STANDARD

ASHRAE™

ANSI/ASHRAE Standard 55-2010

(Supersedes ANSI/ASHRAE Standard 55-2004)

Includes ANSI/ASHRAE addenda listed in Appendix I

Thermal Environmental Conditions for Human Occupancy

See Appendix I for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

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Preface

What would the world look like without ASHRAE Research? Since its beginnings in 1919, ASHRAE Research has grown and expanded to address the ever changing questions and topics facing both its members and the HVAC&R Industry and the world as a whole. ASHRAE Standards are constantly evolving to address these new challenges, fueled by the knowledge and principals developed through ASHRAE Research. As the focus of the industry has evolved from home refrigeration and food safety to improved indoor air quality to sustainability and energy efficiency, ASHRAE Standards continue to be the foremost authority in every ASHRAE Member's career.

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(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.)

FOREWORD

ANSI/ASHRAE Standard [redacted] is the latest edition of Standard [redacted] The [redacted] combines Standard [redacted] and the ten approved and published addenda to the [redacted] into one easy-to-use, consolidated standard. The standard outlines [redacted] The standard is intended for [redacted] Because it is not possible to prescribe the metabolic rate of occupants, and because of variations in occupant clothing levels, operating setpoints for buildings cannot practically be mandated by this standard.

Standard [redacted] was first published in 1966 and republished in 1974, 1981, and 1992. Beginning in 2004, it is now updated on a regular basis using ASHRAE's continuous maintenance procedures. According to these procedures, Standard [redacted]s continuously revised by addenda that are publicly reviewed, approved by ASHRAE and ANSI, and published and posted for free on the ASHRAE Web site.

As with previous updated editions of the standard, the 2004 edition introduced significant changes. Perhaps most notable were [redacted]

Continuing in this spirit of introducing recent research innovations into the standard, several significant improvements have been made in the years since 2004. In particular, the use of [redacted]

The standard previously [redacted] But field studies, including recently published work, show that [redacted] In certain combinations of temperature ranges and personal factors, [redacted] Addenda since 2004 included a [redacted] With these changes, the standard [redacted]

The 2010 edition of the standard includes the following significant changes:

- [redacted]
- *Revises requirements and calculation methods when increased air movement is used to maintain comfort in warm conditions. Standard Effective Temperature (SET) is reintroduced into the Standard as the calculation basis for determining the cooling effect of air movement. In general, the 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 fans for comfort cooling.*
- *Significant revisions to Section 6, "Compliance" that now clearly state the 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 by providing a compliance form for documentation of design compliance.*
- *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 to clarify the requirements in the standard. Wherever possible, the use of informative language in the standard is avoided.*

For more specific information on the changes and on other revisions made to the standard by addenda, refer to [redacted]at the end of this standard. Users of the standard are encouraged to use the [redacted] to suggest changes for further improvements. A form for submitting change proposals is included in the back of this edition. The [redacted] for Standard [redacted] will take formal action on all change proposals received.

1. PURPOSE

The purpose of this standard is to [redacted]

2. SCOPE

2.1 The environmental factors addressed in this standard are [redacted]

2.2 It is intended that all of the criteria in this standard be applied together since comfort in the indoor environment is complex and responds to the interaction of all of the factors that are addressed.

2.3 This standard specifies thermal environmental conditions acceptable for healthy adults at atmospheric pressure equivalent to altitudes up to 3000 m (10,000 ft) in indoor spaces designed for human occupancy for periods not less than 15 minutes.

2.4 This standard does not address such nonthermal environmental factors as air quality, acoustics, and illumination or other physical, chemical, or biological space contaminants that may affect comfort or health.

3. DEFINITIONS

[redacted]

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

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).

[redacted]

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

[redacted]

[redacted]

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.

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.

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): 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 is expressed in met units.

naturally conditioned spaces, occupant controlled: those spaces where the thermal conditions of the space are regulated primarily by the opening and closing of windows by the occupants.

[redacted]

[redacted]

predicted mean vote (PMV): an index that predicts the mean value of the votes of a large group of persons on the seven-point thermal sensation scale.

[redacted]

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

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 feeling commonly 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, dew point (t_{dp}): the temperature at which moist air becomes saturated (100% relative humidity) with water vapor ($p_{sdp} = p_a$) when cooled at constant pressure.

temperature, mean monthly outdoor air ($\overline{t_{a(out)}}$): 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 minimum and mean daily maximum outdoor (dry-bulb) temperatures for the month in question.

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.

[redacted]

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, standard effective (SET): the temperature of an imaginary environment at 50% RH, <0.1 m/s air speed, and $\bar{t}_r = t_a$, 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 ($\bar{v}_a$): an average of the instantaneous air velocity over an interval of time.

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

4. GENERAL REQUIREMENTS

Use of this standard is specific to the [redacted] Any application of this standard must [redacted] Any application of this standard must [redacted]

[redacted] in applying this standard. [redacted] these differences must be considered.

In some cases it will not be possible to achieve an acceptable thermal environment for all occupants of a space due to [redacted]

The thermal environmental conditions required for comfort are determined according to [redacted] or [redacted] of this standard. Any application of this standard must clearly [redacted]

5. CONDITIONS THAT PROVIDE THERMAL COMFORT

5.1 Introduction. Thermal comfort is that condition of mind [redacted] The environmental conditions required for comfort are [redacted] Extensive laboratory and field data have been collected that provide the necessary statistical data to define conditions that a specified percentage of occupants will find thermally comfortable. [redacted] of this standard is used to [redacted]

[redacted] A number of other, secondary factors affect comfort in some circumstances. The six primary factors are listed below. Complete descriptions of these factors are presented in [redacted] and [redacted]

[redacted]

It is possible for [redacted] This standard only addresses [redacted] ***Note:*** As a result, [redacted] The effect of [redacted]

[redacted] is addressed in [redacted]

[redacted] This standard is intended primarily for these conditions. However, it is acceptable to use the standard to [redacted] It does not apply [redacted] The body of available data does not contain [redacted] It is acceptable to apply the information in this standard to [redacted]

[redacted] contains the [redacted] The conditions required for thermal comfort in spaces that are naturally conditioned are [redacted] Field experiments have shown that [redacted]

[redacted] specifies criteria [redacted] The [redacted] may, as an option, be applied to spaces that meet these criteria. The [redacted] may not be applied to other spaces.

[redacted] describes in some detail [redacted] effectively.

5.2 Method for Determining Acceptable Thermal Conditions in Occupied Spaces. When [redacted] is used to determine [redacted] —must be met. This standard recommends a [redacted]

5.2.1 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 [redacted]

This section describes methods that are acceptable for use in determining temperature limits for the comfort zone. [redacted] uses a [redacted] uses a [redacted] For a given set of conditions, the results from the two methods [redacted]

See [redacted] and the [redacted] It is permissible to use [redacted] as a proxy for [redacted] under certain conditions described in [redacted]

5.2.1.1 Graphic Comfort Zone Method for Typical Indoor Environments. It is permissible to apply the method in this section to [redacted] See [redacted] estimation of metabolic rates and [redacted] for estimation of clothing insulation. Most office spaces fall within these limitations.

The range of operative temperatures presented in Figure 5.2.1.1 [redacted] This is based on [redacted] Normative Appendix D [redacted]

Figure 5.2.1.1 [redacted]. [redacted] These insulation levels are typical of [redacted]

[redacted]

where

$T_{max, Icl}$ = [redacted]

$T_{min, Icl}$ = [redacted]

I_{cl} = [redacted]

It is acceptable to use [redacted]

5.2.1.2 Computer Model Method for General Indoor Application. [redacted] See Normative Appendix A [redacted] and Normative Appendix B [redacted]

[redacted]

The predicted mean vote (PMV) model uses heat balance principles to relate the six key factors for thermal comfort listed in [redacted] 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 5.2.1.2. It is based on the assumption that people voting [redacted] are [redacted]

Table 5.2.1.2 [redacted] in Table 5.2.1.2. The PMV model is calculated with the air temperature and mean

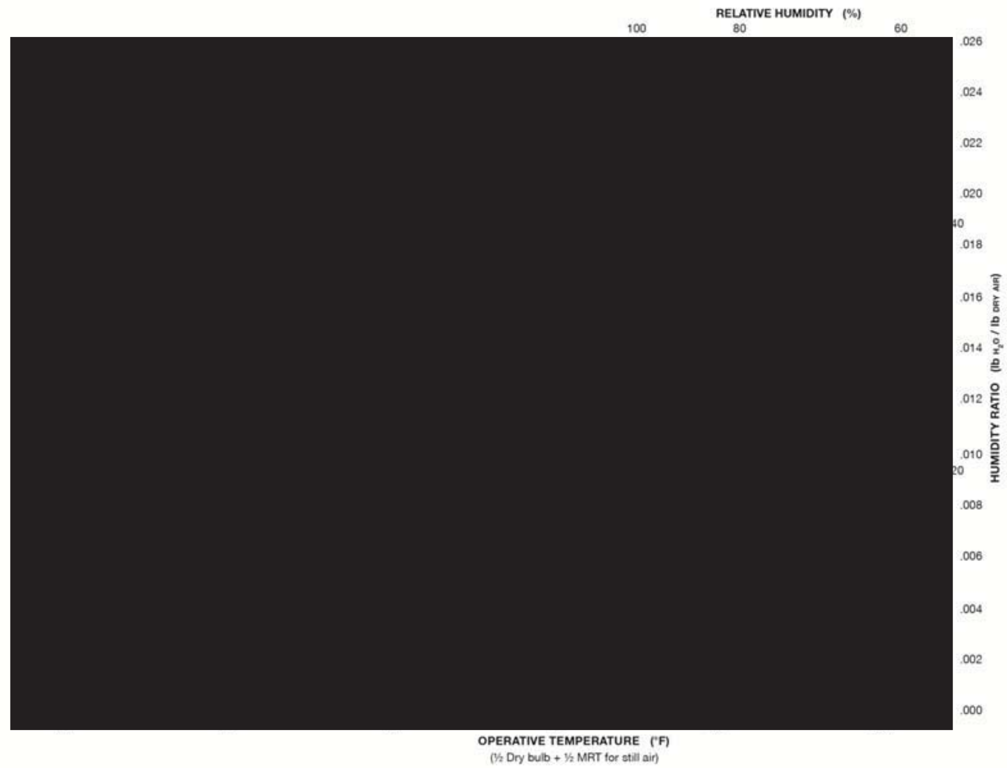

Figure 5.2.1.1 (IP) Acceptable range of operative temperature and humidity for spaces that meet the criteria specified in Section 5.2.1.1.
1.1 met, 0.5 & 1.0 clo

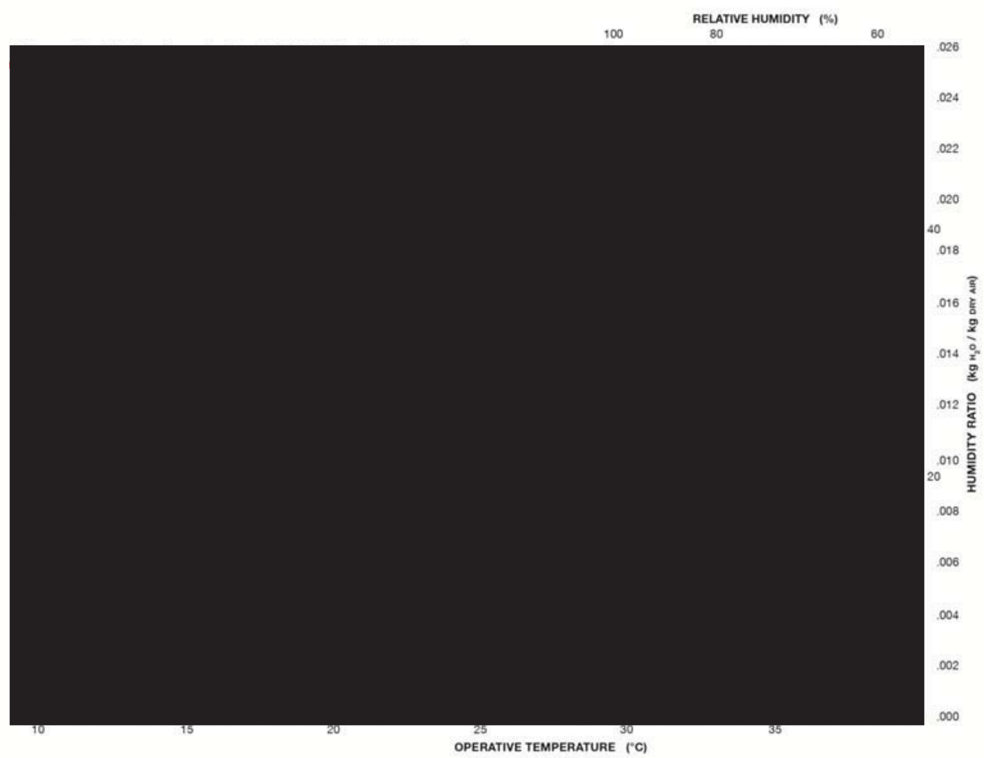

Figure 5.2.1.1 (SI) Acceptable range of operative temperature and humidity for spaces that meet the criteria specified in Section 5.2.1.1.
1.1 met, 0.5 & 1.0 clo

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.

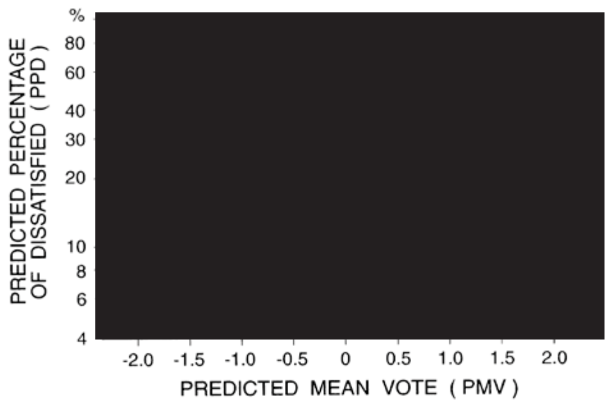

Figure 5.2.1.2 Predicted percentage dissatisfied (PPD) as a function of predicted mean vote (PMV).

TABLE 5.2.1.2
Acceptable Thermal Environment for General Comfort

PPD	PMV Range
[redacted]	[redacted]

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 [redacted]

Use of the PMV model in this standard is limited to [redacted]

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] If any other version is used, [redacted]

5.2.2 Humidity Limits. When the Graphic Comfort Zone Method in [redacted] is used, systems shall be [redacted]

There are [redacted] for thermal comfort; consequently, this standard does not [redacted] *Note:* Nonthermal comfort factors, [redacted]

5.2.3 Elevated Air Speed. This standard allows [redacted] Limits are imposed [redacted]

5.2.3.1 Graphical Elevated Air Speed Method. [redacted] in Figure 5.2.3.1. The combinations of [redacted] as described in [redacted] The figure applies to a [redacted] described in [redacted]

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, [redacted] Conversely, elevated air speed is [redacted] Thus, [redacted] in Figure 5.2.3.1 that corresponds to the [redacted]

[redacted] Any benefits gained by increasing air speed [redacted] Due to increases in skin wettedness, the effect of increased air speed is [redacted] Due to increased amounts of exposed skin, the effect of increased air speed is [redacted] Thus, Figure 5.2.3.1 is [redacted]

Due to increased body coverage, the effect of increased air speed is [redacted] Thus, Figure 5.2.3.1 will [redacted]

5.2.3.2 SET Method. Figure 5.2.3.2 represents [redacted] The model, however, is [redacted] and it is acceptable to [redacted]

The SET model uses a [redacted] This model enables air velocity effects on thermal comfort to be [redacted]

Figure 5.2.3.2 uses [redacted] Figure 5.2.1.1 [redacted] Figure 5.2.1.1 is based [redacted]

[redacted] After this boundary was defined, the curving comfort envelope boundaries above [redacted] were then defined by constant [redacted] The [redacted] lines indicate temperature/air-speed combinations at which skin heat loss is the same as at the [redacted] comfort zone boundary.

[redacted]

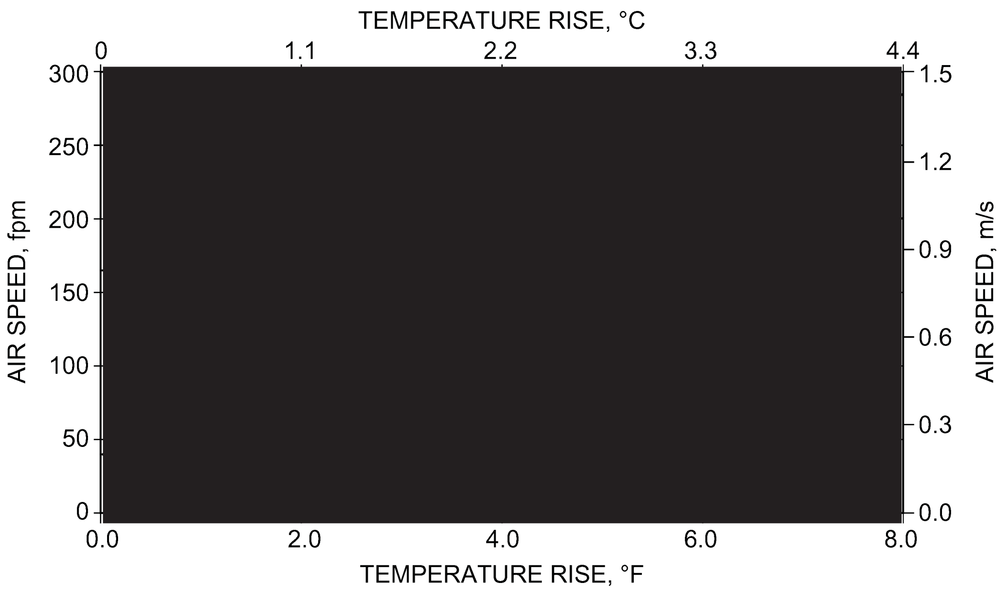

Figure 5.2.3.1 Air speed required to offset increased air and radiant temperature.

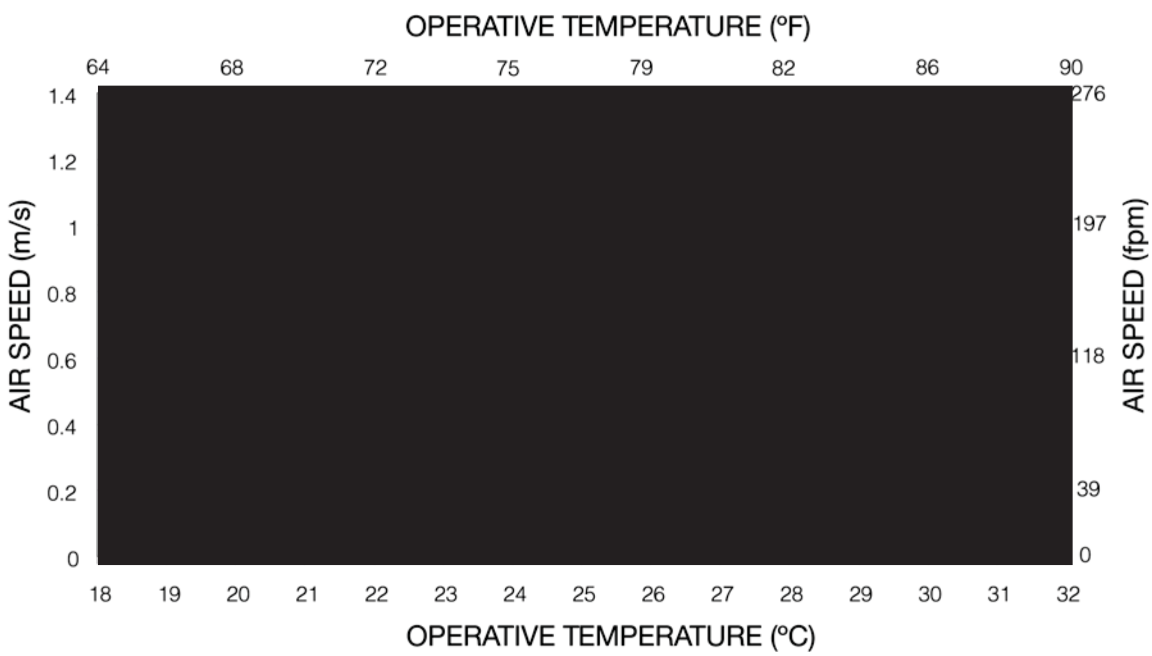

Figure 5.2.3.2 Acceptable range of operative temperature and air speeds for the comfort zone shown in Figure 5.2.1.1, at humidity ratio 0.010.

5.2.3.3 Limits to Air Speed

5.2.3.3.1 With Local Control. [redacted] in Figure 5.2.3.2 contains heat losses equal to those of the [redacted] zone. The full bounded area applies when [redacted] For control over their local air speed, control directly accessible to occupants must be provided [redacted]

Exception: In multi-occupant spaces where groups gather for shared activities, such as classrooms and conference rooms, at least [redacted] Multi-occupant spaces that can be subdivided by moveable walls shall have [redacted]

5.2.3.3.2 Without Local Control. Within the equal-heat-loss envelope, if occupants do not have control over the local air speed in their space, [redacted] in Figure 5.2.3.2.

- For operative temperatures above 25.5°C (77.9°F), the upper limit to air speed shall [redacted] for light, primarily sedentary office activities, such as in offices.
- For operative temperatures below 22.5°C (72.5°F), the limit shall be [redacted] in order to [redacted]
- For operative temperatures between 22.5°C and 25.5°C (72.5°F and 77.9°F), [redacted] shown in Figure 5.2.3.2. [redacted] It is acceptable to approximate the curve in SI and I-P units by the following equation:

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

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

5.2.3.4 Air Speed Measurement. At operative temperatures above 22.5°C (72.5°F), the overall heat balance of the body determines comfort. For this, [redacted] is used.

At operative temperatures below 22.5°C (72.5°F), however, the problem is [redacted] The *maximum* mean air speed of the [redacted] *Note:* To eliminate sources of air movement beyond the designer's control, the measurements should be taken [redacted]

5.2.4 Local Thermal Discomfort. The local thermal discomfort caused by a [redacted]

The requirements specified in this section apply to a [redacted] With higher metabolic rates and/or with more clothing insulation, people are [redacted] and, consequently [redacted] Thus, [redacted] the requirements of this section [redacted] People are more sensitive to local discomfort when the whole body is cooler than neutral and less sensitive to local discomfort when the whole body is warmer than neutral. The requirements of this section are [redacted] These requirements apply [redacted]

Table 5.2.4 specifies [redacted] The criteria for all sources of local thermal discomfort [redacted] to meet the requirements of this standard.

5.2.4.1 Radiant Temperature Asymmetry. The thermal radiation field about the body may be [redacted] This asymmetry may cause [redacted] In general, people are more sensitive to [redacted] caused by [redacted] Figure 5.2.4.1 [redacted] in Table 5.2.4.1. Alternatively, it is acceptable to use Figure 5.2.4.1 in conjunction [redacted] Table 5.2.4 to [redacted]

5.2.4.2 Draft. Draft is unwanted local cooling of the body caused by air movement. It is most prevalent when the whole body thermal sensation is cool (below neutral). Draft

TABLE 5.2.4
Percentage Dissatisfied (PD) Due to Local Discomfort from Draft or Other Sources

PD Due to Draft	PD Due to Vertical Air Temperature Difference	PD Due to Warm or Cool Floors	PD Due to Radiant Asymmetry
[redacted]	[redacted]	[redacted]	[redacted]

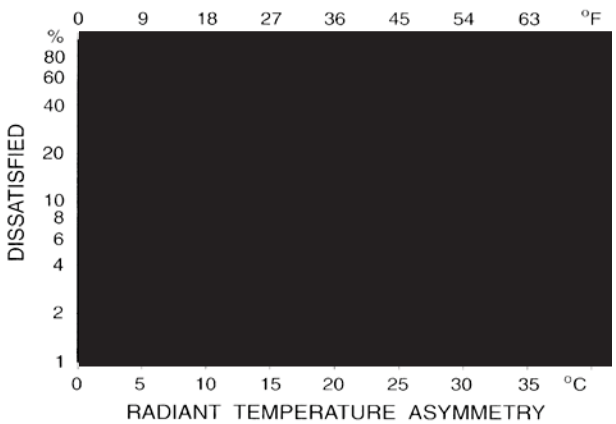

Figure 5.2.4.1 Local thermal discomfort caused by radiant asymmetry.

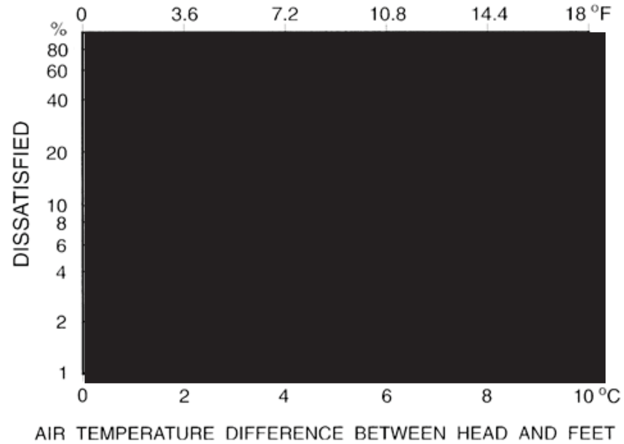

Figure 5.2.4.3 Local thermal discomfort caused by vertical temperature differences.

TABLE 5.2.4.1
Allowable Radiant Temperature Asymmetry

Radiant Temperature Asymmetry °C (°F)			
Warm Ceiling	**Cool Wall**	**Cool Ceiling**	**Warm Wall**
[redacted]	[redacted]	[redacted]	[redacted]

sensation depends on the [redacted] Sensitivity to draft is greatest [redacted]

At operative temperatures below 22.5°C (72.5°F), air speeds within the comfort envelope [redacted] should not exceed [redacted] This limit applies to air movement caused by [redacted] s. [redacted] described in [redacted]

5.2.4.3 Vertical Air Temperature Difference. Thermal stratification that results in the air temperature at the head level being warmer than at the ankle level may [redacted] This section specifies allowable differences [redacted] Thermal stratification in the opposite direction [redacted]

[redacted] from Table 5.2.4.3. Alternatively, it is acceptable to use Figure 5.2.4.3 in conjunction [redacted]

TABLE 5.2.4.3
Allowable Vertical Air Temperature Difference Between Head and Ankles

Vertical Air Temperature Difference, °C (°F)
[redacted]

[redacted]

5.2.4.4 Floor Surface Temperature. Occupants may feel [redacted] due to contact with floor surfaces that are [redacted] Figure 5.2.4.4 gives [redacted] This standard does not address the floor temperature required [redacted]

[redacted] Table 5.2.4.4. [redacted]

5.2.5 Temperature Variations with Time. Fluctuations in the air temperature and/or [redacted] may affect the thermal comfort of occupants. Those fluctuations under the direct control of the individual occupant do not have [redacted] Fluctuations that occur due to factors not under the direct control of the individual occupant [redacted] Fluctuations that occupants experience as a result of moving between locations

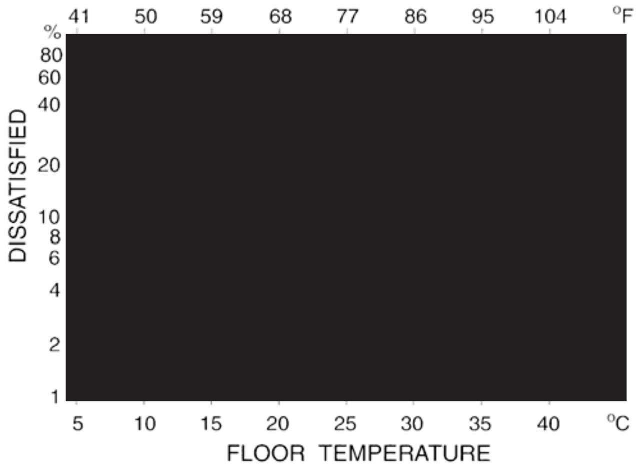

Figure 5.2.4.4 Local discomfort caused by warm and cool floors.

TABLE 5.2.4.4 Allowable Range of the Floor Temperature

Range of Surface Temperature of the Floor, °C (°F)
[redacted]

with different environmental conditions are [redacted]

5.2.5.1 Cyclic Variations. Cyclic variations refer to those situations where the [redacted] and the [redacted] If the period of the fluctuation cycle exceeds [redacted] the variation is treated as a drift or ramp in operative temperature, and the requirements of [redacted] apply. In some situations, [redacted] In these situations, the requirements of [redacted] and the requirements of [redacted]

Table 5.2.5.1 [redacted]

5.2.5.2 Drifts or Ramps. Temperature drifts and ramps are monotonic, noncyclic changes in operative temperature. The requirements of this section also apply to [redacted] The requirements of this section are [redacted]

Table 5.2.5.2 [redacted]

TABLE 5.2.5.1 Allowable Cyclic Operative Temperature Variation

Allowable Peak-to-Peak Variation in Operative Temperature, °C (°F)
[redacted]

TABLE 5.2.5.2 Limits on Temperature Drifts and Ramps

Time Period, h	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Maximum Operative Temperature Change Allowed, °C (°F)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 5.2.5.2 apply. For example, the [redacted] temperature may not change more than [redacted] period, and it also may not change more than [redacted] during any [redacted] period. If variations are created as a result of control or adjustments by the user, higher values may be acceptable.

5.3 Optional Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces.

For the purposes of this standard, [redacted] Field experiments have shown that occupants' thermal responses in such spaces [redacted] This optional method is intended for such spaces.

In order for this optional method to apply, the space in question must be equipped with [redacted] There must be [redacted] It is permissible to use [redacted] It is permissible for the space to be provided with a [redacted] It applies only to spaces where the occupants are [redacted] met. See [redacted] for estimation of metabolic rates. This optional method applies only to [redacted]

For spaces that meet these criteria [redacted] Figure 5.3. This figure includes [redacted] The [redacted] acceptability limits are for typical applications and shall be used when other information is not available. It is acceptable to use the [redacted] limits

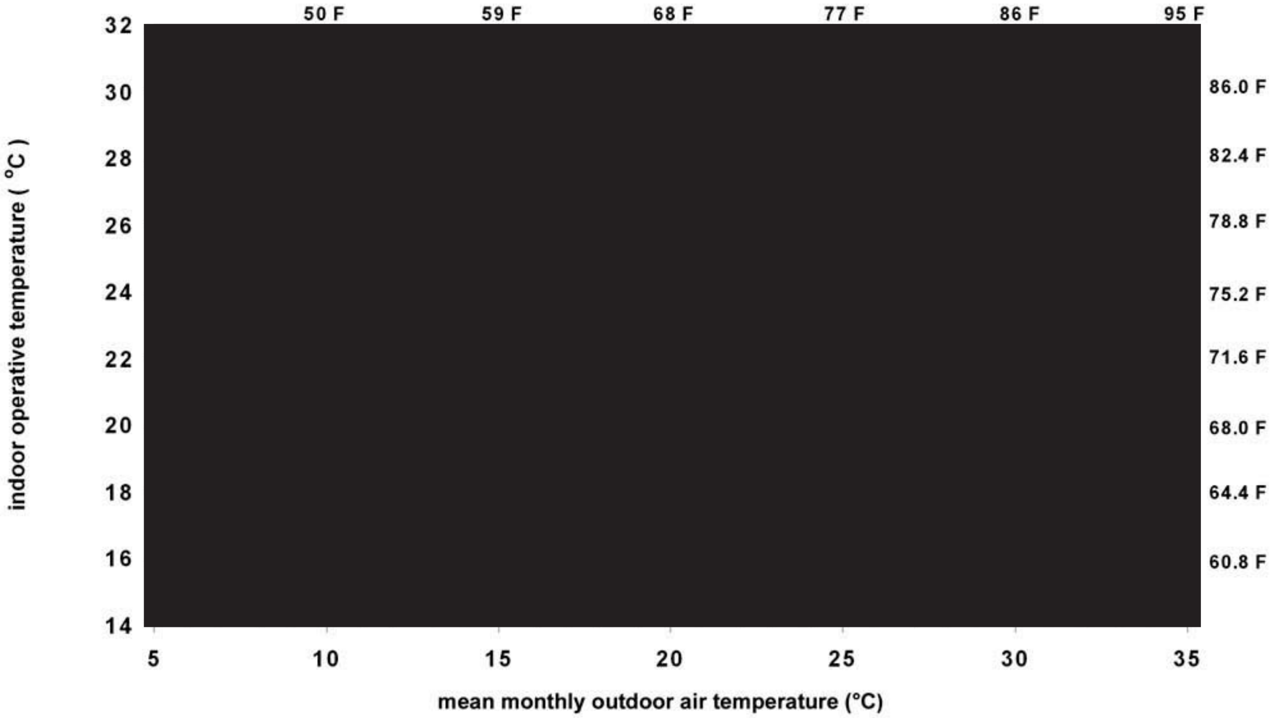

Figure 5.3 Acceptable operative temperature ranges for naturally conditioned spaces.

when a higher standard of [redacted] is desired. Figure 5.3 is [redacted]

The [redacted] limits in Figure 5.3 may not be extrapolated to outdoor temperatures [redacted] If the mean monthly outdoor temperature is less than [redacted] this option may not be used, and no specific guidance [redacted] is included in this standard.

Figure 5.3 [redacted]

Figure 5.3 [redacted]

5.4 Description of Thermal Environmental Variables. The following description of the environmental variables is provided for the purpose of understanding their use in [redacted] It is not intended to be a measurement specification. [redacted] specifies measurement requirements. [redacted]

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 [redacted] These levels are [redacted] respectively, for seated occupants, and [redacted] 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 [redacted] average with at least [redacted] spaced points in time. If necessary, it is acceptable to extend the period up to [redacted] 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 [redacted] 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 [redacted] 2009 *ASHRAE Handbook—Fundamentals*[3] for a [redacted] For the purposes of [redacted] lue. As a minimum, the temporal average is a [redacted] with at least [redacted] equally spaced points in time. If necessary, it is acceptable to extend the period up to [redacted] 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. [redacted] For occupants engaged in near sedentary physical activity (with metabolic rates between [redacted], not in direct sunlight, and not exposed to air velocities greater than [redacted] it is acceptable to approximate the relationship with acceptable accuracy by

[redacted]

where

t_o = operative temperature,

t_a = air temperature, and

$\bar{t}_r$ = 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. [redacted] The radiant asymmetry is determined at [redacted] Time averaging for radiant asymmetry is the same as for mean radiant temperature. [redacted]

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.

Mean monthly outdoor temperature is the arithmetic average of the mean daily minimum and mean daily maximum outdoor (dry-bulb) temperature for the month in question.

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 [redacted] minutes. Variations that occur over a period greater than [redacted] minutes shall be treated as multiple different air speeds. [redacted] 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. [redacted] The proper averaging shall include [redacted]

[redacted] 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.

6. COMPLIANCE

6.1 Design. Building systems (i.e., combinations of mechanical systems, control systems, and thermal envelopes) shall be designed so that at [redacted] in this standard. This standard does not [redacted]

In addition, the mechanical systems, control systems, and thermal envelopes shall be designed so that [redacted]

Because of differences in metabolic rates between [redacted]

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 below may not be applicable to naturally conditioned buildings.

1. [redacted]

[redacted]

2. Values assumed for comfort parameters used in the calculation of design temperatures, including clothing, metabolic rate, and indoor-air speed, shall be clearly stated. 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.
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. 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.
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.

[redacted]

7. EVALUATION OF THE THERMAL ENVIRONMENT

At the design stage, it is permissible to evaluate the thermal environment by calculations. Simple hand calculations and computer models of buildings and systems are available for this purpose. Use this section to evaluate existing thermal environments with respect to this standard. ***Note:*** Full-scale laboratory testing may provide a more controlled validation, however.

7.1 Measuring Device Criteria. The measuring instrumentation used shall meet the requirements for measuring range and accuracy given in ASHRAE Standard 70[5] or Standard 113[6] or in ISO 7726,[1] and the referenced source shall be so identified.

7.2 Measurement Positions

7.2.1 Location of Measurements. Measurements shall be made in occupied zones of the building at locations where the occupants are known to or are expected to spend their time.

Such locations might be workstation or seating areas, depending on the function of the space. In occupied rooms, measurements shall be taken at a representative sample of occupant locations spread throughout the occupied zone. In unoccupied rooms, the evaluator shall make a good-faith estimate of the most significant future occupant locations within the room and make appropriate measurements.

If occupancy distribution cannot be estimated, then the measurement locations shall be as follows:

a. In the center of the room or zone.
b. 1.0 m (3.3 ft) inward from the center of each of the room's walls. In the case of exterior walls with windows, the measurement location shall be 1.0 m (3.3 ft) inward from the center of the largest window.

In either case, measurements shall be taken in locations where the most extreme values of the thermal parameters are estimated or observed to occur. Typical examples might be near windows, diffuser outlets, corners, and entries. Measurements are to be made sufficiently away from the boundaries of the occupied zone and from any surfaces to allow for proper circulation around measurement sensors with positions as described below.

A measure of [redacted] to be determined at [redacted] within the occupied zone in each occupied room or HVAC-controlled zone, provided it can be demonstrated that there is no reason to expect large humidity variations within that space. Otherwise, absolute humidity shall be measured at all locations defined above.

7.2.2 Height Above Floor of Measurements. [redacted]

Radiant asymmetry shall be measured at the [redacted] level for seated occupants and the [redacted] level for standing occupants. If desk-level furniture (that is in place) blocks the view of strong radiant sources and sinks, the measurements are to be taken above desktop level. Floor surface temperatures are to be measured with the anticipated floor coverings installed. Humidity shall be measured at any level within the occupied zone if only one measurement location is required. Otherwise it shall be measured at the [redacted] level for seated occupants and the [redacted] level for standing occupants.

7.3 Measurement Periods

7.3.1 Air Speed. The measuring period for determining the average air speed at any location shall be three minutes.

7.3.2 Temperature Cycles and Drifts. [redacted]

$$\text{Rate of change (degrees/h)} = 60\,(t_{o,\,max} - t_{o,\,min})\;/\;\text{time (minutes)}$$

The measurements shall be made every five minutes or less for at least two hours to establish the nature of the temperature cycle. The use of an automatic recorder is the preferred method of measurement; however, it is possible to make the measurements required in this section without the use of recording equipment.

7.3.3 Clothing and Activity. In buildings, it may be appropriate to measure the clothing and activity levels of the occupants. These shall be estimated in the form of mean values over a period of 0.5 to 1.0 hour immediately prior to measuring the thermal parameters.

7.4 Measuring Conditions. In order to determine the effectiveness of the building system at providing the environmental conditions specified in this standard, measurements shall be made under the following conditions.

To test during the heating period (winter conditions), the measurements required shall be made when the indoor-outdoor temperature difference is [redacted] If these sky conditions are rare and not representative of the sky conditions used for design, then sky conditions representative of design conditions [redacted]

To test during the cooling period (summer conditions), the measurements required shall be made when the outdoor-indoor temperature difference and humidity difference are not [redacted] If these sky conditions are rare and not representative of the sky conditions used for design, then sky conditions representative of design conditions [redacted]

To test interior zones of large buildings, the measurements required shall be made with the zone loaded to at least 50% of the design load for at least [redacted] if the system is not proportionally controlled. Simulation of heat generated by occupants [redacted]

7.5 Validating the Thermal Environment for New Buildings and Installations

7.5.1 Define Criteria. Before validating a thermal environment that meets the requirements of this standard, the original design conditions specified shall be defined. From this definition, the validation team will evaluate the system's ability to meet and maintain the desired comfort level(s). The comfort criteria definition shall include but not be limited to the following:

[redacted]

The environmental conditions that were originally specified shall be defined as well to ensure that measurements taken correspond correctly to the design parameters. Environmental conditions shall include but are not limited to the following:

[redacted]

7.5.2 Select Validation Method. In order to determine the thermal environment's ability to meet the defined criteria as outlined in [redacted]

7.5.2.1 Survey Occupants. [redacted]

It is important, however, that the results of the survey be properly interpreted and used. Because space design conditions might differ from actual operating conditions, survey results are not a definitive means of determining whether the design engineer has succeeded in incorporating the requirements of this standard. In addition, occupant psychosocial conditions can impose a strong influence on subjective assessments of the environment, assumed design variables might be no longer valid, and operating control modules might be different from those the design engineer had anticipated.

But when properly used, occupant surveys are [redacted] Survey results can also help designers enhance design protocols and help building operators identify and address reasons for discomfort.

Note: [redacted]

7.5.2.2 Analyze Environment Variables. The second method for evaluating the comfort conditions is to analyze specific environmental data for compliance with the requirements of this standard. Each application of validating the thermal environment is unique. A specific test plan will be required to accommodate the project scope.

Assess the environment for which comfort conditions are going to be verified. Determine the need to verify floor surface temperature, vertical temperature difference, and radiant temperature asymmetry. When this need exists, it is important to ensure [redacted]

Under all expected operating conditions, air speed (nondirectional), [redacted]

Where variables are going to be trended, successful comfort control shall be a function of steady-state performance. Steady state shall require that the trended variable remain within a specified range without cycling. Cycling is defined as fluctuation over 50% of the permitted range every 15 minutes or more frequently. This verification shall include trending variables for at least one occupied cycle during each seasonal condition. When thermal conditions in the occupied zone have a high sensitivity to time of day and weather conditions, the measurement shall be made such that the high and low extremes of the thermal parameters are determined. [redacted]

7.5.3 Provide Documentation. The effort of validation also involves ensuring a thoroughly documented process. Whichever method of validating the thermal environment is chosen, the process shall be well documented.

7.5.3.1 Documenting Surveys. [redacted]

7.5.3.2 Documenting Variable Analysis. [redacted]

8. REFERENCES

1. *ISO 7726:1998, Ergonomics of the thermal environment—Instruments for measuring physical quantities.*
2. *ISO 7730:2005, Ergonomics of the Thermal Environment—Analytical Determination and Interpretation of Thermal Comfort using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria.*
[redacted]

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX A ACTIVITY LEVELS

Use of Metabolic Rate Data

These data presented in Table A1 are reproduced from [redacted]

It is permissible to use a time-weighted average metabolic rate for individuals with activities that vary over a period of one hour or less. For example, a person who typically spends 30 minutes out of each hour "lifting/packing," 15 minutes "filing, standing," and 15 minutes "walking about" has an average metabolic rate of 0.50 × 2.1 + 0.25 × 1.4 + 0.25 × 1.7 = 1.8 met. Such averaging should not be applied when the period of variation is greater than one hour. For example, a person who is engaged in "lifting/packing" for one hour and then "filing, standing" the next hour should be treated as having two distinct metabolic rates.

As metabolic rates increase above 1.0 met, the evaporation of sweat becomes an increasingly important factor for thermal comfort. The PMV method does not fully account for this factor, and this standard should not be applied to situations where the time-averaged metabolic rate is above 2.0 met. ***Note:*** Rest breaks (scheduled or hidden) or other operational factors (get parts, move products, etc.) combine to limit time-weighted metabolic rates to about 2.0 met in most applications.

Time averaging of metabolic rates only applies to an individual. The metabolic rates associated with the activities of various individuals in a space may *not* be averaged to find a single, average metabolic rate to be applied to that space. The range of activities of different individuals in the space, and the environmental conditions required for those activities, should be considered in applying this standard. For example, the customers in a restaurant may have a metabolic rate near 1.0 met, while the servers may have a metabolic rate closer to 2.0 met. Each of these groups of occupants should be considered separately in determining the conditions required for comfort. In some situations, it will not be possible to provide an acceptable level or the same level of comfort to all disparate groups of occupants (e.g., restaurant customers and servers).

The metabolic rates in this table were determined when the subjects' thermal sensation was close to neutral. It is not yet known the extent to which people may modify their metabolic rate to decrease warm discomfort.

TABLE A1 Metabolic Rates for Typical Tasks

Activity	Metabolic Rate		
	Met Units	W/m^2	(Btu/h·ft^2)
Resting			
Sleeping	[redacted]	[redacted]	[redacted]
Reclining	[redacted]	[redacted]	[redacted]
Seated, quiet	[redacted]	[redacted]	[redacted]
Standing, relaxed	[redacted]	[redacted]	[redacted]
Walking (on level surface)			
0.9 m/s, 3.2 km/h, 2.0 mph	[redacted]	[redacted]	[redacted]
1.2 m/s, 4.3 km/h, 2.7 mph	[redacted]	[redacted]	[redacted]
1.8 m/s, 6.8 km/h, 4.2 mph	[redacted]	[redacted]	[redacted]
Office Activities			
Reading, seated	[redacted]	[redacted]	[redacted]
Writing	[redacted]	[redacted]	[redacted]
Typing	[redacted]	[redacted]	[redacted]
Filing, seated	[redacted]	[redacted]	[redacted]
Filing, standing	[redacted]	[redacted]	[redacted]
Walking about	[redacted]	[redacted]	[redacted]
Lifting/packing	[redacted]	[redacted]	[redacted]
Driving/Flying			
Automobile	[redacted]	[redacted]	[redacted]
Aircraft, routine	[redacted]	[redacted]	[redacted]
Aircraft, instrument landing	[redacted]	[redacted]	[redacted]
Aircraft, combat	[redacted]	[redacted]	[redacted]
Heavy vehicle	[redacted]	[redacted]	[redacted]
Miscellaneous Occupational Activities			
Cooking	[redacted]	[redacted]	[redacted]
House cleaning	[redacted]	[redacted]	[redacted]
Seated, heavy limb movement	[redacted]	[redacted]	[redacted]
Machine work			
sawing (table saw)	[redacted]	[redacted]	[redacted]
light (electrical industry)	[redacted]	[redacted]	[redacted]
heavy	[redacted]	[redacted]	[redacted]
Handling 50 kg (100 lb) bags	[redacted]	[redacted]	[redacted]
Pick and shovel work	[redacted]	[redacted]	[redacted]
Miscellaneous Leisure Activities			
Dancing, social	[redacted]	[redacted]	[redacted]
Calisthenics/exercise	[redacted]	[redacted]	[redacted]
Tennis, single	[redacted]	[redacted]	[redacted]
Basketball	[redacted]	[redacted]	[redacted]
Wrestling, competitive	[redacted]	[redacted]	[redacted]

(This is a normative appendix and is part of this standard.)

NORMATIVE 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, [redacted] Users not familiar with clothing insulation terminology are referred to [redacted]

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, it is permissible to use tables in this appendix to estimate clothing insulation using one of the methods described below. Regardless of the source of the clothing insulation value, this standard shall not be used with clothing ensembles with more than 1.5 clo of insulation. This standard should not be used with clothing that is highly impermeable to moisture transport (e.g., chemical protective clothing or rain gear).

Three methods for estimating clothing insulation are presented. The methods are listed in order of accuracy and should be used in this order of preference.

- **Method 1:** Table B1 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 B2 presents the thermal insulation of a variety of individual garments. It is acceptable to add or subtract these garments from the ensembles in Table B1 to estimate the insulation of ensembles that differ in garment composition from those in Table B1. For example, if long underwear bottoms are added to Ensemble 5 in Table B1, the insulation of the resulting ensemble is estimated as I_{cl} = 1.01 + 0.15 = 1.16 clo.
- **Method 3:** It is acceptable to define a complete clothing ensemble using a combination of the garments listed in Table B2. The insulation of the ensemble is estimated as the sum of the individual values listed in Table B2. 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 clo.

[redacted] A sitting posture results in a decreased thermal insulation due to compression of air layers in the clothing. This decrease may be offset by insulation provided by the chair. [redacted] For many chairs, the net effect of sitting is a minimal change in clothing insulation. For this reason, it is recommended that no adjustment be made to clothing insulation if there is uncertainty as to the type of chair and/or if the activity for an individual includes both sitting and standing.

[redacted]

Body motion decreases the insulation of a clothing ensemble by pumping air through clothing openings and/or causing air motion within the clothing. This effect varies considerably depending on the nature of the motion (e.g., walking versus lifting) and the nature of the clothing (stretchable and snug fitting versus stiff and loose fitting). Because of this variability, accurate estimates of clothing insulation for an active person are not available unless measurements are made for the specific clothing under the conditions in question (e.g., with a walking manikin). A rough estimate of the clothing insulation for an active person is

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

where M is the metabolic rate in met units and I_{cl} is the insulation without activity. For metabolic rates less than or equal to 1.2 met, no adjustment is recommended.

When a person is sleeping or resting in a reclining posture, the bed and bedding may provide considerable thermal insulation. It is [redacted]

Clothing variability among occupants in a space is an important consideration in applying this standard. This variability takes two forms. In the first form, [redacted] Examples include [redacted] In the second form, [redacted] For example, [redacted] The first form of variability may result in differences in the requirements for thermal comfort between the different occupants, and these differences should be addressed in applying this standard. In this situation, [redacted] Where the variability within a group of occupants is of the second form and is a result only of individuals freely making adjustments in clothing to suit their individual thermal preferences, [redacted]

TABLE B1
Clothing Insulation Values for Typical Ensembles*

Clothing Description	Garments Included†	I_{cl}, (clo)
Trousers	1) Trousers, short-sleeve shirt	[redacted]
	2) Trousers, long-sleeve shirt	[redacted]
	3) #2 plus suit jacket	[redacted]
	4) #2 plus suit jacket, vest, T-shirt	[redacted]
	5) #2 plus long-sleeve sweater, T-shirt	[redacted]
	6) #5 plus suit jacket, long underwear bottoms	[redacted]
Skirts/Dresses	7) Knee-length skirt, short-sleeve shirt (sandals)	[redacted]
	8) Knee-length skirt, long-sleeve shirt, full slip	[redacted]
	9) Knee-length skirt, long-sleeve shirt, half slip, long-sleeve sweater	[redacted]
	10) Knee-length skirt, long-sleeve shirt, half slip, suit jacket	[redacted]
	11) Ankle-length skirt, long-sleeve shirt, suit jacket	[redacted]
Shorts	12) Walking shorts, short-sleeve shirt	[redacted]
Overalls/Coveralls	13) Long-sleeve coveralls, T-shirt	[redacted]
	14) Overalls, long-sleeve shirt, T-shirt	[redacted]
	15) Insulated coveralls, long-sleeve thermal underwear tops and bottoms	[redacted]
Athletic	16) Sweat pants, long-sleeve sweatshirt	[redacted]
Sleepwear	17) Long-sleeve pajama tops, long pajama trousers, short 3/4 length robe (slippers, no socks)	[redacted]

* Data are from Chapter 9 in the 2009 *ASHRAE Handbook—Fundamentals*.[3]
† All clothing ensembles, except where otherwise indicated in parentheses, include shoes, socks, and briefs or panties. All skirt/dress clothing ensembles include pantyhose and no additional socks.

For near-sedentary activities where the metabolic rate is approximately 1.2 met, the effect of changing clothing insulation on the optimum operative temperature is approximately 6°C (11°F) per clo. For example, Table B2 [redacted]

TABLE B2
Garment Insulation*

Garment Description†	I_{clu}, clo	Garment Description[b]	I_{clu}, clo
Underwear		**Dress and Skirts****	
Bra	[redacted]	Skirt (thin)	[redacted]
Panties	[redacted]	Skirt (thick)	[redacted]
Men's briefs	[redacted]	Sleeveless, scoop neck (thin)	[redacted]
T-shirt	[redacted]	Sleeveless, scoop neck (thick), i.e., jumper	[redacted]
Half-slip	[redacted]	Short-sleeve shirtdress (thin)	[redacted]
Long underwear bottoms	[redacted]	Long-sleeve shirtdress (thin)	[redacted]
Full slip	[redacted]	Long-sleeve shirtdress (thick)	[redacted]
Long underwear top	[redacted]	**Sweaters**	
Footwear		Sleeveless vest (thin)	[redacted]
Ankle-length athletic socks	[redacted]	Sleeveless vest (thick)	[redacted]
Pantyhose/stockings	[redacted]	Long-sleeve (thin)	[redacted]
Sandals/thongs	[redacted]	Long-sleeve (thick)	[redacted]
Shoes	[redacted]	**Suit Jackets and Vests††**	
Slippers (quilted, pile lined)	[redacted]	Sleeveless vest (thin)	[redacted]
Calf-length socks	[redacted]	Sleeveless vest (thick)	[redacted]
Knee socks (thick)	[redacted]	Single-breasted (thin)	[redacted]
Boots	[redacted]	Single-breasted (thick)	[redacted]
Shirts and Blouses		Double-breasted (thin)	[redacted]
Sleeveless/scoop-neck blouse	[redacted]	Double-breasted (thick)	[redacted]
Short-sleeve knit sport shirt	[redacted]	**Sleepwear and Robes**	
Short-sleeve dress shirt	[redacted]	Sleeveless short gown (thin)	[redacted]
Long-sleeve dress shirt	[redacted]	Sleeveless long gown (thin)	[redacted]
Long-sleeve flannel shirt	[redacted]	Short-sleeve hospital gown	[redacted]
Long-sleeve sweatshirt	[redacted]	Short-sleeve short robe (thin)	[redacted]
Trousers and Coveralls		Short-sleeve pajamas (thin)	[redacted]
Short shorts	[redacted]	Long-sleeve long gown (thick)	[redacted]
Walking shorts	[redacted]	Long-sleeve short wrap robe (thick)	[redacted]
Straight trousers (thin)	[redacted]	Long-sleeve pajamas (thick)	[redacted]
Straight trousers (thick)	[redacted]	Long-sleeve long wrap robe (thick)	[redacted]
Sweatpants	[redacted]		
Overalls	[redacted]		
Coveralls	[redacted]		

* Data are from Chapter 9 in the *2009 ASHRAE Handbook—Fundamentals*[3].
† "Thin" refers to garments made of lightweight, thin fabrics often worn in the summer; "thick" refers to garments made of heavyweight, thick fabrics often worn in the winter.
** Knee-length dresses and skirts.
†† Lined vests.

TABLE B3
Typical Added Insulation when Sitting on a Chair
(Valid for Clothing Ensembles with Standing Insulation Values of 0.5 clo < I_{cl} < 1.2 clo)

Net chair*	[redacted]
Metal chair	[redacted]
Wooden side arm chair†	[redacted]
Wooden stool	[redacted]
Standard office chair	[redacted]
Executive chair	[redacted]

* A chair constructed from thin, widely spaced cords that provide no thermal insulation. Included for comparison purposes only.
† Chair used in most of the basic studies of thermal comfort that were used to establish the PMV-PPD index.

(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 C ACCEPTABLE APPROXIMATION FOR OPERATIVE TEMPERATURE

The assumption that operative temperature equals air temperature is acceptable when these four conditions exist:

1. There is no radiant and/or radiant panel heating or radiant panel cooling system;
2. The average U-factor of the outside window/wall is determined by the following equation:

[redacted]

where

[redacted]

Calculation of the Operative Temperature Based on Air and Mean-Radiant 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, the following formula may be used:

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX D
COMPUTER PROGRAM FOR CALCULATION OF PMV-PPD

(Reference Annex D of ISO 7730. Used with permission from ISO. For additional technical information and an I-P version of the equations in this appendix, refer to the ASHRAE *Thermal Comfort Tool CD* referenced in Section 8 of this standard. The Thermal Comfort Tool allows for I-P inputs and outputs, but the algorithm is implemented in SI units.)

[redacted]

[redacted]

EXAMPLE—Values used to generate the comfort envelope in Figure 5.2.1.1.

Run #	Air Temp. °F	Air Temp. C	RH %	Radiant Temp. °F	Radiant Temp. C	Air Speed FPM	Air Speed m/s	Met.	CLO	PMV	PPD %
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

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INFORMATIVE APPENDIX E
THERMAL ENVIRONMENT SURVEY

[redacted]

All surveys should strive for a meaningful sample size and a high response rate. If the objective of the survey is a broad-brush assessment of a building or installation, an adequate sample size and high response rate help [redacted]

Note that thermal environment surveys are [redacted]

[redacted]

1. "Right-now" or "point-in-time" surveys are used to evaluate thermal sensations of occupants at a single point in time. Thermal comfort researchers have used these point-in-time surveys to correlate thermal comfort with environmental factors, such as those included in the PMV/PPD model: metabolic rate, clothing insulation, air temperature, radiant temperature, air speed, and humidity.

   A sample point-in-time survey is included in Section E1. This is a thermal sensation survey that asks occupants to rate their sensation (from "hot" to "cold") on the ASHRAE seven-point thermal sensation scale. Comfort, or predicted percentage dissatisfied (PPD), is extrapolated from occupant sensation votes, not surveyed directly.

   In order to use the results of a point-in-time survey to assess comfort conditions with respect to the acceptability ranges discussed in this standard over time, the survey would ideally be implemented in multiple conditions and in multiple operating modes. This may limit the feasibility or applicability of the point-in-time survey or its results.

   Note that a point-in-time survey, if repeated a month or a year apart with the same individuals and thermal environmental conditions, may give somewhat different results. Thus, such surveys should not be coupled with each other and interpreted as evidence of changes in the performance of the building's environmental control systems.

2. A second form of thermal environment survey—a "satisfaction" survey—is used to evaluate thermal comfort response of the building occupants in a certain span of time. Instead of evaluating thermal sensations and environmental variables indirectly to assess percentage dissatisfied, this type of survey directly asks occupants to provide satisfaction responses.

   A sample thermal satisfaction survey has been included in Section E2 of this annex. It asks occupants to rate their satisfaction with their thermal environment (from "very satisfied" to "very dissatisfied") on a seven-point satisfaction scale. Acceptability is determined by the percentage of occupants who have responded "neutral" or "satisfied" (0, +1, +2, or +3) with their environment.

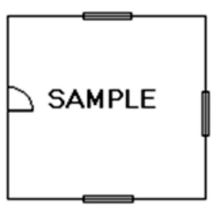
   The basic premise of this survey method is that occupants by nature can recall instances or periods of thermal discomfort, identify patterns in building operation, and provide "overall" or "average" comfort votes on their environment. The surveyor must identify a span of time for the respondents to consider.

   Since the survey results encompass a larger timeframe, the survey can be made every six months or repeated in heating and/or cooling seasons. It is recommended that the first thermal satisfaction survey be done at least six months after a new building has been occupied in order to identify and help avoid typical new-building problems/complaints. Since satisfaction may vary under different operational modes (i.e., seasons, weather), a survey conducted in one mode should not be generalized to other modes of operation.

   The thermal satisfaction survey can be used by researchers, building operators, and facility managers to provide acceptability assessments of building systems' performance and operations in new buildings, in addition to periodic post-occupancy evaluation in existing facilities.

   Note that the longer the time period covered—that is, the longer the period the respondents are asked to recall their thermal satisfaction—the less representative the survey may be of the entire time period. Recall accuracy decreases sharply as the time period recalled increases. Responses will generally be unintentionally weighted by respondents toward more recent experience.

[redacted]



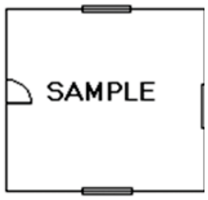
[redacted]

[redacted]

[redacted]

E2. THERMAL ENVIRONMENT SATISFACTION SURVEY[1]

[redacted]



[redacted]

[1] This survey has been adapted from the CBE occupant IEQ survey developed by the Center for the Built Environment at the University of California at Berkeley.

[redacted]

[redacted]

[redacted]

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

[redacted]

The calculated values of SET can be obtained using the [redacted]

[redacted]

[redacted] Figure 5.2.3.1. [redacted]

Example

Input settings at elevated air speed:

Air T	MRT	Air V	RH	Season	Met	Clo
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]						

Input settings at reduced air speed:

Air T	MRT	Air V	RH	Season	Met	Clo
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]						

[redacted]

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INFORMATIVE APPENDIX G
SAMPLE COMPLIANCE DOCUMENTATION

[Forms are located on the following pages.]

SAMPLE COMPLIANCE DOCUMENTATION TEMPLATE

Based on Standard 55-2010 without addenda.

[redacted]

* Operative temperature includes radiant effects. See Standard 55.

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INFORMATIVE APPENDIX I
ADDENDA DESCRIPTION

[redacted]

TABLE I1
Addenda to ANSI/ASHRAE Standard 55-2004

Addendum	Section(s) Affected	Description of Changes*	Approval Dates • Standards Committee • ASHRAE BOD • ANSI
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

* These descriptions may not be complete and are provided for information only.

TABLE I1
Addenda to ANSI/ASHRAE Standard 55-2004 *(Continued)*

Addendum	Section(s) Affected	Description of Changes*	Approval Dates • Standards Committee • ASHRAE BOD • ANSI
i	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

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Product code: 86150 2/12
Errata noted in the list dated 03/22/11 have been corrected.