Managing external environments through preventive conservation: the investigation and control of environmentally-caused deterioration of decorative surfaces in the Marlborough Pavilion, Chartwell, Kent

Katy Lithgow, Tobit Curteis and Linda Bullock

Abstract

The Marlborough Pavilion is a small stone building located in the garden of Chartwell, Sir Winston Churchill's country house in Kent. Open on two sides, the Pavilion's current decorations have deteriorated since their execution in 1934 and restorations in 1949, 1981 and 1989. As the last restoration was conducted under the original artist's supervision, it has historic significance, and therefore research was undertaken by the National Trust to investigate the causes of its deterioration, design ways of reducing the rate of damage, and assess the costs and benefits of conservation and restoration. Environmental surveys demonstrated that damage was caused by both the adverse microclimate (condensation) and the penetration of liquid water, the latter successfully addressed by building repairs. Several approaches to controlling the microclimate were tested during winter months, when the deterioration was most active, and the results were monitored. The most successful system involved the use of a temporary modular enclosure with a high level of hygral and thermal buffering, used in conjunction with a mechanical dehumidifier. By using this system in the winter, instances of high and unstable relative humidity and condensation were prevented, and the rate of deterioration was significantly reduced. The costs were no greater than restoration and had the benefit of maintaining the historic significance of the original decorative scheme.

Figure 1. External view of the Marlborough Pavilion from the south

Figure 2. View of the Pavilion's interior before treatment

Introduction and background to the project

Located in the gardens of Chartwell, Sir Winston Churchill's country house in Kent, the small summerhouse known as the Marlborough Pavilion was built in the mid 1920s of clunch and dressed sandstone, with a lead roof. [1] (Figure 1). Open on two sides, the internal walls are rendered and painted, and embellished with slate and terracotta wall plaques, concrete figurative busts and a low relief painted slate frieze. The building was originally decorated in 1934 by John Spencer Churchill (1909-1992), Sir Winston's nephew, and again in 1949 as a 75th birthday gift for his uncle [2]. The scheme commemorates John Churchill, the first Duke of Marlborough, and victor of the Battle of Blenheim. The house and its gardens were donated to the National Trust in 1946 and occupied by Sir Winston and Lady Churchill in their lifetimes. (Figure 2)

Museum Microclimates, T. Padfield & K. Borchersen (eds.) National Museum of Denmark 2007
ISBN 978-87-7602-080-4

Due principally to the semi-open construction of the Pavilion, the internal surfaces have deteriorated ever since they were executed. After wartime neglect, the 1934 scheme was restored 'in a different and more durable medium' by the artist himself in 1949 [3] and repainted in1981 by the decorator Owen Turville who worked on all the walls, ceiling and the slate frieze under John Spencer Churchill's direct instruction [4]. The ceiling was repainted in 1989.[5] By 1997 the decorative surfaces had deteriorated again through algal growth, erosion by water, cracking, flaking and loss of the paint layer. Between 1998 and 2005 the National Trust researched the causes of deterioration, to design measures to control the damage and to devise a long term conservation strategy for the polychrome decoration. The project involved complex decisions, balancing the significance of the decoration and its difficult location with the costs and benefits of both a conservation and a restoration approach.

Significance

The Pavilion's decoration history showed that the present painted scheme has significance as a first-generation descendant of the 1949 scheme, executed under the original artist's eye.

The 'durable medium' meant using slate as a support and casein as a paint medium. John Spencer Churchill's colour samples and annotated photographs recording the 1949 scheme survive at Chartwell and suggest its tone was more solid and glossy than the washed out pastel colours currently seen. However, according to Owen Turville, by 1981 John Spencer Churchill intended that:

> 'the paintwork should have a weathered or distressed look and indeed he specified that the paint should be applied and then wiped back. Owen used more of a dragged wash technique in Casein Tempura [sic] and finished it on the slate in white wax. Apparently GSC [sic] saw the completed restoration and said that it was exactly right.'[6]

It was felt that this authenticity would be compromised and eventually destroyed by repeated restoration. Preserving the Pavilion's 'spirit of place' meant retaining the building's open sides so that it can function as a summerhouse and enable visitors, for whose benefit the Trust preserves the property, to enjoy the space as it was used by Sir Winston. However, it also meant that the polychrome decoration would continue to deteriorate because of exposure to the weather, requiring periodic conservation and restoration.

Figure 3. Detail of microbiological growth on the slate frieze

Working with change

In common with other conservation bodies, the National Trust accepts that change is inevitable and should be worked with according to the nature of the change and the threat it poses to the material to be preserved. In the field of cultural heritage, change such as increased visitor numbers, can be accommodated by managing visitor flow, or adapted to, by enhancing physical protection. Destructive change can be mitigated by recording cultural material before the change occurs, or by relocating it, for example where cliff top buildings are threatened by coastal erosion. Ultimately, change can be prevented or opposed where there is an adverse and avoidable impact, for example by challenging planning proposals. Thus the Trust aims to understand and preserve significance as much as material evidence, and defines conservation as:

> '…the careful management of change. It is about revealing and sharing the significance of places and ensuring that their special qualities are protected, enhanced, understood and enjoyed by present and future generations'. [7]

Working with change in the Marlborough Pavilion meant minimising the rate of change. The project aimed to assess whether the speed of deterioration could be reduced to increase the periods between interventions beyond the 10 year cycles suggested by recent treatment history, prolonging the life of authentic decoration as long as possible.

Environmental investigations

An assessment of the condition of the building envelope in the 1990s identified failures in the roof which put at risk the internal decorative surfaces. repairs were undertaken on the roof between 1995 and 1996 directed by the architects Purcell Miller

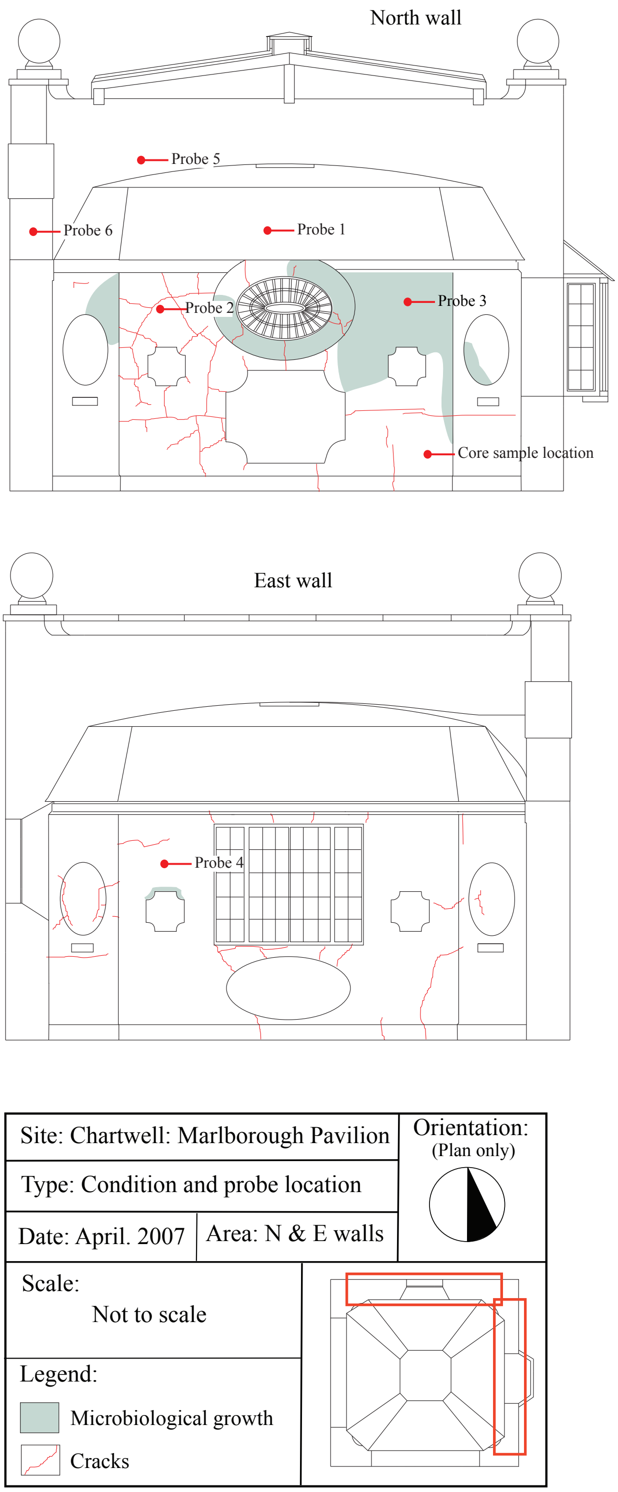

Figure 4. Plan and elevations with the patterns of damage and the location of the monitoring probes and core sample

Tritton.[8] A meeting between Conservation Advisers and property management staff in 1997 identified an overall approach and a range of conservation actions. [9]

In 1998, a survey of the condition of the polychromy, undertaken by The Wallpaintings Workshop, identified patterns of deterioration consistent with environmental factors. Limited remedial treatment was undertaken to prevent further short term loss and improve the decoration's appearance.

A study of the environmental conditions affecting the building, in order to identify factors causing active deterioration to the decorative surfaces and to develop strategies for their control, was subsequently carried out by Tobit Curteis Associates.

The initial stage of the environmental investigation was to undertake a detailed assessment of the patterns and types of deterioration to enable damage associated with liquid water (e.g. penetrating rainwater) to be differentiated from that associated with water vapour (high relative humidity or condensation).[10]

Deterioration of the paint layer was found to be widespread, with considerable delamination and flaking as well as extensive microbiological growth, mostly evenly distributed over large areas. (figure 3) The nature and distribution of the deterioration indicated that while significant areas of damage were associated with microclimatic factors, including air movement and the building's thermal as well as hygral properties, some areas of damage were more likely to be caused by liquid water ingress.

The graphic condition record mapped patterns of deterioration against areas of physical weakness in the building structure, identifying possible liquid water routes. (Figure 4) Following an electrical resistance and capacitance survey of the decoration's surface, core samples were taken where liquid water ingress was indicated, to establish the moisture profile though the depth of the wall. Gravimetric

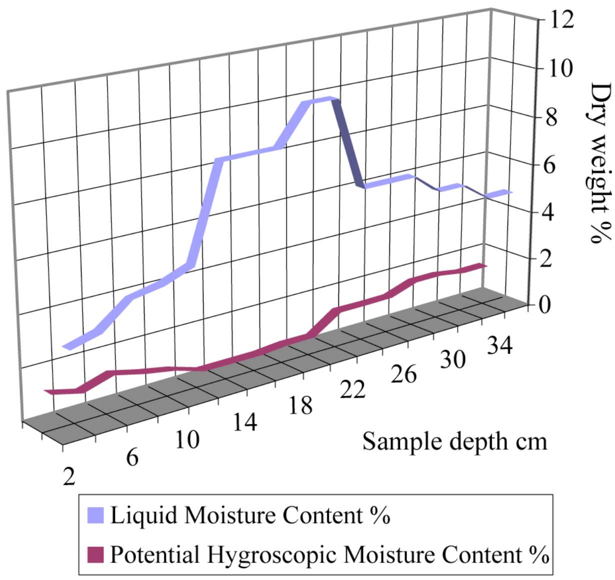

Figure 5. Gravimetric analysis of a core sample on the north wall. The depth is marked from the inside.

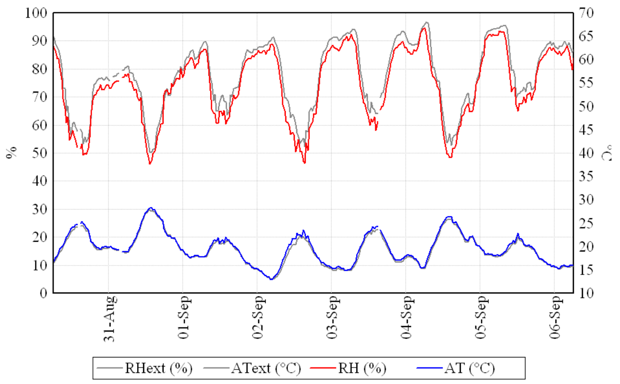

Figure 6. The internal and external relative humidity (RH) and ambient temperature (AT) are almost identical during the open summer of 2005, indicating minimal buffering

analysis [11] of the samples' moisture content enabled calculation of the ratio of liquid water to potential hygroscopic moisture, enabling the routes and sources of moisture to be traced. (Figure 5)

In most areas the wall structure was dry to a depth of over 30cm from the inside surface, suggesting that moisture problems were associated with the microclimate rather than liquid water. On the north wall, high moisture content throughout the wall was associated with a failure of the rainwater drain system on the external wall, and coincided with the most concentrated area of microbiological growth.

Investigating deterioration associated with the microclimate involved monitoring environmental conditions inside the Pavilion, as well as outside.

The data demonstrated that, as expected, conditions within the Pavilion followed the external conditions closely, due to the free air exchange which took place through the two open sides of the building structure. (Figure 6) The fabric provided some minor thermal buffering and the roof protected the internal surfaces from direct rainfall.

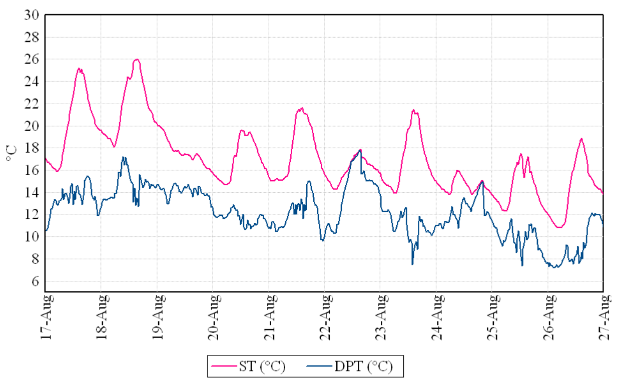

Figure 7. Dew point temperature (DPT) is regularly equal to or in excess of surface temperature (ST) during the autumn and winter of 1999, indicating periods of condensation.

The data showed that high and unstable internal relative humidity (RH) and the thermal lag of the slate frieze and the plaster walls, caused the dew point to rise above the surface temperature on numerous occasions, indicating that superficial condensation was likely to have occurred. Condensation was observed on the painted surfaces many times, including water running down the surfaces of the slate frieze and pooling on the concrete busts, causing slow erosion. (Figure 7) Indeed, sometimes mist accumulating in the valley was seen to fill the Pavilion.

The environmental investigation demonstrated that while some localised areas of deterioration were associated with penetrating rainwater caused by damage to the building envelope, and rainwater disposal system, most of the damage to the decorative surfaces was caused by the instability of the microclimate, and the resulting frequency of condensation. While some damaging conditions were observed throughout the year, by far the worst conditions occurred between October and February.

Environmental control

The concept of providing protection only during the worst months of winter weather reflects the approach of the National Trust and other organisations caring for historic houses to the preventive conservation of garden statuary. Vulnerable pieces are covered between November and March, although the gardens may be accessible during this period, following historic precedent.[15] As any visible methods of protecting historic material can adversely affect its appearance, our initial aim was a method of control that had minimal visual impact. Establishing a system of control was an iterative process, testing defined variables separately over a single winter season. Each intervention was carefully assessed to determine its advantages and disadvantages and the results used to develop the approach tested in the following season. Interpretation panels explained the project to visitors during the winter months. Whilst we hoped that to develop a simple control method with minimal visual impact such as heating tapes, our testing demonstrated the need for a more for a complex form of control.

Heating tapes

Initial tests in November 1999 used electrical anti-condensation trace heating tapes at the base of the wall and on the lower edge of the frieze. The intention was to establish a curtain of warm air which would slightly heat the wall surface and generate gentle air

Figure 8. External view of the Pavilion with the initial plastic-covered enclosure

currents, reducing condensation by raising surface temperature above the dew point temperature. While the principle has worked indoors [16], the tapes' effect in a semi-external location was overwhelmed by wind.

Heating tapes and uninsulated enclosure

In order to reduce the disruptive effect of the wind, and to test if increasing the hygrothermal buffering improved the conditions, further tests were carried out by enclosing the open walls of the pavilion with uninsulated plastic panels inserted into the two wall openings. Monitoring data showed that enclosure reduced the influence of external water vapour concentration on the internal microclimate and also prevented rain entering. However, Although the internal microclimate was somewhat stabilised, enclosure caused the RH to fluctuate at very high levels (often over 90%). During this period the warm airflow generated by the heating tapes had little effect on condensation, apparently due to the overwhelming influence of the high RH.

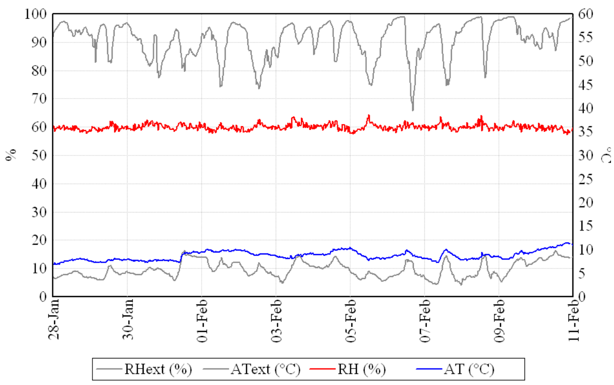

Figure 9. Internal and external relative humidity (RH) and ambient temperature (AT) in the winter of 2005 during enclosure and dehumidification, demonstrating the high level of buffering

Enclosure with thermal insulation

During the first half of the following winter, 2000-2001, thermal buffering was tested by adding rock wool insulation to the plastic panels and polystyrene insulation to the windows. (Figure 8) Although the internal microclimate was stabilised, enclosure again caused the RH to rise to over 90%, as the structure contained a large volume of water absorbed during the rest of the year. As a result, the dewpoint remained close to the surface temperature, resulting in numerous events of condensation and significant microbiological growth.

AH Control

As passive thermal control (thermal insulation only) was clearly unable to maintain the RH at an acceptable level, active thermal control (humidistat controlled heating) was considered. However, calculations suggested that the use of heating would be unsuccessful in reducing the RH due to the possibility that increasing temperature was likely to encourage further desorption of humidity from the porous fabric, thus maintaining the RH at its original high level. In addition, increasing temperature in combination with high RH was likely to encourage microbiological growth.

Dehumidification

Tests using mechanical dehumidification were carried out over the second half of the winter of 2000-2001 and then over the following two winters.

Dessicant dehumidifiers, with an absorbent wheel of silica gel are more efficient in their drying capacity at temperatures approaching 0°C, than those that work on the refrigerant principle. Given that the Pavilion is an outdoor structure, a dessicant model was chosen. Initial trials were made with an

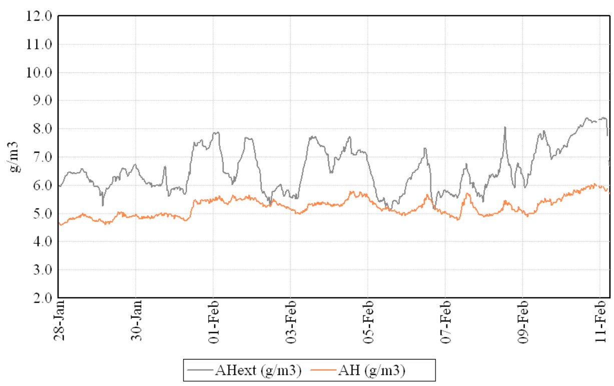

Figure 10. Internal and external absolute humidity (AH) in the winter of 2005 during enclosure and dehumidification

already available small unit which expelled damp air through ducting to outside. A significant reduction in condensation events was monitored, though, through infiltration of external air, the RH reduction levelled off at about 70%. When a condensing desiccant unit was obtained, the performance improved. RH was maintained at approximately 62%, the level set on the humidistat, and below generally accepted levels for mould growth. Mean diurnal fluctuations were generally less than 4% (while externally 35%) and surface condensation was all but eradicated. Combining passive buffering with active reduction of RH achieved conditions beneficial for the conservation of the decoration. (Figures 9 & 10)

Cost-benefit analysis

As tests indicated that a successful means of controlling RH and condensation during winter months was possible, a performance specification was developed for costing an enclosure system to replace the insulated plastic panels, for use between October and April. The enclosure had to be sufficiently robust yet simple in design to enable repeated erection during the winter and removal and storage in the summer. Following the contractor's response, a cost-benefit analysis demonstrated that the costs of enclosure and environmental control were broadly equivalent to the cost of repeated conservation and restoration based on the evidence of the 10 year treatment cycles carried out in recent history. However, the enclosure has the added benefit of prolonging the life of the authentic decoration. The final enclosure system was considerably more efficient than the test system, as well as being aesthetically more acceptable. (Table 1).

Item cost per year	Dehumidified aluminium enclosure	No enclosure
Enclosure (erected by property staff) cost divided by design life of 20 years.	£310	n/a
Dehumidifer cost assuming 10year life cycle.	£130	n/a
Redecoration estimated at £9,000 every 10 years without an enclosure, every 20 years with an enclosure.	£450	£900
Surface cleaning, estimated at every 3 years without an enclosure, and every 6 years with an enclosure	£40	£80
Conservation of slate frieze estimated at 20 years with an enclosure, n/a if redecoration.	£150	n/a
Total	**£1080**	**£1080**

Table 1. Cost-Benefit Analysis

Design of enclosure

The performance specification for the enclosure included criteria that not only addressed conservation - such as reversibility and minimum intervention, and insulation (u values equivalent to the rock wool tested, for example); but practicality (easiness to clean, maintain, carry, erect and store, robustness to prevailing weather, sun and UV, and a lifespan of minimum 20 years); aesthetics; health and safety (including flammability); security and access; value for money; green principles; and most critically, accommodating the dehumidifier.

In practice, this meant a modular system of interlocking panels with carrying handles, formed of rustproof brush-painted aluminium panels with stainless steel fixings. (Figures 11 & 12) The panels are self-supporting and interlock when in place, as well as locking into position from inside. They are erected by property staff (gardeners and house staff), and stored on a rack with a cover. Access is provided by one set of panels having a lap joint on one edge, enabling hinges and locks to be fitted. Viewing panels with rounded corners and rubber trim, enable visitors to see the interior (with illumination) while the enclosure is in place, and the conservation approach is explained with interpretation panels.

Reversible fixing methods that avoided damaging the Pavilion's historic fabric meant that the panels were made slightly smaller than the arched openings. The panels' edges were fitted with 'rubber' gaskets that could be expanded to fit by self tapping spring-loaded screws and bolts at the edge. Seals were formed of Plastazote® strips around the stone aches and brush strips ('Centaur') fitted at the top and bottom. The screen was constructed of aluminium framework with aluminium infill panels insulated with 22mm black Plastazote®. The foam

Figure 11. Detail of the construction of the enclosure

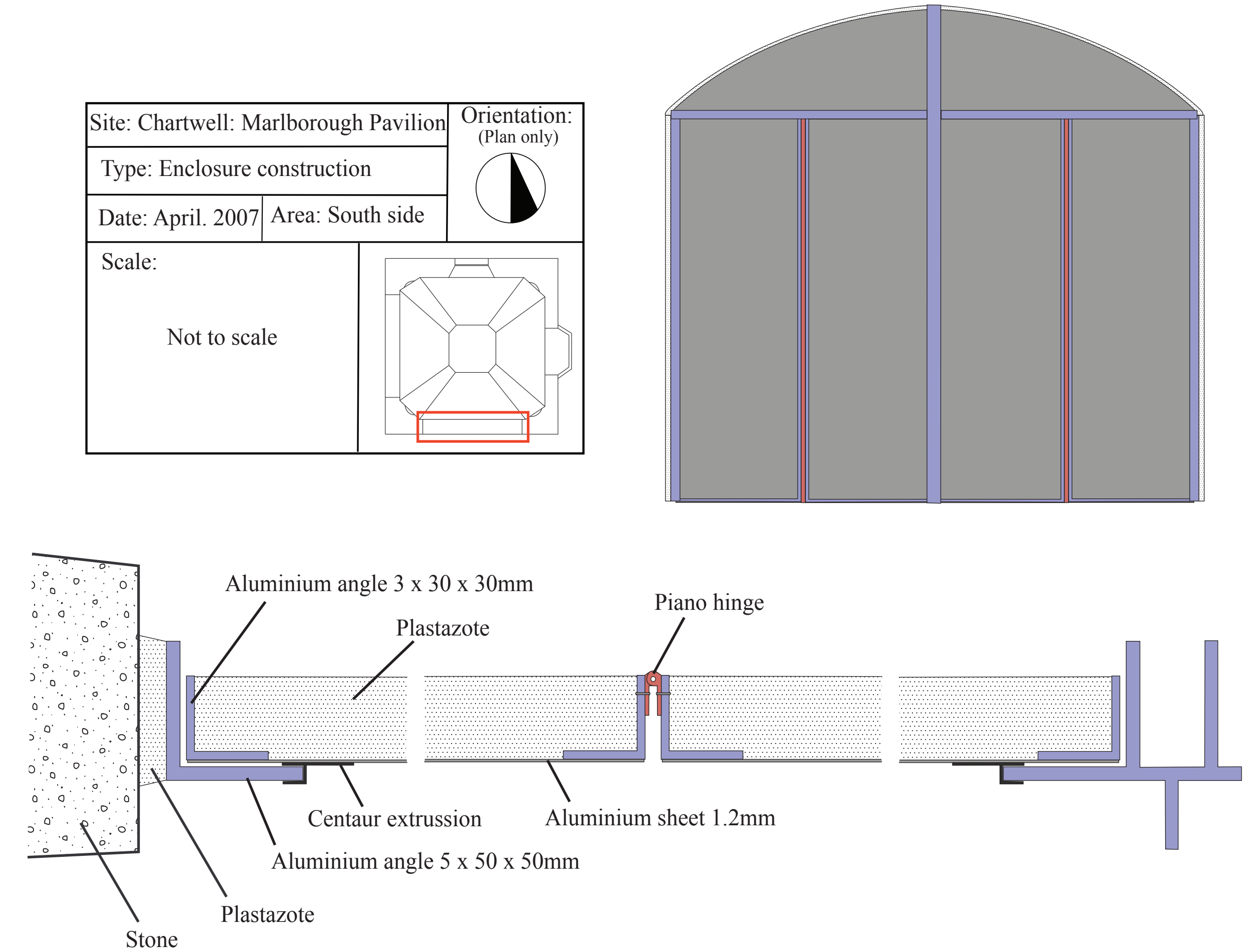

Figure 12. External view of the Pavilion with the final enclosure

was adhered with a UPVA-based glue used to glue insulation to aluminium in the aircraft industry. The design included some points of cold bridging which could produce condensation, but were felt not to be an issue as there was no additional heat to create a significant temperature gradient.

The aluminium and stainless steel elements are projected to last over 20 years, but the finishes will need maintenance. The paint coating will need replacing every 5-10 years, the Plastazote® insulation every 10 years, and the Plastazote® lining to the stonework 5 years. Experience will test the accuracy of these figures and the cost-benefit analysis.

Remedial conservation

Following completion of the research programme and the manufacture of the final enclosure, a phase of remedial conservation was undertaken by The Wallpaintings Workshop to stabilise the paint layer and remove accumulated microbiological growths and particulate matter.

Wishab sponges and soft brushes removed surface dirt and algae deposits from the walls, concrete medallions and slate and terracotta plaques. The paint layer on the frieze was consolidated using a solution of Paraloid B72 (2.5% in toluene), applied through Eltoline tissue to minimise the physical impact on the fugitive pigment layer. Detached and lifting paint on the domed ceiling, within the lettering on the painted wood beneath the frieze and on the walls, was fixed using Tylose™ MH300 [19] (circa 5% in deionised water and IMS 1:4), prewetting with deionised water and IMS (2:1) to aid penetration of the adhesive. [20]

Reintegration of repairs to the frieze and slate wall plaques, to reduce the visual impact of condensation drips running down the frieze decoration, was undertaken using matt Golden™

Acrylics. A second protective application of Paraloid™ B72 (2.5% in toluene) was then brushed over the frieze surface through Eltoline™ tissue. Two coats of this varnish were also applied to the slate wall plaques.

Management solutions

A management system was established with the property staff so that the installation of the enclosure and dehumidifier takes place as part of usual practice, with monitoring of the microclimatic conditions included within the property's standard environmental monitoring programme, using the currently installed Hanwell monitoring system.

Lessons learnt

Lessons cover both technical and management areas: preventive conservation requires combining both.

- A truly passive energy-free solution eluded us. With the addition of a dehumidifier, thermal buffering successfully reduces condensation events and freeze thaw cycles, resulting in significant reduction of microbiological growth and flaking, with a relatively low energy input. The space is now monitored by the same telemetric system installed inside Chartwell. Energy costs remain to be established.
- We did not use air exchange rates as a means of specifying performance as we did not know what was needed, but they could be calculated from the performance of the existing scheme. The National Trust's environmental strategy is based on air exchanges of up to two per hour for a leaky historic house, compared with a display case performance of 0.1 air exchange per day.
- Our failures may be successes in different contexts, for example, thermal heating tapes may help iso-thermal glazing for stained glass.
- The green and disfiguring microbiological growth has not reappeared since the enclosure has been used, so the intervals between treatment cycles will be extended. We anticipate that by reducing the worst effects of the external microclimate on the painted decoration as well as other decorative surfaces, the rate of deterioration will have been considerably reduced and the period between interventions increased to prolong the life of the authentic painted surfaces.
- Real time testing of only one variable at a time meant one year was needed for each phase, totalling 7 years. The learning curves of this project, and increasing data on the behaviour of historic materials enabling computer modelling, mean trials might be speeded up in future. We hope that aspects of the system developed here will assist the preventive conservation of decorative surfaces in external and semi-external environments elsewhere.
- Project outcomes need to be integrated with daily life as they are not a one off solution. The National Trust is fortunate in having staff on the ground given preventive conservation training to implement the solution and recommendations of the project. Our challenge is to ensure that the conservation management is so embedded in property management structures, that it is not affected by changes in staff. However, the longer term maintenance required by preventive conservation is not funded under current UK funding models, which exclude endowments.

Visitors have benefited by explanations of the conservation process, and a more attractive and authentic place in which to contemplate both the detail of the decorative scheme, and the distant views of Churchill's beloved Kentish landscape.

Acknowledgements

The successful conclusion and continuing implementation of this project depended, and depends on: Chartwell's architects, Purcell Miller Tritton; its conservators, Chris Daintith, Sarah Norcross-Robinson, Siobhan Barratt and Gill Nason; its curators, Cathal Moore and Stephen Ponder; and last, and by no means least, past and present property staff who care for both the house and gardens, in particular Carol Kenwright and Neil Walters. We are also very grateful for the help of the contractors involved, Tom Organ of the Wallpaintings Workshop, and Tim Martin of Context Engineering.

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Notes

1 For a history of Chartwell, including the Pavilion and its setting, see The National Trust, Chartwell, Kent, London, The National Trust 1998.

2 For an account of the 1949 decorative scheme, see Churchill, John Spencer, A Crowded Canvas: The Memoirs of John Spencer Churchill, London, Odhams Press Ltd, 1961, pp. 185-6

3 Churchill, op cit, p 185

4 In a letter dated 15/3/1996 in Chartwell's records, the architect Peregrine Bryant reported that Turville said 'that the paint had more or less worn off completely from the slate panels and he was effectively starting from scratch. His recollection also is that the ceiling to the Pavilion and the walls were replastered completely at that time and he was painting onto new surfaces.' This was confirmed in a telephone conversation with Katy Lithgow in 1997 where Turville described that there was virtually no paint left, and how, having cleaned the slates down, he repainted them in casein tempera and waxed them, and repainted the walls, which had all been freshly plastered and finished with Sandtex® on his recommendation.

5 The decorative paint specialist James Finlay scraped down Owen Turville's layer and replaced it with limewash with some casein.

6 Bryant op cit note 4 above.

7 This definition was made by the Conservation Strategy Group of the National Trust in September 2003. The principle of working with change forms one of the Trust's Conservation Principles, common to all of its conservation activities, to be published in 2007.

8 Chartwell files record that Acrypol® was applied to damaged parts of the roof in 1995, and repairs begun in Summer 1996 were completed in January 1997.

9 Unpublished report by Katy Lithgow, Conservation of the Marlborough Pavilion, Chartwell, 26th March 1997.

10 Tobit Curteis Associates, Marlborough Pavilion, Chartwell, Liquid Moisture Survey and Environmental Monitoring of the Painted Decoration, unpublished report, February 1999

11 Drilled core samples were taken from the walls and separated into segments. These samples were weighed and then dried at 50° C until a constant weight was reached. The difference between wet and dry weight indicates the free water content as a percentage of the overall weight of the dry sample, as this temperature is too low to drive off water of crystallisation. In order to establish how much of the moisture content may be associated with hygroscopicity, e.g. absorbed water vapour, the dry samples were then placed in a humidity chamber at 75% RH for 24 hours, and the resulting increase in weight subtracted from the free water content measurement. The result establishes whether water content is wholly or partly liquid water.

12 An Eltek monitoring system was used, initially hard-wired and then using telemetry, with the base station located in the adjacent house. Relative humidity (RH), ambient temperature (T) and surface temperature (ST) were monitored at several internal locations with data logged at 30 minute intervals.[13] Downloading was undertaken remotely via GSM (cellular network) modem, and data was charted and analysed using Microsoft Excel and Eltek's Darca Heritage software.

13 Initially seven sites were monitored to give a representative picture of the walls at various heights and orientations, and these were then reduced to the 3 most significant sites, see Figure 4.

14 Eltek Squirrel 1021NL telemetric logging system. RH and AT were measured using Vaisala HMG Z-2 combined probes and ST was measured using EU-U-V2 thermistors. The published accuracy levels for the probes are: Vaisala HMG Z-2 RH +/- 3%, AT+/- 0.3°C. EU-U-V2, ST +/- 0.2°C.

15 For an assessment of winter protection of external garden statuary, see Berry, J., David, F., Julien-Lees, S., Stanley, B. and Thickett, D. (2005) 'Assessing the performance of protective winter covers for outdoor marble statuary: Pilot investigation', in ICOM-CC 14th Triennial, Rio de Janeiro, eds I. Verger, pp. 879-887. See also http://www.ucl.ac.uk/sustainableheritage/winter_covers.htm for a description of this joint project between English Heritage, The National Trust, and Historic Royal Palaces.

For an account of the National Trust's approach to controlling relative humidity and caring for external objects, see The National Trust, Manual of Housekeeping: The care of collections in historic houses open to the public, London, Butterworth-Heinemann 2006, pp.102-113 and 578-607.

16 The use of heating to create a warm air curtain raising surface temperature above dew point, along with other measures of preventing condensation, is described in Massari, G and I, Damp Buildings, Old and New, Rome, ICCROM 1993, 225.

17 Munters M90L controlled with a Meaco humidistat set at 55% RH

18 Munters MG50 Dri-Box, controlled with a Meaco humidistat set at 62% RH

19 Tylose® MH300 is a cellulose-based water soluble adhesive – methylhydroxy ethyl cellulose produced by Hoechst and available from Kremer, Germany

20 Tylose® was chosen in preference to other fixatives such as Paraloid® B72 or water-based acrylics (Plextol® B500, Primal® AC33, etc.) because it penetrated behind the flakes well and did not alter the hue or tone of the colour being fixed.

Appendix

Heating humidistat control

Meaco Measurement and Control Solutions
26 The Avenue
Basford
Newcastle under Lyme
Staffordshire
ST5 0LY
Tel: 0845 838 6963
Fax: 0845 838 6965
www.meaco.co.uk

Environmental monitoring system (research project)

Eltek 1000RX1 Squirrel datalogger, and Vaisala T/RH probes and surface temperature probes with GSM modem kit + antenna

Eltek Limited
35 Barton Road
Haslingfield
Cambridge CB23 1LL
U.K.
Tel: +44 (0)1223 872111
Fax: +44 (0)1223 872521
www.eltekdataloggers.co.uk

Dehumidifier models M90L & MG50

Munters Ltd
Dehumidification Division
Blackstone Road, Huntingdon
PE29 6EE
Cambridgeshire
Tel: +44 (0)1480-432243
Fax: +44 (0)1480-413147
www.munters.co.uk

Enclosure

Design and manufacture by Tim Martin at Context Engineering
Tower House
Talgarth
Powys
LD3 0BW
Tel: +44 (0) 01874 712252

Plastazote

The grade used for the enclosure lining was black LD29 polyethylene foam 70kg/m3 density), with a u value calculated to be greater than that of brick/stone plaster. Available from:

Polyformes Ltd
Cherrycourt Way
Stanbridge Road
Leighton Buzzard
Beds
LU7 8UH
Tel: +44 (0) 1525 852444
Fax: +44 (0) 1525 850484
www.polyformes.co.uk

environmental monitoring system (main property)

Hanwell Instruments Ltd
12 Mead Business Centre
Mead Lane
Hertford
SG13 7BJ
Tel: +44 (0)1992 550078
Fax: +44 (0)1992 589496
www.hanwell.com