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Experimental and numerical study of room airflow under stratum ventilation

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ABSTRACT

This paper investigates the air movement, air temperature profile and gaseous contaminant transportation in an individual office with stratum ventilation. The room temperature is elevated compared with conventional standards. The experimental investigation is carried out in an environmental chamber with the presence of heat generating rectangles used to simulate an occupant and a computer. Measurements of temperature, velocity, and CO_2 concentration are carried out for nine plumb lines in the chamber. Up to sixteen points are measured along each plumb line. The experimental data of the aforesaid three parameters of the individual office in warm condition under stratum ventilation are presented. The experimental data collected are used to validate a re-normalization group (RNG) $k-\varepsilon$ turbulence model used for the warm condition. The agreements between the predicted values and experimental results are acceptable, which demonstrates the feasibility of simulating indoor airflows at elevated room temperature under stratum ventilation by the RNG $k-\varepsilon$ turbulence model.

1. Introduction

The earth is already showing many signs of worldwide climate change. The Intergovernmental Panel on Climate Change (IPCC) has used its strongest language to link human activities to the current planetary warming [1]. There is international consensus to reduce CO_2 emission (Kyoto Protocol, etc.). Minimizing the energy consumption by air conditioning systems would help to reduce CO_2 emission. Proactive actions in this regard have been taken by several governments in East Asia. The Electrical and Mechanical Services Department (EMSD) of the Hong Kong S.A.R. government issues guidelines to ensure that normally room temperature is adjusted to 25.5 °C in summer [2]. The National Development and Reform Commission (NDRC) of the Chinese State Council issued a similar guideline to set the indoor temperature to 26 °C in the cooling season [3]. The room temperature in the "Office of President" in Taipei has been set to 27 °C after Mr. Ma Ying-jeou's inauguration in May 2008 [4]. Similarly, in the Standard of Energy Management issued in last December, the Ministry of Knowledge and Economy of the Republic of Korea recommended that room temperature of a building should be ranging from 26 to 28 °C in summer [5]. In a more radical move, the Ministry of the Environment (MoE) of Japan has been encouraging people to set the temperature of air conditioners at offices to 28 °C during the summer months [6]. A survey from The International Facility Management Association shows that many facility professionals are adjusting the thermostat to higher settings in the summer to cut energy consumption in the United States [7].

The aforementioned policies seem to be in line with the principle of sustainable development. But at least a question still remains - Would such a practice deteriorate indoor environmental quality, especially thermal comfort? To provide an answer, ANSI/ASHRAE Standard 55-2004 has been updated with new provisions that allow elevated air movement to broadly offset the need to cool the air in warm conditions [8]. Arens et al. reported that when the room air temperature is above 22.5 °C, there is a small risk of draft and a strong preference for more air movement [9]. In revising EN ISO 7730, Olesen adopted Fountain and Arens' (1993) theory that higher air speed was required to offset increased indoor temperature [10,11]. Stratum ventilation was proposed by Lin et al. for small to medium rooms to cope with the elevated room temperatures [12,13]. This air distribution method works by creating a layer of fresher air in occupants' breathing zone. It delivers supply air directly to the occupants with little attention to the indoor air quality (IAQ) and thermal comfort of the upper zone (approximately $>$ 1.5 m from the floor if the occupants are mostly sedentary). The lower zone (approximately $<$ 0.8 m from the floor) is not the target zone of IAQ performance either. This is realized by positioning supply terminal(s) at the side-walls or columns slightly above the height of occupants, standing or sitting depending on the application, whereas for displacement

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