Experimental Study of Temperature Distributions over the Heat Supply Object Surface Located at a Different Height in a Room with a Working Infrared Heater

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Abstract. Experimental studies of heat transfer in the "emitter – air – heat supply object" system have been carried out in order to register the horizontal surface temperatures depending on the distance to the infrared heater. According to the results of the experiments, it was found that the temperature of the equipment surface areas influenced by the heater is significantly uneven. The temperature difference can reach 20 degrees, and an increase in the height of the object by 2 times increases its surface temperature by 67%. It has been established the need of considering the possible overheating of equipment located in zones heated by infrared heaters when developing systems for ensuring the regulatory thermal regime in large industrial premises.

INTRODUCTION

In connection with the problems of falling demand for many goods in 2020 and a negative forecast of the consumption level in at least the next 2-3 years caused by the pandemic consequences, the issues of energy conservation in industrial production are aggravated [1-5]. In the context of large personnel reductions in many enterprises, the task of maintaining production in the face of a significant decrease in volume of the products and, accordingly, the areas of used production facilities, becomes very urgent. This issue is especially relevant for a number of states in connection with the need to ensure regulatory thermal regimes of industrial premises in the cold period (autumn - winter - spring) [5-8]. In this regard, systems for radiant heating of local working zones based on gas infrared emitters are becoming promising [9, 10].

The creation of a comfortable thermal regime for people working in large-sized industrial premises is quite energy-intensive because it is necessary to heat large volumes of air to the specified temperatures [10-13]. One of the options for reducing energy consumption is the use of a radiant heater to create a regulatory regime for those working in a local area [11, 14]. However, there is usually a variety of industrial equipment in the working area. It will also be heated by a gas infrared emitter (GIE). Since industrial equipment has a regulatory temperature regime for its operation, it becomes necessary to determine its surface temperature.

The purpose of this study is to experimentally establish the regularities of surface temperature changes of a remote horizontal panel for placing equipment located at different distances from the gas infrared emitter. Also, there is a need to establish the basic laws of the formation of thermal regime for typical operating conditions, time intervals and heat supplied to the working area from the gas infrared emitter.

EXPERIMENTAL METHOD AND TECHNIQUE

One gas infrared emitter of moderate power (5 kW) was used to achieve the aim of the study. The use of one GIE for experiments is due to the fact that the heat fluxes and temperatures distributions over large areas under the operating conditions of several (3-4) gas infrared emitters are equidistant in the areas heated by one emitter.

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Experiments were carried out in the winter period at an outdoor air temperature T_e from -12 °C to -30 °C (typical experimental results at T_e = -22 °C are listed below). The initial air temperatures in the experimental box have been set in the range of +2 °C to +15 °C. Such temperature range corresponds to two-shift or one-shift industrial premises. Earlier it was established that cooling the room to negative temperatures in the majority of practically significant options is inappropriate due to a number of objective reasons [15]. As a consequence, the main experiments were carried out at an initial temperature of about + 10 °C indoors.

When conducting experimental studies, a setup with the following main elements was used (Fig. 1): 1) gas infrared emitter - GIE-5 of a light type manufactured by Sibshvank with a rated thermal power of 5 kW; 2) gas source; 3) model of the heat supply object (Fig. 1); 4) K-type thermocouples with an insulating coating made of PFA fluoropolymer (junction thickness 0.08 mm); 5) analog-to-digital converter (ADC) - a National Instruments network converter with a DAQ 9181 designed to control clocking, synchronization and data transmission from a 16-channel, 32-bit isothermal temperature measurement module NI 9214 from National Instruments; 6) personal computer (PC).

The experiments were carried out in an enclosed room with dimensions of 10.2×4.9×4.4 m. The walls were made of 70 cm thick brick. The floor and ceiling panel were made of a 25 mm thick reinforced concrete slab. There was a 300 mm unheated air gap between the floor and the ground. 100 mm thick mineral wool insulated the ceiling slab from the outside of the building. The attic space height was 1500 mm. The roof was gable with a 20 mm wooden beam supporting frame. The coating material for the roof was made of 3 mm thick galvanized steel.

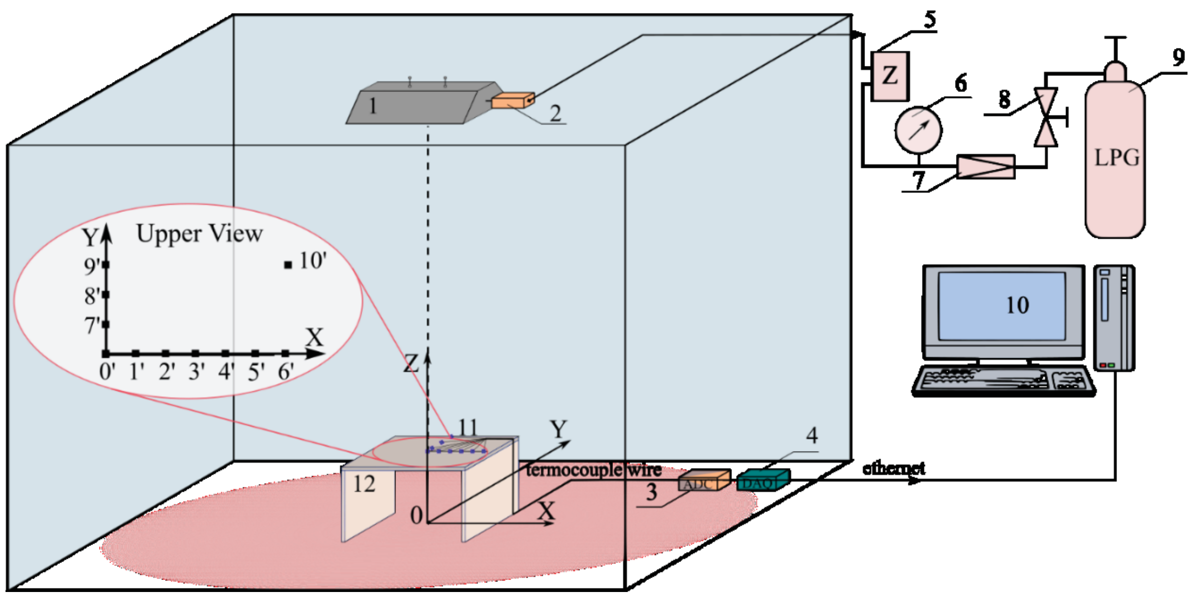


FIGURE 1. Schematic representation of the experimental area and the location of thermocouples on the heat supply object model: 1 - GIE, 2 – a GIE control unit, 3 – an analog-to-digital converter, 4 -a data collection system, 5 - a gas flow meter, 6 – a pressure gauge, 7 – a gas pressure regulator, 8 – a main shut-off device, 9 - a gas cylinder, 10 – a computer, 11 – the thermocouples (0 '- 10' thermocouple numbers), 12 – a heat supply object

The horizontal extension panel with dimensions of 1.2 × 0.55 m was made of 0.04 m thick pine chipboard covered with varnish layer. The thickness of the varnish layer was less than 1 mm. The panel location along the height of the room (Z) varied from 0.75 m to 1.5 m. During each experiment, temperatures at 11 characteristic object surface points were measured (Fig. 1, Table 1).

The measurements were carried out with K-type thermocouples with a junction diameter of 80 μm (the measurement error was no more than 0.4 ° C). To improve the thermal contact of thermocouples with the object surface under study and to protect them from re-radiation, KPT-8 thermal paste was used. The analog-to-digital converter and the data collection system were located on a heat-insulating pad. The distance between these devices and the measurement surface was 4 meters. The protection against re-radiation for thermostatic control of the cold junction was provided.

TABLE 1. Coordinates (X, Y) of the location of the thermocouples on the object model at $Z = 0.75$ and 1.5 m

N of the thermocouples	0	1	2	3	4	5	6	7	8	9	10
X, m	0	0.1	0.2	0.3	0.4	0.5	0.6	0	0	0	0.6
Y, m	0	0	0	0	0	0	0	0.1	0.2	0.3	0.4

All experiments under fixed conditions were carried out at least three times in order to ensure the possibility of evaluating random measurement errors. Then the standard deviations and the corresponding coefficients of variation were calculated. The values of the latter in all experiments did not exceed 4%. The second and third levels of significant factors (air humidity, pressure, exterior temperature changes during long-term experiments) can influence the readings of measuring instruments. Therefore, the statistical processing of the measurement results was necessary. The influence of these factors was insignificant, but they must be evaluated according to the general provisions of the experimental research errors theory.

RESULTS AND DISCUSSION

The measurement results of the horizontal remote panel surface temperatures are shown in Fig. 2-5. It is clearly seen that the process of the object temperature field formation ends 30-40 minutes after the start of the heating.

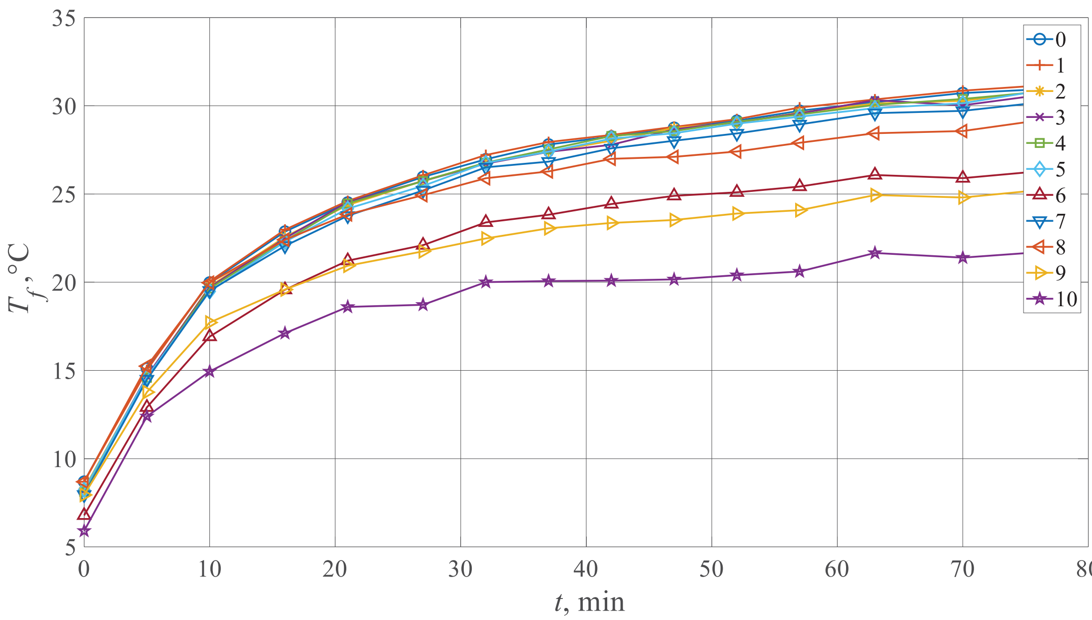


FIGURE 2. Temperature changes of the panel surface located at a height of $Z = 0.75$ m with increasing time (thermocouple numbers according to Table 1)

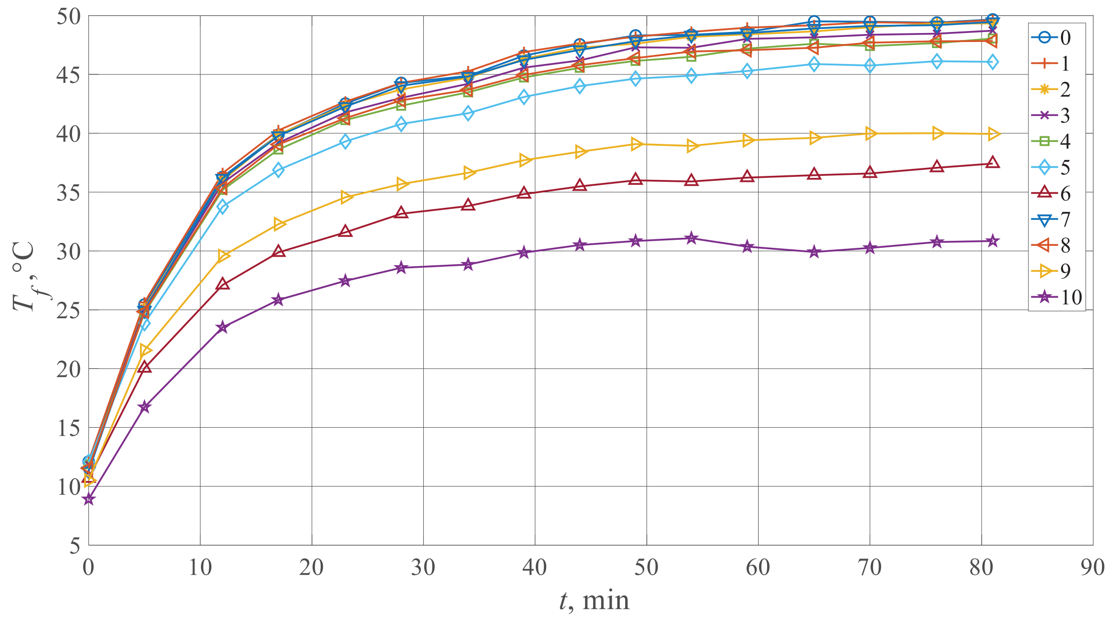


FIGURE 3. Temperature changes of the panel surface located at a height of $Z = 1.5$ m with increasing time (thermocouple numbers according to Table 1)

Based on the obtained experimental results, a number of regularities of the processes under study can be distinguished. As time passes (at $\tau = 80$ min), the near-surface layer of the panel heats up to temperatures of 32 ° C when $Z = 0.75$ m and 50 ° C when $Z = 1.5$ m. This temperature (50 ° C) can be quite critical both for the panel and for the equipment located on it. At high temperatures (50 ° C and above), some panels (chipboards) with an adhesive compound (e.g. epoxy resin) can release substances harmful to humans [14]. Also, the equipment with electronic elements, such as a personal computer, with an optimal operating temperature of about 40 ° C can be overheated and work in an irregular thermal regime.

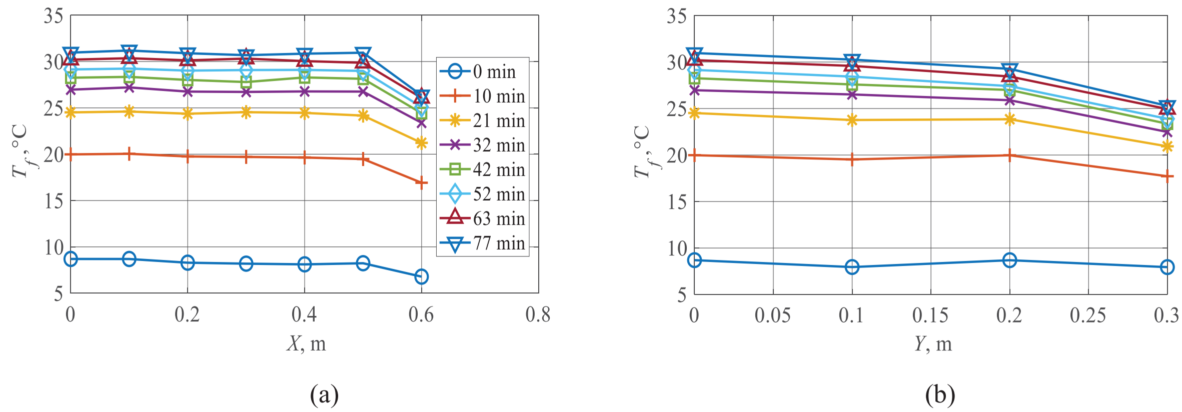
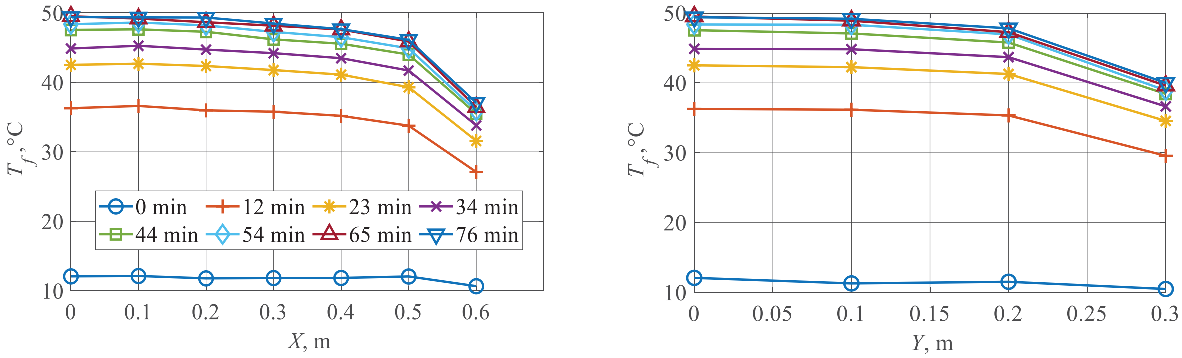


FIGURE 4. Temperature distribution of the panel surface at a height of $Z = 0.75$ m along the coordinate directions X (a), Y (b) at characteristic times



(a) (b)

FIGURE 5. Temperature distribution of the panel surface at a height of $Z = 0.75$ m along the coordinate directions X (a), Y (b) at characteristic times

It is also seen (Fig. 4-5) that the temperatures in the central part of the panel surface change insignificantly. It was found the temperatures decrease closer to the edge of the panel. In this case, the temperature difference (ΔT_f) between the center (thermocouple 0) and the border of the horizontal remote panel (thermocouple 6, 9) significantly depends on the height of its location: when $Z = 0.75$ m $\Delta T_f = 5$ ºC, when $Z = 1.5$ m $\Delta T_f = 15$ ºC. Comparison the temperatures of the central (thermocouple 0) and corner zones (thermocouple 10) of the panel surface showed that when $Z = 0.75$ m $\Delta T_f = 9$ ºC, when $Z = 1.5$ m $\Delta T_f = 20$ ºC.

CONCLUSIONS

Based on the analysis of the experimental results it was found that the horizontal surfaces of the equipment placed in local zones with gas infrared emitters are heated unevenly. In this case, the temperature difference over the object surface can be about 20 degrees. It can lead to deformation of the surface due to thermal stresses arising in it. Furthermore, it was found that an increase in the height of an object can increase its surface temperature to high (critical) temperatures. It is true both for the material of the equipment and for the working radio-electronic devices.

Obtained experimental results can serve as an information base for the development of systems for the thermal regime creation of the local working zones. Moreover, it can be used in assessing the thermal state of equipment located in these zones. The established regularities and characteristics of heat transfer processes in local working zones during the operation of radiant heating systems can be applied to build models of such processes. Also, it can significantly contribute to the theory of equipment thermal regime formation in locally heated working zones of large-sized industrial premises for various purposes.

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