ADDENDA

ASHRAE

ANSI/ASHRAE Addenda i, k, l, m, n, and r to
ANSI/ASHRAE Standard 55-2010

Thermal Environmental Conditions for Human Occupancy

Approved by the ASHRAE Standards Committee on June 22, 2013; by the ASHRAE Board of Directors on June 26, 2013; and by the American National Standards Institute on June 27, 2013.

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FOREWORD

This addendum clarifies calculation of the cooling effect of air movement by moving informative text to an informative appendix and by stating requirements more clearly in normative language. A new definition of "average air speed" is added to clarify that calculations shall use a time and spatial averaged air speed.

Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum i to Standard 55-2010

Add new definition to Section 3 as shown.

3. DEFINITIONS

air speed, average: the combined air speed determining the occupant's heat balance; the average of measurements taken at three prescribed heights at the location of the *representative occupant*, with each measurement time-averaged as described in Section 5.5.

Revise Section 5.2.3 as shown. Note that this section is numbered 5.2.3 in the published standard; if Addendum g is published, it renumbers this section as 5.3.3. The reference to 5.2.1 below references the Operative Temperature section of the currently published standard, which will change to 5.3.1 if Addendum g is published.

5.2.3 Elevated Air Speed. ~~This standard allows elevated air speed to be used to increase the maximum operative temperature for acceptability under certain conditions. Limits are imposed depending on environmental and personal factors and whether the occupants have local control of air speed.~~ This section is permitted to be used to increase the maximum allowable operative temperature and maximum allowable average air speed determined from Section 5.2.1, provided that the conditions described in Sections 5.2.3.1 and 5.2.3.2 are met. Average air speed is specified in Section 5.4.

The Standard Effective Temperature (SET) model is used to evaluate all cases of comfort under elevated air speed. Figure 5.2.3a represents two particular cases of equal skin heat loss contours computed by the SET model.

Note: The SET model is available on the *ASHRAE Thermal Comfort Tool* CD[4], as described in Informative Appendix F of this standard. Any other codings of the SET model must be validated against this code.

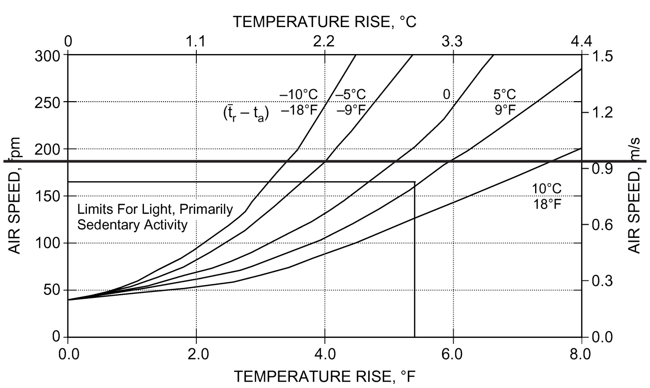
Note: The flowchart in Figure 5.2.3b describes the steps for determining comfort under elevated air speed.

~~**5.2.3.1 Graphical Elevated Air Speed Method.** The amount that the temperature may be increased is shown in Figure 5.2.3.1. The combinations of air speed and temperature defined by the lines in this figure result in equal levels of heat loss from the skin. The reference point for these curves is the upper air-speed limit of the PMV-defined comfort zone, 0.20 m/s (40 fpm), as described in Section 5.2.1.2. The figure applies to a lightly clothed person (with clothing insulation between 0.5 clo and 0.7 clo) who is engaged in near sedentary physical activity (with metabolic rates between 1.0 met and 1.3 met). The curves are generated by the SET thermophysiological model described in Section 5.2.3.2.~~

~~The indicated increase in temperature pertains to both the mean radiant temperature and the air temperature. That is, both temperatures increase by the same amount with respect to the starting point. When the mean radiant temperature is low and the air temperature is high, elevated air speed is less effective at increasing heat loss. Conversely, elevated air speed is more effective at increasing heat loss when the mean radiant temperature is high and the air temperature is low. Thus, the curve in Figure 5.2.3.1 that corresponds to the relative difference between air temperature and mean radiant temperature must be used. It is acceptable to interpolate between curves for intermediate differences.~~

~~Under the Graphical Elevated Air Speed Method, the required air speed for light, primarily sedentary activities may not be higher than 0.8 m/s (160 ft/min)—although higher air speeds are acceptable when using the SET Method in Section 5.2.3.2. Any benefits gained by increasing air speed depend on clothing and activity. Due to increases in skin wettedness, the effect of increased air speed is greater with elevated activity than with sedentary activity. Due to increased amounts of exposed skin, the effect of increased air speed is greater with lighter clothing. Thus, Figure 5.2.3.1 is conservative for activity levels above 1.3 met and/or for clothing insulation less than 0.5 clo and may be applied in these circumstances.~~

~~Due to increased body coverage, the effect of increased air speed is less with higher levels of clothing insulation. Thus, Figure 5.2.3.1 will underestimate the required air speed for clothing insulation greater than 0.7 clo and shall not be applied in these circumstances.~~



~~**Figure 5.2.3.1 Air speed required to offset increased air and radiant temperature.**~~

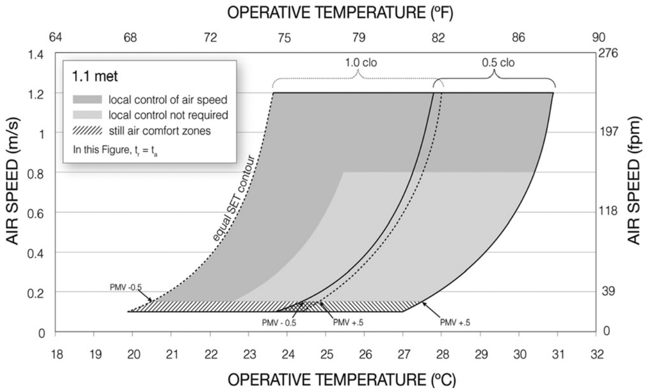


Figure 5.2.3.~~2~~a Acceptable ranges of operative temperature and air speeds for the 1.0 clo and 0.5 clo comfort zones presented~~shown~~ in Figure 5.2.1.1, at humidity ratio 0.010.

~~**5.2.3.2 SET Method.** Figure 5.2.3. 2~~ 1 ~~represents a particular case of equal skin heat loss contours created by the Standard Effective Temperature (SET) model. The model, however, is not restricted to this particular case and it is acceptable to use it to determine the comfort zone for a broad range of applications.~~

~~The SET model uses a thermophysiological simulation of the human body to reduce any combination of real environmental and personal variables into the temperature of an imaginary standard environment in which the occupant's skin heat loss is equal to that of the person in the actual environment. This model enables air velocity effects on thermal comfort to be related across a wide range of air temperatures, radiant temperatures, and humidity ratios.~~

~~Figure 5.2.3.2 uses SET to extend the Figure 5.2.1.1 comfort zones across a range of air speeds for the example humidity ratio of 0.010. Figure 5.2.1.1 is based on PMV calculated for 0.1 m/s air speed (20 fpm). The extension in Figure~~

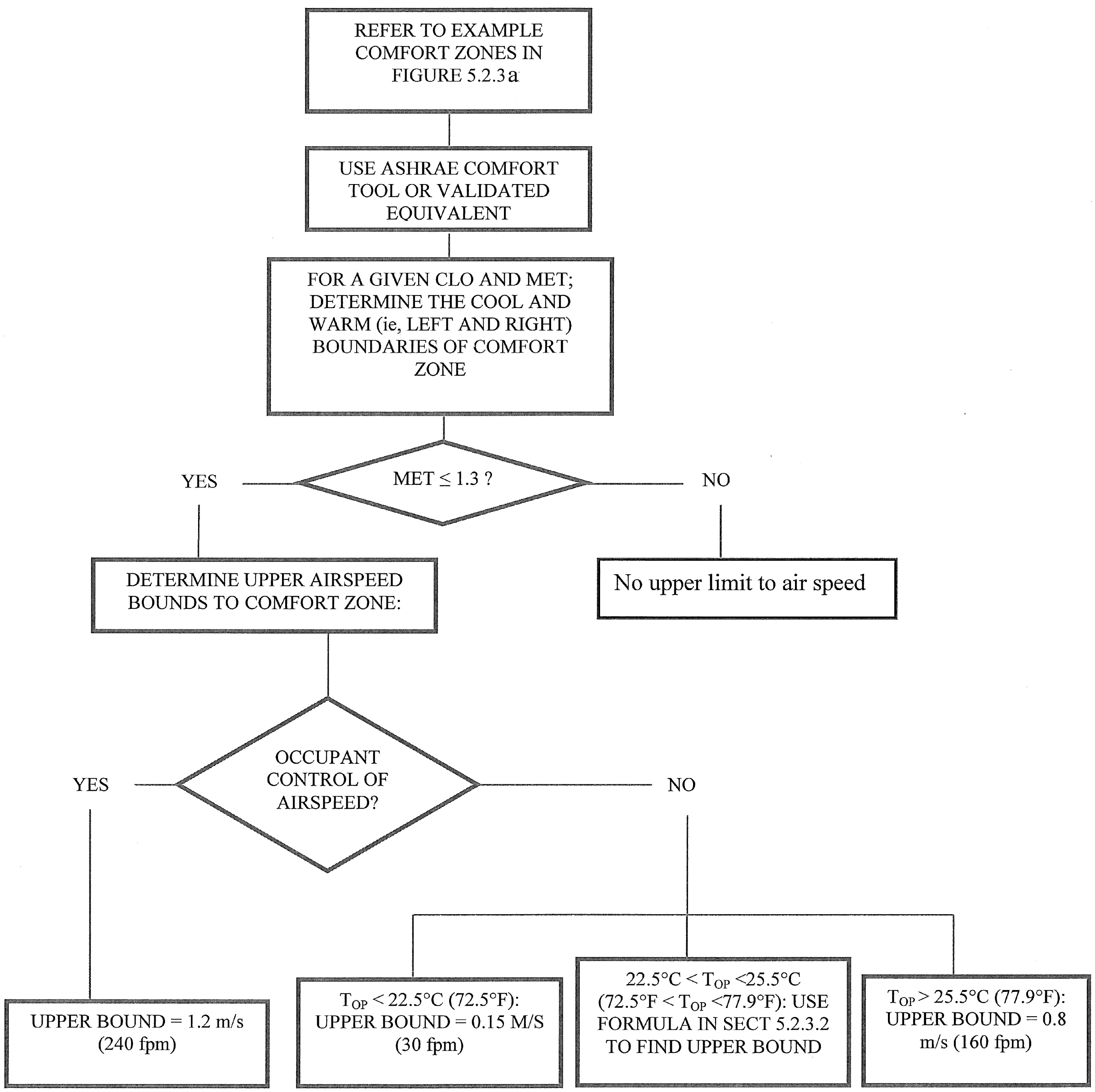


Figure 5.2.3b Flowchart for Determining Comfort Zone under Elevated Air Speed

~~5.2.3.2 was created in two steps. The PMV model was first used to calculate the operative temperature range of ±0.5 PMV at 0.15 m/s (30 fpm) in order to define the upper PMV comfort zone boundary, as specified in Section 5.2.3.1. After this boundary was defined, the curving comfort envelope boundaries above 0.15 m/s (30 fpm) were then defined by constant SET. The SET lines indicate temperature/air-speed combinations at which skin heat loss is the same as at the 0.15 m/s (30 fpm) PMV comfort zone boundary.~~

~~***Note:*** The SET model is available in the ASHRAE *Thermal Comfort Tool CD*[4], as described in the Informative Appendix F of this standard.~~

5.2.3.~~3~~.1 Limits to Average Air Speed ~~W~~with ~~Local~~ Occupant Control. The full bounded area for a given clothing level in Figure 5.2.3a~~.2~~ is acceptable when control of local air speed is provided to occupants. ~~contains heat losses equal to those of the underlying PMV zone. The full bounded area applies when control of local air speed is provided to occupants. For control over their local air speed,~~ Such control shall be directly accessible to occupants ~~must~~ and be provided either (a) for every six occupants or less or (b) for every 84 square meters (900 square feet) or less.

Exception: In multi-occupant spaces where groups gather for shared activities, such as classrooms and conference rooms, at least one control shall be provided for each space, regardless of size. Multi-occupant spaces that can be subdivided by moveable walls shall have one control for each space subdivision.

The ~~range of~~ air speed control ~~shall encompass air speeds suitable for sedentary occupants. The air speed should~~ must extend to still air as measured at the occupant's location and be adjustable continuously or in maximum steps of 0.25 m/s (50 fpm) as measured at the occupant's location.

Exception: Above activity levels of 1.3 met, the 1.2 m/s (240 fpm) limit does not apply.

5.2.3.~~3~~.2 Limits to Air Speed ~~W~~without ~~Local~~ Occupant Control. ~~Within the equal-heat-loss envelope, if occupants do not have control over the local air speed in their space, limits apply, as shown by the light gray area in Figure 5.2.3.2.~~ If occupants do not have control over the local air speed meeting the requirements of Section 5.2.3.1, limits apply, as shown by the light gray area in Figure 5.2.3a and described below.

- For operative temperatures above 25.5°C (77.9°F), the upper limit to average air speed shall be 0.8 m/s (160 fpm). ~~for light, primarily sedentary office activities, such as in offices~~
- For operative temperatures below 22.5°C (72.5°F), the limit to average air speed shall be 0.15 m/s (30 ft/min) ~~in order to avoid local cold discomfort due to draft~~.
- For operative temperatures between 22.5°C and 25.5°C (72.5°F and 77.9°F), the ~~allowable~~ upper limit to average air speed shall follow the curve shown between the dark and light shaded areas in Figure 5.2.3a~~.2~~. ~~This curve is an equal-SET curve for 0.6 clo and 1.1 met.~~ It is acceptable to approximate the curve in SI and I-P units by the following equation:

$$V = 50.49 - 4.4047\, t_a + 0.096425(t_a)^2 \qquad \text{(m/s, °C)}$$

$$V = 31375.7 - 857.295\, t_a + 5.86288(t_a)^2 \qquad \text{(fpm, °F)}$$

~~The curves in Figure 5.2.3.2 shift toward the left or right as the clo or met level changes. An increase of 0.1 clo or 0.1 met corresponds to 0.8°C (1.4°F) or 0.5°C (0.9°F) operative temperature reduction; a decrease of 0.1 clo or 0.1 met corresponds to 0.8°C (1.4°F) or 0.5°C (0.9°F) operative temperature increase.~~

Exception: Above activity levels of 1.3 met, the limits in Section 5.2.3.2 do not apply.

Revise Informative Appendix F as shown.

INFORMATIVE APPENDIX F— PROCEDURE FOR EVALUATING COOLING EFFECT OF ELEVATED AIR SPEED USING SET

The cooling effect of elevated air speed as specified in Section 5.4 in warmer thermal environments at various combinations of metabolism and convective, radiant, and evaporative heat exchange can be estimated using the calculated difference in SET. The 2009 *ASHRAE Handbook—Fundamentals* defines SET as the equivalent air temperature of an isothermal environment at 50% RH in which a subject, wearing clothing standardized for the activity concerned, has the same heat stress (skin temperature) and thermoregulatory strain (skin wettedness) as in the actual environment.

SET is calculated by a thermophysiological simulation of the human body. The SET model reduces any combination of real environmental and personal variables into the temperature of the imaginary standard environment. The standard environment enables air velocity effects on thermal comfort to be related across a wide range of air temperatures, radiant temperatures, and humidity ratios.

The cooling effect of a given air speed may be ~~The~~ calculated using the following steps. ~~values of~~ SET values may ~~can~~ be obtained using the *ASHRAE Thermal Comfort Tool* or similar software.

1. Enter the air temperature, radiant temperature, relative humidity, clo value, and met rate.
2. Set your elevated air velocity in the range from above 0.15 to 3 m/s.
3. Note the calculated value for SET in the output data.
4. Reduce the air speed to 0.15 m/s.
5. The SET will be different from the previous value.
6. Calculate the difference between the two SET values.
7. This difference is the cooling effect of the elevated air speed.

The resulting temperature difference calculated in Step 6, the change in SET from increasing the air speed above 0.15 m/s, is the extent to which operative temperatures determined by PMV-PPD calculations can be increased with elevated air speed. This approach can be used where humidity or clo levels are not addressed by Figure 5.2.3.1. Occupants of a space may be subjected to significant heat stress if air movement is curtailed when temperature and humidity are high.

Example:

Input settings at elevated air speed:

Air *T*	**MRT**	**Air V**	**RH**	**Season**	**Met**	**Clo**
28	28	1.0	50	Summer	1.3	0.8
SET = 27.5, slightly uncomfortable						

Input settings at reduced air speed:

Air *T*	**MRT**	**Air V**	**RH**	**Season**	**Met**	**Clo**
28	28	0.15	50	Summer	1.3	0.8
SET= 29.9, slightly uncomfortable						

Cooling effect of the elevated air speed:

Difference 29.9 – 27.5 = 2.4°C

The above steps are also performed automatically by *ASHRAE Thermal Comfort Tool* (or validated equivalent) to provide the PMV value for any combination of environmental and personal variables and to indicate whether that combination is within the comfort zone or not.

If *ASHRAE Thermal Comfort Tool* is not available, it is possible to approximate the effect of clothing or activity changes as follows: the outer boundary curves in Figure 5.2.3a shift toward the left or right depending on clo and met levels. An increase of 0.1 clo or 0.1 met corresponds approximately to a 0.8°C or 0.5°C (1.4°F or 0.9°F) reduction in operative temperature; a decrease of 0.1 clo or 0.1 met corresponds approximately to a 0.8°C or 0.5°C (1.4°F or 0.9°F) increase in operative temperature.

Average Air Speed: the averaging may be weighted by the designer to account for the following. The SET thermophysiological model described in Section 5.2.3 is based on the assumption that the body is exposed to a uniform air speed. However, spaces with passive or active systems that provide strongly nonuniform air velocity fields cause skin heat losses that cannot be simply related to those of uniform velocity fields. Therefore, the designer shall decide the proper averaging for air speed for use in the Graphical Method (Figure 5.2.3a). The proper averaging shall include air speeds incident on unclothed body parts (e.g., head) that have greater cooling effect and potential for local discomfort than unclothed parts.

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FOREWORD

This addendum adds a new method for the calculation of the clothing insulation using a predictive model of clothing insulation based on outdoor air temperature. This model can be used to predict clothing levels at design conditions, to generate clothing inputs for dynamic annual comfort simulations, or as an input for comfort control systems. The method is based on the work described in the following references:

- *Schiavon, S., and K.H. Lee. 2013. Dynamic predictive clothing insulation models based on outdoor air and indoor operative temperatures.* Building and Environment *59:250–60. http://dx.doi.org/10.1016/j.buildenv.2012.08.024 (link to the journal); http://escholarship.org/uc/item/3338m9qf (link to the freely available preprint version)*
- *Lee, K.H., and S. Schiavon. 2013. Influence of three dynamic predictive clothing insulation models on building energy use, HVAC sizing and thermal comfort. Submitted to* Energy and Buildings*. http://escholarship.org/uc/item/3sx6n876 (link to the freely available preprint version)*

Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum k to Standard 55-2010

Revise Section 5.2.2.2 as shown. Section 5.2.2, Clothing Insulation, was added by Addendum h to Standard 55-2010 and is currently published for free on the ASHRAE website at www.ashrae.org/standards-research--technology/standards-addenda.

5.2.2.2 Insulation Determination. Use one or a combination of the following methods to determine clothing insulation.

a. The data presented in Table 5.2.2.2A for the expected ensemble of each representative occupant.

b. Add or subtract the insulation (I_{clu}) of individual garments in Table 5.2.2.2B from the ensembles in Table 5.2.2.2A to determine the insulation of ensembles not listed.

c. Determine a complete clothing ensemble using the sum of the individual values listed for each item of clothing in the ensemble in Table 5.2.2.2B.

d. It is permitted, but not required, to adjust any of the above methods for seated occupants using Table 5.2.2.2C.

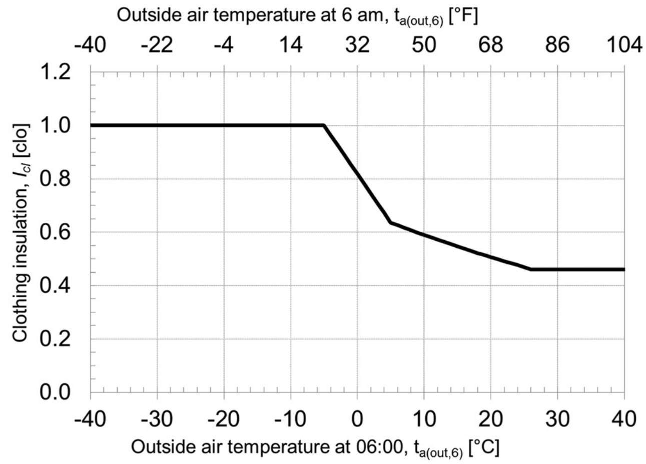


Figure 5.2.2.2 Representative clothing insulation as a function of outdoor air temperature at 06:00 in morning.

e. For moving occupants it is permitted, but not required, to adjust any of the above methods using the following formula:

$$I_{cl,-active} = I_{cl} \times (0.6 + 0.4 / M) \qquad 1.2 \text{ met} < M < 2.0 \text{ met}$$

where M is the metabolic rate in met units and I_{cl} is the insulation without movement.

f. Interpolate between or extrapolate from the values given in Tables 5.2.2.2B and 5.2.2.2C.

g. Use Figure 5.2.2.2 to determine the clothing insulation of a representative occupant for a day as a function of outdoor air temperature at 06:00 in the morning, $t_{a(out,6)}$~~.~~

Exception: The clothing insulation determined according to Figure 5.2.2.2 may be adjusted to higher or lower values to account for unique dress code or cultural norms using other methods in Section 5.2.2.2 or approved engineering methods.

~~g~~h. Use measurement with thermal manikins or other approved engineering methods.

Revise Informative Appendix B as shown. Informative Appendix B was added by Addendum h to Standard 55-2010 and is currently published for free on the ASHRAE website at www.ashrae.org/standards-research--technology/standards-addenda. The rest of Appendix B remains unchanged.

INFORMATIVE APPENDIX B— CLOTHING INSULATION

The amount of thermal insulation worn by a person has a substantial impact on thermal comfort and is an important variable in applying this standard. Clothing insulation is expressed in a number of ways. In this standard, the clothing insulation of an ensemble expressed as a clo value (I_{cl}) is used. Users not familiar with clothing insulation terminology are referred to Chapter 9 of the 2009 *ASHRAE Handbook—Fundamentals*[3] for more information.

The insulation provided by clothing can be determined by a variety of means, and if accurate data are available from other sources—such as measurement with thermal manikins—these data are acceptable for use. When such information is not available, the tables in this standard may be used to estimate clothing insulation using one of the methods described below. Regardless of the source of the clothing insulation value, this standard is not intended for use with clothing ensembles with more than 1.5 clo of insulation. This standard is not intended for use when occupants wear clothing that is highly impermeable to moisture transport (e.g., chemical protective clothing or rain gear).

~~Three~~ Four methods for estimating clothing insulation are presented. ~~The m~~Methods 1, 2, and 3 are listed in order of accuracy. The tables used in the standard are derived from Chapter 9 of the 2009 *ASHRAE Handbook—Fundamentals.*

- **Method 1:** Table 5.2.2.2A lists the insulation provided by a variety of common clothing ensembles. If the ensemble in question matches reasonably well with one of the ensembles in this table, then the indicated value of I_{cl} should be used.
- **Method 2:** Table 5.2.2.2B presents the thermal insulation of a variety of individual garments. It is acceptable to add or subtract these garments from the ensembles in Table 5.2.2.2A to estimate the insulation of ensembles that differ in garment composition from those in Table 5.2.2.2A. For example, if long underwear bottoms are added to Ensemble 5 in Table 5.2.2.2A, the insulation of the resulting ensemble is estimated as

$$I_{cl} = 1.01 + 0.15 = 1.16 \text{ clo}$$

- **Method 3:** It is acceptable to define a complete clothing ensemble using a combination of the garments listed in Table 5.2.2.2B. The insulation of the ensemble is estimated as the sum of the individual values listed in Table 5.2.2.2B. For example, the estimated insulation of an ensemble consisting of overalls worn with a flannel shirt, T-shirt, briefs, boots, and calf-length socks is

$$I_{cl} = 0.30 + 0.34 + 0.08 + 0.04 + 0.10 + 0.03 = 0.89 \text{ clo}$$

- **Method 4:** It is acceptable to determine the clothing insulation with Figure 5.2.2.2 in mechanically conditioned buildings. When people select their clothing as a function of outdoor and indoor climate variables, the most influential variable is outdoor air temperature. Figure 5.2.2.2 can be used to calculate the clothing insulation for each day of the year or for representative days. The curve in Figure 5.2.2.2 is an approximation for typical (or average) clothing. The model is based on field study and may not be appropriate for all cultures and occupancy types. The model represented in Figure 5.2.2.2 is suited to be implemented in building performance simulation software or building control systems. The model graphed in Figure 5.2.2.2 is described by the following equations:

For $t_{a(out,6)} \le -5°C$	$I_{cl} = 1.00$
For $-5°C \le t_{a(out,6)} \le 5°C$	$I_{cl} = 0.818 - 0.0364 * t_{a(out,6)}$
For $5°C \le t_{a(out,6)} \le 26°C$	$I_{cl} = 10^{(-0.1635 - 0.0066 * ta(out,6))}$
or $t_{a(out,6)} \ge 26°C$	$I_{cl} = 0.46$

For $t_{a(out,6)} \le 23°F$	$I_{cl} = 1.00$
For $23°F \le t_{a(out,6)} \le 41°F$	$I_{cl} = 1.465 - 0.0202 \times t_{a(out,6)}$
For $41°F \le t_{a(out,6)} \le 78.8°F$	$I_{cl} = 10^{(-0.0460 - 0.00367 \times ta(out,6))}$
or $t_{a(out,6)} \ge 78.8°F$	$I_{cl} = 0.46$

....

Add the following to Informative Appendix H, Bibliography.

Schiavon, S., and K.H. Lee. 2013. Dynamic predictive clothing insulation models based on outdoor air and indoor operative temperatures. *Building and Environment* 59:250–60.

Lee, K.H., and S. Schiavon. 2013. Influence of three dynamic predictive clothing insulation models on building energy use, HVAC sizing and thermal comfort. Submitted to *Energy and Buildings.*

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

This addendum renames Section 6 from "Compliance" to "Design Compliance" to clarify that Section 6 covers design requirements and documentation, in contrast to Section 7 that covers evaluation of existing spaces. The addendum also removes informative language and clarifies the existing requirements in Section 6.

Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum l to Standard 55-2010

Revise Section 6 as shown. Section 6.1 was modified by Addendum e to Standard 55-2010 and is currently published and posted for free on the ASHRAE website at www.ashrae.org/standards-research--technology/standards-addenda.

6. DESIGN COMPLIANCE

6.1 Design. Building systems (i.e., combinations of mechanical systems, control systems, and thermal ~~envelopes~~ enclosures) shall be designed so that at outdoor and indoor design conditions they are able to maintain the occupied space(s) at indoor ~~design~~ thermal conditions specified by one of the methods in this standard. ~~This standard does not include specific guidance regarding mechanical systems, control systems, or the thermal envelopes for spaces as part of its scope.~~

~~In addition, t~~The ~~mechanical~~ building systems~~, control systems, and thermal envelopes~~ shall be designed so that they are able to maintain the occupied space(s) at the internal thermal conditions within the range specified in this standard ~~at all combinations~~ and within the range of expected operating conditions (indoor and outdoor). ~~that are expected to occur, with the exception of extreme conditions. The expected conditions shall include variations in both internal loads and the external environment. The system shall have controls that enable it to meet comfort requirements at less than full system capacity.~~

~~Because of differences in metabolic rates between individuals and the resultant differences in response to the environment, actual operating building temperatures cannot be specified in this standard.~~

6.2 Documentation. The method and design conditions appropriate for the intended use of the building shall be selected and documented as follows.

Note: Some of the requirements in items 1–~~4~~ 6 below may not be applicable to naturally conditioned buildings.

1. The method of design compliance shall be stated for each space and/or system: Graphic Comfort Zone Method, Analytical Comfort Zone Method, or the use of Section 5.4 for Naturally Conditioned Spaces.

2~~1~~. The design operative temperature and humidity (including any tolerance or range), the design outdoor conditions (see ~~2009~~ *ASHRAE Handbook—Fundamentals*,[3] Chapter ~~14,~~"Climatic Design Information"), and total indoor loads shall be stated. The design exceedance level (the number of hours per year where conditions exceed Section 5 criteria) shall be documented based on the design conditions used. ~~in design. At a minimum, the hours of each seasonal exceedance associated with the outdoor weather percent design conditions (see 2009 ASHRAE Handbook—Fundamentals,3 Chapter 14) used in design shall be stated. In complex and/or passive systems, hours of exceedance may need to be calculated using a dynamic thermal simulation that predicts indoor conditions for every hour of the year.~~

3~~2~~. Values assumed for comfort parameters used in the calculation of thermal conditions including ~~design *temperatures*~~ *operative temperature*, humidity, average air speed, ~~including~~ clothing, and metabolic rate, ~~and indoor-air speed,~~ shall be ~~clearly~~ stated for heating and cooling design conditions. ~~The clo level for the clothing of occupants intended to be satisfied shall be documented, including different clo levels for different seasons. The metabolic rate of occupants intended to be satisfied shall be documented. Where different clo levels or metabolic rates are anticipated in different spaces or at different times, these assumptions shall be documented.~~ If an acceptable level of comfort is not being provided to any representative occupants, this shall be stated ~~in the design documentation~~. Where Table 5.2.1.2 gives a range, the basis for ~~record the basis for~~ selecting a single value within that range shall be stated. If the clothing or metabolic rate parameters for a given space are outside the applicable bounds defined by the standard or if the space is not regularly occupied as defined in Section 2.3, the space shall be clearly identified as not under the scope of the standard.

4~~3~~. ~~Local discomfort effects are difficult to calculate due to limitations in thermal modeling tools, but can be estimated with simplified assumptions.~~ Local discomfort shall be addressed by, at a minimum, a narrative explanation of why an effect is not likely to exceed Section 5 limits. Where calculations are utilized to determine the effect of local thermal discomfort in accordance with Section 5, the calculation inputs, methods, and results shall be stated. ~~When a design has asymmetric thermal conditions (e.g., radiant heating/cooling, areas of glazing that are above 50% window-to-wall ratio, additional air movement, stratified displacement cooling), a calculation of related local discomfort effects shall be included. At a minimum, documentation shall identify the design condition analyzed for each local discomfort effect and any simplifying assumptions used in the calculation.~~

5~~4~~. ~~The system input or output capacities necessary to attain the design indoor thermal comfort conditions stated in~~

~~Item 1 above at design outdoor conditions shall be stated.~~ System equipment capacity shall be provided for each space and/or system documenting performance meeting the design criteria stated. For each unique space, the design system or equipment heating and/or cooling capacity shall meet the thermal loads calculated under the heating and cooling design conditions stated for compliance with this standard.

6. Where elevated air speed with occupant control is employed to provide acceptable thermal conditions, documentation shall be provided to identify the method and equipment for occupant control.

Note: See Informative Appendix G for sample compliance documentation.

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

This addendum separates normative from informative text in the portions of Section 5, Conditions that Provide Thermal Comfort, that describe the analytical and graphic methods.

Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum m to Standard 55-2010

Add the following to Section 5.1, General Requirements. This section was modified by Addendum d to Standard 55-2010 and is currently published and posted for free on the ASHRAE website at www.ashrae.org/standards-research--technology/standards -addenda.

5.1 General Requirements. Section 5 of this standard shall be used to determine the acceptable thermal environmental conditions for each representative occupant of a space. The percentage of occupants of the space who are predicted to find it acceptable shall be specified. Determine operative temperature in accordance with Normative Appendix C.

Modify Section 5.3 as follows. This section is numbered 5.2 in the published standard; if Addendum g is published, it renumbers this section as 5.3, as shown below. References to Section 5.3.3 are to the section entitled Elevated Air Speed. The numbering and content of that section may be changed by other addenda that are published. Section 5.2.1.1 was modified by Addendum b to Standard 55-2010, currently published and posted for free on the ASHRAE website at www.ashrae.org/standards-research--technology/standards-addenda. The references to Sections 5.3.4 and 5.3.5 are to the Local Thermal Discomfort and Temperature Variations with Time sections, respectively.

5.3 General Method for Determining Acceptable Thermal Conditions in Occupied Spaces. ~~When~~ Section 5.3 is permitted to be used to determine the requirements for thermal comfort in all occupied spaces within the scope of this standard.~~,~~ ~~t~~The requirements of ~~all~~ subsections ~~5.3.1, 5.3.2, 5.3.3, 5.3.4, and 5.3.5~~ 5.3.1 or 5.3.2; 5.3.4; and 5.3.5 must be met. ~~This standard recommends a specific percentage of occupants that constitutes acceptability and values of the thermal environment associated with this percentage~~.

~~**5.3.1 Operative Temperature.** For given values of humidity, air speed, metabolic rate, and clothing insulation, a comfort zone may be determined. The comfort zone is defined in terms of a range of operative temperatures that provide acceptable thermal environmental conditions or in terms of the combinations of air temperature and mean radiant temperature that people find thermally acceptable.~~

~~This section describes methods that are acceptable for use in determining temperature limits for the comfort zone. Section 5.3.1.1 uses a simplified Graphical Method for determining the comfort zone that is acceptable for use for many typical applications. Section 5.3.1.2 uses a computer program based on a heat balance model to determine the comfort zone for a wider range of applications. For a given set of conditions, the results from the two methods are consistent, and either method is acceptable for use as long as the criteria outlined in the respective section are met.~~

~~Determine operative temperature in accordance with See Informative Normative Appendix C or the 2009 *ASHRAE Handbook—Fundamentals*,[3] Chapter "*Thermal Comfort*" 9, for procedures to calculate operative temperature. It is permissible to use dry-bulb temperature as a proxy for operative temperature under certain conditions described in Appendix C.~~

5.3.1.~~1~~ Graphic Comfort Zone Method~~ for Typical Indoor Environments~~.

Applicability: Use of this method shall be limited to *representative occupants* with metabolic rates between 1.0 and 1.3 met, and clothing insulation between 0.5 and 1.0 clo.~~,~~ ~~in spaces with~~ Average air speeds ~~less~~ greater than 0.2 m/s (40 ft/min) require the use of Section 5.3.3.

The Graphic Comfort Zone is limited to a humidity ratio at or below 0.012 kg H_2O/kg dry air (0.012 lb H_2O/lb dry air), which corresponds to a water vapor pressure of 1.910 kPa (0.277 psi) at standard pressure or a dew-point temperature of 16.8°C (62.2°F).

Methodology: Figure 5.3.1.~~1~~ specifies the *comfort zone* for environments that meet the above criteria. Two zones are shown—one for 0.5 clo of clothing insulation and one for 1.0 clo of insulation.

~~(***Note:*** These insulation levels are typical of clothing worn when the outdoor environment is warm and cool, respectively.)~~

Comfort zones for intermediate values of clothing insulation shall be determined by linear interpolation between the limits for 0.5 and 1.0 clo, using the following relationships:

$$T_{min,\,Icl} = [(I_{cl} - 0.5\text{ clo})\,T_{min,\,1.0\,clo} + (1.0\text{ clo} - I_{cl})\,T_{min,\,0.5clo}] / 0.5\text{ clo}$$

$$T_{max,\,Icl} = [(I_{cl} - 0.5\text{ clo})\,T_{max,\,1.0\,clo} + (1.0\text{ clo} - I_{cl})\,T_{max,\,0.5clo}] / 0.5\text{ clo}$$

where

$T_{max,\,Icl}$ = upper operative temperature limit for clothing insulation I_{cl},

$T_{min,\,Icl}$ = lower operative temperature limit for clothing insulation I_{cl}, and

I_{cl} = thermal insulation of the clothing in question, clo.

Elevated air speeds increase the upper operative temperature limit for the comfort zone~~ if the criteria~~ in accordance with Section 5.3.3~~ are met~~.

Replace the current Figure 5.3.1 (I-P and SI) with the versions following. The notes have been updated to reflect the changes in the section numbering.

(a)

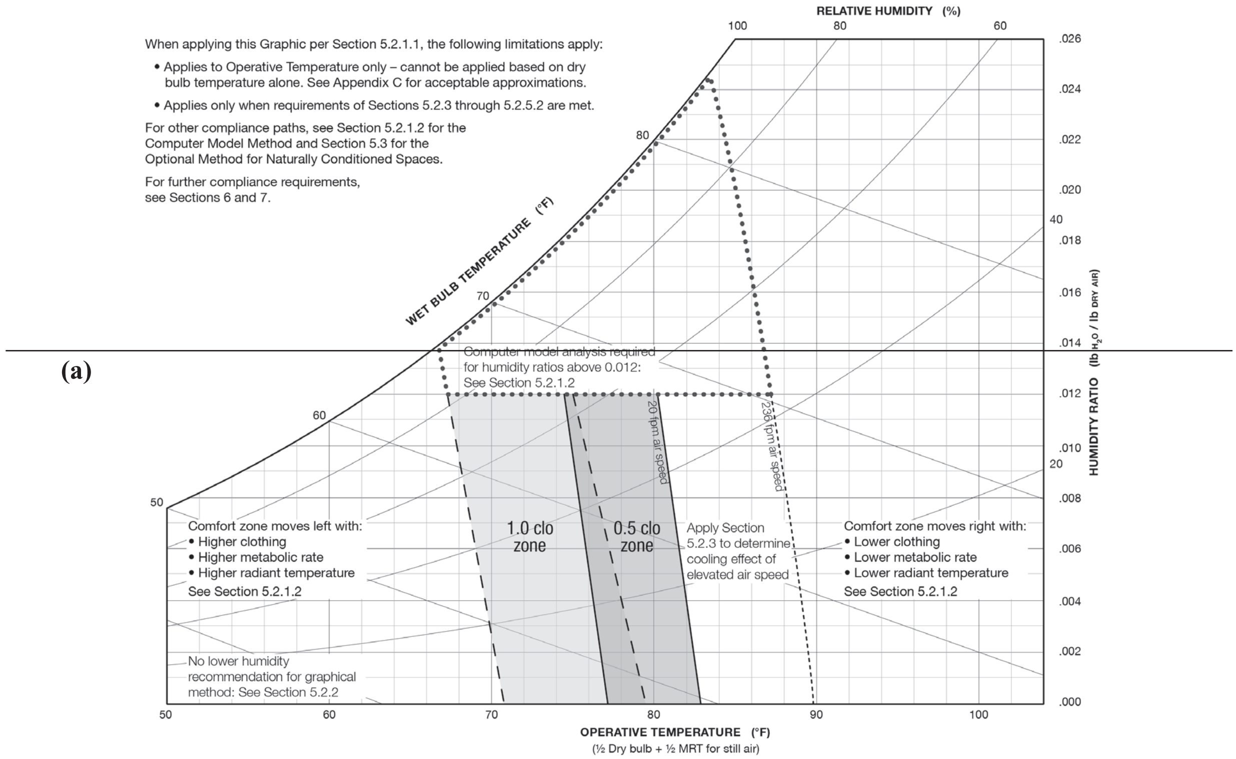


Figure 5.2.1.1 (IP) Acceptable range of operative temperature and humidity for spaces that meet the criteria specified in Section 5.2.1.1.
1.1 met, 0.5 & 1.0 clo

(b)

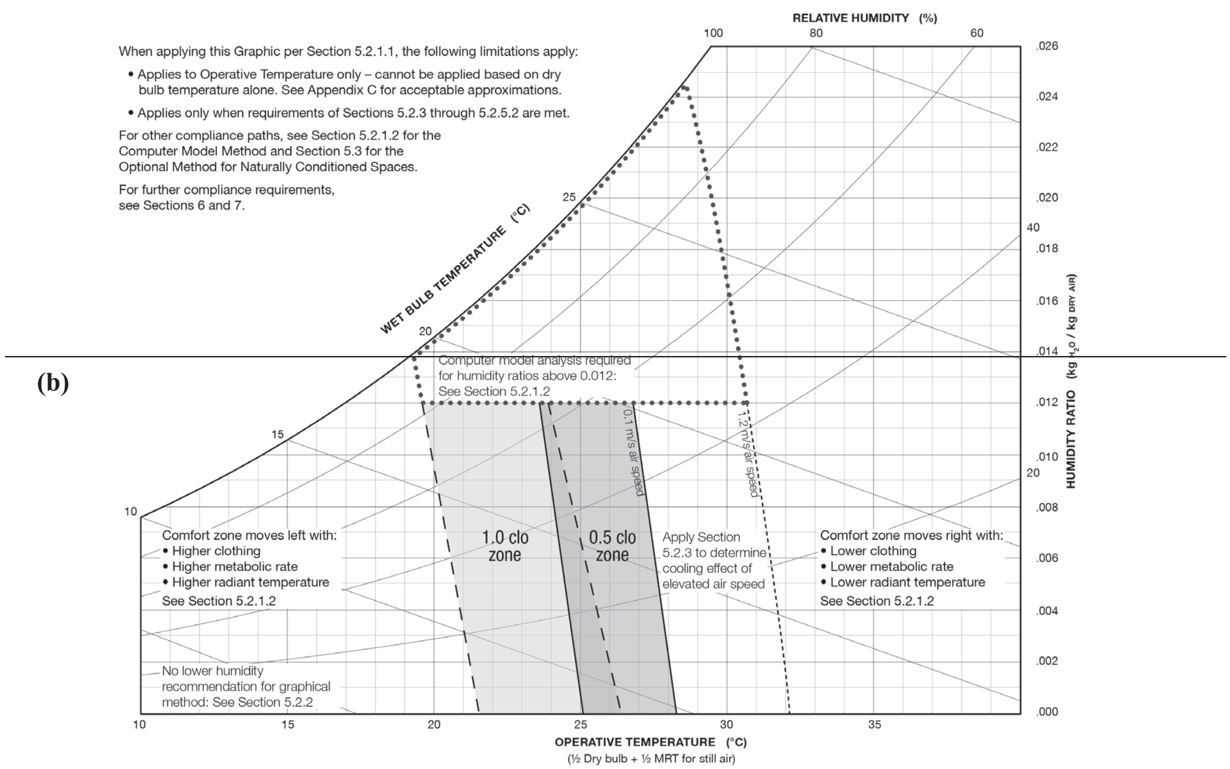
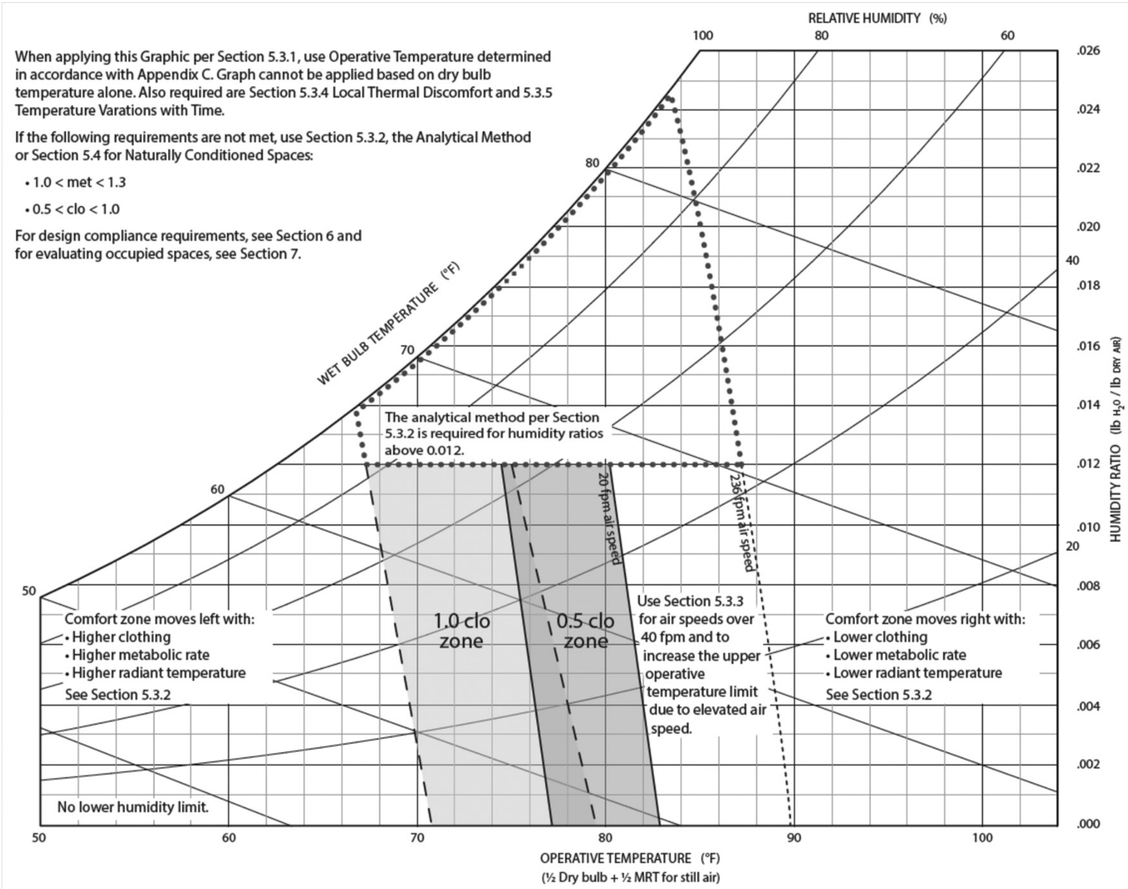


Figure 5.2.1.1 (SI) Acceptable range of operative temperature and humidity for spaces that meet the criteria specified in Section 5.2.1.1.
1.1 met, 0.5 & 1.0 clo

~~Figure 5.2.1.1 Graphic Comfort Zone Method: Acceptable range of operative temperature and humidity for spaces that meet the criteria specified in Section 5.2.1.1 (1.1 met; 0.5 and 1.0 clo)—(a) I-P and (b) SI.~~

(a)



(b)

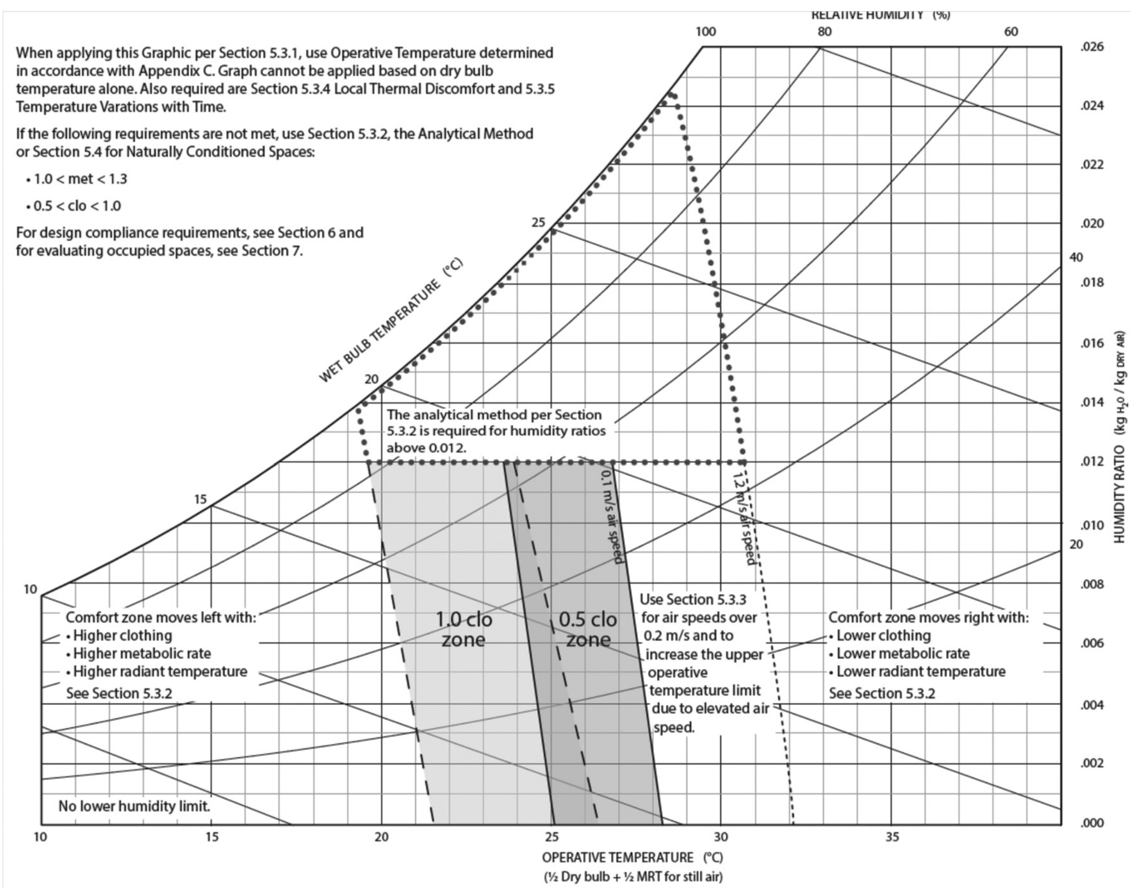


Figure 5.3.~~2.1.~~1 Graphic Comfort Zone Method: Acceptable range of operative temperature and humidity for spaces that meet the criteria specified in Section 5.3.1.~~1~~ (1.~~1~~0 ≤ met ≤ 1.3; 0.5 ~~and~~ ≤ clo ≤ 1.0 ~~clo~~)—(a) I-P and (b) SI.

Modify Section 5.3.2 as follows.

5.3.2 ~~Computer Model~~ Analytical Comfort Zone Method ~~for General Indoor Application~~.

Applicability: It is permissible to apply the method in this section to all spaces within the scope of this standard where the occupants have activity levels that result in average metabolic rates between 1.0 and 2.0 met ~~and where clothing is worn that provides 1.5 clo or less of thermal insulation~~.

~~The ASHRAE thermal sensation scale, which was developed for use in quantifying people's thermal sensation, is defined as follows:~~

~~+3 hot~~
~~+2 warm~~
~~+1 slightly warm~~
~~0 neutral~~
~~–1 slightly cool~~
~~–2 cool~~
~~–3 cold~~

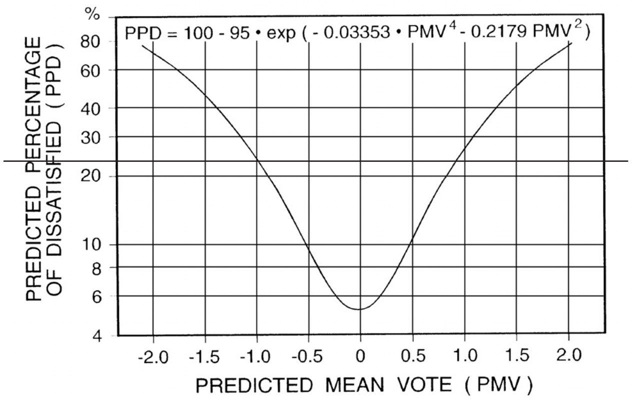
~~The predicted mean vote (PMV) model uses heat balance principles to relate the six key factors for thermal comfort listed in Section 5.1 to the average response of people on the above scale. The PPD (predicted percentage of dissatisfied) index is related to the PMV as defined in Figure 5.3.1.2. It is based on the assumption that people voting +2, +3, –2, or –3 on the thermal sensation scale are dissatisfied and on the simplification that PPD is symmetric around a neutral PMV.~~

~~Table 5.3.1.2 defines the recommended PPD and PMV range for typical applications. This is the basis for the Graphical Method in Section 5.3.1.1.~~

~~The comfort zone is defined by the combinations of the six key factors for thermal comfort for which the PMV is within the recommended limits specified in Table 5.3.1.2. The PMV model is calculated with the air temperature and mean radiant temperature in question along with the applicable metabolic rate, clothing insulation, air speed, and humidity. If the resulting PMV value generated by the model is within the recommended range, the conditions are within the comfort zone.~~

~~Use of the PMV model in this standard is limited to air~~ Air speeds greater than ~~below~~ 0.20 m/s (40 fpm)~~. It is acceptable to use air speeds greater than this to increase the upper temperature limits of the comfort zone in certain circumstances.~~ require the use of Section 5.3.3 ~~describes the method and criteria required for such adjustments~~.

Methodology: ~~There are several computer codes available that predict PMV-PPD.~~ The computer code in Normative Appendix D is to be used with this standard.[4] Compliance is achieved if –0.5 < PMV < +0.5. Alternative methods are permitted ~~If any other version is used, it is the user's responsibility to verify and document that the version used~~ if they yield~~s~~ the same results ~~as the code in Appendix D for the conditions for which it is applied~~. *ASHRAE Thermal Comfort Tool*[4] is permitted to be used to comply with this section.



~~**Figure 5.3.2.1 Predicted percentage dissatisfied (PPD) as a function of predicted mean vote (PMV).**~~

~~**TABLE 5.3.1.2 Acceptable Thermal Environment for General Comfort**~~

~~PPD~~	~~PMV Range~~
~~≤10~~	~~–0.5 < PMV < +0.5~~

Delete the current Section 5.3.2 as shown. The material has been relocated in the renumbered Section 5.3.1, Graphic Comfort Zone Method, as shown previously.

~~**5.3.2 Humidity Limits.** When the Graphic Comfort Zone Method in Section 5.3.1.1 is used, systems shall be able to maintain a humidity ratio at or below 0.012, which corresponds to a water vapor pressure of 1.910 kPa (0.277 psi) at standard pressure or a dew-point temperature of 16.8°C (62.2°F).~~

~~There are no established lower humidity limits for thermal comfort; consequently, this standard does not specify a minimum humidity level. ***Note:*** Nonthermal comfort factors, such as skin drying, irritation of mucus membranes, dryness of the eyes, and static electricity generation, may place limits on the acceptability of very low humidity environments.~~

Modify Appendix C as follows and make it Normative.

~~INFORMATIVE~~ NORMATIVE APPENDIX C— METHODS FOR DETERMINING ~~ACCEPTABLE APPROXIMATION FOR~~ OPERATIVE TEMPERATURE

Determine operative temperature in accordance with one of the following cases or the *ASHRAE Handbook—Fundamentals*[3] Chapter "Thermal Comfort".

Case 1: ~~The assumption that operative temperature equals~~ *Average air temperature* is ~~acceptable~~ permitted to be used in place of *operative temperature* when these ~~four~~ three conditions ~~exist~~ are met:

1. There is no radiant and/or radiant panel heating or radiant panel cooling system;

2. The area weighted average U-factor of the outside window/wall ~~is determined by~~ satisfies the following ~~equation~~ inequality:

$$U_W < \frac{50}{t_{d,i} - t_{d,e}} \quad \text{(SI)}$$

$$U_W < \frac{15.8}{t_{t,i} - t_{d,e}} \quad \text{(I-P)}$$

where

U_w = area weighted average U-factor of window/wall, W/m^2·K (Btu/h·ft^2·°F)

$t_{d,i}$ = internal design temperature, °C (°F)

$t_{d,e}$ = external design temperature, °C (°F);

3. Window solar heat gain coefficients (SHGC) are less than 0.48. ~~and~~
4. ~~There is no major heat generating equipment in the space.~~

Case 2: Calculation of the ~~O~~operative ~~T~~temperature is ~~B~~based on ~~A~~air and ~~M~~mean-~~R~~radiant ~~T~~temperature.

~~In most practical cases where the relative air speed is small (< 0.2 m/s, 40 fpm) or where the difference between mean radiant and air temperature is small (< 4°C, 7°F), the operative temperature can be calculated with sufficient approximation as the mean value of air temperature and mean radiant temperature.~~

~~For higher precision and other environments~~ Operative temperature is permitted to be calculated per~~,~~ the following formula ~~may be used~~:

$$t_{op} = A\, t_a + (1 - A)\, \bar{t}_r$$

where

t_{op} = operative temperature,

t_a = air temperature,

$\bar{t}_r$ = mean radiant temperature (for detailed calculation procedures see the most current edition of the *ASHRAE Handbook—Fundamentals*[3] Chapter “Thermal Comfort”). ~~and the value of~~ *A* can be ~~found~~ selected from the values below as a function of the relative air speed, v_r.

v_r	< 0.2 m/s (<40 fpm)	0.2 to 0.6 m/s (40 to 120 fpm)	0.6 to 1.0 m/s (120 to 200 fpm)
A	0.5	0.6	0.7

Case 3: For *representative occupants* with metabolic rates between 1.0 and 1.3 met, not in direct sunlight, when the *average air speed* is < 0.2 m/s (40 fpm) and where the difference between *mean radiant temperature* and *average air temperature* is < 4°C (7°F), the operative temperature is permitted to be calculated as the mean of the *average air temperature* and *mean radiant temperature*.

Add the following new Informative Appendix D, much of which was informative material previously in the body of the standard.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX XXX— ANALYTICAL METHOD FOR DETERMINING THERMAL CONDITIONS IN OCCUPIED SPACES

X1. DETERMINING ACCEPTABLE THERMAL CONDITIONS IN OCCUPIED SPACES

This standard recommends a specific percentage of occupants that constitutes acceptability and values of the thermal environment associated with this percentage.

For given values of humidity, air speed, metabolic rate, and clothing insulation, a comfort zone may be determined. The comfort zone is defined in terms of a range of operative temperatures that provide acceptable thermal environmental conditions or in terms of the combinations of air temperature and mean radiant temperature that people find thermally acceptable.

This standard contains a simplified Graphical Comfort Zone Method for determining the comfort zone that is acceptable for use for many typical applications. A computer program based on a heat balance model will determine the comfort zone for a wider range of applications. For a given set of conditions, the results from the two methods are consistent, and either method is acceptable for use as long as the criteria outlined in the respective section are met.

See Informative Appendix C and the most current edition of the *ASHRAE Handbook—Fundamentals*[3] chapter “Thermal Comfort” for procedures to calculate operative temperature. Dry-bulb temperature is a proxy for operative temperature under certain conditions described in Informative Appendix C.

X2. GRAPHICAL COMFORT ZONE METHOD

Use of this method is limited to representative occupants with metabolic rates between 1.0 and 1.3 met and clothing insulation between 0.5 and 1.0 clo in spaces with air speeds less than 0.2 m/s (40 ft/min).

The figure in the Graphical Comfort Zone Method section shows the comfort zone for environments that meet the above criteria. Two zones are shown—one for 0.5 clo of clothing insulation and one for 1.0 clo of insulation. These insulation levels are typical of clothing worn when the outdoor environment is warm and cool, respectively.

Comfort zones for intermediate values of clothing insulation are determined by linear interpolation between the limits for 0.5 and 1.0 clo, using the relationships shown in this standard.

Elevated air speeds increase the upper operative temperature limit for the comfort zone if the criteria in the elevated air speed section are met.

X3. COMPUTER MODEL METHOD

This method applies to spaces where the occupants have activity levels that result in average metabolic rates between 1.0 and 2.0 met and where clothing is worn that provides 1.5 clo or less of thermal insulation.

The ASHRAE thermal sensation scale, which was developed for use in quantifying people's thermal sensation, is defined as follows:

+3	hot
+2	warm
+1	slightly warm
0	neutral
–1	slightly cool
–2	cool
–3	cold

The predicted mean vote (PMV) model uses heat balance principles to relate the six key factors for thermal comfort to the average response of people on the above scale. The predicted percentage dissatisfied (PPD) index is related to the PMV as defined in Figure XXX. It is based on the assumption that people voting +2, +3, –2, or –3 on the thermal sensation scale are dissatisfied and on the simplification that PPD is symmetric around a neutral PMV.

Table XXX defines the recommended PPD and PMV range for typical applications. This is the basis for the Graphical Comfort Zone Method in the standard.

The comfort zone is defined by the combinations of the six key factors for thermal comfort for which the PMV is within the recommended limits specified in Table XXX. The PMV model is calculated with the air temperature and mean radiant temperature in question along with the applicable metabolic rate, clothing insulation, air speed, and humidity. If the resulting PMV value generated by the model is within the recommended range, the conditions are within the comfort zone.

Use of the PMV model in this standard is limited to air speeds below 0.20 m/s (40 fpm). Air speeds greater than this can increase the upper temperature limits of the comfort zone in certain circumstances. The elevated air speed section describes the method and criteria required for such adjustments.

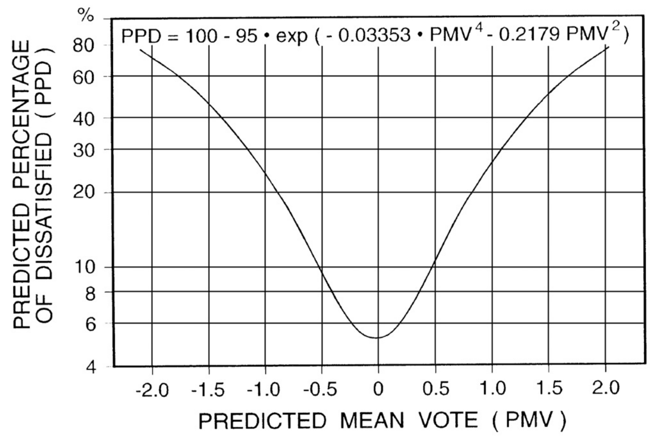


Figure XXX Predicted percentage dissatisfied (PPD) as a function of predicted mean vote (PMV).

TABLE XXX Acceptable Thermal Environment for General Comfort

PPD	PMV Range
<10	–0.5 < PMV < +0.5

There are several computer codes available that predict PMV-PPD. The computer code in Normative Appendix D was developed for use with this standard and is incorporated into *ASHRAE Thermal Comfort Tool*.[4] If any other software is used, it is the user's responsibility to verify and document that the version used yields the same results as the code in Normative Appendix D or *ASHRAE Thermal Comfort Tool* for the conditions for which it is applied.

X4. HUMIDITY LIMITS

When the Graphical Comfort Zone Method is used, systems must be able to maintain a humidity ratio at or below 0.012, which corresponds to a water vapor pressure of 1.910 kPa (0.277 psi) at standard pressure or a dew-point temperature of 16.8°C (62.2°F).

There are no established lower humidity limits for thermal comfort; consequently, this standard does not specify a minimum humidity level. Nonthermal comfort factors, such as skin drying, irritation of mucus membranes, dryness of the eyes, and static electricity generation, may place limits on the acceptability of very low humidity environments.

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

This addendum combines and clarifies definitions by absorbing Section 5.4, Description of Thermal Environmental Variables, into the definitions in Section 3, Definitions. Some definitions that were not used have been deleted, others that are commonly used have been added, and many have been revised to be more clear and specific.

Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum n to Standard 55-2010

Make the following changes to Section 3, Definitions.

3. DEFINITIONS

adaptive model: a model that relates indoor design temperatures or acceptable temperature ranges to outdoor meteorological or climatological parameters.

air speed: the rate of air movement at a point, without regard to direction.

air speed, average: the average air speed surrounding a *representative occupant*. The average is with respect to location and time. The spatial average is for three heights as defined for *average air temperature*. The air speed is averaged over an interval not less than 1 and not more than 3 minutes. Variations that occur over a period greater than 3 minutes shall be treated as multiple different air speeds.

clo: a unit used to express the thermal insulation provided by garments and clothing ensembles, where 1 clo = 0.155 m^2·°C/W (0.88 ft^2·h·°F/Btu).

comfort, thermal: that condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

climate data: hourly, site-specific values of representative meteorological data, such as temperature, wind, speed, solar radiation, and relative humidity~~, for the site at which the proposed design is to be located~~. (***Note:*** See the "Climate Design" chapter of *ASHRAE Handbook—Fundamentals*[3] for data sources. For cities or urban regions with several climate data entries, and for locations where weather data are not available, the designer shall select available weather or meteorological data that best represents the climate at the building ~~construction~~ site.) ~~(*Note*: see *ASHRAE Handbook - Fundamentals*,[3] Chapter 14 for data sources).~~

draft: the unwanted local cooling of the body caused by air movement.

environment, thermal: the local specific characteristics or aspects of the environment that affect a person's heat loss.

environment, acceptable thermal: an environment that a substantial majority (more than 80%) of the occupants find thermally acceptable.

garment: a single piece of clothing.

~~***humidity ratio:*** the ratio of the mass of water vapor to the mass of dry air in a given volume.~~

~~***humidity, relative (RH):*** the ratio of the partial pressure (or density) of the water vapor in the air to the saturation pressure (or density) of water vapor at the same temperature and the same total pressure.~~

humidity: a general reference to the moisture content of the air. It is expressed in terms of several thermodynamic variables, including vapor pressure, dew-point temperature, humidity ratio, and relative humidity. It is spatially and temporally averaged in the same manner as air temperature.

insulation, clothing/ensemble (I_{cl}): the resistance to sensible heat transfer provided by a clothing ensemble. Expressed in clo units. (***Note:*** The definition of clothing insulation relates to heat transfer from the whole body and, thus, also includes the uncovered parts of the body, such as head and hands.)

insulation, garment (I_{clu}): the increased resistance to sensible heat transfer obtained from adding an individual garment over the nude body. Expressed in clo units.

***local thermal discomfort*:** the thermal discomfort caused by locally specific conditions such as a vertical air temperature difference between the feet and the head, by an asymmetric radiant field, by local convective cooling (draft), or by contact with a hot or cold floor.

~~***met:*** a unit used to describe the energy generated inside the body due to metabolic activity, defined as 58.2 W/m^2 (18.4 Btu/h·ft^2), which is equal to the energy produced per unit surface area of an average person seated at rest. The surface area of an average person is 1.8 m^2 (19 ft^2).~~

metabolic rate ~~(M)~~ (met): the rate of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism.~~, usually expressed in terms of unit area of the total body surface.~~ In this standard, metabolic rate (met) is defined as 58.2 W/m^2 (18.4 Btu/h·ft^2), which is equal to the energy produced per unit surface area of an average person seated at rest. ~~expressed in met units.~~

naturally conditioned spaces, occupant controlled: those spaces where the thermal conditions of the space are regulated primarily by occupant-controlled openings in the envelope.

~~***neutrality, thermal:*** the indoor thermal index value corresponding with a mean vote of neutral on the thermal sensation scale.~~

occupant-controlled openings: openings such as windows or vents that are directly controlled by the occupants of a space.

Such openings may be manually controlled or controlled through the use of electrical or mechanical actuators under direct occupant control.

occupant, representative: an individual or composite or average of several individuals that is representative of the population occupying a space for 15 minutes or more.

outdoor design condition: the local outdoor environmental conditions represented by ~~outdoor~~ *climate data* ~~(dry bulb air temperature, humidity, wind speed, solar radiation)~~ at which a heating or cooling system is designed to maintain the specified indoor thermal conditions.

~~***percent dissatisfied (PD):*** percentage of people predicted to be dissatisfied due to local discomfort.~~

predicted mean vote (PMV): an index that predicts the mean value of the *thermal sensation* votes (self-reported perceptions) of a large group of persons on a ~~the seven-point thermal~~ sensation scale commonly expressed using a scale from –3 to +3 corresponding to the categories *cold*, *cool*, *slightly cool*, *neutral*, *slightly warm*, *warm*, and *hot.*

predicted percentage of dissatisfied (PPD): an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people determined from PMV.

~~***radiant temperature asymmetry:*** the difference between the plane radiant temperature of the two opposite sides of a small plane element.~~

radiant temperature asymmetry: the difference between the plane radiant temperature in opposite directions. The plane radiant temperature is defined similarly to mean radiant temperature except that it is with respect to a small planar surface element exposed to the thermal radiation from surfaces from one side of that plane. The vertical radiant asymmetry is with plane radiant temperatures in the upward and downward directions. The horizontal radiant asymmetry is the maximum difference between opposite plane radiant temperatures for all horizontal directions. The radiant asymmetry is determined at waist level—0.6 m (24 in.) for a seated occupant and 1.1 m (43 in.) for a standing occupant. Time averaging for radiant asymmetry is the same as for mean radiant temperature. (See the "Thermal Comfort" chapter of *ASHRAE Handbook—Fundamentals*[3] for a more complete description of plane radiant temperature and radiant asymmetry.)

~~***response time (90%):*** the time for a measuring sensor to reach 90% of the final value after a step change. For a measuring system that includes only one exponential time-constant function, the 90% response time equals 2.3 times the time constant.~~

sensation, thermal: a conscious subjective expression of an occupant's thermal perception of the environment ~~feeling~~ commonly expressed ~~graded~~ using the categories *cold*, *cool*, *slightly cool*, *neutral*, *slightly warm*, *warm*, and *hot*~~; it requires subjective evaluation~~.

~~***step change:*** an incremental change in a variable, either by design or as the result of an interval between measurement; typically, an incremental change in a control setpoint.~~

~~***temperature, air (t_a):*** the temperature of the air surrounding the occupant.~~

temperature, air: the temperature of the air measured at a test point.

temperature, air average (t_a): the average temperature of the air surrounding a *representative occupant*. The average is with respect to location and time. The spatial average is the numerical average of the air temperature at the ankle level, the waist level, and the head level. These levels are 0.1, 0.6, and 1.1 m (4, 24, and 43 in.) for seated occupants and 0.1, 1.1, and 1.7 m (4, 43, and 67 in.) for standing occupants. Time averaging is over a period not less than 3 and not more than 15 minutes.

temperature, dew-point (t_{dp}): the temperature at which the water vapor in a volume of humid air at a given barometric pressure will condense into a liquid water. ~~moist air becomes saturated (100% relative humidity) with water vapor ($p_{sdp} = p_a$) when cooled at constant pressure.~~

temperature, floor (t_f): the surface temperature of the floor where it is in contact with the occupants' feet.

temperature, mean daily outdoor air ($\overline{t_{mda(out)}}$): any arithmetic mean for a 24 hour period permitted in Section 5.3 of the standard. *Mean daily outdoor air temperature* is used to calculate *prevailing mean outdoor air temperature.*

~~***temperature, mean radiant ($\bar{t}_r$):*** the uniform surface temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual nonuniform space; see Section 7.2 for information on measurement positions.~~

temperature, mean radiant ($\bar{t}_r$): the temperature of a uniform, black enclosure that exchanges the same amount of thermal radiation with the occupant as the actual enclosure. It is a single value for the entire body and may be considered a spatial average of the temperature of surfaces surrounding the occupant weighted by their view factors with respect to the occupant. (See the "Thermal Comfort" chapter of *ASHRAE Handbook—Fundamentals*[3] for a more complete description of mean radiant temperature.)

~~***temperature, operative (t_o):*** the uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual nonuniform environment; see Section 7.2 for information on body position within the imaginary enclosure.~~

temperature, operative (t_o): the uniform temperature of an imaginary black enclosure and the air within it in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual nonuniform environment; calculated as the average of the *average air temperature* and the *mean radiant temperature* weighted, respectively, by the convective heat transfer coefficient and the linearized radiant heat transfer coefficient for the *representative occupant*. (See Normative Appendix C or the "Thermal Comfort" chapter of *ASHRAE Handbook—Fundamentals*[3] for a more complete description of operative temperature.)

temperature, plane radiant (t_{pr}): the uniform temperature of an enclosure in which the incident radiant flux on one side of a small plane element is the same as in the existing environment.

temperature, prevailing mean outdoor air ($\overline{t_{pma(out)}}$): when used as input variable in Figure 5.3 for the adaptive model, this temperature is based on the arithmetic average of the *mean daily outdoor temperatures* over some period of days as permitted in Section 5.3.

temperature, standard effective (SET): the temperature of an imaginary environment at 50% RH, <0.1 m/s air speed, and $t_r = t_a$, in which the total heat loss from the skin of an imaginary occupant with an activity level of 1.0 met and a clothing level of 0.6 clo is the same as that from a person in the actual environment, with actual clothing and activity level.

~~***time constant:*** the time for a measuring sensor to reach 63% of the final value after a step change.~~

~~***water vapor pressure (p_a):*** the pressure that the water vapor would exert if it alone occupied the volume occupied by the humid air at the same temperature.~~

~~***water vapor pressure, saturated dewpoint (p_{sdp}):*** the water vapor pressure at the saturation temperature corresponding to the reference pressure and without any liquid phase.~~

~~***velocity, mean (v_a):*** an average of the instantaneous air velocity over an interval of time.~~

zone, comfort: a two dimensional range, ~~often~~ represented on a modified psychrometric chart, of operative temperature and humidity that is predicted to be an acceptable thermal environment at particular values of air speed, metabolic rate, and clothing insulation.

zone, occupied: the region normally occupied by people within a space~~., generally considered~~ In the absence of known occupant locations, the occupied zone is to be between the floor and 1.8 m (6 ft) above the floor and more than 1.0 m (3.3 ft) from external ~~outside~~ walls/windows or fixed heating, ventilating, or air-conditioning equipment and 0.3 m (1 ft) from internal walls.

Delete the entire Section 5.4. Much of this material is being added to Section 3, Definitions.

~~**5.4 Description of Thermal Environmental Variables.** The following description of the environmental variables is provided for the purpose of understanding their use in Section 5. It is not intended to be a measurement specification. Section 7 specifies measurement requirements. If there is a discrepancy between the descriptions in this section and the requirements in Section 7, then the requirements in Section 7 supersede the descriptions in this section for the purpose of measurement.~~

~~For the purposes of Section 5, the thermal environment is defined with respect to the occupant.~~

~~***Air temperature*** is the average temperature of the air surrounding an occupant. The average is with respect to location and time. As a minimum, the spatial average is the numerical average of the air temperature at the ankle level, the waist level, and the head level. These levels are 0.1, 0.6, and 1.1 m (4, 24, and 43 in.), respectively, for seated occupants, and 0.1, 1.1, and 1.7 m (4, 43, and 67 in.) for standing occupants. Intermediate, equally spaced locations may also be included in the average. When the occupant is located in a directed airflow, the air temperature on the upstream side shall be used. As a minimum, the temporal average is a three-minute average with a least 18 equally spaced points in time. If necessary it is acceptable to extend the period up to 15 minutes to average cyclic fluctuations. The temporal average applies to all locations in the spatial average.~~

~~***Local air temperature*** is defined in the same way as the air temperature except that it refers to a single level (e.g., head level). At least one location is required at this level. To determine a better average it is acceptable to include multiple locations around the body.~~

~~***Mean radiant temperature*** is defined as the temperature of a uniform, black enclosure that exchanges the same amount of thermal radiation with the occupant as the actual enclosure. It is a single value for the entire body and may be considered a spatial average of the temperature of surfaces surrounding the occupant weighted by their view factors with respect to the occupant. See Chapter 9 in the *2009 ASHRAE Handbook—Fundamentals*[3] for a more complete description of mean radiant temperature. For the purposes of Section 5, mean radiant temperature is also a time-averaged value. As a minimum, the temporal average is a three-minute average with at least 18 equally spaced points in time. If necessary it is acceptable to extend the period up to 15 minutes to average cyclic fluctuations.~~

~~***Operative temperature*** is the average of the air temperature and the mean radiant temperature weighted, respectively, by the convective heat transfer coefficient and the linearized radiant heat transfer coefficient for the occupant. See Chapter 9 in the *2009 ASHRAE Handbook—Fundamentals*[3] for a more complete description of operative temperature. For occupants engaged in near sedentary physical activity (with metabolic rates between 1.0 met and 1.3 met), not in direct sunlight, and not exposed to air velocities greater than 0.20 m/s (40 fpm), it is acceptable to approximate the relationship with acceptable accuracy by~~

$$t_o = (t_a + t_r)/2 ,$$

~~where~~

t_o	=	~~operative temperature,~~
t_a	=	~~air temperature, and~~
t_r	=	~~mean radiant temperature.~~

~~***Radiant asymmetry*** is the difference between the plane radiant temperature in opposite directions. The plane radiant temperature is defined similarly to mean radiant temperature except that it is with respect to a small planar surface element exposed to the thermal radiation from surfaces from one side of that plane. The vertical radiant asymmetry is with plane radiant temperatures in the upward and downward direction.~~

~~The horizontal radiant asymmetry is the maximum difference between opposite plane radiant temperatures for all horizontal directions. The radiant asymmetry is determined at waist level—0.6 m (24 in.) for a seated occupant and 1.1 m (43 in.) for a standing occupant. Time averaging for radiant asymmetry is the same as for mean radiant temperature. See Chapter 9 in the *2009 ASHRAE Handbook—Fundamentals*[3] for a more complete description of plane radiant temperature and radiant asymmetry.~~

~~***Floor temperature (t_f)*** is the surface temperature of the floor when it is in contact with the occupants' shoes. Since floor temperatures seldom change rapidly, time averaging does not need to be considered.~~

~~***Air speed*** is the average speed of the air to which the body is exposed. The average is with respect to location and time. Time averaging is the same as for air temperature. However, the time-averaging period extends only to three minutes. Variations that occur over a period greater than three minutes shall be treated as multiple different air speeds. As to spatial averaging, the SET thermo-physiological model described in Section 5.2.3.2 is based on the assumption that the body is exposed to a uniform air speed. However, spaces with passive or active systems that provide strongly nonuniform air velocity fields cause skin heat losses that cannot be simply related to those of uniform velocity fields. Therefore, the designer shall decide the proper averaging for air speed for use in the Graphical Method (5.2.3.1) and Informative Appendix F "Procedures for Evaluating Cooling Effect of Elevated Air Speed Using SET." The proper averaging shall include air speeds incident on unclothed body parts (e.g., head) that have greater cooling effect and potential for local discomfort than unclothed parts.~~

~~***Humidity*** is a general reference to the moisture content of the air. It is expressed in terms of several thermodynamic variables, including vapor pressure, dew-point temperature, and humidity ratio. It is spatially and temporally averaged in the same manner as air temperature.~~

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

This addendum adds a requirement that design calculations shall use generally accepted engineering standards. The following definition is reproduced from ASHRAE/IES Standard 90.1-2010 for the convenience of readers:

generally accepted engineering standard: *a specification, rule, guide, or procedure in the field of engineering, or related thereto, recognized and accepted as authoritative.*

Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum r to Standard 55-2010

Add the following to Section 3, Definitions.

generally accepted engineering standard: See ASHRAE/IES Standard 90.1.[X]

Modify Section 6, Design Compliance, as shown. Section 6.2 is also being modified by Addendum l to Standard 55-2010. These changes reflect the revised text if Addendum l is published.

6.2 Documentation. The method and design conditions appropriate for the intended use of the building shall be selected and documented as follows.

7. Air speed, radiant temperature asymmetry, vertical air temperature difference, surface temperatures, and temperature variations with time shall be determined in accordance with *generally accepted engineering standards* (e.g., the *ASHRAE Handbook—HVAC Applications* chapter "Room Air Distribution.") The method used and quantified selection criteria, characteristics, sizes, and indices that are applicable to the method shall be stated.

Add the following to Section 8, References.

[X]ANSI/ASHRAE/IES Standard 90.1-2010, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. ASHRAE, Atlanta, GA.

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the standards and guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive technical committee structure, continue to generate up-to-date standards and guidelines where appropriate and adopt, recommend, and promote those new and revised standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating standards and guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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