

# Indoor temperature monitoring for cultural heritage

**D V Abramkina and K M Agakhanova**

Moscow University of Civil Engineering, 26, Yaroslavskoe Highway, Moscow, 129337, Russia

E-mail: [dabramkina@ya.ru](mailto:dabramkina@ya.ru)

**Abstract.** The preservation of cultural heritage is one of the most important tasks in considering heat and humidity mode of museum premises, which should be as stable as possible. The choice of exhibiting place can significantly affect the safety of museum collections. The formation of temperature gradient on the picture's surface can cause breaks and cracks of colorful layer and substrate (canvas, paper, wood). Moisture, penetrating in gaps of colorful layer of painting, accelerates the aging processes. Increasing relative humidity and indoor air temperature can cause mold growing in glue layer. To reduce risk of thermal stresses throughout a year, it is necessary to provide thermographic measurements of building envelope and exhibit places.

## 1. Introduction

One of the most significant indicators of indoor microclimate in museums influencing the preservation of historic objects is temperature-humidity mode of exhibition halls. The required parameters of internal microclimate during storage of various exhibits are presented in Table 1 [1].

**Table 1.** Required parameters of internal microclimate in museums

Exhibits	Temperature, °C	Relative humidity, %
Archeological artifacts	18-22	20-30
Leather artifacts, parchment	18-22	25-40
Textile, clothing, carpets	18-22	30-50
Painting on canvas	18-22	45-55
Painting on wood	18-22	40-60

However, the analysis of indoor microclimate quality using the average air temperature is a rough estimate of the storage conditions. Air temperature and relative humidity can vary considerably not only within one room, but also within one exhibit. The presence of a temperature gradient on the painting's surface contributes to the destruction of colorful layer and substrate (canvas, paper, wood). Paintings are created from various materials, with different temperature expansion coefficients. Uneven temperature field leads to the appearance of temperature stresses, different equilibrium moisture content in various areas, which leads to stratification and ruptures of paint layers and primers - Figure 1 [2, 3].





**Figure 1.** Breaks in the paint layers and primers as a result of the exhibit aging under the influence of temperature and humidity fluctuations.

One of the measures implemented to maintain optimal microclimate parameters in exhibition halls is the supervision of temperature and relative humidity of building envelopes, which is especially important in countries with a cold or hot and humid climate [4, 5]. The interior surfaces of external walls in the museum are exhibition areas on which paintings could be located. The main risks in this case are: the formation of convective air flows near heating devices, the emergence of decreasing cold flows near translucent building envelopes and condensation (especially behind the picture, where a stagnant zone with a temperature below the dew point may arise). The temperature and humidity mode of the museum premises should be as stable as possible. Small, but often repeated fluctuations lead to delayed aging of materials [6, 7].

Information about temperature on surfaces of building envelopes as well as the relative humidity and temperature of the indoor air, allows estimating the possibility of condensation.

Temperature and humidity fluctuations can occur:

- from hidden elements of construction structures (frozen metal forms, weaknesses in thermal insulation of slabs and walls);
- from cracks and looseness of building envelope;
- from engineering systems (influence of hot elements of water heating system, quality of air distribution in air conditioning and ventilation systems, availability of hidden electrical wiring).

Usage of thermographic cameras can help to identify all of these factors, causing temperature and humidity fluctuations.

## 2. Materials and methods

Thermographic imaging was carried out to measure the temperature fields on the surfaces of walls and exhibits. Several series of measurements were held in the exhibition halls of art gallery to assess the availability of temperature gradients on painting's surfaces. The study was conducted using thermographic camera Testo 875-1i.

## 3. Results and Discussion

Measurements and control of indoor air temperature and relative humidity are performed with data-loggers, which are located in every exhibition hall. Air temperature in exhibition hall 1 is 19.8 °C and

21.3 °C in exhibition hall 2, relative humidity in exhibition hall 1 is 45 % and 52.7 % in exhibition hall 2.

In the case study building all paintings have an air gap between the interior surface of external wall and canvas. It is a very important factor, because it can provide the zone with a particular air velocity in it. Such ventilated area helps to avoid condensation behind the painting. Analysis of experimental studies was made in two steps: identification of the location of heated and cooled surfaces and determination of the temperature gradients on the picture surface. The Figure 2 shows the results of measurements.



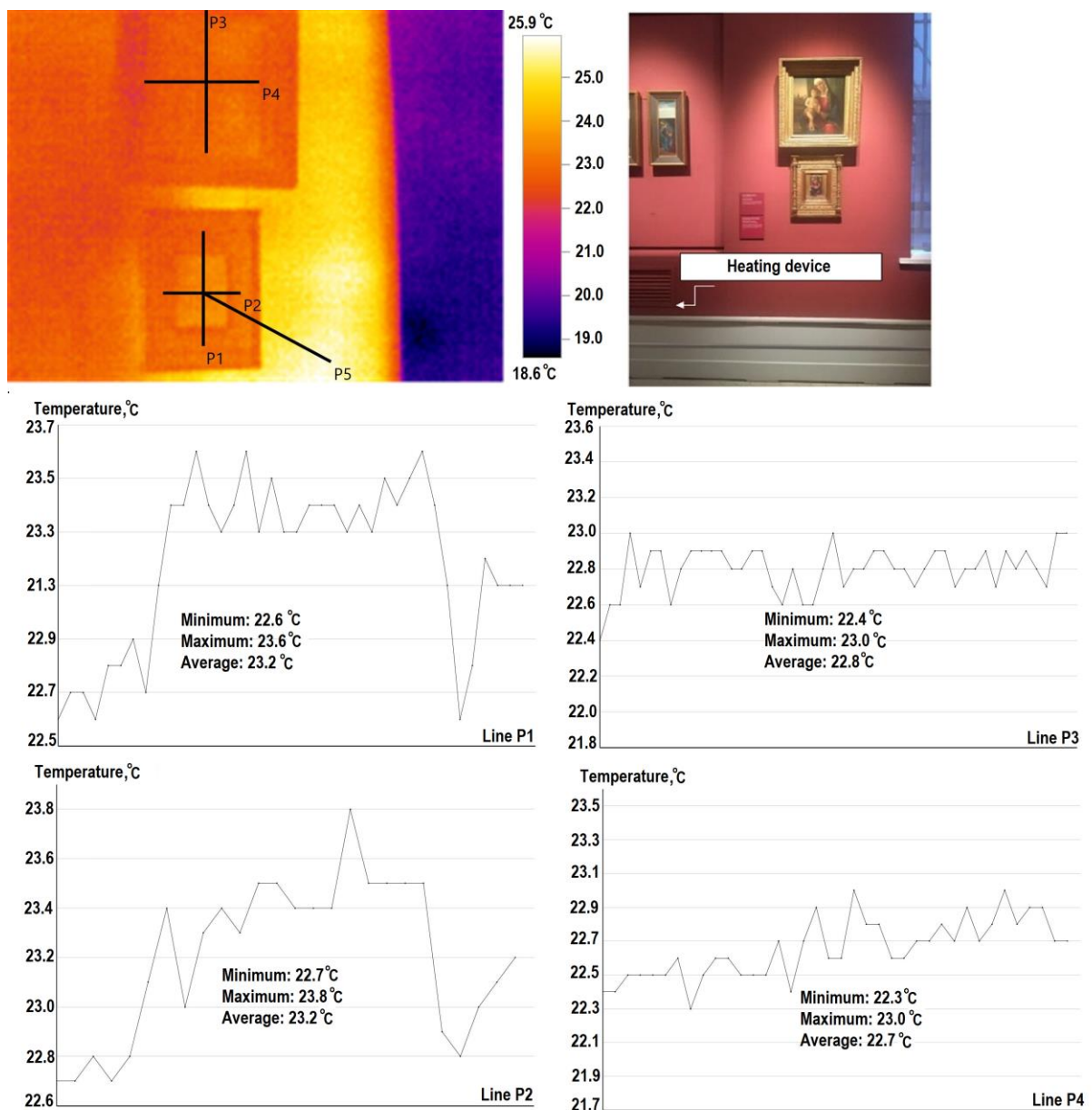
**Figure 2.** The results of experimental studies (exhibition hall 1). Left top picture – thermographic image; bottom left picture – temperature curve (line P3); right picture – photo of exhibit.

Vertical temperature gradient (line P1 – Figure 2) is 1.9 °C, horizontal temperature gradient (line P2 – Figure 2) is 1.6 °C. The lower left corner of the painting located in the zone of high temperature arising under the influence of convective free flows near the hot surface of heating device. Temperature in point M1 is 23.6 °C and 21.9 °C in point M2.

In the exhibition hall 2, both paintings are located in the zone of high temperatures (Figure 3). The main reason of this phenomenon is hidden vertical pipes of water heating system, which are clearly shown in the Figure 5. Vertical temperature gradients on the picture surfaces are 1 °C (line P1) and 0.6 °C (line P3). Horizontal temperature gradients on the pictures are 1.1 °C (line P2) and 0.7 °C (line P4). However, minimal temperature on the surface is higher than required values in both cases (Table 1).

The temperature change from the center of the painting to the hottest point is shown in the Figure 4.

The measurements were made at an external temperature equal to  $-0.8$  °C that is much higher than the estimated temperature for heating system ( $-25$  °C). Therefore, in the case of cold winter, it is possible that the temperature on the surface of the exhibit will grow.

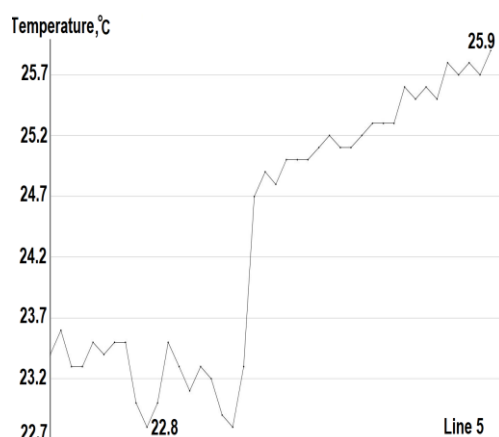


**Figure 3.** The results of experimental studies (exhibition hall 2).

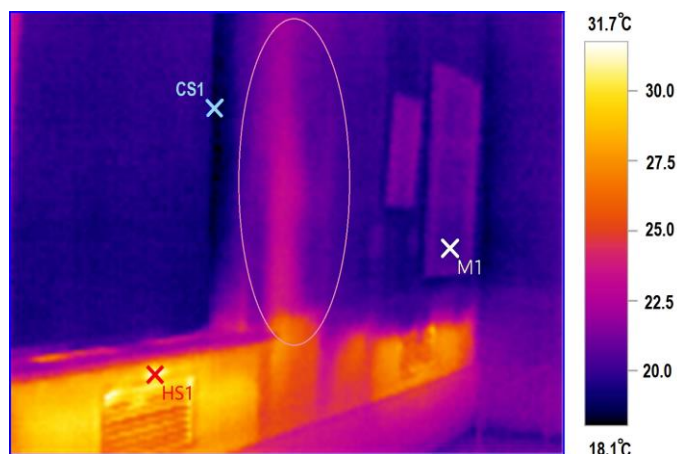
When the temperature increases, the elasticity of the paint layer gets lost and it becomes more rigid [8]. The expansion and contraction of the substrate and primer will have a significant impact on it. Cracks and gaps appear on the painting's surface (Figure 1, left photo). If the connection between the paint layer and the primer is poor, the painting is dissecting and warping.

The glue which is part of paint layer swells and softens when the temperature is growing and the relative humidity increases to 70%. In such conditions, the glue layer becomes a favorable place for the mold development [9-11]. Molds are most commonly found in natural materials (paper, wood, fiber, textiles) [12]. High relative humidity causes swelling of wood canvas. Infection with mold is dangerous by the fact that, arising from high humidity, most molds can develop even after it decreases.





**Figure 4.** Temperature curve (line 5)



**Figure 5.** Thermographic image of exhibition hall 2.

Figure 4 shows the position of the highest (HS1) and lowest (CS1) temperature points. M1 – point on the oil painting surface. Thermographic measurements allow identifying condensation zones. For this purpose, the dew point temperature should be found in each room, which is the most important factor determining the stability of internal microclimate parameters. As the number of visitors increases (which is especially noticeable during temporary exhibitions), the relative humidity and indoor air temperature can increase, which will lead to an increase of dew point temperature. That means that condensation on the building envelope can begin at a higher surface temperature.

#### 4. Conclusion

The following recommendations were compiled as conclusions for the study:

- it is necessary to develop normative requirements for heat-physical characteristics of the museum building envelope and temperature fields on their surfaces;
- the preparation of places for the exhibits accommodation should be carried out after the thermographic studies in the cold period of a year;
- to reduce the possibility of condensation, it is necessary to provide air gaps between the exhibit and the surface of external wall.

#### References

- [1] Abramkina D, Ivanova A 2018 *International Scientific Conference Energy Management of Municipal Facilities and Sustainable Energy Technologies (EMMFT 2018)* 78-83
- [2] Ankersmit B, H.L. Stappers M 2016 *Managing Indoor Climate Risks in Museums* (Berlin: Springer)
- [3] Padfield T, Berg H, Dahlstrom N, Rischel A G 2002 *ICOM committee for conservation 13<sup>th</sup> triennial meeting* 80-85
- [4] Kramer R, Schellen H L and Schijndel J V 2015 *Conference: Healthy Buildings Europe (HB 2015)* 135084
- [5] Napp M, Kalamees T, Tark T and Arumagi E 2016 *Energy Procedia* **96** 592-600
- [6] Froidevaux J 2012 *Wood and paint layers aging and risk analysis of ancient panel painting*. (Montpellier: Université Montpellier)
- [7] Hill Stoner J and Rushfield R 2013 *Conservation of Easel Paintings* (Abingdon: Routledge) p 928
- [8] Camuffo D 2019 *Microclimate for Cultural Heritage: Measurement, Risk Assessment, Conservation, Restoration, and Maintenance of Indoor and Outdoor Monuments* (Amsterdam: Elsevier)
- [9] Korotcenkov G 2018 *Handbook of Humidity Measurement, Volume 1: Spectroscopic Methods of Humidity Measurement* (Florida: CRC Press)

- [10] Jareemit D, Shu S, Heidarinejad M et al. *Conference: Proceedings of CLIMA 2013*
- [11] Li Y, Xie H, Ogura D, Hu S and Guo Q 2016 *Journal of Asian Architecture and Building Engineering* **15:1** 133-138
- [12] Parrot K 2009 *Viginia Tech* 2901-7019