Building and Environment 45 (2010) 996–1005

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Performance of “ductless” personalized ventilation in conjunction with displacement ventilation: Impact of intake height

Barbora Halvoňová [a,b,*], Arsen K. Melikov [b]

[a] Department of Building Services, Slovak University of Technology in Bratislava, 813 68 Bratislava, Slovakia
[b] International Centre for Indoor Environment and Energy, Department of Civil Engineering, Technical University of Denmark, Denmark

ARTICLE INFO

Article history:
Received 6 July 2009
Received in revised form
8 October 2009
Accepted 9 October 2009

Keywords:
“Ductless” personalized ventilation
Displacement ventilation
Perceived air quality
Thermal comfort

ABSTRACT

The importance of the intake positioning height above the floor level on the performance of “ductless” personalized ventilation (“ductless” PV) in conjunction with displacement ventilation (DV) was examined with regard to the quality of inhaled air and of the thermal comfort provided. A typical office room with two workstations positioned one behind the other was arranged in a full-scale room. Each workstation consisted of a table with an installed “ductless” PV system, PC, desk lamp and seated breathing thermal manikin. The “ductless” PV system sucked the clean and cool displacement air supplied over the floor at four different heights, i.e. 2, 5, 10 and 20 cm and transported it direct to the breathing level. Moreover, two displacement airflow rates were used with a supply temperature adjusted in order to maintain an exhaust air temperature of 26 °C. Two pollution sources, namely air exhaled by one of the manikins and passive pollution on the table in front of the same manikin were simulated by constant dosing of tracer gases. The results show that the positioning of a “ductless” PV intake height up to 0.2 m above the floor will not significantly influence the quality of inhaled air and thermal comfort.

1. Introduction

Preferences regarding the indoor environment differ between individuals to a large extent. Even for the same person the preferred environment may change from day to day as well as during the same day. In practice it is impossible at the same time to ensure satisfaction for all room occupants by any total-volume ventilation principle since the indoor environment, although designed according to existing standards [1–3], may not be that preferred by all occupants in the room. Some occupants are more sensitive to the quality of inhaled air and others to the thermal environment. Increasing the supplied flow rate to satisfy occupants who like air movement will increase the dissatisfaction of occupants who are sensitive and who are bothered by air movement. At the same pollution level in a room the perceived air quality will improve when the air temperature decreases, but this may cause thermal discomfort for occupants who prefer a warmer environment. One way to overcome the individual differences is to provide each occupant with individual control of the microenvironment at his/her workstation. The number of dissatisfied occupants will decrease when each workstation is equipped with personalized ventilation providing clean air to the breathing zone and allowing for individual control of the flow rate, i.e. air velocity, flow direction, temperature and in some designs the distance of the air supply device from the body. The preferred thermal environment can thus be achieved [4].

Recently, a novel air distribution idea, namely “ductless“ personalized ventilation (“ductless” PV) in conjunction with displacement ventilation (DV) was introduced [5,6]. The outdoor treated air supplied to the room by a displacement diffuser spreads over the floor and creates a stratified flow of clean and cool air [7]. The main idea behind the “ductless” PV is to transport the clean air from this layer direct to the breathing zone of each occupant. In this way the air from the floor area can be utilized more efficiently. The performance of the “ductless” PV was studied in regard to the arrangement of workstations, the use of partitions, and disturbances caused by walking person(s) [5,6]. It was found that the performance of “ductless” PV will depend on the type and location of pollution sources, within the room. The performance of the “ductless” PV was found to be better than that of DV used alone for some typical conditions in practice (e.g. presence of walking person(s)).

According to REHVA Guidebook [8] the typical height of the stratified flow of clean and cool air above the floor level is

* Corresponding author. Slovak University of Technology in Bratislava, Department of Building Services, 813 68 Bratislava, Slovakia. Tel.: +421 903 904 484; fax: +421 2 5296 11 37.
E-mail address: halvonova_barbora@yahoo.com (B. Halvoňová).

0360-1323/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.buildenv.2009.10.007

approximately 20 cm when displacement ventilation is properly designed and correctly operated. The thickness of the layer of clean and cool air depends on many factors such as supply airflow rate and temperature, type of air supply diffuser, etc. and can vary also within the room. Furthermore, vertical temperature gradients are present in the flow of clean and cool air. This non-uniformity may influence the performance of the "ductless" PV.

The purpose of the present study was to examine the importance of the intake positioning height above the floor on the performance of "ductless" PV in conjunction with DV. Attention was focused on the impact of the intake positioning height on the quality of inhaled air and of the thermal comfort provided.

2. Methods

2.1. Full-scale room

A full-scale room ($4.8 \times 5.4 \times 2.6\ m^3$), was arranged as a typical office with two workstations WS1 and WS2 (Fig. 1). The walls and the floor of the room were made of wooden chipboard with 0.05 m insulation. One of the walls was single-glazed and the ceiling was made of gypsum tiles. The room was located in an air-conditioned tall concrete hall. The operative temperature in the tall hall was kept close to the room air temperature in order to reduce the heat transfer through the walls of the test room. Each workstation consisted of a desk with a "ductless" PV system (Fig. 2), personal computer with monitor, desk lamp and a dressed seated breathing thermal manikin simulating an "occupant".

2.2. Ventilation systems

Displacement ventilation was used as a total-volume ventilation principle. The outdoor treated air was supplied through a semicircular wall unit with a radius in planar projection of 0.25 m and a height of 1 m (position 7, Fig. 1). The unit was fitted with nozzles, which ensured the spread of the supplied air mainly along the adjacent wall. The used air was exhausted from the room through a rectangular perforated air terminal device installed in the middle of the ceiling (position 8, Fig. 1). Recirculation of room air was not utilized in order to increase sensitivity of the performed tracer gas measurements.

The "ductless" PV systems installed at each desk consisted of an air terminal device (ATD) mounted on a moveable arm (diameter 0.08 m) and a small axial fan incorporated in a short duct system (diameter 0.1 m), respectively positions 1, 4 and 5 in Fig. 2. The "ductless" PV sucked the air at the locations of the desks (position 6, Fig. 2) directly from the layer of clean and fresh air and transported it to the breathing zone. In the present study the Round Moveable Panel (RMP) with a diameter of 0.185 m [9] was used as the ATD. During the experiments, the RMPs were positioned in front (0.4 m from the face) and slightly above the face level, the positioning most often preferred by people [10,11], i.e. the personalized flow was directed towards to the manikin face from front and above with supply air velocity of 0.56 m/s. The positioning was identical for both manikins and did not differ between the experimental cases since it has been reported [12,13] that the direction of personalized airflow in relation to the occupant's head may affect the inhaled air quality to a large extent.

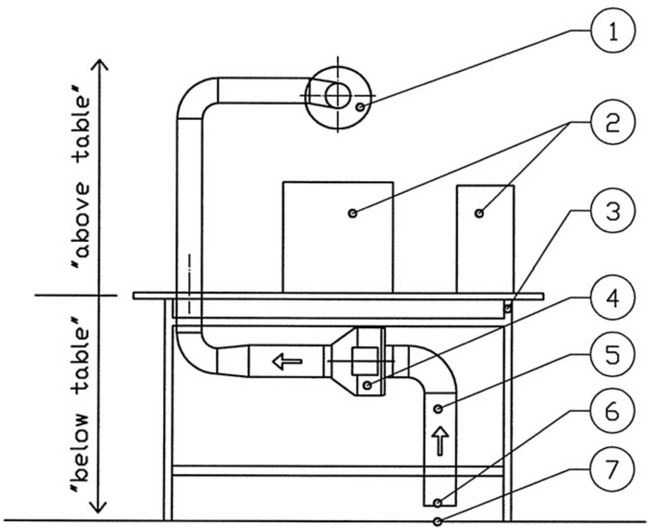

Fig. 2. "Ductless" PV: (1) Round moveable panel (RMP), (2) heat sources, (3) desk, (4) installed fan, (5) short duct system, (6) intake of "ductless" PV, (7) floor level.

2.3. Breathing thermal manikins

The manikins were used to simulate seated occupants performing office work. The bodies of the manikins were shaped as a 1.7 m tall average Scandinavian woman and were divided into several individually controlled and heated body segments. One of the manikins had 17 body segments and the other had 23 segments. The surface temperature of the manikins was controlled to equal the skin temperature of an average person in a state of thermal neutrality while performing light office work [14]. Since the experiments simulated summer conditions the clothing insulation of the manikins, together with the upholstered office chair insulation, was 0.59 clo in total [1].

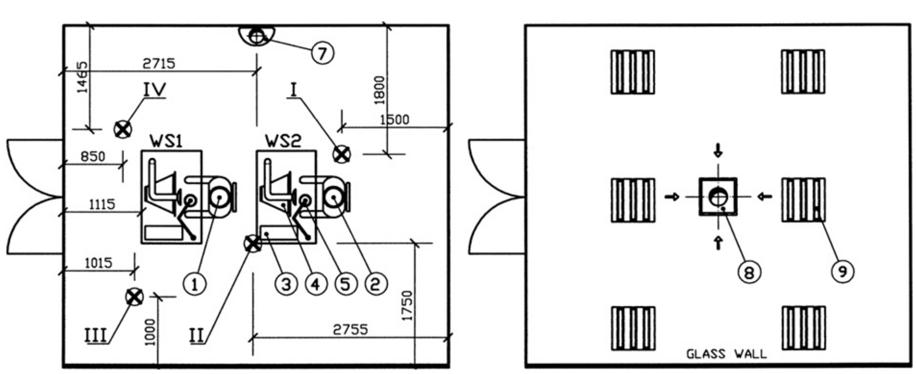

Fig. 1. Full-scale room: (1) polluting manikin, (2) exposed manikin, (4) – (6) heat sources, (7) displacement diffuser. Locations (I), (II) and (III) – measuring points of contaminant distribution, locations (I) and (IV) – measuring points of temperature distribution.