The 15th Canadian Conference on Building Science and Technology (CCBST)

It's Time To Change Bait

Why and How To Use Thermal Comfort Analysis

In Design Stage

To Influence Enclosure and HVAC Designs.

Robert Bean, R.E.T., P.L. (Eng.)
Indoor Climate Consultants Inc.
www.healthyheating.com
info@healthyheating.com
ASHRAE T.C. 2.1, T.C.6.1, T.C.6.5, T.C. 7.4, SSPC 55, RBC

online thermal comfort tools

learning objectives:

1. explain the key components of thermal comfort
2. identify the flaws in architecture contributing to discomfort
3. describe the relationships between architecture, hvac and thermal comfort
4. utilize online thermal comfort tools for assessing architecture choices

presentation is in IP units…users can choose to run the tools in SI.

dual units are given when necessary.

online thermal comfort tools

acknowledgements

Stan Sveen, MBA, Uponor (T.C. 6.5)

Devin Abellon, P.E., Uponor (TC 6.5 Programs et al)

Center for the Built Environment (ASHRAE Standard 55 tool)

Payette (Downdraft and radiant asymmetry tool)

Cardinal Glass (Discomfort and energy tool)

online thermal comfort tools

abstract

this case study

demonstrates the use of thermal comfort analysis

in pre-construction document stages

to improve enclosure performance;

and drive choices in HVAC systems,

improve plant efficiency and

reduce building energy consumption.

online thermal comfort tools

"seventy percent of whole home performance customers **cited comfort as a reason for their upgrade.**"

rocky mountain institute (2015)

source: http://www.rmi.org/Content/Images/replus_unlocking_the_future_infographic_full.jpg

online thermal comfort tools

an increase in comfort

was selected by the largest number of people

as a renovation trigger (70%)

kapedan, e., herssens, j., nuyts, e., verbeeck, g., (2017) the importance of comfort indicators in home renovations: a merger of energy efficiency and universal design. proceedings, plea 2017. edinburgh

online thermal comfort tools

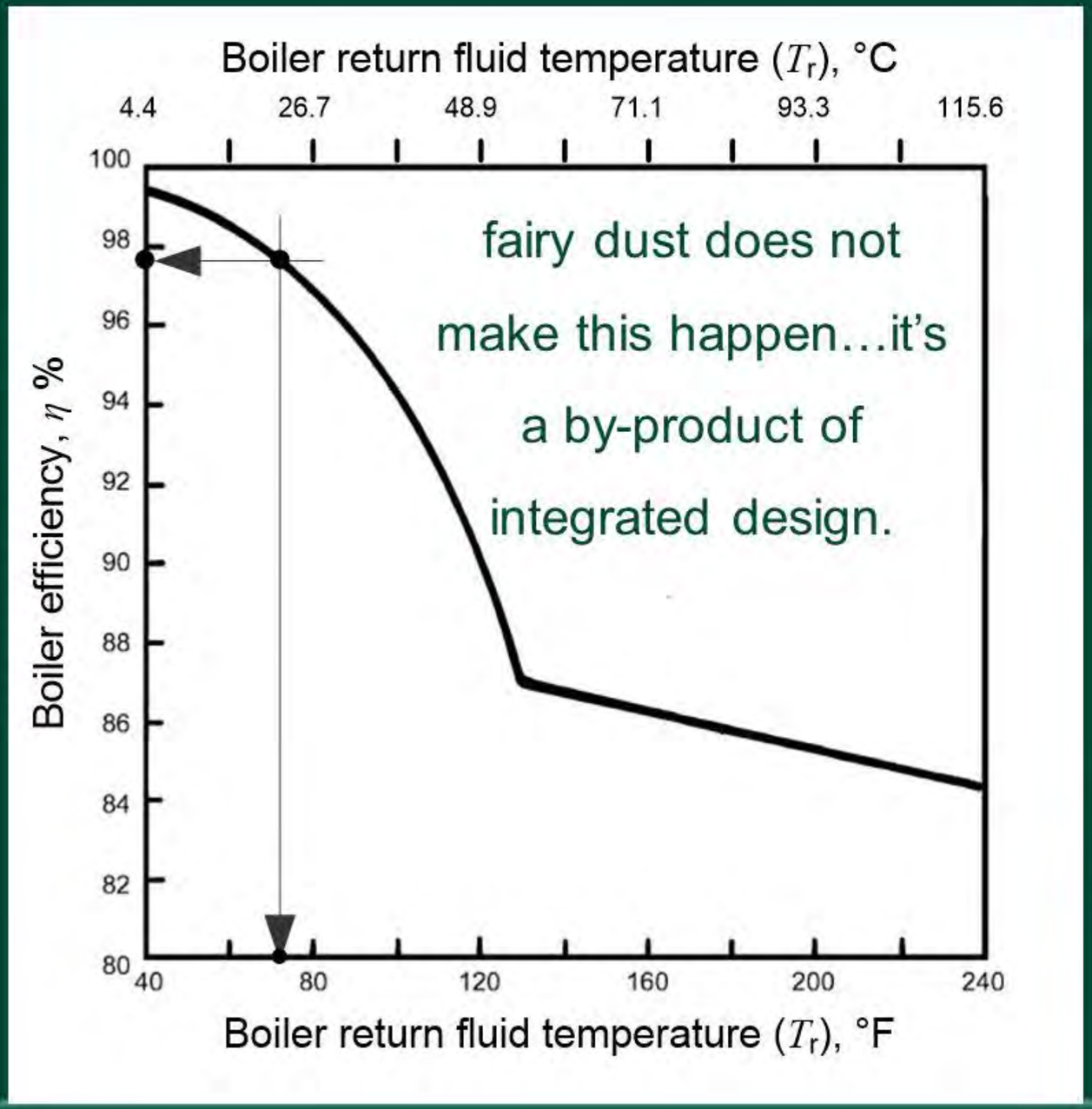
comfort

is more appealing to people

than energy efficiency

healthy homes barometer 2015

follow the logic – it is not that complicated



high heating efficiencies come from

low return temps

low return heating temps come from:

large surface exchangers w/ high fin efficiency

& conductive surfaces and assemblies

& close tube spacing & low flux

low flux comes from efficient enclosures

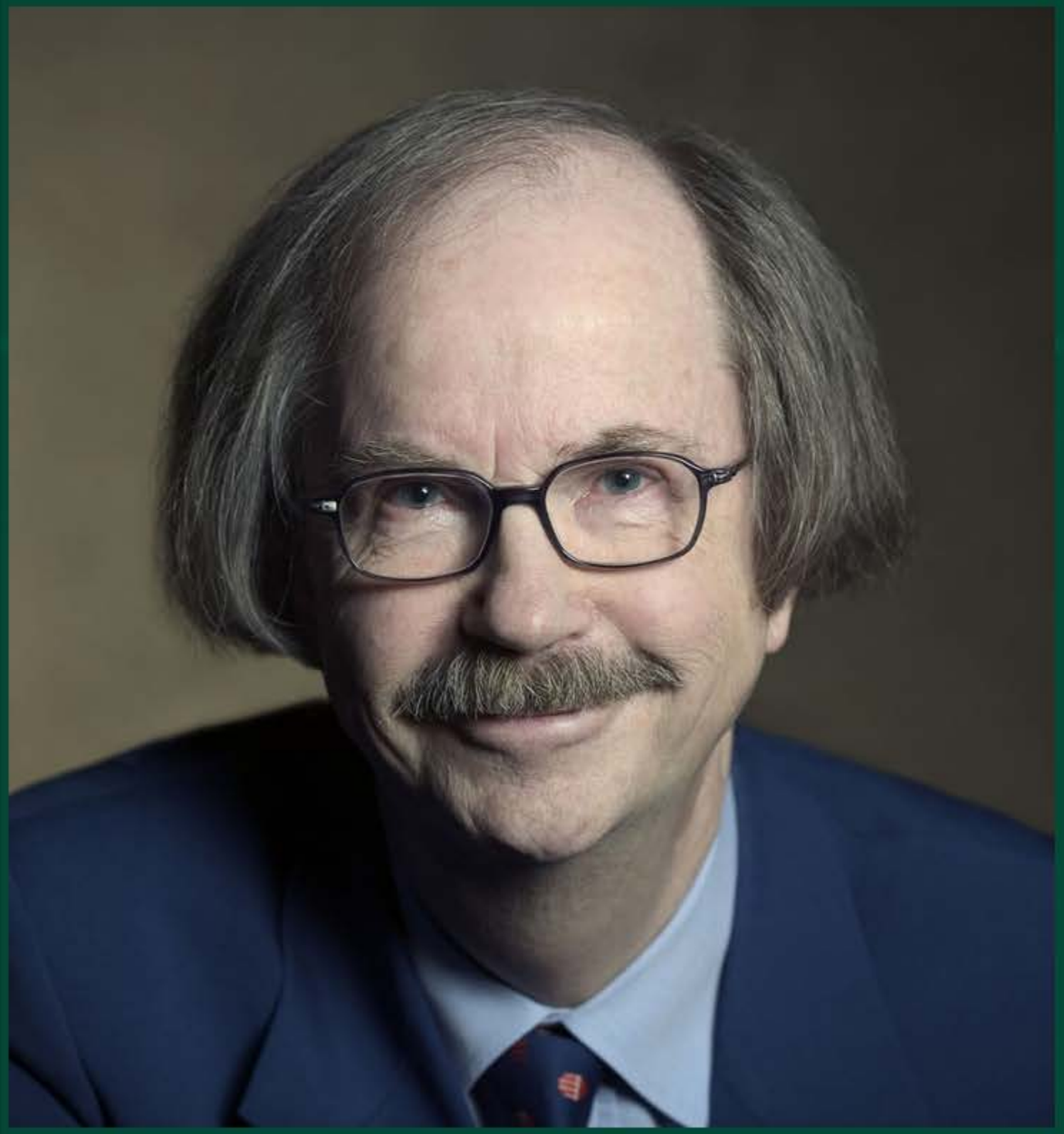
efficient enclosures have

low MRT in summer and high MRT in winter

MRT is a major component in thermal comfort

therefore comfort must drive design

the father of indoor environmental quality said…



"a rational calculation of heating and air-conditioning systems must begin with the conditions for comfort"

ole fanger

national building code of Canada on comfort

an objective of this Code is to limit the probability that, as a result of the design or construction of the *building* or facility, a person in the building or facility will be exposed to an unacceptable **RISK OF ILLNESS** **due to inadequate…**

air quality, thermal comfort, contact with moisture.

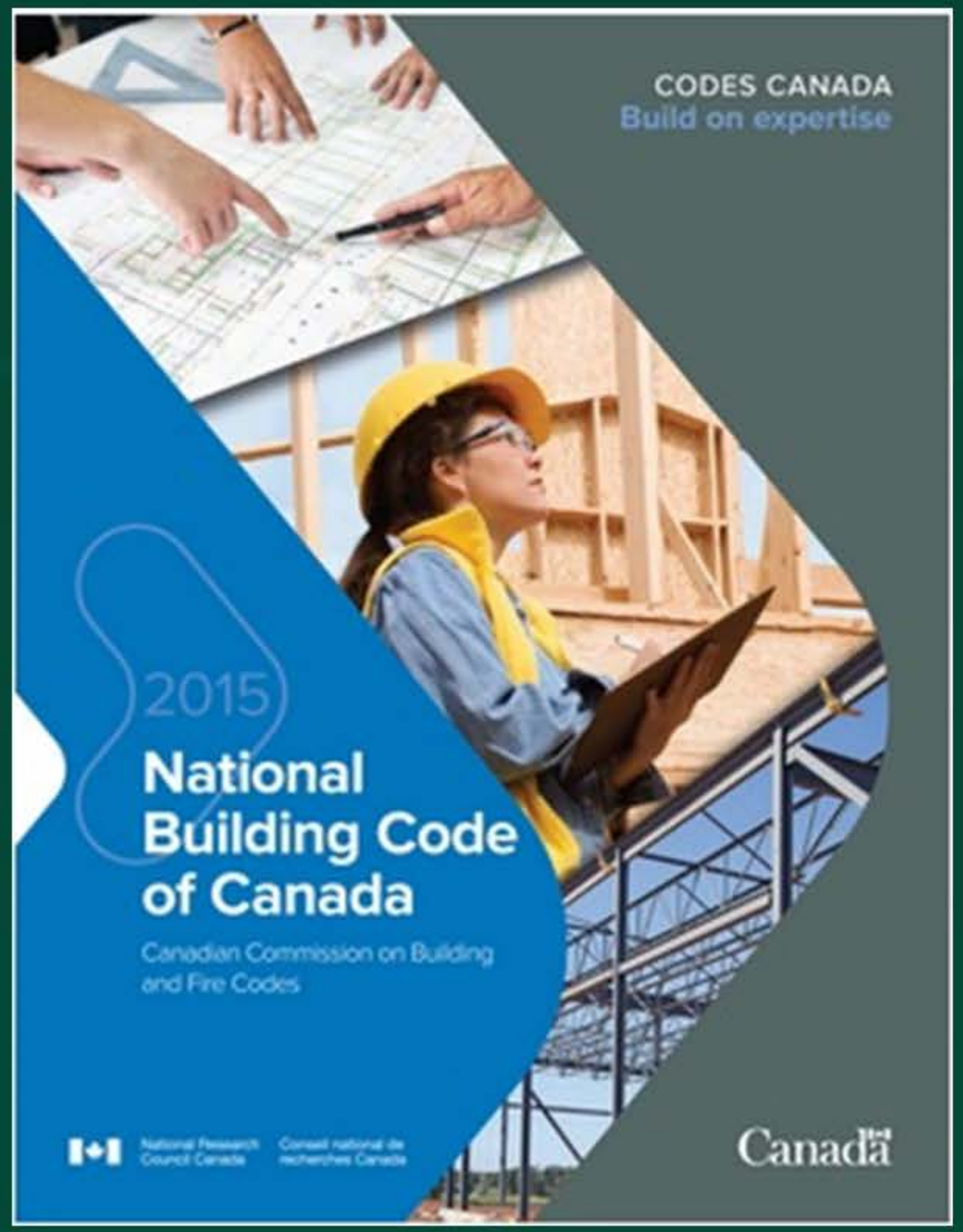
national building code of Canada on comfort

without the blah blah blah…

limit the probability that a person will be exposed to an unacceptable

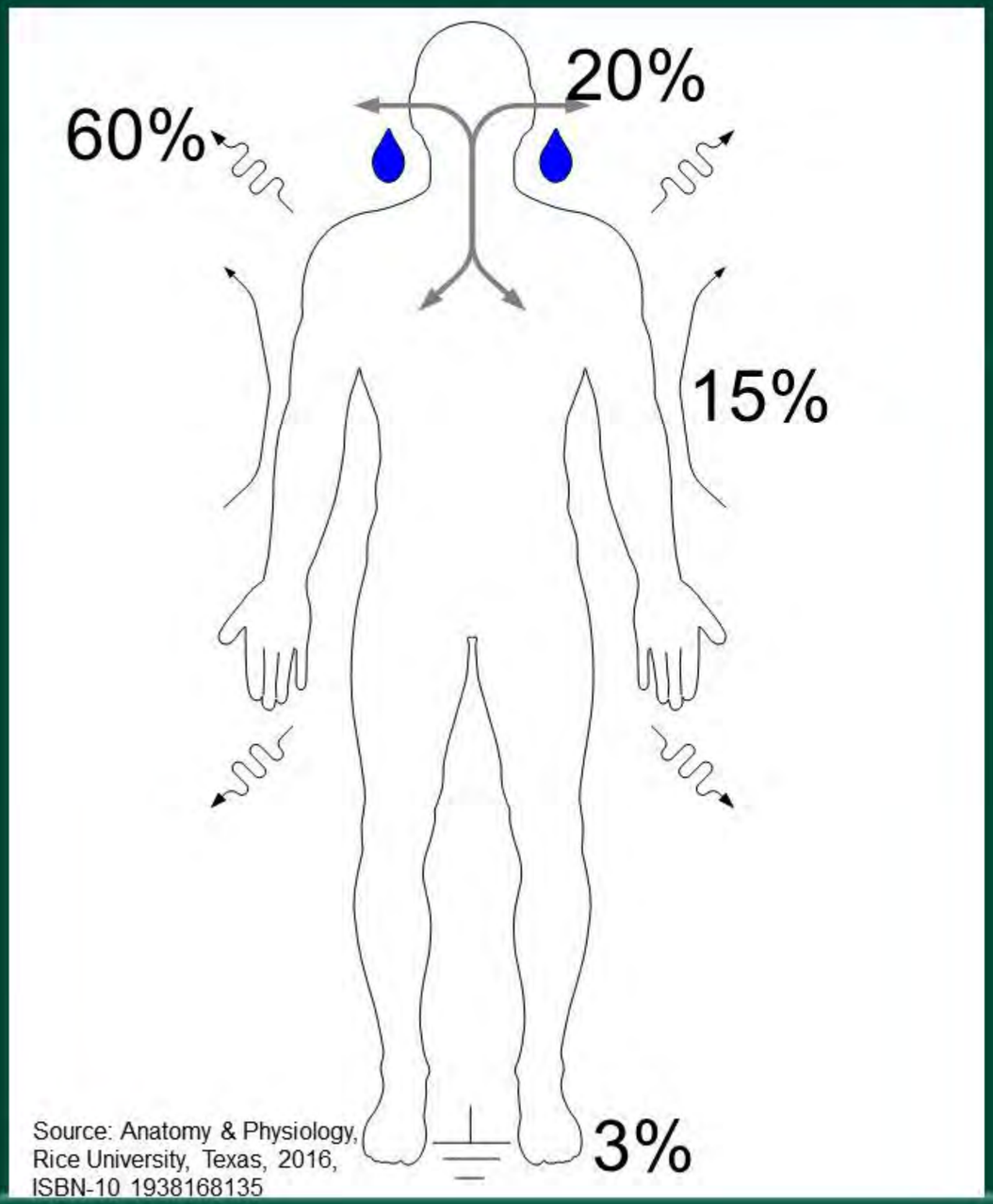
RISK OF ILLNESS

unacceptable “risk of illness” prescribed by…



“at the outside winter design temperature, required heating facilities shall be capable of maintaining an indoor AIR temperature of not less than 22°c (72f) in all living spaces…”

a big shock for those raised on the holy grail of air



Source: Anatomy & Physiology, Rice University, Texas, 2016, ISBN-10 1938168135

when it comes to heat transfer from

the human body the

medical textbooks,

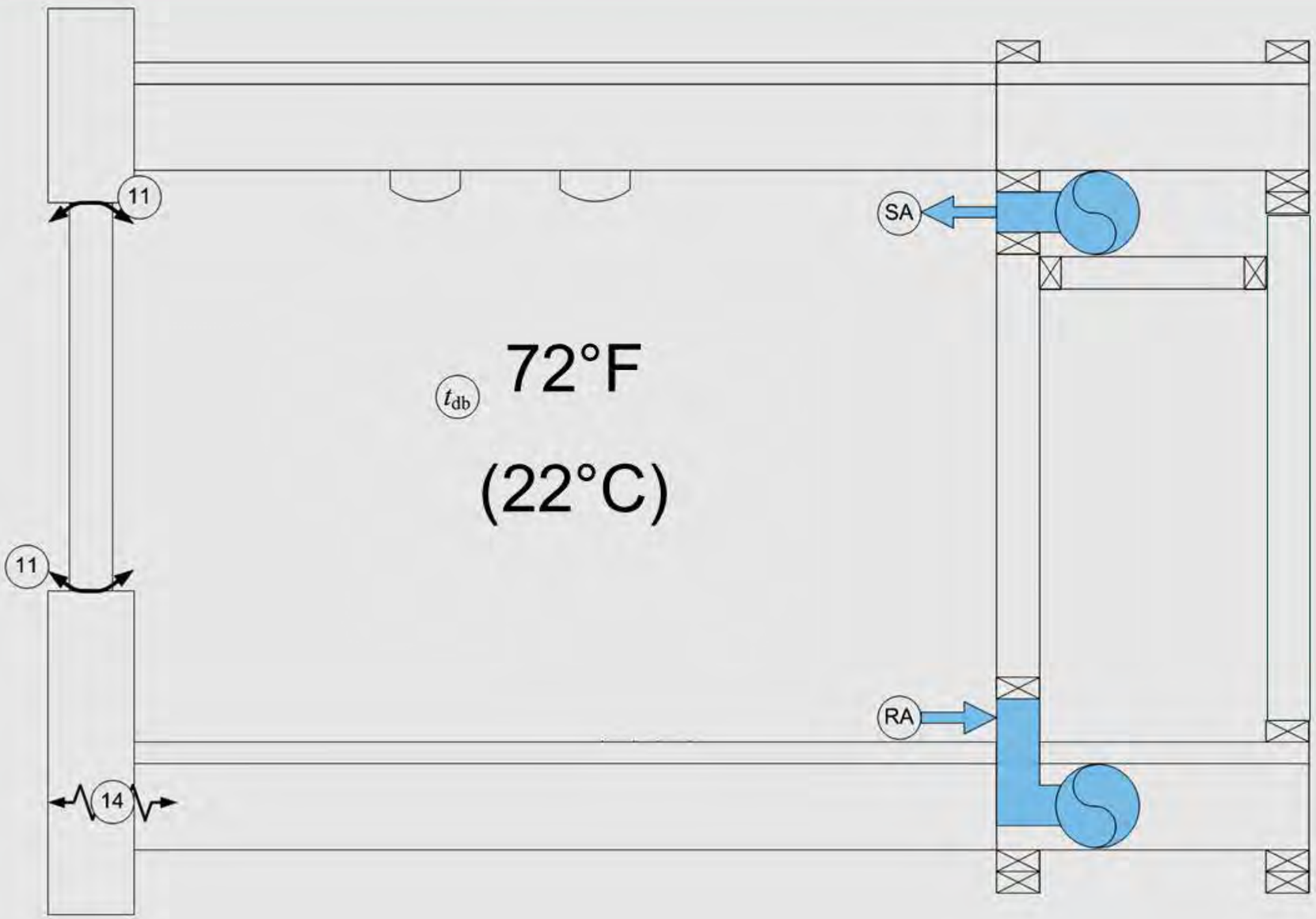
ashrae engineering manuals

& environmental ergonomic guides

are congruent

radiant is the #1 function

codes & utilities promote thermal comfort illiteracy



bean's law #1

minimums in

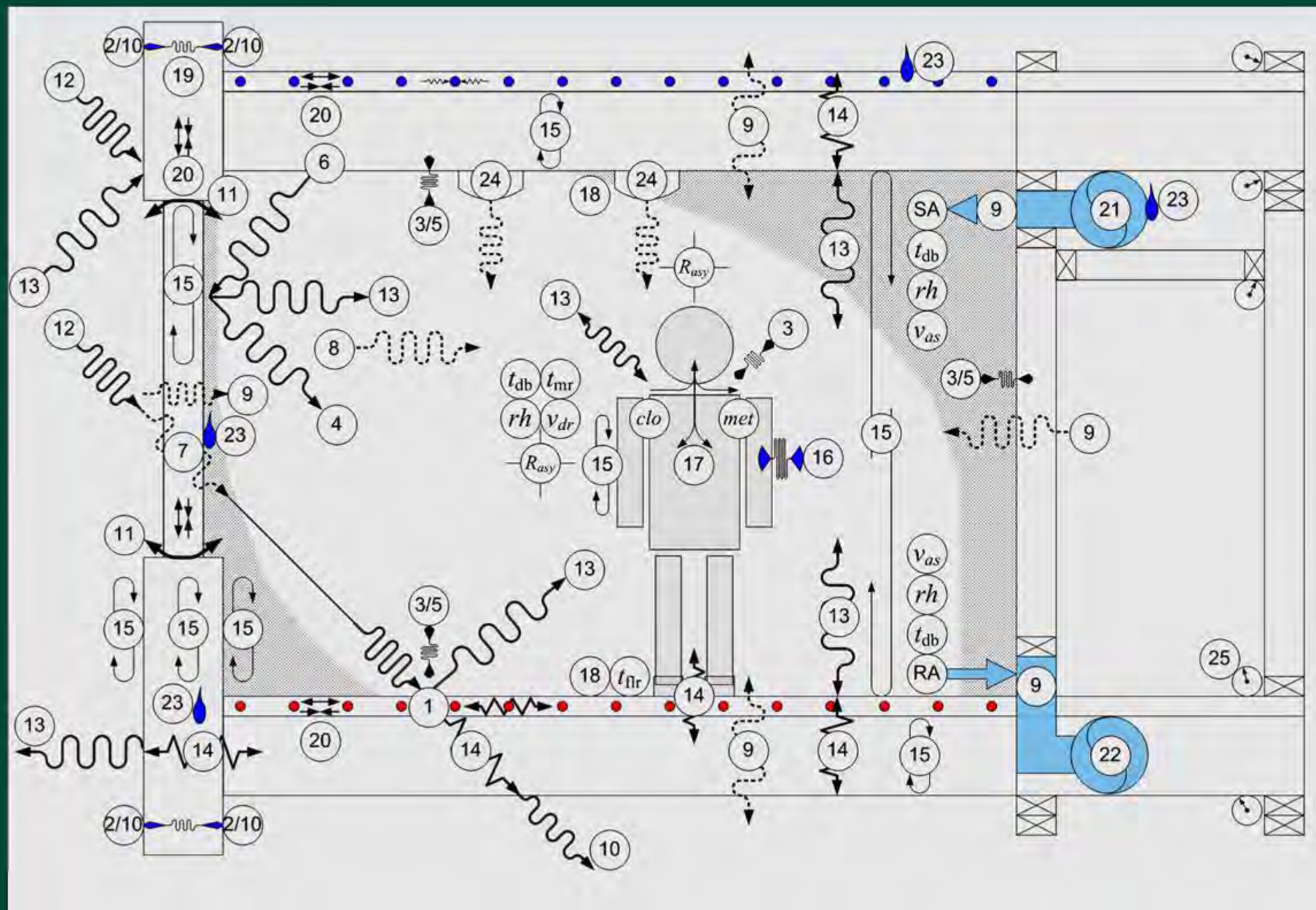
code

become

maximum in

practice

literacy = education + practice + experience



to the educated

the world of

engineering

comfortable

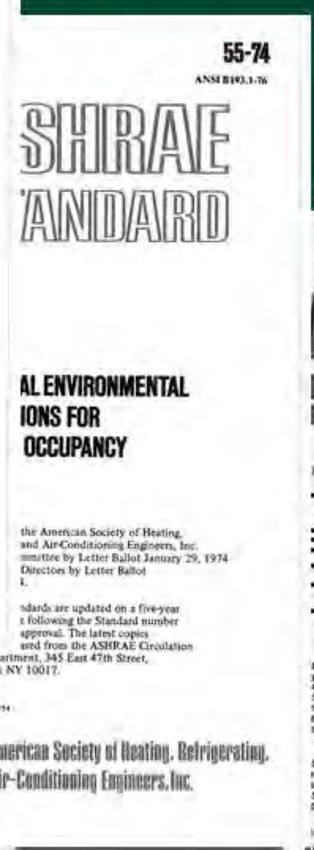
energy efficient

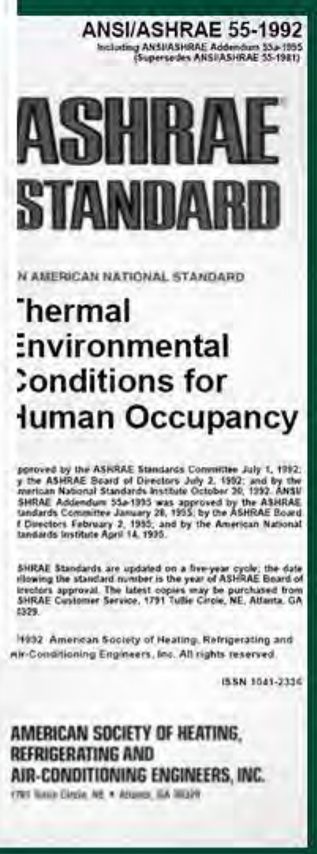
systems looks

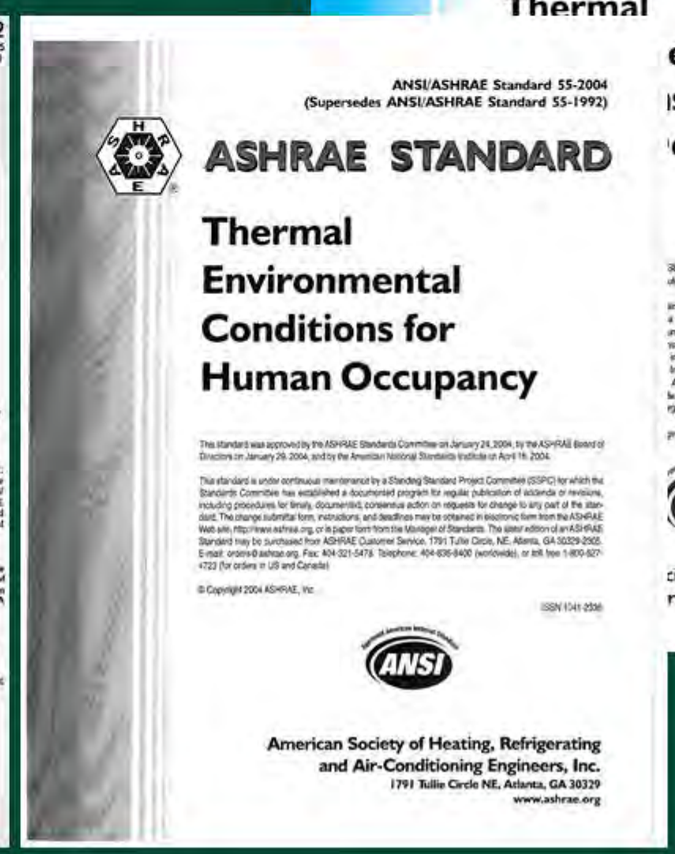
like this

its all spelled out in ASHRAE Standard 55

a 50 year history & counting

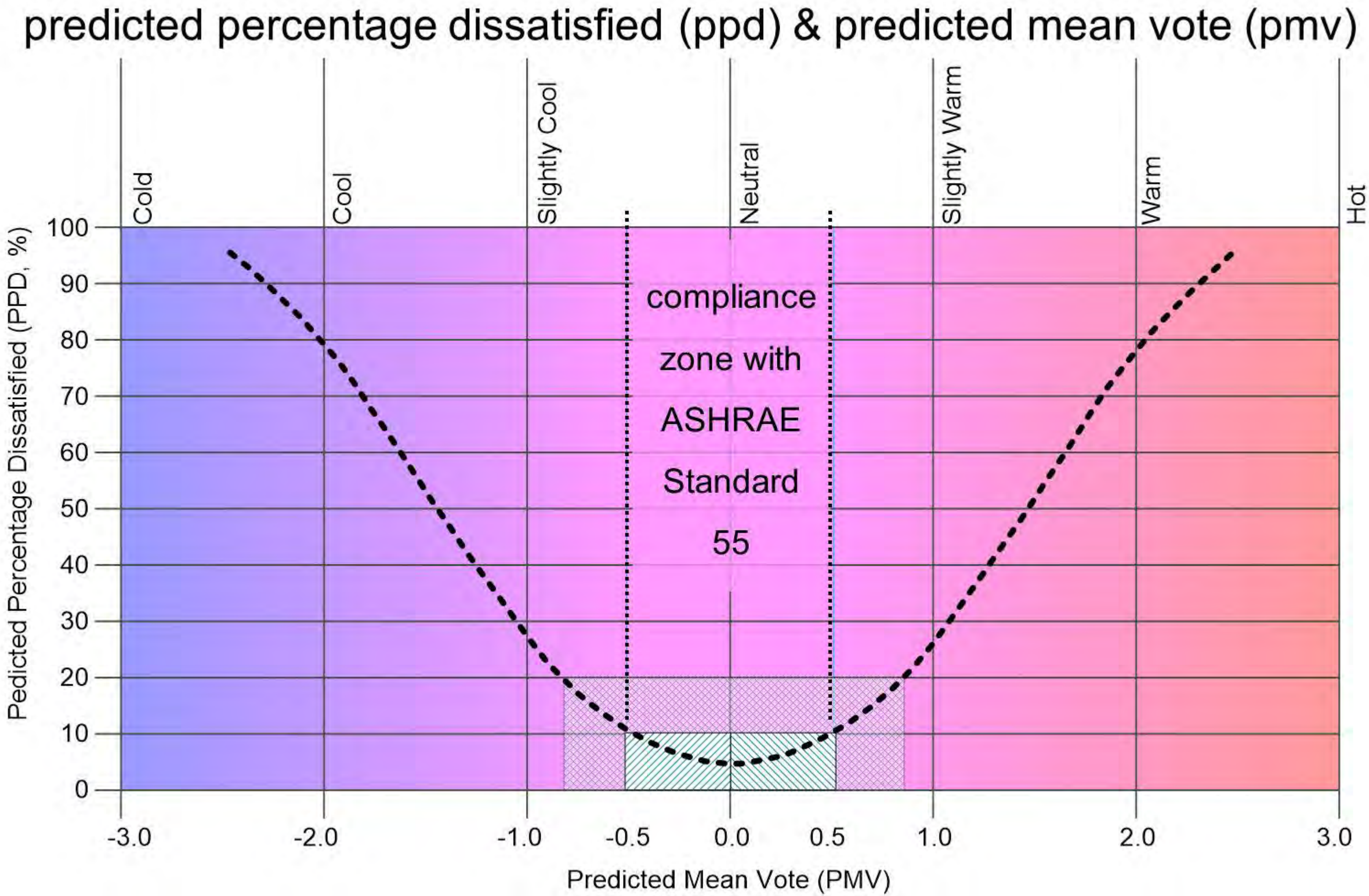




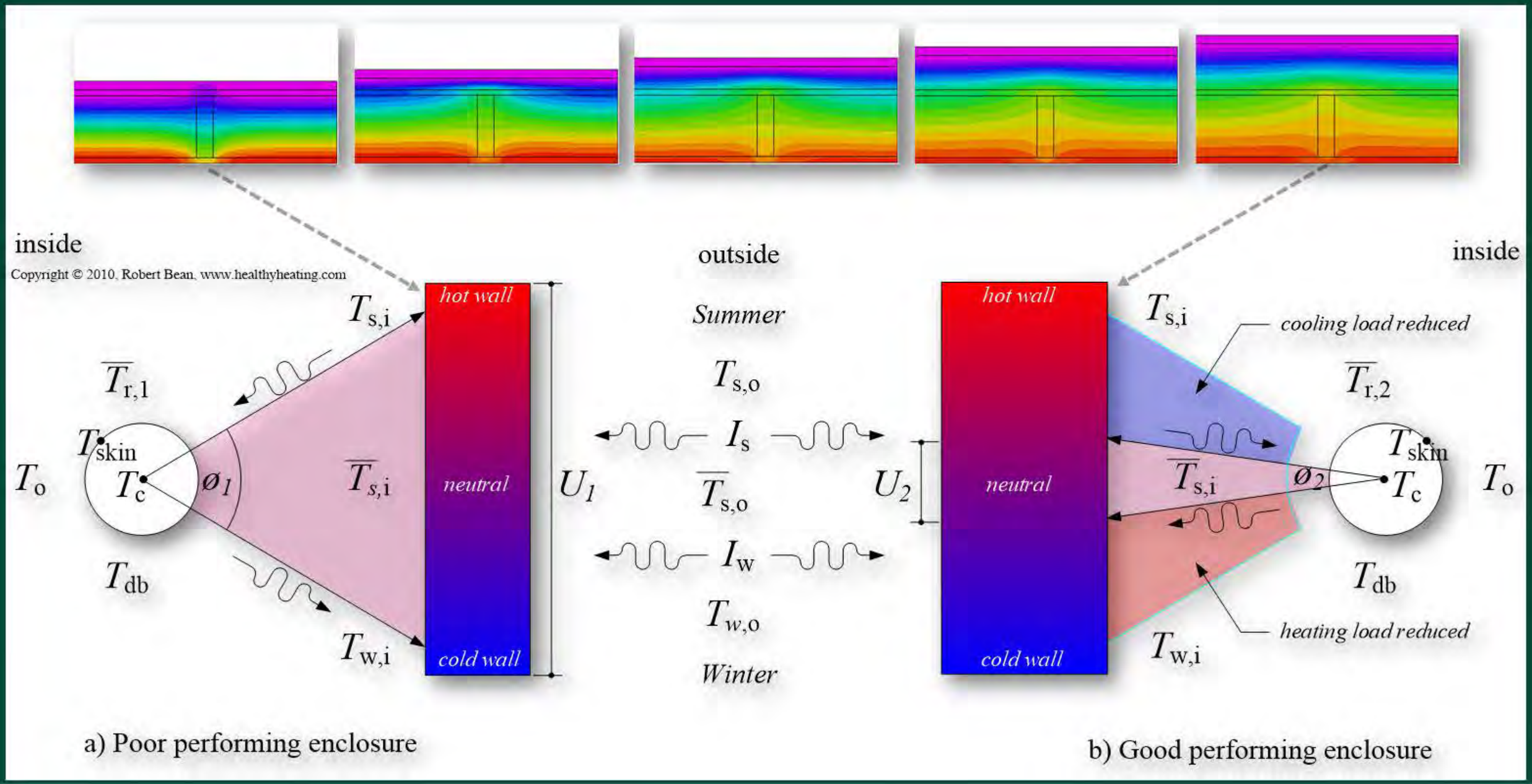


the 10 commandments of thermal comfort

factors affecting thermal comfort (* strictly influenced by enclosure performance; dry bulb & rh is co-influenced by enclosures exclusively conditioned with air based hvac systems.)	
general environmental factors	**localized factors**
dry bulb temperature	vertical air temperature differences*
mean radiant temperature*	radiant temperature asymmetry*
humidity	floor temperature*
air speed	drafts*
personal factors	
metabolic rate	clothing
source/credit: ansi/ashrae standard 55 - thermal environmental conditions for human occupancy	


predicted percentage dissatisfied (ppd) & predicted mean vote (pmv)
Cold
Cool
Slightly Cool
Neutral
Slightly Warm
Warm
Hot
compliance
zone with
ASHRAE
Standard
55
Pedicted Percentage Dissatisfied (PPD, %)
100
90
80
70
60
50
40
30
20
10
0
-3.0
-2.0
-1.0
-0.5
0.0
0.5
1.0
2.0
3.0
Predicted Mean Vote (PMV)

thermal bridging, infiltration & windows: comfort's achilles heel



thermal bridging, infiltration & windows: comfort's achilles heel

Table 2 Indoor Surface Heat Transfer Coefficient h_i in Btu/h · ft^2 · °F, Vertical Orientation (Still Air Conditions)

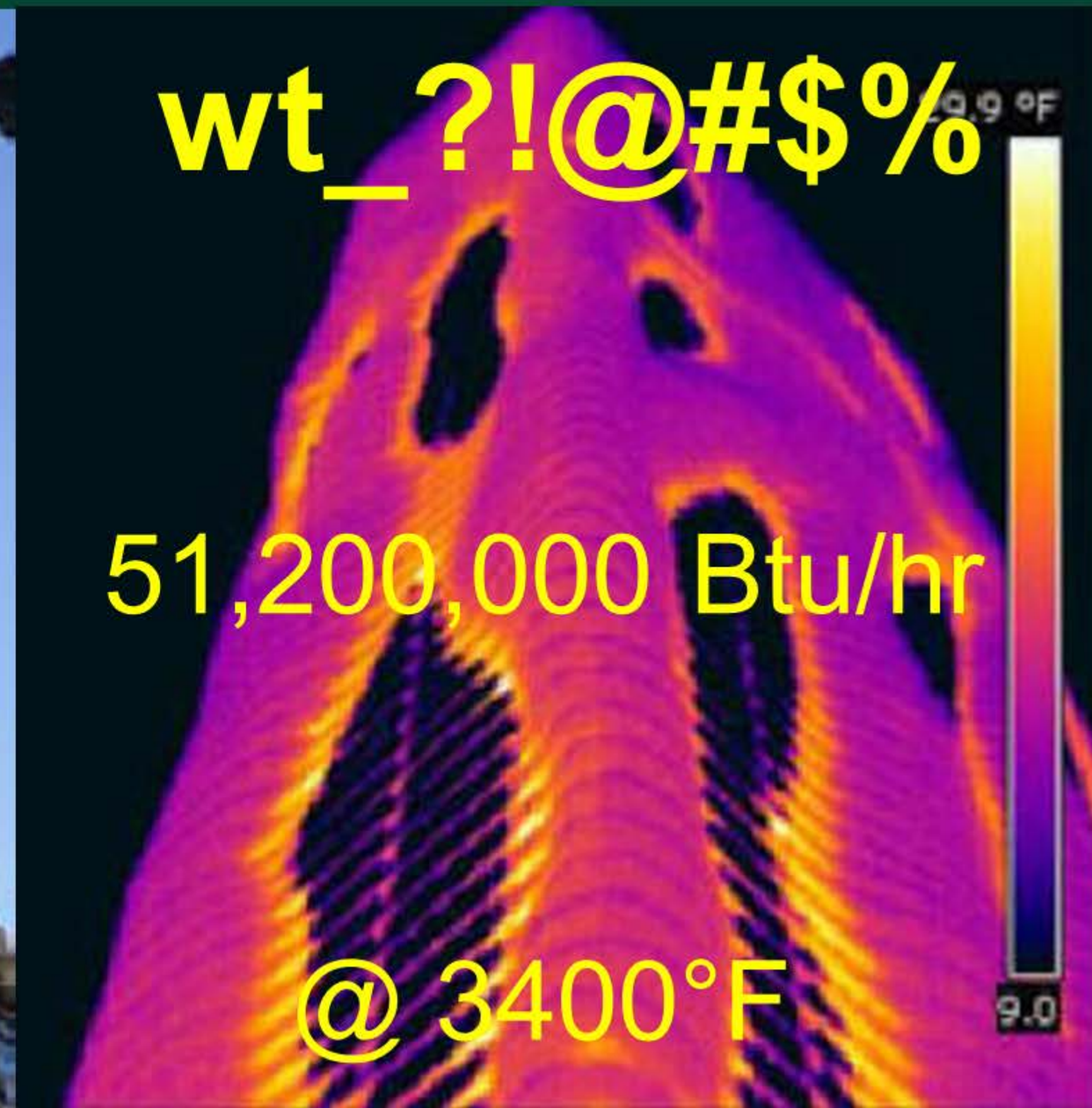
			Winter Conditions[b]			Summer Conditions[c]		
Glazing ID[a]	Glazing Type	Glazing Height, ft	Glazing Temp., °F	Temp. Diff., °F	h_i, Btu/h · ft^2 · °F	Glazing Temp., °F	Temp. Diff., °F	h_i, Btu/h · ft^2 · °F
1	Single glazing	2	17	53	1.41	89	14	1.41
		4	17	53	1.31	89	14	1.33
		6	17	53	1.25	89	14	1.29
5	Double glazing with 1/2 in. air space	2	45	25	1.36	89	14	1.41
		4	45	25	1.27	89	14	1.33
		6	45	25	1.22	89	14	1.29
23	Double glazing with e = 0.1 on surface 2 and 1/2 in. argon space	2	56	14	1.31	87	12	1.38
		4	56	14	1.23	87	12	1.31
		6	56	14	1.19	87	12	1.27
43	Triple glazing with e = 0.1 on surfaces 2 and 5 and 1/2 in. argon spaces	2	63	7	1.25	93	18	1.45
		4	63	7	1.18	93	18	1.36
		6	63	7	1.15	93	18	1.32

Notes:
[a]Glazing ID refers to fenestration assemblies in Table 4.
[b]Winter conditions: room air temperature t_i = 70°F, outdoor air temperature t_o = 0°F, no solar radiation
[c]Summer conditions: room air temperature t_i = 75°F, outdoor air temperature t_o = 89°F, direct solar irradiance E_D = 248 Btu/h · ft^2

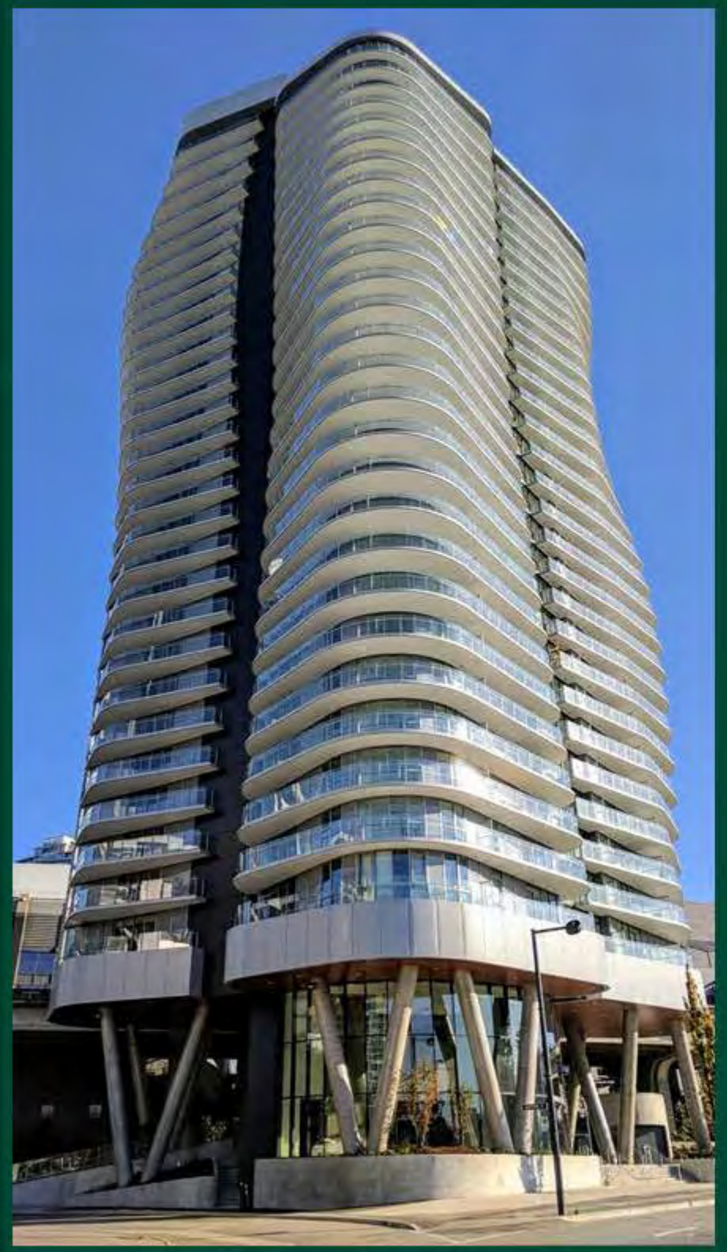
$h_i = h_{ic} + h_{iR} = 0.3(\Delta T/L)^{0.25} + \varepsilon\sigma(T_i^4 - T_g^4)/\Delta T$, where $\Delta T = T_i - T_g$, K; L = glazing height, ft; T_g = glazing temperature, °R, σ = Stefan-Boltzmann constant, and ε = surface emissivity.

see ashrae handbook for si version

energy models ARE NOT eXergy nor comfort models



energy models ARE NOT eXergy nor comfort models



energy models ARE NOT eXergy nor comfort models

=

thermal comfort tools: online, easy and free

tool overview (screenshot)

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature
72.0 °F — Use operative temperature

Mean radiant temperature
72.0 °F

Air speed
20 fpm — Local air speed control

Humidity
50 % — Relative humidity

Metabolic rate
1 met — Reading, seated: 1.0

Clothing level
0.96 clo — Jacket, Trousers, long-

Create custom ensemble

Dynamic predictive clothing

LEED documentation

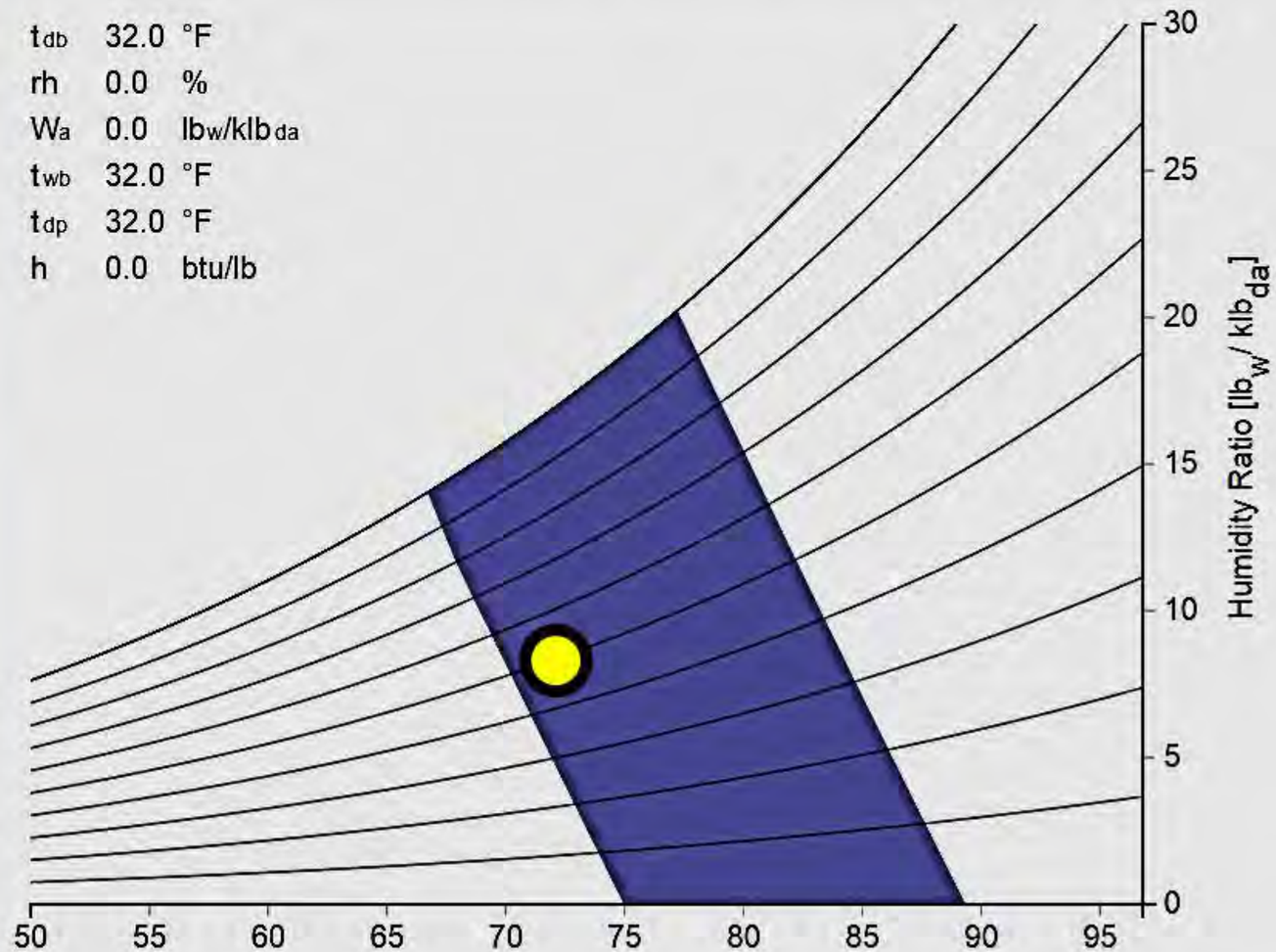
Globe temp | SolarCal | Specify pressure | SI IP | Local discomfort | ? Help

✓ Complies with ASHRAE Standard 55-2013

SI version online

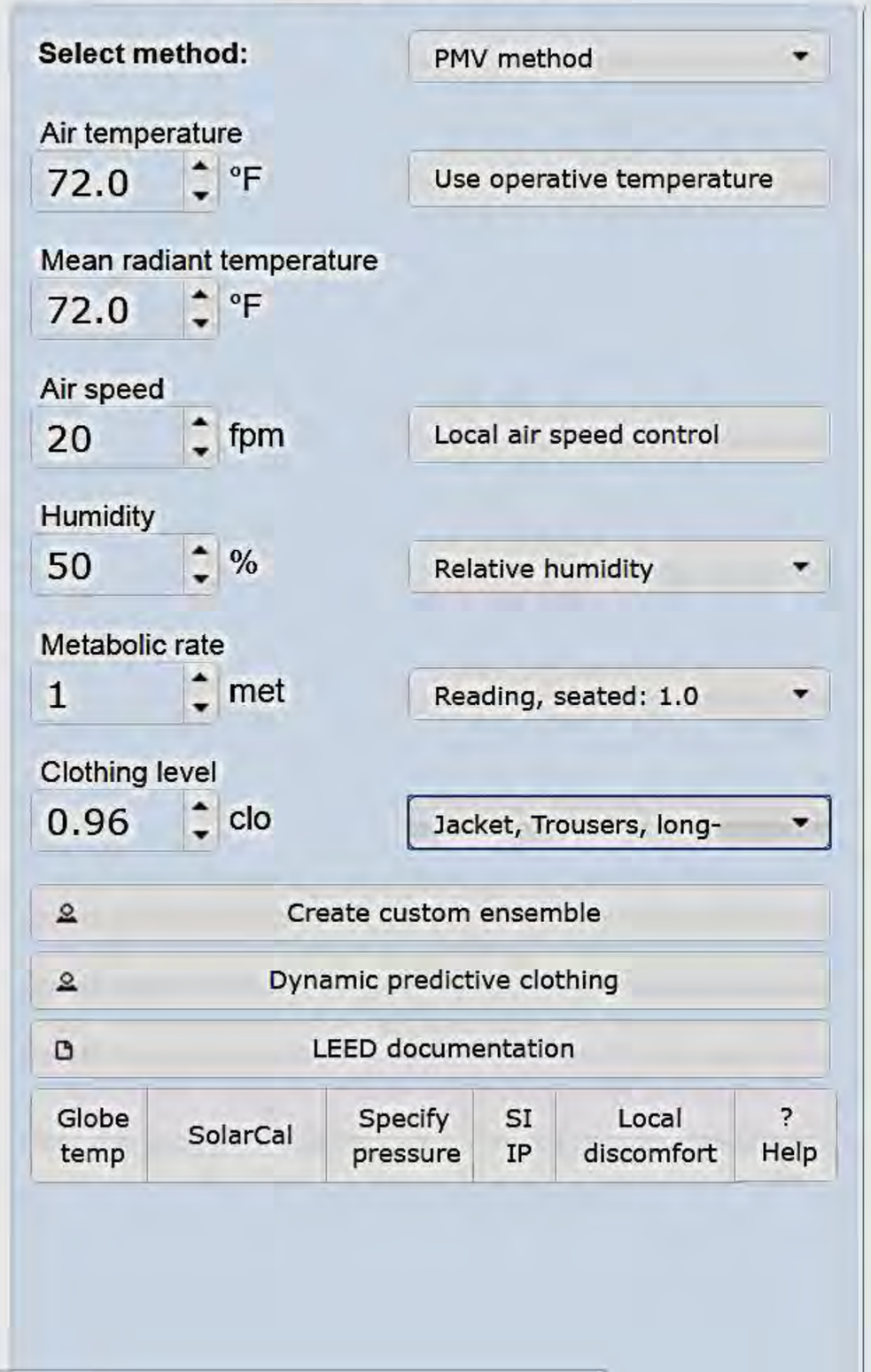
PMV	-0.35
PPD	8%
Sensation	Neutral
SET	75.8°F

Psychrometric chart (air temperature)



tool overview (screenshot)

SI version online



inputs

stated controlled value

calculated value (enclosure performance)

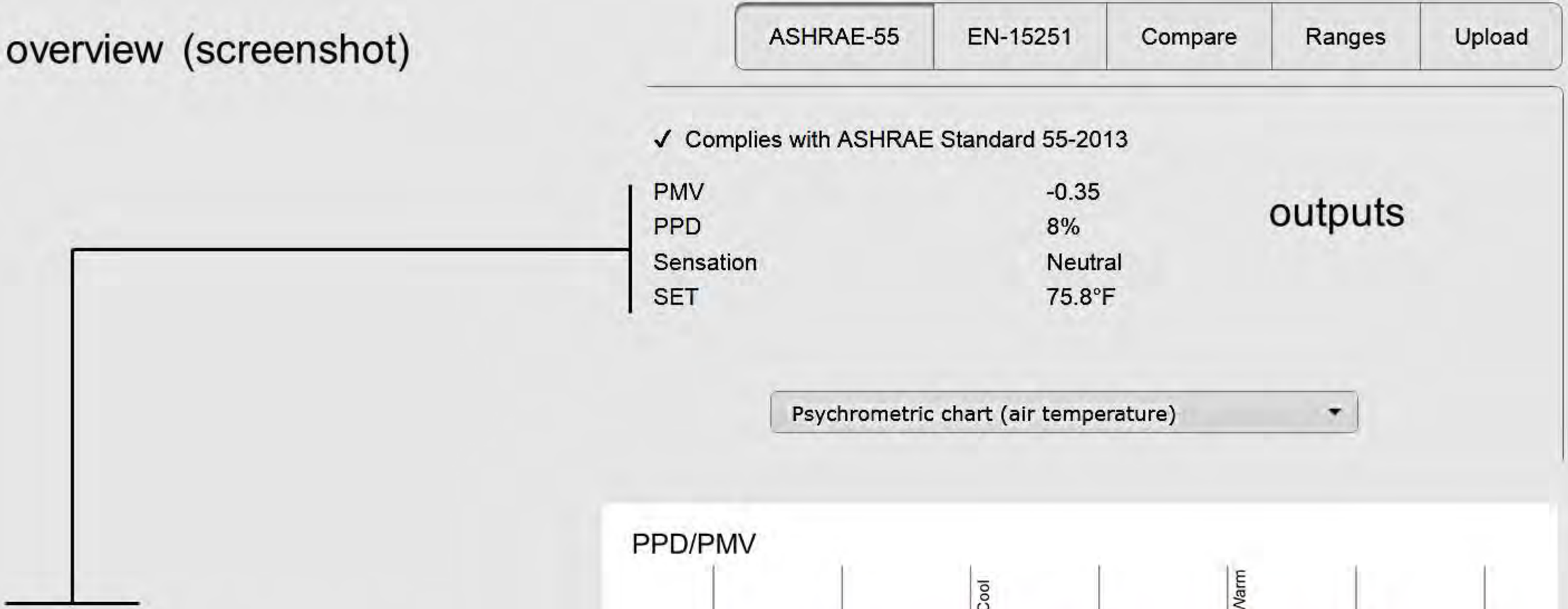
calculated (ADPI) and controlled (distribution) value

stated controlled value

stated assumption value

stated assumption value

tool overview (screenshot)

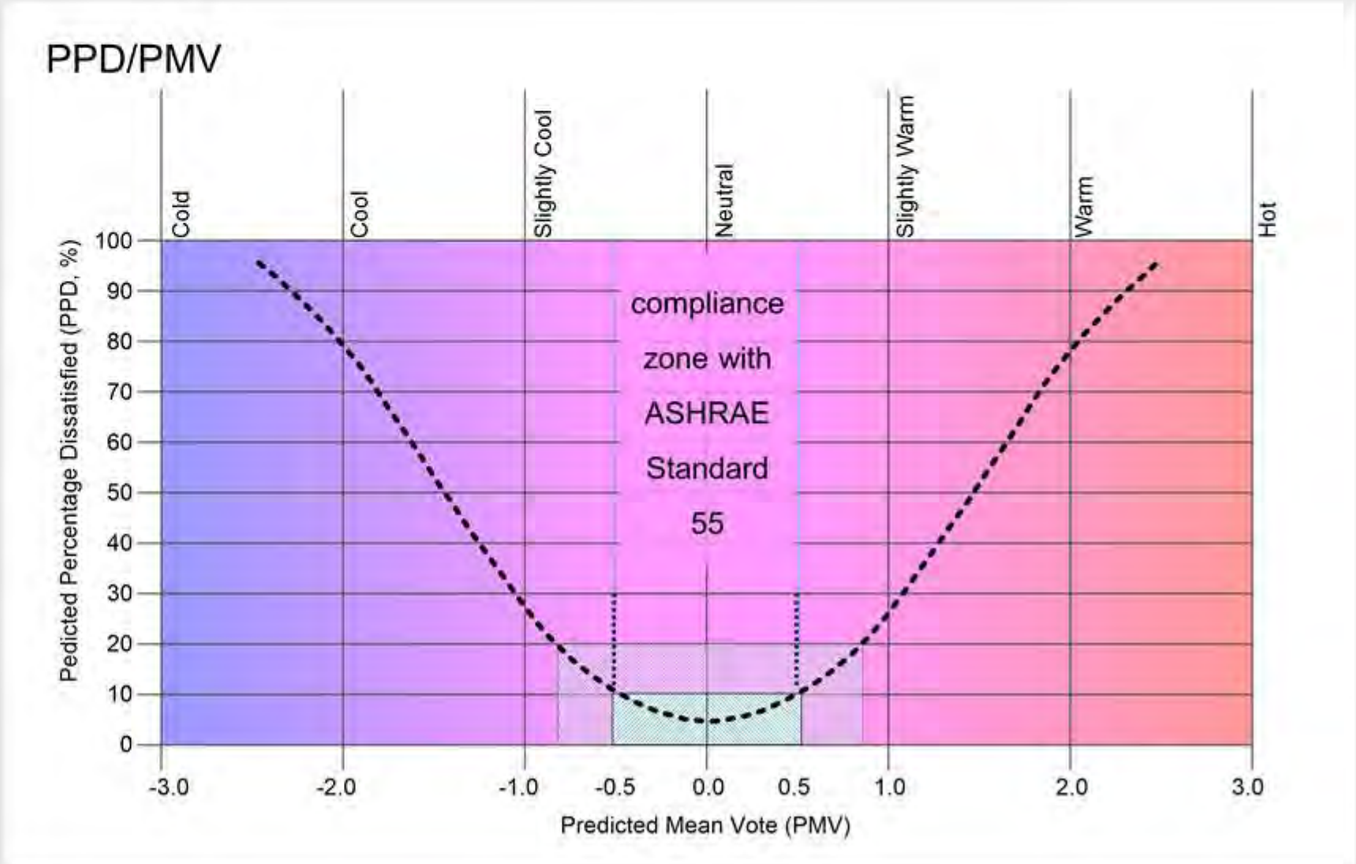


predicted mean vote (PMV)

predicted percentage dissatisfied (PPD)

sensation (corresponds to PMV)

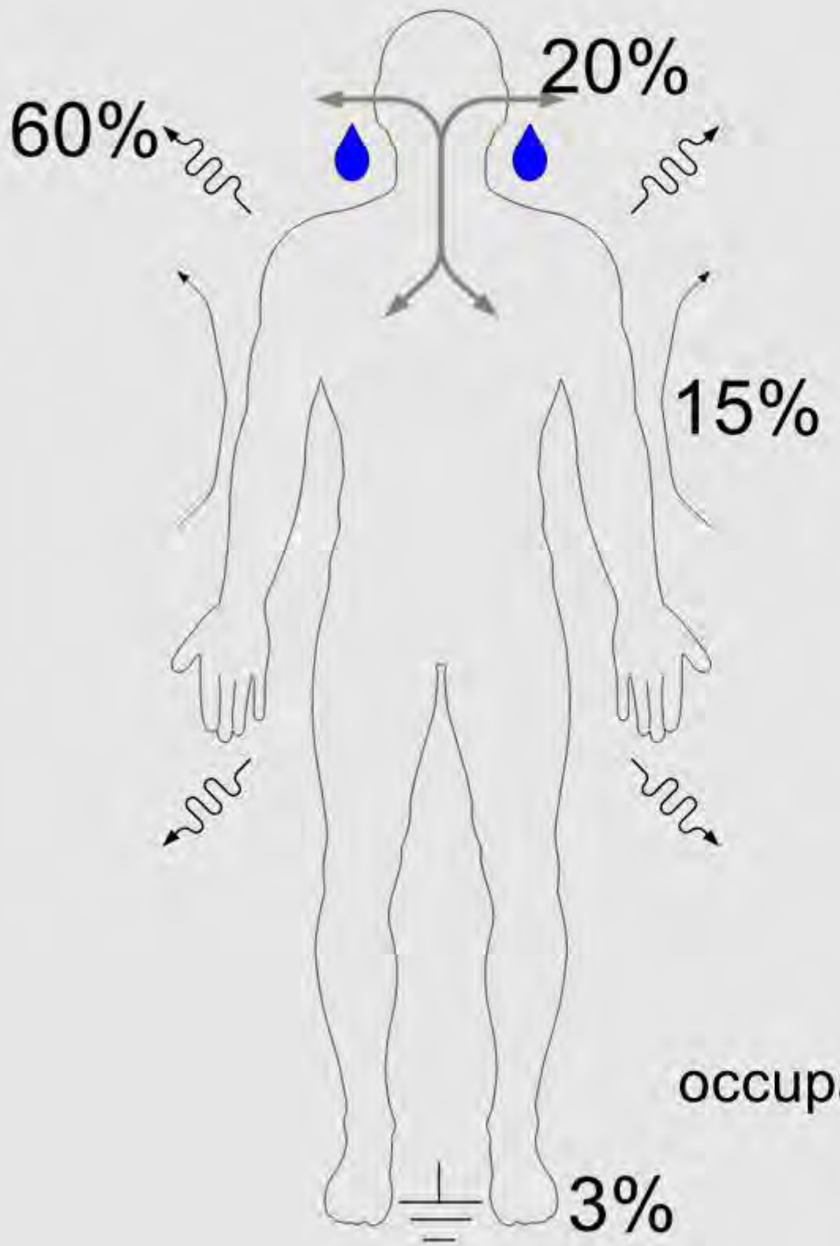
standard effective temperature (SET)



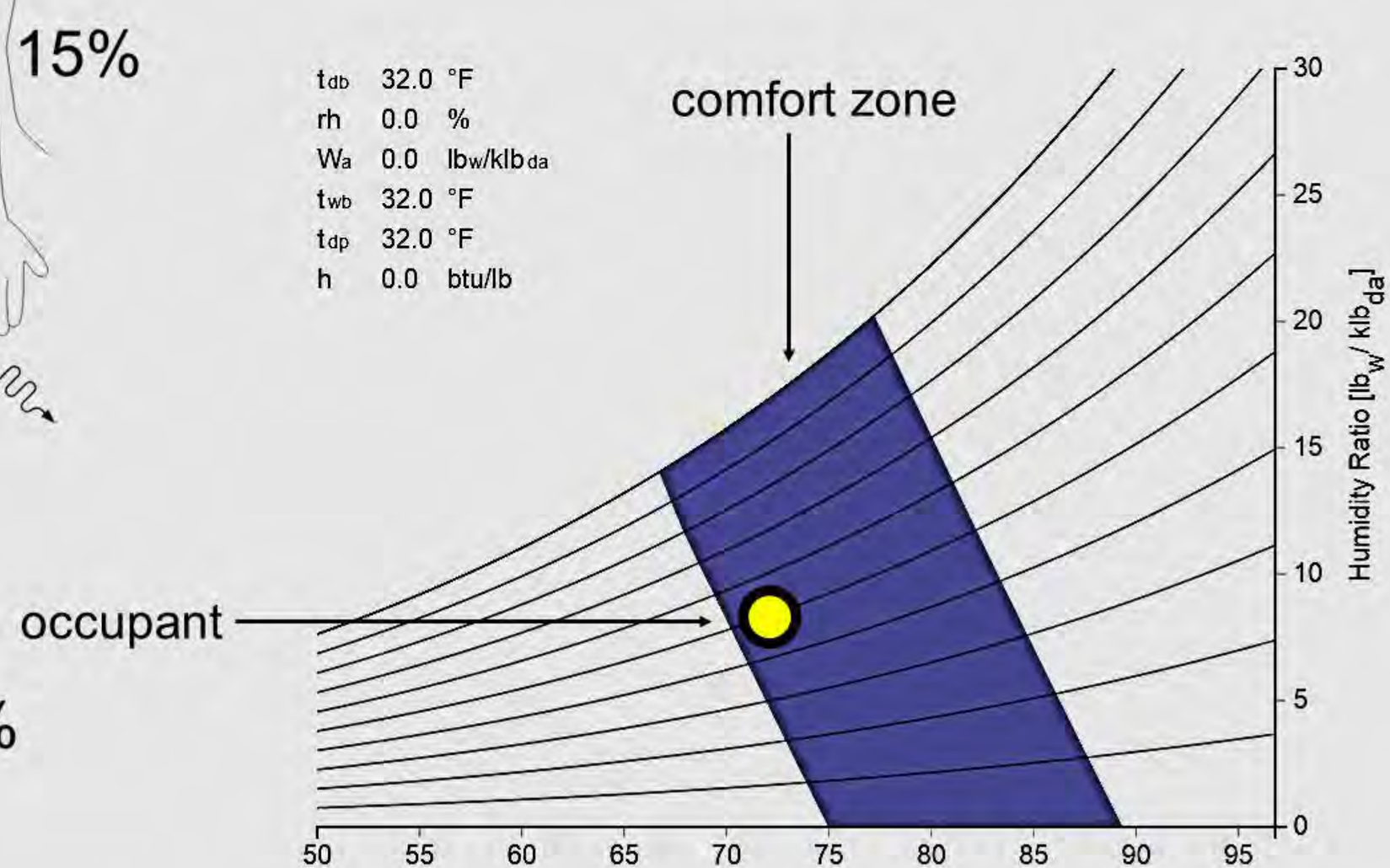
SI version online

overview (screenshot)

SI version online



output psychrometric graphic showing occupant in relationship to comfort zone



example 1

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature
72.0 °F — Use operative temperature

Mean radiant temperature
72.0 °F

Air speed
20 fpm — Local air speed control

Humidity
50 % — Relative humidity

Metabolic rate
1 met — Reading, seated: 1.0

Clothing level
0.96 clo — Jacket, Trousers, long-

Create custom ensemble

Dynamic predictive clothing

LEED documentation

Globe temp | SolarCal | Specify pressure | SI IP | Local discomfort | ? Help

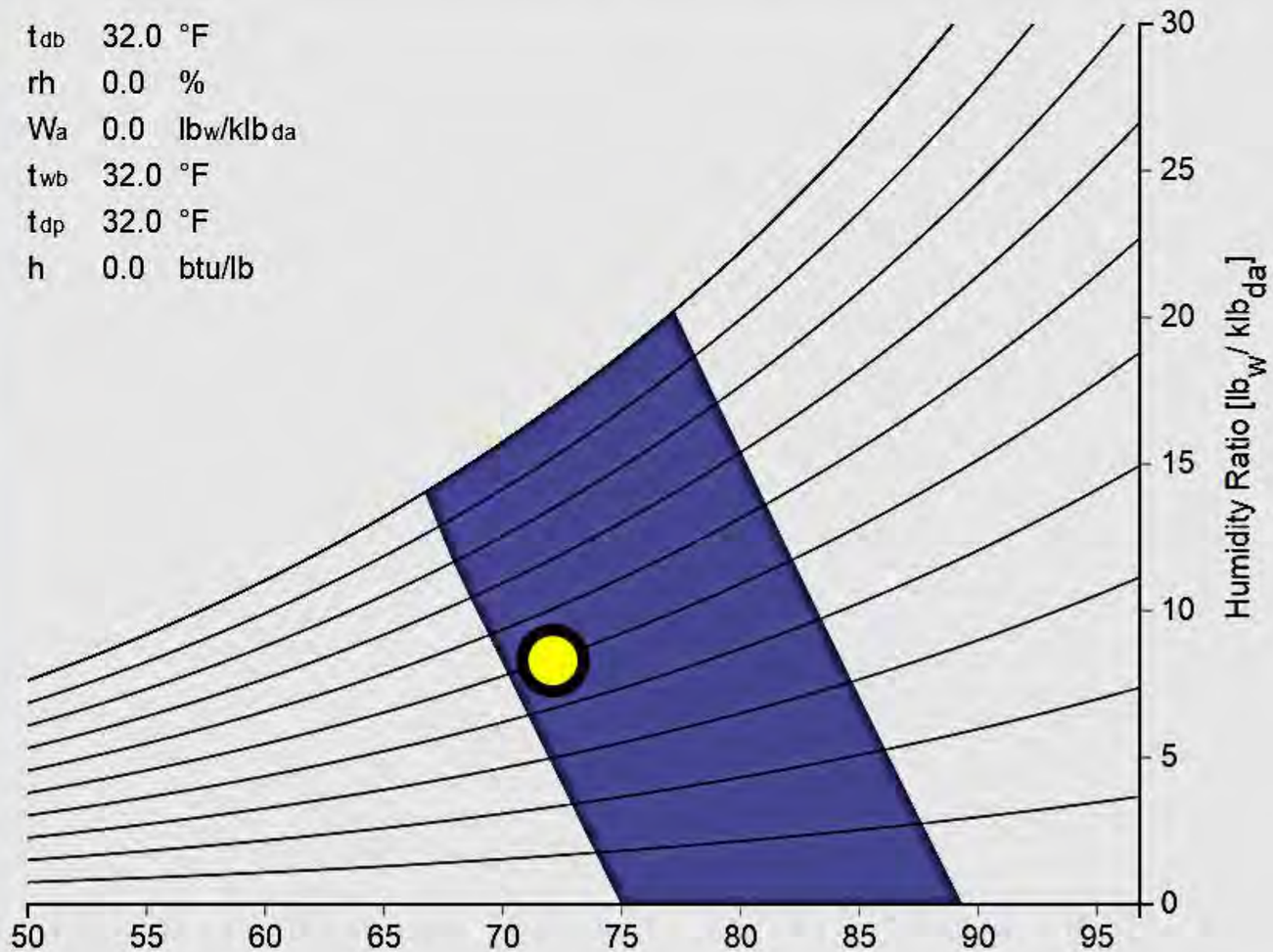
✓ Complies with ASHRAE Standard 55-2013

PMV	-0.35
PPD	8%
Sensation	Neutral
SET	75.8°F

how some men experience a space

Psychrometric chart (air temperature)

t_{db}	32.0	°F
rh	0.0	%
W_a	0.0	lb_w/klb_{da}
t_{wb}	32.0	°F
t_{dp}	32.0	°F
h	0.0	btu/lb



example 2

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature
72.0 °F — Use operative temperature

Mean radiant temperature
72.0 °F

Air speed
20 fpm — Local air speed control

Humidity
50 % — Relative humidity

Metabolic rate
1 met — Reading, seated: 1.0

Clothing level
0.67 clo — Knee-length skirt, long-

Create custom ensemble

Dynamic predictive clothing

LEED documentation

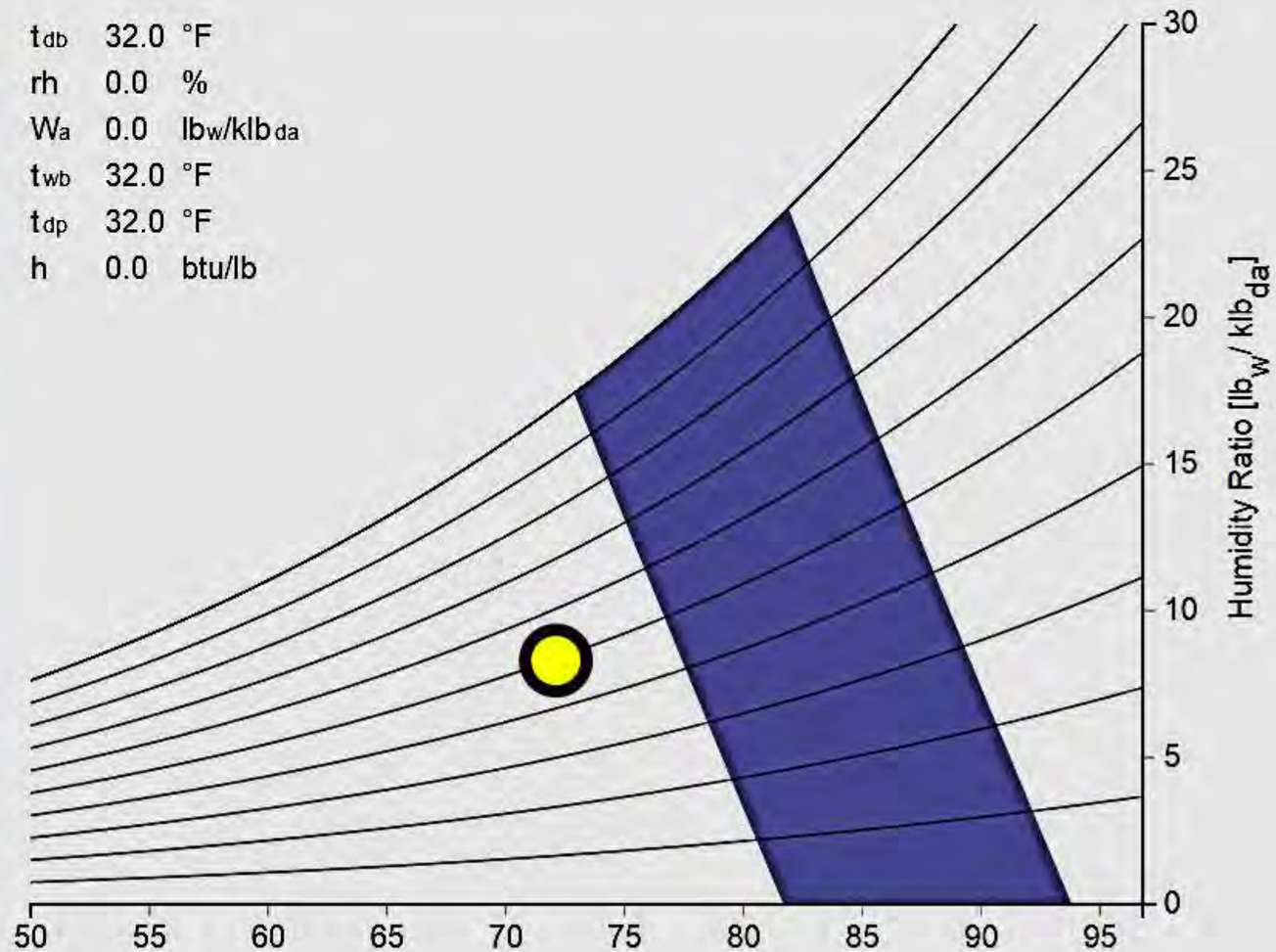
Globe temp | SolarCal | Specify pressure | SI IP | Local discomfort | ? Help

✗ Does not comply with ASHRAE Standard 55-2013

PMV	-0.95
PPD	24%
Sensation	Slightly Cool
SET	72.3°F

how some women experience the very same space

Psychrometric chart (air temperature)



example 3

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature
72.0 °F — Use operative temperature

Mean radiant temperature
78 °F

Air speed
20 fpm — Local air speed control

Humidity
50 % — Relative humidity

Metabolic rate
1 met — Reading, seated: 1.0

Clothing level
0.67 clo — Knee-length skirt, long-

Create custom ensemble

Dynamic predictive clothing

LEED documentation

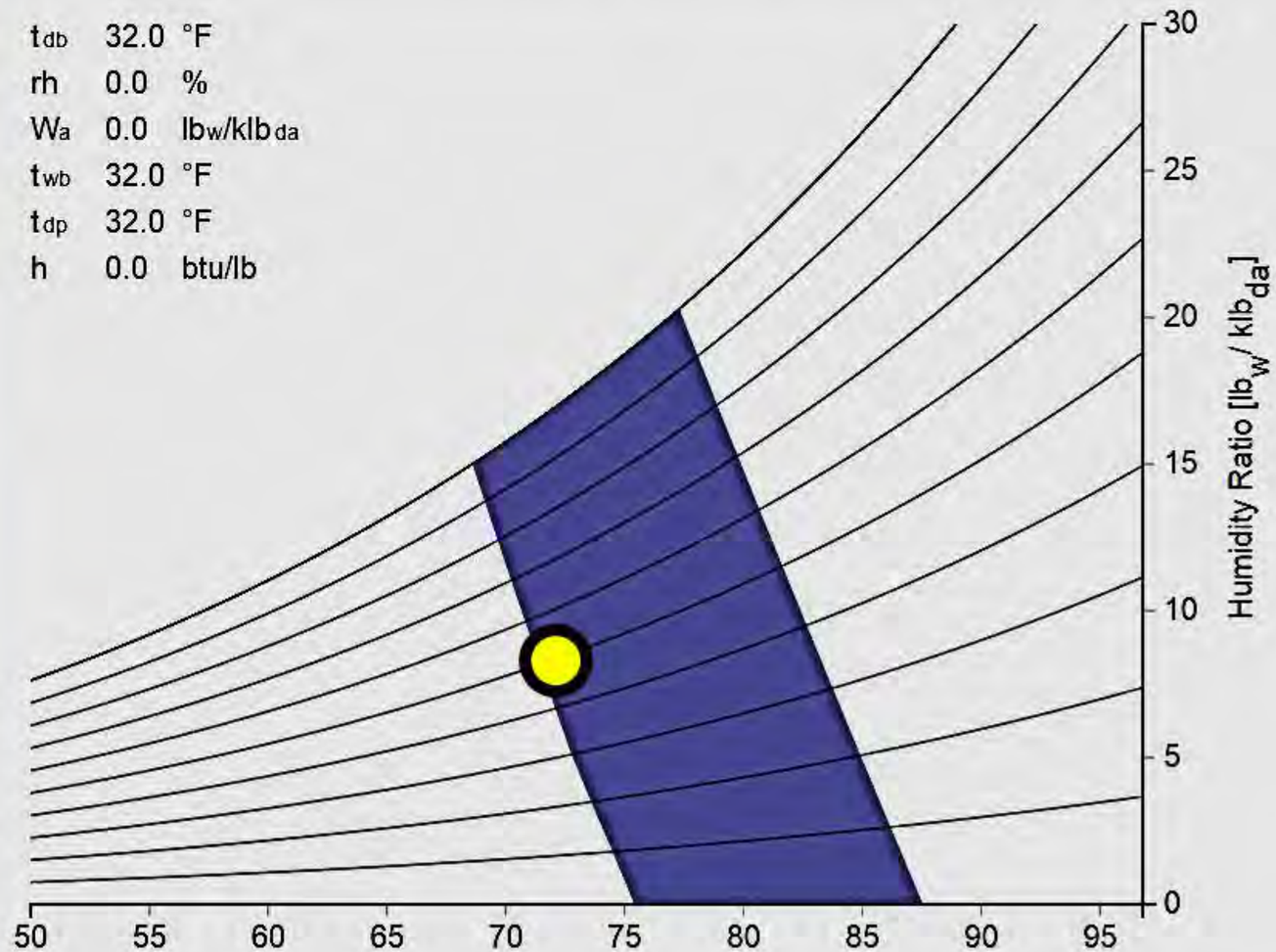
Globe temp | SolarCal | Specify pressure | SI IP | Local discomfort | ? Help

✓ Complies with ASHRAE Standard 55-2013

PMV	-0.44
PPD	9%
Sensation	Neutral
SET	75.8°F

radiant solutions to radiant problems

Psychrometric chart (air temperature)



example 4

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature
78 °F — Use operative temperature

Mean radiant temperature
81 °F

Air speed
20 fpm — Local air speed control

Humidity
80 % — Relative humidity

Metabolic rate
1 met — Reading, seated: 1.0

Clothing level
0.67 clo — Knee-length skirt, long-

Create custom ensemble

Dynamic predictive clothing

LEED documentation

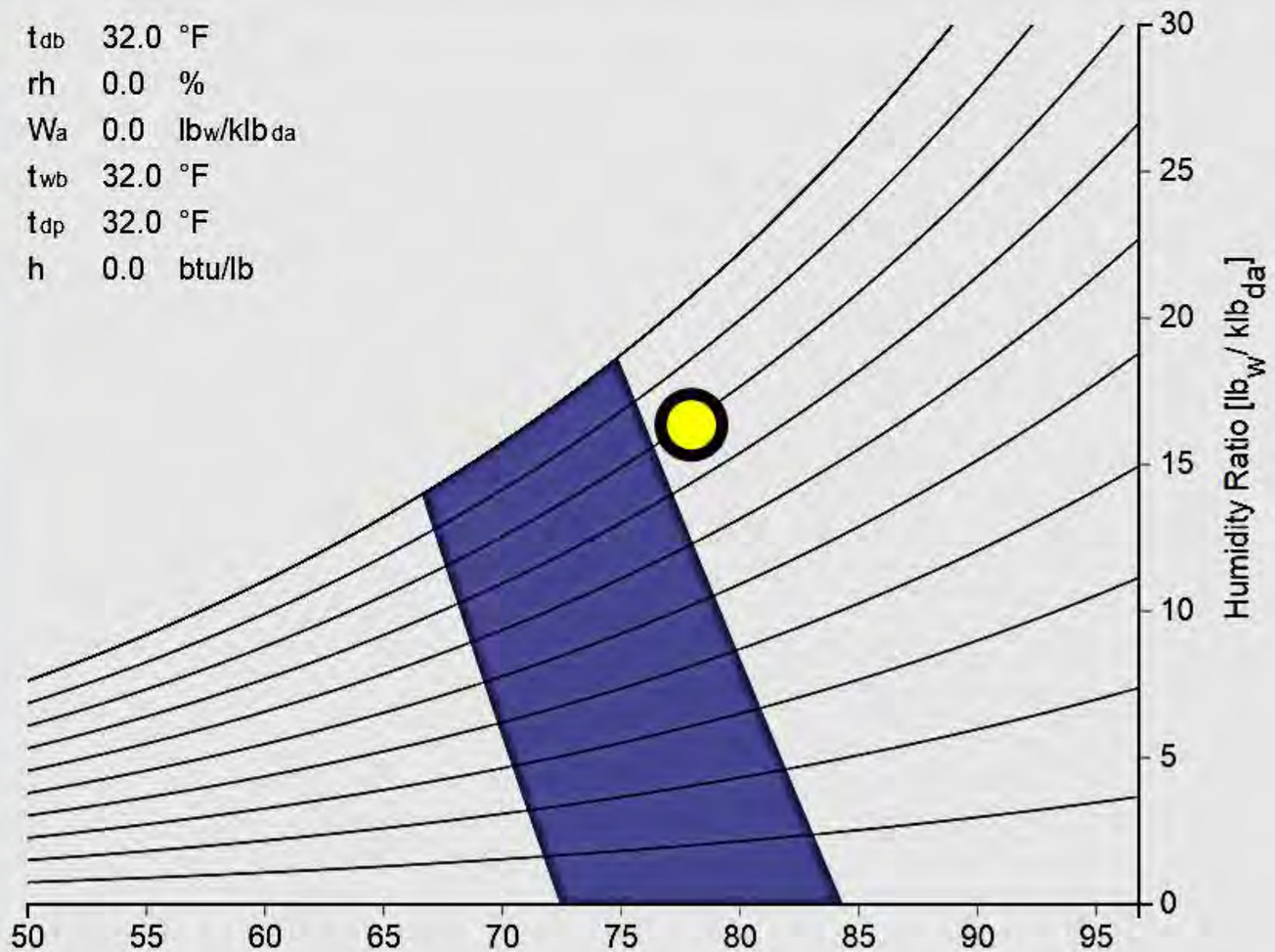
Globe temp | SolarCal | Specify pressure | SI IP | Local discomfort | ? Help

✗ Does not comply with ASHRAE Standard 55-2013

PMV	0.67
PPD	14%
Sensation	Slightly Warm
SET	81.8°F

messing it up (again) with moisture and heat

Psychrometric chart (air temperature)



example 5

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature
78 °F — Use operative temperature

Mean radiant temperature
81 °F

Air speed
39 fpm — Local air speed control

Humidity
80 % — Relative humidity

Metabolic rate
1 met — Reading, seated: 1.0

Clothing level
0.67 clo — Knee-length skirt, long-

Create custom ensemble

Dynamic predictive clothing

LEED documentation

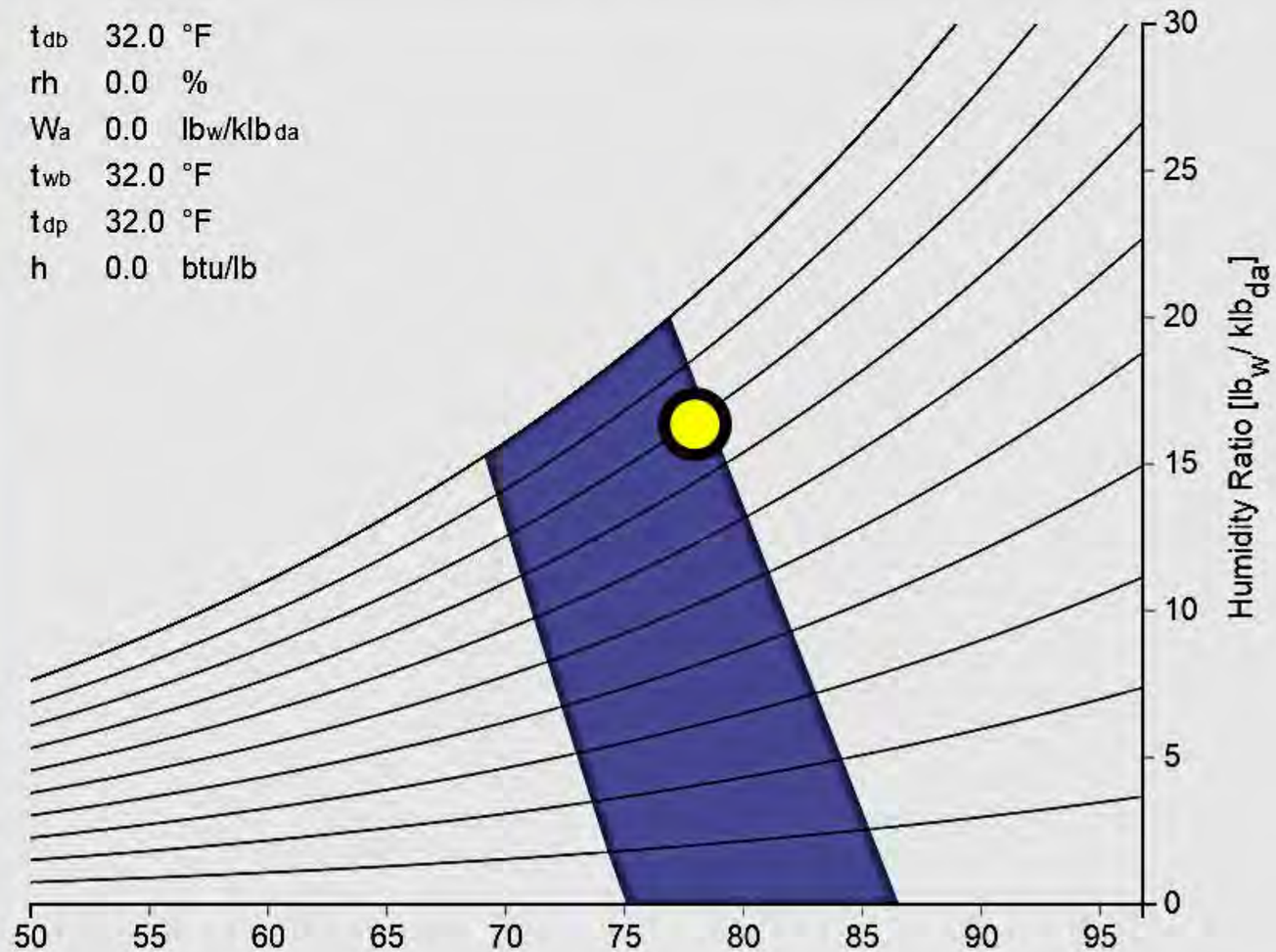
Globe temp	SolarCal	Specify pressure	SI IP	Local discomfort	? Help

✓ Complies with ASHRAE Standard 55-2013

PMV	0.45
PPD	9%
Sensation	Neutral
SET	80.2°F

fixing it with elevated air speed

Psychrometric chart (air temperature)



example 8

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

✓ Complies with ASHRAE Standard 55-2013

Air temperature 78 °F

Mean radiant temperature 81 °F

Air speed 39 fpm

Humidity 80 %

Metabolic rate 1 met

Clothing level 0.67 clo

Create cu

Dynamic p

LEED d

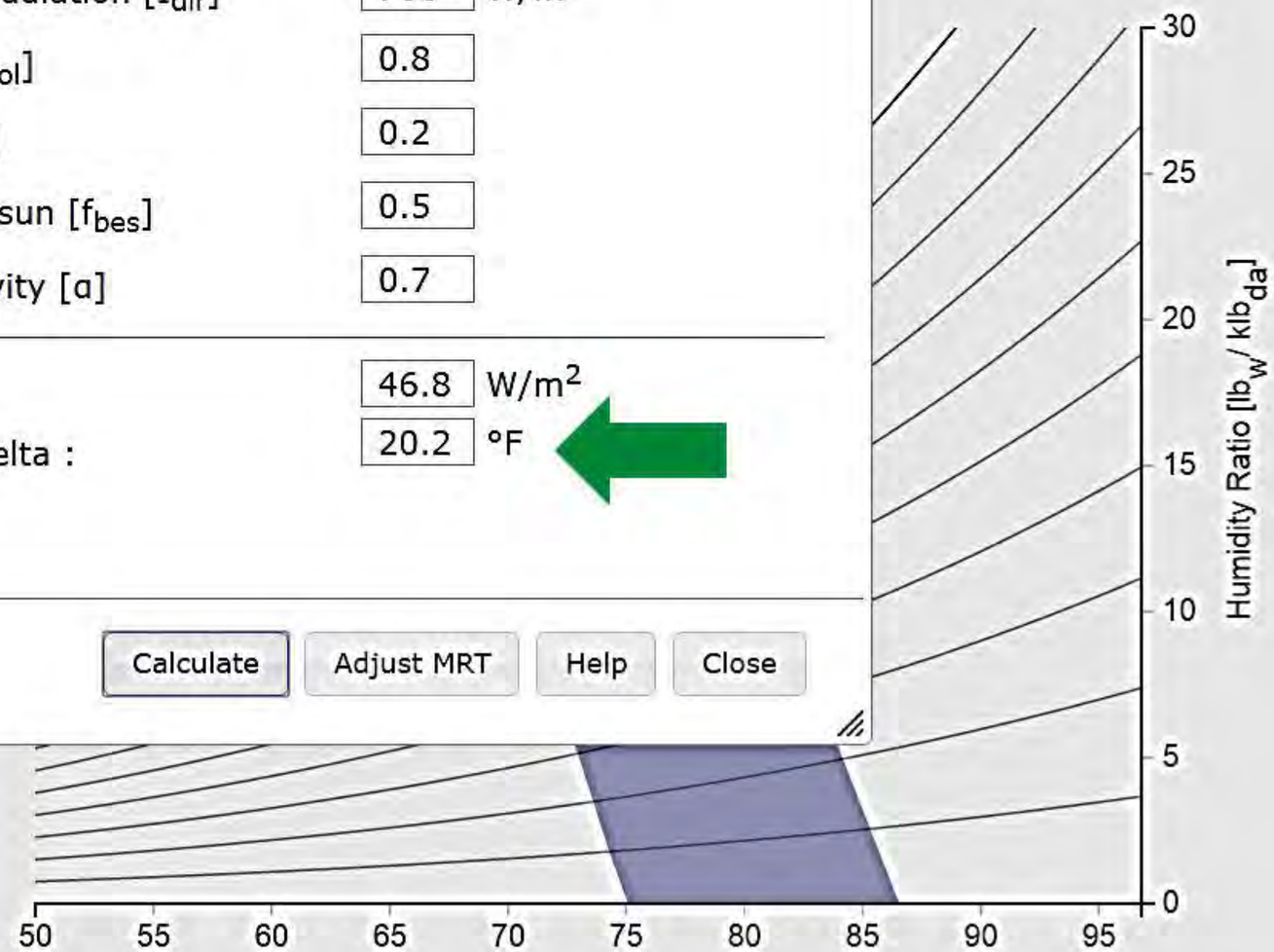
SolarCal | Spe pressure | IP | discomfort | Help

windows & solar gain nice view but…

SolarCal: shortwave radiation calculator

Posture	Seated	
Solar altitude (0 - 90°) [β]	45	°
Solar azimuth (0 - 180°. Facing front = 0°)	120	°
Direct beam (normal) solar radiation [I_{dir}]	700	W/m^2
Total solar transmittance [T_{sol}]	0.8	
Sky vault view fraction [f_{svv}]	0.2	
Fraction of body exposed to sun [f_{bes}]	0.5	
Average shortwave absorptivity [α]	0.7	
ERF :	46.8	W/m^2
Mean radiant temperature delta :	20.2	°F

Calculate | Adjust MRT | Help | Close



example 9

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature
78 °F — Use operative temperature

Mean radiant temperature
101.2 °F

Air speed
39 fpm — Local air speed control

Humidity
80 % — Relative humidity

Metabolic rate
1 met — Reading, seated: 1.0

Clothing level
0.67 clo — Knee-length skirt, long-

Create custom ensemble

Dynamic predictive clothing

LEED documentation

Globe temp | SolarCal | Specify pressure | SI IP | Local discomfort | ? Help

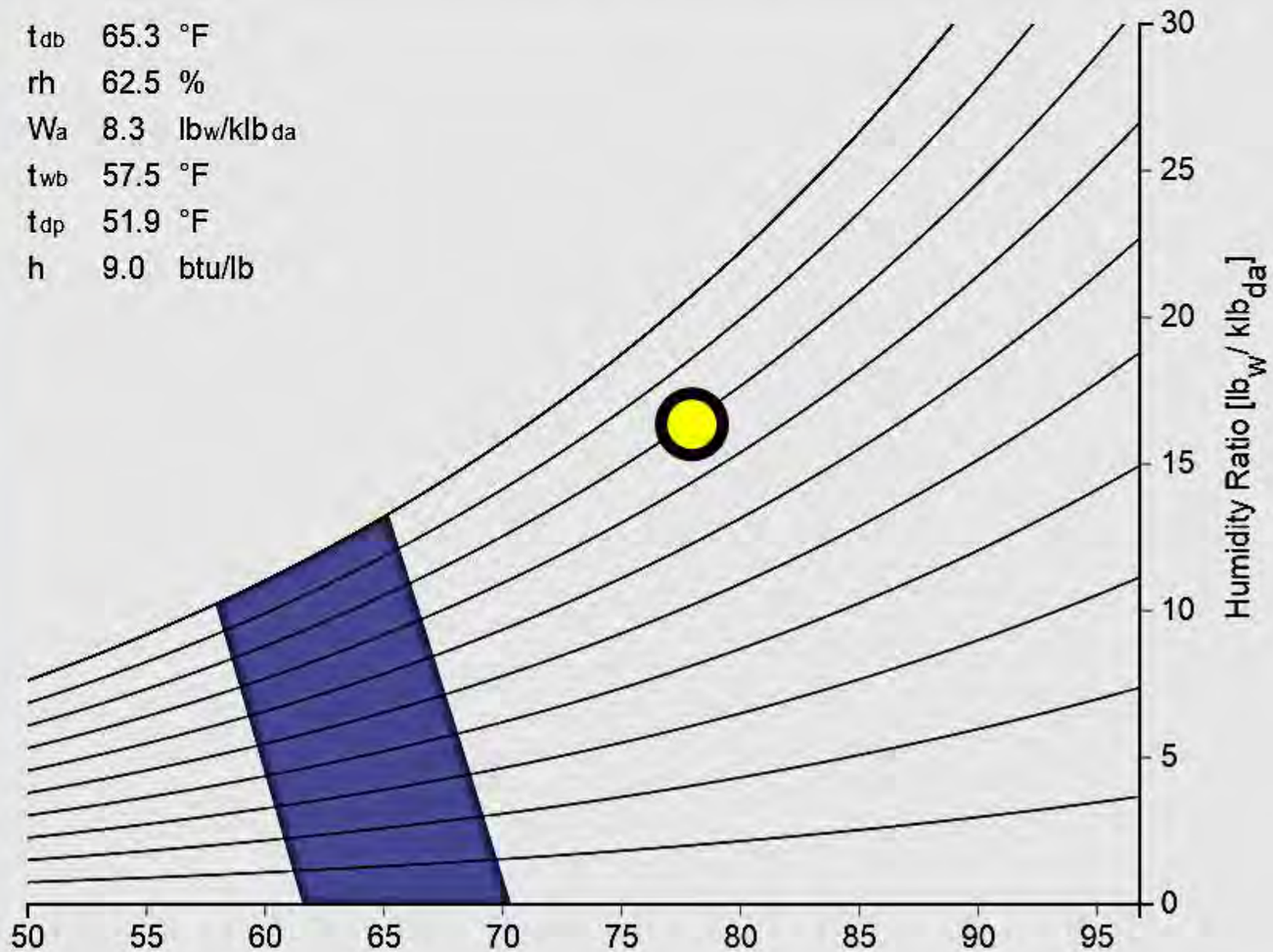
✗ Does not comply with ASHRAE Standard 55-2013

PMV	2.08
PPD	80%
Sensation	Warm
SET	91.3°F

MRT can mess up the thermal environment

Psychrometric chart (air temperature)

t_{db}	65.3	°F
rh	62.5	%
W_a	8.3	lb_w/klb_{da}
t_{wb}	57.5	°F
t_{dp}	51.9	°F
h	9.0	btu/lb



example 10a

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature
72 °F — Use operative temperature

Mean radiant temperature
72 °F

Air speed
20 fpm — Local air speed control

Humidity
30 % — Relative humidity

Metabolic rate
1.2 met — Typing: 1.1

Clothing level
.69 clo — Typical summer indoor

Create custom ensemble

Dynamic predictive clothing

LEED documentation

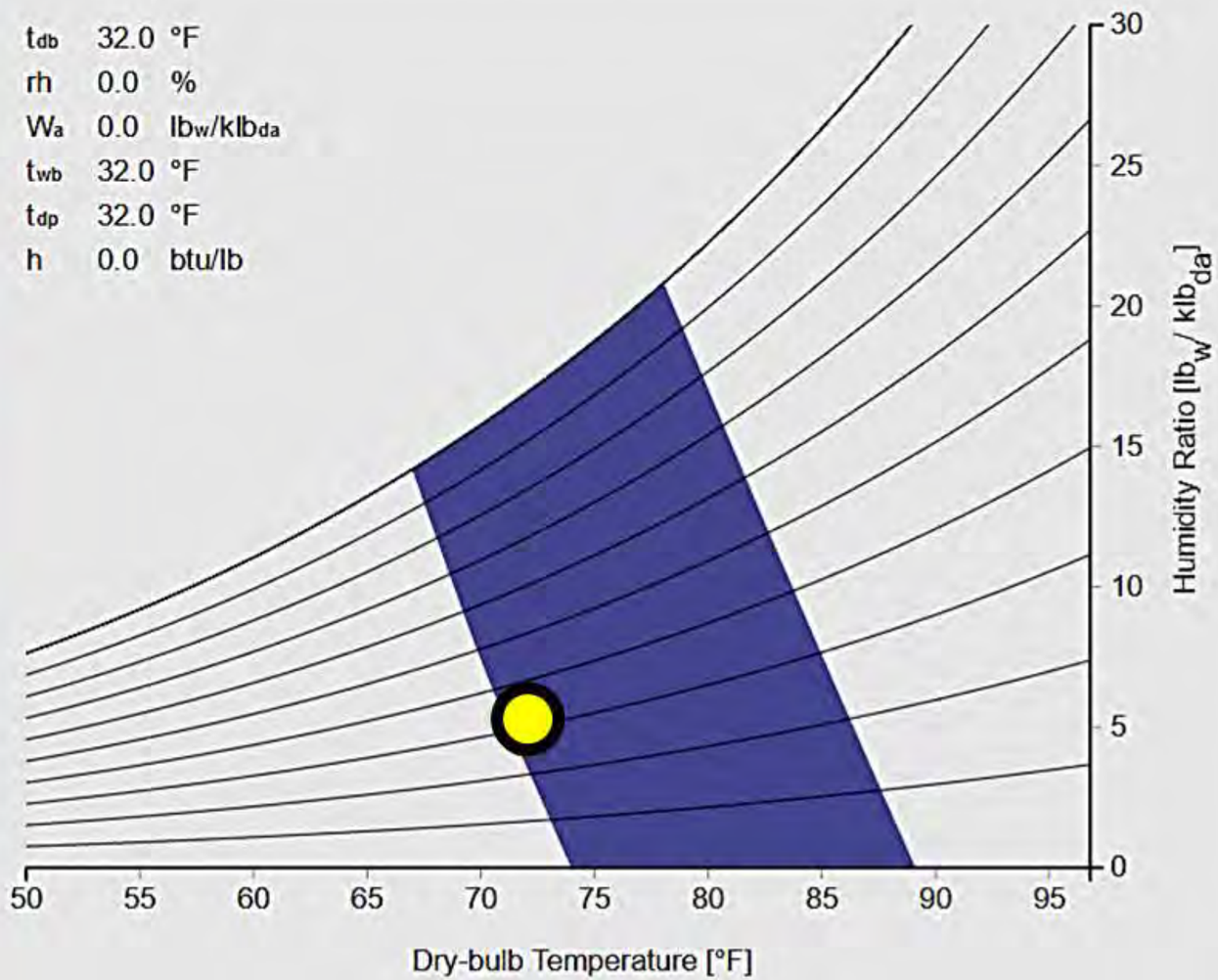
Globe temp | SolarCal | Specify pressure | SI IP | Local discomfort | ? Help

✓ Complies with ASHRAE Standard 55-2013

PMV	-0.45
PPD	9%
Sensation	Neutral
SET	74.6°F

compliance subject to local discomfort

Psychrometric chart (air temperature)



example 10b

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature 72 °F

Mean radiant temperature 72 °F

Air speed 20 fpm

Humidity 30 %

Metabolic rate 1.2 met

Clothing level .69 clo

Use operativ

Local air spe

Relative hur

Typing: 1.1

Typical sum

Create custom ensembl

Dynamic predictive cloth

LEED documentation

Globe temp | SolarCal | Specify pressure | SI IP

✓ Complies with ASHRAE Standard 55-2013

unless there are cold & hot surfaces

Local discomfort assessment

Radiant temperature asymmetry

Warm ceiling asymmetry	0	°F	✓
Cool ceiling asymmetry	0	°F	✓
Warm wall asymmetry	0	°F	✓
Cool wall asymmetry	20	°F	✗

Vertical air temperature difference

Head level temperature	77	°F	
Ankle level temperature	77	°F	✓

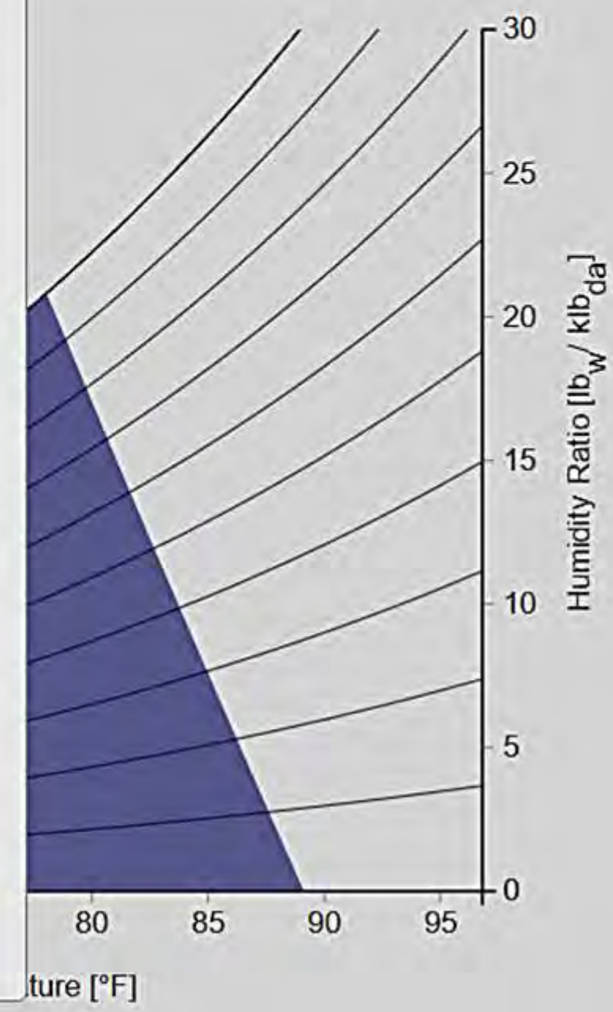
Floor surface temperature

Floor temperature	77	°F	✓

Draft

Operative temperature	77	°F	
Air speed	20	fpm	✓

✗ Does not comply with ASHRAE Standard 55-2013



example 10c

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature 72 °F

Mean radiant temperature 72 °F

Air speed 20 fpm

Humidity 30 %

Metabolic rate 1.2 met

Clothing level .69 clo

Create custom ensembl

Dynamic predictive cloth

LEED documentation

Globe temp | SolarCal | Specify pressure | SI IP

✓ Complies with ASHRAE Standard 55-2013

or…aggressive stratification

Local discomfort assessment

Radiant temperature asymmetry

Warm ceiling asymmetry	0	°F	✓
Cool ceiling asymmetry	0	°F	✓
Warm wall asymmetry	0	°F	✓
Cool wall asymmetry	0	°F	✓

Vertical air temperature difference

Head level temperature	74	°F	
Ankle level temperature	68	°F	✗

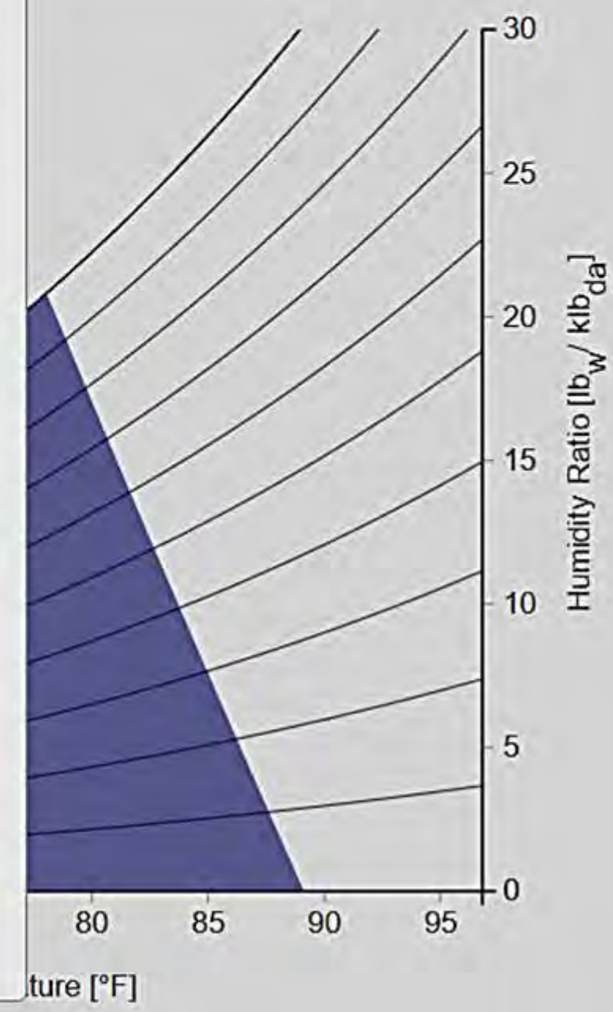
Floor surface temperature

Floor temperature	77	°F	✓

Draft

Operative temperature	77	°F	
Air speed	20	fpm	✓

✗ Does not comply with ASHRAE Standard 55-2013



example 10d

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature
72 °F

Use operativ

Mean radiant temperature
72 °F

Air speed
20 fpm

Local air spe

Humidity
30 %

Relative hur

Metabolic rate
1.2 met

Typing: 1.1

Clothing level
.69 clo

Typical sum

Create custom ensembl

Dynamic predictive cloth

LEED documentation

Globe temp | SolarCal | Specify pressure | SI IP

✓ Complies with ASHRAE Standard 55-2013

al

F

rature)

Local discomfort assessment

Radiant temperature asymmetry

Warm ceiling asymmetry	0	°F	✓
Cool ceiling asymmetry	0	°F	✓
Warm wall asymmetry	0	°F	✓
Cool wall asymmetry	0	°F	✓

Vertical air temperature difference

Head level temperature	73	°F	
Ankle level temperature	72	°F	✓

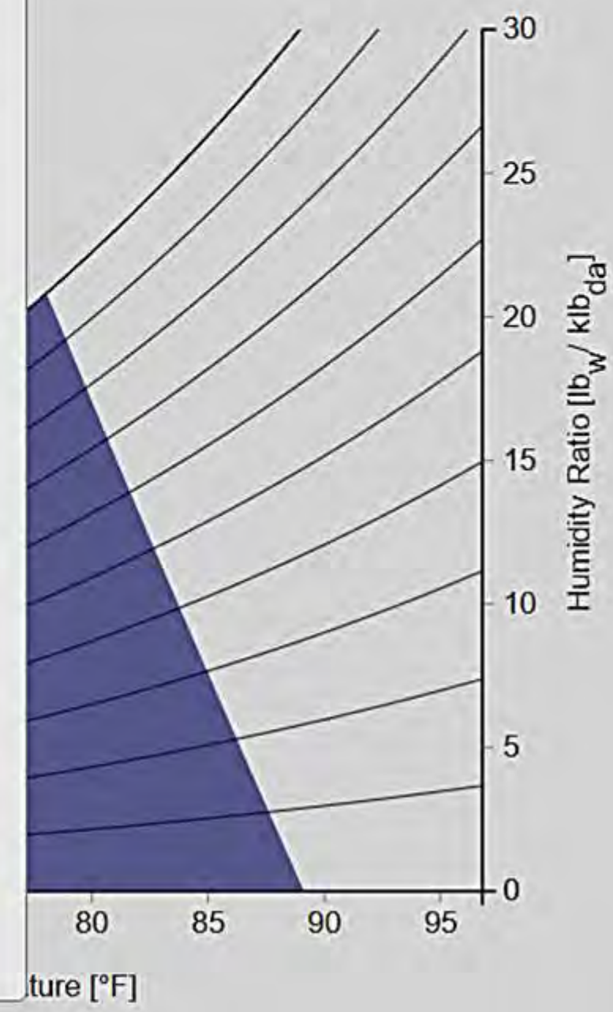
Floor surface temperature

Floor temperature	66	°F	✗

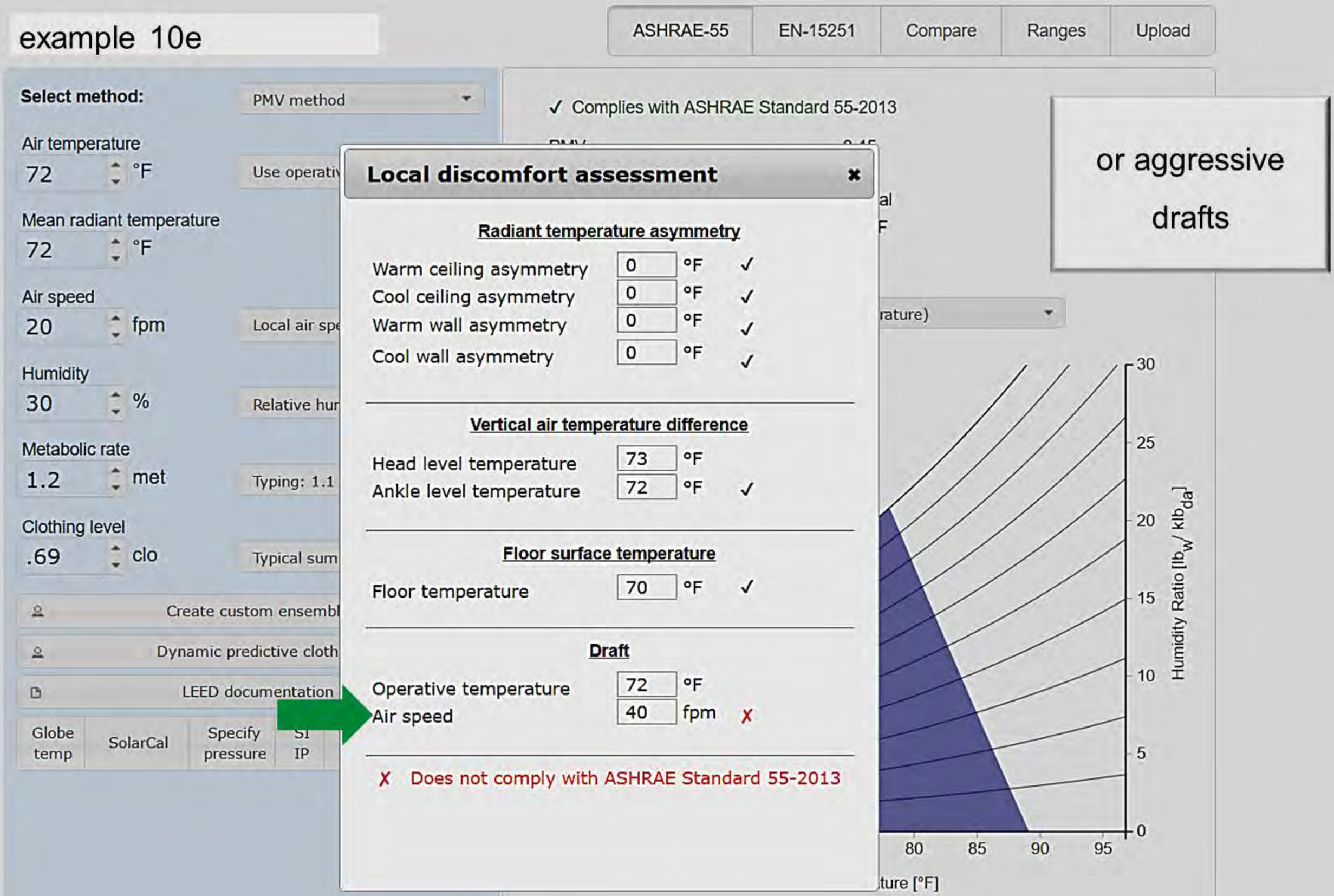
Draft

Operative temperature	77	°F	
Air speed	20	fpm	✓

✗ Does not comply with ASHRAE Standard 55-2013



or cold & hot floors


example 10e
ASHRAE-55
EN-15251
Compare
Ranges
Upload
Select method:
PMV method
Air temperature
72 °F
Mean radiant temperature
72 °F
Air speed
20 fpm
Humidity
30 %
Metabolic rate
1.2 met
Clothing level
.69 clo
Create custom ensembl
Dynamic predictive cloth
LEED documentation
Globe temp
SolarCal
Specify pressure
SI
IP
✓ Complies with ASHRAE Standard 55-2013
Local discomfort assessment
Radiant temperature asymmetry
Warm ceiling asymmetry 0 °F ✓
Cool ceiling asymmetry 0 °F ✓
Warm wall asymmetry 0 °F ✓
Cool wall asymmetry 0 °F ✓
Vertical air temperature difference
Head level temperature 73 °F
Ankle level temperature 72 °F ✓
Floor surface temperature
Floor temperature 70 °F ✓
Draft
Operative temperature 72 °F
Air speed 40 fpm ✗
✗ Does not comply with ASHRAE Standard 55-2013
or aggressive drafts
30
25
20
15
10
5
0
80
85
90
95
Humidity Ratio [lbw/ klbda]

down draft / radiant asymmetry risk assessment tool

down draft / radiant asymmetry risk assessment tool

SI version online

UNITS IP SI SHARE Save as PDF Copy URL

FAÇADE GEOMETRY	CASE 1	CASE 2	CASE 3
Ceiling Height (ft)	10	10	10
Room Length (ft)	14	14	14
Window Height From Sill (ft)	10	8	6
Sill Height (ft)	0	1.5	3
Set Glazing Amount By			
✓ Window Width (ft)	12	12	12
Window-to-Wall Ratio (%)	86	69	51
Window Separation (ft)	14	14	14

down draft / radiant asymmetry risk assessment tool

SI version online

FACADE PERFORMANCE

Window U-Value (Btu/hr*ft^2*°F)	.5	.5	.5
What U-Value meets the target PPD?	0	0	0
Is there a risk of condensation?	NO	NO	NO

ENVIRONMENTAL CONDITIONS

Outdoor Temperature (°F)	20	20	20
Indoor Temperature (°F)	72	72	72
Relative Humidity (%)	35	35	35

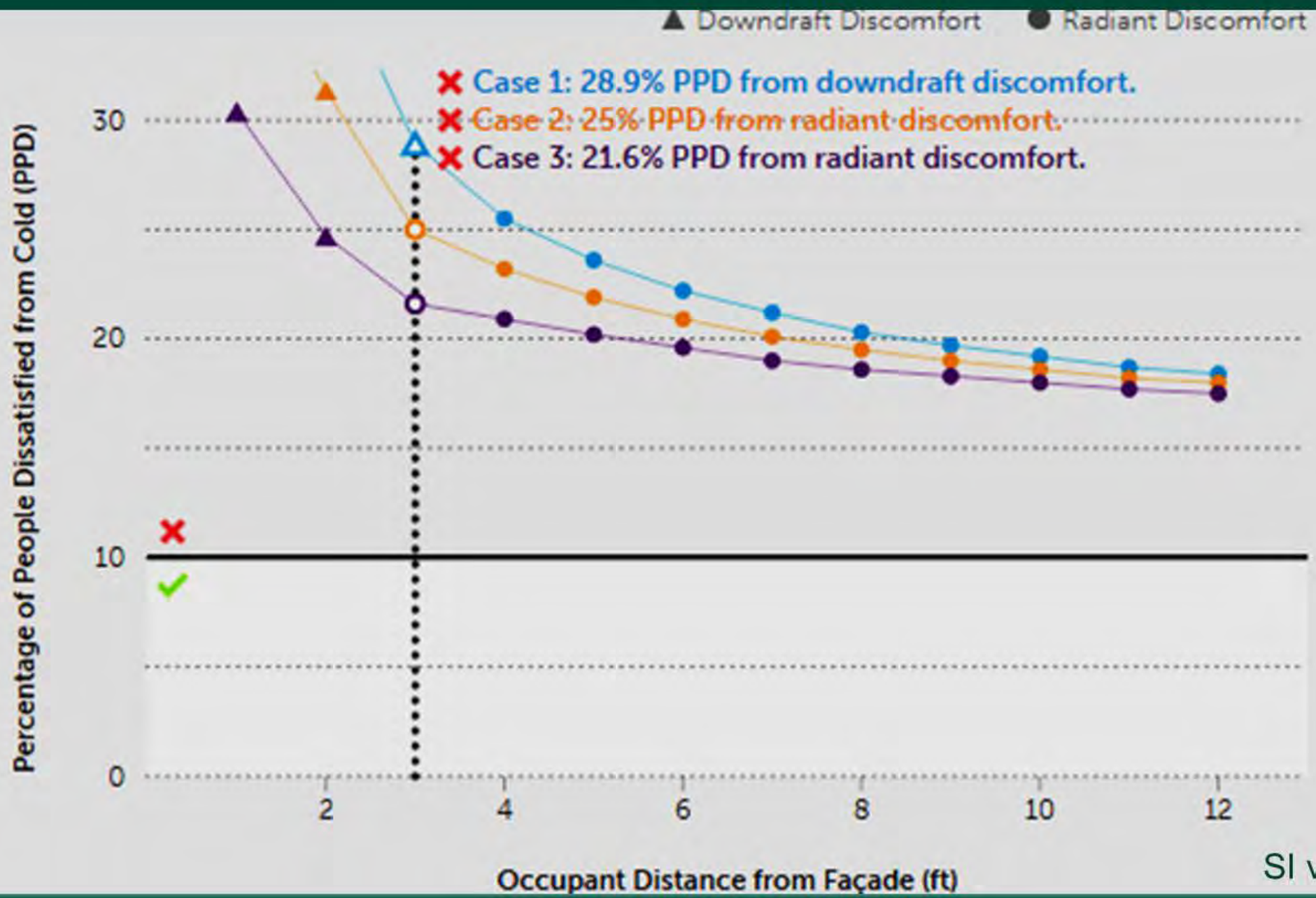
down draft / radiant asymmetry risk assessment tool

SI version online

ADVANCED OPTIONS

Room-side Low-E Coating	✔		
Emissivity	0.3	0.2	0.1
Wall R-Value ($ft^2hr°F/Btu$)	15	15	15
Air Speed (fpm)	10	10	10
Clothing (clo)	0.85	0.85	0.85
Metabolic Rate (met)	1.2	1.2	1.2

down draft / radiant asymmetry risk assessment tool



SI version online

N

IP/SI Units

MRT Calculator

ASHRAE Thermal Comfort Tool (CD)

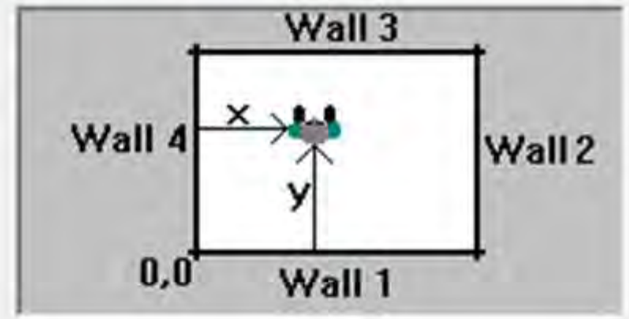
Room dimensions

Room width (x)	27.0	ft
Room length (y)	12.0	ft
Room height	9.0	ft

Occupant

x	6.0	ft
y	6.0	ft
Facing	Average	
Azimuth	Average	

Seated / Standing



	Temperature °F	Emis	Wall view factor	Glass/panel data Temperature °F	Emis	Width ft	Height ft	Centered	Sill ft	L. Jamb* ft	Window view factor
Wall 1	70.0	0.90	0.162								
window/panel											
Wall 2	65.0	0.90	0.019								
window/panel											
Wall 3	60.0	0.90	0.082	55.0	0.25	18.0	6.0	✓	1.5	4.5	0.0800
✓ window/panel											
Wall 4	62.0	0.90	0.070	55.0	0.25	6.0	6.8	✓	1.1	3.0	0.0634
✓ window/panel											
Ceiling	72.0	0.90	0.155								
window/panel											
Floor	68.0	0.90	0.360								
panel											
View factor total	1.0										
MRT	67.3	°F									

@≈-25°F (-32°C)

low surface temp (radiant) problem

*distance from left edge of wall to left jamb when viewed from inside the room

View factors are calculated based on Fanger, P.O., "Thermal Comfort", McGraw-Hill, 1972

OK ✓ Set MRT

Room Viewer - Sample Room

Display
PPD
Normals
Height 0.5 ft
Spacing 1.0 ft
Z amplify
Occlusions

Direct Sun
Enable
Lat 40
Date Jun-21
Hr 12

Scale
40.00 %
37.75
35.50
33.25
31.00
28.75
26.50
24.25
22.00
19.75
17.50
15.25
13.00
10.75
8.50
6.25
4.00
Lock

Conditions

Air temperature	72.0 °F
Relative humidity	30 %
Air speed	19.7 fpm
Activity	1.0 met
Clothing	0.90 clo

Flr
Clg
Wall01
Wall02
Wall03
Wall03_C

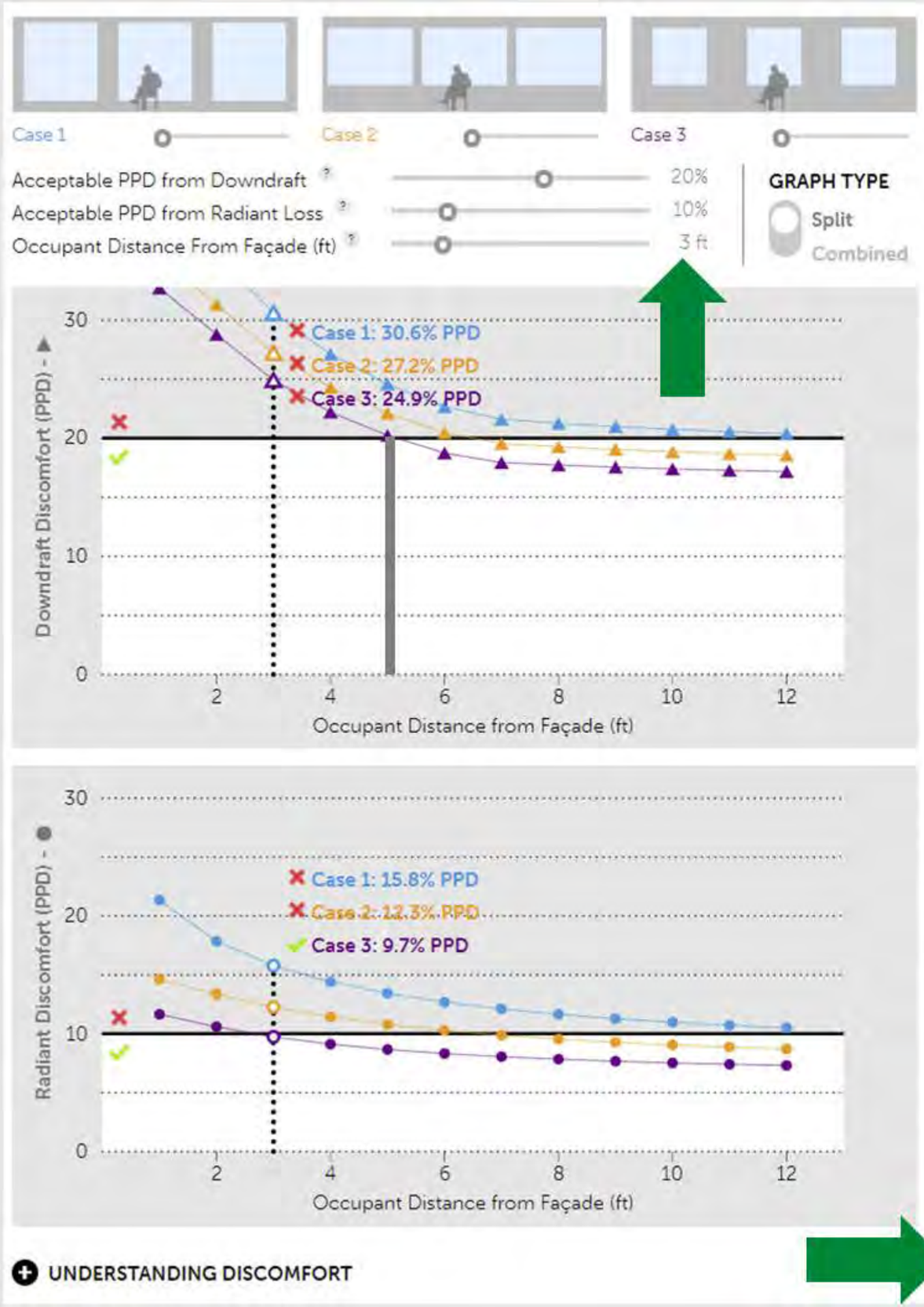
Surface temp (°F)

Window trans

ASHRAE RP-1383

Case
Load File

Export
Close



Glazing and Winter Comfort Tool

This tool displays the impact of glazing geometry and U-value on occupant thermal comfort during winter months. It shows when it is possible to eliminate perimeter heat in cases where the U-value is low and windows are small.

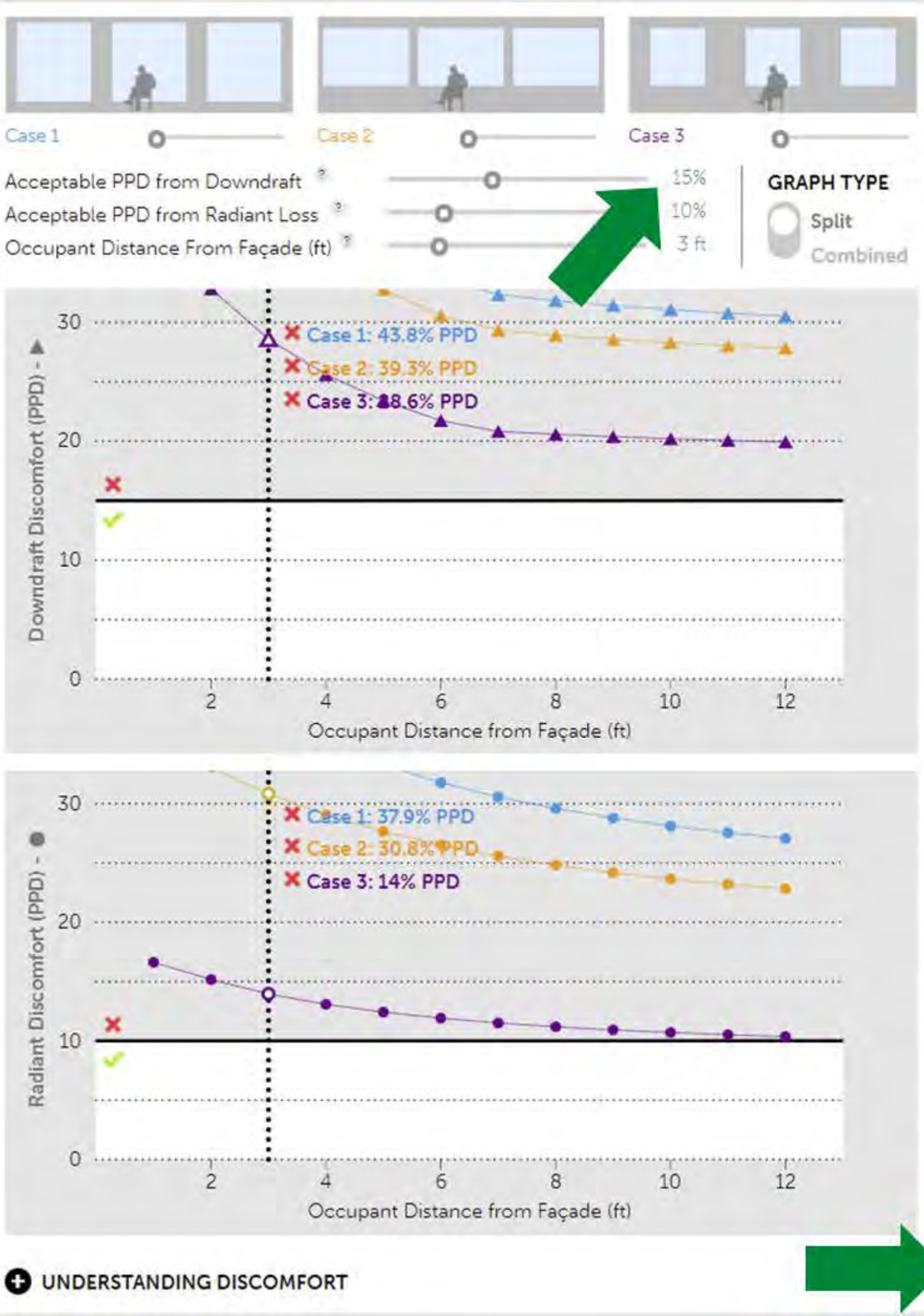
Email the developers, visit our github, and read the license.

We've updated! See the release notes, to learn about this tool's improved downdraft comfort model and interface updates.

UNITS IP SI SHARE Save PDF Save CSV Copy URL

OUTDOOR DESIGN CONDITION	Case 1	Case 2	Case 3
Outdoor Temperature (°F) Search	-35	-35	-35
FAÇADE GEOMETRY			
Ceiling Height (ft)	9	9	9
Room Length (ft)	27	27	27
Window Height From Sill (ft)	7.5	5.5	5.5
Sill Height (ft)	1	2.5	2.5
Set Glazing Amount By			
Window Width (ft)	–	9.1	5.15
✔ Window-to-Wall Ratio (%)	65	55	35
Window Separation (ft)	9	9	9
FACADE PERFORMANCE			
Window U-Value (Btu/ft²hr°F)	0.25	0.25	0.25
U-Value that meets the target PPD	0	0.09	0.14
Is there a risk of condensation?	NO	NO	NO
INDOOR CONDITIONS			
Indoor Temperature (°F)	72	72	72
Relative Humidity (%)	30	30	30
ADVANCED OPTIONS			
Room-side Low-E Coating			
Emissivity			
Wall R-Value (ft²hr°F/Btu)	6	7	8
Air Speed (fpm)	19.7	19.7	19.7
Clothing (clo)	1	1.05	1.1
Metabolic Rate (met)	1	1	1

high probability of downdraft discomfort closer to window (<5ft), radiant discomfort mitigated with increase in clothing



Glazing and Winter Comfort Tool

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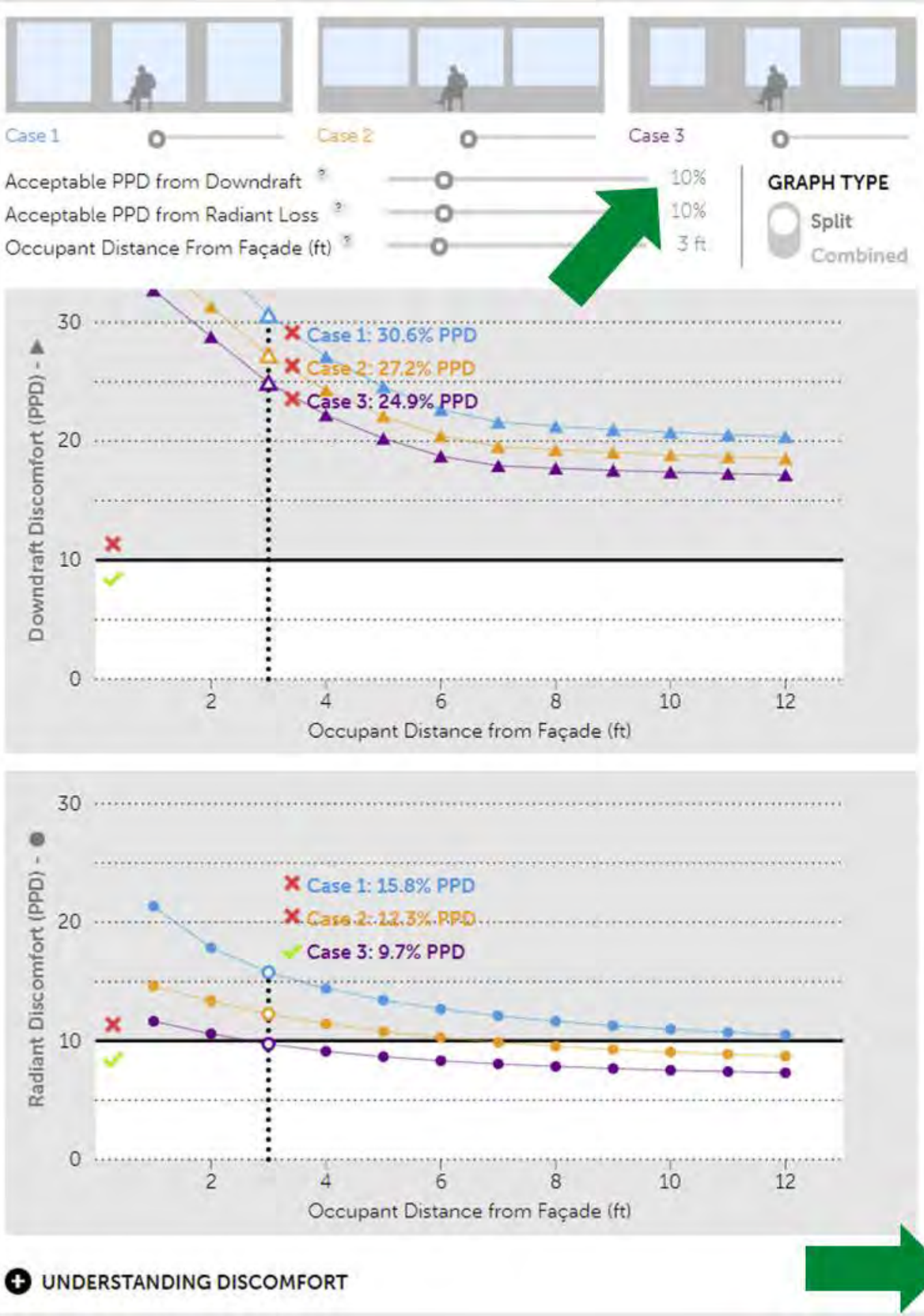
UNITS IP SI SHARE Save PDF Save CSV Copy URL

OUTDOOR DESIGN CONDITION	Case 1	Case 2	Case 3
Outdoor Temperature (°F) Search	-35	-35	-35
FAÇADE GEOMETRY			
Ceiling Height (ft)	9	9	9
Room Length (ft)	27	27	27
Window Height From Sill (ft)	7.5	5.5	5.5
Sill Height (ft)	1	2.5	2.5
Set Glazing Amount By			
Window Width (ft)	–	9.1	5.15
✔ Window-to-Wall Ratio (%)	65	55	35
Window Separation (ft)	9	9	9
FACADE PERFORMANCE			
Window U-Value (Btu/ft²hr°F)	0.25	0.25	0.25
U-Value that meets the target PPD	0	0	0
Is there a risk of condensation?	NO	NO	NO
INDOOR CONDITIONS			
Indoor Temperature (°F)	72	72	72
Relative Humidity (%)	30	30	30
ADVANCED OPTIONS			
Room-side Low-E Coating			
Emissivity			
Wall R-Value (ft²hr°F/Btu)	6	7	8
Air Speed (fpm)	19.7	19.7	19.7
Clothing (clo)	1	1.05	1.3
Metabolic Rate (met)	0.9	0.9	0.9

reducing the ppd from 20% to 15% results in non compliance on downdraft, radiant discomfort at low met rate even with increased clo



Glazing and Winter Comfort Tool

This tool displays the impact of glazing geometry and U-value on occupant thermal comfort during winter months. It shows when it is possible to eliminate perimeter heat in cases where the U-value is low and windows are small.

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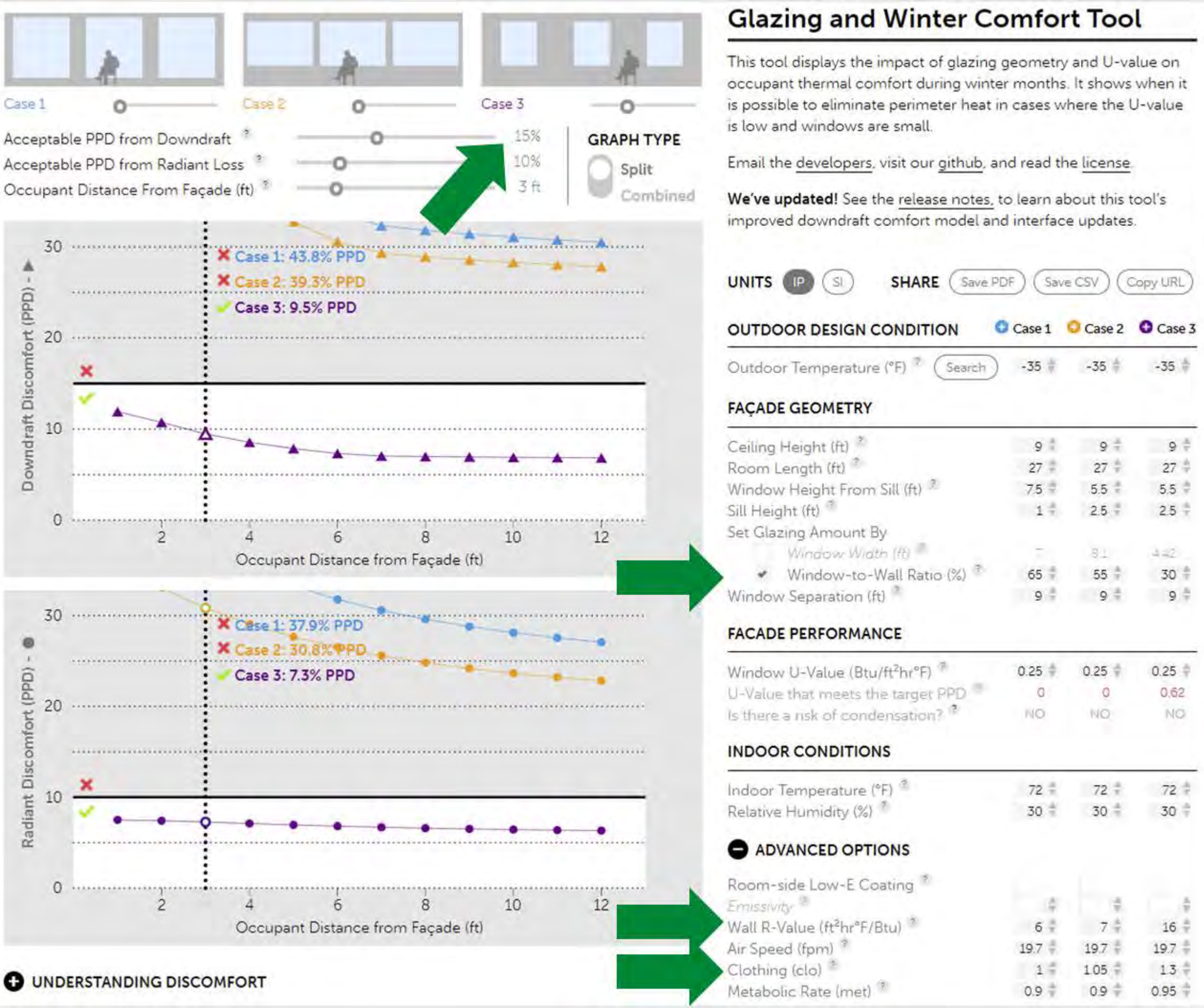
We've updated! See the release notes, to learn about this tool's improved downdraft comfort model and interface updates.

UNITS IP SI SHARE Save PDF Save CSV Copy URL

OUTDOOR DESIGN CONDITION	Case 1	Case 2	Case 3
Outdoor Temperature (°F) Search	-35	-35	-35
FAÇADE GEOMETRY			
Ceiling Height (ft)	9	9	9
Room Length (ft)	27	27	27
Window Height From Sill (ft)	7.5	5.5	5.5
Sill Height (ft)	1	2.5	2.5
Set Glazing Amount By			
Window Width (ft)	–	9.1	5.15
✔ Window-to-Wall Ratio (%)	65	55	35
Window Separation (ft)	9	9	9
FACADE PERFORMANCE			
Window U-Value (Btu/ft²hr°F)	0.25	0.25	0.25
U-Value that meets the target PPD	0	0.09	0.28
Is there a risk of condensation?	NO	NO	NO
INDOOR CONDITIONS			
Indoor Temperature (°F)	72	72	72
Relative Humidity (%)	30	30	30
ADVANCED OPTIONS			
Room-side Low-E Coating			
Emissivity			
Wall R-Value (ft²hr°F/Btu)	6	7	8
Air Speed (fpm)	19.7	19.7	19.7
Clothing (clo)	1	1.05	1.1
Metabolic Rate (met)	1	1	1

increase risk w/ reducing the ppd from 20% to 10% = non compliance on downdraft, radiant discomfort mitigated with met rate & clothing



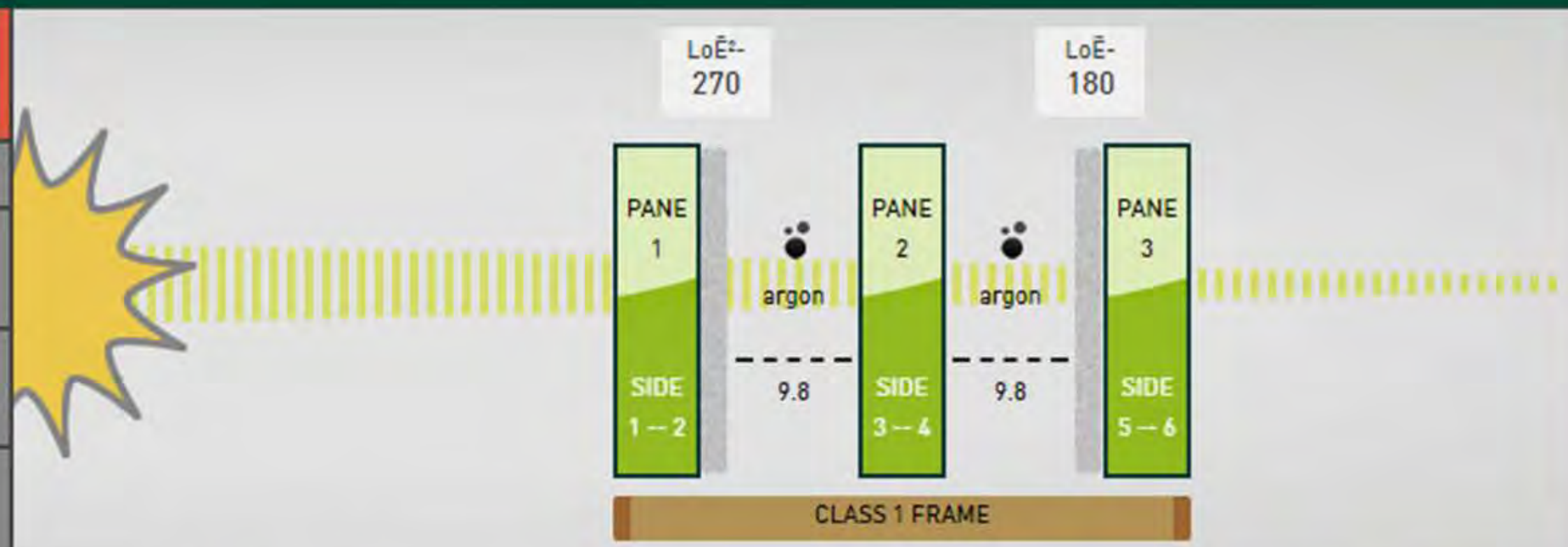
lower risk with decrease WWR from 65% to 30%, increase wall R-6 to R-16 w/ increase in clothing

3P / 270 / 180 / argon ≈ 284 hrs winter discomfort

ENERGY CALC

WINDOW MODE << >> PERFORMANCE MODE

3P-2Ē	9.8
Clear	Ē270
Argon	Class 1



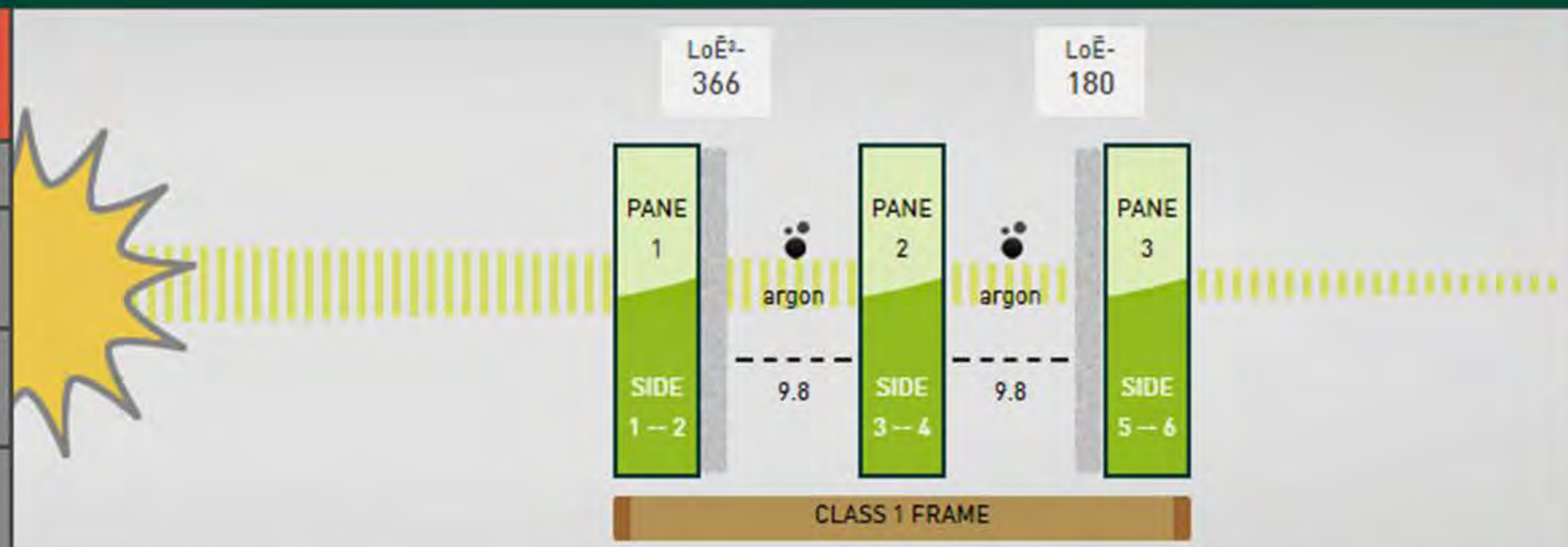
HOUSING	ANNUAL COSTS		PERFORMANCE & CODE COMPLIANCE		HOURS OF DISCOMFORT	
Calgary, AB East/West Orientation	SUMMER	TOTAL	SHGC	U-FACTOR	Summer	18
2-Story / 3000 ft² VINTAGE - New	$154	$1,155	0.26	0.25	Spring / Fall	118
External - None INT. Summer - Some INT. Winter - Some					Winter Day	284
Winter Gas - 0.8 / Therm Summer Electric: 0.12 / kWh	WINTER	CARBON LBS CO_2	CAN MODEL	ENERGY STAR v6.0	Winter Night	155
	$1,000	35,406	●	●	--	--
					Total Hours	575

3P / 366 / 180 / argon ≈ 131 hrs winter discomfort

ENERGY CALC

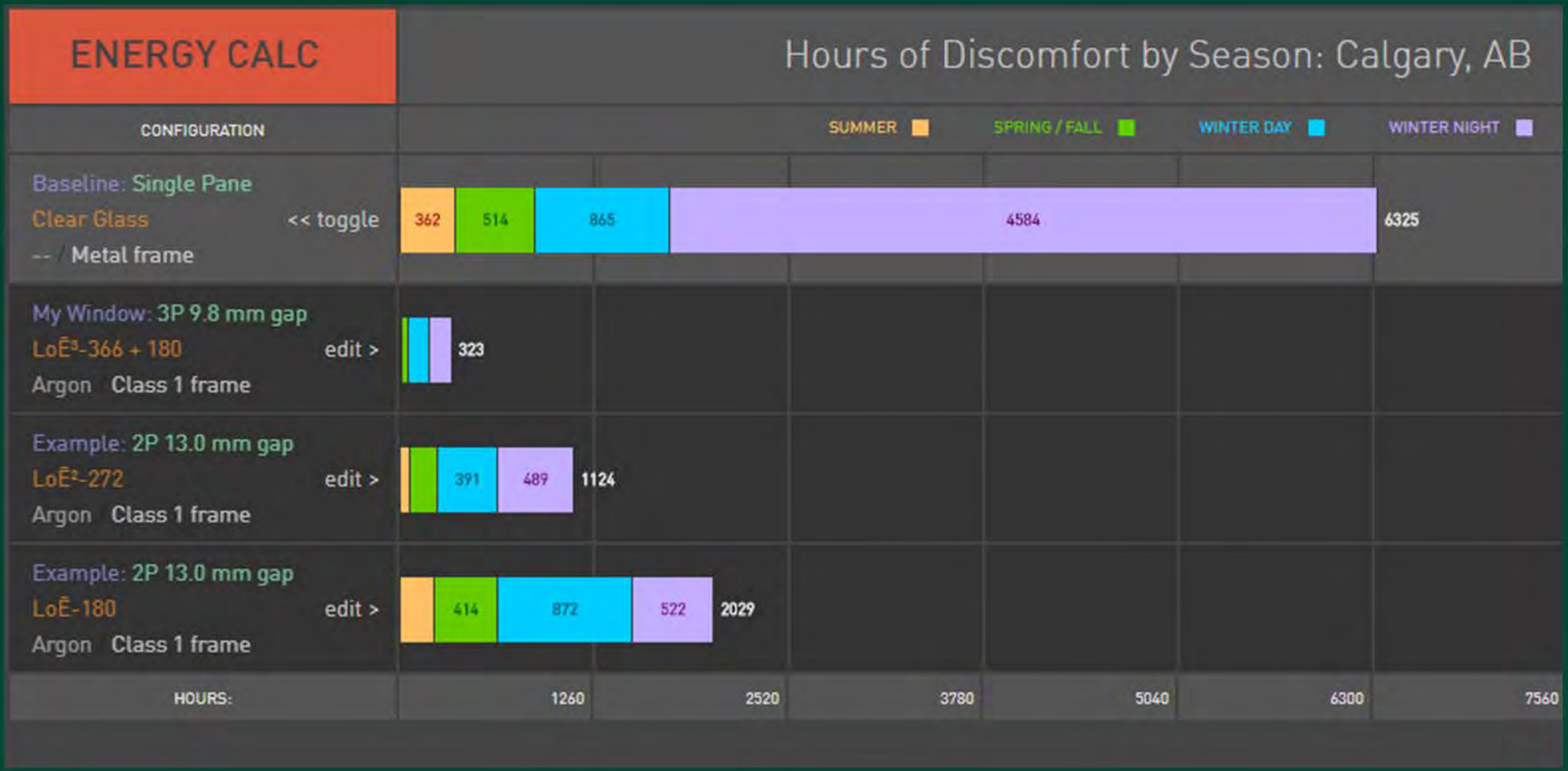
WINDOW MODE << >> PERFORMANCE MODE

3P-2Ē	9.8
Clear	Ē366
Argon	Class 1



HOUSING	ANNUAL COSTS		PERFORMANCE & CODE COMPLIANCE		HOURS OF DISCOMFORT	
Calgary, AB East/West Orientation	SUMMER	TOTAL	SHGC	U-FACTOR	Summer	0
2-Story / 3000 ft² VINTAGE - New	$133	$1,153	0.19	0.25	Spring / Fall	44
External - None INT. Summer - Some INT. Winter - Some					Winter Day	131
Winter Gas - 0.8 / Therm Summer Electric: 0.12 / kWh	WINTER	CARBON LBS CO_2	CAN MODEL	ENERGY STAR v6.0	Winter Night	148
	$1,020	35,832	●	●	--	--
					Total Hours	323

comparison for client discussion



Select method: PMV method

Air temperature
72 °F — Use operative temperature

Mean radiant temperature
67.3 °F

Air speed
20 fpm — Local air speed control

Humidity
30 % — Relative humidity

Metabolic rate
1 met — Seated, quiet: 1.0

Clothing level
0.9 clo — Typical winter indoor

Create custom ensemble

Dynamic predictive clothing

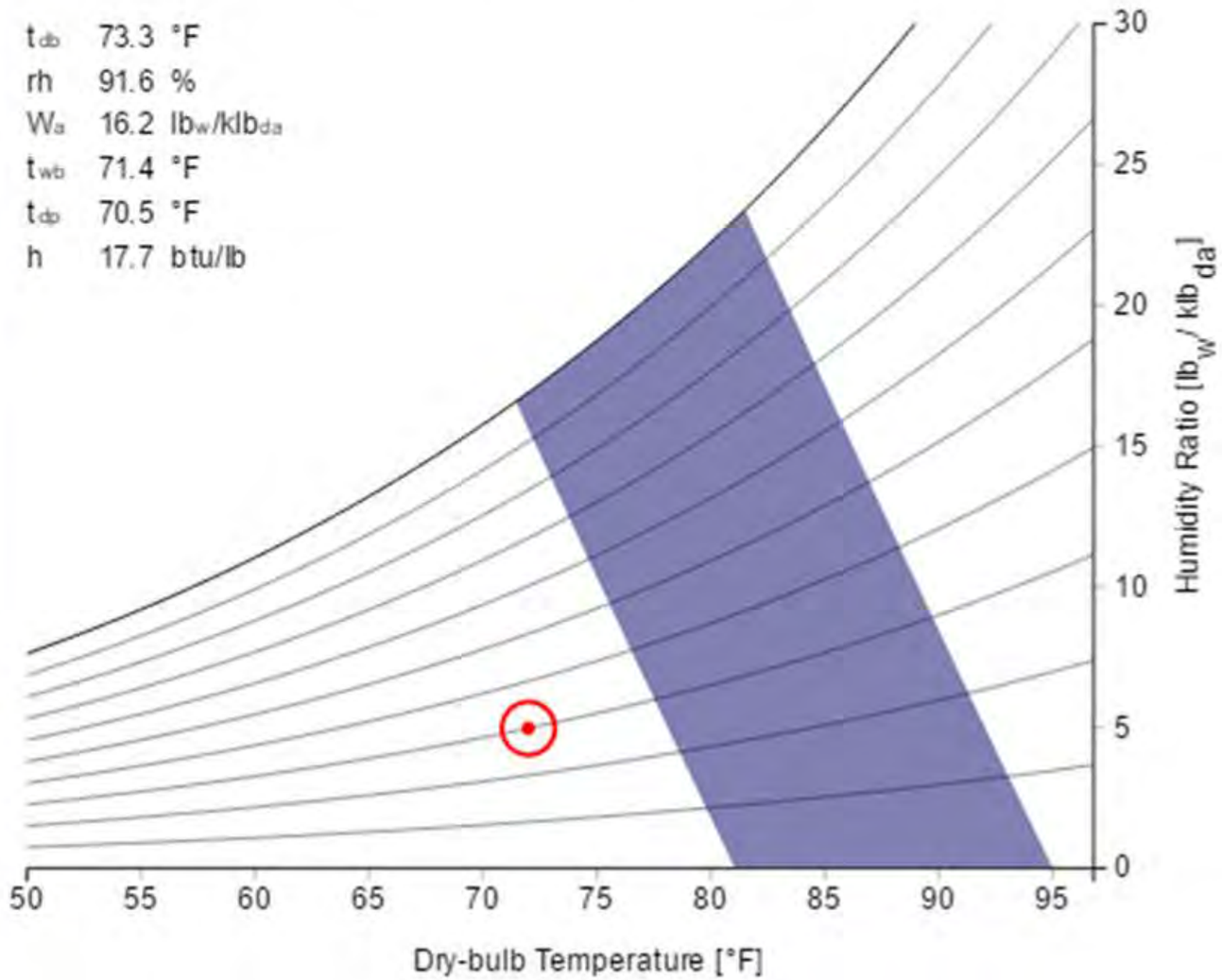
LEED documentation

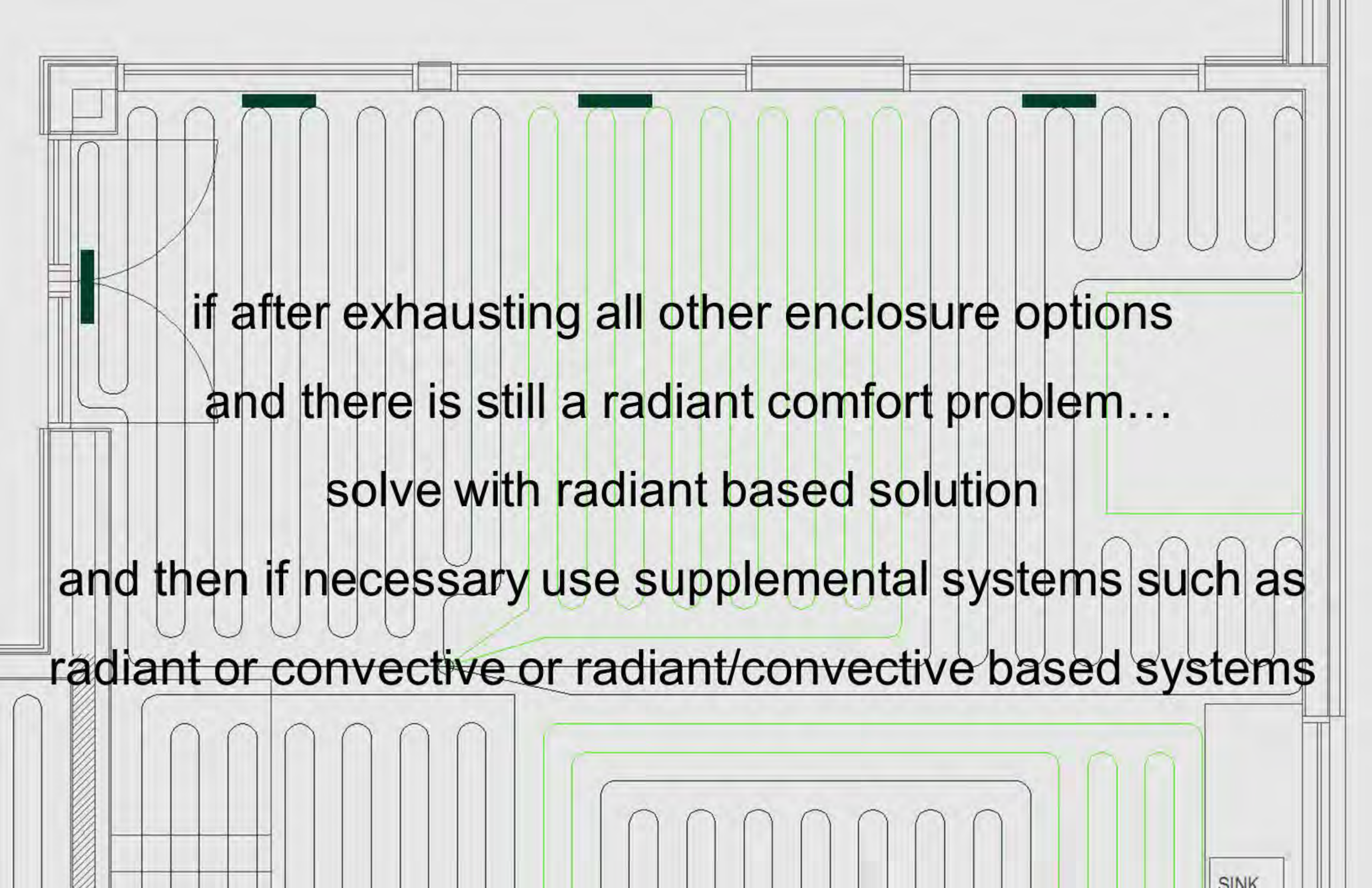
Globe temp	SolarCal	Specify pressure	SI IP	Local discomfort	? Help

✗ Does not comply with ASHRAE Standard 55-2013

PMV	-0.94
PPD	24%
Sensation	Slightly Cool
SET	72.2°F

Psychrometric chart (air temperature)





if after exhausting all other enclosure options

and there is still a radiant comfort problem…

solve with radiant based solution

and then if necessary use supplemental systems such as

radiant or convective or radiant/convective based systems

MRT Calculator

ASHRAE Thermal Comfort Tool (CD)

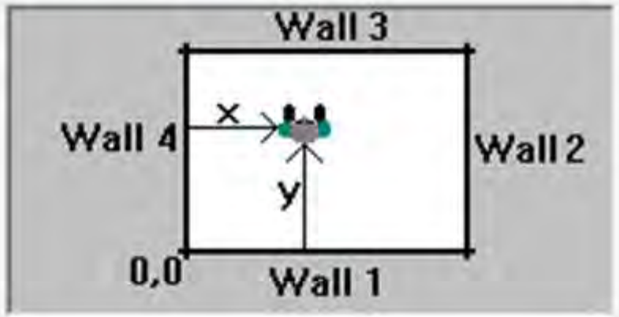
Room dimensions

Room width (x)	27.0	ft
Room length (y)	12.0	ft
Room height	9.0	ft

Occupant

x	6.0	ft
y	6.0	ft
Facing	Average	
Azimuth	Average	

Seated / Standing



	Temperature °F	Emis	Wall view factor	window/panel
Wall 1	70.0	0.90	0.162	☐
Wall 2	65.0	0.90	0.019	☐
Wall 3	60.0	0.90	0.082	☑
Wall 4	62.0	0.90	0.070	☑
Ceiling	72.0	0.90	0.155	☐
Floor	85.0	[illegible]	0.360	panel

Glass/panel data

	Temperature °F	Emis	Width ft	Height ft	Centered	Sill ft	L. Jamb* ft	Window view factor
Wall 3	55.0	0.25	18.0	6.0	☑	1.5	4.5	0.0800
Wall 4	55.0	0.25	6.0	6.8	☑	1.1	3.0	0.0634

@≈-25°F (-32°C)

w/ heated floor @ 85°F (29°C)

@≈-25°F (-32°C)

View factor total 1.0

MRT 74.4 °F

*distance from left edge of wall to left jamb when viewed from inside the room

View factors are calculated based on Fanger, P.O., "Thermal Comfort", McGraw-Hill, 1972

OK ☑ Set MRT

increased mean radiant temperature

Select method: PMV method

Air temperature
72.0 °F — Use operative temperature

Mean radiant temperature
74.4 °F

Air speed
20 fpm — Local air speed control

Humidity
30 % — Relative humidity

Metabolic rate
1 met — Seated, quiet: 1.0

Clothing level
0.9 clo — Typical winter indoor

Create custom ensemble

Dynamic predictive clothing

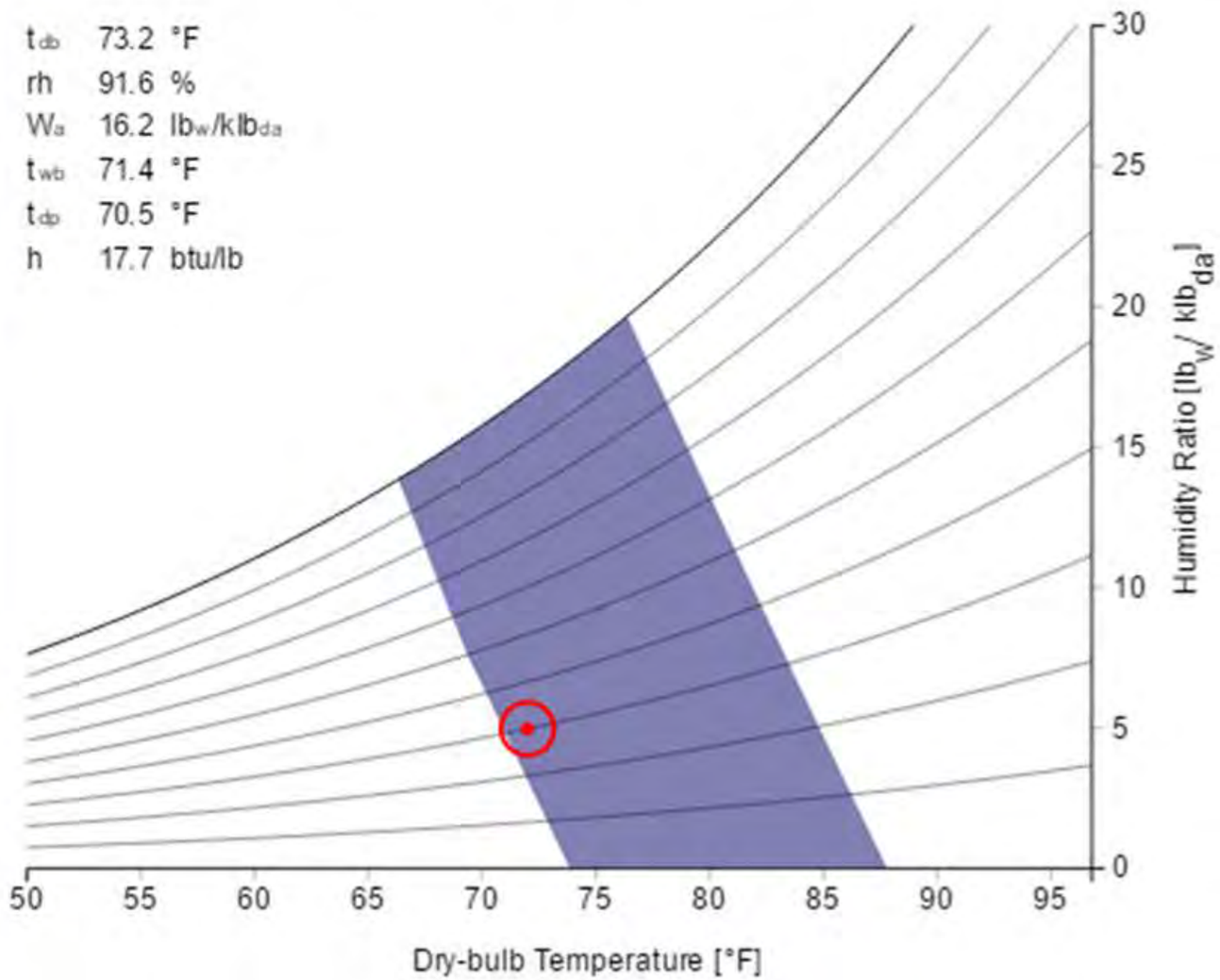
LEED documentation

Globe temp	SolarCal	Specify pressure	SI IP	Local discomfort	? Help

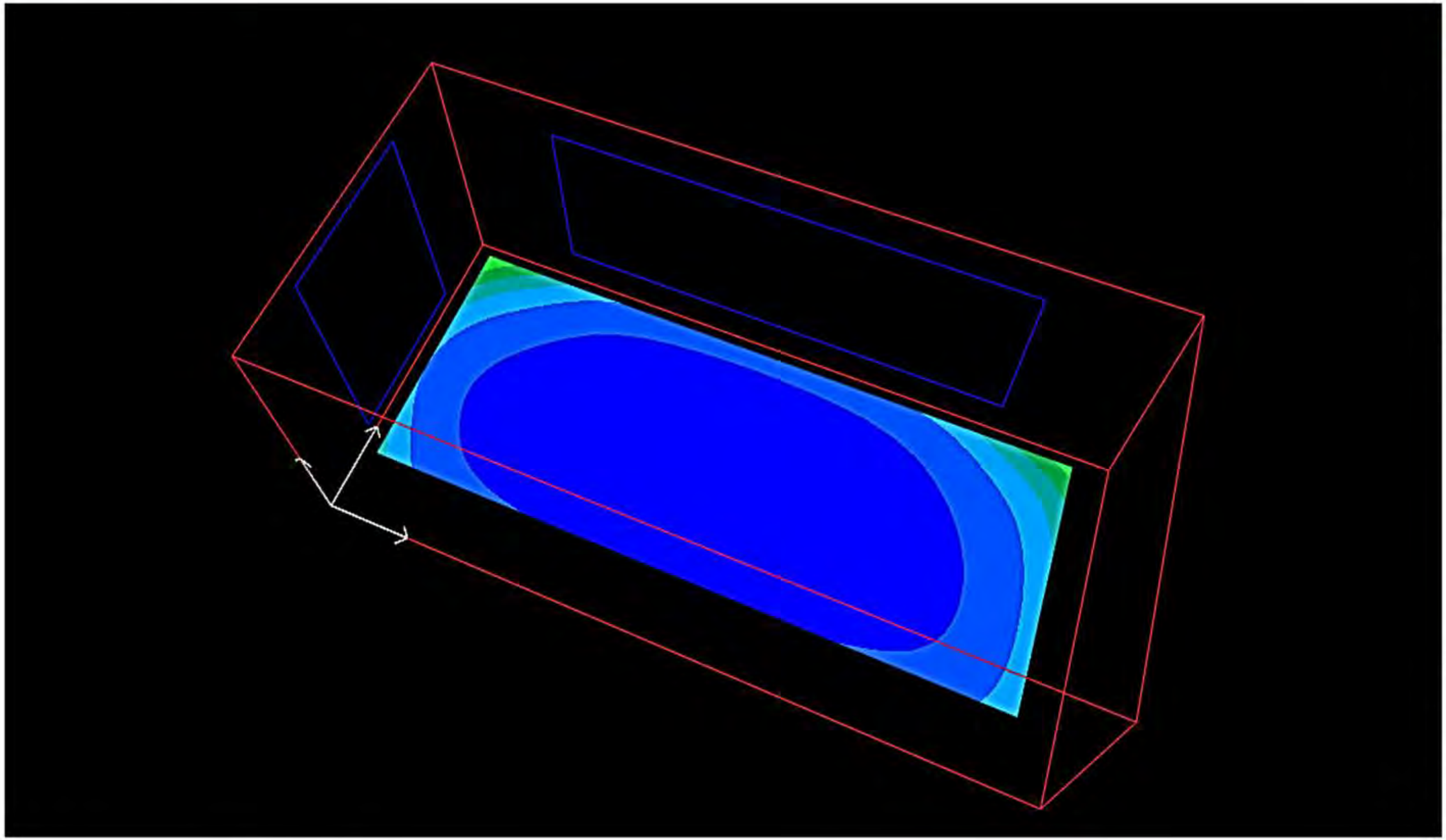
✓ Complies with ASHRAE Standard 55-2013

PMV	-0.42
PPD	9%
Sensation	Neutral
SET	76.0°F

Psychrometric chart (air temperature)



Room Viewer - Sample Room



Display

PPD | Normals ☐

Height 0.6 ft

Spacing 0.1 ft

Z amplify ☐

Occlusions ☑

Direct Sun

Enable ☐ Lat 40

Date Jun-21 Hr 12

Scale

30.00 %
28.38
26.75
25.13
23.50
21.88
20.25
18.63
17.00
15.38
13.75
12.13
10.50
8.88
7.25
5.63
4.00

Lock ☐

Conditions

Air temperature	72.0 °F
Relative humidity	30 %
Air speed	19.7 fpm
Activity	1.0 met
Clothing	0.90 clo

Case

< > Load File

Flr
Clg
Wall01
Wall02
Wall03
Wall03_C

Surface temp (°F)

Window trans

ASHRAE RP-1383

Export Close

ASHRAE-55 | EN-15251 | Compare | Ranges | Upload

Select method: PMV method

Air temperature
72.0 °F — Use operative temperature

Mean radiant temperature
74.4 °F

Air speed
19 fpm — Local air speed control

Humidity
30 % — Relative humidity

Metabolic rate
1 met — Typing: 1.1

Clothing level
0.9 clo — Typical winter indoor

Create custom ensemble

Dynamic predictive clothing

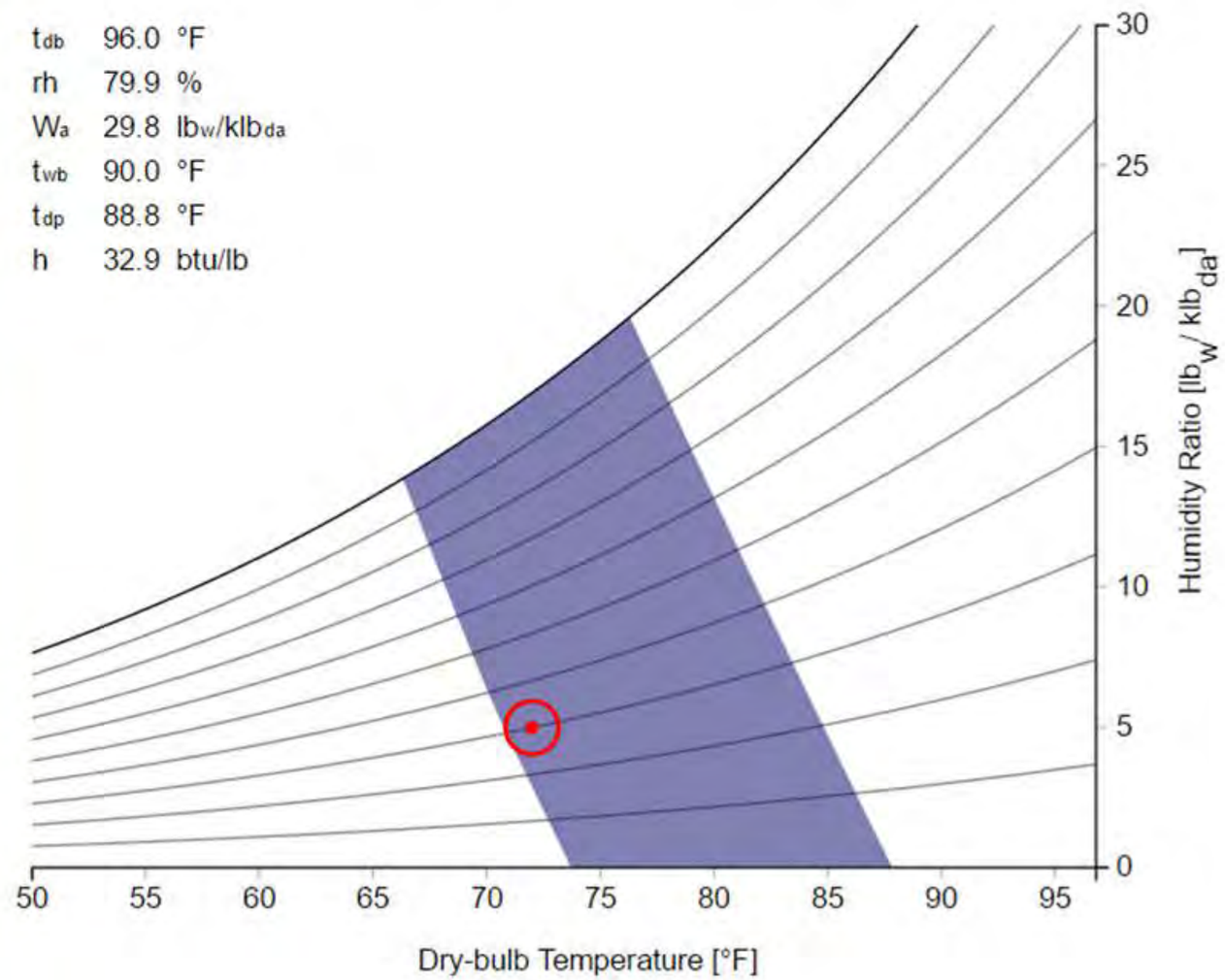
LEED documentation

Globe temp | SolarCal | Specify pressure | SI IP | Local discomfort | ? Help

✓ Complies with ASHRAE Standard 55-2013

PMV	-0.41
PPD	9%
Sensation	Neutral
SET	76.0°F

Psychrometric chart (air temperature)



ASHRAE 55

Local discomfort assessment

Radiant temperature asymmetry

Warm ceiling asymmetry	9	°F	✗
Cool ceiling asymmetry	26	°F	✗
Warm wall asymmetry	42	°F	✗
Cool wall asymmetry	18	°F	✗

Vertical air temperature difference

Head level temperature	72	°F	
Ankle level temperature	66	°F	✗

Floor surface temperature

Floor temperature	66	°F	✗

Draft

Operative temperature	72	°F	
Air speed	40	fpm	✗

✗ Does not comply with ASHRAE Standard 55-2013

case study

Local discomfort assessment

Radiant temperature asymmetry

Warm ceiling asymmetry	7	°F	✓
Cool ceiling asymmetry	0	°F	✓
Warm wall asymmetry	0	°F	✓
Cool wall asymmetry	15	°F	✓

Vertical air temperature difference

Head level temperature	72	°F	
Ankle level temperature	77	°F	✓

Floor surface temperature

Floor temperature	84	°F	✓

Draft

Operative temperature	72	°F	
Air speed	30	fpm	✓

✓ Complies with ASHRAE Standard 55-2013

ASHRAE Std 55 compliance summary for enclosure + hvac

Compliance with ASHRAE Standard 55 based on enclosure performance and choice of HVAC system (IP Units)										
Window Specs		Window U Value (cog)	Wall U Value (eff)	Clg U Value (eff)	Liv/Din Heat Loss	Liv/Din Flux	HVAC	ASHRAE Std 55 PPD	ASHRAE Std 55 - PPD CBE Tool	ASHRAE Std 55 Compliance
		Btu/ft2 hr F	Btu/ft2 hr F	Btu/ft2 hr F	Btu/hr	Btu/hr/ft2	Type	%	%	Y or N
Specified	2P/ Argon / 272 / Clear	0.33	0.06	0.03	12678	42.33	FA	24	22	N
Modified	3P / Argon / 272 / Clear / 180	0.19	0.04	0.03	10363	33.74	FA	20	-	N
Modified	3P / Argon / 366 / Clear / 180	0.19	0.04	0.03	10363	33.74	RFH	7	6	Y

Compliance with ASHRAE Standard 55 based on enclosure performance and choice of HVAC system (SI Units)										
Window Specs		Window U Value (cog)	Wall U Value (eff)	Clg U Value (eff)	Liv/Din Heat Loss	Liv/Din Flux	HVAC	ASHRAE Std 55 - PPD RPE Tool	ASHRAE Std 55 - PPD CBE Tool	ASHRAE Std 55 Compliance
		W/m^2 C	W/m^2 C	W/m^2 C	W	W/m^2	Type	%	%	Y or N
Specified	2P/ Argon / 272 / Clear	1.87	0.34	0.18	3716	134	FA	24	22	N
Modified	3P / Argon / 272 / Clear / 180	1.08	0.22	0.18	3037	106	FA	20	-	N
Modified	3P / Argon / 366 / Clear / 180	1.08	0.22	0.18	3037	106	RFH	7	6	Y

ppd/pmv modeling to drive architectural and hvac choices

1. ppd/pmv modelling draws attention to;
   a) indoor climate problems
   b) enclosure problems
   c) interactions between architectural, interior design & HVAC systems
   d) efficiency deficiencies
2. puts elephant - online - right in front of clients and their design professionals

integration literacy = pulling it all together

enclosures effect mean radiant temp (60% body heat), comfort, sound, outgassing & equipment and system efficiency

interior design effects contact coefficient, comfort, sound, outgassing and equipment and system efficiency

when buildings and interiors are flawed (and most are), radiant based HVAC systems enable conditions for thermal comfort, sound quality, indoor air quality and equipment and system efficiency.

why use thermal comfort tools?

the vocabulary of thermal comfort

is more accessible to society

than energy efficiency

thermal comfort tools are online, easy and free

use them to point out flaws and solutions

end result = energy efficiency

Questions?

Robert Bean, R.E.T., P.L. (Eng.)
info@healthyheating.com

It's Time To Change Bait

Why and How To Use Thermal Comfort Analysis

In Design Stage

To Influence Enclosure and HVAC Designs.

Robert Bean, R.E.T., P.L. (Eng.)
Indoor Climate Consultants Inc.
www.healthyheating.com
info@healthyheating.com

T.C. 2.1, T.C.6.1, T.C.6.5, T.C. 7.4, SSPC 55, RBC