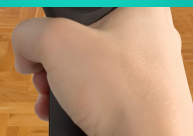


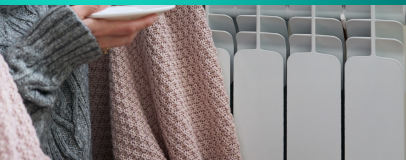


INDOOR ENVIRONMENTAL QUALITY - GREEN BUILDING TECHNOLOGY TRAINING PROGRAM
FOR GREEN BUILDING AND SUSTAINABILITY SPECIALISTS
KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP
GREEN BUILDING SPECIALIST CURRICULUM





THERMAL COMFORT - CREDIT
FOR GREEN BUILDING AND SUSTAINABILITY SPECIALIST
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LEARNING OBJECTIVES



- Intent of Thermal Comfort - Credit
- Behind the intent
- Step by Step Guidance
- Requirements
- Required Documentation
- Connection to Ongoing Performance
- Terms and Definitions





IEQ- CR(1) - DESIGN

INTENT

To promote occupants' productivity, comfort, and well-being by providing quality thermal comfort.

POTENTIAL TECHNOLOGIES & STRATEGIES

Occupants who are able to modify their thermal environment through thermal controls will perceive more comfort regardless of conditioning strategy, and they may exhibit additional satisfaction and productivity. Indoor environment quality surveys administered by the Center for the Built Environment have shown significant increases in satisfaction among occupants who have individual control of a thermostat or an operable window. Likewise, research from the International Centre for Indoor Environment and Energy suggests that giving occupants +/-5°F (3°C) of local temperature control can result in productivity gains of 2.7% to 7%.

THERMAL COMFORT

REQUIREMENTS

Design heating, ventilating, and air-conditioning (HVAC) systems and the building envelope to meet the requirements of ASHRAE Standard 55-2007, Thermal Comfort Conditions for Human Occupancy with errata or a local equivalent. For natatoriums, demonstrate compliance with ASHRAE HVAC Applications Handbook, 2015 edition, Chapter 5, Places of Assembly, Typical Natatorium Design Conditions, with errata.

IMPLEMENTATION

REQUIRED DOCUMENTATION

Documentation	Thermal comfort design Option 1	Option 2	Thermal control controls	Response rate (minutes/annually)
Description of weather data used to determine expected temperatures, relative humidity, solar temperature	X			
How conditions inside building are determined (e.g., ASHRAE Standard 55-2007, ASHRAE Handbook, HVAC Applications Handbook, 2015 edition, Chapter 5, Places of Assembly, Typical Natatorium Design Conditions, with errata or a local equivalent)	X			
How conditions inside building are determined (e.g., ASHRAE Standard 55-2007, ASHRAE Handbook, HVAC Applications Handbook, 2015 edition, Chapter 5, Places of Assembly, Typical Natatorium Design Conditions, with errata or a local equivalent)		X		
List of design by type, quantity, and controls			X	
How conditions inside building are determined (e.g., ASHRAE Standard 55-2007, ASHRAE Handbook, HVAC Applications Handbook, 2015 edition, Chapter 5, Places of Assembly, Typical Natatorium Design Conditions, with errata or a local equivalent)				X

BEHIND THE INTENT

A large body of laboratory and field research has demonstrated how thermal conditions inside buildings directly affect people's satisfaction and performance. Although often associated only with air temperature, thermal comfort is a complex amalgam of six primary factors (Figure 1), all of which are influenced by building design and operation. An effective thermal comfort strategy considers all six dimensions, meaning that close collaboration between the owner, architect, and engineer is critical to achieving this circle.

Figure 1. Primary factors that affect thermal comfort

Modifying one or more of the six comfort factors can greatly improve occupants' perception of the thermal environment while still supporting energy reduction goals. Working closely with the owner during design, the project team can maximize comfort by coordinating design and operational policies. For example, flexible design can allow the project team to optimize design and operation to allow design strategies to be adjusted as needed during the building process and throughout the building process without affecting occupants' perception of comfort. Occupants who are able to modify their thermal environment through thermal controls will perceive more comfort regardless of conditioning strategy, and they may exhibit additional satisfaction and productivity. Indoor environment quality surveys administered by the Center for the Built Environment have shown significant increases in satisfaction among occupants who have individual control of a thermostat or an operable window. Likewise, research from the International Centre for Indoor Environment and Energy suggests that giving occupants +/-5°F (3°C) of local temperature control can result in productivity gains of 2.7% to 7%.

The referenced standards for this model are two indoor predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD). The PMV can be used to predict the percentage of dissatisfied people in a space based on a given level of comfort on a seven-point thermal sensation scale. The scale ranges from plus 1 (too hot) to minus 1 (too cold), with zero representing neutral. The PPD index is the percentage of people in the space who are likely to be dissatisfied with a given thermal condition. The referenced standards for this model are two full-hour research results for the design model, which include indoor design temperature and acceptable temperature ranges to reduce environmental or climatological parameters. *

STEP-BY-STEP GUIDANCE

STEP 1. ESTABLISH THERMAL COMFORT GOALS

Work with the owner to understand expectations for the indoor thermal environment, the level of control that occupants should have, and characteristics of the occupant population.

- Determine whether a tightly controlled environment is required or whether some variation in indoor conditions is acceptable.
- Determine whether occupants would use natural conditioning as a workplace benefit.
- Consider including features and design criteria related to occupants in the owner's project requirements (OPR) for commissioning activities.

Thermal comfort needs for natatoriums are unique (see Further Exploration, Project Type Variations). Data Center and Warehouse and Distribution Center projects also have different needs (see Further Exploration, Rating System Variations).

STEP 2. SELECT CONDITIONING SYSTEM

Based on the thermal comfort goals, determine the best conditioning approach for the project (see Further Exploration, Thermal Comfort Conditioning Approaches).

- Consider whether the project is a candidate for natural conditioning. Examine the climate by season, including temperature, humidity, and air quality, to determine optimal times of the year for natural conditioning.
- Identify program areas that could be designed to accommodate cross or stack ventilation and consider ways they could be organized to create microclimates to expand annual hours of natural conditioning (see Further Exploration, Criteria for Occupant-Controlled Nativity).

Conditioned Spaces

STEP 3. SELECT COMFORT CONTROLS

Determine the best thermal comfort controls for the conditioning system(s) selected, based on the type of project and occupants' activities (see Further Exploration, Rating System Variations and Project Type Variations).

- Consider thermal comfort controls that allow occupants to control air temperature, radiant temperature, air speed, and humidity.
- Examples of single thermal comfort controls include thermostats, ceiling fans, adjustable underfloor airflows, task-mounted controls (such as plug-in desktop fans, humidifiers, or dehumidifiers), and operable windows. Examples of multiple thermal comfort controls include a ceiling diffuser without an accessible control and a thermostat with a fixed setpoint that cannot be adjusted by occupants.
- Zone the conditioning system to ensure that at least 50% of individual occupant spaces have individual thermal comfort controls. Additional controls may be appropriate for some projects but are not required for this credit.
- Provide at least one group thermal comfort control in each shared multi-occupant space. Heating spaces that can be subdivided (e.g., a convention hall with movable walls) must be designed such that each group of occupants can control their area.

STEP 4. SELECT THERMAL COMFORT STANDARD

Decide which standard or set of standards is suited to the project. Either option is appropriate for common space types, such as offices, educational buildings, hospitals, hotels and restaurants, and retail buildings. For other building types, see Further Exploration, Project Type Variations.

- Option 1 is suitable for most U.S. project teams, who are likely familiar with ASHRAE Standard 55-2007. This option also allows project teams to use the same standard for both mechanically and naturally conditioned spaces.
- Option 2 relies on two international standards, ISO 7730-2005 and EN 15251-2007, to document mechanically and naturally conditioned spaces, respectively.

Both options include compliance paths for mechanically and naturally conditioned spaces based on the same comfort models.

STEP-BY-STEP GUIDANCE +

Option 1. ASHRAE Standard 55-2010

STEP 1. SELECT ANALYSIS METHODS

- Select the methodology that will be used for the thermal comfort analysis.
- For mechanically conditioned spaces, select one or more of the following from Section 5.2. Methods for Determining Acceptable Conditions in Occupied Spaces:
 - Section 5.2.1, Graphic Comfort Zone Method for Typical Indoor Environments
 - Section 5.2.2, Computer Model Method for General Indoor Application
 - Section 5.2.3, Graphic Comfort for Special Method
 - Section 5.2.3.2, SET Method
- Section 5.2.4 must also be followed for potential sources of local discomfort.
- For naturally conditioned spaces, select Section 5.3.1, Graphic Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces. The optional method is available only for spaces that meet certain criteria (see Further Explanation, Criteria for Occupant-Controlled Naturally Conditioned Spaces). Spaces that do not meet these criteria must follow one of the mechanically conditioned spaces methods.
- For mixed-mode spaces, each seasonal conditioning strategy must be documented separately. For example, demonstrate heating season compliance using Section 5.2 and cooling season compliance using Section 5.3.

STEP 2. PERFORM ANALYSIS

- If using Section 5.2, perform the analysis as described in the standard.
- Estimate occupants' personal factors, such as clothing and activity levels.
- Using the owner's comfort expectations, energy goals, and occupancy factors, set seasonal comfort criteria for operative temperature, humidity, and air speed for each programmed area. Refer to ASHRAE 55-2010, Appendices A and B, for recommended values.
- Calculate the effects of any likely local discomfort sources, such as radiant temperature asymmetry, vertical air temperature differences, floor surface temperatures, and drafts as described in Section 5.2.4. Confirm that dissatisfaction is within the allowable ranges listed in Table 5.2.4.
- This analysis may be an iterative process in which thermal conditions are revised or refined to meet the ASHRAE requirements. By using the standard in this way, project teams can ensure that the thermal conditions meet the credit requirements before they begin detailed design work.
- If using Section 5.3, perform the analysis as described in the standard.
- Calculate mean monthly outdoor temperatures for the project's location, as described in the ASHRAE standard, for times of the year when natural conditioning is used.
- Use Figure 5.3 to establish the upper and lower operative temperature limits of the comfort zone. It may be helpful to plot mean monthly outdoor temperatures, comfort zone boundaries, and design operative temperatures on Figure 5.3.
- Compare indoor operative temperatures with the comfort zone boundaries.

STEP 3. DESIGN PROJECT'S CONDITIONING SYSTEMS

- Design the project's conditioning systems to provide the acceptable comfort conditions identified in the previous step. Additionally, verify that all spaces at risk for discomfort, such as locations close to entrances prone to drafts or west-facing walls that may retain heat, have been addressed.
- ASHRAE 55-2010, Section 6.1, requires the design to be within the acceptable comfort range at all combinations of conditions that are expected to occur, including variations in thermal loads and the exterior environment, and at both full- and partial-load conditions. Systems that cannot maintain comfort under all conditions (e.g., a constant-volume rooftop unit with a single compressor may have problems controlling humidity levels) do not meet the credit requirements (see Further Explanation, Examples).

STEP-BY-STEP GUIDANCE +

Option 2. ISO 7730-2005 and EN 15251-2007

STEP 1. SELECT ANALYSIS METHODS

- Select the methodology that will be used for the thermal comfort analysis.
- For mechanically conditioned spaces, select ISO 7730-2005.
- Certain criteria (see Further Explanation, Criteria for Occupant-Controlled Naturally Conditioned Spaces). Spaces that do not meet these criteria must follow ISO.
- For mixed-mode spaces, each seasonal conditioning strategy must be documented separately. For example, demonstrate heating season compliance using ISO 7730 and cooling season compliance using EN 15251.
- Identify the space category and comfort threshold for the project based on the selected standard's classifications.
- The ISO and EN standards set different ranges of comfort acceptability for specific building types and occupant temperature (Table 1).
- Category II (EN) and Category II (EN) are appropriate for most new buildings.

Table 1. Comparison of comfort acceptability ranges, ISO 7730-2005 and EN15251-2007				
Category		Description	Alternative predicted mean rate	Alternative predicted percentage dissatisfied
ISO 7730-2005	EN 15251-2007			
A	+	Recommended for spaces occupied by very sensitive and fragile people with special requirements (e.g. elderly, children, etc.)	$-0.2 < PMV < 0.2$	<1%
B	+	Suitable for most new buildings and environments	$-0.1 < PMV < 0.5$	<10%
C	+	Suitable for existing buildings	$-0.1 < PMV < 0.7$	<10%
D	+	Values other than above, acceptable for only part of year	$PMV < -0.2$ or $PMV > 0.7$	>10%

PMV = predicted mean vote index of thermal comfort; PPD = predicted percentage of people dissatisfied.
Source: This project is subject to modification from ISO 7730-2005 and EN 15251-2007 with the permission of ASH in total of ISO, EN 15251, and ASHRAE.

STEP 3. PERFORM ANALYSIS

- If using ISO 7730-2005, perform the analysis as described in the standard.
- Estimate occupants' personal factors, such as clothing and activity levels.
- Using the owner's comfort expectations, energy goals, and occupancy factors, set seasonal comfort criteria for operative temperature, humidity, and air speed for various programmed areas. Refer to ISO 7730-2005, Appendices A and C, for recommended values.
- Use the simplified load-up tables provided in ISO 7730-2005, Annex E, to determine PMV for spaces with 50% relative humidity and minimal difference between air and mean radiant temperature. For spaces that do not meet Annex E criteria, calculate PMV as described in Section 4.1 or Annex D.
- Confirm that PMV falls within the allowable range for general thermal comfort for appropriate building category (Table 1).
- Calculate the effects of any likely local discomfort sources, such as draughts, vertical air temperature differences, floor surface temperature, and radiant temperature asymmetry, as described in ISO 7730-2005, Section 6, and Annex A, Section A.3, and confirm that dissatisfaction is within the allowable ranges listed in Annex A, Table A4.
- This analysis may be an iterative process in which thermal conditions are revised or refined to meet the ISO requirements. By using the standard in this way, project teams can ensure that design criteria meet the credit requirements before they begin detailed design work.
- If using EN 15251-2007, perform the analysis as described in the standard.
- Calculate running mean outdoor temperatures for the project's location, as described in Section 3.1.1 of the EN standard, for times of the year when natural conditioning is used.

STEP-BY-STEP GUIDANCE +

- Use Figure A1 or the equations in Section A.2 of the EN standard to establish the upper and lower operative temperature limits of the comfort zone. It may be helpful to plot running mean outdoor temperatures, comfort zone boundaries, and design operative temperatures on Figure A1.
- Compare design operative temperatures with the comfort zone boundaries.

STEP 4. DESIGN PROJECT'S CONDITIONING SYSTEMS

Design the project's conditioning systems to provide the acceptable comfort conditions identified in the previous step. Additionally, verify that all spaces at risk for discomfort, such as locations close to entrances prone to drafts or west-facing walls that may retain heat, have been addressed.

ISO 7730-2005, Section A.2, requires the mechanical conditioning system design to maintain the specified comfort ranges "at all locations within the occupied zone of a space ... at all times." Systems that cannot maintain comfort under all conditions (e.g., a constant-volume rooftop unit with a single compressor may have problems controlling humidity levels) do not meet the credit requirements (see Further Explanation, Examples).

REQUIREMENTS

Thermal Comfort Design

NC, SCHOOLS, RETAIL, DATA CENTERS, HOSPITALITY, HEALTHCARE

Design heating, ventilating, and air-conditioning (HVAC) systems and the building envelope to meet the requirements of ASHRAE Standard 55-2017, Thermal Comfort Conditions for Human Occupancy with errata or a local equivalent.

For natoriums, demonstrate compliance with ASHRAE HVAC Applications Handbook, 2015 edition, Chapter 5, Places of Assembly, Typical Natorium Design Conditions, with errata.

Data Centers only

Meet the above requirements for regularly occupied spaces.

WAREHOUSES & DISTRIBUTION CENTERS

Meet the above requirements for office portions of the building.

In regularly occupied areas of the building's bulk storage, sorting, and distribution areas, include one or more of the following design alternatives:

- › radiant flooring;
 - › circulating fans;
 - › passive systems, such as nighttime air, heat venting, or wind flow;
 - › localized active cooling (refrigerant or evaporative-based systems) or heating systems; and
 - › localized, hard-wired fans that provide air movement for occupants' comfort.
- or other equivalent thermal comfort strategy.

Thermal Comfort Control

NC, SCHOOLS, RETAIL, DATA CENTERS, WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY

Provide individual thermal comfort controls for at least 50% of individual occupant spaces. Provide group thermal comfort controls for all shared multioccupant spaces.

REQUIREMENTS +

Thermal comfort controls allow occupants, whether in individual spaces or shared multioccupant spaces, to adjust at least one of the following in their local environment: air temperature, radiant temperature, air speed, and humidity.

Hospitality only

Guest rooms are assumed to provide adequate thermal comfort controls and are therefore not included in the credit calculations.

Retail only

Meet the above requirements for at least 50% of the individual occupant spaces in office and administrative areas.

HEALTHCARE

Provide individual thermal comfort controls for every patient room and at least 50% of the remaining individual occupant spaces. Provide group thermal comfort controls for all shared multioccupant spaces.

Thermal comfort controls allow occupants, whether in individual spaces or shared multioccupant spaces, to adjust at least one of the following in their local environment: air temperature, radiant temperature, air speed, and humidity.

CONNECTION TO ONGOING PERFORMANCE

LEED O+M EQ prerequisite Indoor Environmental Quality Performance: Strategies to promote occupant comfort and wellbeing by providing thermal comfort such as designing HVAC systems and building envelope per thermal comfort standards and providing individual thermal comfort controls in newly constructed occupant spaces can contribute to better indoor environmental quality and overall occupant satisfaction during operations phase.

REQUIRED DOCUMENTATION

Documentation	Thermal comfort design		Thermal comfort controls	Warehouses and distribution centers only
	Option 1	Option 2		
Description of weather data used to determine operative temperatures, relative humidity, outdoor temperatures	X			
Plots or calculation results verifying that design parameters meet ASHRAE Standard 55-2010 for 80% acceptability (e.g., psychrometric chart, PMV or PPD calculations, ASHRAE Thermal Comfort Tool results; copy of ASHRAE 55-2010, Figure 5.2.4.1, Figure 5.2.4.3, or Figure 5.2.4.4; or predicted worst-case indoor conditions for each month on copy of Figure 5.3)	X			
Documentation to verify thermally conditioned spaces meet ISO 7730 or EN 15251, as applicable (e.g., for ISO, calculations based on Sections A1 and 6 or Annex H; computer program results based on Annex D; tables based on Annex E; or copy of Figures 2, 3, 4, A.1, A.2, for EN; documentation of worst-case indoor conditions for each month on copy of Figure A1)		X		
List of spaces by type, quantity, and controls			X	
List of regularly occupied bulk storage, sorting, and distribution areas				X
Narrative describing design strategy used in each space				X



REFERENCED STANDARDS

- ASHRAE 55-2010 ASHRAE 55-2017 (updated version)
- ASHRAE Applications Handbook 2011 edition ASHRAE Applications Handbook 2015 edition (updated version)
- ISO 7730-2005 Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria: iso.org
- European Standard EN 15251: 2007, Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics: cen.eu



TERMS AND DEFINITIONS

Occupied space is an enclosed space intended for human activities, excluding those spaces that are intended primarily for other purposes, such as storage rooms and equipment rooms, and that are only occupied occasionally and for short periods of time. Occupied spaces are further classified as regularly occupied or non-regularly occupied based on the duration of the occupancy, individual or multi-occupant based on the quantity of occupants, and densely or non-densely occupied spaces based on the concentration of occupants in the space.

Regularly occupied space an area where one or more individuals normally spend time (more than one hour per person per day on average) seated or standing as they work, study, or perform other focused activities inside a building. The one-hour timeframe is continuous and should be based on the time a typical occupant uses the space. For spaces that are not used daily, the one-hour timeframe should be based on the time a typical occupant spends in the space when it is in use.

Unoccupied space an area designed for equipment, machinery, or storage rather than for human activities. An equipment area is considered unoccupied only if retrieval of equipment is occasional.

