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HVAC SYSTEMS – CONSERVATIONAL CLIMATE CONDITIONING IN MUSEUM BUILDINGS

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Ivan Mijailović[1], Aleksandar Milojković[2], Marko Nikolić[2]

[1]Faculty of Occupational Safety, University of Niš
E-mail: ivan.mijailovic@znrfak.ni.ac.rs
[2]Faculty of Civil Engineering and Architecture, University of Niš

Abstract. *Museums presuppose collecting, an activity that is a universal phenomenon as old as mankind itself. As a particular kind of collection, the museum is a compilation of natural objects or art objects - the latter term understood in the widest sense - that have been taken out of economic circulation, either temporarily or permanently, which are carefully protected and exhibited in a self-contained place specially furnished for that purpose.*
Although museum buildings possess similar features as other public building types, their design is particularly specific due to their specific function. The exhibition and storing of artworks as well as the circulation of visitors are functions unified in the same building, requiring specific microclimate conditions. Therefore, one of the most important tasks in the process of museum design is the planning of an appropriate heating, ventilation and air conditioning (HVAC) control system.

Key words: *Museum building, microclimate conditions, HVAC, mechatronic system, SCADA*

INTRODUCTION

The end of the 20th and the beginning of the 21st century was a critical period in which numerous museum buildings were built worldwide. Along with already existing museums, they were a part of phenomenon known as the 'museum boom'.

Although museum buildings possess similar features as other public building types, their design is particularly specific due to their specific function. The exhibition and storing of artwork as well as the circulation of visitors are functions unified in the same building, requiring specific microclimate conditions. Therefore, one of the most important tasks in the process of museum design is the planning of an appropriate heating, ventilation and air conditioning (HVAC) control system.

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The culture of modern communication has changed the limitative concept of a museum as a simple stock of artwork; so, near the primary functions of stock, exhibition, collection, registration, management and administration, a new concept of a museum as the promoter of culture and communication, with the related spaces such as laboratory, conference, restoration and study centers, greeting areas, and communication is proposed. Specific plant solutions correspond to these new functions, with the related problems concerning control of thermal-hygrometric and IAQ parameters, safety and energy saving.

MICROCLIMATE PARAMETERS IN MUSEUMS

The interaction between the museum and the outside environment, if not adequately controlled, can accelerate the processes of the deterioration of both the museum building envelope and the artwork kept in it. The principal risks factors are certain physical mechanisms (changes in the size and form of objects), chemical reactions, and biological agents (proliferation of micro-organisms).

Lull et al. (2001) have proposed the main agents responsible of the degradation processes of the historical-artistic works stored in museums: the electromagnetic radiations coming from sources of natural and artificial light; the thermal-hygrometric conditions, the velocity and the air quality of the air in contact with the object. A suitable microclimate for conservation has to be chosen, taking into account both the direct impact that it has on the materials of the objects and the indirect one in creating a favorable habitat for biological degradation and for undesired chemical reactions, especially in the presence of atmospheric pollutants.

In general, it is possible to identify the following criteria:

- if an object is in an favorable microclimate and there are no degradation processes acting, the object must be kept in such environmental conditions;
- the original microclimate can be improved by removing or attenuating the perturbing causes, such as day cycles, fluctuations, quick transitions (ASHRAE, 2003);
- if absolutely necessary, the microclimate of an object must be changed on the basis of specific studies and the transition to the new conditions must be very slow;
- in the absence of knowledge of the precedent history of an object, the choice of microclimate has to be made on the basis of its chemical-physical characteristics.

HVAC DESIGN CRITERIA FOR MUSEUMS

The importance of the HVAC design in controlling the environment in which museum collections are stored should be clearly realized. Maintenance of certain parameters is of vital importance for collection integrity. The most important are temperature, relative air humidity (RH), particulate content and gaseous contaminants, as well as an adequate ventilation rate. A rise in temperature of approximately 8^{o} C doubles the deterioration rate of organic products in museum environments. HVAC Design Guidelines recommend maintaining temperature between 18-24°C throughout the year, allowing seasonal fluctuations between the two extremes, but holding daily fluctuations at ± 2-3° C.

Humidity is most often associated with an increased probability of bio-deterioration. Levels at 60% Relative Humidity (RH) should be considered the threshold for damage. HVAC Design Guidelines recommend maintaining relative humidity between 40% and

55% throughout the year, allowing seasonal fluctuations between the two extremes, but holding daily fluctuations at ± 3%.

Particulate content of museum air may also affect preservation. Particulates are common hosts for mold, are often abrasive, and may permanently soil collections. Particulates also increase user discomfort and increase maintenance costs. HVAC Design Guidelines recommend filtration of dust particulates to remove at least 50% of particulates using the ASHRAE Dust Spot Efficiency Test.

Gaseous contaminants, such as oxides of nitrogen and sulfur dioxide can attack organic materials by conversion into acids, while ozone is a powerful oxidant, severely damaging all organic material. Other gaseous pollutants, such as formaldehyde, may be off-gassing from storage cabinets, shelves or glues within the museum. HVAC Design Guidelines recommend filtration of gaseous contaminants to maintain preservation standards throughout the facility, coupled with localized auxiliary filtration with air purifiers in highly critical areas.

Adequate ventilation rates are essential to avoid stagnant air and inhibit the growth of microorganisms. Ventilation is critically important for museums, since it not only ensures the health and wellbeing of staff and visitors, but also helps to minimize the potential for mold outbreaks by providing adequate circulation of the air through high efficiency filters. Stagnant air can promote mold growth and should be correctly attended to in the HVAC design.

THE HVAC SYSTEM DESIGN FOR MUSEUMS

The design of the air-conditioning system is only one aspect of a wider problem, which also involves the quality of the building envelope (thermal insulation and vapor barriers) and managerial factors. The logic of design adopted in the case study proposes the differentiation of the spaces for the collections (exposure space and stock) with respect to the places destined for other functions (offices, bars, etc.), in order to limit the costs and the risks in preserving the artwork.

The conservation of artwork requires stable conditions, above all in the rooms for temporary exposures, where strong insurance ties imposed by the owners of the works exist, and in the stocks. The HVAC system must guarantee the control of the transient phenomena, the ambient microclimatic control (T and RH) and integration of the technology in the building structure. The control of the transient phenomena is strongly related to the variability of the thermal loads that the HVAC system must balance in operating time (Redondi, 2004). In particular, the fraction of the internal load due to the occupancy can create problems for the time stability of the ambient thermal-hygrometric conditions: in fact, this is an impulsive and not attenuated load because of the high occupancy variation. Such a discontinuous flow of people can cause significant and sudden changes in the environment conditions; so the reaction of the HVAC system must be extremely quick in order to restore the design values of the thermal-hygrometric conditions for conservation (Giusti, 1999). The outside thermal load, instead, changes more slowly because the layers of most buildings destined to museums (heavy structures) induce a high thermal inertia and then an attenuation of the instantaneous thermal gains: therefore the HVAC system is able to keep the design conditions without significant indoor changes.

A multizone air handling unit with zone reheat and humidification can be a stable and relatively energy-efficient solution. With proper layout and equipment, a multizone system can reduce the amount of reheat and can be very energy-efficient (Bovill, 1988); so constant volume and multizone systems in collection spaces are preferred.

The variable air volume system is characterized by flexibility, fewer space requirements for the equipment, reduction of the operating cost; it can be conveniently used for various zones served by the same air handling unit, but it presents some limits related to the capacity in balancing the changes of the thermal loads, both sensible and latent, because it is rarely possible to reduce the air flow rate more than 25 – 30% in respect to the design one.

The adoption of adsorption dehumidification systems allows the reduction of the humidity also when the required dew point temperature is very low; so an easier handling of high latent loads is obtained. These systems are better as regards hygienic characteristics because the absence of condensed water strongly reduces the presence of bacteria, fungi and microbes. Absorption dehumidification systems, instead, should be avoided, because of the potential risk of acid particles (i.e. chlorine solutions) or drops released in the air flow, with consequent risk of damage for the collections.

Because the goal is the strict control of the ambient microclimatic parameters, excessive amounts of outside air can be economically problematic. Even when free-cooling is convenient, outside air can introduce particles and gaseous pollution. So, outside air must be of the minimum amount required to provide fresh air for occupants and to pressurize collection spaces.

High, monumental spaces are prone to thermal stratification; if this risk is real for collections, then appropriate return and supply air points may be required to ensure air motion across the entire space. Supply air should not blow directly onto collections.

Sensors, thermostats and humidistats must be located in the collection space, not in the return air stream. Temperature variation is usually preferable to prolonged humidity swings. This strongly affects control design, because conventional control systems treat temperature as the primary goal and humidity as supplementary (ASHRAE, 2003).

MONITORING EQUIPMENT

Systems engaged in the control of museum microclimate parameters are often actually a part of a more complex system, composed of mechanical, electrical and computing components. This complex system also functions as a heating, air conditioning and ventilation monitoring system. Generally speaking, this is a mechatronic system, which manages the building comfort parameters. A typical mechatronic system consists of mechanical, electrical and computer components. The process of system data acquisition begins with the measurement of a physical value with a sensor. The sensor is able to generate some form of signal, generally an analog signal in the form of a voltage level or waveform. This analog signal is sent to an analog-to-digital converter (ADC). The microcontroller consists of a microprocessor, memory and other attached devices. The program in the microprocessor uses the digital value along with other input and preloaded value called calibrations in order to determine output commands. Like the input to the microprocessor, these outputs are in digital form and can be represented as a set of bits. A digital-to-analog converter (DAC) is often used for converting the digital value into an ana-

log signal. The analog signal is used by an actuator to control physical devices or affect the physical environment. The sensor then takes new measurements and the process is repeated, thus completing a feedback control loop. The timing for the entire operation is synchronized by the use of a clock. Relevant physical variables (temperature, humidity, oxygen, carbon dioxide and fine particles concentrations) are converted by sensors into appropriate electrical values suitable for further transfer and processing. The reception level of the microcomputer module for the regulation of those relevant physical variables transfers the electrical signal of the measured values into a form suitable for further processing (ADC, frequency-to-digital converter, among others). The algorithm for the automatic regulation of the relevant physical variables is implemented using a microcomputer module. As a result of the processing of the measured values, the microcomputer module generates a control action that excites the actuators. The selected **SCADA** system (*Supervisory Control and Data Acquisition*) is a system for the measuring, monitoring and control of industrial systems. This system has existed in various forms since the 1960s, but from the 1990s it has experienced a big expansion with the advent of faster and more efficient computing and micro controller devices. It can be used to easily monitor temperature, humidity and pressure, but it can also be used for more complex monitoring and control of production processes in factories or railway traffic. It is known that the limiting values of the parameters, which are significant for museum conditions, are defined by the maximum concentrations of carbon dioxide and humidity of the ambient air, as well as by the minimum necessary concentrations of oxygen and temperature levels. Convenient microclimate conditions are provided by HVAC installations and devices for microclimate quality monitoring and environmental comfort control. A microclimate control system consists of software and hardware components that take the maximum allowable concentrations of microclimate parameters as alarm thresholds and then make control decisions based on them.

CONCLUSION

Museums are often theme-oriented: art, natural and social history, scientific, maritime, space and other specialized themes. They include the entrance and exhibit areas, working and office areas, and artifact storage areas and vaults. Some exhibits are exposed for public viewing and others may be enclosed in cases or special rooms, or warehoused for future exhibits.

A preventative conservation program must begin with an intensive museum-wide study which examines the collection, the indoor environment, the building, and the current HVAC system. This type of detailed preservation study provides baseline data and allows you to demonstrate the benefits of improvements.

The collection should be examined since different materials require different handling and environmental conditions. Without knowledge of the condition of the collection and its environmental needs, there is no baseline for any conservation program.

Maintenance of constant microclimate parameters in museums is of vital importance for collection integrity. The most important parameters are temperature, relative air humidity (RH), particulate content and gaseous contaminants, as well as an adequate ventilation rate. A rise in temperature of approximately $8^{o}C$ doubles the deterioration rate of organic products in museum environments. HVAC Design Guidelines recommend main-

taining temperatures between 18-24°C throughout the year, allowing seasonal fluctuations between the two extremes, but holding daily fluctuations at ± 2-3° C.

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Particulate content of museum air may also affect preservation. Particulates are common hosts for mold, are often abrasive, and may permanently soil collections. Particulates also increase user discomfort and increase maintenance costs.

All of the abovementioned facts about museum microclimates are the fundamental premises of museum building design. Therefore, all existing museum buildings as well as any future museum design project must take these facts into consideration, as an essential part of the museum design process.

REFERENCES

1. Ayres J.M., Lau H., Haiad J.C., 1996, Energy impact of various inside air temperatures and humidities in a museum when located in five U.S. cities, ASHRAE Transaction, n.2, pp.100- 111.
2. ASHRAE, 2003, ASHRAE Handbook - HVAC Applications, Chapter 21, Museums, libraries, and archives, pp. 21.1-21.16.
3. Bovill C., 1988, Qualitative engineering, ASHRAE Journal, April, pp. 29-34.
4. Hartman T., 1996, Library and Museum HVAC: New Technologies/New Opportunities – Heating/piping/air conditioning, part 1, n.4, pp. 57-60.
5. Hartman T., 1996, Library and Museum HVAC: New Technologies/New Opportunities – Heating/piping/air conditioning, part 2, n.5, pp. 63-73.
6. Lull W., Harriman L., 2001, Museums, Libraries & Archives, Humidity control design guide for commercial and institutional buildings, ASHRAE, Chapter 23, pp. 334-358.
7. Mecklenburg M., Tumosa C., 1999, Temperature and relative humidity effects on the mechanical and chemical stability of collections, ASHRAE Journal, April, pp. 77-82.

SISTEMI KGH – MIKROKLIMATSKI USLOVI KONZERVACIJE U MUZEJSKIM ZGRADAMA

Muzeji pretpostavljaju kolekcioniranje, aktivnost koja je predstavlja univerzalni fenomen star kao i samo čovečanstvo. Muzeji mogu sadržati kolekcije različitih vrsta, od prirodnih do umetničkih dela koja ne ne nalaze na ekonomskom tržištu, bilo trenutno ili permanentno i sa velikom pažnjom čuvanih i izloženih u specijalnom prostoru opremljenom za tu svrhu.

Iako muzejske zgrade poseduju slične karakteristike kao i ostale javne zgrade, njihov dizajn je posebno specifičan zbog njihove specifične funkcije. Izlaganje i čuvanje umetničkih dela, kao i stalna cirkulacija posetioca su funcije ujedinjene u istom prostoru i samim tim postoje zahtevi za specifičnim mikroklimatskim uslovima. Zbog toga je jedan od najvažnijih zadataka u procesu projektovanja muzejskih zgrada, planiranje odgovarajućih kontrolnih sistema KGH.

Ključne reči: *muzejske zgrade, mikroklimatski uslovi, KGH, mehanotronički sistemi, SCADA*