BALANCING ENERGY EFFICIENCY AND THERMAL COMFORT

The need for energy efficient building designs has increasingly gained acceptance by the public. The A/E industry has been developing methods to create more efficient buildings for decades, with more innovative designs and equipment available today with the aid of powerful computerized analysis and design tools. In the pursuit of efficiency, the designer needs to always consider the needs of the occupants first, because buildings are built to serve people.

There are many forces promoting energy efficient designs, with code mandated building energy performance routinely driving this trend. The availability of green building codes for state or local agency adoption, such as International Green Construction Code (IGCC) and ASHRAE/USGBC/IESNA Standard 189.1, has made green building design the norm and not the exception now in 2017. The willingness of sustainability leaders to exceed minimum code performance, including LEED certified and Net Zero Energy building owners, will continue to pave the path for the A/E/C industry to newer practices. This article explores some modern HVAC system design considerations and their potential impact on building efficiency and occupant comfort.

HOW IS EFFICIENCY IMPROVING?

One simple path to achieve better efficiency is to utilize more efficient traditional HVAC equipment, whether they are rooftop packaged units or water cooled chilled water plants. The use of non-standard systems has also become more prevalent today. Not long ago, the use of systems such as radiant cooling, under floor HVAC and displacement ventilation systems, and even passive ventilation systems were generally considered exotic. While some are still novel today, they are past experimental and regarded to be effective and efficient IF designed properly for the right application. Finally, the traditional concept of human comfort has been challenged, with building designers and HVAC engineers seeking to expand the acceptable indoor environmental design range.

Does the latter strategy compromise occupant comfort? Occupant well-being and improved productivity are all worthwhile rewards to avoid this compromise.

WHAT DOES THE A/E/C TEAM HAVE CONTROL OVER?

New building design teams can influence each area affecting thermal comfort, including building orientation, envelope performance, and HVAC system sizing.

- By employing an integrated design process informed by building energy models, the design team can optimize the design through an iterative process to meet building performance and cost goals.
- By hiring contractors experienced in building efficient buildings and the specific systems selected, major installation issues can be avoided, and the systems can perform as designed.
- By conducting a thorough commissioning process, the building will be tested for operations under typical and edge conditions with verification of the building's baseline potential for efficient operations.

The design team or contractors ultimately do not determine actual building performance, it is the behavior of the building occupants and operators that determines performance. Their tolerance for the thermal design envelope and equipment maintenance is crucial. The resulting energy bill is the report card that really counts. After the building is turned over, occupants and operators have control over many factors affecting thermal comfort and energy use. These factors include:

- Process loads: Appliances are becoming more efficient with Energy Star and other codes such as California Title 20. However, other processes may not be well controlled, and energy use not easily predicted. If not properly accounted for, these loads can create excessive internal heat gain and affect thermal comfort.
- Plug loads: Are starting to be controlled with the recent development and requirement for controlled receptacles in certain states and jurisdictions. However, there are easy work arounds to defeat energy efficient features.
- Lighting control system: Are mostly automated in modern buildings, which is one key to minimizing energy use and building internal heat gain.
- Thermostat setting: Sometimes this setting is locked, but some systems either give occupants full access or limited access to adjust setpoints and afterhours operations. Since different building occupants have different thermal tolerances, individual controls may be the most efficient way to satisfy comfort and energy efficiency needs, but at higher costs.

QUANTIFYING HUMAN COMFORT

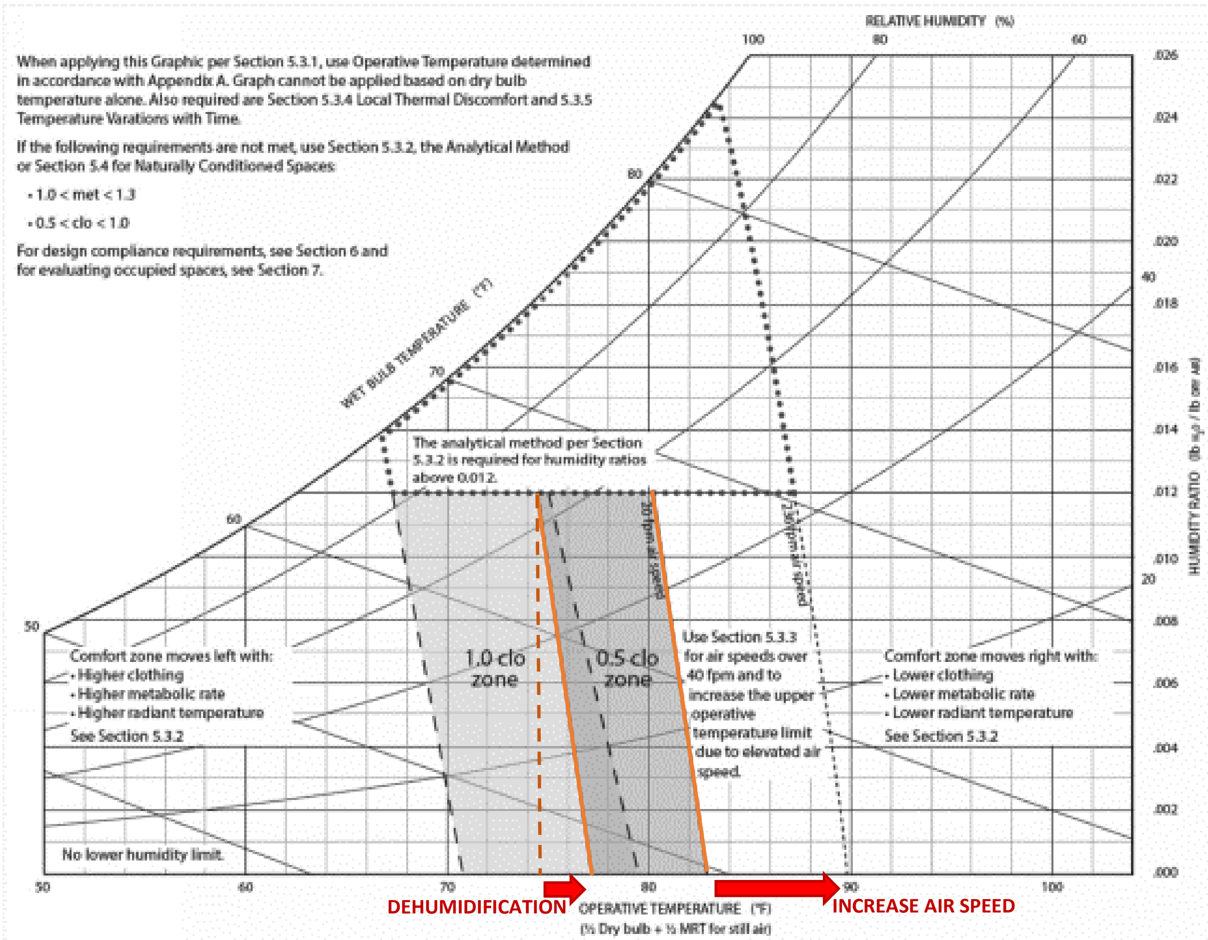
Thermal comfort and satisfaction can be attributed to both physiological and psychological factors. ANSI/ASHRAE Standard 55 (Thermal Environmental Conditions for Human Occupancy) defines minimum acceptable indoor thermal conditions. First published in 1966, it continues to be updated to account for modern design techniques, including natural ventilation. It should be noted that ANSI/ASHRAE Standard 62.1 (Ventilation for Acceptable Indoor Air Quality) also deals with an important aspect of human comfort and wellness. In practice ventilation should be considered together with thermal comfort.

ASHRAE 55-2013 Figure 5.3.1 defines acceptable thermal comfort envelopes for typical winter office clothing (clo=1.0) and summer office clothing (clo=0.5) conditions. This figure is derived from statistical analysis of over 21,000 thermal comfort surveys conducted worldwide. The summer design envelope ranges from 75°F up to 83°F operative temperatures, depending upon two variables under the HVAC designer's control: air humidity levels and air speed. The greater the air speed and the lower the humidity, the higher the acceptable operative temperature.

(SIDEBAR)
It is important to note that practitioners using Figure 5.3.1 or calculations to generate project specific thermal envelopes realize these are operative temperatures, not dry bulb temperatures. The operative temperature is the weighted average of room dry bulb temperature and mean radiant temperature for still air. Designers substituting only room dry bulb temperature should only do so if there are no radiant heating or cooling systems used, there is no major heat generating equipment in the space and the exterior wall and windows meet minimum U-factor and solar heat gain performance. Not accounting for these factors can result in the designer erroneously concluding the acceptable thermal window is broader and higher that it actually is and risk the HVAC system not being able to maintain intended indoor space temperature.

Dehumidification: In this case, the summer thermal comfort window can be increased by 3°F by significantly reducing room humidity. For buildings which need significant outside ventilation air, desiccant systems may be more efficient at dehumidifying than refrigerated air coils, and are especially relevant if the intended system does not include mechanical cooling.

Increase Air Speed: In this case, the thermal comfort window can be increased by 7°F by increasing air speed from 20 fpm to 236 fpm without additional mechanical cooling. The ability to affect indoor design temperatures so significantly with air speed is one reason ceiling fans are becoming more prevalent in energy efficient designs, especially with natural ventilation or mixed mode ventilation systems.



ASHRAE Standard 55-2013 – Figure 5.3.1 Graphic Comfort Method

<u>RISKS TO EXTENDING THERMAL COMFORT RANGE</u>

Increasing the space design temperatures by employing some of the tactics mentioned above can save energy, but there are certain risks:

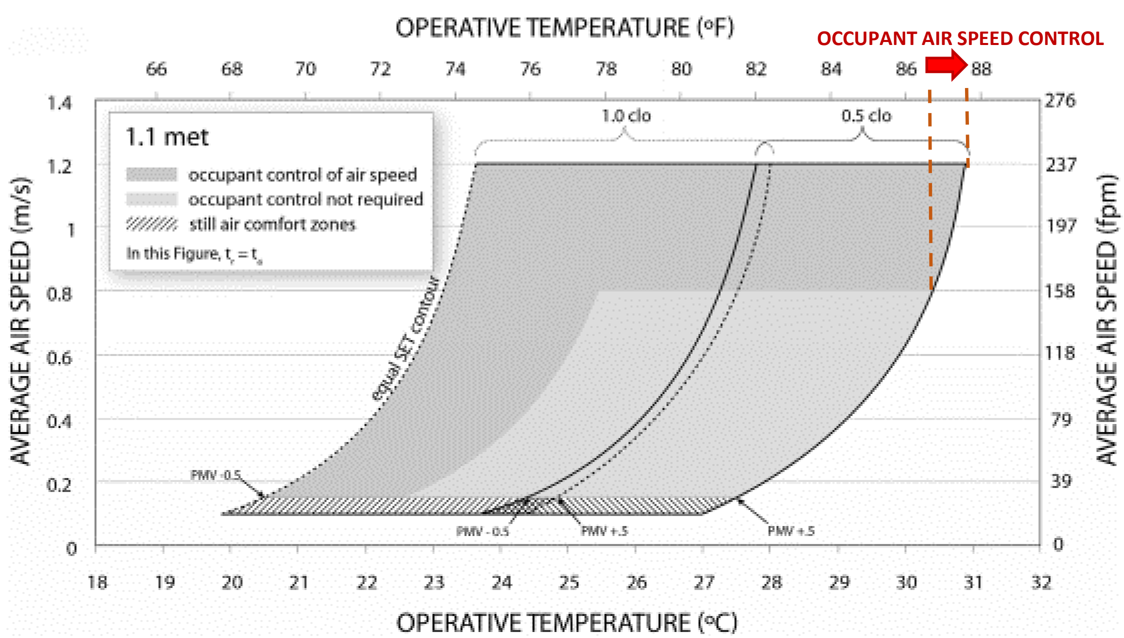
- Air speed not uniformly increased: causes some areas with too much draft and other areas with not enough cooling effect.
- Activity level not properly accounted for: Figure 5.3.1 is based on a standard set of assumptions for office buildings, including variables for clothing, air speed, and activity levels. These all affect the human physiological responses in maintaining comfort.

- Human physiological responses vary: Different people have different responses to their environmental conditions, so predicted effects of dehumidification or increased air speed may be greater or less than intended. The ability of occupants to control air speed may partially mitigate this risk.

OCCUPANT CONTROL OF THE INDOOR ENVIRONMENT

Statistical analysis of thermal comfort surveys suggests there is correlation between a person's perceived control over their environment and their thermal satisfaction.[1] Perceived control may include anything available to the occupant that helps them adapt to the indoor thermal environment. This includes opening windows or doors, turning on fans or personal heating devices, adjusting thermostats, changing clothing and even moving to other parts of the building. The analysis also suggests that when perceived control is high, occupants' comfort threshold may be more adaptive. The more aggressive the design, such as natural ventilation, the more perceived control the occupant many need to allow them to adapt. The analysis saw stronger correlations in dry climate areas during the summer, and almost no correlation in humid climates or during the winter, where opening a window may result in less comfort.

Therefore, psychology can be considered in certain situations in addition to physiology when extending thermal comfort range. ASHRAE Standard 55-2013 Figure 5.3.3A attempts to quantify the additional operative temperature range allowed when occupant control of air speed is available. When attempting to make such argument, the designer should consider the available controls and the climate of the project site. While a casual office worker in California may be comforted by some level of perceived controls, the same cannot be assumed for a grade school student in Florida.



ASHRAE Standard 55 Figure 5.3.3A – Acceptable ranges of operative temperature and average air speed for comfort zone presented in Figure 5.3.1 at humidity ration 0.010.

[1] Jared Langevin, Jin Wen & Patrick L. Gurian (2012): Relating occupant perceived control and thermal comfort: Statistical analysis on the ASHRAE RP-884 database, HVAC&R Research, 18:1-2, 179-194

CONCLUSION

It is possible to maintain occupant thermal comfort while achieving energy efficient designs. Relying on efficient equipment in traditional designs is a conservative path towards modest energy savings. Aggressive designs which seek to extend the thermal comfort range can yield even greater savings and allow the use of non-traditional systems such as radiant and natural ventilation. However, the designer must take great care to carefully consider all aspects of design guides and standards such as ASHRAE Standard 55, to realistically estimate the upper (and lower) limits of the design temperature envelope. Because comfort is subjective, giving the occupants some level of control over their environment may increase the chance that your next leading-edge design, no matter how sophisticated, can reliably serve the thermal comfort needs of the building occupants.