#6710

Indoor Environ 1992;1:363–366

P. O'Sullivan
T. Oreszczyn

The Bartlett, School of Architecture, Building, Environmental Design and Planning, University College London, UK

Environmental Control in Historic Galleries and Museums

Key Words
Museums
Art galleries
Historic buildings

Abstract
It is a complex problem to create an environment suitable for both objects and people within museums and galeries housed in historic buildings, which house some of the most important exhibits and require highly controlled conditions. The need to maintain historic buildings intact during restoration often prevents the installation of full air-conditioning, which is required to adequately control the relative humidity, temperature and pollutants. This paper examines how the natural operation of historic buildings can be enhanced to improve environmental control without resorting to full air-conditioning. Also discussed is how to control and predict air movement so as to provide an adequate supply of fresh air for visitors at the same time as a suitable environment for the objects, and what effect the visitors have on the objects and fabric of the galleries.

Introduction

The key purpose of museums (hereafter 'museums' refers to both museums and galleries) is to preserve the building contents for future generations. Over the last 20 years, the importance of environmental control in preventing the decay of museum objects has become clear [1]. Museums and galleries are increasingly borrowing objects from other collections in order to attract more visitors. The owners of these objects demand strict environmental control as a condition of loan. Therefore, there is considerable and growing pressure for museums to maintain a carefully controlled environment in order to reduce the decay of exhibits.

Maintaining a stable temperature and relative humidity (RH) is considered to be particularly important in preventing object decay. The recommended conditions for mixed collections is an RH of between 45 and 55% and a temperature of 19–23 °C. More important than the absolute values of RH and temperature is the rate of change. The faster the speed of the indoor climatic change and the wider the band of tolerance within which it fluctuates, the faster is the rate of decay of materials subjected to these conditions [2]. Therefore, the environmental requirements for object care are far more demanding than those for human comfort, which lie in the range of 18–28 °C with 30–70% RH.

Air-Conditioning

The solution normally recommended for museum exhibits is full air-conditioning [1]. This alone can achieve the very strict temperature and RH values required for

Accepted:
July 7, 1992

Prof. P. O'Sullivan
The Bartlett School of Architecture,
Building, Environmental Design and Planning
University College London, 22 Gordon Street
London WC1H 0QB (UK)

the optimal care of objects. However, the installation of air-conditioning is not a feasible option in many historic buildings because of the considerable alterations required to the building fabric and the high cost. The operation and maintenance costs of air-conditioning systems are also high; for example, on average, the fuel bills for air-conditioned museums are double those of naturally ventilated museums [3]. There is also considerable concern that incorrectly maintained and designed air-conditioning systems can result in large fluctuations in the environmental conditions. This is particularly true when the air-conditioning plant develops a fault and needs to be switched off. It is not known to what extent such rapid changes may be, more or less, detrimental than the fluctuations that occur in naturally ventilated buildings. In the worst case, we have observed an air-conditioned building where the environmental control during normal operation was considerably worse than that of naturally ventilated buildings.

Installing centralised air-conditioning in historic buildings is particularly difficult for the following reasons.

(1) Physically installing the air-conditioning plant and related duct work without altering the aesthetics of an historic building is both difficult and expensive. Historic buildings are often 'listed' buildings: in the UK, 57% of museums sampled in recent survey occupied listed buildings [5], where any modification to the fabric of the building is strictly controlled.

(2) High ceilings and the lack of insulation result in large air-conditioning loads.

Passive Control

Because of the difficulty in installing full air-conditioning in historic buildings and the cost and questions of its performance, museums have investigated maximising the passive control of the environment, with additional mechanical control when and where they are necessary, i.e. mixed mode. In general, historic buildings are heavyweight in construction, and therefore the fabric of the building can be used to dampen out variations in both temperature and water vapour. Variations due to the external climate are most successfully damped if the air infiltration between the outside and inside is reduced to a minimum.

Measurements have shown that sealing a heavyweight building can substantially reduce the effect of external climatic variations on the internal environment. For example, during a day when external conditions varied by 10 °C and 50% RH, the temperature inside the building varied only by 3 °C and the RH by 30% [4].

Sealing up the building is a particularly attractive solution for museums located in cities where external pollution levels are high. Thompson [1] recommends that 'the proportion of dirt reaching the exhibits (should be) well below 5% by weight of the outside levels' and that gaseous pollution should also be controlled, with ozone reduced to trace levels and sulphur dioxide and nitrogen dioxide reduced to no more than 10 $\mu g/m^3$. Without reducing air infiltration, these conditions will not be met in most historic buildings.

Sealing a heavyweight historic museum appears attractive from the point of view of object care, stabilising external variations in temperature and RH and reducing gaseous and particulate pollutants. For the reasons given above, when the Courtauld Institute Galleries moved their collection into a heavyweight building, they sealed the building as much as possible in order to stabilise the environment. The collection, which included some of the best examples of easel paintings and panel paintings from the 15th–20th centuries, was moved to a refurbished wing of Somerset House, The Strand, London.

When the exhibits were first moved into Somerset House, the temperature and RH were almost stable. However, when the museum opened to the public in the summer of 1990 and there were approximately 2,000 visitors per day [6], the internal temperature was found to fluctuate from 19 to 26 °C and the RH between 49–85% within a 24-hour period. Many visitors complained of feeling faint. Subsequent measurements of the ventilation rate in the gallery showed it to be only 0.25 air changes per hour (approximately 0.8 litres/s/person during peak occupancy). Carbon dioxide levels $>3{,}000$ ppm were recorded during days when there were $<1{,}000$ visitors. Thus it is estimated that levels $>5{,}000$ ppm would have occurred when visitor numbers were at their highest.

The variations in moisture, temperature and carbon dioxide were due to emissions from the large number of visitors in the galleries. As a temporary measure, the number of visitors had to be controlled in order to protect both the exhibits and the visitors themselves.

The effects of too much carbon dioxide on humans are headache and lethargy, followed by breathlessness, sweating, visual impairment and tremor. Finally, unconsciousness develops as the level increases. As a consequence, the exposure to carbon dioxide is legislated in the UK by the Control of Substances Hazardous to Health Regulation

[7] and The Health and Safety at Work Act [8], both of which set a maximum limit of 5,000 ppm of carbon dioxide in buildings, in order to prevent the dangerous effects of too high an exposure. However, levels of $CO_2 > 1,000$ ppm indicate high levels of other pollutants too. Office studies have shown that the occupants of buildings with carbon dioxide levels > 1,500 ppm suffer a higher incidence of headaches and tiredness, and, as a consequence, worker efficiency may drop [9, 10]. Consequently, in the UK, it is considered a safe and healthy practice to design ventilation systems that can achieve carbon dioxide levels of ≤ 1,000 ppm.

Utilising the thermal and hygroscopic storage of the building fabric cannot on its own result in the degree of environmental control required in the UK without the addition of heat and also humidification. However, cooling and dehumidification can be avoided, provided gains from internal sources can be limited and the building fabric affords sufficient damping [2].

Enhanced Passive Control (Mixed Mode)

There is a conflict beween the demands of the objects (a sealed building) and the requirements for visitors (a fixed supply of fresh air) which needs to be balanced. This can be done by the introduction of fresh air into the building in a controlled manner. In historic buildings, this is normally limited to the supply or extraction of air via existing chimneys.

In the past, chimneys have provided ventilation into buildings, and their use in a controlled fashion can be advantageous. Air naturally flows up chimneys as a result of the stack effect. Fans can be used to enhance this flow. Alternatively, fans can be arranged to blow the air down the chimneys. In theory, air entering the building down the chimneys can be filtered before it enters the building. In practice, this apparent advantage is difficult to achieve for the following reasons.

(1) Only a proportion of the pollutants originate outside the building. Visitors and internal furnishings are themselves a source of both particulate and gaseous pollutants. Some studies have shown that wet woollen garments, as worn by visitors entering a museum on a rainy day, may be of particular concern. Human bioeffluents may themselves damage exhibits [11].

(2) Filters need to be regularly maintained in order to prevent outdoor pollutants from entering the building. All filtration systems need regular maintenance. Carbon filters are expensive and, if not correctly maintained, they may themselves produce fine particulate matter which can enter a building.

(3) Unless high flow rates are maintained down the chimney and the building is positively pressurised, air will still enter the building through other paths, thus allowing pollutants to enter the bulding. Simple theoretical calculations have shown that this is likely to occur in historic buildings for a substantial portion of the time. When the galleries are closed to the public, no mechanical ventilation will be required: pollutants will then enter into the building through natural cracks and openings, bypassing the filters. It has been estimated that, in practice, 50% of air entering the building will evade the filters.

For the above reasons, supplying air via chimneys is not very effective compared with extraction up chimneys, which enhances the natural movement of air. When air enters the building through natural cracks and openings, the degree of filtration that this creates is not known. Having the air extracted from the building as opposed to supplied via the chimneys also has the advantage of creating a more uniform indoor environment. Non-conditioned air entering through several different paths should reduce the variation in temperature and RH within the space, compared with when non-conditioned air enters from one location within a gallery through a single fireplace.

In order to make maximum use of the thermal and hygroscopic features of the building fabric, ventilation needs to be kept to a minimum. This is best achieved by controlling the extraction fans via a carbon dioxide monitor, set so as to provide adequate ventilation for human health and comfort. Minimising the ventilation in this way reduces the humidification load. In the winter, the cold, dry air entering the building needs to be humidified. By confining the use of input air to periods when visitors are present and generating moisture, additional humidification can be kept to a minimum. This additional humidification can then be achieved with local steam or drum humidifiers.

Conclusions

The first conflict is between the environmental requirements of art objects and visitors in museums, yet there is increasing pressure for the two to cohabit in the same space. Only under special circumstances is it advantageous to use display cases to create a separate microclimate for the artwork. The high RH levels required for the optimal care of objects may also lead to damage to the fabric of historic buildings from interstitial condensation. Therefore, in historic buildings there may be a second conflict between preventing deterioration of the building itself whilst maintaining the objects in good condition.

Air-conditioning can provide the high level of environmental stability required for object care, but this is limited to new museum buildings, and the UK, most museums were constructed between 1850 and 1899 [5]. The installation of air-conditioning in older buildings is not practical for aesthetic and financial reasons. A mixed mode of air-conditioning is recommended, which maximises the passive control of the environment, with mechanical assistance during extreme conditions.

References

1 Thompson G: The Museum Environment. London, Butterworths, 1978.
2 Cassar M: Controlling the Environment in Museums in the United Kingdom with Special Reference to Relative Humidity and Temperature; dissertation, The Bartlett, University College London, 1991.
3 Oreszczyn T, Mullany T, Ni Rian C: Survey of Energy Efficiency in Museums and Galleries. Conf on Energy Efficiency in Museums and Galleries. London, National Gallery, Nov 16, 1991.
4 Orchard Partners, Courtauld Institute Somerset House: Response of Temperature and Relative Humidity inside the Great Room. Report No JS/MRN/414/1/R1. London, June 1986, p 2.
5 Lord B, Dexter Lord G, Nicks J: The Cost of Collecting: Collection Management in UK Museums. London, HMSO, 1989, p 28.
6 The Bartlett: The Courtauld Galleries: Environmental study. Report to the Courtauld, Somerset House. London, University College London, January 1991.
7 Control of Substances Hazardous to Health Regulations 1988, SI 1988, No 1657.
8 Health and Safety at Work Act, HMSO, 1974.
9 Indoor Air Quality and Ventilation, p 113.
10 WHO:EURO Reports and Studies, No 21: Health Aspects Related to Indoor Air Quality. Copenhagen, WHO Regional Office for Europe, 1979.
11 London Observer, Nov 24, 1990.