University of Hawaii at Manoa

DRAFT Thermal Comfort Standard, for consideration in Kuykendall Hall Renovation Project – January 20, 2011
For Inclusion with the Architectural Design Program

The following criteria have been developed to set a thermal comfort standard for interior environmental conditions. Criteria are described for three different environmental classifications, based on the approach used for space conditioning. These criteria will be further refined to address the particular nature of the Hawaiian climate in a future amendment to the ADP.

1. Spaces that are Conditioned Solely by Natural Ventilation

Interior spaces shall meet the Adaptive Comfort criteria as outlined in ASHRAE Standard 55-2010 (Section 5.3). Recent years have seen a significant shift in international standards towards the concept of adaptive thermal comfort, particularly in the U.S. and Europe (de Dear and Brager 1998; Nicol and Humphreys 2009). The basic concept of adaptive comfort is that the comfort zone, or range of acceptable indoor temperatures, drifts upwards in warm weather and downwards in cooler weather, particularly in environments where occupants have a variety of adaptive opportunities at their disposal. Adaptive comfort is not applicable to environments where occupants are detached from the thermoregulation of the space such as in centrally air-conditioned, sealed façade, open-plan offices. But for naturally ventilated buildings in which occupants have access to operable windows, the adaptive comfort concept is particularly relevant.

In 2004 the American Society of Heating, Refrigerating and Air-Conditioning Engineers was the first standards organization to formally incorporate this adaptive comfort concept into a regulatory document (Brager and de Dear 2000; ASHRAE 2010), with the comfort chart depicted in Figure 1.

Figure 1 indicates the optimum indoor temperature as a linear function of mean monthly outdoor temperature, with two acceptable comfort zones straddling the optimum – 80% and 90% acceptability. These meaning of these percentages is as follows; an indoor operative temperature falling within the 80% range should be regarded as acceptable or satisfactory to at least 80% of building occupants who are exposed to it, and the tighter 90% acceptable temperature range is likely to satisfy 90% of occupants.

For the purposes of the current criteria we propose the 80% acceptable temperature range, the upper limit of which can be written as:

$$\textit{Upper 80\% Acceptable Limit} = 0.31\ t_{a(out)} + 21.3 \qquad (^{o}C)$$

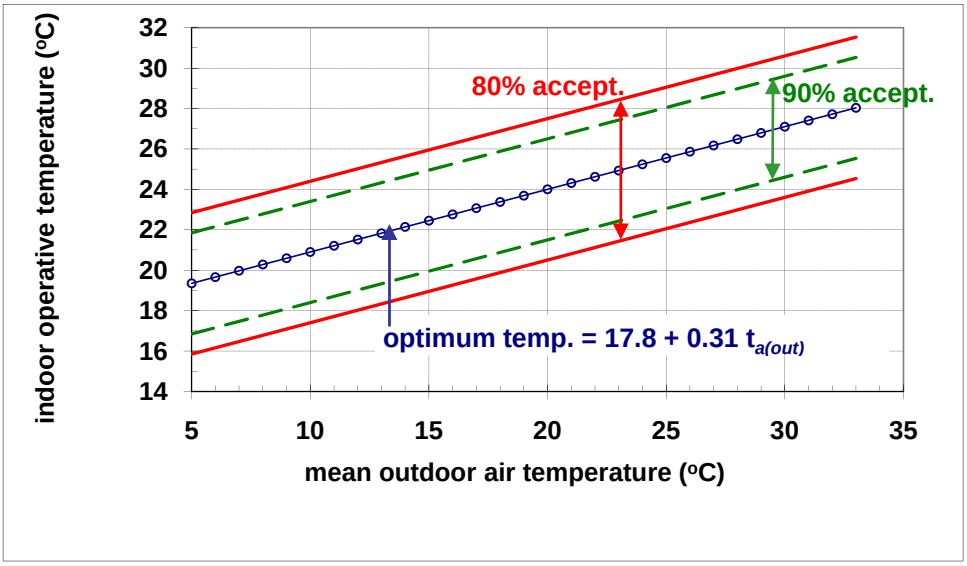

Figure 1: The ASHRAE 2010 adaptive comfort standard in naturally ventilated spaces as a function of prevailing outdoor temperature. $t_{a(out)}$ *is simply an arithmetic average of the mean monthly minimum and maximum daily air temperatures for the month in question*.

The outdoor temperature driving ASHRAE's comfort zone ($t_{a(out)}$) was defined pragmatically as the mean monthly dry-bulb temperature simply because those climatic data are readily available for virtually every site across the globe. However, recent research has led to the development of a more sophisticated method to analyze daily local climate data to provide a more representative driving function for the adaptive model comfort zone. Further information on this and other criteria will be provided in a future amendment.

2. <u>Spaces that are Conditioned by Either Natural Ventilation or Mechanical Space Conditioning (i.e. 'Mixed Mode')</u>

Mixed-mode refers to a hybrid approach to space conditioning that uses a combination of natural ventilation from operable windows (either manually or automatically controlled) or other passive inlet vents, and mechanical systems that provide air distribution and some form of cooling. A well-designed mixed mode building allows spaces to be naturally ventilated during periods of the day or year when it is feasible or desirable, and uses air-conditioning for supplemental cooling when natural ventilation is not sufficient. The goal is to provide acceptable comfort while minimizing the significant energy use and operating costs of air conditioning (Brager 2006).

At first glance, the assessment of thermal comfort in a mixed-mode building requires the evaluation of three different operating regimes.

a. *Occupied hours when spaces are conditioned solely by natural ventilation.* For these hours, interior spaces shall meet the Adaptive Comfort criteria as outlined in ASHRAE Standard 55-2010 (Section 5.3). Assessment of thermal comfort would follow the same criteria described above in section (1)
b. *Occupied hours when spaces are conditioned by mechanical conditioning only.*
   Comfort criteria for this operating regime are not yet well-defined. To date, the evidence suggests that comfort criteria for periods of mechanical cooling in a building that is predominantly conditioned by natural ventilation are not the same as criteria for a building that is only conditioned by mechanical cooling. See further discussion below under transition mode (c) for one proposed approach. Further information on comfort criteria will be provided in a future amendment.
c. *Occupied hours that fall within an hour or two of the transition from one mode of space conditioning to the other.*
   The short answer for this operating regime is that this transition mode represents an active research area around the world. Clear thermal comfort guidelines are not yet well-defined and additional field data is needed.

   The key point is that it is unlikely that comfort conditions should immediately flip between the two comfort criteria when the building switches from one mode to another. Whether or not people will find the PMV-based (conventional systems) or adaptive-based (natural ventilation) comfort zone acceptable has a lot to do with how the building is designed, and how it is operated throughout the year. One proposed way of thinking about it is if the building operates primarily as a naturally ventilated building, then you can use mechanical cooling only when the temperature rises above the adaptive comfort maximum temperature, and continue using it until the space temperature cools down again just to that maximum acceptable temperature.

   Further information on comfort criteria during the transition mode will be provided in a future amendment. The following list of factors that may influence the development of these criteria are provided below to initiate further thinking and discussion on the topic.

   - envelope design, % of windows that are operable
   - access to windows (and management attitude about occupant use of windows)
   - % of windows that are manual vs. automatic control
   - occupant education about building operation
   - availability of other means of personal control; flexible dress code in the workplace
   - zoning of naturally ventilated vs. air-conditioned spaces

3. Spaces that are Conditioned by Mechanical Conditioning Only

Interior spaces shall meet the comfort criteria as outlined in ASHRAE Standard 55-2010 (Section 5). Spaces of this classification are representative of conventional design in which mechanical systems provide 100% of the space conditioning requirements. Thermal comfort is assessed and evaluated using normal methodologies described in Standard 55.

References

ASHRAE (2010). *ANSI/ASHRAE Standard 55R - Thermal Environmental Conditions for Human Occupancy.* Atlanta, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Brager, G.S. (2006). "Mixed mode cooling." *ASHRAE Journal*, **48**(8): 30-37.
August 2006.

Brager, G. S. and R. de Dear (2000). "A standard for natural ventilation." *ASHRAE Journal* **42**(10): 21-27.

de Dear, R. J. and G. Brager (1998). "Developing an adaptive model of thermal comfort and preference." *ASHRAE Transactions* **104**(1A): 145-167.

Nicol, J. F. and M. A. Humphreys (2009). "New standards for comfort and energy use in buildings." *Building Research and Information* **37**(1): 68-73.