Dragan Cvetkovic[1)]
Milorad Bojic[1)]
Verimir Stefanovic[2)]
Dragan Taranovic[1)]
Marko Miletic[1)]
Sasa Pavlovic[2)]

1) *Faculty of Mechanical Engineering, University of Kragujevac, Serbia*
dragan_cw8202@yahoo.com, milorad.bojic@gmail.com, tara@kg.ac.rs, marko.m.miletic@hotmail.com

2) *Mechanical Engineering Faculty, University of Niš, Serbia*
veljas@masfak.ni.ac.rs, sasap208@yahoo.com

DEVELOPMENT OF EXPERIMENTAL PROCEDURE FOR INVESTIGATION LOW-TEMPERATURE HEATING SYSTEMS

Abstract: *Low temperature heating opens for better utilisation of low valued and environmentally sustainable energy sources. The main objective of this paper is to define an experimental procedure in order to comparison low temperature radiant systems for a net-zero-energy house in Kragujevac, Serbia. Consideration of the experimental procedure consists of two objectives: create a valid test model which consist testing heating panels, and examine the possibility of using existing heat pump (in the laboratory of Thermodynamics on Faculty of Engineering at Kragujevac) with the test model. In this study, besides the usual panel heating system the testing of newly developed floor-ceiling panels is provided.*

Keywords: *radiant panel, experiment, energy consumption, test room, heat pump*

1. INTRODUCTION

Low temperature heating panel systems offer distinctive advantages in terms of thermal comfort and energy consumption, allowing work with low energy sources. Saving energy with panel system according to some studies more than 30% [1-2]. Low temperature radiant systems are very complex because they involve different mechanisms of heat transfer, conduction through the walls, convection between the building surface and indoor air, radiation between the panel and surrounding areas and the conduction between the floor area and ground. The main essence of the low-temperature air systems is to provide adequate thermal comfort at significantly lower temperatures and to prevent overheating of the rooms in heating mode.

Hasan et al [3] are compared combined low temperature water heating systems with three conventional radiator and floor heating systems. Besides, the analyses of primary energy consumption for heating, the thermal comfort analyses regard to temperature gradient are done. The measurements was done in test room (4.025m x 3.0m x 2.6m) at different height of measurement points,0.1, 0.6, 1.1, 1.7 and 2.5m from the floor surfaces. However, the authors conclude that using radiator and floor heating indicate that there is a small vertical difference of air temperature inside the test room, which would not produce any significant thermal discomfort. Rahimi and Saberbaeeni [4] are investigated the impact of heated floor on the suroundings surfaces. This research is conducted in test room (2.4x2.4x2.4) equipped with under-floor heating system.

Temperatures of both sides of the elements were measured using an infrared thermometer under steady state heat flow conditions. Based on the results, 75-80% of the heat is transferred by radiation from the heated floor to the surfaces of the enclosure. The contribution of the radiation decreases slightly as the floor temperature is increased. Rekstad et al [5] are developed a new approach of temperature control and energy metering in low temperature heting systems. Temperature controling is based on a ambiental temperature for Norwegian conditions. Also, the demonstrated method has accurate within ±5%.

This work relies on previous research on panel heating systems. Beside standards panel heating systems (wall, floor and ceiling) Bojic et al [6] are devised a novel panel heating system with name “floor-ceiling” panel. Also, in the wall heating panels the impact of thermal insulation inside the wall is studied [7]. As a consequence of conduction transfer from pipe through the wall, the wall heating panels are more sensitive to presence of thermal insulation compared to the radiators.

The main objective of this paper is to define an experimental procedure in order to comparison low temperature radiant systems. The analysed system are floor panel heating, wall panel heating, ceiling panel heating and new developed floor-ceiling panel heating. The analysed system will be apply in experimental room and connected with existing heat pump installation with proper modification.

2. EXPERIMENTAL PROCEDURES

2.1 Model of house

The purpose of this experiment is to compare the low-temperature panel heating systems. In devising the test model the starting point was from certain restrictions on the possible location of the test model ie the knowledge that in the laboratory for Thermodynamics and Thermal Engineering Faculty of Engineering Sciences in Kragujevac, already exists a heat pump adequate thermal performance. So that was concluded that the mentioned laboratory it is the best location for the testing of model. This location imposes system of dry construction.

The test model would consist of two rooms, which will be located one above the other in order to test a new concept of floor-ceiling heating (Figure 1). All room dimensions, it is necessary to be the same, in order to examine the effect of the panels on the surrounding area. On figure 2 it showed cross section of test room. The dimension of test model are 1x1x2m were the each room have a height of 1m. The window dimensions are 0.4x0.4. The support structure will be made of aluminium or steel profiles to which will be placed envelope elements.

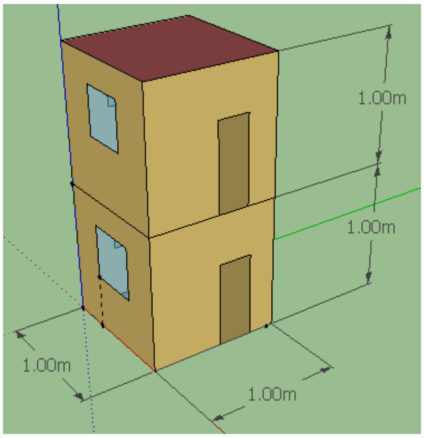

Figure 1. Experimental house

The structure of the heating panel is shown in Figure 3. The supporting structure is made of aluminum profiles to which attaches envelope construction. The construction of the wall is made of plasterboard (8 and 6) between them is located polystyrene insulation (7). On plasterboard (6) is set panel board that consists of pipe coils (4) which is placed on the plate (5) by using the rails (2). Over the pipe coils and rails lime plaster is applied (1). Also over the gypsum board (5) the aluminum foil (3) is placed.

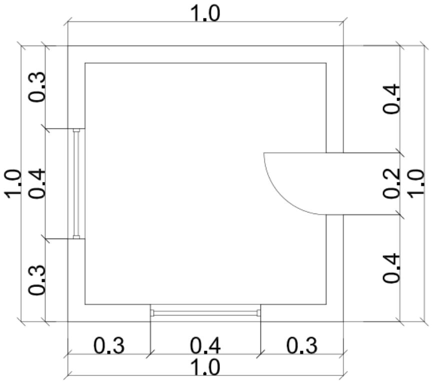

Figure 2. Cross-section of the house

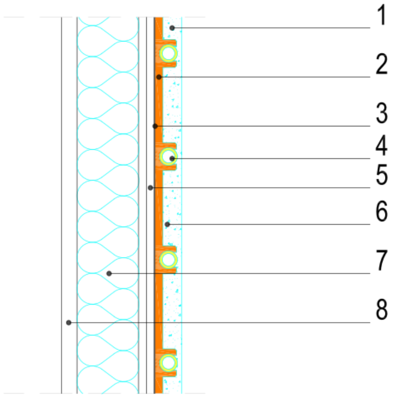

Figure 3. Detail of panel construction

2.2 Installation of heat pump

On figure 4 the existing installation of heat pump and solar collector are present. The installation is located in laboratory of thermodynamics on faculty of engineering in Kragujevac, Serbia. The scheme on fig 4 shows that the installation consists of heat pump (1), solar collectors (14), the heater floor heating (2), a radiator (3), heater (fan-coil units) (7), the boiler for heating domestic hot water (SV) (5), closed expansion vessels (4), pump on secondary coils (12), pump on primary coils (13), accumulation tanks (9 and 6), and following armatures (pipes and valves) and measurements equipment (thermometers and manometers).

The characteristics of some parts of the installation are describes here: heat pumps, under floor heating systems, radiators, heating systems and hot water heaters.

The heat pump type water-water is the heart of the installation (Figure 5). It transfers heat from a lower temperature heat source (here is water in the primary) to a higher temperature heat sink (there is water in the secondary). Heat transfer is performed using Freon R22. Generally heat pump is purchased as a finished product and is composed of the following elements: Freon compressor, two coaxial heat exchanger type refrigerant-to-water, expansion valve, the refrigerant dryer, pressure switch in order to protect the compressor and installation of high and low pressure, electrical part for turning the compressor and water pumps in the primary and secondary coils, and microprocessor controller.

Technical characteristics of used heat pump are: (1) evaporation temperature of refrigerant R22 at P_i = 5.85 bar is t_i=5 °C, the dew point temperature at P_c=12.55 bar is t_c=32 °C, heating power is 3.78 kW when are t_c=55 °C and t_i= 5 °C, and the compressor power is 0.98 kW, the maximum number of switching of the compressor is 6 per hour, nominal flow rate is 0.72 m^3/h at t_w= 12 °C, the minimum temperature of primary inlet water is $t'_{w\text{-}min}$ = 10 °C and a minimum flow of primary water ≥ 0.28 m^3/h, the maximum temperature of primary inlet water is 35 ° C ≤ $t'_{w\text{-}max}$ ≤ 40 °C and the maximum primary flow is ≤ 0,15 m^3/h for $t'_{w\text{-}max}$, the water flow in the secondary is 0.65 m^3/h, the maximum temperature is 50 °C, and nominal pressure drop is 30 kPa.

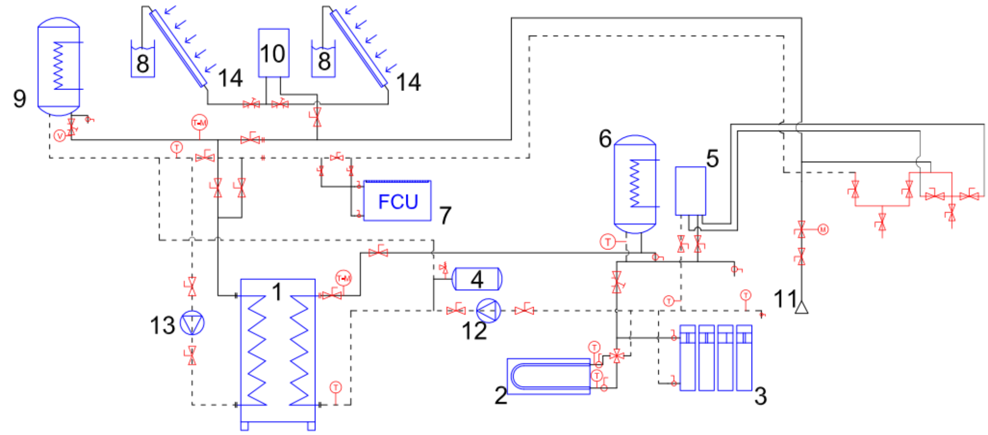

Figure 4. Hydraulic schema of existing installation of heat pump and solar collectors

Figure 5. Heat pump

The underfloor heating system that is used as a heater in existing installation is shown in Fig. 6. It consists of a one tube with outer diameter of 14 mm and a length of 4 m, which is bent into a loop and placed on Al foil through which the heat is distributed in space. The pipe material is cross-linked polyethylene (PEX) networked Al wire. Foil is placed on the surface of polystyrene (2 x 0.5 m), which prevents the heat is transferred down to the ground. The amount of heat delivered by underfloor heating depends on the distance between the pipes, water temperature, water flow, and the type of floor finish.

Figure 6. Floor panel

3. MODIFICATION OF INSTALATION

As planned experiment provides analysis of the heating performance of panel systems need to be connected to an existing installation of the heat pump. Existing installation aims to present the operation of heat pump in conjunction with different types of heaters (floor, wall etc.). So it necessary to installed redundant elements put out of function.

3.1 Primary side

On the primary side does not require any modification. Heat pump (1) using the tap waters as a heat source (11), which flows through pipe to the accumulation tank (9) and a by pump (13) the primary water is transported through the evaporator of heat pump. The water that passes through the evaporator using a piping flows to the drain tap on the sink which is discharged and sent to a sewage system.

3.2 Secondary side

In the condenser unit the cooling fluid in the heat pump transfers of heat from heated Freon to the secondary water. The heated water is transported through pipeline to the first accumulation reservoir (6) and from there through a mixing valve transported to the floor panels and then using a circulation pump is transported back through the condenser of heat pump.

In fact on the secondary side in place of floor panel connections is provides the connection of the experimental model. In order to preserve the function of the existing floor panels after mixing valve will be installed collector and distributor (Figure 7). Necessary number of collectors and dividers are five (by one for existing floor panel and for each of the heating system by one). The connecting the mixing valve with collectors and dividers can be achieved using AL-PEX pipes. Also, an experimental model and existing installation will be connected by AL-PEX pipes. Connecting AL-PEX pipe with pipe coils in the heating panels will be realized by fast couplings (Figure 8).

Figure 7. Collectors and dividers

Figure 8. Fast coupling

4. MEASUREMENTS PROCEDURES

By connecting with exist the heat pump of the experimental model it enables the testing of the heating system for four different types of the heating panels. For heat supplying of the experimental model, the heat pump uses water from the mains and electricity from the grid. By placing the power meter between the heat pump connection and the plugs can be measured power consumption at any time. Also, by using the flow meter of the primary water which is placed directly before the accumulation tank (9) can be measured the consumption of primary water that passing through the condenser. On the primary and secondary piping on entry location ie exit location of heat pumps the thermo-manometers are installed.

On the collectors and dividers beside flow controller is necessary to set the thermo-manometers. How, in practice the same temperature of heated water sends in all panels of the heating system it will be enough the set up a common thermometer on the collector i.e. on the dividers.

When considering the measurement in the experimental model, it is necessary to monitor the parameters which affect on the thermal comfort in the room. Monitoring of these parameters is based on the setting of the temperature sensor on middle of the room and measures the multiple points vertically in order to define the temperature gradient. It is also necessary to perform the measurement at the furthest points of the tested panels. In addition to measuring the air temperature inside the room and it is necessary to measure the temperature on the surface structure and the determination of the heat flux through the construction of panels. This is necessary in order to determine the impact of the panels to the external environment and identify the best solutions in terms of increasing the efficiency of them.

5. CONCLUSION

This paper defines the experimental procedure aimed at testing of panel heating systems. Investigated types of panels are floor panels, wall panels, ceiling panels and floor-ceiling panels.

Analysis of the existing installation of heat pump has shown that a relatively simple intervention on the installation can be enabling to connect with experimental model. It is necessary to install the collector and distributor with additional measuring equipment. Also, in this paper is defined an experimental model in which will be applied the analyzed panel systems. Procedure has shown that a single model can be used for examine of all heating panels.

REFERENCES:

[1] Stetiu, C. (1999). Energy and peak power potential of radiant cooling systems in US commercial buildings. *Energy and Buildings, 30*, 127-138.

[2] Yost, A., Barbour, E., & Watson, R. (1995). An evaluation of thermal comfort and energy consumption for a surface mounted ceiling radiant panel heating system. *ASHRAE Transactions, 101*(1), 1221-35.

[3] Hasan, A., Kurnitski, J., & Jokiranta, K. (2009). A combined low temperature water heating system consisting of radiators and floor heating. *Energy and Buildings, 41*(5), 470-479.

[4] Rahimi, M., & Sabernaeemi, A. (2011). Experimental study of radiation and free convection in an enclosure with under-floor heating system. *Energy Conversion and Management, 52*(7), 2752-2757.

[5] Rekstad, J., Meir, M., Kristoffersen, A. R. (2003). Control and energy metering in low temperature heating systems. *Energy and Buildings, 35*(3), 281-291.

[6] Bojić, M., Cvetković, D., Marjanović, V., Blagojević, M., & Đorđević, Z. (2013). Performances of low temperature radiant heating systems. *Energy and Buildings*, *61*, 233-238.

[7] Bojic, M., Cvetkovic, D., Miletic, M., Malesevic, J., & Boyer, H. (2012). Energy, cost, and CO2 emission comparison between radiant wall panel systems and radiator systems. *Energy and Buildings, 54*, 496-502.

Acknowledgment: This paper is a result of two investigations: (1) project TR33015 of Technological Development of Republic of Serbia, and (2) project III 42006 of Integral and Interdisciplinary investigations of Republic of Serbia. The first project is titled “Investigation and development of Serbian zero-net energy house”, and the second project is titled “Investigation and development of energy and ecological highly effective systems of poly-generation based on renewable energy sources. We would like to thank to the Ministry of Education and Science of Republic of Serbia for their financial support during these investigations.