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The effect of temperature and direction of airflow from the personalised ventilation on occupants' thermal sensations in office areas

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ABSTRACT

Proper technical solutions used in the HVAC systems help to reduce cooling or heating load delivered to buildings. Potentially, personalised ventilation (PV) can serve as one of such solutions. The aim of the study was twofold: to determine proper airflow direction using PV and to define air parameters necessary to reduce energy consumption in office spaces without detriment to thermal comfort of office occupants. The focus of the study was the effect of PV on local thermal sensation and comfort of users.

The tests were carried out with a participation of 20 volunteers. Two directions of airflow were used (at the face and ankle level). Simulated conditions corresponded to winter and summer temperatures. During each of a measurement session PV continued to supply a constant flow of fresh air in the amount of 20 l/s. Following the test, volunteers were requested to fill in a questionnaire on their subjective assessment of thermal sensation. The results of the survey showed a correlation between thermal sensation on particular body parts and a direction of supplied airflow. Change of the direction of supplied airflow was sensed with particular intensity on the face and the upper body parts.

1. Introduction

Proper technical solutions used in the HVAC systems help to limit energy consumption, i.e. they reduce cooling or heating load delivered to buildings. Potentially, personalised ventilation (PV) can serve as one of such solutions. It makes it possible to control air parameters in some range in the closest vicinity of a human [26]. Moreover, PV enables fresh properly adjusted air to be supplied directly to local zones of a room. Specifically, each user has a possibility of controlling a temperature of the supplied air, its flow rate or its direction.

The said properties allow to reduce energy consumption. This can be achieved by employing a number of strategies. First of all, given PV's ability to control a microclimate within a certain range, it is possible to expand the range of room temperature comfort limits. Secondly, higher effectiveness of PV allows reduction of fresh airflow rate. And thirdly, the personalised air can be supplied only when a workstation is occupied.

According to some estimates the benefits to energy efficiency can range from 5% [1,29] up to 60% [2,3]. Other findings show possible cooling energy savings up to 34% [30] or from 17 to 48% only by increasing air speed and offsetting the impact of increasing room air temperature on occupants' thermal sensation. As a result, the maximum cooling power can be reduced within the range of 10–28% [4].

It is important to stress the need of ensuring appropriate thermal sensation [5]. The subject matter literature contains a number of items describing a positive influence of PV on thermal comfort and quality of inhaled air in comparison to MV (mixing ventilation) [6–8,27–29] and to DV (displacement ventilation) [9,10,28]. The studies [11,12] show that there is considerable improvement of thermal comfort sensation and air quality when PV's temperature is 3–6 K lower than ambient temperature set at 26 °C. Enhancement of thermal sensation is not only perceptible when PV airflow supply is several degrees lower than ambient temperature in the summer season [1,13]. It is also noticeable when supplied airflow is several

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degrees higher in the winter season [14]. Furthermore, the studies show a positive correlation between personalised adjustment of air temperature and workers' satisfaction from ambient working conditions. It was found out that more than 90% of users were thermally satisfied if air temperature remained within the range ±2 K and the working environment allowed them to adjust clothing to their individual needs. When personalised adjustment of air temperature was within the limits of ±2.3 K, the percentage of users claiming thermal satisfaction was at the level of 95%. It was even higher, i.e. 99% if set within ±3 K [15,16].

Not much information can be found on the influence of direction of personalised air on thermal comfort and on possibilities of expanding the range of room temperature comfort limits in relation to the values accepted in the international standards [17–19]. The aim of the presented studies was to determine the effect of personalised airflow direction and temperature in different room conditions on local and whole body thermal comfort.

2. Experimental method

2.1. Experimental facilities

The experiments were performed in the climatic chamber (2.5 × 3.0 × 3.0 m) with a simulated ambient temperature characteristic of office working environment. The chamber provided the grounds for controlling ambient air parameters with an accuracy of ±0.5 K, but in order to accurately determine the temperature in a climatic chamber at a height of 1.1 m (the height of the person sitting) was used microclimate meter with an accuracy of ±0.1 K. The device controlling the supply air temperature worked with accuracy of ±0.1 K. The climatic chamber and PV cooling/heating system worked steadily and on the basis of the data of said temperature sensor set measurement uncertainty of ±0.4 K. Radiant temperature of the climatic chamber's walls has a value close to the value of the air temperature, so that the operative temperature was the same as the air temperature. Air velocity did not exceed 0.05 m/s. A high degree of precision in controlling model environment conditions was ensured by an additional set of microclimatic sensors. The chamber was equipped with a testing stand. The stand consisted of a desk with in-built ADs (air diffusers), specially designed for the test to channel prepared airflow to the face and ankles (Fig. 1). ADs were installed in the middle part of the desk at the head level. Rectangular grilles with movable horizontal blinds were used.

Fresh airflow from the PV system was filtered through and then prepared by the means of an assembly of heating or cooling device put in a double rear wall of the desk. After preparation fresh air was directed through air damper to the upper or the lower AD depending on the examined variant. A detailed description of the testing stand is given in Ref. [20]. During the experiment a fresh supply of air was ensured only via PV with a constant airflow rate at 20 l/s. Measurement of airflow volume was made by sharp-edge orifice made in accordance with the ISO 5221 standard [21]. Used AD provide velocity at the outlet ca. 0.5–0.7 m/s. During the test user was in a distance of about 50 cm from AD's the front panel. At this distance, the maximum velocity of the airflow was 0.3–0.35 m/s.

Twenty subjects (male of the academic age), participated in the experiment (winter and summer conditions). Prior to the experiment a preliminary classification of the volunteers was made. It was based on physical features (age, height, weight). An average age of the volunteers was 22.4 (standard deviation sd = 1.7 yrs),

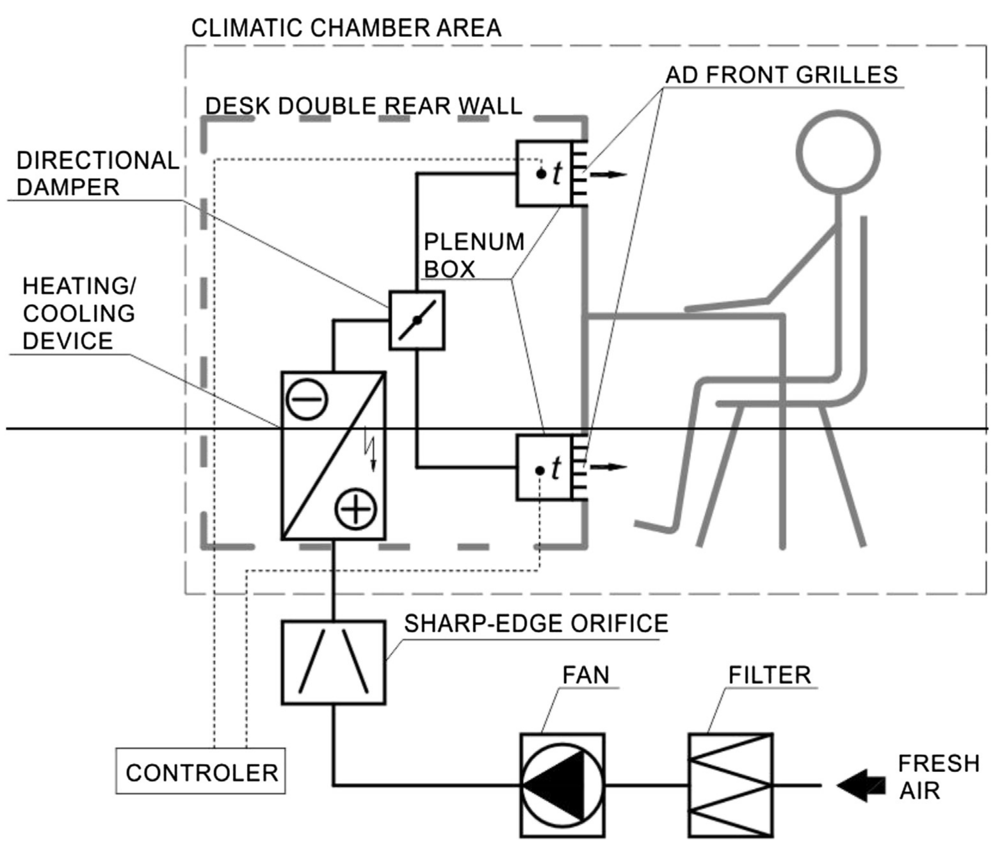

Fig. 1. Scheme of the test stand with a build-in PV system.