Budownictwo o Zoptymalizowanym Potencjale Energetycznym 2(20) 2017, s. 83-90
DOI: 10.17512/bozpe.2017.2.11

Vasyl ZHELYKH, Nadiia SPODYNIUK, Bogdan GULAI
Lviv Polytechnic National University, Institute of Building and Environmental Engineering
Heat, Gas supply and Ventilation Department, Ukraine
Volodymyr SHEPITCHAK
Lviv Polytechnic National University, Department of Labor Protection, Ukraine

MODELING OF THE PROCESS OF HEAT REGIME FORMATION IN THE IRRADIATION AREA OF INFRARED HEATER

One of the important issues of energy policy the EU and Ukraine is the economical use of energy. An effective way to provide temperature conditions in production facilities is the use of infrared heaters. The main advantage of them is that they heat only the areas where heating is required. The purpose of the publication was mathematical modeling of heat regime formation in the irradiation area of infrared heater, which was designed the graphics dependence on the results of study. The results of mathematical studies were done concerning the determination of the intensity of radiation surface by the infrared heaters depending on surface temperature radiant heater, outside air temperature, air temperature and floor area. For analytical studies were used MATCAD 15.01. packages.

Keywords: air temperature, infrared heater, staying zone, heat transfer

INTRODUCTION

On this time in Ukraine plenty of energy resources are spent for heating of productive and agricultural apartments. It is related to that these apartments of large volumes, in connection with what considerable resources spend indemnification of heat lost and providing of technological processes. These moments substantially complicate the engineering, technical and scientific aspects of decision of problems warm providing industrial apartments. It explains circumstance that on this time only all-round reasonable conception and methodology of development of the systems are absent warm providing of productive complexes with the use of the energy effective heating systems.

The effective heating systems of high production premises are systems based on the use of electric infrared heaters. The main advantage of them consists in the heating only the areas where it is required. As a result, the use of such heating systems warms only the certain surfaces and objects. Thus, we can achieve the desired thermal condition in different areas or in individual workplaces [1-3]. However, the use of radiation heating system the meaning of radiant energy distribution on the surface is uniform. Therefore, the task is to ensure uniform distribution of heating system on all area of workplace.

The purpose of the publication was development of research setting based on the infrared heater for the study of the intensity of radiation surfaces, which was designed the graphics dependence on the results of study.

1. EXPERIMENTAL STUDIES

For providing an analytical research of temperature conditions on working surface of production facilities a simplified model of heat flow has developed (Fig. 1). It displays a direction of heat flow and their interaction with heat sources. Operating the thermal parameters it can be possible to develop heat balance in the staying zone with further definition of temperature regime.

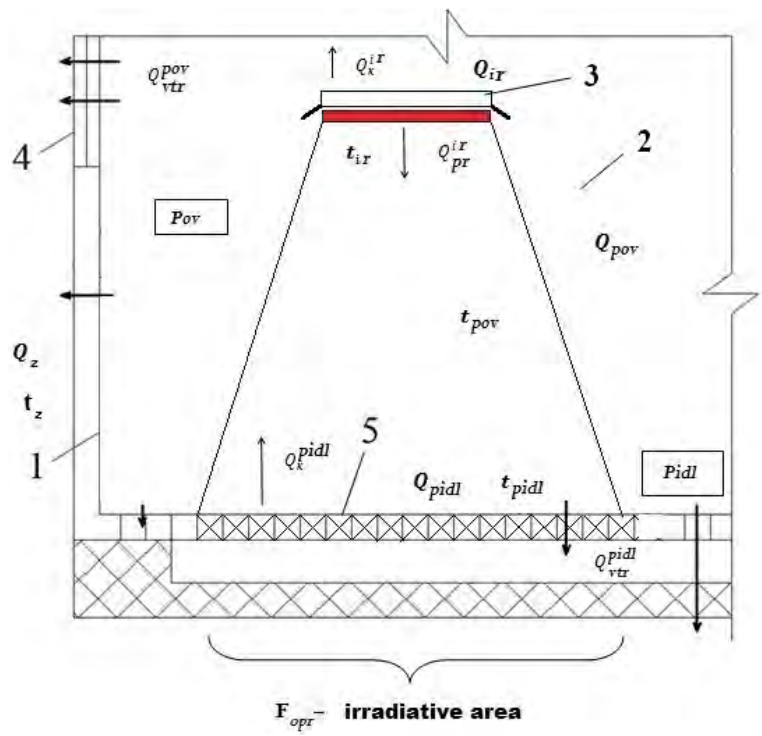

Fig. 1. The scheme of heat flow in the staying zone: 1 - external wall, 2 - staying zone, 3 - infrared heater, 4 - window, 5 - floor

Thermal balance will take the following form:

$$Q_{pr} + Q_k^{ir} + Q_k^{pil} - Q_k^{pov} - Q_p - Q_K = 0 \tag{1}$$

where:

Q_p [W] - heat flow (conductivity) through the floor;

Q_k^{pov} [W] - heat flow (convection) from floor to air;

Q_{pr} [W] - heat flux (radiant) from the infrared source to the floor;
Q_k^{ir} [W] - heat flow (convection) from the infrared heater to the air;
Q_k^{pidl} [W] - heat flow (convection) from the air to the floor;
Q_K [W] - heat flow (heat transfer) through the floor to the environment.

Thermal conductivity through the floor determined as follows:

$$dQ_п = \frac{\lambda}{\delta} \cdot \left(t_{pidl} - t_z\right) \cdot dF_{pidl} \tag{2}$$

where:
λ [W/(m·°C)] - the thermal conductivity of the floor;
δ [m] - the thickness of the floor;
t_{pidl} [°C] - temperature of the floor;
t_z [°C] - outdoors air temperature;
F_{pidl} [m^2] - floor area that is irradiated.

Heat transfer from floor to air is determined as:

$$dQ_k^{pov} = \alpha_{pidl} \cdot \left(t_{pidl} - t_{pov}\right) \cdot dF_{pidl} \tag{3}$$

where:
α_{pidl} [W/(m^2·K)] - coefficient of heat transfer from surface of the floor;
t_{pov} [°C] - air temperature.

Irradiation of the floor by infrared heater found as follows:

$$dQ_{pr}^{ir} = c_{pr} \left(t_{ir}^4 - t_{pidl}^4\right) \cdot dF_{pidl} \tag{4}$$

where c_{pr} [W/(m^2·K^4)] - reduced rate of radiation;

$$c_{pr} = \varepsilon_{pr1-2} \cdot c_0 \cdot \varphi_{1-2} \cdot 10^{-8} \tag{5}$$

where:
$\varepsilon_{pr1-2} = \left(\varepsilon_1^{-1} + \varepsilon_2^{-1} - 1\right)$ - factors of emission of working surfaces;
c_0 - Stefan-Boltzmann constant;
φ_{1-2} - angular rate of surfaces exposure, $\varphi_{1-2} = \frac{a}{h \cdot \pi}$;
h - distance from the radiator to the floor,
a - half of the width of the exposure zone.
t_{ir} [°C] - the surface temperature of the infrared source.

The value of the effective heat transfer coefficients is defined as the sum of the coefficients of convective and radiative heat transfer:

$$a = a_k + a_p = a_k + c_{pr} \cdot 10^{-8} \cdot \left(T_1^2 + T_2^2\right)\left(T_1 + T_2\right) \tag{6}$$

Heat transfer from the infrared heater to the air is equal to:

$$dQ_k^{ir} = \alpha_{ir} \cdot \left(t_{ir} - t_{pov}\right) \cdot dF_{ir} \tag{7}$$

where:

α_{ir} [W/(m^2·K)] - heat transfer coefficient from the screen of infrared radiator to the air;

F_{ir} [m^2] - the surface area of the screen of infrared emitter.

Heat transfer from the air to the floor is calculated:

$$dQ_k^{pidl} = \alpha_{pidl} \cdot \left(t_{pov} - t_{pidl}\right) \cdot dF_{pidl} \tag{8}$$

Heat transfer through the floor is given by the following formula:

$$dQ_K = k \cdot \left(t_{pov} - t_z\right) \cdot dF_{pidl} \tag{9}$$

where k [W/(m^2·K)] - coefficient of heat transfer through the floor, is determined by:

$$k = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{1}{\alpha_2}} \tag{10}$$

2. RESULTS AND DISCUSSION

To simulate the thermal interactions of radiation area graph theory is proposed. This zone is represented as a system of heat capacities between elements of which heat exchange is happen and it interacting with heat sources of (Fig. 2) [1-3].

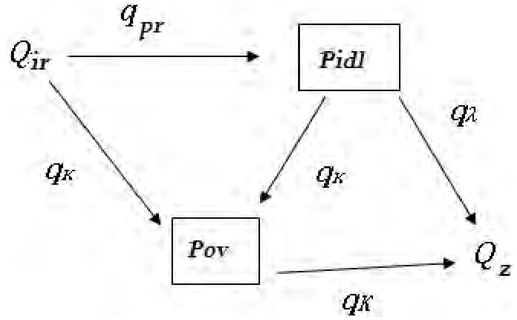

Fig. 2. Figure of heat flow in radiation area

In the investigated area are marked thermal capacity: Air (Pov) and floor (Pidl) of production facilities. For technological areas heat sources are: Infrared heater (Q_{ir}); Environment (Q_z) that appear as peaks (V_1) of the graph (G_1). Heat flows indoors, corresponding to heat transfer between i-heat source and thermal capacities shown on the graph as edges (E_1), which connect the top.

Thus, the set vertices of a graph is:

$$V_1(G_1) = \{Pov; Pidl.; Q_{ir}; Q_z\} \tag{11}$$

a plurality of edges:

$$E_1(G_1) = \{(Q_{ir}, Pidl); (Q_{ir}, Pov); (Q_z, Pidl); (Q_z, Pov); (Pidl, Pov)\} \tag{12}$$

For thermal capacities included in the graph as vertices, number of edges is:

$$\deg(Pidl) = 3$$
$$\deg(Pov) = 3$$

Matrix intsydentsiy M_1 for graph G_1, which lines correspond to peaks (thermal capacity), and columns - edges (heat flux) is as follows (Table 1):

Table 1.

	q_p	q_K^{pov}	q_{pr}	q_K^{ir}	q_K^{pidl}	q_K
Pidl	1	1	1	0	0	0
Pov	0	0	0	1	1	1

So intsydentsiy matrix is a binary matrix whose elements are equal to 0 or 1. From an algorithmic perspective matrix is probably the worst way to image graph. First, this method requires m and n memory cells (m-column, n-lines), most of these cells are occupied by zeros and secondly, access to the information is inconvenient [4, 5].

In accordance expanded matrix of heat sources display will be:

$$\begin{array}{cccc} & Pidl & Pov & Q \\ Pidl & 0 & Q_{Pidl-Pov} & Q_p + Q_k^{pov} + Q_{pr}^{ir} \\ Pov. & Q_{Pov-Pidl} & 0 & Q_k^{ir} + Q_k^{pidl} + Q_K \end{array} \tag{13}$$

where: Q_{i-y} - the elements of the matrix corresponding to the heat capacity and capacity y; Q - column element of heat source that corresponds to the heat of these sources in the capacity in line of which they placement.

Thus, the system of equations for thermal capacity of floor (Pidl) looks like:

$$Q_k^{pov} = \begin{cases} Q_p = \dfrac{\lambda}{\delta} \cdot \left(t_{pidl} - t_z\right) \cdot F_{pidl} \\ \alpha_{pidl} \cdot \left(t_{pidl} - t_{pov}\right) \cdot F_{pidl} \\ Q_{pr}^{ir} = c_{pr}\left(t_{ir}^4 - t_{pidl}^4\right) \cdot F_{pidl} \end{cases} \tag{14}$$

The system of balance equations for heat capacity of air (Ppov) becomes:

$$Q_k^{pidl} = \begin{cases} Q_k^{ir} = \alpha_{ir} \cdot \left(t_{ir} - t_{pov}\right) \cdot F_{ir} \\ \alpha_{pidl} \cdot \left(t_{pov} - t_{pidl}\right) \cdot F_{pidl} \\ Q_K = k \cdot \left(t_{pov} - t_z\right) \cdot F_{pidl} \end{cases} \tag{15}$$

We assume that the heat capacity (Pidl) temperature is lower than the temperature of the floor. Thus, the equation of energy conservation of floor is as follows:

$$\begin{aligned} Q_{pidl} = c_{pr}\left(t_{ir}^4 - t_{pidl}^4\right) \cdot F_{pidl} - \frac{\lambda}{\delta} \cdot (t_{pidl} - t_z) \times \\ \times F_{pidl} - \alpha_{pidl} \cdot (t_{pidl} - t_{pov}) \cdot F_{pidl} \end{aligned} \tag{16}$$

If the balance between heat capacities of air (Pov) and floor (Pidl) there is thermal equilibrium:

$$dQ_{pidl} = dQ_{pov} \tag{17}$$

The temperature of the floor (surface) is taken as the average area of exposure F_{pidl}. This is in magnitude bigger than temperature of the floor.

The equation of conservation of energy for air is:

$$\begin{aligned} Q_{pov} = \alpha_{ir} \cdot \left(t_{ir} - t_{pov}\right) \cdot F_{ir} + \\ + \alpha_{pidl} \cdot \left(t_{pov} - t_{pidl}\right) \cdot F_{pidl} - k \cdot \left(t_{pov} - t_z\right) \cdot F_{pidl} \end{aligned} \tag{18}$$

From these equations defined temperature of the floor (surface) in the area of radiation F_{pidl}:

$$\begin{aligned} c_{pr} \cdot t_{pidl}^4 + \frac{\lambda}{\delta} \cdot t_{pidl} = \kappa \cdot \left(t_{pov} - t_z\right) + \\ + c_{pr} \cdot t_{i.r} + \frac{\lambda}{\delta} \cdot t_z - \alpha_{ir} \cdot \left(t_{ir} - t_{pov}\right) \cdot \frac{F_{ir}}{F_{pidl}} \end{aligned} \tag{19}$$

For the dependence between main parameters that form the heat radiation zone status - surface temperature radiant heater t_{ir} [°C], outside air temperature,

t_z [°C], air temperature, t_{pov} [°C], and floor area, F_{pidl} [m^2] - used software packages MathCAD 15.01.

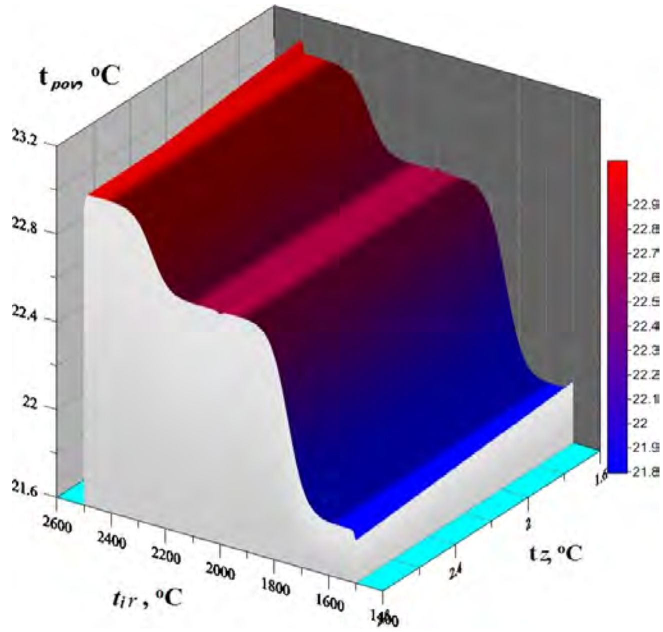

Fig. 3. Dependence between main parameters that form the heat radiation zone

As seen from the graph, temperature regime in the radiation area directly proportional to the capacity of the heater and depends on the temperature on the surface.

CONCLUSIONS

In this paper was develope research setting based on the infrared heater for the study of the intensity of radiation surfaces, which was designed the graphics dependence on the results of study. For building graphical dependence was used software packages MathCAD 15.01. Temperature regime in the radiation area directly proportional to the capacity of the heater and depends on the temperature on the surface.

REFERENCES

[1] Piotrowski J., Faryniak L., The Application of Chromatography Method in the Research into Infiltration Heat Losses, Institute of Heating and Ventilating Warsaw University of Technology, Warsaw 1994, 111-114.

[2] Radiative Transfer-1: Proceeding of the First International Symposium on Radiation Transfer, ed. M. Pinar Mengus, Kusadasi, Turkey ICHMT, 1995, 800.

[3] Siegel R., Thermal radiation heat transfer, R. Siegel, J.R. Howell. - 4th ed., 2001, 840 p.

[4] Zhelykh V., Ulewicz M., Spodyniuk N., Shapoval S., Shepitchak V., Analysis of the processes of heat exchange on infrared heater surface, Diagnostyka 2016, 17, 3, 81-85.

[5] Shcherbovskykh S., Spodyniuk N., Stefanovych T., Zhelykh V., Shepitchak V., Development of a reliability model to analyse the causes of a poultry module failure, Eastern-European Journal of Enterprise Technologies 2016, 4, 3(82), 4-9.

SYMULACJA POWSTAWANIA WARUNKÓW TERMICZNYCH W STREFIE NAPROMIENIANIA PROMIENNIKA PODCZERWIENI

Jedną z ważnych kwestii polityki energetycznej UE i Ukrainy jest oszczędne użytkowanie energii. Efektywnym sposobem zapewnienia odpowiednich warunków temperaturowych w zakładach produkcyjnych jest wykorzystanie promienników podczerwieni. Główną zaletą tego sposobu ogrzewania jest to, że ogrzewa się tylko obszary, w których jest ono wymagane. Celem publikacji było matematyczne modelowanie reżimu cieplnego w obszarze napromieniania przez promiennik podczerwieni, który został zaprojektowany na podstawie wyników badań. Rezultatem modelowania matematycznego było określenie natężenia promieniowania promiennika podczerwieni na daną powierzchnię w zależności od temperatury powierzchni promiennika, temperatury powietrza na zewnątrz, temperatury powietrza w pomieszczeniu oraz powierzchni podłogi. Do wykonania analizy matematycznej użyto pakietu MathCAD 15.01.

Słowa kluczowe: **temperatura powietrza, promiennik podczerwieni, strefa przebywania, wymiana ciepła**