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Energy performance of radiators with parallel and serial connected panels

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ABSTRACT

Laboratory measurements were conducted for radiators with parallel and serial connected panels in EN 442-2 test room to quantify the possible energy saving of serial radiator. Measured results needed recalculation for the comparison, and simulations were used for annual performance assessment. Serial radiator showed 4 °C higher and 3 °C lower temperatures of the front and rear panels at 50 °C flow temperature. Parallel radiator had slightly faster dynamic response and its 3% higher heat output at ΔT 50 °C increased to about 10% at ΔT 25 °C. Measured heat emission of serial radiator was 2% lower in one and 4% higher in another test and it was not possible to quantify very small differences between radiators. Simulation showed 0.11–0.13 °C lower air temperatures of serial radiator at fixed operative temperature. In simulated EN 442-2 test room, the heat emission of radiators was exactly the same, but in the case of a residential room with less intensive radiation heat exchange, serial radiator showed 0.3% smaller heat emission and 0.7% smaller annual heating energy use. Generally, the effect of radiant temperature was possible to see from results, but in terms of energy savings there was no considerable difference between studied radiators.

1. Introduction

Emission losses of heat emitters are commonly described by EN 15316-2-1:2007 [1] where they are divided into three factors, which are losses due to non-uniform temperature distribution (stratification), losses to the outside from heating devices embedded in the structure, and losses due to imperfect control of the indoor temperature. These factors have been derived with measurements and simulation as described in [2]. The standard provides tabulated values for all of these factors as efficiency values which when can be used to calculate the total emission efficiency. In the case of radiators there are no embedded components. Stratification losses depend on over-temperature and losses via external components, i.e. location of the radiator. For a radiator with 55/45 °C flow/return temperature and normal location on external wall, the stratification efficiency is $\eta_{str} = 0.95$. If we assume an ideal control, the emission losses becomes $q_{em,\,loss} = (1/0.95-1)100 = 5.3\%$. This value can be seen quite conservative for modern buildings as reference [3] reports additional emission loss up to 5% of the heat emission of radiator in old buildings with poor insulation and less than 1% in new buildings with good insulation. The latter is supported with recent studies for well insulated buildings. In such buildings additional losses via external wall are as low as 0.2% [4]. In rooms with mechanical supply air there is very small temperature gradient [5] and stratification losses (due to temperature gradient and losses via external wall) remain around 0.4% [4].

Available data on emission efficiency of radiators thus allows to take into account the heating curve and insulation level of the building. To quantify the differences due to radiator configuration, more detailed methods are needed.

It is reported that radiators with serial connected panels can provide 11% energy saving [7] and this has been argued with up to 100% higher radiation heat transfer and also shorter heating up time of radiator. The objective of this study was to quantify the effect of parallel and serial connected radiator panels on emission losses and energy use with controlled laboratory measurements and dynamic simulation. The motivation was to show which differences can be measured in the laboratory and how these can be generalized to annual energy performance of conventional and low temperature radiator systems.

The limitation of the standard EN15316-2.1: 2007 is that the effect on operative temperature on heat emission is not accounted as the calculation procedure is fully based on air temperature. In

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Nomenclature

q	heat transfer rate (W)
q_{tot}	heat emission of radiator (W)
q_{loss}	heat loss (W)
T_a	air temperature (°C)
T_r	radiator front panel surface temperature (°C)
T_s	cooled room surfaces temperature (°C)
A_r	area of the radiator (m^2)
A_s	area of the non-insulated room surfaces (m^2)
ΔT	over-temperature between the water and the air (°C)
ΔT_{ln}	logarithmic temperature difference between the water and the air (°C)

reality different radiators have some effect on radiant temperature and the operative temperature is the basic parameter of thermal comfort standard ISO 7730:2005 [6]. Operative temperature is calculated as an average of air and mean radiant temperature and is the temperature human being is sensing. Therefore, for the exact comparison of heat emitters energy efficiency, the measurements and simulations are needed to be conducted at the same operative temperature, that was taken into account in this study.

In this study we conducted laboratory measurements for the same size and type radiator with parallel and serial connected panels in EN 442-2:2003 [8] test room at same conditions to quantify the energy saving. Because of very small differences, we needed to analytically model the heat transfer process in EN 442-2:2003 test room in order to be able to correct operative temperature levels up to 0.2 °C. This allowed the comparison at exactly the same temperature levels. Additionally we analysed the seasonal performance in dynamic simulation software which has limitations for radiator model, but allowed to model the radiator surface temperature according to the measurement results.

2. Methods

2.1. Radiator configurations

The studied radiator configurations are shown in Fig. 1. The parallel connected panels are in theory most effective in respect of the heat output, utilizing maximally the flow temperature level. In the case of serial connected panels, the hot water flows first through the front (room-side) panel and then to the back (wall side) panel. The cooled water then returns to the heating pipework. The idea of serial connection is to increase the room side surface temperature of the radiator which will increase radiation heat transfer and operative temperature.

2.2. Heat output and temperature measurements

Heat emission of two radiators at given room air temperature were measured in the test chamber conforming EN 442-2:2003 requirements. The radiators were 2-panel radiators physically of the same size, 0.6 m height and 1.4 m length, with parallel and serial connected panels and two convection fin plates in between, both types 22-600-1400. The rated heat output of parallel was 2393 W and for serial 2332 W at over-temperature ΔT 50 °C according to EN 442-2:2003. The air temperature and heat emission of the radiators was controlled with the same proportional thermostat, which was a typical radiator thermostat complying with EN 215:2004 [9] and operating across the proportional band of 2 °C with the set point of 20 °C in all tests.

In addition to the standard heat output measurement arrangements, the radiators and all surfaces were equipped with temperature measurement sensors. The effect of radiant heat transfer was estimated with measuring the 150 mm globe temperature. Figs. 2 and 3 illustrate the measurement arrangement and measurement points of the temperatures.

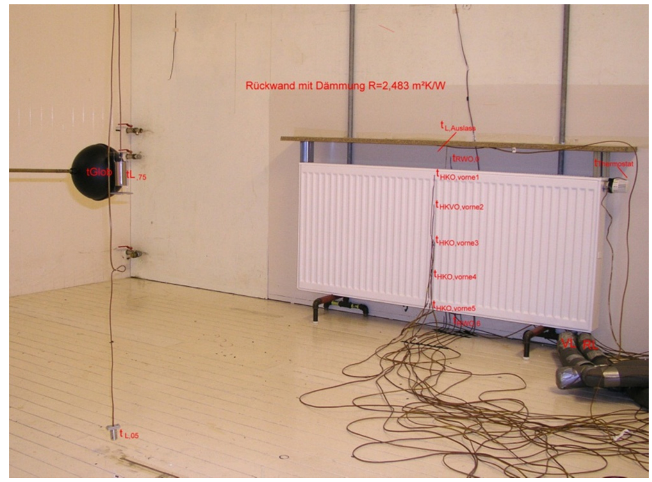

Fig. 2. Photo of the measurement arrangement.

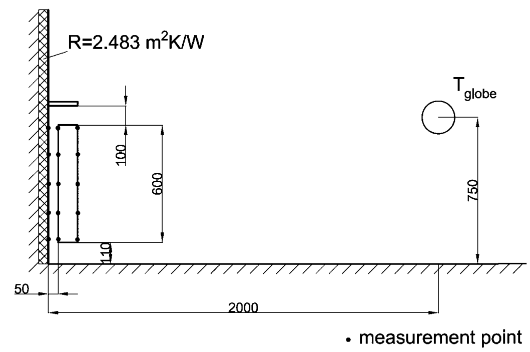

Fig. 3. Radiator and temperature measurement points locations. The room floor area is 4.0 by 4.0 m and the room height 3.0 m.

2.3. Analytical model of EN 442-2 test room heat transfer

In laboratory measurements, the room air temperature set point was 20 °C, but in reality the air temperature varied by 0.1...0.2 °C in different test runs. To enable the comparison at exactly the same operative temperature in the room, the correction was applied

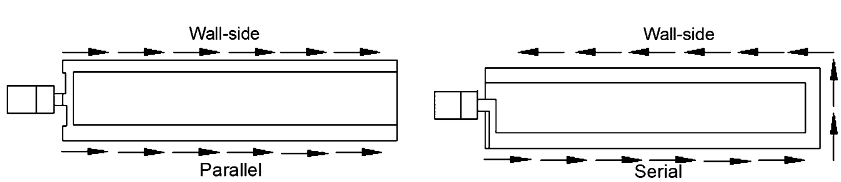

Fig. 1. Studied radiator types with parallel and serial connected panels.