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Nadiia SPODYNIUK[1]
Olena GUMEN[2]
Oksana OMELCHUK[3]

THERMAL PROCESSES IN INDUSTRIAL PREMISES WITH USING INFRARED HEATING SYSTEMS

Saving issues are important for any country with an appropriate level of economic development; taking into account the modern conditions of development of Ukraine. This problem is very important, especially considering incremental resource constraints in all areas of the national economy's development. The component of quality of such a process requires certain conditions in which there are a need to develop innovative approaches to training and maintenance of production, one of which is to ensure a comfortable temperature conditions in production facilities.
The article presents the results of experimental research of thermal processes in industrial premises with energy-saving technologies of heating and their analysis by geometric modeling tools and graphic computer technologies. The effectiveness of using the method of forced feeding of air heated by infrared emitter involving compromise graphical optimization was analyzed by geometric way.
As a result of research of thermal processes in industrial premises the problem of establishing a comfortable way of heating of the working zone combining the use of infrared heaters with forced ventilation was formulated and solved.
On the basis of use dependences obtained experimentally of three parameters of thermal process – air temperature, heat flow power and height of installation of infrared heater – graphical tools were proposed and approved in processing experimental data. This made it possible to apply the dependence of these parameters by second order surface of three-dimensional parameter space of the thermal process.

Keywords: energy-saving systems, infrared heating, graphic computer technologies, geometric modeling

[1] Author for correspondence / autor do korespondencji: Nadiia Spodyniuk, Department of Heat and Gas Supply and Ventilation at Lviv Polytechnic National University, St. Bandery, 12, 79013, Lviv - 13, Ukraine, +380971210924, e-mail: n_spoduniuk@meta.ua
[2] Olena Gumen, Department of Descriptive Geometry, Engineering and Computer Graphics at National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Peremohy pr., 37, 03056, Kyiv, Ukraine, +380634909195, e-mail: gumens@ukr.net
[3] Oksana Omelchuk, Department of Heat and Gas Supply and Ventilation at Lviv Polytechnic National University, St. Bandery, 12, 79013, Lviv - 13, Ukraine, +380672540485, e-mail: oksana.o@meta.ua

1. Introduction

Eurointegrational vector of Ukraine's development covers all the components of its factors of life, and energy (energetics) is the basis and the guarantee of these factors. The use of energy requires fundamentally new approaches to their practical application, mainly among which is energy savings. Experience of the global economy confirms the main conclusion that the efficient use of fuel resources is the key to stable economic development and indicates the appropriate level course positive processes in the country.

Saving issues are important for any country with an appropriate level of economic development; taking into account the modern conditions of development of Ukraine. This problem is very important, especially considering incremental resource constraints in all areas of the national economy's development. Because of it problem of economy is extremely important, especially energy carriers. First of all, there are issues of resource provision is extremely relevant in the fields of industrial and agricultural production with the use of technological processes in industrial buildings and structures. It is obvious that in matters of price-quality software process flow can be no compromise [1-3]. The component of quality of such a process requires certain conditions in which there are a need to develop innovative approaches to training and maintenance of production, one of which is to ensure a comfortable temperature conditions in production facilities.

The goal of the article is to study regularities of thermal processes in industrial premises using combined energy-saving technologies of heating.

One of the many variants of the use of infrared emitting is its attraction as a main element of the internal heating systems of buildings and structures. The beam component, which is constructed on the basis of the use of this type of emitting heater, has the advantage of providing proper conditions of stay in the staff room at lower air temperatures in working areas. Note also its positive effect on equipment located in the room [4, 5].

2. Experimental research

The property of warm air is that due to convection it goes up to the upper zone of the room and does not participate in the space heating process. One of the measures to attract it to the heating system is the forced ventilation. The experimental setup contains necessary active elements for research – an infrared heater and a fan, and a control instrument – thermometer with its operational installation anywhere in the turbulent area of industrial premises (Fig. 1). It is possible to carry out research at enabled and disabled modes of fan.

In the room 1 over infrared heater 2, fan 3 is located, which is powered via a switch 4 from block 5, which is attached to the infrared heater 2. The thermometer 6 can be located at any point of the room 1. However, by given the

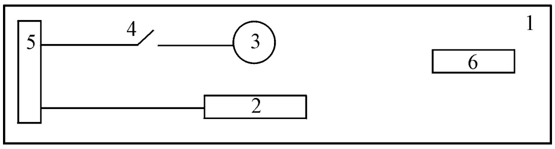

Fig. 1. Block diagram of the experimental system equipment of infrared heating
1 – room; 2 – infrared heater; 3 – fan; 4 – switch; 5 – block; 6 – thermometer

Rys. 1. Schemat blokowy eksperymentalnego wyposażenia systemu podczerwieni
1 - pokój; 2 - podgrzewacz podczerwieni; 3 - wentylator; 4 - przełącznik; 5 - blok; 6 - termometr

technical possibilities of experiment, thermal power of infrared heater Q changed between operating range of 500...1500 W in increments ΔQ = 500 W, and height of its installation h was 1.13...1.73 m in increments Δh = 0.3 m [6,7].

Based on the physiological characteristics of growth in staff, conducted an experiment with the measurement of relative air temperature $\bar{t}$ from the density of the heat flow of the emitter q at height of installation 1.73 m (Fig. 2).

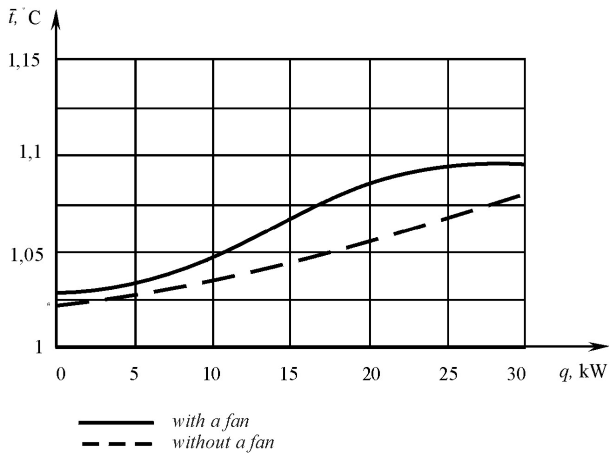

Fig. 2. Effect of the fan to relative air temperature $\bar{t}$ indoors, h = 1.73 m (curves plotted for the five values of density of the heat flow q)

Rys. 2. Wpływ wentylatora na względną temperaturę $\bar{t}$ w pomieszczeniu, h = 1,73 m (krzywe zbudowane na pięć wartości q)

3. Geometric modeling of graphic dependencies

The results of the experiment without and with fan (Fig. 2) show that the intensity of change of relative air temperature $\bar{t} = f(q)$ in working area of change of heat flow density of the emitter q in the range 0...30 kW/m^2 can be divided into a number of ranges (Fig. 3).

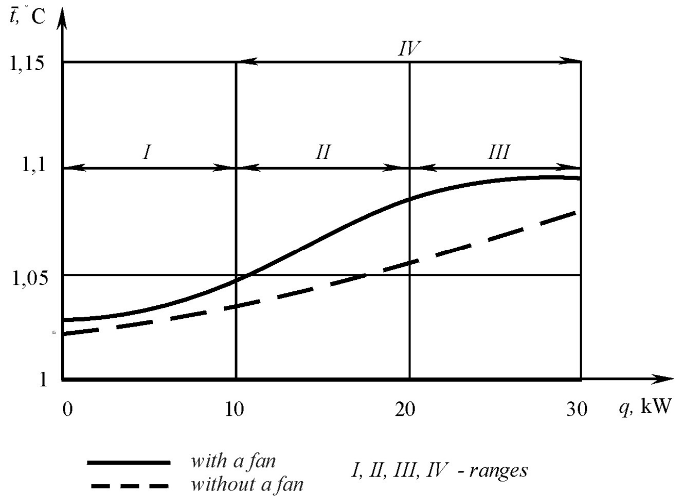

Fig. 3. Ranges of change of relative air temperature $\bar{t}$

Rys. 3. Zakresy zmian względnej temperatury powietrza konwekcyjnego $\bar{t}$

In the absence of a fan relative air temperature $\bar{t}$ almost linearly rises in a I range and in a IV range. In the I range when changing the density of the heat flow q between 0...10 kW/m^2, relative air temperature $\bar{t}$ changes by $\Delta\bar{t}$ = 0.01 (Fig. 3), and in the IV range when changing the density of the heat flow q in the range of 10...30 kW/m^2 increase in temperature by $\Delta\bar{t}$ = 0.045 is indicated.

In general, the temperature rise is not uniform in two ranges, and changing the density of the heat flow of emitter q in the range 0...30 kW/m^2 increase in temperature $\Delta\bar{t}$ = 0.055.

When the fan is switched-on relative air temperature $\bar{t}$ varies almost exponentially by the law in three ranges. The intense temperature change takes place in the II range: when you change the density of the heat flow of the emitter q in the range of 10...20 kW/m^2 relative air temperature $\bar{t}$ changes by $\Delta\bar{t}$ =0.03, and the intensity of relative temperature increase is less in the I and III ranges and, respectively, amounts $\Delta\bar{t}_I$ = 0.02 and $\Delta\bar{t}_{III}$ =0.01.

In the operating range of change of heat flow density in both cases, when using a fan and without it, extrema is absent. The maximum and minimum values of relative temperature are attained at the beginning and the end of range of heat flow density change of emitter q.

In three-dimensional space $O\bar{t}hQ$ parameters associated with simple analytical expression $\bar{t} = f(Q,h)$ are visualized by the surface, and graphic dependences are projections of this surface obtained at constant thermal power of the infrared heater Q (Fig. 4).

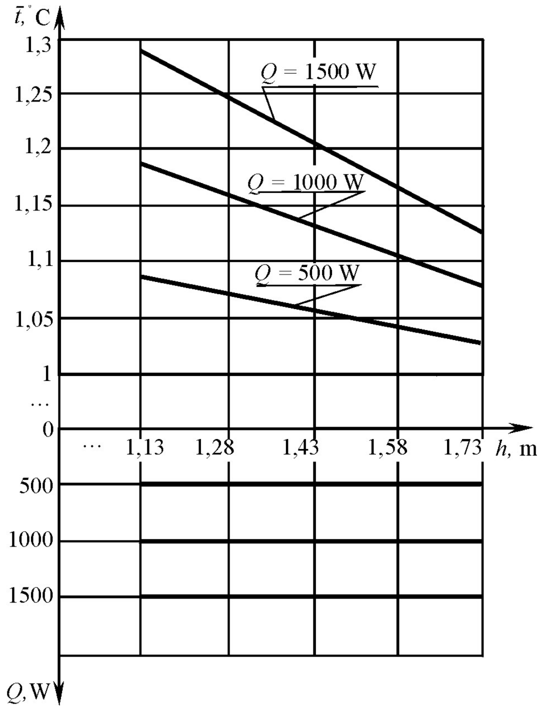

Fig. 4. Surface projections $\bar{t} = f(Q, h)$

Rys. 4. Projekcja powierzchni $\bar{t} = f(Q, h)$

Constant values of thermal power of the infrared heater Q determine position in the space of intersecting front level planes whose intersections with the surface $\bar{t} = f(Q, h)$ produce a set of curves $\bar{t} = f(h)$ in the frontal plane of projections $O\bar{t}h$ (Fig. 5).

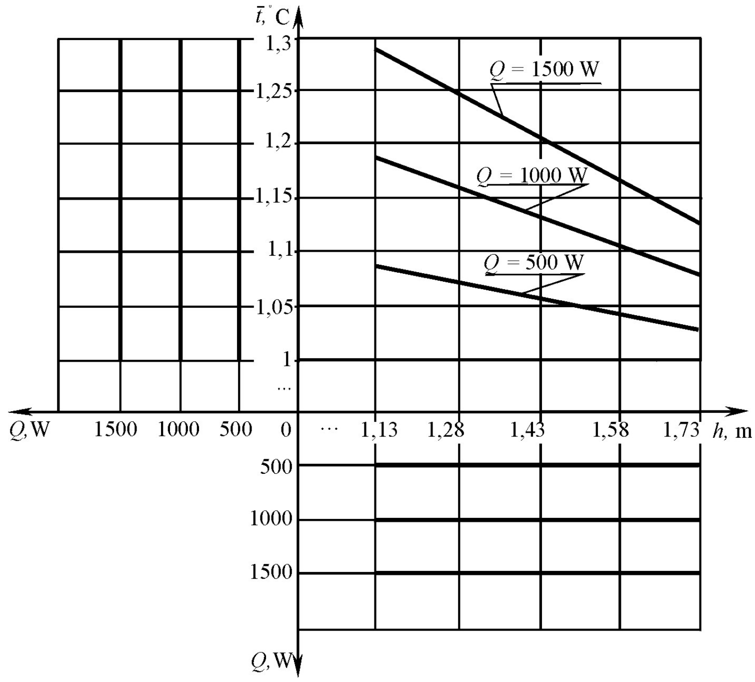

Fig. 5. Setting the surface $\bar{t} = f(Q,h)$ by line frame

Rys. 5. Przypisanie powierzchni $\bar{t} = f(Q,h)$ do ramy linii

Each of obtained curves $\bar{t} = f(h)$ project on the horizontal plane of projections OhQ in the corresponding following projection intersecting the front level plane. It is evident that such projections placed in the profile plane of projections $O\bar{t}Q$ and collectively form a discrete frame of surface $\bar{t} = f(Q,h)$.

This frame makes it possible to receive the projections, and consequently, the coordinates, the numerical values of parameters of point B, belonging to the surface $\bar{t} = f(Q,h)$.

Complete the following projection of arbitrary frontal project plane φ in the frontal plane of projections (Fig. 6) which point *B* belongs to. After the corresponding constructions, we obtain the projection of point B in the horizontal plane of projections OhQ (B_1) and profile plane of projections $O\bar{t}Q$ (B_3). According to the projections we determine the numerical values of parameters $\bar{t}_B$, Q_B, h_B.

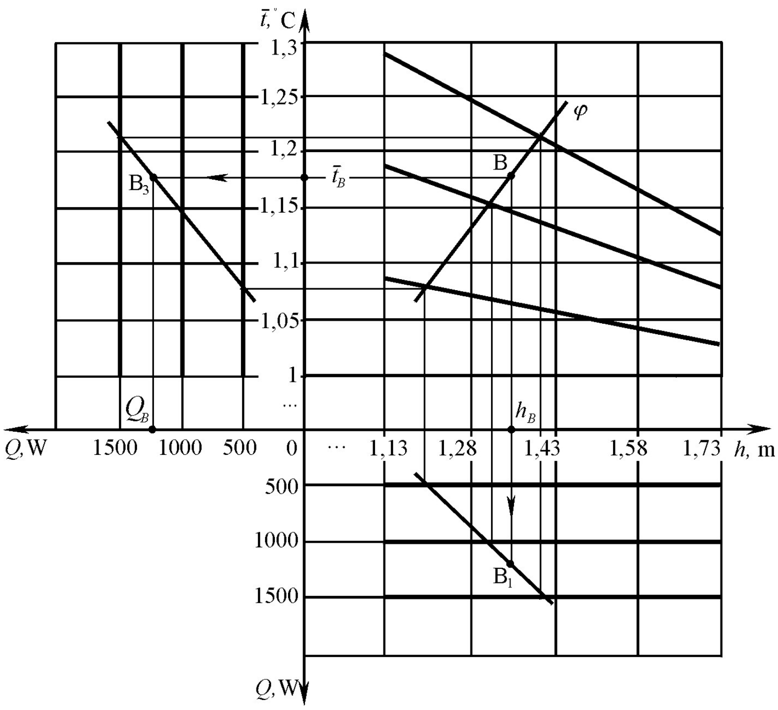

Fig. 6. Definition of the numerical values of parameters h, Q, $\bar{t}$ at any point in the space of premises

Rys. 6. Określenie wartości liczbowych parametrów h, Q, $\bar{t}$ w dowolnym miejscu pokoju

According to position of the section plane φ, such diagrams give the opportunity to build dependences of parameters that in the experimental conditions are often difficult to obtain, if not impossible. In addition to specific coordinates of point B, plane φ made it possible to build dependences $Q = f(h)$ and $\bar{t} = f(Q)$.

Using the proposed method, we construct the frame of the surface $\bar{t} = f(Q,h)$ based on values Q = 500 W, Q = 625 W, Q = 750 W, Q = 875 W, Q= 1000 W, Q = 1125 W, Q = 1250 W, Q = 1375 W and Q = 1500 W (Fig. 7).

Built surface of the frame makes it possible to both determine the numerical values of parameters h, Q, $\bar{t}$ at an arbitrary point in space in working area of parameters changes, and build relationships which are impossible to obtain due to the technical conditions of the experiment. Figure 7 shows the dependence at constant h = 1.2 m section of the surface of the profile plane with trace levels of δ-projection of h = 1.2 in the Oh axis.

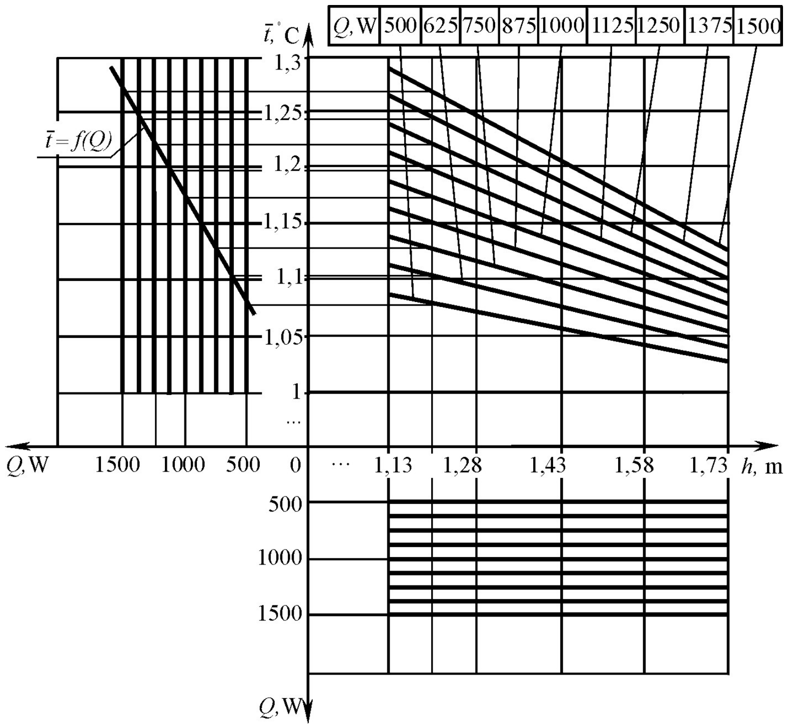

Fig. 7. Construction of the surface frame for nine thermal power values of infrared heater Q

Rys. 7. Konstrukcja ramy powierzchniowej dla dziewięciu wartości mocy cieplnej grzejnika podczerwonego Q

Built surface of the frame can also be used to find equation of the surface. Let us assume that $Q = y$, we have there $z = f(x, y)$.

By analyzing each of the curves at a constant value, we take a lot of curves as algebraic curves of the second order. They are forming an algebraic surface lines of the second order:

$$\begin{aligned} &Ax^2 + By^2 + Cz^2 + 2Dxy + 2Exz + \\ &+ 2Fyz + 2Gx + 2Hy + 2Kz + L = 0. \end{aligned} \tag{1}$$

Cutting this surface with a cross-section plane of the level, for example, y_1=500, we obtain a surface line, which in the Figure 7 is supplied with graphical dependence at y_1 = 500. Substituting the value y_1 in (1), we obtain the equation of the line:

$$Ax^2 + By_1^2 + Cz^2 + 2Dxy_1 + 2Exz + \\ + 2Fy_1z + 2Gx + 2Hy_1 + 2Kz + L = 0. \tag{2}$$

To determine constant values of coefficients of algebraic equation of the second order we set some constant values y_i (2). Solving the system of nine equations, we obtain the numerical values of the coefficients (1), which uniquely identify the equation of the surface:

$$\bar{t} = 1.14 + 1.54e^{-4}(Q - 1000) - 0.2(h - \\ - 1.43) - 1.53e^{-4}(Q - 1000)(h - 1.43). \tag{3}$$

It is obvious that such an equation approximately describes the surface and corresponds to a received working range of the variation of the parameters Q and h.

Computer visualization of equation (3) gives the opportunity to present a surface shape of temperature in the room (Fig. 8).

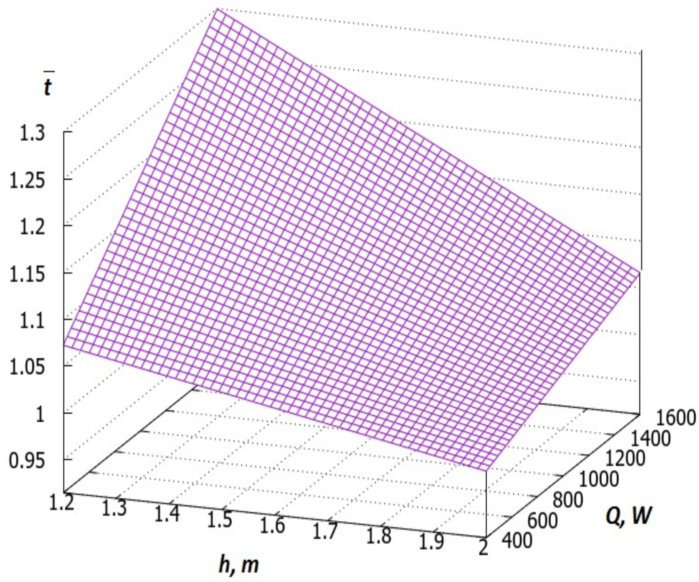

Fig. 8. The surface of temperature in service area

Rys. 8. Powierzchnia temperatury w obszarze serwisowym

The limits of variation of the input factors have changed as follows. For thermal capacity of infrared heater: 500W $\leq Q \leq$ 1500W; for height of installing the heater: $1.13 \leq h \leq$ 1.73.

4. Conclusion

The results of experimental studies as well as their geometric interpretation lead to the following conclusions:

As a result of research of thermal processes in industrial premises the problem of establishing a comfortable way of heating of the working zone combining the use of infrared heaters with forced ventilation was formulated and solved.

On the basis of use dependences obtained experimentally of three parameters of thermal process – air temperature, heat flow power and height of installation of infrared heater – graphical tools were proposed and approved in processing experimental data. This made it possible to apply the dependence of these parameters by second order surface of three-dimensional parameter space of the thermal process.

Using all suggested geometric tools can significantly reduce the costs for carrying out the experiment and get the results, the accuracy of which is determined by the accuracy and correctness of the experiment.

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TERMICZNE PROCESY W POMIESZCZENIACH PRZEMYSŁOWYCH Z WYKORZYSTANIEM SYSTEMÓW OGRZEWANIA NA PODCZERWIEŃ

Streszczenie

Zapewnienie oszczędności jest ważne dla każdego kraju w celu zapewnienia odpowiedniego poziomu rozwoju gospodarczego, jak również dla rozwoju Ukrainy. Ten problem jest bardzo ważny, szczególnie biorąc pod uwagę ograniczenia zasobów we wszystkich dziedzinach rozwoju gospodarki narodowej. Komponent jakości takiego procesu wymaga pewnych warunków, w których istnieje potrzeba opracowania innowacyjnego podejścia do szkolenia i utrzymania produkcji, jednym z nich jest zapewnienie komfortowych warunków termicznych w obiektach produkcyjnych.

W artykule przedstawiono wyniki eksperymentalnych badań nad procesami termicznymi w pomieszczeniach przemysłowych za pomocą energooszczędnych technologii ogrzewania i ich analizy za pomocą narzędzi do modelowania geometrii i graficznych technologii komputerowych. Analizowano sposób wykorzystania przymusowego zasilania powietrzem podgrzewanego przez emitery podczerwone z optymalną kompromisową interpretacją graficzną.

W wyniku badań nad procesami termicznymi w pomieszczeniach przemysłowych sformułowano i rozwiązano problem utworzenia komfortowego sposobu ogrzewania strefy roboczej, łączącego zastosowanie podczerwieni z wymuszoną wentylacją.

Na podstawie zależności użytkowych uzyskanych eksperymentalnie z trzema parametrami temperatury termicznej temperatury powietrza procesowego, mocy cieplnej i wysokości instalacji podgrzewacza podczerwieni zaproponowano i zatwierdzono narzędzia graficzne w przetwarzaniu danych eksperymentalnych. Umożliwiło to zastosowanie zależności tych parametrów przez powierzchnię drugiego rzędu trójwymiarowej przestrzeni parametrów procesu termicznego.

Słowa kluczowe: systemy oszczędzania energii, ogrzewanie podczerwone, graficzne technologie komputerowe, modelowanie geometryczne

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