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Energy-efficient use of infrared heaters in production rooms

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Abstract: When creating a microclimate in a production room, considerable attention is paid to the use of highly efficient, energy-saving and economical systems. Different aspects of the use of infrared heating systems in the heating of production rooms are investigated in Ukraine and around the world. This article deals with experimental studies on the determination of the temperature of irradiated surfaces and the density of radiation energy depending on the mode of operation, the power and height of the installed infrared heater.

Keywords: energy-efficient heating, infrared heaters, radiant energy, irradiation intensity, temperature regime

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Nowadays, saving energy is one of the most urgent problems in heating systems. Their efficiency, these days, is especially important because of the lack of fuel and energy resources. Huge amounts of energy is spent on creating artificial microclimates in production rooms. Heating such rooms is a complicated task as the majority of them are large and have high ceilings.

Currently, traditional convection systems such as water, steam and air systems have been used for heating large production rooms. The analysis of microclimate control systems in production rooms makes it possible to draw attention to certain design features and principles of operation.

The most economical way of heating high-ceiling buildings is using systems based on infrared heaters, the advantage of which lies in the fact that only the areas where heating is required are heated. Only targeted objects are heated as a result of radiation. Hence, partial heating of different areas of the room or separate working places becomes possible. In addition, after switching on an infrared heater, it quickly reaches a nominal power level and thus reduces the heating time compared to traditional heating systems.

Radiation heating is one of the varieties of heating systems, where infrared heaters are used as a heat source. It can be used independently or as a auxiliary heating source. Infrared or heat radiation consist of electromagnetic waves which lie in the spectrum of 750 to 10,000 nm. They are emitted from a source in a straight line in any uniform physical environment including vacuums, gases, liquids and solids. Infrared heaters operate on the same principle of heat energy generated from sunlight. Initially, the room and its surfaces accumulate heat, in particular: the floor, the bottom of the enclosing structures, equipment and people. After that, these heated surfaces, through heat transfer, transmits the heat to the surrounding air. At the same time, the perceived temperature is always higher than the air temperature in the room, because the person receives energy not from the air, but directly from the radiation.

Infrared heaters are the source of energy for infrared heating. Depending on the wavelength in the infrared spectrum, the radiant heaters are divided into:

– long-wave, or low-temperature infrared heaters, with a surface temperature from +45°C to +300°C;
– medium-wave, with a surface temperature from +300°C to +750°C;
– short-wave, or high-temperature, with temperatures above +750°C.

Since there are restrictions on the use of gas infrared heaters in production rooms, electric infrared heaters are becoming more widespread. Experiences of using infrared heaters for heating production rooms shows a number of advantages over convection heaters. The infrared heater makes it possible to create a comfortable thermal regime for the room through the autonomous supply of radiant heat directly to the surface of a person or to a certain area of the room. This significantly reduces the thermal load of the radiant heating system compared with convection systems.

The comfortable thermal state of a person is supported by a more intense heat emission from the person's body through convection and less intense heat emission through radiation. This is favourable in physiological terms and corresponds to human heat emission under natural environmental conditions, the so-called process of thermoregulation.

In infrared heaters, there is virtually unlimited possibilities in terms of heating different rooms, this is because there is no need for additional ventilation systems to be installed as the heaters do not burn oxygen, do not dry the air and do not make noise and vibration. There is no need for the supply of fuel, the installation of heating mains or the use of additional equipment and staff when using radiant heaters. There is a small temperature gradient in relation to the height of the room, which virtually ensures the absence of a thermal pillow close to the ceiling. In addition, when using infrared heaters, a sense of comfort can be achieved at lower air temperatures than usual. The heating of the surfaces of the external enclosing structures also avoids the build up of condensation. Particular attention should be given to the fact that infrared heaters are simple to maintain and do not require regular repair work. They are expected have an operational lifespan of at least 25 years.

Despite fixed installation, such a heating system can be easily dismantled and transported to a new room. Also, since in most cases, infrared heaters are installed on the ceiling, they do not reduce the usable area of the room. However, a disadvantage of radiant heating systems is that the distribution of radiation energy on surfaces is uneven. Therefore, the task is to ensure a uniform distribution of heat energy throughout the area of the working zone. For the analytical study of the temperature regime of working surfaces in production rooms a simplified model of heat flows was developed (Fig. 1).

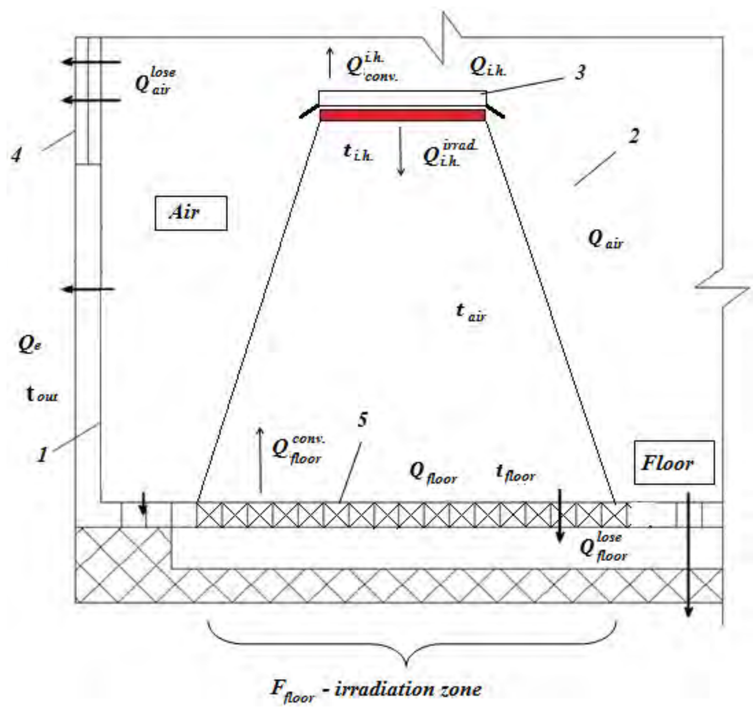


Fig. 1. Scheme of the heat flows in the radiation zone: 1 - external wall, 2 - zone of stay, 3 - infrared heater, 4 - window, 5 - floor

The model shows the direction of heat flows and their interaction with the heat source. To model the thermal interactions of the irradiation area, graph theory is proposed. This zone is represented as a system of thermal capacities, between the elements of which is the heat exchange that interacts with heat sources (Fig. 2).

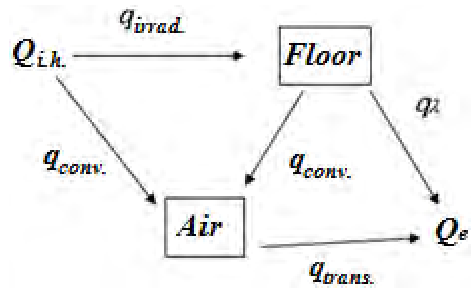


Fig. 2. Graph of thermal capacities in the radiation zone

The following thermal capacities are distinguished in the studied area: air (Air) and floor (Floor). For a technological zone, heat sources are: the infrared heater ($Q_{i.h.}$); the environment (Q_e) that is depicted as the vertex (V_1) of the graph (G_1). Heat flows in the room q_i^{room} that correspond to the heat exchange between i-th sources of heat and thermal capacities on the graph are depicted in the form of edges (E_1), which connect the vertices.

In the case of an equilibrium state between thermal air capacities (Air) and floor (Floor) there is a thermal equilibrium state:

$$dQ_{floor} = dQ_e$$

The temperature of the floor (surface) in the irradiation zone is determined:

$$c_{irrad} \cdot \left(\frac{T_{floor}}{100}\right)^4 + \frac{\lambda}{\delta} \cdot T_{floor} = k \cdot (T_{air} - T_{out}) + c_{irrad} \cdot \left(\frac{T_{i.h.}}{100}\right)^4 + \frac{\lambda}{\delta} \cdot T_{out} -$$
$$- \alpha_{i.h.} \cdot (T_{i.h.} - T_{air}) \cdot \frac{F_{i.h.}}{F_{floor}}$$

To get the dependence between the main parameters forming the thermal state of the irradiation zone - the temperature of the surface of the radiator heater $t_{i.h.}$, °C, the temperature of the outside air t_{out}, °C, air temperature, t_{air}, °C, and the floor area, F_{floor}, m^2 - the MATLAB program was used.

An experimental study for determining the temperature of the irradiated surface by the infrared heater was conducted on the basis of a planned experiment, taking into account such factors as the thermal power of the infrared heater $Q_{heater.}$, W, the height of its installation H, m, and the degree of blackness of the irradiated surface.

Experimental studies were conducted to determine the temperature field of the surface, finding the necessary factors of influence such as the height of the installation, the power of the infrared heater and its rotational movements in the plane, the degree of blackness of the irradiated surface and establishing the nature of the distribution of temperatures on the irradiated surface.

The study of the temperature fields of the irradiated surface was carried out on an experimental installation, the scheme of which is shown in Figure 3.

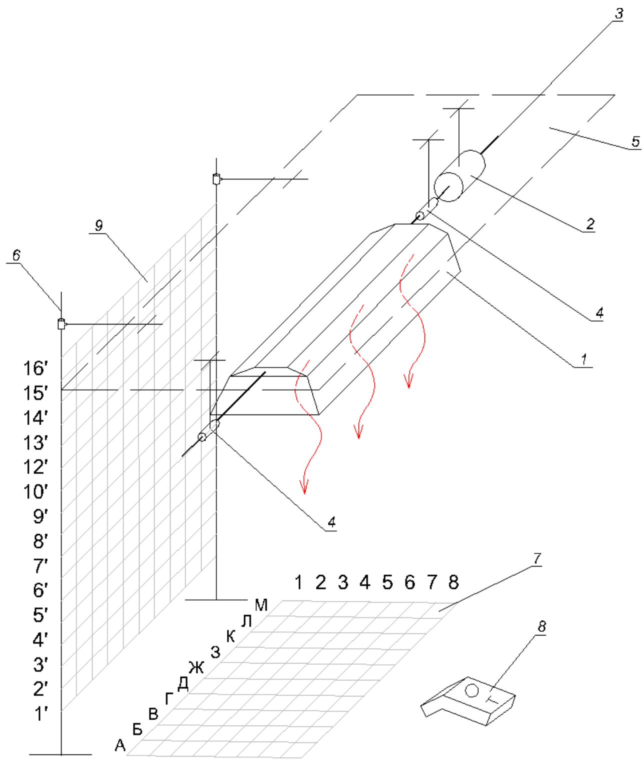
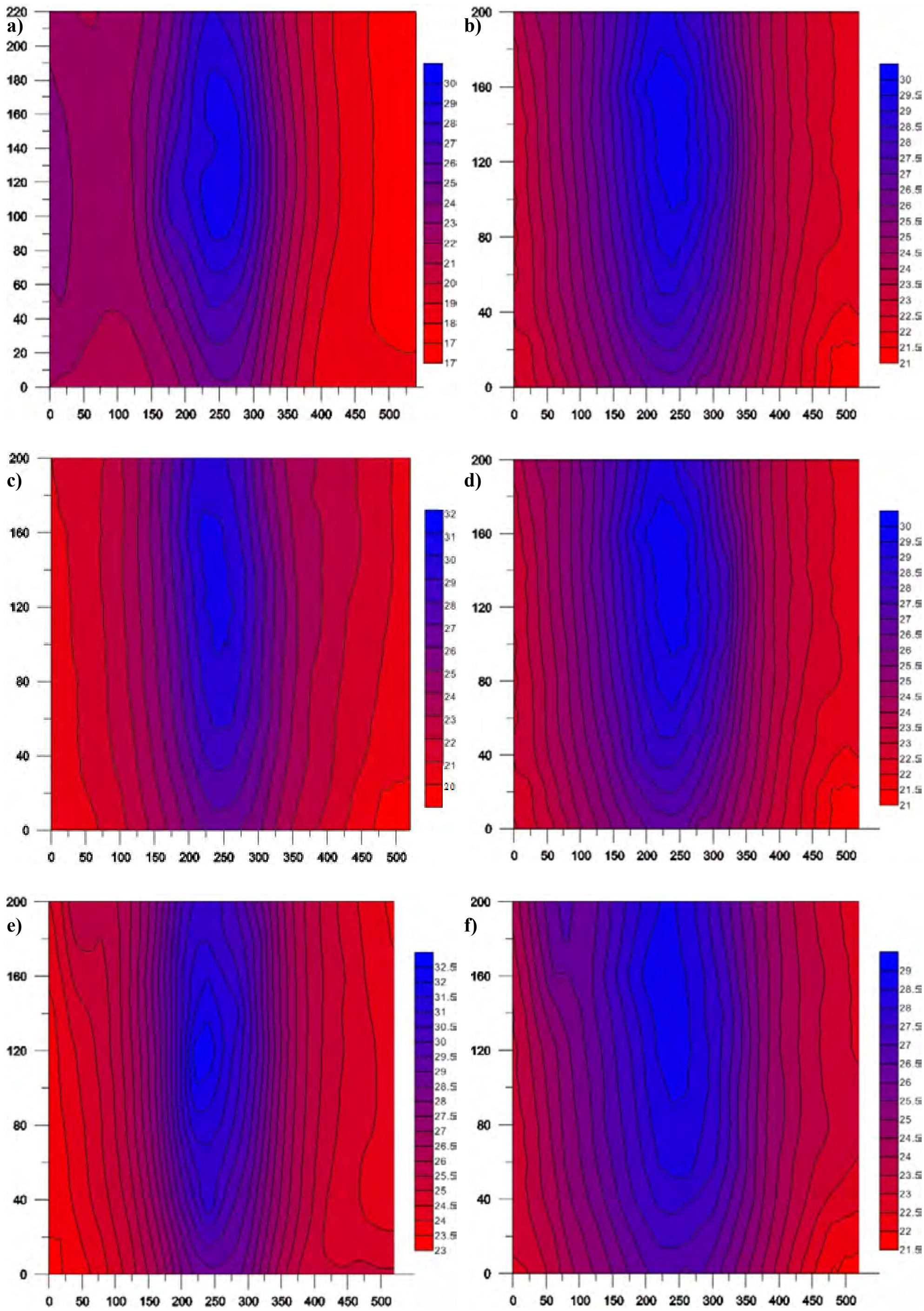


Fig. 3. Experimental facility for determining the temperature fields of exposure zone: 1 - the source of infrared radiation, 2 - electromotor with reducer, 3 - rotation axis, 4 - bearing assembly, 5 - fastening surface of infrared radiator, 6 - stand, 7 - surface of exposure, 8 - pyrometer, 9 - coordinate grid

The temperature fields of irradiation by the heater in the stationary position and the heater which makes oscillatory motions of 30° were determined with the help of the experimental setup.

An infrared source with a power of 1.4, 2 and 2.5 kW was used in the experiment, which heated a surface with a certain degree of blackness. The heater was located at 5 different heights - 1.6, 1.9, 2.2, 2.5 and 2.8 m. As can be seen from Figure 4 in the irradiation area, the maximum temperature difference on the irradiated surface is about 12°C and the distribution of the radiation energy density by using a stationary infrared source is uneven.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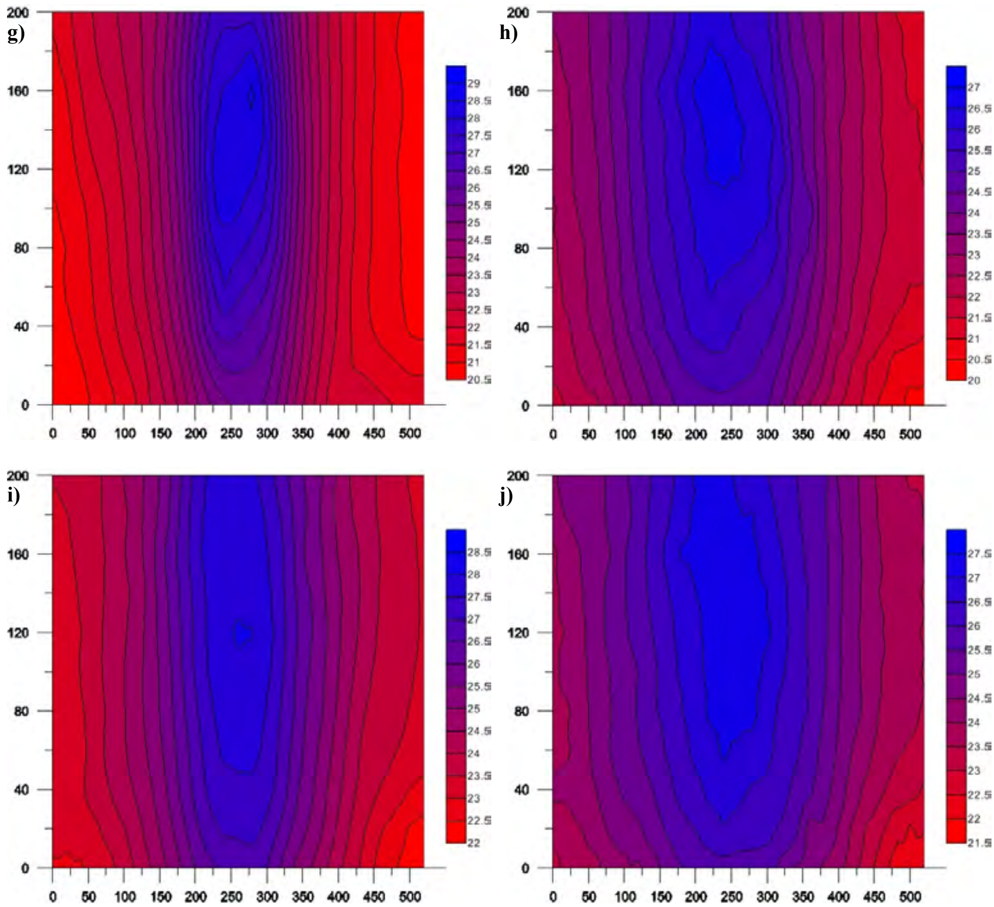

Fig. 4. Temperature fields of an irradiated surface with an infrared heater with stationary (a, c, e, g, i) and rotary (b,d, f, h, j) operating modes at an installation height of 1.6, 2.2, 2.5 and 2.8 m

Under the same conditions, but in a rotary mode - the maximum temperature difference is already about 9°C, and as can be seen from Figure 4b, d, f, h, j, the distribution of the intensity of the irradiation is more uniform. As the radius of the radiator increases, the heating area increases. The temperature gradient in the horizontal plane is decreased and the intensity of irradiation becomes more uniform.

Thus, as it is shown in the experiment, the use of rotary sources of infrared irradiation enables them to increase the area of heating, as well as to achieve a more even distribution of thermal energy. Rotary heaters provide a more efficient way to maintain the temperature regime of the work area.

In order to determine the temperature distribution along the irradiated surface from the infrared heater in the stationary and rotary modes, at different heights, a series of experimental studies have been carried out.

Experimental studies were done using infrared heaters with power Q 1,4 kW, 2.0 kW and 2.5 kW, which were set at heights of 1.6, 2.2, 2.8, 3.4, 4, 4.6, 5, 5.3, 6.0 m. The heating of the surface was carried out in stationary and rotary modes. According to the experimental studies the graphic distribution has been plotted (Fig. 5).

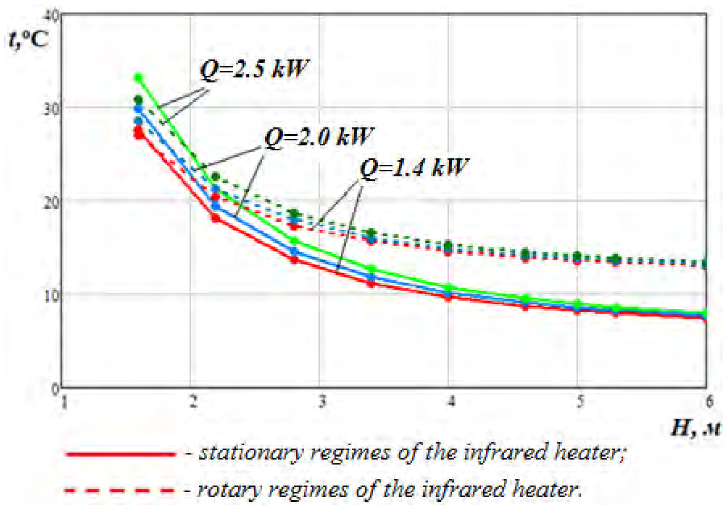

Fig. 5. Dependence of the temperature of the irradiated surface based on the height of the heater installation and its power at the degree of blackness of the irradiated surface for the rotary and stationary regimes of the infrared heater

Natural studies on the irradiation of the surface with a degree of blackness $\varepsilon = 0.75$ also confirmed the effectiveness of the use of a rotary infrared heater (Fig. 5).

Experimental data shows that the maximum surface temperature reached by irradiation with a stationary infrared source of 2.5 kW at an installation height of 1.6 m is 35°C and the minimum is 8°C. The temperature of the irradiated surface when using an energy-efficient heating system with the same initial data is 32 and 14°C. As a result, the temperature gradient on the irradiated surface is reduced by 33%.

As mentioned, the density of radiative energy is important when using infrared heating sources. In order to determine the intensity of the radiation energy on the irradiated surface, a number of experimental studies were carried out, the results of which are shown in Figure 6. On the basis of the experimental data, the dependence of the intensity of irradiation of the infrared heater with its thermal powers $Q = 1.4$ kW, $Q = 2.0$ kW and $Q = 2.5$ kW has been used.

It has been established that the intensity of irradiation increases with the increase of the heater power, as well as with the decrease of the distance to the vertical axis of the location above the irradiated surface. In order to achieve the ordinary value of the intensity of the radiation energy, it is necessary to reduce the power of the radiation source or to increase the height of its location. When using a traditional heating system with a stationary infrared heater, the maximum intensity of radiation is observed on the vertical axis of the source of radiation.

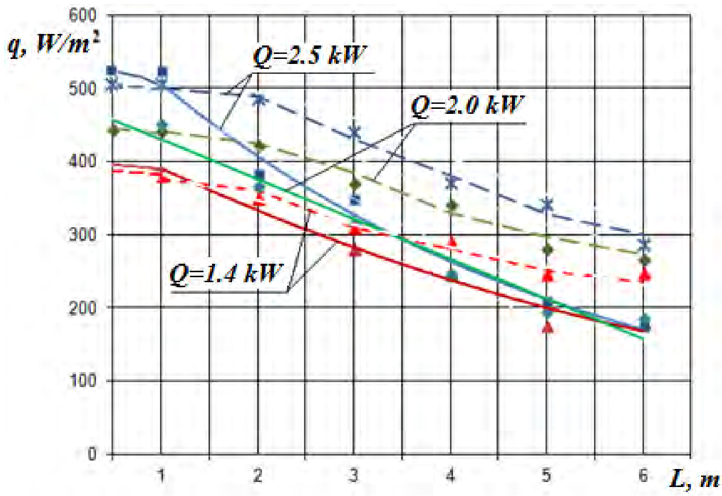

Fig. 6. The change of the intensity of the heat flow on the irradiated surface by a rotary and stationary infrared heater at a distance L on a horizontal axis from the centre of the heater (at $H = 1.6$ m)

Thus, the experiment shows, the use of rotary infrared irradiation sources makes it possible to increase the heating area, as well as to achieve a more even distribution of heat energy. The rotary heaters give the opportunity to establish a more efficient way of maintaining the temperature regime of the work place.

References

Andrews, J. & McKeon, R. (eds.) (1979) *Mathematical Modeling* (trans. with English). Moscow, Mir, 278 p.

Ango, M.A. (1957) *Infrared radiation*. L.:, Gosenergoizdat, 82 p.

Bakowski, K. (2002) *Sieci i instalacje gazowe*. Warszawa, WNT.

Burakovsky, T., Gizinsky, E. & Salya A. (1978) *Infrared emitters. Per. with the floor*. L.:, Energy, 408 p.

Itsikson, V.S. & Denisov Yu.L. (1969) *Infrared gas emitters*. Moscow, Nedra, 278 p.

Malyarenko, V.A., Redko, A.F. & Chaika, Yu.I. (2001) *Technical thermal physics of building envelopes of buildings and structures*. Kharkov, Rubicon, 280 p.

Mathematical modeling in engineering calculations of complex systems (1997) (Sat. scientific tr.). Dnepropetrovsk, DSU, 236 p.

Lykov, A.V. (1972) *Heat and Mass Transfer: A Directory*. Moscow, Energy, 560 p.

Patent of Ukraine for useful model Nr 81275. Infrared heater. V.B. Shepitchak, N.A. Spodynyuk, V.M. Zhelyh, 2013.

Zhelikh, V.M. & Shepitchak, V.B. (2012) *Energy-efficient heating systems for production facilities. Modern technologies, materials and constructions in construction: scientific and technical collection*. Vinnytsia, UNIVERSUM - Vinnytsia, 2(13), 157-161.

Shepitchak, V. & Zhelyh, V. (2015) *The study of temperature fields exposure zone of the rotary infrared heaters*. Czestochowa.

Zhelykh, V. & Shepitchak, V. (2013) *Experimental studies of the temperature regime of the irradiation zone by rotary infrared heaters*. The Collection of Proceeding Kiev National University of Building and Architecture Energy Efficiency in Civil Engineering and Architecture, Kyiv, Issue No 4.

Zhelyh, V., Shepitchak, V. & Spodyniuk, N. (2016) *The study of the intensity of infrared heating systems radiation*. Scientific Journal of Building Physics in Theory and Practice, VIII, 3, 29-32.

Zhelyh, V., Ulewicz, M., Spondyniuk, N., Shapoval, S. & Shepitchak, V. (2016) *Analysis of the processes of heat exchange on infrared heater surface*. Diagnostyka, 17(3), 81-85.

Energooszczędne zastosowanie promienników podczerwieni w pomieszczeniach produkcyjnych

Streszczenie: Podczas kształtowania warunków mikroklimatu w hali produkcyjnej dużą uwagę przywiązuje się do stosowania wysoce wydajnych, energooszczędnych i ekonomicznych systemów. Zarówno na Ukrainie, jak i na świecie bada się różne aspekty zastosowania systemów grzewczych na podczerwień do ogrzewania pomieszczeń produkcyjnych. W artykule omówiono eksperymentalne badania dotyczące wyznaczania temperatury napromieniowanych powierzchni i gęstości strumienia energii promieniowania w zależności od trybu pracy, mocy i wysokości zainstalowanego promiennika podczerwieni.

Słowa kluczowe: energooszczędne ogrzewanie, promienniki podczerwieni, energia promieniowania, natężenie promieniowania, reżim temperaturowy