Economizers: Design, Performance, and Commissioning Issues

Integrating the Economizer with the Climate

Instructor:

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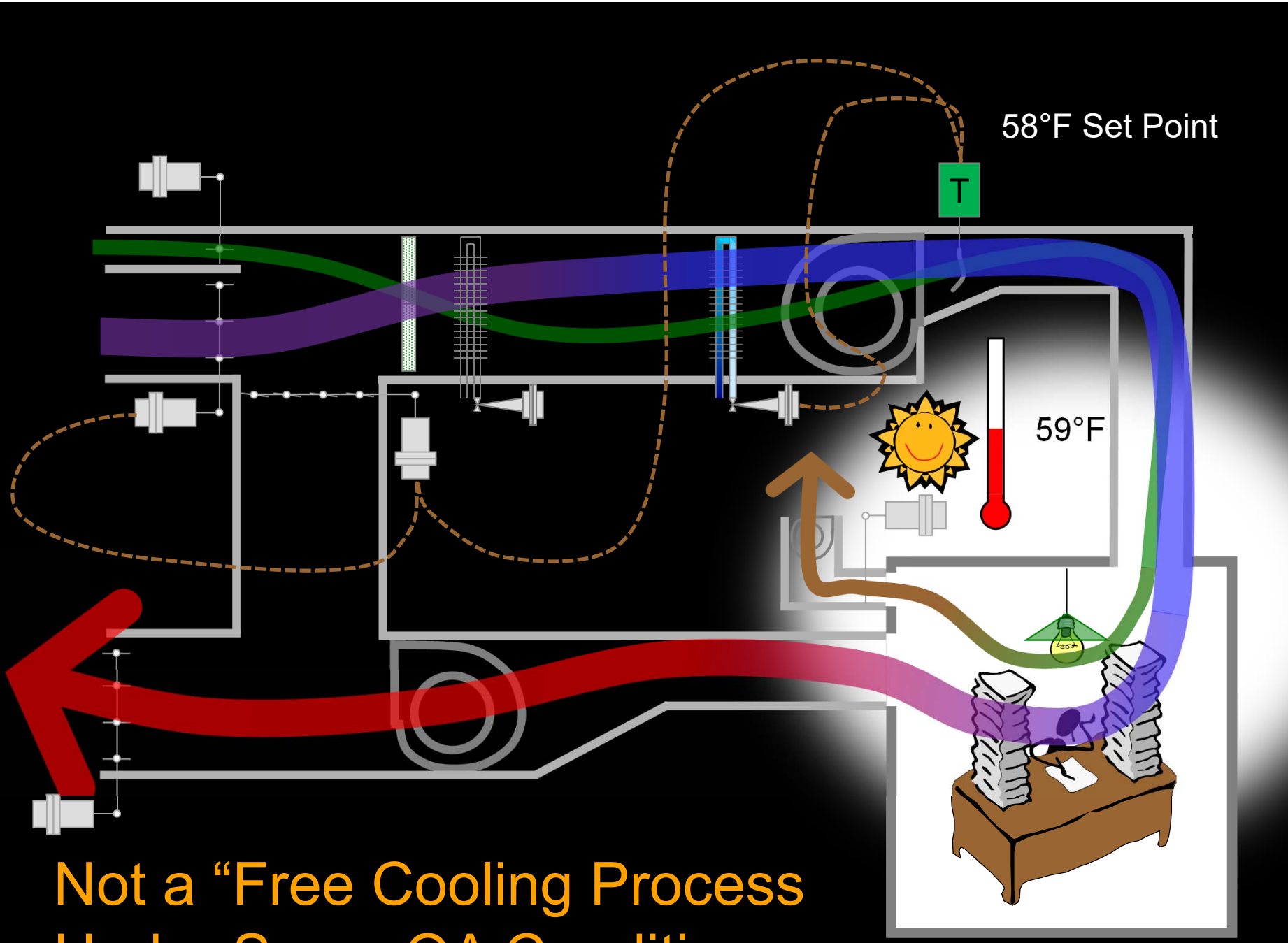
- Senior Engineer
- Facility Dynamics Engineering

- February 6, 2018

What's In This Module

- When and why economizers stop being beneficial
  - The meaning of the term "enthalpy"
  - Measuring enthalpy
- The cumulative effect of sensor error on a critical process parameter
- Methods for disabling an economizer process when necessary



Not a “Free Cooling Process Under Some OA Conditions

The General Idea Behind an Integrated Economizer Cycle

- Use outdoor air when it will take less energy to cool it than it would take to cool the return air steam when it is mixed with the outdoor air required for ventilation purposes (a.k.a Minimum Outdoor Air or MOA)
- Air stream energy content is a combination of sensible energy and latent energy

Definitions

Sensible energy, Q_S (Btu's, Btu's/lb)

Energy that causes a temperature change we can feel

Dry bulb temperature, T_{db} (°F)

An indication of sensible energy measured by a standard thermometer exposed to air; increasing dry bulb temperature = increasing sensible energy

Definitions

Latent energy, Q_L (Btu's, Btu's/lb)

Energy that is used to keep water in a vapor state

Wet bulb temperature, T_{wb} (°F)

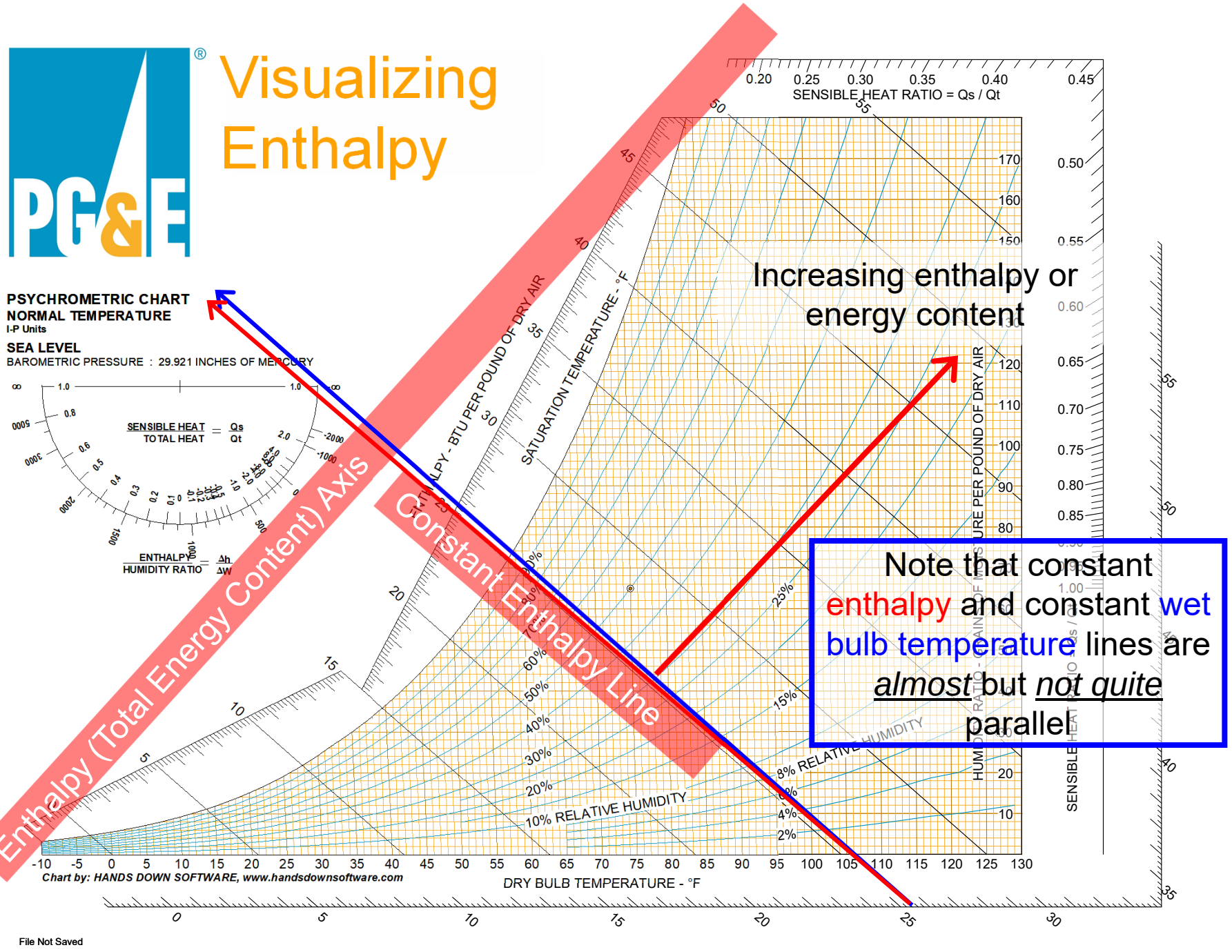
An indication of latent energy measured by a standard thermometer with its bulb covered by a wick that is saturated with water and exposed to moving air; increasing wet bulb temperature = increasing latent energy

Definitions

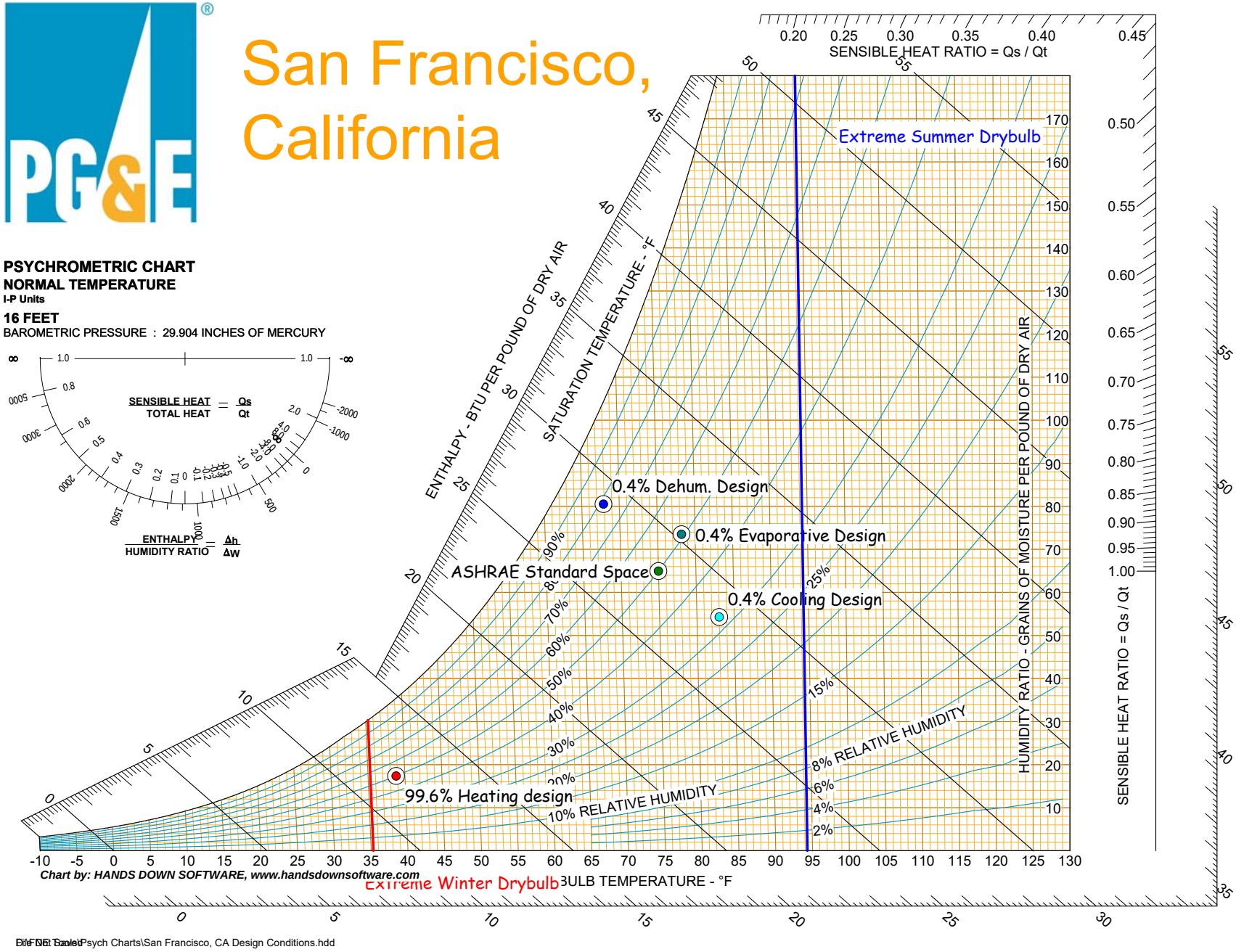
Enthalpy, η (Btu/lb$_{\text{dry air}}$)

A measure of the total energy content of air including both sensible and latent energy; increasing enthalpy = increasing energy content

Visualizing Enthalpy



San Francisco, California

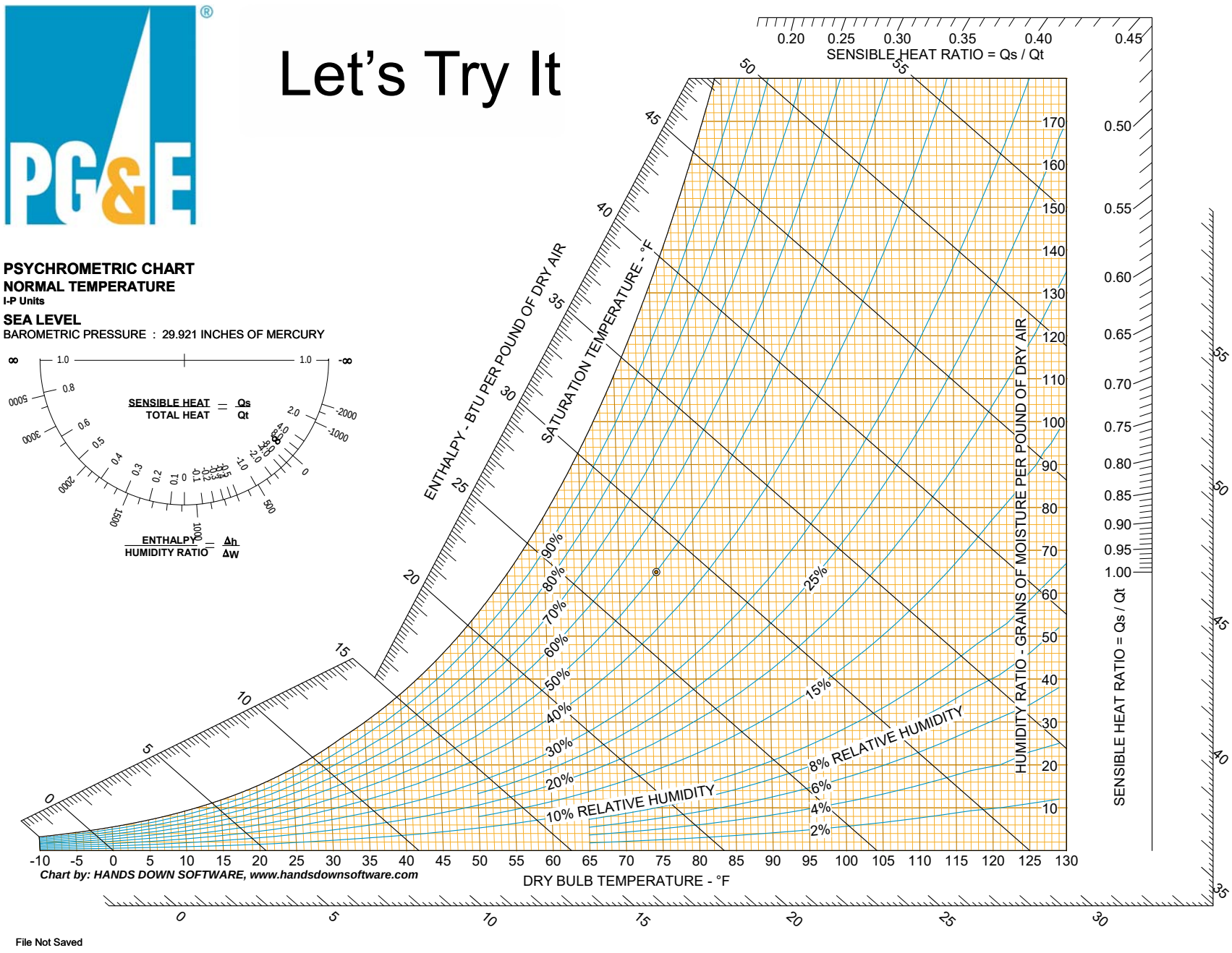


Psych Charts\San Francisco, CA Design Conditions.hdd

Measuring Enthalpy

- Not measured directly
  - Measure dry bulb temperature as an indication of sensible energy
  - Measure moisture as an indication of latent energy
    - Dew point
    - Relative humidity
    - Specific humidity
    - Wet bulb temperature
  - Use a psych chart (or microprocessor and the equation of state) to determine enthalpy

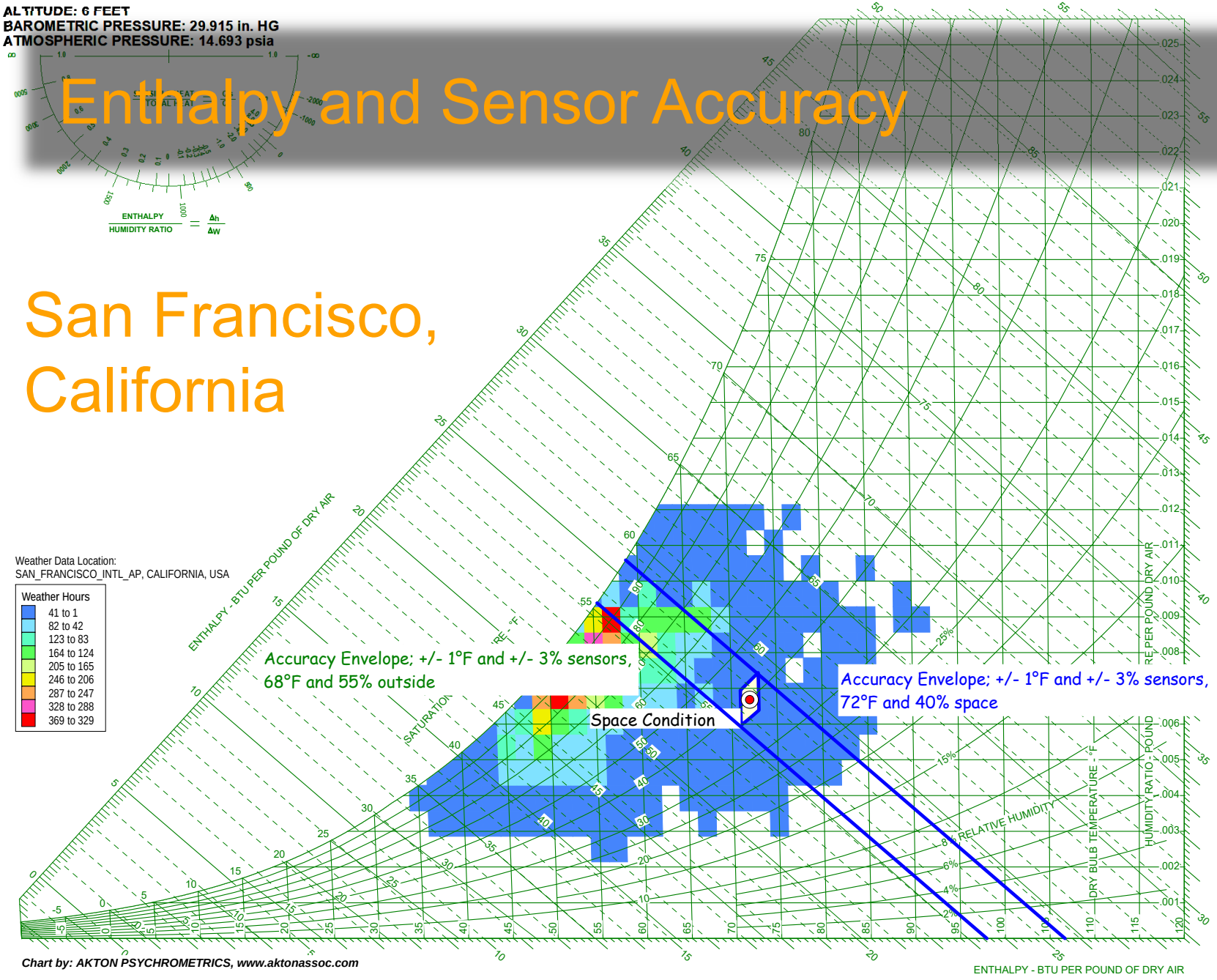
Let's Try It

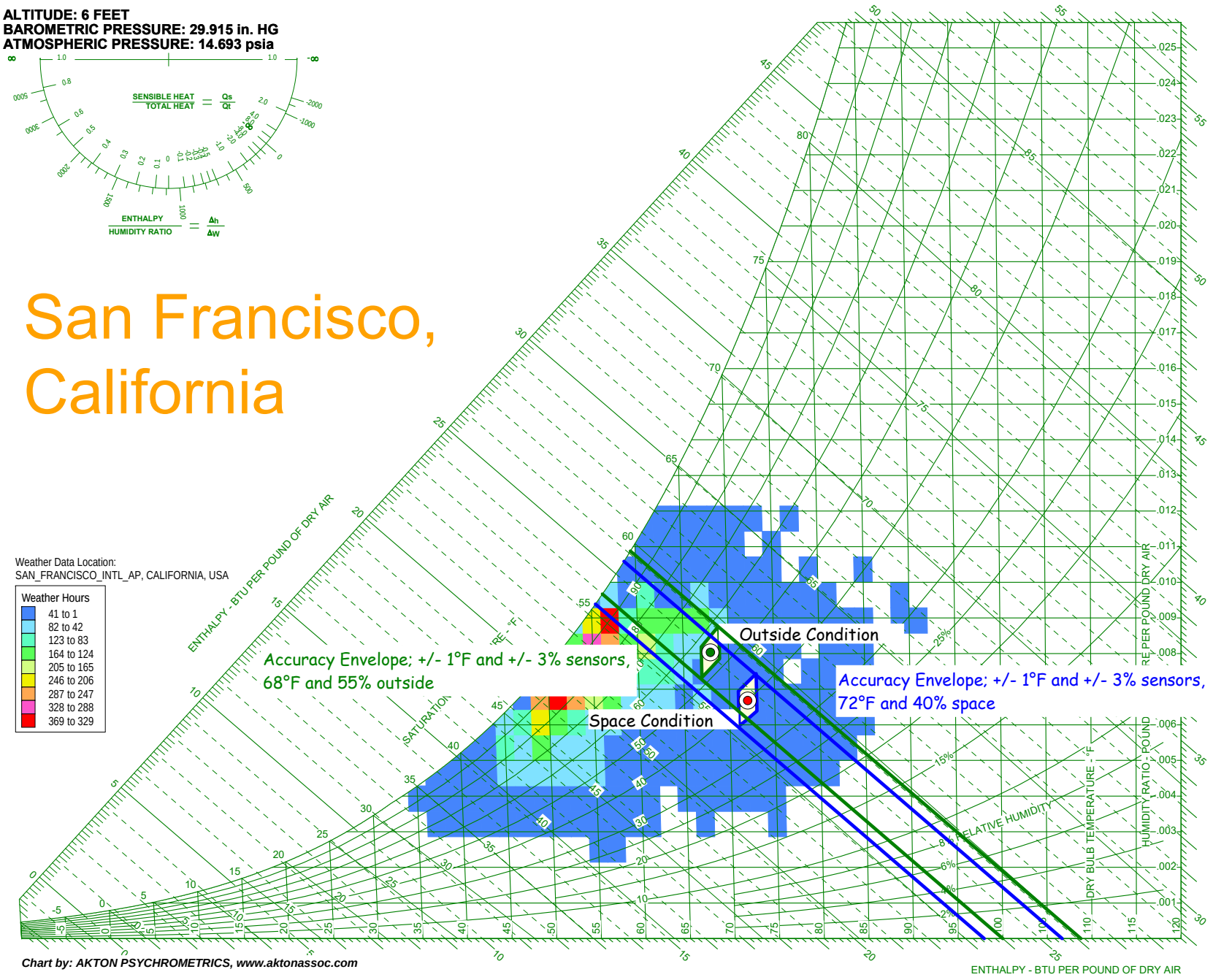

PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
SEA LEVEL
BAROMETRIC PRESSURE : 29.921 INCHES OF MERCURY
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
SENSIBLE HEAT RATIO = Qs / Qt
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
DRY BULB TEMPERATURE - °F
90%
80%
70%
60%
50%
40%
30%
20%
25%
15%
10% RELATIVE HUMIDITY
8% RELATIVE HUMIDITY
6%
4%
2%
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com
File Not Saved

Enthalpy and Sensor Accuracy

Assumptions					
1.	Given Condition -	72.0	°F		
2.	-	40%	RH		
3.	Pressure -	14.7	psi		
Enthalpy with perfect measurements					
	Enthalpy =	24.55	Btu/lb		
Enthalpy based on a perfect humidty sensor and a temperature sensor that is accurate to +/- 1°F					
	Error band -	1.0	°F, +/-		
	Maximum possible temperature -	73.0	°F		
	Minimum possible temperature -	71.0	°F		
	Maximum possible enthalpy -	25.0	Btu/lb		
	Minimum possible enthalpy -	24.1	Btu/lb		
Enthalpy based on a perfect temperature sensor and a humidty sensor that is accurate to +/- 3%					
	Error band -	3%	+/-		
	Maximum possible humidity -	43%			
	Minimum possible humidity -	37%			
	Maximum possible enthalpy -	25.1	Btu/lb		
	Minimum possible enthalpy -	24.0	Btu/lb		
Enthalpy based on a temperature sensor that is accurate to +/- 1°F and a humidty sensor that is accurate to +/- 3%					
	RH sensor error band -	3%	+/-		
	Maximum possible humidity -	43%			
	Minimum possible humidity -	37%			
	Temperature sensor error band -	1.0	°F, +/-		
	Maximum possible temperature -	73.0	°F		
	Minimum possible temperature -	71.0	°F		
	Maximum possible enthalpy -	25.6	Btu/lb		
	Minimum possible enthalpy -	23.5	Btu/lb		

Enthalpy and Sensor Accuracy




ALTITUDE: 6 FEET
BAROMETRIC PRESSURE: 29.915 in. HG
ATMOSPHERIC PRESSURE: 14.693 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / Δw
San Francisco, California
Weather Data Location:
SAN_FRANCISCO_INTL_AP, CALIFORNIA, USA
Weather Hours
41 to 1
82 to 42
123 to 83
164 to 124
205 to 165
246 to 206
287 to 247
328 to 288
369 to 329
Accuracy Envelope; +/- 1°F and +/- 3% sensors, 68°F and 55% outside
Outside Condition
Space Condition
Accuracy Envelope; +/- 1°F and +/- 3% sensors, 72°F and 40% space
ENTHALPY - BTU PER POUND OF DRY AIR
HUMIDITY RATIO - POUNDS PER POUND DRY AIR
DRY BULB TEMPERATURE - °F
RELATIVE HUMIDITY
SATURATION
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

Differential Enthalpy
The “Gold Standard”

- Direct measurement and comparison of the energy content of the outdoor air stream vs. the return air stream

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The "Gold Standard"

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- Good news:

  Measuring temperature to +/- 1°F or better is common and persistent

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- Bad news:

  Measuring humidity persistently and accurately is not so easy

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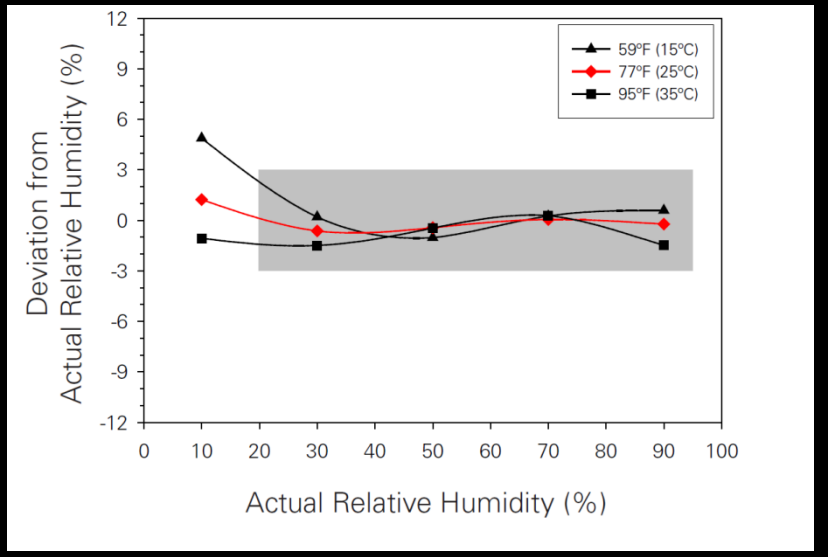
Is your humidity measurement accurate:

Maybe …



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- Direct measurement and comparison of the energy content of the outdoor air stream vs. the return air stream
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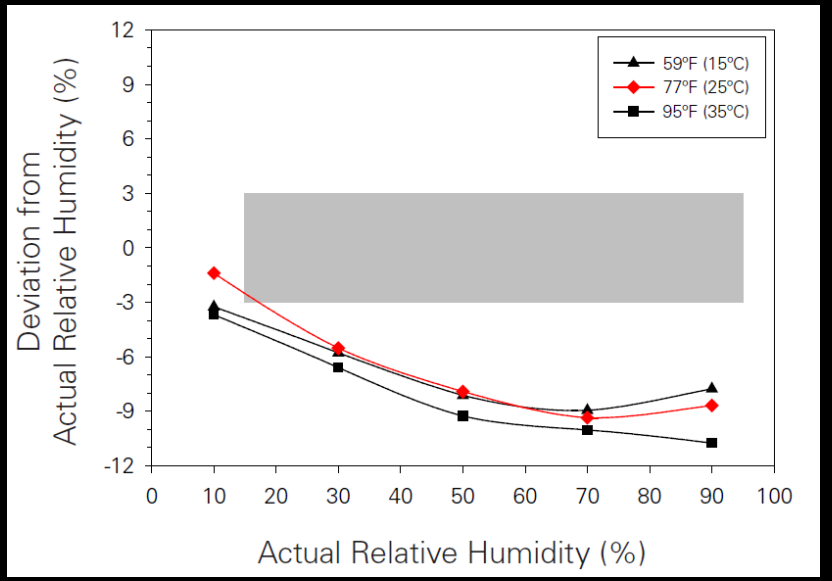
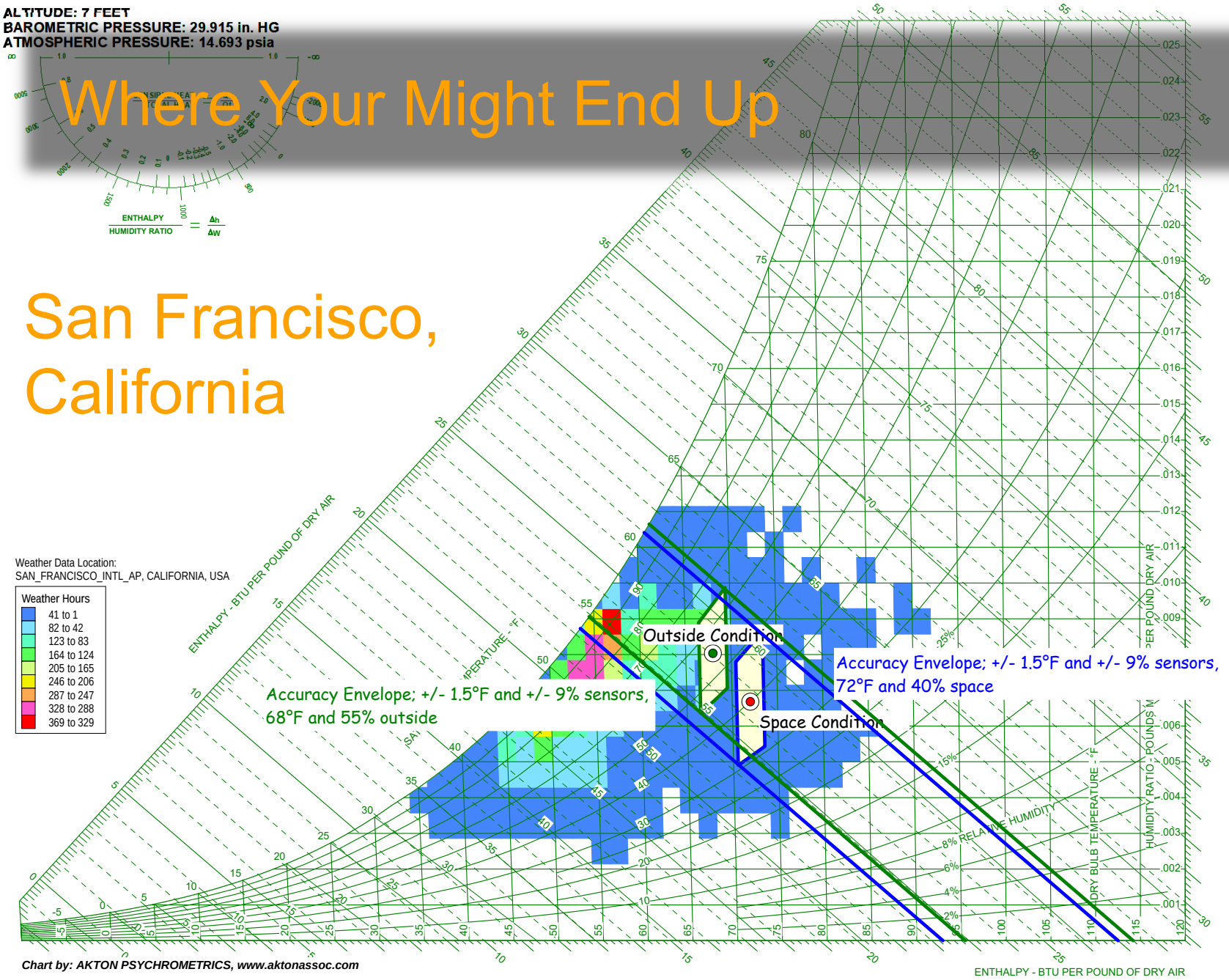
  Measuring humidity persistently and accurately is not so easy

Is your humidity measurement accurate:

Maybe … or maybe not



Where Your Might End Up



Other Alternatives

OA Enthalpy Relative to an Assumed Constant

Good News

- Eliminates one set of moisture sensors

Bad News

- The word “assumed”
- Still have to buy a good moisture sensor
- Still have to maintain a good moisture sensor
- Have to know where the sensor is

Other Alternatives

Outdoor/Return Air Differential Dry Bulb Temperature

Good News

- Eliminates moisture sensors
- Uses a more stable, persistent measurement technology
- Takes what is going on in the building into consideration

Bad News

- Does not consider latent effects and loads
- Still have two sensors to maintain
- Have to know where the sensor is

Other Alternatives

Outdoor Air Dry Bulb Temperature

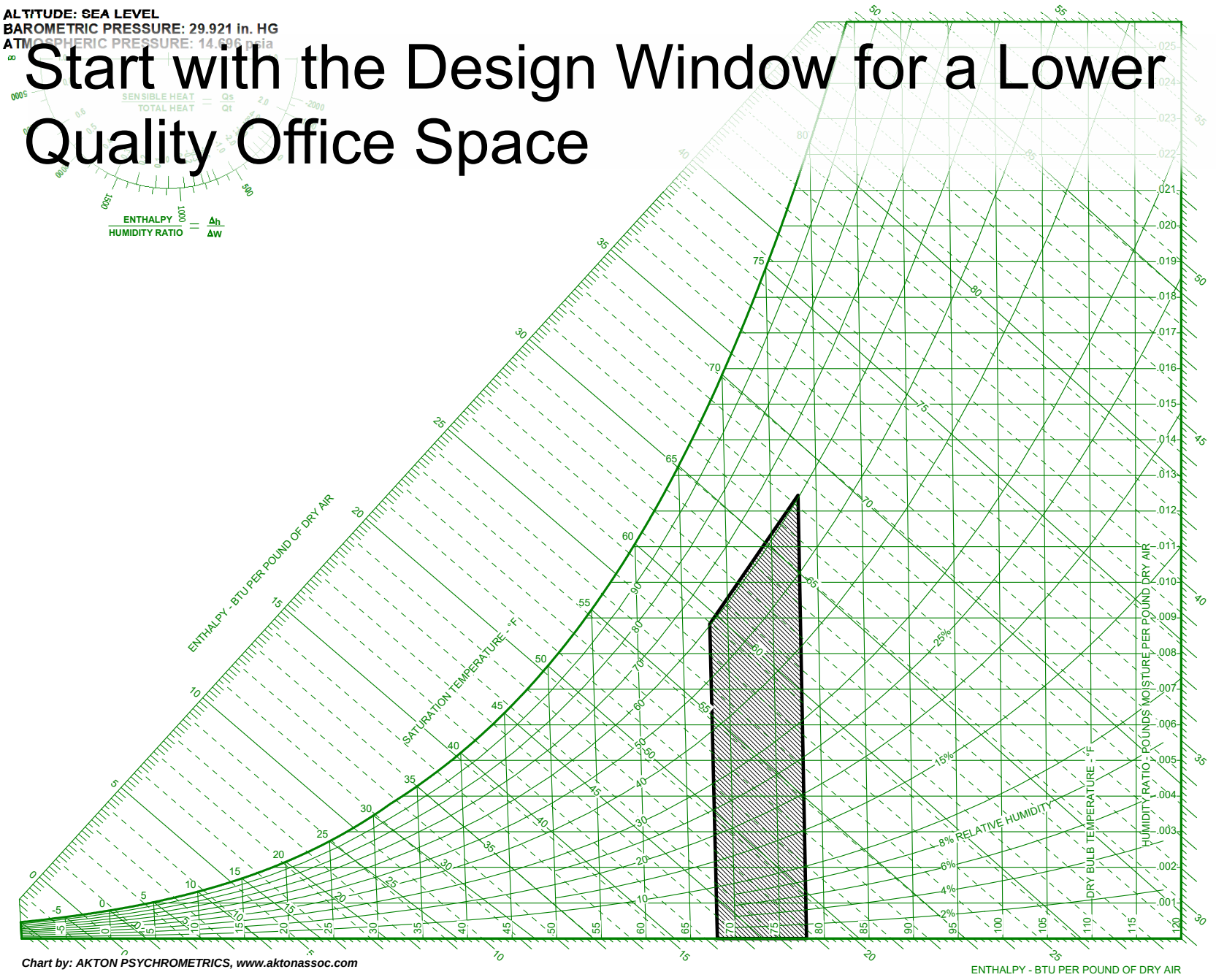
Good News

- Eliminates moisture sensors
- Uses a more stable, persistent measurement technology
- Uses just one sensor

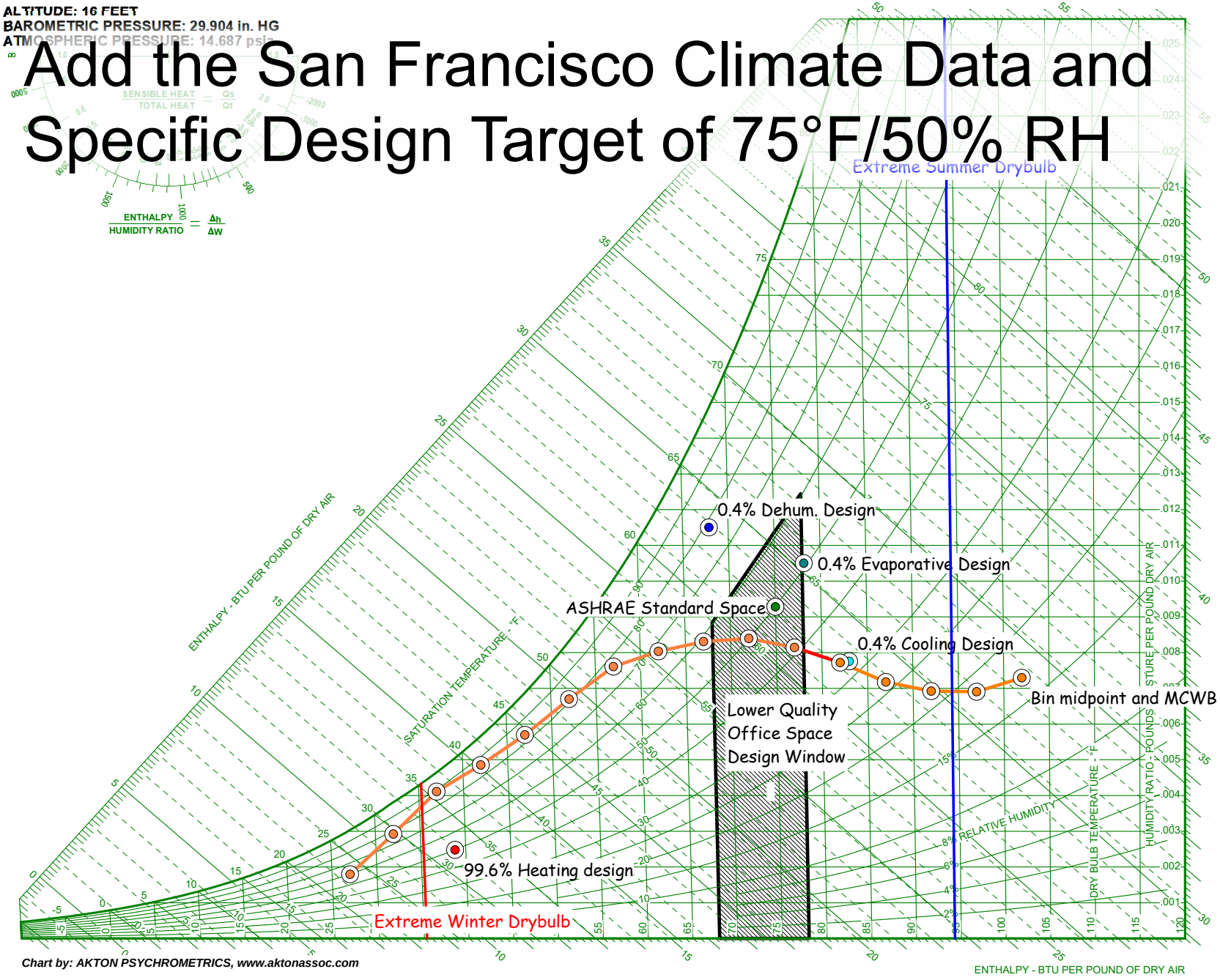
Bad News

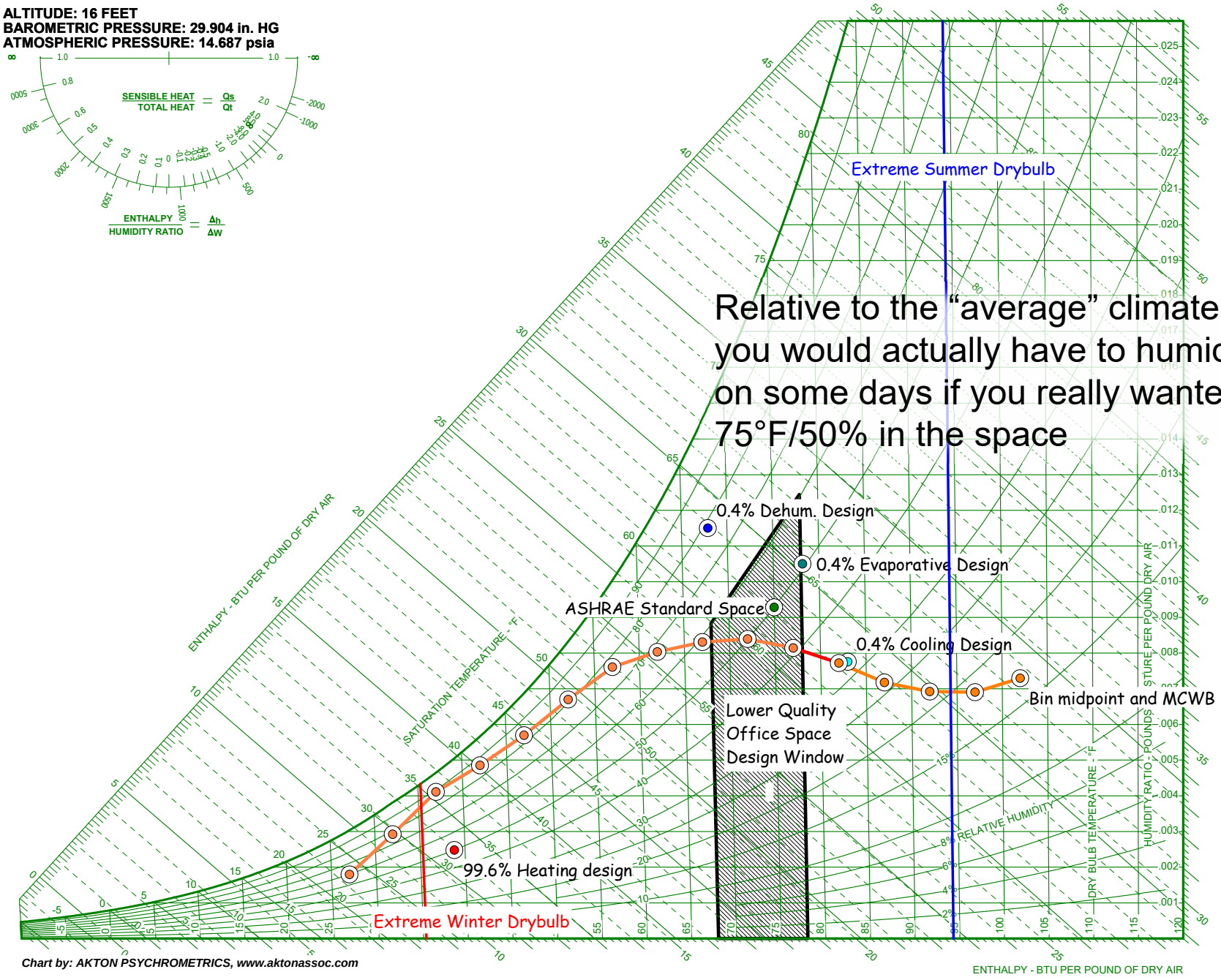
- Does not consider latent effects and loads
- Only considers outdoor air, thus makes an assumption about what is going on in the building
- Have to know where the sensor is

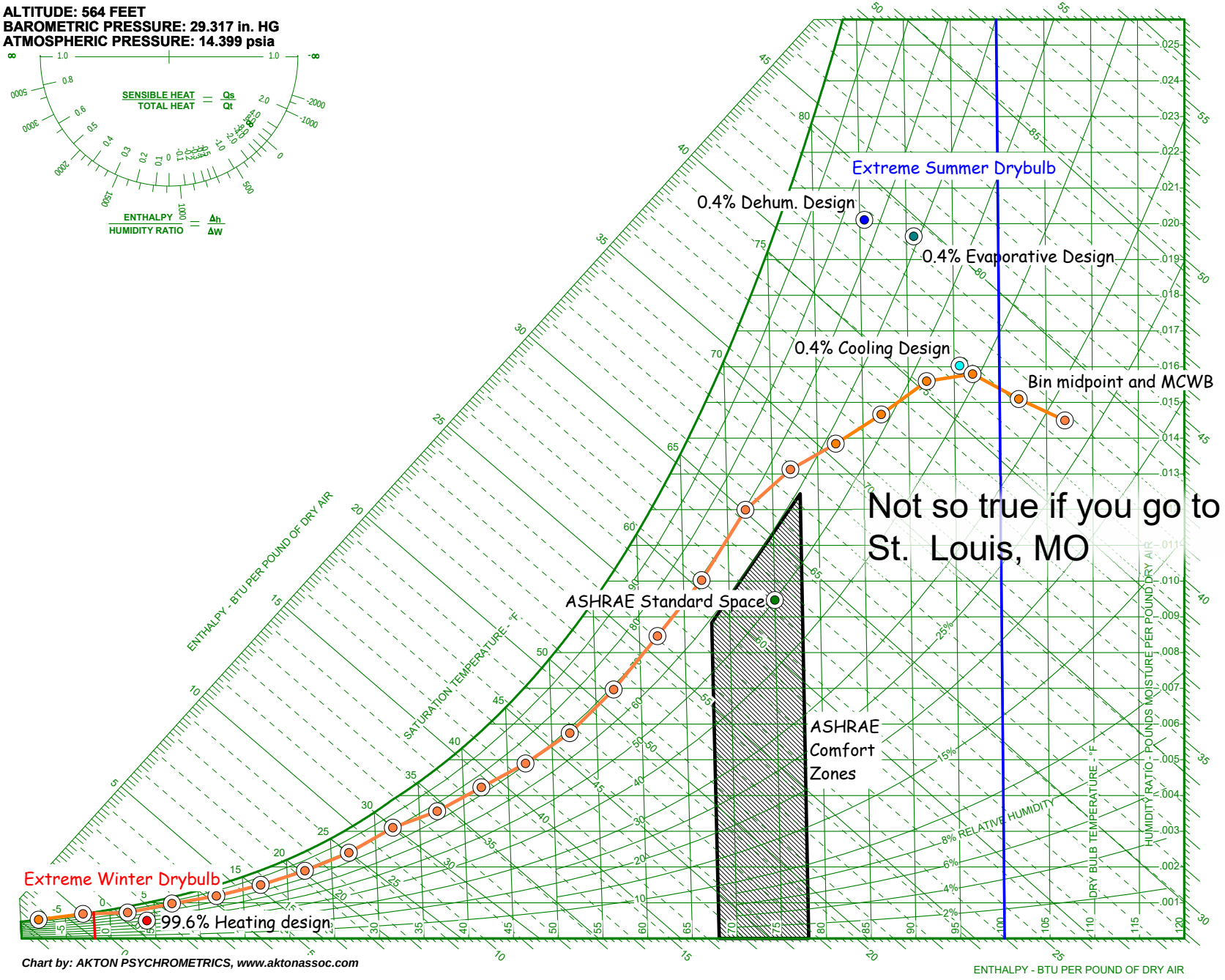
Start with the Design Window for a Lower Quality Office Space



Add the San Francisco Climate Data and Specific Design Target of 75°F/50% RH



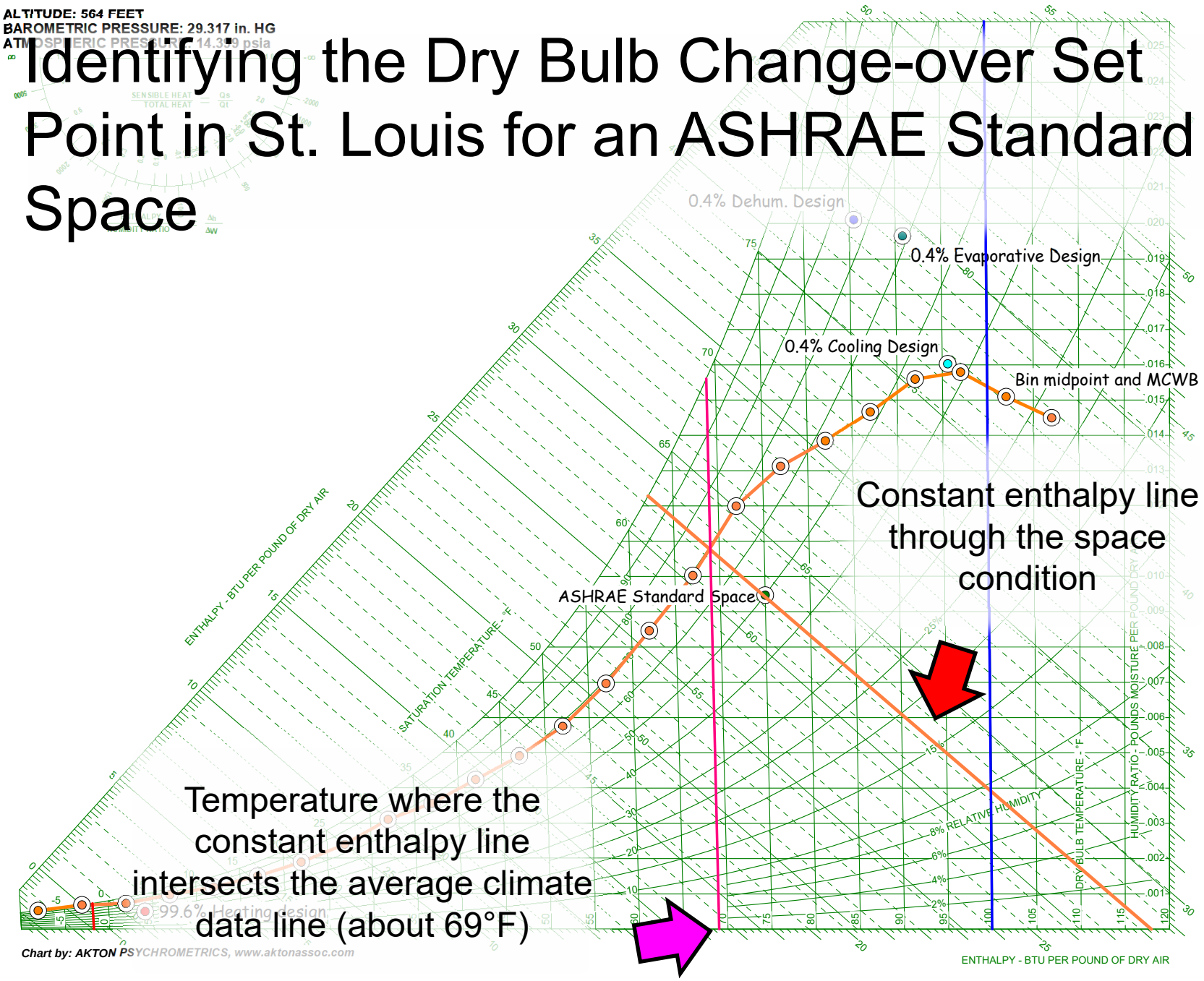

ALTITUDE: 16 FEET
BAROMETRIC PRESSURE: 29.904 in. HG
ATMOSPHERIC PRESSURE: 14.687 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / Δw
Extreme Summer Drybulb
Relative to the "average" climate, you would actually have to humidify on some days if you really wanted 75°F/50% in the space
0.4% Dehum. Design
0.4% Evaporative Design
ASHRAE Standard Space
0.4% Cooling Design
Bin midpoint and MCWB
Lower Quality Office Space Design Window
99.6% Heating design
Extreme Winter Drybulb
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com


ALTITUDE: 564 FEET
BAROMETRIC PRESSURE: 29.317 in. HG
ATMOSPHERIC PRESSURE: 14.399 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / Δw
Extreme Summer Drybulb
0.4% Dehum. Design
0.4% Evaporative Design
0.4% Cooling Design
Bin midpoint and MCWB
Not so true if you go to St. Louis, MO
ASHRAE Standard Space
ASHRAE Comfort Zones
Extreme Winter Drybulb
99.6% Heating design
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
% RELATIVE HUMIDITY
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

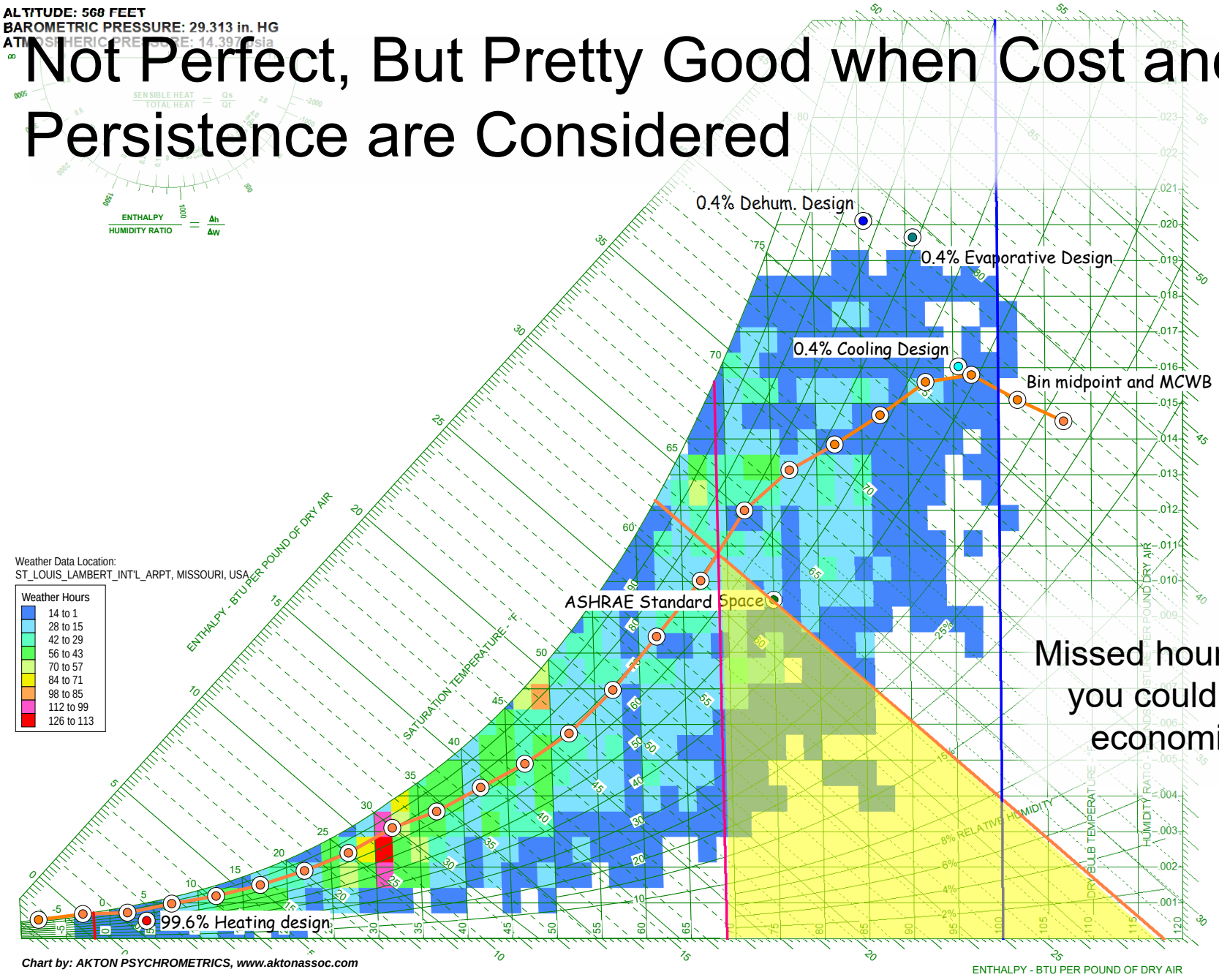
A Few Observations

- Climate can be very variable
- We think of economizers as a cooling process but they are also humidification or dehumidification processes depending on the moisture content of the outdoor air relative to the area served
- An economizer serving a space that requires tight humidity control may do more harm than good in a dry climate if the humidification requirement is not considered
- No matter where the system is and no matter what the target condition is in the space, there will likely be some hours when using outdoor air for cooling is undesirable

Identifying the Dry Bulb Change-over Set Point in St. Louis for an ASHRAE Standard Space

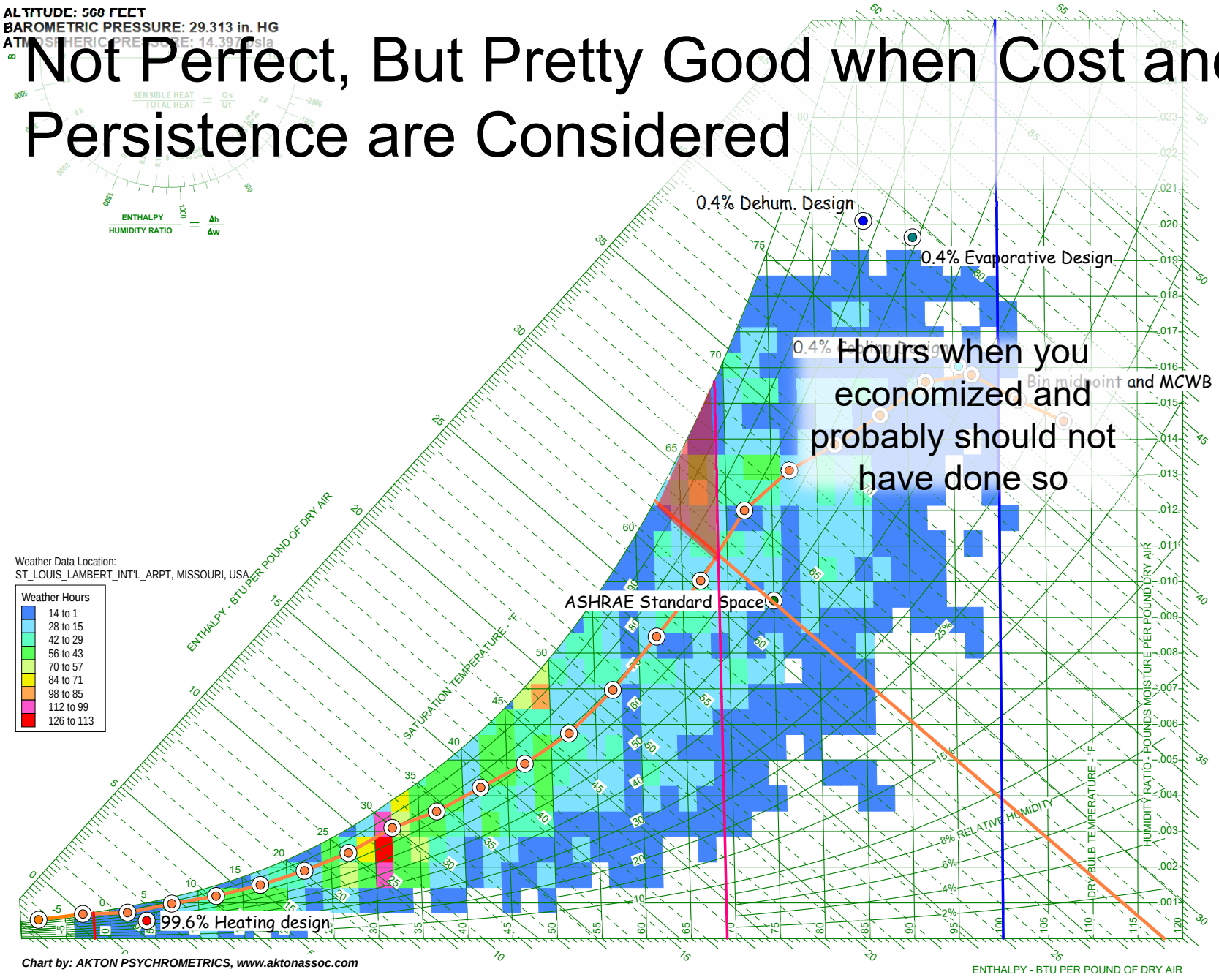


Not Perfect, But Pretty Good when Cost and Persistence are Considered



Missed hours when you could have economized

Not Perfect, But Pretty Good when Cost and Persistence are Considered



Bottom Lines

- Economizers will only deliver savings if cooling the outdoor air stream takes less energy than cooling the return air stream mixed with a minimum outdoor air stream
- Enthalpy is a scary sounding word for “total energy content”
- Relatively small sensor errors can make a big difference in terms of making a correct decision
- Some sensing technologies are less robust, reliable, and persistent than other technologies
- There are multiple ways to determine when to stop using an economizer, each with its pros and cons