**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, office spaces. 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:

*Upper 80% Acceptable Limit* = 0.31 *ta(out)* + 21.3 (oC)

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

**Elevated air speed**. The ASHRAE Committee that manages Standard 55 has recently approved additions for consideration during public review, which would allow increases in the acceptable maximum indoor temperature when there is elevated air speed. This new addition would be analogous to the recent addition of allowances for elevated air speed in the more traditional sections of the standard (section 5.2.3.). This proposed addition is being included here for consideration in the Kuykendall Architectural Design Program.

Figure 1 above includes the effects of people’s indoor air speed adaptation in warm climates, up to 0.3 m/s (59 fpm) in operative temperatures warmer than 25°C (77 °F). In naturally conditioned spaces where mean air speeds within the occupied zone exceed 0.3 m/s (59 fpm)*,* the upper acceptability temperature limits in Figure 1 can be increased by the corresponding *to* in Table 1 below. These were calculated based on equal Standard Effective Temperature (SET) values as described in Section 5.2.3.2 of Standard 55-2010. For example, increasing mean air speed within the occupied zone from 0.3 m/s (59 fpm) to 0.6 m/s (118 fpm) increases the upper acceptable temperature limits in Figure 1 by a *to* of 1.2°C (2.2°F). These adjustments to the upper acceptability temperature limits apply only at to > 25°C (77 °F) in which the occupants are engaged in near sedentary physical activity (with metabolic rates between 1.0 met and 1.3met).

**TABLE 1**

**Increases in Acceptable Operative Temperature Limits (*to*) in the Adaptive Comfort Standard (Figure 5.3) Resulting from Increasing Mean Air Speed Above 0.3 m/s (59 fpm).**

|  |  |  |
| --- | --- | --- |
| **Mean Air Speed = 0.6 m/s** | **Mean Air Speed = 0.9 m/s** | **Mean Air Speed = 1.2 m/s** |
| 1.2°C (2.2°F) | 1.8°C (3.2°F) | 2.2°C (4.0°F) |

**Impact of outdoor humidity.** . The outdoor temperature driving ASHRAE’s adaptive comfort zone (*ta(out)*) was defined pragmatically in Figure 1 as the mean monthly dry-bulb temperature simply because those climatic data are readily available for virtually every site across the globe. However, in the original ASHRAE research project (RP-884) that led to the development the adaptive comfort standard, mean outdoor effective temperature, ET\*, was used as the driving function (de Dear and Brager 1998). ET\*is defined as the temperature at 50% relative humidity which would cause the same sensible plus latent heat exchange from a person as would the actual environment. This combines temperature and humidity into a single index, so two environments with the same ET\* should provide the same thermal response even though they have different temperatures and humidities, as long as they have the same air velocities. RP-884 developed a linear regression model for adaptive comfort limits, similar to that shown in Figure 1, but with mean outdoor ET\* on the x-axis. In the original model, the optimum indoor operative temperature is given as follows:

optimum indoor temperature = 18.9°C + 0.255 \* (outdoor mean *ET\**)

Acceptable temperature ranges around the optimum in naturally ventilated buildings were specified as ±3.5°C for 80% general acceptability and ±2.5°C for 90% general acceptability, corresponding to the two acceptability deadbands shown in Figure 1. Daily outdoor temperatures and relative humidities at 600 hours and 1500 hours were collected, and daily effective temperatures (*ET\**) for these times were calculated with *WinComf*© (Fountain and Huizenga 1996). If desired, this WinComf comfort tool can be made available to the UHM team to assist in calculation of ET\* from available hourly weather data.

In addition, 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.

1. Spaces that are Conditioned by Either Natural Ventilation or Mechanical Space Conditioning (i.e. ‘Mixed Mode’)

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.

* 1. *Occupied hours when spaces are conditioned solely by natural ventilation.*
  2. *Occupied hours when spaces are conditioned by mechanical conditioning only.*
  3. *Occupied hours that fall within an hour or two of the transition from one mode of space conditioning to the other.*

There is no agreement in either the research or professional communities about how to best define the thermal comfort operating conditions for mixed mode buildings in any of these regimes. There does seem to be agreement, however, that the chosen approach requires considered discussion between the design team and the building owners (and/or managers for the occupants, if different), as well as eventual occupant education about the building operation and the occupants’ role in managing their own thermal environments (if appropriate). In all of these approaches, there need to be decisions about the extent to which you want to control (i.e., limit) or educate occupants about how to use the windows. These can be through automated windows, window locks, or red/green light signalling systems. In any of these approaches, 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.

Conceptually, there is a continuum of strategies for how to approach this:

1. Conventional / conservative approach. Operate the building year-round to meet conventional setpoints (i.e., PMV-based comfort zone), no differently than as if it was a sealed building. Operable windows are seen merely as an amenity, and at best function like an economizer cycle. This approach may be appropriate if it is expected that mechanical cooling will be in operation for most of the warm season, occupants have minimal access to windows, and natural ventilation mode is expected for only a very short period of time.

2. Conventional / relaxed approach. Again use the conventional, PMV-based comfort zone. Use a slightly relaxed deadband from the conventional setpoints (i.e., 4°F) while heating/cooling equipment is operating. During times when the windows are open, expand the heating and cooling setpoints by an additional 2°F in each direction. So in this example, a conventional deadband of 70°F (heating) to 74°F (cooling) would be expanded to 68°F to 76°F. This is a compromise that allows for improved energy efficiency, while still allowing for relatively quick recovery when the equipment turns on.

3. Adaptive / ramped approach

During periods when the spaces are conditioned solely by natural ventilation, 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). If windows are then sealed and mechanical cooling is operating (changeover mixed-mode approach), a transition period would maintain conditions at the top of the Adaptive Comfort criteria. If mechanical cooling has been operating for an extended period, conditions would then ramp down to the top of the conventional PMV-based comfort zone

4. Adaptive / conserving approach

In this approach, the Adaptive Comfort criteria are consistently maintained through alternative operation scenarios. Natural ventilation is used exclusively as long as conditions are maintained within the Adaptive Comfort limits as described above in section (1), and mechanical cooling is used only as needed to ensure the building temperature does not rise above the adaptive comfort maximum temperature. This is most appropriate if the building operates primarily as a naturally ventilated building during significant periods of the year, the occupants are well-educated about building performance, and they are willing to play an active role in managing their own thermal environment (i.e., there is sufficient adaptive opportunity so that expectations are relaxed as well).

Further information on comfort criteria can be developed once the design team and building owners decide which approach they want to pursue. 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

1. 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

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