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THE IMPACT OF INPUT TEMPERATURE AT PANEL HEATING SYSTEM TO HEAT THE SPORTS HALL

Dragan Cvetković[1], Aleksandar Nešović, Ljubiša Bojić,

Summary: *Low temperature heating panel systems offer distinctive advantages in terms of thermal comfort and energy consumption, allowing work with low energy sources. The low temperature panel systems, by their nature work at a low temperature sources. However, this method of application panel system is not suitable for work in large spaces such as the sports hall. The aim of this study was to investigate the effect of inlet temperature of the panel systems in order to facilitate their application in sport halls. Simulation models are developed in the EnergyPlus software package developed by Lawrence Berkeley Laboratory in the United States.*
Key words: *energy, radiant panel heating, temperature, Energy Plus*

1. INTRODUCTION

Low temperature heating panel systems have been increasingly used in Europe today for purpose of heating and cooling of residential buildings and houses. According to some studies, spread of these systems go over 50% [1,2]. It is possible to save even 30% of energy when using this system [3, 4]. On the other hand, application of low temperature heating panel systems is questioned in case of big spaces and volumes.

Radiation systems are very complex because they involve different heat transfer mechanisms, transfer through wall, convection between space and air in these interiors, radiation between panels and surrounding areas and transfer between floor and ground.

Many studies are dedicated to lab research of panel systems in terms of heat transfer and development of new ways to manage them [5-10]. When looked through the prism of modeling, there are few analytical studies about thermal characteristics of panel systems. In the first model, Kollmar and Lises [11] show that heat is mainly lost on the upper side of panel. Leal and Miler [12] have been using analytical numeric methods to determine temperature in installation used to heat pedestrian roads. Zhang and Pate developed two dimensional method of final elements for ceiling heating, that was used for modeling of NTS heating [13,14]. Kilkis [15] developed stationary composite model for modeling of radiation systems for heating and cooling. After that, Kilkis and Sapci [16] together with Kilkis and Coley [17] used this model to develop software for design of floor heating and cooling systems.

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Maloney [18] developed model of radiation heating panels for BLAST program. Strand and Pederson [19, 20] used conduction transfer method to develop radiation model for heating and cooling within the EnergyPlus software. Miriel [21] used TRNSYS software for modeling of ceiling panels for heating and cooling.

Aim of this paper is to explore the possibility to apply panel heating systems to big spaces and volumes. Because of balanced acting, the system with wall panels is connected to natural gas boiler. Inlet temperatures were changed from 40°C to 90°C.

2. DESCRIPTION OF THE BUILDING

Analyzed building shown on figure 3 is a standard sports hall. Building consists of main room and annex space that is used for fitting room, showers space and toilets. Surface area of sports hall is around 1130 m^2. Walls of the hall consist of hollow bricks of 190mm, Styrofoam insulation layer of 50mm and lime mortar of 20mm. Coefficient of heat passage is 0.57 W/(m^2K). Windows are two layered with coefficient of heat passage of 2.72 W/(m^2K).

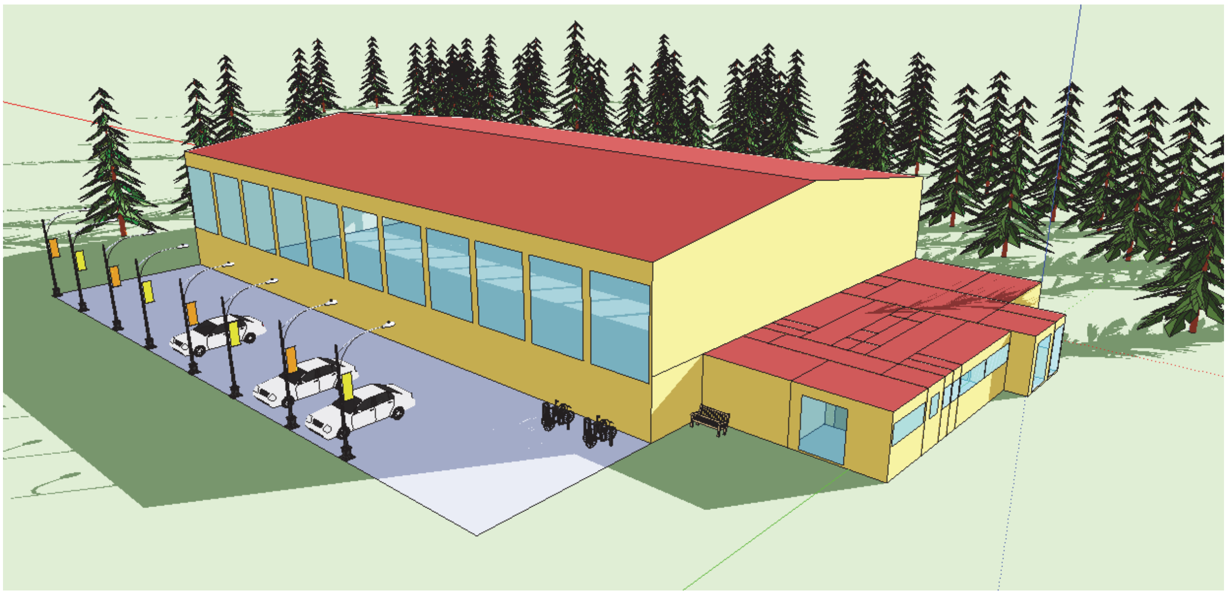

Figure 3. *Analyzed sports hall*

3. LOCATION AND CLIMATE CONDITIONS OF THE BUILDING

Analyzed building is located in Kragujevac, Serbia. Altitude above sea level of Kragujevac city is 209m. The sports hall is located on 44°1N and 20°55E. Climate is moderately continental with different seasons such as summer, autumn, winter and spring. Weather file generated inside Metenorm software was used for EnergyPlus calculations [23]. Heating season in the city of Kragujevac lasts from 15th October to 15th April [24].

Table 1 *Climate parameters for Kragujevac, Serbia [25]*

Month	Average temperature °C		Average falls (mm)	Number of rain days
	Daily minimum	Daily maximum		
Jan	-3.8	3.8	4.1	11.6
Feb	-1.7	6.7	3.87	10.4
Mar	1.4	11.8	4.44	10.6
Apr	5.5	17.3	4.94	12.2
May	10.1	22.0	7.38	13.1
Jun	13.0	25.0	8.47	12.9
Jul	14.2	25.0	6.8	9.3
Aug	13.7	27.2	5.33	9.3
Sep	10.7	23.9	4.48	8.1
Oct	6.3	18.2	3.82	8.6
Nov	2.4	11.5	4.82	10.3
Dec	-1.6	5.6	4.76	12.3

4. MATHEMATICAL MODEL

4.1. PANEL SYSTEMS DESCRIPTION

In case of panel heating, panels are integrated within construction elements - walls. These elements are heated to the temperature higher than the temperature of the surrounding air, so that they transfer heat by convection and radiation.

Wall panels are applied increasingly because limits in floor and ceiling temperatures. They are installed on cold outside walls thus stopping heat transfer through them. Differently from the ceiling panels, floor panels provide the most of heat by radiation, therefore being better for functioning on higher temperatures of fluids, which outcomes with higher heat flux.

The way heat pipes are positioned increases complexity to determine heat transfer. Usually two types of heat pipe layouts are used; spiral and serpentine (Figures 1 and 2). In case of the serpentine, heat flux moves across the surface of the pipe, while in case of spiral layout, it is radial.

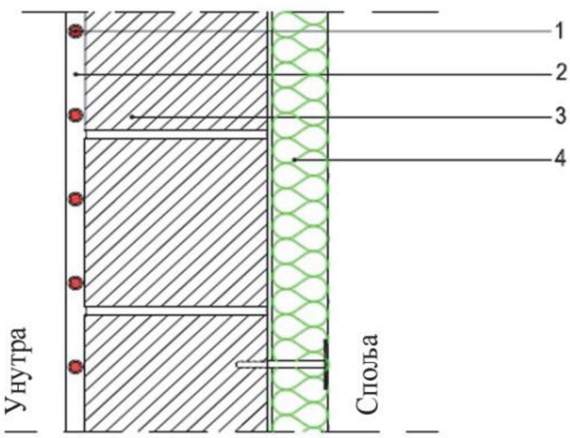

Figure 1 *Wall panel*
1 – heating pipe, 2 – mortar, 3 – hollow brick, 4 – Styrofoam

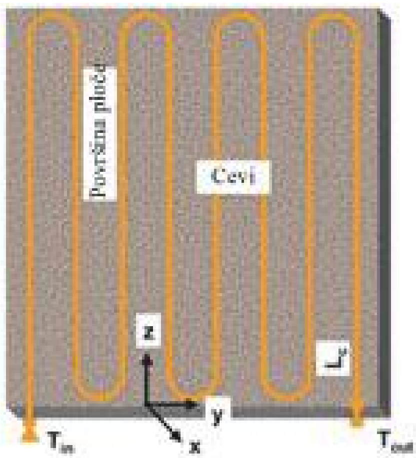

Figure 2 *Wall panel*

4.2. AMOUNT OF SPENT ENERGY OF THE HEATING SYSTEM

Amount of spent primary energy per heating period of the analyzed building was calculated by using the following formula:

$$E_{sys} = E_{ng} + E_{el} \cdot R \quad (1)$$

E_{ng} is natural gas consumption per heating period, E_{el} is power consumption per heating period to empower heating system and R coefficient of primary energy transformation. This coefficient is defined as relationship between total input energy from different energy sources (hydro energy, coal, oil and natural gas) and final production of electric energy. This value for produced electric energy for Serbia is R = 3.61 [26].

5. RESULTS AND DISCUSSION

This research inquiry simulates heating panel system connected to gas boiler with an aim to heat sports hall. Wall heating was chosen for this purpose. It was placed on the outside surface which contains thermo insulation. Non-condensation boiler was used to generate heat based on natural gas with continuous flow circulation pump.

Low temperature panel systems are not convenient to be used in big inside spaces. Because of that, impact of input temperature on panels was considered, with an aim to adjust certain temperature inside the heated space. Panel inlet temperatures are changed from 40 to 90°C. Wall panels that work with input temperatures until 50°C can be considered low temperature panels, while wall panels with inlet temperatures of 60 and more degrees can be considered high temperature panels.

5.1. RESULTS

Results of the simulation for every of the analyzed cases were first shown through energy consumption of fluids.

Energy consumption that involves consumption of natural gas and electric energy to keep the pump working was shown on figure 4. First case resembles wall panel with inlet temperature of 40°C and, as such, it represents classical low temperature wall panel. Its consumption of final energy is around 244.8 kWh/m2a. Heating system consumption with inlet temperature of 50°C is 7.6% higher and it is around 263.4 kWh/m2a. Heating system consumption with inlet temperature of 60°C is around 9.7% higher than in the case when inlet temperature is 40°C and it is around 268.5 kWh/m2a.

Heating system with inlet temperature of 70°C consumes more than 11% than if the inlet temperature is 40°C and it is around 271.6 kWh/m2a. If the panel inlet temperature is 80°C then the consumption is around 12.6% higher than the case when inlet temperature is 40°C which in that case is 275.7 kWh/m2a. Consumption of the heating system in case of inlet temperature of 90°C is around 14.1% higher than the case in which the inlet temperature is 40°C and it accounts to around 279.2 kWh/m2a.

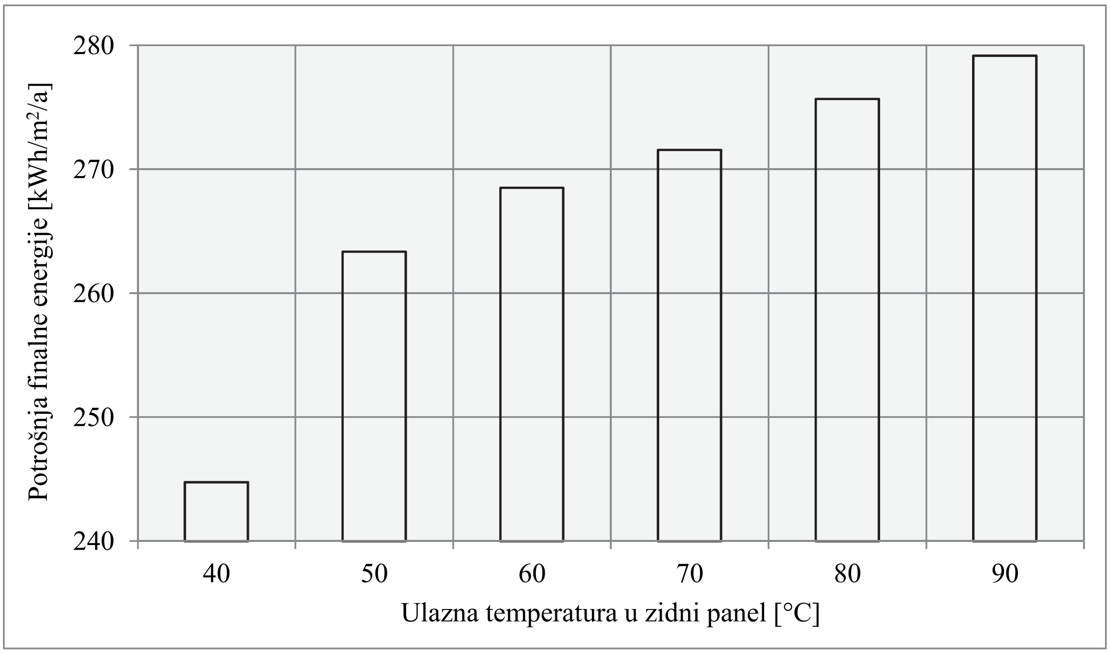

Figure 4. *Final energy consumption for heating with different inlet temperatures to wall panel*

Mean air temperature, Mean radiant temperature, Operative temperature in heated spaces and Design temperature are shown on figure 5. Operative temperature was regulated with thermostat and its value was 18°C. It can be noticed that goal value is reached only for panels working with inlet temperature of 60°C and higher. On the other hand, mean air temperature was too low for cases in which inlet temperatures are 40°C or 50°C. Mean radiant temperature was below given values only in case when inlet temperature was 40°C.

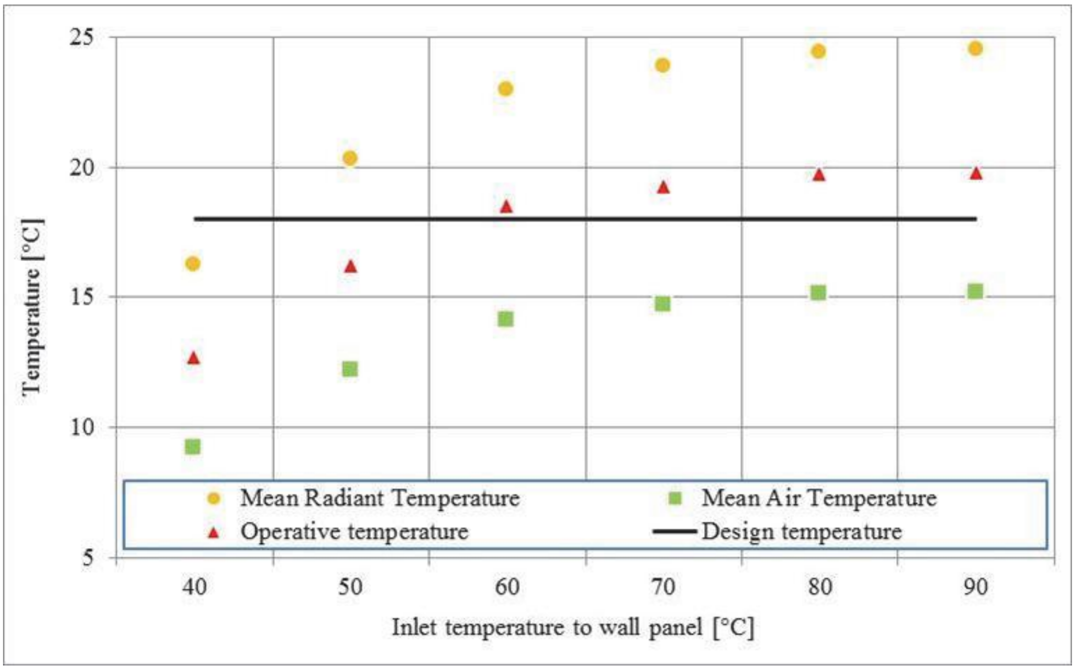

Figure 5 *Temperature inside sports hall with different inlet temperatures to wall panel*

Mean radiant temperature with different inlet temperatures was shown on figure 6. Heating system was not working in period from 24 to 09h. In this case, temperature had a tendency to drop, depending from the accumulative features of the sports hall and amount of radiated heat during the previous day. Time needed to achieve aimed temperature differs because of different inlet temperatures. For example, in order to achieve 18.3°C, with inlet temperature of 40°, there was 2h late, while for inlet temperatures from 50 to 90°C aimed temperature was achieved very quickly.

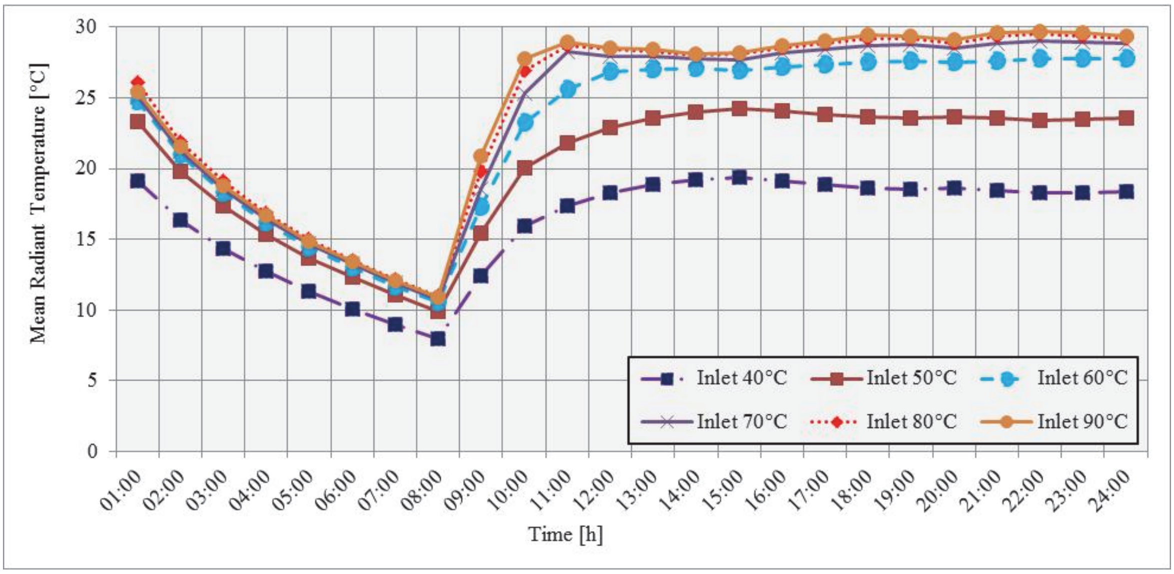

Figure 6 *Dependence of mean radiant temperature from the inlet temperature to the wall panel*

Mean air temperatures for different values of inlet temperatures to the wall panel are shown on figure 7. There was no heating from 24 to 09h as indicated from the graph. In this period, temperature was dropping as dependent from accumulative feature of the space and amount of radiated heat during the previous day. Time needed to achieve aimed temperature differs depending from the inlet temperature to the wall panel. For example, aimed temperature could not be achieved if inlet temperature is from 40°C to 50°C. For inlet temperatures of 60, 70, 80 and 90°C there is a delay of 4h, 3h, 2h, 2h and 2h, respectively.

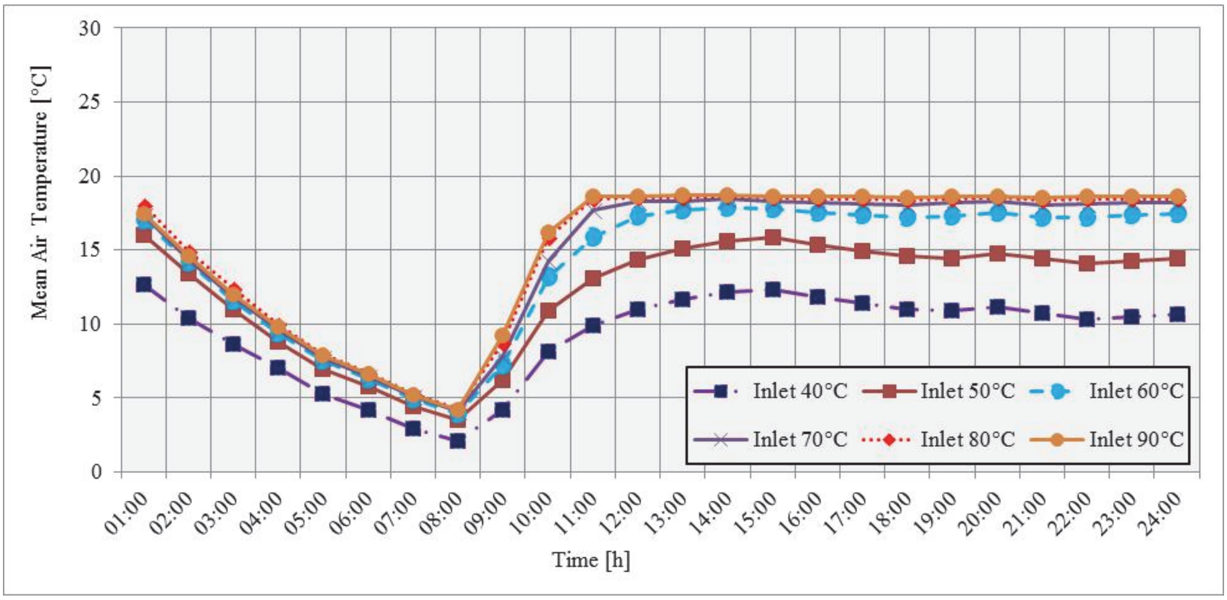

Figure 7 *Dependence of mean air temperature from inlet temperature to panel*

Values of operative temperature depending from different inlet temperatures to the wall panel are shown on figure 8. As written before, there was no heating in the period from 24 to 09h. Temperature has a tendency to drop in this period depending from accumulative feature of the space and radiated heat during the previous day. Time needed to achieve aimed temperature differs from the inlet temperature to the wall panel. Aimed temperature has not been achieved for inlet temperature of 40°. Aimed temperature was achieved for inlet temperatures of 50, 60, 70, 80 and 90°C with delay of 2h, 1h, 1h, 1h, 1h and 1h, respectively.

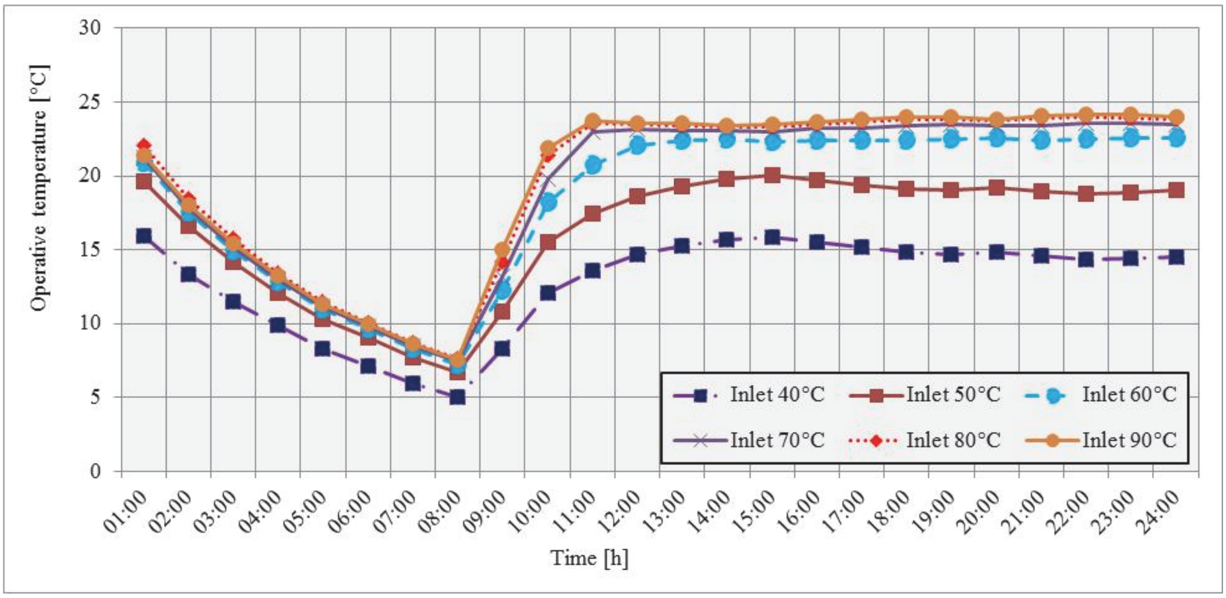

Figure 8 *Dependence of operative temperature from inlet temperature to the wall panel*

Figure 9 shows dependence of outlet temperature from the panel in relation to given values of inlet temperature to wall panel. It is possible to conclude that more values of inlet temperature have greater variation and less stable workflow. Thus, temperature difference is greatest if inlet temperature is 90°C and it goes to 37°C, while the lowest inlet temperature is from 40°C to 5°C

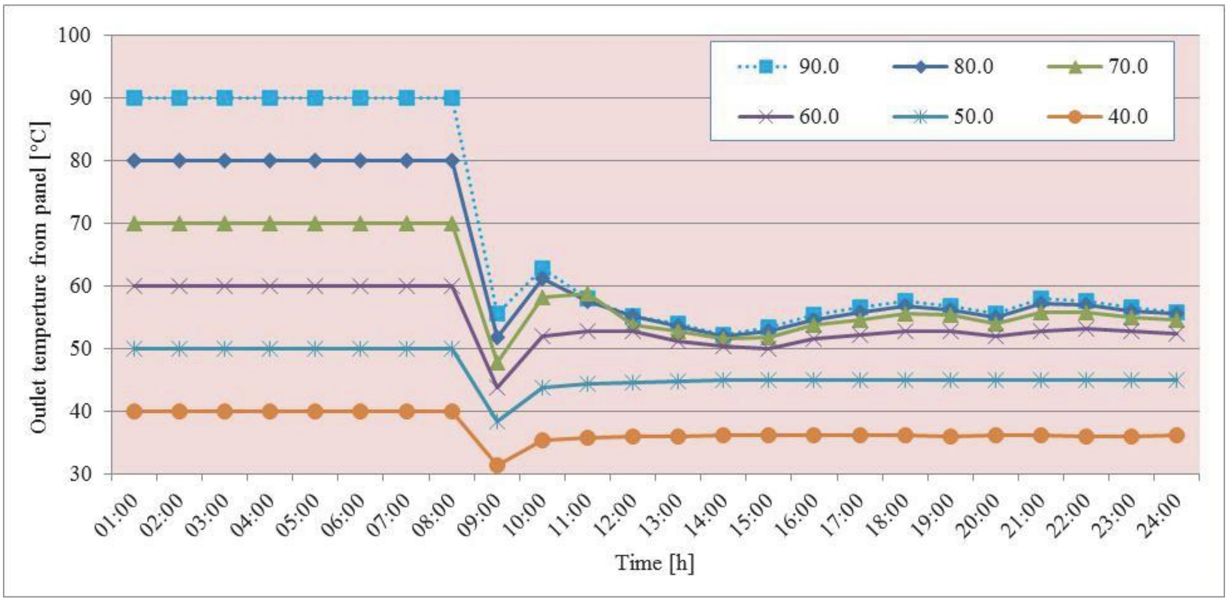

Figure 9 *Dependence of outlet temperature from outlet temperature from the wall panel*

6. CONCLUSION

This research inquiry analyzes impact of inlet temperatures for the heating systems, with wall panels to the energy consumption and temperature inside heated space. As source of heat, classical non-condensation boiler was used, based on natural gas, connected to circulation pump, with constant flow. Analyzed sports hall is located in Kragujevac city area. Its architecture represents typical way of construction for this kind of buildings in Serbia.

Heating system with inlet temperature of 40°C has lower consumption of energy, while system with inlet temperature of 90°C has highest consumption of energy. Panel systems of heating with inlet temperature cannot achieve aimed values and thus its use is unacceptable for this sports hall. Its use may be acceptable if different architectural concept is in question, with fewer transparent surfaces and better heat insulation. Heating system with inlet temperature of 50°C is not satisfactory in terms of aimed temperatures, but it is near that point. Heating system with inlet temperature of 60°C is the first system that achieves aimed values of temperature. Its energy consumption is around 9.7% higher than if the inlet temperature 60°C.

Also, higher inlet temperature outcomes with greater temperature difference and thus greater exergy unbalance. Low inlet temperatures are of no use for this kind of building because of huge volume of space to heat and bad heat insulation. Its eventual application can be achieved by changing the architecture of the building.

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