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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Research Promotion Committee
The 2010 edition of the standard includes the following significant changes:

- 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 [the addenda at the end of this standard]. Users of the standard are encouraged to use the [form for change proposal] to suggest changes for further improvements. A form for submitting change proposals is included in the back of this edition. The [form for Standard 55] will take formal action on all change proposals received.

1. PURPOSE
The purpose of this standard is...

2. SCOPE
2.1 The environmental factors addressed in this standard are...
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

*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 m²·°C/W (0.88 ft²·h·°F/Btu).

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

*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 (Icl)*: 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 (Igl)*: 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/m² (18.4 Btu/h·ft²), 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 m² (19 ft²).

*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.

*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.

*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 (tₐ)*: the temperature of the air surrounding the occupant.

*temperature, dew point (tₛₜ)*: the temperature at which moist air becomes saturated (100% relative humidity) with water vapor (Pₛₜ = Pₛ) when cooled at constant pressure.

*temperature, mean monthly outdoor air (tₐ,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 (tᵣ)*: 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.
5. CONDITIONS THAT PROVIDE THERMAL COMFORT

5.1 Introduction. Thermal comfort is that condition of mind

The environmental conditions required for comfort are

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. Of this standard is used to

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 and

It is possible for

This standard only addresses

Note: As a result of

The effect of

is addressed in

This standard is intended primarily for these conditions. However, it is acceptable to use the standard to

It does not apply

The body of available data does not contain

It is acceptable to apply the information in this standard to

contains the

The conditions required for thermal comfort in spaces that are naturally conditioned are

Field experiments have shown that
5.2 Method for Determining Acceptable Thermal Conditions in Occupied Spaces. When inhabited, a building must be maintained in thermal conditions that are acceptable to the occupants. This standard recommends a graphic method for determining acceptable thermal conditions or in terms of a range of operative temperatures that provide comfort to the occupants.

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 terms of a range of operative temperatures that provide thermally acceptable conditions and are consistent, and either hot or cool.

The comfort zone for environments with clothing is worn that provides between 0.5 and 1.0 clo of thermal insulation. See Normative Appendix A for estimation of metabolic rates and Normative Appendix B for estimation of clothing insulation. Most office spaces fall within these limitations.

The range of operative temperatures presented in Figure 5.2.1.1 is for 80% occupant acceptability. This is based on results from the PMV-PPD method. See Table 5.2.1.2 in Table 5.2.1.2. The PMV model is calculated with the air temperature and mean.

Figure 5.2.1.1 are for 80% occupant acceptability. This is based on ...

where

\[ T_{\text{min, Icl}} = \]...

\[ T_{\text{max, Icl}} = \]...

\[ I_{\text{cl}} = \]...

It is acceptable to use elevated air speeds to increase the range of operative temperatures.

For a given set of conditions, the results from the two methods—5.2.1 and 5.2.1.2—may differ, and the combination that yields the most occupants who vote +2, +3, –2, or –3 on the thermal scale is chosen as the comfort zone. The method used depends on the space and the number of occupants.

See Table 5.2.1.2, 9.3 Chapter 9, for procedures to estimate metabolic rates and clothing insulation.
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

<table>
<thead>
<tr>
<th>PPD</th>
<th>PMV Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

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

Use of the PMV model in this standard is limited to

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,

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

There are for thermal comfort; consequently, this standard does not

Note: Nonthermal comfort factors,

5.2.3 Elevated Air Speed. This standard allows

imposed

Limits are

5.2.3.1 Graphical Elevated Air Speed Method. in Figure 5.2.3.1. The combinations of

as described in

The figure applies to a

described in

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,

Conversely, elevated air speed is

in Figure 5.2.3.1 that corresponds to the

Any benefits gained by increasing air speed Due to increases in skin wettedness, the effect of increased air speed is

Due to increased amounts of exposed skin, the effect of increased air speed is

Thus, Figure 5.2.3.1 is

Due to increased body coverage, the effect of increased air speed is

Thus, Figure 5.2.3.1 will

5.2.3.2 SET Method. Figure 5.2.3.2 represents

The model, however, is and it is acceptable to

The SET model uses a

This model enables air velocity effects on thermal comfort to be

Figure 5.2.3.2 uses Figure 5.2.1.1

Figure 5.2.1.1 is based
Figure 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 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.

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.

In Figure 5.2.3.2 contains heat losses equal to those of the unclad zone. The full bounded area applies when.

For control over their local air speed, control directly accessible to occupants must be provided.

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

#### 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, in Figure 5.2.3.2.

- For operative temperatures above 25.5°C (77.9°F), the upper limit to air speed shall for light, primarily sedentary office activities, such as in offices.
- For operative temperatures below 22.5°C (72.5°F), the limit shall be in order to.
- For operative temperatures between 22.5°C and 25.5°C (72.5°F and 77.9°F), shown in Figure 5.2.3.2.

It is acceptable to approximate the curve in SI and I-P units by the following equation:

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

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

### 5.2.4 Local Thermal Discomfort

#### 5.2.4.1 Radiant Temperature Asymmetry.

The thermal radiation field about the body may be. This asymmetry may cause.

In general, people are more sensitive to local discomfort caused by Figure 5.2.4.1 . Alternatively, it is acceptable to use Figure 5.2.4.1 in conjunction with the PD limits from Table 5.2.4 to meet the requirements of this standard.

#### 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>
<thead>
<tr>
<th>PD Due to Draft</th>
<th>PD Due to Vertical Air Temperature Difference</th>
<th>PD Due to Warm or Cool Floors</th>
<th>PD Due to Radiant Asymmetry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**TABLE 5.2.4**

Percentage Dissatisfied (PD) Due to Local Discomfort from Draft or Other Sources
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 cause a negative impact on thermal comfort, and the requirements of this section do not apply to these fluctuations. Fluctuations that occur due to factors not under the direct control of the individual occupant are not covered in this section. The criteria in Table 5.2.4.3 give the predicted percentage of dissatisfied occupants as a result of moving between locations of different temperature.[Figure 5.2.4.4 gives the predicted percentage of dissatisfied occupants as a result of moving between locations of different temperature.]

TABLE 5.2.4.3
Allowable Vertical Air Temperature Difference Between Head and Ankles

<table>
<thead>
<tr>
<th>Vertical Air Temperature Difference, °C (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.4 &lt; 9.0</td>
</tr>
</tbody>
</table>

5.2.5 Temperature Variations with Time. Fluctuations in the air temperature and/or mean radiant temperature may affect the thermal comfort of occupants. Those fluctuations under the direct control of the individual occupant do not have a negative impact on thermal comfort. However, fluctuations that occur due to factors not under the direct control of the individual occupant may cause negative effects on thermal comfort. This standard does not address the floor temperature required for people not wearing shoes, nor does it address acceptable floor temperature as a function of floor temperature. The criteria in Table 5.2.4.4 give the predicted percentage of dissatisfied occupants as a function of floor temperature. The limits for floor temperature are specified in this section are based on people wearing lightweight indoor clothing. Table 5.2.4.4.

5.2.4.4 Floor Surface Temperature. Occupants may feel a negative impact on thermal comfort due to contact with floor surfaces that are too warm or too cool. The temperature of the floor, rather than the air temperature at head level, is perceived more favorably by occupants, and is not addressed in this standard.

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with different environmental conditions are...  

5.2.5.1 Cyclic Variations. Cyclic variations refer to those situations where the temperature allowed during a period of time. For any given period, the requirements of this section also apply to the component of the variation with a period greater than 15 minutes, and the requirements of Section 5.2.5.2 apply to the component of the variation with a period not greater than 15 minutes are superimposed on variations with a longer period. In some situations, variations with a period not greater than 15 minutes, the conditions at all of these locations are within the comfort limits—one for 80% acceptability and one for 90% acceptability. Table 5.2.5.1 specifies the maximum allowable peak-to-peak variation in temperature limits for spaces where the operative temperatures are those spaces where the thermal environment limits are for typical applications and shall be used when other information is not available. It is acceptable to use the limits for determining acceptable thermal conditions in naturally conditioned spaces. For the purposes of this standard, field experiments have shown that occupants’ thermal responses in such spaces are... This optional method is intended for such spaces.

In order for this optional method to apply, the space in question must be equipped with operable windows that open... It is permissible to use the space to be provided with a cooling, or desiccant cooling). It is permissible to use... It applies only to spaces where the occupants are... For spaces that meet these criteria... Figure 5.3. This figure includes...
Figure 5.3 Acceptable operative temperature ranges for naturally conditioned spaces.

5.4 Description of Thermal Environmental Variables. The following description of the environmental variables is provided for the purpose of understanding their use in this standard. It is not intended to be a measurement specification. Section 7 provides for the purpose of understanding their use in Section 5. It is not intended to be a measurement specification. Section 7

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

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, waist, and head levels (e.g., head level, waist level, and ankle level). These levels are, respectively, for seated occupants, and 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 at least equally spaced points in time. If necessary, it is acceptable to extend the period up to 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. 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 ANSI/ASHRAE Standard 55-2010, Section 5.2.3.2 for a more complete description of operative temperature. For the purposes of this standard, the average is with respect to location and time. As a minimum, the temporal average is a three-minute average with at least equally spaced points in time. If necessary, it is acceptable to extend the period up to hours 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.

For occupants engaged in near sedentary physical activity (with metabolic rates between , not in direct sunlight, and not exposed to air velocities greater than , it is acceptable to approximate the relationship with acceptable accuracy by

where

\[ t_o = \text{operative temperature}, \]
\[ t_a = \text{air temperature}, \]
\[ t_r = \text{mean radiant temperature}. \]

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 radiant asymmetry is determined at .

Time averaging for radiant asymmetry is the same as for mean radiant temperature.

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 minutes. Variations that occur over a period greater than minutes shall be treated as multiple different air speeds.

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.

The proper averaging shall include .

In 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 any is not in this standard. This standard does not

Because of differences in metabolic rates between \( 0.6 \text{ and } 1.4 \) Chapter 14) used

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.
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.

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 705 or Standard 113 or in ISO 7726, 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 radiant asymmetry shall be determined at the position of the most significant future occupant locations 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.

Radiant asymmetry shall be measured at the level for seated occupants and the 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 level for seated occupants and the 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.
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 . If these sky conditions are rare and not representative of the sky conditions used for design, then sky conditions representative of design conditions.

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 . If these sky conditions are rare and not representative of the sky conditions used for design, then sky conditions representative of design conditions.

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 if the system is not proportionally controlled. Simulation of heat generated by occupants.

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:

- Temperature (air, radiant, surface)
- Activity expected
- HVAC system
- Minimum supply-air temperature. When this need exists, it is important to consider the maximum potential for variance is exploited.
- Where variables are going to be trended, successful comfort control shall be a function of steady-state perfor-

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

7.5.2.1 Survey Occupants. 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 .

Survey results can also help designers enhance design protocols and help building operators identify and address reasons for discomfort.

Note:

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 .

Under all expected operating conditions, air speed (nondirectional). Where variables are going to be trended, successful comfort control shall be a function of steady-state perfor-
mance. 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.

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.

7.5.3.2 Documenting Variable Analysis.

8. REFERENCES

(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 Chapter 9 of the 2009 ASHRAE Handbook—Fundamentals. 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 $0.50 \times 2.1 + 0.25 \times 1.4 + 0.25 \times 1.7 = 1.8$ 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>
<thead>
<tr>
<th>Activity</th>
<th>Metabolic Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Met Units</td>
</tr>
<tr>
<td>Resting</td>
<td></td>
</tr>
<tr>
<td>Sleeping</td>
<td>0.7</td>
</tr>
<tr>
<td>Reclining</td>
<td>0.8</td>
</tr>
<tr>
<td>Seated, quiet</td>
<td>1.0</td>
</tr>
<tr>
<td>Standing, relaxed</td>
<td>1.2</td>
</tr>
<tr>
<td>Walking (on level surface)</td>
<td></td>
</tr>
<tr>
<td>0.9 m/s, 3.2 km/h, 2.0 mph</td>
<td>2.0</td>
</tr>
<tr>
<td>1.2 m/s, 4.3 km/h, 2.7 mph</td>
<td>2.6</td>
</tr>
<tr>
<td>1.8 m/s, 6.8 km/h, 4.2 mph</td>
<td>3.8</td>
</tr>
<tr>
<td>Office Activities</td>
<td></td>
</tr>
<tr>
<td>Reading, seated</td>
<td>1.0</td>
</tr>
<tr>
<td>Writing</td>
<td>1.0</td>
</tr>
<tr>
<td>Typing</td>
<td>1.1</td>
</tr>
<tr>
<td>Filing, seated</td>
<td>1.2</td>
</tr>
<tr>
<td>Filing, standing</td>
<td>1.4</td>
</tr>
<tr>
<td>Walking about</td>
<td>1.7</td>
</tr>
<tr>
<td>Lifting/packing</td>
<td>2.1</td>
</tr>
<tr>
<td>Driving/Flying</td>
<td></td>
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<tr>
<td>Automobile</td>
<td></td>
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<tr>
<td>Aircraft, routine</td>
<td></td>
</tr>
<tr>
<td>Aircraft, instrument landing</td>
<td></td>
</tr>
<tr>
<td>Aircraft, combat</td>
<td></td>
</tr>
<tr>
<td>Heavy vehicle</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous Occupational Activities</td>
<td></td>
</tr>
<tr>
<td>Cooking</td>
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</tr>
<tr>
<td>House cleaning</td>
<td></td>
</tr>
<tr>
<td>Seated, heavy limb movement</td>
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</tr>
<tr>
<td>Machine work</td>
<td></td>
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<tr>
<td>sawing (table saw)</td>
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<tr>
<td>light (electrical industry)</td>
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<tr>
<td>heavy</td>
<td></td>
</tr>
<tr>
<td>Handling 50 kg (100 lb) bags</td>
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<tr>
<td>Pick and shovel work</td>
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<td>Miscellaneous Leisure Activities</td>
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<tr>
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<td>Tennis, single</td>
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<tr>
<td>Basketball</td>
<td></td>
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<tr>
<td>Wrestling, competitive</td>
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</tr>
</tbody>
</table>
(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, users not familiar with clothing insulation terminology are referred to

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 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.

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.

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

$$I_{cl,\text{active}} = I_{cl} \times (0.6 + 0.4 / M)$$

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

*Examples include*

In the second form,

For example,

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,

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,
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 indicates that adding a thin, long-sleeve sweater to a clothing ensemble increases clothing insulation by approximately 0.25 clo. Adding this insulation would lower the optimum operative temperature by approximately 6°C/clo × 0.25 clo = 1.5°C (11°F/clo × 0.25 clo = 2.8°F). The effect is greater with higher metabolic rates.

### TABLE B1

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

* Data are from Chapter 9 in the 2009 *ASHRAE Handbook—Fundamentals*.
† 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.
### TABLE B2
Garment Insulation*

<table>
<thead>
<tr>
<th>Garment Description†</th>
<th>$I_{clu}$, clo</th>
<th>Garment Descriptionb</th>
<th>$I_{clu}$, clo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underwear</td>
<td></td>
<td>Dress and Skirts**</td>
<td></td>
</tr>
<tr>
<td>Bra</td>
<td></td>
<td>Skirt (thin)</td>
<td></td>
</tr>
<tr>
<td>Panties</td>
<td></td>
<td>Skirt (thick)</td>
<td></td>
</tr>
<tr>
<td>Men's briefs</td>
<td></td>
<td>Sleeveless, scoop neck (thin)</td>
<td></td>
</tr>
<tr>
<td>T-shirt</td>
<td></td>
<td>Sleeveless, scoop neck (thick), i.e., jumper</td>
<td></td>
</tr>
<tr>
<td>Half-slip</td>
<td></td>
<td>Short-sleeve shirtdress (thin)</td>
<td></td>
</tr>
<tr>
<td>Long underwear bottoms</td>
<td></td>
<td>Long-sleeve shirtdress (thin)</td>
<td></td>
</tr>
<tr>
<td>Full slip</td>
<td></td>
<td>Long-sleeve shirtdress (thick)</td>
<td></td>
</tr>
<tr>
<td>Long underwear top</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Footwear</td>
<td></td>
<td>Sweaters</td>
<td></td>
</tr>
<tr>
<td>Ankle-length athletic socks</td>
<td>0.00 clo</td>
<td>Sleeveless vest (thin)</td>
<td></td>
</tr>
<tr>
<td>Pantyhose/stockings</td>
<td></td>
<td>Sleeveless vest (thick)</td>
<td></td>
</tr>
<tr>
<td>Sandals/thongs</td>
<td></td>
<td>Long-sleeve (thin)</td>
<td></td>
</tr>
<tr>
<td>Shoes</td>
<td></td>
<td>Long-sleeve (thick)</td>
<td></td>
</tr>
<tr>
<td>Slippers (quilted, pile lined)</td>
<td>0.02 clo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calf-length socks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee socks (thick)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boots</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shirts and Blouses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleeveless/scoop-neck blouse</td>
<td>0.08 clo</td>
<td>Double-breasted (thin)</td>
<td></td>
</tr>
<tr>
<td>Short-sleeve knit sport shirt</td>
<td>0.12 clo</td>
<td>Double-breasted (thick)</td>
<td></td>
</tr>
<tr>
<td>Short-sleeve dress shirt</td>
<td>0.17 clo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-sleeve dress shirt</td>
<td>0.20 clo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-sleeve flannel shirt</td>
<td>0.21 clo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-sleeve sweatshirt</td>
<td>0.23 clo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trousers and Coveralls</td>
<td></td>
<td>Short-sleeve pajamas (thin)</td>
<td></td>
</tr>
<tr>
<td>Short shorts</td>
<td></td>
<td>Long-sleeve long gown (thick)</td>
<td></td>
</tr>
<tr>
<td>Walking shorts</td>
<td></td>
<td>Long-sleeve short wrap robe (thick)</td>
<td></td>
</tr>
<tr>
<td>Straight trousers (thin)</td>
<td>0.34 clo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight trousers (thick)</td>
<td>0.36 clo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweatpants</td>
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<td>Overalls</td>
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<tr>
<td>Coveralls</td>
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</tbody>
</table>

* Data are from Chapter 9 in the 2009 ASHRAE Handbook—Fundamentals/.
† “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 < $I_{clu}$ < 1.2 clo)

| Net chair* | 0.00 clo |
| Metal chair | 0.10 clo |
| Wooden side arm chair† | 0.15 clo |
| Wooden stool | 0.17 clo |
| Standard office chair | 0.18 clo |
| Executive chair | 0.19 clo |

* 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.
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:

\[ U_w = \frac{t_d, i - t_d, e}{U_w} \]

where

- \( t_d, i \) = internal design temperature, °C (°F);
- \( t_d, e \) = external design temperature, °C (°F);
- \( U_w \) = average U-factor of window/wall, W/m²·K (Btu/h·ft²/°F);

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

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:

\[ t_{op} = \frac{A t_a + t_r}{A} \]

where

- \( t_{op} \) = operative temperature,
- \( t_a \) = air temperature, and
- \( t_r \) = mean radiant temperature.

The value of \( A \) can be found from the values below as a function of the relative air speed, \( v_r \).

\[
\begin{align*}
A & = 0.5, \quad v_r < 0.2 \text{ m/s} \\
A & = 0.6, \quad 0.2 \text{ to } 0.6 \text{ m/s} \\
A & = 0.7, \quad 0.6 \text{ to } 1.0 \text{ m/s}
\end{align*}
\]
(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.)
EXAMPLE—Values used to generate the comfort envelope in Figure 5.2.1.1.

<table>
<thead>
<tr>
<th>Run #</th>
<th>Air Temp. °F</th>
<th>RH %</th>
<th>Radiant Temp. °F</th>
<th>Air Speed FPM</th>
<th>Met.</th>
<th>CLO</th>
<th>PMV</th>
<th>PPD %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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Values used to generate the comfort envelope in Figure 5.2.1.1.
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.
E2. THERMAL ENVIRONMENT SATISFACTION SURVEY\textsuperscript{1}

1. Either (a) place an “X” in the appropriate place where

2. On which floor of the building is your space located?

3. Which of the following do you personally adjust or

4. How satisfied are you with the temperature in your

5. When is this most often a problem? (check all that apply).

6. Which of the following contribute to your dissat-

Note to survey designer:
This list can be modified at your
discretion. Include a scale or, as
appropriate, check boxes.

\textsuperscript{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.
d. How would you best describe the source of this discomfort? (Check all that apply):

- Humidity too high (damp)
- Humidity too low (dry)
- Air movement too high
- Air movement too low
- Incoming sun
- Heat from office equipment
- Drafts from windows
- Drafts from vents
- My area is hotter/colder than other areas
- Thermostat is inaccessible
- Thermostat is adjusted by other people
- Clothing policy is not flexible
- Heating/cooling system does not respond quickly enough to the thermostat
- Hot/cold surrounding surfaces (floor, ceiling, walls, or windows)
- Deficient window (not operable)
- Other: ___________________________________

Note to survey designer: This list can be modified at your discretion.

e. Please describe any other issues related to being too hot or too cold in your space:
   __________________________________________
   __________________________________________
   __________________________________________
   __________________________________________
   __________________________________________
   __________________________________________
   __________________________________________
   __________________________________________
   __________________________________________
(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 F
PROCEDURE FOR EVALUATING COOLING EFFECT OF ELEVATED AIR SPEED USING SET

Example
Input settings at elevated air speed:

<table>
<thead>
<tr>
<th>Air T</th>
<th>MRT</th>
<th>Air V</th>
<th>RH</th>
<th>Season</th>
<th>Met</th>
<th>Clo</th>
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The calculated values of SET can be obtained using the

Input settings at reduced air speed:

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<thead>
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INFORMATIVE APPENDIX G
SAMPLE COMPLIANCE DOCUMENTATION

[Forms are located on the following pages.]
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INFORMATIVE APPENDIX H

BIBLIOGRAPHY


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**INFORMATIVE APPENDIX I**

**ADDENDA DESCRIPTION**

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* These descriptions may not be complete and are provided for information only.
TABLE I1
Addenda to ANSI/ASHRAE Standard 55-2004 (Continued)

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* These descriptions may not be complete and are provided for information only.
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Errata noted in the list dated 03/22/11 have been corrected.