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FUNCTIONAL FEATURES OF PANEL HEATING AND PRIORITIES OF ITS USE

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Abstract- Despite its location in the Eastern Hemisphere's southern geographic latitudes, Azerbaijan is classified as a "Heating" country, not a "Cooling", since a large portion of the country's final energy balance (21%) is spent on the operation of building heating systems. In terms of building energy efficiency, the ability to use renewable energy sources, and ensuring optimal parameters of the internal microclimate, the most optimal is the use of panel heating systems on the premises, which emit heat primarily through radiation rather than convection. Panel heating is a low-temperature hydronic system with the operating temperatures of the heat carrier are (35-55) °C, as opposed to (65-90) °C for radiators. The inertia of the system and the time required to reach the design room air temperature are clarified in this article based on experiments and thermal engineering calculations of the features of the panel heating system. The dependency of surface heat transfer from the panel by radiation at various values of surface heat flux density was computed and visually displayed based on field observations. Panel heating has several advantages in terms of energy efficiency, economy, ergonomics, and comfort. The obstacles that prevent Azerbaijan from actively using panel heating are listed. A panel heater's energy efficiency is two times that of a radiator, thanks to space heating by radiation, making it an excellent choice.

Keywords: Panel Heating, Heating Surface, Heat Transfer by Radiation, Energy Efficiency of Buildings, System Inertia, Panel's Surface Heat Flux Density.

1. INTRODUCTION

When choosing the design of a particular heating system, the top criterion is internal environmental comfort, and the next priority criteria are energy efficiency and environmental friendliness, which in turn implies the use of renewable energy sources [1, 2]. From the point of view of ensuring the optimal parameters of the internal microclimate, the closest to ideal heating is the use of so-called surface heating systems on the premises, which are, surfaces with a significant heating area, such as walls, ceilings, and floors, which give off heat mainly by radiation, and not by convective flows [3, 4].

It must be admitted that the underfloor heating system, as one of the varieties of panel heating, is very popular in Azerbaijan for use both in high-rise and low-rise construction and in the reconstruction of buildings. Unfortunately, large-scale works on the reconstruction of buildings in the period before the adoption of the law on energy efficiency in the country in 2021 were carried out without following the thermal protection requirements and the characteristics of external enclosing structures and standard recommendations for them, as a result of which a significant part of the operated building stock does not provide the expected savings of both thermal and electrical energy.

According to expert opinion, there are still fewer than a dozen buildings in the country that meet international energy efficiency standards [5]. Energy consumption by the main sectors in Azerbaijan buildings, industry, transport, and others are shown in Figure 1. As can be seen from the diagram, the heating systems are utilized the most energy consumed in buildings 21%, 16% is for lighting, and 8% for others [6]. It means that building heating systems have significant potential for improving their energy efficiency.

Despite the rather high outdoor temperatures for the heating period, for Baku +1 °C, for Shusha -5 °C, and the location in the southern geographic latitudes of the Eastern Hemisphere Azerbaijan (between 38-41 °N and 44-50 °E) is considered not a "cooling", but a "heating" country, because a significant percentage of the final energy balance of the country is spent on the operation of heating systems for buildings and structures [5].

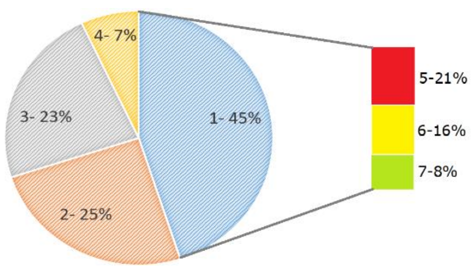

Figure 1. Major energy consumers in Azerbaijan: 1- buildings, 2- industry, 3- transportation, 4- others, 5- heating systems, 6- lighting, 7- others

This article examines the benefits of using hydronic panel heating in Azerbaijan based on an analysis of the thermal performance of this system. The results of field studies and calculations on the inertia of the system are given, and the time of warming up the room air is calculated according to the design of the panels. Also, based on the results of field measurements, a graphical dependence of the surface heat flux density of the panel on the share of heat transfer by radiation is given.

2. MATERIALS AND METHODS

The main requirement for the independent use of panel heating is a quantitative indicator of the specific heat loss of the building, which should $Q_s \le (60-65)\ \frac{\text{W}}{\text{m}^2}$ [7]. Figure 2 shows the installation of a panel heating system [8]. To assess the characteristic parameters of panel heating systems and make technical decisions, it is necessary to [9, 10]:

- calculate the distribution of radiant energy over the surfaces of the internal objects in the room;
- calculate the total heat load of the system depending on the selected type of the panels and the design of the panels;
- calculate the required number of panels and place them in the room interior;
- draw up an energy passport of the panel heating system.

Analyzing functional features of panel heating systems and their use in Azerbaijan demanded experimental and analytical studies based on materials from published scientific sources. The results of studies on various types of panel heating are successfully given in [11-13]. The task of analyzing the use of panel heating in Azerbaijan is based on experimental measurements carried out by the author, and analytical studies involving published works in this area, taking into account the experience and characteristics of construction in the country [14].

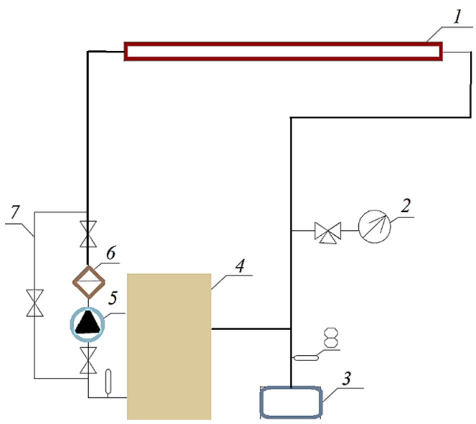

Figure 2. Installation of a radiant heating system:1- radiant heating panel; 2- hot water meter; 3- expansion tank; 4- heat generator- boiler; 5- circulation pump; 6- filter; 7- bypass; 8- thermometer [7]

Panel heating of buildings is quite popular both in Europe and around the world. But unfortunately, in Azerbaijan, this type of heating is almost absent in practice.

The main reason for this is the insufficient knowledge of the physics of the process of space heating employing heating panels in local climatic conditions. It is known that the human body loses up to 50% of heat through radiation, 30% through evaporation, 15% through convection, and 5% through heat transfer. Therefore, the most comfortable heating of the human body occurs when the perception of heat in rooms happens with radiant heating [15, 16], the source of which is panel heating. The heat transfer of a person by radiation depends on many factors, including the temperatures of the internal surrounding surfaces- building structures, furniture, equipment, etc. The average temperature of the internal surfaces is determined by the formula [17].

$$t_R^o = \frac{\sum (t_{i.s.} \times f_{i.s.})}{\sum f_{i.s.}}\ ^\circ\text{C} \quad (1)$$

where, $t_{i.s.}$, $f_{i.s.}$ are temperature, °C, and surface area, m^2, of external structures.

Panel heating is a low-temperature heating system, where the heat carrier- water has a significant heat capacity, $c = 4.174\ \frac{\text{kJ}}{\text{kg}\,^\circ\text{C}}$ in comparison with the heat capacity of air- $c = 1.005\ \frac{\text{kJ}}{\text{kg}\,^\circ\text{C}}$ [18, 19]. Here the water has operating temperature parameters of (35-55) °C in contrast to conventional radiator heating operating at a temperature of (65-90) °C. As a heat generator for panel heating, it is possible to use condensing boilers, heat pumps, wood pellet boilers, city heating networks, and other energy-efficient sources of thermal energy. The main thermal performance of the system is given in Table 1. Figure 3 shows the sectional distribution of main pipelines, which is optimal for multi-story buildings [7].

Table 1. Main technical characteristics of panel heating

No	Indicators	Unit of measurement and values
1	The temperature difference between room air and heat carrier	15-20 °C
2	Heat dissipation of 1 m^2 panels to room air	≤115 W
3	System water temperature, when heat carrier is water	+(35-55) °C
4	Water temperature difference for supply and return pipes	3-5 °C
5	Water flow rate in pipes	0.6 m/sec

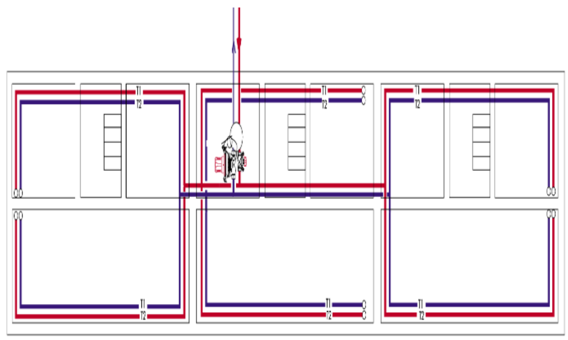

Figure 3. The optimal location of the mains of PH is sectional, with lower wiring: T_1 - supply pipeline, T_2 - return pipeline

3. RESULTS

The design structure of PH is such that pipes with a heat carrier at a certain distance between them, usually 20-30 cm, are located on a heat-insulating layer filled with cement screed if it is floor heating, or covered with plasterboard in the case of wall and ceiling heating. Heat is transferred to the finish coating and then radiated into the room [20, 21]. The heating rate of the coating occurs according to an exponential pattern, the total thermal energy received in the first n hours is determined by the formula, W:

$$Q = \frac{(t-t_0)}{R_k} = \int_0^n q dn = CT_0\left(1-e^{-F_0}\right) \quad (2)$$

where, t - initial temperature of the heat carrier, °C

t_0 - final temperature of the heat carrier, °C

R_k - total thermal resistance of all layers located after the main concrete structure, $\frac{\text{m °C}}{\text{W}}$

q- heat flow per unit of time, $\frac{\text{W}}{\text{sec}}$

C- heat capacity of the heating surface layer, $\frac{\text{J}}{\text{°C}}$

T_0 - the surface temperature concerning the room air temperature for some time n, °C

F_0 - similarity criterion summarizing the temporal and spatial characteristics of the surface heating process, which is calculated by the formula:

$$F_0 = \frac{n}{CR_k} \quad (3)$$

R_k - total heat transfer resistance of heating surface, $\frac{\text{m °C}}{\text{W}}$;

n - time of heating surface to the required temperature, °C.

Panel heating systems are inertial, they require some time to reach the design heating temperature, that is, the time from the start of the commissioning of the system until the required room air temperature is reached. The time required to reach the design room air temperature is determined according to Equation (2) [16].

$$n = F_0 \cdot C \cdot R_k \quad (4)$$

The time to reach the design room air temperature can conditionally be considered for four stages as shown in Figure 4. Initially, the temperature of the heating panel rises in direct proportion to its total heat capacity (C_{total}) taking into account the heat capacity of the layers located after the main concrete structure, i.e., thermal insulation layer, cement screed or drywall, topcoat, with a higher value of the total heat capacity, the heating time is longer.

Also, the time to reach the design room air temperature depends on the thickness of the constituent layers δ_{layers}, the heat carrier temperature τ_{agent}, and the initial temperature of the panel τ_0, i.e.:

$$n_1 = f\left(C_{total}, \delta_{layers}, \tau_{agent}, \tau_0\right) \quad (5)$$

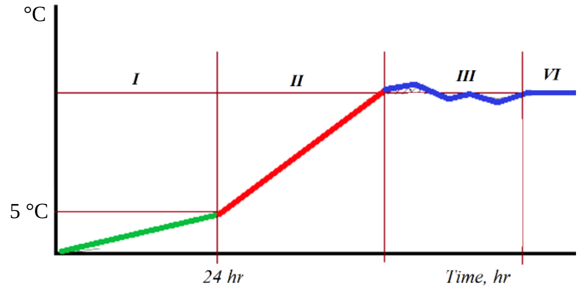

Figure 4. A generalized graph of the inertia of the surface heating system [5]

There is an inverse proportional relationship between the heat carrier temperature and n. Surface heating systems operate on low-temperature sources, so $\tau_{agent} \le 55$ °C. In the second stage, the panel heats up more quickly, which means that the required room air temperature is reached faster; at the third stage, heating up may exceed the required design air temperature for some time, but after a certain time the temperature stabilizes and it is maintained at the design level.

Field studies show the following results:

- with specific heat losses of the room (55-65) $\frac{\text{W}}{\text{m}^2}$ and panel thickness of (30-40) mm, heating-up time of the covering panel from 0 °C to +5 °C is achieved almost in a day;
- for a panel 2 times thicker i.e., (60-80) mm heating-up time is almost 2 times longer;
- for the climatic conditions of Baku, the initial temperature of the panel is (3-4) °C, therefore, heating-up to +7 °C is carried out within 15 hours;
- the heating of the room air begins in the second stage of heating. The value of the indicator n_2 is determined primarily by the heat losses of the room $Q_{premise}$, and the ratio of the panel area to the area of the external structures (Table 2):

$$A = \frac{A_{panels}}{A_{enclosurestructures}} \quad (6)$$

$$n_2 = f\left(Q_{premises}, A\right) \quad (7)$$

Panel heating time n_2 is also determined by the presence and combination of:

- accelerated heat losses- through glazed doors, walls, through windows;
- slow heat losses - through opaque structures - walls, ceiling, roof, foundation.

Table 2. Dependence of the heating time of the panel on the specific heat losses of the room

No	Room heat losses $Q_{premise}$, $\frac{\text{W}}{\text{m}^2}$	The heating time of the panel, n_2, hours
1	50	40
2	60	48
3	70	64

In addition, transparent exterior structures increase the operating costs of the heating system and the building as a whole. The third stage of heating the panel n_3. is characterized by slight fluctuations in the actual panel temperature according to the designed temperatures. The oscillation amplitude depends on the inertia of the system and the method of automation of the heating system, the oscillation frequency is determined by changes in the outside air temperature. The fourth stage is the stable operation of the heating system.

Figure 5 depicts the relationship between the panel's surface heat flux density and its heat transfer by radiation. Based on the results of field studies, it was found that with an increase in the heating duration of the panel, its surface heat flux density changes exponentially.

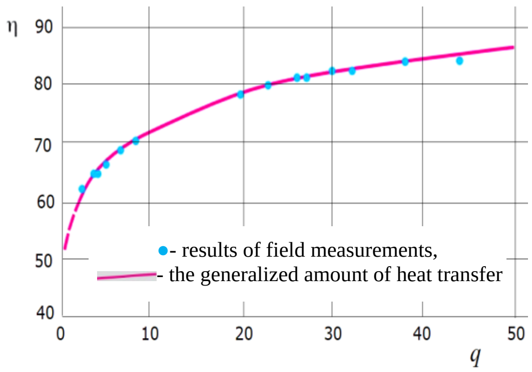

Figure 5. Dependence of the surface heat flux density of the panel, $q, \frac{W}{m^2}$, on the share of radiant heat transfer, η, %

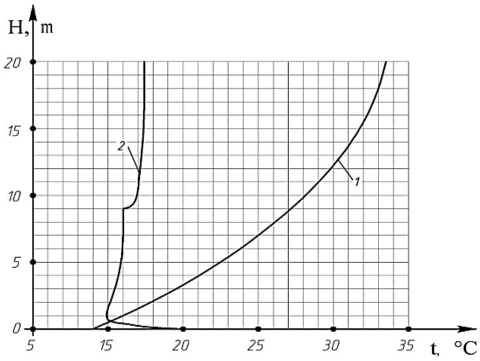

Figure 6. Distribution of air temperature along with the room height when heating with 1- convection, 2- radiation

The distribution of air temperature along the height inside the heated premises for heating panels and radiators are different and this, of course, affects both the well-being of a person and the energy consumption of the system. Figure 6 shows graphs of the distribution of the temperature of the internal air along with the height in a room heated by radiators and heating panels. They show that with radiators, the air temperature increases significantly with height, and with radiative heating, it changes slightly. With the heating panels, the increase in air temperature from the floor to the ceiling is (0.3-0.5) $\frac{°C}{m}$, and with radiators, (1.5-2.5) $\frac{°C}{m}$.

With panel heating, due to the direct absorption of energy from the panel, a person feels a higher temperature in comparison with the average air temperature in the room. The additional temperature formed by the radiant flux is determined by the formula:

$$t_r = q' \times 0.0716 \text{, °C} \quad (8)$$

where, q' is irradiation intensity, $\frac{W}{m^2}$; and 0.0716 is empirical conversion coefficient, $\frac{m^2\,°C}{W}$.

Due to t_r the room air temperature can be maintained several degrees below the set temperature. This indicates another advantage of using panel heating.

4. DISCUSSION

The factors hindering the active use of PH heating in Azerbaijan are shown on Figure 7.

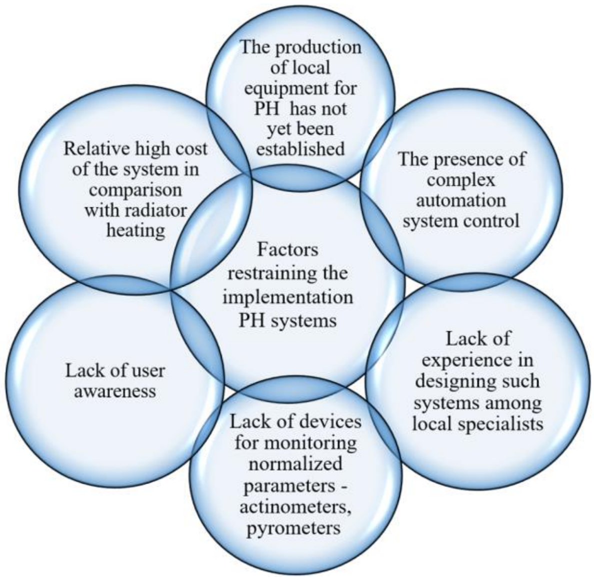

Figure 7. Reasons inhibiting the use of panel heating in Azerbaijan

The advantages of modern panel heating systems regarding their energy efficiency, ergonomics, and comfort are as follows:
- it is a low-temperature heating system, for which year-round use is possible for both heating and cooling;
- heating panels have a laconic design and are well combined with modern finishing materials, they do not occupy usable space, and therefore do not create problems during redevelopment;
- panel heating system operates in a silent mode, does not create drafts, and the temperature distribution along the height of the room is uniform;
- panel heating installation is possible both for new and reconstructed objects.

5. CONCLUSIONS

At the present stage of Azerbaijan's development, the issue of energy efficiency in the construction, reconstruction, and operation of buildings is relevant along with the issues of creating and maintaining a healthy microclimate and environmental friendliness of the construction sector. The construction industry of Azerbaijan consists of 15-25% of new buildings, and the rest is old and reconstructed buildings and structures.

Therefore, the certainty of priorities in heating system design is an urgent issue. Panel heating systems as priority ones, operating on a low-temperature heat carrier, fully meet today's requirements, and research on optimizing their operation will significantly reduce the amount of thermal energy for heating buildings and structures.

As well as the possibility of using renewable energy sources for panel heating today, which makes them out of competition compared to traditional convection heating. In this article, the results of clarifying the inertia of the panel heating system are obtained. Due to heating by radiation, the energy efficiency of a panel heating system is 2 times higher than that of a traditional radiator one. Further research in this direction will optimize the operation of panel heating systems and reduce the specific consumption of thermal energy in buildings.

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