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Low-temperature baseboard heaters with integrated air supply – An analytical and numerical investigation

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ABSTRACT

The functioning of a hydronic baseboard heating system with integrated air supply was analyzed. The aim was to investigate thermal performance of the system when cold outdoor (ventilation) airflow was forced through the baseboard heater. The performance of the system was evaluated for different ventilation rates at typical outdoor temperatures during the Swedish winter season. Three different analytical models and Computational Fluid Dynamics (CFD) were used to predict the temperature rise of the airflow inside the baseboard heater. Good agreement between numerical (CFD) and analytical calculations was obtained. Calculations showed that it was fully possible to pre-heat the incoming airflow to the indoor temperature and to cover transmission losses, using 45 °C supply water flow. The analytical calculations also showed that the airflow per supply opening in the baseboard heater needed to be limited to 7.0 l/s due to pressure losses inside the channel. At this ventilation rate, the integrated system with one air supply gave about 2.1 more heat output than a conventional baseboard heating system. CFD simulations also showed that the integrated system was capable of countering downdraught created by 2.0 m high glazed areas and a cold outdoor environment. Draught discomfort in the case with the conventional system was slightly above the recommended upper limit, but heat distribution across whole analyzed office space was uniform for both heating systems. It was concluded that low-temperature baseboard heating systems with integrated air supply can meet both international comfort requirements, and lead to energy savings in cold climates.

1. Introduction

Water-based (hydronic) thermal devices are predominantly used for internal heat emission within the residential sector and office buildings in Europe. Although the design of the thermal units is similar the variation of the supply water temperature is high among the European countries, ranging from 55 to 90 °C for radiator/convector heating [1] and from 35 to 45 °C for floor heating [2]. Generally hydronic heating systems are classified by their supply water temperature. Heaters supplied by 75–90 °C water flow are normally considered as high-temperature systems while 55 and 45 °C supply flows are used in medium and low-temperature heating systems, respectively. Thermal energy for the heating systems can be produced by several different methods. The most energy efficient and sustainable technical solution may be to combine a heating system with a low-valued energy device such as a heat pump. To make this integration efficient the supply water temperature to the heating units should be lower than 50 °C. Recent studies have shown that different kinds of heating arrangements supplied with 45 °C water flow were fully able to cover transmission and ventilation heat losses of modern buildings [3,4]. Low-temperature heat emitters showed many advantages, such as energy savings and ability to generally create a good indoor thermal climate, but also a weakness in countering cold air downflow (downdraught) [3,4]. Usually, the thermal energy supplied by the conventional low-temperature heating systems is mainly emitted by the thermal radiation. Natural convection is also present but its influence on air movement is much weaker than in traditional high-temperature heating systems where natural convection accounts for the main part of total heat emission. Weak convective power among low-temperature heating systems is probably the main reason for problems with cold downdraught. Cold air downflow, normally caused by low outdoor temperature and large areas of glazing, could be blocked by directing the warm ventilation airflow towards the glazed surfaces. This technical arrangement might also be a solution to the elimination of cold draughts in spaces served by low-temperature heating systems.

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