



The Basics -
Practical Psychrometrics

Jerry Cohen
President
Jacco & Assoc.

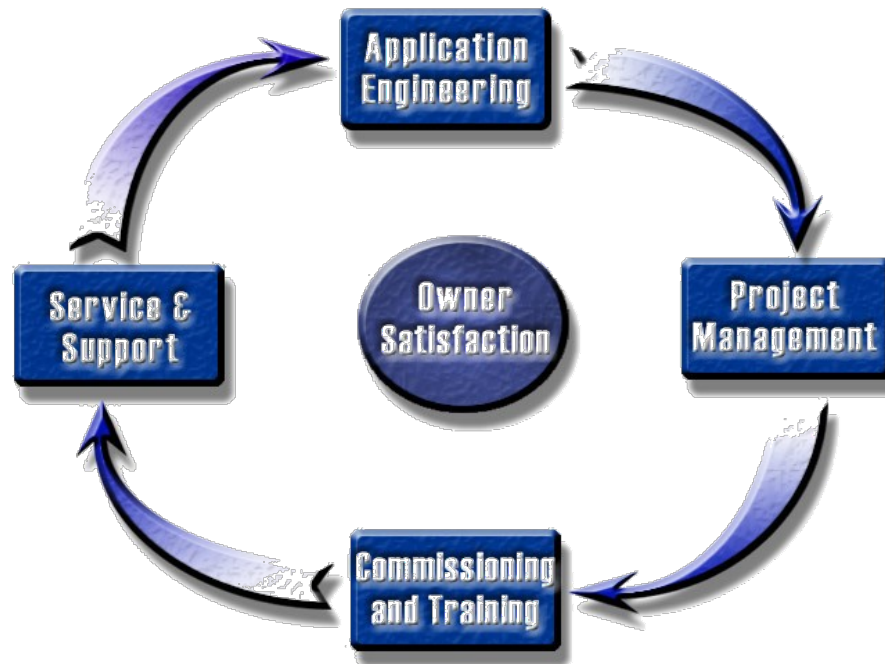
Who is Jacco

- Established 1968
 - Hudson, Ohio
 - Columbus, Ohio
 - Toledo, Ohio
- Focused on the Engineered Environment
- Systems Knowledgeable
 - HVAC Systems
 - Service & Maintenance
 - Parts



Purpose Statement

The purpose of our Company is to solve our customers problems, in the most economical way, at all times optimizing the owning experience.



Who is Jacco

- Operations
 - Brenda Homjak
 - Mike Spangler
 - Chad Russell
 - Mike Mueller
- Contractor Owning Experience
 - Dan Duignan
 - Rick Baker
- Engineering Owning Experience
 - Greg Drensky
 - Jerry Cohen
- Owning Experience
 - Steve Leister
 - Alicia Patsva
 - Jeff Watson

Who is Jacco

- 30 Minute Pledge
 - Design
 - Questions
 - Problems
 - Answers



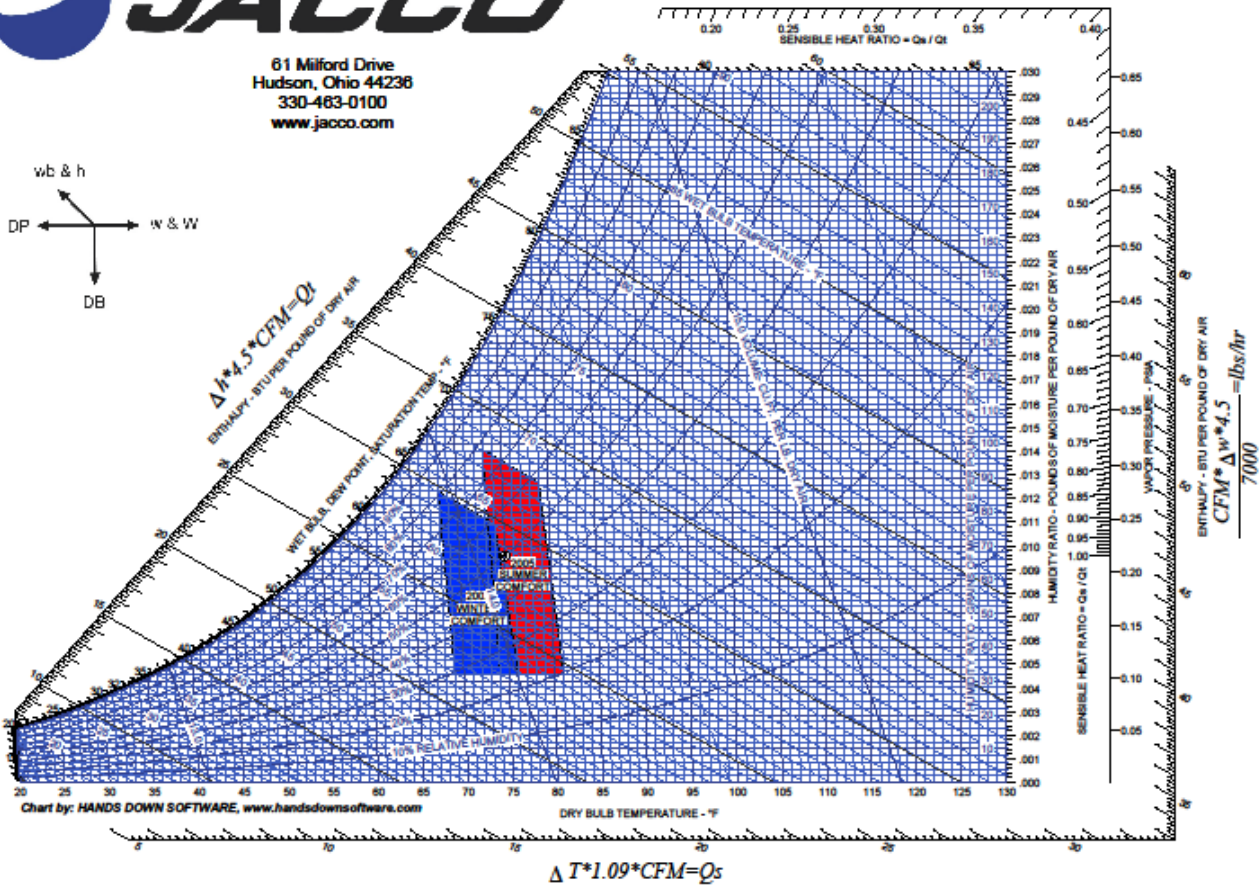
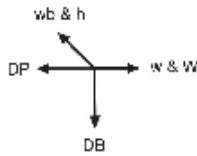
Psycho or Psychro



What is the Purpose of your Job?



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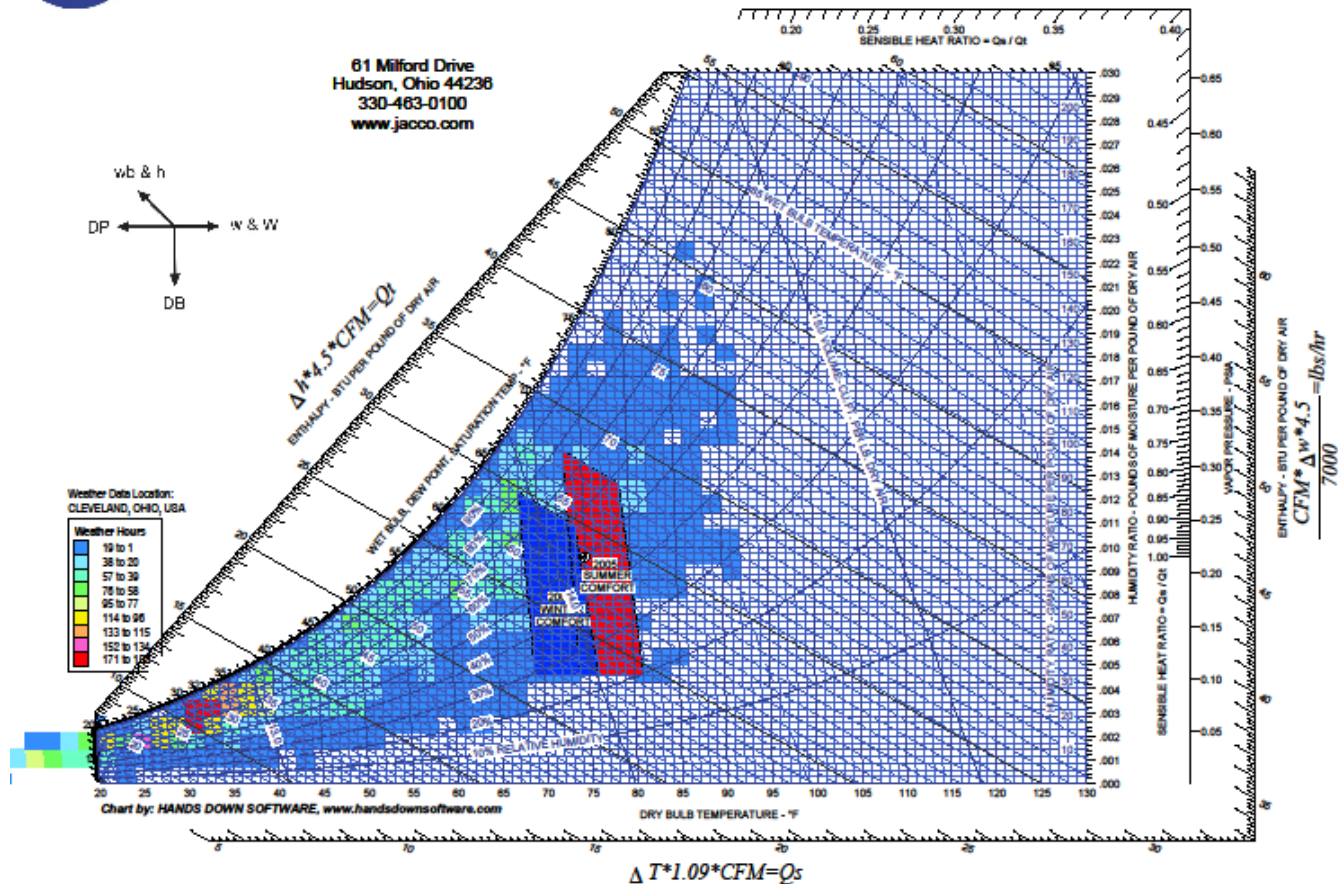
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How Hard is it to Fulfill Your Purpose?



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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.

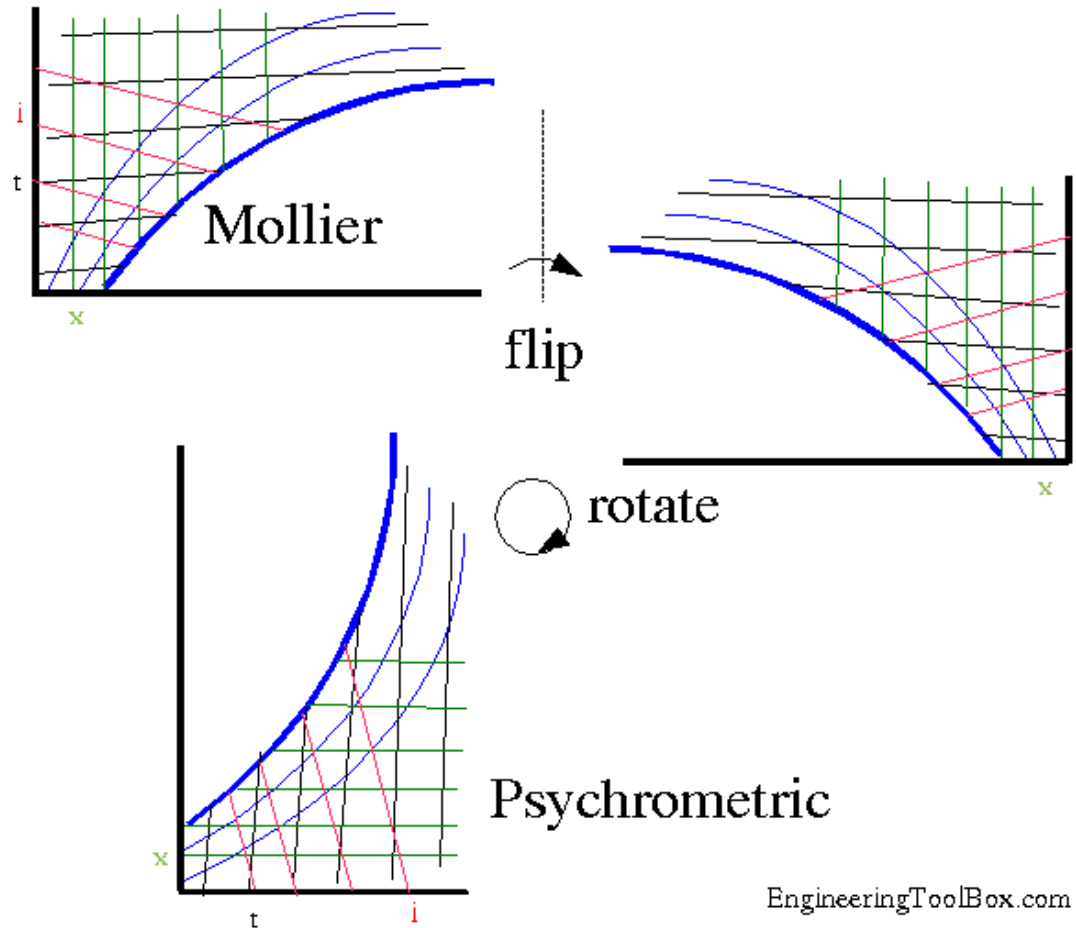
The Psychrometric Chart

- Graphical Representation of Properties of Air / Water Mixtures.
 - Dry-Bulb ($^{\circ}\text{F db}$)
 - Wet-Bulb ($^{\circ}\text{F wb}$)
 - Dew-Point ($^{\circ}\text{F dp}$)
 - 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.

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



EngineeringToolBox.com

So really, what is Psychrometrics?

- Study of Air / Water (Vapor) Mixture

What is Air?

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

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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Stable in Gas Phase.

So Who Cares?

- Reconsider the Components of Air:
 - Water Vapor

So Who Cares?

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

Stable in Gas Phase

- Water Vapor

Phase Changes (liq./gas)

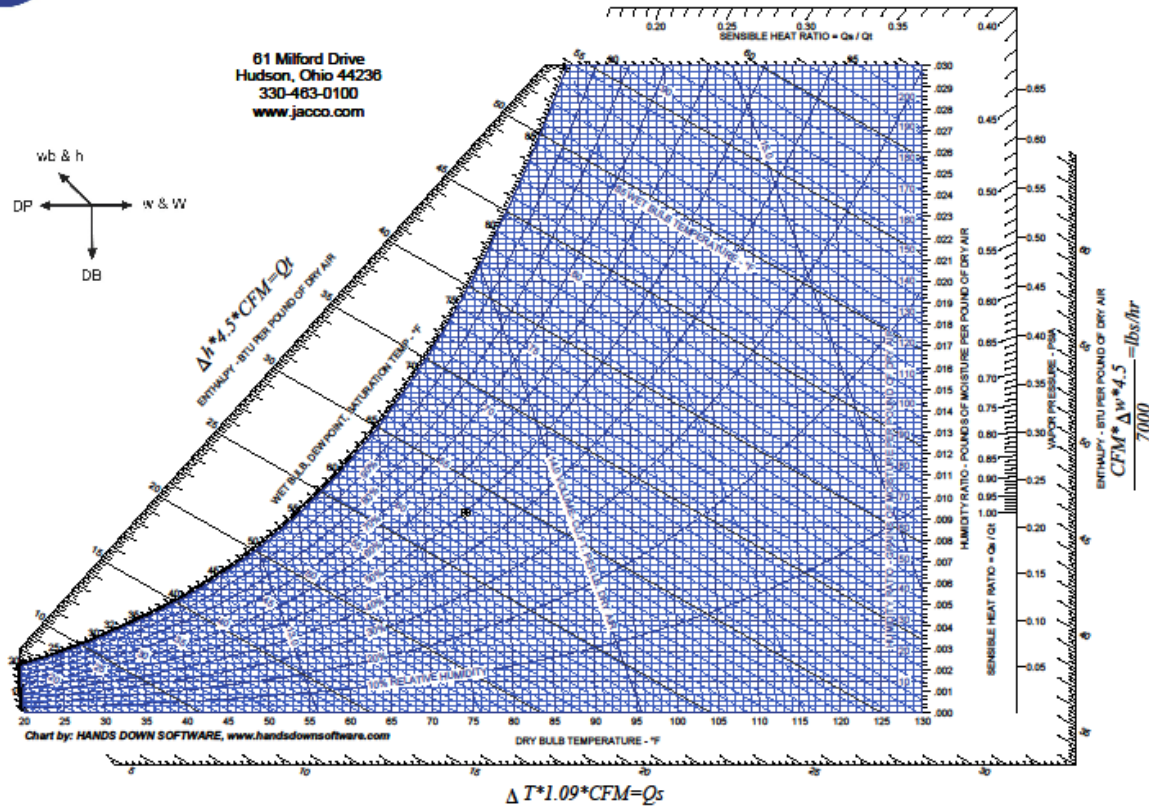
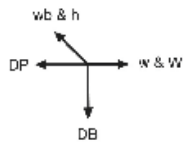
If it's Not the Heat, It's the Humidity



Psychrometric Cheat Sheet



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Psychrometric Cheat Sheet

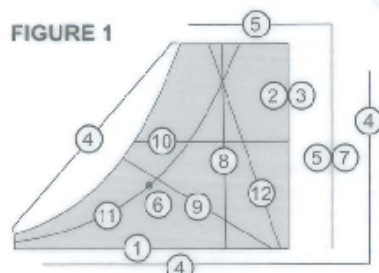


FIGURE 1

- 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

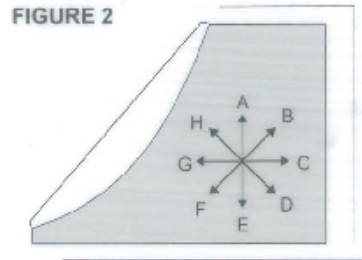


FIGURE 2

- A - Humidify Only
- B - Heat & Humidify
- C - Sensible Heat Only
- D - Desiccant Dehumidify
- E - Dehumidify Only
- F - Cool & Dehumidify
- G - Sensible Cool Only
- H - Evaporative Cool

Helpful Formulas

- Sensible (Qs) = $\Delta t \times 1.09 \times \text{cfm}$
- Total (Qt) = $\Delta h \times 4.5 \times \text{cfm}$
- Water (Qt) = $\Delta t \times 500 \times \text{gpm}$
- Lbs/hr/air (lba) = $(\text{cfm} / \text{specific volume of air}) \times 60$
- Lbs/hr/water (lbw) = $\text{lba} \times \Delta W$
- Humidity ratio (W) = $\text{grains (w)} / \text{grains/lb (7000)}$
- Δ humidity ratio (ΔW) = $(w1 / 7000) - (w2 / 7000)$
- Lbs/hr/water (lbw) = $(\text{cfm} \times \Delta w \times 4.5) / 7000$
- Condensate GPM = $\Delta \text{lbw} / 8.33 / 60$
- 1 KW = 3.415 Btu/h
- 1 HP = 2.546 Btu/h and .7547 KW
- EER = $(\text{MBH} - \text{motor heat}) / \text{KW}$
- Room CFM = $\text{room sensible} / 1.09 / \Delta T$
- Air Changes = $(60 \times \text{cfm}) / \text{room volume in cu. ft.}$
- HP = $\text{existing HP} \times (\text{req'd speed} / \text{existing speed})^3$
- True Electric Heat = $\text{nominal KW} \times (\text{actual voltage} / \text{nominal voltage})^2$
- Mixed Air cfm = $(\text{oa db} \times \text{oa cfm} / \text{total cfm}) + (\text{ra db} \times \text{ra cfm} / \text{total cfm})$

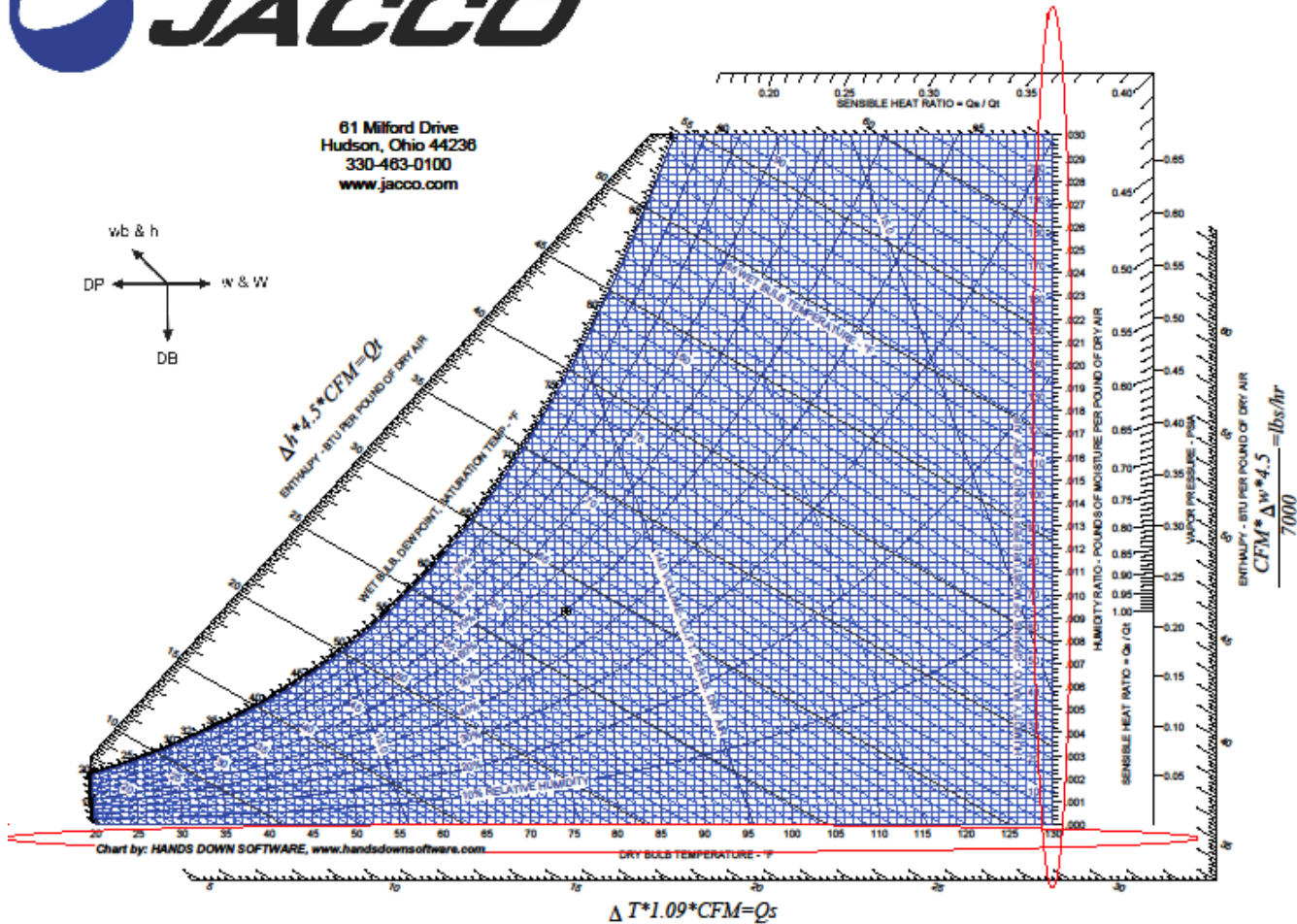
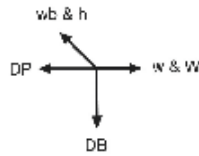
Definitions

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

Psychrometric Chart



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Some Definitions

- Sensible heat 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

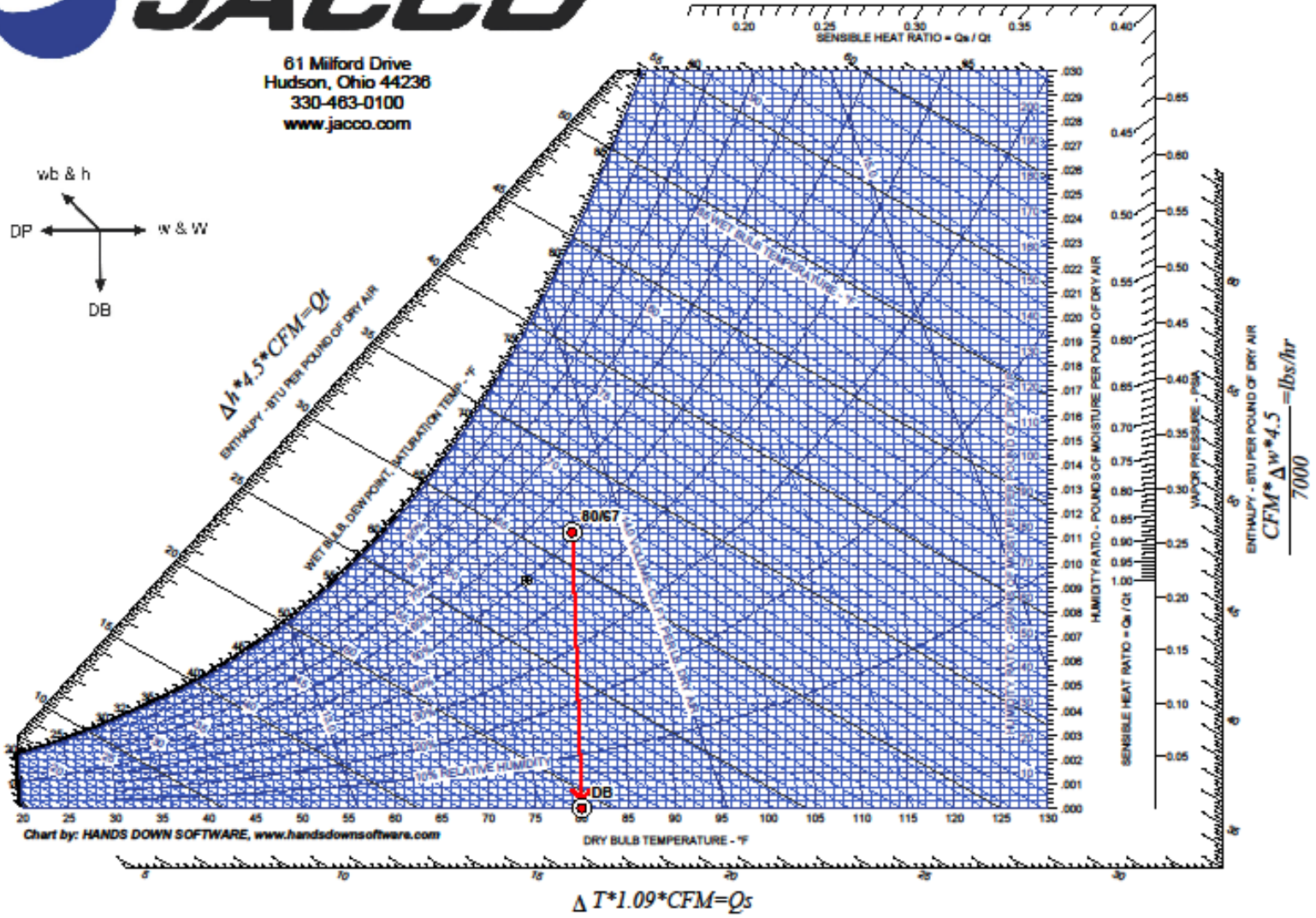
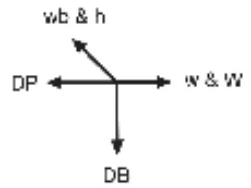
- The total heat, or enthalpy, of the atmosphere is the sum of the sensible heat, latent heat, and superheat of the vapor above the saturation or dew-point temperature. Total heat is relatively constant for a constant wet-bulb temperature, deviating only about 1.5–2% low at relative humidity's below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

Some Definitions

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

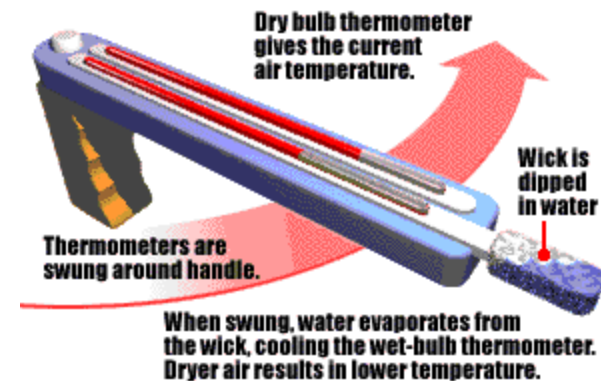


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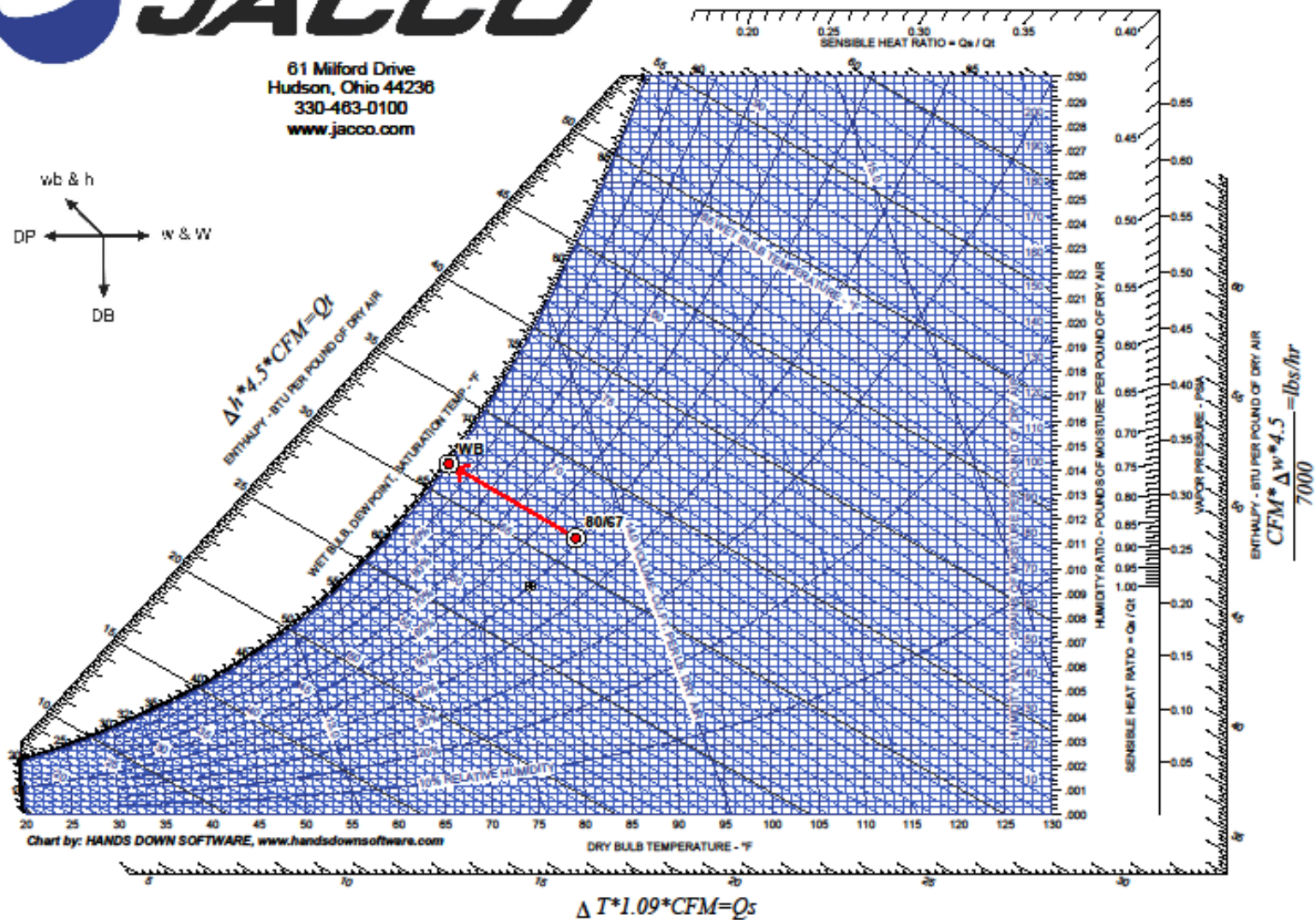
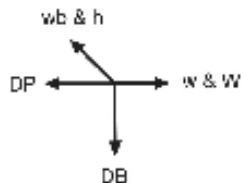
Some Definitions

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





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Some Definitions

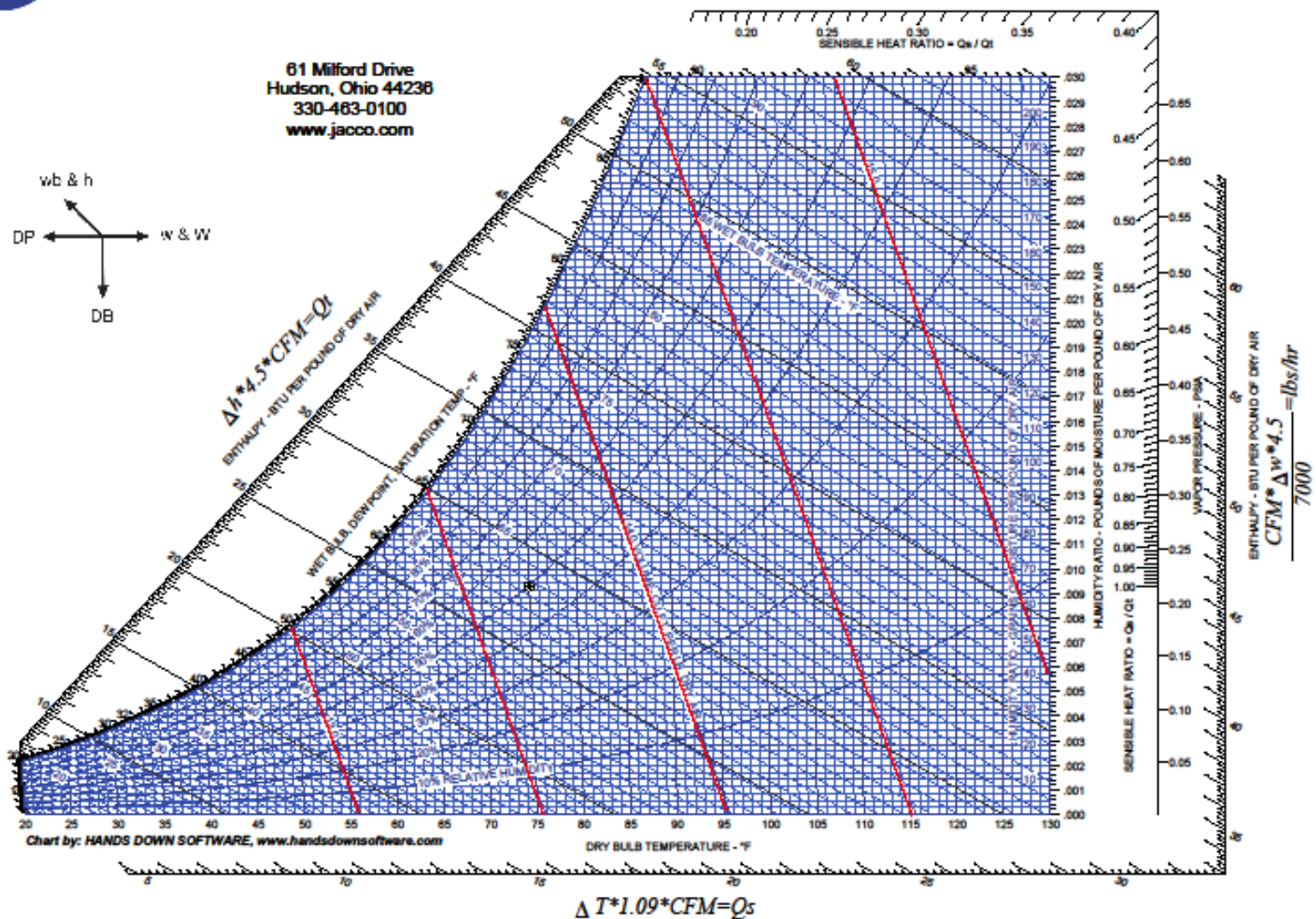
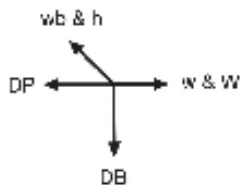
- Relative Humidity
 - The ratio of vapor pressure to saturation pressure.

Some Definitions

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



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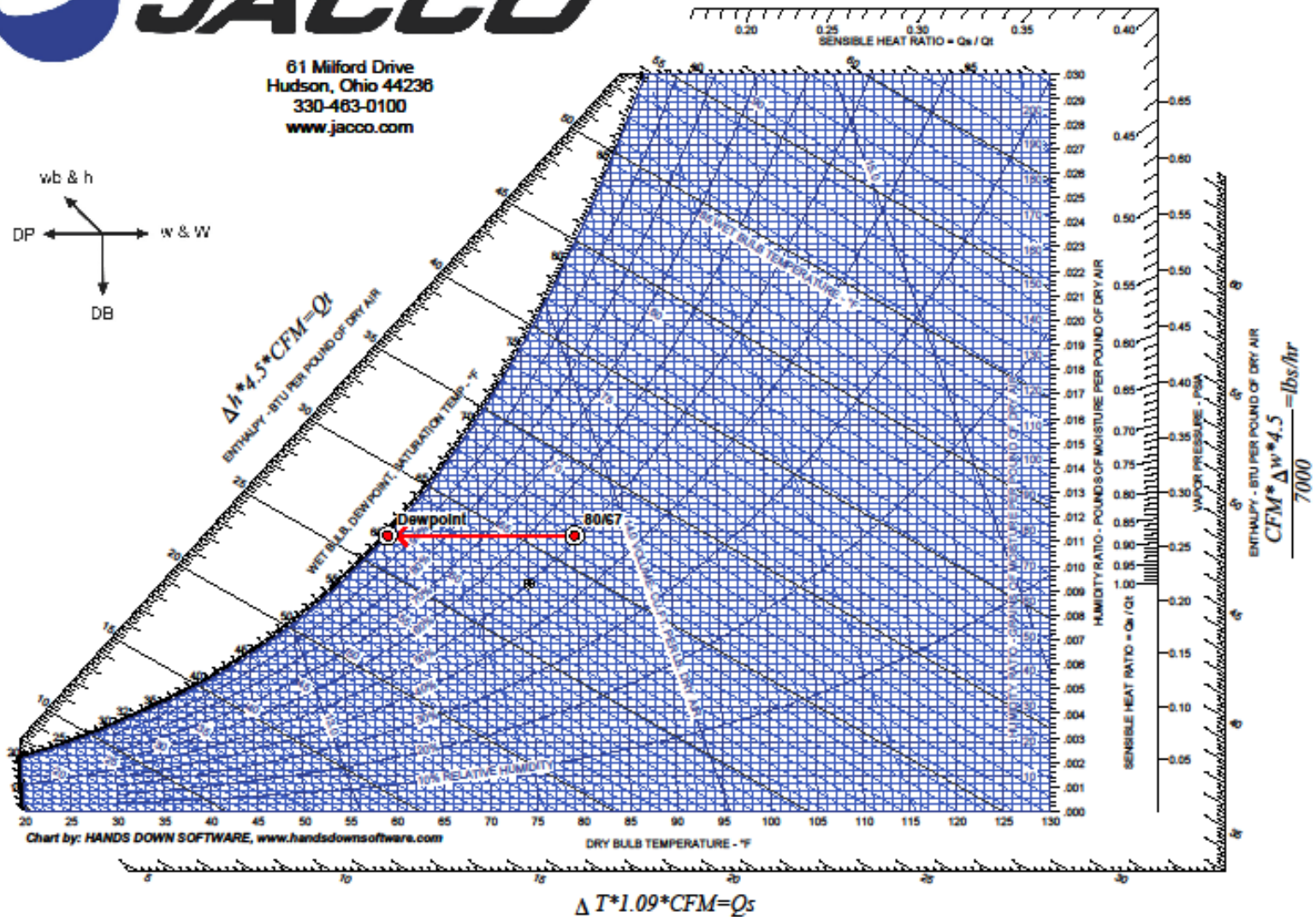
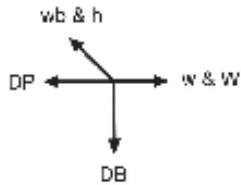
Some Definitions

- 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.



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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).



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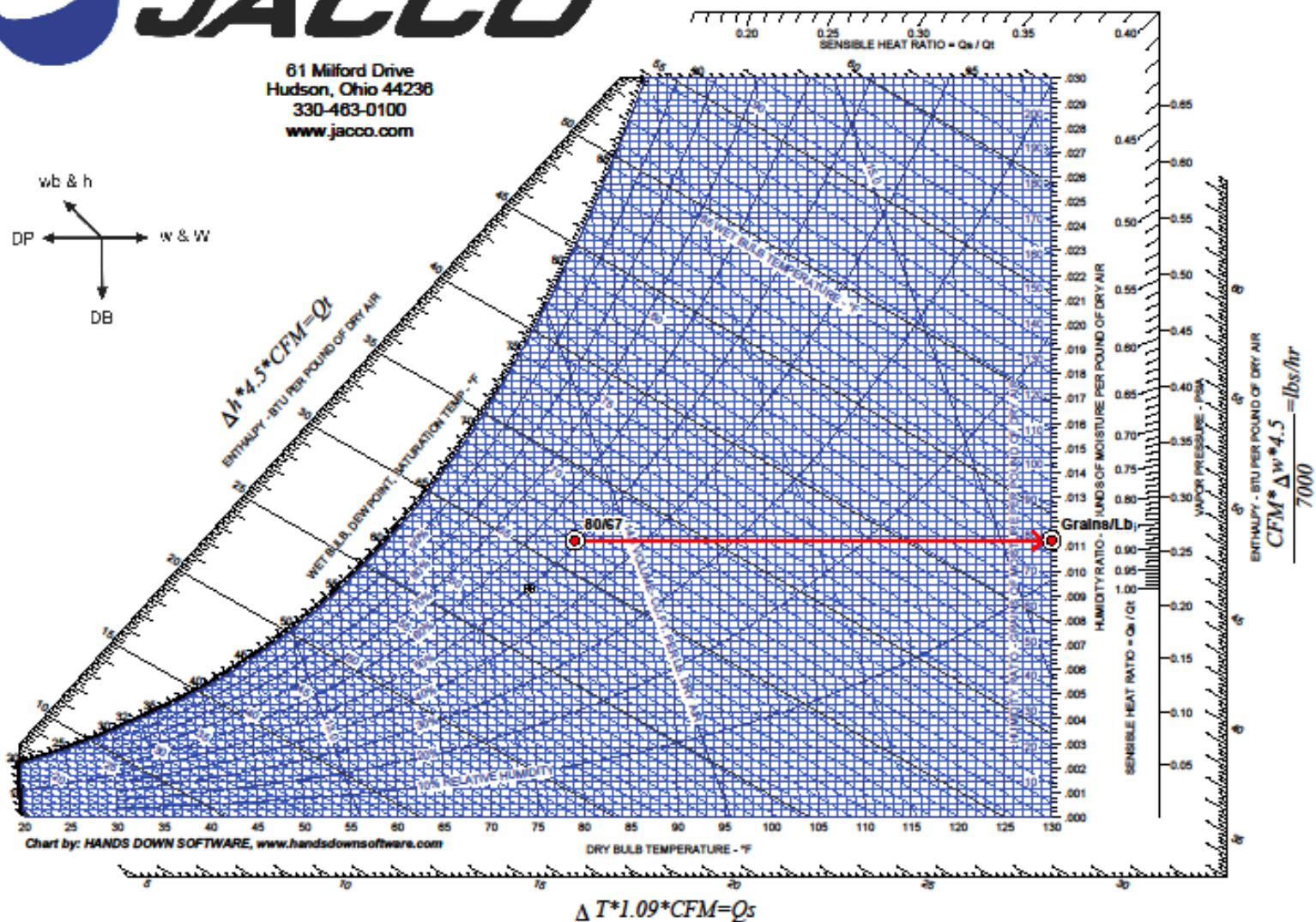
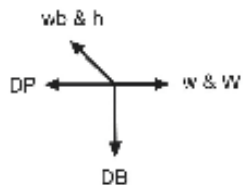


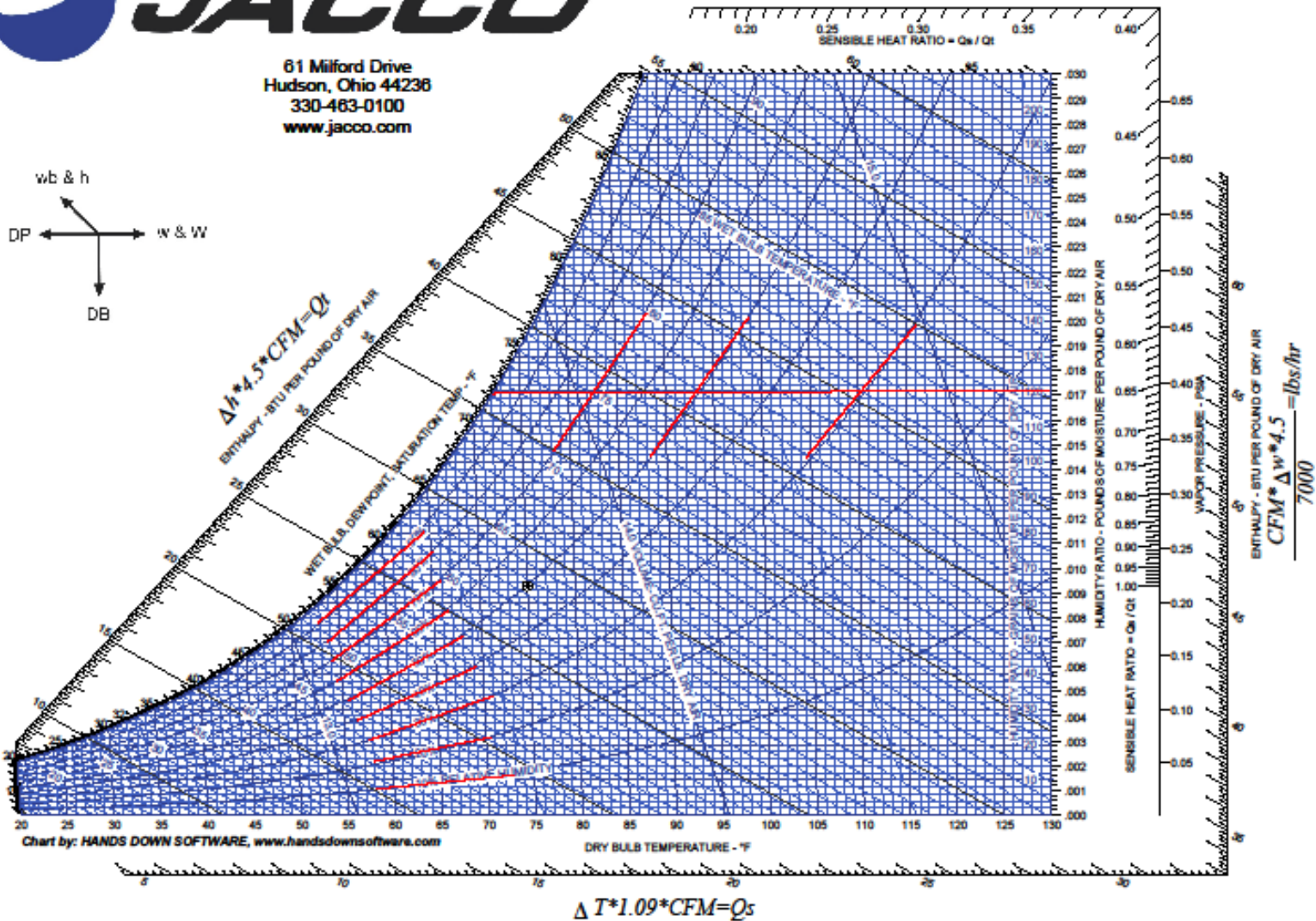
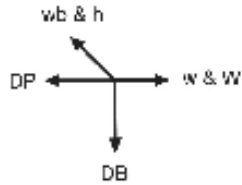
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

Some Definitions

- Humidity Ratio vs. Relative Humidity



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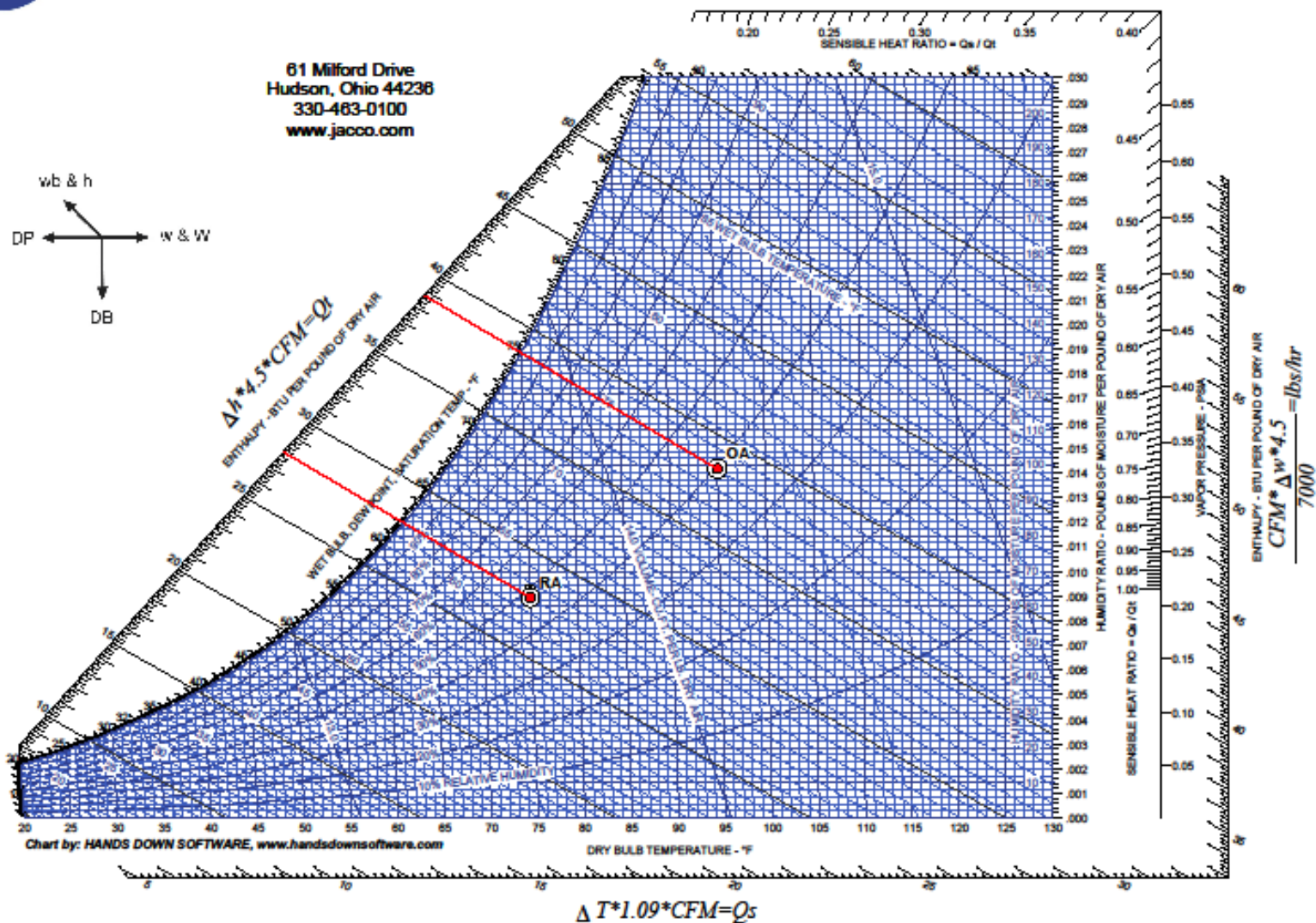
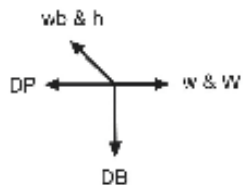


Some Definitions

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



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Some Definitions

- Sensible Heat Ratio
 - The ratio of sensible cooling to total cooling in a space.
 - $\text{Sensible/Total} = \text{SHR}$



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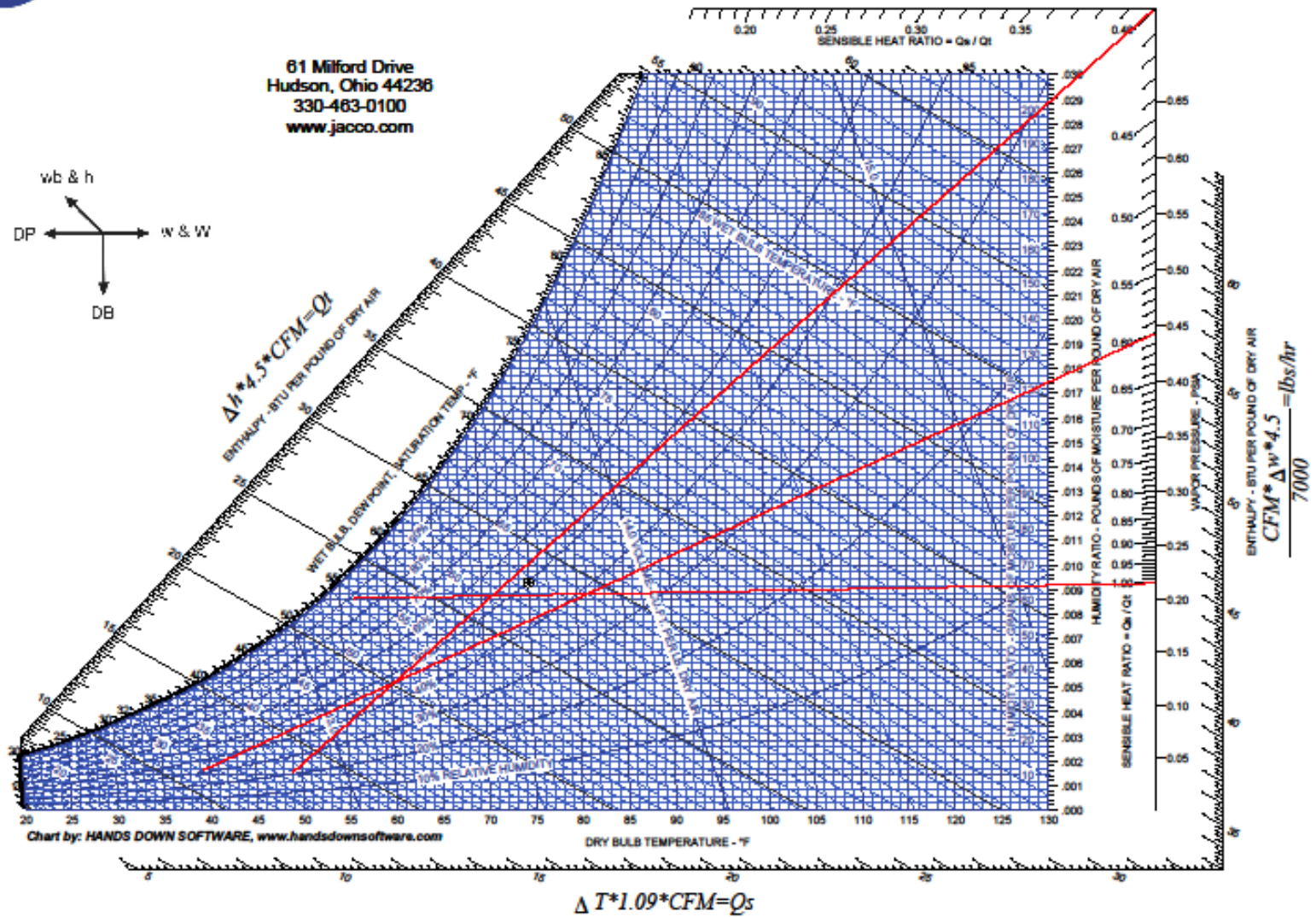
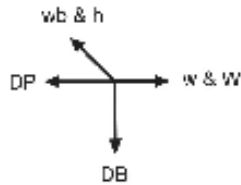


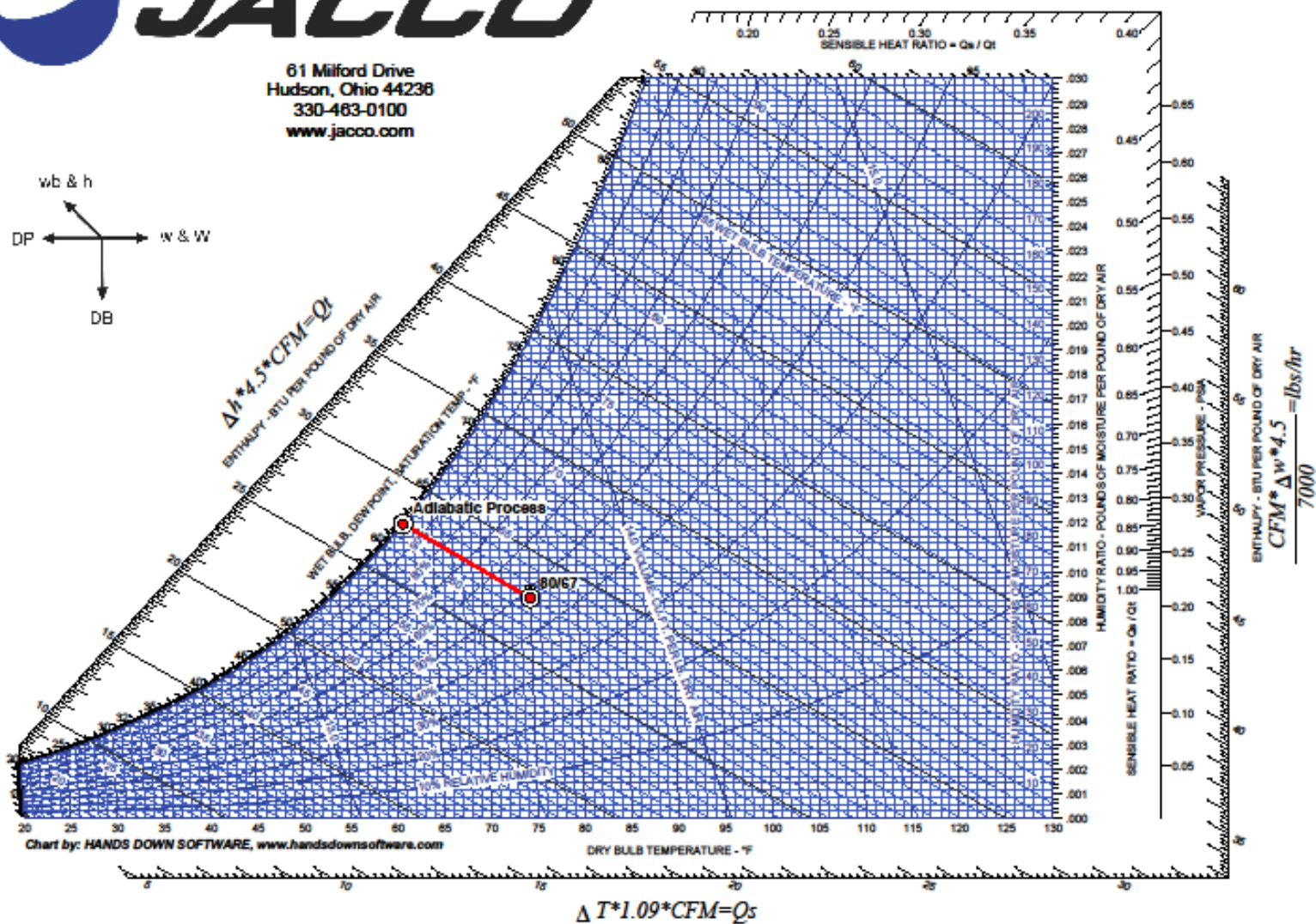
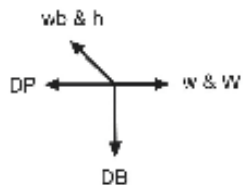
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

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.



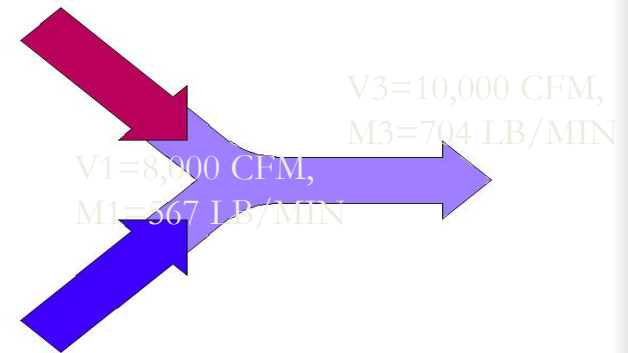
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Useful Psychrometric Calculations - Air Mixing

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

V1=2,000 CFM,
M1=137 LB/MIN

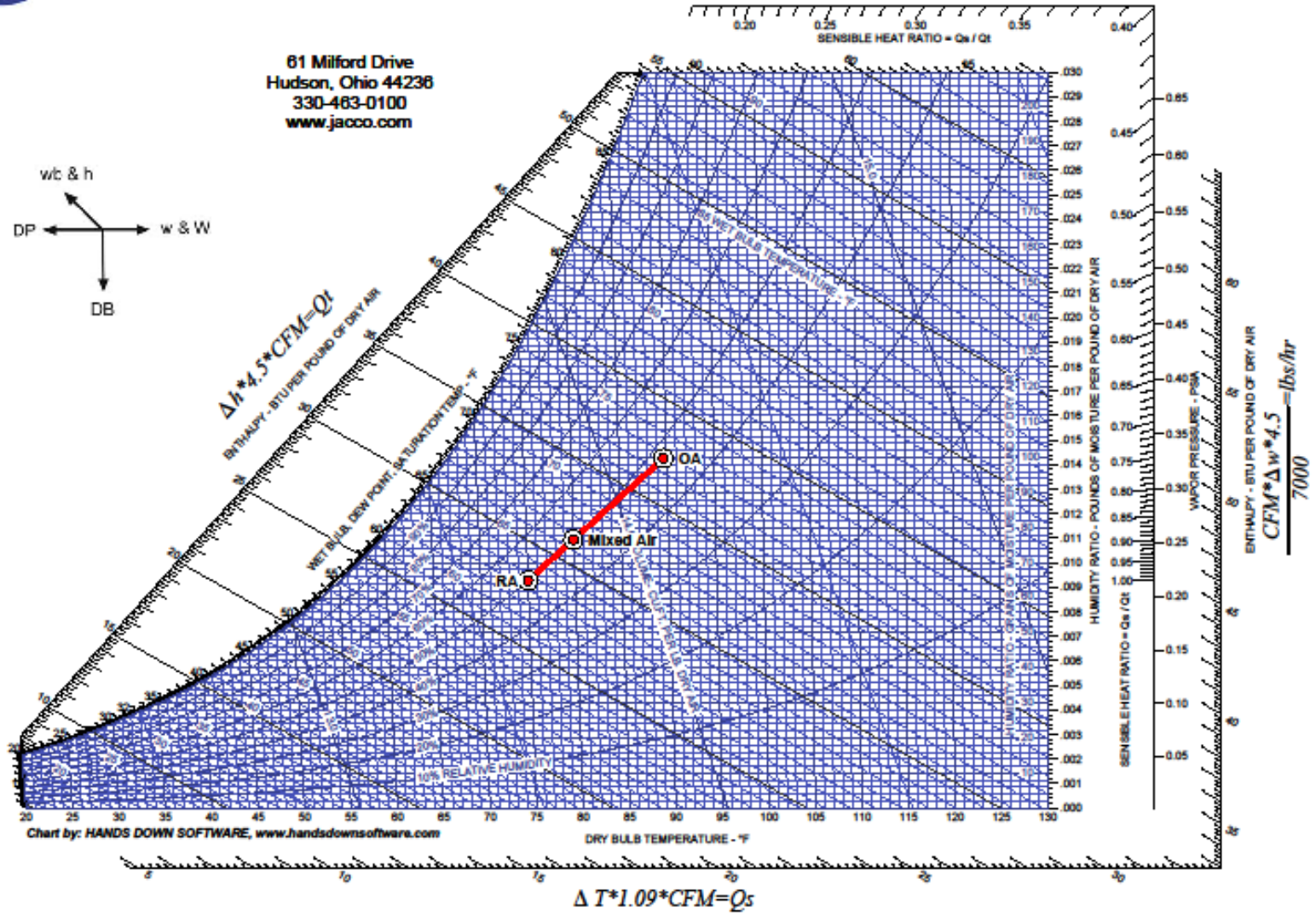
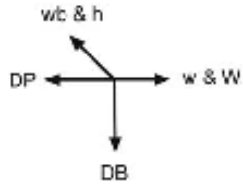


Air Mixing - Mathematically

- Plot both points on chart and connect with a line
- Mixed air dry bulb =
$$\begin{aligned} & (\text{Stream 1 DB} \times \text{Stream 1 CFM} / \text{Total CFM}) \\ & + \\ & (\text{Stream 2 DB} \times \text{Stream 2 CFM} / \text{Total CFM}) \end{aligned}$$
- Plot mixed air dry bulb on above referenced line to calculate mixed air wet bulb

Mixing Air

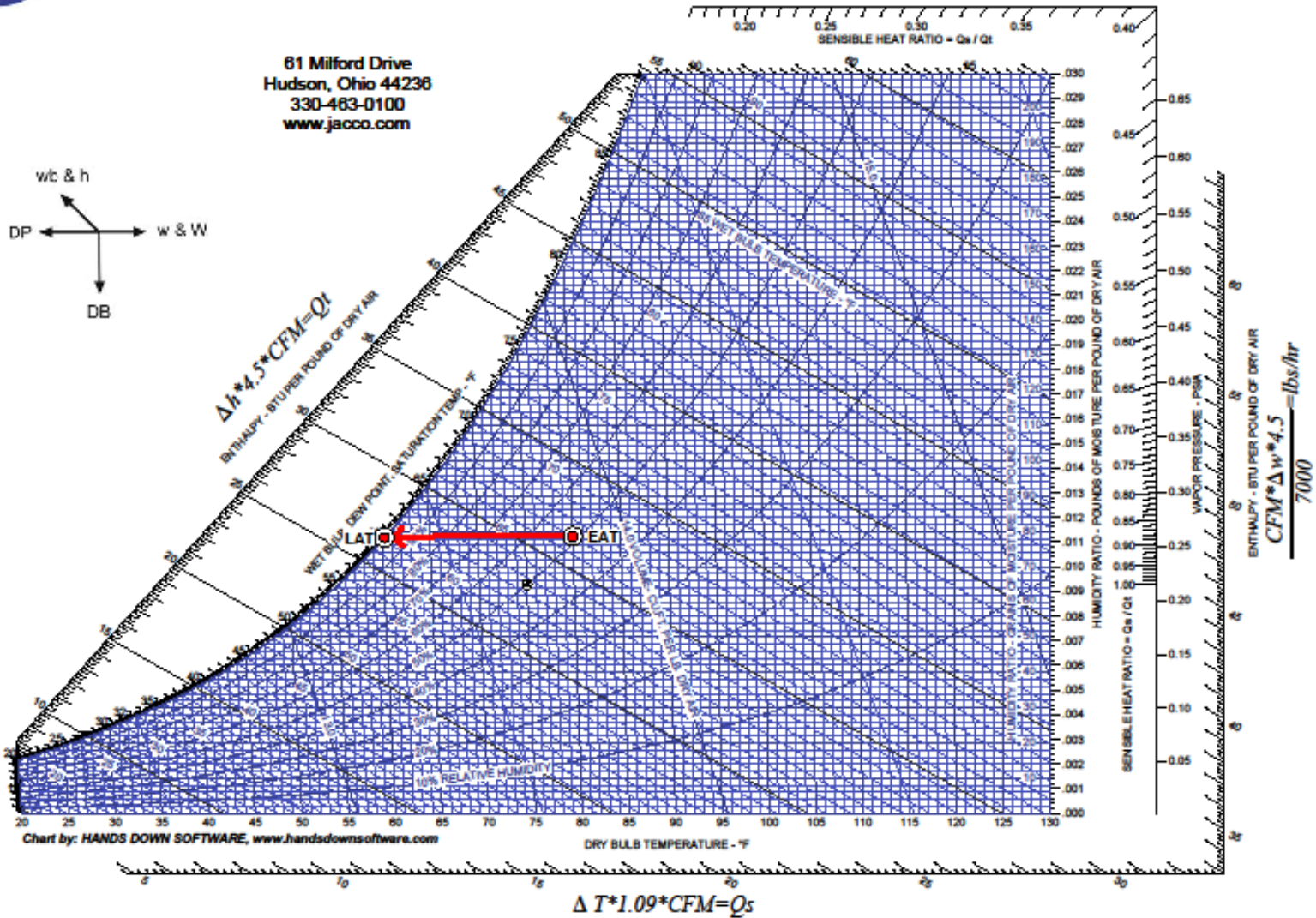
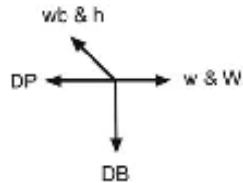
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Sensible Cooling

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

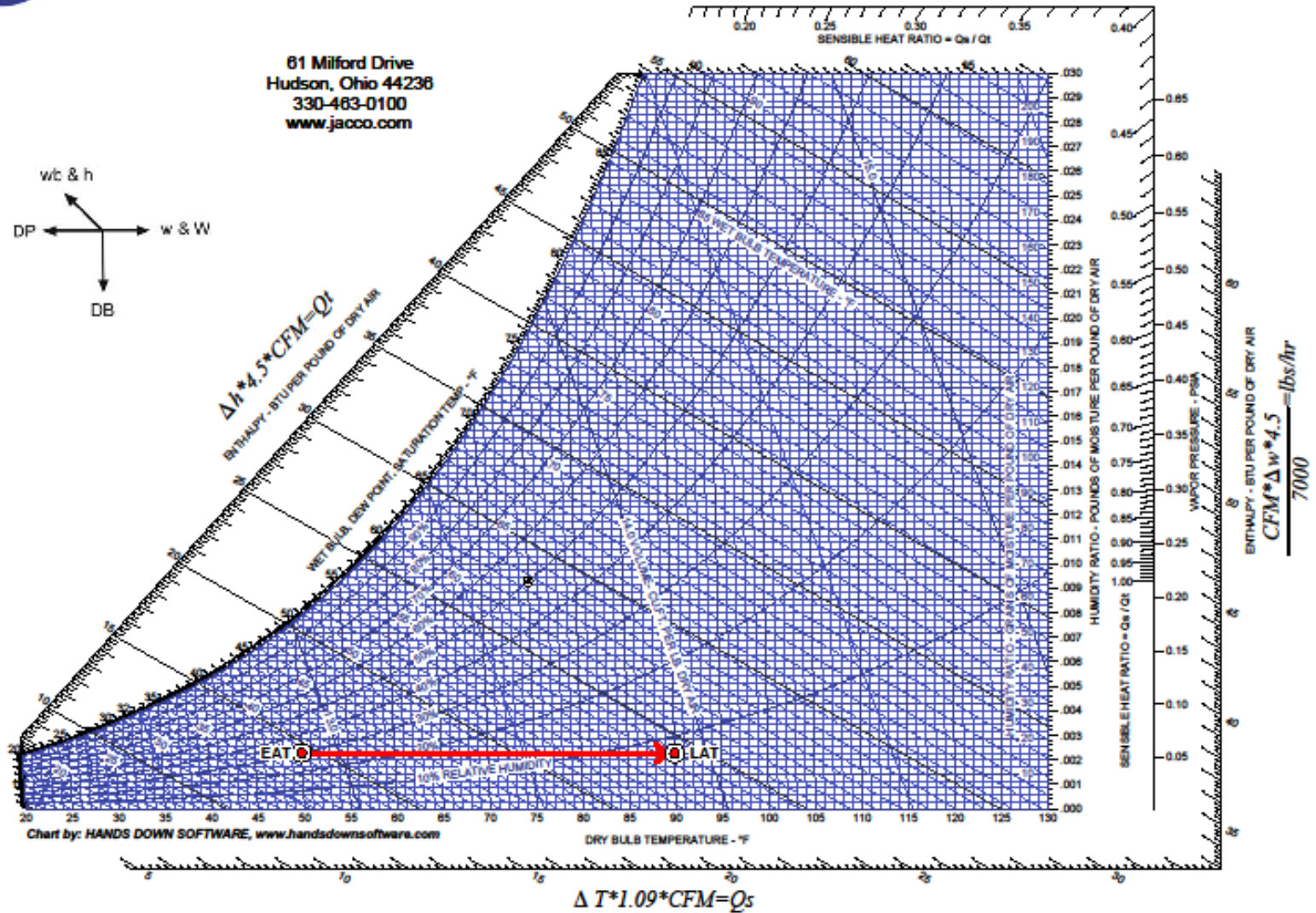
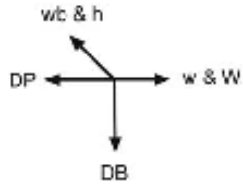
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Sensible Heating

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

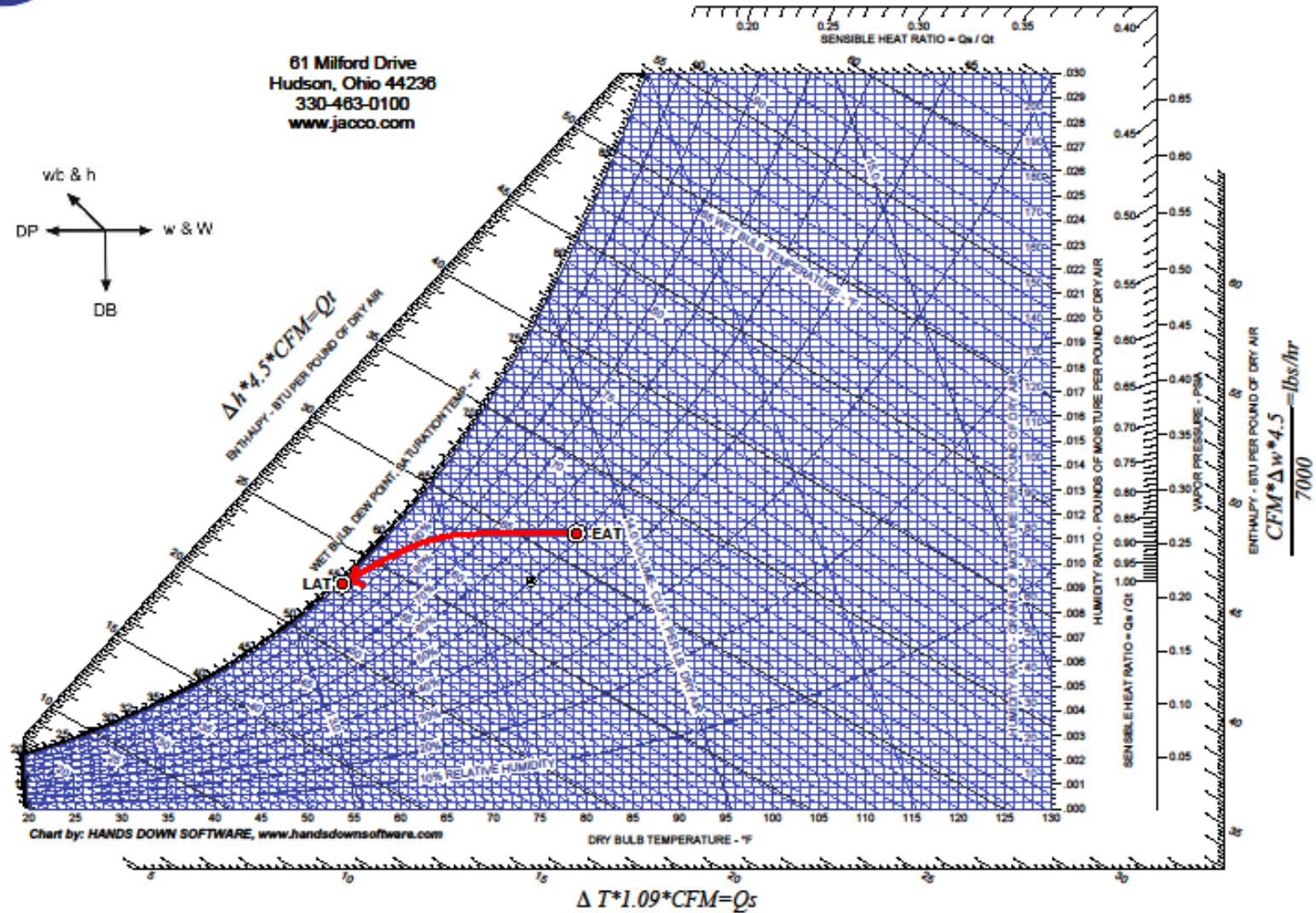
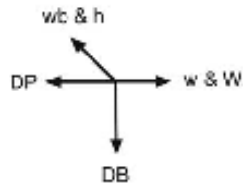
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Total Cooling Cycle

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

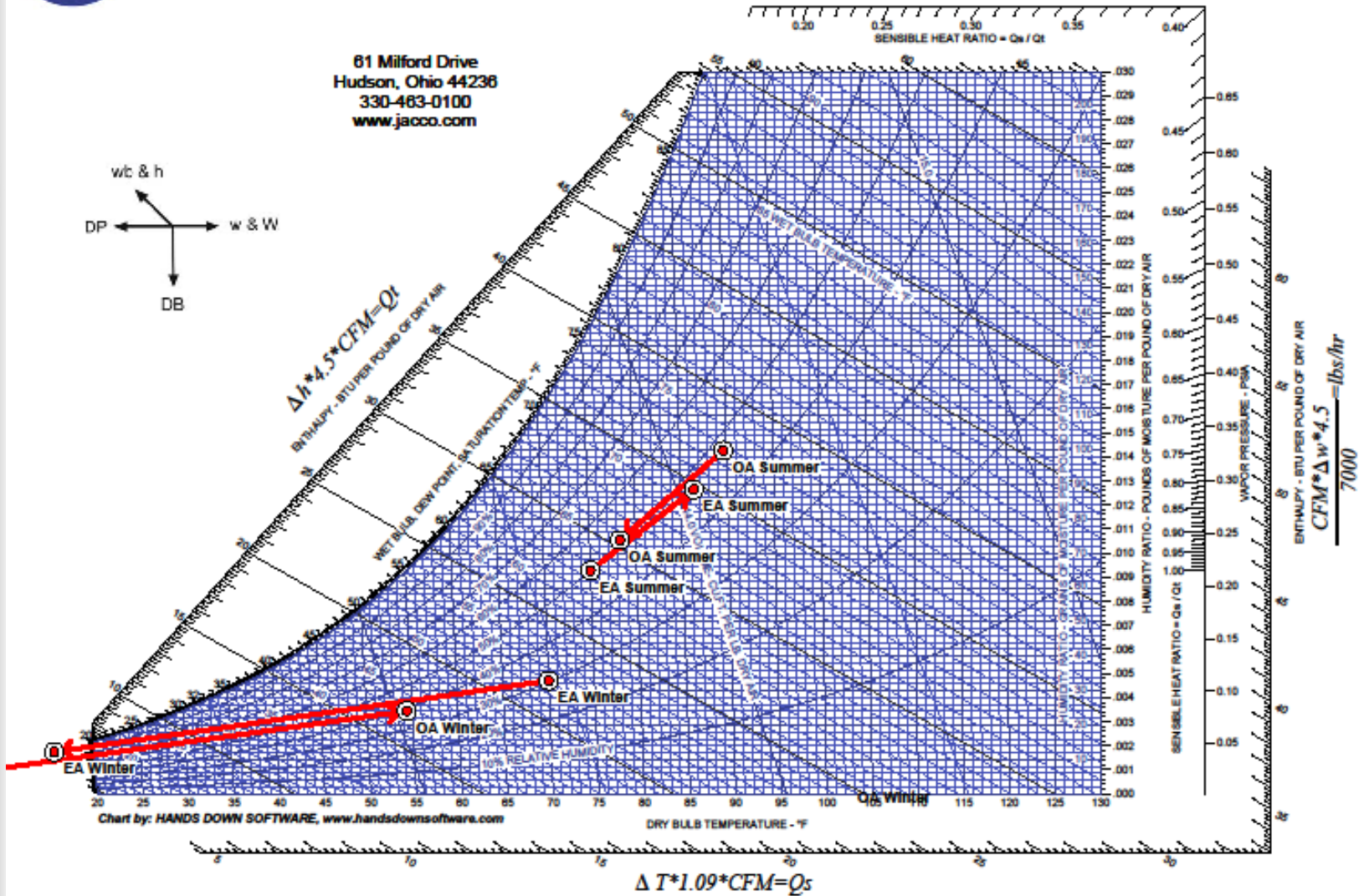
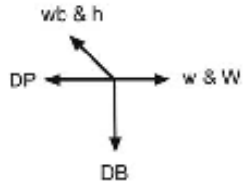
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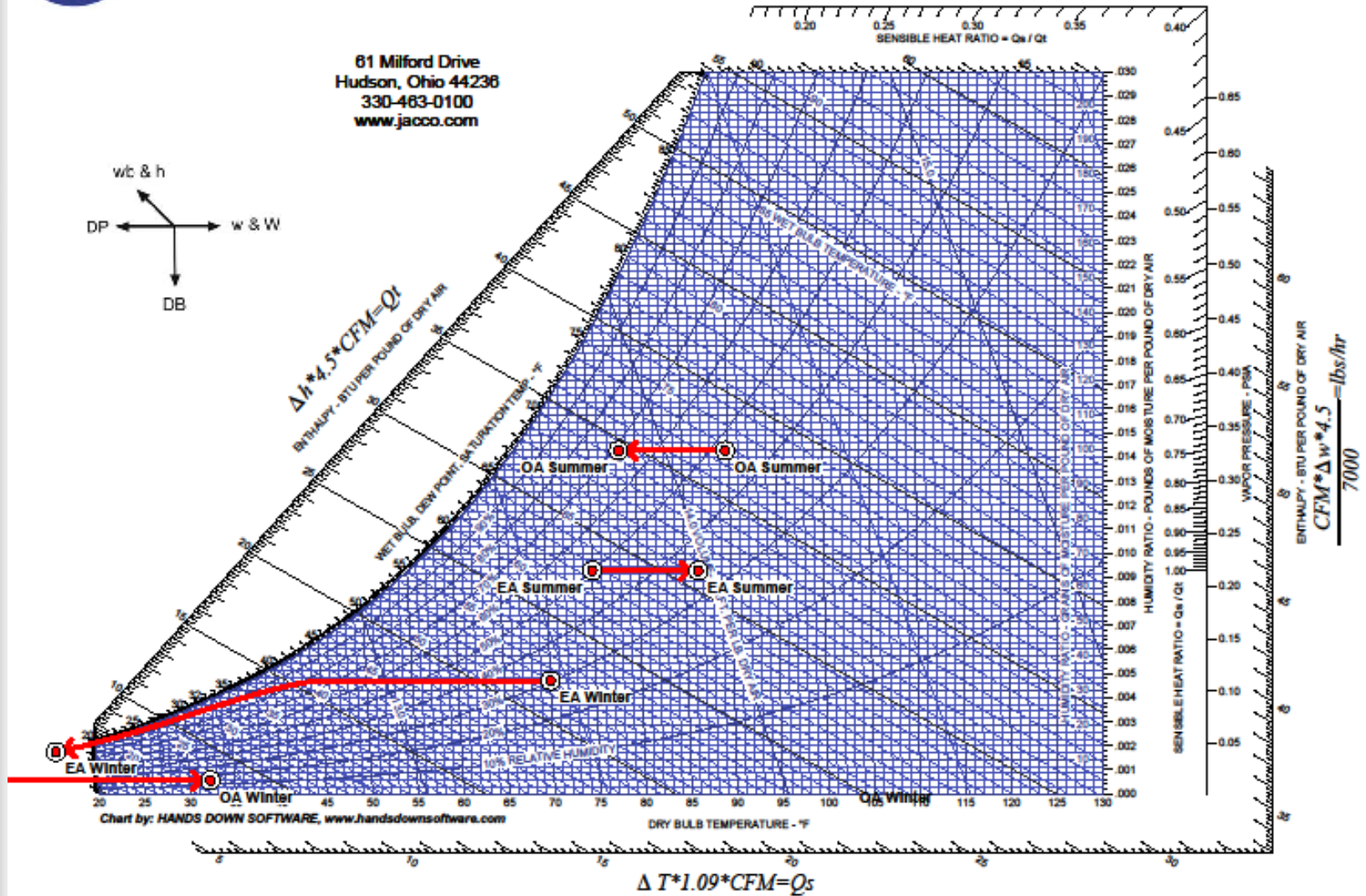
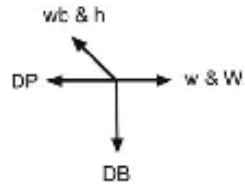
Applications – Heat Recovery

- Anything above 30% OA

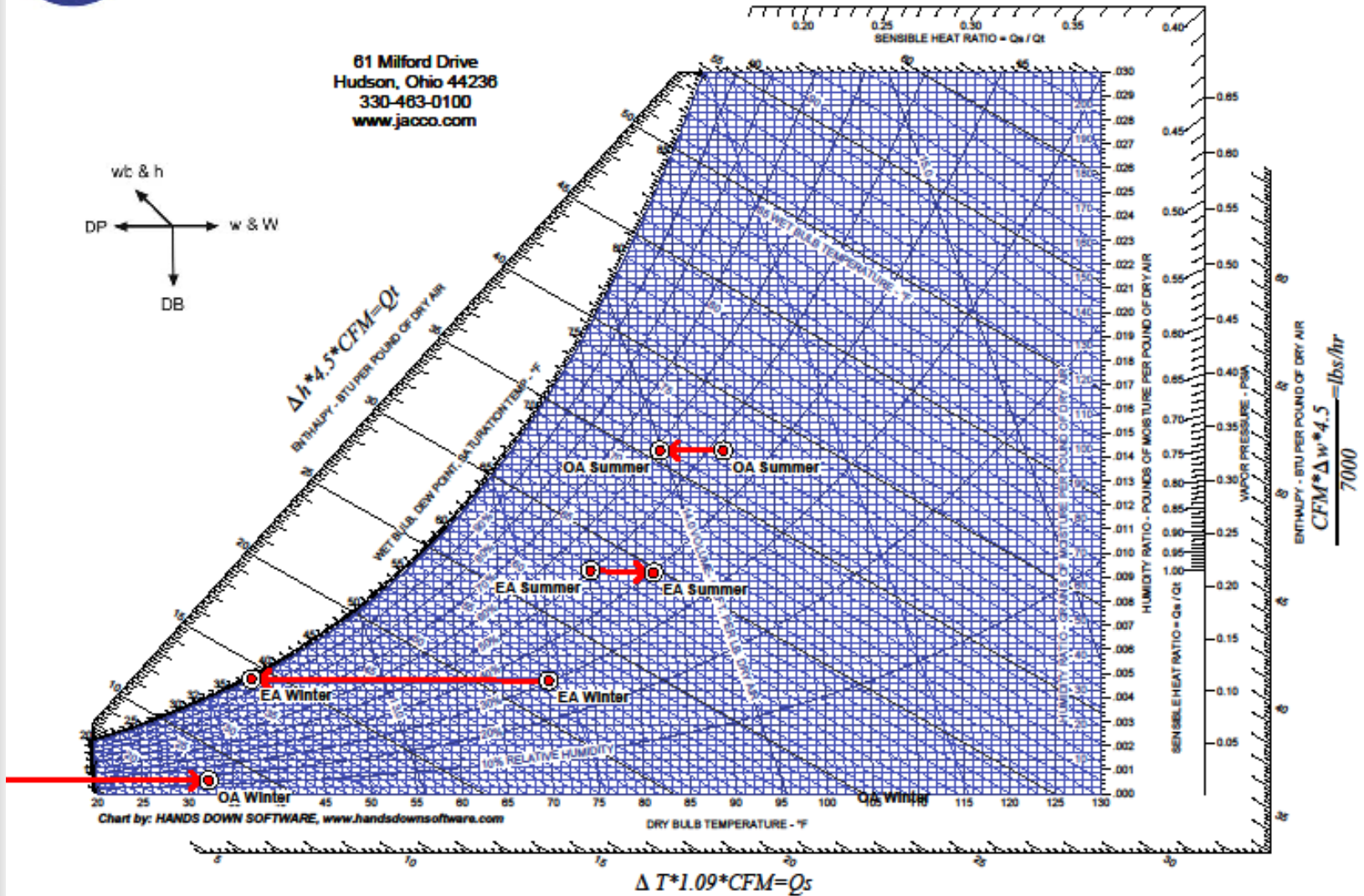
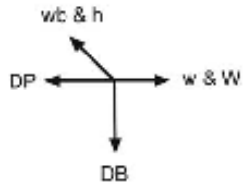
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Applications – Humidification

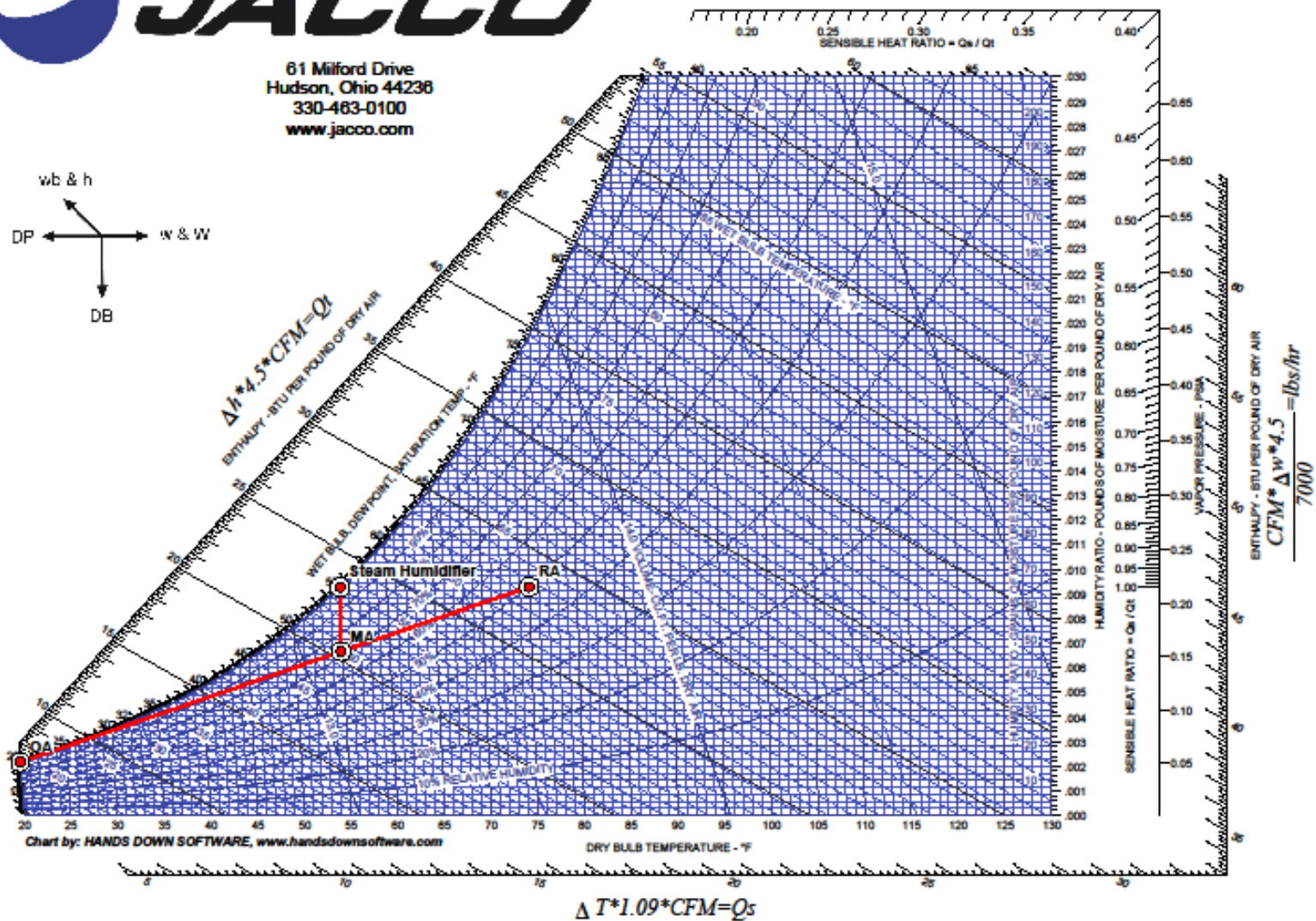
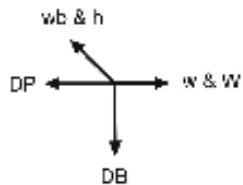
- OR rooms
- Laboratories
- Wood / Printing
- Adiabatic especially economical with economizer systems

Steam Humidification

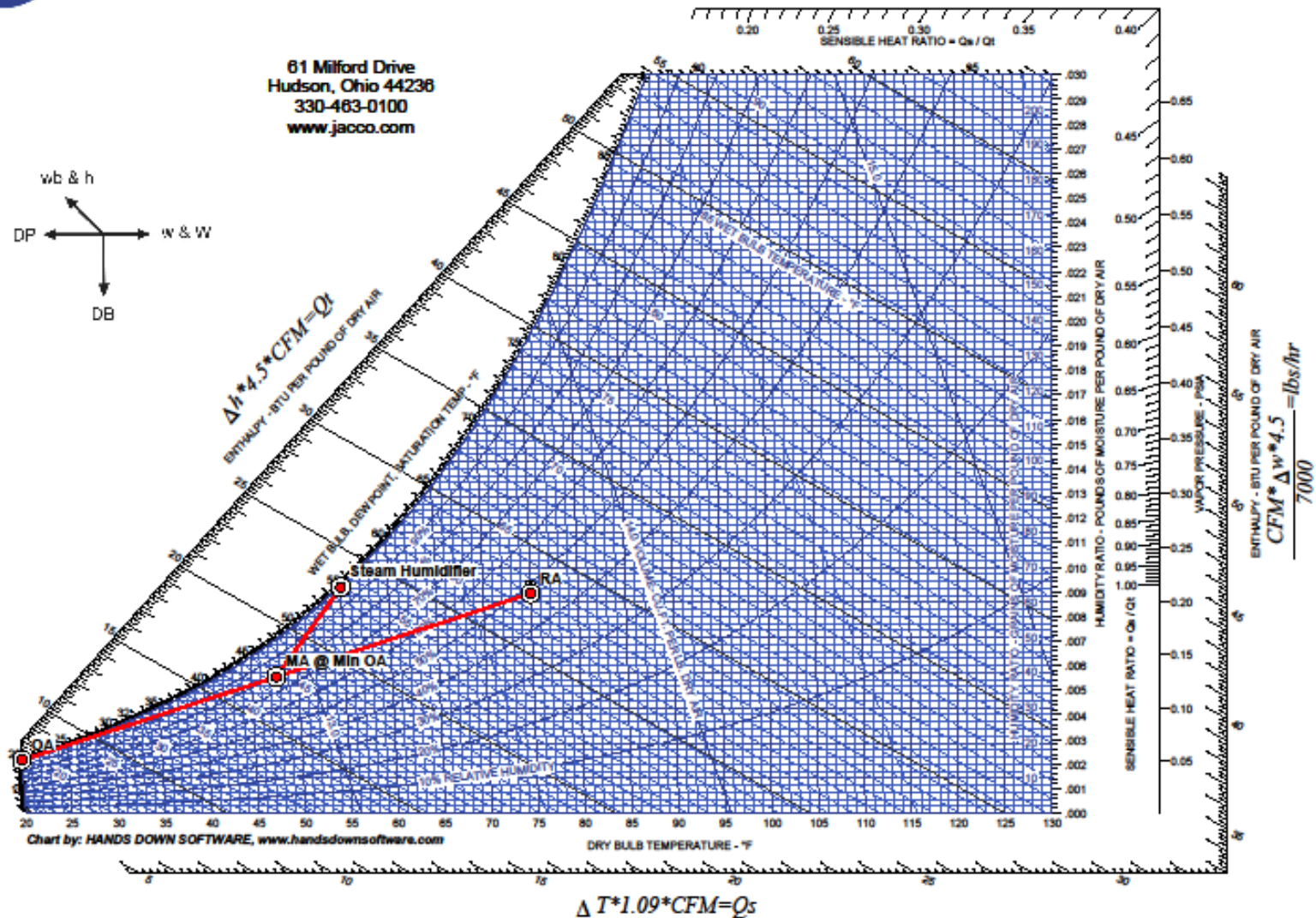
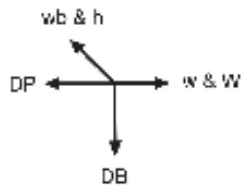
- Full Airflow w/ Minimum OA
- Partial Airflow w/ Minimum OA



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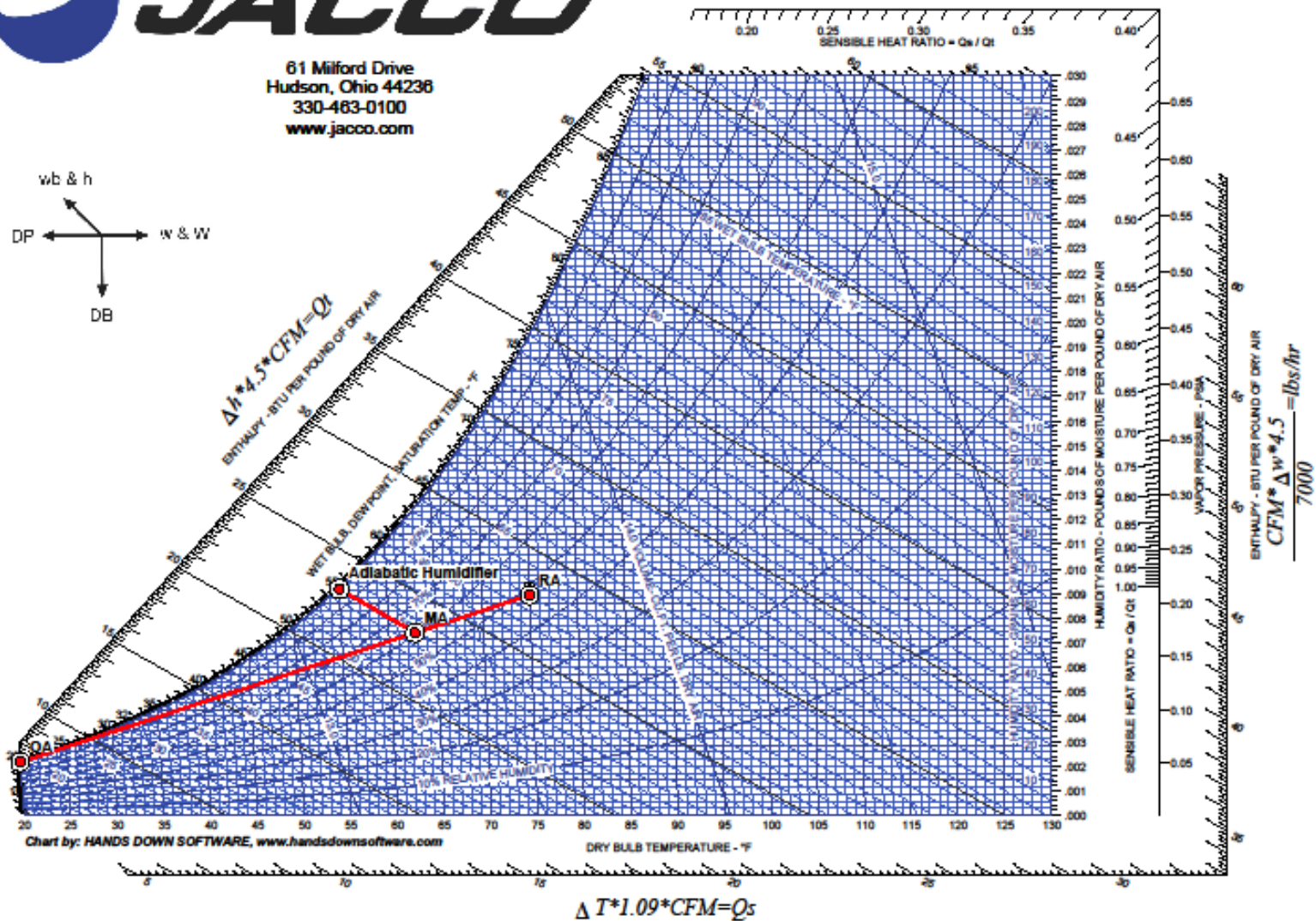
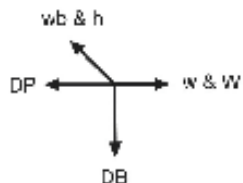


Adiabatic Humidification

- Full Airflow w/ Minimum OA
- Partial Airflow w/ Minimum OA

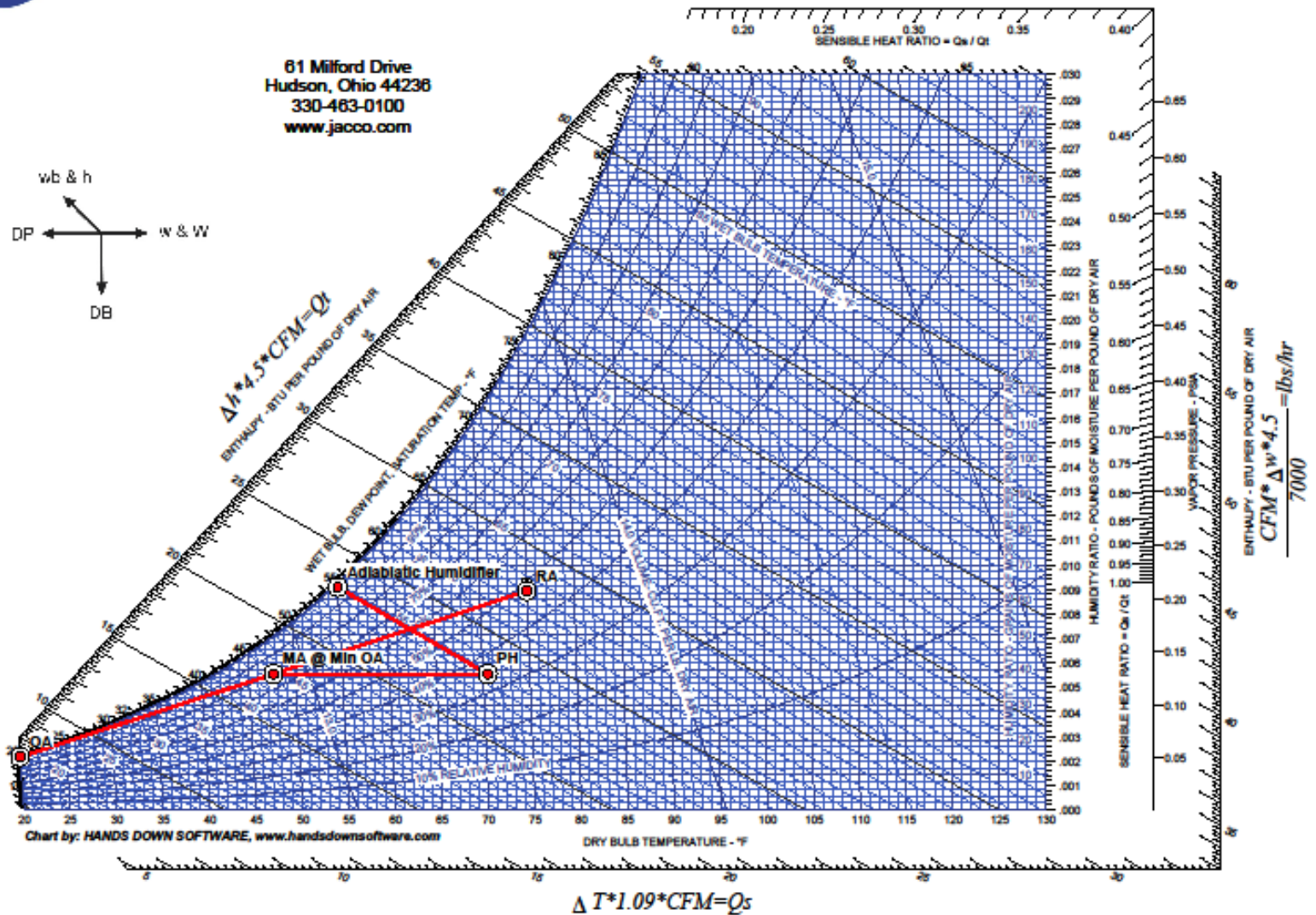
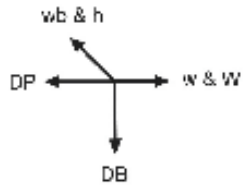


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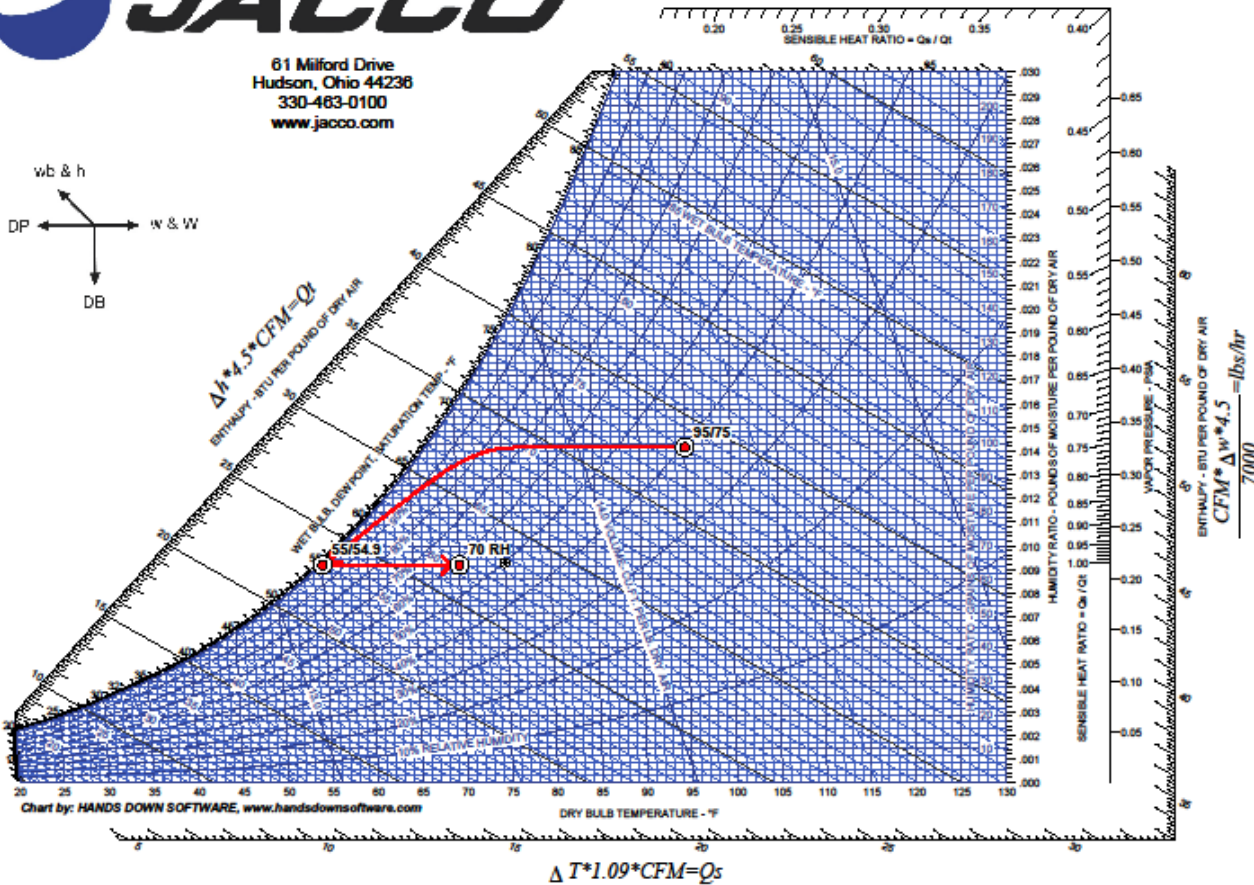
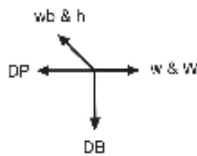
Applications - Dehumidification

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

Mechanical Dehumidification



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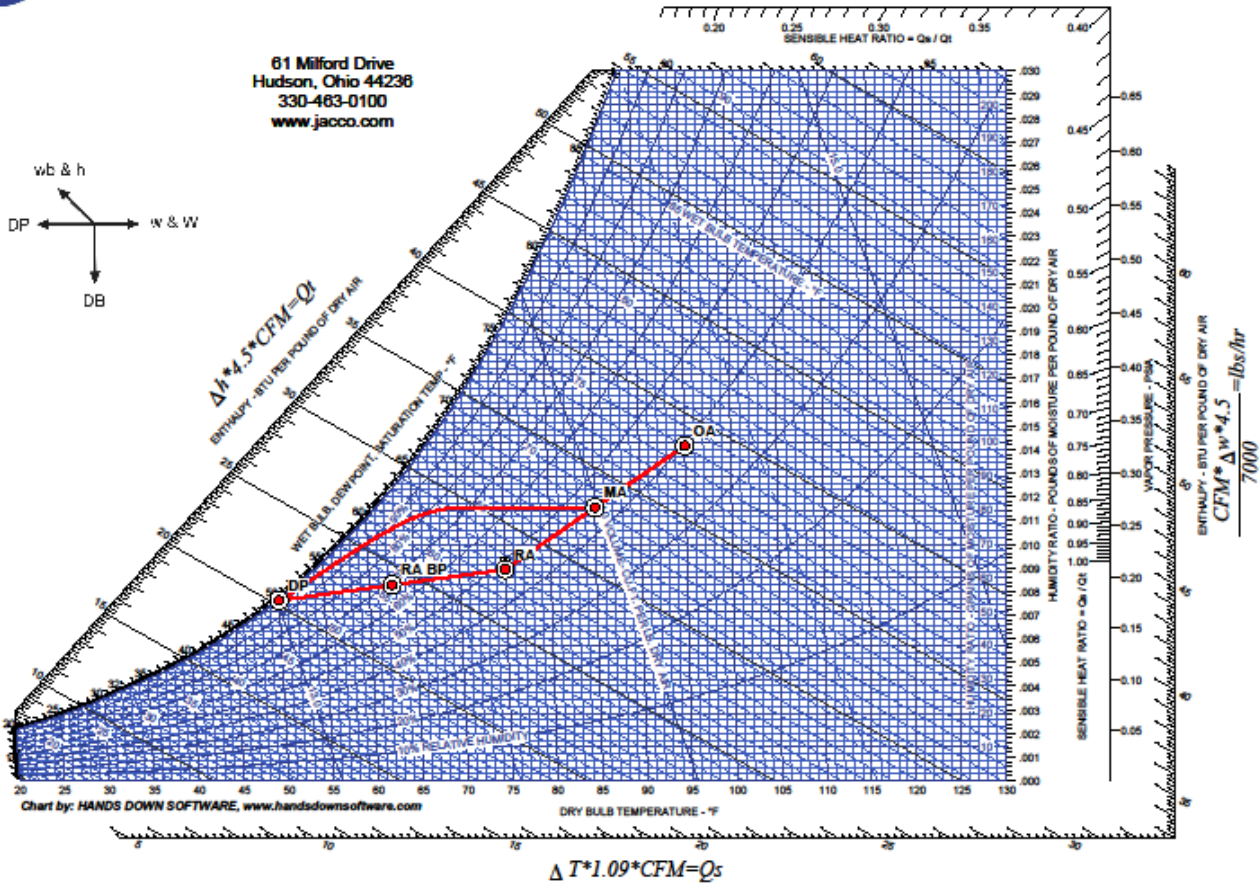
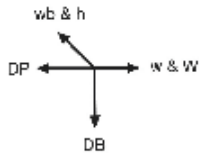
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Return Air Bypass



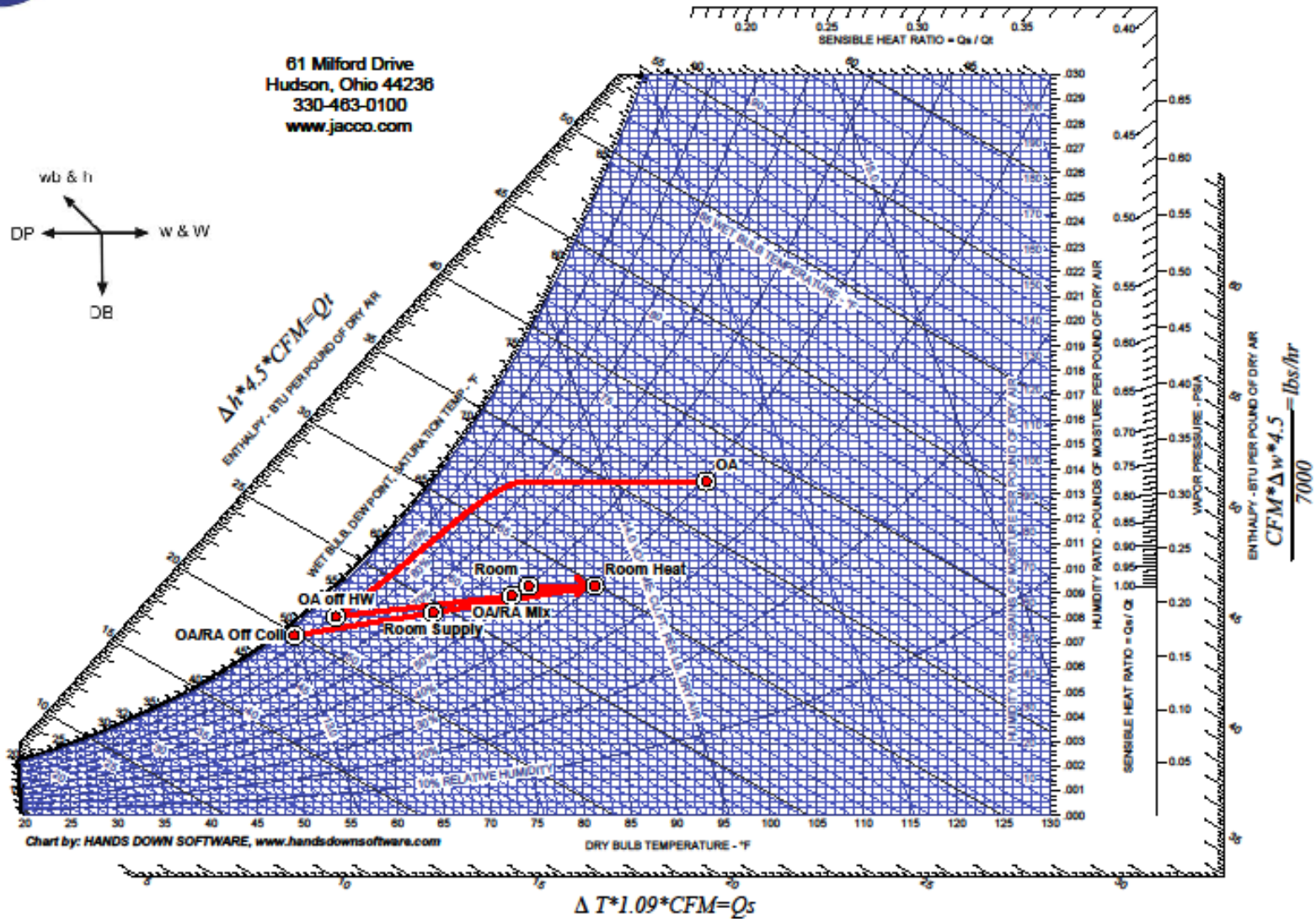
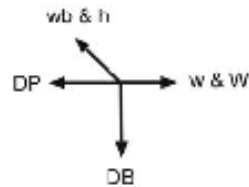
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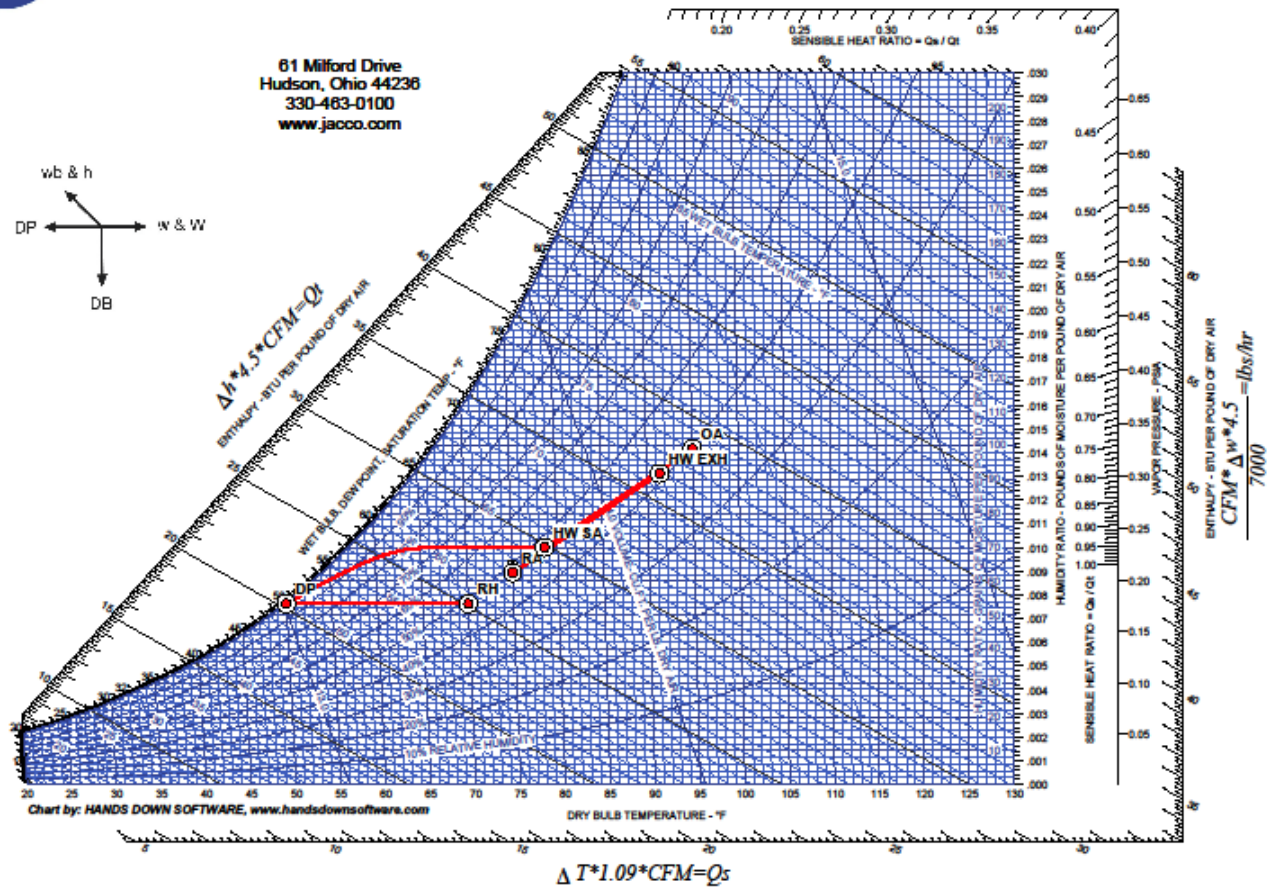
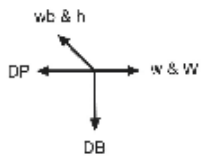
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Heat Wheel



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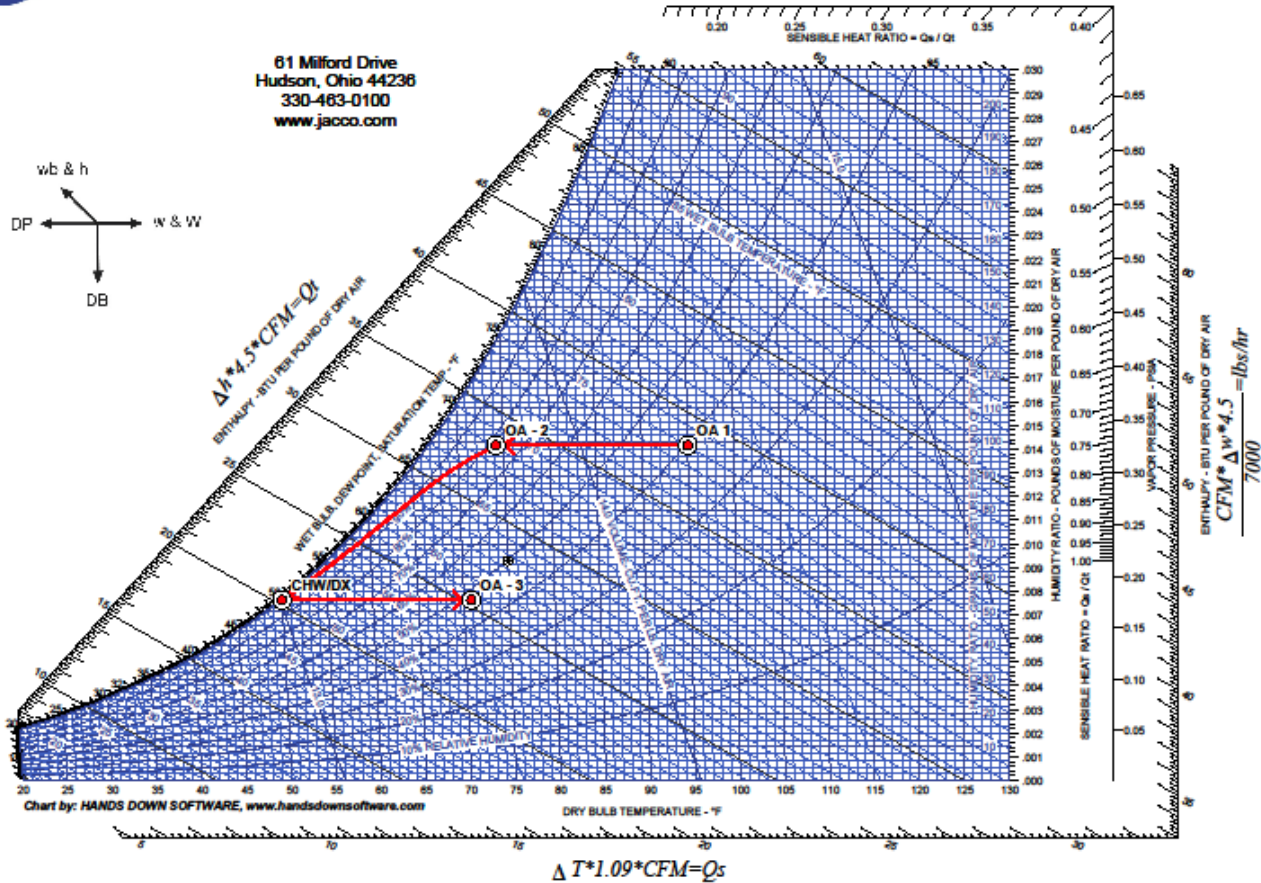
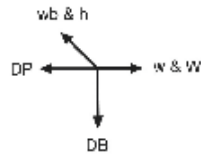


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Single Pipe/Plate HX



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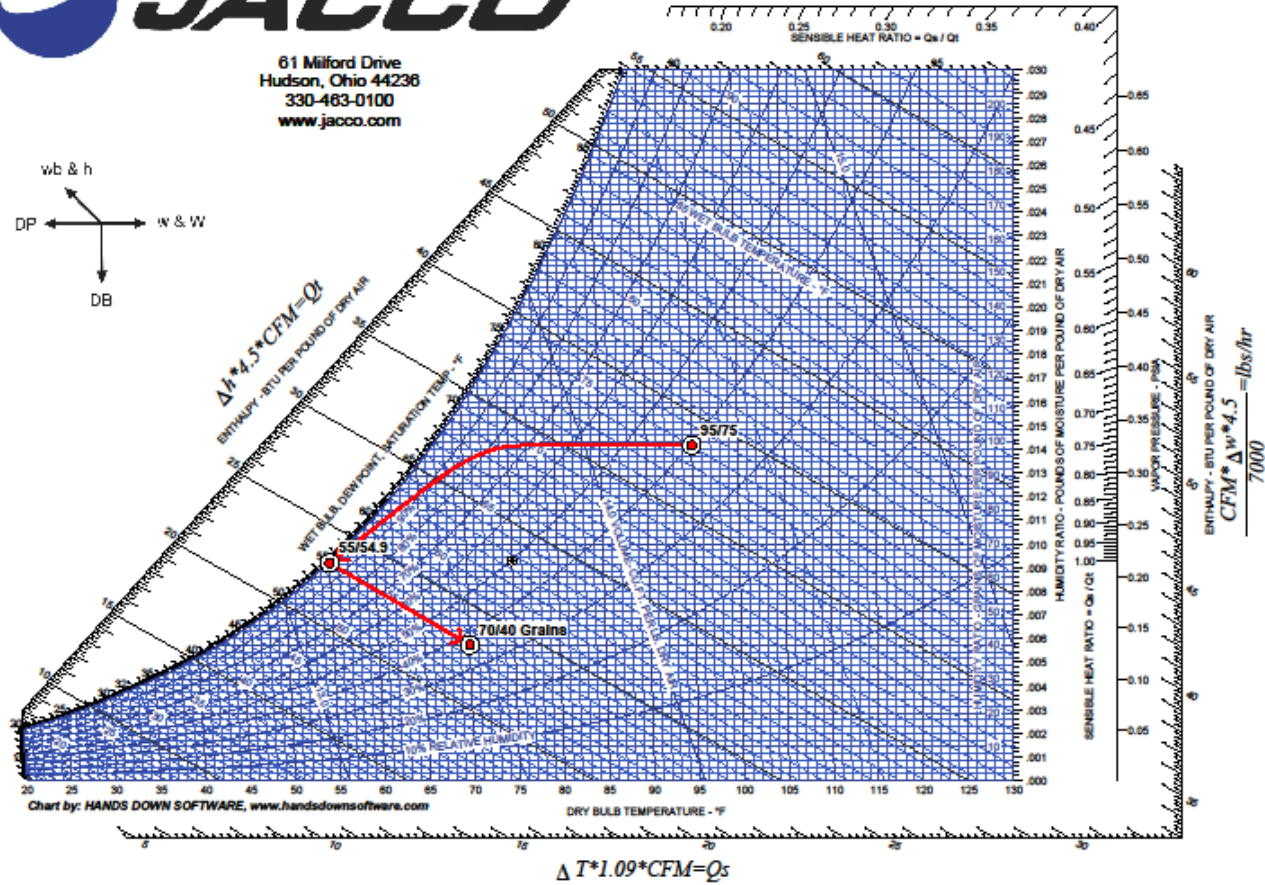
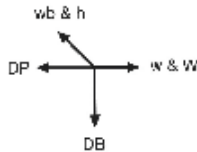
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Desiccant Dehumidification Pre-Cool



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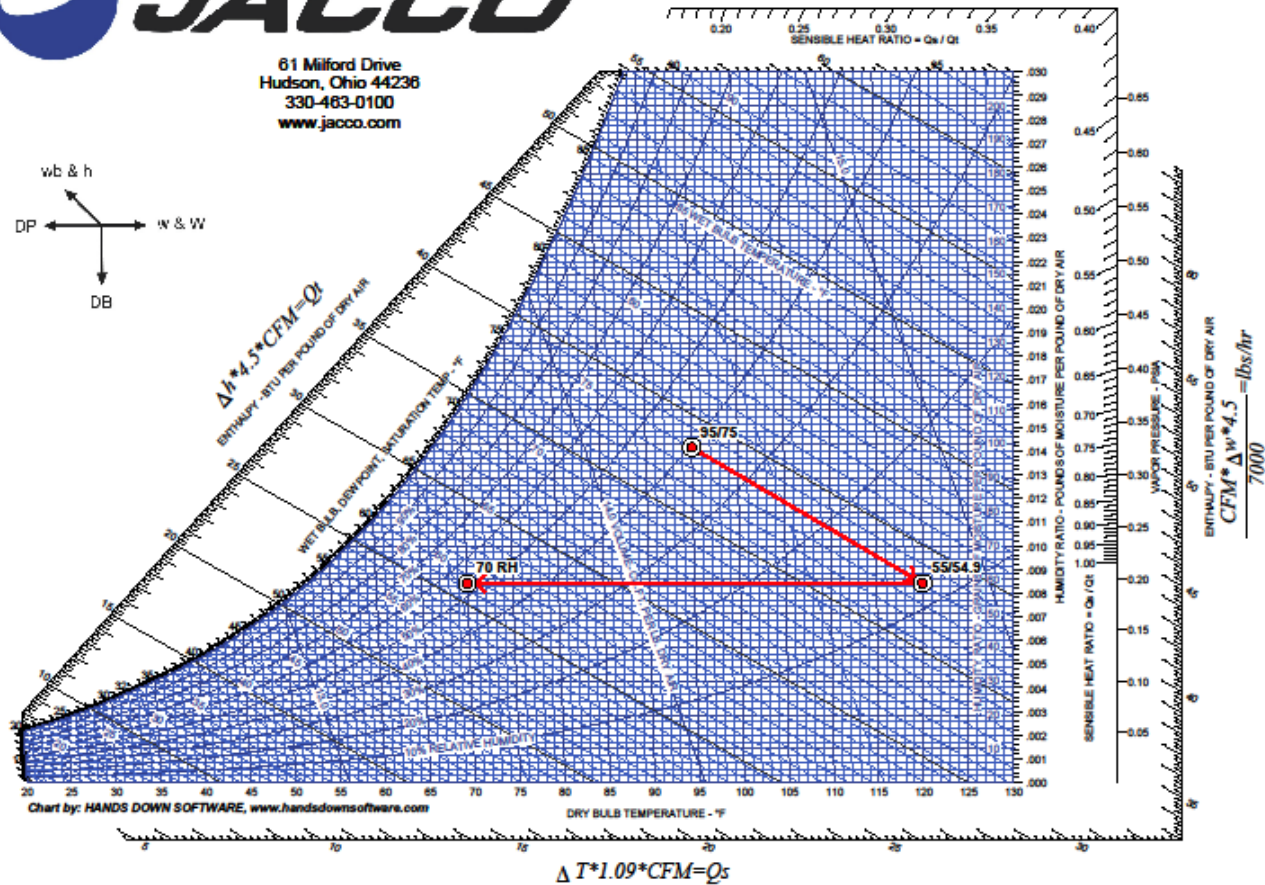
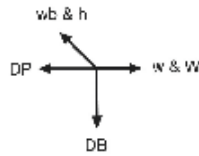
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Desiccant Dehumidification - Post-Cool



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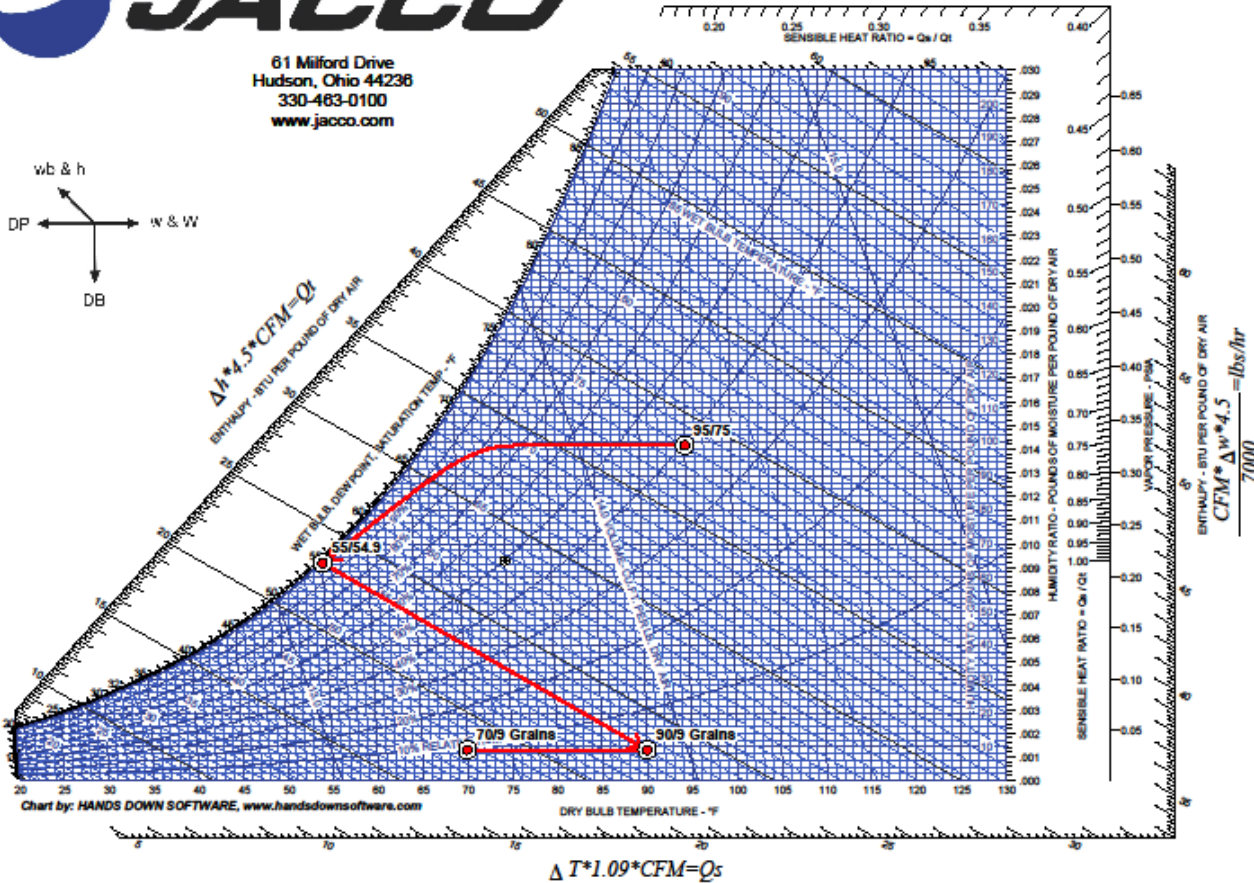
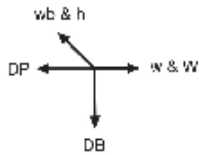
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Desiccant Dehumidification, Pre & Post-Cool



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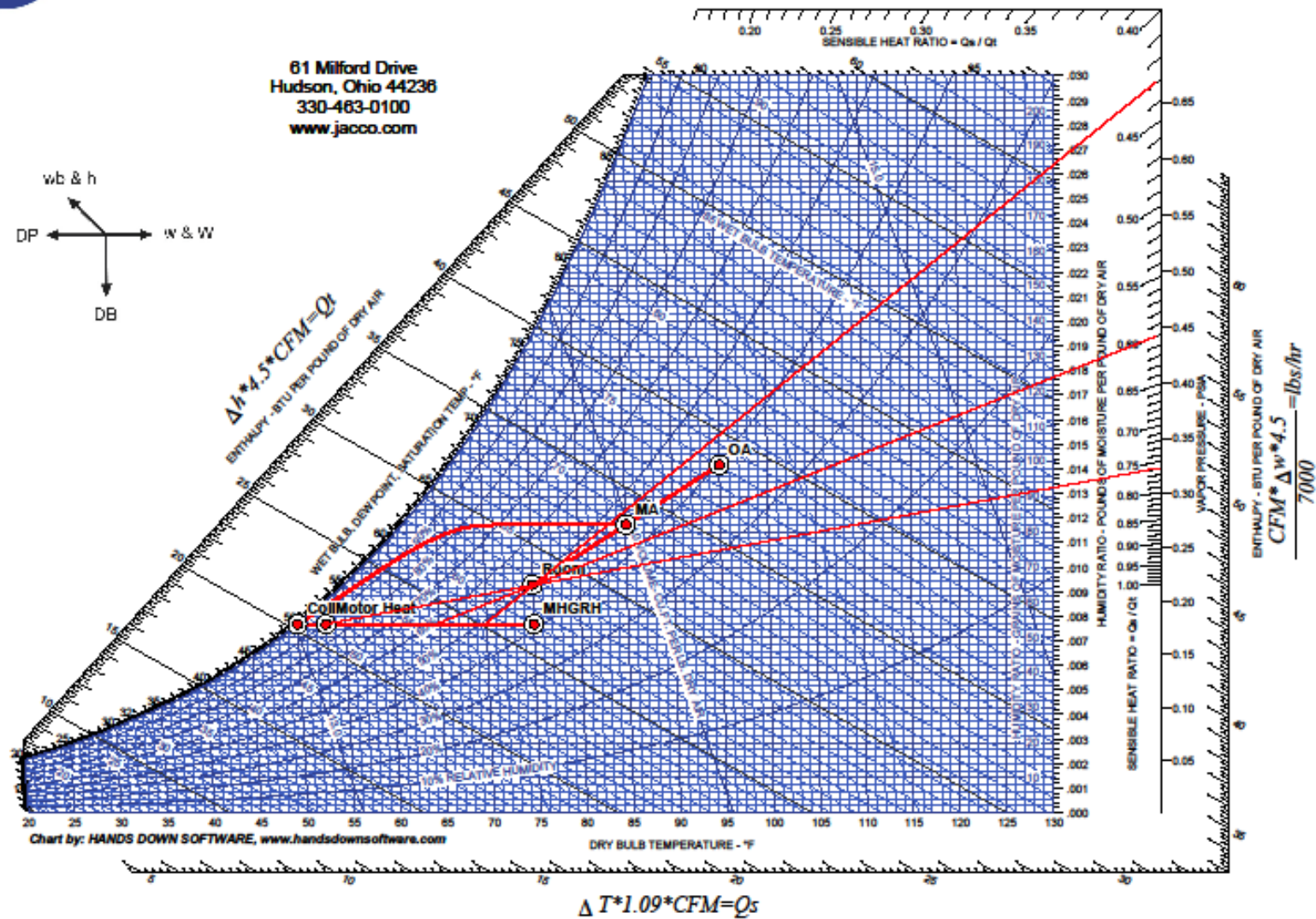
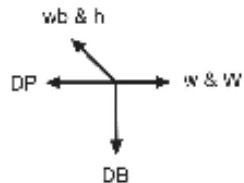


Tight Temperature and Humidity Control

- Sensible/Total = SHR
- High SHR Equipment
- Low SHR Equipment



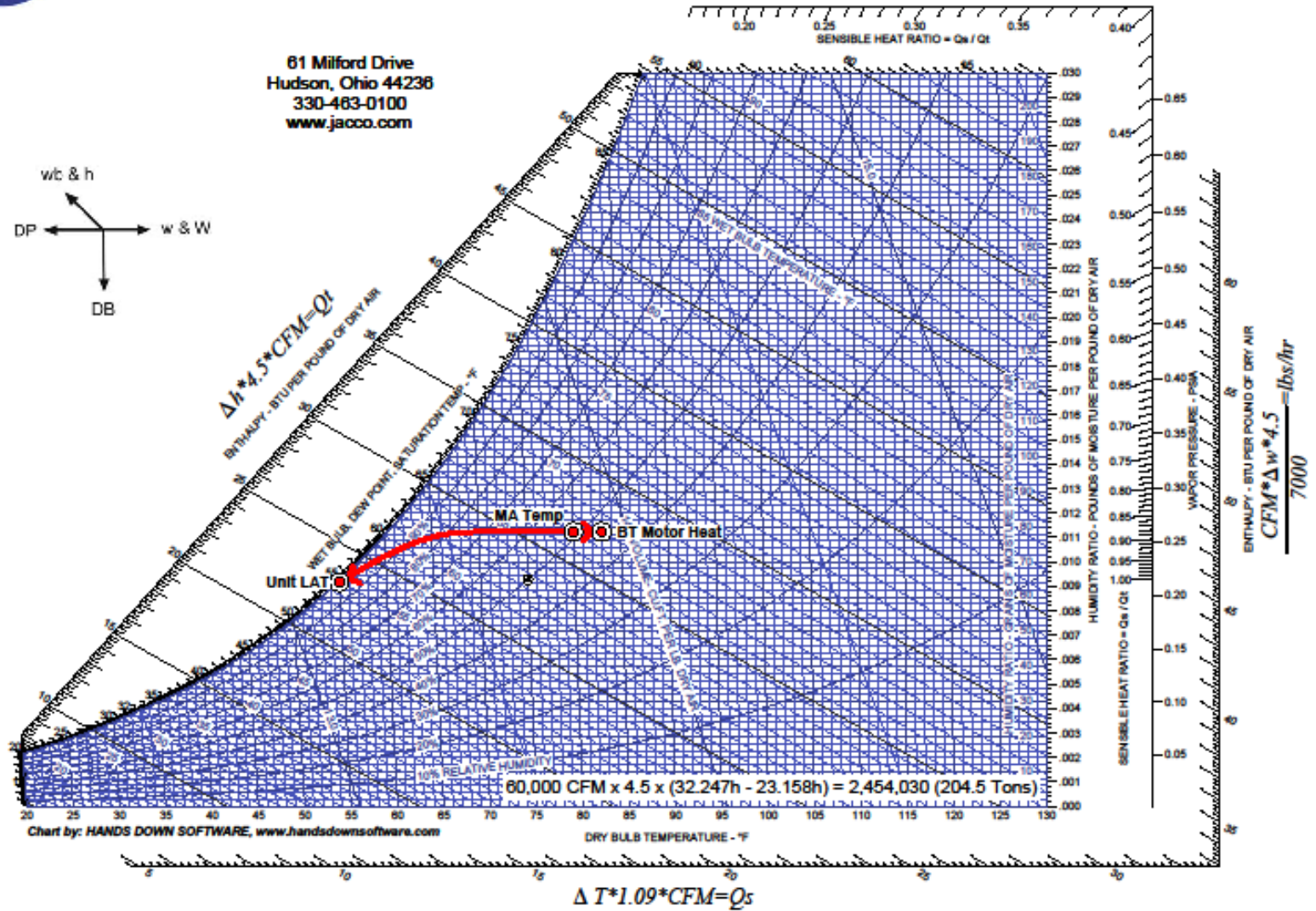
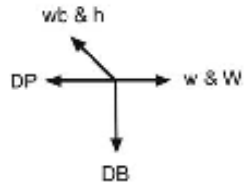
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Applications – Blow Through

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

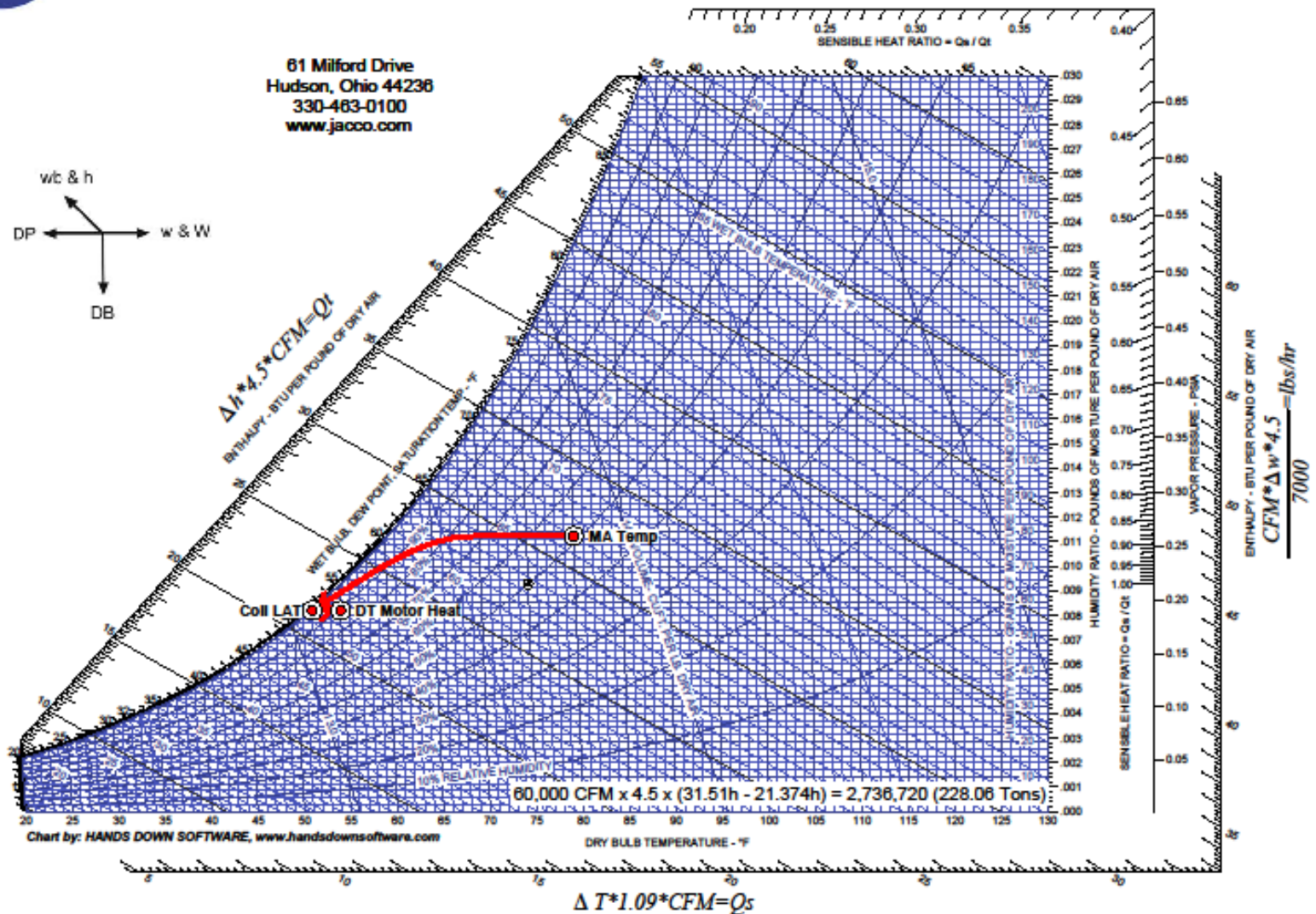
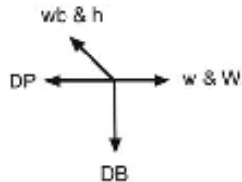
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Applications – Draw Through

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

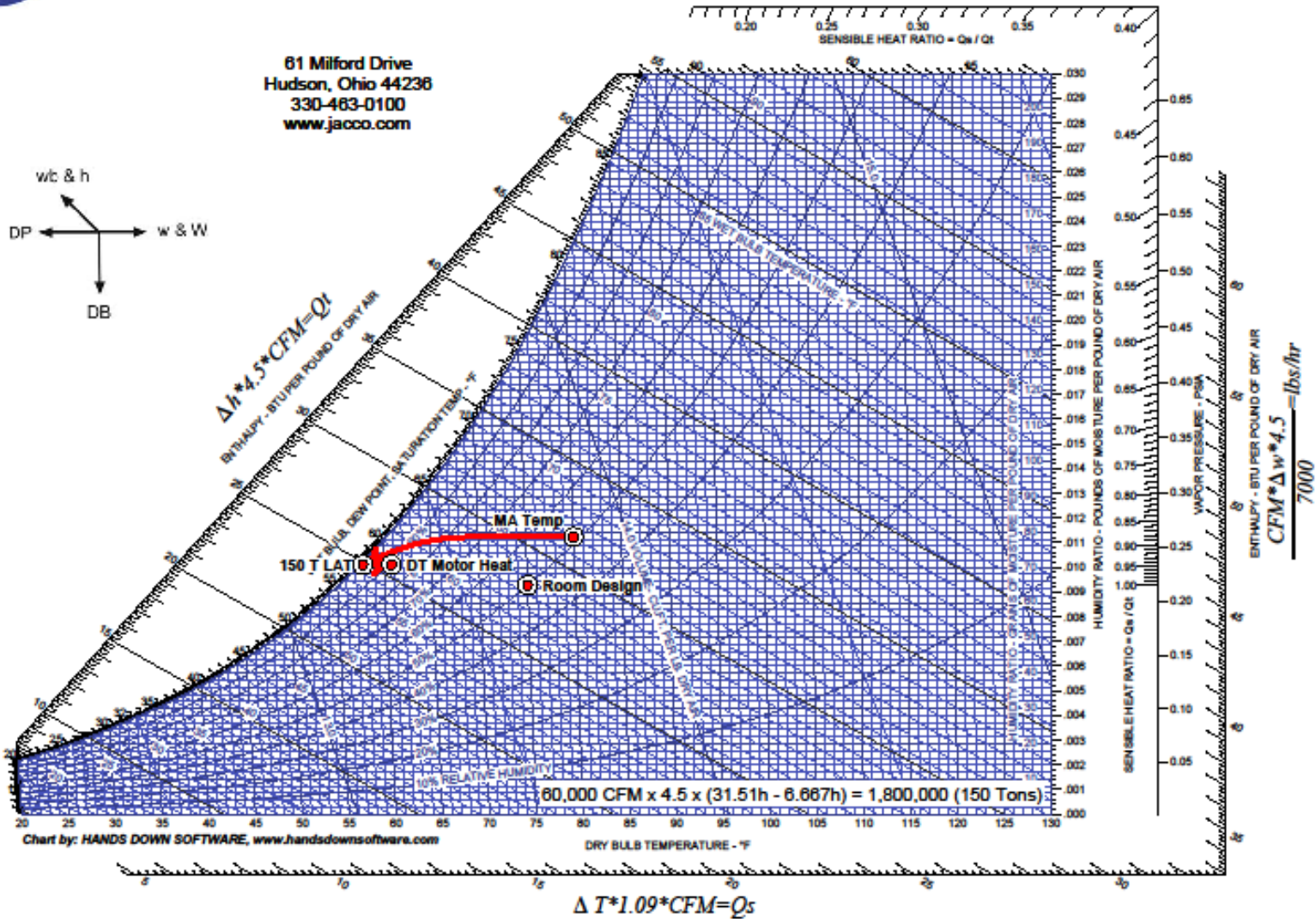
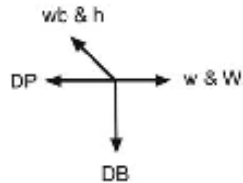
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Applications – Draw Through

- $60,000 \text{ ft}^2 / 400 \text{ ft}^2 = 150 \text{ Tons}$
- Does this work?

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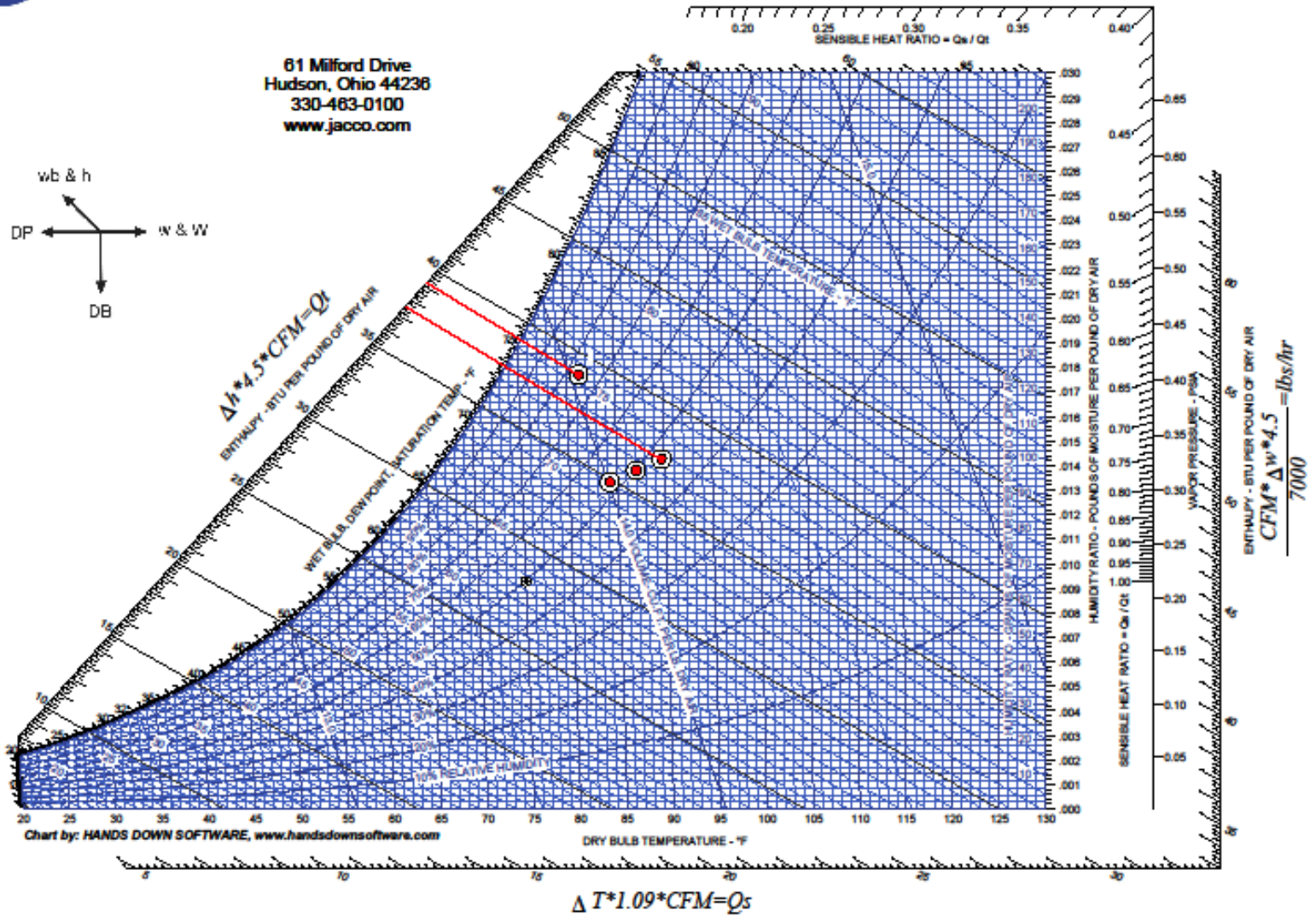
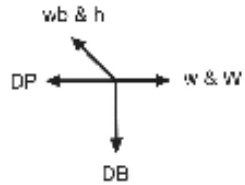


ASHRAE Data Sets

- 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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Break