BUILDING ENERGY 15

MARCH 3-5, 2015 AT THE SEAPORT WORLD TRADE CENTER

AIA Provider: Northeast Sustainable Energy Association

Provider Number: G338

Sensible Solutions to Latent Problems

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March 5 2015

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

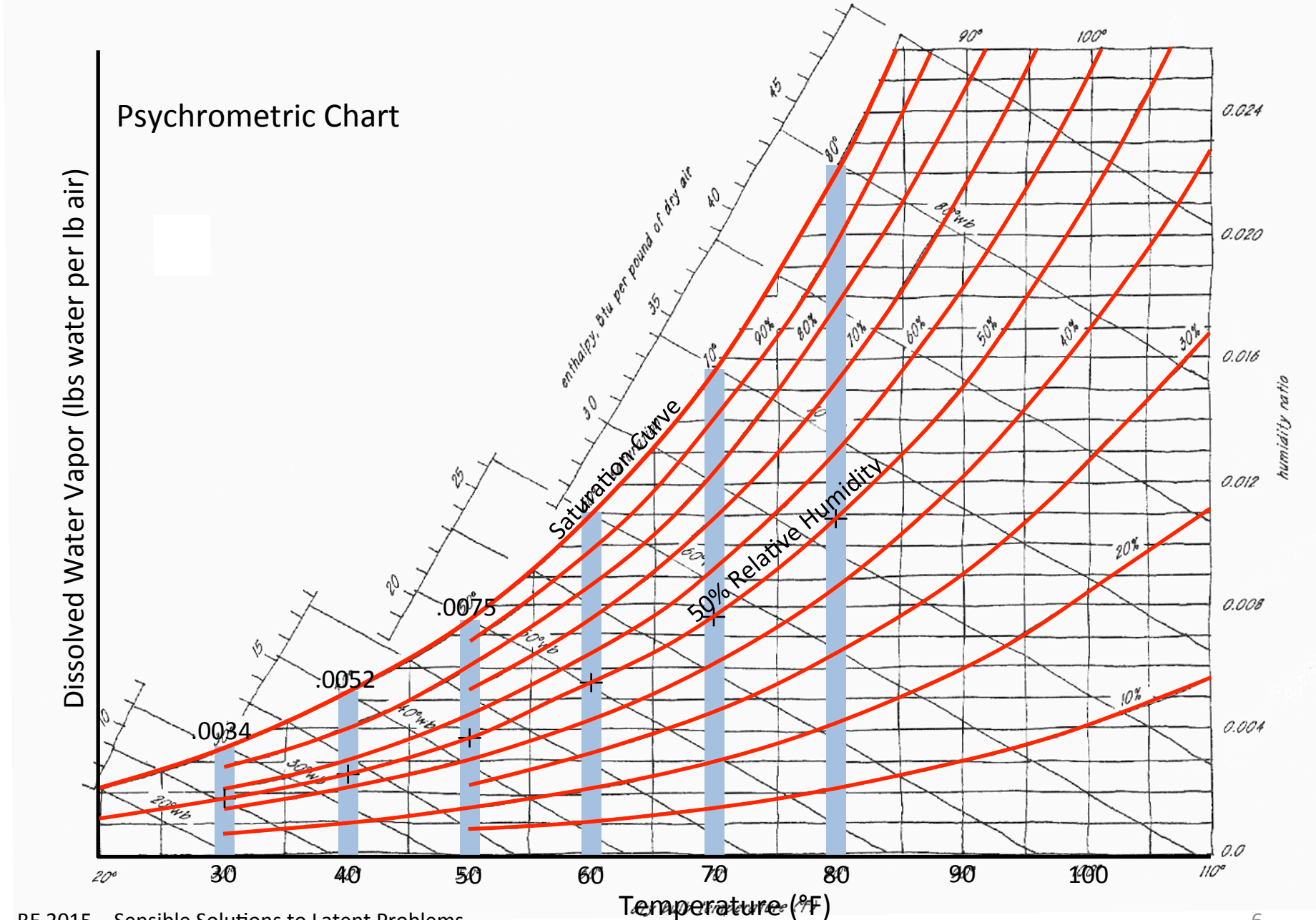
Low-load homes struggle with summertime humidity more than conventional homes, and the Northeast isn't getting any less tropical. Let's get ready. We will consider how latent and sensible loads differ for low-load homes, how to calculate required equipment performance, and what our equipment options are. After reviewing the basics of the psychrometric chart, we'll use it as our playbook, loading it with zippy-looking graphics galore. We will also present monitoring from recently built low-load homes.

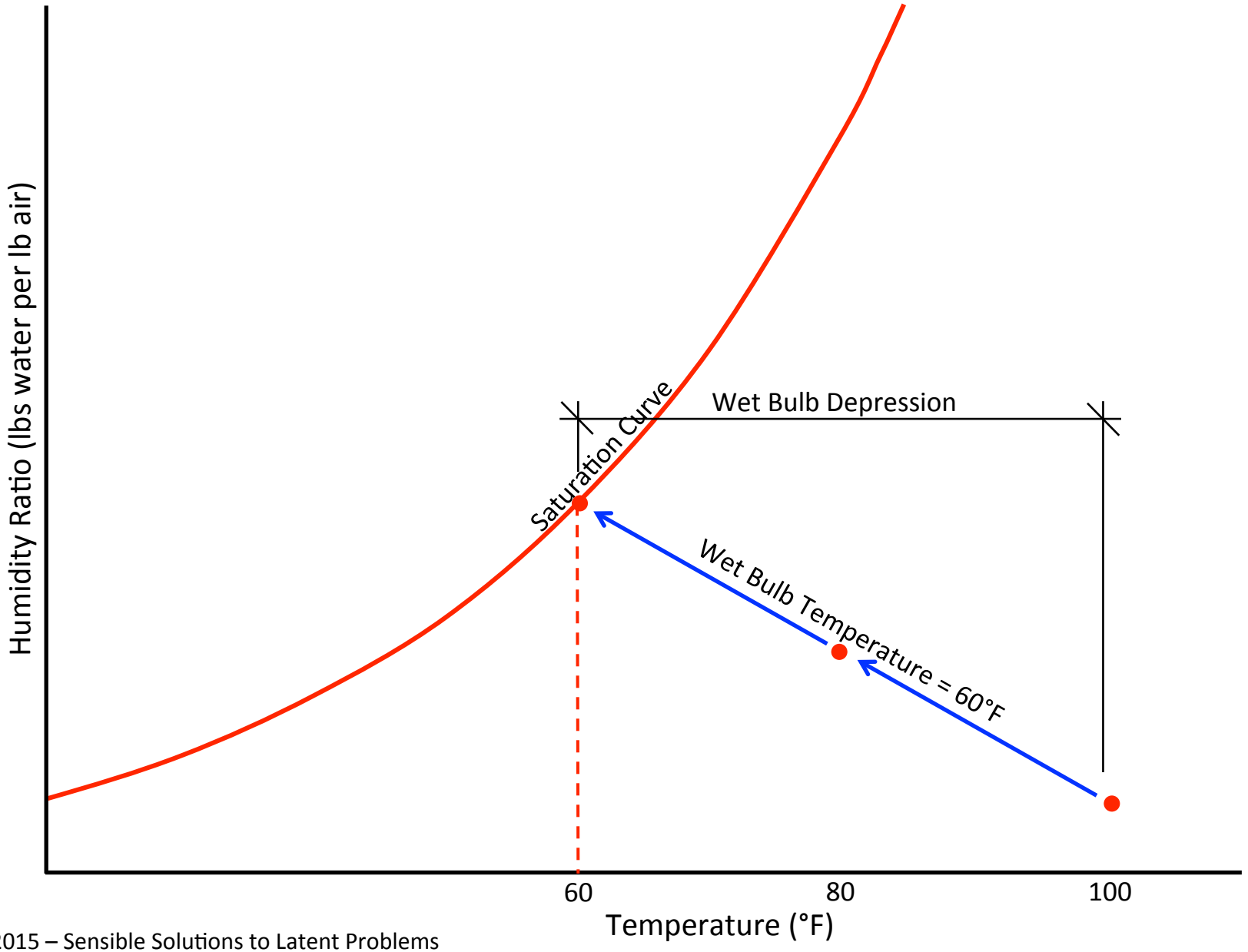
Learning Objectives

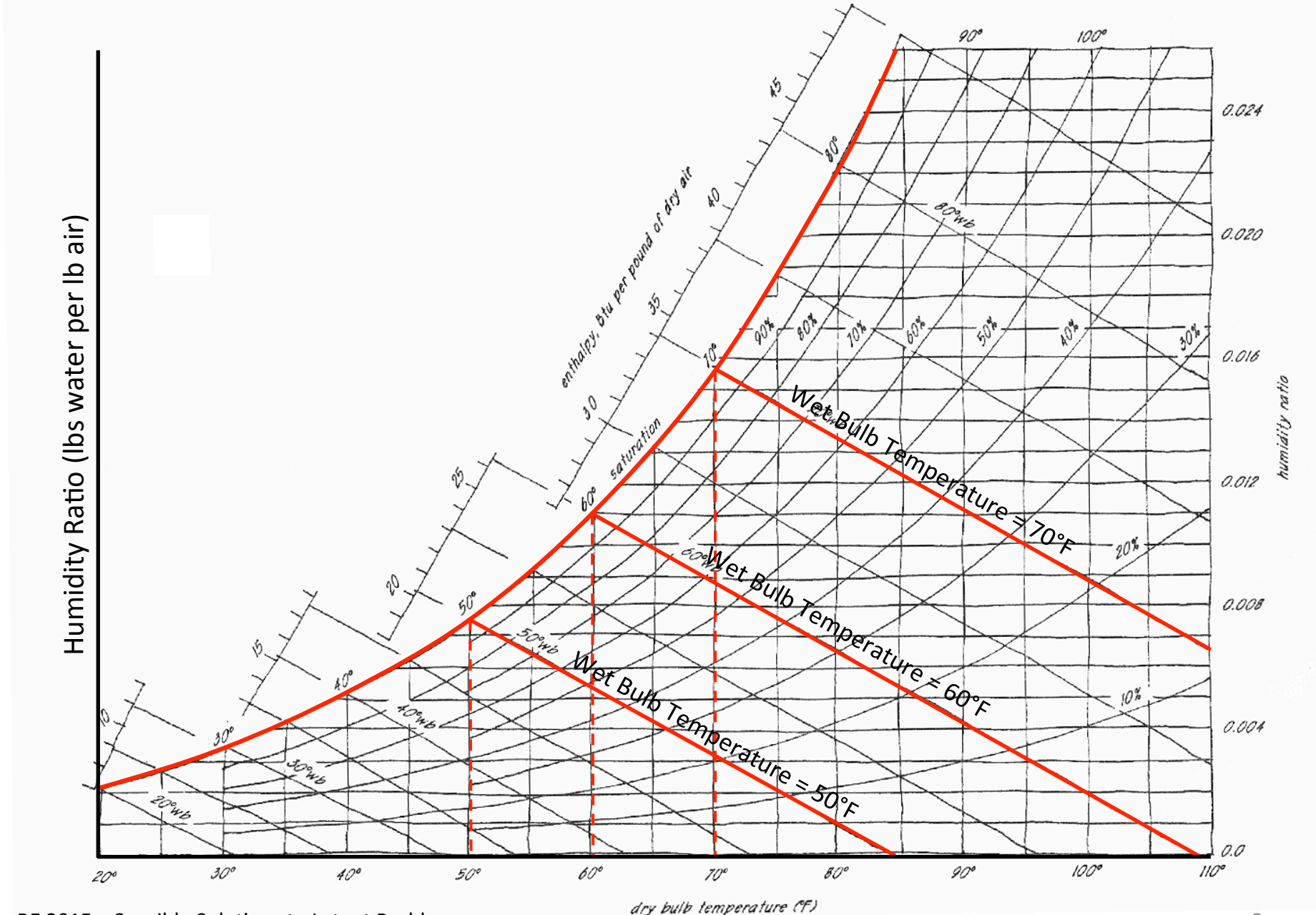
At the end of the this course, participants will be able to:

1) Understand the difference between sensible and latent loads.
2) Be better equipped to evaluate mechanical system proposals for high-efficiency residential buildings.
3) Distinguish between relative humidity and total moisture content of air.
4) Use the psychrometric chart.

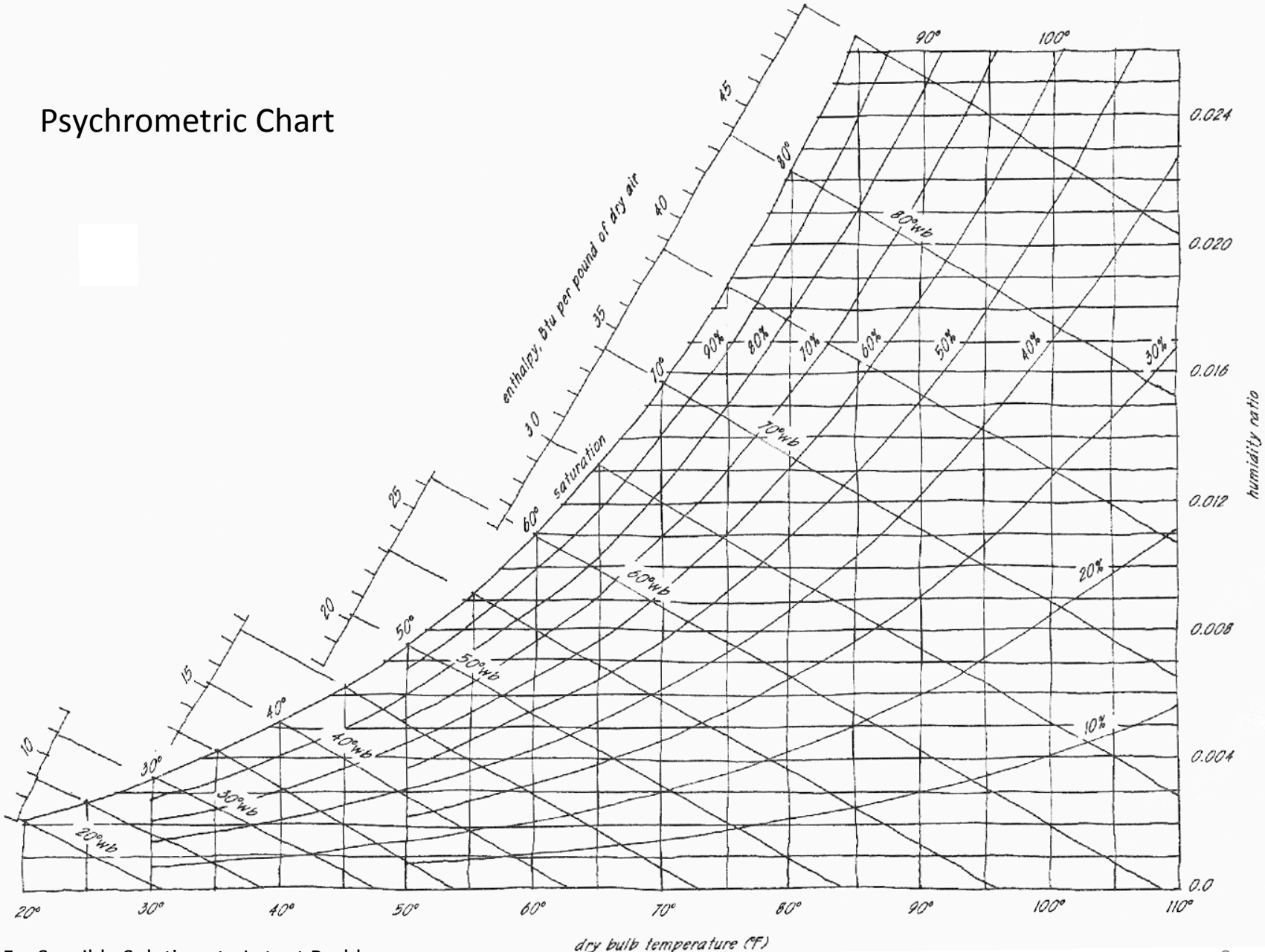
This concludes The American Institute of Architects
Continuing Education Systems Course

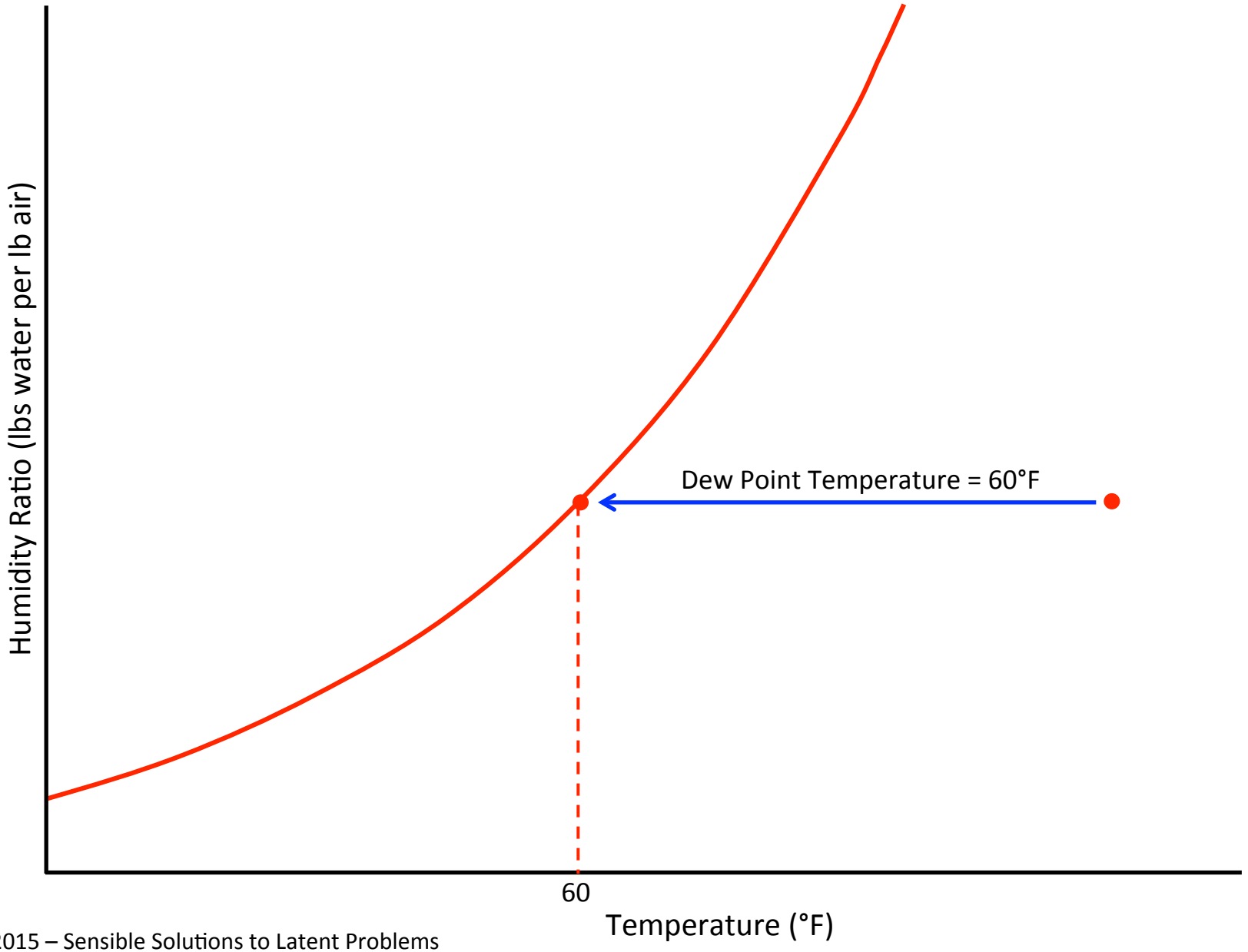

Psychrometric Chart
Dissolved Water Vapor (lbs water per lb air)
Temperature (°F)
humidity ratio
enthalpy, Btu per pound of dry air
Saturation Curve
50% Relative Humidity
.0034
.0052
.0075
0.024
0.020
0.016
0.012
0.008
0.004
0.0
20°
30
40
50
60
70
80
90
100
110°
10%
20%
30%
40%
50%
60%
70%
80%
90%

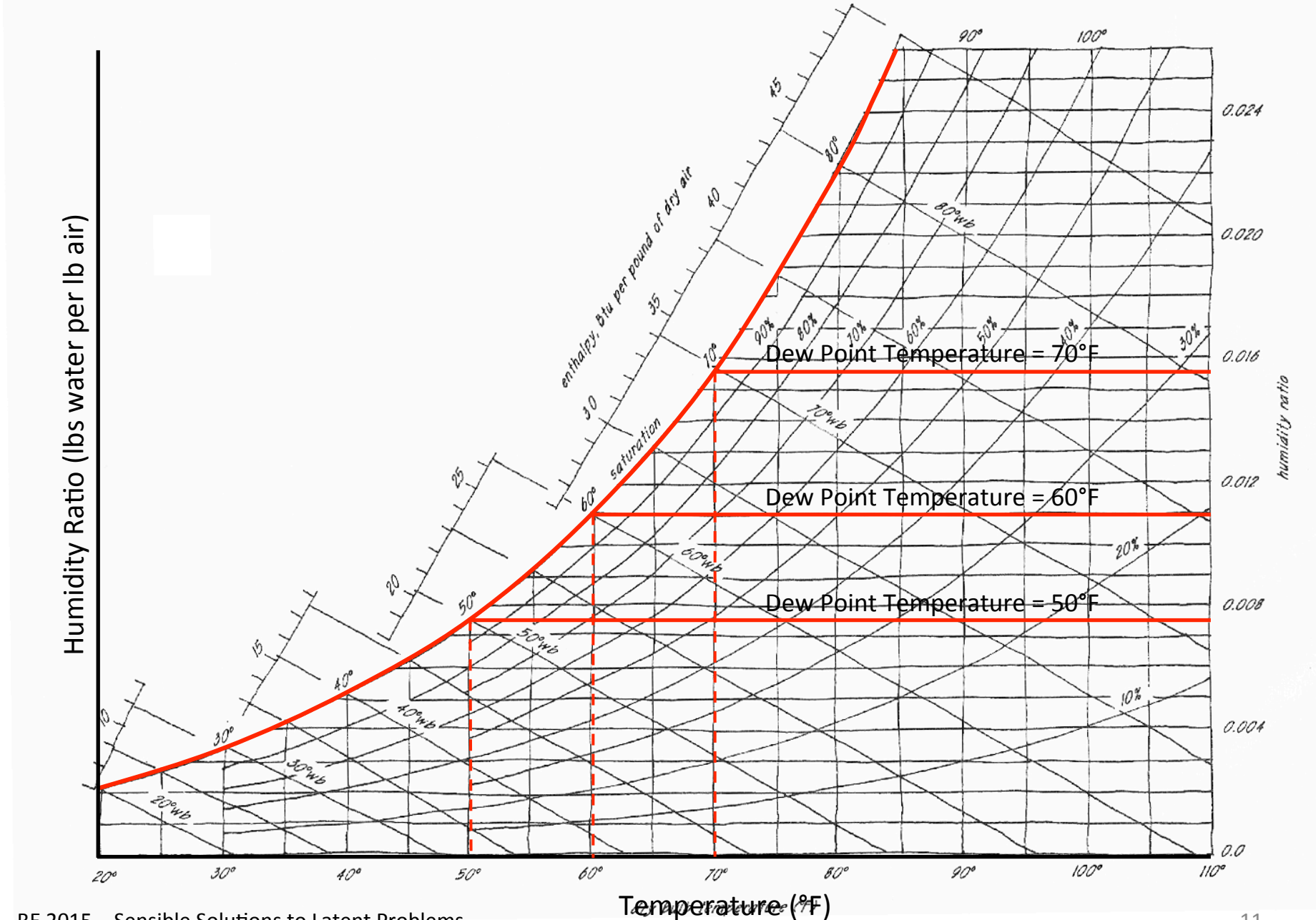

Humidity Ratio (lbs water per lb air)
Saturation Curve
Wet Bulb Depression
Wet Bulb Temperature = 60°F
60
80
100
Temperature (°F)

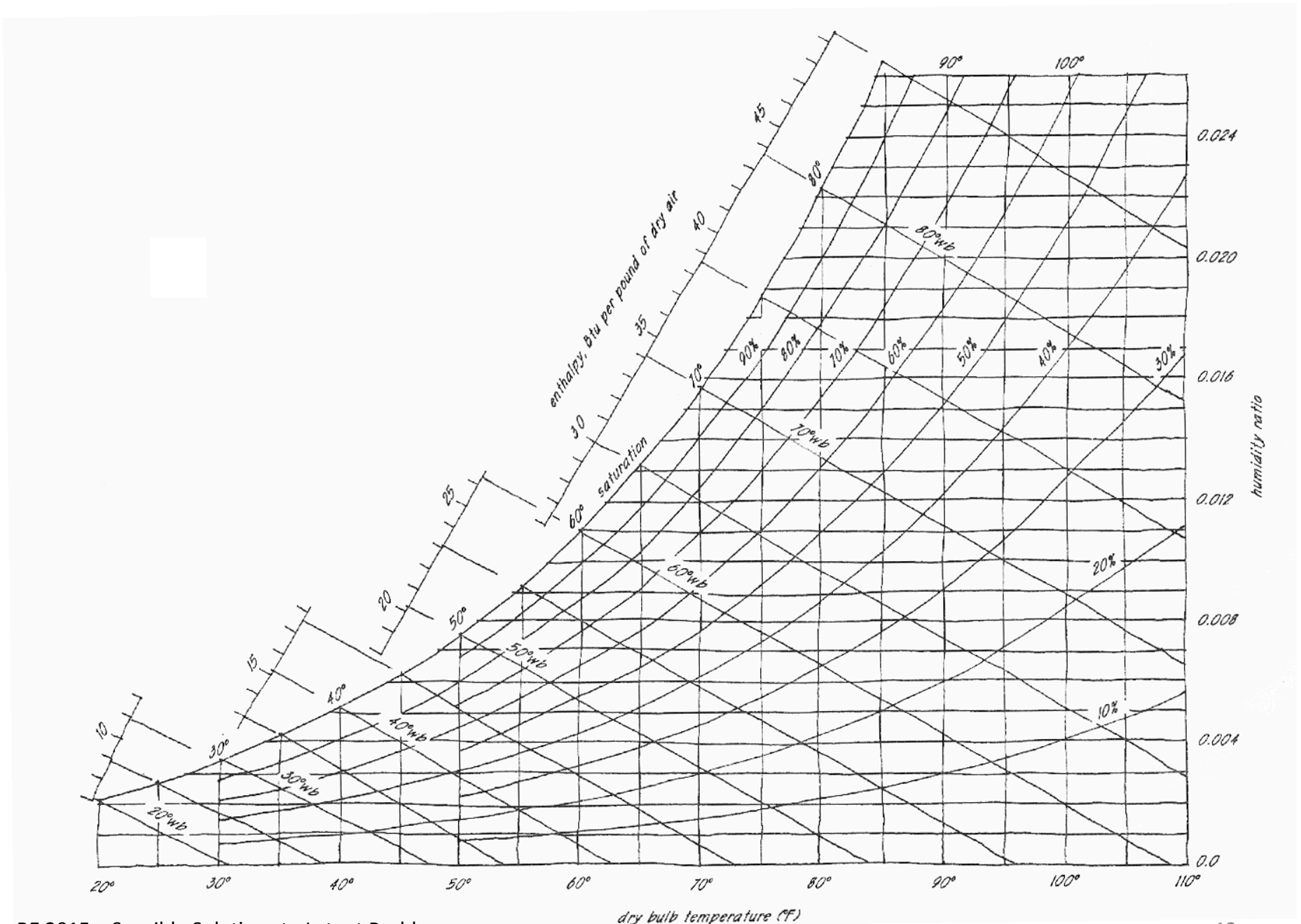

Humidity Ratio (lbs water per lb air)
enthalpy, Btu per pound of dry air
saturation
humidity ratio
dry bulb temperature (°F)
Wet Bulb Temperature = 70°F
Wet Bulb Temperature = 60°F
Wet Bulb Temperature = 50°F
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
0.024
0.020
0.016
0.012
0.008
0.004
0.0

Psychrometric Chart



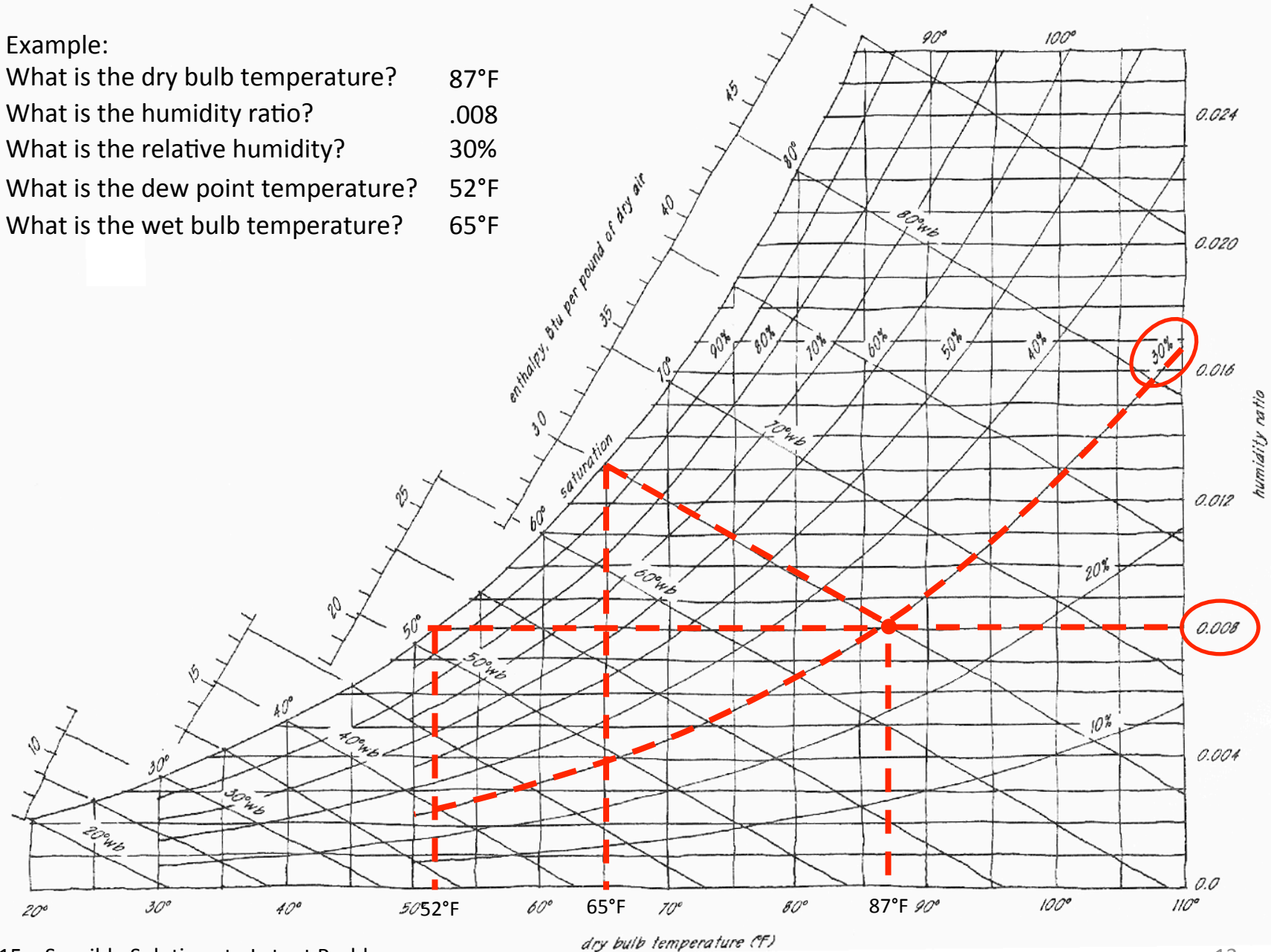

Humidity Ratio (lbs water per lb air)
Dew Point Temperature = 60°F
60
Temperature (°F)


Humidity Ratio (lbs water per lb air)
Temperature (°F)
enthalpy, Btu per pound of dry air
saturation
humidity ratio
Dew Point Temperature = 70°F
Dew Point Temperature = 60°F
Dew Point Temperature = 50°F
0.024
0.020
0.016
0.012
0.008
0.004
0.0
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°


enthalpy, Btu per pound of dry air
humidity ratio
dry bulb temperature (°F)
saturation
10
15
20
25
30
35
40
45
0.024
0.020
0.016
0.012
0.008
0.004
0.0
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
90%
80%
70%
60%
50%
40%
30%
20%
10%
80°wb
70°wb
60°wb
50°wb
40°wb
30°wb
20°wb

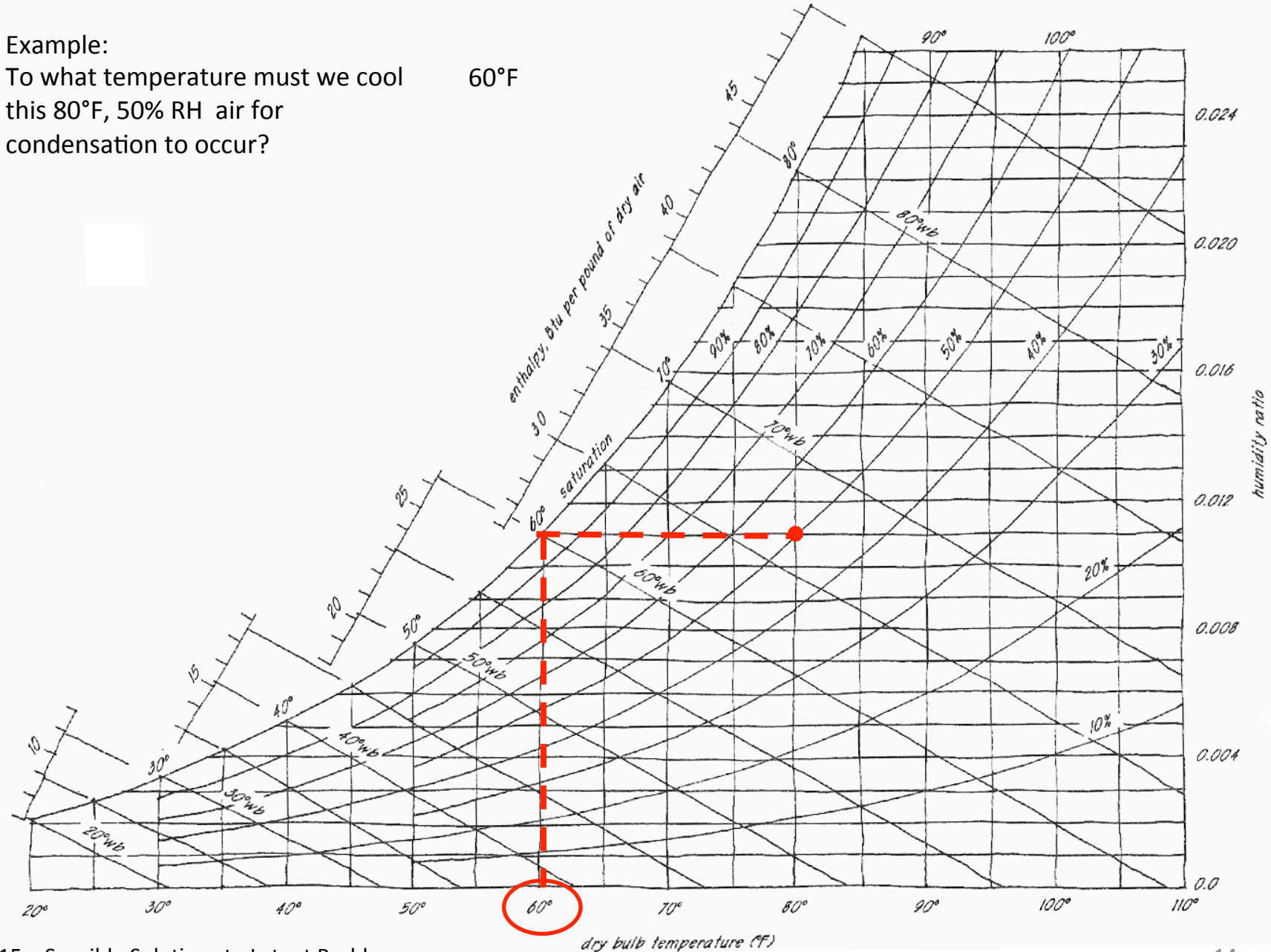
Example:

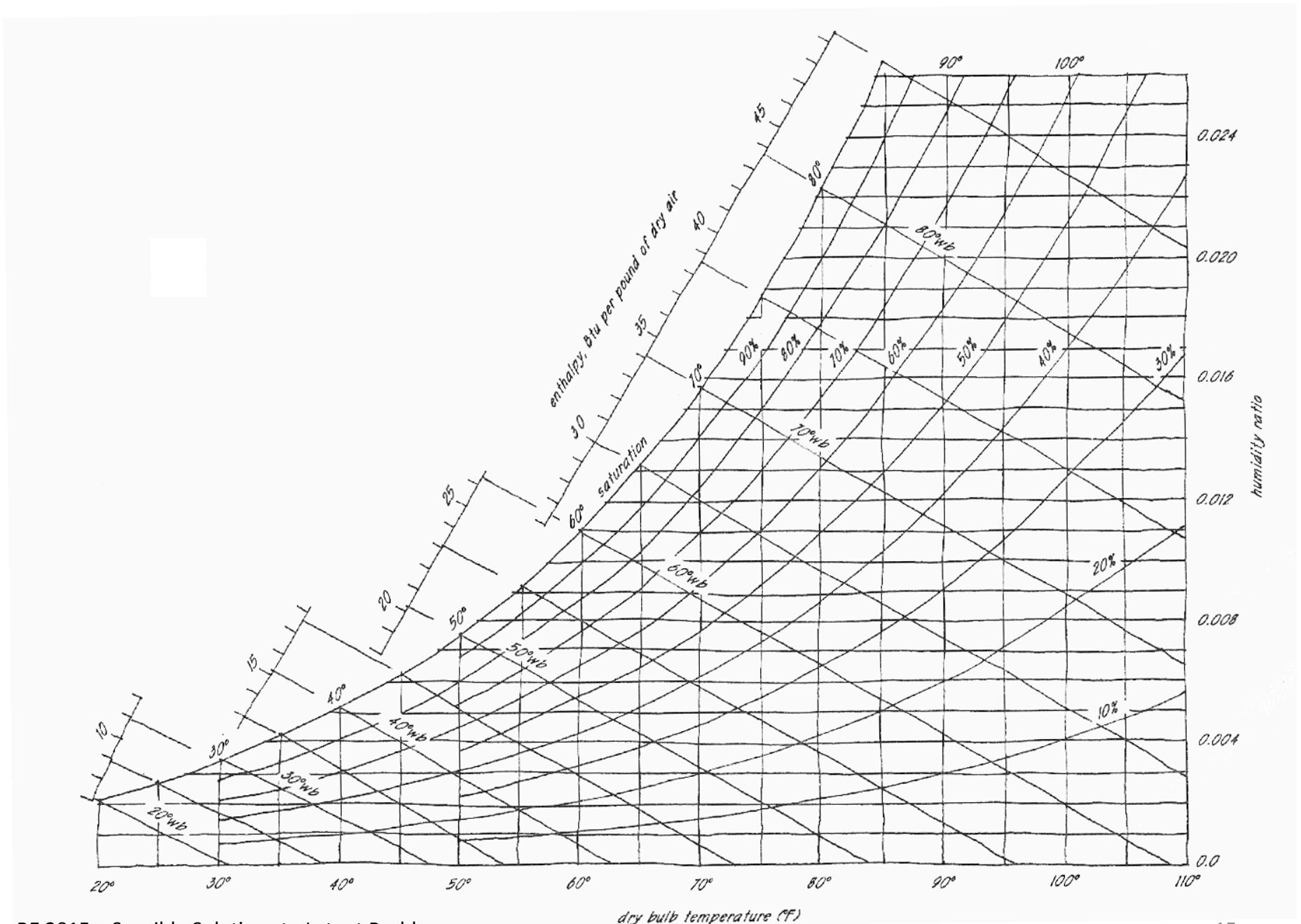
What is the dry bulb temperature?	87°F
What is the humidity ratio?	.008
What is the relative humidity?	30%
What is the dew point temperature?	52°F
What is the wet bulb temperature?	65°F



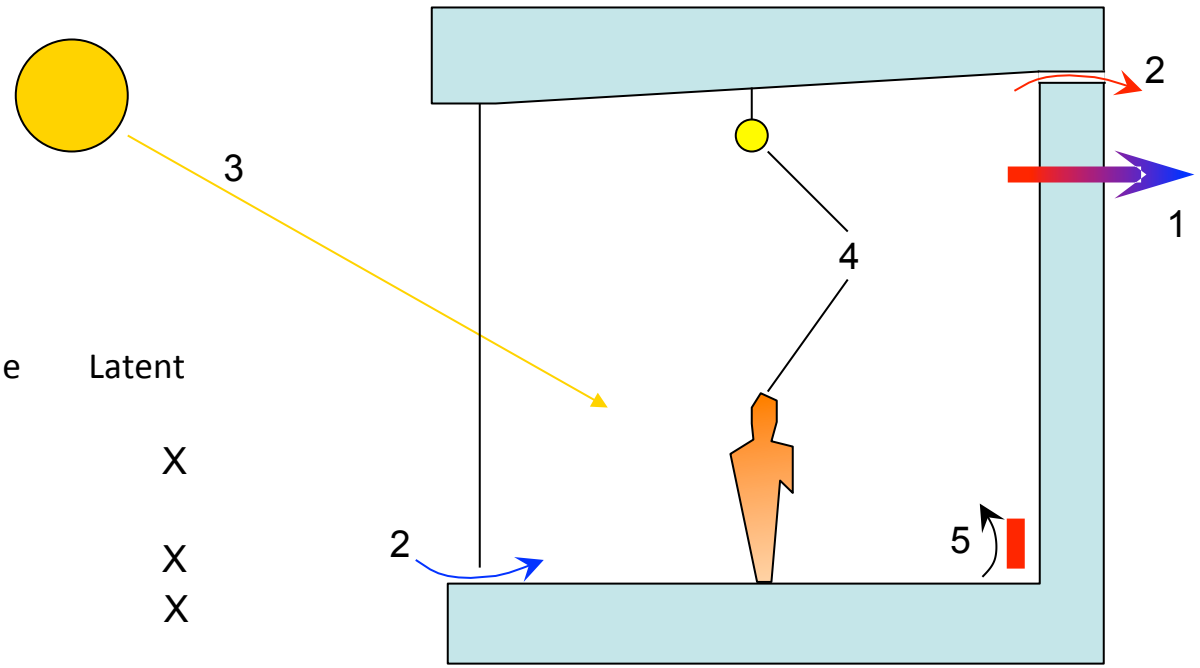
Example:
To what temperature must we cool this 80°F, 50% RH air for condensation to occur?

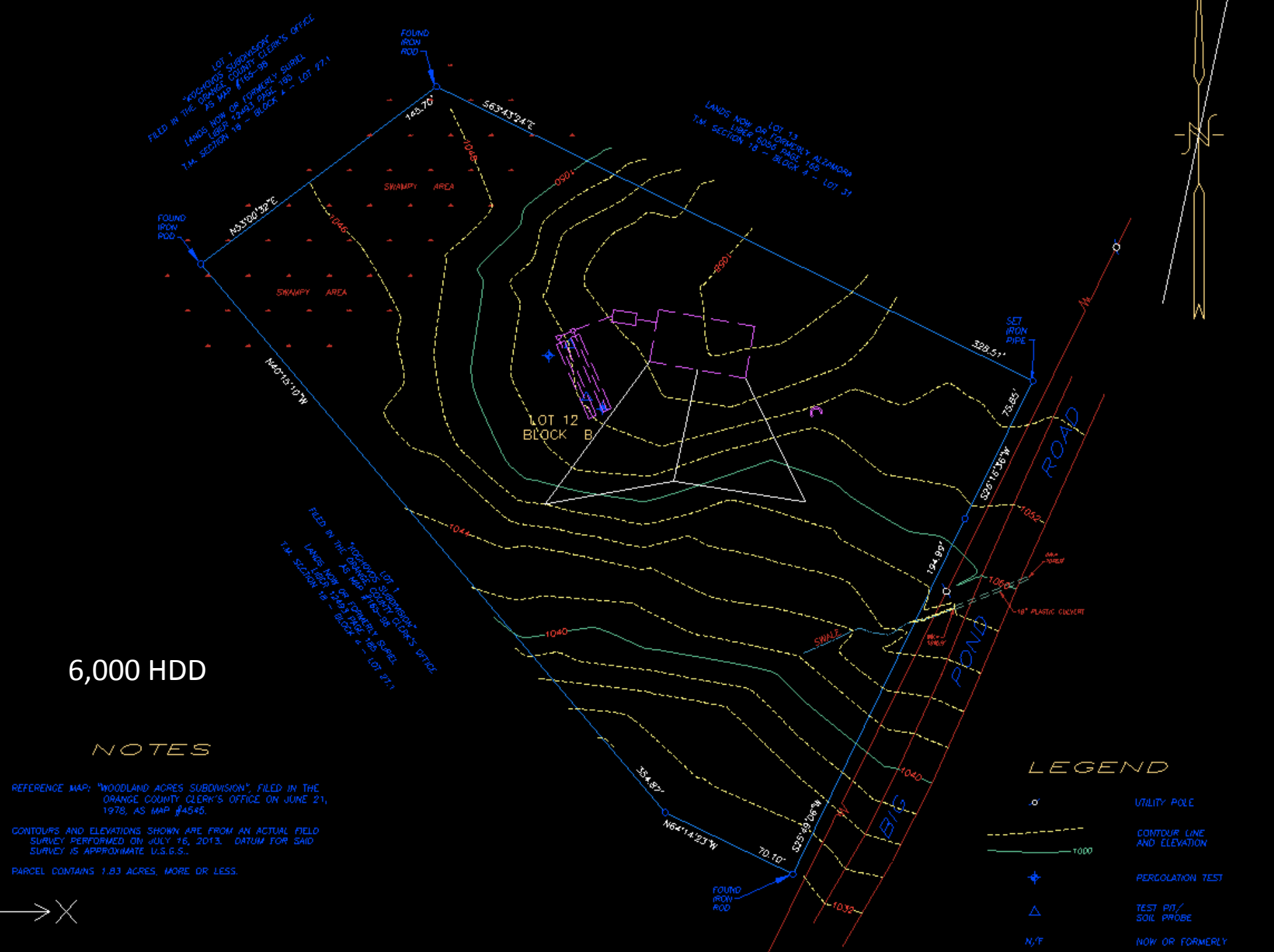
60°F




enthalpy, Btu per pound of dry air
humidity ratio
dry bulb temperature (°F)
saturation
10
15
20
25
30
35
40
45
0.024
0.020
0.016
0.012
0.008
0.004
0.0
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
90%
80%
70%
60%
50%
40%
30%
20%
10%
80°wb
70°wb
60°wb
50°wb
40°wb
30°wb
20°wb

		Sensible	Latent
1	Transmission	X	
2	Infiltration/Ventilation	X	X
3	Solar Gain	X	
4	Internal Gain	X	X
5	Artificial Heating/Cooling	X	X





6,000 HDD

NOTES

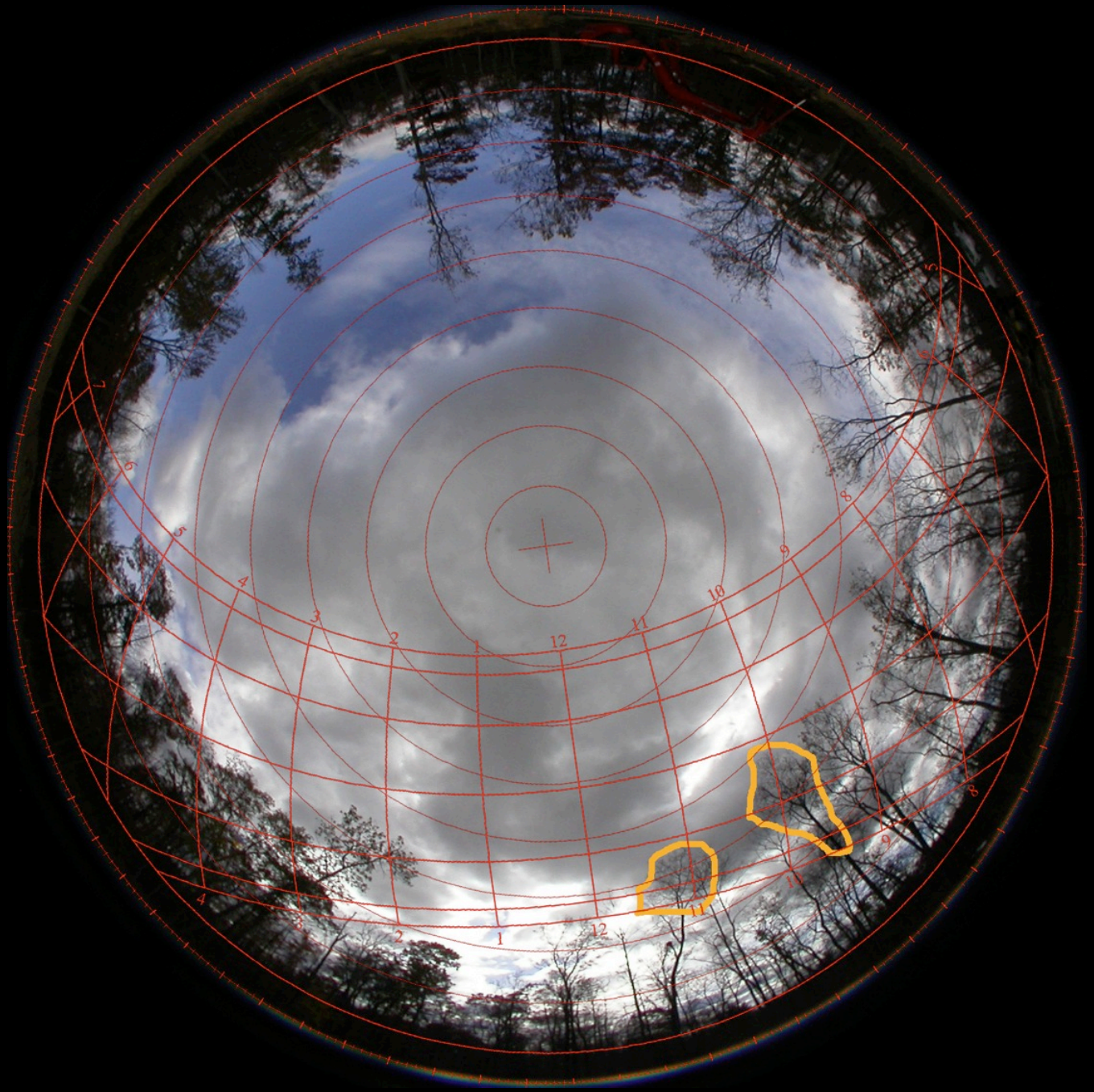
REFERENCE MAP: "WOODLAND ACRES SUBDIVISION", FILED IN THE ORANGE COUNTY CLERK'S OFFICE ON JUNE 21, 1978, AS MAP #4545.

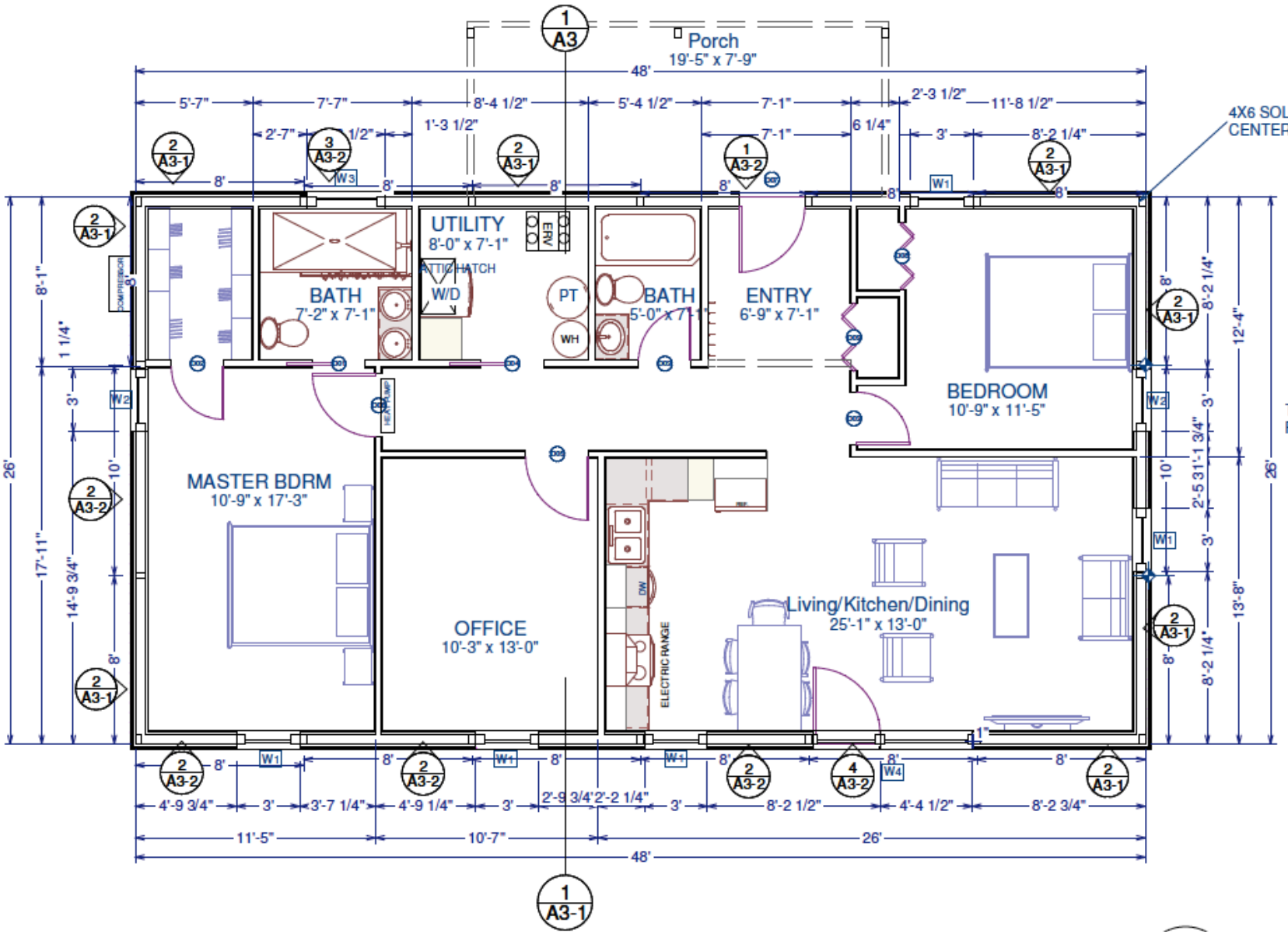
CONTOURS AND ELEVATIONS SHOWN ARE FROM AN ACTUAL FIELD SURVEY PERFORMED ON JULY 16, 2013. DATUM FOR SAID SURVEY IS APPROXIMATE U.S.G.S..

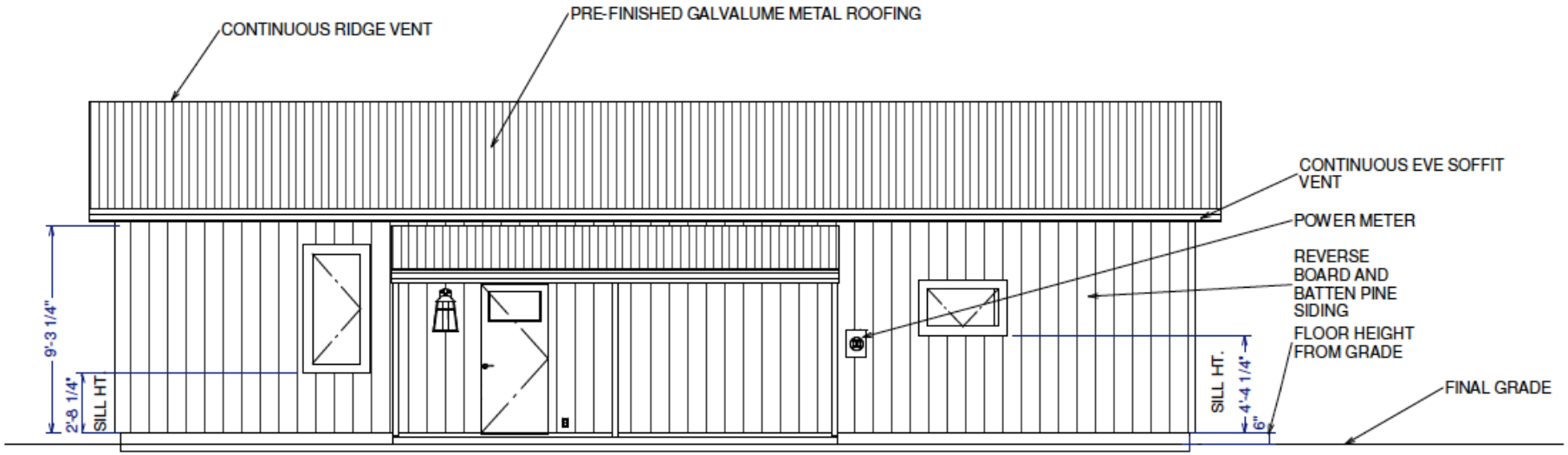
PARCEL CONTAINS 1.83 ACRES, MORE OR LESS.

LEGEND

- UTILITY POLE
- CONTOUR LINE AND ELEVATION
- TODD
- PERCOLATION TEST
- TEST PIT/ SOIL PROBE
- N/F NOW OR FORMERLY

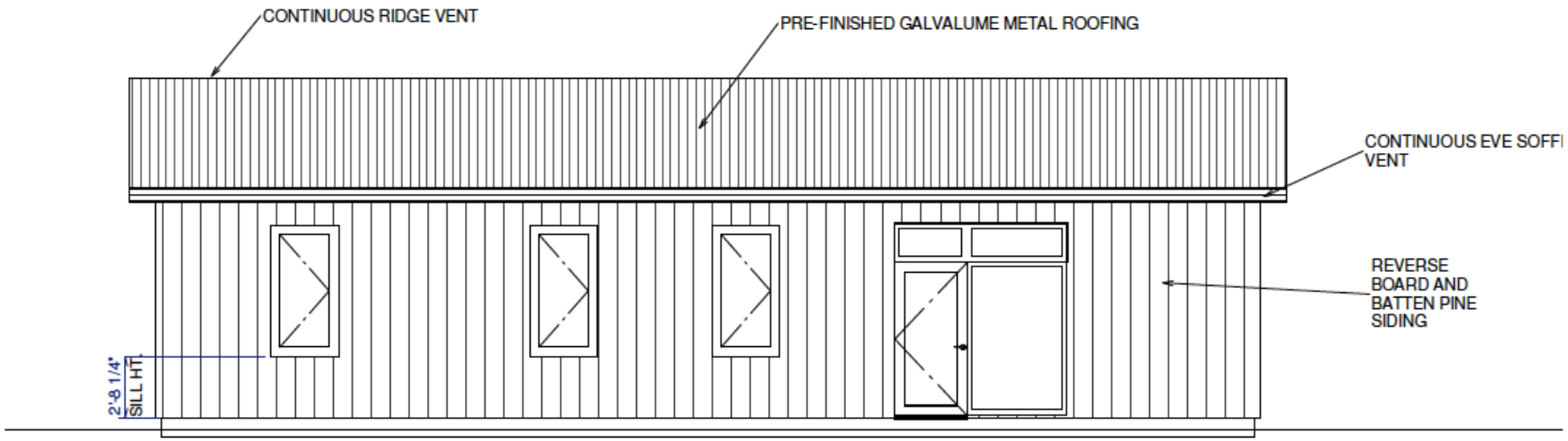

12
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11


Porch
19'-5" x 7'-9"
48'
4X6 SOLID SAWN POSTS 8' ON CENTER OR AS NOTED
UTILITY
8'-0" x 7'-1"
ATTIC HATCH
W/D
ERV
BATH
7'-2" x 7'-1"
PT
WH
BATH
5'-0" x 7'-1"
ENTRY
6'-9" x 7'-1"
BEDROOM
10'-9" x 11'-5"
MASTER BDRM
10'-9" x 17'-3"
OFFICE
10'-3" x 13'-0"
Living/Kitchen/Dining
25'-1" x 13'-0"
ELECTRIC RANGE
DW
HEAT PUMP
TOTAL SQUARE FOOTAGE: 1248



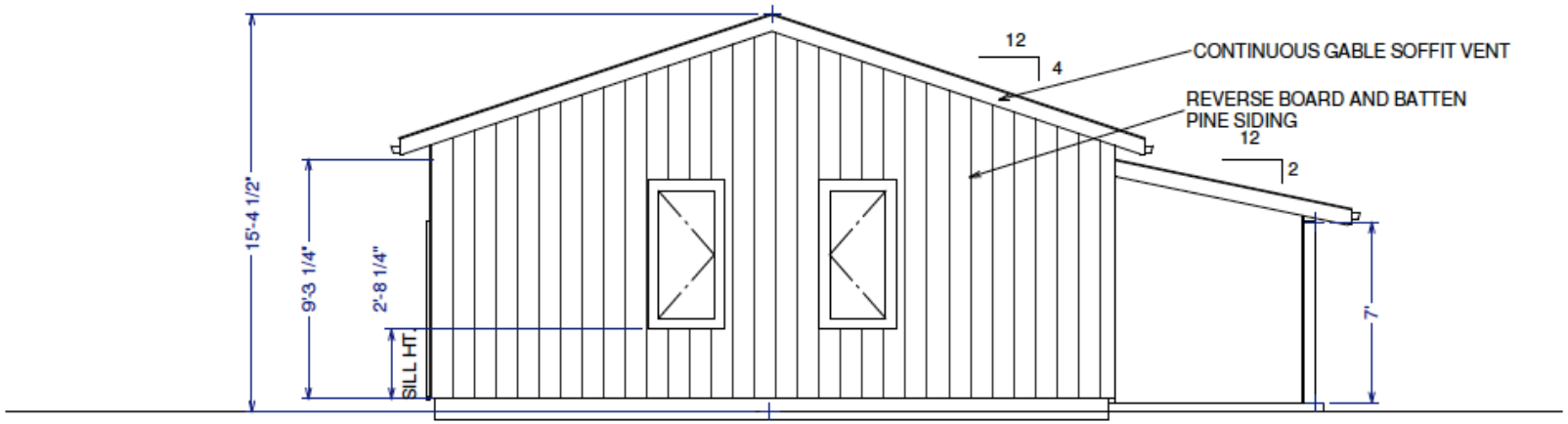
1 / A4-1 NORTH ELEVATION
SCALE: 3/16" = 1'

N glazing 1.3% of GFA



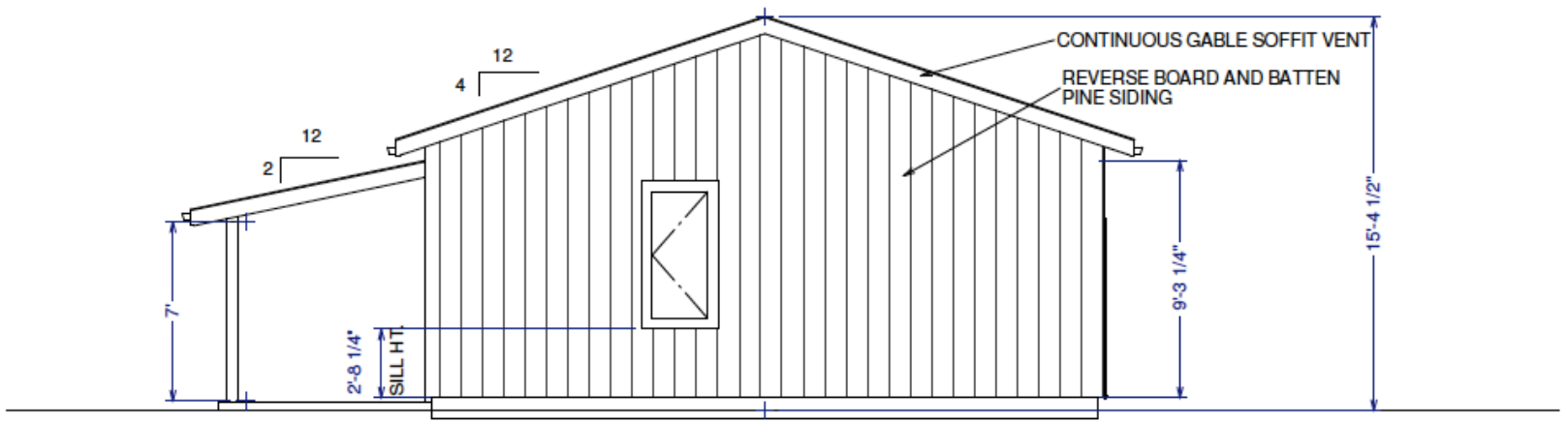
2 / A4-1 SOUTH ELEVATION
SCALE: 3/16" = 1'

S glazing 6.3% of GFA



1 / A4-2 EAST ELEVATION
SCALE: 3/16" = 1'

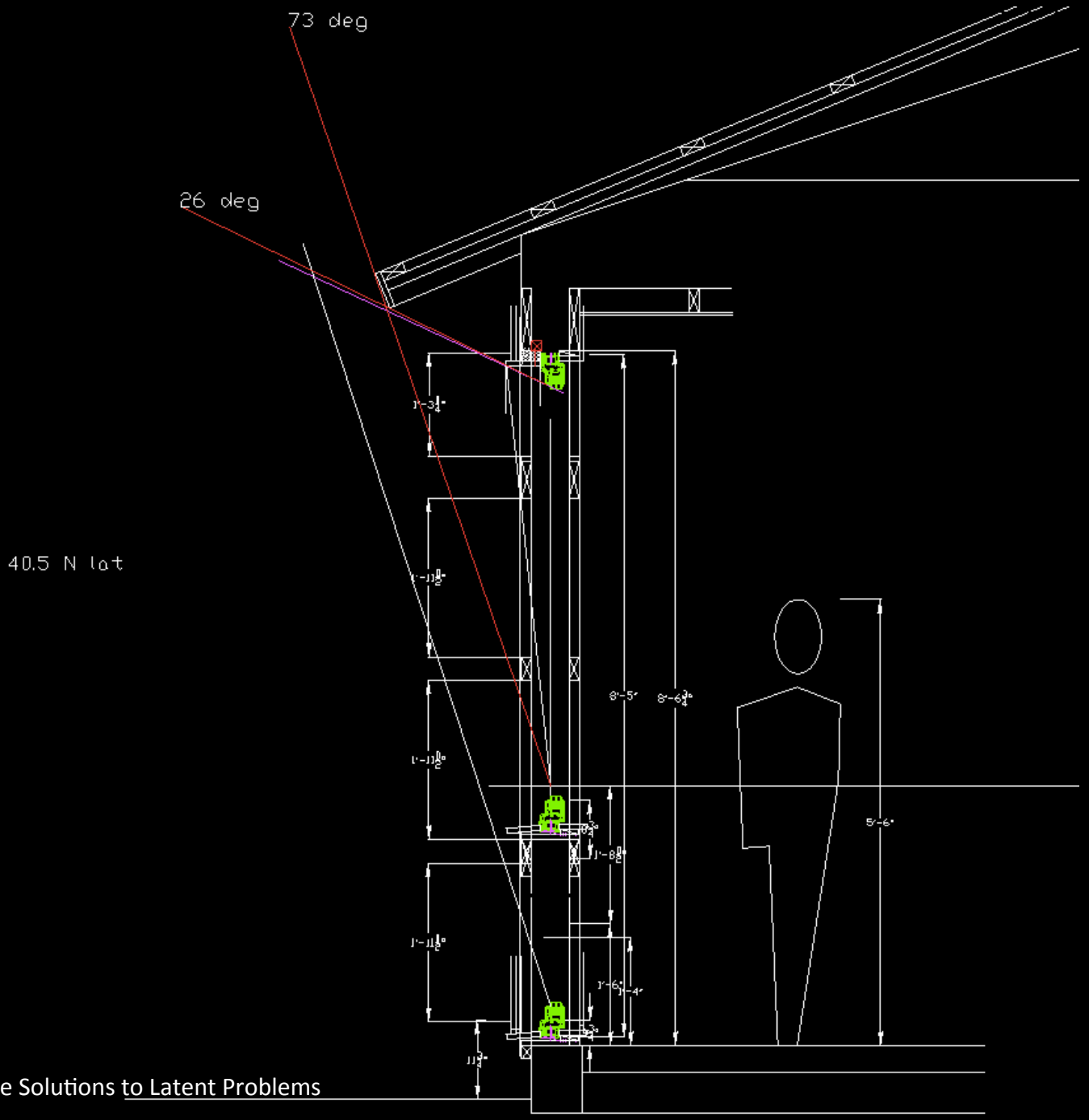
E glazing 1.7% of GFA

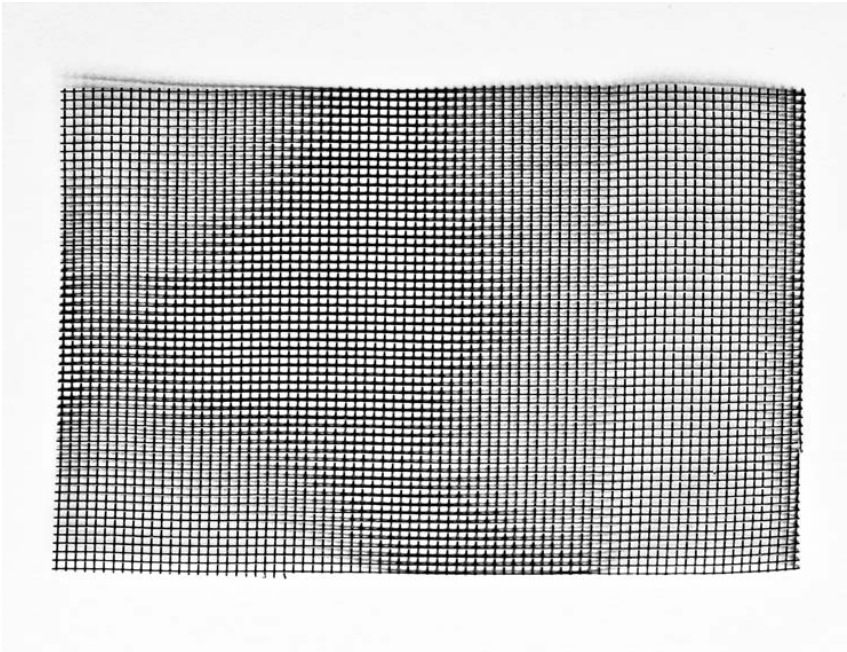


2 / A4-2 WEST ELEVATION
SCALE: 3/16" = 1'

W glazing 0.9% of GFA

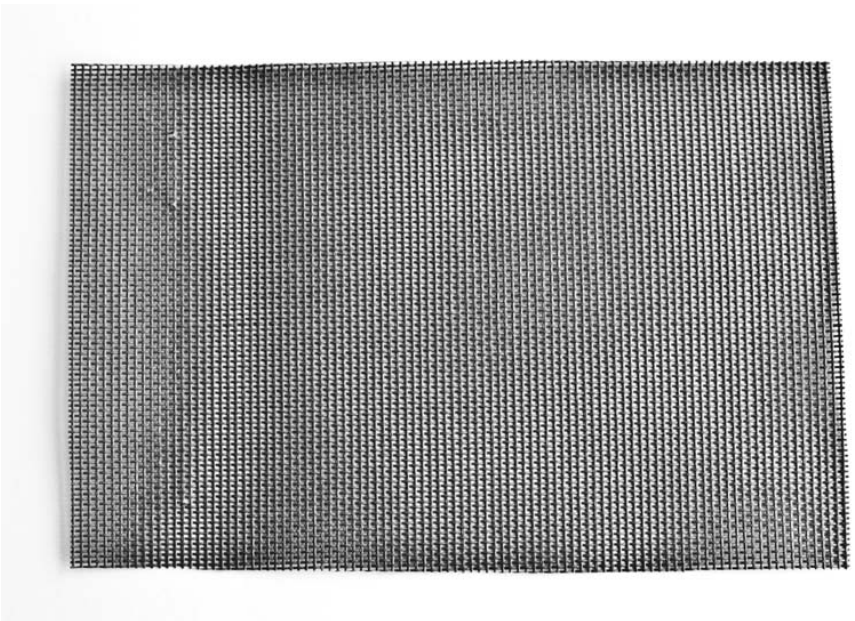
Total glazing 10% of GFA


73 deg
26 deg
40.5 N lat
8'-5"
5'-6"



STANDARD MESH

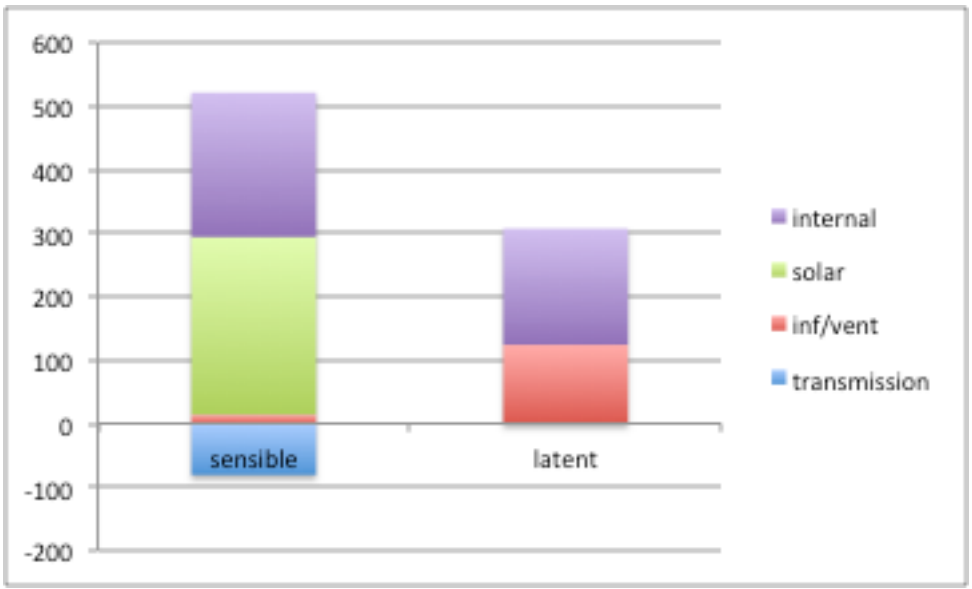
SHGC reduction factor 33%



THERMO MESH

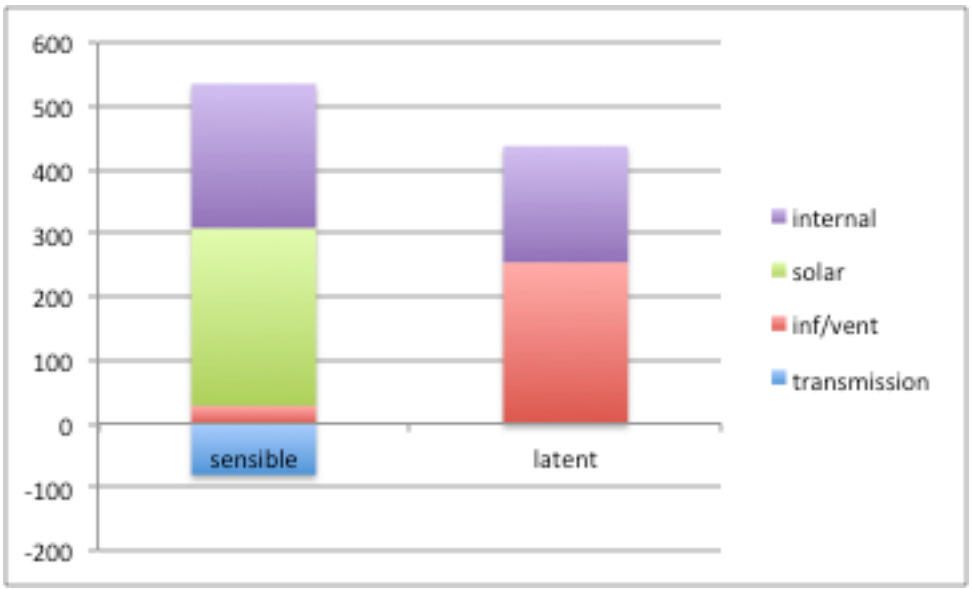
SHGC reduction factor 64%

Base Case SHF = 0.59



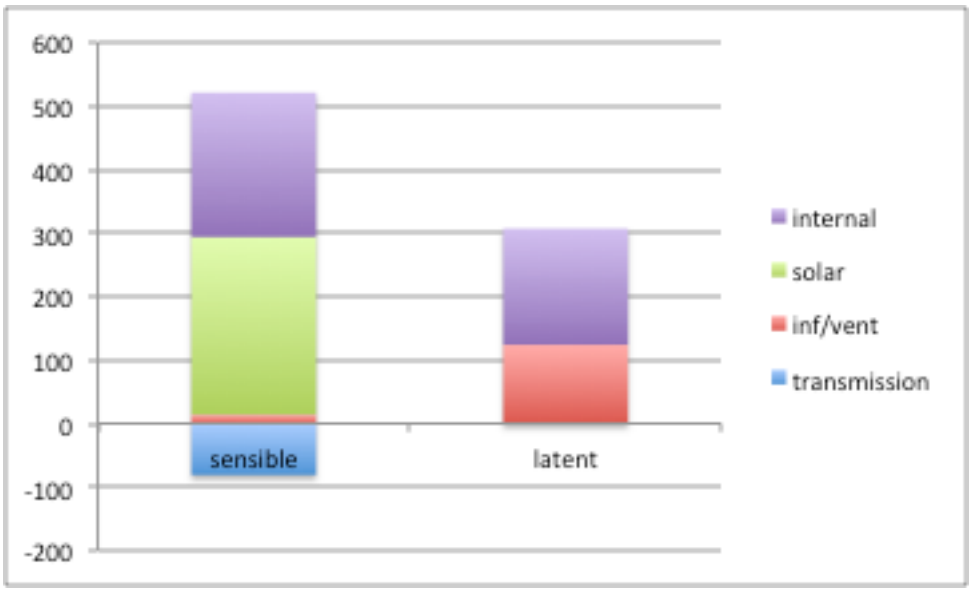
42 cfm vent, 0.5 ach50, 0.5 SHGC glass

Leaky House SHF = 0.51



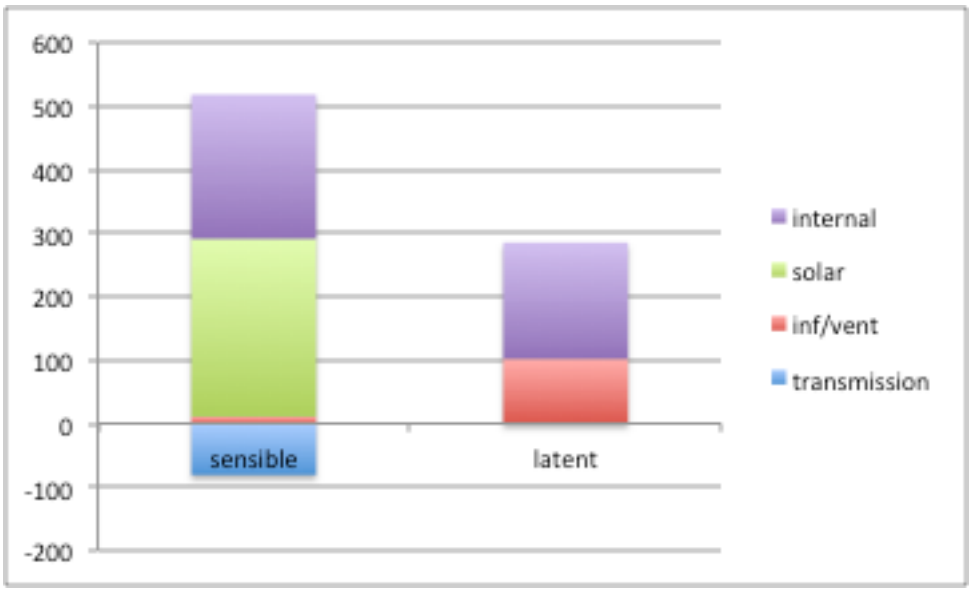
2 ach50

Base Case SHF = 0.59



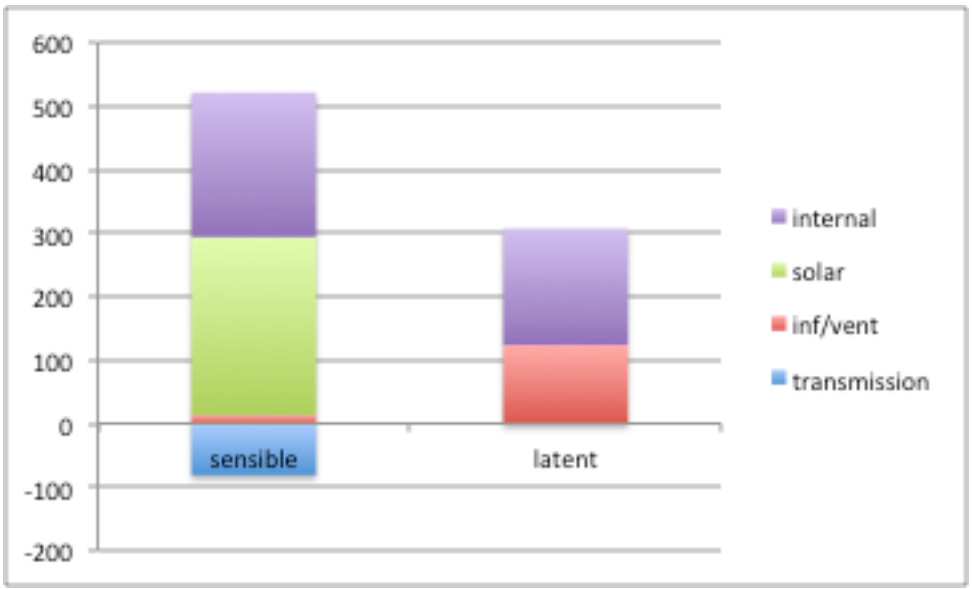
42 cfm vent, 0.5 ach50, 0.5 SHGC glass, 77%/62% ERV

Crazy Tight House SHF = 0.61



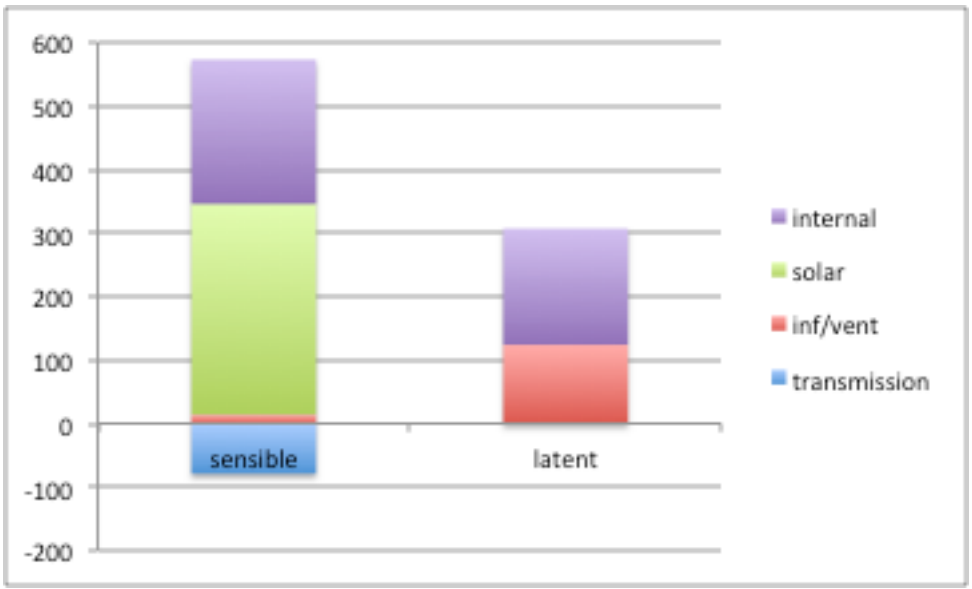
0.25 ach50

Base Case SHF = 0.59



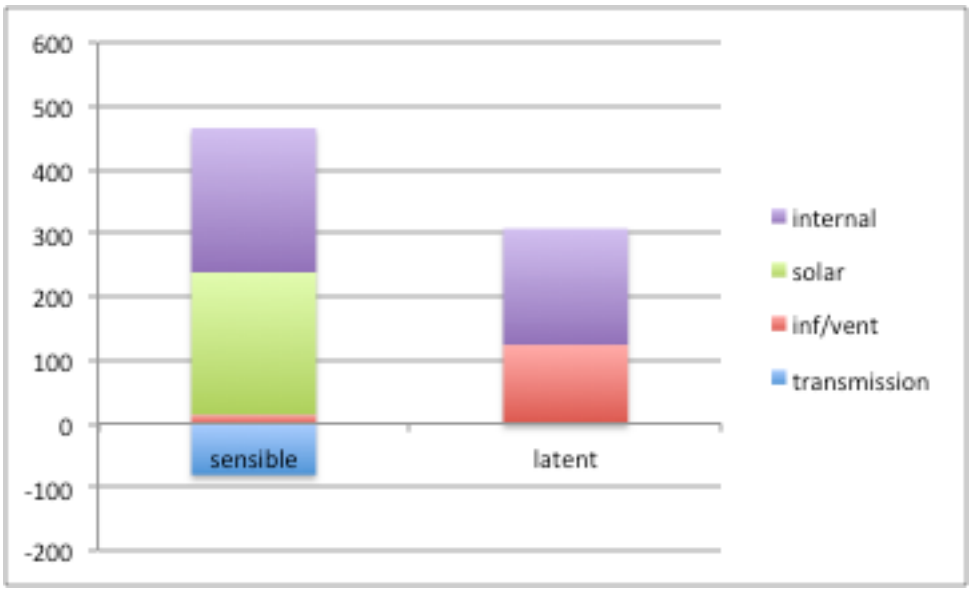
42 cfm vent, 0.5 ach50, 0.5 SHGC glass, 77%/62% ERV

High Gain Glass SHF = 0.62



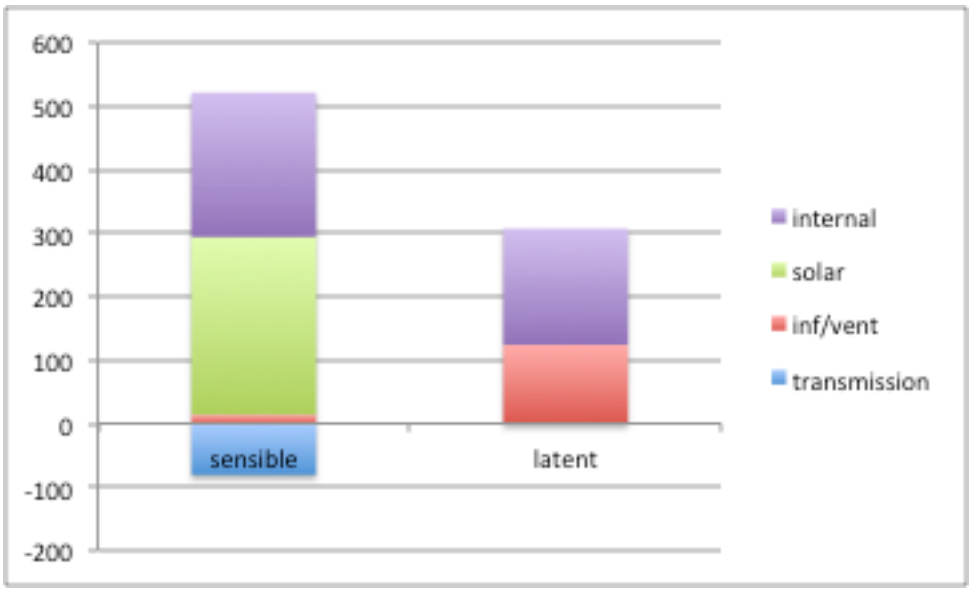
SHGC = 0.62

Low Gain Glass SHF = 0.56



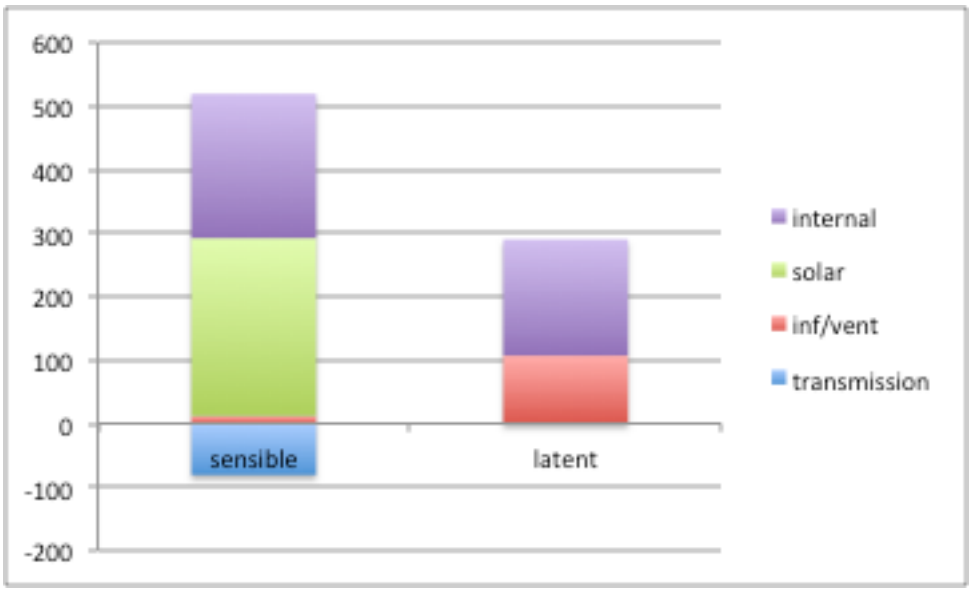
SHGC = 0.37

Base Case SHF = 0.59



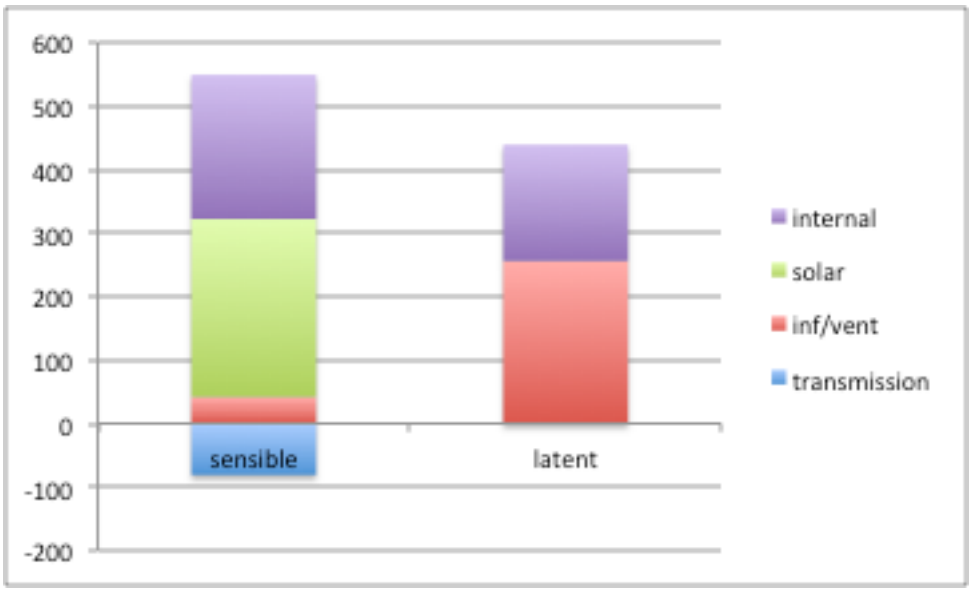
42 cfm vent, 0.5 ach50, 0.5 SHGC glass, 77%/62% ERV

Vent to ASHRAE 62.2-2010 SHF = 0.60



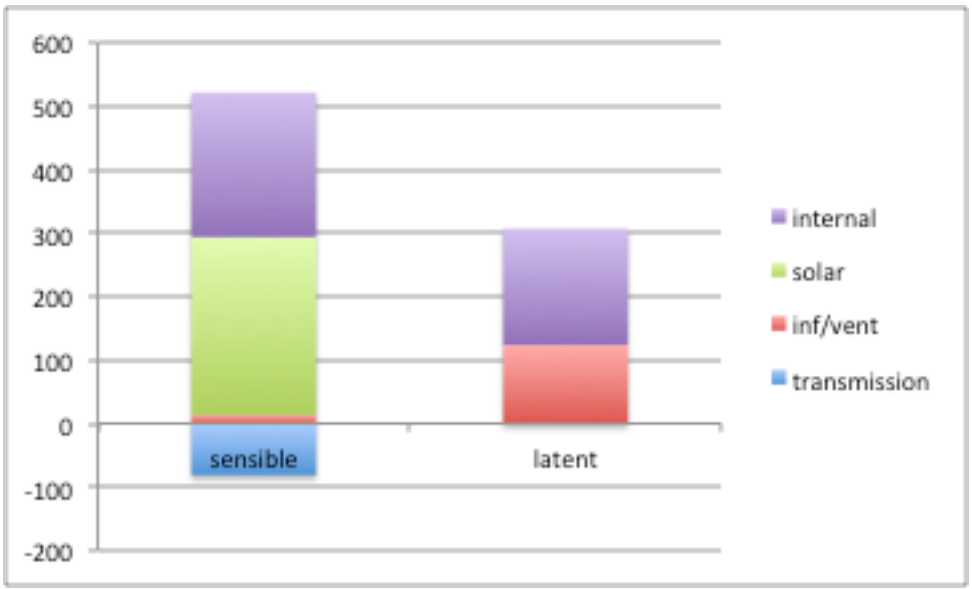
35 cfm ventilation

Vent to ASHRAE 62.2-2013 SHF = 0.57



60 cfm ventilation

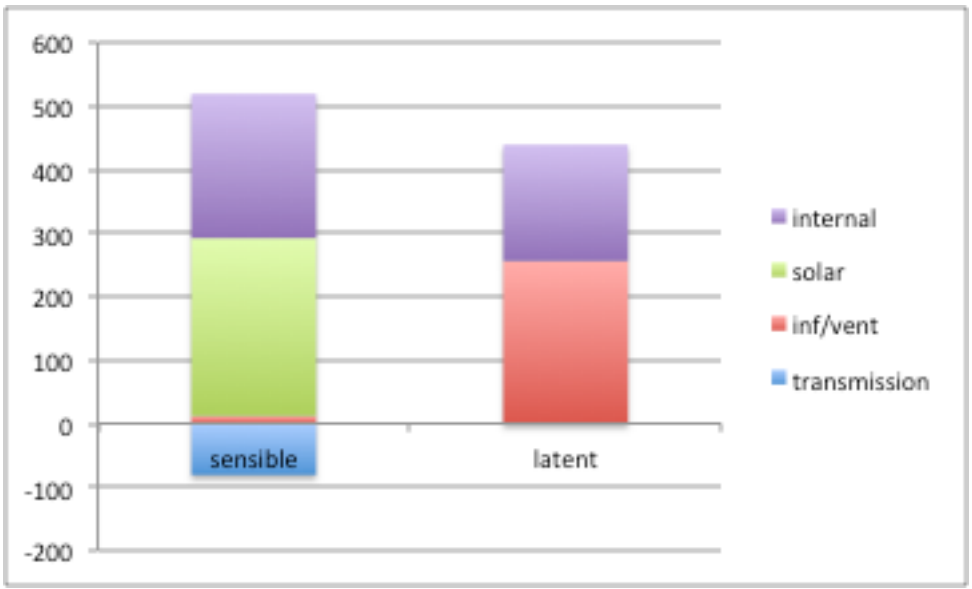
Base Case SHF = 0.59



42 cfm vent, 0.5 ach50, 0.5 SHGC glass, 77%/62% ERV

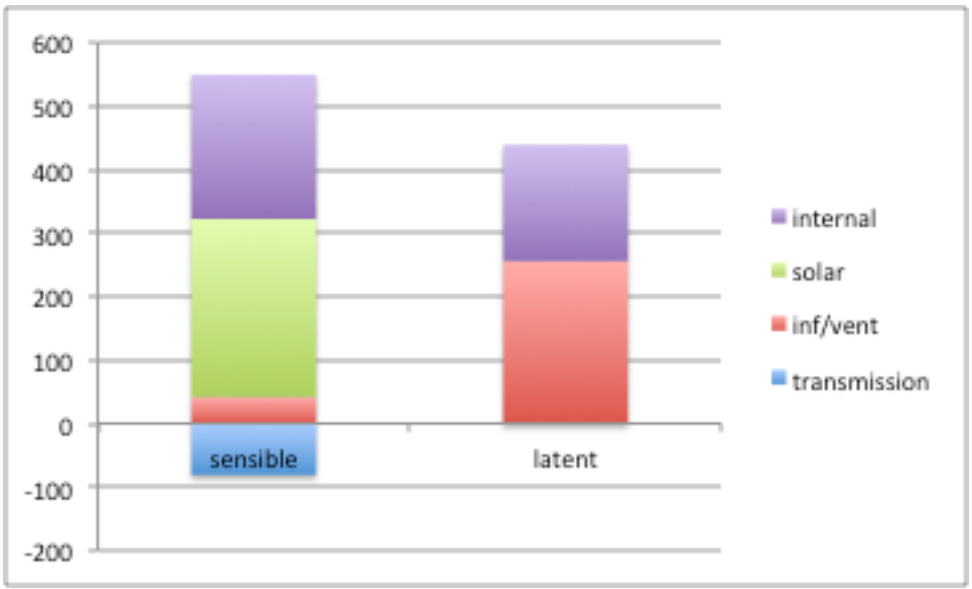
HRV

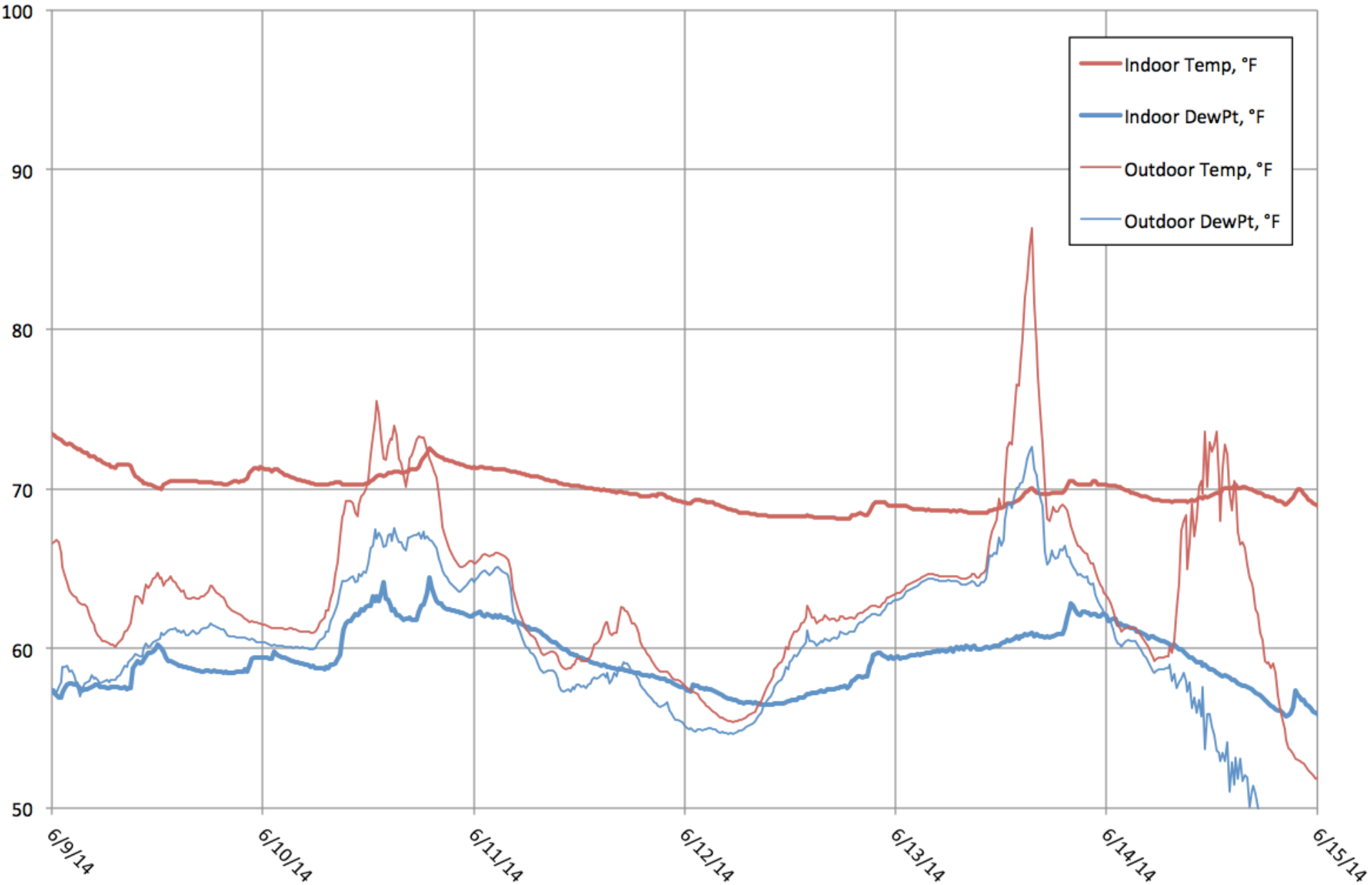
SHF = 0.50

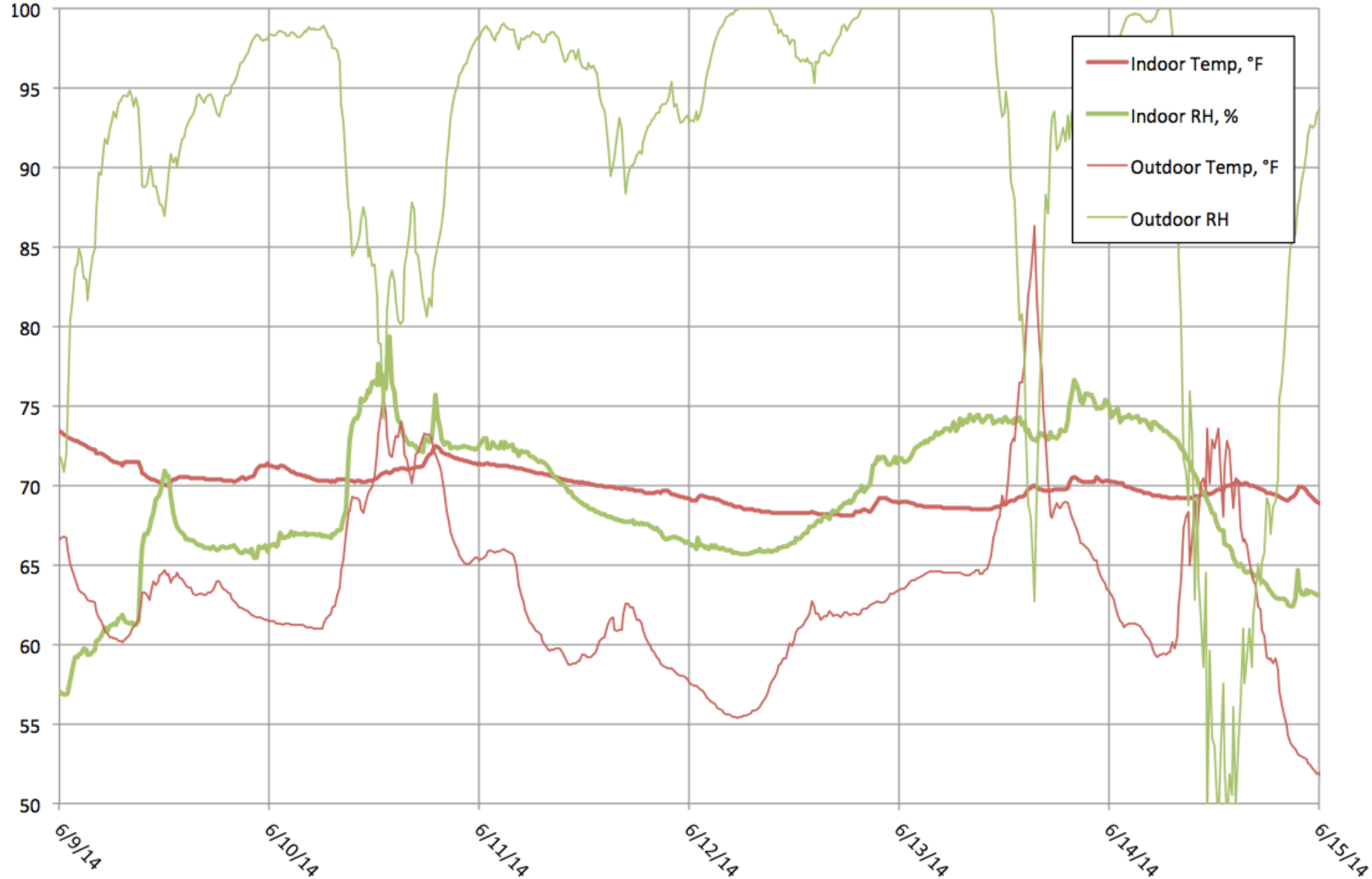


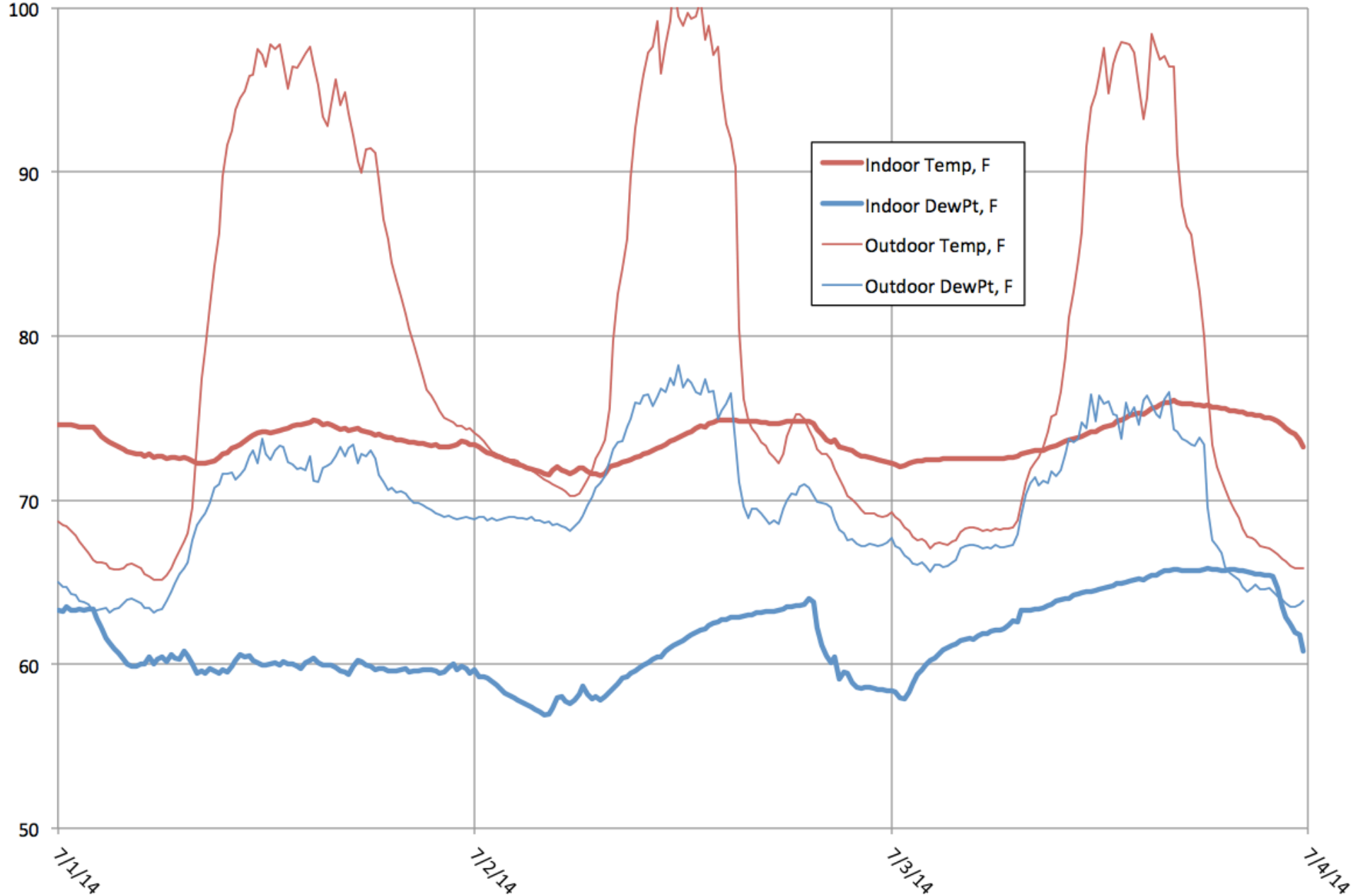
Eff = 84%

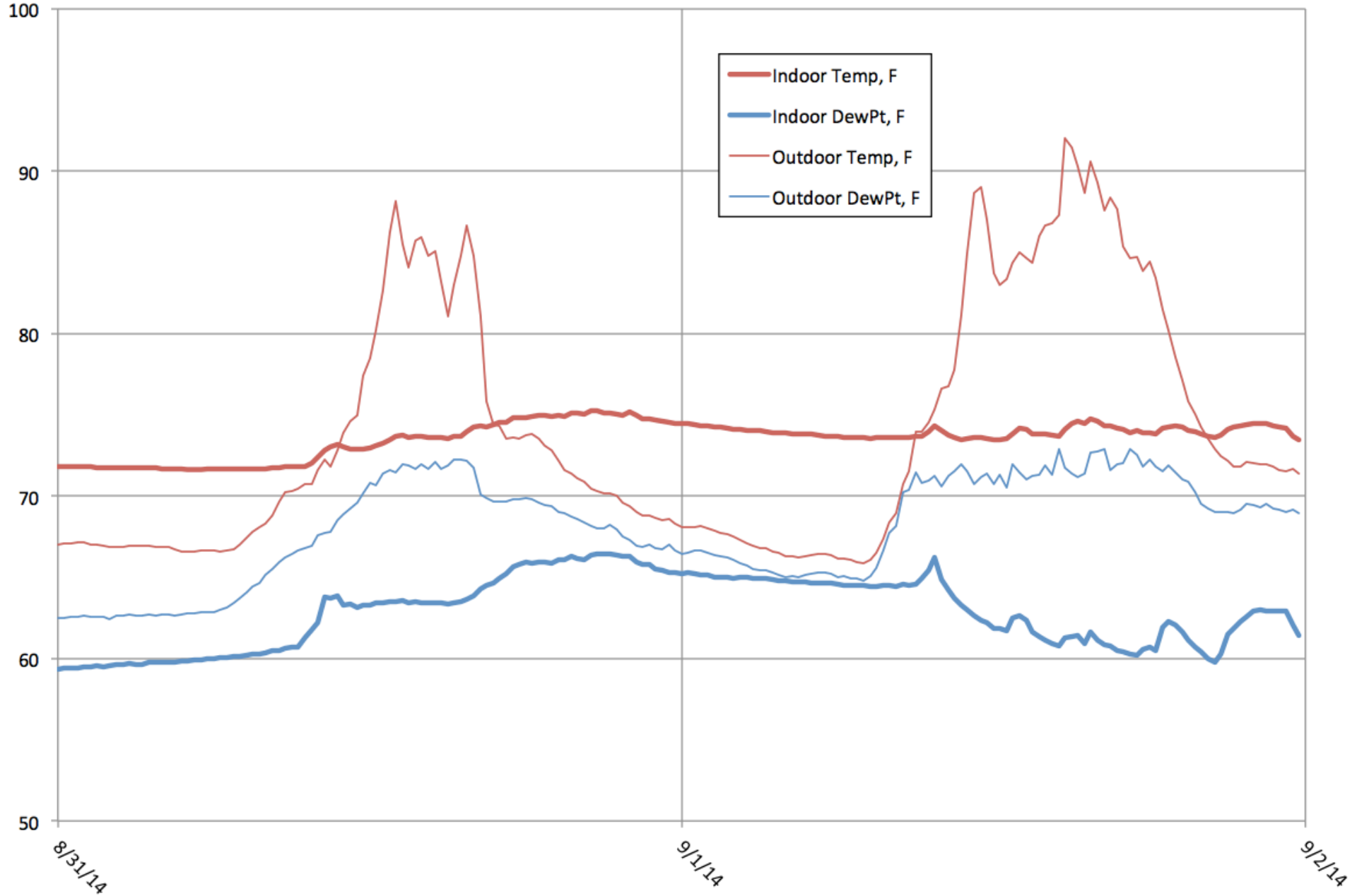
No HRV or ERV (as operated) SHF = 0.52




100
90
80
70
60
50
Indoor Temp, °F
Indoor DewPt, °F
Outdoor Temp, °F
Outdoor DewPt, °F
6/9/14
6/10/14
6/11/14
6/12/14
6/13/14
6/14/14
6/15/14


100
95
90
85
80
75
70
65
60
55
50
6/9/14
6/10/14
6/11/14
6/12/14
6/13/14
6/14/14
6/15/14
Indoor Temp, °F
Indoor RH, %
Outdoor Temp, °F
Outdoor RH


100
90
80
70
60
50
Indoor Temp, F
Indoor DewPt, F
Outdoor Temp, F
Outdoor DewPt, F
7/1/14
7/2/14
7/3/14
7/4/14


100
90
80
70
60
50
Indoor Temp, F
Indoor DewPt, F
Outdoor Temp, F
Outdoor DewPt, F
8/31/14
9/1/14
9/2/14

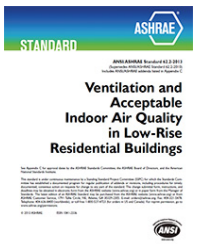
Conclusions

- Humidity can probably be controlled in above-grade, low-load homes in the Northeast without the need for a dehumidifier
- Climate may become more humid in coming decades

Ventilation: How much air do we need?

Depends upon who you ask…

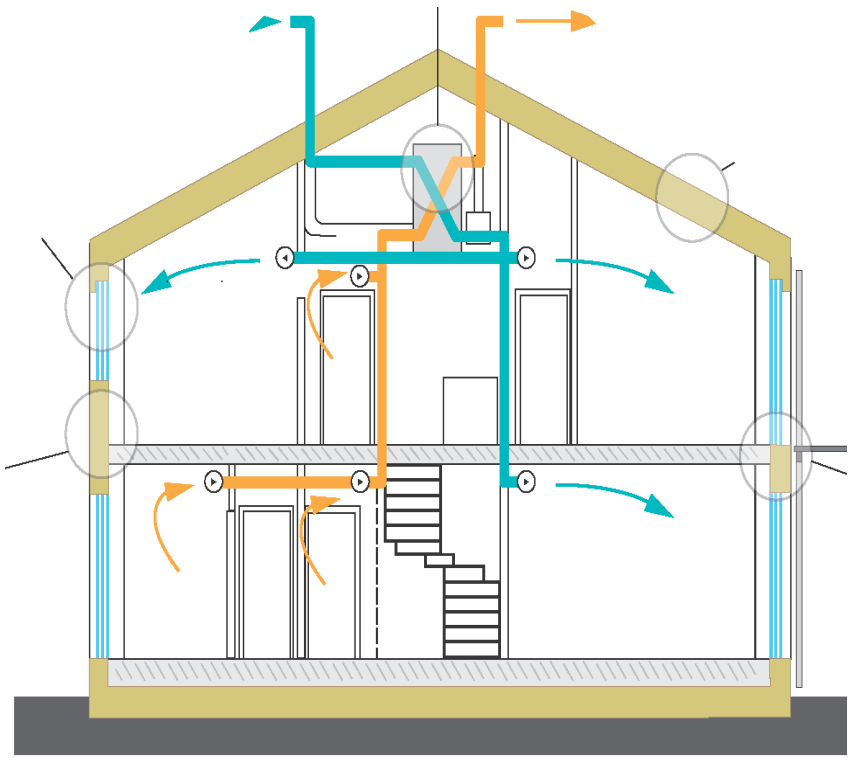
International Mechanical Code (IMC) 2012



ASHRAE Standard 62.2
Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings
2010 Version and 2013 Version

Passive House Institute (PHI)

Example House for Ventilation



2,600 SF (2,400 TFA for PHI)
8 FT Ceilings
4 bedrooms
2-1/2 Bathrooms

IMC 2012 Airflow

Referenced by the International Residential Code (IRC)
Adopted by all Northeast states except Vermont

0.35 Air Changes per Hour (ACH)
- But not less than 15 CFM per person
Kitchen exhaust: 25 CFM continuous
Bathroom exhaust: 20 CFM continuous
Toilet room exhaust: 20 CFM continuous

2600SF * 8FT = 20,800 CF at 0.35 ACH **121 CFM**

Kitchen + 2 Bathrooms + Toilet Room **85 CFM**

ASHRAE Standard 62.2-2010 Airflow

Referenced by LEED for Homes, EnergyStar, Mass Tier III Program
Tends to lead the IMC

7.5 CFM per person (number of bedrooms +1)
AND 0.01 CFM/SF
Kitchen exhaust: 5 ACH continuous (!)
or 100 CFM intermittent hood
Bathroom exhaust: 20 CFM continuous

Bathroom: Any room containing a bathtub, a shower, a spa, or similar source of moisture

7.5(4+1) + 0.01(2600) = **64 CFM**
2 Bathrooms (+ Toilet Room) **40 CFM (60 CFM)**
If assume a modest 150 SF Kitchen **100 CFM !**
- Best to include an intermittent range hood.

ASHRAE Standard 62.2-2013 Airflow

Option for Mass Tier III
Controversial new version of 62.2

7.5 CFM per person (number of bedrooms +1)
AND 0.03 CFM/SF
Kitchen exhaust: 5 ACH continuous (!)
or 100 CFM intermittent hood
Bathroom exhaust: 20 CFM continuous

Bathroom: Any room containing a bathtub, a shower, a spa, or similar source of moisture

7.5(4+1) + 0.03(2600) =	**116 CFM**
2 Bathrooms (+ Toilet Room)	**40 CFM (60 CFM)**
Likely range hood for Kitchen	

Passive House Institute Airflow

Airflows required for a certifying Passive House project

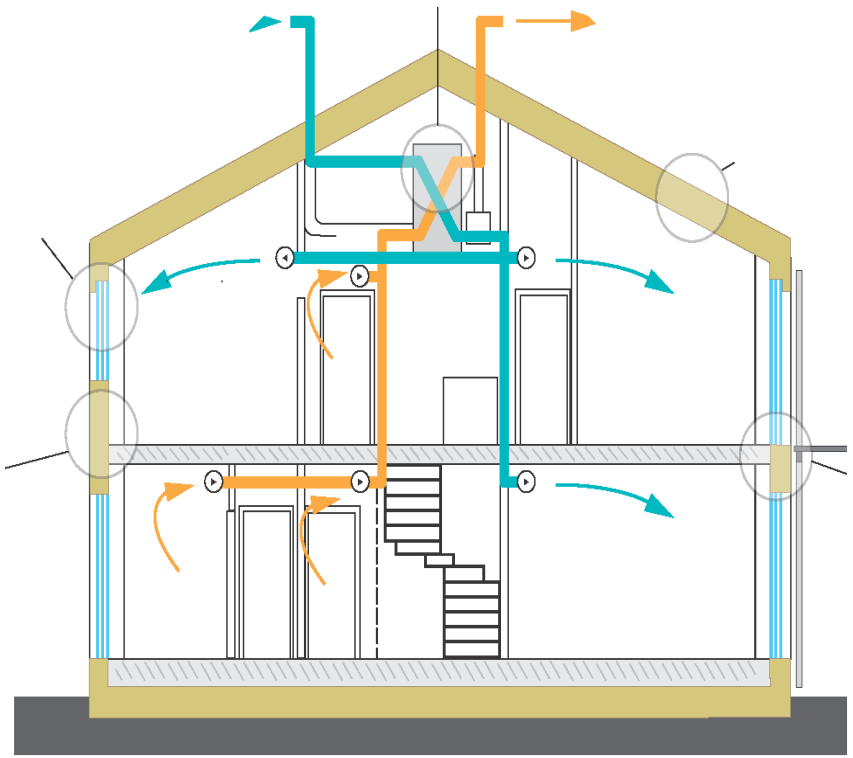
0.30 Air Changes per Hour (ACH) of TFA

Kitchen exhaust:	35 CFM continuous
Bathroom exhaust:	24 CFM continuous
Toilet room exhaust:	12 CFM continuous
Laundry room exhaust:	12 CFM continuous

2400SF * 8FT = 19,200 CF at 0.30 ACH **96 CFM**

Kitchen + 2 Bathrooms + Toilet Room **95 CFM**

Example House for Ventilation



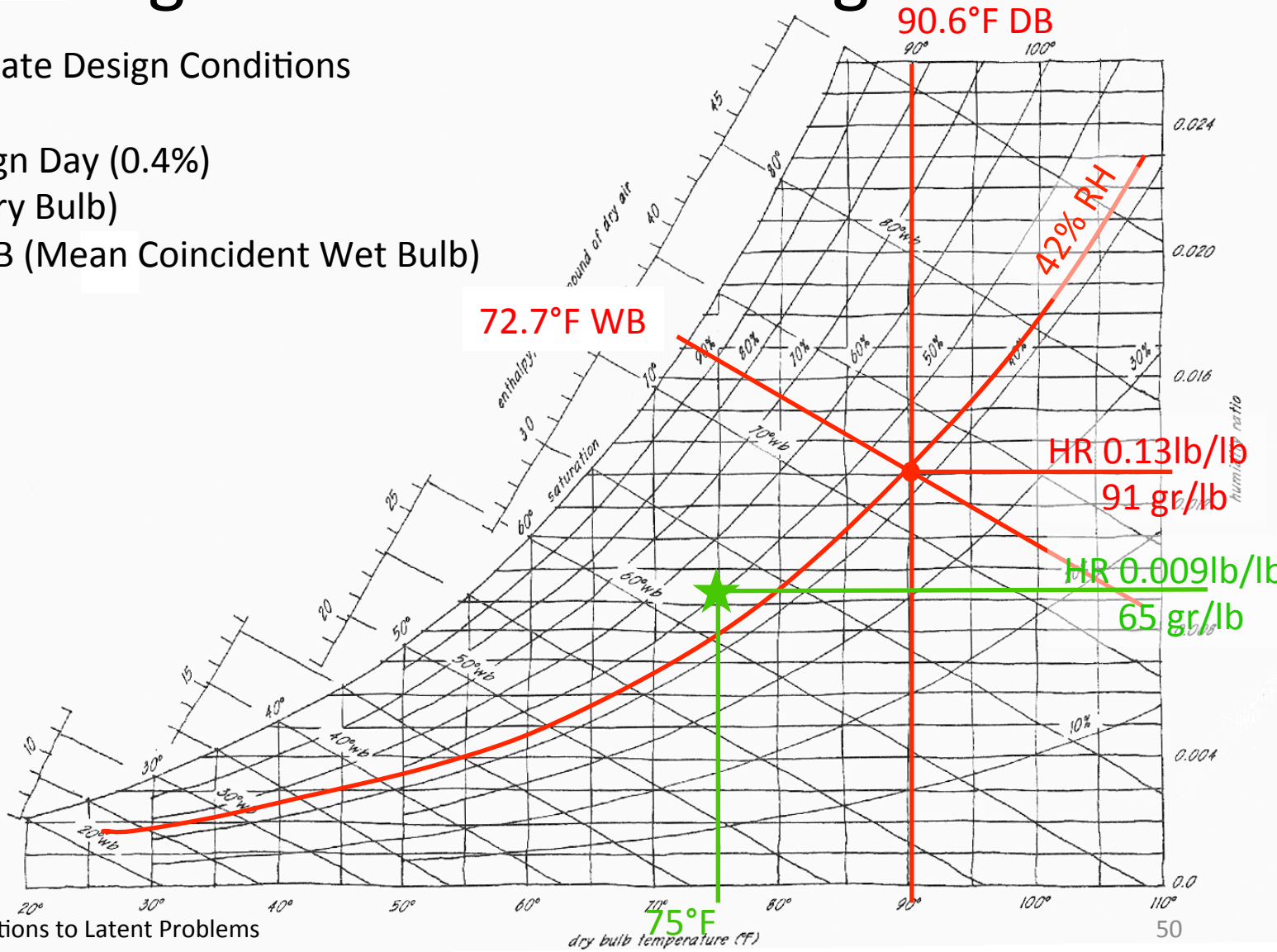
2,600 SF (2,400 TFA for PHI)
8 FT Ceilings
4 bedrooms
2-1/2 Bathrooms

Standard	Supply	Exhaust
IMC	121 CFM	85 CFM
62.2-2010	63 CFM	60 CFM*
62.2-2013	116 CFM	60 CFM*
PHI	96 CFM	95 CFM

* With Intermittent range hood

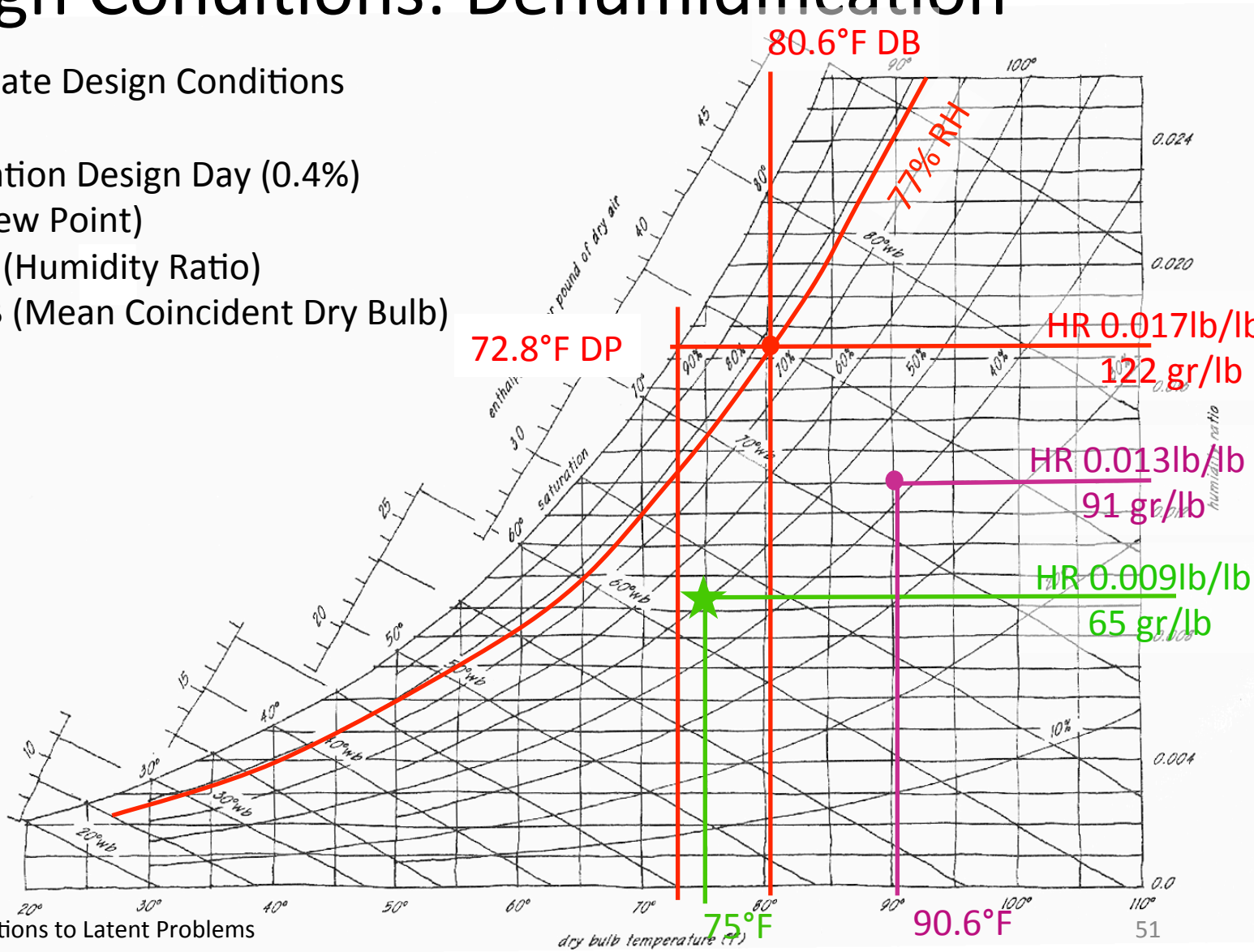
Design Conditions: Cooling

ASHRAE Climate Design Conditions
Boston, MA
Cooling Design Day (0.4%)
90.6°F DB (Dry Bulb)
72.7°F MCWB (Mean Coincident Wet Bulb)



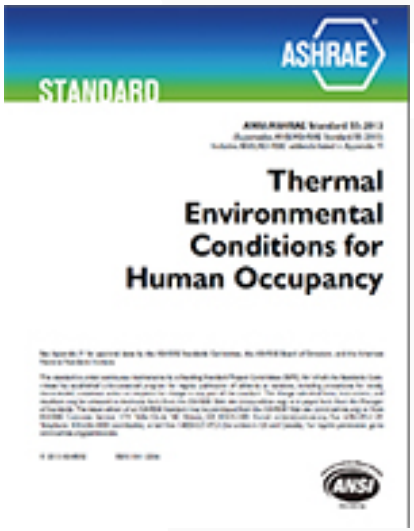
Design Conditions: Dehumidification

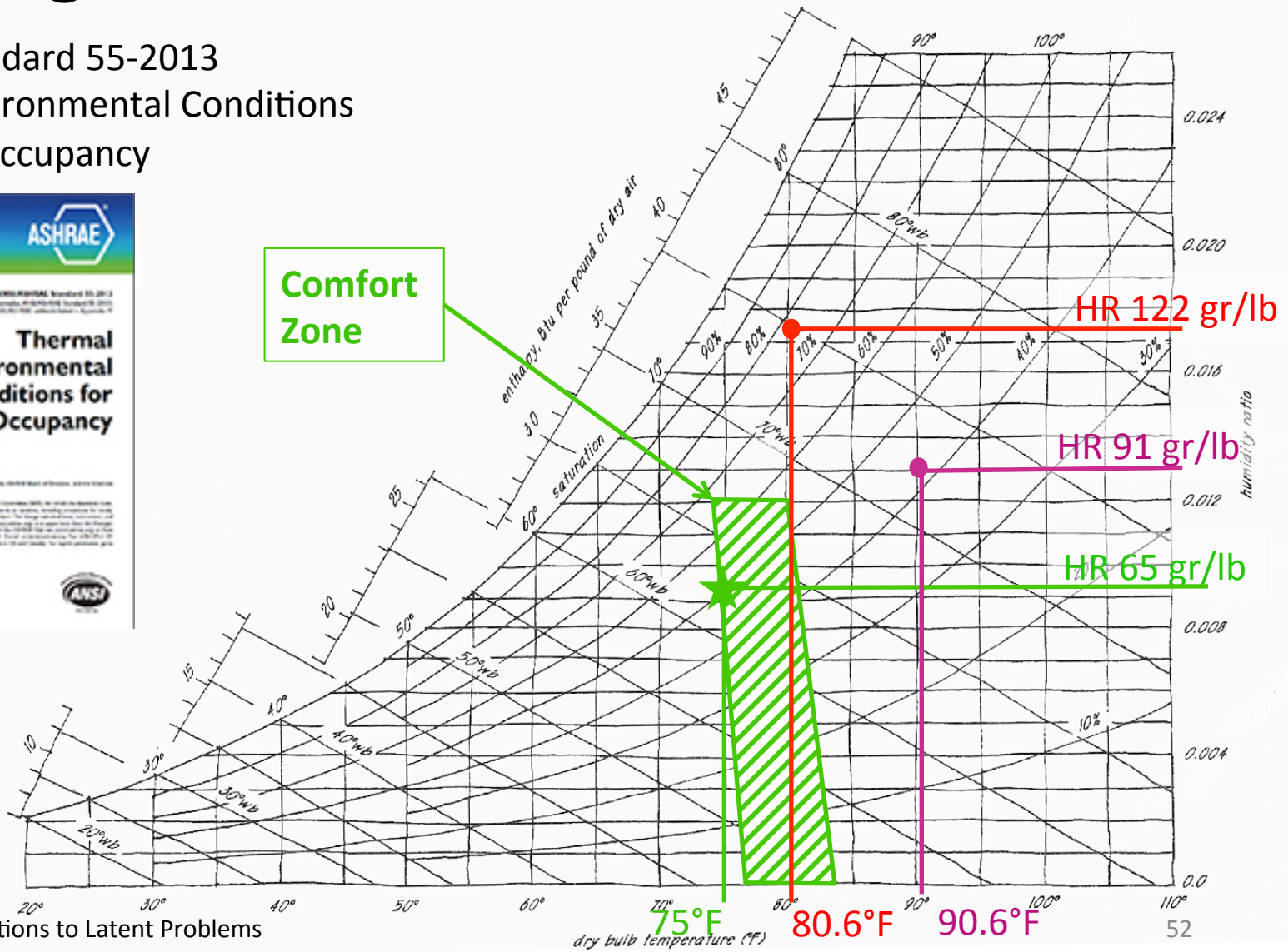
ASHRAE Climate Design Conditions
Boston
Dehumidification Design Day (0.4%)
72.8°F DP (Dew Point)
122 gr/lb HR (Humidity Ratio)
80.6°F MCDB (Mean Coincident Dry Bulb)



Design Conditions: Comfort Zone

ASHRAE Standard 55-2013
Thermal Environmental Conditions
for Human Occupancy





Ventilation loads: Cooling Design Day

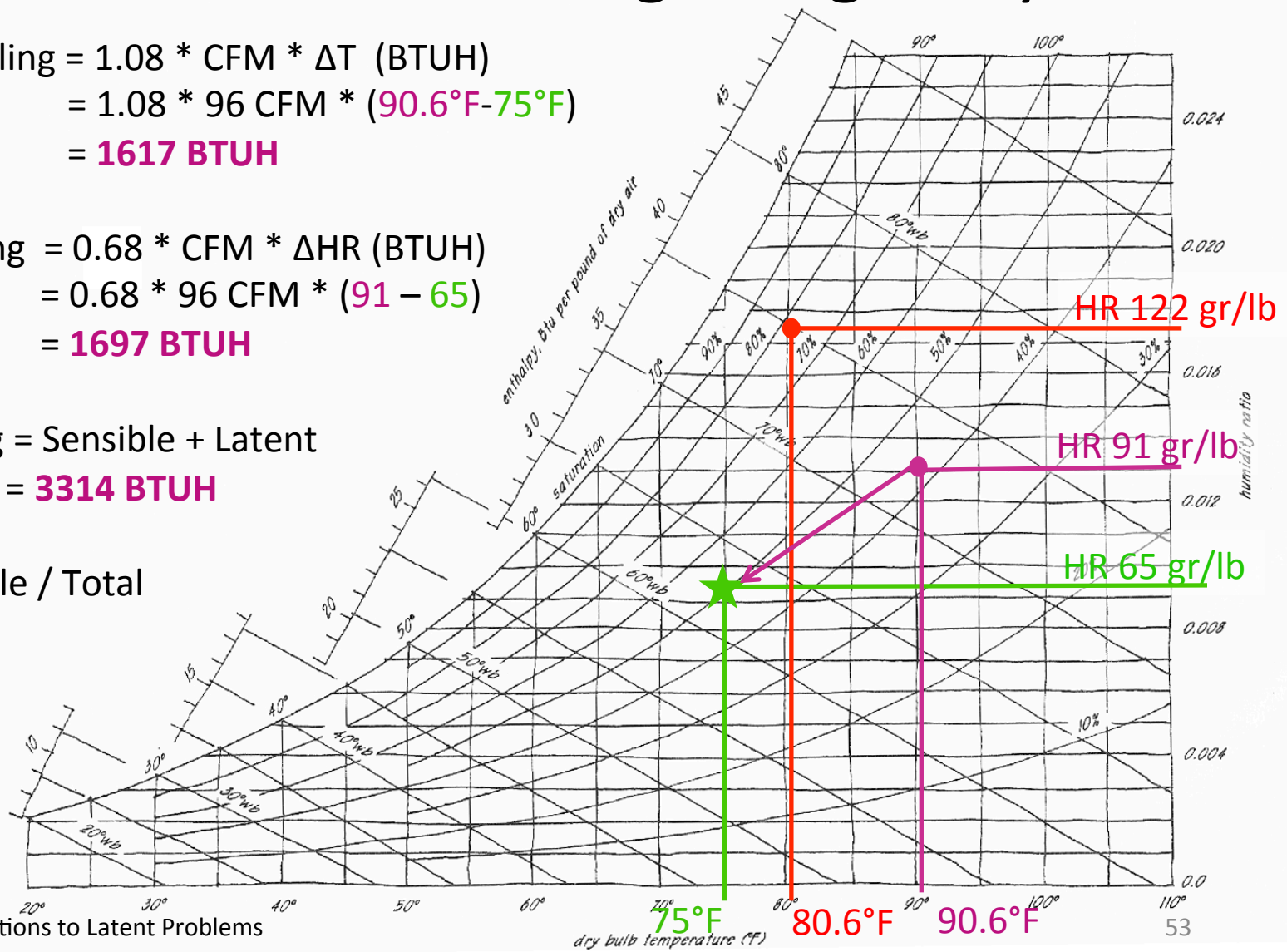
Sensible Cooling = 1.08 * CFM * ΔT (BTUH)
= 1.08 * 96 CFM * (90.6°F-75°F)
= **1617 BTUH**

Latent Cooling = 0.68 * CFM * ΔHR (BTUH)
= 0.68 * 96 CFM * (91 – 65)
= **1697 BTUH**

Total Cooling = Sensible + Latent
= **3314 BTUH**

SHR = Sensible / Total

SHR = 0.48



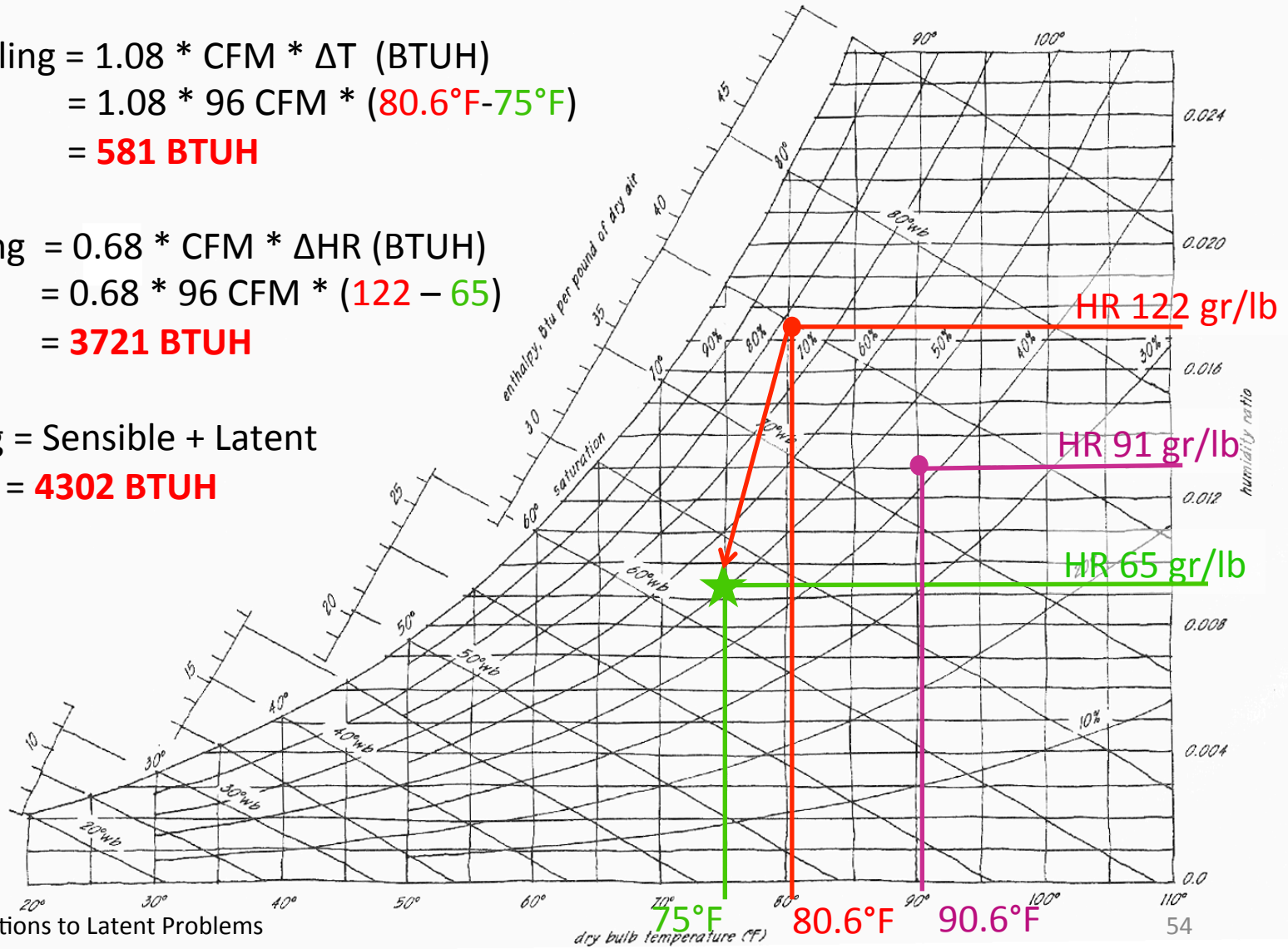
Ventilation loads: Dehumidification Design Day

Sensible Cooling = 1.08 * CFM * ΔT (BTUH)
= 1.08 * 96 CFM * (80.6°F-75°F)
= **581 BTUH**

Latent Cooling = 0.68 * CFM * ΔHR (BTUH)
= 0.68 * 96 CFM * (122 – 65)
= **3721 BTUH**

Total Cooling = Sensible + Latent
= **4302 BTUH**

SHR = 0.13

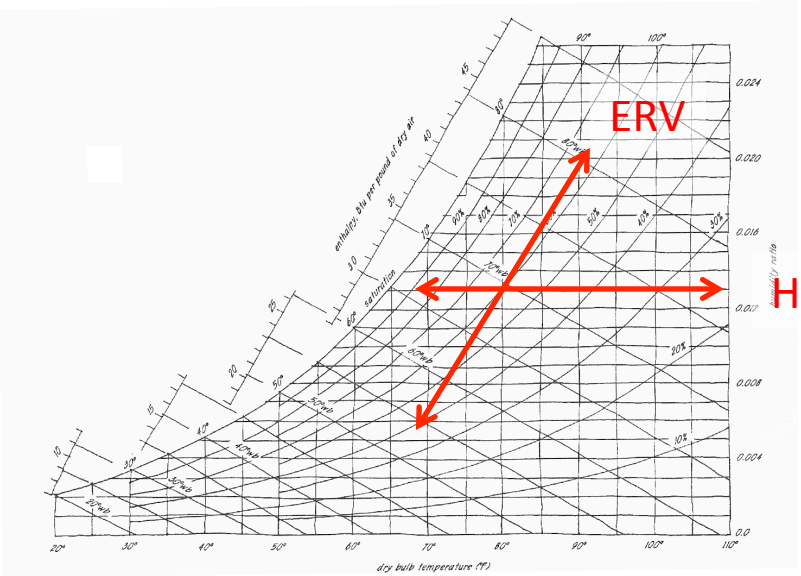


Energy Recovery Ventilation

Two Main Types: HRVs and ERVs

HRV: Heat Recovery Ventilator
Transfers sensible energy

ERV: Enthalpy (or Energy) Recovery Ventilator
Transfers sensible and latent energy

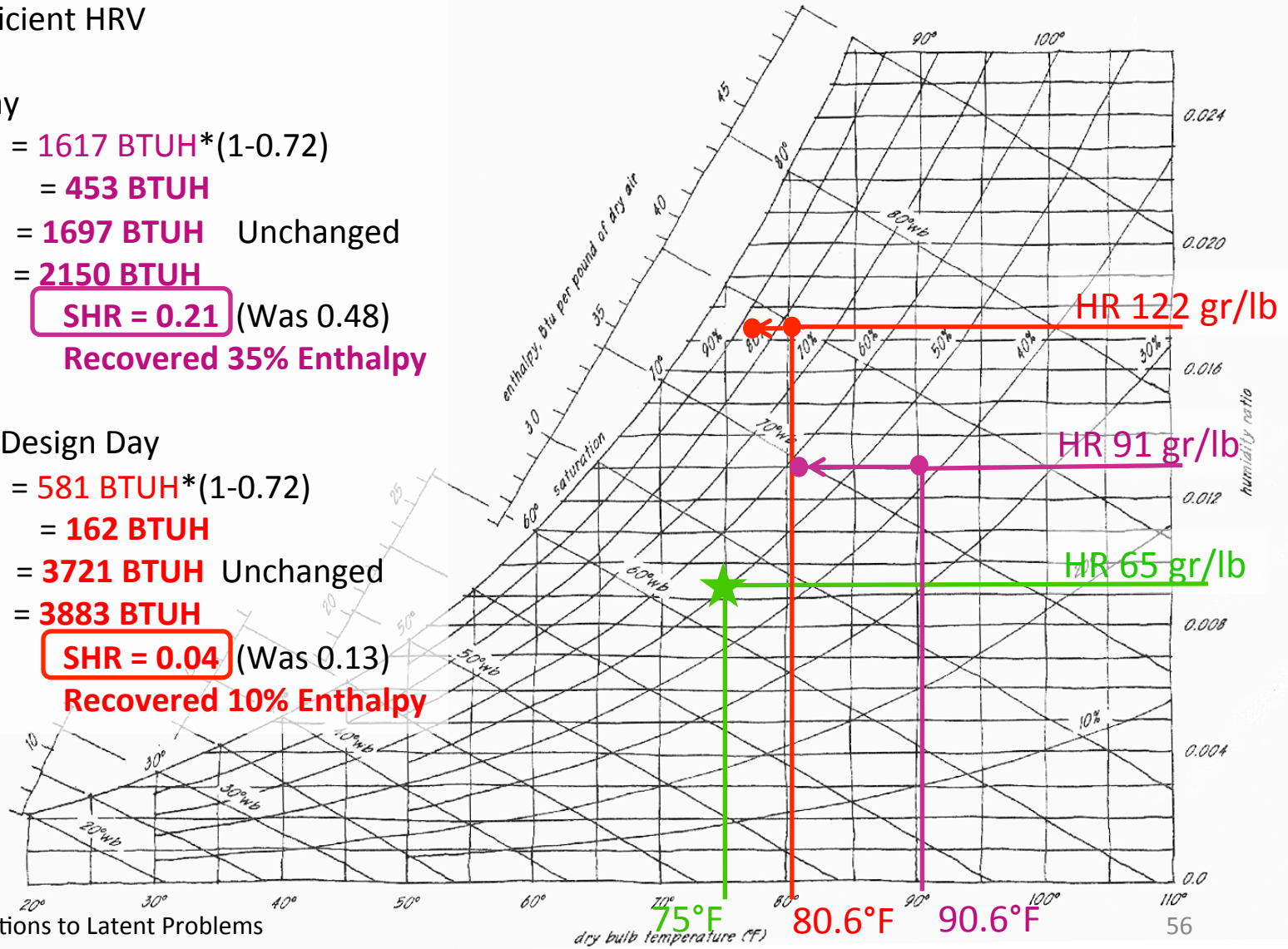


Ventilation loads: HRV Effect

Assume a 72% Efficient HRV

Cooling Design Day
Sensible Cooling = 1617 BTUH*(1-0.72)
= **453 BTUH**
Latent Cooling = **1697 BTUH** Unchanged
Total Cooling = **2150 BTUH**
SHR = 0.21 (Was 0.48)
Recovered 35% Enthalpy

Dehumidification Design Day
Sensible Cooling = 581 BTUH*(1-0.72)
= **162 BTUH**
Latent Cooling = **3721 BTUH** Unchanged
Total Cooling = **3883 BTUH**
SHR = 0.04 (Was 0.13)
Recovered 10% Enthalpy

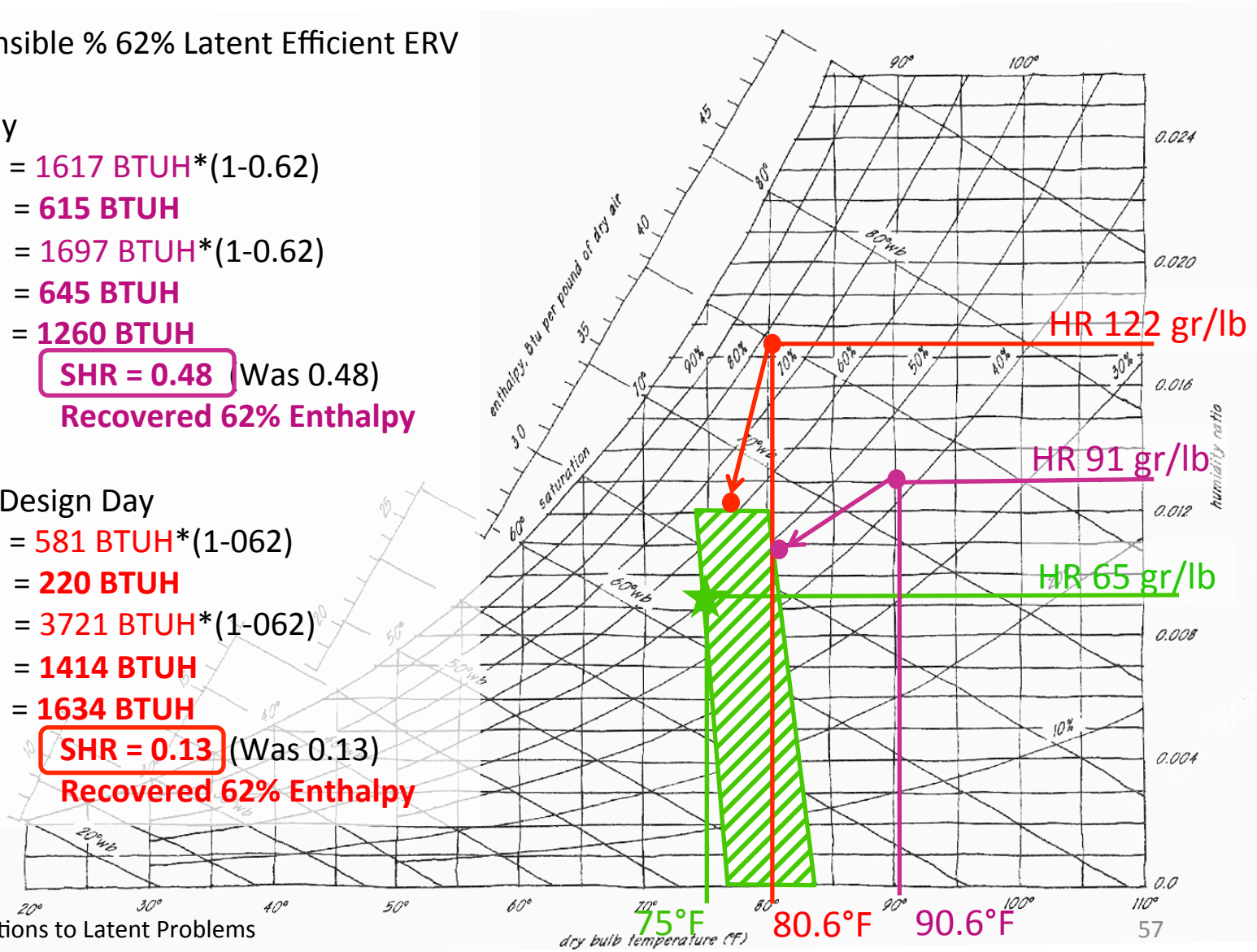


Ventilation loads: ERV Effect

Assume a 62% Sensible % 62% Latent Efficient ERV

Cooling Design Day
Sensible Cooling = 1617 BTUH*(1-0.62)
= **615 BTUH**
Latent Cooling = 1697 BTUH*(1-0.62)
= **645 BTUH**
Total Cooling = **1260 BTUH**
SHR = 0.48 (Was 0.48)
Recovered 62% Enthalpy

Dehumidification Design Day
Sensible Cooling = 581 BTUH*(1-062)
= **220 BTUH**
Latent Cooling = 3721 BTUH*(1-062)
= **1414 BTUH**
Total Cooling = **1634 BTUH**
SHR = 0.13 (Was 0.13)
Recovered 62% Enthalpy

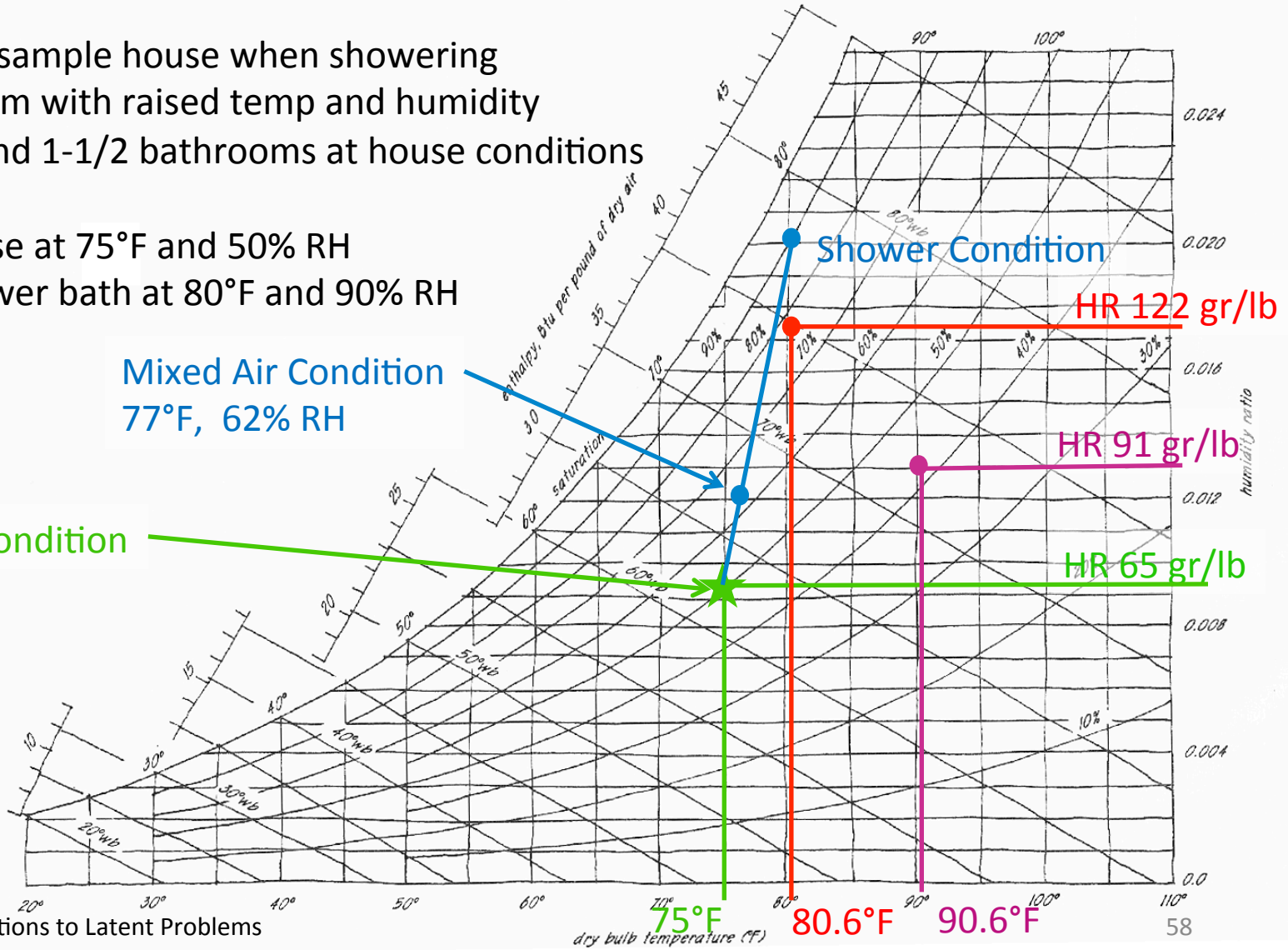


Should ERVs ventilate bathrooms?

Condition in sample house when showering

- 1 bathroom with raised temp and humidity
- Kitchen and 1-1/2 bathrooms at house conditions

Assume house at 75°F and 50% RH
Assume Shower bath at 80°F and 90% RH



Mitigation Strategies: Heat Pumps

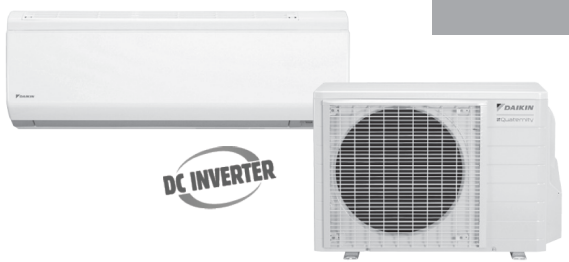
Popular in low load buildings

- Provide heating and cooling (& dehumidify)
- Energy efficient
- Relatively simple installation

Limitations

- Primarily designed for cooling
- Hard to estimate part-load moisture removal
- SHR is dependent upon conditions and air flow

"So the rated SHR of any unit is, in my view an entirely unsatisfactory and unproductively theoretical misimpression of actual DH performance." - Lew Harriman



Heat Pumps with Dry Mode

Both Mitsubishi & Fujitsu (likely others) have "Dry Mode" operation

- Reduces airflow over the evaporator (cooling) coil
- Maintains coil temp at slightly below dew point
- Attempts to dehumidify with the minimal amount of cooling

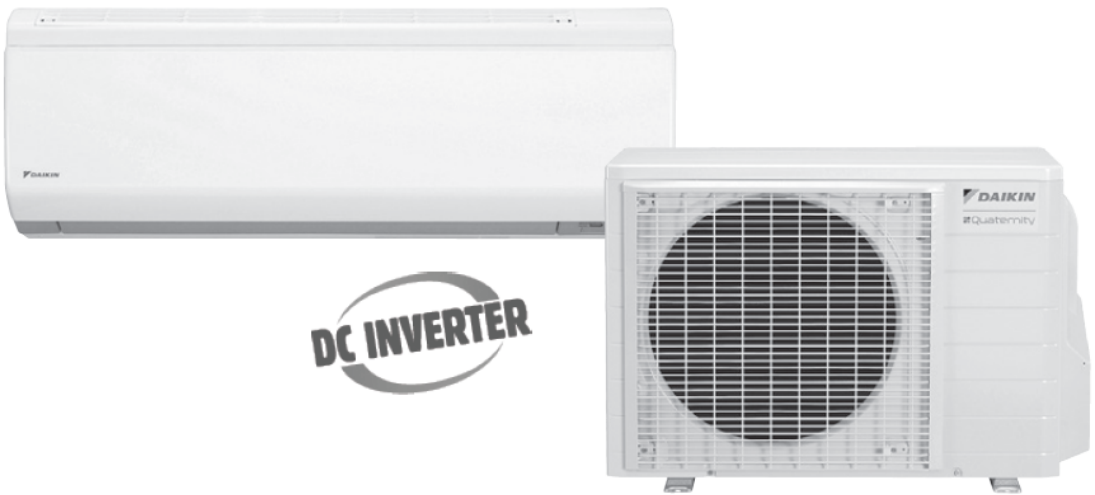
For 3/4 ton to 1-1/4 ton heat pumps:

- Mitsubishi SHR range from 0.92 – 0.7
- Fujitsu 2.6 – 4.0 pint/hour
  - Approx. SHR range 0.71 – 0.78

Heat Pump Acting Like a Dehumidifier

Daikin has **Quaternary** model with dehumidification mode

- Can set and monitor relative humidity levels
- Has a reheat coil to prevent overcooling
- Lists dehumidification capacity of 3.3 – 4.8 pints/hour



Mitigation Strategy: Dehumidifiers

Use the same basic technology as AC Units with 2 main differences:

- Designed for dehumidification
  - Relative humidity set point
  - Deeper coil
  - Lower air flow
- Condenser coil (heat rejection) inside
  - Heaters!

For EnergyStar rating must use 15% less energy than “conventional” models.

Large variability:
range from 1.85 L/kWh to 4.2 L/kWh

Stand-alone Dehumidifiers

Good solution for damp basements and finished basements

- Large thermal mass mitigates heat rejection
- Warmer and drier can be a benefit to these spaces even in summer months

Can also work in remainder of the house If located properly

- Locate near ducted heating/cooling system return and run air handler fan for distributing dry air
- Can mitigate the heat rejection by dispersing it.

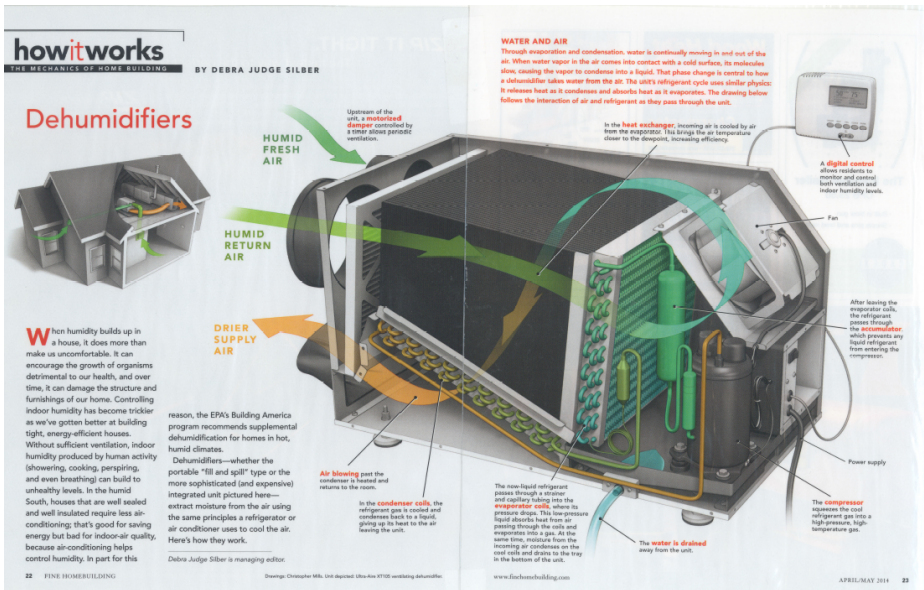
Whole House Dehumidifiers

Ducted solution for whole house dehumidification

- Distributing to whole house can help mitigate the heat rejection
- Will increase the sensible load when running.
- Has ventilation intake port so can *possibly* be coupled with ERV supply air distribution with careful planning.

Ultra-Air has highest efficiency models

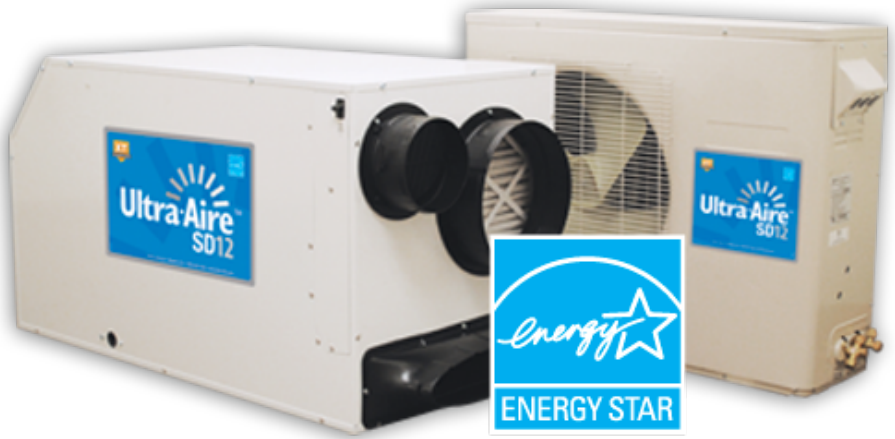
- Utilizes and air to air heat exchanger to pre-cool air and reduce compressor power consumption.


howitworks
THE MECHANICS OF HOME BUILDING
BY DEBRA JUDGE SILBER
Dehumidifiers
HUMID FRESH AIR
HUMID RETURN AIR
DRIER SUPPLY AIR
WATER AND AIR
When humidity builds up in a house, it does more than make us uncomfortable. It can encourage the growth of organisms detrimental to our health, and over time, it can damage the structure and furnishings of our home. Controlling indoor humidity has become trickier as we've gotten better at building tight, energy-efficient houses. Without sufficient ventilation, indoor humidity produced by human activity (showering, cooking, perspiring, and even breathing) can build to unhealthy levels. In the humid South, houses that are well sealed and well insulated require less air-conditioning; that's good for saving energy but bad for indoor-air quality, because air-conditioning helps control humidity. In part for this reason, the EPA's Building America program recommends supplemental dehumidification for homes in hot, humid climates.
Dehumidifiers—whether the portable "fill and spill" type or the more sophisticated (and expensive) integrated unit pictured here—extract moisture from the air using the same principles a refrigerator or air conditioner uses to cool the air. Here's how they work.
Debra Judge Silber is managing editor.
Power supply

Whole House Split-Dehumidifiers

Ducted split-system solution for whole house dehumidification

- Heat rejection to the outside so also provides some sensible cooling
- Rated at 4,300 BTUH sensible and 7.7 pints/hr latent SRE ~ 0.34
- Has ventilation intake port so can *possibly* be coupled with ERV supply air distribution with careful planning.
- For low-load house may be an excellent cooling/dehumidification solution but does not provide heating.



One Last Option…