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Thermal sensations of the whole body and head under local cooling and heating conditions during step-changes between workstation and ambient environment

Quan Jin [a,*], Lin Duanmu [a], Hui Zhang [b], Xiangli Li [a], Hongbo Xu [a]

[a] Institute of Building Environment and Facility Engineering, Dalian University of Technology, Dalian, Liaoning 116024, PR China
[b] Center for the Built Environment, University of California, Berkeley 94720, USA

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ABSTRACT

This paper examines people's thermal sensations during step-changes between ambient and workstation environments with a local ventilation device installed to supply-air motion around heads. We conducted human subject tests in a controlled environment chamber for summer and winter conditions. We performed 29 tests. The ambient air temperatures were 28 and 30 °C for summer conditions and 19 °C for winter conditions. The local supply-air temperatures were at 24, 28 and 30 °C for summer and 50 °C for winter. The supply-air velocities of the local ventilation device were at 3, 3.5, and 5 m/s for summer and 3.5 m/s for winter. The air temperatures near heads were 26–30 °C for summer and 32 °C for winter. The velocities along the jet-flow line at a distance of 10 cm from heads were 1.4–2.6 m/s for summer and 1.8 m/s for winter. In total, 23 subjects participated in the tests, and each subject participated in 1 ~ 2 test conditions. Both the dynamic and stable thermal sensations of head and whole body were analyzed. When head is cooled by local ventilation, head thermal sensation has an effect on overall thermal sensation. When subjects moved from the workstation, where local devices were installed, to the ambient environment that was warmer in summer and colder in winter than the workstation, both overshooting and hysteresis were found. These thermal sensation changing trends in non-uniform step-change environments are helpful in personalizing environment control designs and exploring the possibilities of saving energy in buildings.

1. Introduction

Step-changes between two environments are common in daily life, such as walking from the indoors to the outdoors, walking from the office into the hallway and getting into and out of a car. When installing local ventilation device at a workstation (also called personal environmental control systems, PEC systems), there is another type of step-change that occurs between the workstation and the ambient environment. This paper examines changing patterns of overall and head thermal sensation during step-changes between a workstation at where a local ventilation device is installed to blow air toward occupants' heads, and the ambient environment where there is no local ventilation device installed.

There have been a number of studies to examine thermal sensation responses in the step-change process. Gagge [1] in 1967 carried out experiments that had subjects move between two uniform environments with a temperature difference of 6 ~ 20 °C and proposed the important phenomena of thermal sensation's anticipatory and hysteresis. When the step-change is from cold to neutral or to warm, or from hot to neutral or to cold, anticipatory occurs which is probably caused by the sense of comfort that occurs before the body temperature changes. When step-change is from neutral to cold or to warm, hysteresis is especially obvious. Later, Wyon [2], Glickman [3] and Nagano [4] also found similar responses. de Dear [5] studied overall thermal sensation responses during up-step and down-step-changes when people moved between two twin chambers. Immediate sensations resulting from the temperature up-steps (from neutral to slightly warm, from slightly cool to neutral, and from neutral to neutral) showed a sharp increase, which approximately equaled the final steady-state value, while initial impressions of temperature down-steps (slightly warm to slightly cool, slightly warm to neutral, and neutral to slightly cool) overshot the final steady-state responses considerably. The author explained that the dynamic component of the thermal sensory system is capable of anticipating the steady-state response to a suddenly warmer environment. While the overshoot in sudden step-down tests appeared to result from cold thermo receptors being closer to the skin surface than heat thermo

* Corresponding author.
E-mail address: jq51yyy@gmail.com (Q. Jin).

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