Environmental Health Committee (EHC) Emerging Issue Brief

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Dynamic Thermal Environment

What is the issue?

Dynamic thermal environment for humans, parallel to the ASHRAE Standard 55-2020 (2020) definition of thermal comfort, can be described as the *transient* thermal environment that enables the condition of mind to express satisfaction and is assessed by subjective evaluation. The thermal state of humans exhibits diurnal (daily) variations, expressed in changes in both skin and core temperature (Schmerling 2022, Oura 2020). A model of thermal comfort is needed that encompasses the nature of these daily thermal variations. Dynamic thermal environment involves changes in one or more thermal parameters including air temperature, mean radiant temperature, humidity, and air speed, and is perceived by occupants as a subjective experience. This can occur in outdoor or indoor settings, particularly in climate-responsive buildings (e.g. operable windows), or can be mechanically reproduced. Selected research suggests dynamic comfort can be perceived more positively than steady-state thermal comfort, and is a source of thermal delight (Heschong, 1979, Cao et al. 2021, Miura et al. 2016). Dynamic environments can save energy by embracing wider HVAC deadbands beyond ASHRAE 55 limitations (not under direct control of individual occupants) with regard to the holistic thermal parameters, magnitude of each parameter, and duration of exposures (Mishra et al. 2016). It saves energy by allowing indoor environments to vary with prevailing outdoor conditions. This approach can be augmented with low-energy personal comfort systems to improve comfort and pleasure responses (Zhai et al. 2013). Selected research suggests HVAC energy reduction by 7-15% per degree C (Hoyt et al, 2014, Miura et al. 2016, Cao et al. 2021). Occupants have reported higher thermal comfort across a wider range of temperatures in naturally ventilated environments compared to air-conditioned environments (Zhu et al. 2016, van Marken Lichtenbelt et al. 2009). These findings also indicate that significant questions related to dynamic thermal comfort remain unanswered. In contrast, long-term exposure to constant, moderate thermal conditions may lead to the degeneration of occupants' inherent ability to combat thermal stress, thereby weakening thermal adaptability (Zhu et al. 2016).

Interest in dynamic thermal environments is increasing (Vellei et al. 2021) due to the desire both to bring more outdoor elements indoors and to bring indoor activities outdoors. The new Chinese mandated energy standard for buildings, effective on April 1st, 2022, requires operable window considerations (Kenji 2021). Some green building certifications, such as the Living Building Challenge, have explicit

requirements for operable windows (International Living Future Institute 2019). Ongoing passive survivability discussions have led to more interest in thermal and ventilation autonomy with operable devices (Ko et al. 2018). During the COVID-19 pandemic, the ASHRAE Epidemic Task Force (ASHRAE ETF 2021) and CIBSE (2020) discussed use of operable windows as a consideration to provide clean air, especially when mechanical ventilation is not sufficient. The United Nations WHO (2021) issued a "Roadmap to improve and ensure good indoor ventilation in the context of COVID-19", which included operable devices to provide natural ventilation as elements to provide clean air. The pandemic caused an increase in outdoor dining, and some suggest this will continue even after COVID (Fox 2022), especially with the growing interest in biophilic design.

Other issues related to this topic include the understanding of the differences and similarities between dynamic thermal comfort and adaptive comfort (de Dear + Brager 1998); the alliesthesia framework (Parkinson and de Dear, 2014) in understanding dynamic thermal perception; the potential benefits of more diversified microbes outdoors with less pathogens and the potential benefits of more diverse microbes indoor (Mahnert et al. 2018); the impact of the new United Nations WHO (2021) PM 2.5 standards on outdoor ambient environments and how it is brought indoors by natural and mechanical means.

What does this mean for ASHRAE?

Understanding the dynamic thermal environment aligns with the 2019-2024 ASHRAE Research Strategic Plan (2021), global trend toward passive buildings, and need for guidelines or standards on this topic. The ASHRAE Strategic Plan addresses indoor environmental quality which is increasingly recognized as the leading priority, with implications extending beyond simple acceptability of indoor conditions to its influence on productivity, learning and health. ASHRAE can convene and collaborate with experts and stakeholders across the industry to engage in discussion and exploration of this topic to accelerate collective knowledge in the field to develop thought leadership and promote understanding of indoor environmental quality (IEQ) among practitioners. The ASHRAE Research Strategic Plan 2021 mentioned: "...outdoor and semi-outdoor environments where people spend a substantial amount of time both for avoiding the risks and promoting the benefits", is a research gap and "ASHRAE should collaborate with other associations to develop guidelines…". ASHRAE members have been encountering heightened global interest in dynamic thermal environments for post pandemic design, and also passive design to lower energy consumption through operable windows. ASHRAE can benefit from coming up with guidelines and standards to address dynamic thermal environments.

What Actions Should ASHRAE Considered?

- Identify the knowledge gaps and support research, including but not limited to:
    - The biodynamic and physiological comfort parameters of the human body
    - The acceptable range of fluctuation of different parameters
    - Frequency of air flow, and other climatic fluctuations
    - Simulation of natural wind
    - Thermal prediction model of dynamic comfort
    - The use of intelligent detection equipment
    - Impact of larger diversity of microbes from the outdoor environment

    - Health and performance metrics associated with dynamic thermal comfort
- Develop dynamic thermal environment standards or guidelines. While ASHRAE Standard 55 addresses "adaptive comfort", additional guidelines and standards are required for a holistic dynamic thermal environment.
- Research the global and local outdoor environmental qualities and inform the dynamic thermal environment decisions with outdoor environmental ambient conditions, e.g. PM 2.5 ambient in global cities (Stephens et al. 2016)

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