Psychrometrics

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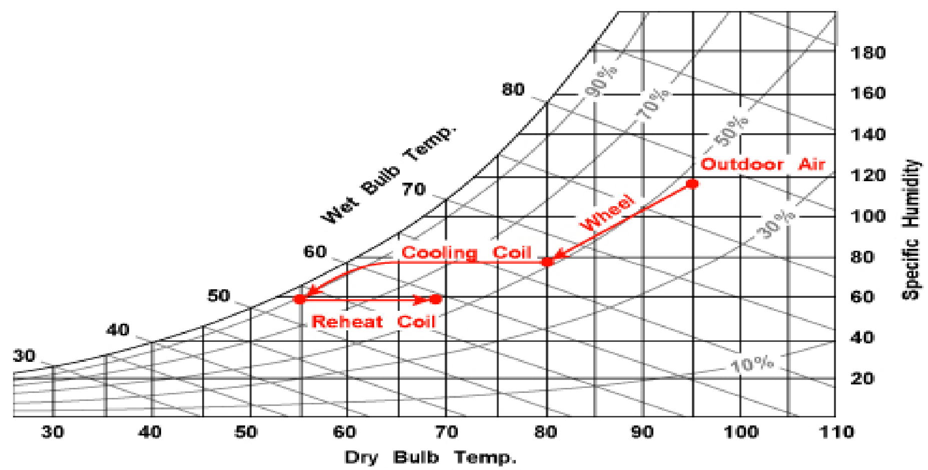
Agenda

- Properties of Air
- The Psychrometric Chart
- Applications
  - Mixed Air
  - Cooling
  - Dehumidification
  - Energy Recovery



Course Objectives

- At the completion of this session, you should be able to use a Psychrometric Chart to:
  - Identify the properties of air at a given state condition
  - Illustrate the performance characteristics of basic heating and cooling processes
  - Demonstrate how the use of Energy Recovery devices can reduce heating and cooling loads in building designs

Psychrometrics

- Psychrometrics is the science dealing with the physical laws or air – water mixtures

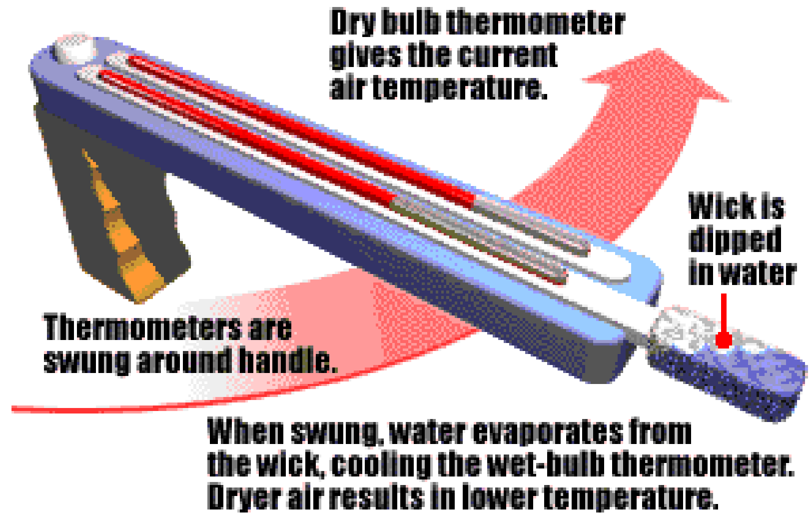
- Important in the design of HVAC systems as numerous air properties can be found over a broad range of conditions

Properties of Air

- Properties of Air
  - Dry-Bulb Temperature
  - Wet-Bulb Temperature
  - Dew-Point Temperature
  - Relative Humidity
  - Humidity Ratio
  - Enthalpy
- If any two of the above properties are known, the Psychrometric Chart can be used to find the remaining properties

Properties of Air

- Dry-bulb temperature is the temperature read from a standard thermometer
  - Representative of the ***sensible heat energy*** at the given condition
- Wet-bulb temperature is read from a thermometer with the bulb covered by a wet wick
  - "Sling Psychrometer"
- Difference between dry-bulb and wet-bulb represents the dryness of air



Properties of Air

- Dew-point temperature is the temperature at which moisture leaves the air and condenses on objects
- When the dry-bulb, wet-bulb, and dew-point temperatures are equal, the air is ***saturated***
  - Fog occurs when the air is saturated

Properties of Air

- <u>Relative humidity</u> is the measure of how much moisture the air is holding versus how much moisture the air can hold *at a given dry-bulb temperature*
  - Expressed as a percentage
  - As the dry-bulb temperature increases, the amount of moisture the air can hold increases

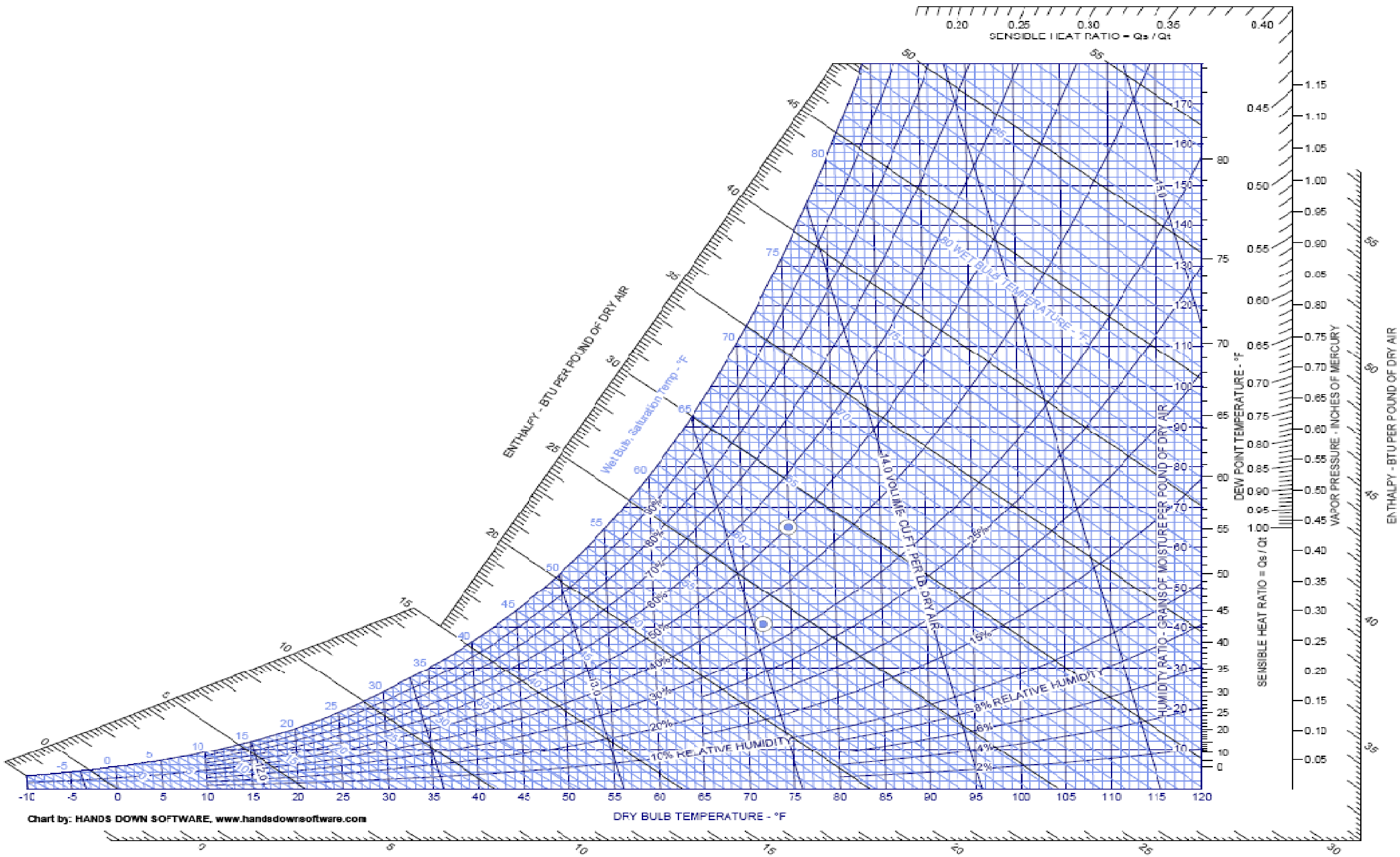
$$\text{Relative Humidity} = \frac{\text{Amount of moisture the air } \textcolor{red}{\text{is holding}}}{\text{Amount of moisture the air } \textcolor{red}{\text{can hold}}}$$

Properties of Air

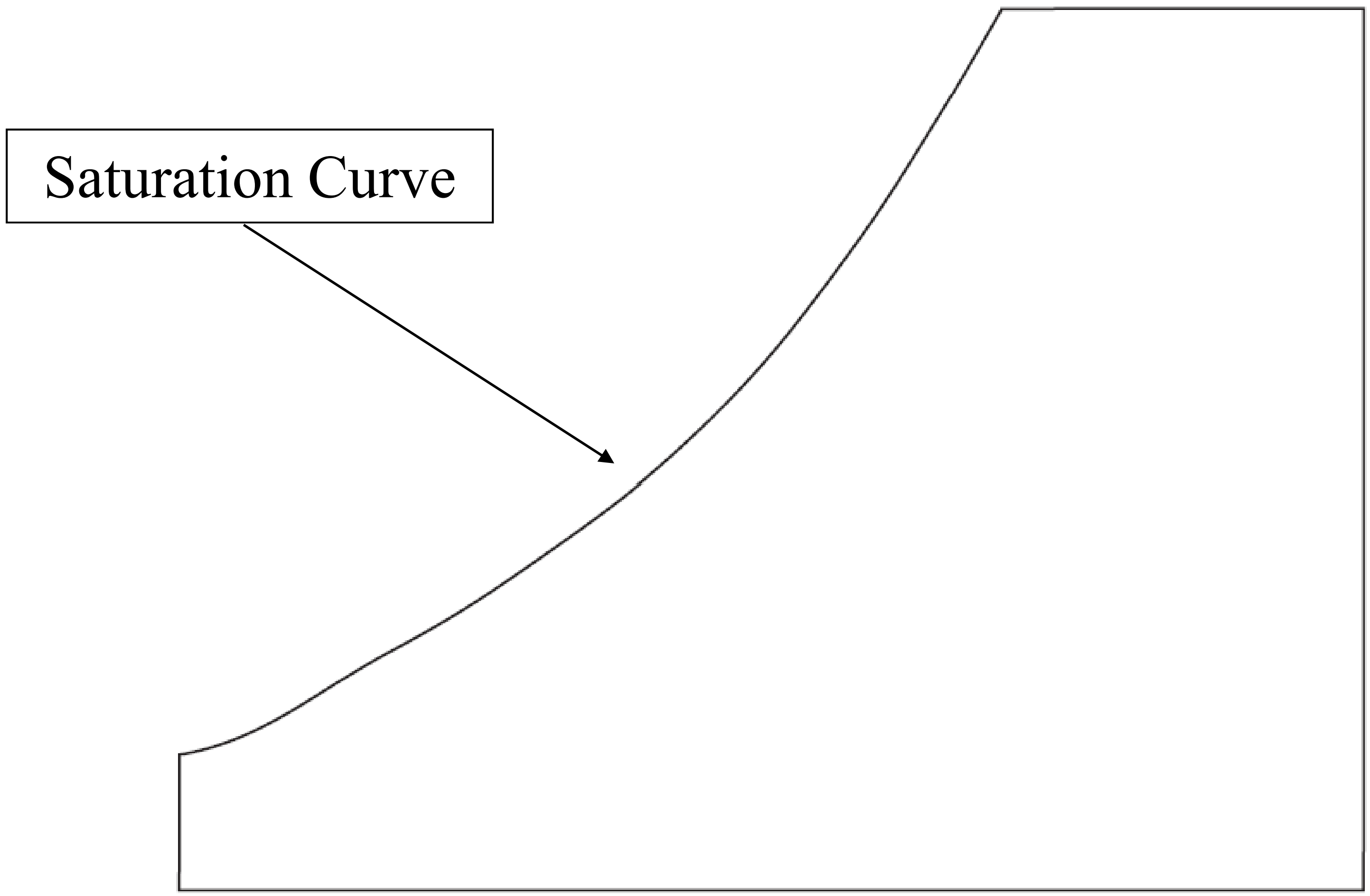
- Humidity Ratio is a measure of the weight of water in a given amount of air
  - Also referred to as Specific Humidity
  - Can be expressed in ***grains***
  - 7,000 grains equals one pound of water

$$\text{Humidity Ratio} = \frac{\text{Pounds of moisture}}{\text{Pounds of dry air}}$$

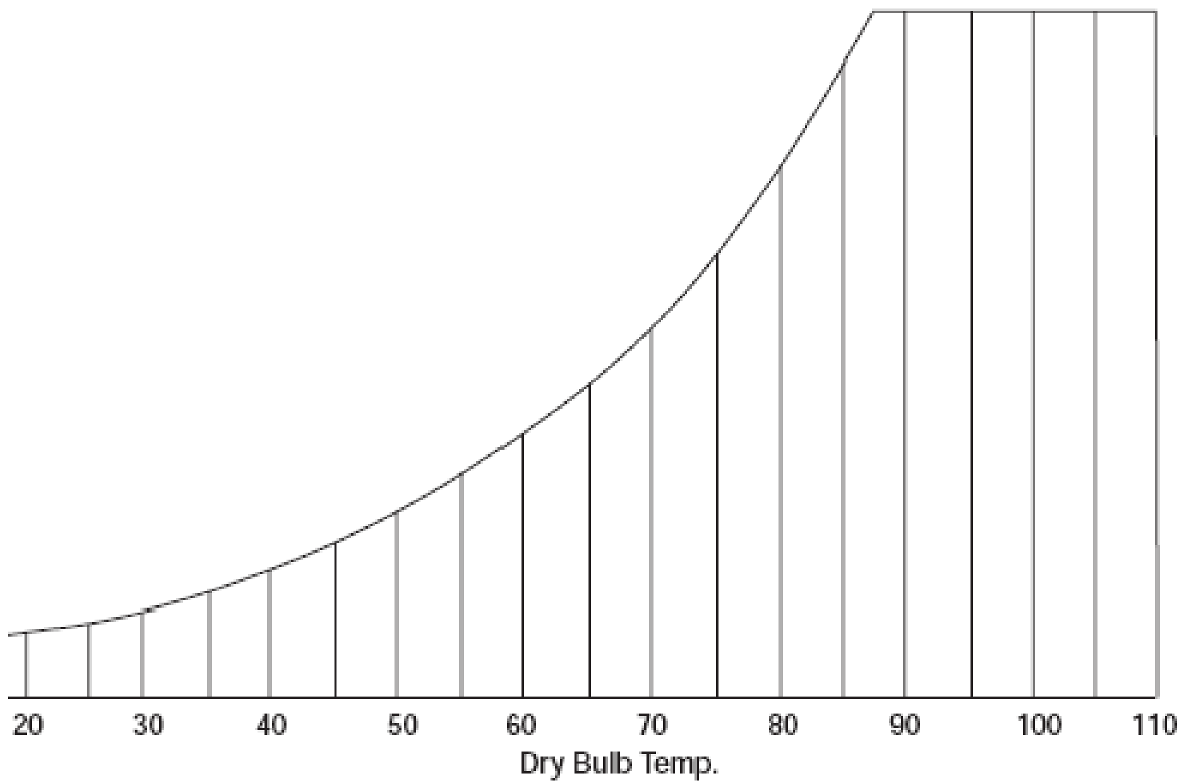
The Psychrometric Chart



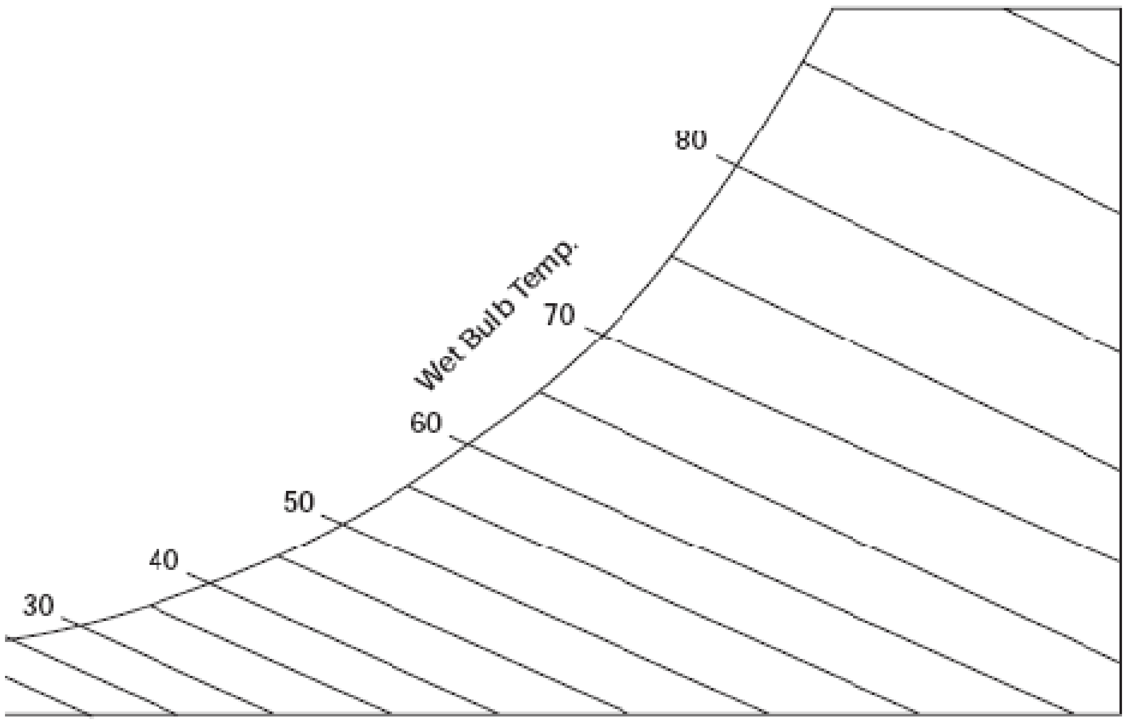
Saturation Curve



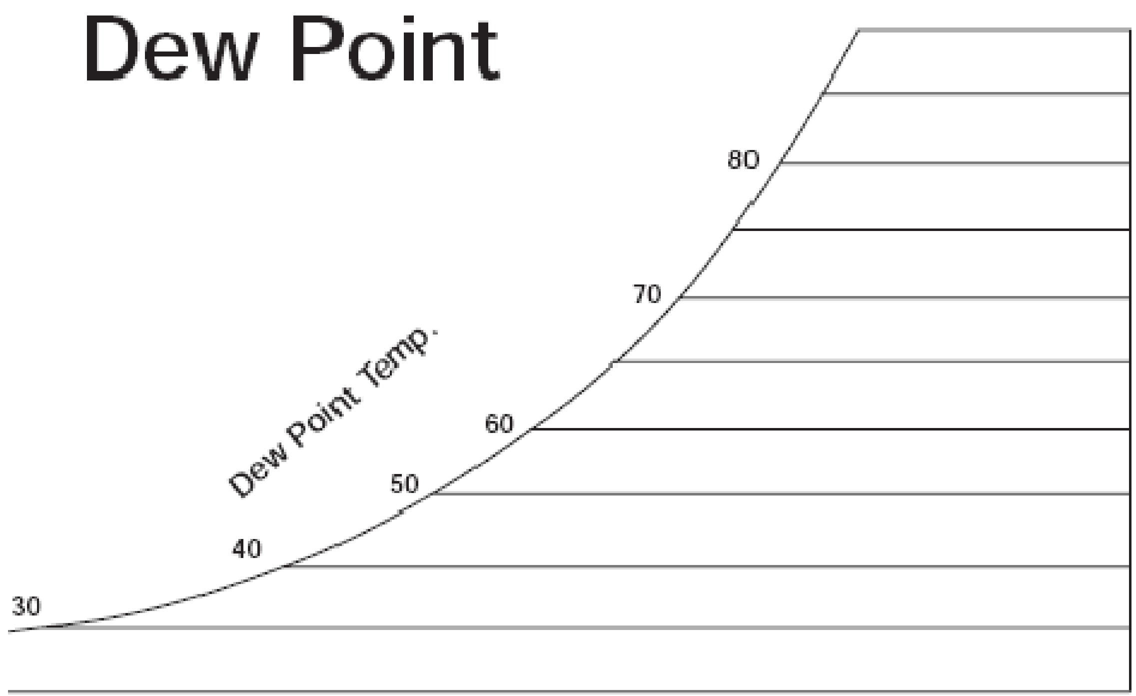
Dry-Bulb Temperature



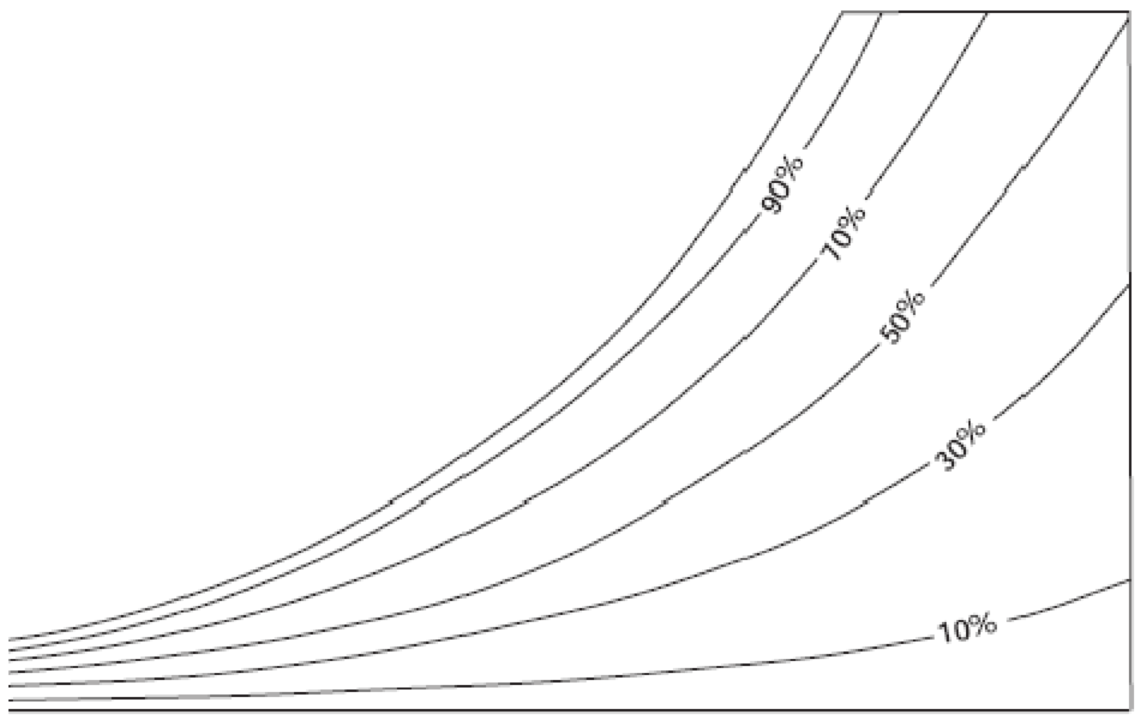
Wet-Bulb Temperature



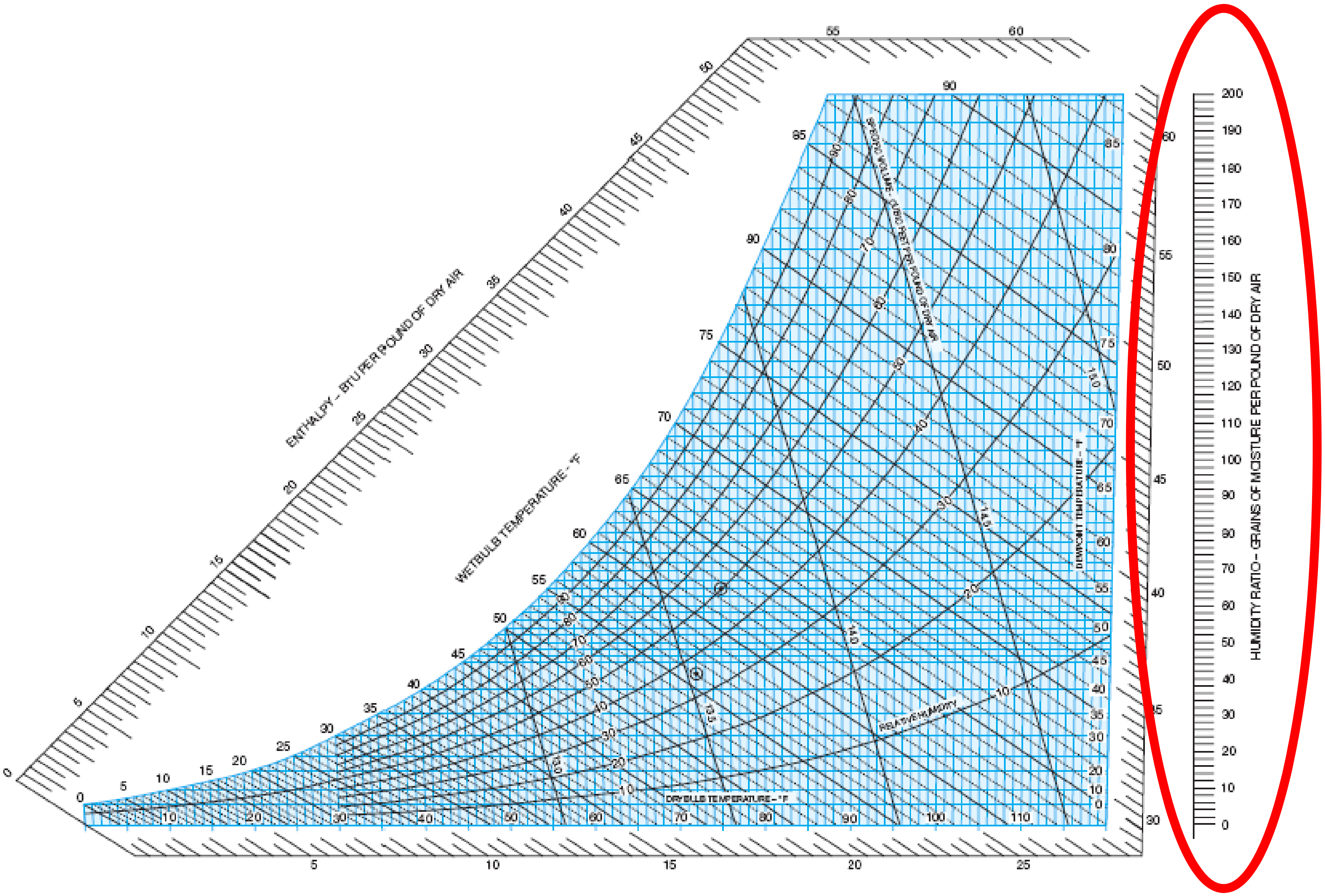
Dew-Point Temperature



Relative Humidity



Humidity Ratio

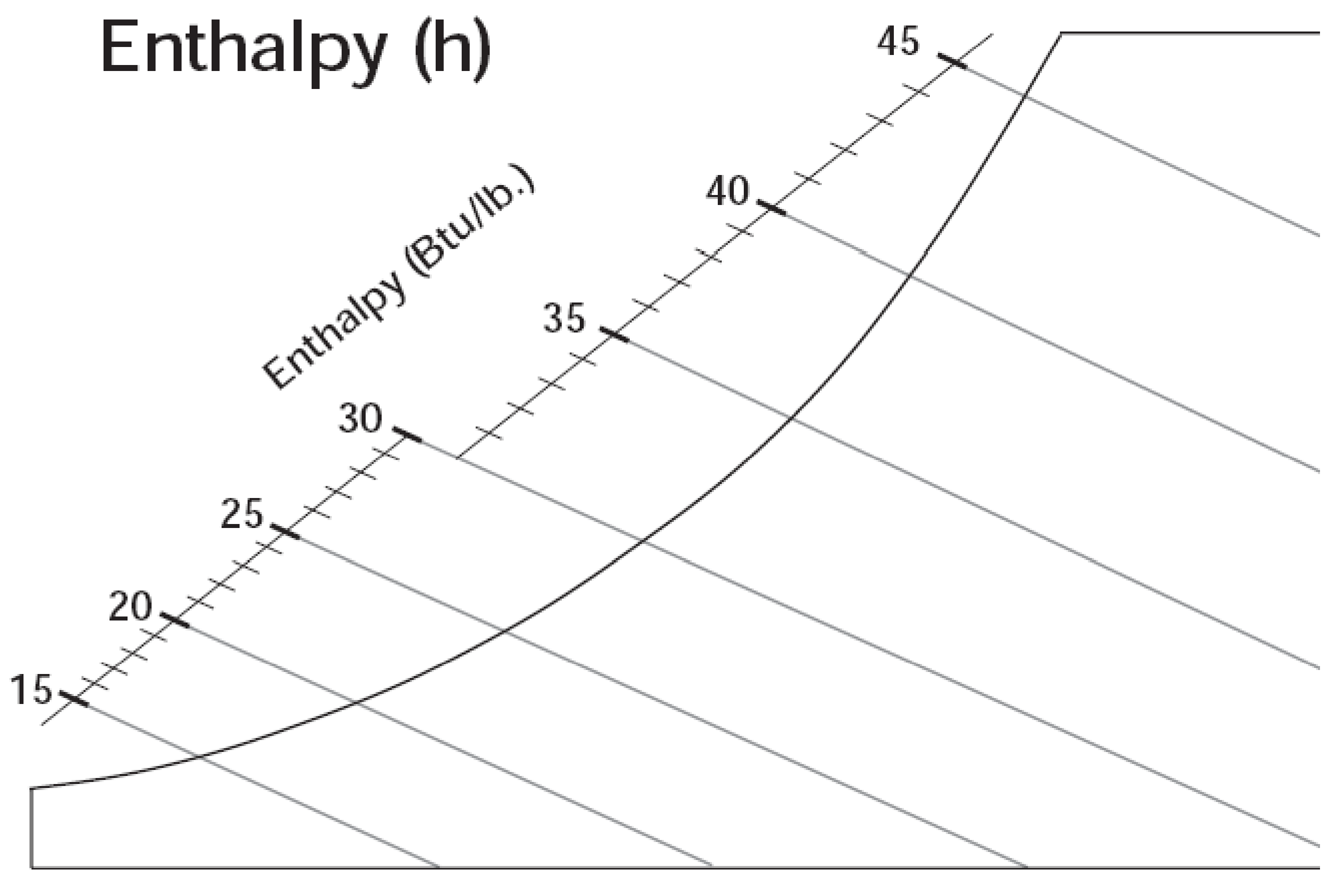


Sensible and Latent Energy

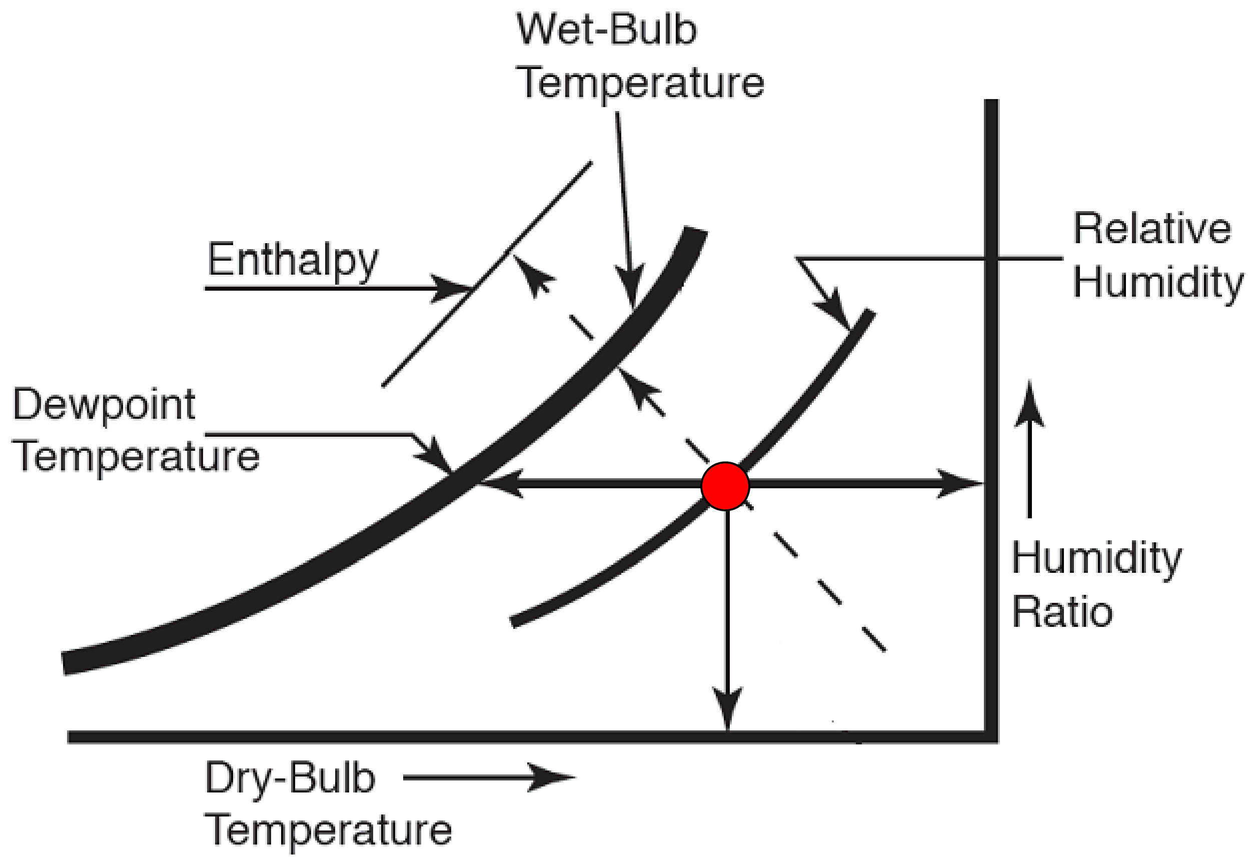
- Sensible Energy is the heat that causes changes in the air's dry bulb temperature
- Latent Energy is the heat associated with phase change. It is representative of changes in the air's moisture content with no change to the dry-bulb temperature
- Enthalpy is the total energy in a given amount of air at its present conditions

$$\text{Enthalpy } (h) = \text{Sensible Energy} + \text{Latent Energy}$$

Enthalpy



Psychrometric Chart Reconstructed



Example:

93°F DB, 65°F WB

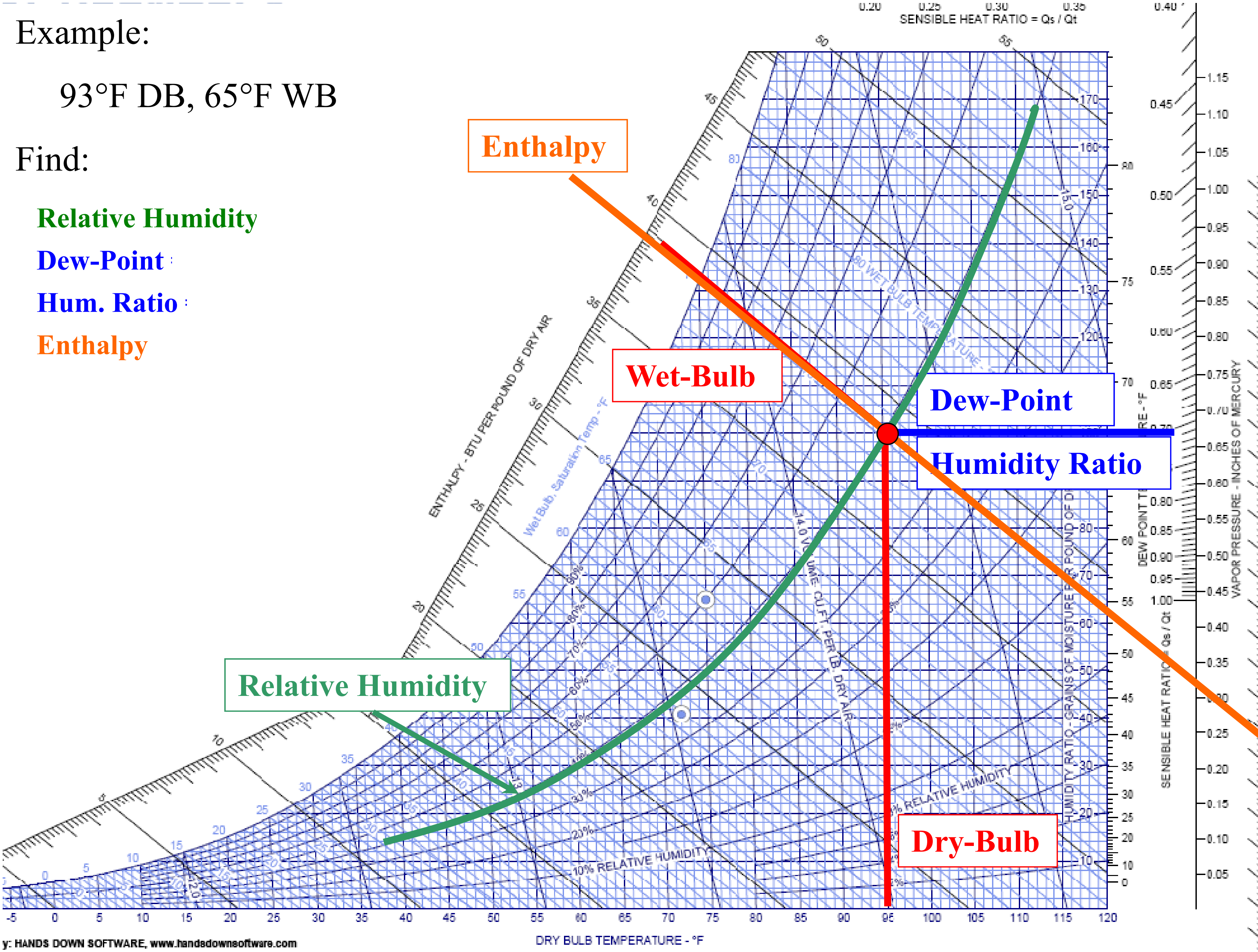
Find:

Relative Humidity

Dew-Point

Hum. Ratio

Enthalpy

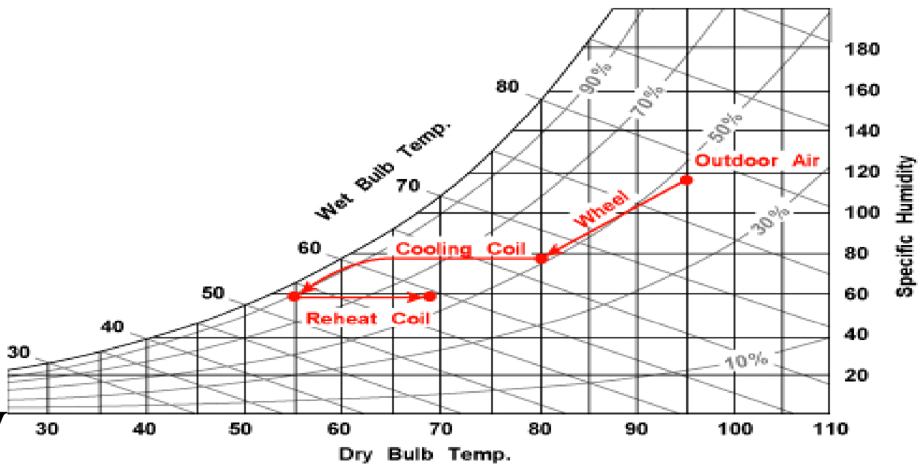


Air Density Corrections

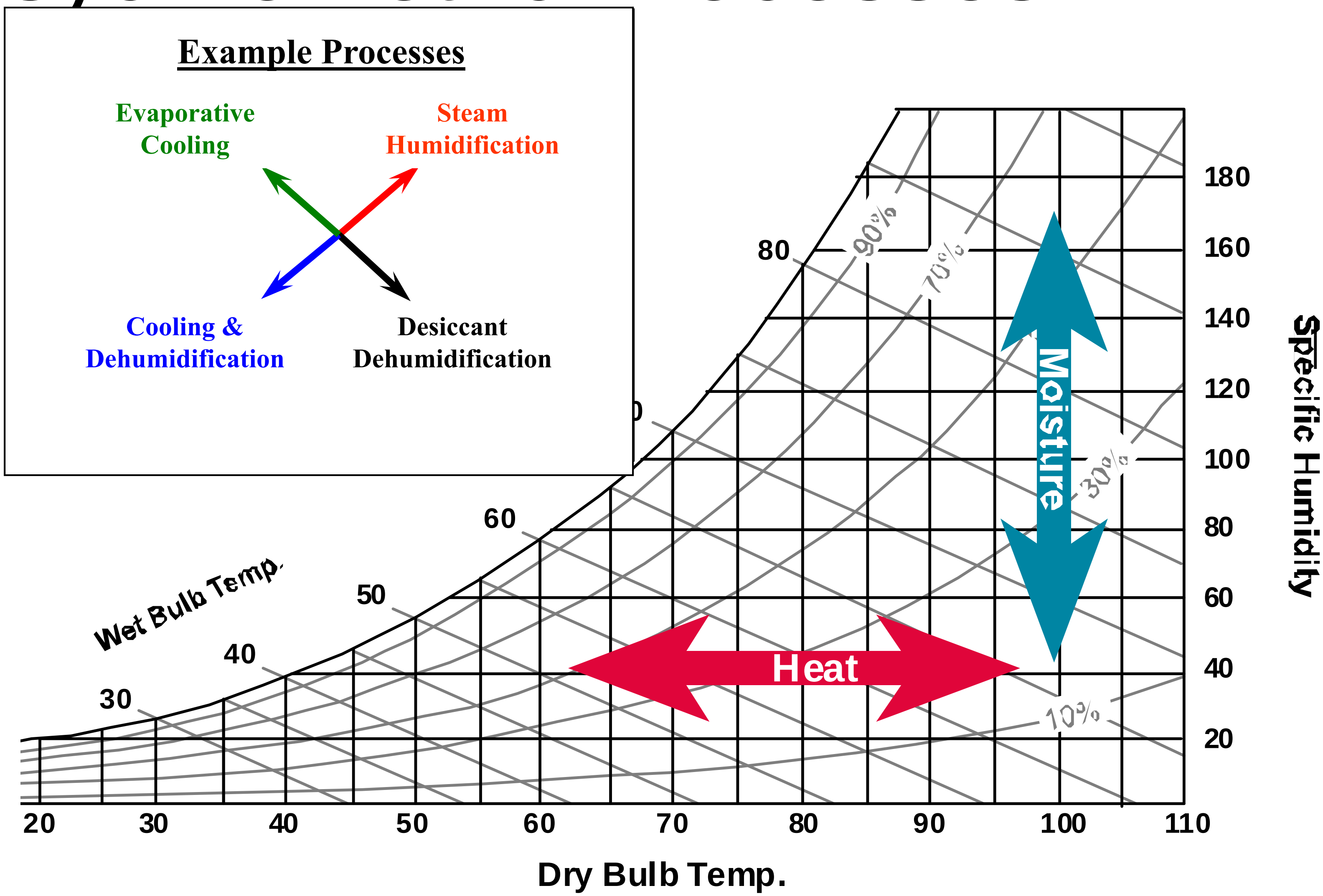
- *Do <u>NOT</u> forget about elevation!*
- Above 2,000 feet elevation, the air density is reduced by approximately 3.6% per every 1,000 feet
- A change in air density also changes the physical and thermodynamic properties of air-water mixtures

Psychrometric Processes

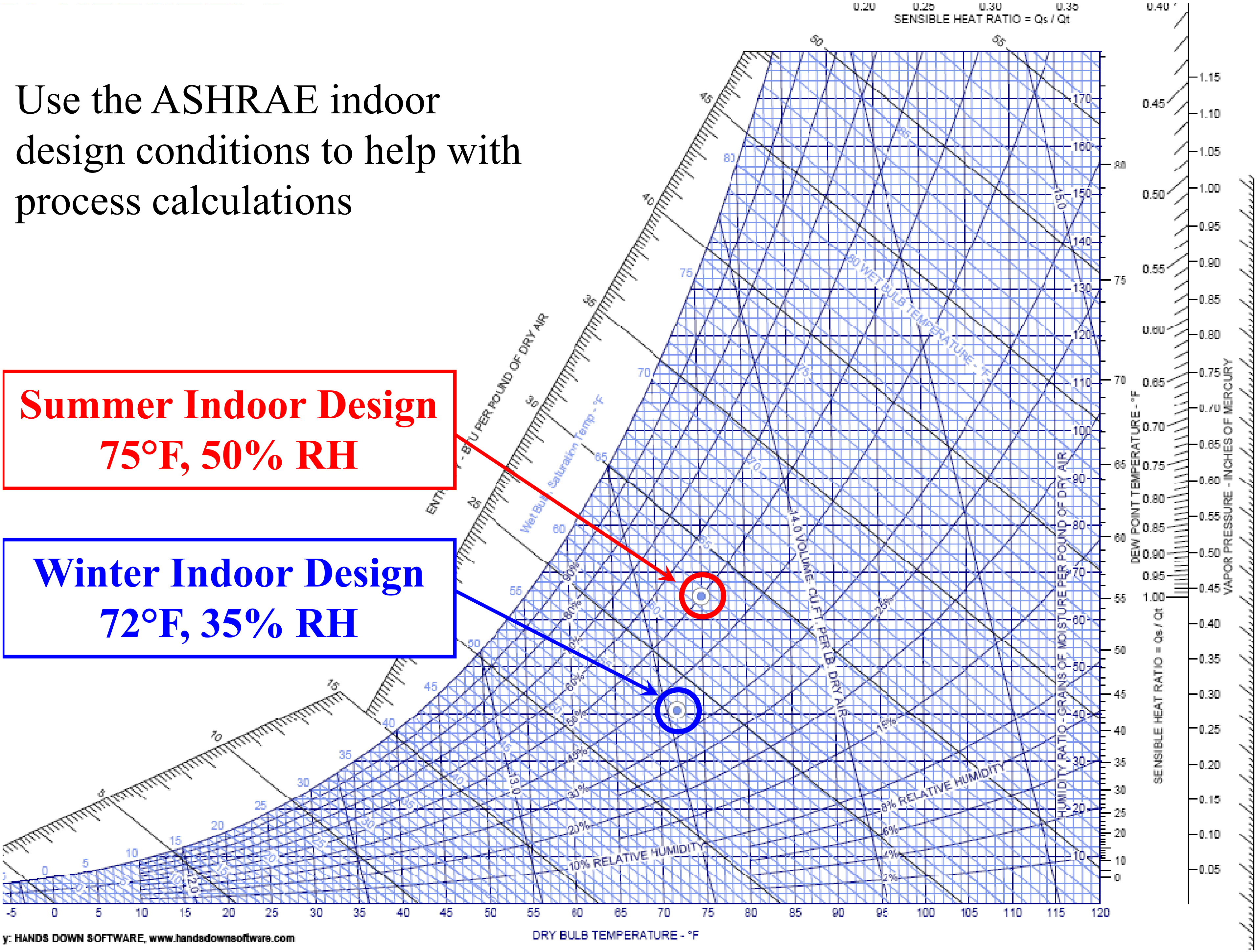
- Air Conditioning
  - Mixed Air
  - Cooling Coils
  - Reheat
  - Calculations
- Energy Recovery
  - Sensible Devices
  - Total Enthalpy Devices



Psychrometric Processes



Use the ASHRAE indoor design conditions to help with process calculations

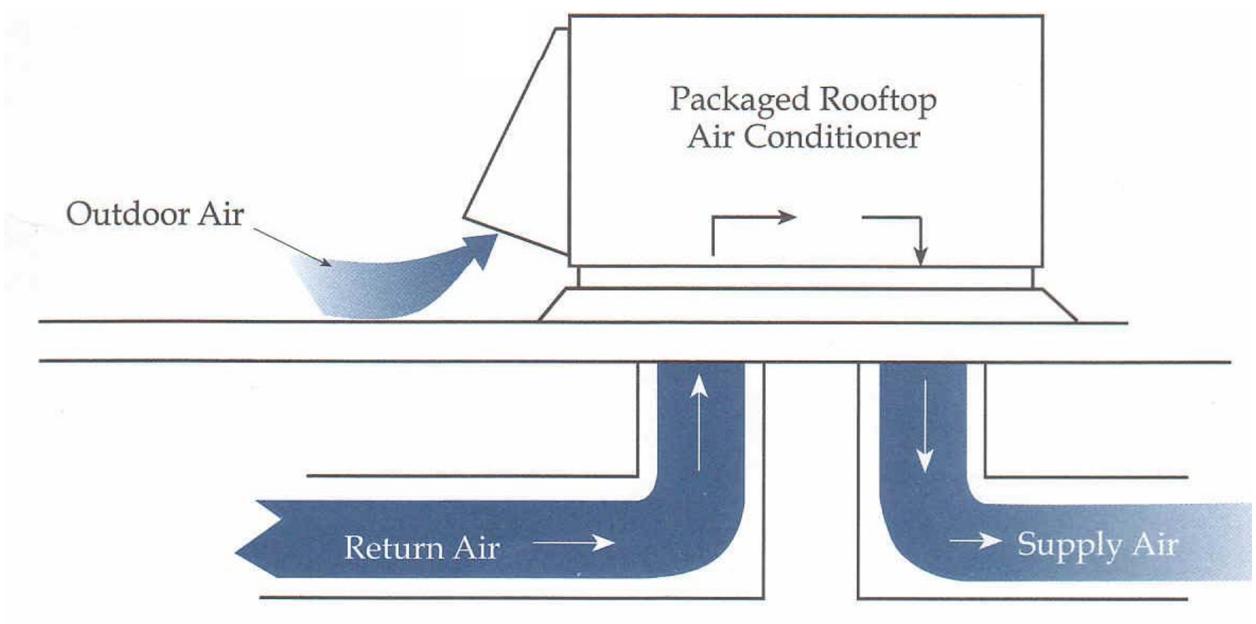


Summer Indoor Design
75°F, 50% RH

Winter Indoor Design
72°F, 35% RH

Mixed Air Conditions

- Step 1: Identify outdoor condition, indoor condition, and ventilation rate (% outside air)
- Step 2: Draw a straight line between the outdoor and indoor conditions
- Step 3: Draw a straight line between points 1 and 2



Mixed Air Example

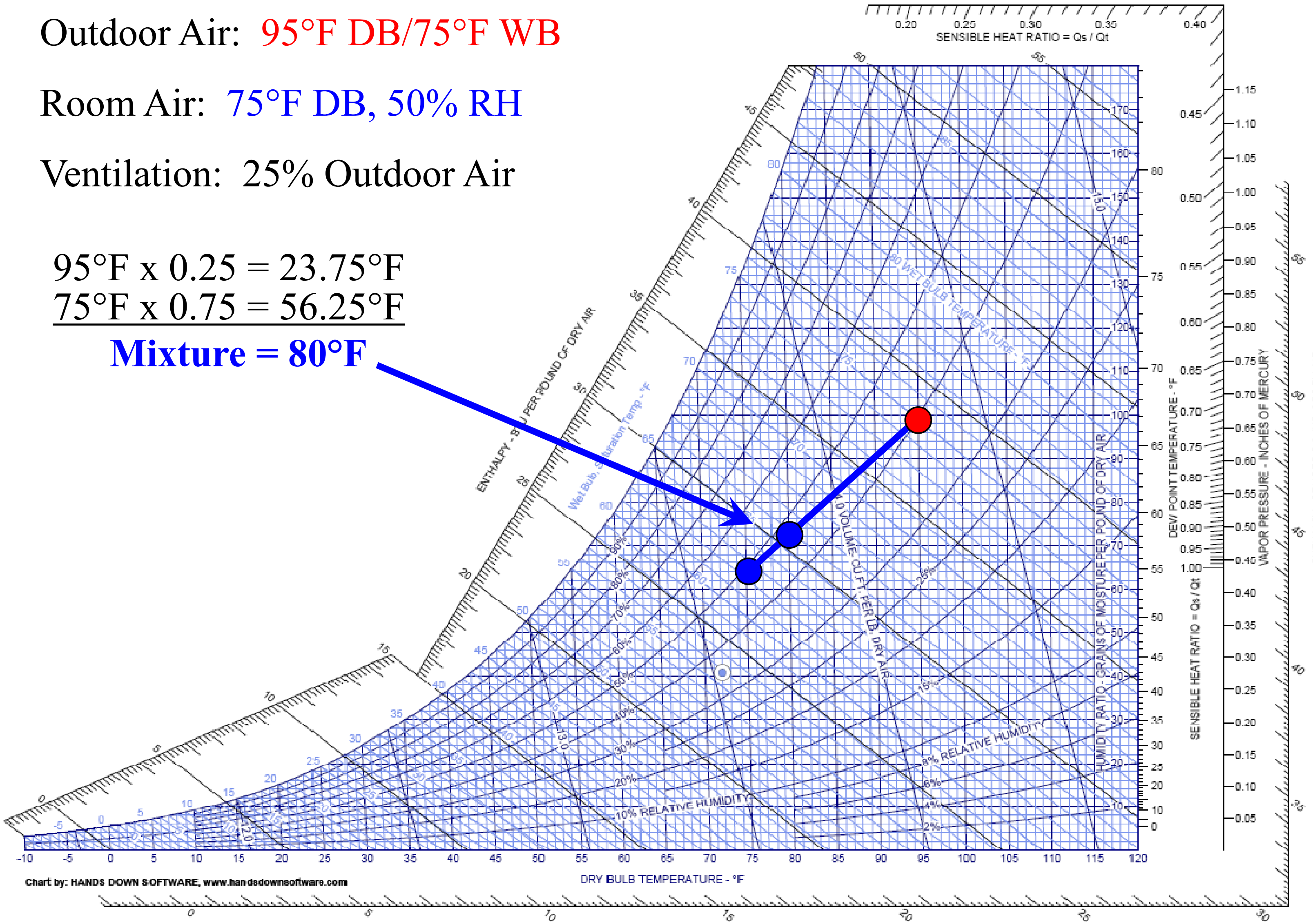
Outdoor Air: 95°F DB/75°F WB

Room Air: 75°F DB, 50% RH

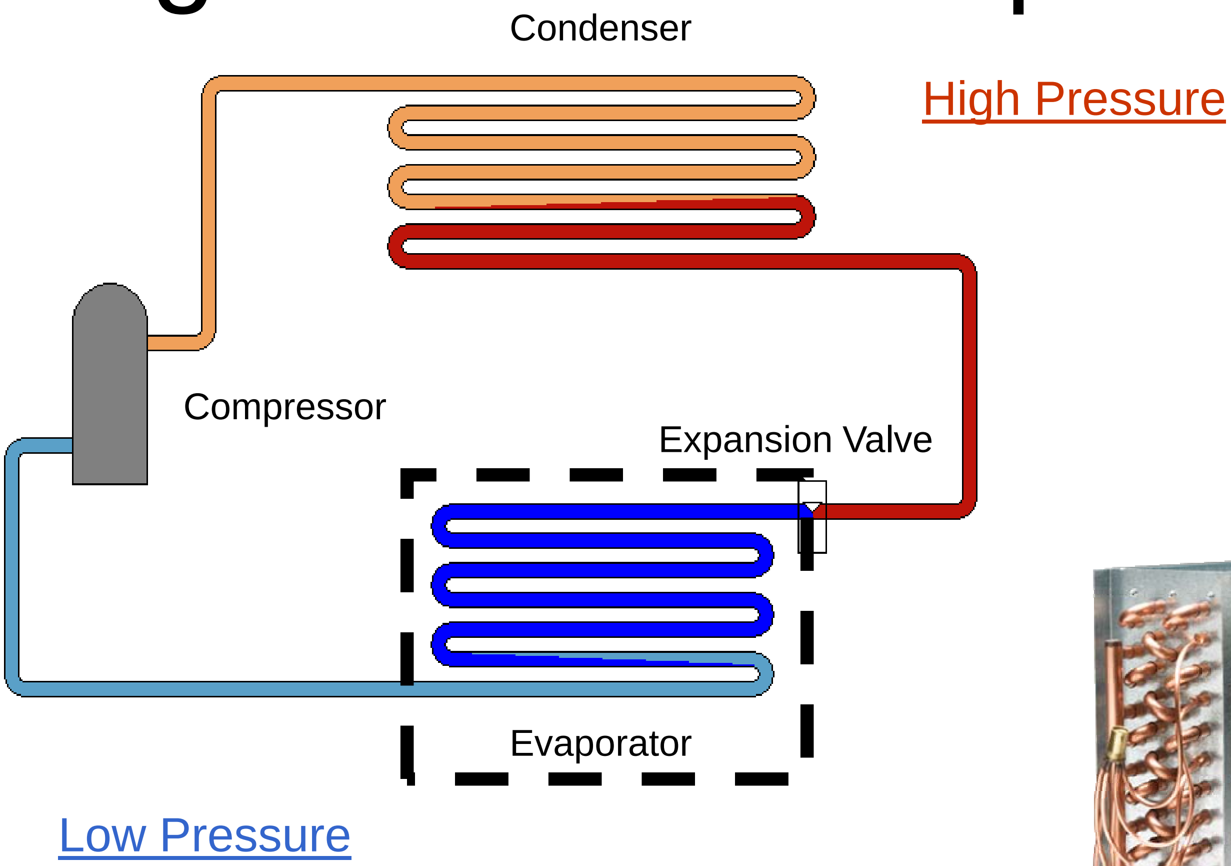
Ventilation: 25% Outdoor Air

95°F x 0.25 = 23.75°F
75°F x 0.75 = 56.25°F

Mixture = 80°F



Cooling Process Example

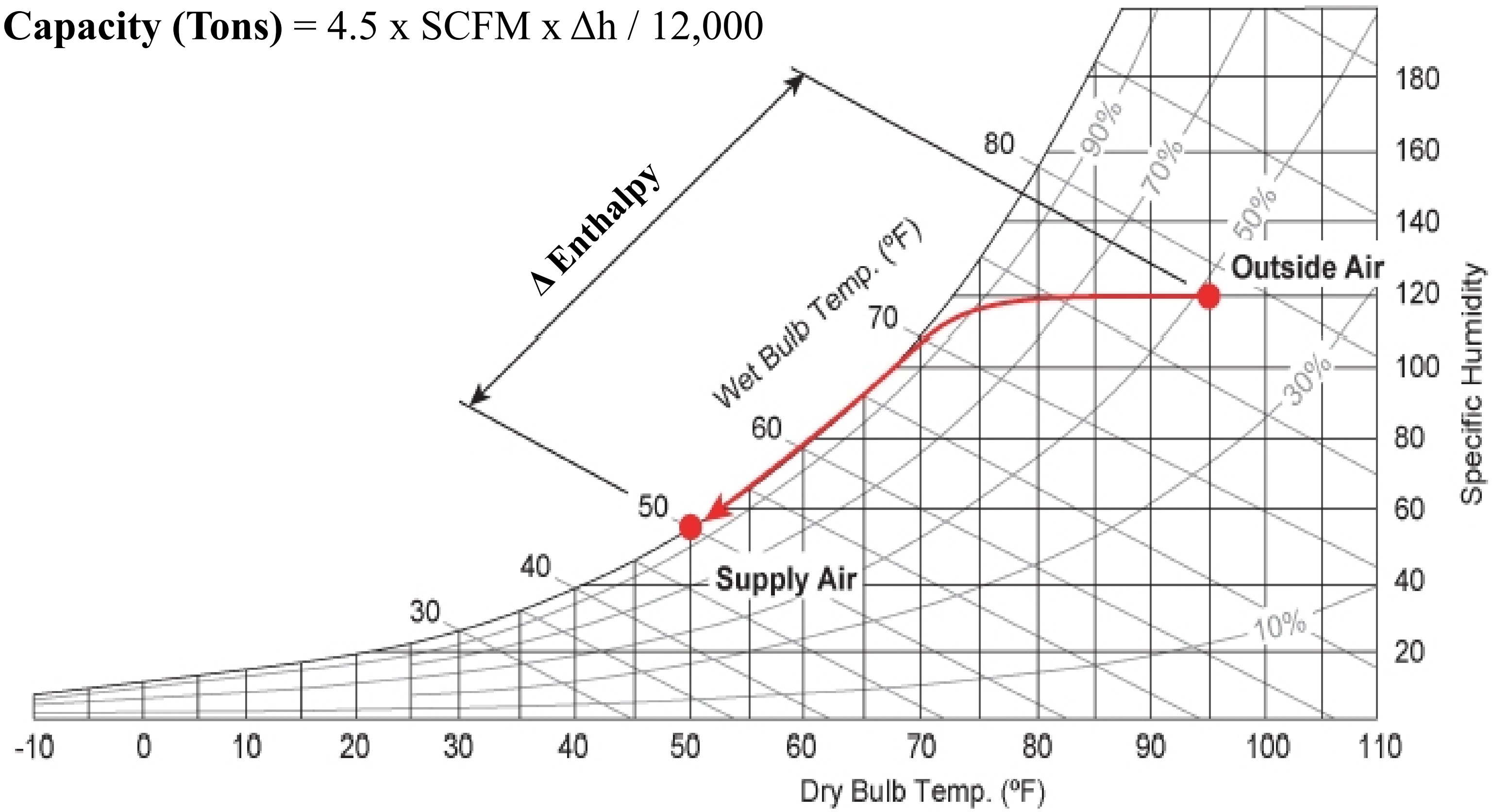


Cooling Coil Processes

Capacity (Btu/hr) = 4.5 x SCFM x Δh

→ 1 Cooling Ton = 12,000 Btu/hr

Capacity (Tons) = 4.5 x SCFM x Δh / 12,000



Cooling Exercise

- Exercise 2: A customer wants to cool 4,000 SCFM of outside air from 93°F DB / 65° WB to 50°F saturated air
- Find the following parameters for 50°F saturated air:

Property
Relative Humidity
Dew Point
Humidity Ratio
Enthalpy

- What is the change in enthalpy from 93DB/65WB to 50DB/50WB?

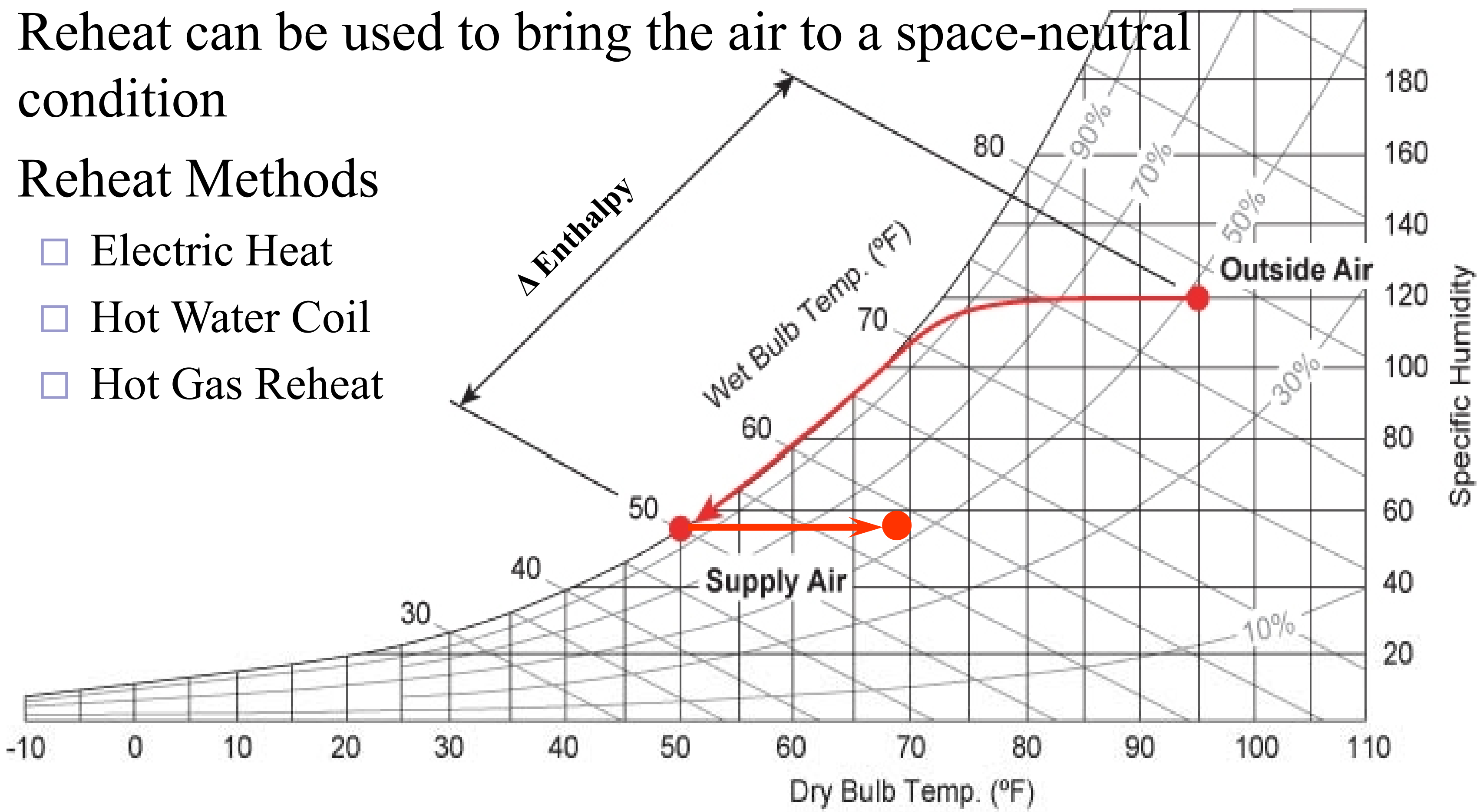
  → Δh = 10.9 Btu / lb dry air

- Determine the cooling tonnage required in this process.

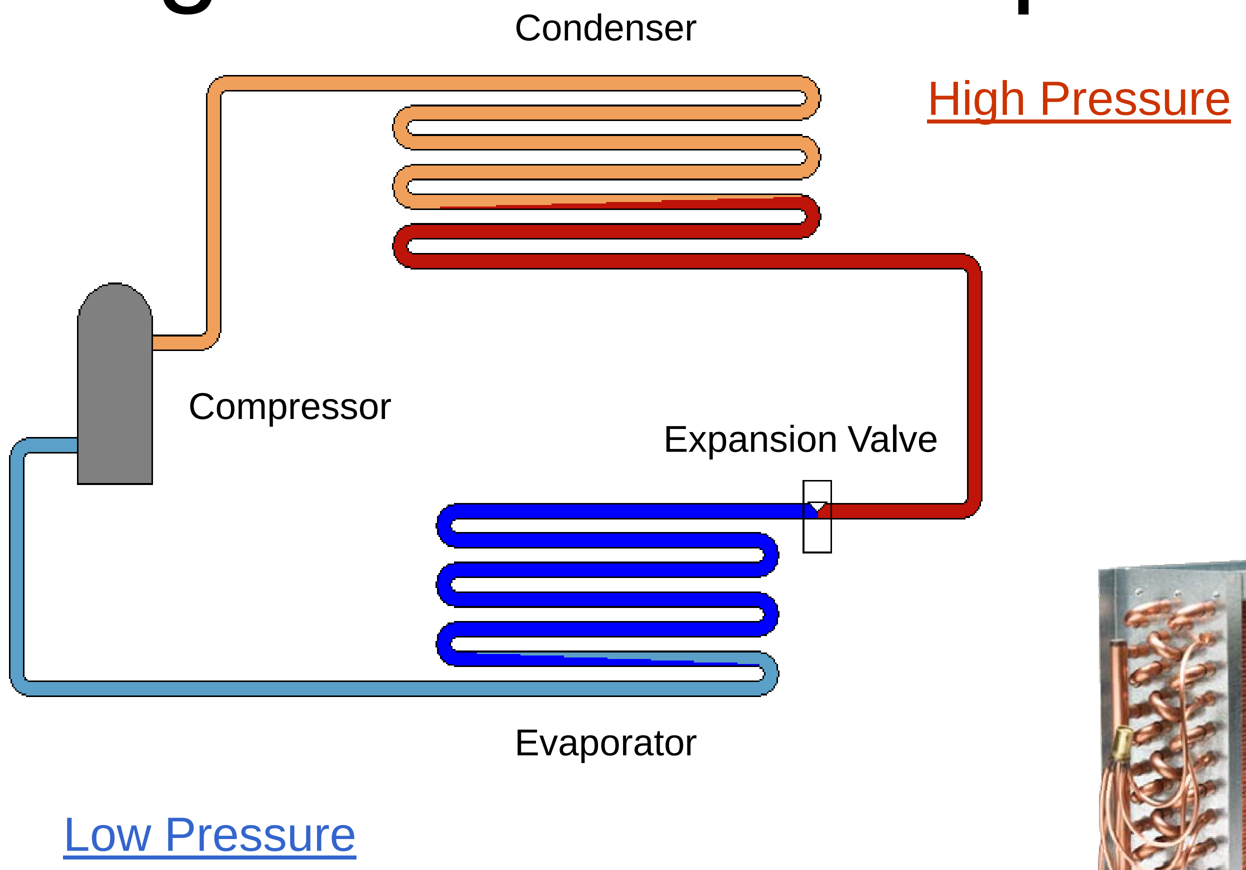
  → Capacity = 16.4 Tons

Dehumidification w/ Reheat

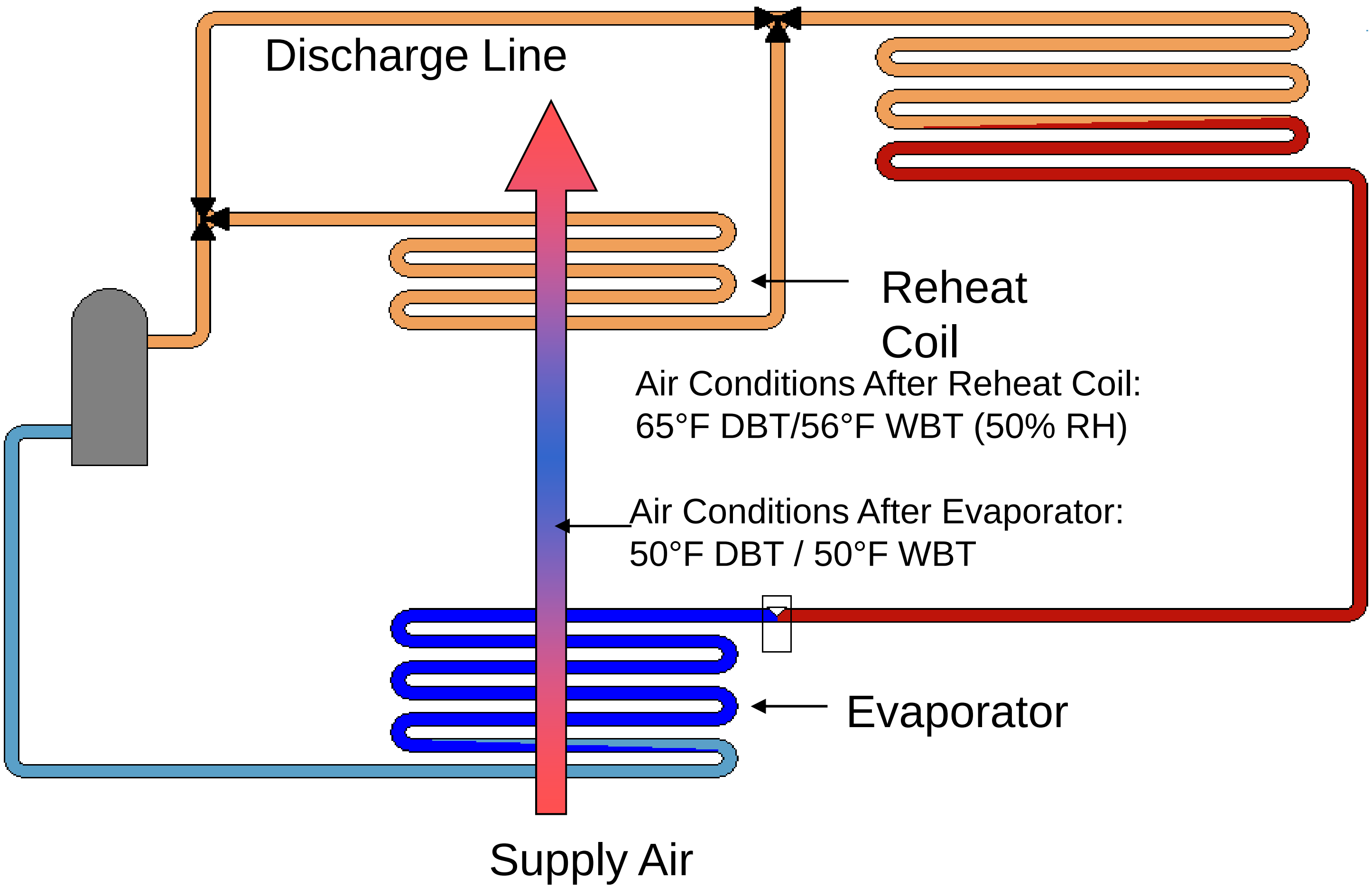
- Introducing cold, saturated air directly into an occupied space may be too cool for occupant comfort
- Reheat can be used to bring the air to a space-neutral condition
- Reheat Methods
  - Electric Heat
  - Hot Water Coil
  - Hot Gas Reheat



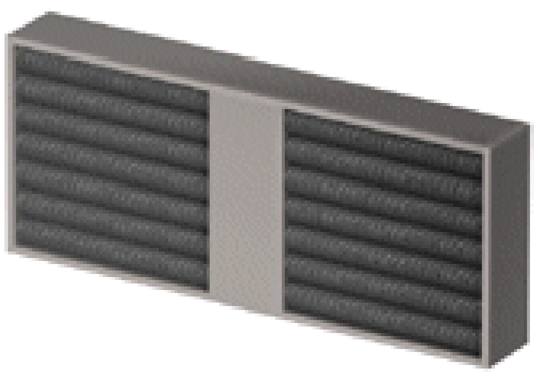
Cooling Process Example



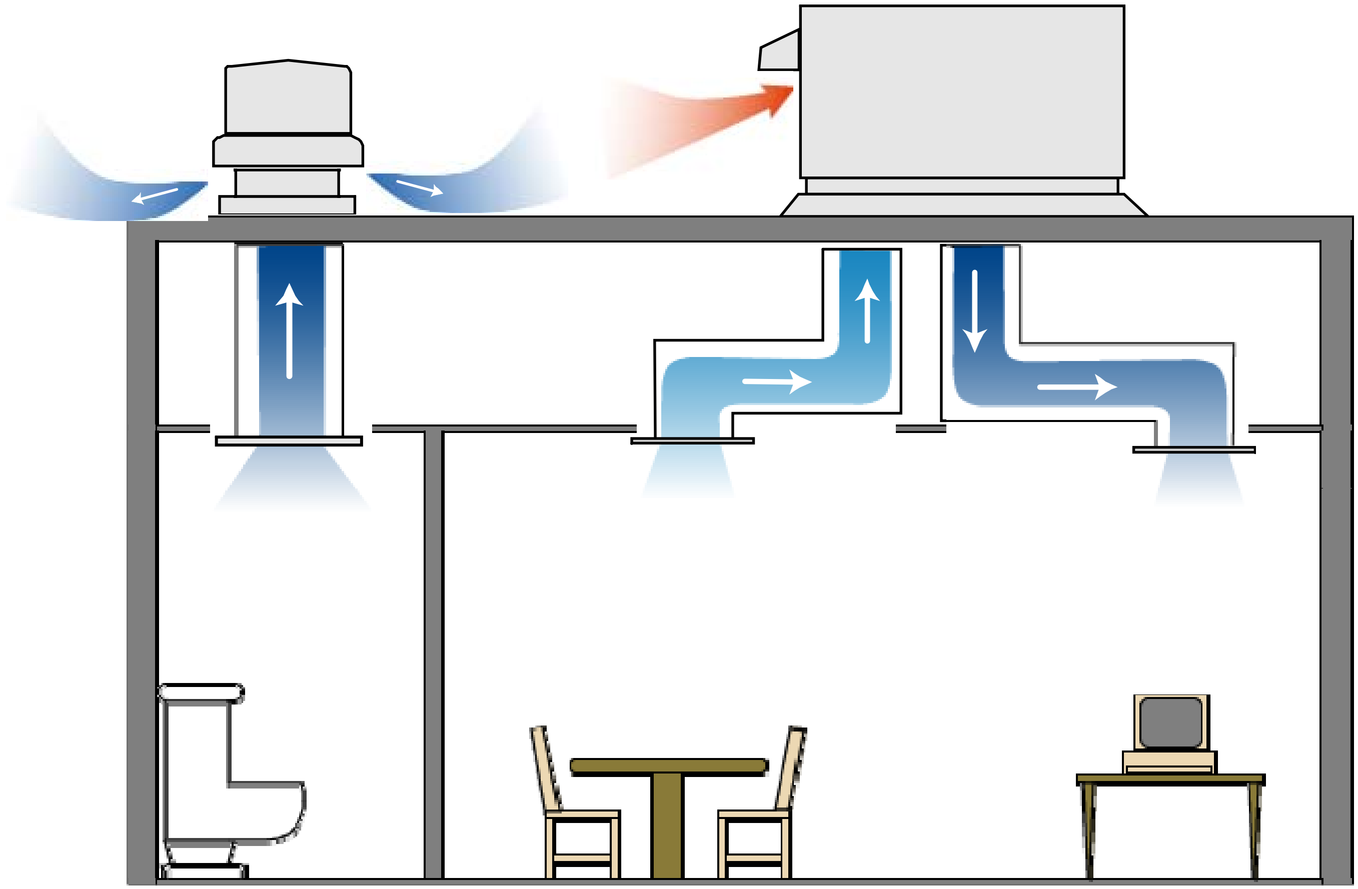
Hot Gas Reheat

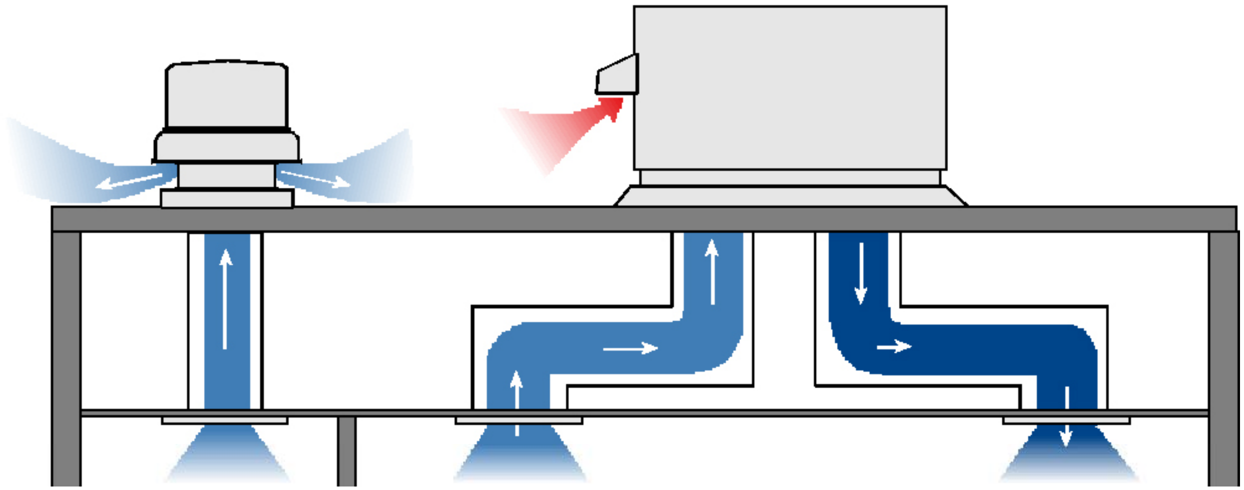


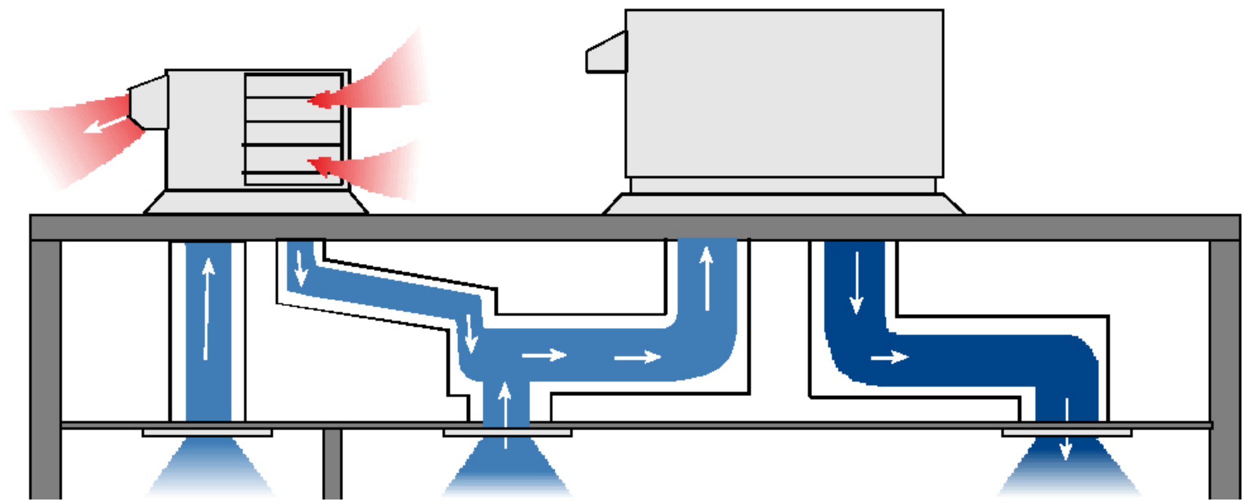
Energy Recovery



Traditional HVAC System

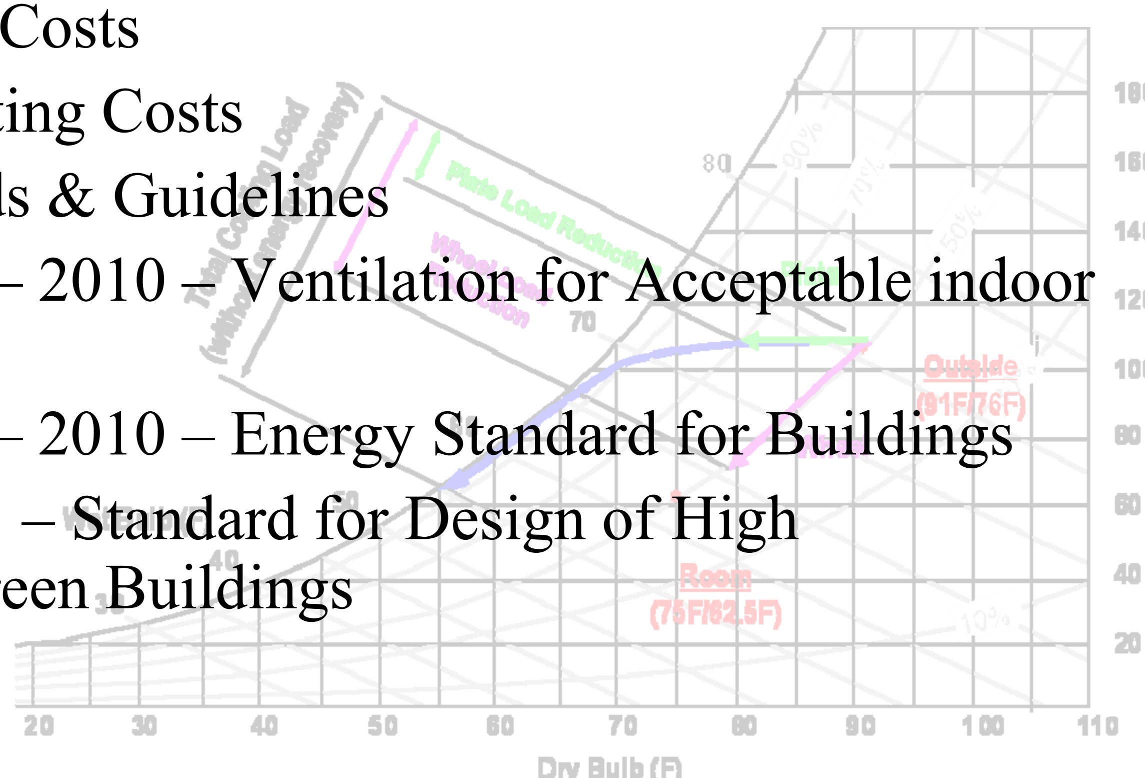






Why Energy Recovery?

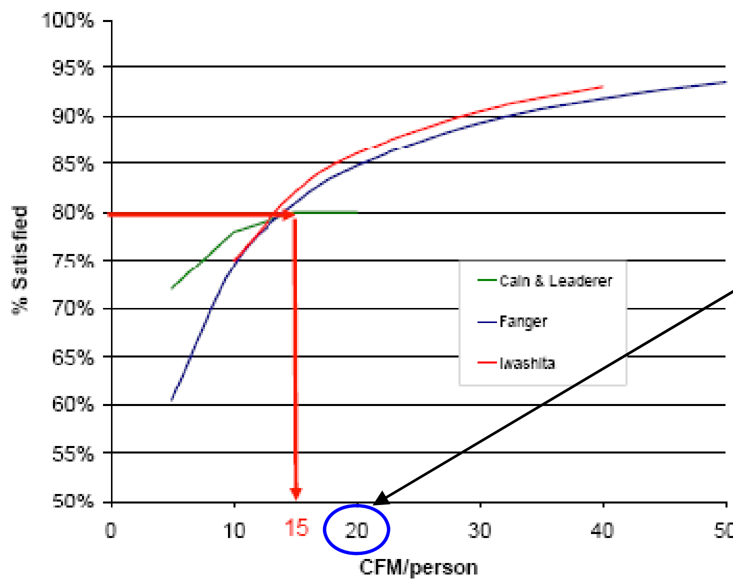
- Economic Benefits
  - Reduced Initial Costs
  - Reduced Operating Costs
- ASHRAE Standards & Guidelines
  - ASHRAE 62.1 – 2010 – Ventilation for Acceptable indoor air quality
  - ASHRAE 90.1 – 2010 – Energy Standard for Buildings
  - ASHRAE 189.1 – Standard for Design of High Performance Green Buildings



ASHRAE Standard 62

“Ventilation for Acceptable Indoor Air Quality”

- Must supply fresh outdoor air to occupied spaces to minimize the potential for adverse health effects.
- Typical ventilation rates:
  - 15 CFM per person for Classrooms
  - 17 CFM per person for Offices



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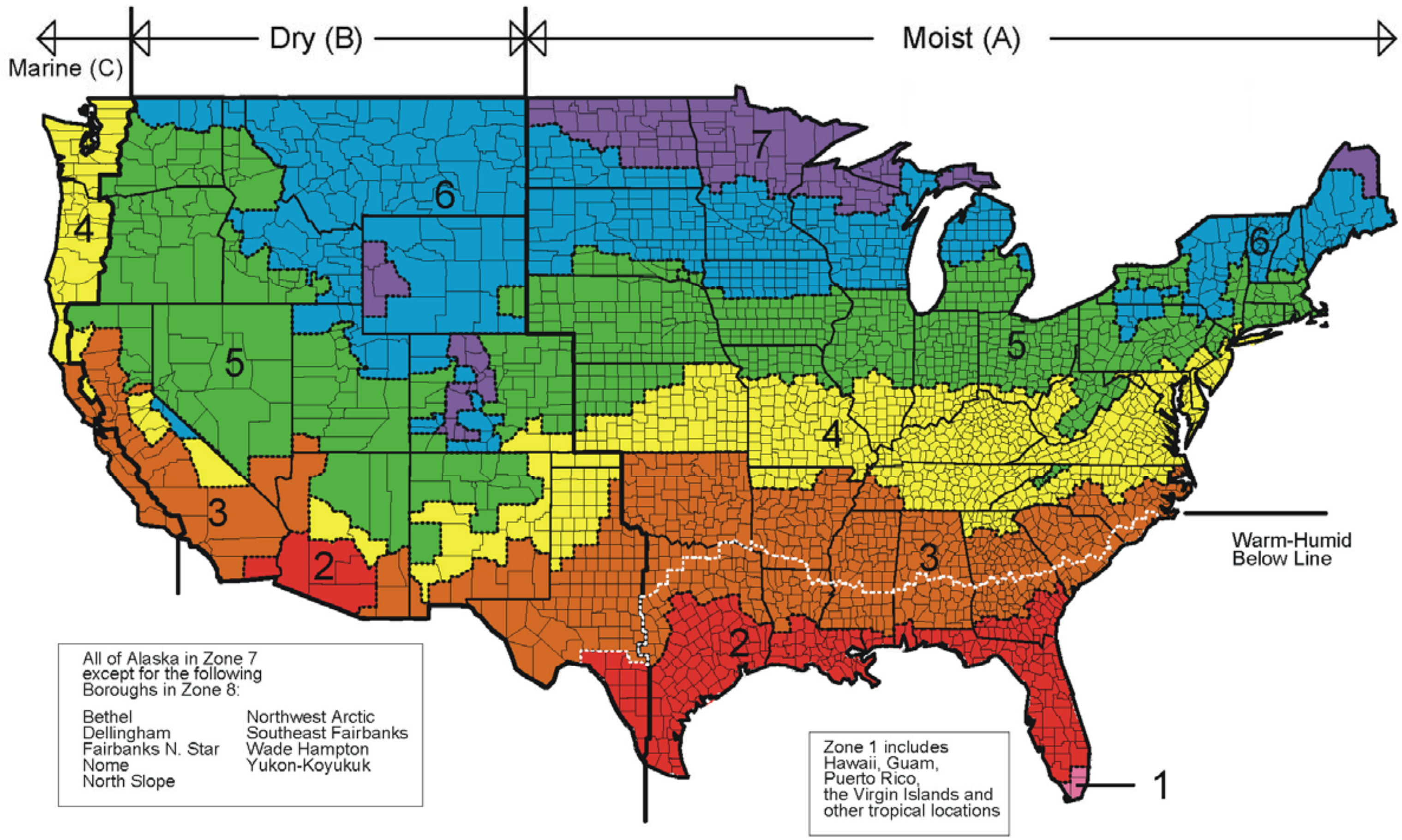
ASHRAE 90.1-2010

- Exhaust Air Energy Recovery (6.3.6)
  - Supply air is greater than 5000 CFM
  - 70% or more of supply is outdoor air (3500 CFM)
- Energy recovery system shall have a total effectiveness of greater than 50%

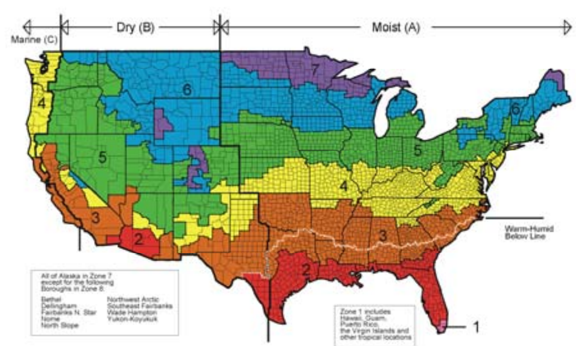
ASHRAE Climate Zones



ASHRAE 90.1-2010

Table 6.5.6.1 Energy Recovery Requirement (IP)

Zone	% Outdoor Air at full design airflow rate (cfm)					
	30% ≤ 40%	40% ≤ 50%	50% ≤ 60%	60% ≤ 70%	70% ≤ 80%	≥ 80%
	Design Supply Fan airflow rate (cfm)					
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥ 5000	≥ 5000
1B, 2B, 5C	NR	NR	≥ 26000	≥ 12000	≥ 5000	≥ 4000
6B	≥ 11000	≥ 5500	≥ 4500	≥ 3500	≥ 2500	≥ 1500
1A, 2A, 3A, 4A, 5A, 6A	≥ 5500	≥ 4500	≥ 3500	≥ 2000	≥ 1000	≥ 0
7, 8	≥ 2500	≥ 1000	≥ 0	≥ 0	≥ 0	≥ 0



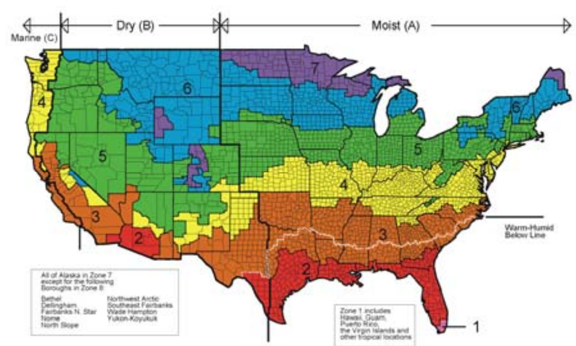
ASHRAE 189.1

“Standard for Design of High-Performance Green Buildings”

www.ashrae.org/greenstandard

Table 7.4.3.8 Energy Recovery Requirement (IP)

Zone		% Outdoor Air at full design airflow rate (cfm)						
	10% ≤ 20%	20% ≤ 30%	30% ≤ 40%	40% ≤ 50%	50% ≤ 60%	60% ≤ 70%	70% ≤ 80%	≥ 80%
	Design Supply Fan airflow rate (cfm)							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	≥ 5000	≥ 5000
1B, 2B, 5C	NR	NR	NR	NR	≥ 26000	≥ 12000	≥ 5000	≥ 4000
6B	NR	≥ 22500	≥ 11000	≥ 5500	≥ 4500	≥ 3500	≥ 2500	≥ 1500
1A, 2A, 3A, 4A, 5A, 6A	≥ 30000	≥ 13000	≥ 5500	≥ 4500	≥ 3500	≥ 2000	≥ 1000	≥ 0
7, 8	≥ 4000	≥ 3000	≥ 2500	≥ 1000	≥ 0	≥ 0	≥ 0	≥ 0

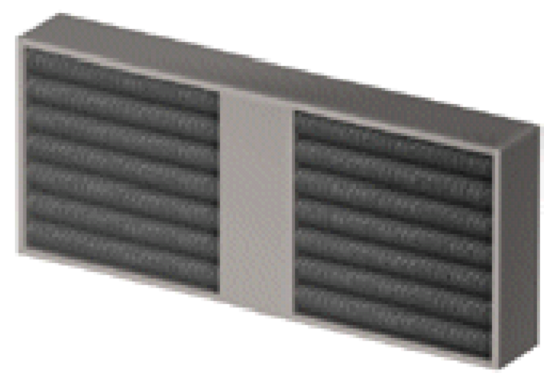


Energy Recovery Basic Terms

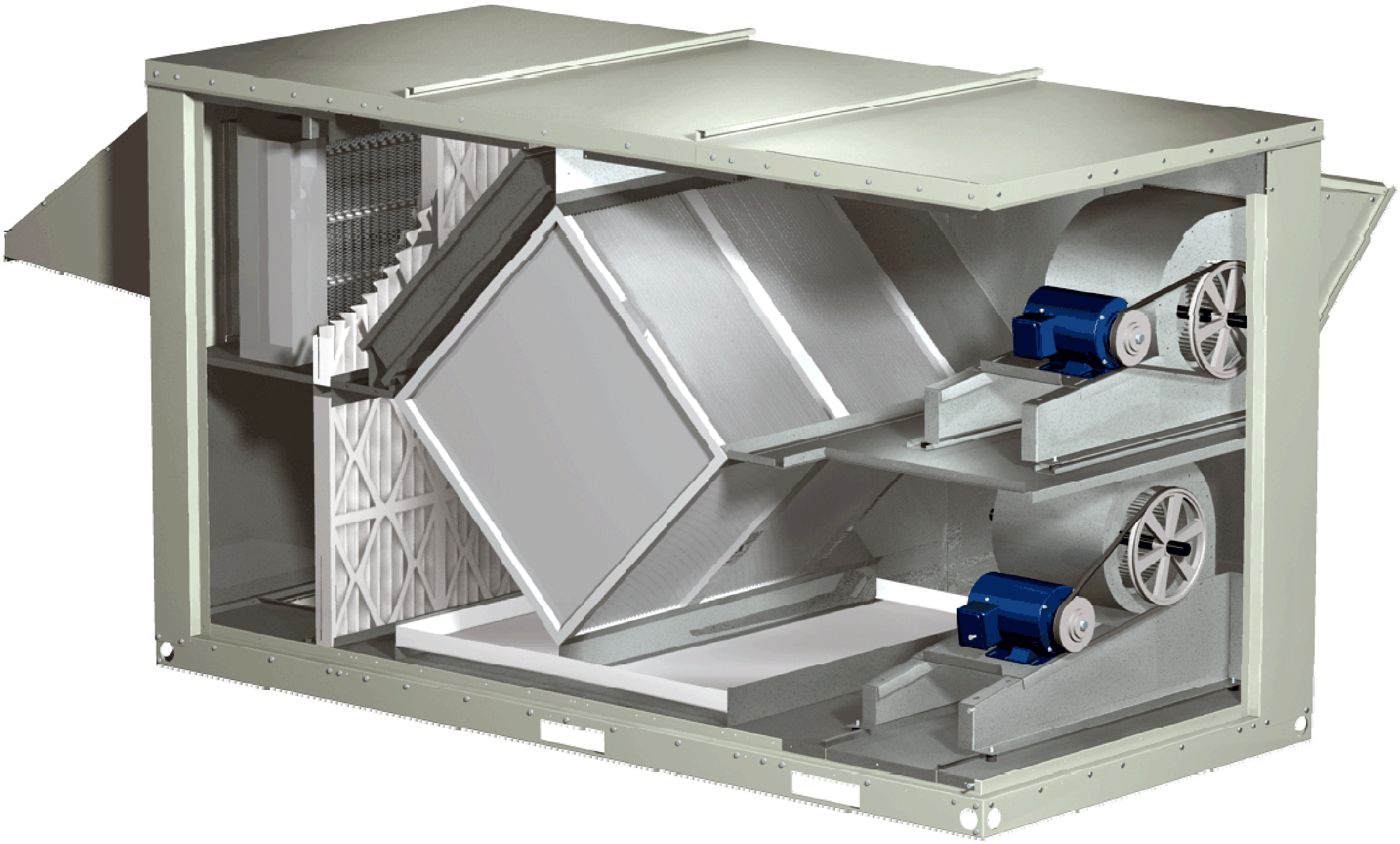
- Sensible Energy Recovery transfers only sensible energy (no moisture)
  - Also referred to as heat recovery
- Total Energy Recovery transfers both sensible and latent energy
- Effectiveness refers to the efficiency of the energy recovery device (expressed as a percentage)
  - Sensible effectiveness
  - Total effectiveness

Sensible Heat Recovery

- Sensible Heat Recovery
  - Aluminum fixed plate
  - Run-around coils
  - Heat-pipe heat exchangers
  - Sensible wheels (no desiccant)
- Transfers sensible energy only (no moisture transfer)

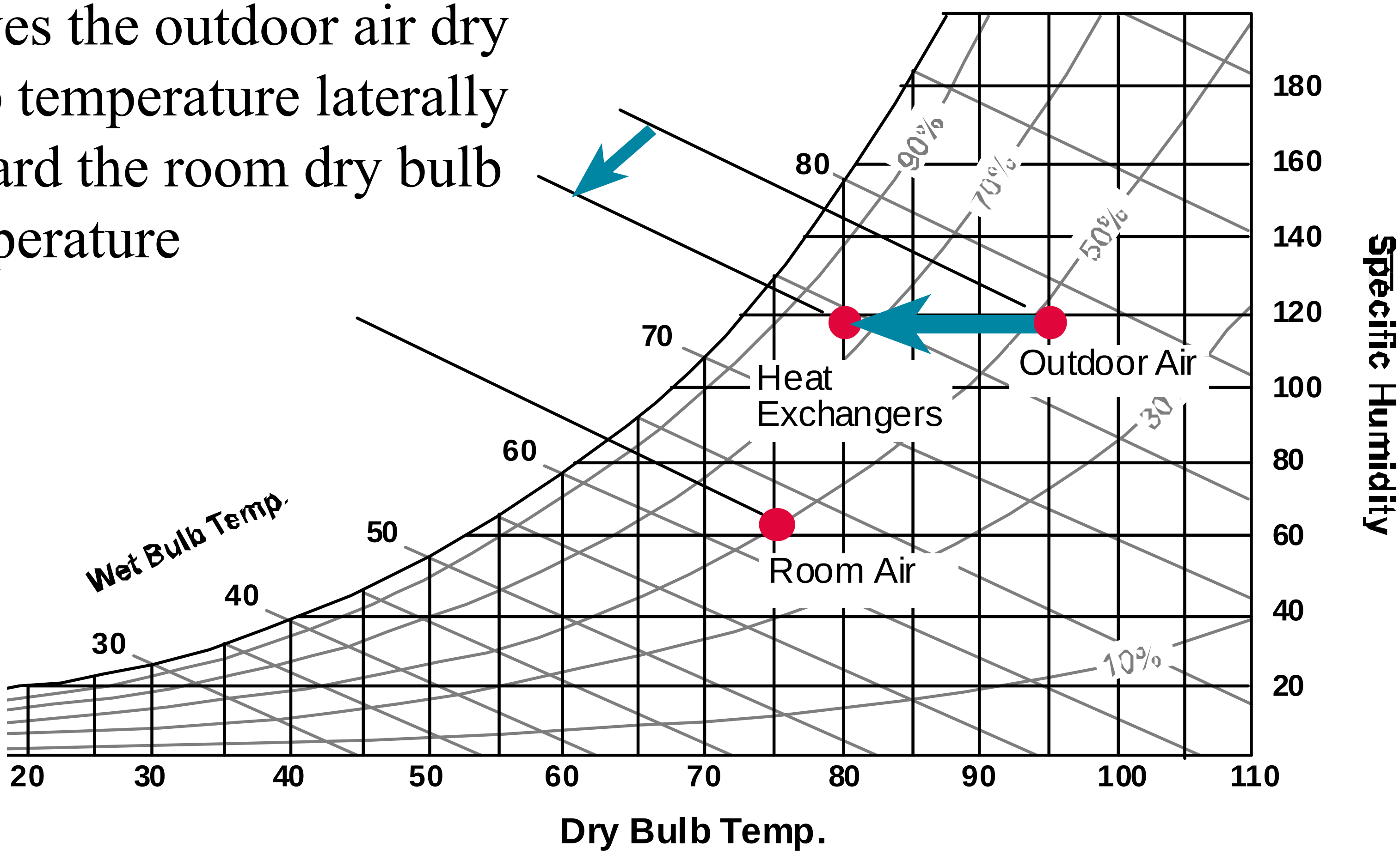


Sensible Plate HRV



Sensible Energy Recovery

- Sensible Energy recovery moves the outdoor air dry bulb temperature laterally toward the room dry bulb temperature



Total Energy Recovery

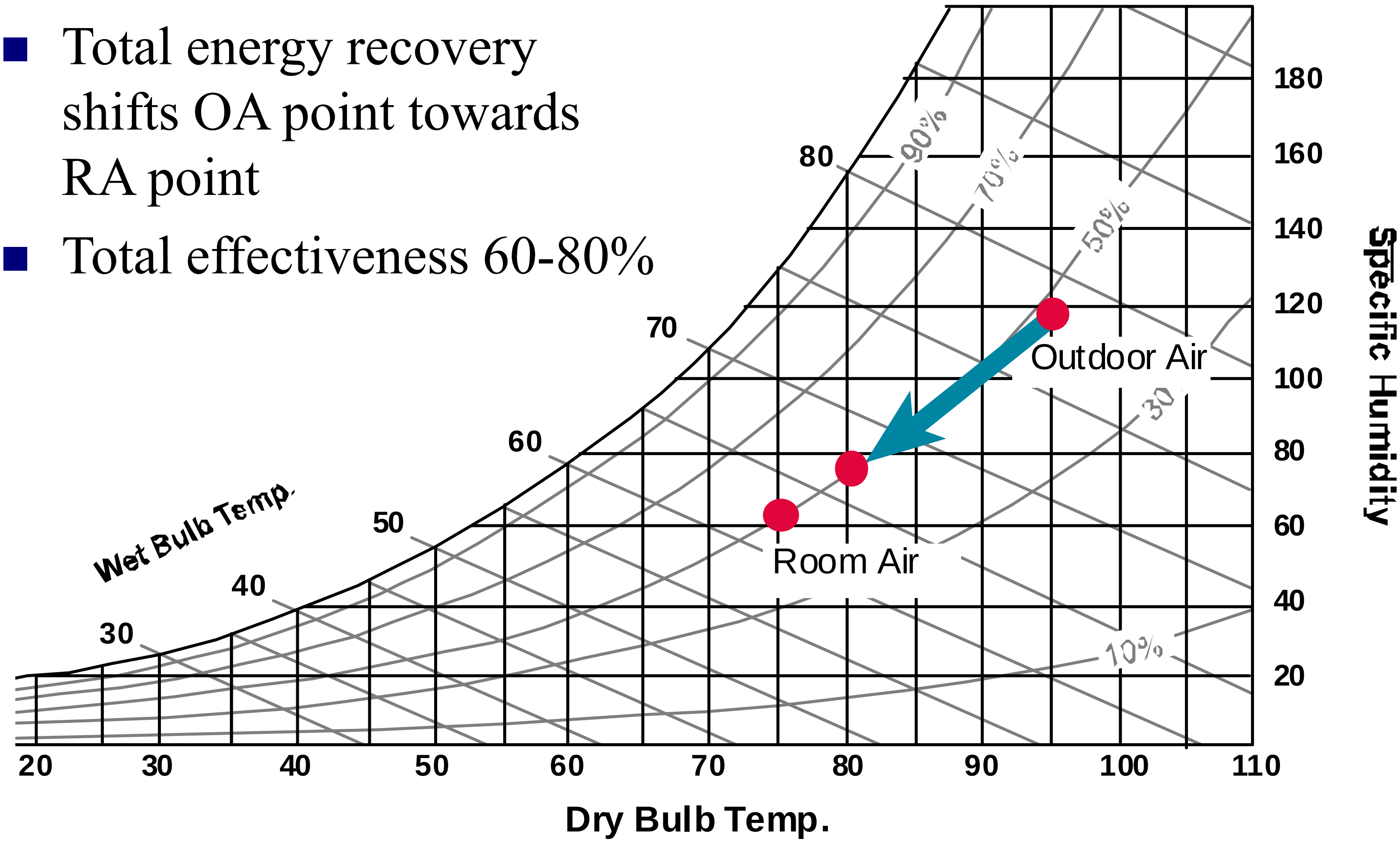
- Total Energy Recovery
  - Enthalpy wheels
  - Enthalpy plates (or cores)
- Transfers sensible energy through the media
- Transfers latent energy through a desiccant (wheel) or molecular transfer (core)

Energy Recovery

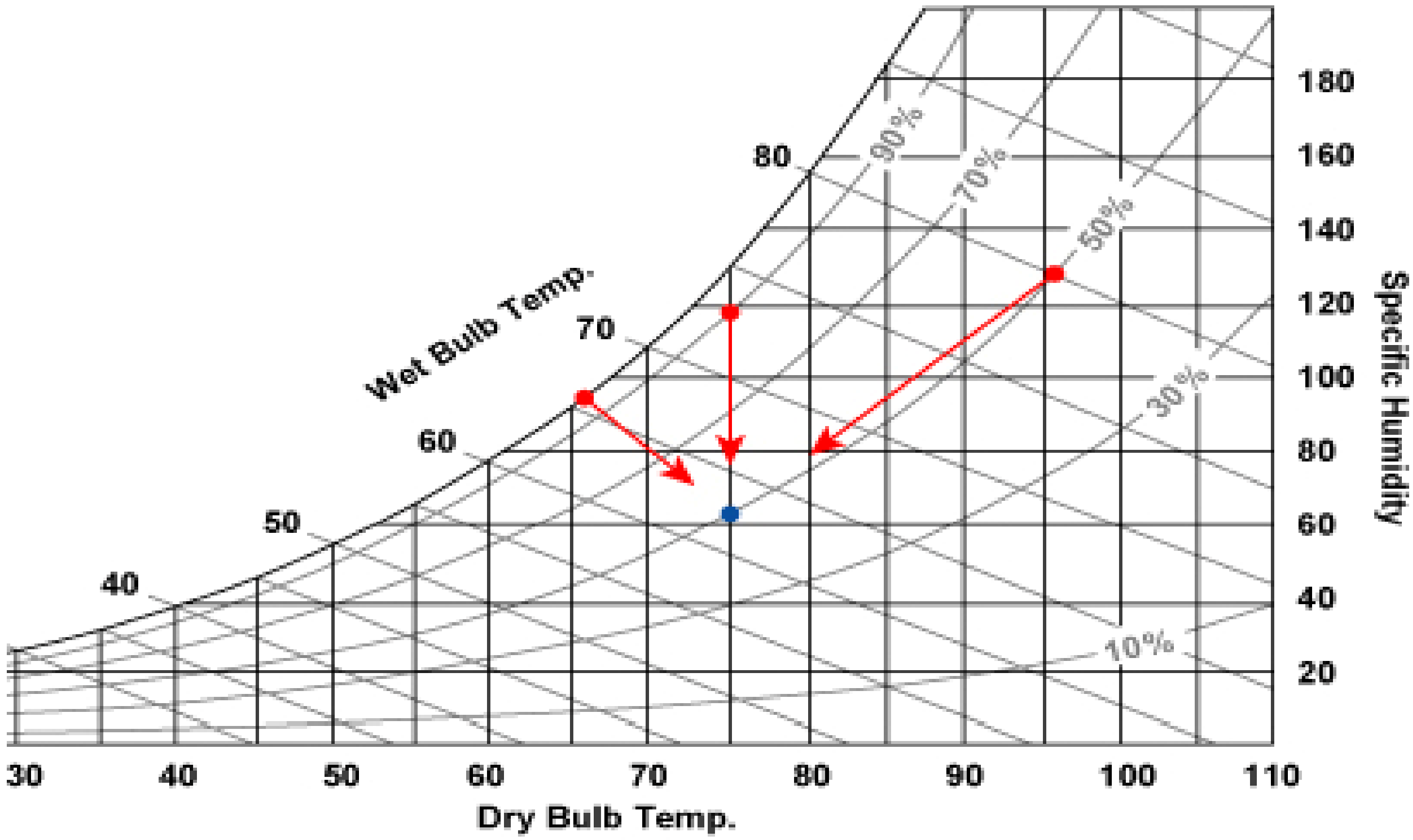
Summer Operation w/ Rotary Wheel

Total Energy Recovery

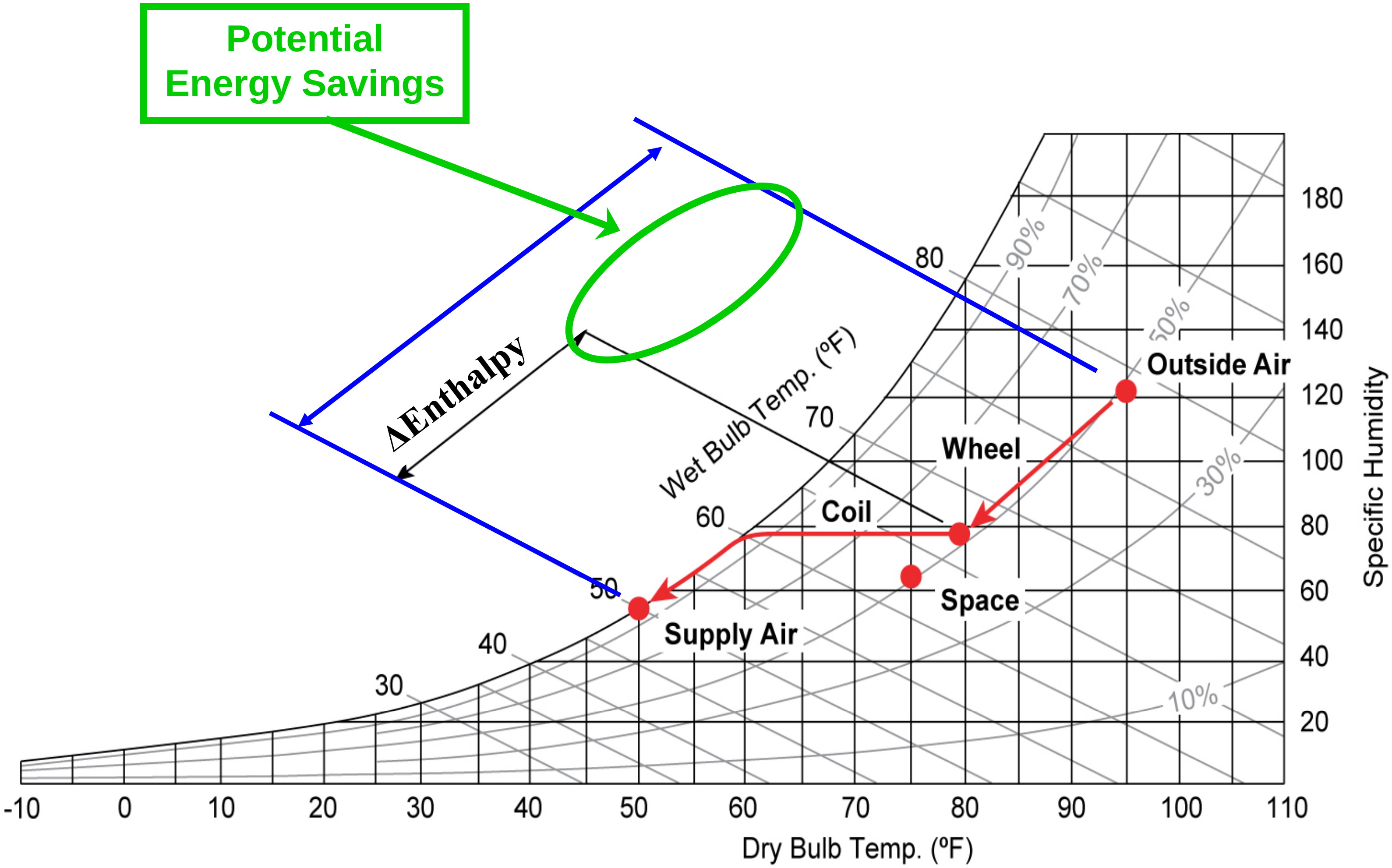
- Total energy recovery shifts OA point towards RA point
- Total effectiveness 60-80%



Part-Load Conditions



Energy Recovery and Cooling



Winter Operation

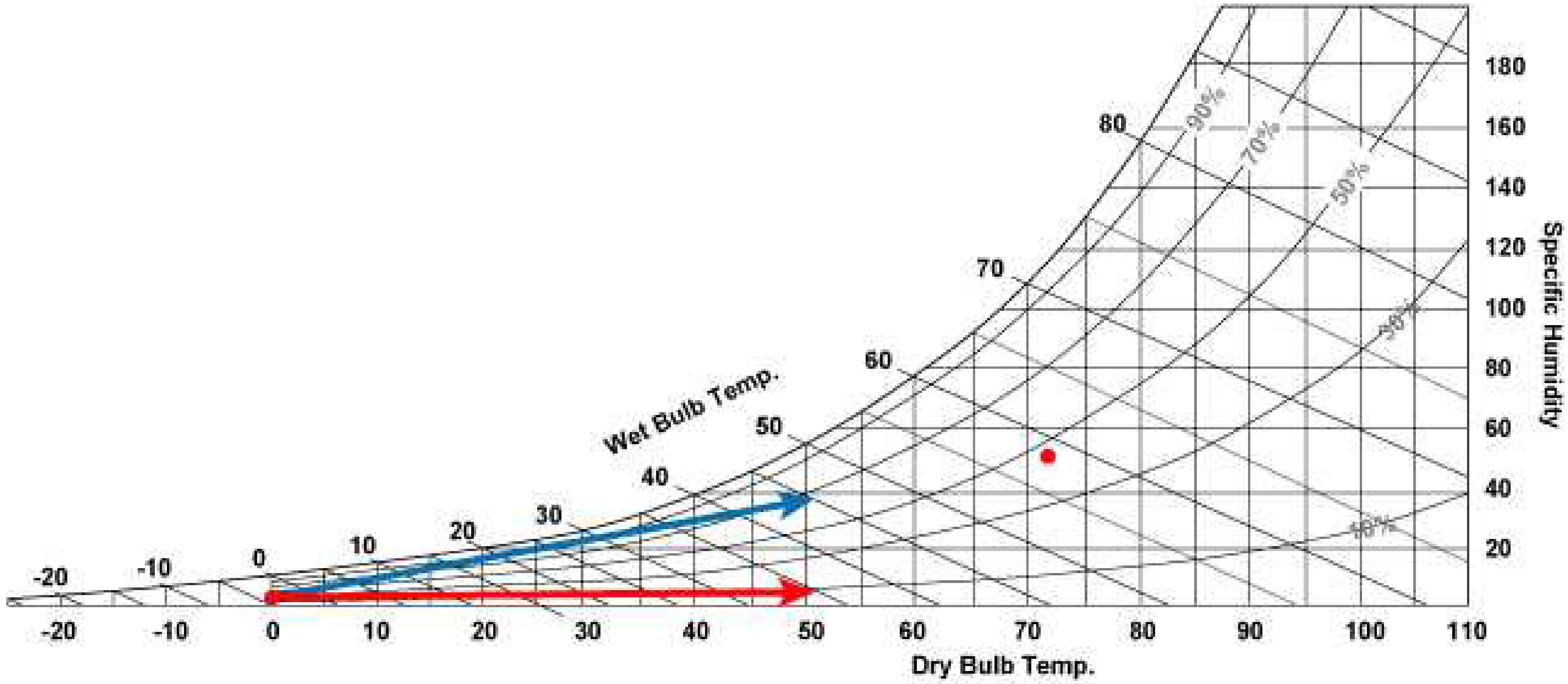
Supply Air
Dry Bulb 54°F
Humidity 31 grains

Room Air
(to be exhausted)
Dry Bulb 72°F
Humidity 41 grains/lb.

Outdoor Air
Dry Bulb 0°F
Humidity 2 grains/lb.

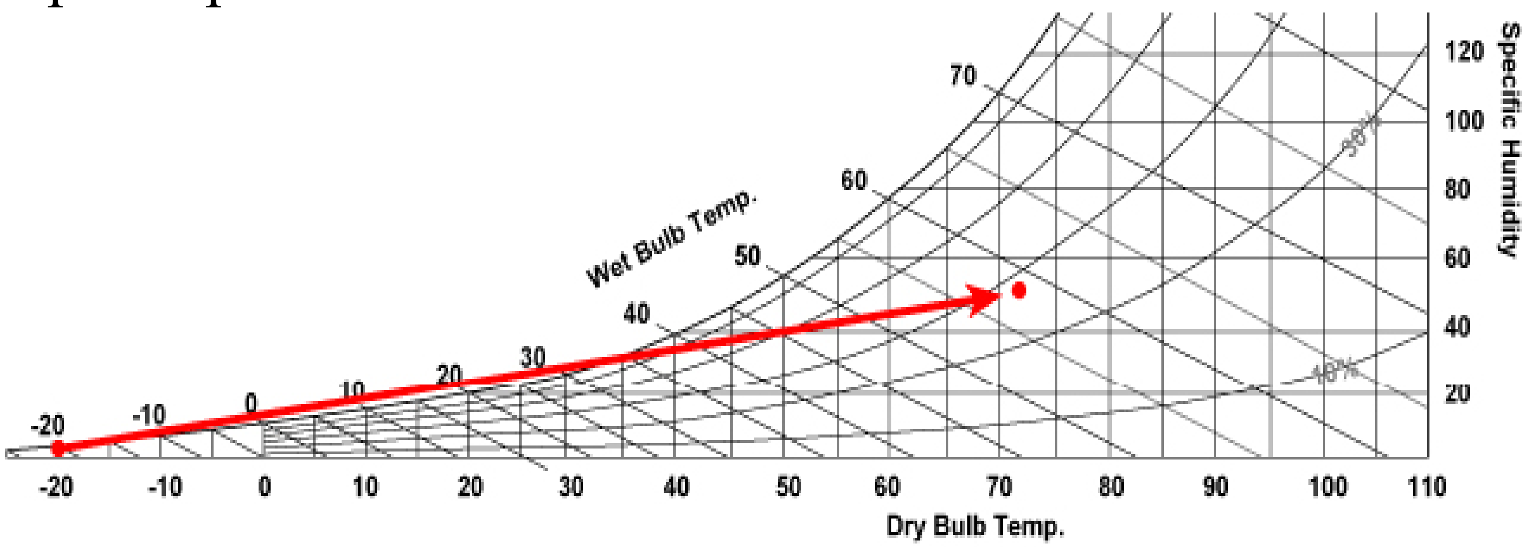
Exhaust Air
Dry Bulb 18°F
Humidity 12 grains/lb.

Winter Operation
Sensible vs. Total ERV

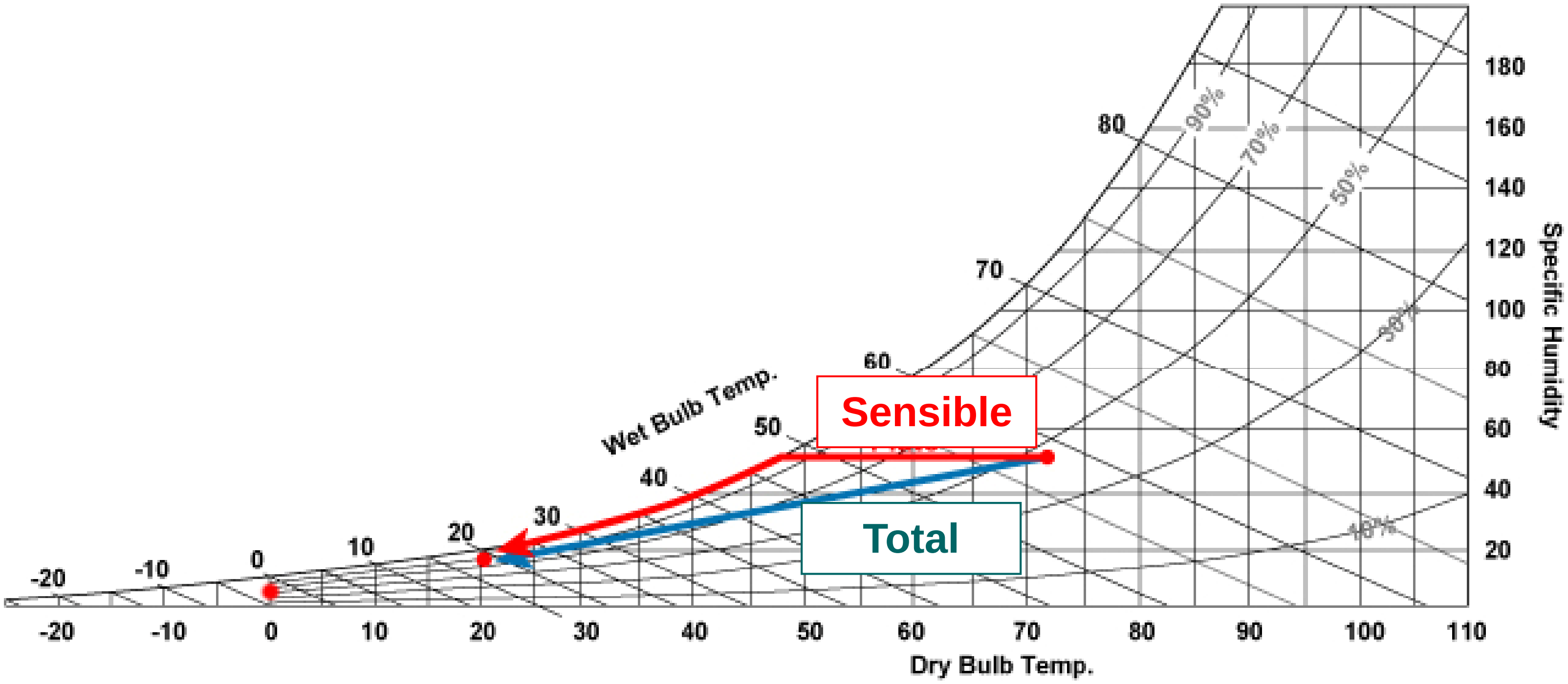


Energy Recovery and Frost

- Possibility of condensation forming whenever a warm, moist air stream comes in contact with a cold surface
- Always consider frost control methods in when winter design temps drop below 5°F



Winter Exhaust Air Process
Sensible vs. Total ERV



Question?

Review

- Psychrometric Charts are useful tool for understanding HVAC processes
  - Easily find properties of air across numerous conditions
  - Allows us to plot, predict, and calculate the heating and cooling capacities
  - An understanding of psychrometrics is the foundation of energy recovery

THANK YOU!