Archives of Materials Science and Engineering

Volume 124
Issue 2
December 2023
Pages 56-61

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

**DOI:** 10.5604/01.3001.0054.3234

# Experimental studies of the thermal regime of the premise while using heating ceramic panels

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## ABSTRACT

**Purpose:** The purpose of this paper is to analyse the obtained experimental data, which is advisable to use to verify the thermophysical model of the thermal regime of a separate premise while using ceramic electric heating panels for heating purposes.

**Design/methodology/approach:** The experimental studies were carried out at the scientific thermophysics laboratory with the help of up-to-date equipment (including the design for these studies). After gathering experimental data, it was analysed, and with its help, a CFD model of the thermal regime of the laboratory premise would be verified.

**Findings:** The conducted experimental studies showed that in the artificially created quasi-stationary thermal regime of the laboratory premise, the air temperature varied with height in a small interval. This makes it possible to state that when using ceramic electric heaters as heating devices, the air temperature is relatively evenly distributed over the height of the premise.

**Research limitations/implications:** The research provides original experimental data and findings for further CFD modelling of the thermal regime of the premise while using heating ceramic panels.

**Practical implications:** The mentioned in the paper research methods as well as obtained experimental data, could be used in further studies of modern heating systems. Another use of the results – during the validation of CFD models.

**Originality/value:** The paper includes the design and methodology of creating the original experimental stand for research of the different heating systems types.

**Keywords:** Ceramic heater, Experimental research, Temperature monitoring

**Reference to this paper should be given in the following way:**

B.I. Basok, O.M. Nedbailo, K.M. Bozhko, I.K. Bozhko, M.O. Markin, O.M. Markina, V.O. Marteniuk, Experimental studies of the thermal regime of the premise while using heating ceramic panels, Archives of Materials Science and Engineering 124/2 (2023) 56-61. DOI: https://doi.org/10.5604/01.3001.0054.3234

## PROPERTIES

## 1. Introduction

Heating systems are one of the largest heat consumers in residential and industrial buildings. Nowadays, there are many ways of heating the premises. Using radiator ceramic panels is one of the possible measures to achieve thermal comfort for people staying in the relevant premises.

In modern scientific literature, you can find works devoted to studying the parameters of various heating systems. Both experimental works and works in which CFD modelling has been used, as well as those that combine both research methods, are presented.

So, for example, article [1] is devoted to studying the performance of radiant panel heaters. During the study, the temperatures inside the room and on its walls were experimentally measured. Also, in order to predict the temperature distribution along the premise, the numerical model has been designed. In works [2,3], the results of experimental studies on determining the temperature by height of a model room with its radiant floor heating are separately given. In the works mentioned above, a model describing the temperature distribution in the model room was proposed. The authors used the k-ε model of turbulence to calculate the aerodynamic components. The radiation heat transfer parameters were calculated using the DO (discrete ordinates) radiation model. The researchers proved that the CFD models they developed describe the processes with sufficient accuracy and could be used to predict the air temperature distribution in the room when the initial conditions of the heating surface temperature distribution are changing. With the help of such models, it is possible to analyse the influence of the location of the panel and its geometric dimensions on the temperature distribution in the room.

In [4], Miren and Holmberg investigated the different heating systems using CFD modelling (S2S radiation model and low Re k-ε turbulence model). As a result, the authors concluded that low-temperature heating systems provide a more comfortable temperature difference along the height of the room and provide a low speed of air movement at the same time. In contrast, radiation heating devices with higher surface temperatures resist cold air flow if they are located under windows.

In [5], a comparison of the indicators of three types of heating systems, namely ceiling radiation, regular radiator and air heating, is provided. The work results showed that the temperature difference between the surface of the walls and the air in the room is within the acceptable range of values to ensure thermal comfort during the operation of all types of the considered systems.

The article [13] deals with the research results of temperature distribution on infrared heater surfaces. A mathematical model of the heat exchange process on an infrared heater surface was developed. The experimental measurements have been carried out, and the verification temperature data on the infrared heater surface have been obtained to verify the reliability of the results of theoretical studies. The results of the studies showed that the temperature gradient of the area of the heater changed no more than 4.5°C.

Air temperature was measured, but humidity and carbon dioxide concentration measurements were omitted. The relationship between these air parameters is presented in the publication [14]. The partial results of investigating the interrelationship of individual parameters of indoor air - temperature, relative humidity and $CO_2$ concentration, obtained during the experimental measurement, are presented. The experimental measurements have been performed in a selected room, and temperature, relative humidity and $CO_2$ concentration have been recorded.

Therefore, the purpose of this study was to conduct an experimental study and analyse the obtained experimental data, which was supposed to be used to verify the thermophysical model of the thermal regime of a separate laboratory premise of 30 $m^2$ while using ceramic electric heating panels for heating. As well as to be sure that ceramic electric heating panels can ensure the proper artificially created quasi-stationary thermal regime of the premise for further studies.

## 2. Research materials and methods

Experimental studies were carried out at the scientific thermophysics laboratory of the Institute of Engineering Thermophysics of the National Academy of Sciences of Ukraine located at Kyiv, str. Bulakhovskogo, 2. The existing scientific thermophysics laboratory is a full-scale building used for experimental measurements of heat flow values during its interaction with the environment, as well as for further optimisation of building components and its engineering heat supply systems [6-12]. Sigvolt LLC provided electric ceramic heaters for scientific research.

Structurally, ceramic heaters consist of two layers. The first is ceramic tile (Fig. 1). The second layer is an electrothermal flat element applied to the surface of the back side of the ceramic tile (situated behind the ceramic tile layer, which is shown in Fig. 1). The geometric dimensions of the heaters are 1.2x0.6 m. The thickness of each ceramic tile is 0.008 m.

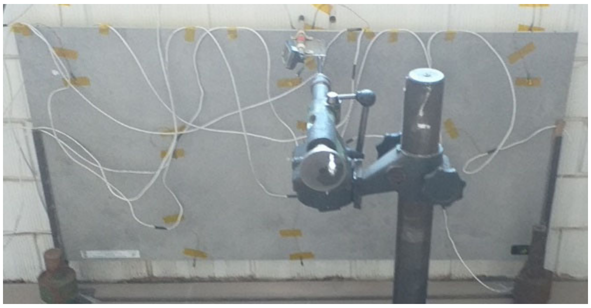

Fig. 1. Electric ceramic heater "Teplokamin" with a group of temperature sensors on the surface and a thermal anemometer in the tripod

Two ceramic heaters were located in a rectangular laboratory premise with a height of 2.75 m and dimensions of 9.28 × 3.3 m under the windows at a distance of 0.1 m from the surface of the outer wall (Fig. 2). The room has two hermetic window openings of 1.0 × 1.5 m in western orientation and a door opposite the windows, which was tightly closed during the experiments.

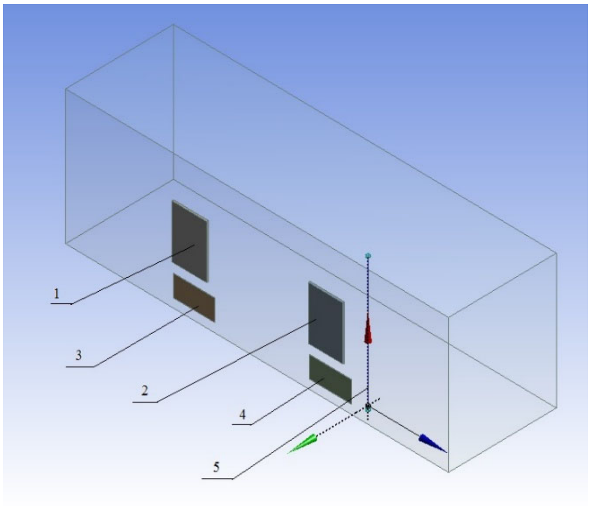


Fig. 2. Scheme of placement of ceramic electric heaters in the space of the premise: 1, 2 – windows, 3, 4 – ceramic electric heaters, 5 – string with temperature sensors to measure its distribution along the height of the room

Measurement of the temperature values on the surface of each ceramic heater was carried out using microcontroller secondary devices (Fig. 3), which were developed and manufactured in the Department of Thermophysical Basics of Energy-saving Technologies (TBET) of the Institute of Engineering Thermophysics of the National Academy of Sciences of Ukraine.


Fig. 3. Secondary devices for continuous monitoring of temperature values of the experimental stand

The available equipment allows simultaneous continuous monitoring and data storage in digital form on a microSD card of 12 DS18B20 temperature sensors. The technical characteristics of the sensors are given in Table 1.

Table 1.
Characteristics of DS18B20 temperature sensors

| Parameter | Value |
|---|---|
| Supply voltage | 3.0…5.5 V |
| Temperature measurement range | -55°C +125°C |
| Accuracy of temperature readings | 0.5°C |
| Interface | 1-Wire |
| Electric current | 1 mA |

The scheme of placement of temperature sensors on each ceramic heater is shown in Figure 4. Sensors T1-T3 are fixed on the surface of the wall outside the ceramic heater. Sensors T10-T12 are placed 0.02 m below the lower edge of the ceramic heater in the air space between the heater and the floor.

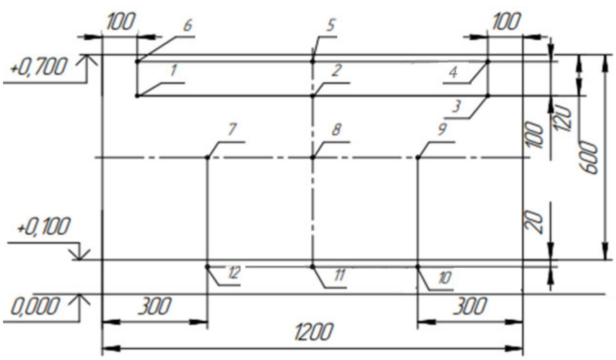


Fig. 4. The scheme of placement of temperature sensors (marked by numbers 1-12) on and around the ceramic electric heater

For measuring movement speed and air temperature using the TESTO 405i thermal anemometer (speed measurement ranges up to 2 m/s and temperature -20...50°C) in a tripod with discrete data transmission in digital form to a computer via a wireless Bluetooth interface. At the same time, the error of measuring the speed of air movement was ± (0.1 m/s + 5% of the measured value in the range from 0...2 m/s), and the temperature was ±0.5°C.

## 3. Results and discussion

During the time of experimental studies, the laboratory premise was heated simultaneously by two electric ceramic heaters. Temperature values were continuously measured from March 02nd to March 18th 2021. The premise was heated by ceramic electric heaters from February 15th to March 18th 2021 to obtain a quasi-stationary thermal regime. Such a regime was reached on February 26th, 2021, and maintained in this condition until March 9th (Fig. 5).

The outer wall of the laboratory premise is made of materials whose characteristics are given in Table 2.

During the period of measurements, the temperature of the outside air varied from -14°C to +5°C. Ceramic electric heaters were operated at a voltage of 205 V and an electric current of 10.38 A.

The temperature on the surface of the ceramic electric heater varied in the range from 51.9°C to 56.2°C. It was determined that it is slightly higher in the central area and decreases when approaching the edges of the panel. Since detailed CFD models of non-stationary heat exchange objects are usually difficult to develop and require a lot of computer time to process and get the results of calculations based on them, some simplifications and assumptions are usually made during research.

In the case of the ceramic heater considered in work, CFD modelling can assume that the surface temperature of the ceramic heater is evenly distributed over the surface and is equal to 55°C.

The profile of the temperature distribution along the height of the laboratory premise on February 3rd 2021, is shown in Figure 6, where $H$ – the height of the laboratory premise, [m] and $T$ – the air temperature [°C]. Here and further, to simplify the analysis, the cause-and-effect relationship in the form of profiles between the physical quantities indicated on the axes of the graphs is intentionally broken.

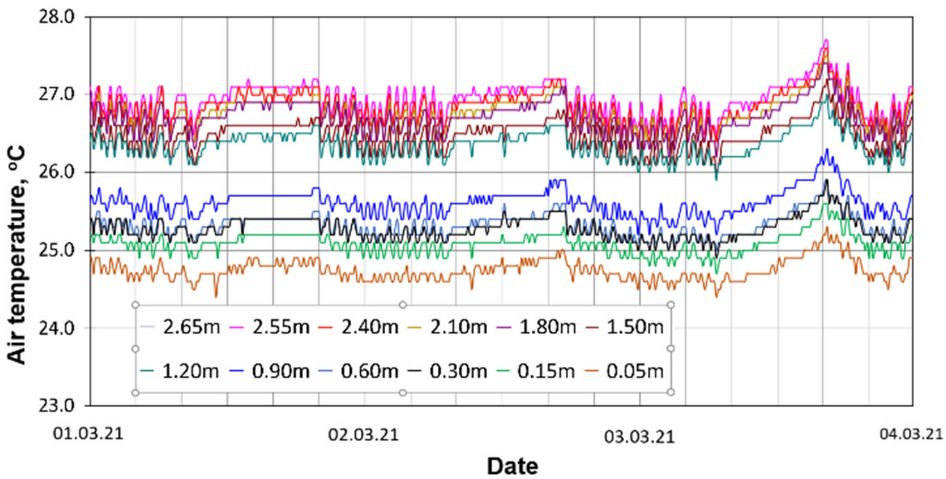


Fig. 5. Temperature dependence on time at different values of height in the room

Table 2.
Thermophysical properties of the materials of the outer wall of the laboratory premise

| Name of the material | Thickness, m | Specific heat capacity $C_p$, kJ/(kg·K) | Density $\rho$, kg/m$^3$ | Effective thermal conductivity $\lambda$, W/(m·K) |
|---|---|---|---|---|
| Brickwork from hollow bricks | 0.12 | 0.88 | 1200 | 0.470 |
| Styrofoam filler | 0.07 | 1.34 | 15 | 0.045 |
| Foam concrete | 0.20 | 0.84 | 1000 | 0.380 |
| Mineral wool | 0.25 | 0.84 | 150 | 0.048 |

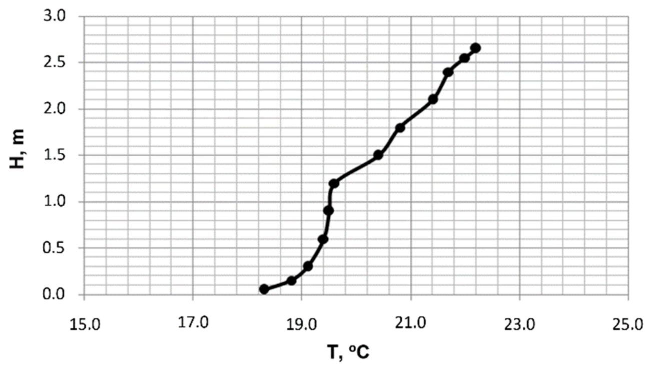


Fig. 6. Temperature distribution along the height of the laboratory premise

As can be seen from the figure, the air temperature is slightly lower near the floor, but on average, corresponds to the value of 20±2°C, which, in turn, corresponds to the state regulations.

As can be seen from Figure 7, where $H$ – heights of the laboratory premise, [m] and $T$ – air temperature [°C], electric ceramic heaters heat the air evenly along the height of the room. At the same time, the air temperature difference between the bottom and the top of the premise while heating is about 2 to 4°C.

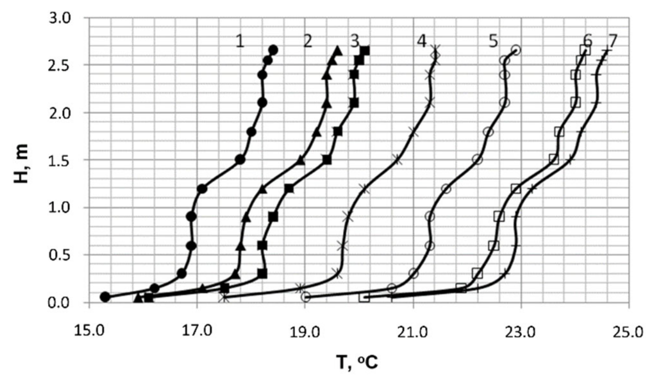


Fig. 7. The air temperature profile change while heating the room with electric ceramic heaters: 1 – February 17th; 2 – February 19th; 3 – February 20th; 4 – February 21st; 5 – February 22nd; 6 – February 23rd; 7 – February 24th

The results of measuring the air temperature on the horizontal section of the slot gap with a thickness of $\delta_W$ between the electric ceramic heater and the outer wall are shown in Figure 8 where $T$ –air temperature [°C], $\delta w$ – thickness of the gap between the outer wall of the building and the ceramic heater [mm].

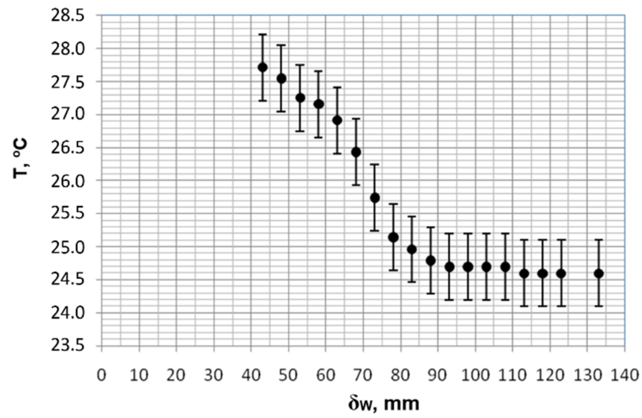


Fig. 8. Temperature distribution in the gap between the outer wall of the building and the ceramic heater

The experimental measurement data shown in Figures 5-8 can be used to verify the thermophysical model that is currently under development. In addition, with the help of such a model, it would be possible to conduct numerical studies and, based on them, determine the optimal place for the location of ceramic electric heaters in the space of the premise in relation to the outer wall.

## 4. Conclusions

The experimental study showed that the temperature of the ceramic tile surface of the heater is higher in the centre and decreases when approaching the edges. When numerically modelling a ceramic electric heater, it can be assumed that the temperature of the surface of the ceramic heater is uniform over the surface.

The experimental studies showed that in the artificially created quasi-stationary thermal regime of the laboratory premise of 2.75 m heights, the air temperature varied with height in a small interval of about 2.0 to 4.0°C depending on the outdoor air temperature. This makes it possible to state that when using ceramic electric heaters as heating devices, the air temperature is relatively evenly distributed over the height of the premise.

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