CITY OF FORT WORTH ADMINISTRATIVE REGULATIONS			SECTION: F NUMBER: 1
SUBJECT:	Air Temperature Regulation within Conditioned Spaces		PAGE 1 OF 7
REPLACES:	AR F-1 Effective 01Oct09	EFFECTIVE DATE: 01Oct13	REVIEW DATE: 30Sep24
PREPARED BY:	Department of Transportation and Public Works	APPROVED BY CITY MANAGER:	

1.0 PURPOSE

This Administrative Regulation (AR) establishes policy, practice and procedures that assist in providing effective air temperature regulation within City facility's conditioned spaces. This AR is intended to improve environmental air quality through sustainable resource conservation.

2.0 KEY WORDS

2.1 Air Temperature Regulation
2.2 Conditioned Space
2.3 Environmental Air Quality
2.4 Resource Conservation
2.5 Texas Senate Bills 5, 12, & 898

3.0 DEPARTMENTS AFFECTED

All departments are responsible for complying with this AR.

4.0 SPECIAL DISTRIBUTION

All staff dealing with or responsible for acceptable thermal environments in conditioned spaces.

5.0 REFERENCES

5.1 Senate Bill 5, 77th Texas Legislative Session, 2001

5.2 Senate Bill 12, 80th Texas Legislative Session, 2007

5.3 Senate Bill 898, 82nd Texas Legislative Session, 2011

5.4 Standard 55-2004, ANSI/ASHRAE, 2004

6.0 DEFINITIONS

6.1 Acceptable Thermal Environment – An environment within a conditioned space that a substantial majority of occupants would find thermally acceptable.

6.2 Air Temperature Regulation – Control of space air temperature to achieve acceptable thermal environments in conditioned spaces.

6.3 ANSI/ASHRAE – American National Standards Institute/American Society of Heating, Refrigerating and Air-conditioning Engineers

6.4 Conditioned Space – Area of a facility that is provided air temperature control through heating, ventilating and air conditioning (HVAC) system equipment and controls.

6.5 Environmental Air Quality – Qualitative assessment of outdoor air based on the quantitative chemical composition of that air, relative to human health.

6.6 Resource Conservation – Use of techniques and methodologies to achieve a reduction in use of energy, water and other natural resources in the interest of sustainability.

6.7 Sustainability – An ethic expressed by working to reduce the negative impacts of human activities on natural environmental systems through activities such as resource conservation.

6.8 Texas Senate Bill 5 (SB5) – Legislation amending the Texas Health & Safety Code (Section 388.005), encouraging political subdivisions within designated counties, including Tarrant, to conserve electricity in assisting the state with complying with federal Clean Air Act standards. Establishes the Texas Emissions Reduction Plan (TERP) with a goal for designated areas to reduce electricity consumption by 5% per year for 5-years, starting in 2001.

6.9 Texas Senate Bill 12 (SB12) – Legislation amending the TERP with a goal for designated areas to reduce electricity consumption by 5% per year for 6-more years, starting in 2006.

6.10 Texas Senate Bill 898 (SB898) – Legislation amending the TERP with a goal for designated areas to reduce electricity consumption by 5% per year for 10-more years, starting in 2011.

6.11 Thermal Comfort – Condition of mind that expresses satisfaction relative to the conditioned space's thermal environment as assessed by subjective evaluation.

7.0 POLICY

The City of Fort Worth shall provide sustainable resource conservation and utility cost containment by regulating air temperatures within conditioned spaces in establishing and maintaining acceptable thermal environments, all while endeavoring to provide reasonable thermal comfort for occupants.

8.0 GENERAL

8.1 FOREWORD, ANSI/ASHRAE Standard 55-2004

Standard 55-2004, "Thermal Environmental Conditions for Human Comfort," is a revision of Standard 55-1992. The standard specifies conditions in which a specified fraction of the occupants will find the environment thermally acceptable. The revision is a consensus standard that has undergone public and ASHRAE review; it incorporates the relevant research and experience gained since the 1992 revision... ...The standard is intended for use in design, commissioning, and testing of buildings and other occupied spaces and their HVAC systems and for the evaluation of thermal environments. Because it is not possible to prescribe the metabolic rate of occupants, and because of variations in occupant clothing levels, operating set points for buildings cannot be practically mandated by this standard....

...This standard may also be used for evaluation of existing thermal environments in buildings, during experimental conditions, and for the development and testing of products.

This standard is in close agreement with ISO Standards 7726 and 7730.

8.2 PURPOSE, ANSI/ASHRAE Standard 55-2004

The purpose of this standard is to specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants within the space.

8.3 CONDITIONS THAT PROVIDE HUMAN COMFORT - Introduction, ANSI/ASHRAE Standard 55-2004

Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment. Because there are large variations, both physiologically and psychologically, from person to person, it is difficult to satisfy everyone in a space. The environmental conditions required for comfort are not the same for everyone. However 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...

There are six primary factors that must be addressed when defining conditions for thermal comfort. A number of other, secondary factors affect comfort in some circumstances. The six primary factors are listed below...

1. *Metabolic Rate*
2. *Clothing Insulation*
3. *Air Temperature*
4. *Radiant Temperature*
5. *Air Speed*
6. *Humidity*

All six of these factors may vary with time. However this standard only addresses thermal comfort in a steady state... As a result, people entering a space that meets the requirements of this standard may not immediately find the conditions comfortable if they have experienced different environmental conditions just prior to entering the space. The effect of prior exposure or activity may effect comfort perceptions for approximately one hour...

9.0 RESPONSIBILITY/AUTHORITY

9.1 General Fund Facilities

9.1.1 Authority over air temperature regulation within conditioned spaces rests with the Department of Transportation and Public Works' (TPWs) Facilities Management Group. This includes only City-occupied facilities with City-paid utilities.

9.1.2 Responsibility for air temperature regulation within conditioned spaces rests with TPWs' Facilities Management Group, with the exception of areas as noted below:

9.1.2.1 Management of the Public Events Department is responsible for the areas of assembly within the City's Convention Center and Will Rogers' facilities;

9.1.2.2 Management of the Fort Worth Fire Department (FWFD) is responsible for the occupied areas within the City's Fire Stations; and

9.1.2.3 Management of the Parks & Community Services Department (PaCS) is responsible for the areas of assembly within the City's Botanic Gardens facility.

9.2 Internal Service, Enterprise, and Special Fund Facilities

9.2.1 Authority over air temperature regulation within conditioned spaces rests with TPW's Facilities Management Group. This includes only City-occupied facilities with City-paid utilities.

9.2.2 Responsibility for air temperature regulation within conditioned spaces rests with the respective department (e.g. City Departments of Equipment Services, Information Technology Services, Aviation, and Water.)

10.0 PRACTICE

10.1 The City shall endeavor to maintain acceptable thermal environments within its facilities conditioned spaces in the interest of sustainable resource conservation and utility cost containment. Facility HVAC systems shall be adjusted to regulate conditioned space air temperatures within the following bounds based on building occupancy and HVAC mode:

Occupancy/HVAC Mode	Heating	Cooling
Occupied Hours (STD Ex.)	70°F, maximum	73°F, minimum
Occupied Hours (CMO Ex.)	68°F, maximum	76°F, minimum
Occupied Hours (PaCS)	72°F, maximum	72°F, minimum
Occupied Hours (Code)	60°F, maximum	78°F, minimum
Unoccupied Hours (All Ex.)	50°F, maximum	85°F, minimum
Unoccupied Hours (Library)	52°F, maximum	82°F, minimum

10.2 City conditioned space air temperature targets are within the range of ANSI/ASHRAE Standard 55-2004 as referenced in Appendix 12.2 of this AR. These air temperature targets assume:

- ✓ average *Metabolic Rates* of conditioned space occupants;
- ✓ seasonally- and business-appropriate *Clothing Insulation* for conditioned space occupants;
- ✓ surface *Radiant Temperatures* relatively close to that of the air within the conditioned space;
- ✓ reasonable *Air Speed* from the HVAC system and within the conditioned space; and
- ✓ *Relative Humidity* of air between 30% and 70% within the conditioned space.

10.3 "Heating" and "Cooling" temperature set points are within accepted best-practice limits recommended by ASHRAE, and correspond to those set in an Energy Savings Performance Contract (ESPC) between the City and its Energy Services Company (ESCo) of-record. *NOTE: These limits allow a guarantee of cost savings by the ESCo to the City, as necessary to repay City financial obligations that funded City-facility improvements.*

10.3.1 Temporary pre-cooling is allowed for areas of assembly such as City Council Chambers, and large meeting areas such as those within Public Events, PaCS and Library facilities.

10.3.2 Temperature set points outside those listed are allowed for City Fire Stations with the understanding that the adjustable limits of the control equipment are 54°F to 100°F*.

*NOTE: *Comfort air-conditioning equipment is not designed to meet these limits. HVAC system capabilities vary based on outside air temperature and humidity in relation to a given Fire Station's design and construction – equipment capacity, insulation values, and facility condition, in particular. Operating outside of the tabulated set points may increase the need for equipment service and shorten the useful life of HVAC equipment.*

10.4 "Occupied Hours" are those hours when a given facility or area is typically staffed on an annual basis, inclusive of normal business hours. Acceptable thermal environments shall be maintained during all Occupied Hours.

10.4.1 "STD Ex." set points shall be maintained as standard practice for all normally occupied areas with exceptions as listed in the table above and as noted below.

10.4.2 "CMO Ex." set points may be invoked upon specific City Manager's Office request and subsequent notice to City staff during times of City budget or local utility constraint.

10.4.3 "PaCS" set points shall be maintained as standard practice only for areas normally occupied as *Senior Activity*, *Child Care*, and *Health Clinic* areas due to the special nature of serving those that are predominantly younger, older, and infirm.

10.4.4 "Code" set points shall be maintained as standard practice only for areas normally occupied by animals in the City Animal Care & Control facility's kennel areas due to the special requirements of that population. *NOTE: Texas State Department of Health §169.26 states that temperatures of kennel spaces are to be kept between 50°F and 85°F.*

10.5 "Unoccupied Hours" are those hours when a given facility or area is not typically staffed on an annual basis, outside of the referenced Occupied Hours.

10.5.1 "All Ex." set points shall be maintained as standard practice for all normally unoccupied areas with exceptions as listed in the table above and as noted below.

10.5.2 "Library" set points shall be maintained as standard practice only for areas normally unoccupied as housing *books*, *archives*, and *paintings* due to the special requirements of those items.

10.6 "HVAC Modes" are determined by the predominant necessity for either heating or cooling equipment to be utilized to provide a conditioned space temperature within the above-specified ranges. HVAC Mode settings are typically determined as relative to both outdoor and indoor temperatures and humidity, as well as relative activity within the conditioned area.

10.7 Not included in this AR are conditioned space air temperature targets necessary for the proper operations and maintenance of process equipment, or to satisfy other, non-human comfort requirements.

11.0 PROCEDURE

11.1 General Fund Facilities

11.1.1 General questions or concerns from General Fund Departments regarding this AR shall be directed to TPW's Facilities Management Group. Requests for deviations from stated occupancy hours and air temperature set points shall be addressed to the Conservation Specialist of TPW's Facilities Management Group.

11.1.2 With the exception of facilities managed by the Public Events Departments, occupant concerns regarding specific comfort issues within General Fund facilities shall be addressed to the Facilities Maintenance Division of TPW's Facilities Management Group.

11.1.3 Occupant concerns regarding specific comfort issues and occupancy hours within Public Events Department facilities shall be addressed by contacting their immediate supervisor, citing this AR.

11.2 Internal Service, Enterprise, and Special Fund Facilities

11.2.1 Questions or concerns from Internal Service, Enterprise, and Special Fund Departments regarding this AR shall be directed to TPW's Facilities Management Group. Requests for deviations from stated occupancy hours and air temperature set points shall be addressed to the Conservation Specialist of TPW's Facilities Management Group.

11.2.2 Occupant concerns regarding specific comfort issues within Internal Service, Enterprise, and Special Fund Department facilities shall be addressed to their immediate supervisor, citing this AR.

12.0 APPENDICES (attached)

12.1 Acceptable Range of Operative Temperatures and Humidity (for Spaces that meet the Criteria specified in Section 5.2.1.1), ANSI/ASHRAE Standard 55-2004

12.2 Informative Appendix E – Thermal Environment Survey, ANSI/ASHRAE Standard 55-2004

STANDARD

ANSI/ASHRAE Standard 55-2017
(Supersedes ANSI/ASHRAE Standard 55-2013)
Includes ANSI/ASHRAE addenda listed in Appendix N

Thermal Environmental Conditions for Human Occupancy

See Appendix N for approval dates.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336

Approved American National Standard
ANSI
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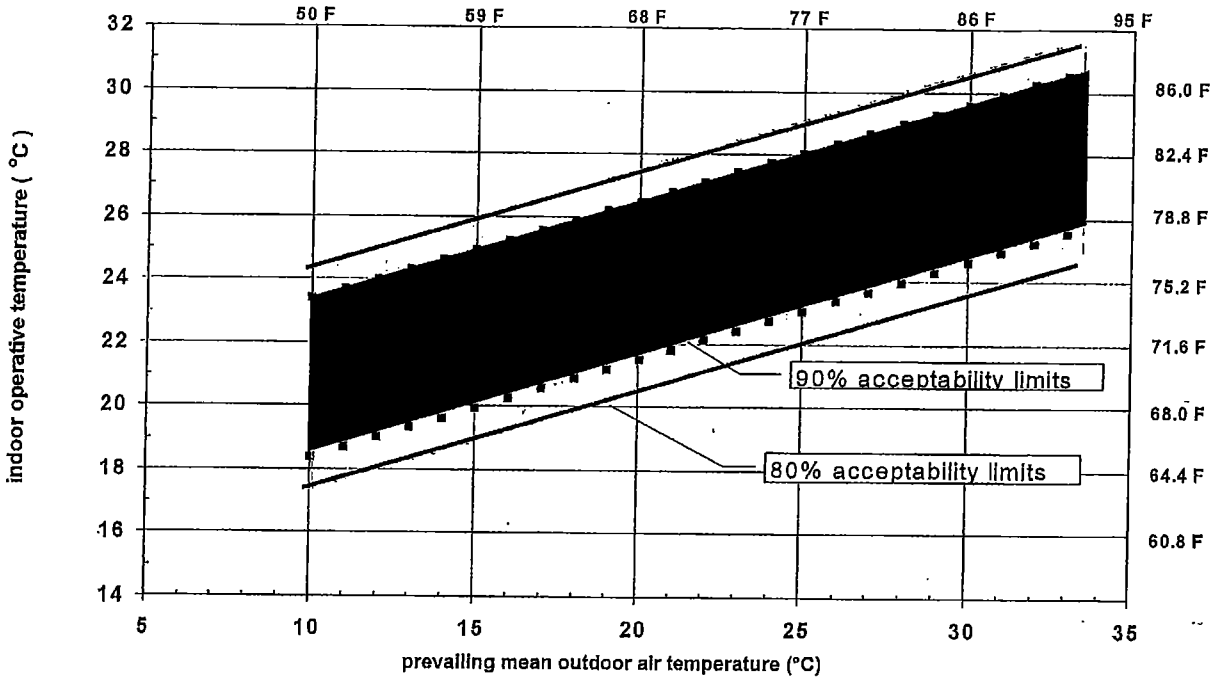


Figure 5.4.2 Acceptable operative temperature t_o ranges for naturally conditioned spaces.

Table 5.4.2.4 Increases in Acceptable Operative Temperature Limits (Δt_0) in Occupant-Controlled Naturally Conditioned Spaces (Figure 5.4.2) Resulting from Increasing Air Speed above 0.3 m/s (59 fpm)

Average Air Speed V_a 0.6 m/s (118 fpm)	Average Air Speed V_a 0.9 m/s (177 fpm)	Average Air Speed V_a 1.2 m/s (236 fpm)
1.2°C (2.2°F)	1.8°C (3.2°F)	2.2°C (4.0°F)

c. Values assumed for comfort parameters used in the calculation of thermal conditions, including operative temperature t_o, humidity, average air speed V_a, clothing insulation I_{cl}, and metabolic rate, shall be stated for heating and cooling design conditions. If an acceptable level of comfort is not being provided to any representative occupants, this shall be stated. Where Table 5.2.1.2 gives a range, the basis for selecting a single value within that range shall be stated. If the clothing insulation or metabolic rate parameters for a given space are outside the applicable bounds defined by the standard, or if the space is not regularly occupied as defined in Section 2.3, the space shall be clearly identified as not under the scope of the standard.

d. Local thermal discomfort shall be addressed, at a minimum, by a narrative explanation of why an effect is not likely to exceed Section 5 limits. Where calculations are used to determine the effect of local thermal discomfort in accordance with Section 5, the calculation inputs, methods, and results shall be stated.

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

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

g. Air speed, radiant temperature asymmetry, vertical air-temperature difference, surface temperatures, and temperature variations with time shall be determined in accordance with generally accepted engineering standards (e.g., *ASHRAE Handbook—HVAC Applications*, Chapter 57). The method used, and quantified selection criteria, characteristics, sizes, and indices that are applicable to the method, shall be stated.

h. When direct-beam solar radiation falls on a representative occupant, documentation shall include solar design condition (solar altitude, direct beam intensity), the method in Section 5.3.2.2.1 used for compliance, and the resultant mean radiant temperature $\bar{t}_r$.

Informative Note: See Informative Appendix K for sample compliance documentation.

7. EVALUATION OF COMFORT IN EXISTING BUILDINGS

7.1 Introduction. Evaluation of comfort in existing buildings is not a requirement of this standard. When such evaluation is otherwise required (e.g., by code or another standard) use one of the following methods:

1. **Record the approximate outside-air temperature _____ and seasonal conditions:**

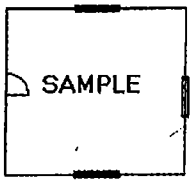
☐ Winter ☐ Spring ☐ Summer ☐ Fall

2. **What is your general thermal sensation? (Check the one that is most appropriate)**

(Note to survey designer: This scale must be used as-is to keep the survey consistent with ASHRAE Standard 55.)

☐ Hot
☐ Warm
☐ Slightly Warm
☐ Neutral
☐ Slightly Cool
☐ Cool
☐ Cold

3. **Either (a) place an "X" in the appropriate place where you are located now:**



(Note to survey designer: Provide appropriate sketch for your space or building.)

or (b) place an "X" in the check box that best describes the area of the building where you are located now.

☐ North
☐ East
☐ South
☐ West
☐ Core
☐ Don't know

4. **On which floor of the building are you located now?**

☐ 1st
☐ 2nd
☐ 3rd
☐ Other (provide the floor number):

5. **Are you near an exterior wall (within 15 ft)?**

☐ Yes
☐ No

6. **Are you near a window (within 15 ft)?**

☐ Yes
☐ No

7. **Using the list below, please check each item of clothing that you are wearing right now. (Check all that apply):**

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

☐ Short-Sleeve Shirt	☐ Dress	☐ Nylons
☐ Long-Sleeve Shirt	☐ Shorts	☐ Socks
☐ T-shirt	☐ Athletic Sweatpants	☐ Boots
☐ Long-Sleeve Sweatshirt	☐ Trousers	☐ Shoes
☐ Sweater	☐ Undershirt	☐ Sandals
☐ Vest	☐ Long Underwear Bottoms	
☐ Jacket	☐ Long Sleeve Coveralls	
☐ Knee-Length Skirt	☐ Overalls	
☐ Ankle-Length Skirt	☐ Slip	

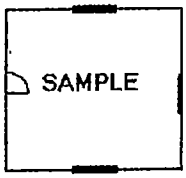
☐ Other: (Please note if you are wearing something not described above, or if you think something you are wearing is especially heavy.) _____

8. **What is your activity level right now? (Check the one that is most appropriate)**

☐ Reclining
☐ Seated
☐ Standing relaxed
☐ Light activity standing
☐ Medium activity standing
☐ High activity

Figure L2.1 Thermal environment point-in-time survey.

1. **Either (a) place an "X" in the appropriate place where you spend most of your time:**



(Note to survey designer: Provide appropriate sketch for your space or building.)

or (b) place an "X" in the check box that best describes the area of the building where your space is located.

- ☐ North
- ☐ East
- ☐ South
- ☐ West
- ☐ Core
- ☐ Don't know

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

- ☐ 1st
- ☐ 2nd
- ☐ 3rd
- ☐ Other (provide the floor number)_____

3. **Are you near an exterior wall (within 15 ft)?**

- ☐ Yes
- ☐ No

4. **Are you near a window (within 15 ft)?**

- ☐ Yes
- ☐ No

5. **Which of the following do you personally adjust or control in your space? (Check all that apply.)**

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

- ☐ Window blinds or shades
- ☐ Room air-conditioning unit
- ☐ Portable heater
- ☐ Permanent heater
- ☐ Door to interior space
- ☐ Door to exterior space
- ☐ Adjustable air vent in wall or ceiling
- ☐ Ceiling fan
- ☐ Adjustable floor air vent (diffuser)
- ☐ Portable fan
- ☐ Thermostat
- ☐ Operable window
- ☐ None of these
- ☐ Other: _____

Please respond to the following questions based on your overall or average experience in the past [six] months.

(Note to survey designer: The above statement can be modified for a different span of time.)

6. **How satisfied are you with the temperature in your space? (Check the one that is most appropriate)**

Very Satisfied ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Dissatisfied

7. **If you are dissatisfied with the temperature in your space, which of the following contribute to your dissatisfaction:**

   a. **In warm/hot weather, the temperature in my space is (check the most appropriate box):**

   (Note to survey designer: Include a scale or, as shown below; check boxes.)

   - ☐ Always too hot
   - ☐ Often too hot
   - ☐ Occasionally too hot
   - ☐ Occasionally too cold
   - ☐ Often too cold
   - ☐ Always too cold

   b. **In cool/cold weather, the temperature in my space is (check the most appropriate box):**

   (Note to survey designer: Include a scale or, as shown below; check boxes.)

   - ☐ Always too hot
   - ☐ Often too hot
   - ☐ Occasionally too hot
   - ☐ Occasionally too cold
   - ☐ Often too cold
   - ☐ Always too cold

   c. **When is this most often a problem? (check all that apply):**

   - ☐ Morning (before 11am)
   - ☐ Midday (11am–2pm)
   - ☐ Afternoon (2pm–5pm)
   - ☐ Evening (after 5pm)
   - ☐ Weekends/holidays
   - ☐ Monday mornings
   - ☐ No particular time
   - ☐ Always
   - ☐ Other:

Figure L2.2 Thermal environment satisfaction survey (continued on next page).

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

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

- ☐ 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: _____

e. **Please describe any other issues related to being too hot or too cold in your space:**

_____
_____
_____
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_____
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_____
_____

Note: 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.

Figure L2.2 (Continued) Thermal environment satisfaction survey.

L3. EVALUATION OF COMFORT IN EXISTING SPACES

The evaluation approach depends on the intended application. The list of possible evaluation applications is extensive. They require evaluation over varying time periods, from short term (ST) to long term (LT):

a. Real-time operation of a building using comfort metrics (ST)
b. Evaluating HVAC system performance (ST, LT)
c. Building management decisions regarding upgrades, continuous commissioning, and rating the performance of operators and service providers (LT)
d. Real-estate portfolio management: rating building quality and value (LT, ST)
e. Validating compliance with LEED existing-buildings requirements (ST, LT)
f. Validating compliance with requirements of codes—energy, hospital, etc. (ST)

There are two main approaches to evaluating thermal comfort in operating buildings. One is to directly determine occupant thermal sensations and satisfaction through the statistical evaluation of occupant surveys. The other is to use comfort models to estimate sensations and satisfaction of the occupants from measured environmental variables. The measurements needed for each of these approaches are described in Sections L1 and L2.

Surveys and physical measurements may be used in combination with each other for the purpose of problem diagnosis and research (see Table L3). In the short-term, point-in-time surveys are used to obtain comfort perceptions coincident with short-interval logged environmental measurements or BAS system trend data. For evaluating building performance over time, occupant satisfaction surveys results are correlated with averages of long-term measurements of environmental conditions.

L3.1 Analysis Based on Occupant Surveys. Surveys can assess comfort directly, in contrast to the indirect approach of calculating comfort through comfort models using measured environmental variables.

a. Short-Term Analyses (Using Instantaneous Comfort Determinations)

1. Measures from Point-in-Time (Right-Now) Surveys

i. Thermal acceptability votes.
ii. Thermal sensation (TSENS) votes. (When averaged for a population, TSENS votes correspond directly to PMV votes.)
iii. Temperature preference votes and air-movement preference votes ("less"/"no change"/"more").

2. Criteria for Passing

i. –0.5 to +0.5 on the PMV scale, inclusive, is the Standard 55 criterion for passing.
ii. Field surveys usually consider TSENS values of –1 and +1 as representing "satisfied"; the break along the categorical seven-point thermal sensation scale is at –1.5 and +1.5, inclusive.

3. Local Thermal Discomfort Determination

i. Questions about any local thermal discomfort (e.g., ankle, neck discomfort).
ii. Questions addressing solar radiation effects on comfort.

Table L3 Comfort Evaluation Approaches for Various Applications

Measurement Method	Nature of Application: Short-Term	Nature of Application: Long-Term
Occupant Surveys	**Right-Now/Point-in-Time Survey (must survey relevant times and population):** • Binning (TSENS scores) leads to % comfort exceedance during period of survey. • Needs coincident temperature to extrapolate to full range of conditions. *(Used for research, problem diagnostics)*	**Occupant Satisfaction Survey:** • Survey scores give % dissatisfied directly. ("dissatisfaction" may be interpreted to start either below –1, or below 0). • Time period of interest can be specified to survey takers. *(Used for building management, commissioning, rating operators and real estate value, compliance with green building rating systems)*
Environmental Measurements	**Spot Measurements, Temporary (Mobile) Sensors (must select a relevant time to measure):** • Use measurements to determine PMV (Sections 5.3.1, 5.3.3). • Use measurements to determine compliance with adaptive model (Section 5.4). *(Used for real-time operation, testing and validating system performance)*	**Logging Sensors over Period of Interest, or Trend Data from Permanently Installed (BAS) Sensors:** • Exceedance hours: sum of hours over PMV or adaptive model limits. • Binned exceedances may be weighted by their severity. • Instances of excessive rate-of-temperature change or of local thermal discomfort can be counted. *(Used for evaluating system and operator performance over time)*

b. **Long-Term Analyses (Representing Time Periods Such as Season or Year).** In an occupant satisfaction survey, thermal environment questions apply over time (three to six months or more). The survey includes diagnostic questions to identify sources of dissatisfaction. Point-in-time surveys may be repeated over time to obtain a long-term record of comfort. Because occupants have other responsibilities and limited time, repeated surveys must be very short and quickly completed.

1. **Measures from Occupant Satisfaction Surveys**
   i. Thermal satisfaction scale ("very satisfied" to "very dissatisfied").
2. **Criteria for Passing**
   i. From neutral (0 scale unit) to +3. (Votes below this range generally comprise 40% of a building's total votes in the CBE survey benchmark database [ASHRAE 2013]).
   ii. Scale units –1 to +3. (Votes below this range generally comprise 20% of a building's total votes in the CBE survey benchmark database).
3. **Branching Dissatisfaction Questions (Count Responses and Tally by Category)**
   i. Used to identify and correct problems. Analysis involves documenting the improvements made, resurveying the areas in which the problem occurred, and tallying the differences in responses obtained before and after the improvements.
4. **Accumulated Scores from Repeated Point-in-Time Surveys**
   i. If point-in-time surveys can be repeated sufficiently, the distribution of accumulated votes can be used to evaluate long-term comfort in the building. Such repetition becomes feasible, with short computer applications available to occupants via desktop and mobile devices.

L3.2 Analysis Based on Measurements of Environmental Variables. Environmental measurements are linked to occupant comfort through comfort models. Two comfort models, PMV and adaptive, are specific to mechanically conditioned and naturally ventilated buildings, respectively. Some "mixed-mode" buildings include a combination of both comfort model types. Active investigation is underway into how the two models apply in these cases.

The following measures and criteria underlie the documentation of comfort performance based on physical environmental measurements.

L3.2.1 Point-in-Time (Short-Term) Analyses

a. **PMV Model**
   1. **Measures.** PMV heat-balance model prediction of thermal sensation and satisfaction from environmental measurements are described in Section 5.3 (including air movement extension in Section 5.3.3). Limits to local thermal discomfort are described in Section 5.3.4, and rates of temperature change are described in Section 5.3.5.
   2. **Criteria for Passing.** –0.5 to +0.5 on the PMV scale, inclusive. This represents an estimated 90% satisfied with the thermal environment. Expressed as a comfort zone on a psychrometric chart, this represents a temperature range of 3 K to 5 K (5°F to 8°F), depending on clothing level and humidity (Figure 5.3.1).

b. **Local Thermal Discomfort Limits.** Local thermal should, by itself, not exceed the limits prescribed in Section 5.3.4. At a minimum, an assumed 10% dissatisfaction caused by local discomfort is added to PMV-predicted discomfort to obtain the overall thermal dissatisfaction of an environment.

Solar radiation on occupants in neutral or warm conditions should not exceed 10% of outdoor solar radiation incident on the window. The best-practice upper limit is 5% (ASHRAE 2013).

c. **Adaptive Model (Section 5.3).** The adaptive model is an empirical model of adaptive human responses to environments offering operable window control. The comfort zone on a given day is dependent on a running mean of previous outdoor air temperatures to which people continuously adapt over time.

1. **Measures**
   i. Air temperature indoors
   ii. Running mean of outdoor air temperature, defined in Section 3 as the prevailing mean outdoor air temperature $t_{pma(out)}$
2. **Criteria for Passing.** An environmental condition passes if it is within the 80% boundaries predicted by the adaptive model.

d. **Limits to Rate of Environmental Change**

1. **Measures**
   i. Operative temperature t_o rate of change
   ii. Instances of rate-of-change exceedance within a defined time period

L3.2.2 Time-Integrated Analyses, (Long-Term over Typical Day, Season, or Year)

a. **Measures**

1. Trend logging of physical measurements over time.
2. Temperature and humidity in the occupied zone. Globe temperature (temperature measured within a globe exposed to radiation exchange with surrounding surfaces) closely approximates operative temperature t_o in most indoor situations. For greater accuracy, globe temperature measurements may be combined with shielded air temperature measurements to calculate MRT, which, when averaged with the shielded air temperature, provides operative temperature.
3. Measuring indoor air movement over time is very difficult and rarely done. In many indoor situations the indoor air speed conforms to the still air conditions of the PMV comfort zone (0.2 m/s [40 fpm]), in which case air speed measurement is not necessary.
4. The number of hours in which local discomfort may be expected is estimated using the local thermal discomfort limits in Section 5. Local discomfort exceedance hours are added to hours in which the comfort zone requirements are exceeded (exceedance occurs when $|PMV| > 0.5$).

b. **Criteria Metrics**

1. The prescribed metric is the exceedance hour (semantically equivalent to discomfort hour) predicted during occupied hours within any time interval. See definition in Section 3 and formulas in Section 7.4.2.2.1. Units are in hours. No limits are prescribed.
2. In addition, it is possible to account for the severity of exceedance at any time, using a metric analogous to the familiar degree-day. Weighted exceedance hours (equivalent to degree-of-discomfort hours) are the number of occupied hours within a defined time period in which the environmental conditions in an occupied zone are outside of the comfort zone boundary, weighted by the extent of exceedance beyond the boundary. Units are thermal sensation scale units times hours. The formula for the PMV comfort zone uses terms defined in Section 7.4.2.2.1:

$$WEH = \Sigma [H_{disc} (|PMV| - 0.5)]$$

Units are thermal sensation scale units times hours. This is a useful metric but is not required in Standard 55. No limits are recommended.

3. Temperature-weighted exceedance hours. It may be useful to convert PMV comfort zone WEHs to a temperature times hours scale using the conversion 0.3 (thermal sensation scale units)/°C (0.15 [thermal sensation scale units]/°F). The unit for temperature-weighted exceedance hours is temperature times hours.).

This is a useful metric but is not required in Standard 55. No limits are recommended.

4. The WEH for the adaptive model also uses a temperature times hours scale:

$$WEH = \Sigma [H_{>upper} (T_{op} - T_{upper}) + H_{<lower} (T_{lower} - T_{op})]$$

This is a useful metric but is not required in Standard 55. No limits are recommended.

5. Expected number of episodes of discomfort, rate-of-change exceedances, local discomfort exceedances within a time period of interest.

These are useful metrics but not required in Standard 55. No limits are recommended.