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What's New in ASHRAE's Standard on Comfort

By Stephen C. Turner, P.E., Member ASHRAE

Eighty-seven years ago, the first thermal comfort standard determined the boundaries of comfort by seating unclothed subjects in front of fans.[1] Of course, research is more sophisticated now. In the 45 years since ASHRAE first published Standard 55, *Thermal Comfort Conditions*, the standard has incorporated the latest research in every edition.

In the 2010 version of Standard 55, *Thermal Environmental Conditions for Human Occupancy*, recent research helped inform significant changes required to improve and clarify the three distinct compliance paths established in Standard 55-2004. After summarizing some of the technical changes, this article explains these three compliance paths, highlights the differences between them, and summarizes the changes to each path.

Changes in the 2010 Version

Here is a brief description of some of the changes to the standard. For more information, visit www.ashrae.org/technology/page/132#55-2004 for the addenda since 2004 that have been incorporated into the new version.

Standard 55-2010 includes extended provisions[2] for evaluating the impacts of elevated air speed. Elevated air movement increases the maximum operative temperature that occupants will find acceptable, so equivalent comfort can be maintained in a wider range of operative temperatures. Therefore, the use of elevated air speeds to widen the acceptable range of thermal conditions has been modified and expanded (Section 5.2.3). The standard had previously allowed modest increases in operative temperature beyond the PMV-PPD (Computer Model Method for General Indoor Applications [Computer Model Method] in Section 5.2) limits as a function of air speed and turbulence intensity. But field studies including recently published work show that occupants, especially when neutral or slightly warm, prefer higher air speeds than were previously allowed. In certain combinations of temperature ranges and personal factors, the preference for more air movement is greater than it is for less air movement. As a result, the standard provides a new method for expressing and selecting air speed limits, and alternatives for determining the boundaries of comfort at air speeds above 0.15 m/s (30 fpm).

With these changes, the standard continues to focus on defining the range of indoor thermal environmental conditions acceptable to a majority of occupants, while accommodating an increasing variety of design solutions intended to both provide comfort and to respect today's imperative for sustainable buildings.

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The maximum permissible operative temperature increases dramatically from traditional still-air comfort zones. Two important notes: the permissible air speeds for cooler temperatures without local occupant control *have not changed*, and for a certain elevated air speed the lower limit on temperature increases as well, not just the upper limit.

The standard clarifies that the upper humidity limit shown on the psychrometric chart in the graphical method only applies to the Graphic Comfort Zone Method for Typical Indoor Environments (Graphic Comfort Zone Method). Higher humidity limits are allowed if evaluated with the Computer Model Method, and no limits are imposed on the Adaptive Method.

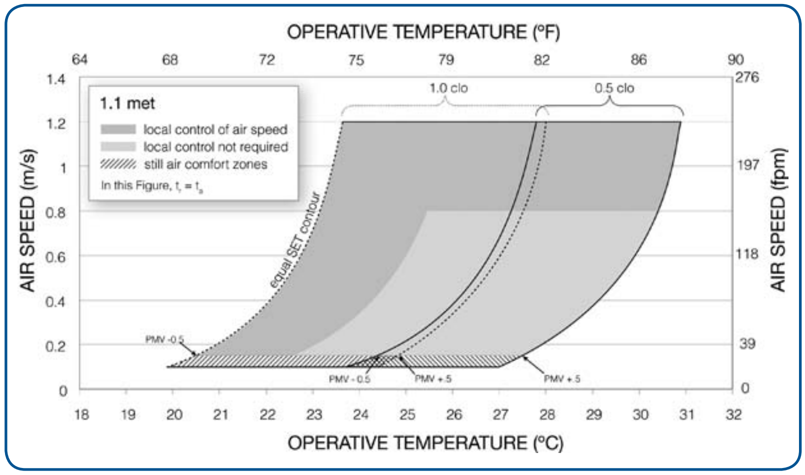

Figure 1: Acceptable range of operative temperature and air speeds for the comfort zone shown in *Figure 2*, at humidity ratio 0.010 (Standard 55-2010).

Revised requirements and calculation methods apply when increased air movement is used to maintain comfort in warm conditions. Standard Effective Temperature (SET) is re-introduced into the standard as the calculation basis for determining the cooling effect of air movement. This calculation method has been simplified with the removal of turbulence intensity and draft risk calculations and the personal control limitations have been relaxed based on the results of new research. This change is expected to give clear requirements for application of ceiling and other in-room fans for comfort cooling.

Section 6, Compliance, contains new mandatory minimum requirements for analysis and documentation of a design to show that it meets the requirements in the standard. Informative Appendix G expands on Section 6, Compliance, by providing a compliance form for documentation of design compliance. This form is the basis for the U.S. Green Building Council LEED template for documenting compliance with the requirements of the Thermal Comfort design credit in the New Construction (NC) rating system's Indoor Environmental Quality Credit 7.1.

A new general satisfaction survey has been added to Section 7.5.2.1 as a method to evaluate thermal comfort in occupied spaces. The previous survey in the 2004 version of the standard was meant for evaluating comfort at a point in time (e.g., "how do you feel right now?"), and the new survey is meant to evaluate the overall comfort of a space (e.g., "how do you feel in general?"). Addition of a general satisfaction survey aligns Standard 55 with current practice for survey based post-occupancy evaluations (POEs).

Editorial changes have been made throughout the standard to clarify requirements. Wherever possible, the use of informative language in the standard is avoided.

Compliance Paths & Methods in Standard 55-2010

As with the 2004 standard, there are three primary compliance paths in Standard 55-2010: the Graphic Comfort Zone Method, the Computer Model Method, and the Optional Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces (Adaptive Method). The Graphic Comfort Zone Method is the simplest, the time-honored Graphic Method based on the (in?)famous thermal comfort chart. It is based on the Computer Model Method, but minimizes calculations. It includes a "comfort zone" graphic in the standard that applies to projects where the assumptions and limitations stated in the method apply.

The second method is the Computer Model Method, which requires calculations that allow—and require—the use of project specific inputs. This method applies to some projects or spaces not suited for the graphic comfort zone method. The third method is the Adaptive Method introduced in 2004 to extend the applicability of the standard to naturally ventilated spaces. This approach is for use in naturally ventilated spaces without mechanical cooling, and applies to times when no heating system is in use. In such projects and conditions, it better describes the range of thermal conditions that provide comfort as occupants "adapt" to changing outdoor conditions.

Graphic Comfort Zone Method

In the past, I attended many ASHRAE chapter programs that incorporated a scanned version of the tiny chart that appeared in earlier versions of the standard. This was invariably presented with misinformation or missing information about the related requirements of the standard. Unfortunately, an evaluation of compliance documentation examples collected and reviewed by the committee in recent years shows similar oversimplification of design for compliance with Standard 55. To help improve compliance with the Graphic Comfort Zone Method and *all* of its requirements, the committee has made significant editorial improvements to the comfort zone graphic.

Today, the improved and enlarged comfort zone graphic (*Figure 1*) in the 2010 standard better represents the several conditions and opportunities related to this compliance method. Foremost, this graphic *cannot be applied based on dry-bulb temperature alone!* As is true in all three compliance

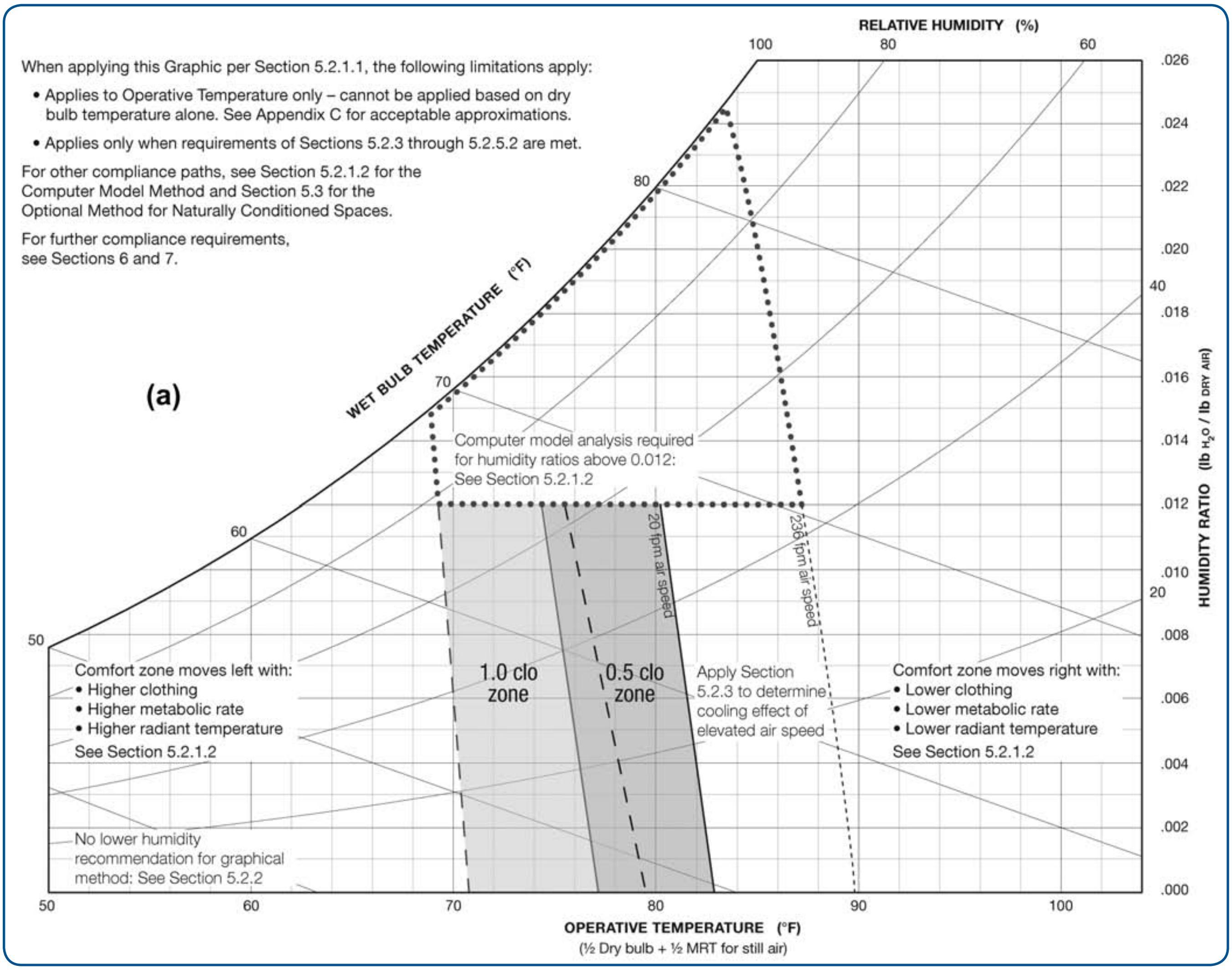

Figure 2: The new Graphic Comfort Zone Method, Figure 5.2.1.1 in Standard 55-2010 (IP version shown).

paths, and indeed in much of the standard, the graphic represents *operative temperature*.

The standard in certain cases allows air or space temperature to be used as an approximation for operative temperature, but only in spaces where mean radiant temperature does not unduly depart from air temperature. Appendix C of the standard provides more detail on when this simplifying approximation is justifiable. In today's architecture with abundant glazing, this simplifying assumption may not always apply. So, the building and its systems must be able to provide *operative temperatures* in the ranges shown, at and between the warmer and colder outdoor design conditions applicable to the project.

The upper limits for humidity with this simple Graphic Comfort Zone Method are more strict than with the other compliance paths. An upper limit of 0.012 humidity ratio applies, which gives us the "flat top" of the comfort zone in *Figure 1*. For the "summer" comfort zone based on lightweight clothing towards the right side of the figure, this represents relative humidities between 67% and 56%. Bear in mind that, with respect to humidity, ANSI/ASHRAE Standard 62 is more restrictive than Standard 55, which does not deal with IAQ nor the impact to building materials and envelopes.

Additionally, as is now stated in the graphic, the requirements of Sections 5.2.3 through 5.2.5.2 must be met. Though previously true, these requirements were often ignored in design processes and documentation evaluated by the committee. These sections require that, in addition to being able to achieve operative temperatures within the applicable comfort zone, designs claiming compliance with Standard 55-2010 must also address specific limits and provisions for evaluating the impacts of elevated air speed (§5.2.3), as well as the following causes of local thermal discomfort:

• Radiant temperature asymmetry (§5.2.4.1);
• Draft (§5.2.4.2);
• Vertical air temperature difference (§5.2.4.3); and
• Floor surface temperature (§5.2.4.4).

Perhaps most often overlooked, are requirements limiting temperature variations with time: cyclic variations (§5.2.5.1) and drifts or ramps (§5.2.5.2). As stated previously, the elevat-

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Evaluating Acceptable Thermal Conditions Using Standard 55-2010			
Step	Evaluation Question	If Yes	If No
1	Are expected met rates between 1.0 and 1.3 met and are expected clo values between 0.5 and 1.0 clo, to meet the limitations of the graphical method in Section 5.2.1.1?	Proceed to Step 3	Proceed to Step 2
2	Are expected met rates between 1.0 and 2.0 met and are expected clo values 1.5 or less, to meet the limitations of the computer model method in Section 5.2.1.2?	Proceed to Step 4	Unless space complies under Table 2 method for "Naturally conditioned spaces," Standard 55-2010 does not apply.
3	Is operative temperature, determined per Section 7 & Appendix C, within acceptable ranges in Figure 5.2.1.1-1 for expected clo value, per Graphical Method Section 5.2.1.1?	Proceed to Step 5	Same as Above
4	Are assumed values for clo, met, design, air temperature, mean radiant temperature, relative air velocity, and relative humidity or water vapor pressure such that calculated PPD is under 10% (calculated PMV range is between −0.5 and +0.5), per Computer Model Method Section 5.2.1.1?	Proceed to Step 6	Same as Above
5	Is humidity ratio controlled to below 0.012, per Humidity Limits, Section 5.2.2?	Proceed to Step 6	Use computer method or adaptive method, if applicable.
6	If any increased air temperature or mean radiant temperature is expected, does elevated air speed offset this, per Elevated Air Speed, Section 5.2.3?	Proceed to Step 7	Same as Above
7	Will wall and ceiling temperatures be within limits in Table 5.2.4.1, or is PD less than 5% using Figure 5.2.4.1, per Radiant Temperature Asymmetry Section 5.2.4.1?	Proceed to Step 8	Same as Above
8	Will draft be within limits for air temperature and air speed per Section 5.2.4.2, or are elevated air speed requirements of Section 5.2.3 including local control met?	Proceed to Step 9	Same as Above
9	Will temperature difference taken from ankle to head level be less than 3°C (5.4°F), per Vertical Air Temperature Difference Section 5.2.4.3?	Proceed to Step 10	Same as Above
10	Will the floor temperature be between 19.0 and 29.0°C (66.2 and 84.2°F), per Floor Surface Temperature Section 5.2.4.4?	Proceed to Step 11	Same as Above
11	Are there any expected changes in operative temperature with periods under 15 minutes less than 1.1°C (2.0°F), per Cyclic Variations Section 5.2.5.1?	Proceed to Step 12	Same as Above
12	Are any components of variations in operative temperature with periods over 15 minutes within the respective limits in Table 5.2.5.2, per Drifts or Ramps Section 5.2.5.2?	Proceed to Step 13	Same as Above
13	Have design and documentation compliance requirements in Section 6 been met (see Appendix G for compliance documentation forms)?	Recommendations in Standard 55-2010 are met.	Must be completed to meet requirements of Standard 55-2010.

Table 1: Use this table for evaluating compliance using Section 5.2, the Graphic Comfort Zone Method for Typical Indoor Environments and the Computer Model Method for General Indoor Application, for spaces being served by heating and mechanical cooling systems.

ed air speed provisions can be applied when using the Graphical Comfort Zone Method.

Computer Model Method

This method is the basis for the comfort zones drawn in the Graphic Comfort Zone Method, derived from the Predicted Mean Vote (PMV) and Predicted Percent Dissatisfied (PPD) indices developed by the late Professor Ole Fanger in his seminal doctoral thesis (first published in book form in 1970). The use of these indices as the basis for this method makes Standard 55-2010 consistent with ISO Standard 7730. The computer code that calculates these indices is in Appendix D of the standard, and is widely available from other sources. This approach allows users of the standard to predict the extent to which comfort will be provided based on a specific set of expected clothing level (clo), activity level (met), air temperature, radiant temperature, air speed, and humidity.

The same additional requirements enumerated above for the Graphic Comfort Zone Method also apply to the Computer Model Method; the only difference is that instead of an absolute upper limit on humidity ratio, calculated limits pertain that allow, in certain conditions, even higher humidity. As stated previ-

Evaluating Acceptable Thermal Conditions Using Standard 55-2010			
Step	**Evaluation Question**	**If Yes**	**If No**
1	Are thermal conditions of the space regulated primarily by the occupants through opening and closing of the window?	Proceed to Step 2	Unless space complies under Table 1 method, Standard 55-2010 does not apply.
2	Is space equipped with operable windows that open to the outdoors and that can be readily opened and adjusted by the occupants of the space?	Proceed to Step 3	Same as Above
3	Will the building be free of mechanical cooling systems (e.g., refrigerated, radiant, or desiccant)? (only mechanical ventilation allowed)	Proceed to Step 4	Same as Above
4	Is this method applied only for times when heating system is not in operation?	Proceed to Step 5	Same as Above
5	Are expected met rates between 1.0 and 1.3 met and may occupants freely adapt their clothing to indoor and/or outdoor conditions?	Proceed to Step 6	Same as Above
6	Is operative temperature for each occupied space, determined per Section 7 & Appendix C, within acceptable ranges for 80% in Figure 5.3-1 for mean monthly outdoor air temperatures, per Optional Method for Naturally Conditioned Spaces Section 5.3?	Proceed to Step 7	Same as Above
7	Have design and documentation compliance requirements in Section 6 been met (see Appendix G for compliance documentation forms)?	Recommendations in Standard 55-2010 are met.	Must be completed to meet requirements of Standard 55-2010.

Table 2: Use this table for evaluating compliance using Section 5.3, the Optional Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces (Adaptive Method), where thermal conditions of the space are regulated primarily by the occupants through opening and closing of windows.

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ously, with respect to humidity limits, ANSI/ASHRAE Standard 62 is more restrictive than Standard 55, which does not deal with IAQ nor the impact to building materials or envelopes.

As stated above, the elevated air speed provisions can be applied when using the Computer Model Method.

The Adaptive Method

When Standard 55 added the Optional Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces method (Adaptive Method) found in section 5.3 in the 2004 version, it was the first national or international standard to do so. Subsequently, ISO 7730 and others have likewise offered this important approach to designers. Standard 55-2010 brings no changes to this method. Refinements to this method and its underlying calculation are in progress, and will soon be published as an Addendum to Standard 55.

As with the 2004 version, this method accommodates the design of naturally ventilated buildings. In these buildings, occupants are comfortable over an even wider range of thermal conditions than can be predicted by chamber studies or field studies of occupants of climate-controlled buildings. This method recognizes the role not only of adaptivity but of self-mitigating strategies such as opening user-accessible windows.

While the elevated air speed provisions do not apply to the Adaptive Method, Standing Standards Project Committee 55 has processed forthcoming changes to the Adaptive Method to introduce these provisions within the Adaptive Method.

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What All This Means for Practitioners

Users of the standard who take the time to fully understand, appreciate, and properly apply the 2010 changes will be able to propose dramatically different systems from their competitors. The elevated air speed provisions include attendant restrictions and requirements. The intent of these requirements is to allow systems that can deliver dramatic reductions in gross cooling requirements and associated energy consumption in exchange for modest local fan energy penalties.[2]

Choosing the best of the three available compliance paths for the project at hand is essential; fluency with the Computer Model Method is increasingly important on complex or high performance projects. The changes empower designers and operators alike to implement an important high performance building precept: there is more than just one way to provide for occupant comfort, and it need not be as energy intensive as previously required.

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1. Spengler, J.D., J.M. Samet, J.F. McCarthy. 2000. *Indoor Air Quality Handbook.* N.Y.: McGraw-Hill Professional.

2. Arens, E., et al. 2009. "Moving air for comfort." *ASHRAE Journal* 51(5).