The historical indoor climate. A long-term approach to conservation environments within heritage buildings

M. Legnér1; A. Luciani2

1 Uppsala University Campus Gotland, Department of Art History, Visby, Sweden; 2 Politecnico di Milano, Department of Architecture and Urban Studies, Milan, Italy

1. Introduction
The aim of this paper is to demonstrate the usefulness of archival sources and architectural analysis in tracing the indoor climate history of an historic building such as an old museum, a church or a palace. References to past indoor climate have often been used either to defend status quo or to justify radical changes in the climate control of a building.

The concept of historical climate can be used in many different contexts. In the field of conservation, it has recently been defined by the European standard EN15757:2010 as the “climatic conditions in a microenvironment where a cultural heritage object has always been kept, or has been kept for a long period of time (at least one year) and to which it has become acclimatized”. Unlike many previous environmental standards, the priority is here not so much in specifying hygrothermal ranges, but in measuring the existing climatic conditions and in understanding whether the environment to which a cultural object has been exposed for a long period of time is harmful or not. As a consequence the focus should be shifted to the climatic history of the object, intended as the complex set of interactions developed throughout an extended period of time between a cultural object, its environment and the surrounding architecture. The term “conservation environment” introduced in this paper proposes a development of the analysis by including outdoor and indoor climate and the microenvironments which can influence buildings and artworks.

When a cultural object is preserved within a historic building, further questions arise: which climate control strategies determined the conditions of conservation environments in the past? On what grounds were these strategies chosen and subsequently used? Which were their consequences on the conservation of cultural objects and buildings? To answer these questions environmental data gathered by indoor climate monitoring are useful but they are obviously not enough. A critical analysis of historical sources has proved to be a constructive way forward.

2. Background and methodology
As a result of the growing interest in climate change and more efficient energy use in buildings, there have been a number of studies performed on historical indoor climate and its possible effects on cultural objects. We have become more alert on the fact that historical buildings have been designed with the relationship of indoor-outdoor climate in mind [Hawkes, 2010]. This recent research may roughly be divided into two categories depending on their aims. Firstly, there have been studies on actual historical climate and what it has been like [Taylor et al., 2005]. Camuffo et al has studied the influence of historical indoor climate on a single artwork. [Camuffo et al, forthcoming] Eibl and
Burmester [2013] have analysed indoor climate from the viewpoint of building history. Luciani [2012] has recalled the modern history of climate control strategies in museums, developing observations first made by Michalski [1993] and Brown and Rose [1996]. Further, Bylund Melin and Legnér [2013] have recently used records on past fuel consumption and technical documentation to reconstruct the heating history of churches.

Secondly, past perceptions and reactions of curatorial management on indoor climate have also been studied recently. This perspective emphasizes views and actions of actors involved in the decision making processes affecting climate control [Legnér, 2011, 2012; Legnér & Geijer, 2012]. An actor perspective may be useful to apply in order to understand how decisions affecting the management of both buildings and collections are the combined result of considerations on comfort, conservation, economy and design. Museums have rarely monitored their own climate in a consistent way, or the data may not have been saved, but control strategies may be better documented in archives. Furthermore, museums are seldom prone to recognize that serious mistakes may have been made in the past or that proper knowledge has been missing. For different reasons this knowledge has far from always been applied in museums. It is important to explore to what extent existing knowledge on preventive conservation is utilized in museums, since the results may point to weaknesses in curatorial management [Luciani, 2012, 137]. Curatorial response on indoor climate may also be interesting to study as a management issue. These kinds of study may focus on how the indoor climate of a specific building has been documented and whether this documentation has resulted in any measures of preventive conservation, or they may focus on the communication between different professionals involved in managing a museum building.

With support from this recent research we propose the adoption of an extended concept of historical climate, i.e. the study of indoor climate history and climate control strategies applied in the past to conservation environments. The historical method, acknowledging the importance of identifying and analyzing the actors involved, is chosen for this study. Consequently primary sources, archival documents, articles, papers or chapters published in international journals, conference proceedings, manuals and/or treatises are used for gathering information about how indoor climate was managed in museums and historic buildings in the past.

Two case studies, one from Sweden and one from Italy, will be presented here for presenting interesting applications of this method. Both cases are museums housed in historic buildings, since we think that this context is particularly significant to show how historical research can be used to gather information on the implications and consequences of different climate control strategies applied in the past. In the first case study, archival research on Stockholm’s Nationalmuseum shows how heating and ventilation did not actually solve identified problems but caused new ones challenging the preventive conservation of the building and its collections. The second case study, the Gallery of Modern Art of Milan, will show how research on the historical development of the heating systems installed within the building was coupled
with indoor climate analyses to better understand the hygrothermal behaviour of the building and to deepen the knowledge of environmental mechanisms affecting the artworks.

3. Nationalmuseum, Stockholm
By examining the case of Nationalmuseum, which is the national museum of art and design in Sweden, it has become possible to paint a picture of how museum environment and collections care were discussed and handled at the leading arts institution in Sweden until the early 1930s. Until that time almost all attention on indoor climate was focused on keeping a somewhat stable temperature, whereas relative humidity (RH) was harder to measure and was considered less important [SOU 1931]. In the winter of 1932 there were signs of furniture and panels dehydrating following the installation of a forced air ventilation system. Outside air was taken in from the museum entrance, filtered and heated, but not humidified. Indoor temperature had been raised and air circulation increased. Instead of lowering the temperature, humidity was added to the air from 1932, but the air would still be too dry for much of the furniture, panel paintings and polychrome wooden objects [Legnér 2011, 133-134].

As a consequence more attention was paid to the relationship between temperature and RH inside the museum, and more humidifiers were installed. Evidence of the dry climate of the building was the return of the collections from their wartime storage space in 1945. They had been stored underground in a very stable climate. Upon their return to the museum, furniture had soon been damaged by the much drier air. This posed a problem for the museum in the way that objects needed expensive conservation. Despite adding humidifiers to the heating system did not prove to solve the problem of keeping a stable indoor climate, it was a technology that remained in use for the rest of the century. Windows in the galleries were single sash, which caused condensation on the inside of the glass panes. They were not added with secondary glazing for a very long time because of the costs involved. The building was managed by a government agency responsible for the care of state owned properties used for civilian purposes. The agency preferred having higher running costs for heating and ventilation rather than investing in costly improvements of the building. The introduction of moveable humidifiers in the early 1950s was made possible by technological development and was based on the idea that the microclimate could be controlled in every gallery individually. Increased international cooperation put pressure on the museum to better control the indoor climate. This was however not possible to do in the smaller cabinets since these had outer walls with single sash windows. The individualized control of humidity meant that exhibitions had to be organized according to groups of objects: canvas paintings could not be exhibited together with furniture or paper [Riksarkivet, 1953]. This solution proves how pragmatically museum management looked at the issue of indoor climate. When foreign museums demanded a certain climate in order to put artworks on loan, the museum made some efforts to meet the stricter requirements. The in-house collection was instead subjected to seasonal variations
in temperature and RH. This management issue could be documented only by using the archive of the museum.

In other countries it was becoming common to introduce HVAC in national art museums at this time. Increasing car traffic outside the museum would bring the indoor climate of the museum to the fore in the 1960s. Research on air pollution showed that the building with its untight windows and entrances functioned as a “chimney” drawing outside air with its particles of dust and tar into the building, making the pollution stick to walls and artworks [Bjurström, 1976, 144]. Museum management was profoundly sceptical to the idea of sealing the building and introducing full HVAC in order to clean incoming air. The museum was protected by national legislation and according to management it should not be retrofitted. Experience from the Louvre in Paris which recently had been fitted with HVAC proved that the system would only collect particles in the air. Sulfur and dioxide coming from industrial outlets and car traffic would not be stopped in this way, and these were pollutants damaging paintings, paper and sculpture [Bjurström, msc., 9].

One unpredictable factor affecting indoor climate was visitor attendance. A Rembrandt exhibition in 1956 proved immensely popular as it attracted 290,000 visitors, but despite the humidity added by the bodies additional humidifiers were used in the exhibit space [Riksarkivet, 1955]. The agency responsible for caring for the building meant that the indoor climate should be possible to control without the addition of these extra humidifiers. Museum management was of another opinion and went against the advice of the agency. In an international study of 1960 the museum stated that it attempted to keep an indoor temperature of 18 degrees Celsius and RH of 50-60% [ICOM, 1960, 279]. There is no possibility that the climate was actually kept within this very strict interval, since it was a 19th century building which was far from airtight and did not use an HVAC system. However, in order not to make international loans impossible it was important to state for the records that indoor climate should be kept as stable as possible.

An exhaustive report on the indoor climate problems of Nationalmuseum of 2004 showed that infiltration continued to be seen as a main problem for a very long time. Every hour half of the air volume of the building was exchanged. This uncontrolled inflow of air accounts both for the infiltration of pollutants and for making the air inside very dry in winter. In winter RH could fall well below 40% [Nationalmuseum, 2004, 55]. In fact, infiltration of outdoor air has been a permanent feature of the building since the 19th century, and this problem has gained increasing attention since the 1950s as the outdoor air became more polluted. It has not been possible to add humidified air to an extent which would be satisfactory to objects made of organic materials, since the building is damaged by this addition of extra moisture in wintertime. The very reason behind this problem, however, is today’s paradigm of museum climate which makes it necessary to keep indoor climate in Nationalmuseum within a tight interval.

4. Gallery of Modern Art (GAM), Milan
The Gallery of Modern Art of Milan (GAM) is housed in Villa Reale, a late 18th
century building which was turned into a museum in 1921. The museum collections consist nowadays of paintings, mainly on canvas, and sculptures in marble, bronze, gypsum and wax from the 19th and 20th centuries. Climate control in the galleries is still based on historic heating systems: radiators are installed in the wings while in the main body an old air heating system still supplies the galleries with non-filtered air at uncontrolled values of temperature and relative humidity. Even though these systems are a rare material evidence of historical technology and something that should be considered heritage and preserved, the resulting environmental conditions are considered unsafe for artworks and, especially in summer, uncomfortable for visitors and museum attendants. This complex situation required a specific and integrated approach to understand the indoor climate of Villa Reale: environmental monitoring and diagnostics were merged with the study of the past uses of Villa Reale and with a deep research on the history of the heating systems installed within the building [Del Curto et al., 2011].

Bibliographic and archival research on the maintenance activities on the traditional climate control systems in Villa Reale during 18th and 19th centuries highlighted the constant attention paid to heating devices throughout the whole history of this building [Villa, 2008]. The disposition of the main halls and rooms, facing the garden and exposed to the south and west, would suggest that the orientation of the building was probably originally intended for exploiting the solar radiation. The indoor climate monitoring has confirmed that, due to the daily incomes of solar radiation, the thermal level of these rooms is in general higher than the outdoor level throughout the year.

The resulting uncomfortable and unsafe environment inside the Villa during summer, together with what was discovered by the historical research on heating systems, led to the hypothesis of a dwelling mainly intended for winter use: at the time it was a common habit for Milanese highest classes to reside in the city in winter and to move in countryside villas during the warm season. The indoor climate monitoring has also proved that the removal in recent times of the traditional solar shading systems in some south-facing rooms has even worsened the situation.

Some interesting discoveries on the behaviour of the air heating system came out also by the comparison between microclimatic analyses and old technical treatises. Thermography was used to analyse how the heating system influenced the indoor environment of the museum since the ducts circulating air to the rooms are cut into the walls and not insulated, on the contrary to modern air-conditioning ducts which must be well insulated. Heat is thus transferred firstly from warm air to the walls and then slowly released to the rooms; as a result the heating system works not only through convection generated by the air flows, but also through radiation. Documentation from old treatises [Meissner, 1821; Engel, 1830 quoted in Manfredi, 2008a, b] was used to better understand the reference scheme of the historic heating system and to support the assumptions on the fact that this behaviour of the system was deliberately designed. Looking back to an hypothetical original thermal behaviour of the villa, something similar must have happened also with all the chimneys of the fireplaces, nowadays not in use.
One of the main worries with the heating system was that it may cause dangerous variations in temperature and relative humidity inside the rooms. Thermographic analysis confirmed what common sense suggested: hanging paintings close to the inlets would expose them to overheating. Psychrometric mapping identified a concentration of the sharpest gradients near the air inlet, while the rest of the room maintains quite homogeneous values in the space. Indoor climate monitoring showed that the air heating causes a general drop in the relative humidity levels inside the rooms throughout the winter. This case study suggests that the opportunity to study in situ the complex interactions between artworks and an old air heating system could be used to improve our knowledge on the conditions to which collections were exposed in other old museums equipped with similar heating systems in the past. On the other hand, it was quite surprising to discover that all these phenomena, the related risks and their possible remedies had already been clearly identified and addressed in the 1940 Manual on the conservation of paintings [OIM, 1940]. At the time those old air heating systems could still be quite common and it is therefore understandable that specific indications were to be given to conservators about their management and their consequences on artworks. Nowadays these systems have been largely substituted by air-conditioning and even basic precautions on their use, at least in this case, seem to have been forgotten. The comparison between the current environmental management at the GAM and the 1940 indications shows that what we can learn from history (or what we should already have learnt but went forgotten or is undervalued) can be almost as important as what we can discover nowadays from our current technical and scientific knowledge.

5. Conclusions
Besides proposing the use of the term “conservation environment”, this paper has presented an overview of previous research on historical indoor climate and also two case studies of old art museums located in parts of Europe with different climates. Both of these buildings were erected with expectations on indoor climate which obviously differed considerably from contemporary requirements for art museums. The use of archive materials describing improvements of the building, modifications of heating and ventilation, and management issues serve to shed light on how the conservation environment has developed over time. Problems with keeping an environment suitable for the artworks have proved to be aged, but difficult to solve. In both of these cases the museums have not been prone to document problems with indoor climate since this kind of information can prove to be negative to the public image or internal management of the institution. This was clearly the case with Nationalmuseum post-WWII: the museum wished to keep a very strict climate for blockbuster exhibitions on loan from foreign museums, while it was accepted that national collections were displayed in a much less controlled climate. The only way of proving that this actually happened at different occasions has been to visit the archives. It has also become clearer why so little was done for a long time to minimize infiltration of outdoor air. Sensitive objects were not moved to other premises where
climate could easier be controlled except for conservation measures. Seen as a management issue, the conservation environment can be said to be influenced by a combination of factors of economy, human comfort, preventive conservation and design. By studying how these factors have affected the choices of involved actors, or even prevented choices from being made, we can better understand why it has been difficult to apply practical as well as scientific knowledge to the indoor climate in museum buildings. In a different way the peculiar situation of the Gallery of Modern Art of Milan made evident that a historical perspective is needed to understand the complex environmental phenomena that can arise in conservation environments within historic buildings. The environmental behaviour of historic buildings follows schemes which are the result of old and established technical knowledge which nowadays is often forgotten, disregarded and/or misunderstood. That is why we need to recover this knowledge in order to manage satisfactorily the environmental issues and to develop low-impact and energy-efficient mitigation strategies for our architectural heritage.

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