Integration of Heat Pumps with Large-Area Radiant Systems



MARTIN ŠIMKO
Department of Building Services
Faculty of Civil Engineering
Slovak University of Technology,
Bratislava, Slovakia
martin.simko@stuba.sk

DUŠAN PETRÁŠ
Department of Building Services
Faculty of Civil Engineering
Slovak University of Technology,
Bratislava, Slovakia

DANIEL SZABÓ
Department of Building Construction
Faculty of Civil Engineering
Slovak University of Technology,
Bratislava, Slovakia

The paper deals with the description of the laboratory of large-scale radiant systems. The objective of this study is to experimentally verify the performance of floor, ceiling, and wall radiant systems and thermal comfort in rooms operating in cooling mode. The measurement campaign was conducted during hot summer days. The experimental laboratory comprises three identical rooms with uniform boundary conditions, all located on the east side of the building. Each room is equipped with a different type of radiant system: the first with a floor system, the second with a ceiling system, and the third with a wall system. The laboratory is located in an office building owned by the Faculty of Civil Engineering in Bratislava. The energy source for both heating and cooling is an air-to-water heat pump installed on the building's roof. The primary aim of the measurements is to compare the operational performance of the three radiant systems under identical boundary conditions in cooling mode. In each room, temperature profiles, cooling capacities of the radiant systems, indoor and outdoor air temperatures, and supply and return water temperatures in the distribution pipes were recorded. The results suggest that the ceiling radiant system was superior in terms of cooling capacity and room temperature distribution. Radiant systems achieved satisfactory results in the cooling mode in terms of ensuring the indoor air temperature.

A wide range of heating and cooling systems are currently available. One of the promising solutions for both functions is the use of water-based radiant systems. These systems are particularly suitable for integration with renewable energy sources, offer high sensible heat transfer rates, and can operate efficiently in both heating and cooling modes [1, 2, 3].

Ceiling radiant systems can provide both heating and cooling. In heating mode, they warm walls, furniture, and occupants evenly, creating a comfortable environment with fast thermal response and high energy efficiency. Radiant heat mimics sunlight and avoids direct heating of objects, improving overall distribution [2, 8]. In cooling mode, the ceiling absorbs room heat gently. Limitations include higher installation costs, precise design requirements, temperature control to prevent condensation, and unsuitability for humid spaces.

Floor radiant systems also support heating and cooling. Floor heating offers warm floors and even temperature distribution without air movement, though furniture can reduce effective heat exchange and thermal response is slower [2, 8]. Floor cooling is cost-effective where heating systems exist, with large active surfaces, low energy use, and minimal condensation risk. Limitations include lower cooling capacity and reliance on shading and insulation [4, 8].

Wall radiant systems combine comfort and fast response, providing efficient heating with potential energy savings. Proper spatial planning is required to keep walls unobstructed. Wall heating can complement floor heating, allowing lower fluid temperatures and reduced energy use. Wall cooling offers gentle, draught-free cooling, useful as a supplementary solution, though less effective than ceiling systems [5, 6, 7].

Experimental measurements design

The experimental measurements were carried out in 3 office rooms of a north-east facing office building, with the same boundary conditions (**Figure 1**). These 3 office rooms are in the building of the central laboratories of the Faculty of Civil Engineering in Bratislava Trnávka.

Office building with three measuring rooms with radiant systems

In room number 201 is technology room. In technology room there are control unit, expansion vessel, circulation pump, buffer tank, (**Figure 2**). In the first office room number 202.1, a dry radiant floor system was installed in two circuits with 150 mm pipe spacing, using Pipe 14 x 2.0 mm, with a radiant area of 15 m² (**Figure 2**).

In the second room number 202.2, a dry radiant ceiling system using PE-Xa pipe 9.9 x 1.1 mm with 8 panels with dimension 2000 x 625 mm was installed with a radiant area of 10 m² (**Figure 2**). In the third office room number 203 a dry wall-mounted radiant system with Uponor PE-Xa 9.9 x 1.1 mm pipes with 8 panels with dimension 2000 x 625 mm and a radiant area of 10 m² was installed (**Figure 2**). The heat and cooling source was an air-to-water heat pump F2040-6 (**Figure 2**).

Measuring sensors and their position

The floor plan in **Figure 2** shows blue dots that represent measurement points. T1 represents temperature sensor of exterior air temperature. T2 represents temperature sensor of interior air temperature in technology room. T3 represents temperature sensor of interior air temperature in corridor. T4 represents temperature sensor of interior air temperature in room without radiant system next to the room with the wall system. At the TF, TC and TW measurement points, air temperature sensors were installed at different height levels (0.03 m, 0.1 m, 0.6 m, 1.1 m, 1.7 m and 2.5 m) according to ASHRAE 55 and ISO 7726 (0.1 m – ankle height, 0.6 m – seated person, 1.1 m – head height of seated person and 1.7 m – head height of standing person) [9, 10]. The temperature sensors at the TF, TC and TW measurement points are PT100 CRZ-2005-100-A-1-Ni type. In rooms with various radiant systems, heat flow sensors of the FQA017C type were installed with an accuracy of ± 5% of the measured value. The measurement points T1, T2, T3 and T4 represent the Weatherhub TFA30. The temperatures in the supply and return pipes were also measured by PT100 temperature sensors. The labels P1, P2, P3, and P4 indicate the level of room insulation based on the thickness of the thermal insulation (**Figure 2**).

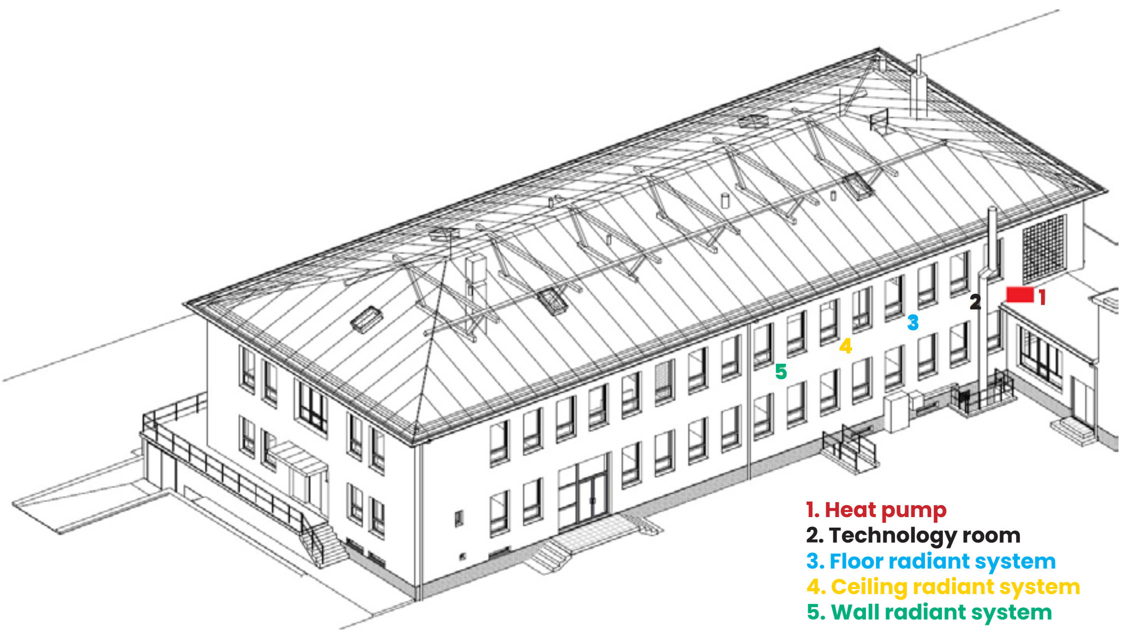

Figure 1. Office building with three measuring rooms. (Author: Martin Jamnický)

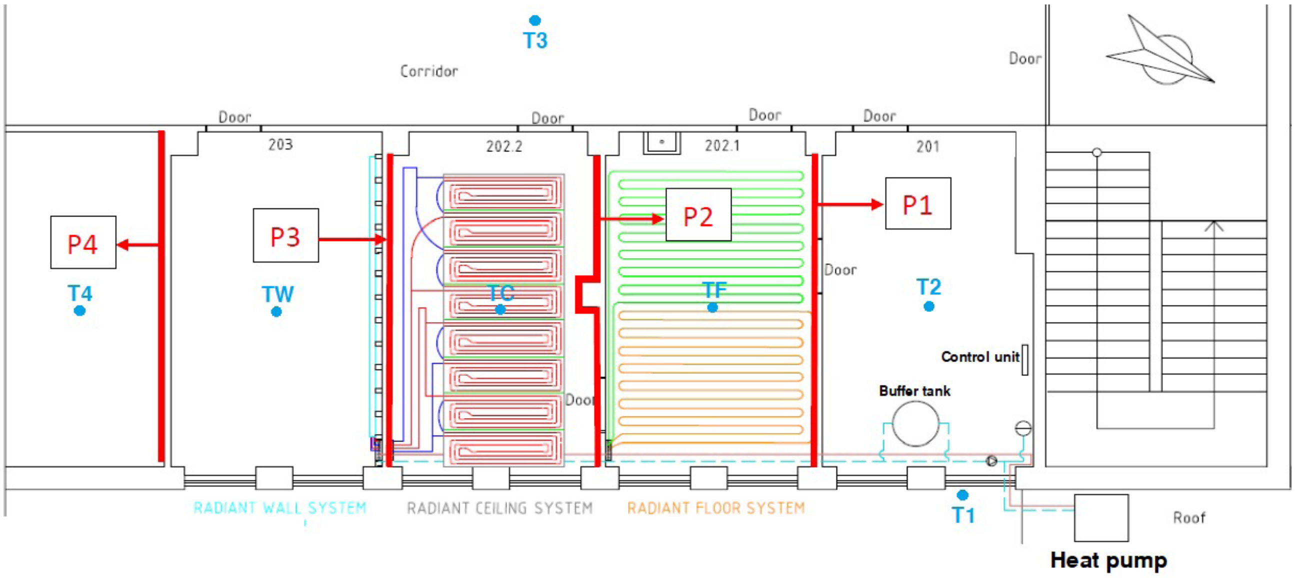

Figure 2. Floorplan of measured offices. (Author: Martin Šimko)

Experimental measurements

The measurements focused on the operation of three types of large-area radiant systems in cooling mode, conducted between August 11 and August 22, 2025. The study recorded outdoor air temperature, the indoor air temperatures at various height levels within the measured rooms, the air temperatures in the adjacent rooms, and the water temperatures in the supply and return pipes.

Air temperatures and thermal profiles in measured rooms

The heat pump control was set to a target outlet water temperature of 16 °C. When the temperature difference (ΔΘ) between the supply and return water became very small, the system automatically switched off the circulation pump. Measurements confirmed that compressor cycling did not occur during the monitored period. The compressor started on average only once per day. This stable operation was supported by the thermal insulation of the building partitions, which reduced heat gains and helped maintain the desired indoor temperature in the cooled rooms for a longer time.

Figure 3 shows interior air temperatures in rooms with floor, ceiling, and wall radiant systems, the corridor, the technology room, and exterior air. Curves: orange – exterior, gray – corridor, yellow dashed – technology

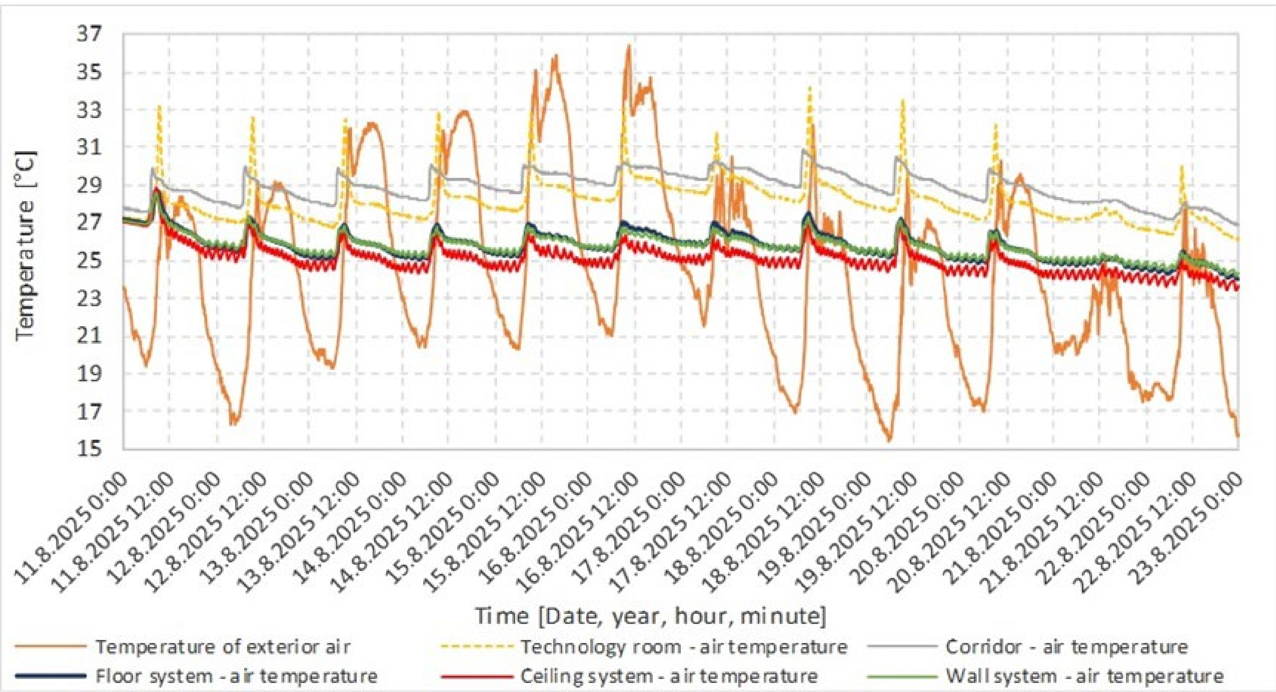

Figure 3. Temperature of exterior air and air temperature in corridor, in rooms during the measured period.

room, blue – floor system, green – wall system, red – ceiling system. The highest interior air temperatures during hot summer days were in the corridor, which represents a gray curve. In uncooled rooms, the air temperature was at a level that also did not represent thermal comfort. The course of air temperatures in rooms with radiant systems compared to air temperatures in the corridor and in uncooled rooms shows a significant temperature difference, which represented 3 to 4 °C. It is evident that radiant cooling systems were able to cool a certain area to the desired level with respect to thermal comfort, and during the days the outdoor air temperature was close to 35 °C. Ceiling cooling system cooled the room the best, but both the floor and wall cooling systems were able to ensure thermal comfort in the rooms.

Figure 4 illustrates the temperature profiles of the rooms equipped with different types of radiant systems. The dark blue curve corresponds to August 12, the red curve to August 14, the green curve to August 16, the yellow curve to August 19, and the light blue curve to August 21.

Figure 4 shows that, based on the uniformity of temperature distribution observed in the temperature profiles, the ceiling radiant system demonstrated the best performance. It can be noted that on August 21, the temperature profiles in all rooms equipped with radiant systems differed from those recorded on other days. This variation is attributed to the lower maximum outdoor air temperature of 25.3 °C on that day, which reduced the cooling demand compared to the hotter days. In contrast, during the peak summer days of August 15 and 16, 2025, when the maximum outdoor air temperatures reached 35.9 °C and 36.4 °C respectively, all three radiant cooling systems performed effectively, as evidenced by the temperature profiles of the individual rooms.

Table 1 presents the average, maximum, and minimum outdoor air temperatures recorded during the measurement period from August 11 to August 22, 2025.

Conclusion and recommendations

This paper presents an experimental investigation of the performance of three types of radiant cooling systems, floor, ceiling, and wall, installed in separate test rooms. The study focuses on comparing the thermal comfort achieved by these systems under identical boundary conditions in cooling mode. The effectiveness of the comparison was enhanced by the application of thermal insulation between the measured rooms, which also eliminated the issue of heat pump compressor cycling. During the measurement period from August 11 to August 22, 2025, the results indicated that the ceiling radiant system exhibited the most stable and reliable performance in terms of thermal comfort. This conclusion is supported by the observed temperature profiles, temperature trends, and measured cooling capacities of the three systems. The air-to-water heat pump used

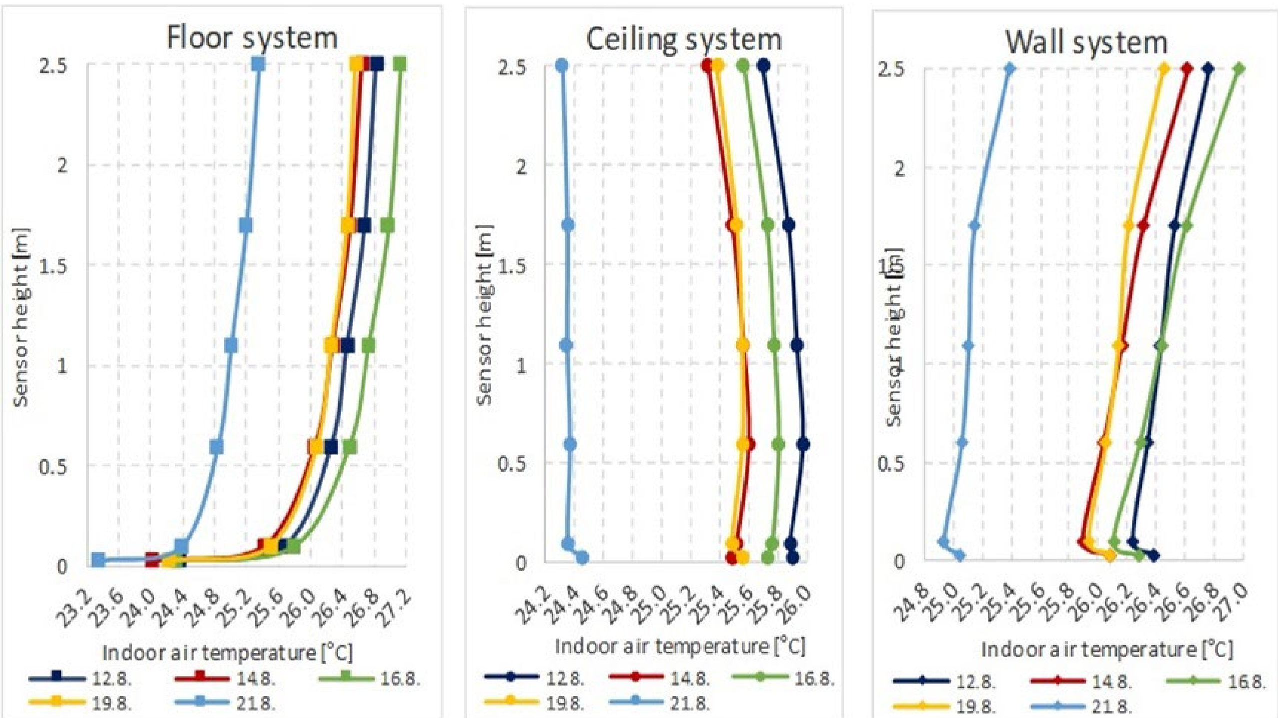

Figure 4. Temperature profiles of the room with floor, ceiling and wall system.

Table 1. Average, maximum and minimum exterior air temperature during 8am to 16pm measured days.

Date	11.8.	12.8.	13.8.	14.8.	15.8.	16.8.	17.8.	18.8.	19.8.	20.8.	21.8.	22.8.
Average Θ_e	26.7	26.8	29.8	30.8	**33**	**33.4**	27.8	26.9	25.4	27.5	**22.9**	24.4
max. Θ_e	28.6	29.2	32.3	32.9	**35.9**	**36.4**	30.5	32.2	29.8	30.3	**25.3**	28.1
min. Θ_e	21.6	19.8	21.7	24	**24.9**	**25.5**	24.1	21	18.5	20.1	**20.7**	19.6

as the cooling source, with its control system set to maintain a target outlet water temperature of 16 °C, demonstrated excellent operational compatibility with all radiant systems.

Acknowledgment

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References

[1] J. Babiak, B.W. Olesen, D. Petráš. Low temperature heating and high temperature cooling. Rehva Guidebook No 7. 3rd revised ed. Brussels, Belgium: Rehva (2013).

[2] M. Krajčík, M. Arıcı, O. Šikula, M. Šimko, Review of water-based wall systems: Heating, cooling, and thermal barriers, Energy and Buildings. vol. 253 (2021).

[3] M. Krajčík, M. Šimko, O. Šikula, D. Szabó, D.Petráš, Thermal performance of a radiant wall heating and cooling system with pipes attached to thermally insulating bricks, Energy and Buildings. vol. 246 (2021).

[4] U. Akbulut, O. Kıncay, Z. Utlu. Analysis of a wall cooling system using a heat pump. Renew Energ 85 (2016).

[5] D. Petráš, M. Krajčík, J. Bugáň, E. Ďurišová. Indoor Environment and Energy Performance of Office Buildings Equipped with a Low Temperature Heating / High Temperature Cooling System. Adv Mater Res 899 (2014).

[6] X. Wu, L. Fang, B.W. Olesen, J. Zhao, F. Wang. Comparison of indoor air distribution and thermal environment for different combinations of radiant heating systems with mechanical ventilation systems. Building Serv. Eng. Res. Technol. 39 (2018).

[7] Á. Lakatos. Comprehensive thermal transmittance investigations carried out on opaque aerogel insulation blanket. Mater. Struct. 50 (2017).

[8] EN ISO 11855-2:2012. Building environment design - Design, dimensioning, installation and control of embedded radiant heating and cooling systems - Part 2: Determination of the design heating and cooling capacity.

[9] ASHRAE. Thermal Environmental Conditions for Human Occupancy. ANSI/ASHRAE: Standard 55, 2010.

[10] STN EN ISO 7726. Ergonomics of the thermal environment. Instruments for measuring quantities. (ISO 7726: 1998). 2023. ■