating visitors on the evolution of the historic house, Brodsworth Hall was acquired by English Heritage in 1990. The National Heritage Memorial Fund purchased the collections and English Heritage agreed to spend the equivalent sum of money on repairs and other work in order to be able to open the property to the public.

Today Brodsworth Hall is managed jointly by two part-time curators, three visitor operation managers and two conservation cleaners. The day-to-day running of the property is hugely dependent on the work of a large group of volunteers.

Performance requirements
The aim of environmental improvements and management, once the written conservation plan was completed, was to stabilise conditions and slow down decay. Operational success was to be achieved by supplementing the existing technology within the property with a modern environmental control system. Planning for environmental improvements had to consider the comfort needs of the small core group of staff and volunteer stewards.

Planning for comfort
In project planning terms, it is important to control not only the environmental requirements of the building and its collections, but also how the comfort requirements of staff, volunteers and visitors will be met. It is imperative that any environmental control system for human comfort – such as heating – does not cause excessive dryness in any historic areas adjacent to staff areas.

Solution concept
Successful conservation and presentation of a historic property, in a physical state that denotes the passage of time, requires close and constant collaboration between the curators and conservators. Materials deteriorate at different rates and the amount of conservation needs to be carefully balanced with the need to avoid visual differences between materials in the same historic room setting.

Control strategy
The need for different levels of environmental control for different uses was recognised right at the start of the project. The installation of a Building Management System (BMS) in the property was seen as key to the operational management of different areas: conservation heating in the display areas and comfort heating in the rest and services areas. A BMS consists of sophisticated engineering software that is designed to control automatically a range of environmental services including heating, cooling, ventilation, humidification and dehumidification.

Monitoring the environment through the BMS is relatively unusual because the software normally discards data after an engineer has made sure that the control equipment is operating correctly. A radio telemetry based temperature and relative humidity (RH) monitoring system was also installed to give independent verification of the performance of the BMS controlled heating. Such systems also allow placing of sensors closer to vulnerable objects, whereas the position of the wired-in sensors for the BMS can require substantial thought and compromise. Other features of a BMS can include fire detection and security protection.

The installation of a BMS improves the management of a complex building where technical support is assured. At Brodsworth Hall, the environmental control strategy involves a BMS managing relatively simple heating equipment that is intended to work in harmony with the environment and to assist the building’s natural buffering capability. If a BMS is being used in an unusual way then management needs to be aware that they will need to be more heavily involved in its operation and that external expertise may be required. Project planning must therefore consider both the capital cost of physical installation and the revenue consequences for downloading of datasets, routine environmental management and maintenance.

Maintaining the building
The consequence of neglect is rapid deterioration from water penetration and pest ingress, leading to a range of serious problems from dry rot to collapsing ceilings or floors. One of the main aims of the Brodsworth Hall project was to weather-proof the building so that it is able to resist the weather for its own survival. Essential risk-reducing work at Brodsworth Hall took place to make the building water-tight and so that later it could contribute towards stabilising internal conditions for the exhibits.

Fundamental to good management is ongoing maintenance. A building maintenance programme will ensure that these regular inspections take place and are acted upon. The asset management project presently running within English Heritage will develop building maintenance programmes, among other functions and ensure that the appropriate resources are available.

Achieving and maintaining an acceptable solution
The quality of environmental management at Brodsworth Hall was assured by a clear strategy to divide the building into environmental zones.

It is not unusual for different members on a major project such as Brodsworth Hall to have different perceptions of when a project is finished. Often the pressure to open the building is so great that the commissioning, testing and handover of equipment such as the BMS must be completed before the official opening.

The success of a project in stabilising the environment within a property and the effectiveness of subsequent environmental management system can best be determined through diagnostic monitoring. Monitoring of internal and external relative humidity and temperature was undertaken throughout the project.
Information management: In projects such as Brodsworth Hall, involving several inputs, and particularly where collections are removed from the building to enable major repair work to be done, it is not only important for individuals to maintain personal records (such as ledgers, treatment and survey reports), but it is also imperative that project information is properly managed. Some of the questions that should be addressed are:

- Who is recording what information, in what form and where is it being kept?
- Who has access to individual project records?
- Do these records belong to the property or to both places?
- Who is responsible for updating records?
- When should records be weeded and archived?

Records should not remain in individual files after a project is completed. To ensure operational continuity and corporate learning, an appropriate information management system should be set up.

Evaluation and feedback: All projects must be evaluated and the conclusions fed back into the organisation to allow it to learn. Best practice recommends that a project is reviewed in a rolling programme of condition checks, routine maintenance (such as an annual ‘deep-clean’), the national ten-year audit and the quinquennial survey of the historic estate, all of which will ensure that there are regular inspections of buildings and collections.

Lessons learned
- At Brodsworth, opening to visitors had conservation consequences that were not foreseen during the planning process, because the project lacked the services of a dedicated conservator; a vacancy that has now been filled through the appointment of a regional conservator. When the shutters, which had not been used for years, were opened, an unexpected amount of daylight entered the property. The situation was remedied by the use of neutral density film, as well as by moveable blinds, for daylight control. Neither was there sufficient appreciation of the extent to which the fragile interior of the property would suddenly be subjected to heavy use. Part of the project management needs to consider how the property will function when the project is complete and the skills, time and resources are available in the property to support it.

Points to consider
- In summary, the following were points or steps in Brodsworth project plan:
  1. Ensuring that an experienced project manager is appointed to oversee the whole conservation project including collections, buildings and gardens.
  2. Discussing the conservation approach to be adopted by different elements of the property – collections, buildings and gardens – as soon as the project is conceived.
  3. Being prepared to explain any differences in conservation approach to front-of-house staff and the public, using it as an educational opportunity.
  4. Carrying out a risk assessment of the property as a whole in order to prioritise conservation needs and resources.
  5. Being aware of overlaps and possible tensions among the different conservation programmes for collections, buildings and gardens.
  6. Ensuring that the different programmes are clear to all in the project and those responsible for the proper on-going operation.
  7. Ensuring that the level of technology that is introduced to manage the environment of the property is commensurate with the physical and financial resources available at the property itself.
  8. Providing local training to ensure smooth running of instruments and equipment.
  9. Instigating a clear policy for recording project decisions and documenting the progress of a project in order to ensure that the ‘corporate memory’ of a project is available to provide a learning resource for the future.

Case study 3 Secret Wartime Tunnels, Dover Castle, Kent

Demonstrating the multidisciplinary nature of decision making for environmental control

Aim
To understand the nature and environmental performance of the Secret Wartime Tunnels at Dover Castle, in response to a particular set of problems in order to produce a workable solution to meet the requirements of all parties.

Statement of significance
Dover Castle is the only medieval castle to have had layers of tunnels excavated under it during the Second World War to form a Combined Headquarters and a Forward Dressing Station… The castle also had a Regional Seat of Government [set up within the tunnels], which functioned from c 1962 to 1984 and which still contains significant amounts of contemporary equipment. "Dover Castle the key to England: a conservation statement", Jonathan Coast, revised March 2004, English Heritage.

The role of the wartime tunnels in national affairs during the Second World War has...
can result in potentially damaging high levels of RH and harmful carbon dioxide levels. Relying solely on natural air exchange between the exterior and interior ... and its adverse effect on the stability of the indoor environment. Instead, controlled ventilation can be achieved by:

• mechanically assisted natural ventilation – the installation of fans in unobtrusive places to draw air from or into an interior;
• and by mechanical ventilation – the installation of fans and ductwork systems to an interior. (A historic ductwork system already existed in the Secret Wartime Tunnels, so this could be utilised.)

In comparing these two options, the extent of potential control, invasiveness to the building fabric and cost were found to be different: the first option moderates ... tried elsewhere with some success, while the second is generally considered to be intrusive to a historic site. The level of

contributed significantly to the long and stirring history of Dover Castle. The tunnels survive as a unique testament to military planning, defence and operations, as part of the forward operations centre for the eventual invasion of northern Europe on June 6, 1944.

**Project outline**

To further English Heritage’s duty to preserve one of its most visited and significant monuments and to maintain a safe environment for visitors and staff.

**Performance requirements**

**Site description:** Some of the chalk wartime tunnels are lined either with brick or with steel. The Napoleonic Casemate barrack rooms were extended and two other levels of tunnels, known as Dumpy and Annex, were constructed to house the operations headquarters and an underground hospital. The tunnels at Casemate contain features and items of equipment known to have remained in place since their original installation when the tunnels became operational. Annex accommodates a rare example of a British underground military hospital, although its original equipment had been removed and it is now fitted out with contemporary equipment from other collections.

Presentation and interpretation: The objectives for the presentation of the Secret Wartime Tunnels could be described as follows:

• To communicate the history of the tunnels within the context of Dover Castle;
• To highlight significant historical developments that are associated with major events in History;
• To demonstrate important architectural and civil engineering advances that are unique to this site;
• To keep technological interventions for lighting and environmental control to a minimum and to maintain the quality of the interior fixtures and fittings;
• To sustain continued use of historic objects, which are essential to the presentation and understanding of the spaces;
• To maintain the fabric and collections in a sympathetic way while controlling relative humidity (RH), ventilation and temperature;
• To enhance the interest and the educational relevance of the tunnels to a wide range of visitors, while reducing the adverse impact of these visits on the tunnels.

**Solution concept:** The tunnels contain a variety of historic artefacts made from a range of materials. They are, in themselves, a complex environment with various ventilation routes. Natural ventilation was improved using original fans and ducting. However, it was decided to turn off the fans in the Casemate level and to rely on natural ventilation, prompted by the continued mechanical failure of that plant. In 2001 a spectacular outbreak of mould growth in those tunnels occurred, which appeared to be the result of this action. Investigations were undertaken to understand and solve the environmental problems.

**Control strategy:** An environmental control strategy must be based on an in-depth understanding of natural and deliberate changes that have occurred in the tunnels and systems in the past. The following measures summarise the process of developing a control strategy:

• Bring together key local, regional and central English Heritage staff and their consultants to develop a coherent action plan;
• Understand and communicate in full the inherent features and condition of the structure that promote environmental stability, including responses to weather conditions;
• Understand and communicate the impact of change to links between spaces within the tunnels, and how this might affect environmental stability. Explain how open doors encourage natural airflow, the importance of which was not fully appreciated;
• Understand and communicate the wider impact of changes in the operation of ventilation equipment, and how it might affect human health and comfort;
• Ensure that solutions, whether technologically sophisticated or simple, can be operated easily by staff without a large extra burden.

Any control strategy needs to be sustained by an effective monitoring, renewal and maintenance programme.

**Achieving and maintaining an acceptable solution**

It is important to define what is ‘an acceptable solution’ in the context of the tunnels. High RH can encourage rapid mould growth, and therefore mechanical ventilation was re-instated in the Casemate tunnels to make the environment less conducive to mould growth. The following measures were taken:

• Airborne mould was sampled and identified.
• Effective cleaning regimes were introduced to reduce the level of mould spores in the air, and the importance of maintaining a good housekeeping regime emphasised.
• Every infected object was removed from the affected area, and cleaned in a controlled manner.
• Monitoring the moisture profiles in the tunnel walls confirmed that evaporation would generate high RH if there was insufficient ventilation to carry the moisture away.
• Air flows in critical areas were measured and improved where necessary. Many moulds have been found unable to germinate their spores and grow in air velocities greater than 0.2m-s, even at very high RH.

**Natural ventilation or mechanical ventilation?**

Ventilation is often a challenging issue in the context of an enclosed historic site. Natural air currents are not an acceptable alternative to controlled ventilation, while neither is sealing an occupied and lit space to control RH and temperature, or to prevent the ingress of dust, air pollution and pests. Inadequate ventilation can result in potentially damaging high levels of RH and harmful carbon dioxide levels. Relying solely on natural air exchange between the exterior and interior stepping through grates and gaps in the fabric has often been found to be inadequate, while opening windows is not an acceptable solution because of safety, security and pollution risks, and its adverse effect on the stability of the indoor environment. Instead, controlled ventilation can be achieved by:

• mechanically assisted natural ventilation – the installation of fans in unobtrusive places to draw air from or into an interior;
• and by mechanical ventilation – the installation of fans, filters, ductwork and perhaps also heaters and coolers to condition the air before it is supplied to an interior. (A historic ductwork system already existed in the Secret Wartime Tunnels, so this could be utilised.)

In comparing these two options, the extent of potential control, invasiveness to the building fabric and cost were found to be different: the first option moderates...

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**Fig 10** (above) Mould growth on telephone exchanges and under plotting table.

**Fig 11** (right) Mould growth on telephone exchanges and under plotting table.

**Fig 12** (above) Original ventilation ductwork in tunnel casemate.

**Fig 13** (right) Environmental Conditions in the tunnels; screenshot of part of the wireless monitoring system.
specialist equipment for cleaning. It is important that this significant investment is not wasted and that an ongoing cleaning regime is put in place to keep objects and the tunnel environment clean and free from the risk of further outbreaks of mould.

Monitoring: Monitoring of airflow, RH and temperature, and diagnostic studies of mould growth have been essential to understand the environmental conditions within the tunnels. It is important to realise that the weather, geology and resulting moisture levels in the chalk heavily influence the tunnel environment.

A real-time monitoring system has been installed to give early warning of conditions conducive to mould spore germination. It will also enable a more pro-active approach to be taken with the management and maintenance of the tunnels and their collections.

Lessons learned
The biggest lesson that can be learned from the Secret Wartime Tunnels project is that no single discipline on its own can have solved the problem. Everyone was concerned about the problem for different reasons:

- staff were concerned about health issues
- curators and conservators were concerned about the objects
- facilities managers were concerned about the condition of the chalk fabric

A solution was developed through constructive team working bringing together several disciplines and strands of expert advice. Open discussion of past experience enabled lessons to be learned. All parties worked together to find an acceptable solution to the problems that existed at that time, respecting each other’s areas of expertise and knowledge, and not attempting to allocate ‘blame’ or to criticise past decisions, which had been based on the best available information at the time.

Points to consider
In summary, the following were points or steps in the Secret Wartime Tunnels project plan:

1. Accepting that there may be situations and locations where environmental management will be challenging and that the best efforts might only achieve modest improvements.

2. Recognising that ‘museum’ conditions for collections may cause serious damage to unusual structures, such as chalk tunnels.

3. Understanding that the best solutions are developed through constructive team working to bring together unusual strands of expertise, such as mould identification.

4. Remembering that environment management often requires complex decision-making, centred around risk reduction of damage to shelters and to the collections, staff, and visitor health and comfort within the context of available resources.

5. Being open to advice from a variety of sources, both internal and external, while critically evaluating the benefits.

6. Ensuring that an environmental control strategy is based on an in-depth understanding of the natural and deliberate changes that occurred to the shelter systems in the past.

References and further reading
Florian, M. L. 1997 Heritage Eaters. London: James and James


Case study 4 Royal Garrison Artillery Barracks, Dover Castle
Demonstrating environmental control for storing archaeological and historic material in a building not constructed for this purpose

Aim
To understand the nature and performance of Royal Garrison Artillery Barracks at Dover Castle, and its suitability for the storage of collections.

Statement of significance
The Royal Garrison Artillery Barracks are one of the most recent barracks to survive at Dover. They are important for their link with coastal artillery, specifically to man coast batteries. The interior of the barracks is capable of sympathetic adaptation to collection storage.

Project outline
Mission: The Royal Garrison Artillery Barracks have been used almost unaltered as a regional store for archaeological and more recent material since the mid-1970s. This material is available for study by appointment to external researchers and is a rich resource for English Heritage local and regional staff. A study room has recently been provided for this purpose.

Function: To further English Heritage’s duty to manage its collections, while making minimal impact on the building in an effort to improve environmental conditions. The material stored in the Royal Garrison Artillery Barracks consists of small boxed archaeological finds, large archaeological finds, architectural reference materials, 20th-century artefacts (particularly from the Second World War and the Cold War), textiles and paper archives, including many archaeological plans from the south-east region of England.

Performance requirements
Site description: The Royal Garrison Artillery Barracks store is an early 20th-century stone building constructed originally as accommodation barracks. As such, it has rows of sash windows on both stories at each elevation. The building is orientated north-south, with the south-facing elevation orientated towards the English Channel. The timber windows frames on the south-facing elevation are protected from the weather, in particular from salt-laden wind, rain and sun. The interior of the building is a combination of open plan and smaller rooms, with solid floors, which makes it suited for storing heavy objects on the ground floor. Solar heat gain in the south-facing rooms is not a problem because the windows are shaded and the more environmentally sensitive materials such as the archives and modern materials associated with 20th-century artefacts are stored in the rooms that face north.

Storage: Before solution concept and control strategies can be developed, the conditions required by the stored material need to be assessed. This can be a complex process for archaeological collections, as their burial conditions and history can make objects of the same material type have a range of stability. For example, limestone ladeen with salt from burial is easily damaged by fluctuating relative humidity (RH), whereas a similar limestone with little or no salt is less vulnerable. The storage strategy is best informed with information about:

- the collections to be housed, and any plans for expansion or new acquisition;
- internal storage boxes and systems;
- the condition and buffering capacity of the building;
- available studies and internal environmental monitoring data;
- localised and centralised environmental improvements;
- use patterns and duration;
- and external weather conditions in particular rain, particularly wind-driven rain, solar radiation, wind speed and wind direction.

The priorities for the regional archaeological store could be described as follows:

- To make the collections safe and accessible to a wider range of users.
- To complete the documentation of the collections.
- To provide the environmental conditions appropriate to the different stored materials.
- To monitor RH and temperature, to analyse the data and to act upon the information.
- To implement an integrated pest management plan.

Solution concept: The nature of the structure and its limitations need to be assessed in order to design the right control strategy. The building has a number of large windows and sunlight could cause seasonal heating of the interior air. The poor condition of the timber on the south-facing windows will allow ingress of dust and transport pollution, and could allow insect pests to enter the store. It is also important to assess the vulnerability of the stored collections, and ideally to assign them to rooms known to provide the best environmental conditions for their protection. The most vulnerable elements of the stored collections were considered to be the Second World War and Cold War collections and archives. These are stored in the rooms that face north, having windows in the best condition, and hence the best buffered, and receive the least solar gain.

Control strategy: An environmental control strategy must be based on an in-depth...
understanding of the prevailing conditions in the building, and include steps to control the factors that influence them. The following 13 measures summarise the process of developing a control strategy for a storage building:

1. Examining the condition of the building, particularly the walls and windows most exposed to the prevailing weather (especially wind driven, salt-laden rain) that can infiltrate the building through weak points such as badly fitting windows.

2. Assessing the condition and capacity of the rainwater goods, including gutters and down pipes, in order to avoid the wetting of walls.

3. Ensuring through thorough maintenance that rainwater and groundwater is carried away from the building.

4. Checking that groundwater is not penetrating into the storage areas or into the building fabric.

5. The previous four factors can all lead to wet walls. It is important that if rooms with wet walls have to be used for storage, that sufficient gap is left between the interior of the wall and the collections to enable air circulation.

6. Deciding on the preventive conservation threats that present the greatest risk to the stored materials.

7. Undertaking routine inspection for pests and thorough cleaning of surfaces.

8. Deciding whether diagnostic, alarm-based or routine monitoring is required.

9. Undertaking routine sample condition checks and documenting the stored collections, concentrating on the materials known to be at greatest risk from the most severe threats.

10. Implementing an approach to environmental control in the building that is appropriate to the available time and skill of the staff.

11. Ensuring that materials vulnerable to poor environmental conditions are stored in the most stable parts of the building.

12. Adding additional environmental control to some rooms to provide more suitable environments.

13. Providing additional protection and stability for environmentally sensitive items through the use of passively controlled microclimates within boxes.

A control strategy can only be sustained through an effective renewal and maintenance programme, with resources allocated according to local needs and regional priorities.

Achieving and maintaining an acceptable solution

Maintenance of the fabric: When dealing with a store in a historic building, it is imperative that the requirements of the building are not forgotten. The building must be kept weatherproofed by ensuring that it is kept in good condition, following its original design and construction. In this way the building is able to resist the weather for its own survival and contribute towards stabilising internal conditions for the stored items.

Heating and dehumidification: Monitoring of the environment in the Royal Garrison Artillery Barracks has shown that the RH is generally high. The RH is currently controlled by a combination of heating and stand-alone dehumidifiers. This solution using low-temperature control has much to recommend it, although it is important to remember that some types of dehumidifiers need plumbing into the drain system to avoid flooding.

Conservation heating is used in the archive room and stabilises RH between 51% and 65%, with the temperature at about 6°C higher than outside temperature during winter. However, this approach needs to be balanced against the potential to increase the deterioration rate of the paper by raising the temperature. In the winter the temperatures are often too low for human comfort, and other methods, such as warm clothing or local heating, will be required if staff are to work in that area. However, the archive room is not habitually occupied.

Microclimates: The building’s natural RH is much too high for vulnerable archaeological metals, such as iron or copper alloy. Microclimates can be achieved in polypropylene boxes buffered with dry or conditioned silica gel. These provide reliable and relatively low-maintenance control of the environment immediately around the artefacts.

Zoning: All buildings have natural environmental zones that behave differently owing to their orientation on the site, the size of glazed areas, the volume of the spaces and the amount of air exchange with the exterior. Environmental zoning can be used deliberately in the management of a property. Diagnostic monitoring may reveal that the environment of a store could be improved if the spaces were to be divided into a number of manageable environmental zones, bearing in mind the following points:

• that the ambient zone that staff and visitors occupy could be conditioned similar to domestic premises, includes the study room and offices;

• that the microclimates described above collectively make up the tightly controlled zone for sensitive objects;

• and that the differently oriented faces of the building create different environmental conditions (for example, the north face is more stable and the south face is less stable).

By taking advantage of naturally occurring conditions, additional control is made simpler and cheaper.

Alarm-based monitoring: Currently, monitoring consists of a couple of decades’ experience of observing changes in objects and intermittent checks of particular problem areas or areas with vulnerable materials, using dataloggers and thermoanographs. Condition checks of the collections, the building and the environment also take place as part of the national audit of collections every ten years. The archaeological materials have been in storage for long enough to be known to be stable, but because the paper archive and textile store are relatively recent, regular monitoring should focus on these last two.

Diagnostic monitoring is currently underway using dataloggers. A discreet wireless telemetric data logging system to monitor RH and temperature has been acquired for the store and the site as a whole.

Considerations for the future

Staff resources: The pressure of work on a small staff limits the time that can be dedicated to routine environmental and collection management, including monitoring, condition checks, documentation and repacking. Although additional resources can be pulled together for special projects, the available time for routine tasks can dwindle in the face of requests for information, research, organising exhibitions and administration. It is therefore important to draw up a management plan for each store, and that one person is given overall responsibility and the resources to implement the plan.

Points to consider

In summary, the following were points or steps in the Royal Garrison Artillery Barracks project plan:

1. Drawing up a management plan for the store in order to overcome the inevitable peaks caused by other projects.

2. Improving the environmental stability of the building fabric, with due care for fire safety, before introducing technological improvements.

3. Giving one person overall responsibility and the resources to implement the plan.

4. That environmental monitoring data can be analysed using psychrometry to assess changes in moisture content and aid in the design of appropriate solutions to environmental control.

5. Considering the usefulness of zoning spaces and that creating microclimates in boxes is integral to environmental management with minimal energy input.

6. Understanding the advantages and disadvantages of heating and dehumidification to reduce RH in stores.

7. Assessing the condition and future use of stored collections in order to establish their vulnerability and environmental management options.

References


Achieving and maintaining acceptable conditions

“I can imagine that providing a listed building as beautiful as Chiswick House as a function venue can be a difficult task to manage with all the understandable restrictions and excited clients and suppliers and you do this very well.”

(A happy wedding couple, August 2003)

Fundamental to good management is good maintenance; and this is even more so in a historic property that is used for external events where the appearance of the building is at the forefront of client expectations. Routine annual inspections and corrective measures take place. This is essential if acceptable conditions are to be achieved and maintained.

Heating and cooling:

In English Heritage properties, the fires are usually unused and the heating and cooling systems are designed to maintain the rooms at constant temperature and humidity levels. The aim is to ensure that the building is comfortable and safe for the occupants and that the historic fabric is protected.

When Chiswick House is used as a venue for events, the aim is:

- to give a sense of splendour for hospitality, corporate and private functions, thus ensuring that a memorable occasion is had by everyone;
- to ensure that appropriate measures are in place to protect the furnishings, fittings and other vulnerable surfaces during functions (low-level paintings are glazed, perspex covers are placed on vulnerable horizontal surfaces and some furniture is stationed off or moved out of the way or into temporary storage);
- to provide comfortable conditions for the guests of Chiswick House;
- to manage the numbers of guests at any one time, in order to protect the property from excessive wear and tear;
- and to assess the impact of different functions on the conservation of Chiswick House.

Solution concept: Ambient temperature, relative humidity and ventilation need to be controlled during functions, both for the comfort of attendants and the protection of the room interiors. The impact on the internal environmental conditions of opening windows needs to be assessed and managed. With relatively recently heating systems in historic properties, they are not designed to deal with the demands of busy functions. Furthermore, the existing warm air heating system at Chiswick House causes large temperature differences across the building, with a 7°C difference having been recorded.

Control strategy: English Heritage manages other risks associated with the organisation of hospitality events by issuing a publication entitled ‘Practical Conservation Guidelines for Successful Hospitality Events in Historic Houses’. The guidelines are intended to provide advice on how to manage the risks associated with hospitality events, such as the serving of food, inadequate cleaning or waste disposal.

Post-function reports are written and questionnaires are completed after every event in order to evaluate their costs and benefits. Yet it is environmental monitoring information that is critical in assessing the impact of events on the building.

A typical function increases the RH by 15% and the temperature by 5°C, which is similar to the natural fluctuations experienced in these rooms. However, event-driven fluctuations of this magnitude may cause damage in other properties.

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A typical function increases the RH by 15% and the temperature by 5°C, which is similar to the natural fluctuations experienced in these rooms. However, event-driven fluctuations of this magnitude may cause damage in other properties.
Chimneys are normally capped, and ventilated capping ensures air flow through the chimney to avoid the risk of rain ingress, damp penetration, disintegration of the flue lining or pest infestation. Alternatively, rather than remaining unused, the chimney flues could be converted for use as vertical ducts to improve the distribution of conditioned air by allowing it to diffuse throughout the space and be vented out of the building by natural or assisted means.

Sealing a historic building can damage the fabric and the interiors, and it could contravene legislation that requires minimum ventilation for the health and comfort of occupants. Ventilation is particularly challenging in buildings where the level of occupancy can vary considerably between events and times when there are only staff on the premises. The quality that makes natural ventilation in a historic building desirable becomes a problem when the building has a large gathering in it. In such circumstances it is inevitable that ventilation will need some mechanical assistance.

Zoning: All buildings have natural environmental zones that behave differently due to their orientation on the site, the size of glazed areas, the volume of the spaces and the amount of air exchange with the exterior. The environmental differences can be accentuated by the activities that take place in the different spaces. Therefore, environmental zoning can be used deliberately in the environmental management of a property.

Chiswick House can be considered as two environmental zones: the first floor containing the decorative finishes and sensitive objects; and the ground floor which contains less sensitive objects. Activities that have a high impact on the environment, such as cooking and dancing, are only allowed in specific rooms on the ground floor.

Monitoring: Diagnostic monitoring of temperature and relative humidity can help evaluate the effects of functions and their impact on collections and interiors. When occupancy can influence environmental conditions, it may be advisable to monitor another environmental parameter namely, carbon dioxide, before, during and after functions, in order to establish the adequacy of ventilation provision.

Future actions
Working with the building: Opening doors and windows to improve ventilation moves large volumes of air into the building and with it dust, other pollutants and pests. Traditional buildings as environmental systems behave very differently to modern buildings, and therefore the building design and the environmental behaviour of any architectural precedents should be investigated in order to understand how they worked before trying to improve their performance with new equipment.

Burlington modelled Chiswick House on the design of Palladian villas where thermal windows and doors are known to have been opened to encourage air flow and to alleviate the oppressive heat of the Italian Veneto. Currently the thermal walls at Chiswick House are kept closed because of concerns that wind-driven rain could damage the paintings hanging in the octagonal salon and could allow the ingress of pests such as insects, squirrels, mice and birds. The use of Chiswick House today is very similar to the use for which it was originally designed. The regulations that govern human comfort and the environmental factors that must be controlled to protect interiors and furnishings in a historic property need to be clearly understood.

Understanding the architectural history of a site can also help to ensure that the environmental control potential of the building fabric is exploited as part of any design decisions. A computer model has been generated of Chiswick House, and it will be used to test proposed heating strategies for a complete refit of the services. It is not a change in use that often necessitates the use of technology to boost the inherent design features of a building that was originally designed for hospitality but rather the expectations and regulations that govern human comfort and health in buildings today. Too often a technological solution for an environmental problem is suggested before the building and its inherent environmental design features have been considered.

Points to consider
In summary the following points should be considered for historic buildings used for events:
1. Ensuring that reputable contractors, with experience in working in historic properties, are engaged.
2. Taking nothing for granted – the most invisible of all risks, the impact on the stability of relative humidity and temperature of high occupancy also needs to be managed.
3. Working out the carrying capacity of the property for different events – and stick to it.
4. Working out how the occupancy load can be diffused over space and time.
5. Ensuring that all property staff are trained to anticipate and to minimise risks of damage either human or from the environment.
6. Communicating your instructions clearly through methods that are most appropriate for the different recipients of it.
7. Occupancy, use, functions and loans
8. Structural studies, repairs and maintenance of heritage architecture
9. Communication by methods that are most appropriate for the different recipients of it.
10. Displays: Before a strategy based on solution and control can be developed, activities that could affect the displays need to be assessed. These are:
   - Occupancy, use, functions and loans
   - Construction work, refurbishment, disaster prevention and maintenance routines

Case Study 6 Ranger’s House, Blackheath
Demonstrating environmental control for a museum-type exhibition in a historic property

To display and interpret the Wernher Collection on loan to English Heritage at Ranger’s House, the aim is to give visitors a stimulating and engaging experience of work of art of great variety and an insight into the life of Sir Julius Wernher.

Aim
We hope that this presentation will encourage new and diverse audiences to learn more about Europe’s rich culture of Decorative art.

(Professor Simon Thurley)

Functional statement
The objects themselves are beautiful and extraordinary in equal measure, demanding an inspired installation and display of the highest standards.

Sir Julius Wernher

Function: To further English Heritage’s policy of enhancing its historic houses for visitors; and to save the Wernher Collection from dispersal after the closure of Luton Hoo in 1998. English Heritage negotiated a 125-year loan with the Wernher Foundation, a charitable trust, for the collection to go on public view at Ranger’s House.

Performance requirements
Each vitrine must be like a picture.

(Sir Julius Wernher)

Presentation and interpretation: The presentation of the Wernher Collection at Ranger’s House recreates an elegant 18th-century interior on the ground floor and a museum exhibition on the first floor. The latter being the focus of this case study. The museum exhibition represents Sir Julius’s museum room in Bath House, with its Renaissance-style furniture, Old Master paintings, gothic ivories, Renaissance bronzes, finely detailed enamels, majolica and other objects of art. English Heritage generally prefers displays in its properties uninterrupted by display cases. Nevertheless, where required, display cases are used to improve the environment and security of vulnerable objects.

Displays: Before a strategy based on solution and control can be developed, activities that could affect the displays need to be assessed. These are:

- To give a sense of the opulence of the Red Room in Bath House through the use of original and reproduction display cases.
- To juxtapose contrasting types of objects, as preferred by Sir Julius, instead of being grouped together by date or type, as was customary in museums at the time.
- To use discreet display lighting to enhance the quality of the objects.
- To use a passive method of relative humidity and temperature control within the display cases.

The objectives of the exhibition at Ranger’s House were as follows:

- To give a sense of the uncluttered and open nature of the Wernher Collection
- To give a sense of the opulence of the Red Room in Bath House
- To juxtapose contrasting types of objects, as preferred by Sir Julius, instead of being grouped together by date or type
- To use discreet display lighting to enhance the quality of the objects
- To use a passive method of relative humidity and temperature control within the display cases
- To be able to cope effectively with each party, private view and other functions, such as lectures, parties and dinner linked to the Friends and the Wernher Foundation

Solution concept: The reference to display cases in these objectives gives a strong indication that the focus of the solution had to be on the presentation. The reference to RH-control in the cases provides humidity control for the objects. The reference to display cases in these objectives gives a strong indication that the focus of the solution had to be on the presentation. The reference to RH-control in the cases provides humidity control for the objects.
An understanding of the inherent features of a historic property that promote environmental stability these are given and are free. The strategic choice of Ranger’s House for the display of The Wernher Collection coupled with the selection of the north-east (or cooler) side of the house for the display of organic objects and the south-west (or warmer) side for the display of inorganic and metallic objects ensuring that full use was made of the inherent environmental zones of the property.

2. Taking any further actions to enhance passive control would mainly involve capital expenditure. Works were carried out to improve the capability of the house to resist the weather. These included repairs to the roof, chimneys and rainwater goods.

English Heritage produced a specification for the procurement of display cases for the Wernher Collection. The environmental specification included the following requirements:

• that all materials were tested to ensure that there were no corrosive emissions (including the coating of wooden elements to reduce emissions);
• provision of humidity control with silica gel conditioned to certain material-dependent RH bands (ie silica gel cassettes, monitored with a radio-telemetry system);
• pollution control, using activated charcoal cloths;
• and lighting that causes a temperature increase of no more than 5°C per eight hours, using fibre optic, cabling and low-voltage tungsten halogen room lamps.

Achieving and maintaining an acceptable solution

Fundamental to good management is good maintenance, and this is important for a historic property that is used as a museum exhibition. A building maintenance programme should ensure that regular inspections take place. This is essential if acceptable conditions are to be achieved and maintained.

Sound environmental management decisions must be based on quantitative, semi-quantitative or qualitative evidence and data, all of which can be useful in environmental management decision-making. Quantitative environmental data and close inspection of exhibits are necessary to determine the early sign of deterioration. English Heritage advises value effective and clear presentation of environmental monitoring records for diagnostic purposes. This enables anyone unfamiliar with a problem to grasp its significance quickly and to provide the appropriate advice.

Heating and cooling: As in most English Heritage properties, none of the open fires at Ranger’s House are lit. This has a number of management and maintenance consequences both for the house and for the museum exhibits:

1. The chimney pots above unused fireplaces should be capped in a manner that enables ventilation of the stack to continue, while avoiding the risks of rain wetting the inside of the stack, damp penetration, disintegration of the flue lining and pest infestation.

2. Chimney flues could be used as vertical ducts. They have the potential, with some mechanical assistance, to bring fresh air into the house when external conditions are cooler. This can help alleviate any effects of overheating caused by display lighting and human occupancy.

At Ranger’s House, heating is provided by a system of hot-water radiators located under the windows. Heating is managed in an exemplary way with comfort heating to meet the needs of visitors during the day and humidistat control of heating at night, when the primary function of environmental control is preventative conservation for the collections. The buffering capacity of the display cases effectively protects vulnerable objects from the variations in the operation of the heating system.

Zoning: The environmental differences that naturally occur in different parts of a building can be used deliberately in the environmental management of a property. Managing the environment of a museum exhibition in a historic property can be made easier through diagnostic monitoring showing that the spaces can be mapped as smaller distinct environmental zones, comprising:

• the ‘ambient zone’ that staff and visitors occupy;
• the ‘microclimates within display cases’, which collectively make up the zone occupied by objects;
• and the different faces of the building that correspond to cardinal directions (for example, the north-east face is cooler, while the south-west is warmer at Ranger’s House).

Alarm-based monitoring: Relative humidity and temperature are monitored using a discreet wireless data-logging system, which is used widely in English Heritage’s historic properties. The graph below shows a two-month winter monitoring period of conditions in a room and a case containing Limoges enamels. The yellow box delineates narrow relative humidity control limits of between 35% and 42%. RH has been set low enough to retard alkali migration from the gel layer and high enough to stop the gel layer from dehydrating and cracking.

Ventilation: Ranger’s House had a combination of draughty fireplaces and windows, which were initially sealed to prevent the ingress of dust, pollution and pests. Overheating during the summer exacerbated by ventilated display case lighting, meant that the windows had to be unassembled and opened to provide natural ventilation. When openings are closed but not sealed, air infiltration seeped through the cracks and gaps around closed windows and doors as in an ordinary house. During summer Ranger’s House could not rely solely on natural air leakage to reduce overheating from a combination of display lighting, occupancy and solar radiation, all of which together had upset the thermal balance within the building. Yet natural ventilation by opening windows is not an acceptable long-term solution because of safety security and pollution risks, and its adverse effect on the stability of the internal environment.

Future actions to enhance visitor enjoyment of Ranger’s House

Mechanically assisted natural ventilation: The fireplaces and chimney flues in Ranger’s House have already been compared to vertical ducts. One potential approach is to enhance ventilation, by installing a motorised fan at the top of the chimney to draw fresh air into the rooms. On summer nights when the external air is cooler than daytime temperatures, combined RH-temperature sensors installed inside and outside can switch the fan on to purge the rooms with cooler air. A particle filter can be installed to reduce the ingress of dust, debris and pests. If a higher-duty-fan is feasible. While the feasibility of such a system is explored, suitable mobile cooling units that can be securely vented externally have been installed.

Points to consider

In summary, the following points or steps were raised as the Ranger’s House project was implemented:

1. That naturally occurring zones in buildings can be used to provide environments suited for sensitive objects.

2. That display cases can provide significant environmental protection for their contents, provided that they are carefully designed. Particular care is required for the selection of construction and dressing materials for display cases.

3. That determination of suitable RH conditions for vulnerable objects should ideally be based on relevant published research, specialist evaluation of the condition and stability of the object, and an understanding of the behaviour of water vapour in the air and its interaction with materials (known as psychrometry).

4. That the performance of RH-controlled display cases should always be monitored to assess compliance with the specified conditions and improvements that need to be instigated if the display case fails to perform.

5. That object lighting needs careful specification in particular, internal lighting of display cases and glare from natural light on the glass can obscure the displays.

6. That the heat gain from large amounts of lighting also needs to be considered. Overheating of cases can seriously affect the environment within them and this problem should be addressed at the design stage.

7. That the positioning of the cases is another important consideration, both within the building, and in particular places within the room (ie avoiding extreme conditions such as direct solar radiation, which can stress the efficacy of cases).

8. That wireless telemetry data-logging systems are ideal for monitoring conditions in cases and rooms within historic properties.

References

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Front cover (main photograph): Rangers House, Blackheath, London.
Micrographs from top to bottom:
i boat bedroom, Brodsworth House, near Doncaster;
ii mould infestation in telephone exchange, Dover Secret Wartime Tunnels;
iii Chiswick House, London.

Back cover: Interior Chapel of St Leonard, Farleigh Hungerford Castle, Somerset.