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The influence of draught on a seat with integrated personalized ventilation

Peter V. Nielsen[1,*], Ewa Barszcz[1], Tomasz Czarnota[1], Dariusz P. Dymalski[1], Michal A. Jasienski[1], Artur Nowotka[1], Agata Mozer[1], Sylwia M. Wiankowska[1] and Rasmus L. Jensen[1]

[1]Aalborg University, Denmark

[*]*Corresponding email: pvn@civil.aau.dk*

SUMMARY
Normally we protect ourselves from cross infection by supplying fresh air to a room by a diffuser, and this air is distributed in the room according to different principles such as: mixing ventilation, displacement ventilation, vertical ventilation, etc. Often this air distribution has the consequence that it is necessary to supply a very large amount of air to the whole room to obtain a sufficient dilution of the airborne infections.

When people are seated, a way to supply air direct to the breathing zone is to use “Personalized Ventilation”. Personalized ventilation has shown to be very efficient in the protection of people from cross infection.

A personalized ventilation device has been developed in the form of a neck support pillow. The air is supplied to the free convection boundary layer of the person, and the layer then transports the air to the breathing zone. The velocities in this process are very small and draught may be able to disturb the process. Therefore, this research work deals with the effectiveness of the system with different levels and directions of draught.

The measurements are made with a full-scale manikin in a wind tunnel. The results show that the boundary layer and the process in the breathing zone are rather independent of draught at velocities up to 0.2 m/s.

KEYWORDS
Airborne cross infection, Personal ventilation, Aircraft seat, Neck support pillow, Room air distribution

INTRODUCTION
More and more people are spending a considerable amount of time seated at their work, e.g. at office work and during transportation. It is important to minimize the amount of pollutants that people are exposed to in order to give an experience of a good air quality, and to minimize the danger of cross infection. The problem was clearly demonstrated in the worldwide SARS outbreak in 2003, where SARS was spread rapidly around the world, largely because persons infected with the SARS-associated coronavirus travelled by aircraft to distant cities, (Olsen et al., 2003). Also an airborne disease as tuberculosis (TB) is reported to have been spread in aircraft cabins during transportation (Kenyon et al., 1996). A further discussion of the importance of the ventilation system, and the possibility to protect people from airborne infection, is given from a literature review (Li et al., 2007) where it is concluded that there is a strong and sufficient evidence of a connection between ventilation and control of air flow directions in the environment and the transmission and spread of infectious diseases such as measles, TB, chicken pox, anthrax, influenza, smallpox and SARS.

Different air distribution systems such as mixing ventilation, vertical ventilation and displacement ventilation offer different possibilities in the protection of people against pollutants. The pollutants are almost fully mixed in the occupied zone in a room or in a vehicle ventilated by mixing ventilation or vertical ventilation, and they are removed by a diluting process (Nielsen et al., 2003, 2005 and 2006). If the pollutant source is also a heat source, then displacement ventilation offers possibilities to work with two zones, a low zone with clean air and an upper zone with pollutants. It is possible to design a system with a low exposure of people (Skistad et al., 2002), but in certain situations both a very low and a high exposure can exist in rooms with displacement flow as shown by Bjoern and Nielsen (2002) and Qian et al. (2004). Displacement ventilation is difficult to use in ventilation of vehicles because of the low room height.

A reduction of cross infection can be obtained by personalized ventilation as shown by Nielsen et al. (2007a, b and c). The personalized ventilation system (Low Velocity Personalized Ventilation (LVPV)) discussed in this paper has a design which utilizes the situation where the head or the body is in natural contact with surfaces as chairs, neck support pillows, headrests, pillows, clothing, etc. Those surfaces are designed also to be a supply opening of fresh air by the use of fabric as a diffuser. Figure 1 shows examples of the use of low velocity personalized ventilation.

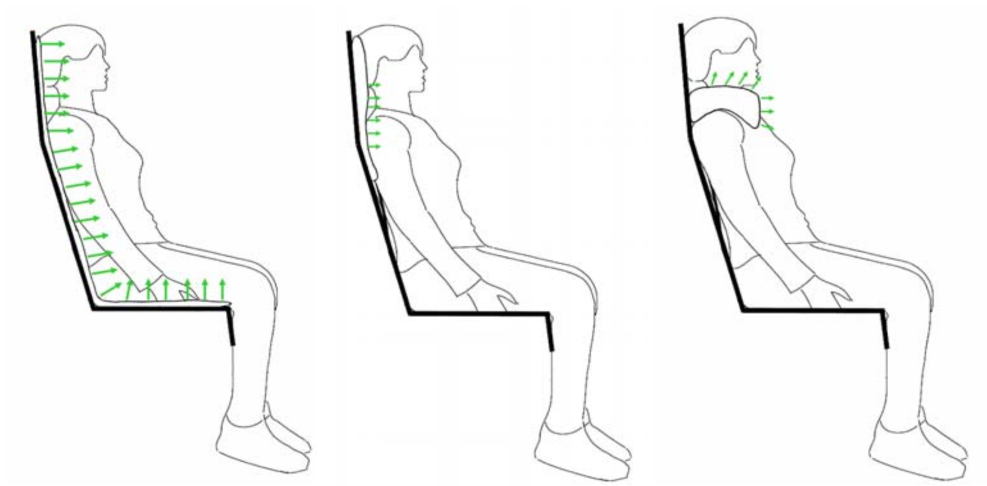

Figure 1. Chair with totally integrated air distribution system. A pillow used as a diffuser and a neck support pillow used as diffuser in e.g. an aircraft.

The LVPV system is based on the principle that

- the air is supplied to the breathing zone with a low momentum flow
- the air is supplied to the boundary layer of the person, and the boundary layer transports the air further to the breathing zone. (The inhaled air originates mainly from the person's boundary layer)
- the air is supplied to the boundary layer, and also to the surroundings of the boundary layer of a person for entrainment back into the boundary layer
- the air is supplied to the breathing zone and to the boundary layer, but also supplied outside the boundary layer with a direction away from the person to create a microenvironment which is difficult to penetrate for infected particles

The experiments in this paper are focused on minimizing cross infection, but the described personalized ventilation system has of course all the features known from conventional PV systems, as e.g. the possibility to have individual control of the thermal environment, which in itself could be a positive feature in an office environment. A low air temperature, different from the overall temperature in the room, can be supplied to the breathing zone, which will improve the perceived air quality.

An LVPV system may be strongly influenced by draught because the velocities at the surface of the textile and in the boundary layer are low. It is the purpose of this paper to study those effects as well as thermal comfort in connection with the use of a neck support pillow.

METHODS

The experiments with draught are made in the wind tunnel at Aalborg University. This wind tunnel has earlier been used for the study of velocity distribution around a person and a person's thermal comfort, see (Topp et al., 2003), (Nilsson et al., 2007) and www.cfd-benchmarks.com .

The design of the wind tunnel is seen in Figure 2. It has a contraction, then a working section of 2.5 m x 2.44 m x 1.18 m for the manikin sitting in an aircraft seat. The air is extracted from the working section, and exhausted to the outdoor surroundings.

Figure 2. Wind tunnel for experiments with draught and personalized ventilation.

The experiments with draught are made for velocities up to 0.2 m/s. Velocity distribution, temperature distribution and concentration distribution are measured in the working area of the tunnel. Temperatures are measured with thermocouples type K, and the concentration of N_2O is measured by a Bruel & Kjaer Multigas Monitor. Six tracer gas monitoring points are located in the following places: in the inhalation flow (nose), in an adjacent point representing the concentration in the breathing zone without personalized ventilation, in the supply air to the PV diffuser, in the inlet of the wind tunnel, in the outlet of the wind tunnel and outside the room in the laboratory, respectively.

The Breathing Thermal Manikin (BTM) is a 1.7 m high woman of average size. It consists of a 4 mm fibreglass polyester shell rolled in a nickel wire used for heating of the manikin and measuring of the skin temperature. The wire is protected with a 1 mm thick shield. The BTM is controlled in order to obtain a skin temperature and a heat loss corresponding to a person's thermal comfort. The manikin is divided into 16 parts. Each part is equipped with individual systems for heating and control. The skin temperature is measured in the range of 18° C to 37° C with an accuracy of 0.1° C, and a maximum heat loss of 140 W/m^2. The BTM is wearing tight-fitting clothes with an insulation value Icl = 0.8 clo. During the measurements the manikin was connected to an artificial lung, which simulates breathing. The manikin inhaled and exhaled through the nose. The lung machine has an air flow of 0.6 l per respiration, with a frequency of respiration of 12 min^{-1}. The manikin is sitting in an aircraft seat.

The personalized ventilation system consists of a neck support pillow. The neck support pillow is permeable on one side and airtight on the other. The air supply system to the neck support pillow can supply from 0.0 to 16 l/s. The air supply is isothermal. The textile diffusers have been produced by KE Fibertec AS.

Figure 3. Manikin with a neck support pillow as a personalized ventilation device.

N_2O tracer gas is used for measuring the effectiveness of the PV system. The tracer gas is added to the supply flow through the PV device, and the amount of tracer gas in the inhalation of the manikin expresses the effectiveness of the system. This is a reverse use of tracer gas, because the clean air is marked with N_2O, and the contaminated air is modelled as clean air. This method saves tracer gas.

The effectiveness of personalized ventilation ε_{PV} is defined as

$$\varepsilon_{PV} = \frac{c_{\exp,PV} - c_{\exp,o}}{c_{PV} - c_{\exp,o}} \tag{1}$$

$c_{\exp,o}$	Contaminant concentration in the inhaled air without PV
$c_{\exp,PV}$	Contaminant concentration in the inhaled air with PV
c_{PV}	Contaminant concentration in the supply from PV

Thermal comfort is studied by measuring the heat release from the manikins' 16 segments, and calculation of the equivalent homogeneous temperature *EHT*. The equivalent homogeneous temperature *EHT* is defined as the temperature of a homogeneous environment in which the same amount of heat is lost as in the actual environment. Homogeneous conditions are achieved when the air temperature is equal to the mean radiant temperature, when air temperature gradients and radiant temperature asymmetry in all directions are negligible and when air velocity is lower than 0.05 m/s.

Variations in *EHT* for the face express the degree of thermal discomfort “experienced” by the manikin with and without the PV system.

RESULTS

Draught and effectiveness of the PV system

Figure 4 shows the flow and effectiveness when the direction of the draught is towards the face of the manikin. The smoke picture is valid for a draught velocity of 0.1 m/s, and a flow rate in the neck support pillow of 10 l/s. The system has an effectiveness of 75 % at a low level of draught, but the effectiveness is reduced at a high level of draught.

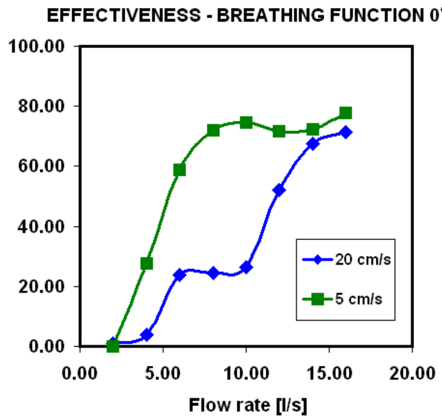

Figure 4. Smoke picture showing the distribution of “clean air” around the breathing zone of the manikin, and the effectiveness of the system. The draught is directed towards the face (0^{o}).

Figure 5 shows the flow and effectiveness when the direction of the draught is directed towards the side of the manikin. The smoke picture is again valid for a draught velocity of 0.1 m/s and a flow rate in the neck support pillow of 10 l/s. The system has an effectiveness of 80 to 90 % at both a low and a high level of draught, and the smoke picture shows how the clean air is directed towards the breathing zone when the draught is at 90° at the manikin.

Figure 6 shows the flow and effectiveness when the direction of the draught is from behind of the manikin. The smoke picture is again valid for a draught velocity of 0.1 m/s and a flow rate in the neck support pillow of 10 l/s. The system has an effectiveness of 90 % at both a low and a high level of draught, and the smoke picture shows how the clean air is directed towards the breathing zone from both sides of the face. In practice, the direction of draught and the turbulence in the air in a cabin can have any direction, and the averaged effectiveness will be a value between the results given in the Figures 4, 5 and 6.

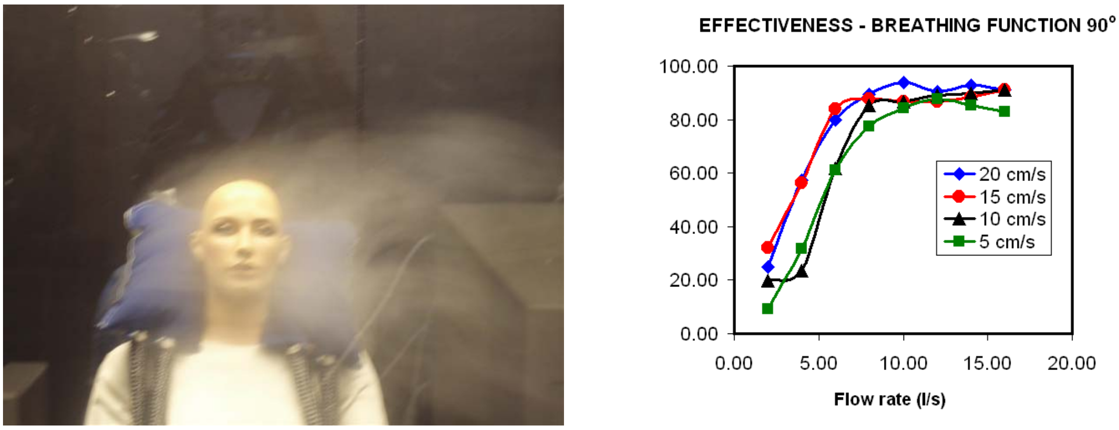

Figure 5. Smoke picture showing the distribution of “clean air” around the breathing zone of the manikin, and the effectiveness of the system. The draught is directed towards the side of the face (90^{o}).

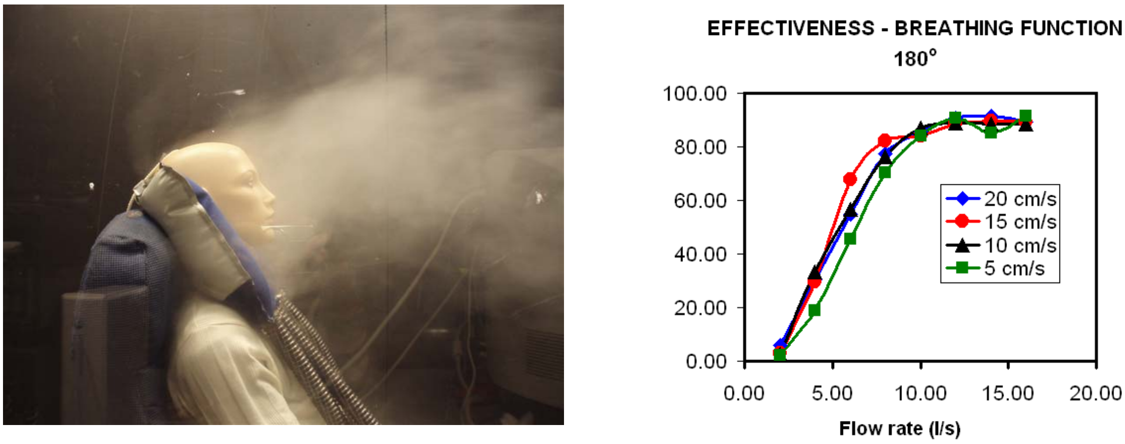

Figure 6. Smoke picture showing the distribution of “clean air” around the breathing zone of the manikin, and the effectiveness of the system. The draught is flowing from behind (180^{o}).

The personalized ventilation system reaches its optimal effectiveness for fresh air flow rates above 7 to 8 l/s.

Thermal comfort

Preliminary experiments with personal assessment of comfort parameters as e.g. draught, noise and temperature levels have been carried out. It is concluded that the noise factor should be further evaluated after a product development has been made. The velocity level is low (2 to 5 cm/s), and the measurements of the *EHT* for the different body segments shown in Figure 7 express the degree of thermal discomfort “experienced” by the manikin. It is obvious that the variation of *EHT* because of differences in clothing, insulation from the chair, etc. is larger that the decrease in *EHT* for the face generated by the PV system. Any discomfort due to draught can probably be handled by the temperature control of the system.

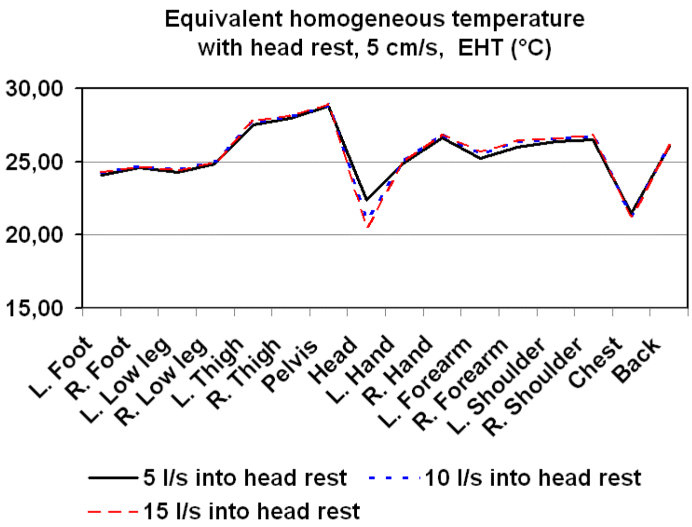

Figure 7. Equivalent homogeneous temperature for the body segments. The manikin is equipped with a neck support pillow.

CONCLUSIONS

A personalized ventilation system designed as a neck support pillow gives a high protection against cross infection in an aircraft cabin or in other kinds of transportation. The effectiveness is influenced by draught in the surroundings, and dependent on direction of the draught, high levels of effectiveness can be achieved. If the direction of the flow in the general air distribution system is controlled, it is possible to obtain a very high level of effectiveness (approx. 90 %).

Measurements of EHT on the manikin show that the draught from the textile surface only has a small effect on the thermal comfort.

REFERENCES

Bjoern E. and Nielsen P.V. 2002. Dispersal of exhaled air and personal exposure in displacement ventilated rooms. *Indoor Air*, Vol. 12, No. 3, pp. 147-164.

Topp C., Hesselholt P., Trier M.R., Nielsen P.V. 2003. Influence of geometry of thermal manikins on room airflow. *Proceedings of Healthy Buildings* 2003, Singapore.

Nilsson H.O., Brohus H., and Nielsen P.V. 2007. CFD modeling of thermal manikin heat loss in a comfort evaluation benchmark test. *Roomvent 2007*, 10th International Conference on Air Distribution in Rooms, Helsinki.

Kenyon T.A., Valway S.E, Ihle W.W. et al. 1996. Transmission of multidrug-resistant mycobacterium tuberculosis during a long airplane flight. *New England Journal of Medicine*, 334, pp. 933–938.

Li Y., Leung G.M., Tang J.W., Yang X., Chao C.Y.H, Lin J.Z., Lu J.W., Nielsen P.V., Niu J., Qian H., Sleigh A.C., Su H.-J.J., Sundell J., Wong T.W., Yuen P.L. 2007. Role of ventilation in airborne transmission of infectious agents in the built environment - a multidisciplinary systematic review. *Indoor Air*, 17, pp. 2-18.

Nielsen P.V., Heby T., and Moeller-Jensen B. 2006. Air distribution in a room with ceiling-mounted diffusers – comparison with wall-mounted diffuser, vertical ventilation and displacement ventilation. *ASHRAE Transactions*.

Nielsen P.V., Hyldgaard C.E., Melikov A., Andersen H., and Soennichsen M. 2007a. Personal exposure between people in a room ventilated by textile terminals – with and without personalized ventilation. *HVAC&R Research*, Vol. 13, No. 4, July 2007.

Nielsen P.V., Larsen T.S., and Topp C. 2003. Design methods for air distribution systems and comparison between mixing ventilation and displacement ventilation. *Proceedings of Healthy Buildings 2003,* Singapore.

Nielsen P.V., Topp C., Soennichsen M., and Andersen H. 2005. Air distribution in rooms generated by a textile terminal – comparison with mixing and displacement ventilation. *ASHRAE Transactions*, 111, Part 1, pp. 733-739.

Olsen S.J., Chang H.L., Cheung T.Y. et al. 2003. Transmission of the severe acute respiratory syndrome on aircraft. *New England Journal of Medicine*, 349, pp. 2416–2422.

Nielsen P.V., Jiang H., and Polak M. 2007c. Bed with integrated personalized ventilation for minimizing cross infection. *Roomvent 2007,* 10th International Conference on Air Distribution in Rooms, Helsinki 2007.

Nielsen P.V., Bartholomaeussen N.M., Jakubowska E., Jiang H., Jonsson O.T., Krawiecka K., Mierzejewski A., Thomas S.J., Trampczynska K., Polak M., and Soennichsen M. 2007b. Chair with integrated personalized ventilation for minimizing cross infection. *Roomvent 2007*, 10th International Conference on Air Distribution in Rooms, Helsinki 2007.

Qian H., Nielsen P.V., Li Y., and Hyldgaard C.E. 2004. Airflow and contaminant distribution in hospital wards with a displacement ventilalation system. *The 2nd International Conference on Build Environment and Public Health*, BEPH 2004, Shenzhen, China.

Skistad H., Mundt E., Nielsen P.V., Hagström K., and Railio J. 2002. Displacement ventilation in non-industrial premises. *REHVA Guidebook No 1.*