Practical Psychrometrics

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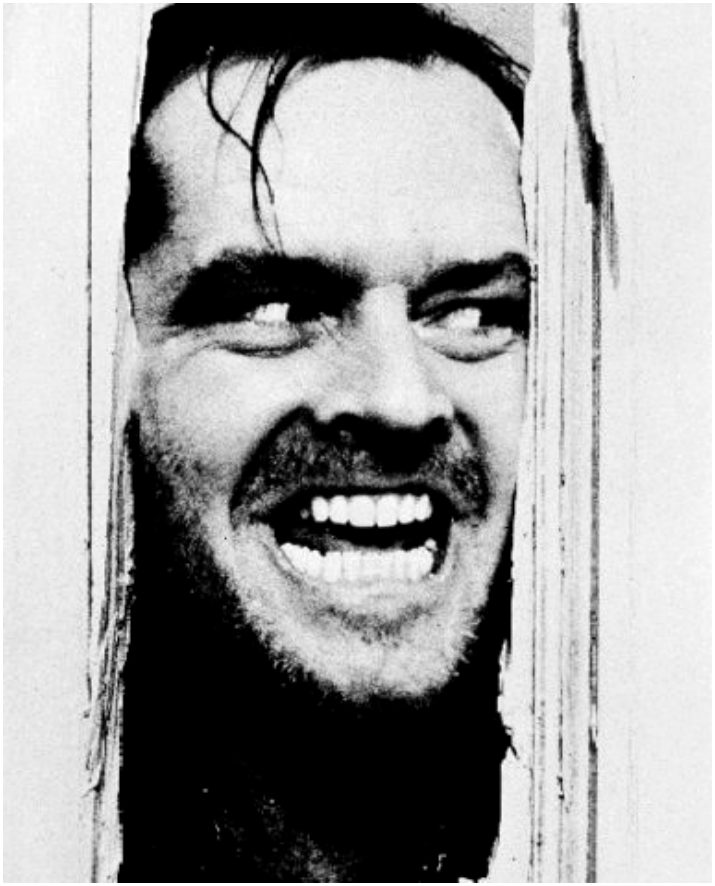
President
Jacco & Assoc.

Psycho or Psychro



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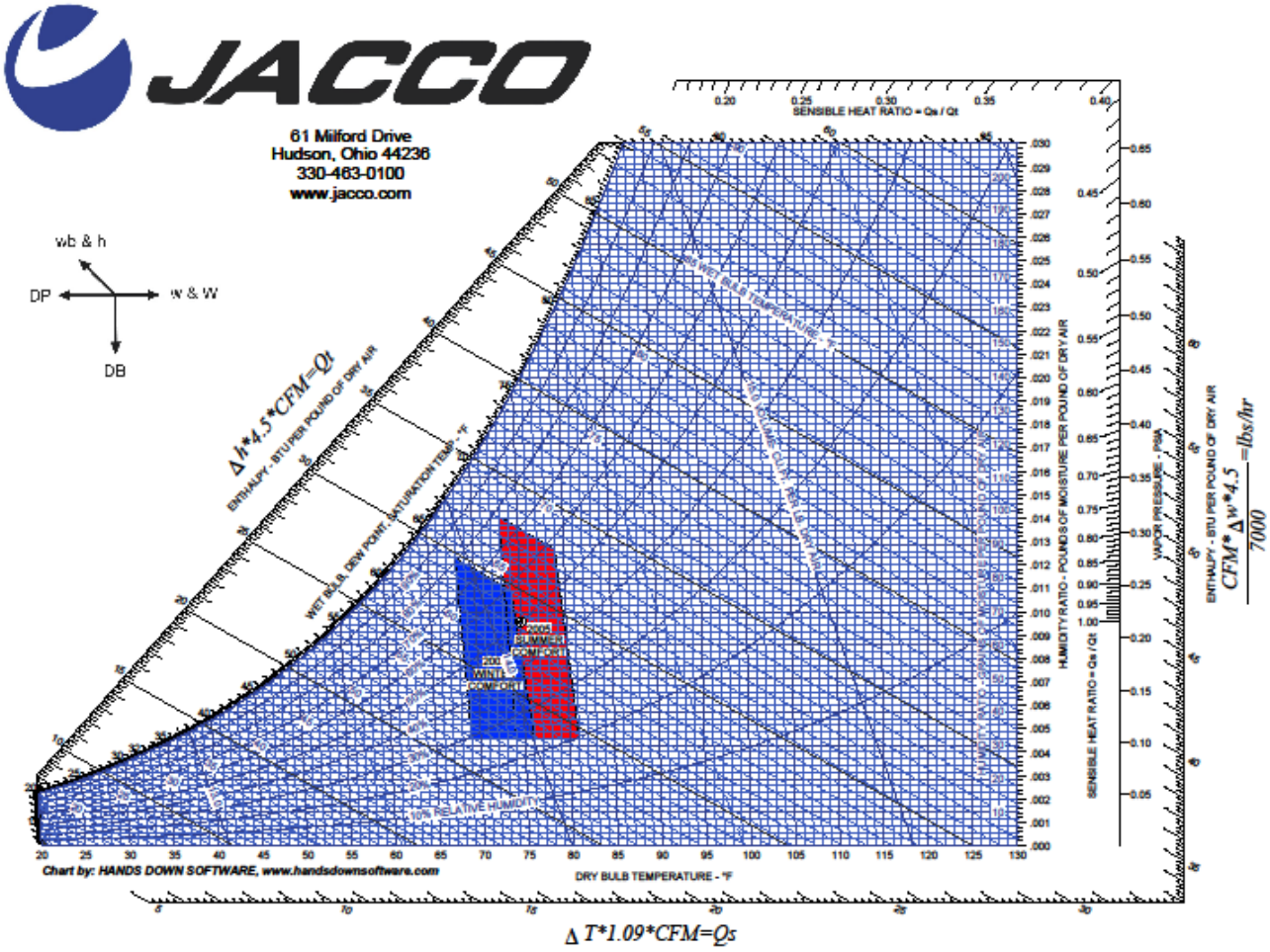
What is the Purpose of your Job?



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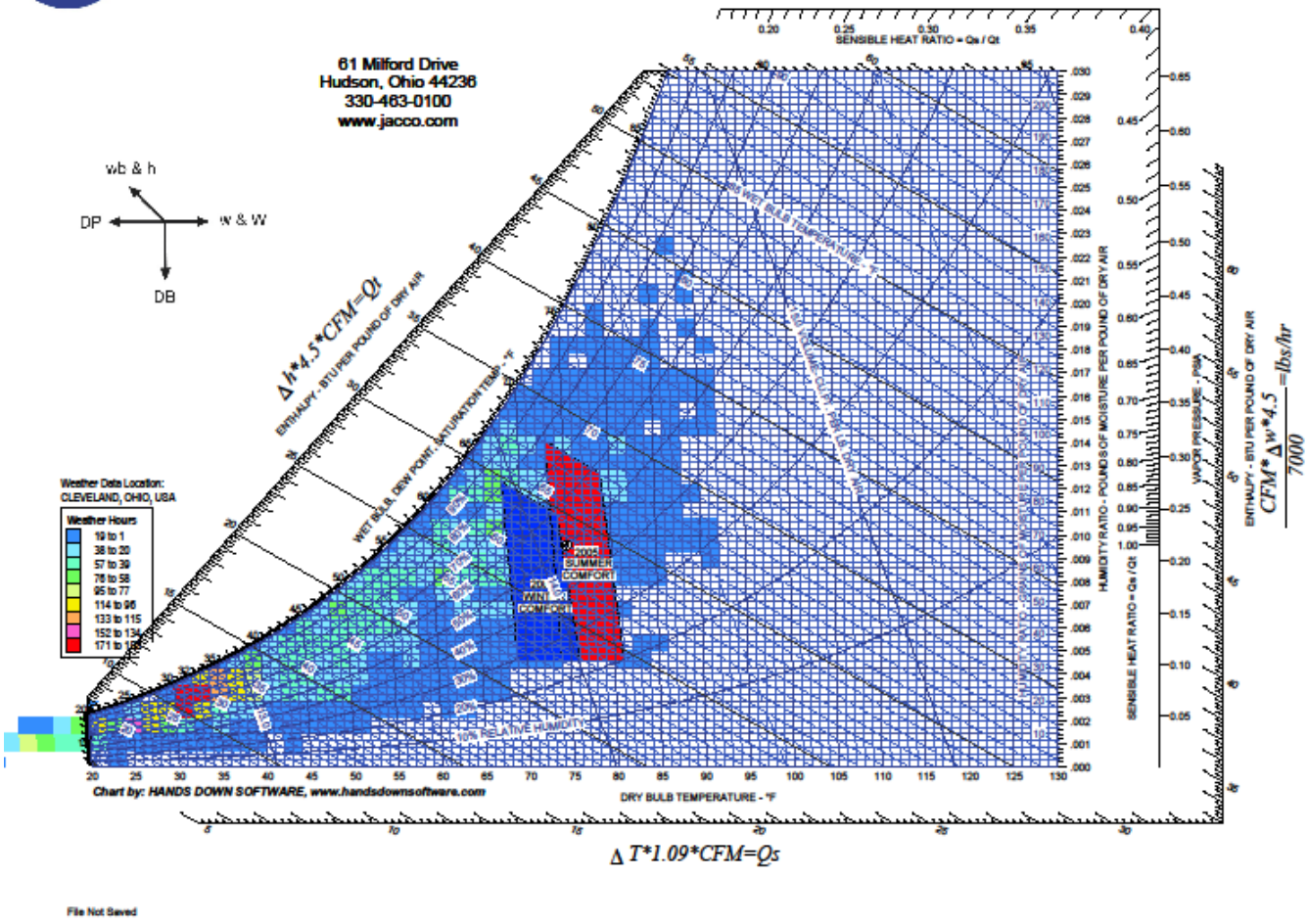
How Hard is it to Fulfill Your Purpose?



Psychrometrics

- from Greek *Psychro* – To breathe, blow, or make cold. *Metrics* – to measure.
- the field of engineering concerned with the determination of physical and thermodynamic properties of gas-vapor mixtures.

The Psychrometric Chart

- Graphical Representation of Properties of Air / Water Mixtures.
  - Dry-Bulb (°F db)
  - Wet-Bulb (°F wb)
  - Dew-Point (°F dp)
  - Specific Volume (ft^3/lb)
  - Humidity Ratio (Gr/lb)
  - Enthalpy (Btu/lb)
- Two state points required to fix properties – i.e. DB/WB, DB/%RH, DB/H, etc.

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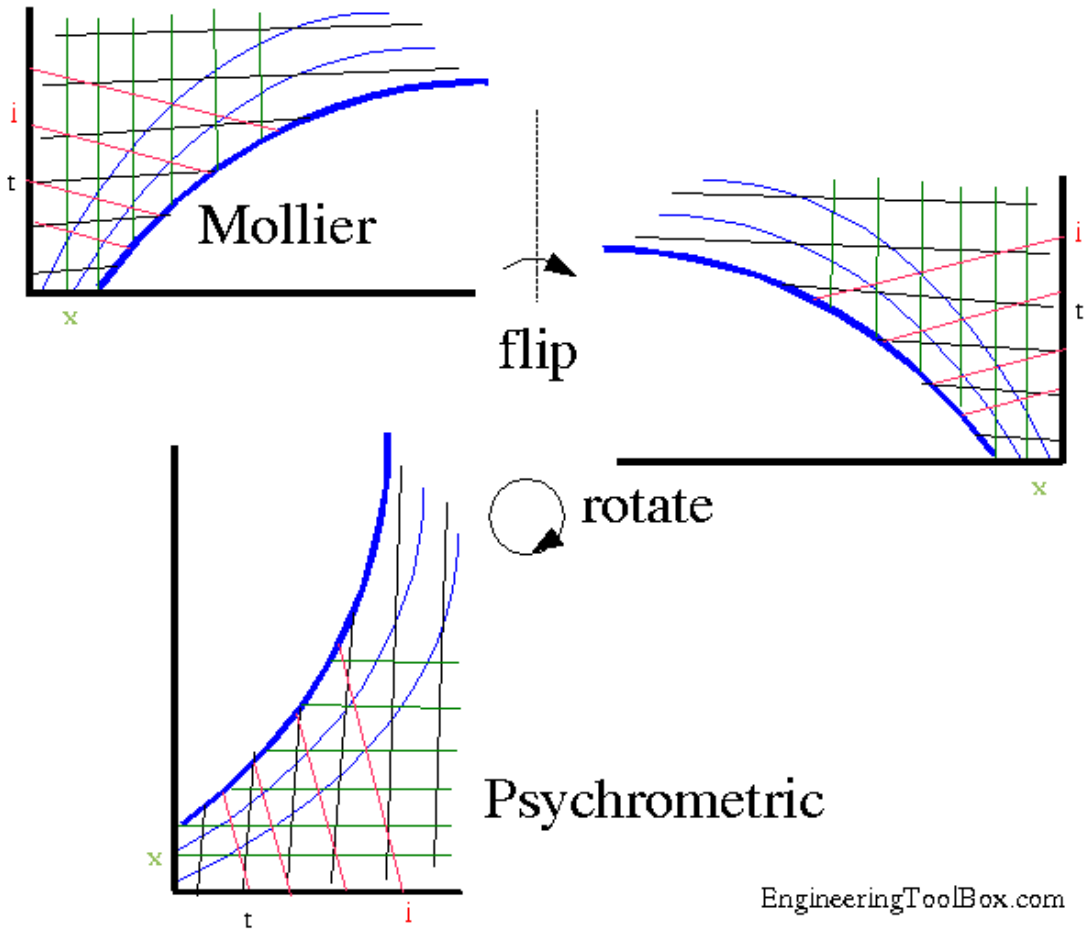
Psychrometric Chart

The relationship between DB, WB, and RH is given by the Mollier diagram (pressure-enthalpy) for water in air, developed by Richard Mollier. Willis Carrier rearranged the Mollier diagram for moist air to allow graphical solutions. Many variations and improvements to the Psychrometric charts have occurred since. ASHRAE now publishes what are considered the modern, standard Psychrometric charts, in both I-P and SI units, for a variety of elevations or air pressures.

Clever that Carrier guy



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So really, what is Psychrometrics?

- Study of Air / Water (Vapor) Mixture

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What is Air?

- Mixture of Gases:
  - Nitrogen – 4 Parts
  - Oxygen – 1 Part
  - Other: Argon, Helium, Krypton, Xenon, Neon, Carbon Dioxide.

and

- <u>Water Vapor</u>

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So Who Cares?

- Reconsider the Components of Air:

So Who Cares?

- Reconsider the Components of Air:
  - Nitrogen
  - Oxygen
  - Noble Gases
  - Carbon Dioxide

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So Who Cares?

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  - Nitrogen
  - Oxygen
  - Noble Gases
  - Carbon Dioxide

Stable in Gas Phase.

So Who Cares?

- Reconsider the Components of Air:
    - Water Vapor

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So Who Cares?

- Reconsider the Components of Air:
  - Nitrogen
  - Oxygen
  - Noble Gases
  - Carbon Dioxide

<u>Stable in Gas Phase</u>

  - Water Vapor

<u>Phase Changes (liq./gas)</u>

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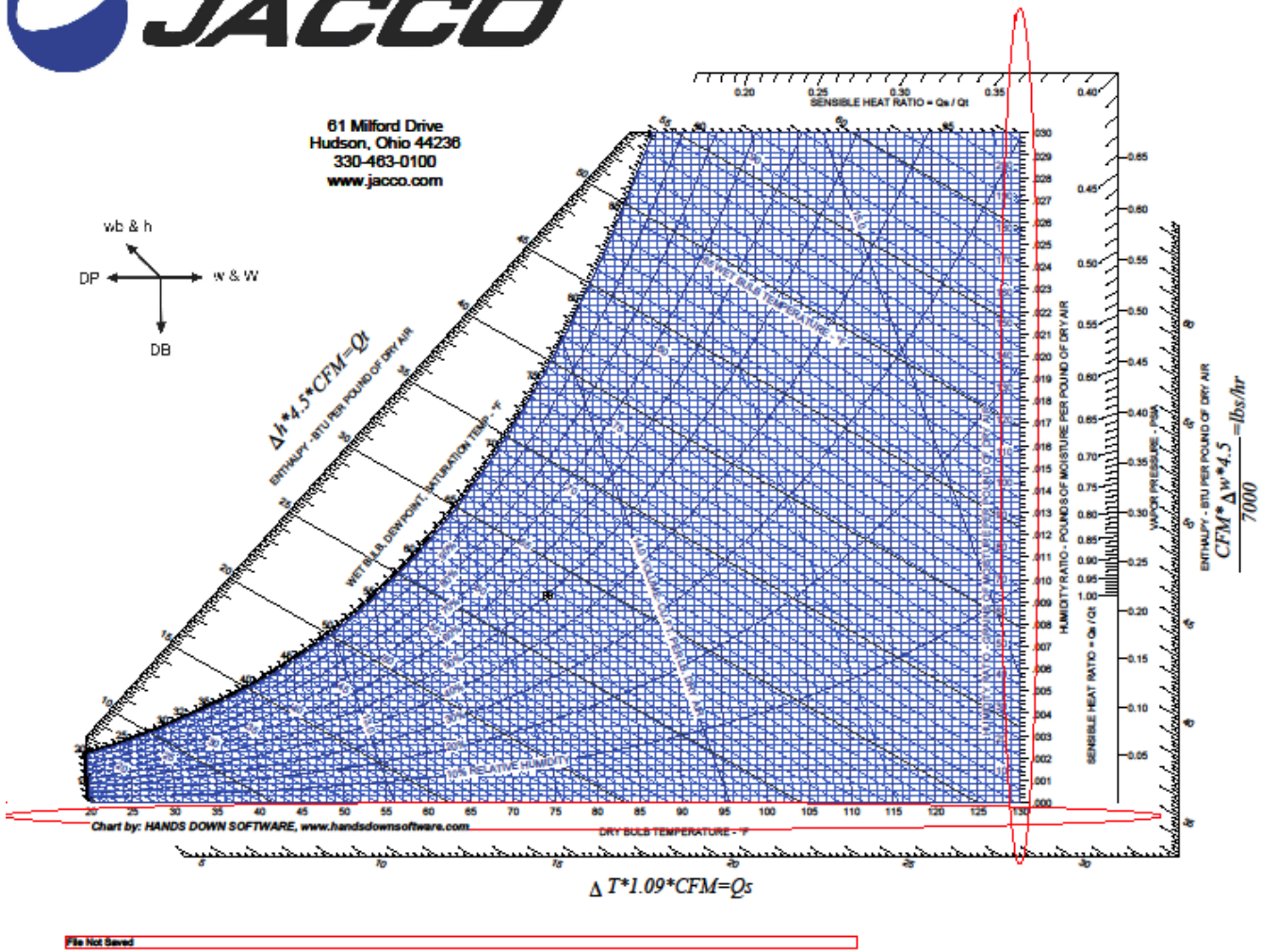
If it's Not the Heat, It's the Humidity

Psychrometric Chart



Some Definitions

- Sensible heat, or enthalpy of dry air, is heat which manifests itself as a change in temperature.
- Latent heat is the amount of energy in the form of heat released or absorbed by a substance during a change of phase (i.e. solid, liquid, or gas), also called a phase transition

Some Definitions

- The total heat, or enthalpy, of the atmosphere is the sum of the sensible heat, latent heat, and superheat of the vapor above the saturation or dew-point temperature. Total heat is relatively constant for a constant wet-bulb temperature, deviating only about 1.5–2% low at relative humidity's below 30%.

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Some Definitions

- Dry Bulb Temperature
  - Temperature as read by regular (dry) thermometer.

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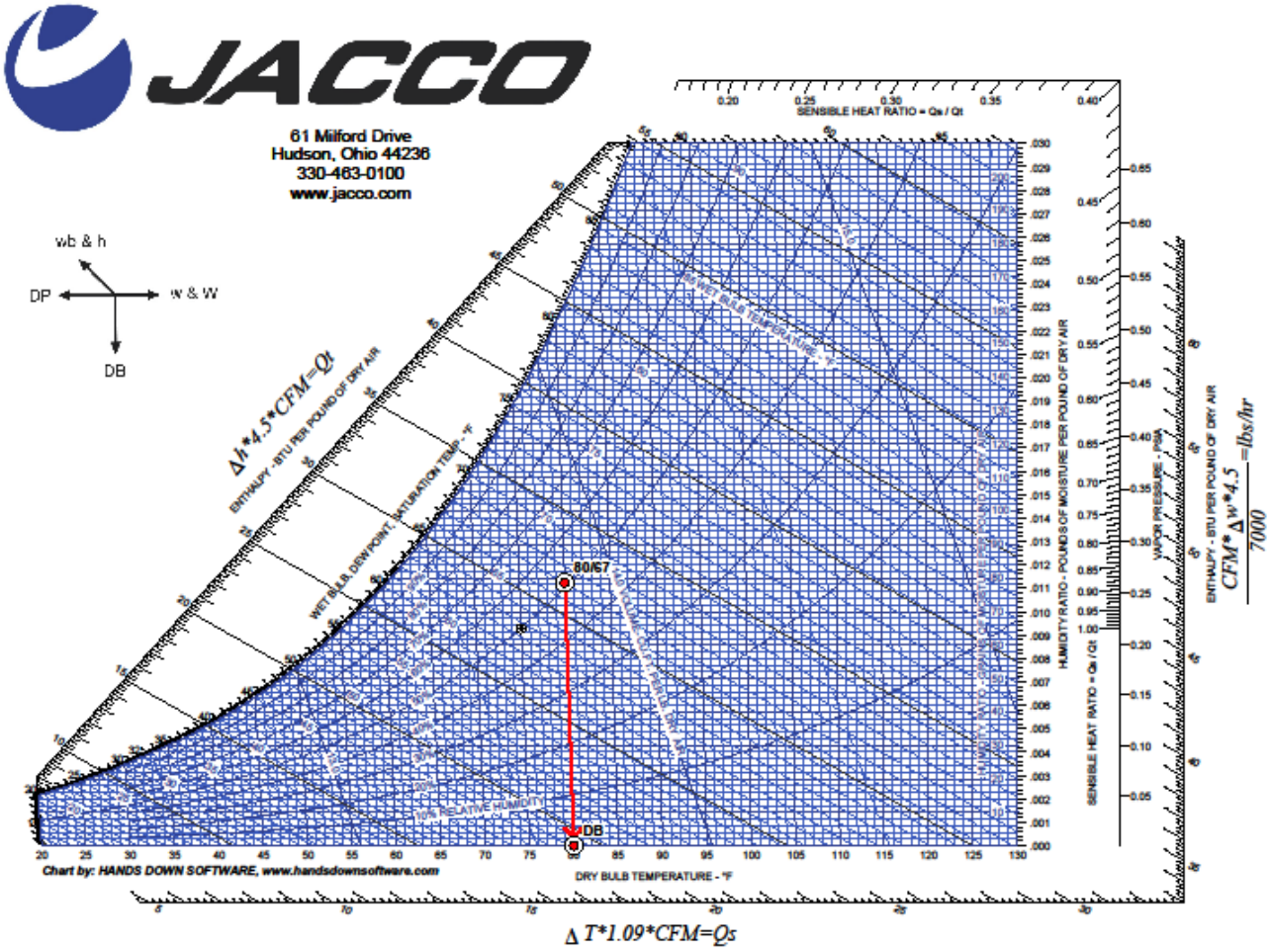
Dry Bulb



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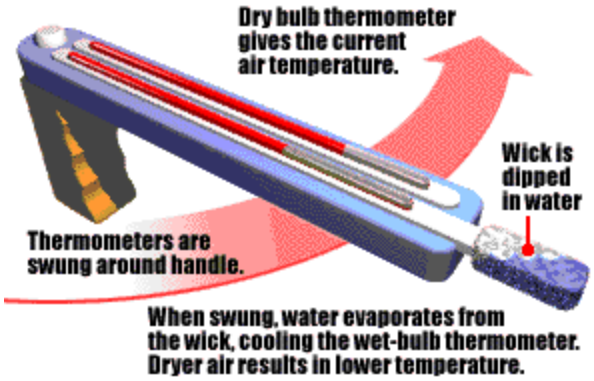
Some Definitions

- Wet Bulb Temperature
  - Temperature of air that has gone through an adiabatic saturation process.



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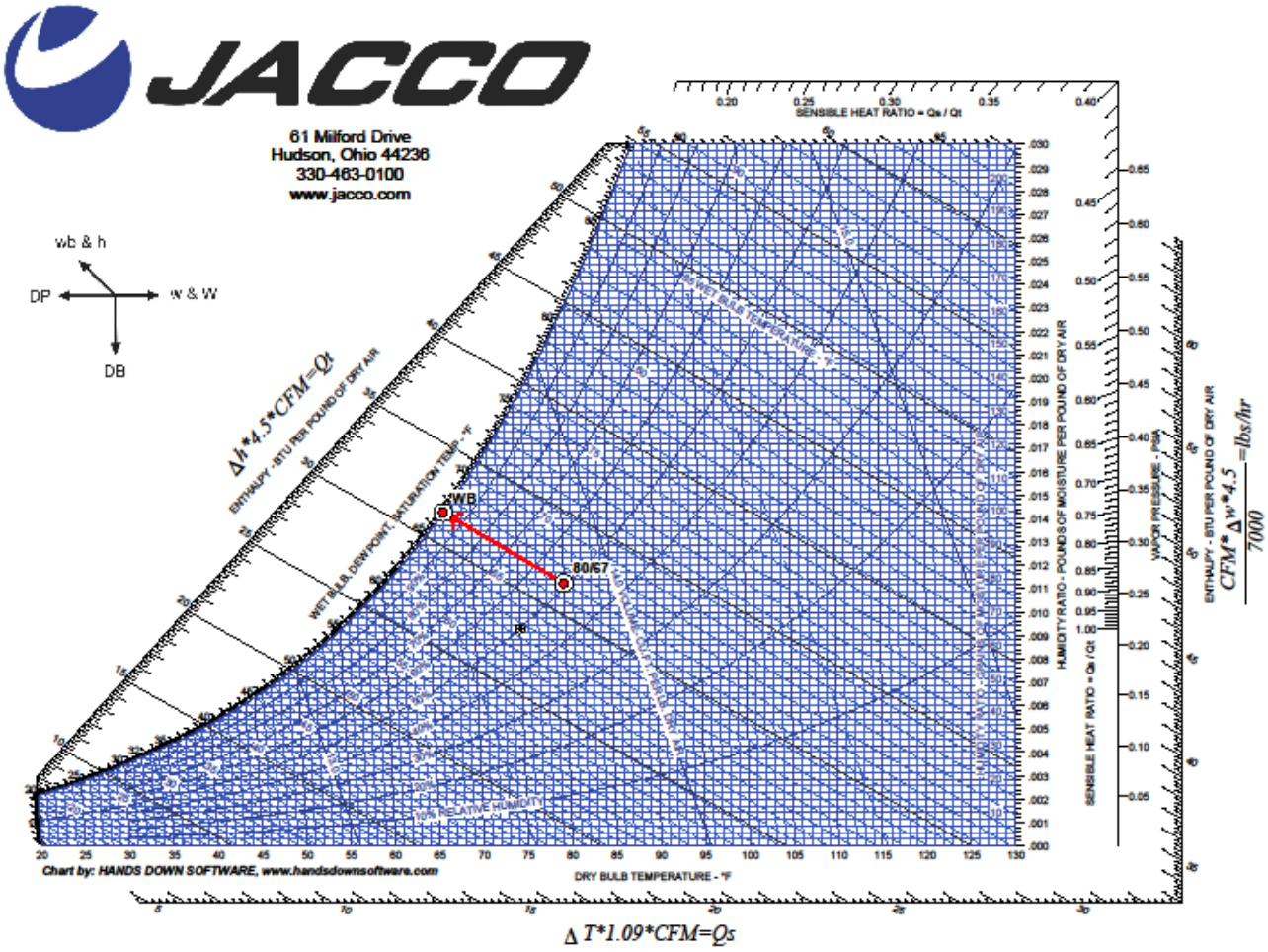
Wet Bulb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wb & h
DP
w & W
DB
Δh*4.5*CFM=Qt
XWB
80/67
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com
DRY BULB TEMPERATURE - °F
Δ T*1.09*CFM=Qs
CFM*Δw*4.5/7000=lbs/hr
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Some Definitions

- Relative Humidity
  - The ratio of vapor pressure to saturation pressure.

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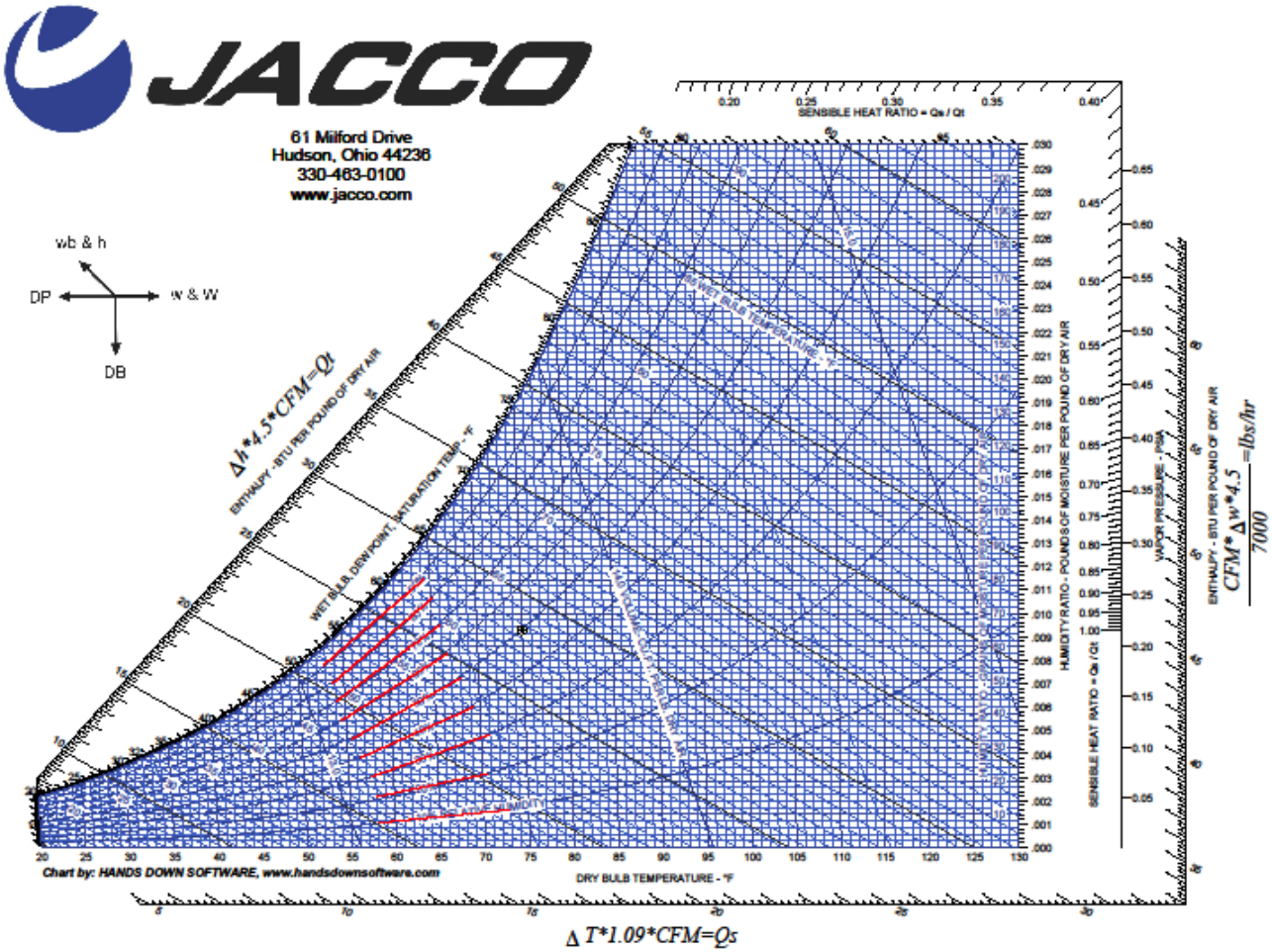
Relative Humidity



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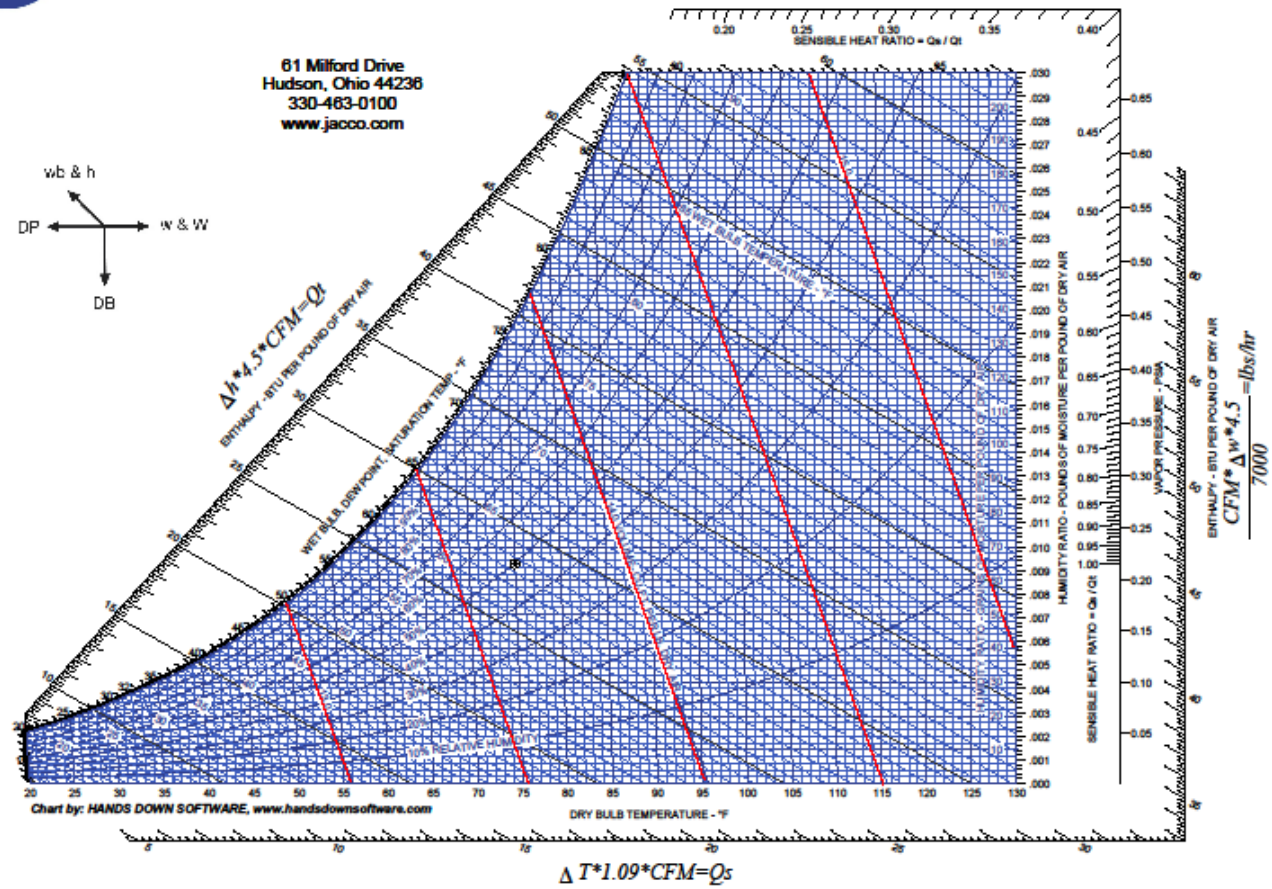
Some Definitions

- Specific Volume
    - cubic feet of air per lb. of air

Specific Volume



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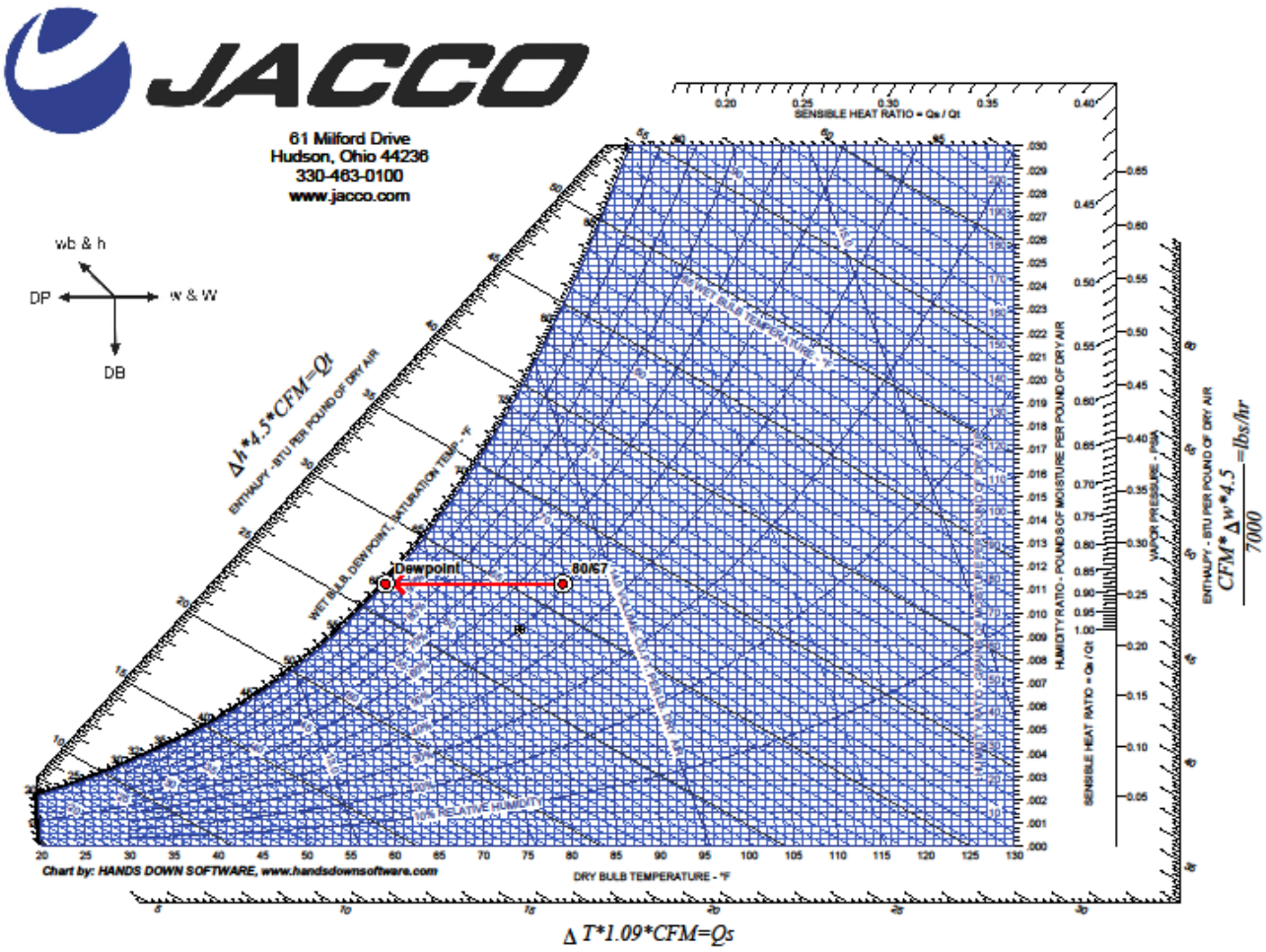
Some Definitions

- Dew Point
  - Temperature at which moisture begins to condense in a particular air / water vapor mixture.
  - This corresponds to the intersection of the wet-bulb and the saturation curve.

Dew Point



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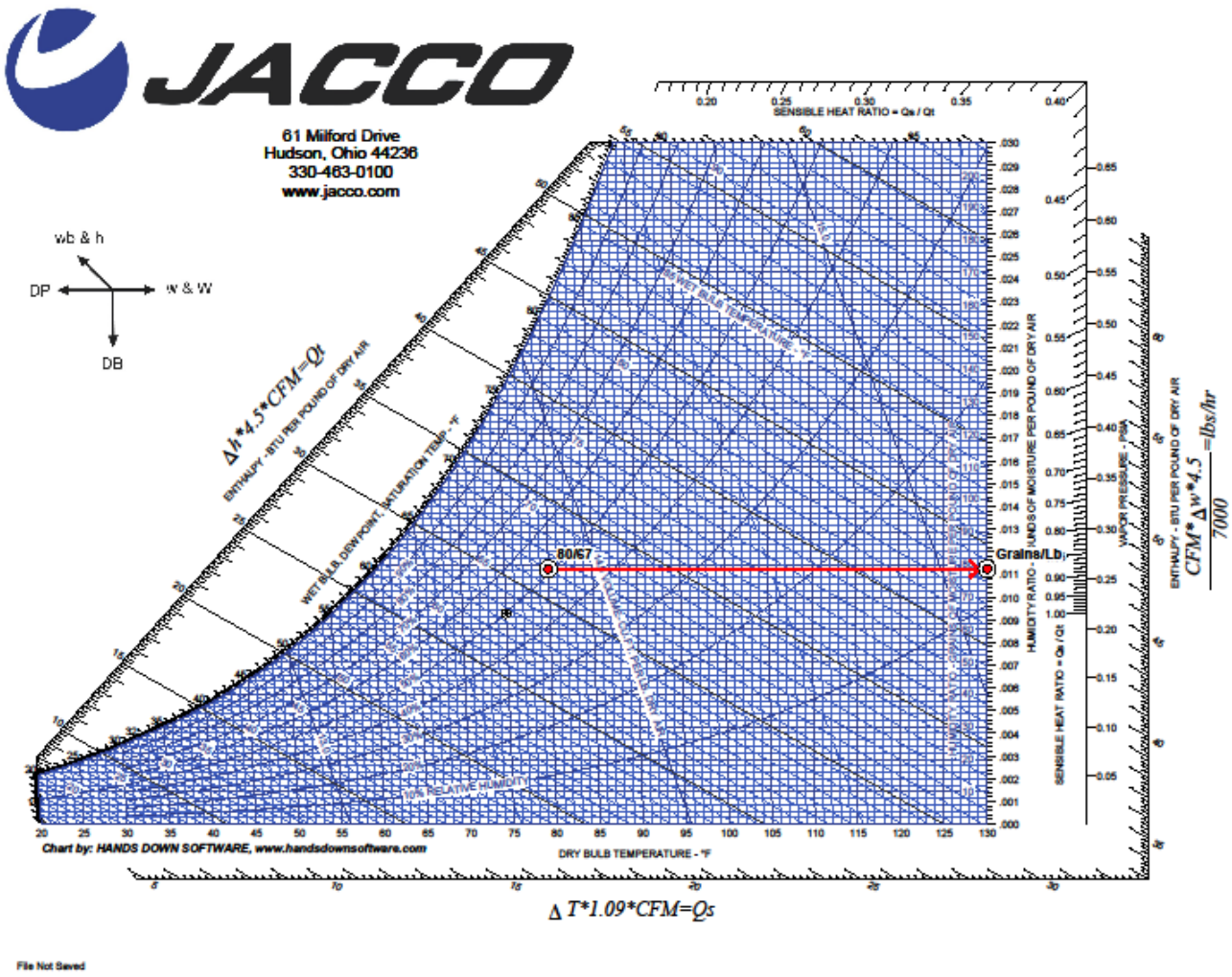
Some Definitions

- Humidity Ratio
  - The ratio of water vapor (mass) to total air (mass).
  - Can be expressed as lb (water) / lb (dry air), or Gr (water) / lb (dry air).

Humidity Ratio



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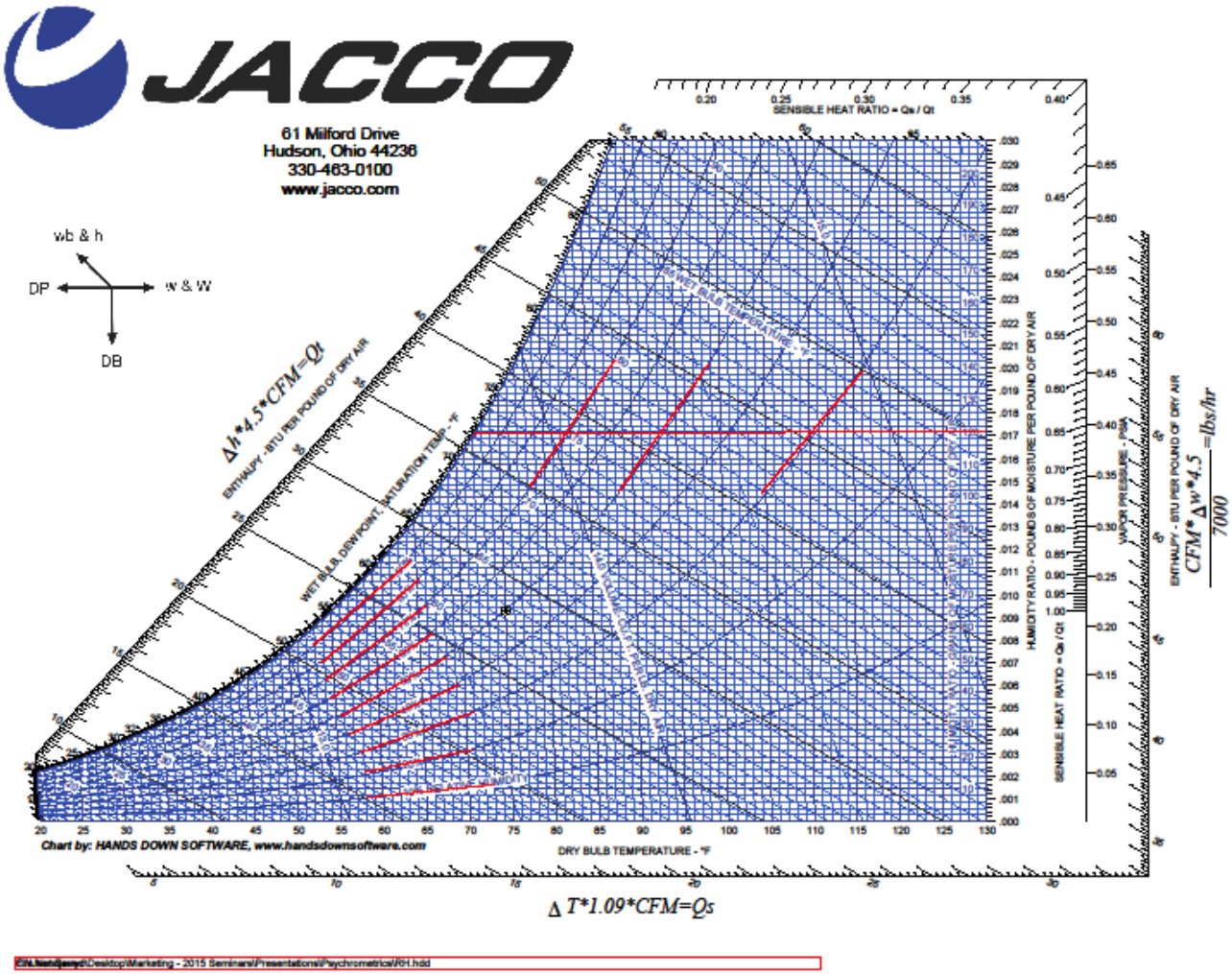
Relative Humidity vs. Humidity Ratio



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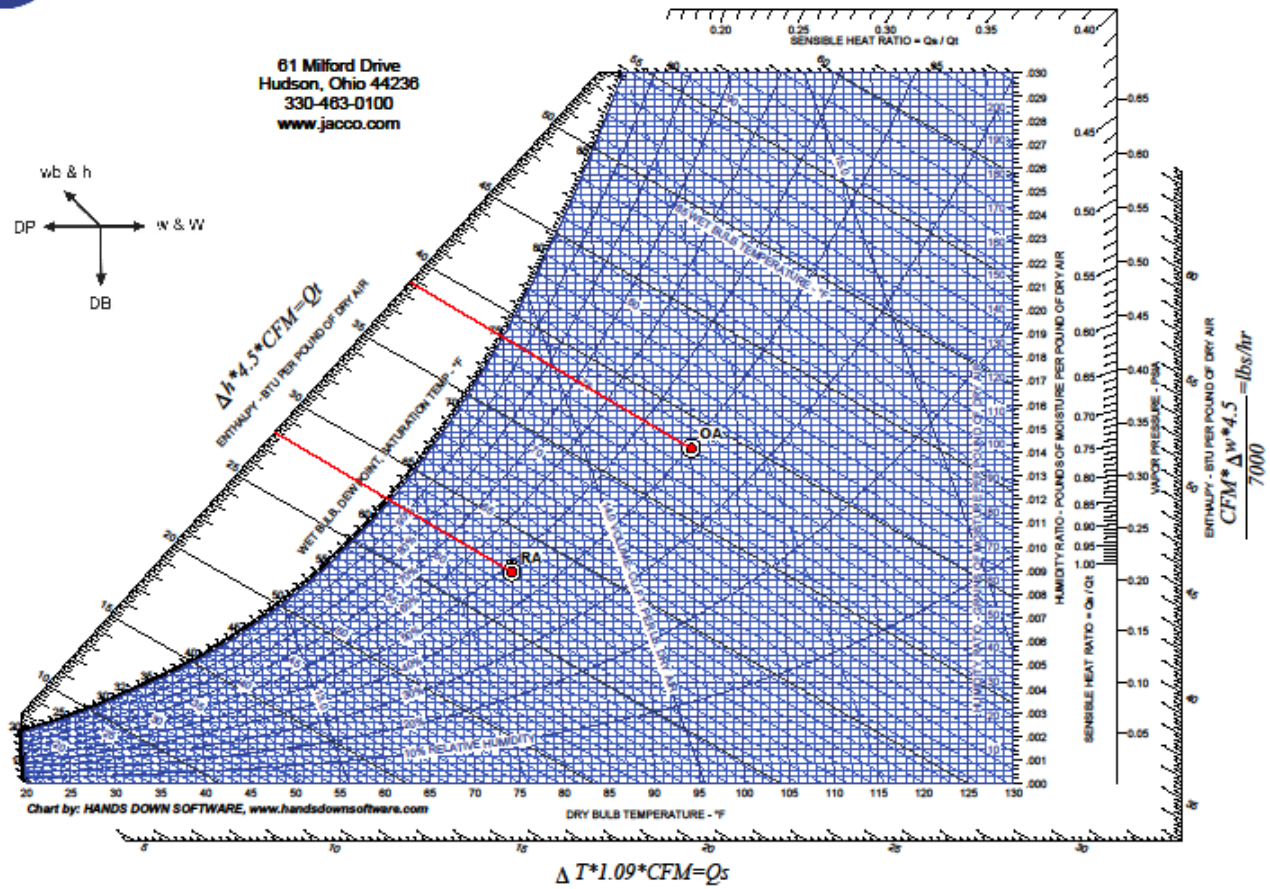
Some Definitions

- Enthalpy
  - Total amount of energy contained in Air / Water Mixture.

Enthalpy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DB
OA
RA
Δh*4.5*CFM=Qt
ENTHALPY - BTU PER POUND OF DRY AIR
WET BULB, DEW POINT, SATURATION TEMP - °F
DRY BULB TEMPERATURE - °F
SENSIBLE HEAT RATIO = Qs / Qt
HUMIDITY RATIO - POUNDS OF MOISTURE PER POUND OF DRY AIR
VAPOR PRESSURE - PSI
ENTHALPY - BTU PER POUND OF DRY AIR
CFM*Δw*4.5 / 7000 =lbs/hr
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com
Δ T*1.09*CFM=Qs
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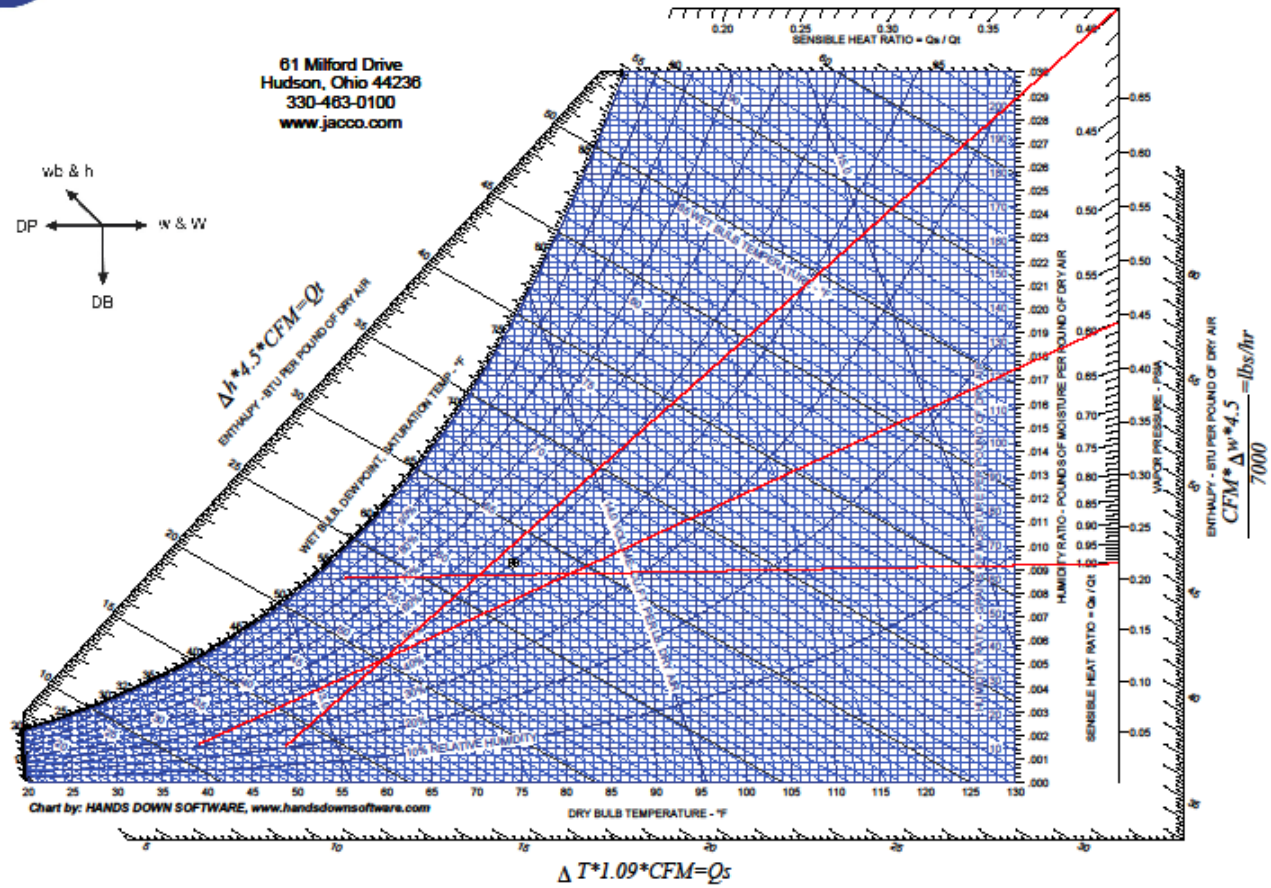
Some Definitions

- Sensible Heat Ratio
  - The ratio of sensible cooling to total cooling in a space.

Sensible Heat Ratio



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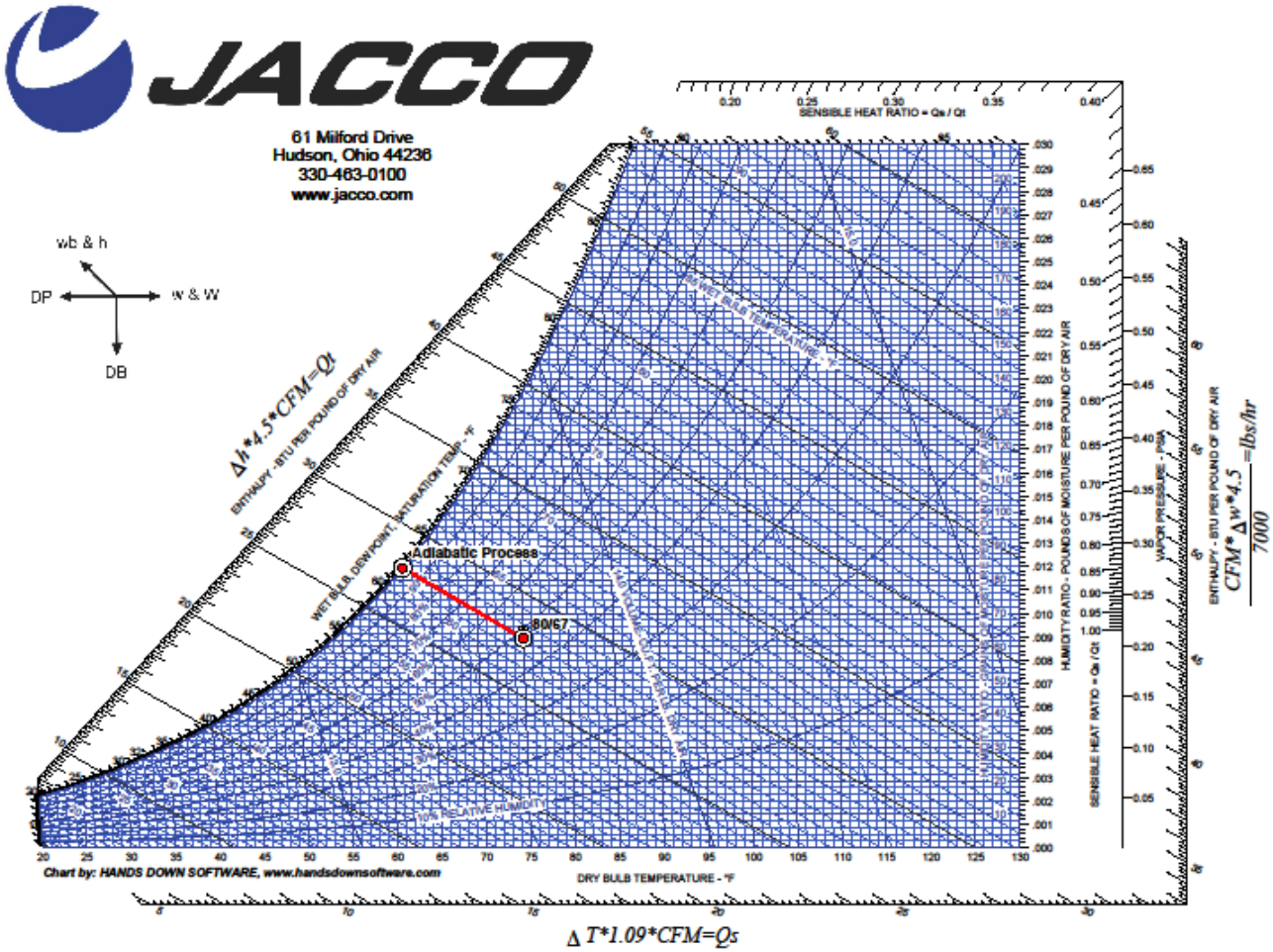
Some Definitions

- Adiabatic Saturation Process
  - Process follows lines of constant enthalpy/wet bulb.
  - Change occurs in: dry-bulb temperature, specific volume, relative humidity, humidity ratio, dewpoint temperature, and vapor pressure of the moist air.
  - No change occurs in: wet-bulb temperature and enthalpy
  - Representative of any process involving evaporation
    - Cooling Towers, Evaporative Cooling, Fog & Ultrasonic Humidification, etc.

Adiabatic Saturation Process



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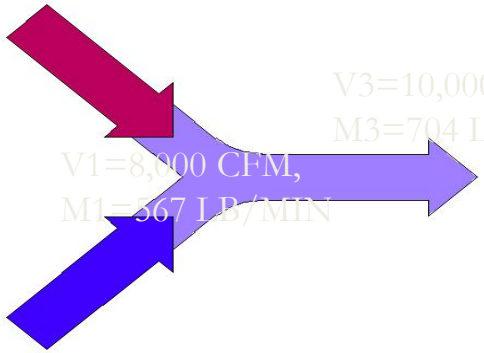
Useful Psychrometric Calculations - Air Mixing

- Based on ratio of mass flows
- Stream 1: 95 DB / 75 WB
- Stream 2: 75 DB / 50% RH



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Air Mixing - Mathematically

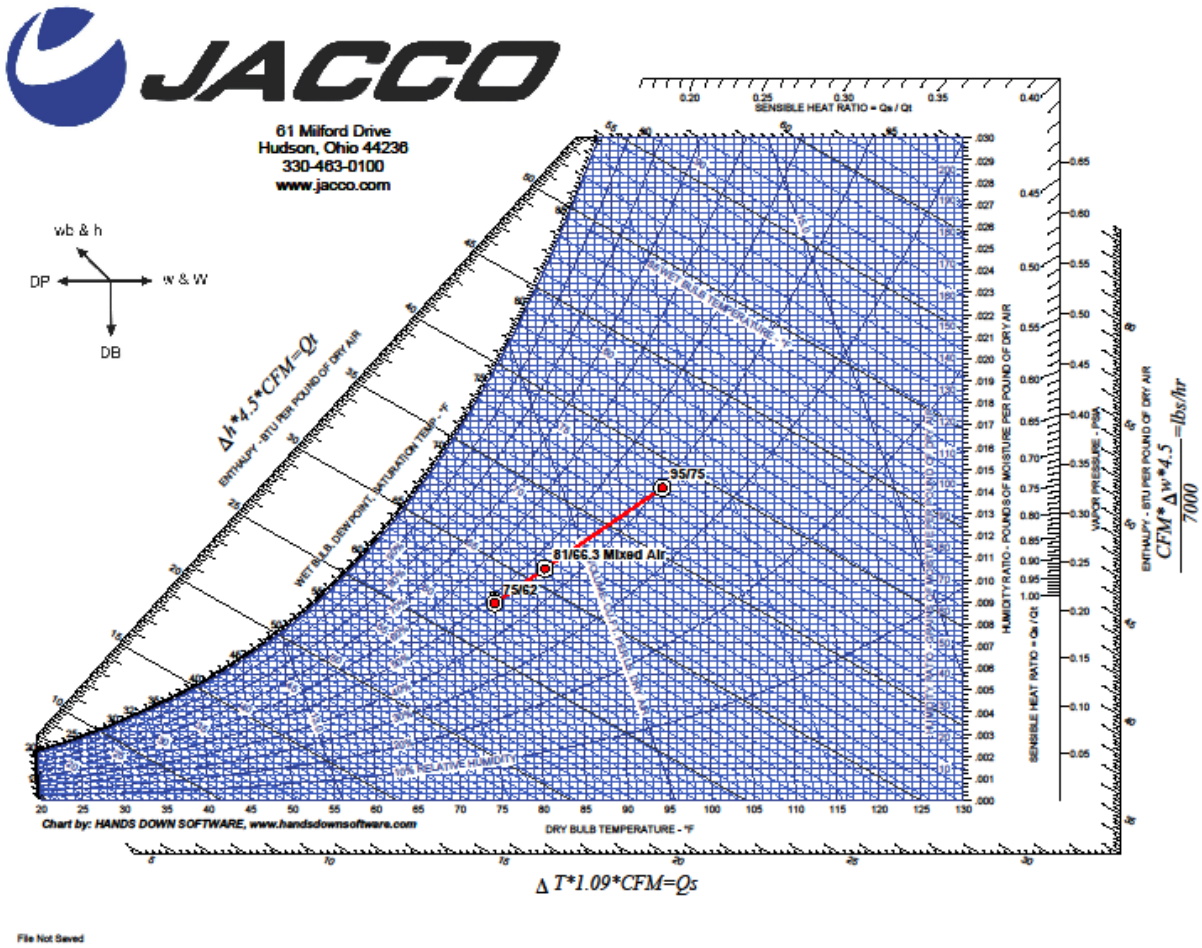
- Plot both points on chart and connect with a line
- Mixed air dry bulb =

  (Stream 1 DB x Stream 1 CFM / Total CFM)

  +

  (Stream 2 DB x Stream 2 CFM / Total CFM)
- Plot mixed air dry bulb on above referenced line to calculate mixed air wet bulb

Air Mixing - Measuring



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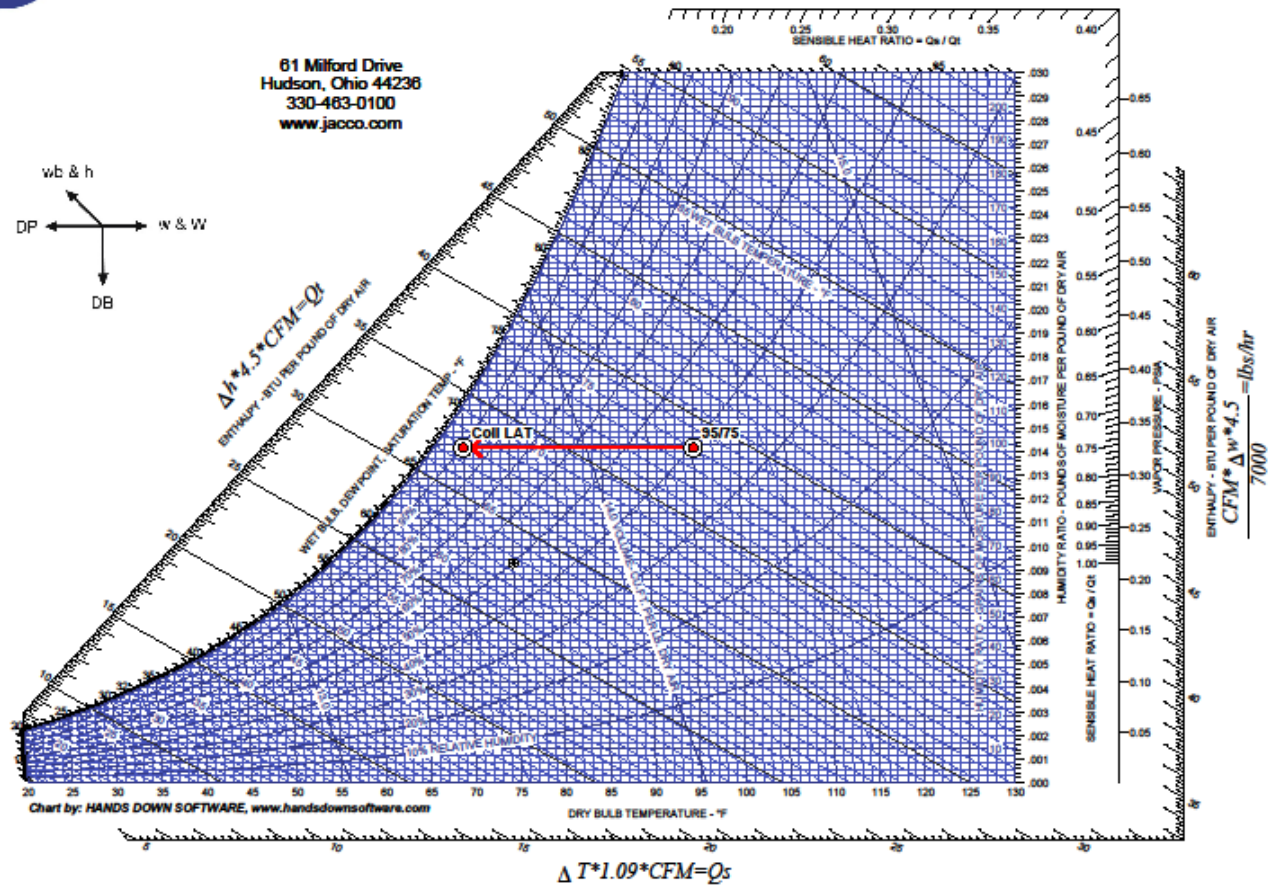
Sensible Heating / Cooling

- Process line is horizontal on Psych. Chart.
- Humidity Ratio does not change
- Relative Humidity does change.

Sensible Cooling



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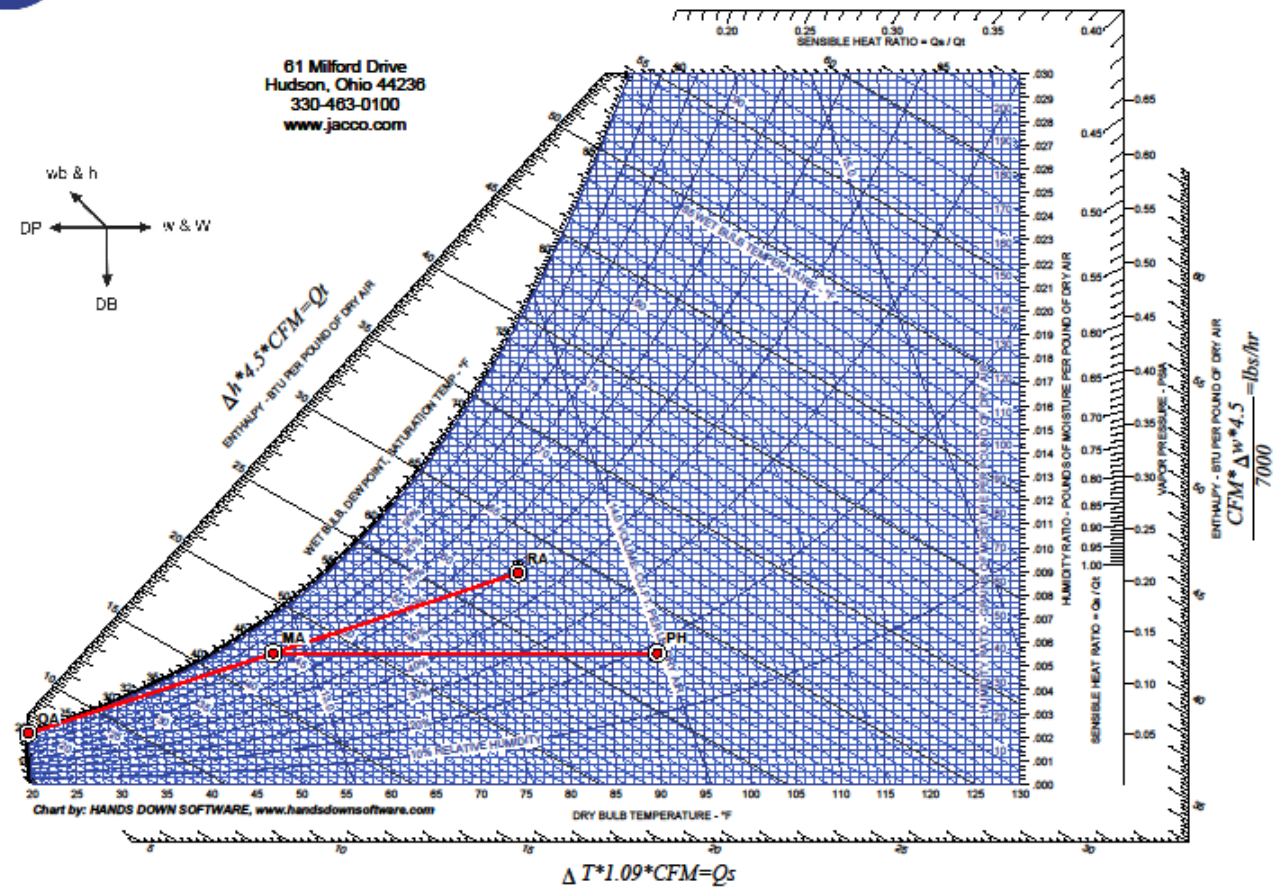
Sensible Heating



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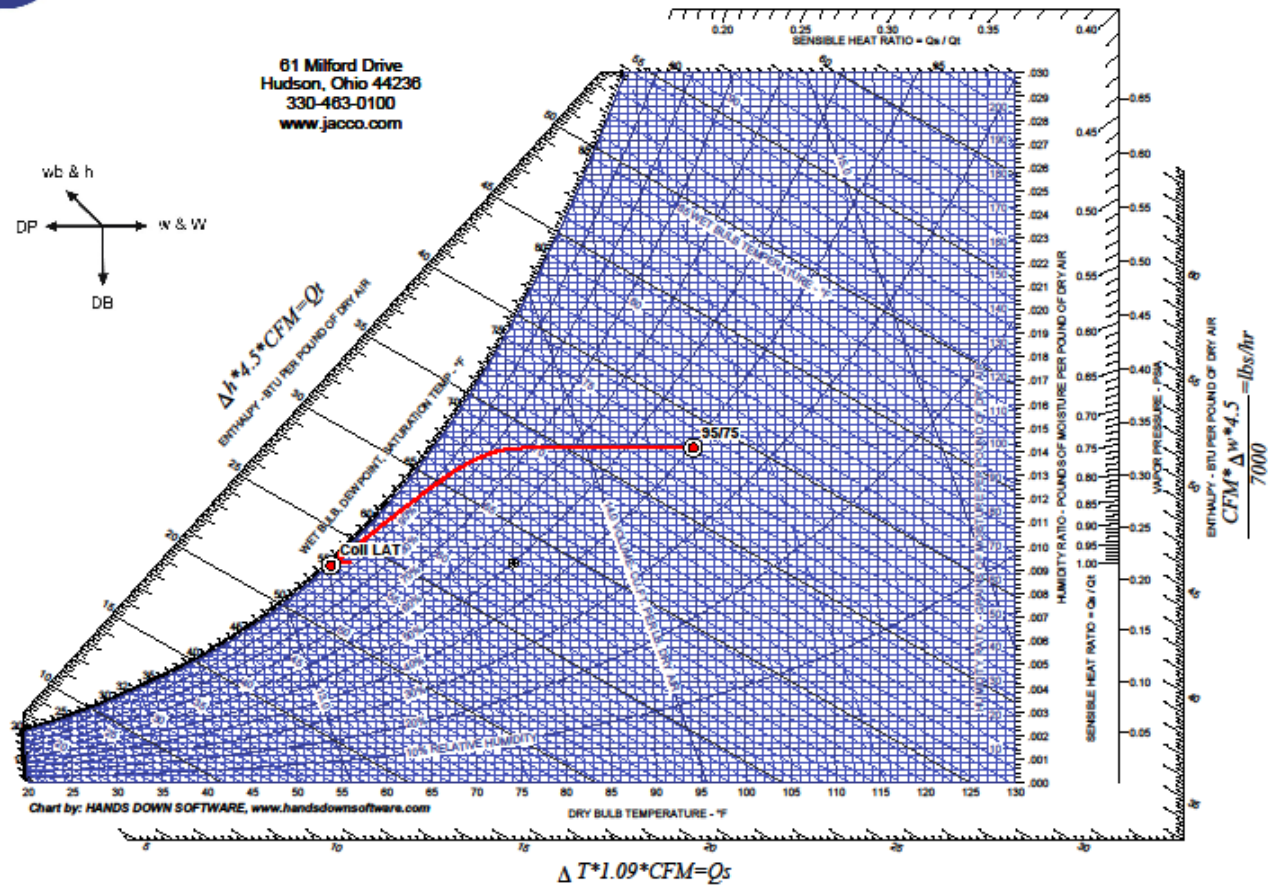
Total Cooling Cycle

- Process line is horizontal & vertical on Psychrometric Chart.
- Humidity Ratio does change
- Relative Humidity does change.

Total Cooling Cycle



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Applications – Blow Through

- Large VAV systems
- High sensible loads
- Higher efficiency requirements
- Sound sensitive applications

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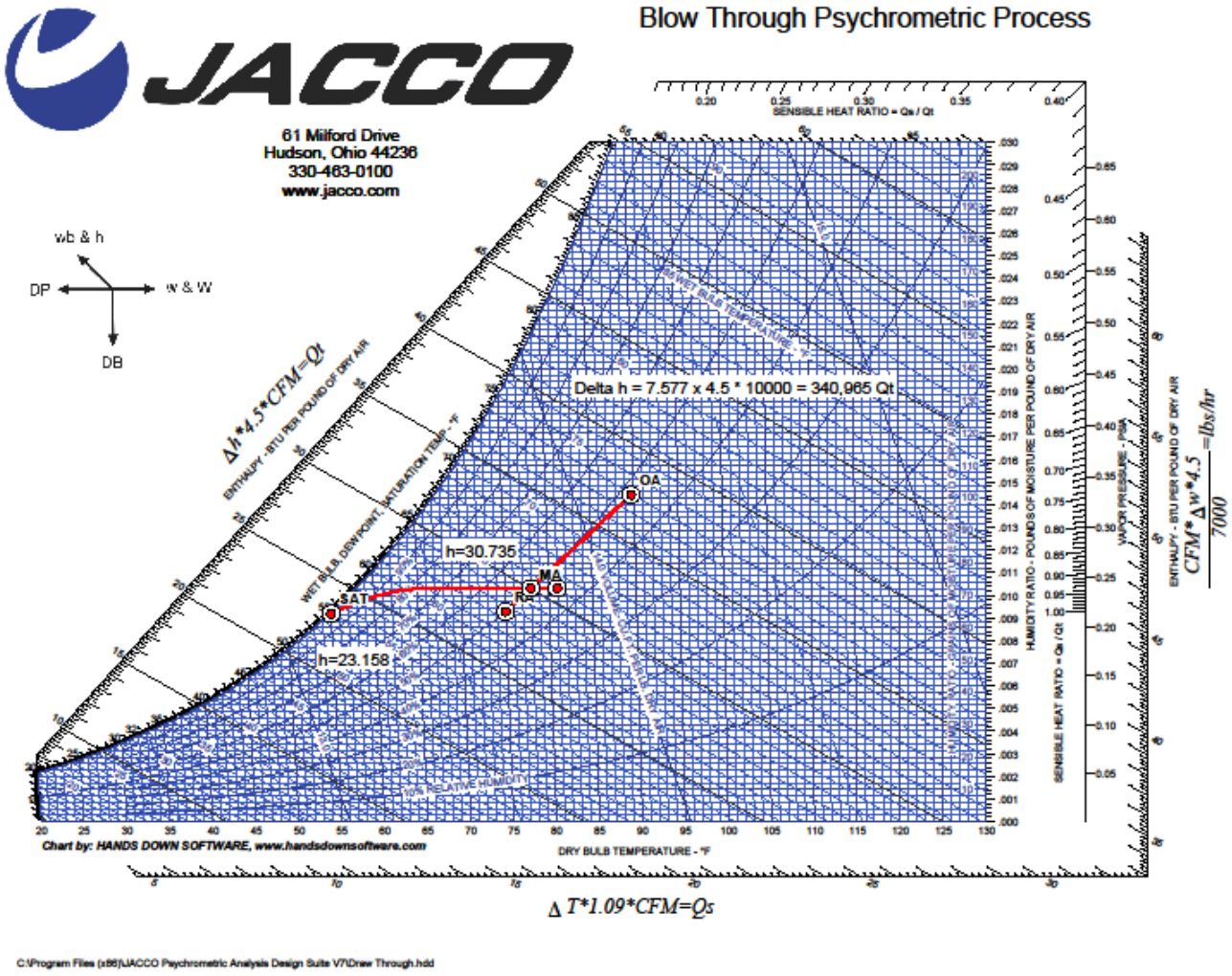
Blow Through



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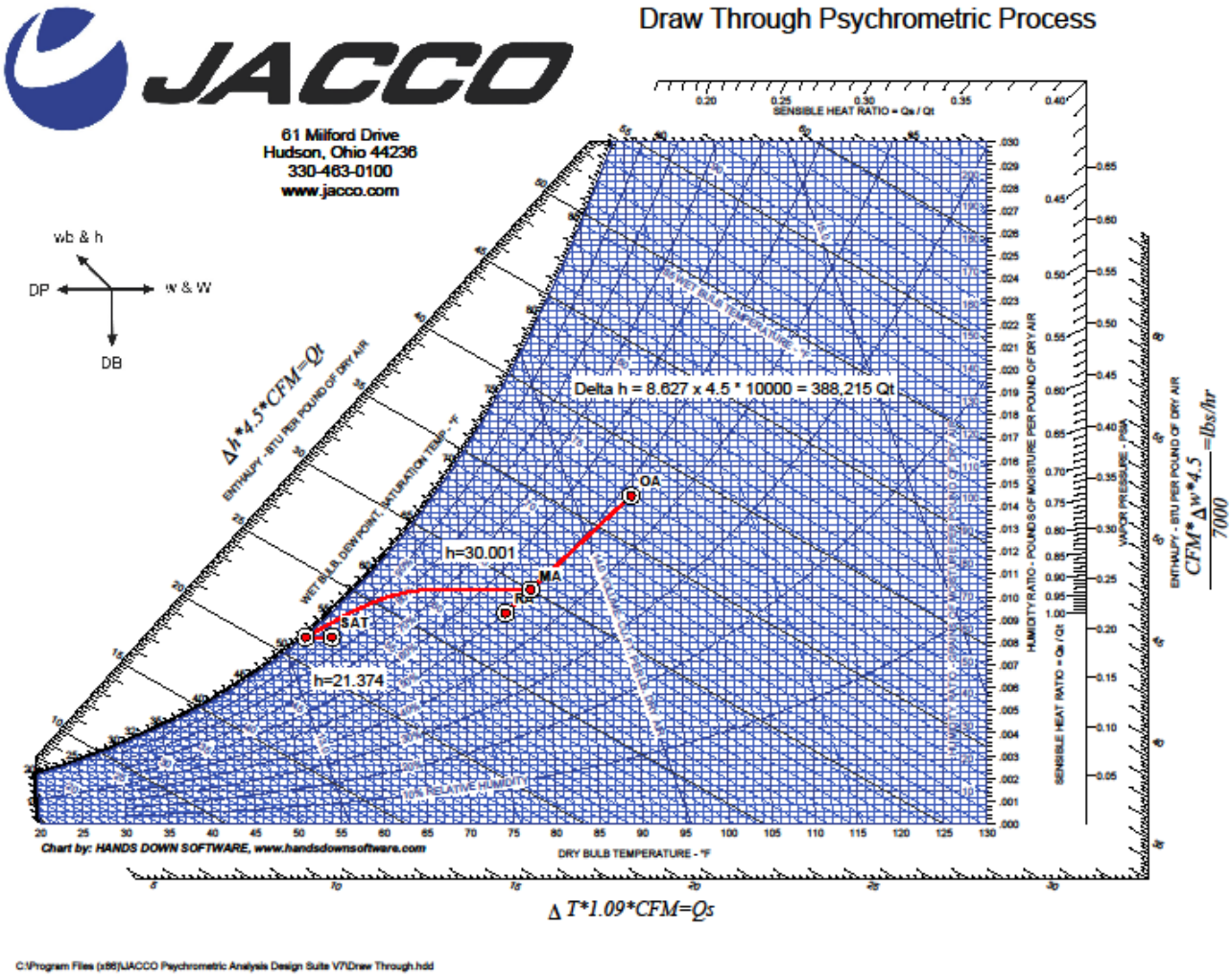
Applications – Draw Through

- Compact space requirements
- High latent loads
  - Pools
  - Underfloor or Displacement
- Initial cost constraints

Draw Through



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Applications – Heat Recovery

- Anything above 30% OA

Heat Wheel

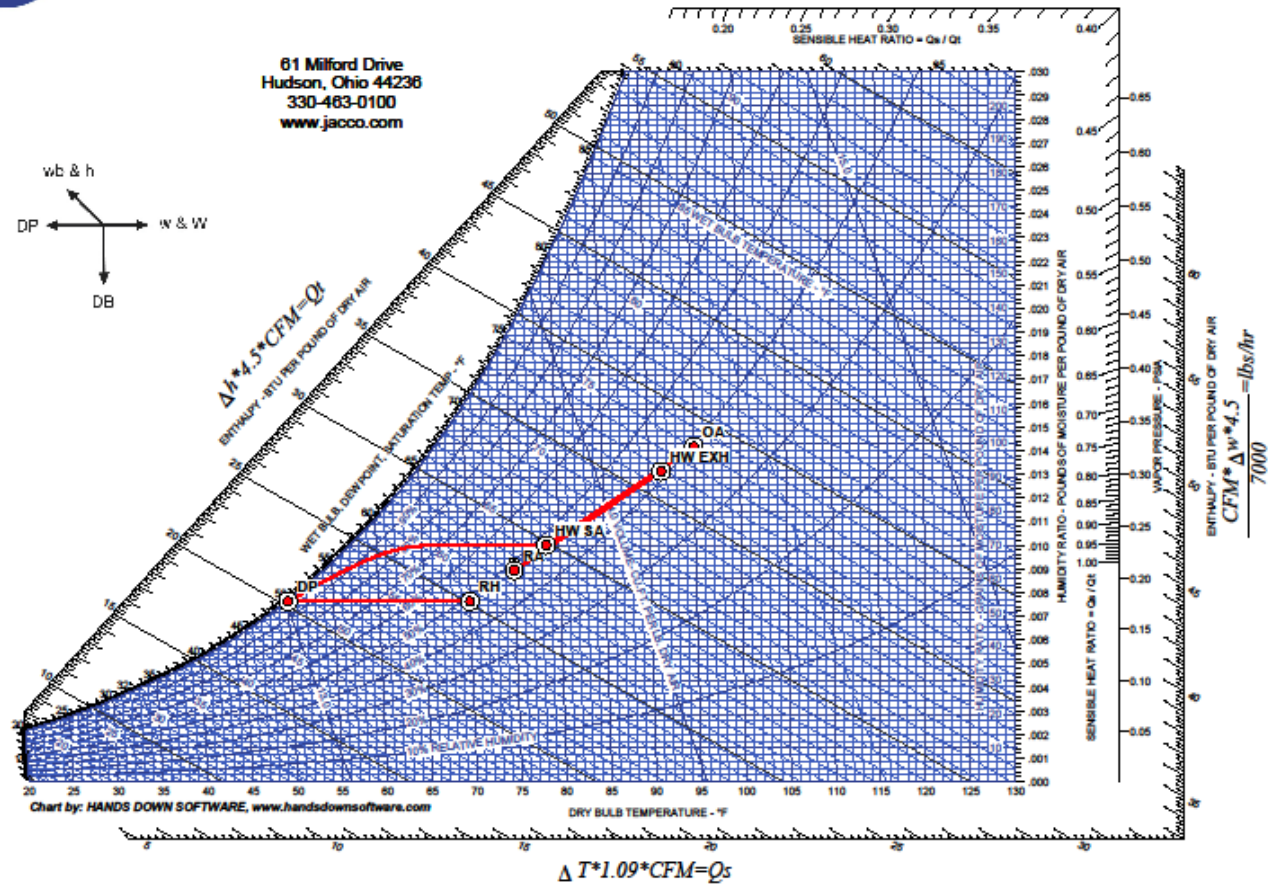
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Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com
DRY BULB TEMPERATURE - °F
SENSIBLE HEAT RATIO = Qs / Qt
ENTHALPY - BTU PER POUND OF DRY AIR
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WET BULB, DEW POINT, SATURATION TEMP - °F
VAPOR PRESSURE - PSIA
CFM*Δw*4.5/7000=lbs/hr
Δ T*1.09*CFM=Qs
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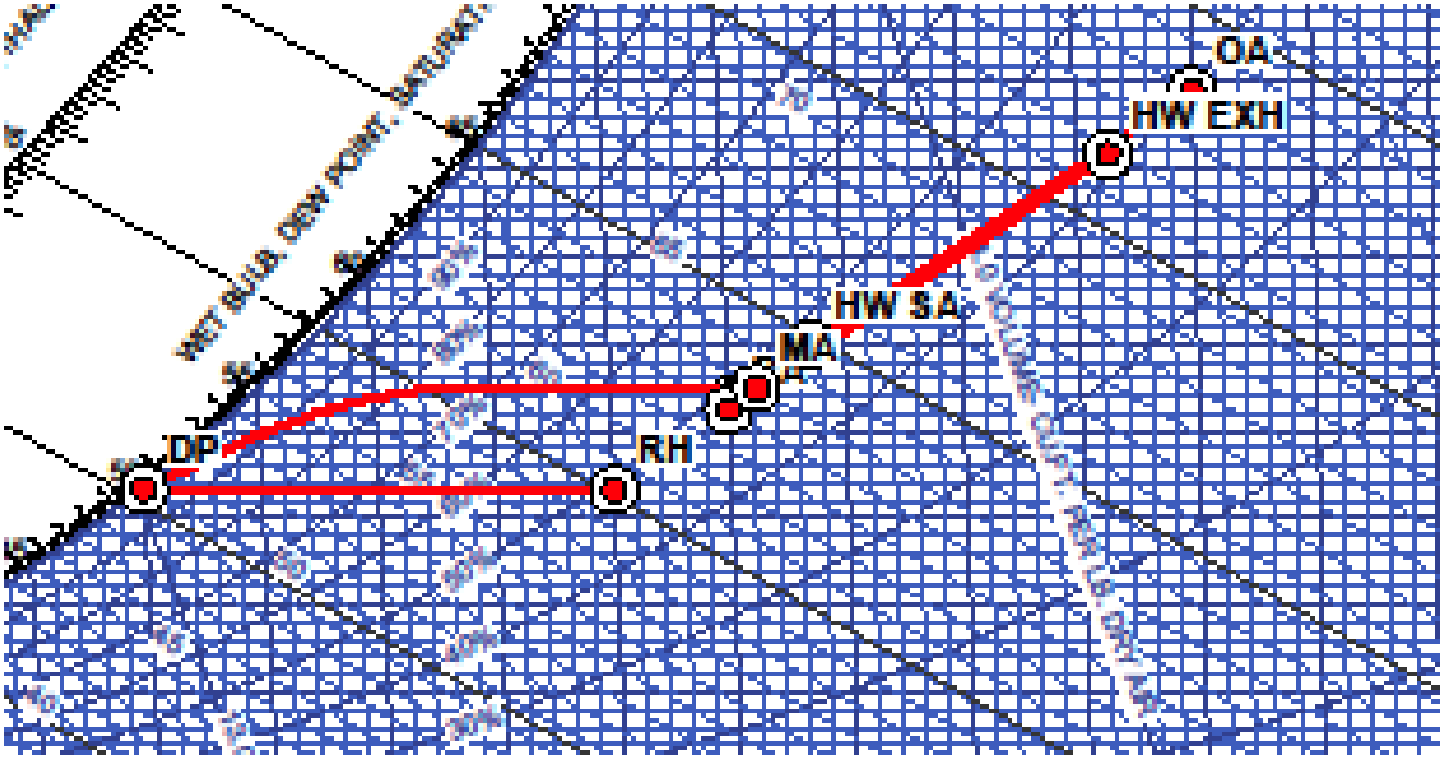
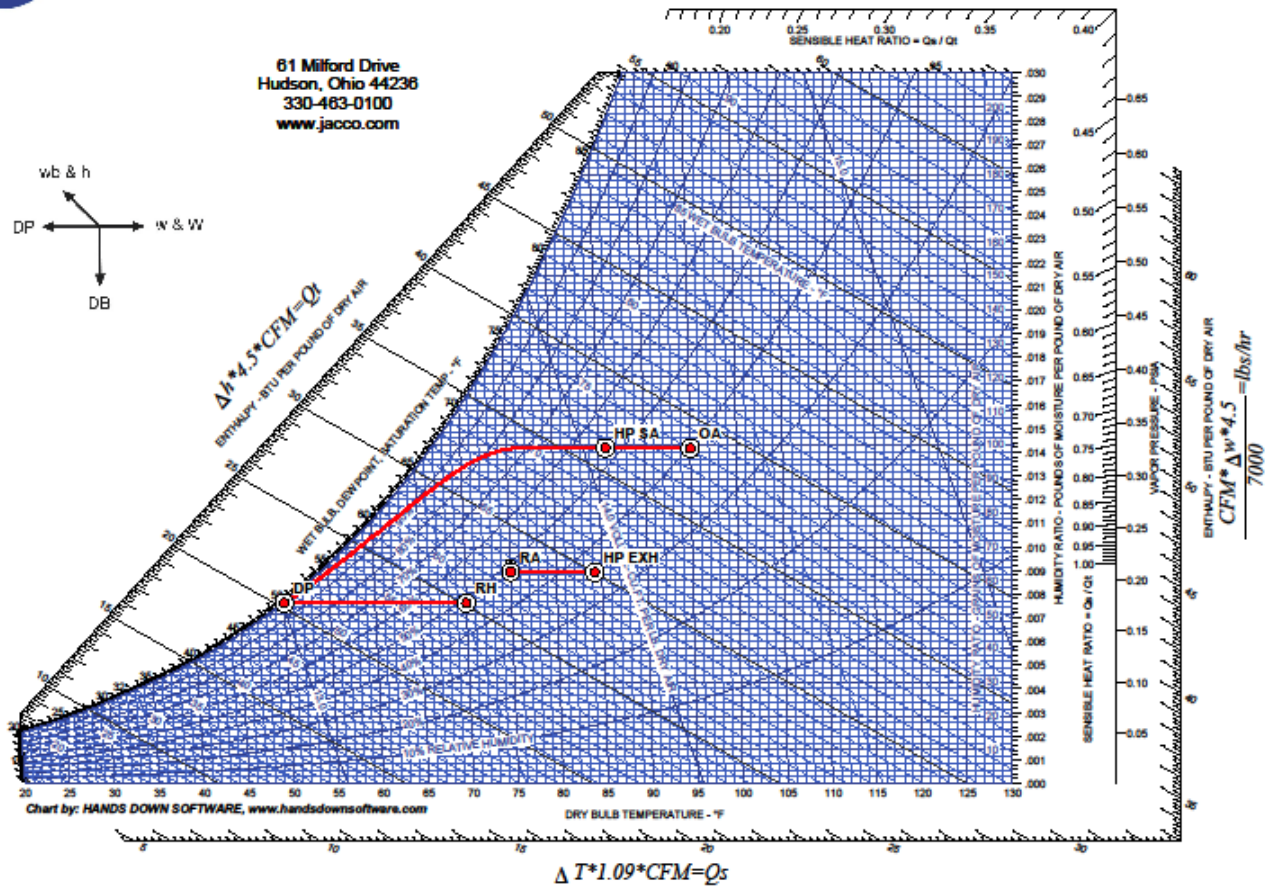
Heat Wheel – 33% OA



Heat Pipe/Plate



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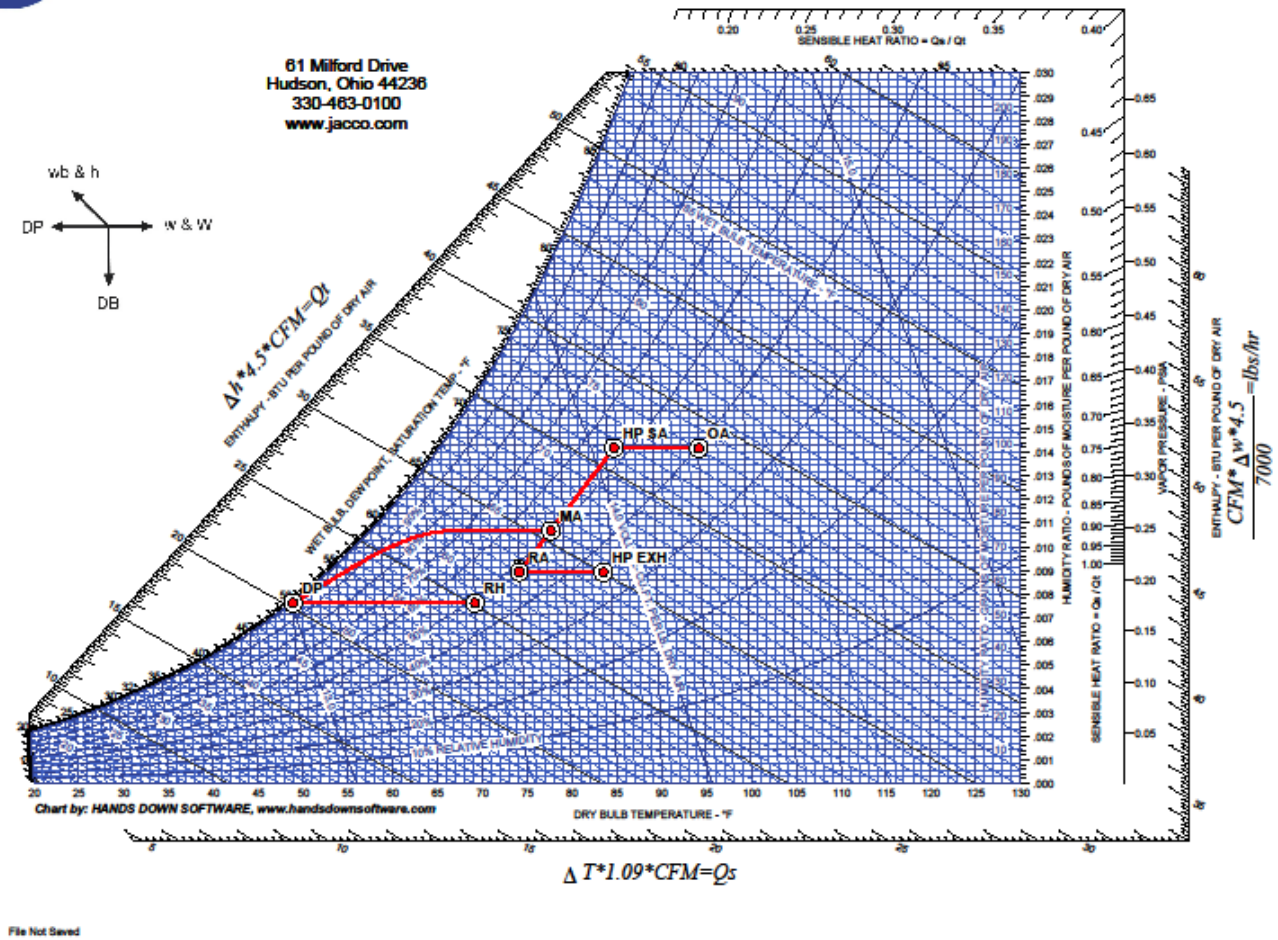
Heat Pipe/Plate – 33% OA



Applications – Humidification

- OR rooms
- Laboratories
- Wood / Printing
- Adiabatic especially economical with economizer systems

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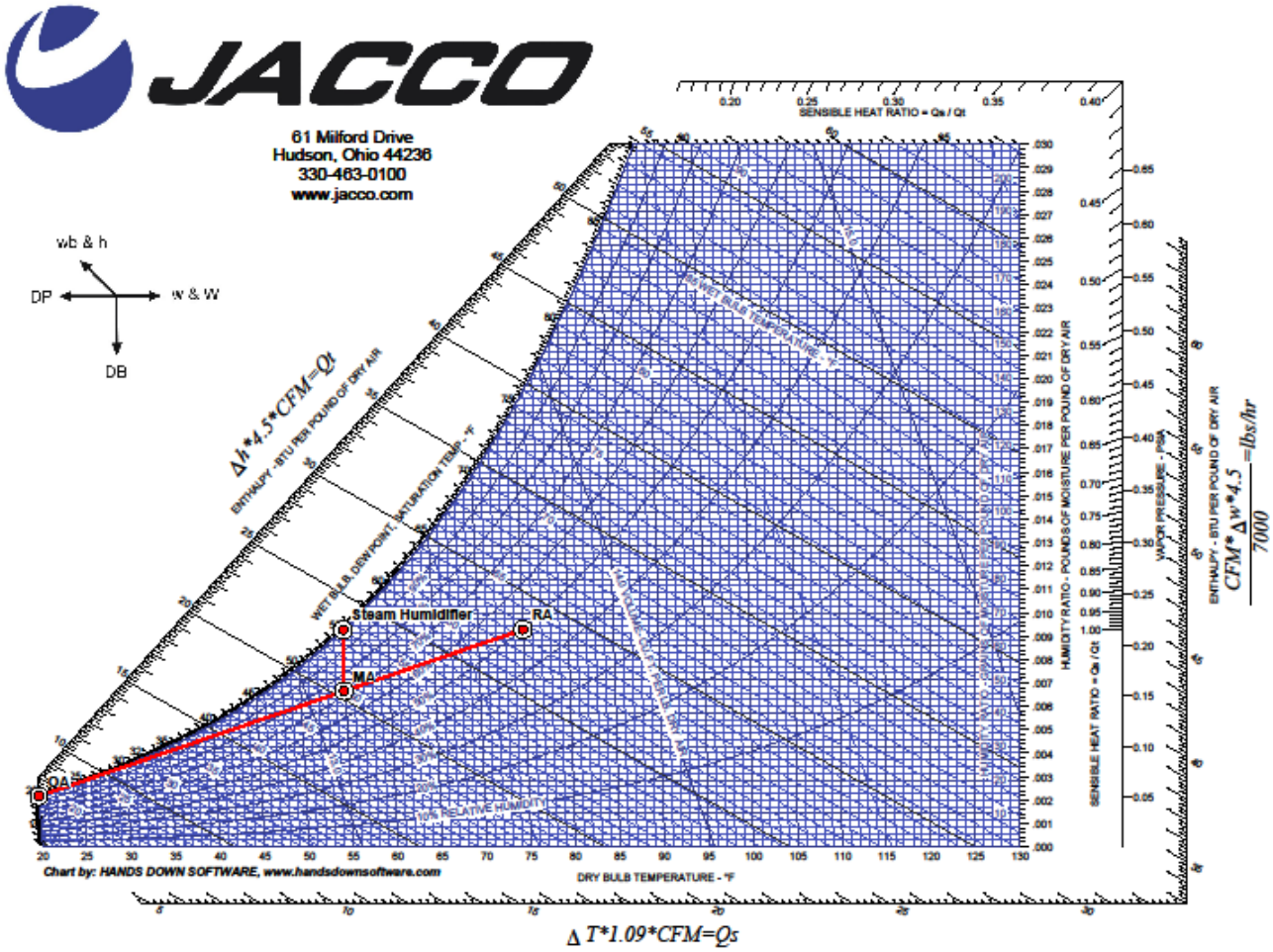
Steam Humidification



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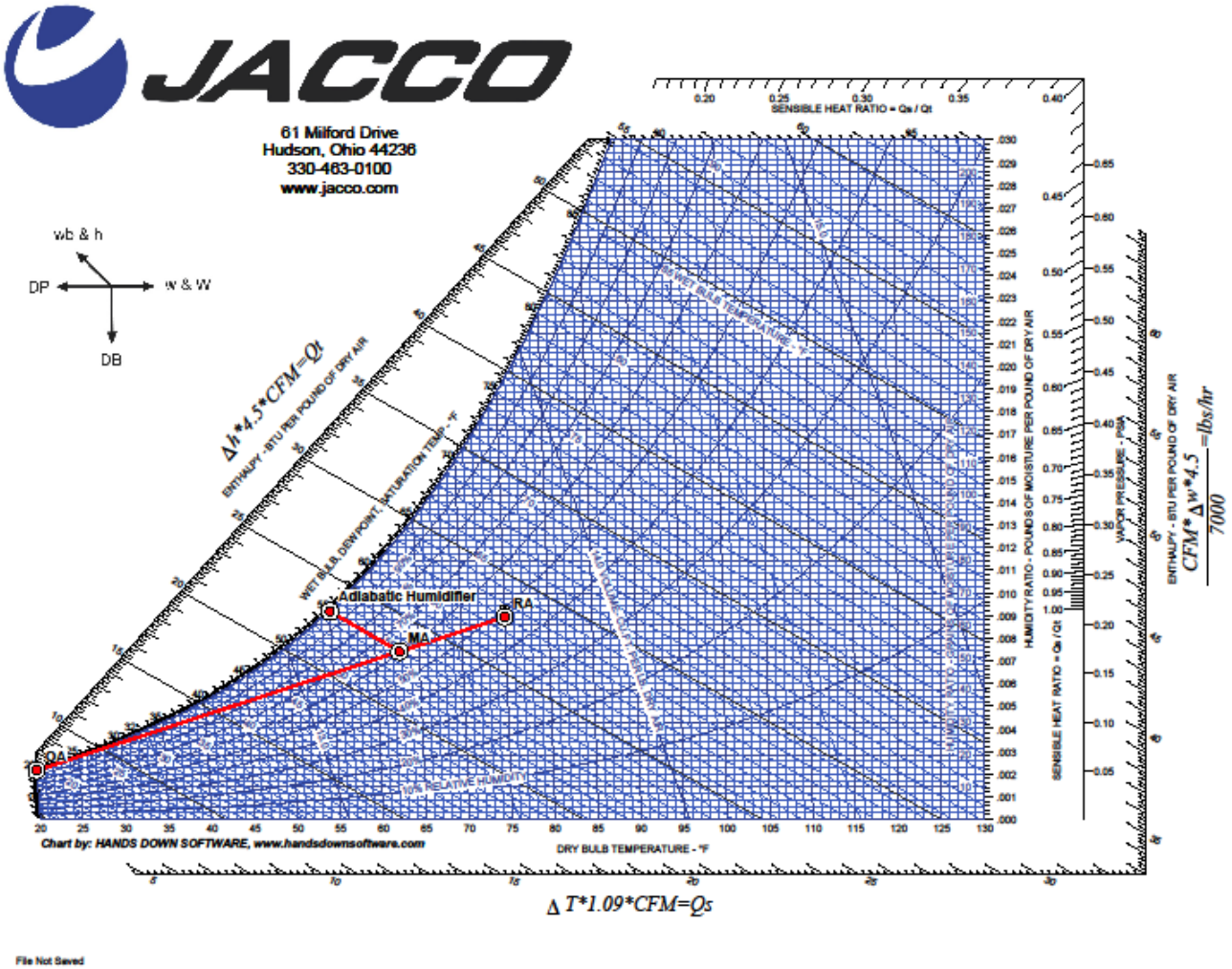
Adiabatic Humidification



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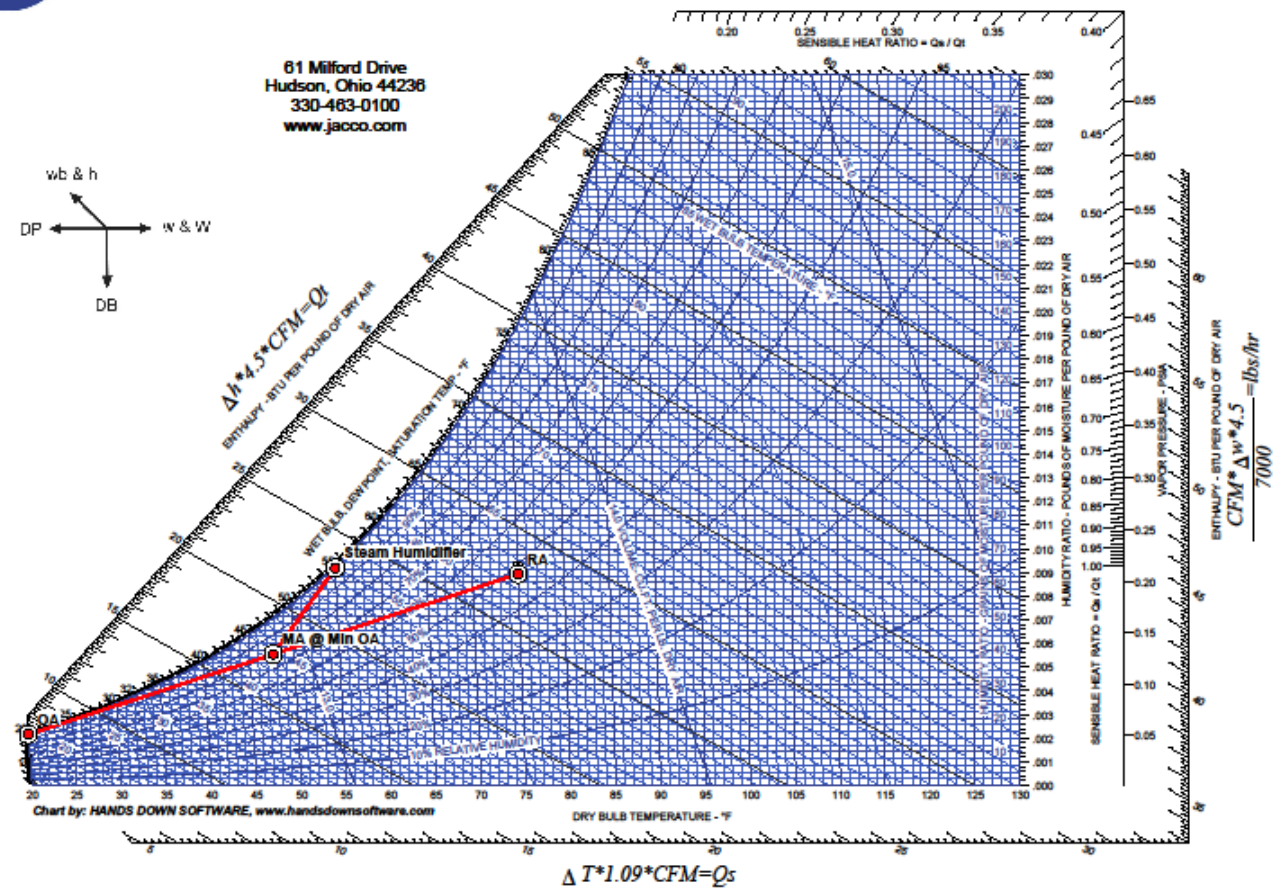
Steam Humidification @ Min OA



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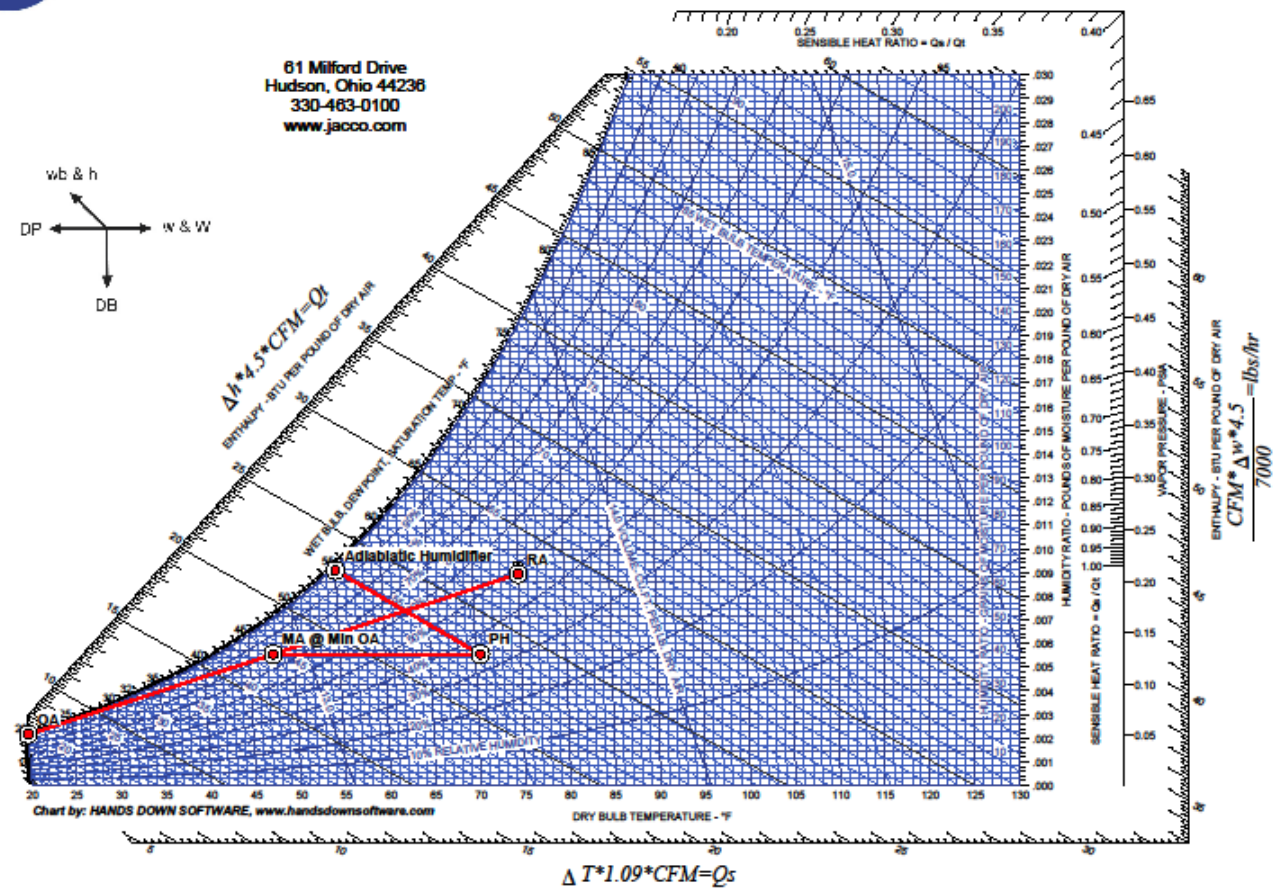
Adiabatic Humidification @ Min OA



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Applications - Dehumidification

- Desiccant best for < 40 DP
- Mechanical best for > 40 DP
- Ice Rinks
- Swimming Pools
- Surgery Suites
- DOAS
  - VRF
  - Geothermal
  - Chilled Beam
  - Corridor Ventilation

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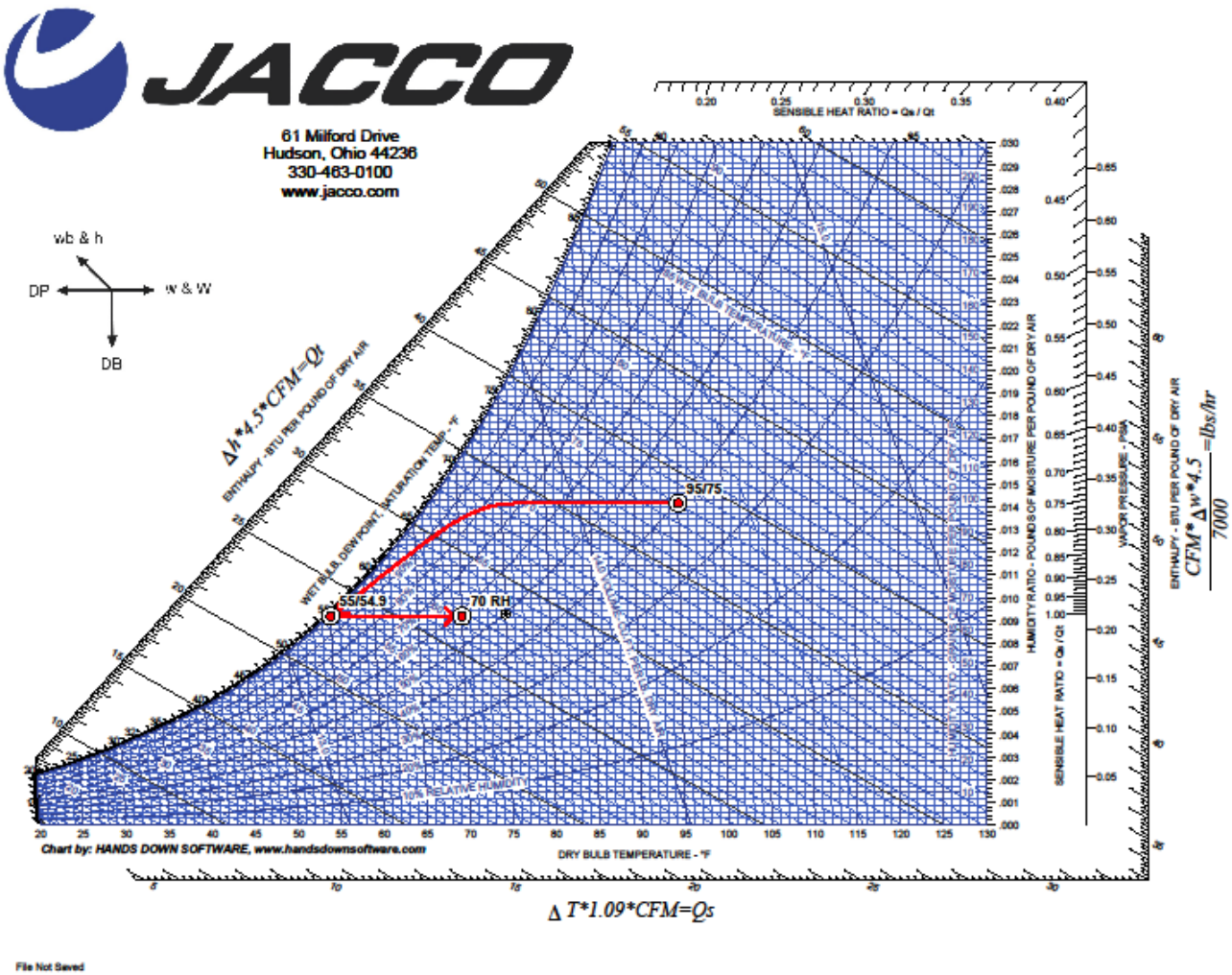
Mechanical Dehumidification



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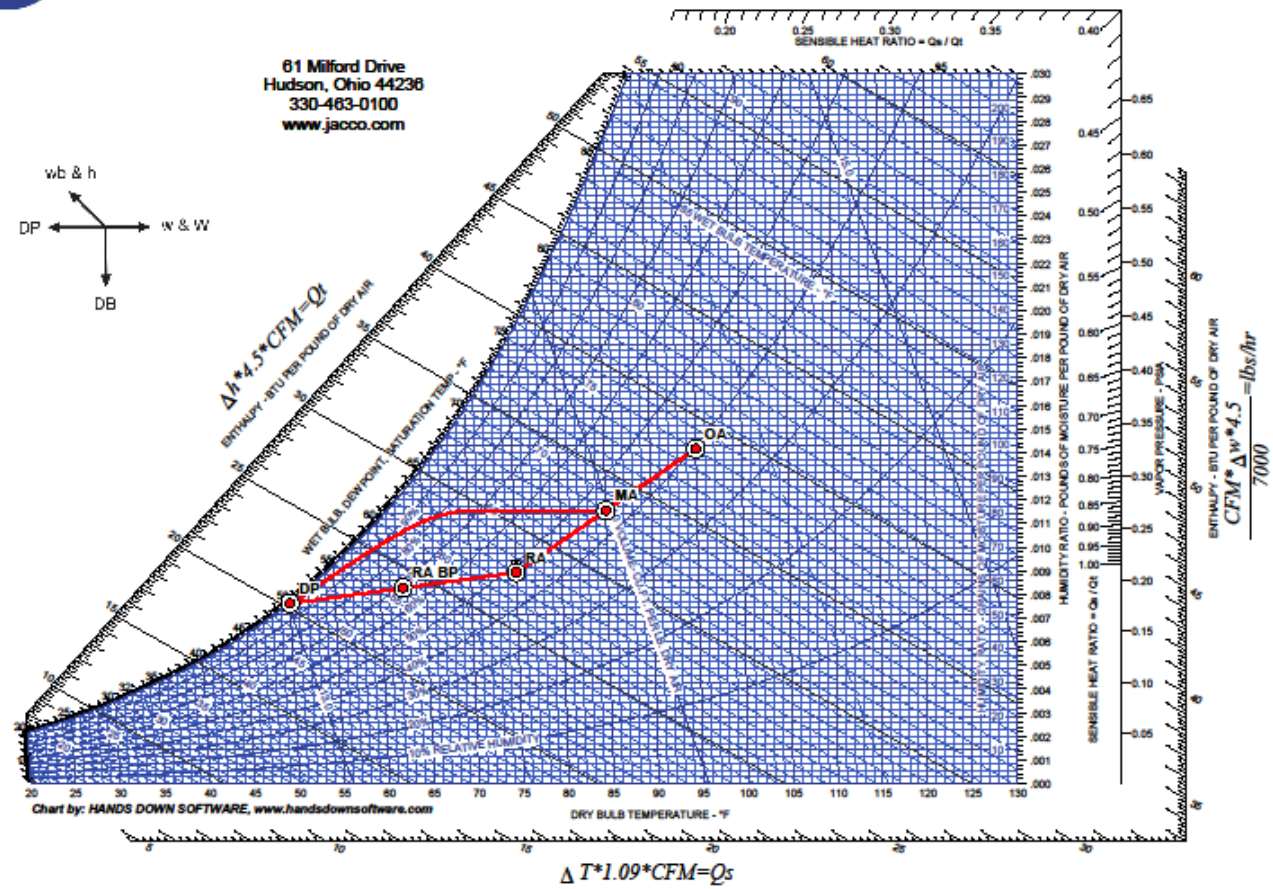
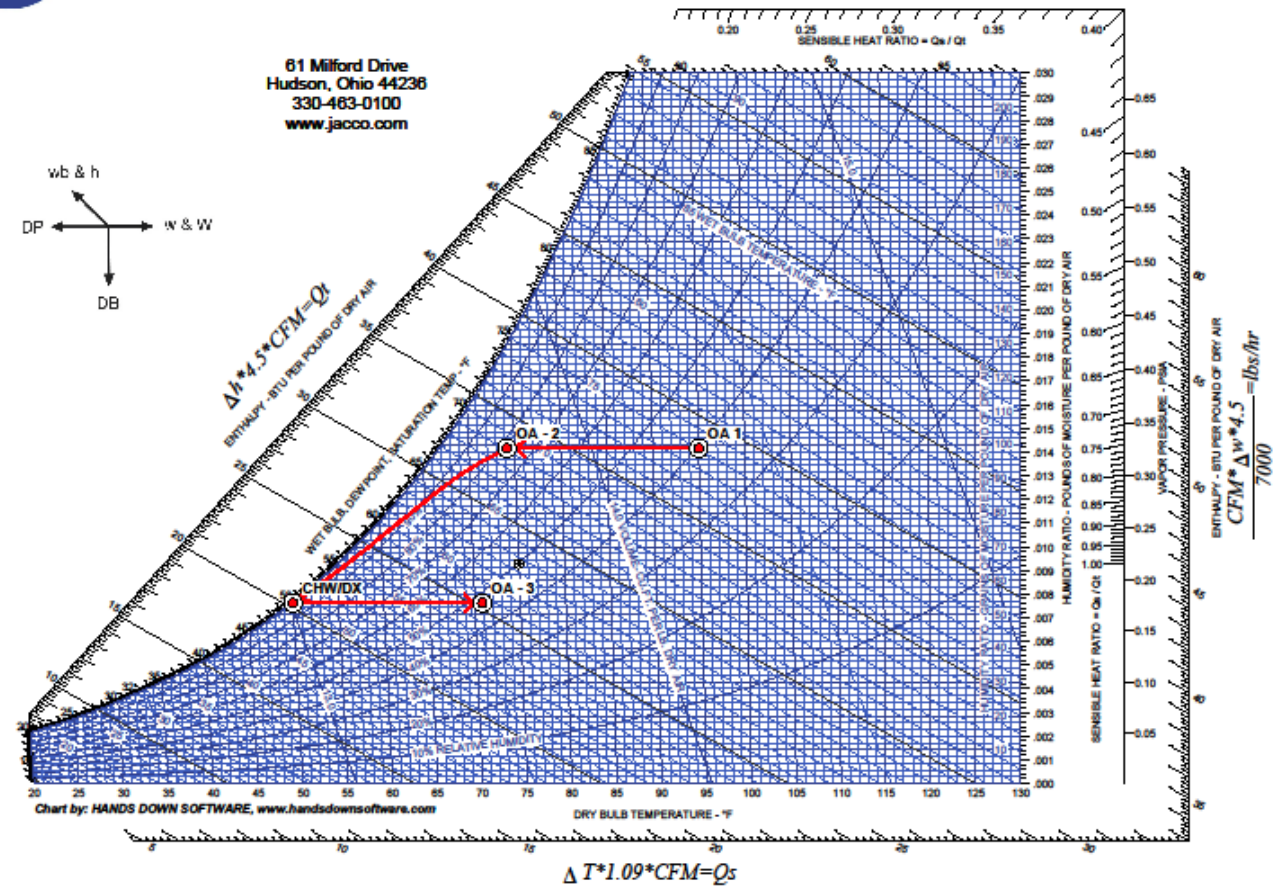
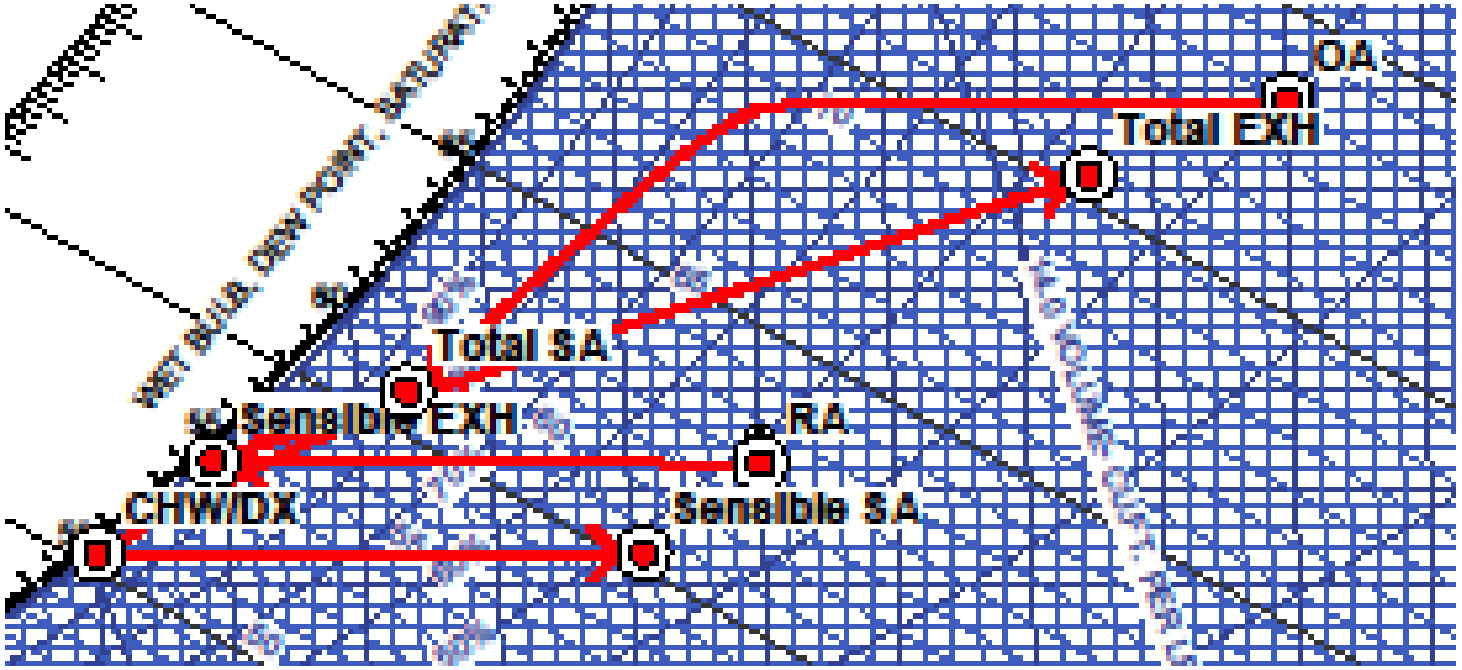
Return Air Bypass



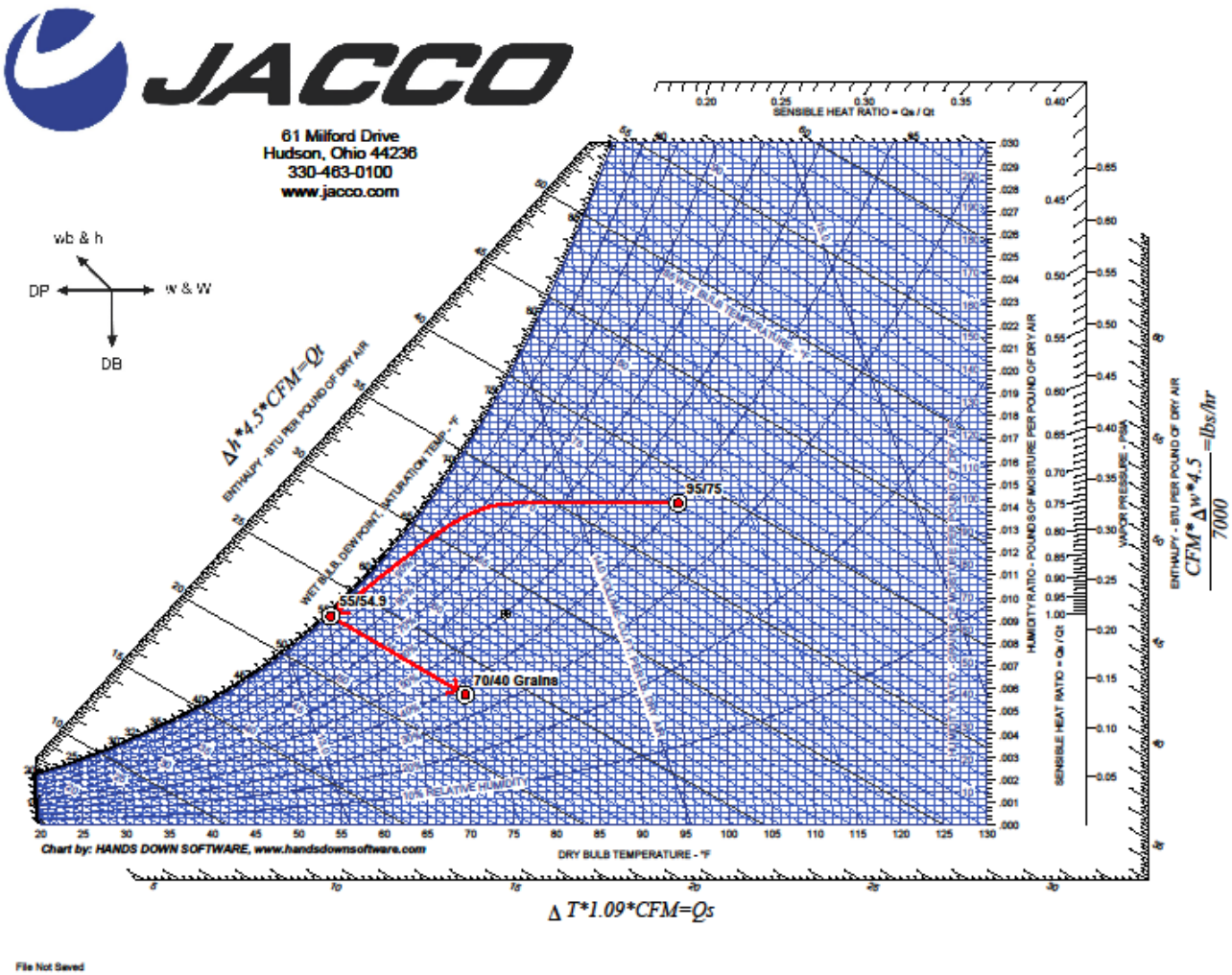
Single Pipe/Plate HX



Dual Wheel – Latent & Sensible



Desiccant Dehumidification Pre-Cool



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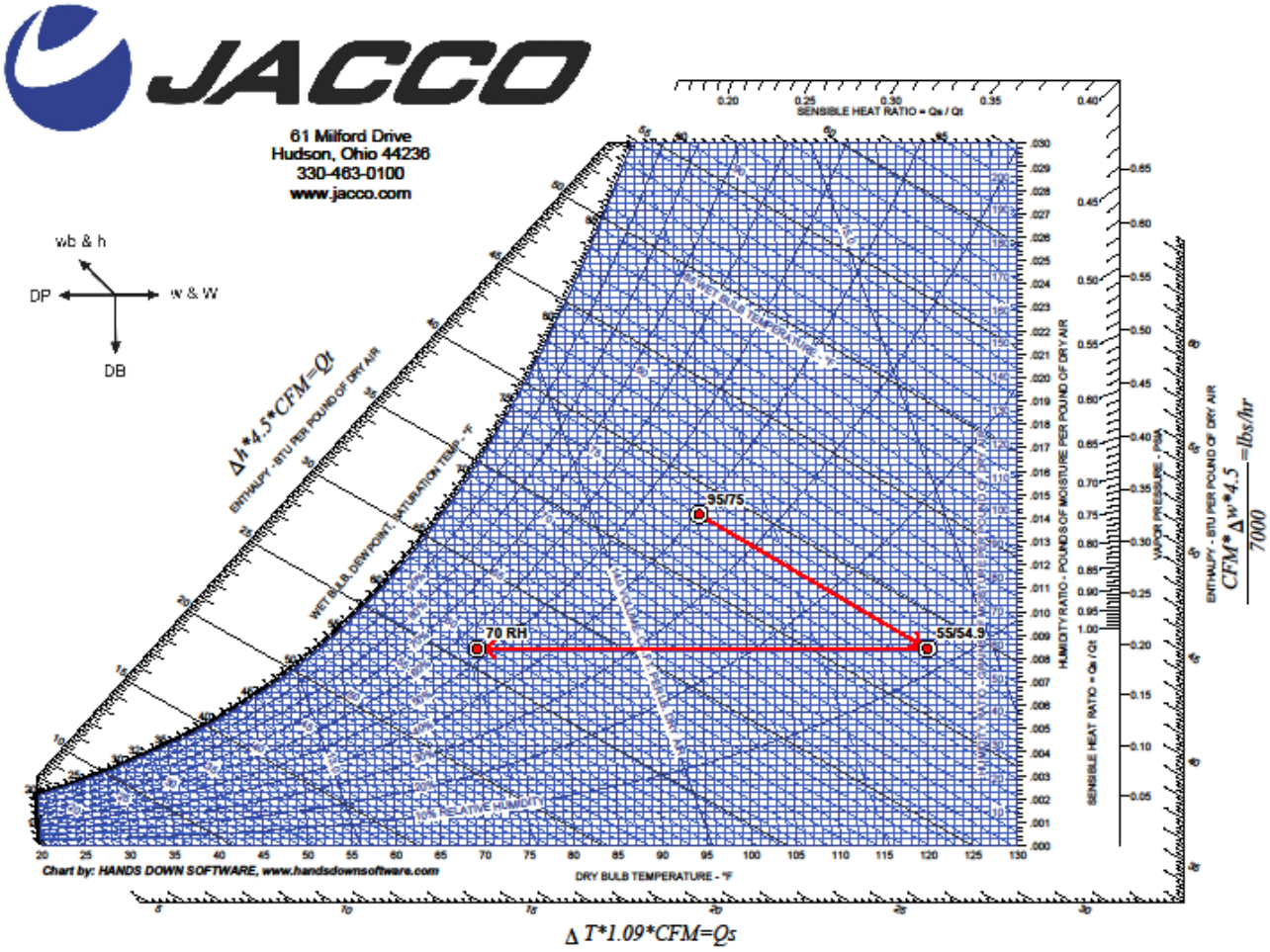
Desiccant Dehumidification - Post-Cool



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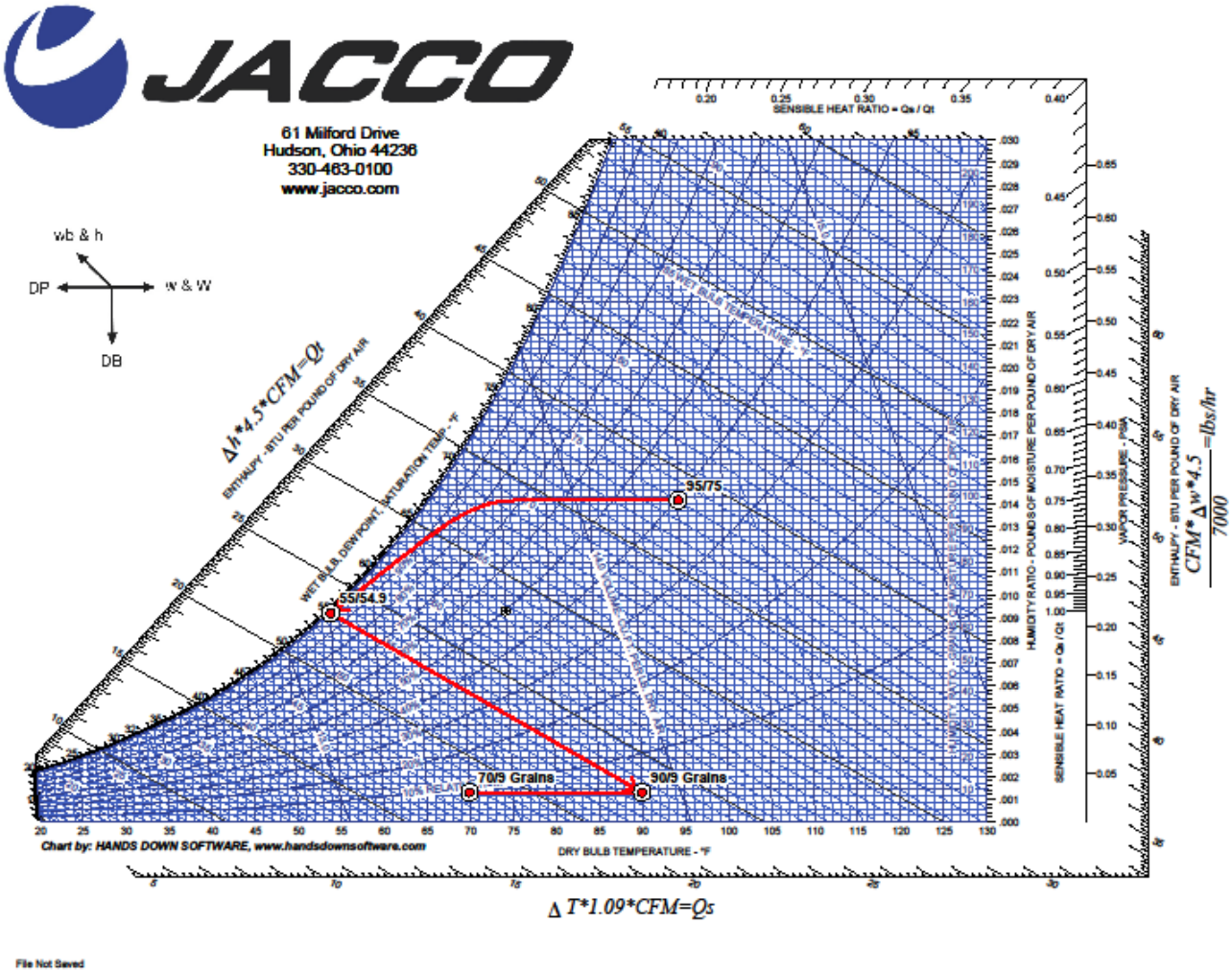
Desiccant Dehumidification, Pre & Post-Cool



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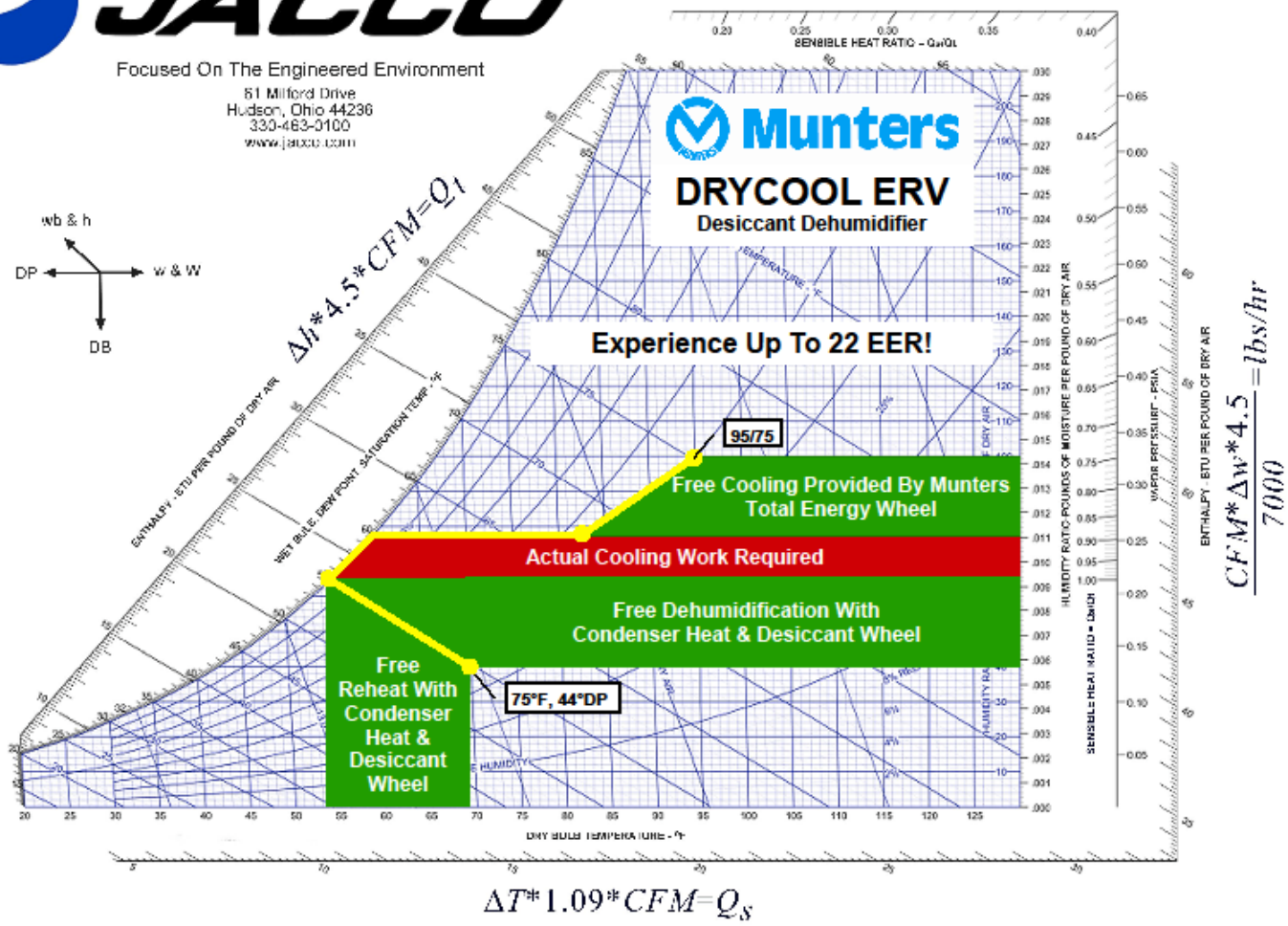
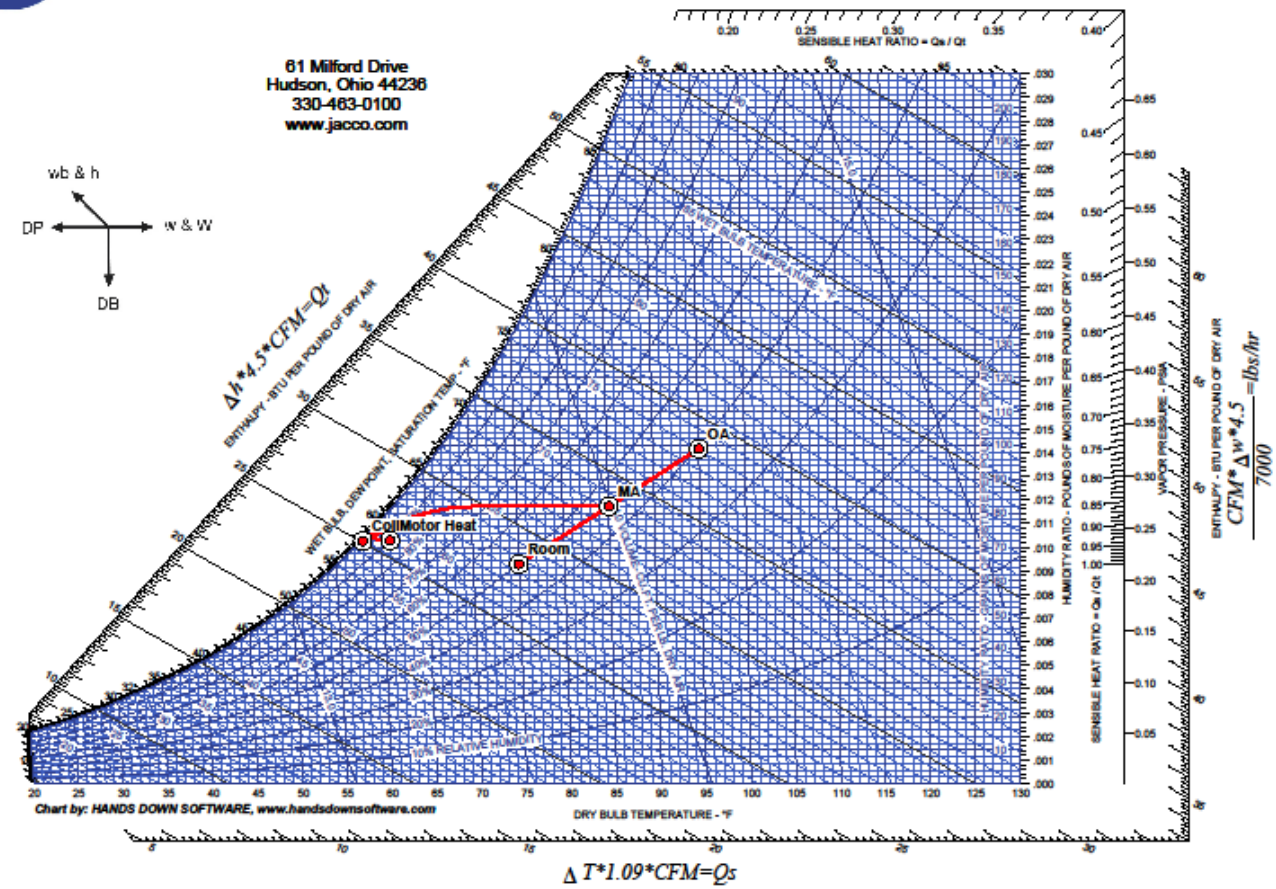
Dual Wheel, Low Temp Regeneration Desiccant Dehumidification, Pre Cool



Is this Dehumidified?



Tight Temperature and Humidity Control

- High SHR Equipment
- Low SHR Equipment

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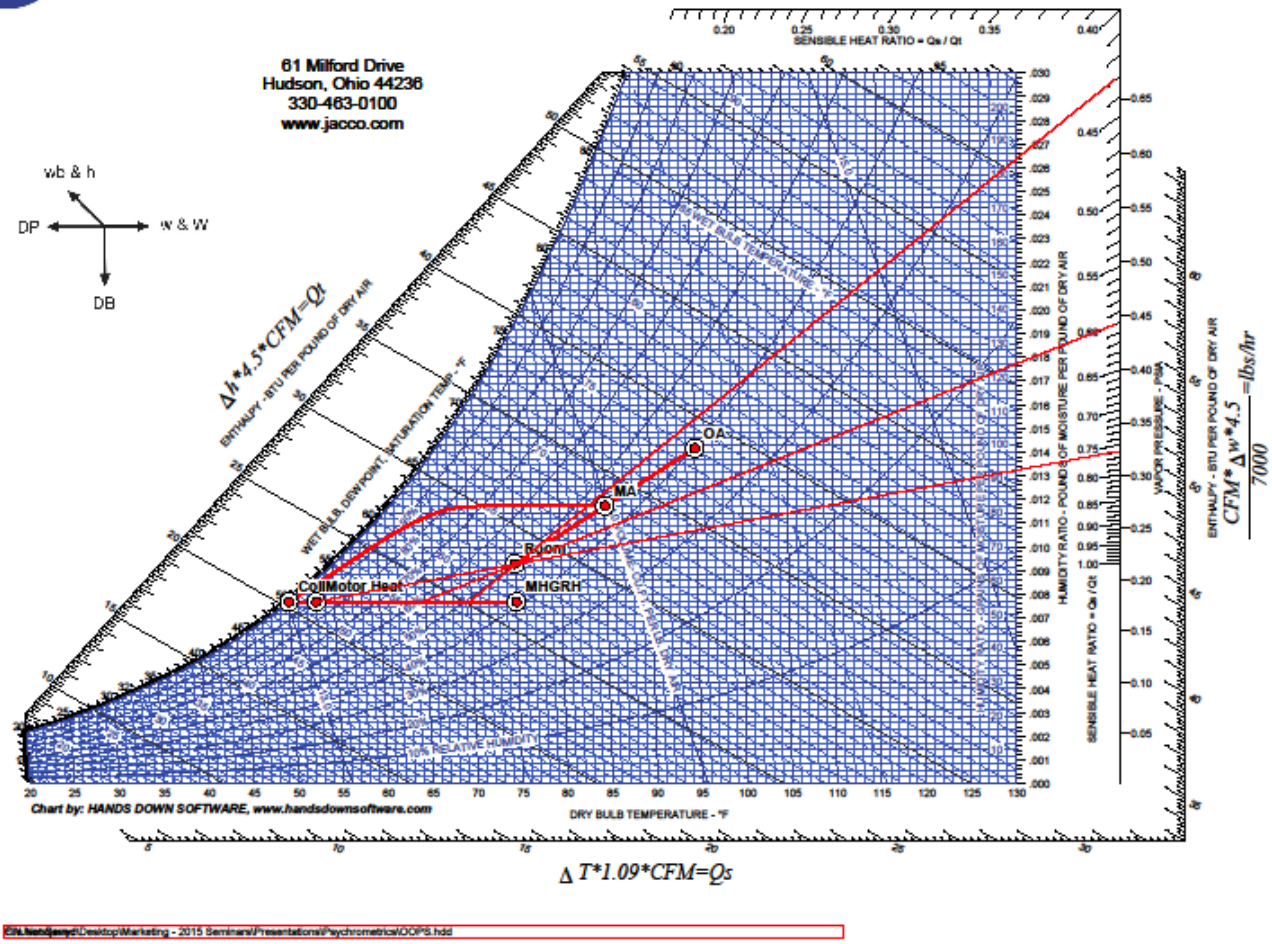
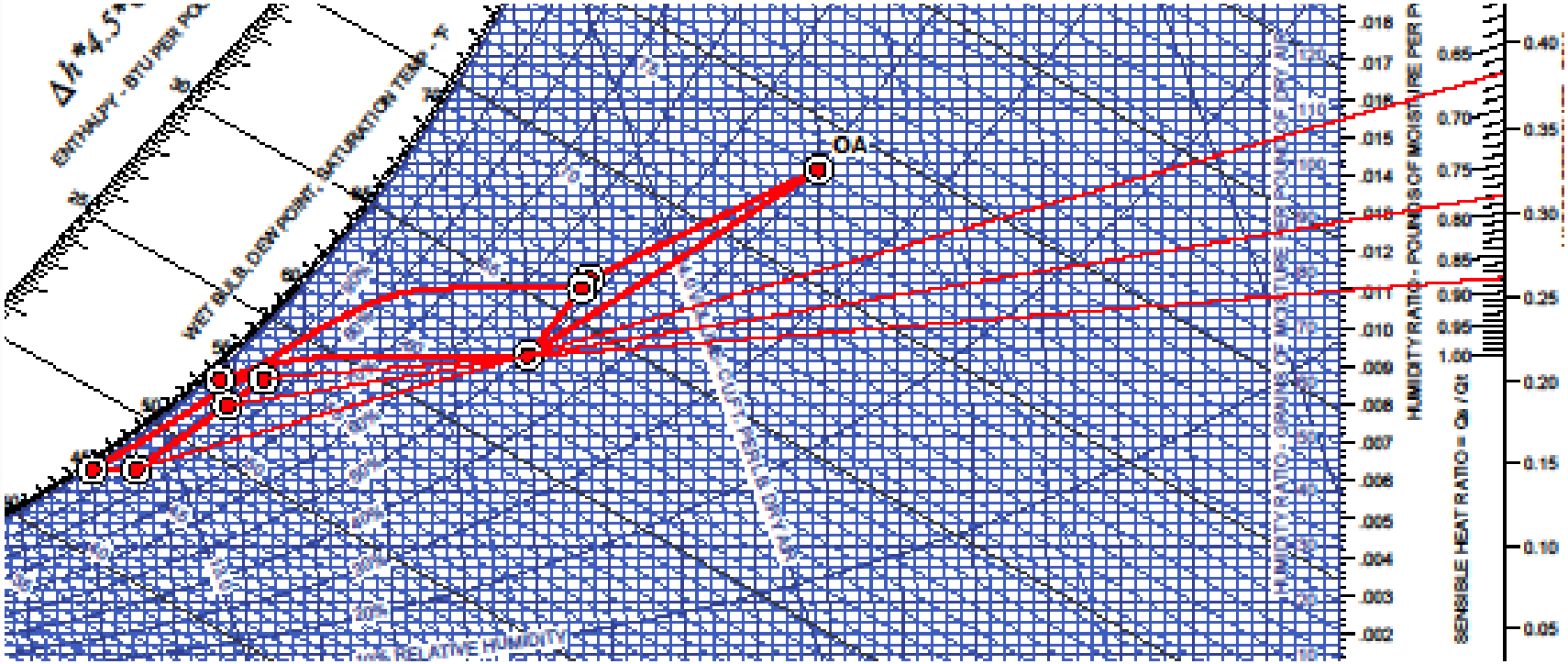
Reheat for SHR



Conquer & Divide for SHR



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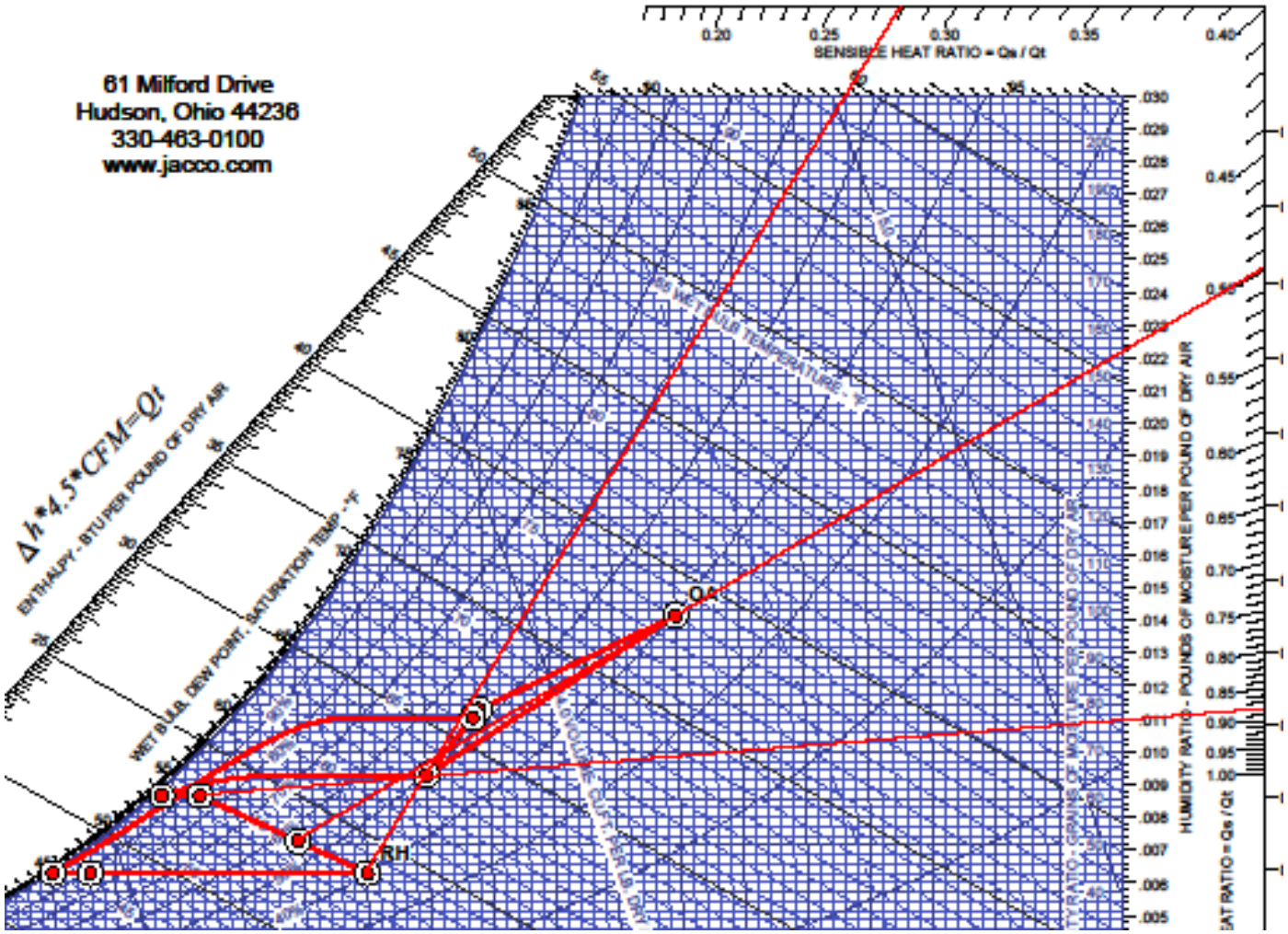
Conquer & Divide for SHR



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ASHRAE Data Sets

- Nine Cooling Data Sets:
- Presented as 0.4%, 1%, 2% Values.
  - DB/MCWB: Useful for Typical Mixed Air Cooling.
  - WB/MCDB: Useful for Adiabatic Saturation Processes: Cooling Towers, Evaporative cooling
  - DP/MCDB: Highest moisture content of Outside Air. Useful for De-humidification and 100% Ventilation Systems.

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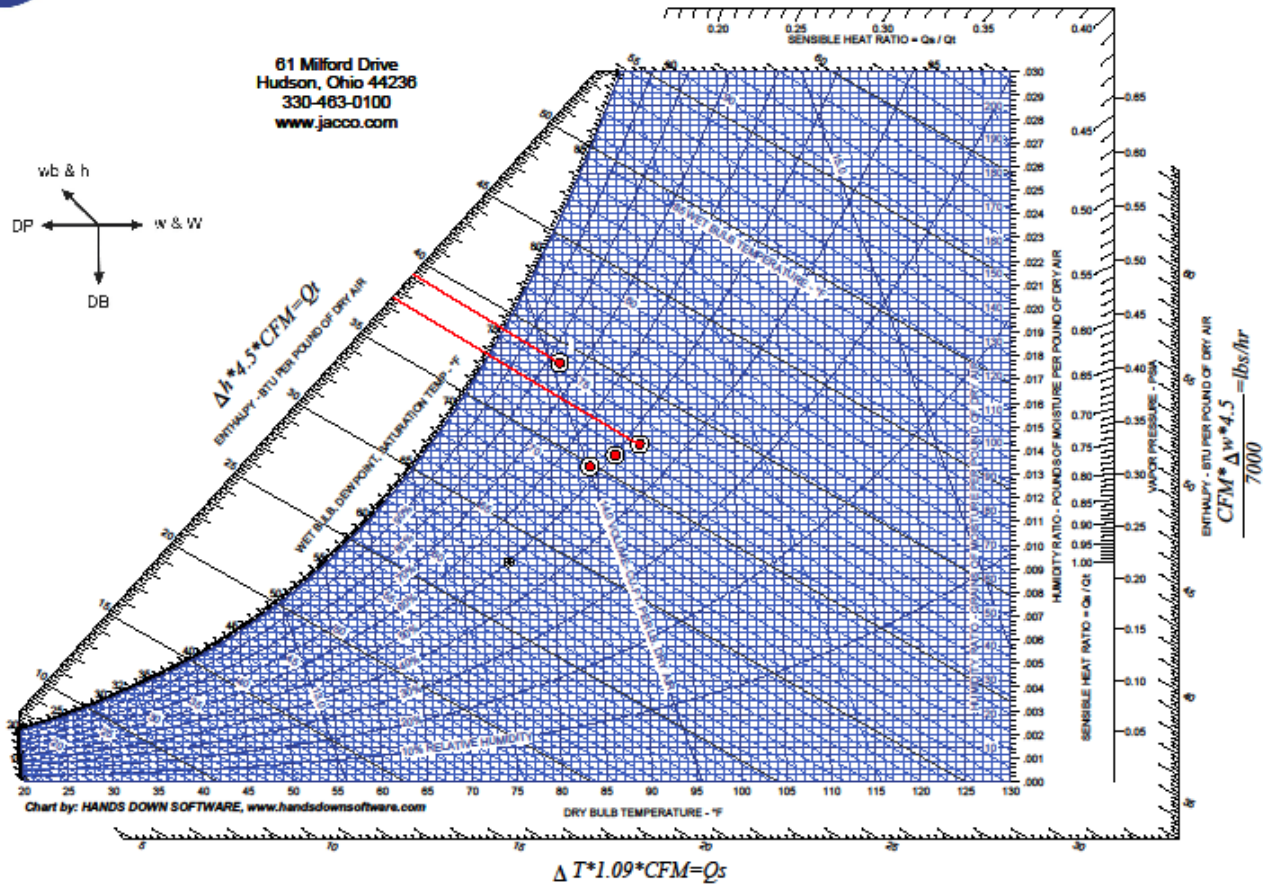
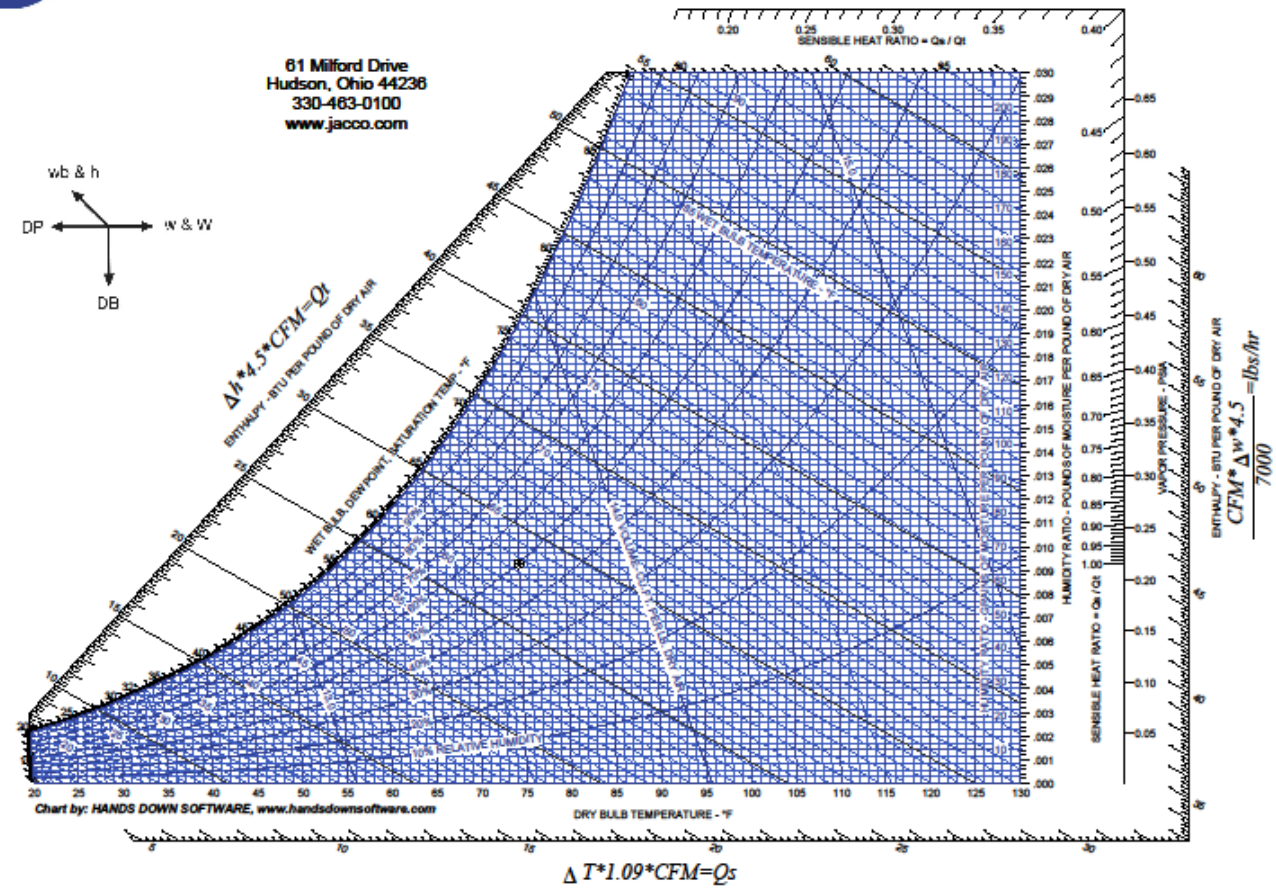
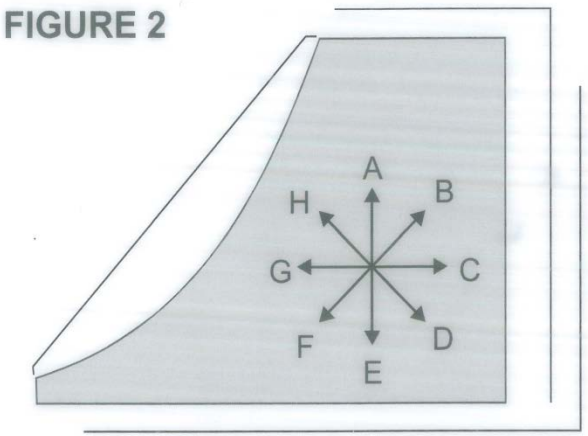
ASHRAE Data Sets



Psychrometric Cheat Sheet



Psychrometric Cheat Sheet



A – Humidify Only

B – Heat & Humidify

C – Sensible Heat Only

D – Desiccant Dehumidify

E – Dehumidify Only

F – Cool & Dehumidify

G – Sensible Cool Only

H – Evaporative Cool

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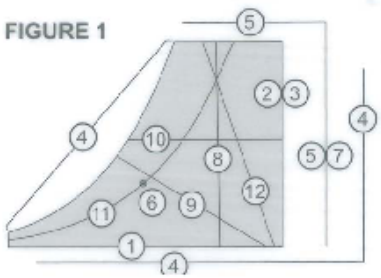
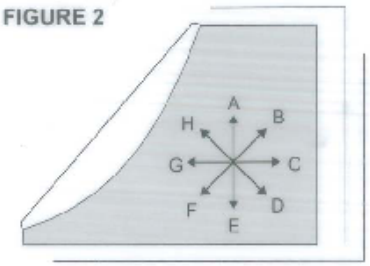
Psychrometric Cheat Sheet

FIGURE 1



1 – Dry Bulb (DB)
2 – Humidity Ratio in Grains (w)
3 – Humidity Ratio Scale (W)
4 – Enthalpy Scale (h)
5 – Sensible Heat Ratio Scale (SHR)
6 – Sensible Heat Ratio Origin
7 – Vapor Pressure Scale
8 – Dry Bulb Temperature Line
9 – Wet Bulb Temperature Line
10 – Humidity Ratio Line
11 – Relative Humidity Line
12 – Specific Volume Line

FIGURE 2



A – Humidify Only
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Helpful Formulas

- Sensible (Qs) = Δt x 1.09 x cfm
- Total (Qt) = Δh x 4.5 x cfm
- Water (Qt) = Δt x 500 x gpm
- Lbs/hr/air (lba) = (cfm / specific volume of air) x 60
- Lbs/hr/water (lbw) = lba x ΔW
- Humidity ratio (W) = grains (w) / grains/lb (7000)
- Δ humidity ratio (ΔW) = (w1 / 7000) – (w2 / 7000)
- Lbs/hr/water (lbw) = (cfm x Δw x 4.5) / 7000
- Condensate GPM = Δ lbw / 8.33 / 60
- 1 KW = 3.415 Btuh
- 1 HP = 2.546 Btuh and .7547 KW
- EER = (MBH – motor heat) / KW
- Room CFM = room sensible / 1.09 / ΔT
- Air Changes = (60 x cfm) / room volume in cu. ft.
- HP = existing HP x (req'd speed / existing speed)^3
- True Electric Heat = nominal KW x (actual voltage / nominal voltage)^2
- Mixed Air cfm = (oa db x oa cfm / total cfm) + (ra db x ra cfm / total cfm)

Definitions

1. Dry Bulb Temperature (DB) – The temperature of air
2. Wet Bulb Temperature (WB) – The temperature to which air can be cooled to by the adiabatic evaporation of water
3. Humidity Ratio (w) – Grains per lb of dry air
4. Humidity Ratio (W) – The ratio of the mass of water vapor to the mass of dry air in the air vapor mixture
5. Relative Humidity (RH) – The ratio of water pressure in the air vapor mixture to the water pressure of water saturated at the same dry bulb temperature
6. Specific Volume – The volume of air per pound of dry air
7. Enthalpy (h) – The energy content of the air vapor mixture per pound of dry air
8. Dew Point Temperature (DP) – The temperature at which condensation of water vapor in an air vapor mixture occurs
9. Vapor Pressure (VP) – The pressure of saturated water at the Dew Point Temperature
10. Sensible Heat Ratio (SHR) – The ratio of the sensible heat transferred to the total heat transferred in an air conditioning process

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How Can Jacco Help You?

- Tight Temperature & Humidity Control
- Low SHR Applications with Aaon, Munters, Seasons 4 & Energy Labs
- High SHR Applications with WaterFurnace, Samsung, TROX, Beka & Whalen
- Standard SHR Applications with Aaon
- Humidification with MeeFog & Vapac
- Dehumidification with Aaon, Munters, Seasons 4 & Energy Labs

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Thank You

Jerry Cohen
President
Jacco & Assoc.