

ENVIRONMENTAL PARAMETERS IN THE NATIONAL GALLERY OF COSENZA: A CASE OF STUDY

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Abstract: The environmental conditions of the museum exhibition facilities and storage areas are the most crucial factors, concerning the preservation of collections and artifacts.

This paper describes the distributed measurement system used to monitor the environmental conditions of the National Gallery of Cosenza.

The pollution, the humidity, the temperature and the lighting can possibly deteriorate or even destroy the material cultural goods that are kept, protected and displayed in museum collections. Therefore, the aim of the present report is to evaluate whether the environmental parameters monitored are within some critical values. The study demonstrates few parameter values may comprise the preservation of painting materials.

Keywords: Environmental Parameters, monitoring, distributed measurement system.

1. INTRODUCTION

In the past, the environmental control in public place, (museum and national gallery, also), was orientated towards the convenience of the visitors and the staff. However, recent research studies [1]–[5] show that the control of environmental parameters in indoor areas in which cultural collections are housed should be based on the preservation of the materials, otherwise there is a danger of deterioration or even destruction of exhibitions.

Objects stored or displayed in museums and galleries are constantly subjected to decay. The environment in the interior of a museum or a historic building and the microclimate surrounding the object constitute a complex set of multivariate factors, which determines the nature and rate of decay. The quality of the museum environment determines the rate of chemical and physical changes in paintings.

Important factors are temperature, relative humidity, concentration of air pollutants, light intensity and wavelength distribution [6]. Painted works of art on display in museums are inevitably subjected to changes as time progresses. Such changes include not only discoloration of the varnish, but also discoloration of pigments and degradation of the binding medium.

Suitable control of the environment can retard the rate of deterioration of artworks. In the majority of museums a lot

of effort and expense are put on controlling whether standard environmental parameters are within some critical values. The detailed understanding of the mechanisms of degradation due to environmental factors is an open research field, and big effort is given in the design of monitoring system able to monitor the environment. The main difficult is that artworks are often stored in rooms with no climate control, displayed in public buildings (historic buildings, palaces, churches) and are exposed to larger environmental fluctuations. Fluctuations produce gradients, which affect the mechanical and chemical stability of the paint films [7]. This may even lead to migration of organic constituents and cause blanching phenomena (e.g. in paintings by Stanley Spencer in the Sandham Chapel). Such conditions require repeated interventions by trained conservators, which do not improve the condition and the overall stability of the artworks.

In the paper the monitoring of the national gallery of Cosenza (south of Italy) (Fig.1) is considered as a case of study. The National Gallery of Cosenza is housed in Palazzo Arnone Triglio-located on the hill - also home to the Superintendence for the Historical, Artistic and ethno-anthropological of Calabria. It collects many different manufactures, and paintings made with different techniques and then with different glues and pigments. Therefore, the effect of different environments can deteriorate them in different manners.

The paper is organized as follow. In section II parameters under monitoring are described. In section III the distributed monitoring system is defined.

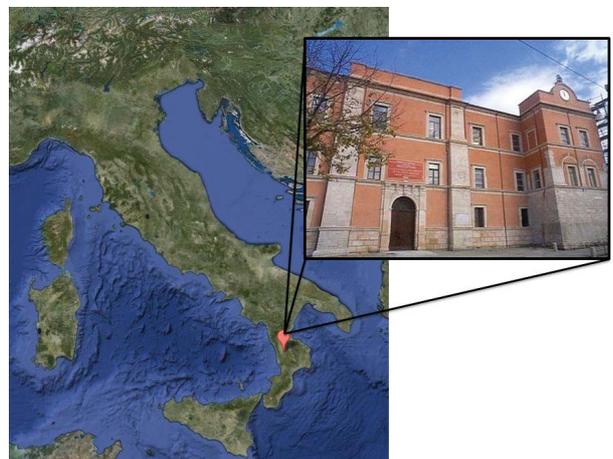


Fig. 1 National gallery of Cosenza

2. PARAMETERS UNDER MONITORING

The parameters that strongly influence the degradation of the glues in the paintings are humidity and temperature. Therefore, the monitoring of the humidity flux and heat flux between the environment and the surface of the paintings is important.

The heat flux, denoted with H , from and to a surface depends on the air temperature gradient. It is:

$$H = -K_H \frac{\partial T}{\partial N} \quad [\text{cal cm}^{-2} \text{s}^{-1}] \quad (1)$$

Where $\frac{\partial T}{\partial N}$ is the temperature gradient along the normal

direction n of the painting surface and K_H is the exchange coefficient along n depending on the laminar or turbulent air movement close to the painted surface.

Also the humidity flux, denoted with M_v , depends on the gradient of vapour in the air. It is:

$$M_v = -\rho K_w \frac{\partial rm}{\partial n} \quad [\text{g cm}^{-2} \text{s}^{-1}] \quad (2)$$

Where $\frac{\partial rm}{\partial n}$ is the gradient of the mixing ratio along

direction n , ρ is the density of the air, K_w is the coefficient of vapour diffusion along n . K_w is not a constant and it depends on the dynamic conditions of the air. The increasing of the temperature due to the environment or radiations on the painting surface propagates with a delay from lower to higher surface layers. Therefore, the temperature of the lower layers depends upon the distance from the painting surface and the propagation delay. In the case of different layer materials, as in the painting, the quantity of thermal energy Q expressed by the Fourier formula, is

$$Q = A \Delta T \frac{\Delta t}{\left(\frac{d_1}{\lambda_{c1}} + \frac{d_2}{\lambda_{c2}} \right)} \quad (3)$$

where A is the surface area of the painting, Δt is the time, ΔT is the different temperature among the layers, d_1 and d_2 are the width of each layer, and λ_1 λ_2 , the thermal conductivity coefficients of each layer.

A fast fluctuation of temperature generates a higher ΔT , that produces a mechanical stress in the material and speeds up the degradation processes.

The relative humidity has an important role in the biological processes of the painting. Such an example, in the wood the internal quantity of the water is:

$$M = \frac{m_w - m_d}{m_d} * 100 \quad [\%] \quad (4)$$

Where m_w is the mass of the wood with moisture and m_d is the mass of dry wood. The equilibrium moisture content is the moisture content at which the wood is neither gaining nor losing moisture; however this is a dynamic equilibrium and changes with relative humidity and temperature.

The equilibrium moisture content mainly depends on (i) the moisture in the air, (ii) the temperature, (iii) the adsorption/de-adsorption processes in the wood, and (iv) mechanical compression or stress [8].

3. DISTRIBUTED MEASUREMENT SYSTEM

The Distributed Measurement System [9]-[11] is composed by the Babuc/A, the infrared thermometer Raytek-Raynger ST Pro Plus.

The Babuc/A is a semi portable data logger equipped by different sensors for the acquisition, display, storage and processing of a large variety of physical and chemical parameters. It is connected to a PC for the acquisition of real time information. In our case we use it in permanently installed modality for long-term data acquisition. Once transferred to the PC, the acquired data are processed, stored and made available from remote monitoring from the University of Calabria.

With the Babuc/A the following parameters were monitored:

- dry bulb temperature ($^{\circ}\text{C}$), i.e. the temperature of air measured by thermometer freely exposed to the air but shielded from radiation and moisture. Dry bulb temperature is the temperature that is usually thought of as air temperature, and it is the true thermodynamic temperature. It indicates the amount of heat in the air and it is directly proportional to the mean kinetic energy of the air molecules.
- mean radiant temperature ($^{\circ}\text{C}$), i.e. the uniform temperature of an imaginary enclosure in which the radiant heat transfer from the painting is equal to the radiant heat transfer in the actual non-uniform enclosure.[1]
- mean radiant temperature (MRT) arises from the fact that the net exchange of radiant energy between two objects is approximately proportional to their temperature difference multiplied by their ability to emit and absorb heat (emissivity). This is valid as long as the absolute temperatures of objects in question are large compared the temperature differences, allowing linearization of the Stefan-Boltzmann Law in the relevant temperature range.
- Relative humidity (%), i.e. the amount of water vapor in the air at any given time is usually less than that required to saturate the air. The relative humidity is the percent of saturation humidity, generally calculated in relation to saturated vapor density.

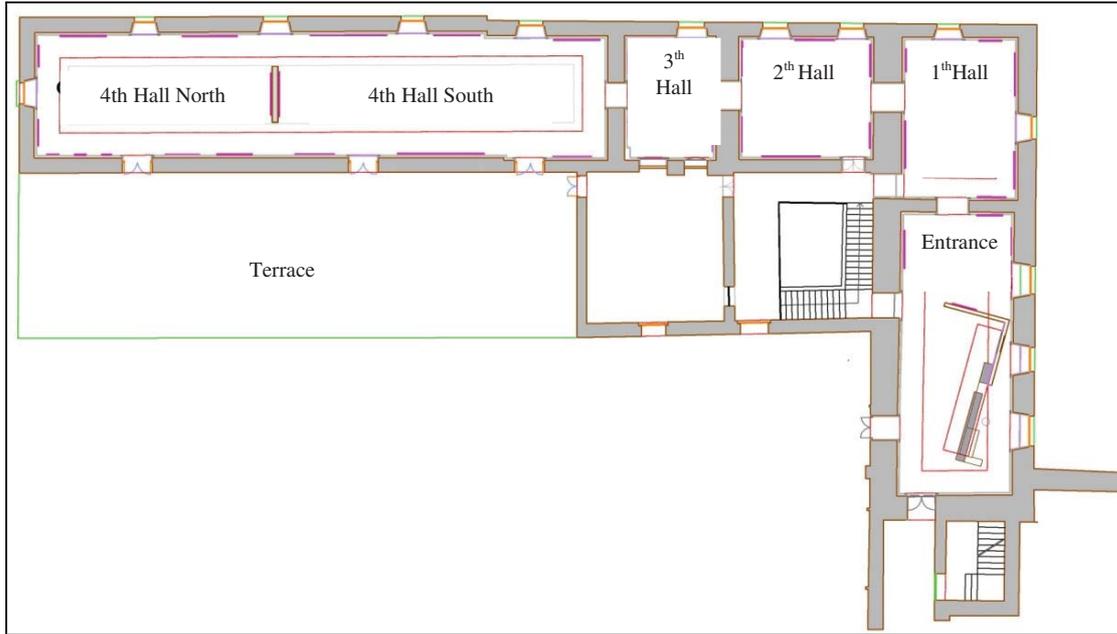


Fig. 3 Planimetry of the National gallery of Cosenza

The Babuc/A was positioned in the centre of each room of the National Gallery of Cosenza (see Fig.2). In Fig. 3 the planimetry of the national gallery is reported to show the exposure of each room respect the cardinal points and one each other.

The infrared thermometer Raytek-Raynger ST Pro Plus was used to monitor the surface temperature of the paintings. It is an infrared non-contact thermometers that offer accurate readings in the range (-32, 535) °C with accuracy $\pm 1\%$ of reading or $\pm 1^\circ\text{C}$, whichever is greater.



Fig. 2 The Babuc/A installed in the center of the room of the National gallery of Cosenza

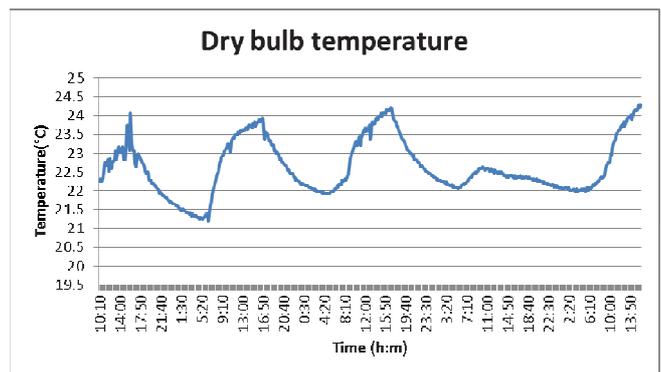


Fig. 4 Trend of the dry bulb tempertaure

4. EXPERIMENTAL RESULTS

The monitoring was performed in 5 days. Fig.4 shows the trend of dry bulb temperature. Fig. 5 shows the trend of the mean radiant temperature. The regular trend of the temperature ($22 \pm 1^\circ\text{C}$) in the fourth day is because it is a

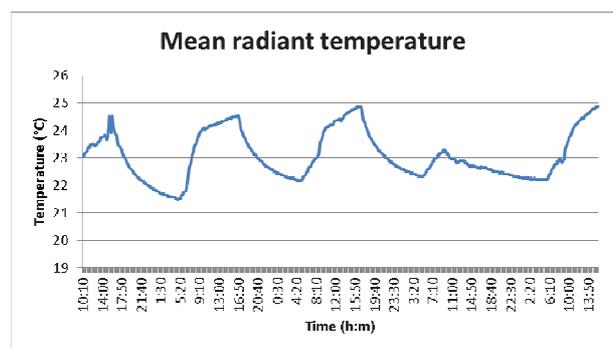


Fig. 5 Trend of the mean radiant temperature

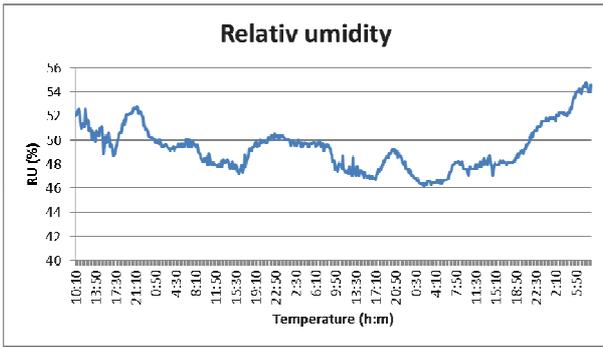


Fig. 6 Trend of the mean radiant temperature

closing day and the artificial lights are not used. The temperature trend has a mean value equal to $23 \pm 1^\circ\text{C}$, a maximum value equal to $24 \pm 1^\circ\text{C}$ and a minimum value equal to $21 \pm 1^\circ\text{C}$.

Fig. 6 shows the trend of the relative humidity. The simultaneous monitoring of such parameters was allowed by the Babuc hardware and software architecture.

Fig.7 shows a) the painting of Pietro Negrone – Sacra Famiglia con San Giovannino (170x115) and b) the table of the monitored temperatures. The painting is logically divided in 12 cells. Each cell was monitored during the time. Therefore the temperature is monitored both in time and space. Fig.7 highlights that the cells localized in the top of

the picture have higher temperature respect to the one on the bottom. This is due both to the normal thermal movement of the air that brings the hot air on the top and the cold one on the bottom, but also to the positioning of the artificial light. Indeed, in the fourth day, when the artificial lights are not used, the temperature is practically constant in all the cells of the painting.

5. CONCLUSIONS

In the paper the distributed measurement system is proposed to monitor the environment of the national gallery of Cosenza. Recent studies have highlighted that the environmental conditions of the museum exhibition facilities and storage areas are the most crucial factors, concerning the preservation of collections and artifacts.

The pollution, the humidity, the temperature and the lighting can possibly deteriorate or even destroy the material cultural goods that are kept, protected and displayed in museum collections. Preliminary study on the temperature in the rooms of the national gallery and on the painting has highlighted the importance of the lighting system on the preservation of the paintings. Indeed, the wrong positioning of the lights generates a thermic gradient between the top and bottom of the painting generating a mechanical stress in the material and the speed up of the degradation processes.

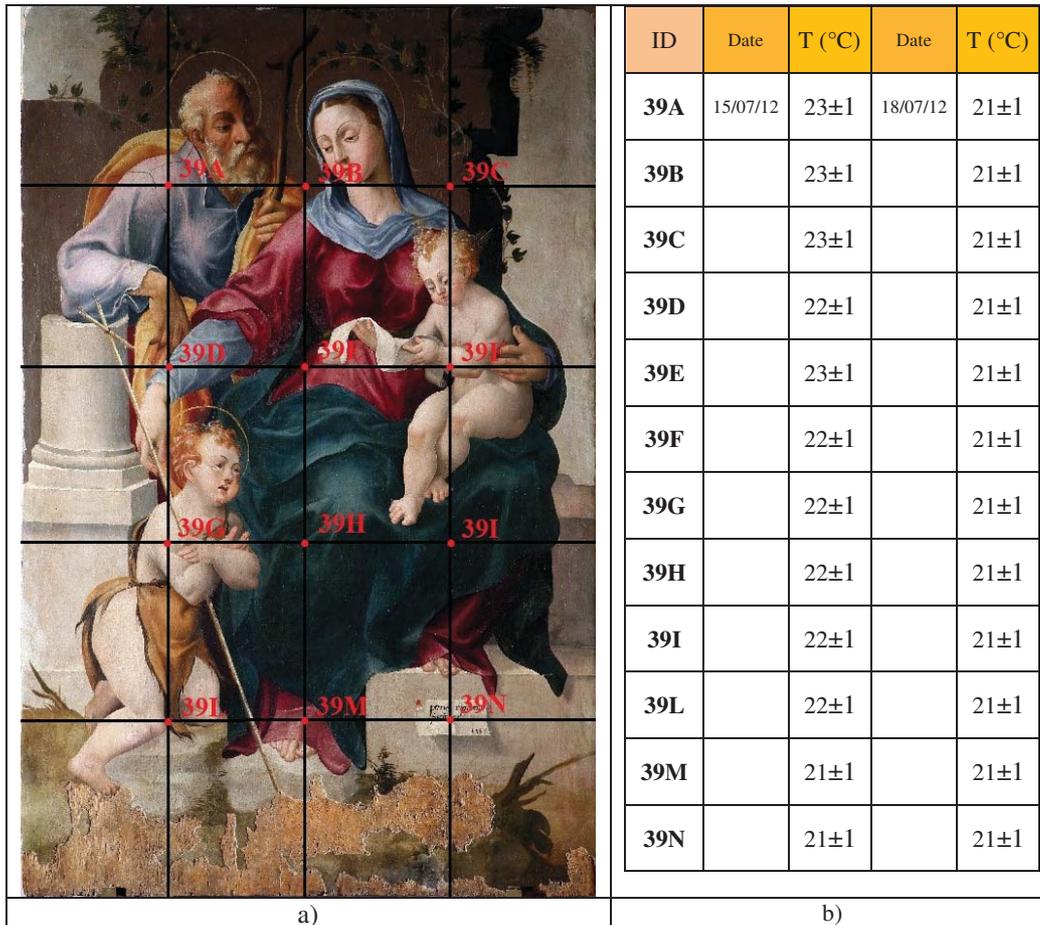


Fig. 7 Painting of Pietro Negrone – Sacra Famiglia con San Giovannino (170x115).

6. ACKNOWLEDGMENTS

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7. REFERENCES

- [1] G. Pavlogeorgatos “Preservation of material cultural heritage”. Thessaloniki, Greece: Paratiritis Publishing House S.A., 2003.
- [2] D. Camusso, R.V. Grieken, H.J. Busse, G. Sturaro, A. Valentino, A. Bernardi, A. Blades, D. Shooter, K. Gyssels, F. Deutsch, M. Weiser, O. Kim, U. Ulrych, “Environmental monitoring in four European museums”, *Atmospheric Environment*, Vol. 35, Issue 1, 2001, pp.127–40.
- [3] N. Blades, T. Oreszczyn, B. Bordass, M. Cassar, “Guidelines on pollution control in museum buildings”, *Museum Practice*, Museums Association, London, 2000.
- [4] R.S. Morten, editor, “Third indoor air quality meeting”, Presentation abstracts from the meeting held at Oxford Brookes University, 10–12 July 2000.
- [5] Schultz AW, editor. *Caring for family treasures*. New York: Harry N. Abrahms Inc.; 2000.
- [6] G. Thomson, “The Museum Environment”, Butterworth/Heinemann, Oxford, 1995, pp. 293.
- [7] O. F. van den Brink, G. B. Eijkel, Jaap J. Boon, “Dosimetry of paintings: determination of the degree of chemical change in museum-exposed test paintings by mass spectrometry”, *Thermochimica Acta* 365, 2000, pp. 1-23
- [8] A. Bernardi, Environmental monitoring in four European museums. *Atmospheric Environment* 2001.
- [9] G. Pizzuti, F. Lamonaca, N. Arcuri, "Data Acquisition for Green Roof", 19th IMEKO TC 4 Symposium and 17th IWADC Workshop on Advances in Instrumentation and Sensors Interoperability, July 18-19, 2013, Barcelona, Spain, pp.
- [10] F. Lamonaca, D. Grimaldi, R. Morello, A. Nastro, "Sub- ms Synchronization Accuracy in Distributed Measurement System by PDAs and PCs' triggers realignment", Proc. of I2MTC 2013– IEEE International Instrumentation and Measurement Technology Conference (I2MTC 2012), Minnesota, USA, 6-9 May, 2013, pp.
- [11] F. Lamonaca, D. Grimaldi, “Trigger Realignment by Networking Synchronized Embedded Hardware”, *IEEE Transaction on Instrumentation and Measurement*, Vol.62, Issue 2, 2013, pp. 38-49.