Benchmark Tests for a Computer Simulated Person with Personal Ventilation

By

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Introduction

The use of thermal manikins in the indoor environment has become a useful tool to examine the flow fields, contaminant distributions and personal exposure in full-scale experiments (Brohus and Nielsen, 1996; Bjorn and Nielsen, 2002; Zhu et al., 2005; Melikov and Kaczmarczyk, 2007; Khalifa et al. 2008). The use of thermal manikins makes it possible to acquire detailed measurements surrounding the manikin concerning the air quality in the breathing zone (BZ) and thermal comfort.

Another valuable tool is the computer simulated person (CSP) which is used in Computational Fluid Dynamics (CFD) as an alternative or in conjunction with full-scale experiments to offer a wider range of data efficiently and cost efficiency. Many authors have studied the indoor environment with the use of CSPs (Bjorn and Nielsen, 2002; Hayashi et al., 2002; Topp et al., 2002; Sorensen and Voigt, 2003; Gao and Niu, 2004; Zhu et al., 2005; Deevy et al., 2008; Kilic and Sevilgen, 2008; Russo et al., 2008). CSPs can vary in detail, size, and heat emission, while CFD models can vary in turbulence model, grid resolution, boundary conditions, etc. These variations can lead to different results and discrepancies between experimental data and CFD results. From this point, a benchmark case is introduced to test CSPs in a displacement ventilation system with personal ventilation (PV).

The experimental measurements are made with a detailed manikin shown in Figure 1. In the experiment the design and performance characteristics of PV systems are investigated in combination with displacement ventilation where no more clean air was supplied to the room than indicated by ASHRAE 62.1-2004. The total air supply into the chamber was 18.9 l/s (5ACH) where 2.4 l/s was delivered through the PV nozzle and 16.5 l/s through the floor diffuser. Tracer gas concentration measurements were taken in the BZ of the manikin by six sampling probes that were mounted on a transversing vertical rake along a vertical line in the manikins bisecting plane. The measurements were made with a multi-gas monitor based on the photo-acoustic infrared detection method. For more information about the experimental set up refer to Khalifa et al. (2008).

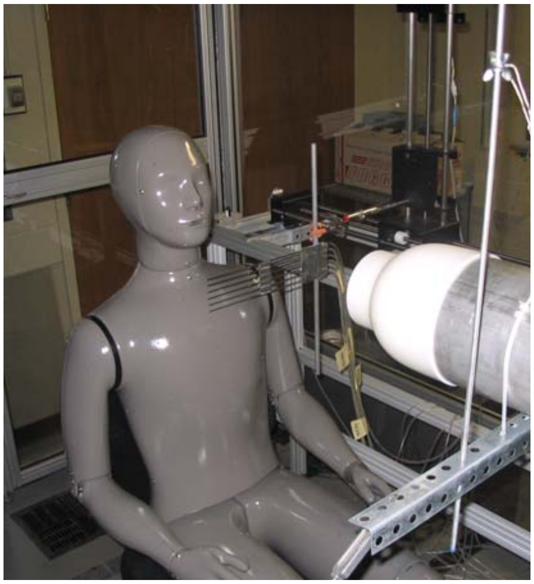

Figure 1: Thermal manikin used for experimental measurements.

Personal Ventilation Case

The CSP considered in this case is a seated manikin centered in a *2.03 x 2.64 x 2.49 m* domain sitting on a *3.05 x 3.66 x 0.46* m raised floor plenum, in which there is a manikin, a mixing box, a PV nozzle, a floor diffuser and a ceiling exhaust vent as shown in Figure 2.

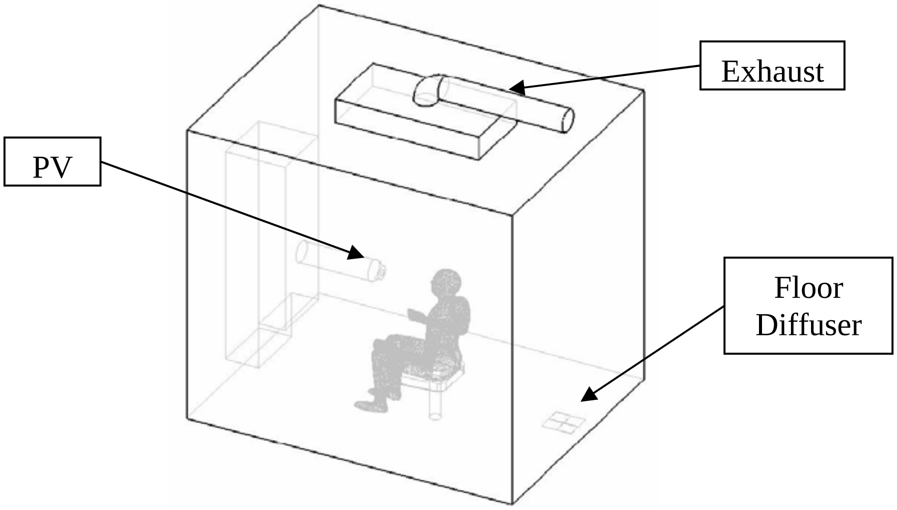

Figure 2: Domain for CFD modeling.

The walls and ceiling of the chamber are made of clear plexiglass panels with an aluminum frame. The floor of the chamber is made of *0.61 x 0.61 m* steel panels. Inside the chamber there is an office chair with a seated segmented thermal manikin placed facing the PV nozzle. The thermal manikin represents a *1.8 m* tall average male that was not clothed and was seated upright in the chair with the tip of its nose *406 mm* away from the nozzle exit. The PV nozzle is a convergent nozzle with flow straighteners (honeycomb) and a set of screens and has a diameter of *50.8 mm*. The details of the placement of the thermal manikin are shown in Figure 3. Conditioned air enters the domain through the floor diffuser and the PV nozzle and exits the domain through the exhaust opening. The under-floor ventilation is provided to the chamber through a *0.23 x 0.24 m* VAV system and a four way directional grill panel insert. The air entering the room through the floor diffuser was seeded with SF6 to represent re-circulated “old” air. The air is exhausted through a *0.58 x 1.17 m* perforated ceiling outlet.

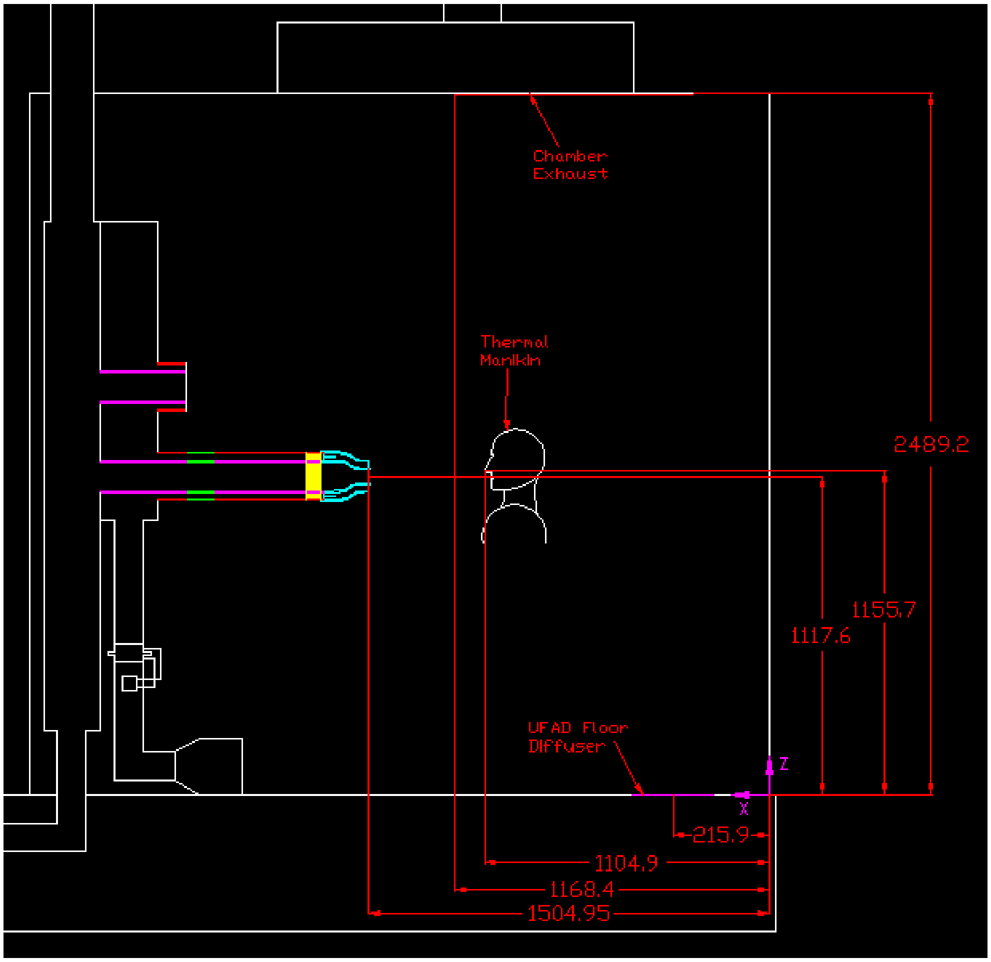

Figure 3: Dimensions of the placement of the CSP and ventilation systems on the symmetry plane.

Numerical Methods and Boundary Conditions

The air temperature in the experimental setup was measured to be ~ 20 °C in the laboratory, 24.5 °C in the experimental chamber and 20.5 °C for the underfloor air temperature. The temperature conditions at the walls, ceiling and floor of the chamber were not directly measured and had to be interpreted from the existing measurements in the experiment. Since the walls and the ceiling of the chamber are clear plexiglass, the boundary conditions at the walls and ceiling are modeled as 23.5 °C and since the floor is made of steel, the boundary condition applied at the floor was modeled between the underfloor temperature and the experimental chamber temperature to be ~22 °C.

The floor diffuser has the following values:

	Q (L/s)	T (°C)	Tu (%)	L (m)	C (ppm)
Case 1	16.5	20.5	10.0	0.005	46.56
Case 2	14.1	21.3	10.0	0.005	50.39

The PV nozzle has the following values:

	Q (L/s)	T (°C)	Tu (%)	L (m)	C (ppm)
Case 1	2.4	23.5	1.7	0.003	0.69
Case 2	4.7	23.5	1.7	0.003	0.56

The length scale for the floor diffuser and the PV nozzle were not measure in the experimental setup, but were determined based on the size of the slots of the panel insert for the floor diffuser and the size of the screen in the PV nozzle.

CFD Code

Turbulence model:	free
Algorithm:	free
Scheme:	free
Grid (format, number):	free

Computer Simulated Person (CSP)

Posture:	seated
Geometry:	free
Surface Temperature:	32°C
Breathing:	free

Grid

There are no restrictions on the grid. The specification of the grid should be indicated or reported.

Quality of the CFD Prediction

Comments should be made on the quality of the predictions by:

- The order of accuracy of the numerical scheme
- The turbulence model used

- Grid quality, grid resolution and *y+* values

Results

Participants of the benchmark test case must make predictions for the individual CPS used.

For ease of comparison, simulation results should be reported at the following locations:

- Vertical profile at 1 cm and 2.5 cm from the manikin's nose.

Literature

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