Thermal Environmental Conditions for Human Occupancy: How ANSI/ASHRAE Standard 55-2020 Can Benefit Occupants

EDUCATION PARTNER

ENGINEERING RCEP

CONTINUING EDUCATION AIA

Christian Taber - A Little Background

- Principal Engineer—Codes and Standards
- BS - Chemical Engineering, MS - Mechanical Engineering, MS - Biosystems Engineering
- ASHRAE - HBDP & BEMP, AEE - CEM
- ASHRAE
  - SSPC 90.1 - Full Committee & ECB subcommittee
  - Standards Committee (2020-2023)
  - ASHRAE Journal - author/co-author of 4 articles on ceiling fans/air movement
- AMCA
  - Standards 340, 230, 214, 210, 208, 99
  - Publication 11, 211, 410
  - Air Movement Code Action Review Committee - Current Chair
  - Board of Directors
- Odd Things
  - I.S.S. Experiment - Air Flow and Thermal Characterization of Active Cooling in a Sealed Environment (Cygnus CRS-11 mission)
  - Provided technical support to Congress for the Ceiling Fan Improvement Act of 2020

"Big Ass Fans has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP."

ENGINEERING RCEP

REGISTERED CONTINUING EDUCATION PROGRAM

PURPOSE AND LEARNING OBJECTIVES

The purpose of this presentation is to provide an introduction to ANSI/ASHRAE Standard 55, which explains occupant thermal comfort requirements and how they affect design, and consider changes incorporated in the 2017 & 2020 versions of the standard.

At the end of this presentation you will be able to:

1. Understand the purpose of Standard 55 and how the Standard impacts sustainable design and occupants.
2. Learn how to energy-efficiently meet comfort standards in both air-conditioned and naturally conditioned spaces.
3. Describe how to evaluate compliance with comfort standards in various environments and how they affect occupants.
4. Discuss the updates to Standard 55-2017 & 55-2020 and how they accommodate design solutions in sustainable building.

OVERVIEW

- Timeline of Comfort Standards
- Summary of Standard 55
- Thermal Comfort in Air-Conditioned Spaces
- Graphic Comfort Zone Method
- Analytical Comfort Zone Method
- Elevated Air Speed Comfort Zone Method
- Thermal Comfort in Naturally Conditioned Spaces
- Adaptive Method
- Evaluation
- Changes in Standard 55-2017 & 2020

THERMAL COMFORT

TIMELINE OF COMFORT STANDARDS

1924 – ASHVE Comfort Standard established

1938 – Code of Minimum Requirements for Comfort

1966 – Standard 55 – 1st Published

1974 – 1st Standard 55 revision, comfort speed = 30 fpm

1981 – Winter & Summer Comfort Zones added to Standard 55

1992 – Air Movement >50 fpm allowed

2004 – ISO Standard 7726 & ISO Standard 7730 and the Adaptive Method added to Standard 55

2010 – Continuous maintenance (republished every 3 years)

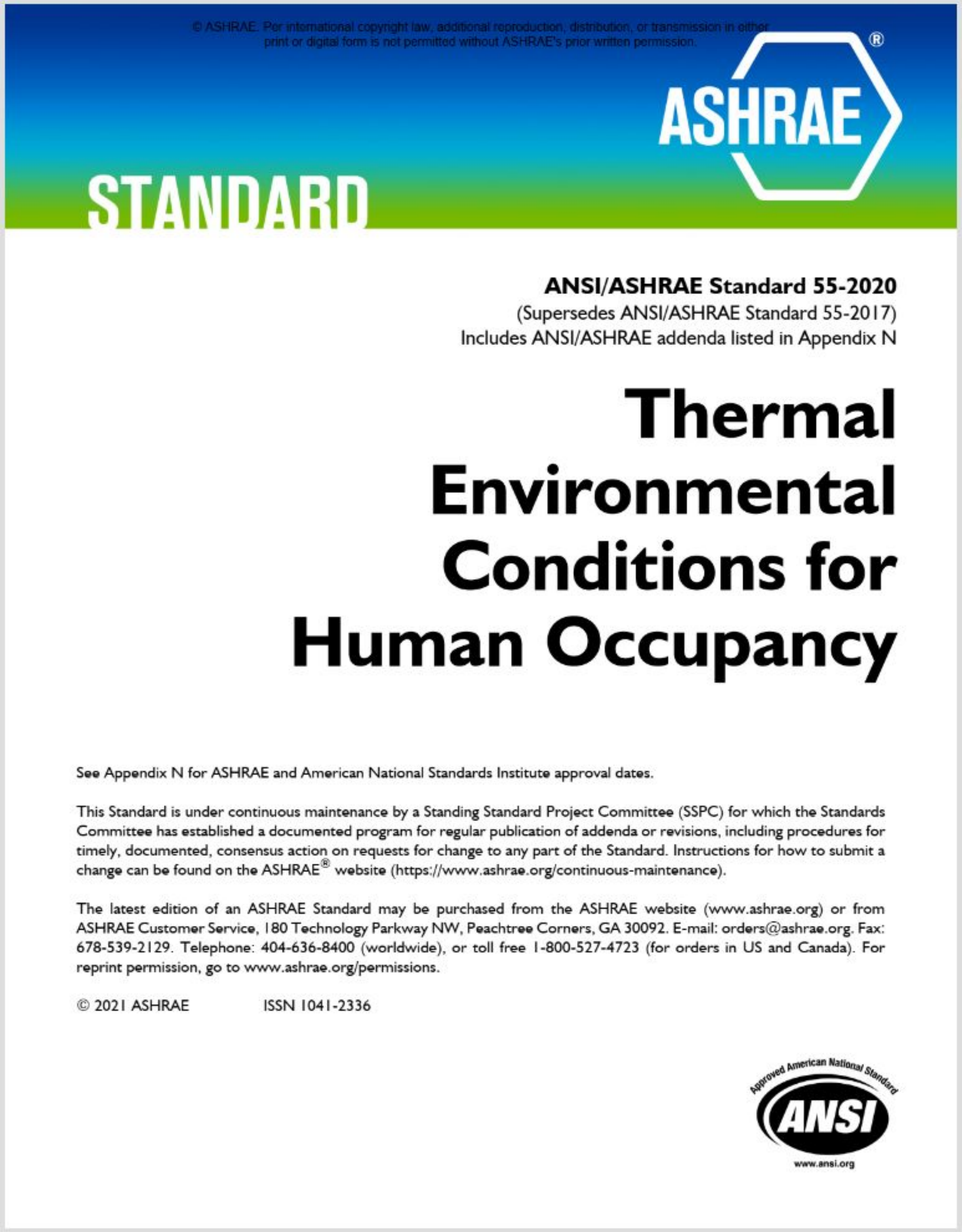
2013 – Language updated from informative to normative, allowing Standard 55 to be code enforceable

2017 – Clarification of three comfort calculation approaches, removal of permissive language, and updated Scope

2020 – Graphical Method removed, Control Classification Levels, Adaptive Method expanded, CBE Thermal Comfort Tool

Fountain, M.E., and E.A. Arens. 1993. "Air Movement and Thermal Comfort." ASHRAE Journal, Vol. 35, No. 8, August, pp. 26-30

ASHRAE Standard 55-2020: Thermal Comfort



ASHRAE

STANDARD

ANSI/ASHRAE Standard 55-2020
(Supersedes ANSI/ASHRAE Standard 55-2017)
Includes ANSI/ASHRAE addenda listed in Appendix N

Thermal Environmental Conditions for Human Occupancy

See Appendix N for ASHRAE and American National Standards Institute 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. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org/continuous-maintenance).

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Approved American National Standard
ANSI
www.ansi.org

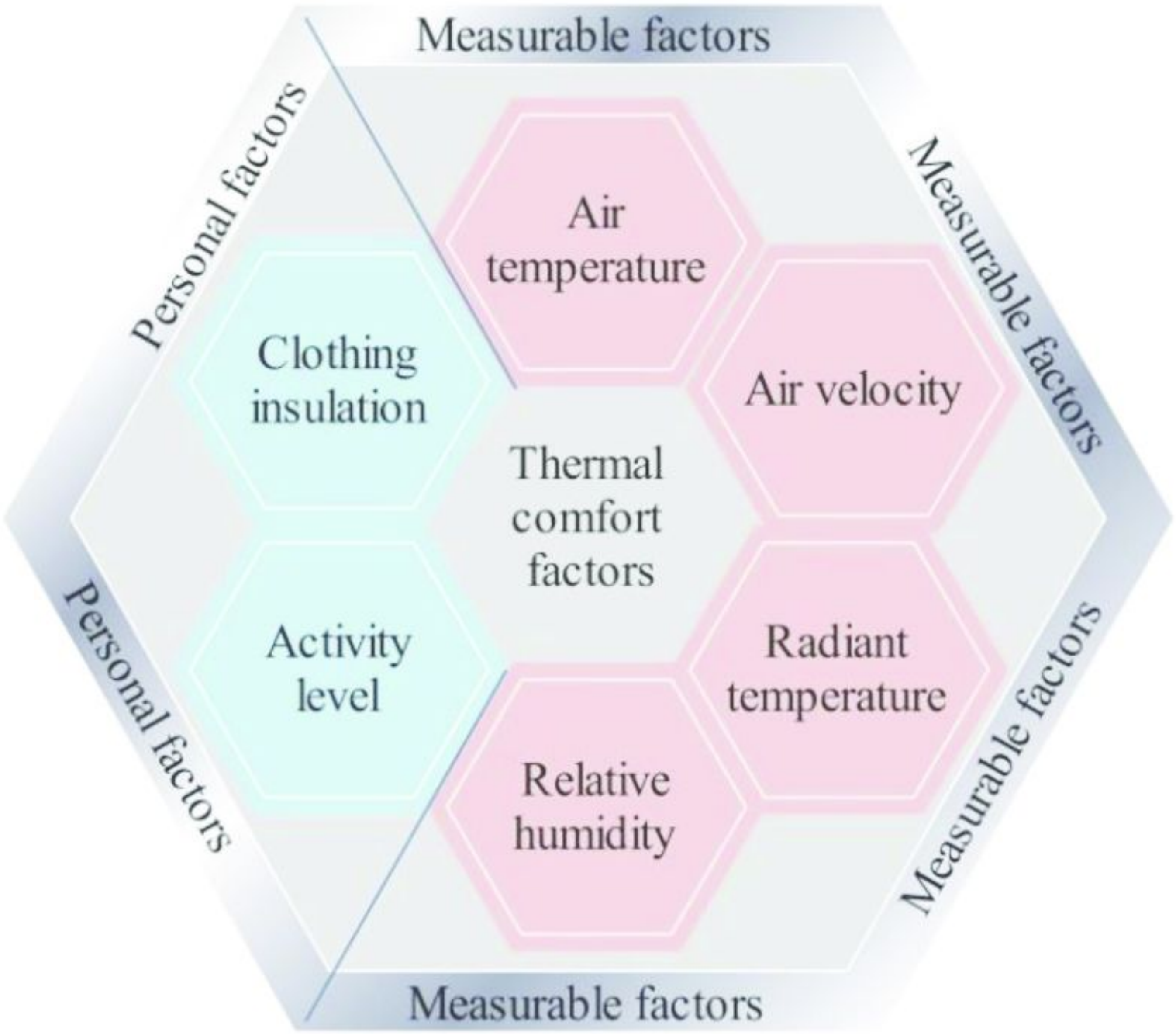
PURPOSE OF STANDARD 55

"Specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants…"

Said another way…

Quantify comfort for most

(Standard 55-2020)



Factors which Influence the Thermal Comfort Inside of Vehicles; M. Simion, L. Socaciu, P. Unguresan

SCOPE OF STANDARD 55

- Healthy adults
- Atmospheric pressure ≤ 10,000 ft.
- Occupied ≥ 15 minutes
- Doesn't consider non-thermal environmental factors (IAQ, acoustics, etc.)
- Does not override safety/health requirements

WHAT IS THERMAL COMFORT?

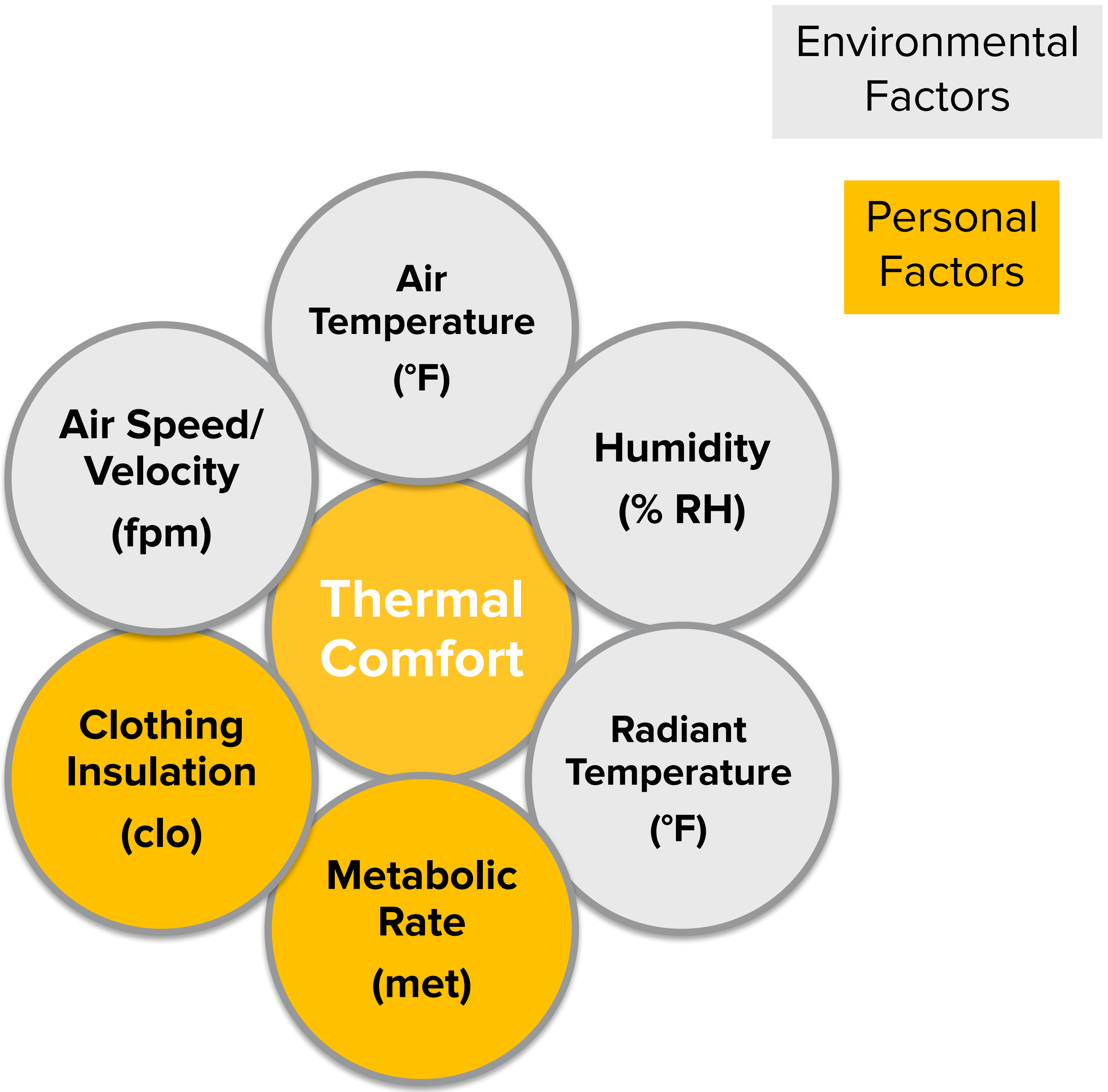
Definition:
"That condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation."

ANSI/ASHRAE Standard 55-2020, Section 3

WHAT IS THERMAL COMFORT?

- **It’s all a matter of perspective**
- Thermal comfort is a lack of noticing discomfort
- Ability to focus on the work at hand

Thermal Comfort – what affects it?



UNIT DEFINITIONS

met: Metabolic activity

- 1 met ≈ energy produced for an average person seated at rest (~105 W)

Feet per minute: Air speed

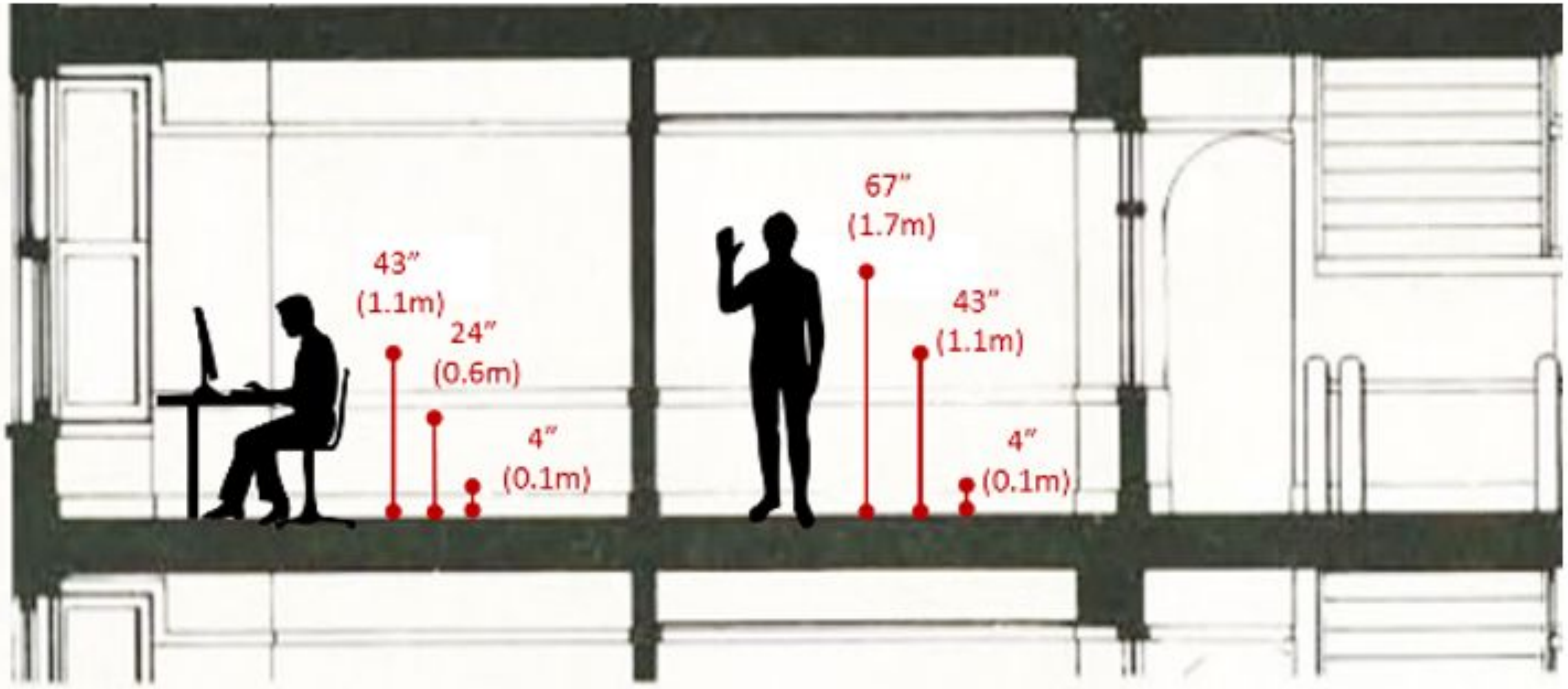
- 1 mph is approximately 90 fpm (0.45 m/s)

clo: Thermal insulation from garments and clothing

Clothing	Clo*
Shoes	0.02
Socks	0.03
Underwear	0.04
Trousers	0.15
Polo	0.17
Total	**0.41**

UNIT DEFINITIONS

Average air speed: average air speed around an occupant, based on three heights (4”, 24”, 43” for seated, 4”, 43”, 67” for standing), 3-minute average



ASHRAE Standard 55 User’s Manual

Definitions

Predicted Percentage of Dissatisfied (PPD)

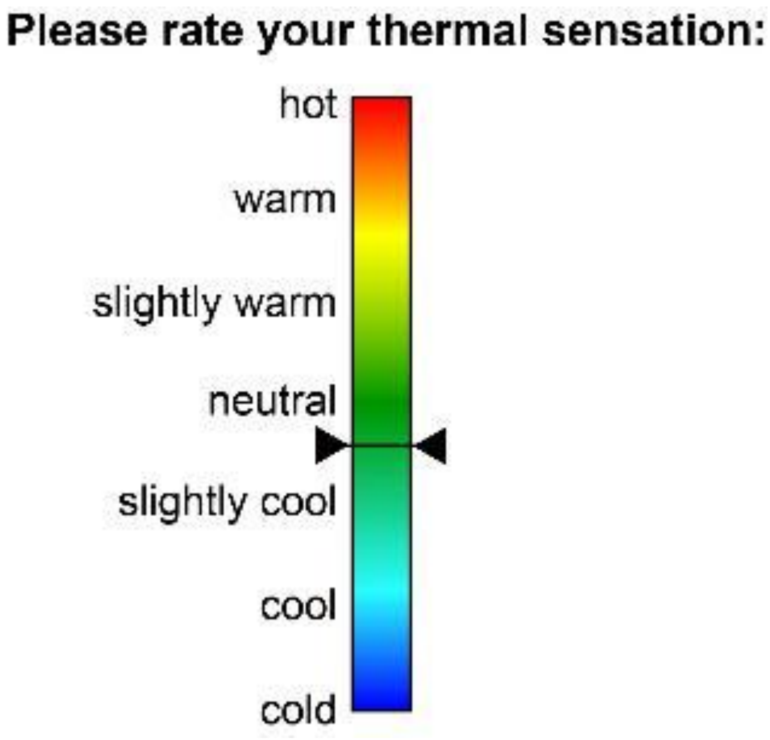
Predicted Mean Vote (PMV)

Standard Effective Temperature (SET)

Comfort Zone

PMV: -0.5 to +0.5

PPD < 10%



REVIEW

What is thermal comfort?

a. A lack of noticing discomfort
b. The ability to focus on the work at hand
c. A thermostat set to 75 F with 50% relative humidity
d. Both A and B

REVIEW

Air Temperature and Humidity are the only important factors in determining thermal comfort.

a. True
b. False

REVIEW

Which of the following are not typically controllable by the designer of a space?

a. Metabolic rate
b. Air velocity
c. Clothing insulation
d. A and C

OCCUPANT CHARACTERISTICS

METHOD FOR DETERMINING OCCUPANT CHARACTERISTICS

5.2.1 Metabolic Rate

- Determine representative occupant(s)
- Time weighted averages for varying met rate of occupant
- Multiple occupants if avg met rate differs by more than 0.1 met
- 2.0 met upper limit

5.2.2 Clothing Insulation

- Determine representative occupant(s)
- Time weighted averages for varying met rate of occupant
- Multiple occupants if insulation differs by more than 0.15 clo
- 1.5 clo upper limit

OCCUPANT CHARACTERISTICS EXAMPLE

Restaurants

	Customer	Server
Top	0.08 clo	0.18
Bottom	0.08 clo	0.14
Shoes	0.02 clo	0.02
Socks	0.02 clo	0.02
Undergarments	0.04 clo	0.04
Total	**0.24 clo**	**0.40 clo**

	Customer	Server
Met	1.1 met	1.7 met

THERMAL COMFORT IN OCCUPIED SPACES

ACCEPTABLE THERMAL ENVIRONMENT IN OCCUPIED SPACES

Section 5.3

- Graphic Comfort Zone Method (REMOVED)
- Analytical Comfort Zone Method
- Elevated Air Speed Comfort Zone Method

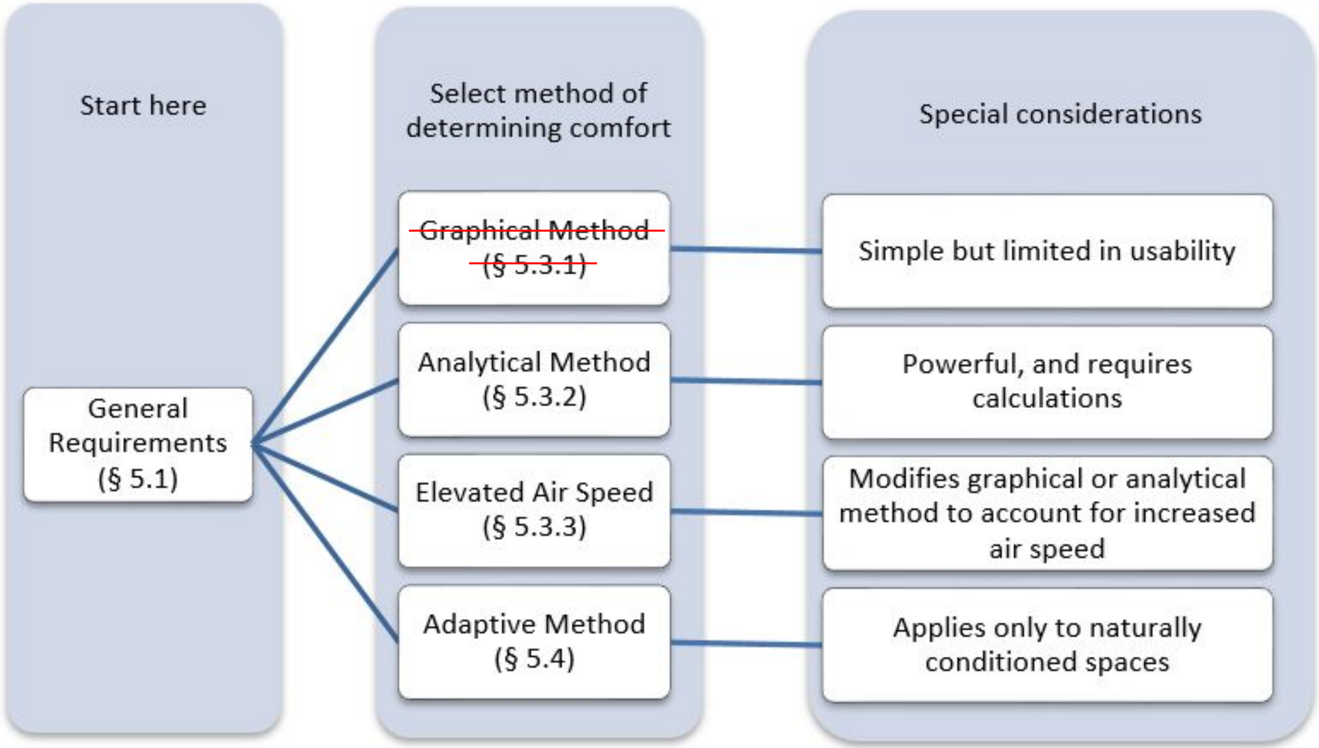
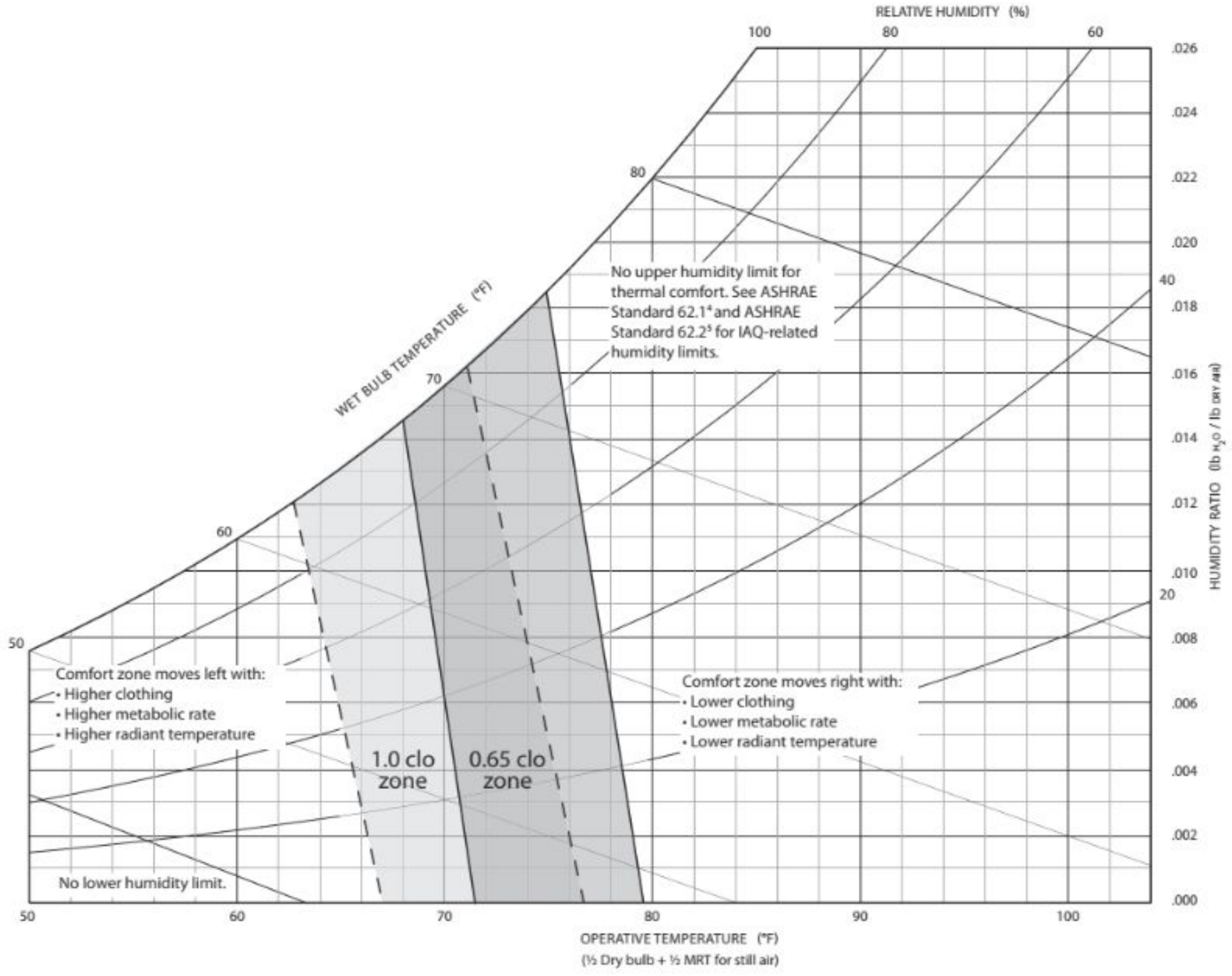


Figure 5-B: Methods of Determining Thermal Comfort

ASHRAE Standard 55 User's Manual

DEFINITIONS

Psychrometric chart: Physical and thermal properties of moist air in graphical form



ASHRAE Standard 55

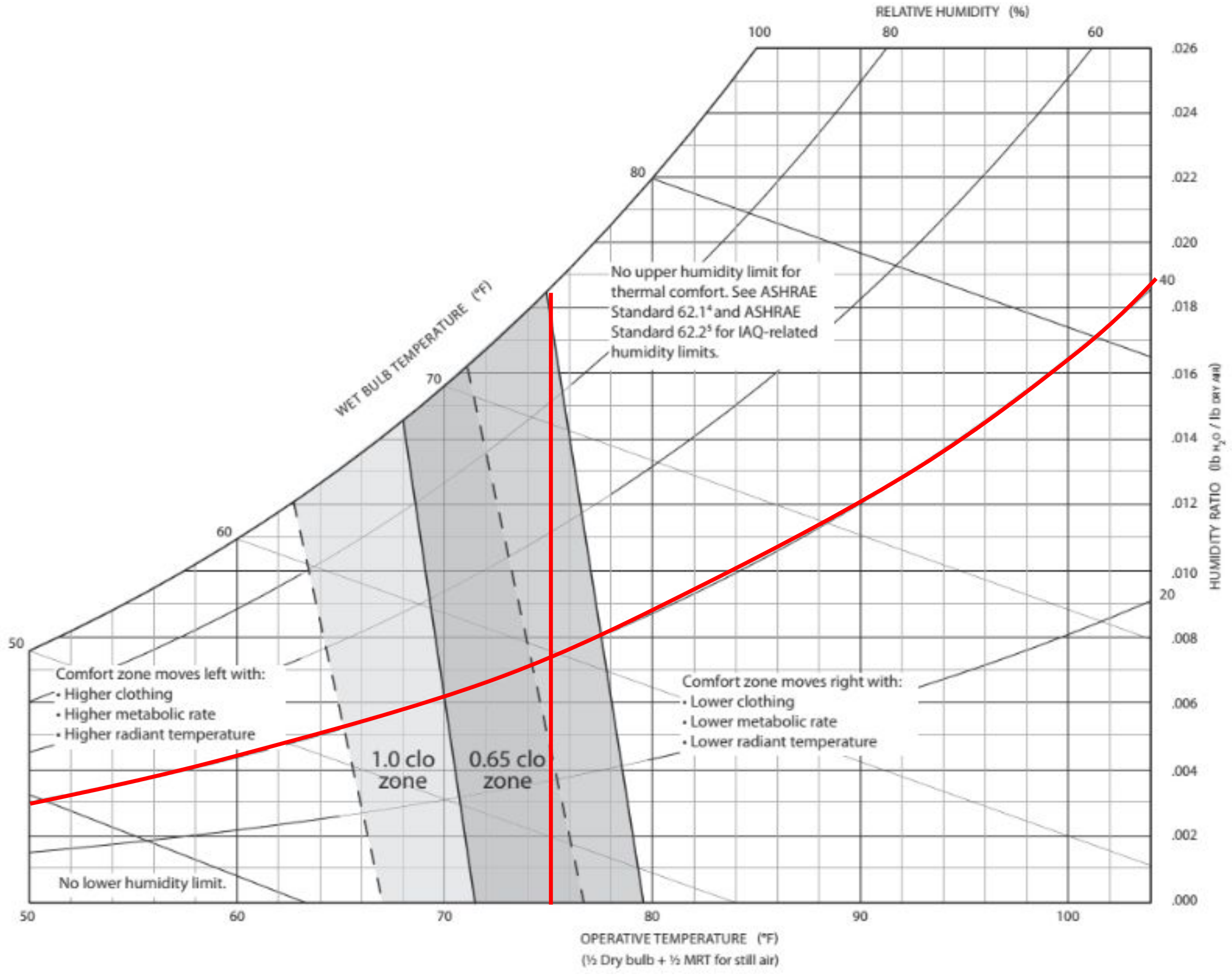
READING A PSYCHROMETRIC CHART

Dry Bulb (DB)/ Operative Temperature Lines :

- Scale is shown along the base of the chart
- DB temp increases from left to right

Relative Humidity:

- Curved lines



ASHRAE Standard 55

5.3.X GRAPHIC COMFORT ZONE METHOD – Removed in 2020 Edition

Requirements for use:

- Mechanically conditioned space
- Occupant activity level = 1.0 – 1.3 met
- Clothing worn = 0.5 - 1.0 clo
- ≤ 0.012 humidity ratio
- Air Speed ≤ 40 fpm

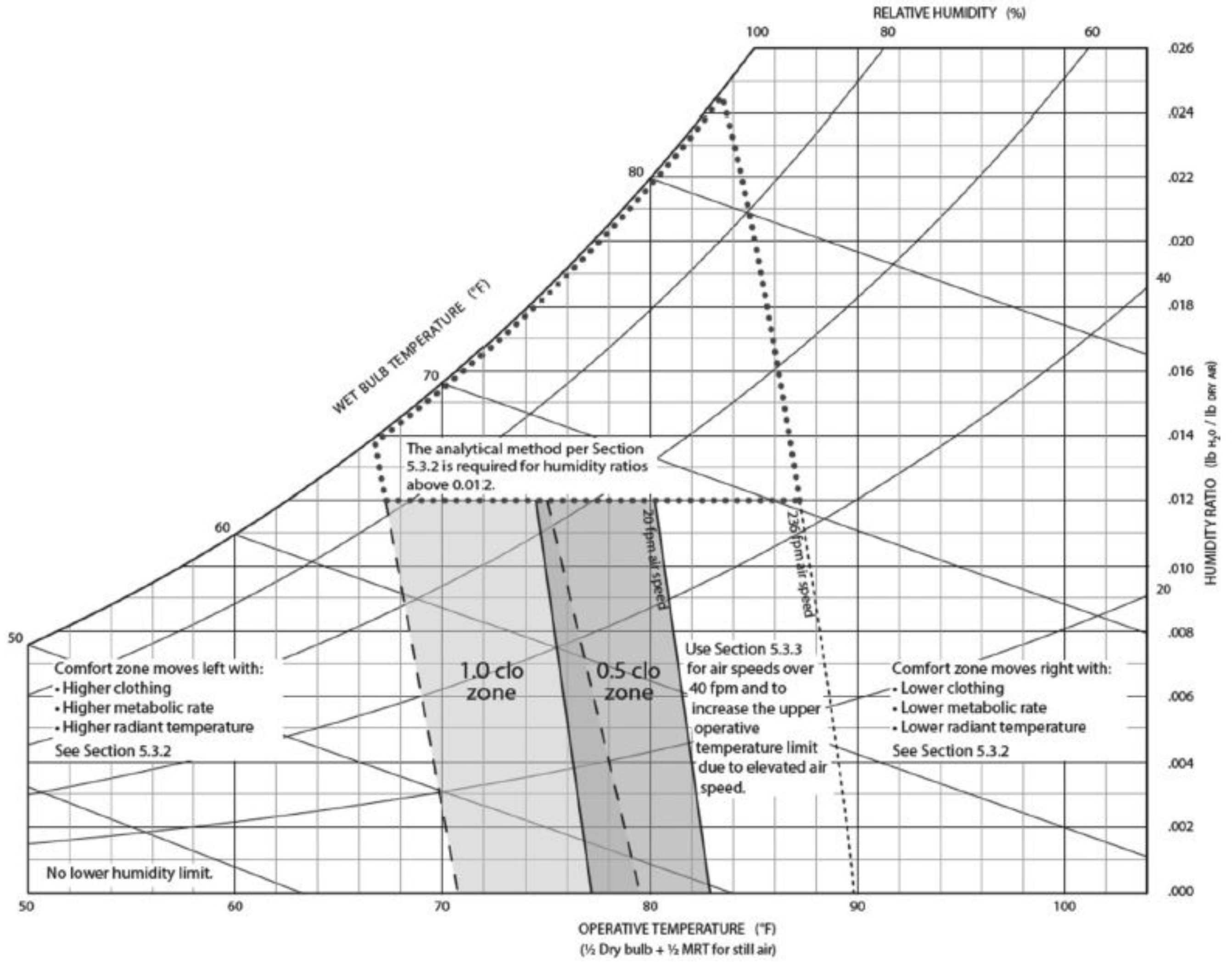
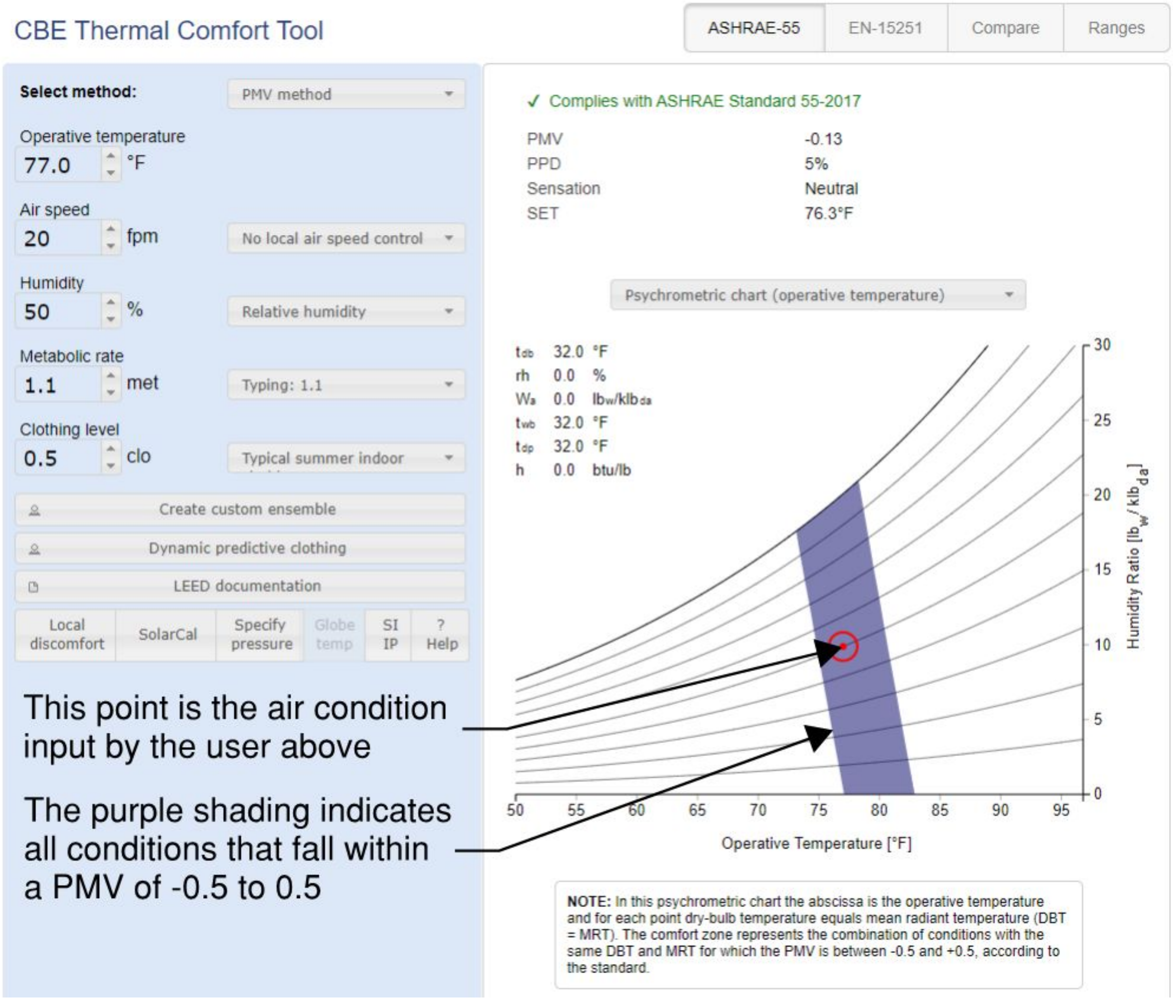


Figure 5.3.1 Graphical Comfort Zone Method – ASHRAE Standard 55 -2017

5.3.1 ANALYTICAL COMFORT ZONE METHOD

Requirements for use:

- Occupant activity level 1.0-2.0 met
- Clothing ≤ 1.5 clo
- Air Speed ≤ 40 fpm



Tyler Hoyt, Stefano Schiavon, Federico Tartarini, Toby Cheung, Kyle Steinfeld, Alberto Piccioli, and Dustin Moon, 2019, CBE Thermal Comfort Tool. Center for the Built Environment, University of California Berkeley.

Example 2: Analytical Comfort Zone Method

Scenario:

Restaurant Server

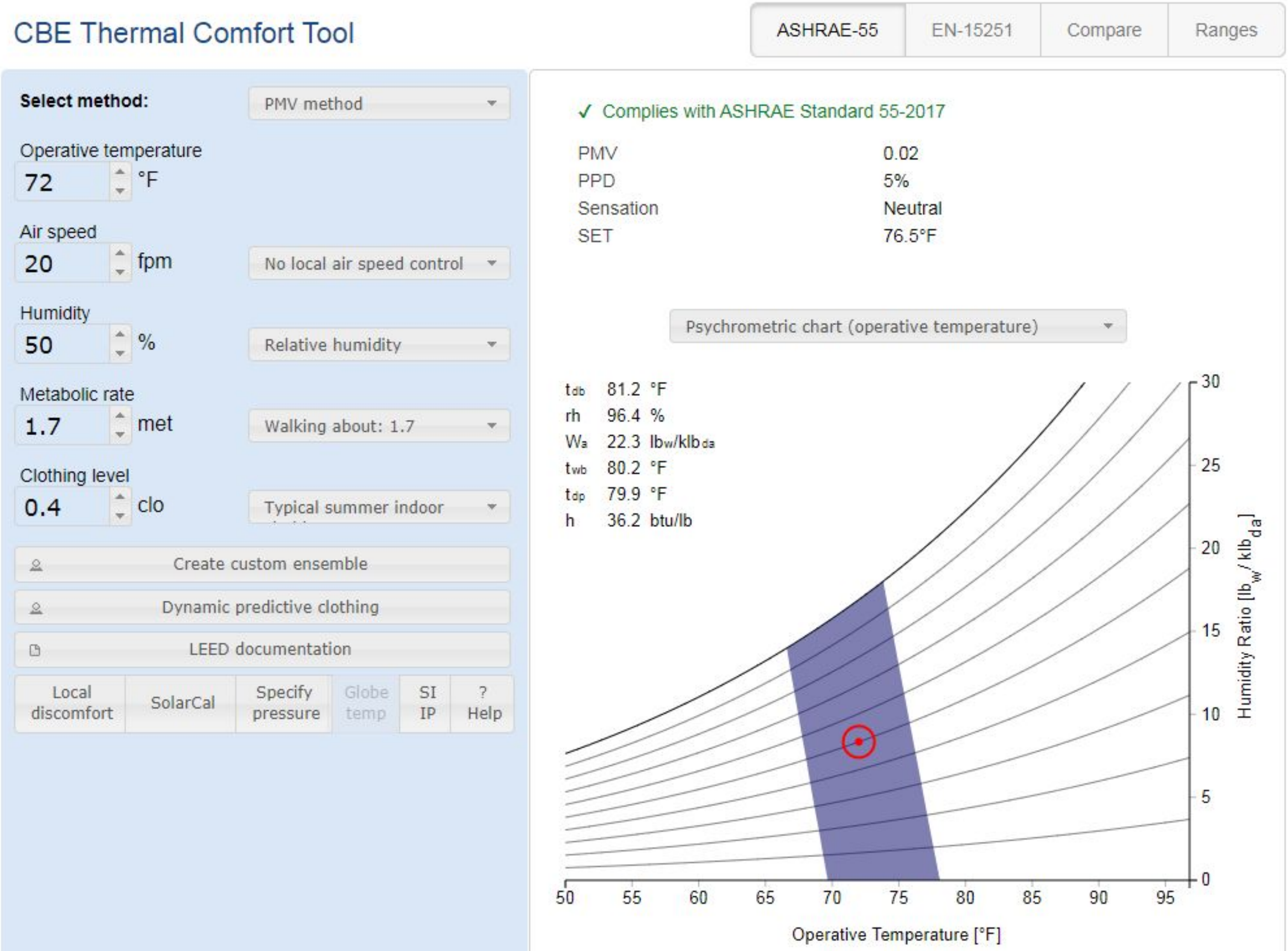
Clothing = 0.40 clo

Air speed = 20 fpm

Activity = 1.7 met

Mean Radiant Temp = Air DB

EXAMPLE 2: ANALYTICAL COMFORT ZONE



5.3.2 ELEVATED AIR SPEED COMFORT ZONE METHOD

Requirements for use:

- Occupant activity level ≤ 2.0 met
- Clothing ≤ 1.5 clo
- Air Speed > 40 fpm

NORMATIVE APPENDIX D
PROCEDURE FOR EVALUATING COOLING EFFECT OF ELEVATED AIR SPEED USING SET

D1. CALCULATION OVERVIEW

Section 5.3 requires that the Elevated Air Speed Comfort Zone Method be used when average air speed V_a is greater than 0.20 m/s (40 fpm). The SET model shall be used to account for the cooling effect of air speeds greater than the maximum allowed in the Analytical Comfort Zone Methods. This appendix describes the calculation procedures for the Elevated Air Speed Comfort Zone Method.

For a given set of environmental and personal variables, including an elevated average air speed, an average air temperature t_a, and a mean radiant temperature $\bar{t}_r$, the SET is first calculated. Then the average air speed V_a is replaced by still air (0.1 m/s [20 fpm]), and the average air temperature and radiant temperature are adjusted according to the cooling effect (CE). The CE of the elevated air speed is the value that, when subtracted equally from both the average air temperature and the mean radiant temperature, yields the same SET under still air as in the first SET calculation under elevated air speed. The PMV adjusted for an environment with elevated average air speed is calculated using the adjusted average air temperature, the adjusted radiant temperature, and still air (0.1 m/s [20 fpm]).

a. Enter the average air temperature t_a, radiant temperature, relative humidity, clo value, and met rate.
b. Set the average air speed V_a.
c. Note the calculated value for SET in the output data.
d. Reduce the average air speed V_a to 0.1 m/s (20 fpm).
e. Reduce the average air temperature t_a and radiant temperature t_r equally in small increments until the SET is equal to the value noted in Step (c).
f. The CE is the quantity by which the average air temperature and radiant temperature have been reduced. The resulting air temperature value is the adjusted average air temperature, and the resulting radiant temperature is the adjusted mean radiant temperature.
g. The PMV adjusted for elevated average air speed is calculated using the following inputs:
   1. Adjusted average air temperature from Step (f)
   2. Adjusted mean radiant temperature from Step (f)
   3. Average air speed V_a of 0.1 m/s (20 fpm)
   4. Original relative humidity
   5. Original clo value
   6. Original met rate

5.2.3 ELEVATED AIR SPEED

- Pairs Analytical Method with Change in Standard Effective Temperature (SET)
- Either:
  - Use Figure 5.3.3A or
  - Appendix D
  - Thermal Comfort Tool
- No upper limit on air speed with local control

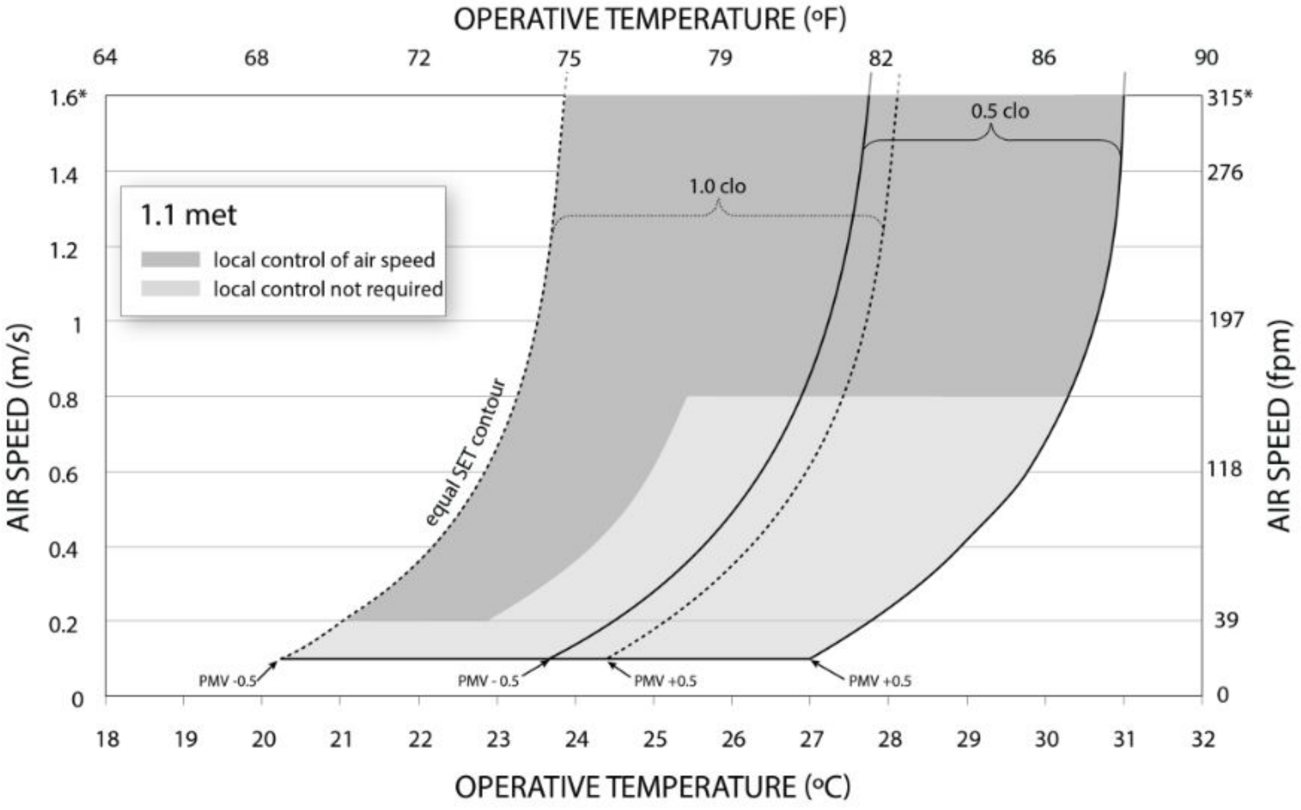


Figure 5.4 - ASHRAE Standard 55 -2020

WHAT DOES THIS MEAN IN A DESIGN?

- Raise thermostat setpoint while maintaining acceptable level of comfort
- Energy savings
- Equivalent or better comfort

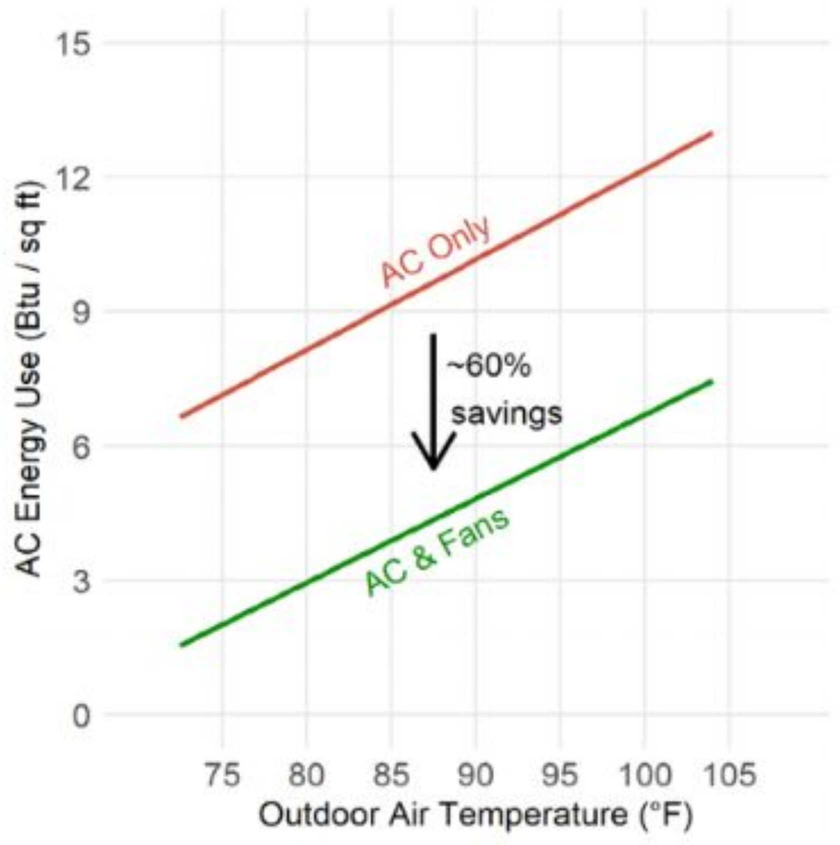


Figure 1. HVAC energy use in the common room was reduced by 60% by raising setpoints and using fans to cool occupants when temperatures were above 74 °F. Source: Dana Miller.

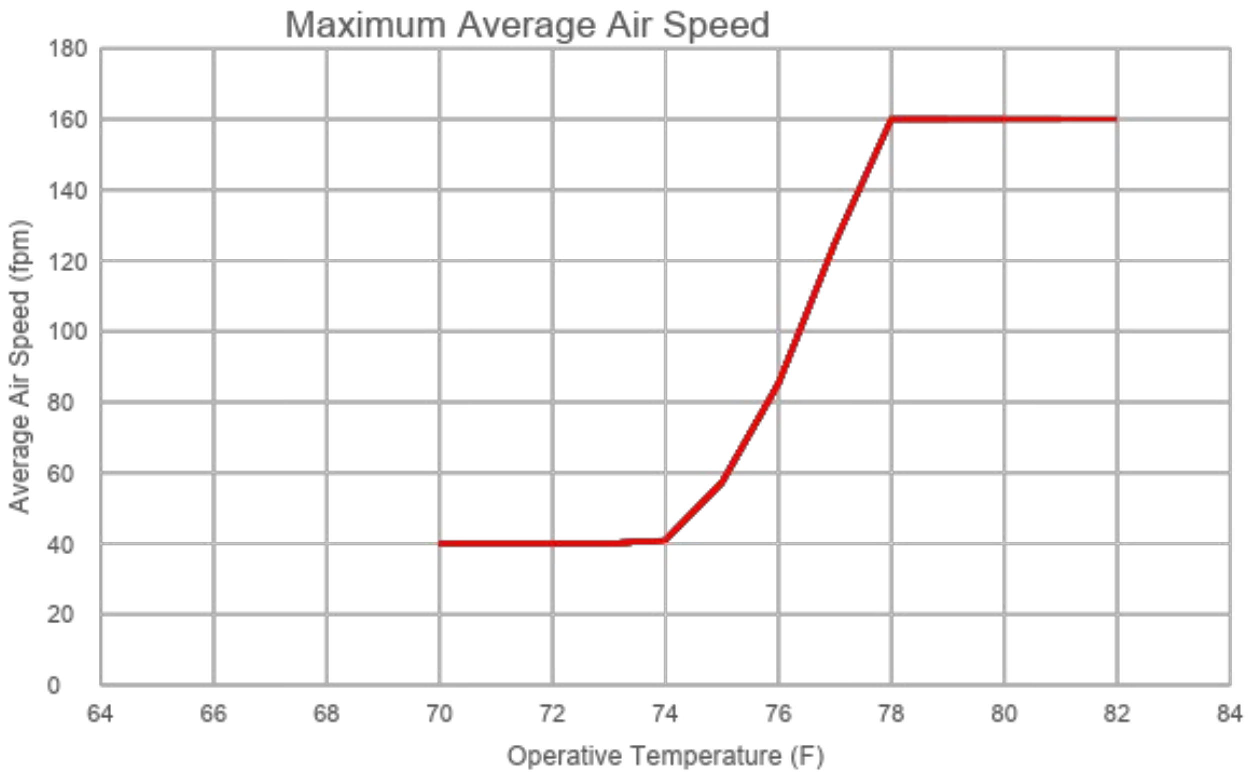
5.3.2.3 EAS WITH OCCUPANT CONTROL

- 1 control per 6 occupants
- 1 control per 900 ft^2
- 1 control per space/cubical
- No upper limit on average air speed

Wall of Wind (WOW) Experimental Facility (EF) at Florida International University (FIU)

5.3.2.4 EAS WITHOUT OCCUPANT CONTROL

- Below 74F, average air speed ≤40 fpm (draft)
- Above 78F, average air speed ≤ 160 fpm
- Between 74F and 78F, air speed limit varies by dry bulb temp



Example 3: EAS Comfort Zone Method

Scenario:

Office building in the summer

0.41 clo

Air speed = 20 fpm (imperceptible)

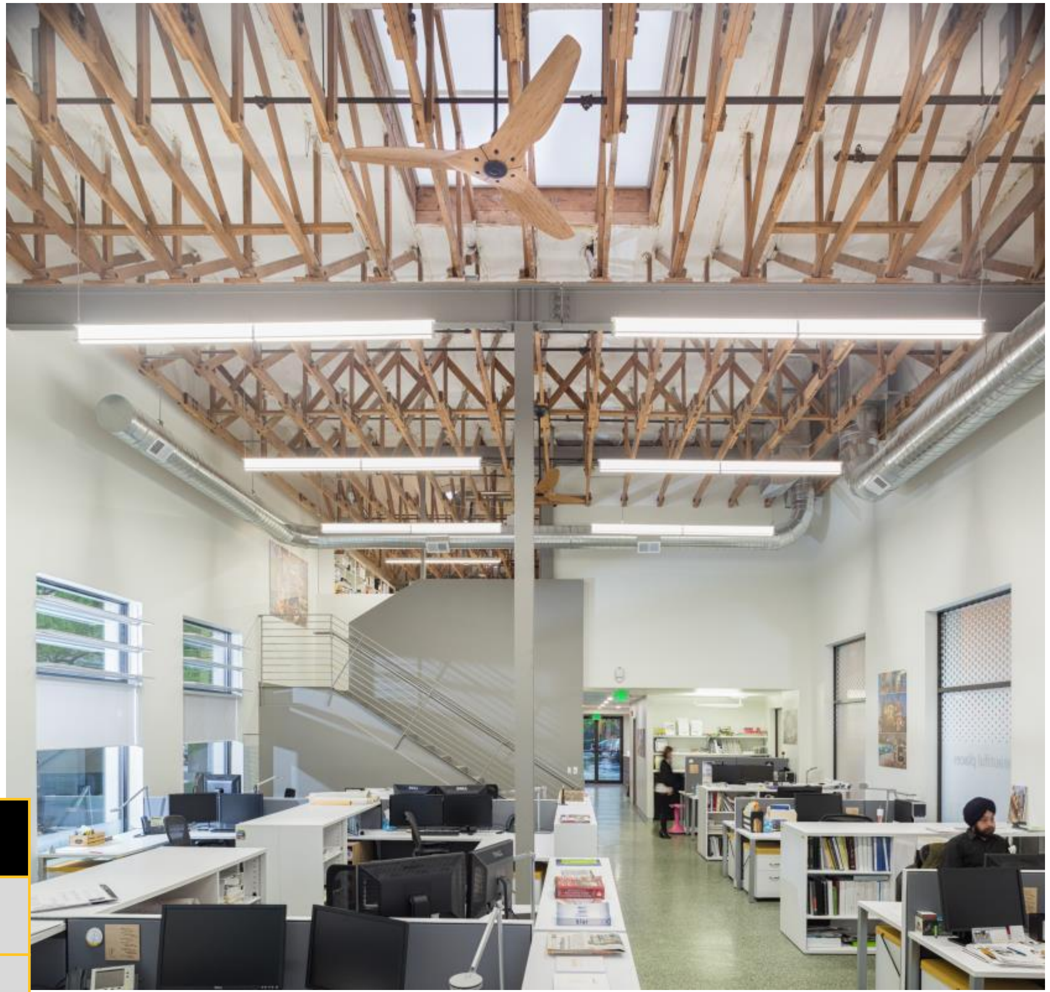
1.2 met

MRT ≒ Air DB 83°F

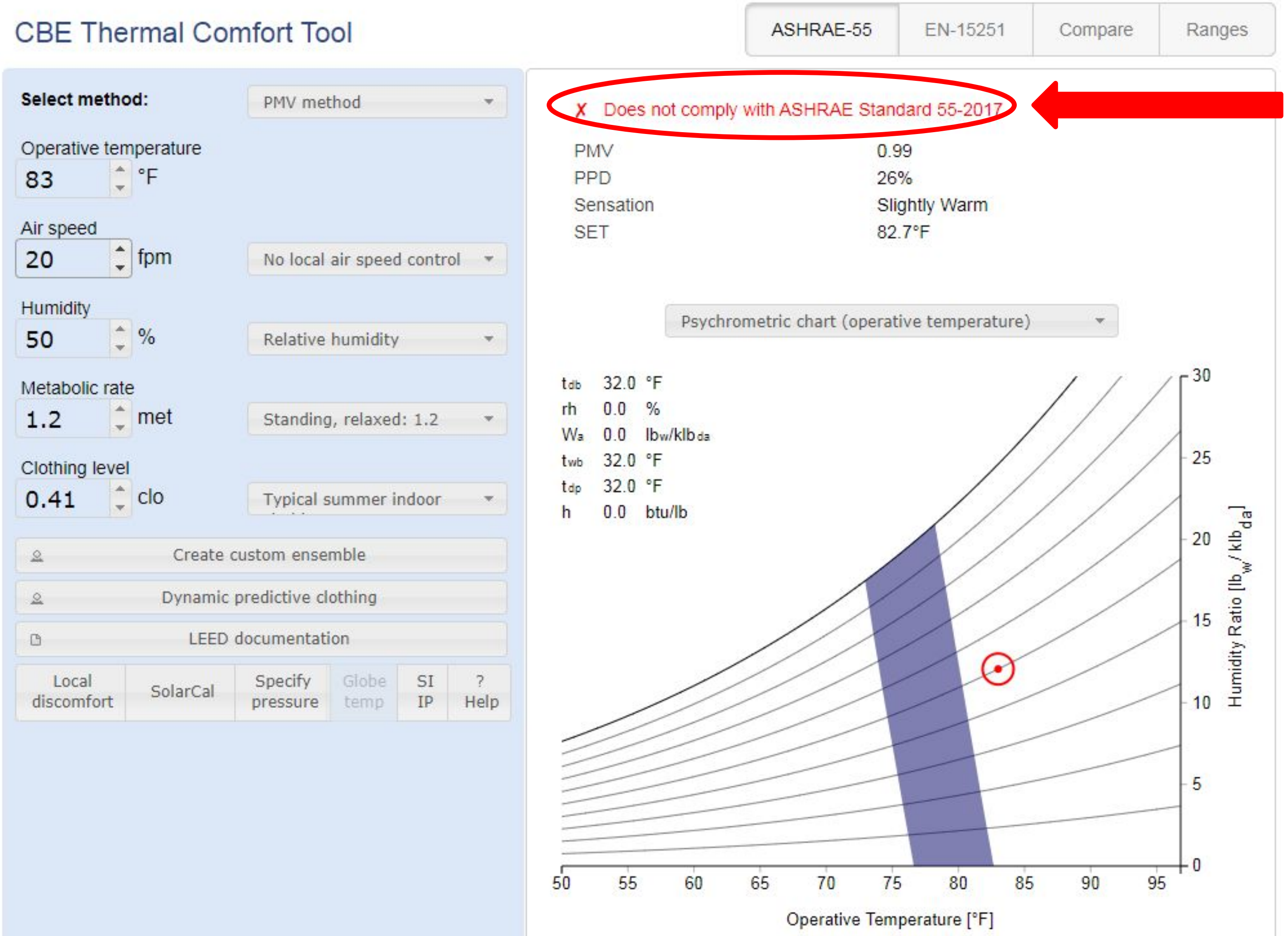
Indoor Ambient Temp = 83°F

Humidity = 50%

Clothing	Clo*
Shoes	0.02
Socks	0.03
Underwear	0.04
Trousers	0.15
Polo	0.17
Total	**0.41**



EXAMPLE 3: COMPUTER MODEL METHOD



PMV = 0.99

PPD = 26%

SET = 82.7F

Does not comply with Standard 55

EXAMPLE 4: COMPUTER MODEL METHOD

Scenario:

Office building in the summer

0.41 clo

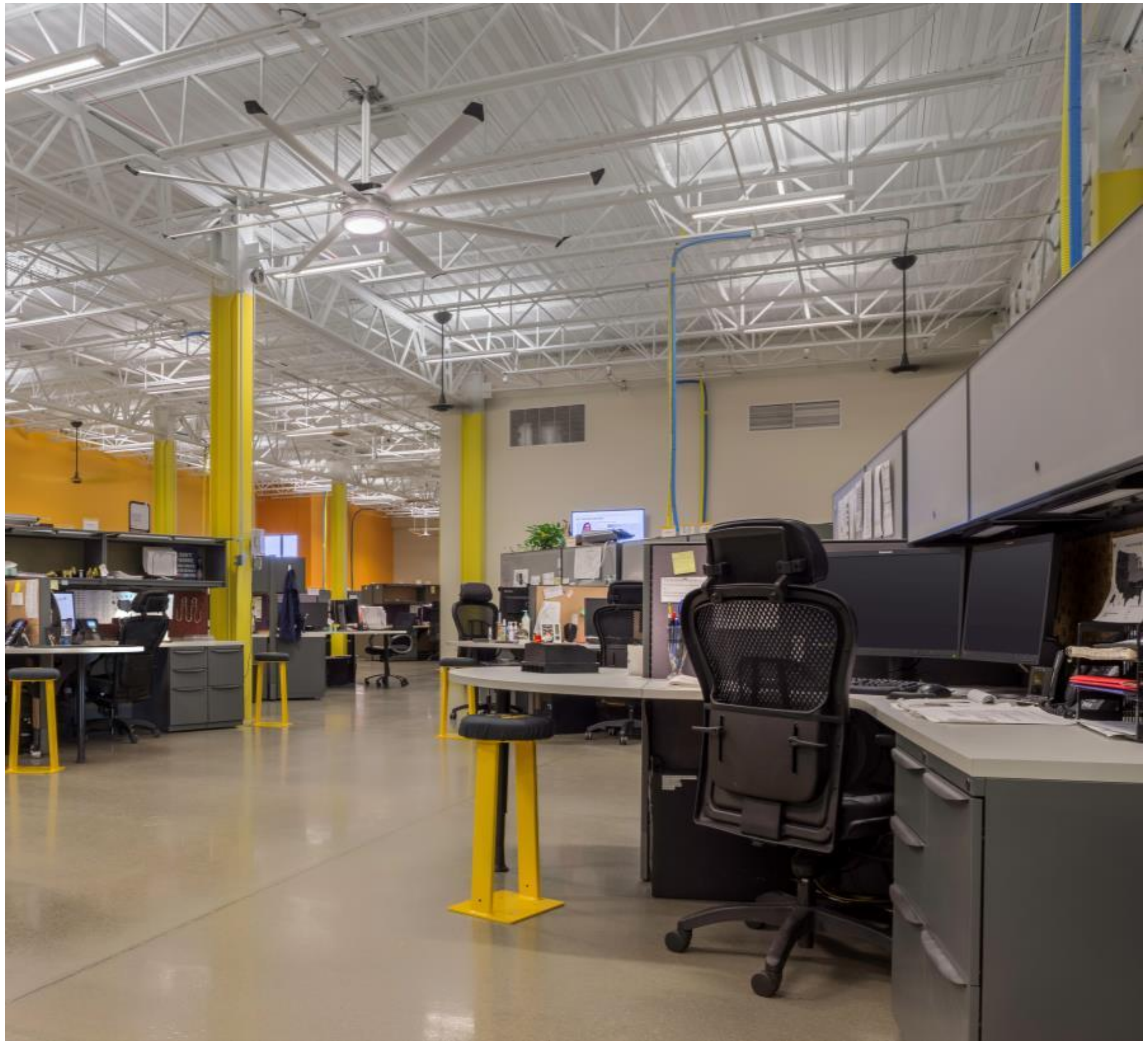
Air speed = 120 fpm

1.2 met

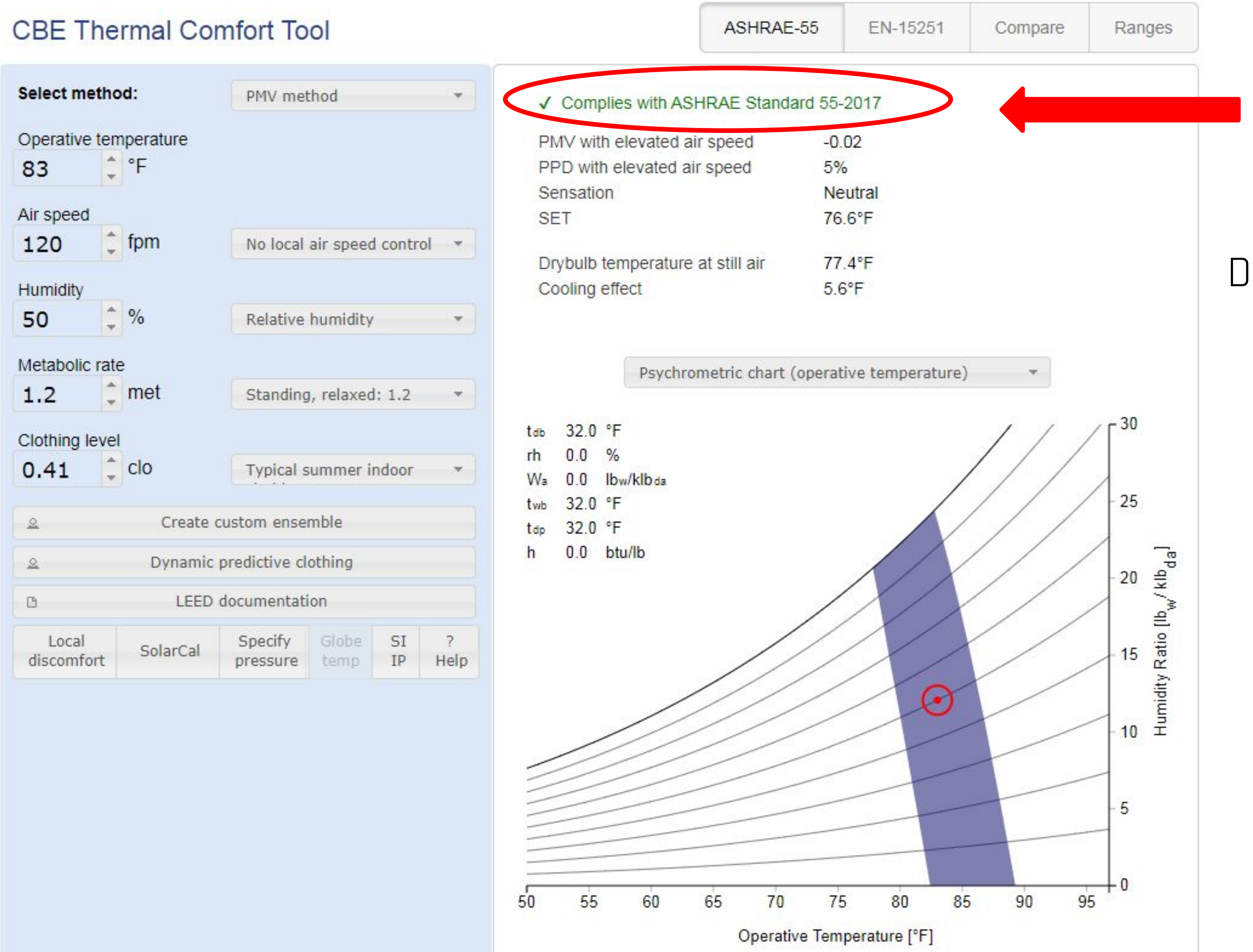
MRT ≈ Air DB 83°F

Indoor Ambient Temp = 83°F

Humidity = 50%



EXAMPLE 4: COMPUTER MODEL METHOD



PMV = -0.02

PPD = 5%

SET 76.6F

Does comply with Standard 55

SECTION 5.3.3: LOCAL THERMAL DISCOMFORT

Section 5.3

- Clo < 0.7, Met < 1.3
- Requirements:
  - Radiant temp asymmetry
  - Vert air temp diff
  - Floor surface temp
  - Temp variation with time

REVIEW

The Graphic Comfort Zone method and the Computer Model Method are equally valid for compliance with Standard 55-2020.

a. True
b. False

REVIEW

Which of the following statements about draft is correct?

a. Draft is most prevalent when the body’s thermal sensation is warm
b. Draft is not a concern when the operative temperature is above 74 F
c. Draft becomes a consideration anytime elevated air speed is present

REVIEW

A space can maintain the same level of comfort using just air conditioning or using air conditioning paired with elevated air speed.

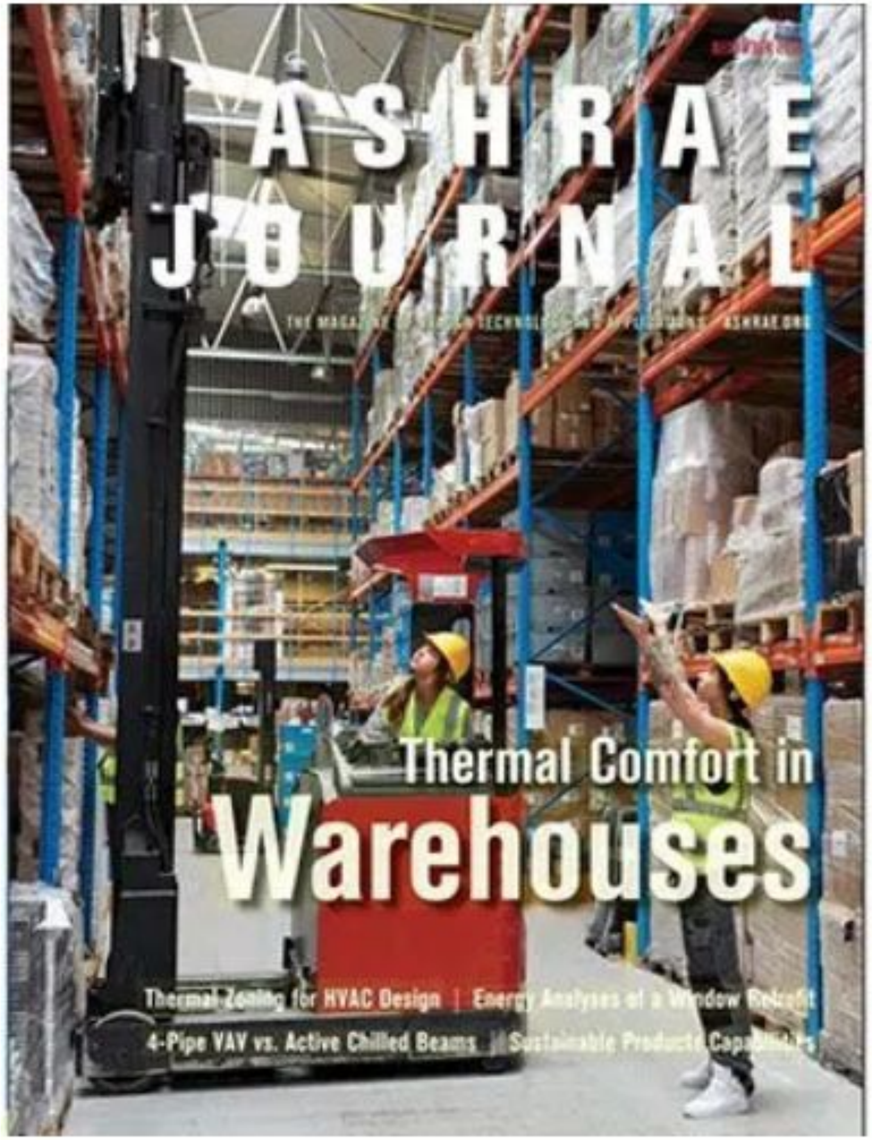
a. True
b. False

THERMAL COMFORT IN OCCUPANT-CONTROLLED NATURALLY CONDITIONED SPACES

THERMAL COMFORT IN OCCUPANT-CONTROLLED NATURALLY CONDITIONED SPACES

Section 5.4

- The "Adaptive Method"
- Requirements:
  - No mechanical cooling or heating system in operation
  - Met 1.0-1.5
  - Occupants can freely adjust clothing
  - Mean OADB 50F-92F



ADAPTIVE METHOD

Method to determine the acceptable range of indoor operative temperatures, using monthly outdoor mean temperature

- Calculate prevailing mean outdoor air temperature
- TMY3 weather data
- 30 previous days
- Simple mean

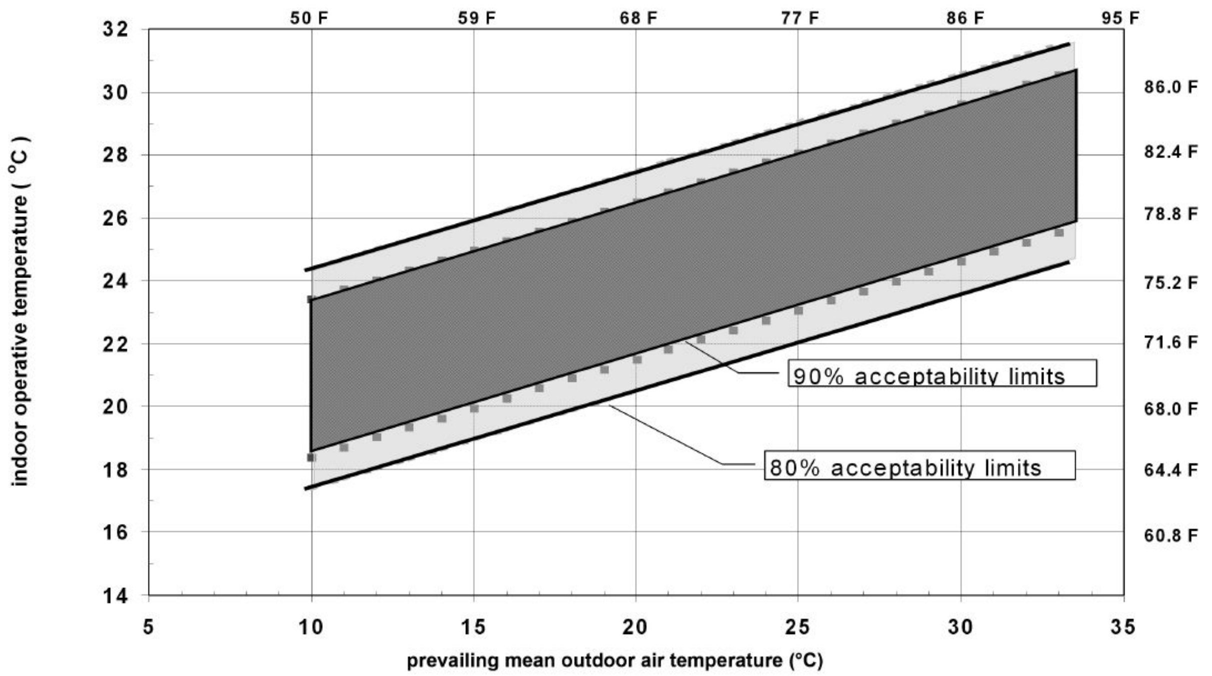
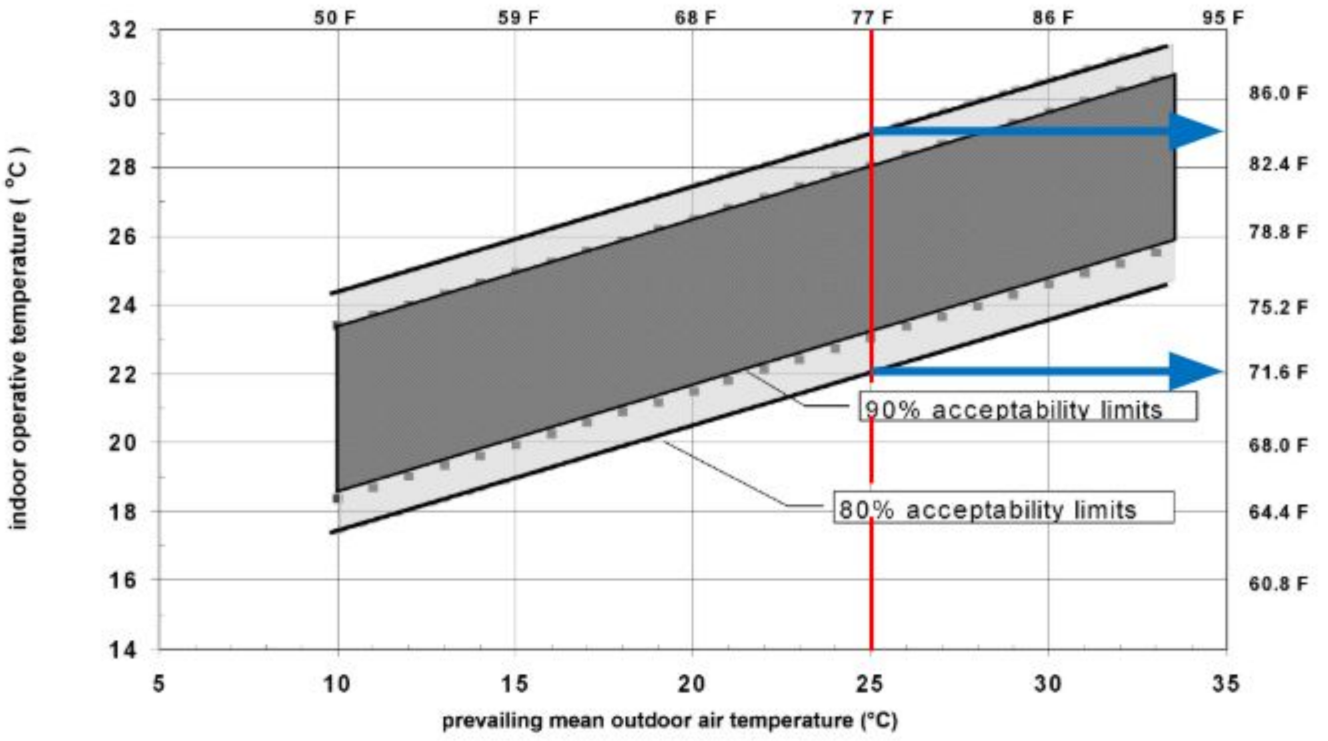


Figure 5-8 – Acceptable Operative Temperature Ranges for Naturally Conditioned Spaces - ASHRAE Standard 55 -2020

ADAPTIVE METHOD

Method to determine the acceptable range of indoor operative temperatures, using monthly outdoor mean temperature

- 80% for compliance
- 90% informational
- 120 fpm = 2F cooling
- 180 fpm = 3F cooling
- 240 fpm = 4F cooling



EXAMPLE 5: ADAPTIVE METHOD

Scenario:

Heated-only building in July

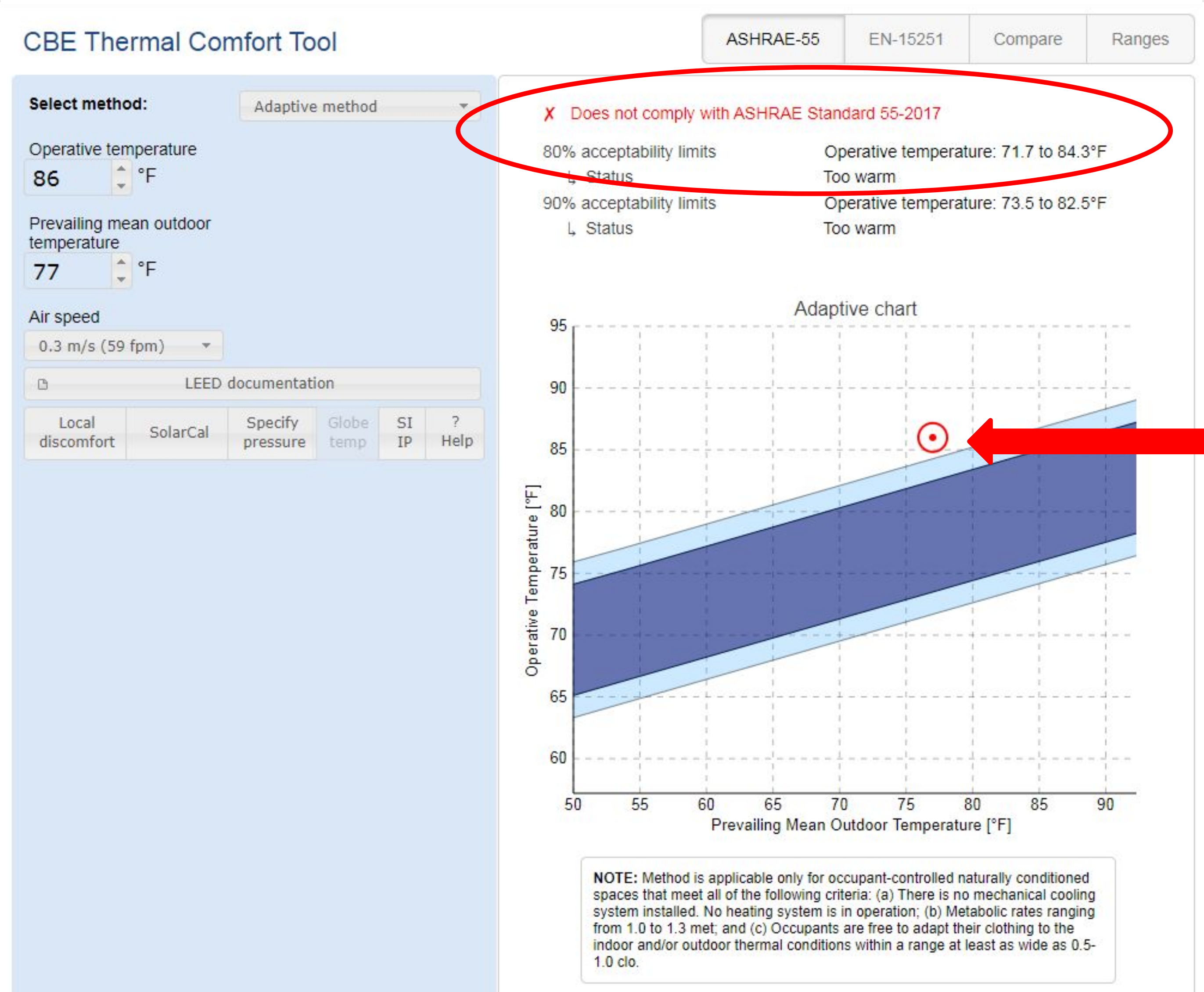
- Envelope & Overhead Lighting = 30% Advanced Energy Design Guide Levels
- Design for Mean Max Monthly Temp (MT)
- Based on Lexington, KY climate data

EXAMPLE 5: ADAPTIVE METHOD

Month	Mean Max Monthly Temp (°F)	Mean Min Monthly Temp (°F)	Mean Monthly Temp (°F)
Jan	40	24	32
Feb	45	26	36
Mar	54	35	45
Apr	66	44	55
May	75	54	64
Jun	83	62	73
July	86	66	77
Aug	85	65	75
Sept	79	58	68
Oct	68	46	57
Nov	54	36	46
Dec	44	28	36

86 F, July in Lexington, Ky.

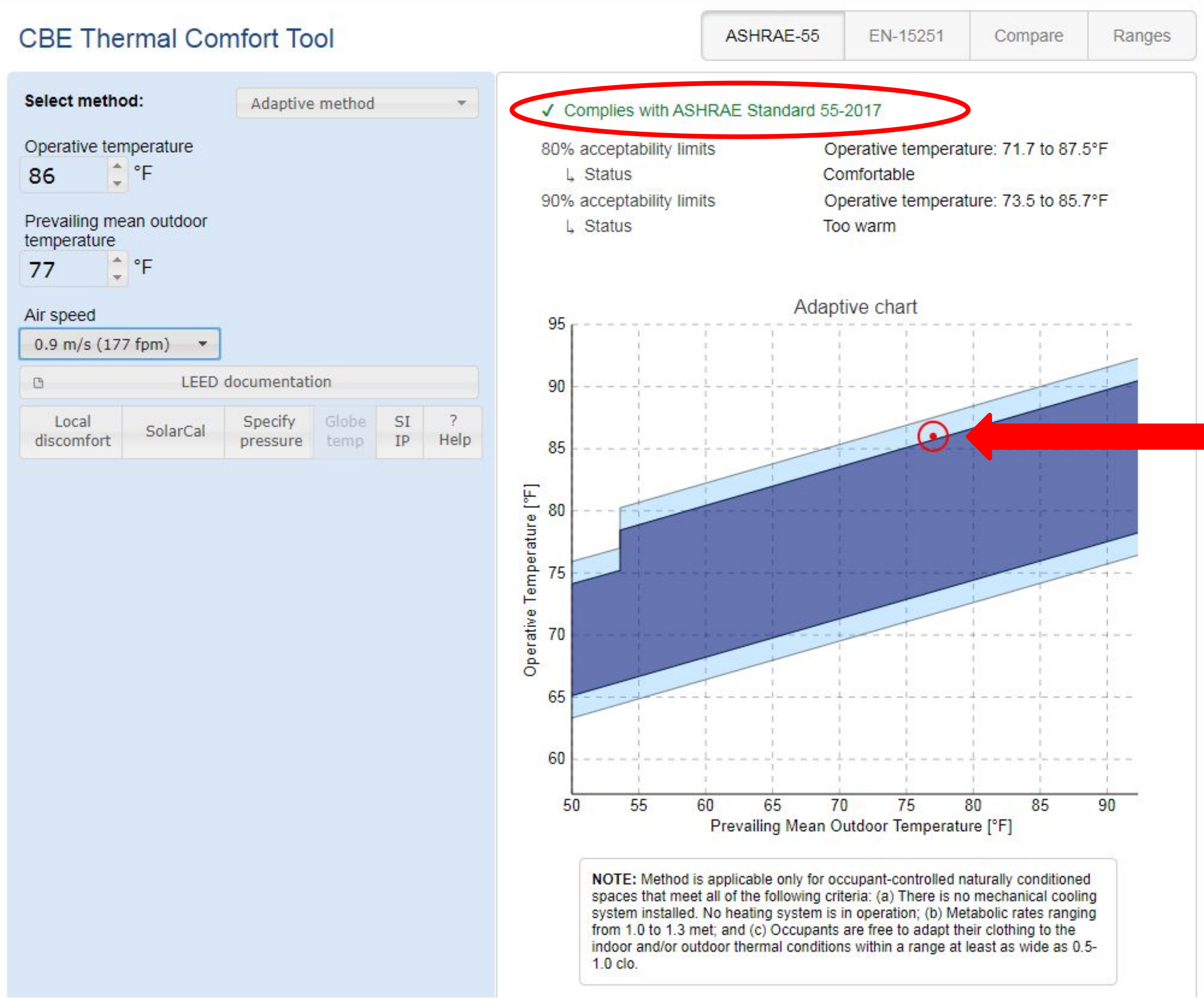
EXAMPLE 5: ADAPTIVE METHOD



Does not comply with Standard 55

Dot is outside comfort limit

EXAMPLE 5: ADAPTIVE METHOD



Complies with Standard 55

Dot is inside the comfort limit

AIR SPEED = 177 FPM

REVIEW

Which of the following is a requirement of the Adaptive Method?

a. Windows must NOT be operable
b. The space must have a mechanical cooling system in operation
c. Occupant clothing insulation values are able to be adjusted

REVIEW

When evaluating thermal comfort in an existing space, which evaluation requirements are specified?

a. Heights at which thermal conditions are measured
b. Duration of time thermal conditions are measured
c. Instruments used to measure thermal conditions
d. All of the above

DESIGN COMPLIANCE

6.1 DESIGN COMPLIANCE

- Control Classification levels
- Cooling
  - MRT or DB -5F
  - Air Speed +60 fpm
  - Corrective Power -4F
- Heating
  - MRT or DB +5F
  - Corrective Power +4F

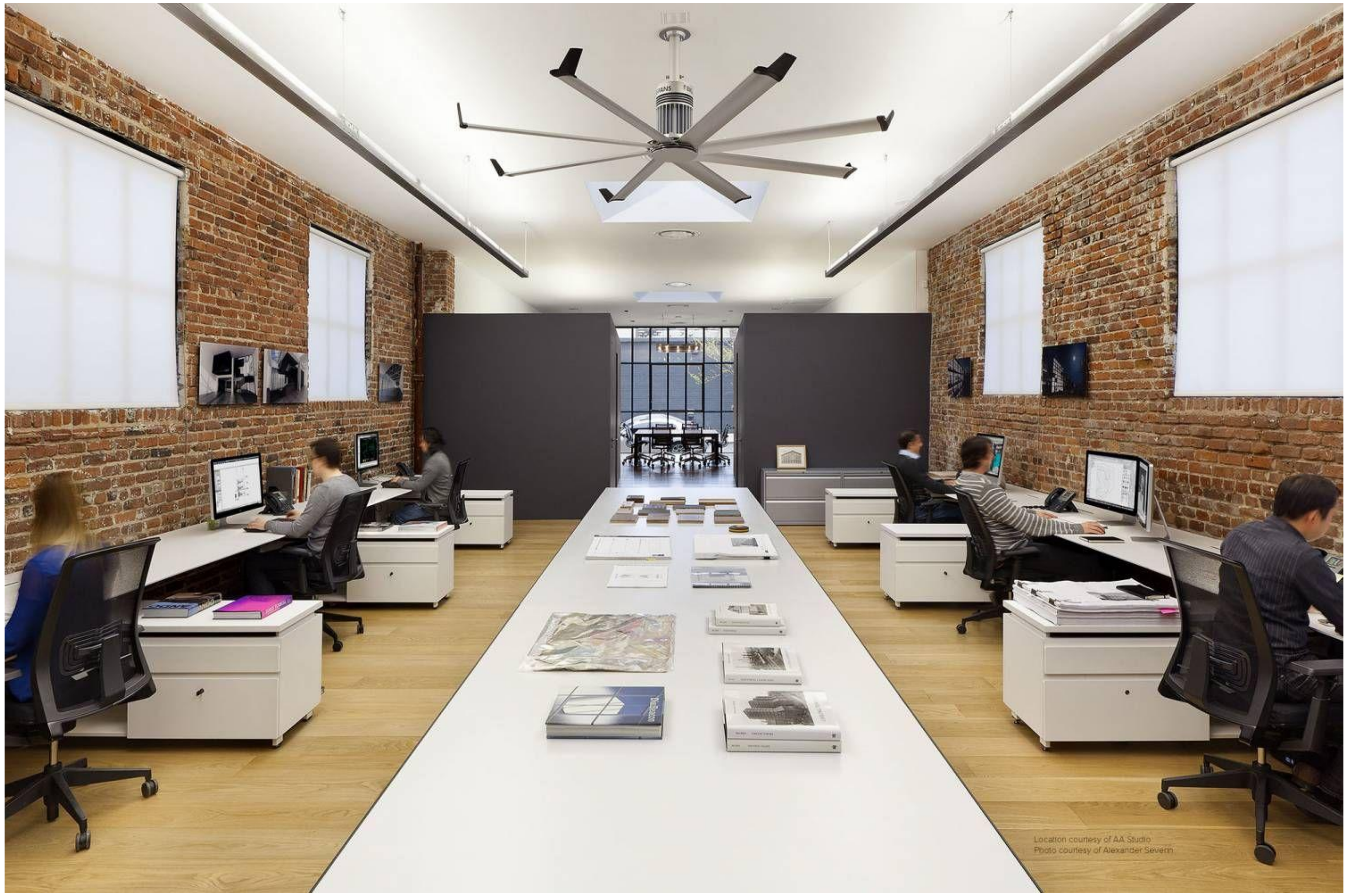
Table 6-1 Thermal Environmental Control Classification Levels

Thermal Environmental Control Classification Level	Control Measure(s) for Environmental Factors Required to Achieve Level
1	Each occupant is provided two or more control measures for their personal environment.
2	Each occupant is provided one control measure for their personal environment.
3	The room or thermal zone provides multioccupant control of at least two control measures in their shared environment.
4	The room or thermal zone provides multioccupant control of one control measure in their shared environment.
5	No occupant control of any environmental factors

ASHRAE Standard 55-2020 Table 6-1

6.1.1 DESIGN THERMAL ENVIRONMENTAL CONTROL CLASSIFICATION - EXAMPLE

- Shared Office Space
    - Adjustable Thermostat
        - +/- 5F
    - Adjustable Ceiling Fan
        - +120 fpm
- Thermal Environmental Control
    - Two multi-occupant control measures
    - Classification Level 3



EVALUATION OF COMFORT IN EXISTING BUILDINGS

EVALUATION OF COMFORT

Section 7.1

- Evaluation of comfort not required

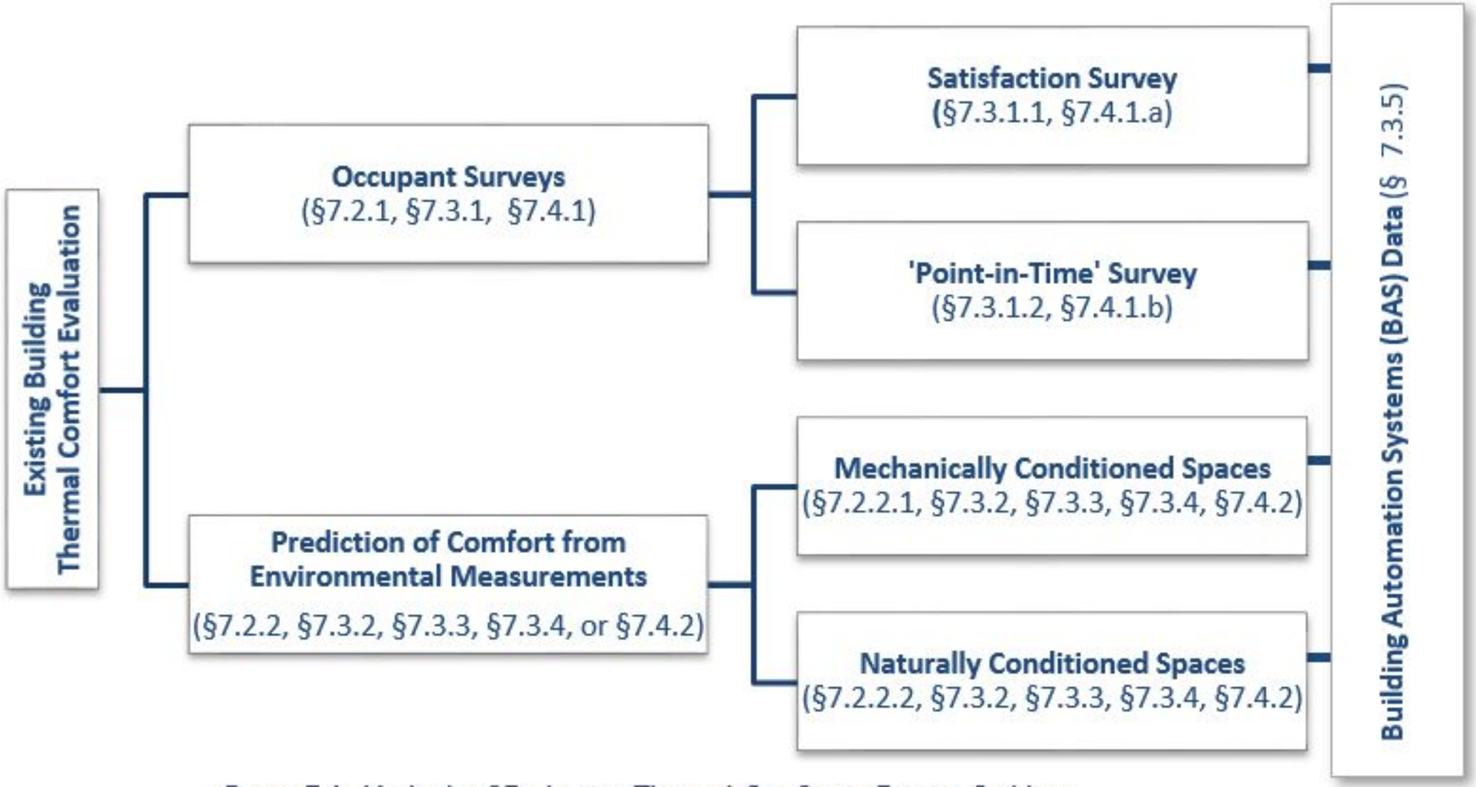
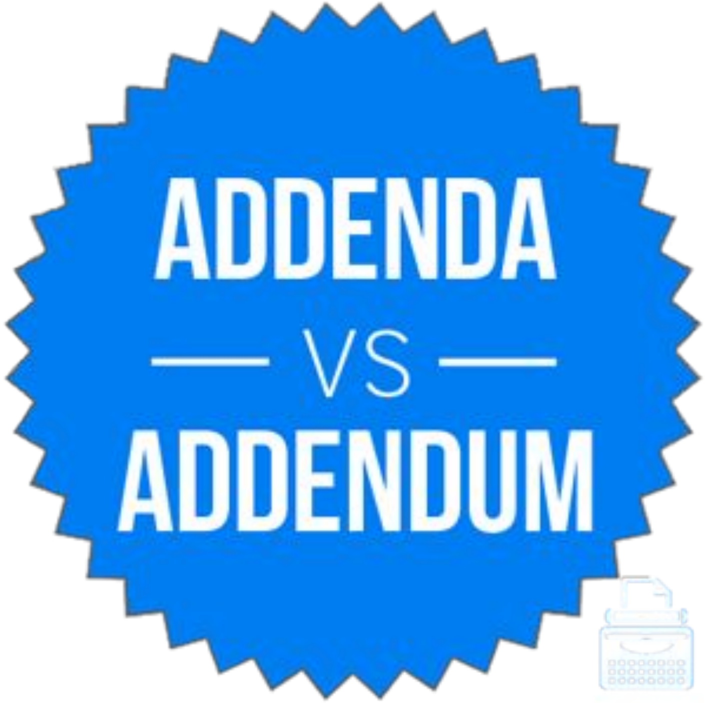


Figure 7-A: Methods of Evaluating Thermal Comfort in Existing Buildings

STANDARD 55 - REVISIONS AND PROPOSED REVISIONS

Addendum (2013→2017):

a) Vertical strat clarifications
b) Separates 3 comfort methods
c) Simplified operative temp calculation
d) “Still air” = 40 fpm
e) Removes permissive language
f) Scope change for safety
g) Direct solar radiation calculations



Addendum (2017→2020):

a) Draft Risk / Local Discomfort
b) Calc/Code for 2017- App B
c) Comfort Classes
d) Graphical Method Deletion
e) Solar Cal Calc/Code Fixes
f) Adaptive Method update
g) Figure 5.3.2C correction
h) CBE Thermal Comfort Tool

IS STANDARD 55 COMPLIANCE REQUIRED?

References to Standard 55

1. ASHRAE 189.1/IgCC
2. *LEED Rating Systems*
3. *Green Globes*
4. *Well Building Standard*
5. *Owners Requirements*
6. *Standard of Care….*

SUMMARY

- Thermal Comfort Factors
- Graphic Comfort Zone Method
- Analytical Comfort Zone Method
- Elevated Air Speed Comfort Zone Method
- Adaptive Method
- Evaluation of Comfort

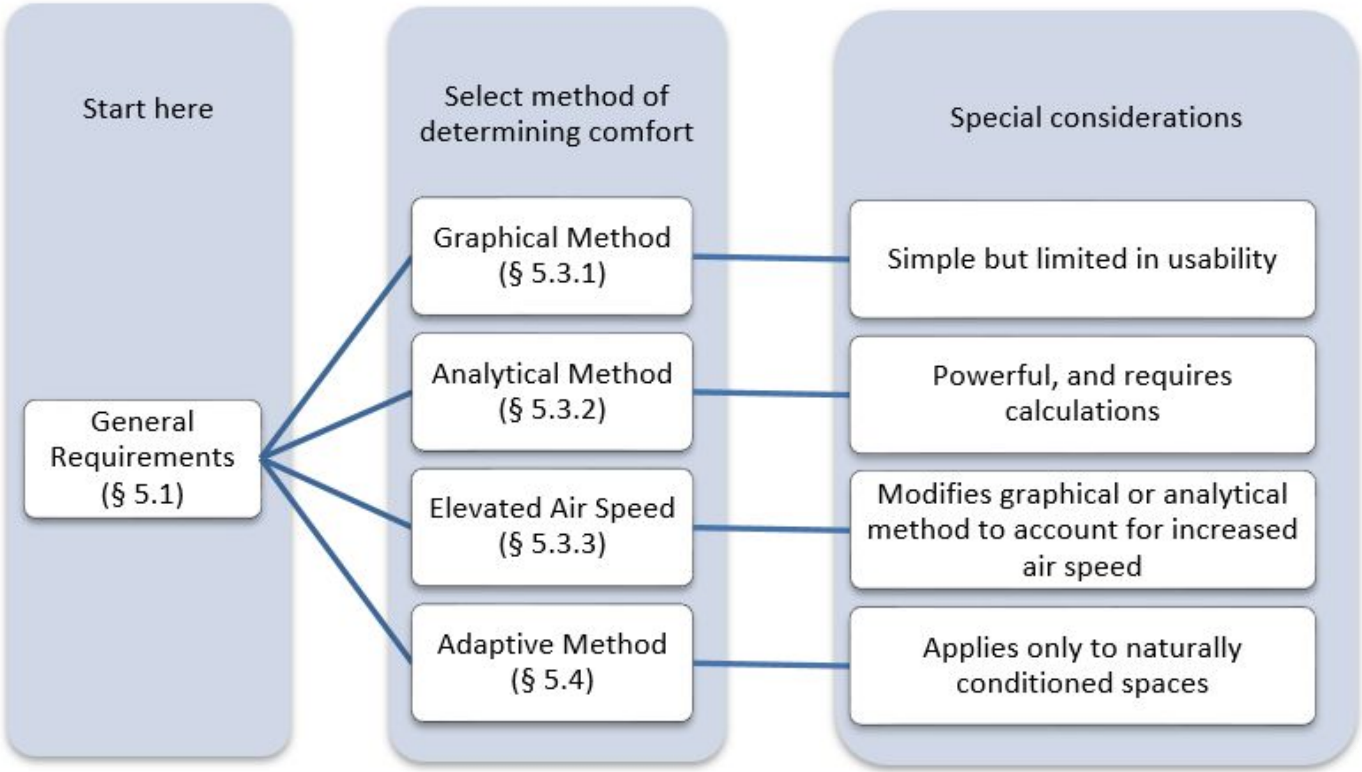


Figure 5-B: Methods of Determining Thermal Comfort

PROGRAM EVALUATION

Program Title ____

Presenter ______________________________ Date ______________________

1. Were the program learning objectives stated clearly and concisely? Y P N

Comment ______________________________________

2. Did this program meet your expectations? Y P N

Comment ______________________________________

3. Are you confident that you could accomplish these learning objectives?

Understand the purpose of Standard 55 and how the Standard impacts sustainable design. Y P N

Learn how to energy-efficiently meet comfort standards in both air-conditioned and naturally conditioned spaces. Y P N

Describe how to evaluate compliance with comfort standards in various environments. Y P N

Identify the updates to Standard 55-2020 and how they accommodate design solutions in sustainable building. Y P N

PROGRAM EVALUATION CONTINUED

4. Did you find the program content current and relevant? Y P N
Comment____

5. Did the presenters help you understand the content? Y P N
Comment ____

6. Were the audio and visual materials effective? Y P N
Comment ____

QUESTIONS?