Micro-Environmental Control System to Maintain Thermal Comfort Under Relaxed Temperature Control to Save Energy

Meng Kong¹, Thong Dang¹, Jianshun Zhang³, Chetna Chianese², Teng Teng³, Alan Hedge³, Edward Bogucz¹,², and H. Ezzat Khalifa¹
1. Department of Mechanical and Aerospace Engineering, Syracuse University; 2. Syracuse Center of Excellence, Syracuse University; 3. Department of Design and Environmental Analysis, Cornell University

Summary
This study aims at developing a Cooling/Heating Delivering Device (CDD/HDD) for a micro-environmental control system (μX) to restore occupants’ thermal comfort when the building indoor temperature thermostat is expanded from 21.1-23.9 °C (70.0-75.0 °F) to 18.9-26.1 °C (66.0-79.0 °F) to reduce HVAC load. A comprehensive methods was implemented for the design, including Computational Fluid Dynamics (CFD) simulation at the initial stage, manikin test at the middle stage and final verification using human subject test (HST). The results show that with proper design of the CDD/HDD, the μX can restore occupant’s thermal comfort by maintaining the thermal balance of the human body.

Objective and Methods

Objective
1. Developing a micro-environmental control system (μX) to restore occupants’ thermal comfort.
2. Validating the μX using experimental data.

Method
1. Cooling/Heating Delivering Device (CDD/HDD) with a single desk diffuser.
2. Design of the μX with a single desk diffuser.

Initial Stage Design – CFD Simulation

- CFD Model
- Manikin Test
- Human Subject Test

Middle Stage Design – Manikin Test

- Three CDDs all work to remove 23 W more from the manikin with a minimum flow rate of 17 cfm;
- The performance of the CDDs were evaluated while the manikin was within a semi-circle movement range (R=0.61 m);
- For the single diffuser, when the manikin was moved to the side, the most heat was removed; for the split diffuser, when the manikin was moved to the furthest, the most heat was removed;
- Heating mat is more efficient than heating bulb;
- Heating with only a heating mat is able to reduce the total heat loss by more than 18 W with 60 W heating power, while using 40 W heating mat with 20 W heating bulb only reduce the heat loss by 14 W.

Final Verification – Human Subject Test

- Statistical analysis of the cooling HST results for 44 participants (23 men, 21 women) with counter-balanced treatment (21 did OFF/ON, 23 did ON/OFF);
- Significant interaction of μX and thermal comfort (p=0.04);
- The preliminary HST shows people preferred bulb heating;
- Analysis of the Heating HST results for 31 participants (16 men, 15 women) with counter-balanced treatment (13 did OFF/ON, 18 did ON/OFF);
- Taking into account the effects of MEQ and clothing values, significant interaction of μX and thermal sensation (P<0.01);

Acknowledgement
The information, data, or work presented herein was funded in part by the Advanced Research Projects Agency-Energy (ARPA-E), U.S. Department of Energy, under Award Number DE-AR0000526. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Reference