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

JACCO

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.

JACCO

Who is Jacco

- Operations
  - –Brenda Homjak
  - –Mike Spangler
  - –Chad Russell
  - –Mike Mueller
- Contractor Owning Experience
  - –Maggie Sawicki
  - –Rick Baker
- Engineering Owning Experience
  - –Greg Drensky
  - –Jerry Cohen
- Owning Experience
  - –Steve Leister
  - –Gloria Schwartz
  - –Jeff Watson

JACCO

Who is Jacco

- 30 Minute Design
  - Unit Performance
  - Drawing
  - Weights
  - Electrical
  - Specifications?
  - Sequence of Operation?
  - Cartoon?
  - Narrative?

JACCO

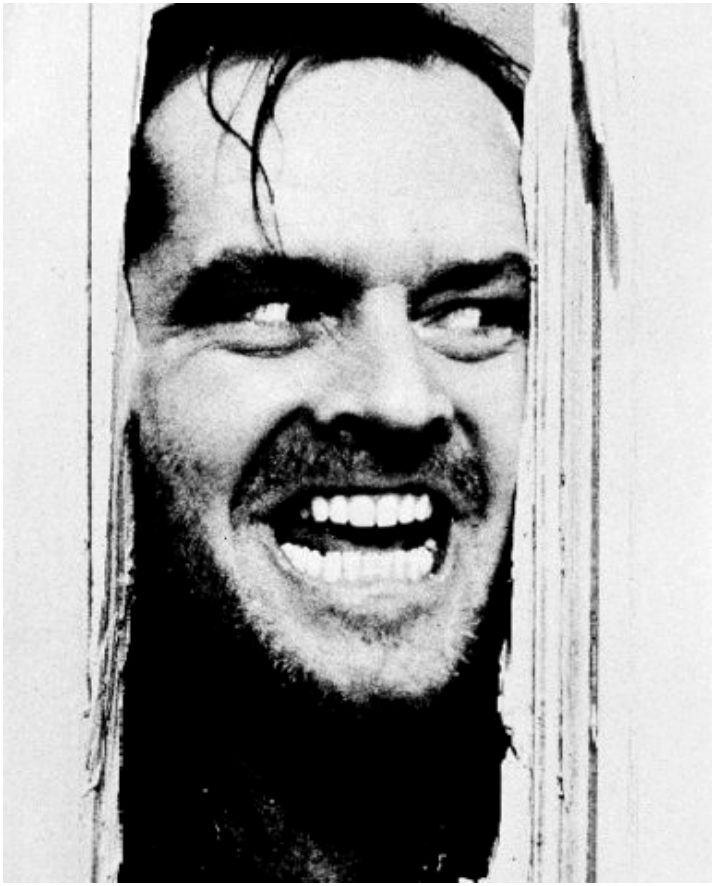
Who is Jacco

2016 Seminars

Seminars	Instructor	Date
Psychrometrics	Jerry Cohen	13-Jan
The Refrigeration Cycle	Jerry Cohen	10-Feb
Best Practices for VRF Systems - Design	Greg Drensky	9-Mar
Best Practices for VRF Systems - Installation	Steve Leister	13-Apr
Best Practices for Applied Rooftop Systems, Applications & Installation	Jerry Cohen	11-May
Best Practices for Geothermal Systems, Applications and Installation	Greg Drensky	14-Sep
Vertical Market Systems	Greg Drensky	12-Oct
Applying Building Pressure & Air Flow Measurement Instrumentation	Greg Drensky	9-Nov
Controlling HVAC Systems with Special Emphasis on Sequence of Operations	Jerry Cohen	14-Dec

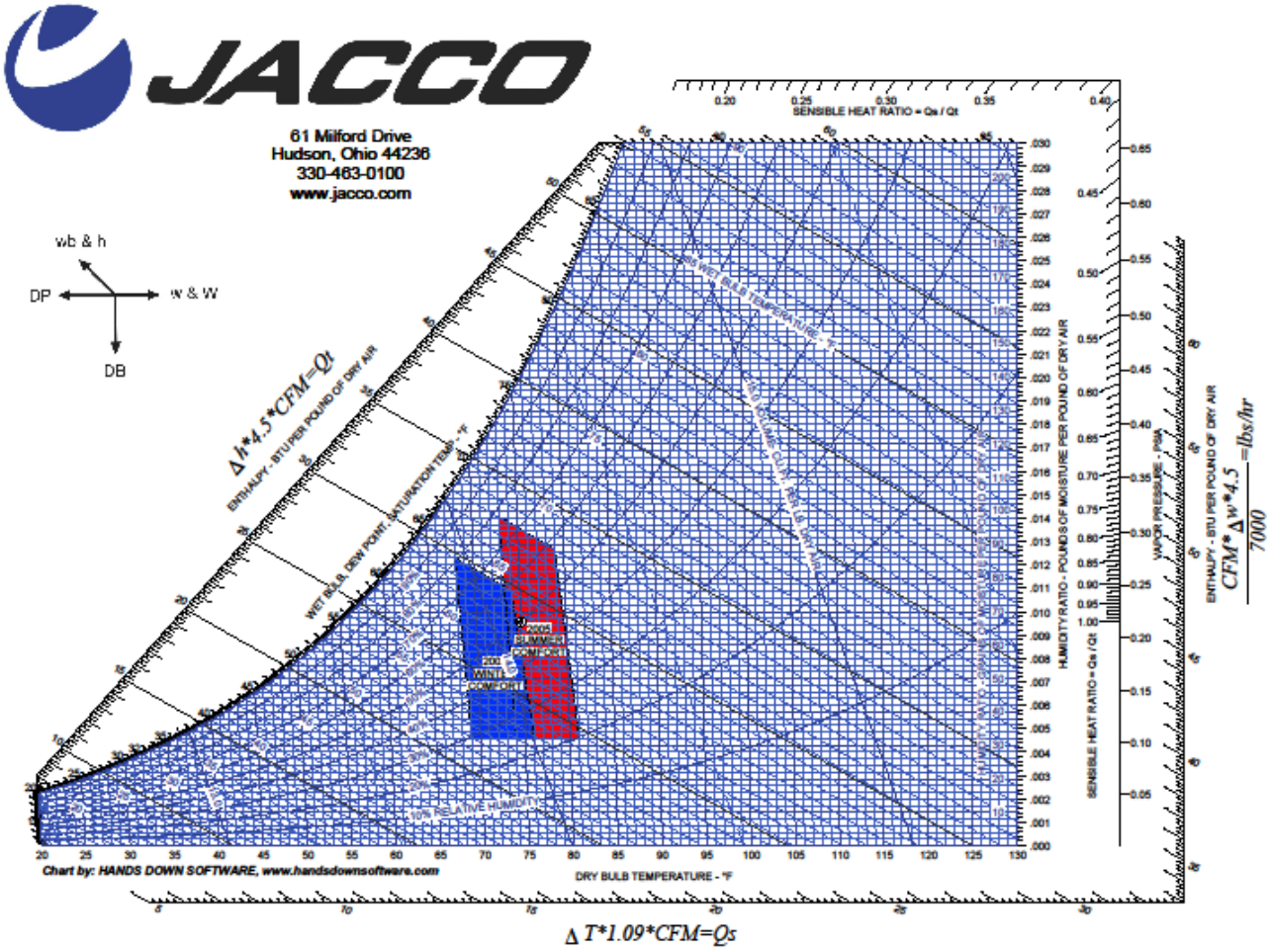
JACCO

Psycho or Psychro



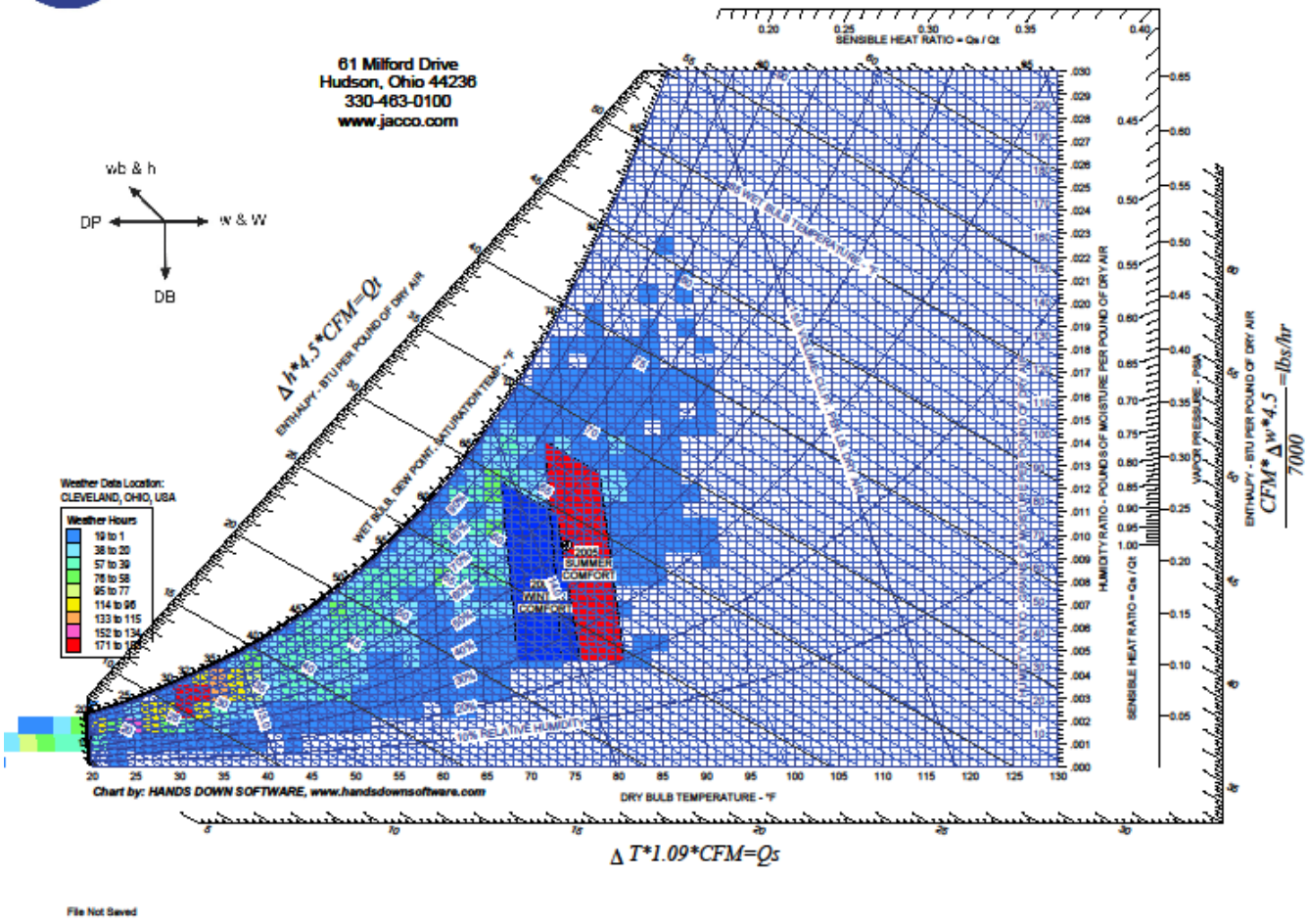
JACCO

What is the Purpose of your Job?



JACCO

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.

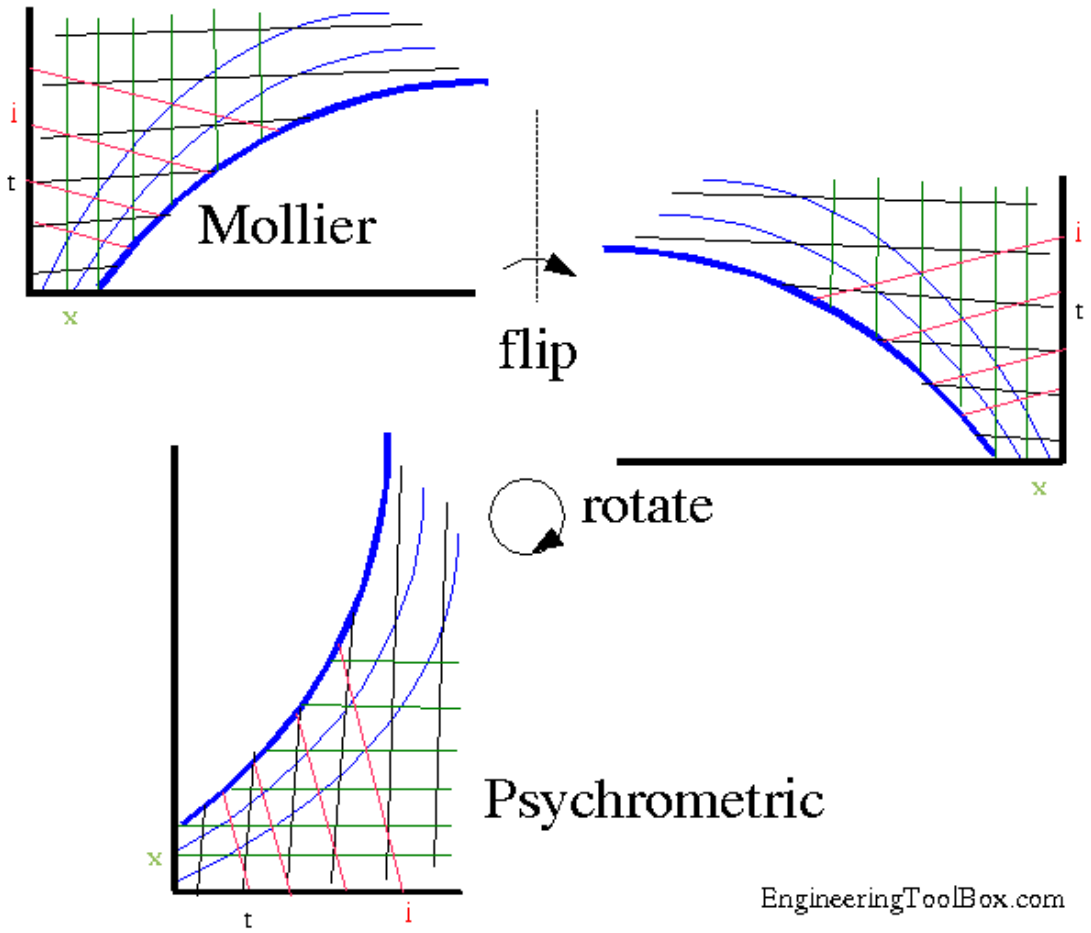
The Psychrometric Chart

- 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.

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



JACCO

So really, what is Psychrometrics?

- Study of Air / Water (Vapor) Mixture

JACCO

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>

JACCO

So Who Cares?

- Reconsider the Components of Air:

So Who Cares?

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

JACCO

So Who Cares?

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

Stable in Gas Phase.

So Who Cares?

- Reconsider the Components of Air:
    - Water Vapor

JACCO

So Who Cares?

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

<u>Stable in Gas Phase</u>

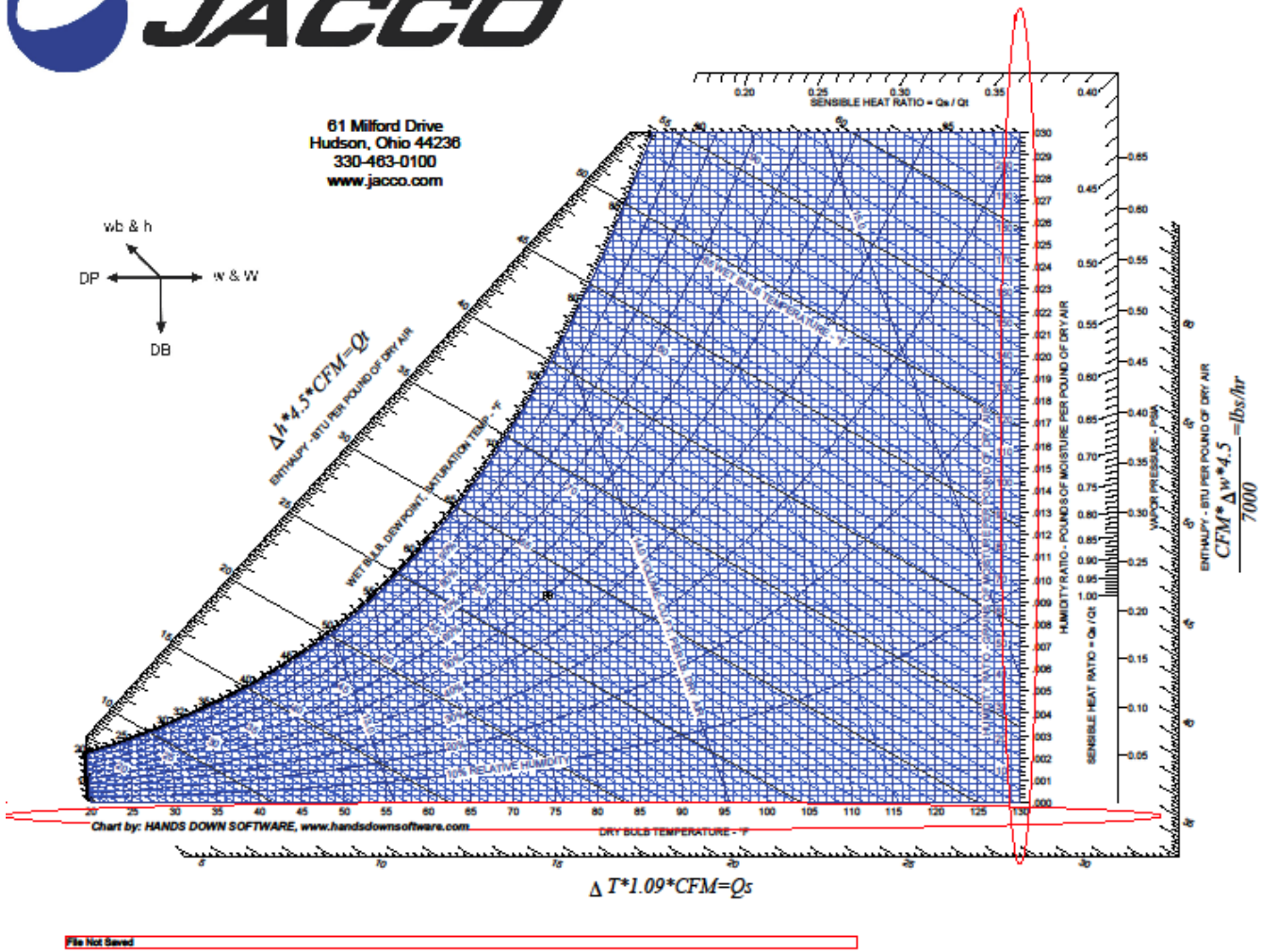
  - Water Vapor

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

JACCO

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

Psychrometric Chart



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%.

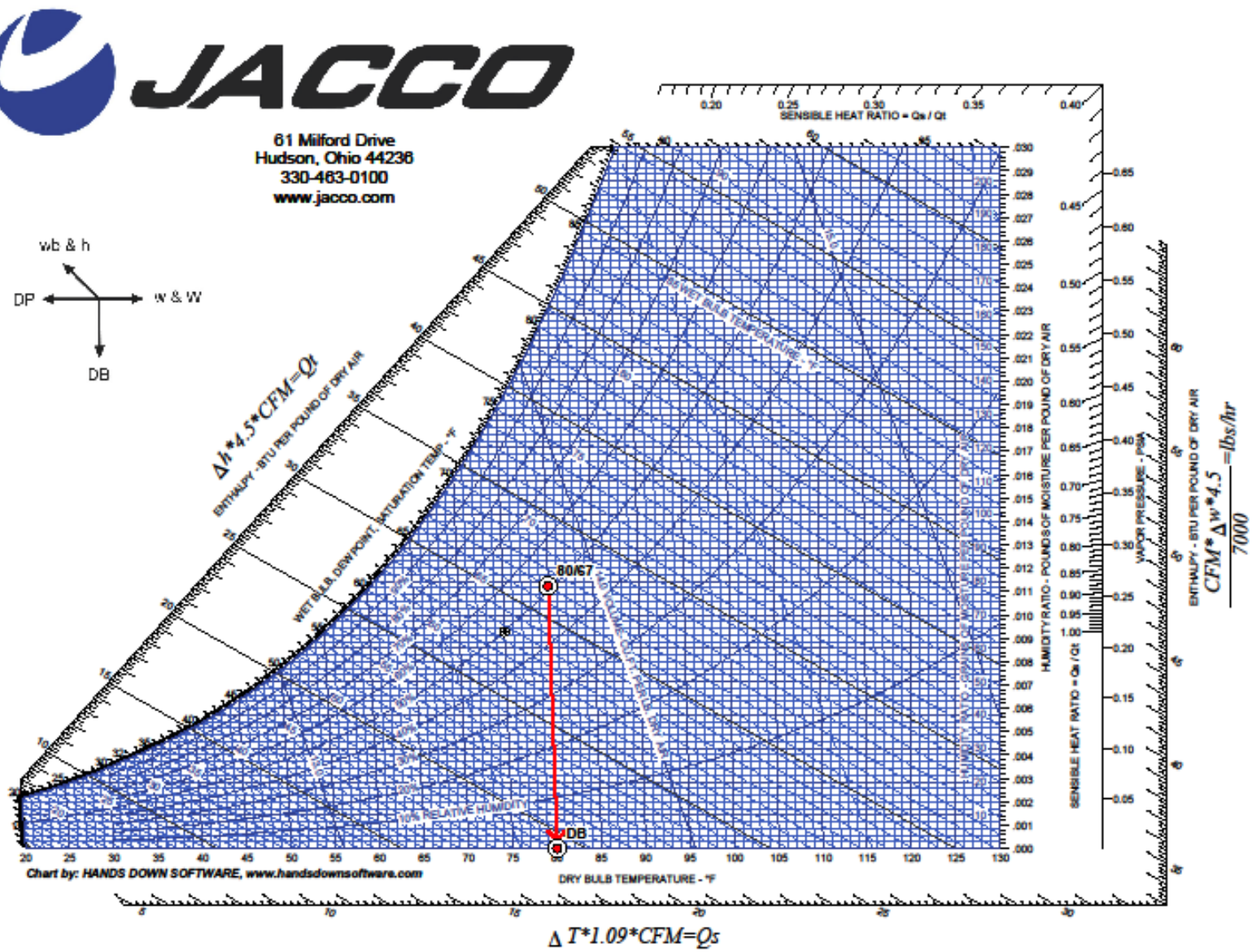
JACCO

Some Definitions

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

JACCO

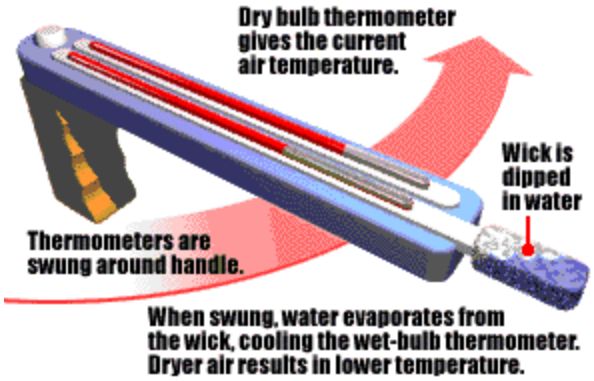
JACCO
61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com



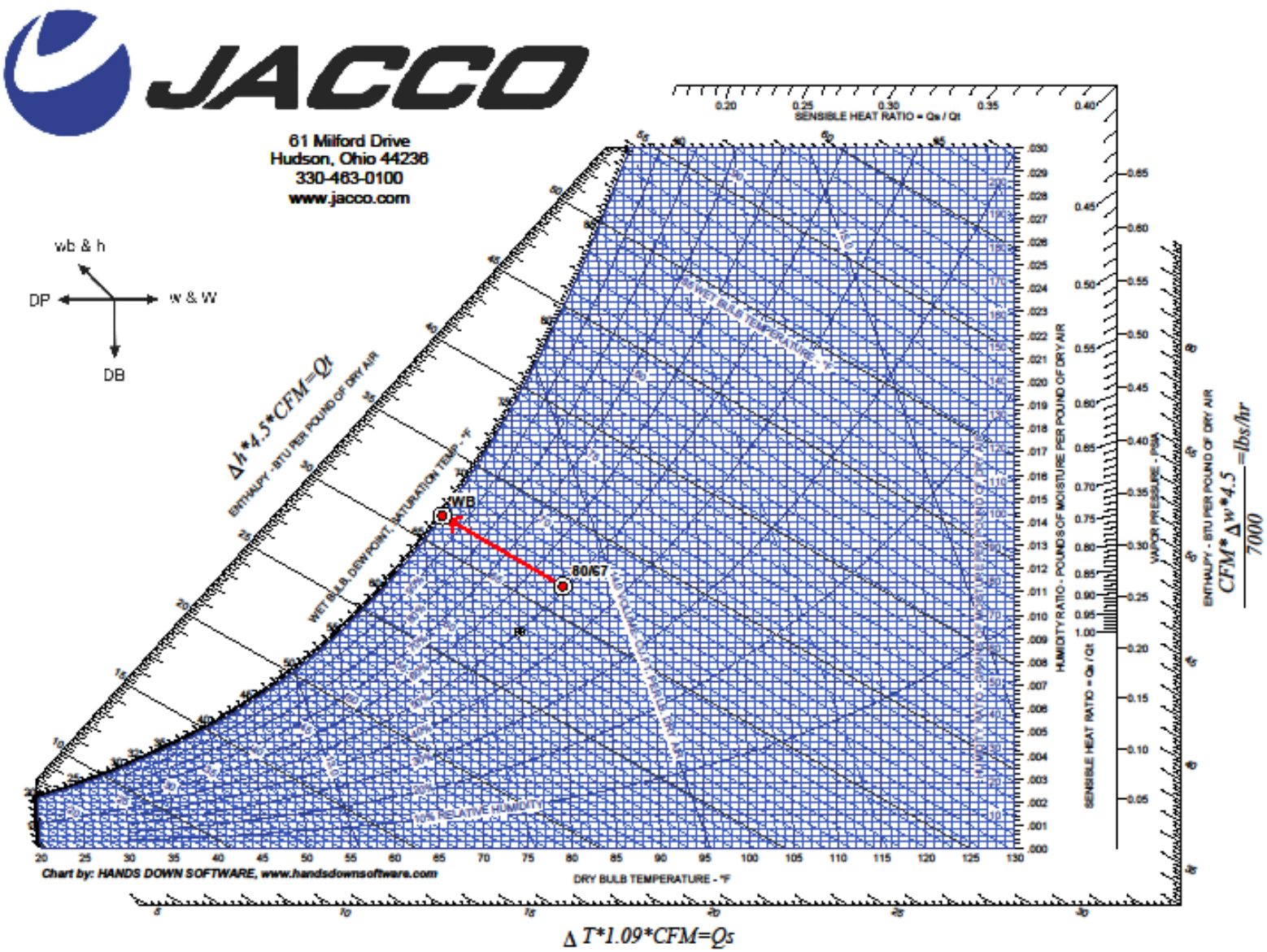
File Not Saved

Some Definitions

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



JACCO

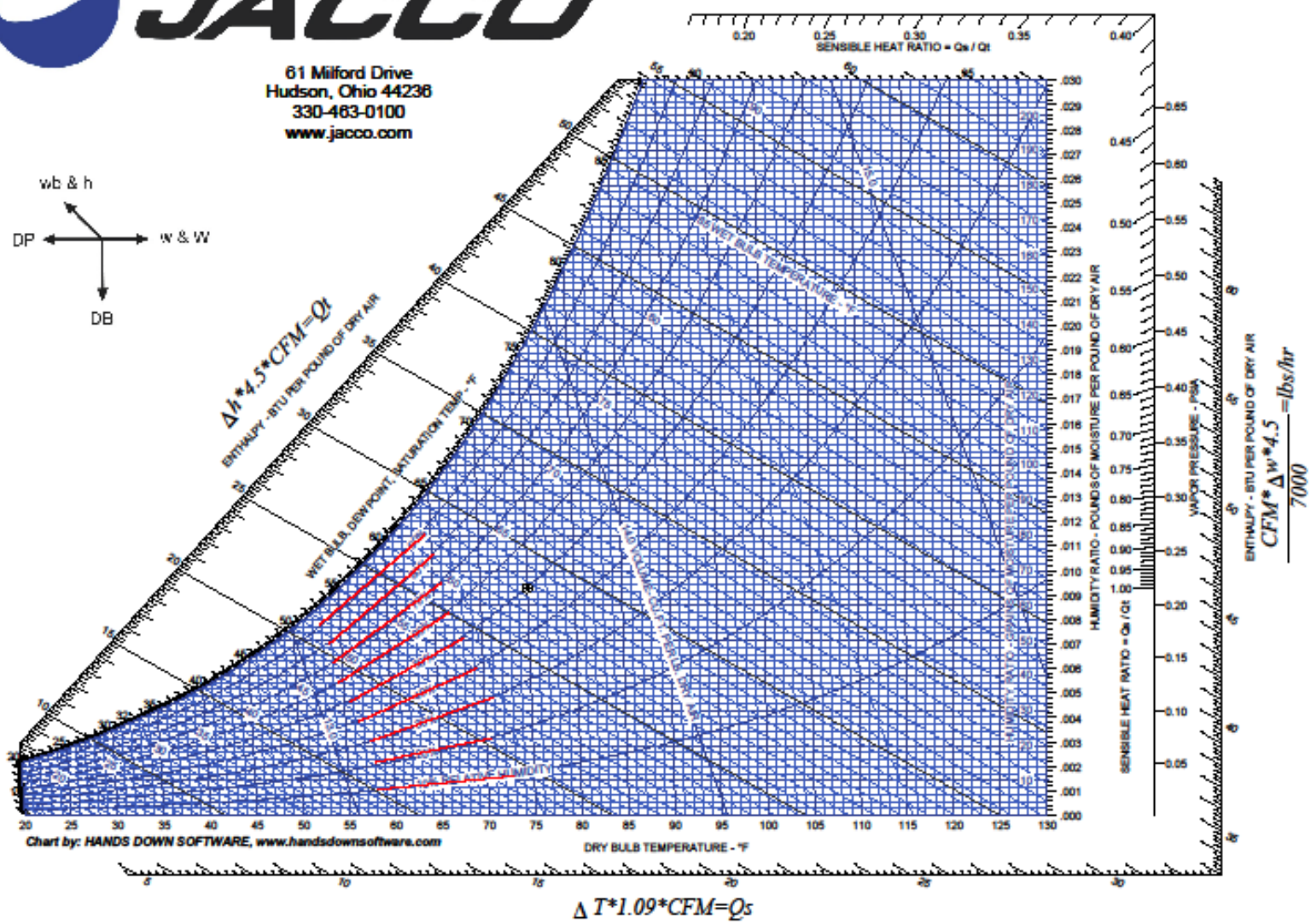

JACCO
61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com
wb & h
DP
w & W
DB
ΔH*4.5*CFM=Qt
ENTHALPY - BTU PER POUND OF DRY AIR
WET BULB DEW POINT, SATURATION TEMP - °F
WB
80/67
RH
DRY BULB TEMPERATURE - °F
SENSIBLE HEAT RATIO = Qs / Qt
HUMIDITY RATIO - POUNDS OF MOISTURE PER POUND OF DRY AIR
VAPOR PRESSURE - PSIA
ENTHALPY - BTU PER POUND OF DRY AIR
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com
ΔT*1.09*CFM=Qs
CFM*Δw*4.5/7000=lbs/hr
File Not Saved

Some Definitions

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

JACCO

JACCO
61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com



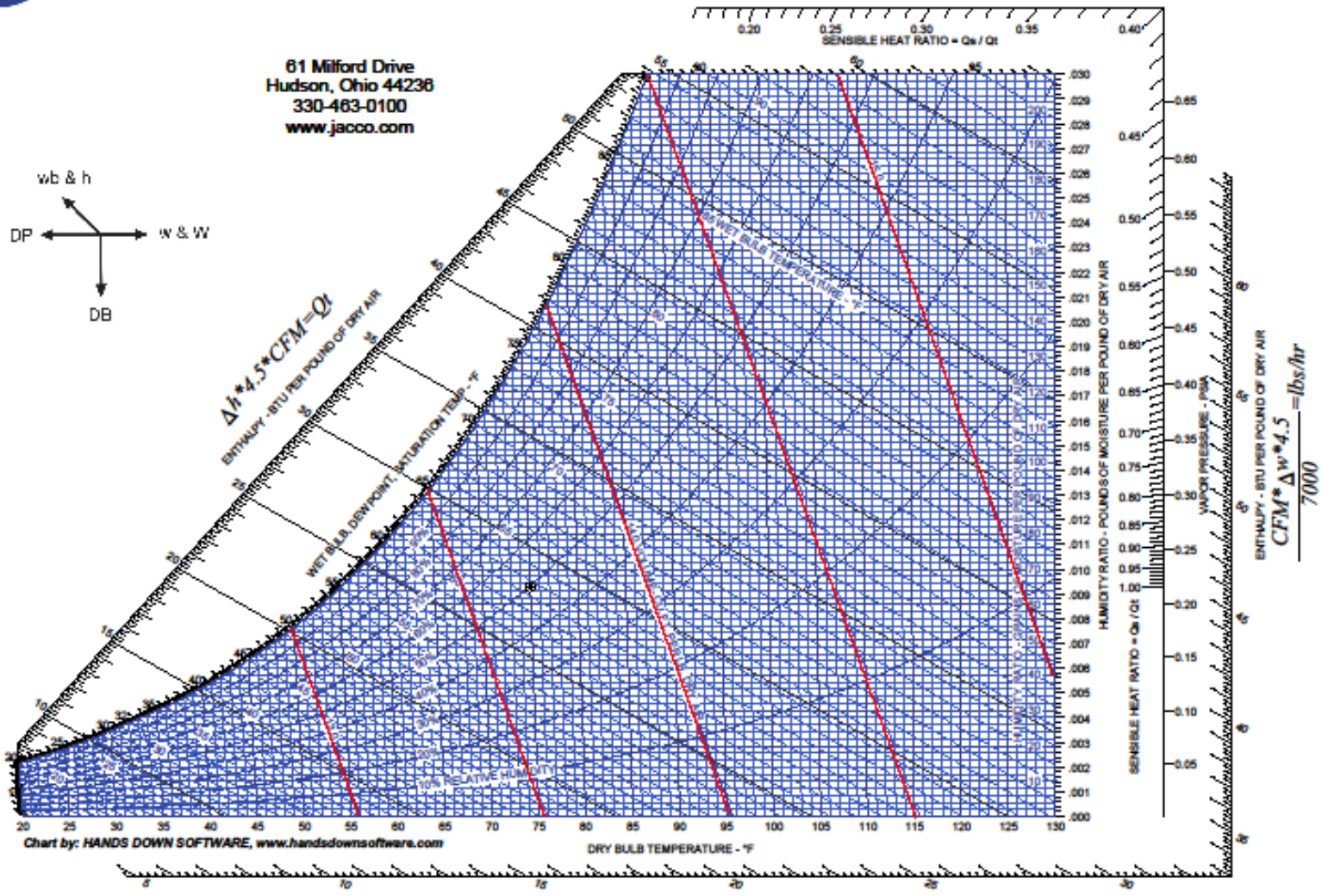
File Not Saved

Some Definitions

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

JACCO

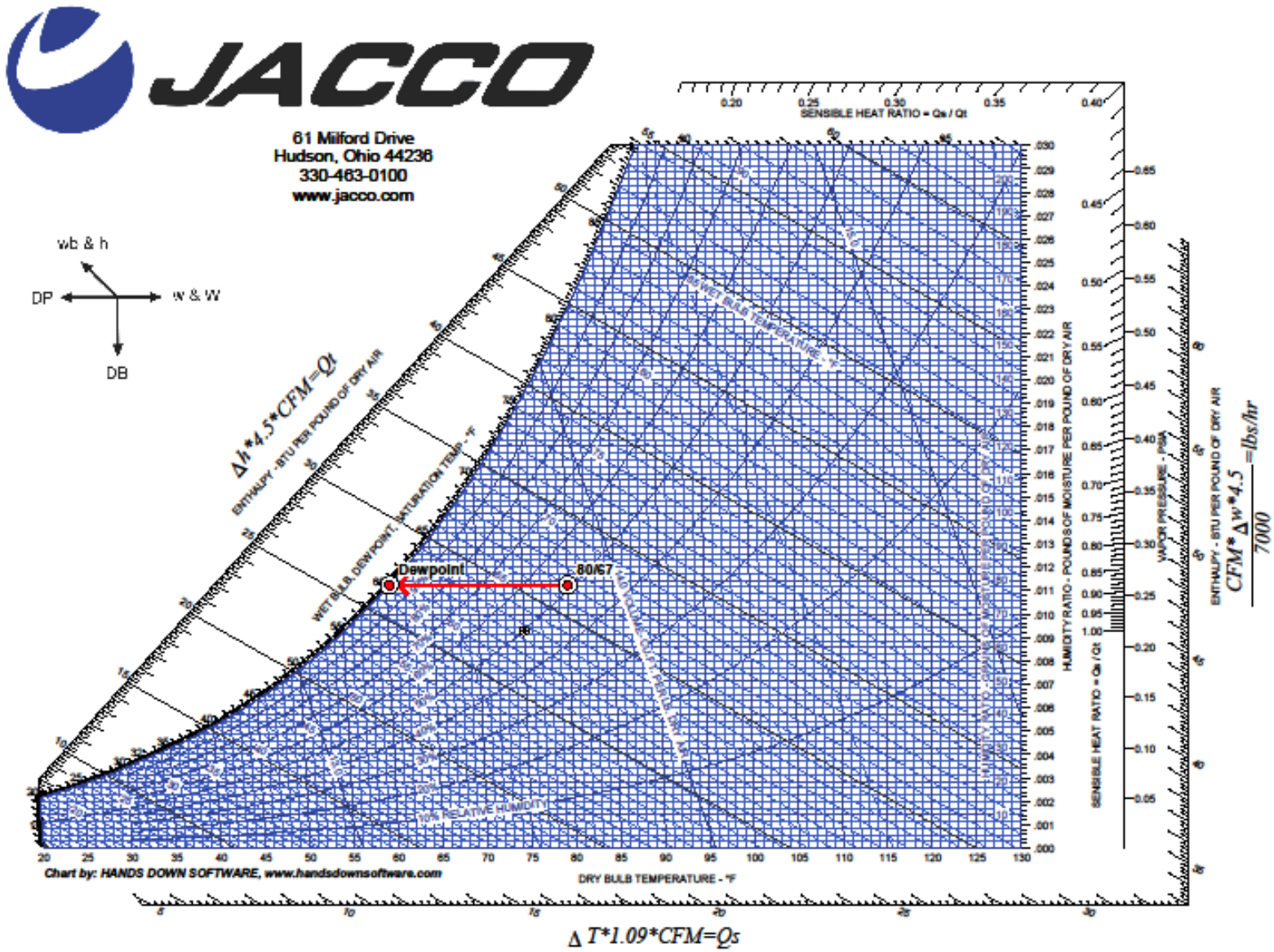
61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com



File Not Saved

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.

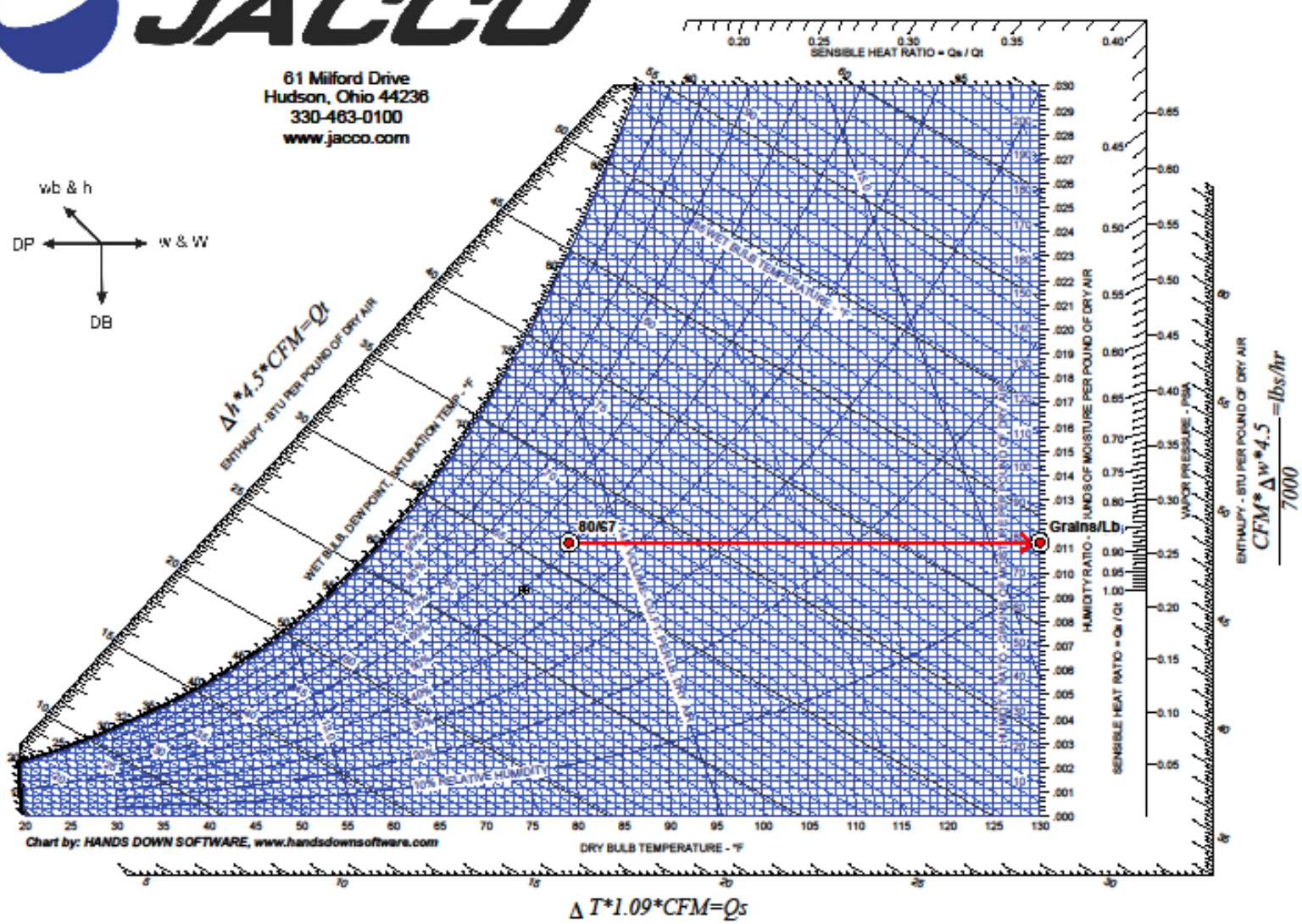


File Not Saved

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).

JACCO
61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com



$$\Delta h * 4.5 * CFM = Qt$$

$$\frac{CFM * \Delta w * 4.5}{7000} = lbs/hr$$

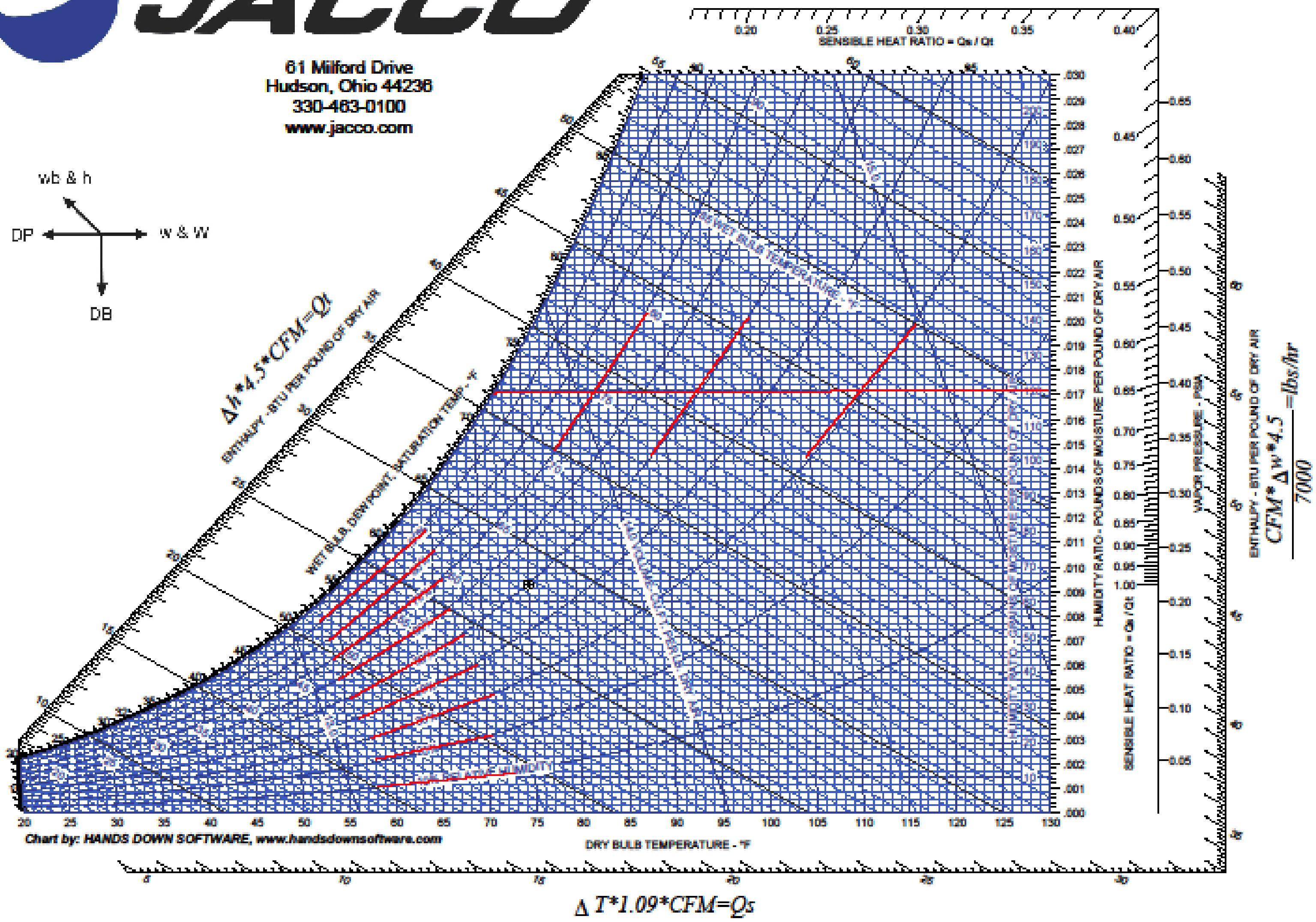
$$\Delta T * 1.09 * CFM = Qs$$

File Not Saved

Some Definitions

- Humidity Ratio vs. Relative Humidity

61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com

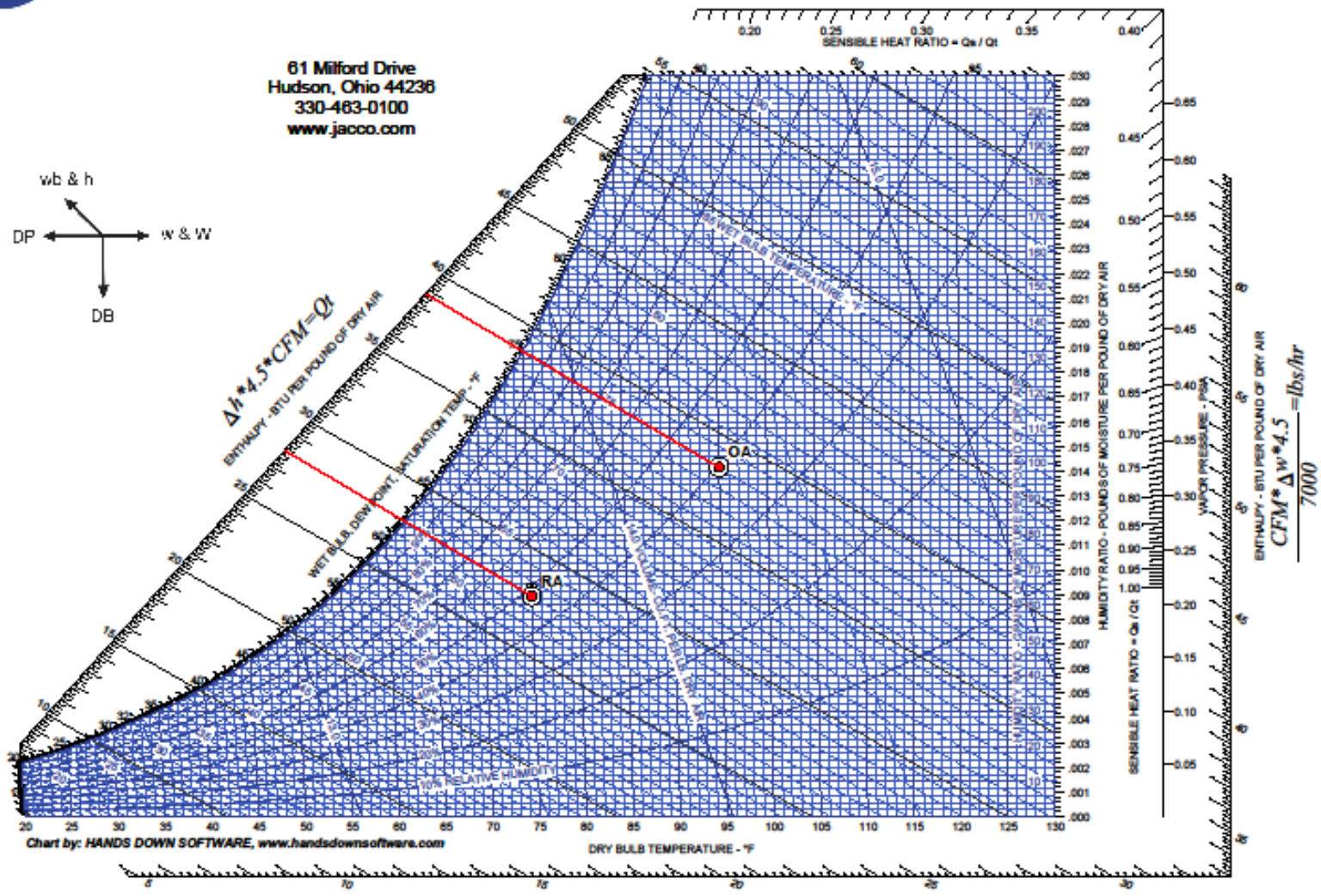


C:\Users\...\Desktop\Marketing - 2015 Seminars\Presentations\Psychrometrics\RH.hdd

Some Definitions

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

JACCO



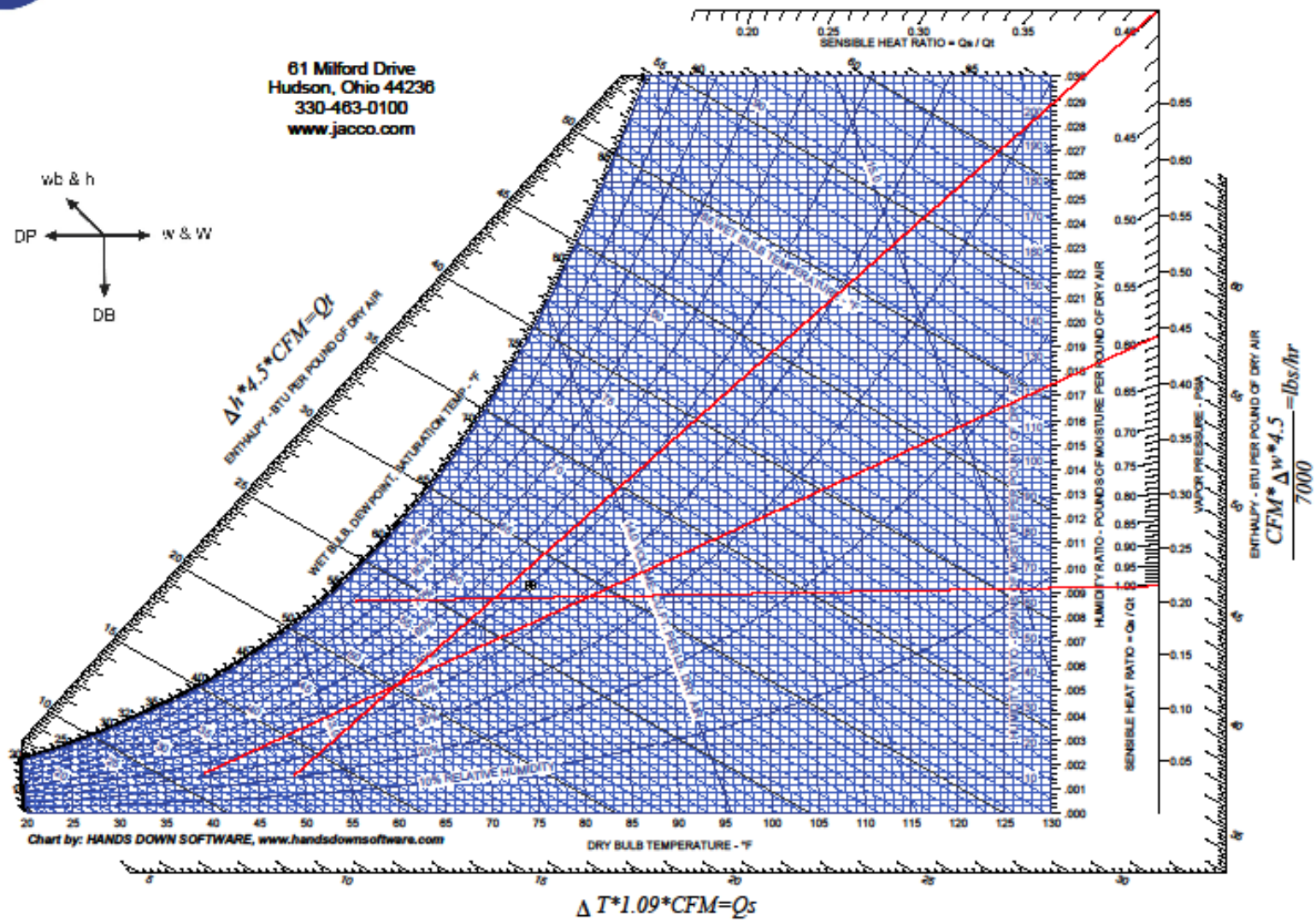
File Not Saved

Some Definitions

- Sensible Heat Ratio
  - The ratio of sensible cooling to total cooling in a space.
  - Sensible/Total = SHR

JACCO

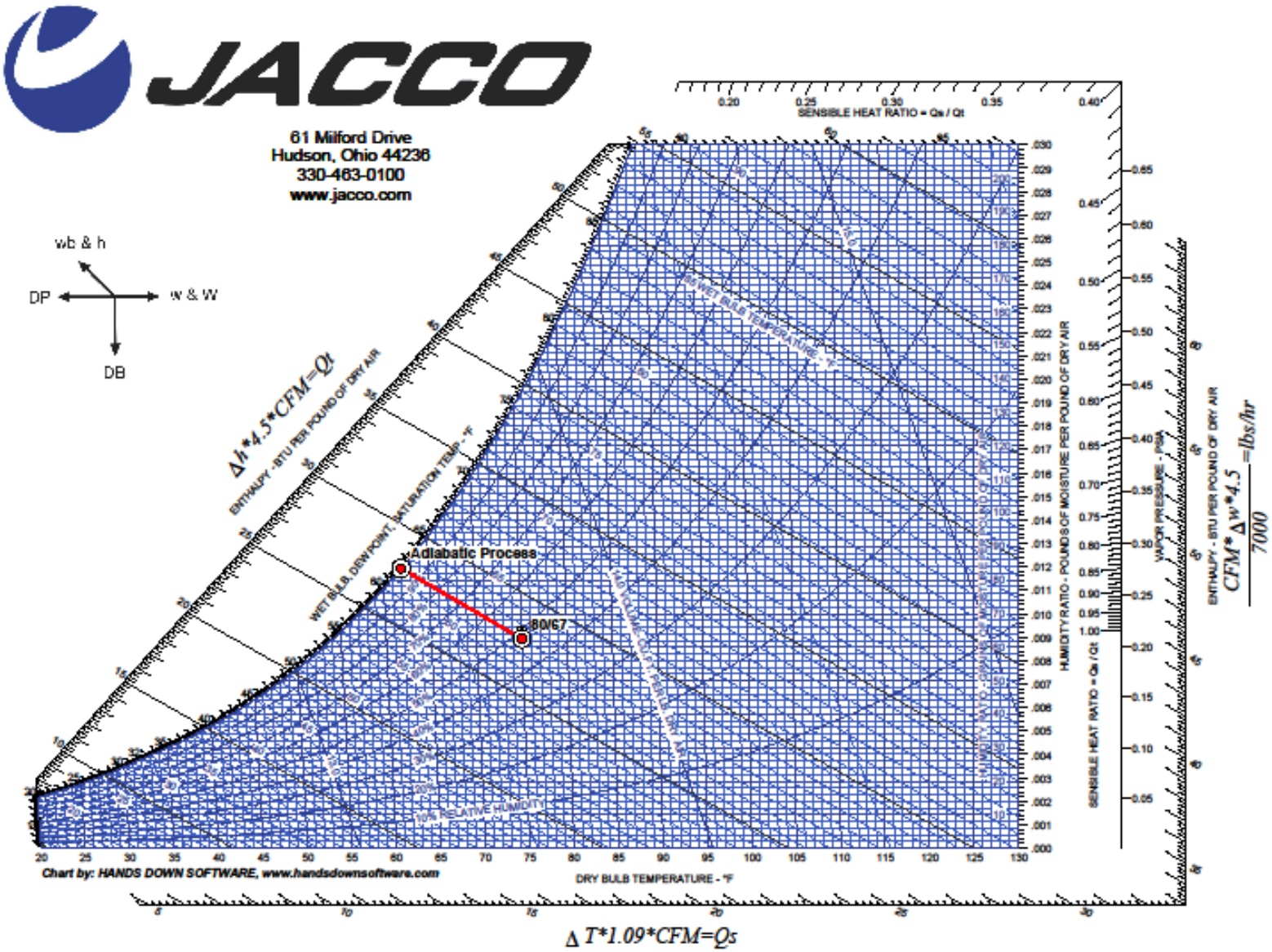
61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com



File Not Saved

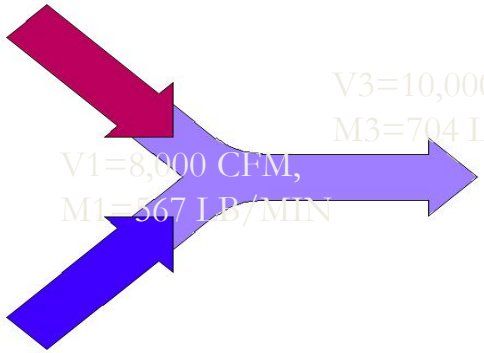
Some Definitions

- 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.


JACCO
61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com
wb & h
DP
w & W
DB
Δh*4.5*CFM=Qt
Adiabatic Process
80/67
SENSIBLE HEAT RATIO = Qs / Qt
HUMIDITY RATIO - POUNDS OF MOISTURE PER POUND OF DRY AIR
ENTHALPY - BTU PER POUND OF DRY AIR
WET BULB, DEW POINT, SATURATION TEMP - °F
DRY BULB TEMPERATURE - °F
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com
Δ T*1.09*CFM=Qs
CFM*Δw*4.5/7000 =lbs/hr
File Not Saved

Useful Psychrometric Calculations - Air Mixing

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



JACCO

Air Mixing - Mathematically

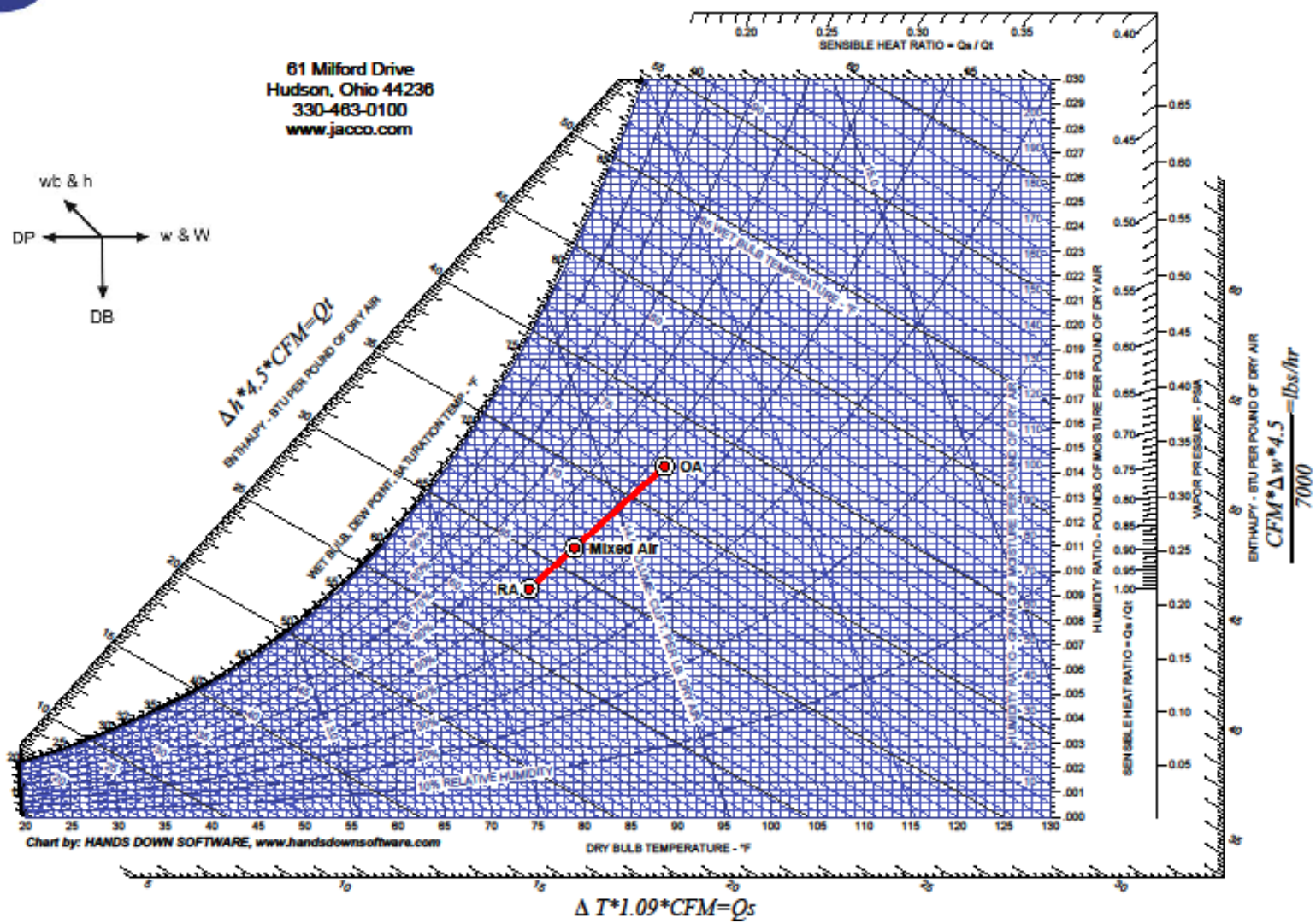
- Plot both points on chart and connect with a line
- Mixed air dry bulb =

  (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

Mixing Air

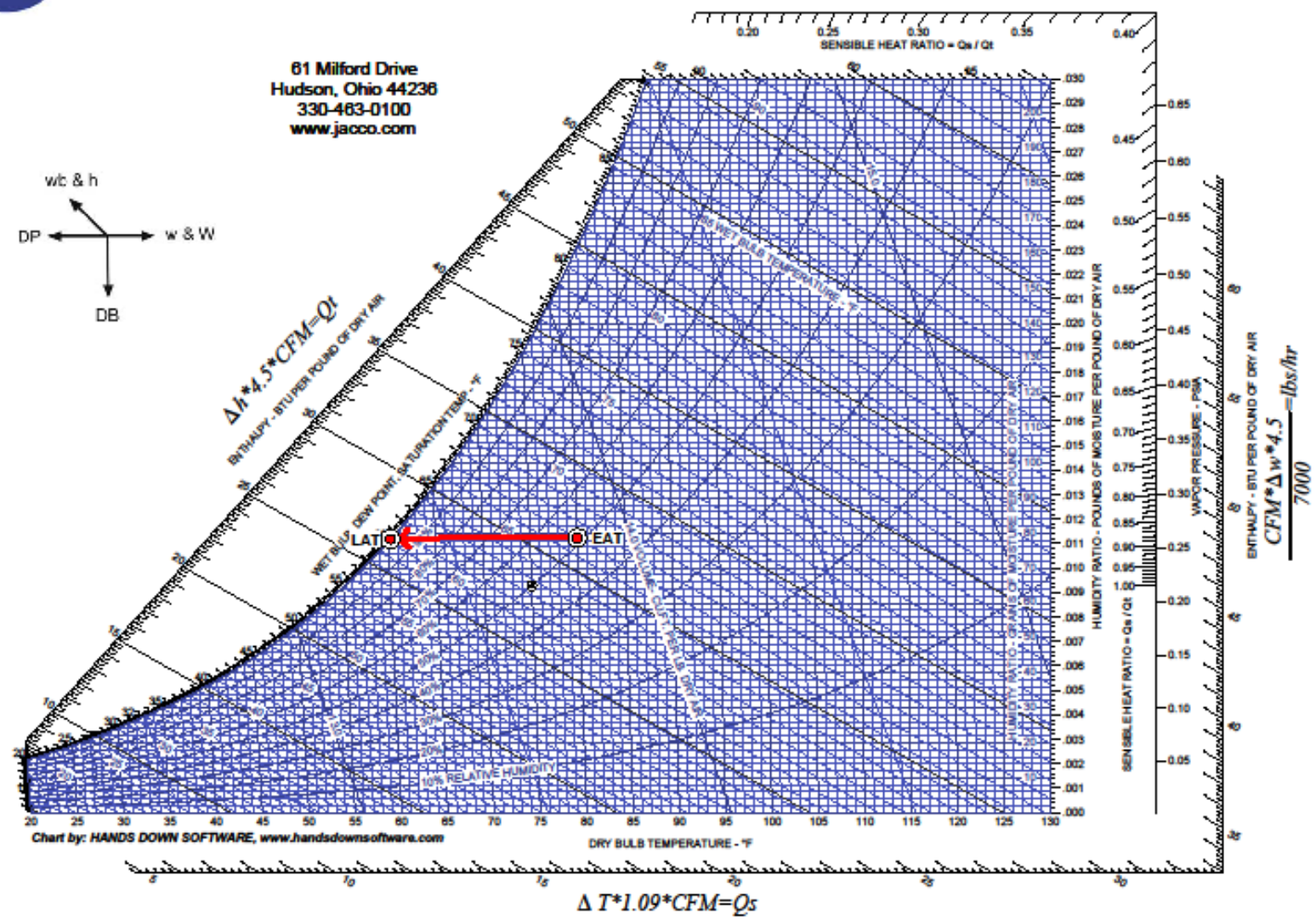


C:\Users\jerryc\Desktop\Marketing - 2015 Seminars\Presentations\Psychrometrics\11-22-15 Mixed Air.hdd

Sensible Cooling

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

Sensible Cooling

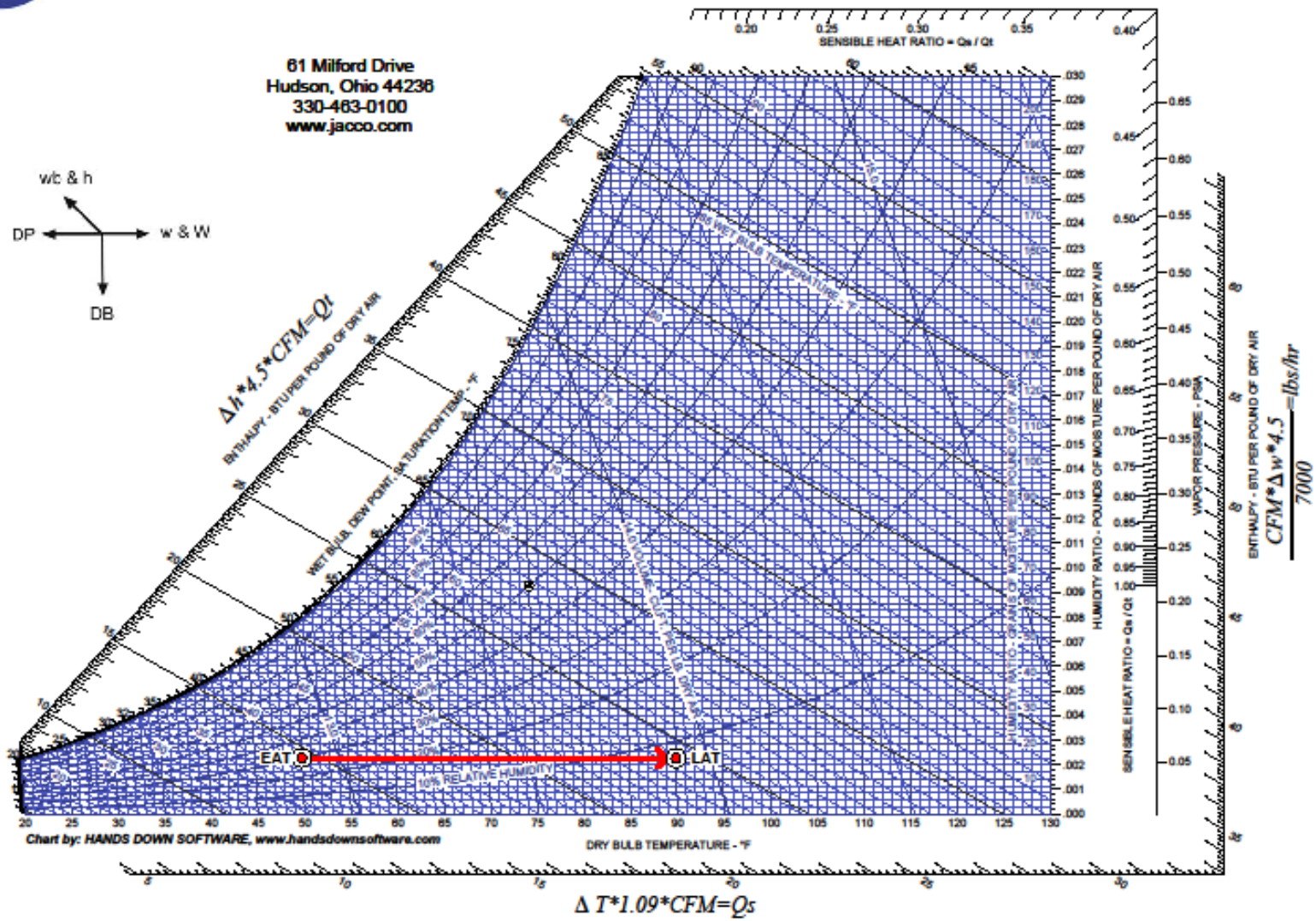


C:\Users\jerryc\Desktop\Marketing - 2015 Seminars\Presentations\Psychrometrics\11-22-15 Sensible Cooling.hdd

Sensible Heating

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

Sensible Heating

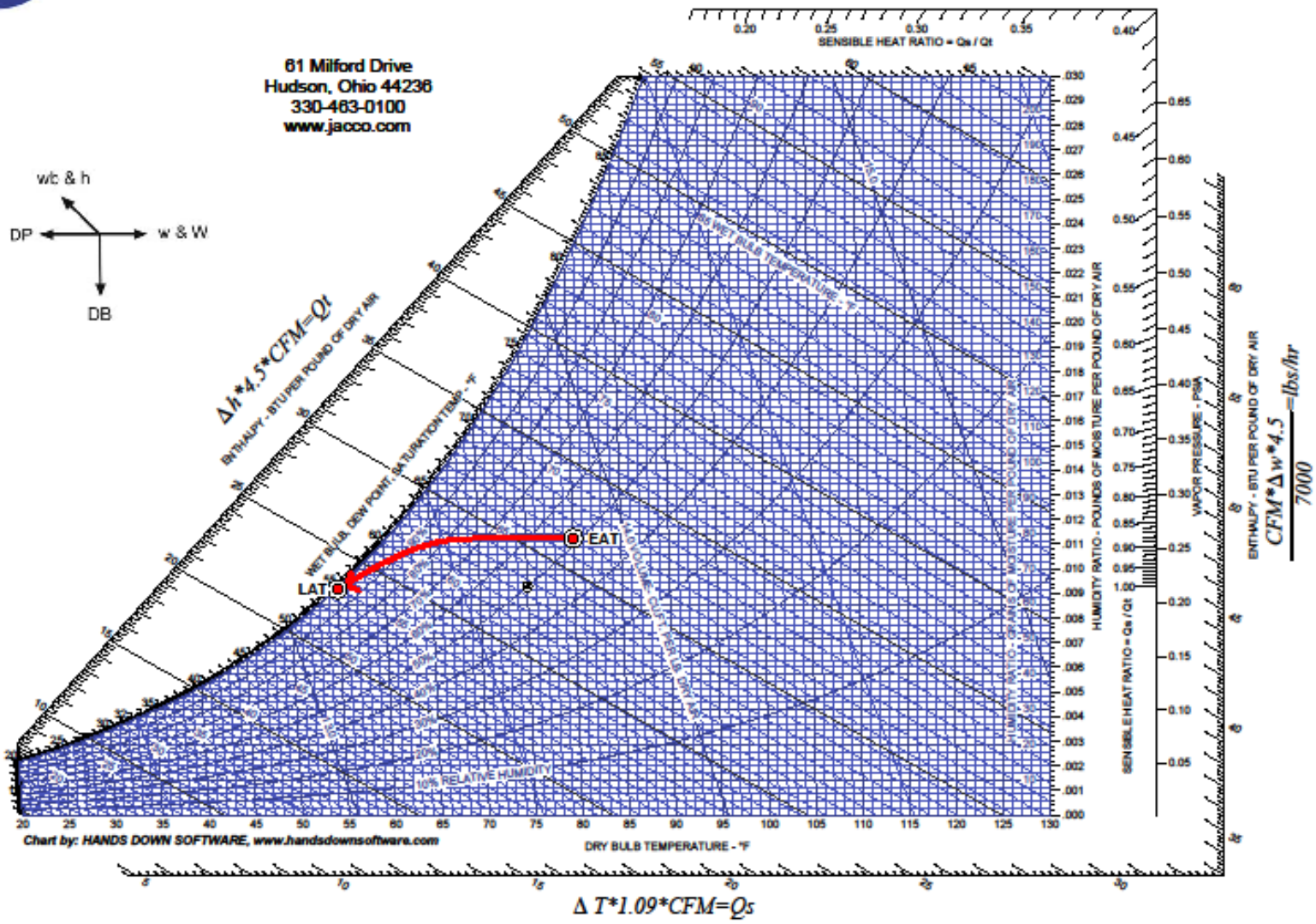


C:\Users\jerryc\Desktop\Marketing - 2015 Seminars\Presentations\Psychrometrics\11-22-15 Sensible Heating.hdd

Total Cooling Cycle

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

Total Cooling



C:\Users\jerryc\Desktop\Marketing - 2015 Seminars\Presentations\Psychrometrics\11-22-15 Total Cooling.hdd

Wind Chill

Hands Down Software - 1108 Olde Bridge Road - Edmond, OK 73034 - Phone/Fax (405) 844-6314 - www.handsdownsoftware.com

WINDCHILL TEMPERATURE & FROSTBITE CHART

Frostbite Times: 30 Minutes 10 Minutes 5 Minutes

		Temperature (°F)																	
Wind (mph)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
	5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
	10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
	15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
	20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
	25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
	30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
	35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
	40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
	45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
	50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
	55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
	60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Note: Reference source is the National Weather Service and the National Oceanic and Atmospheric Administration.

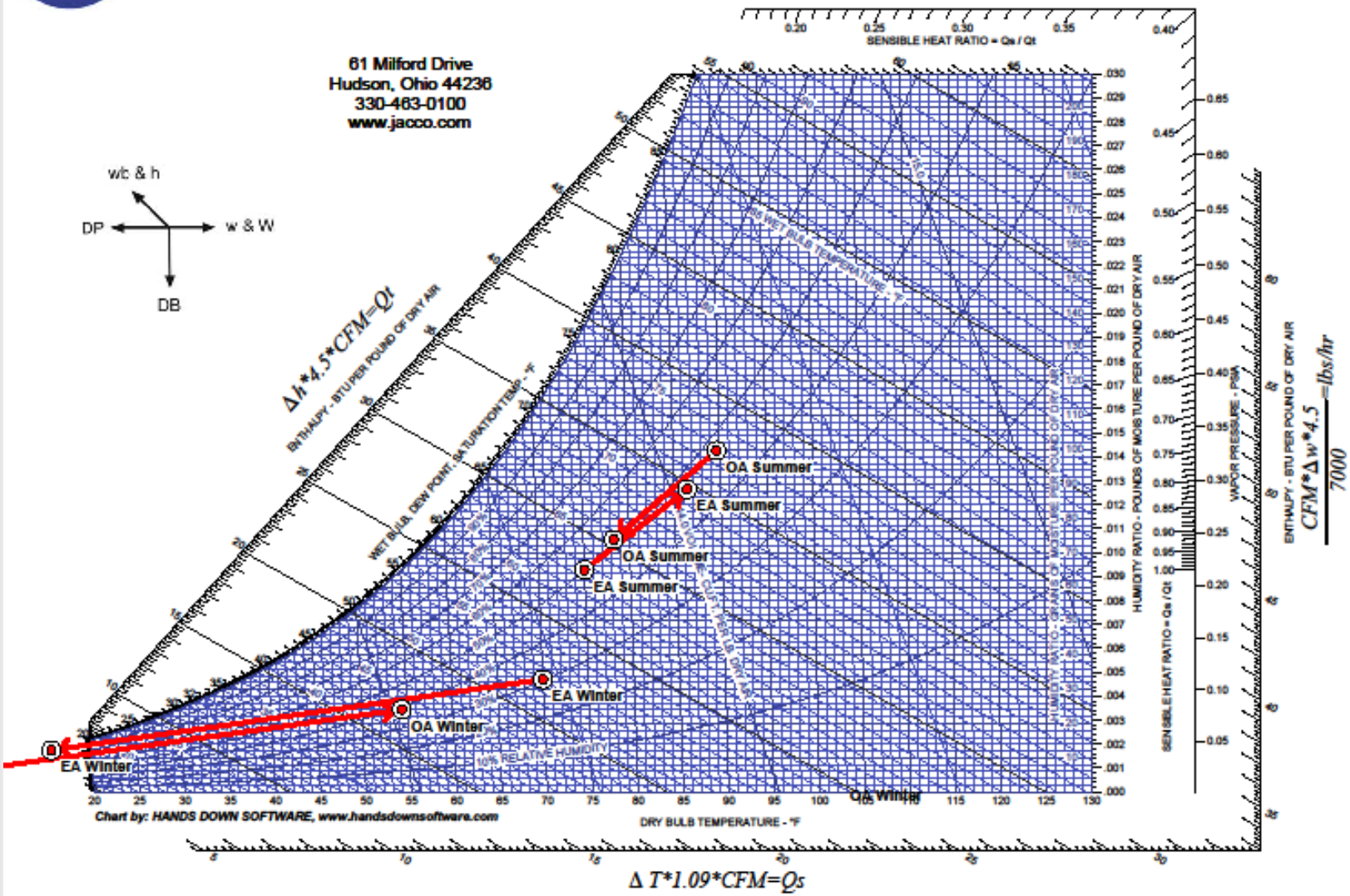
HDPsyChart - Psychrometric Analysis - Professional Edition

JACCO

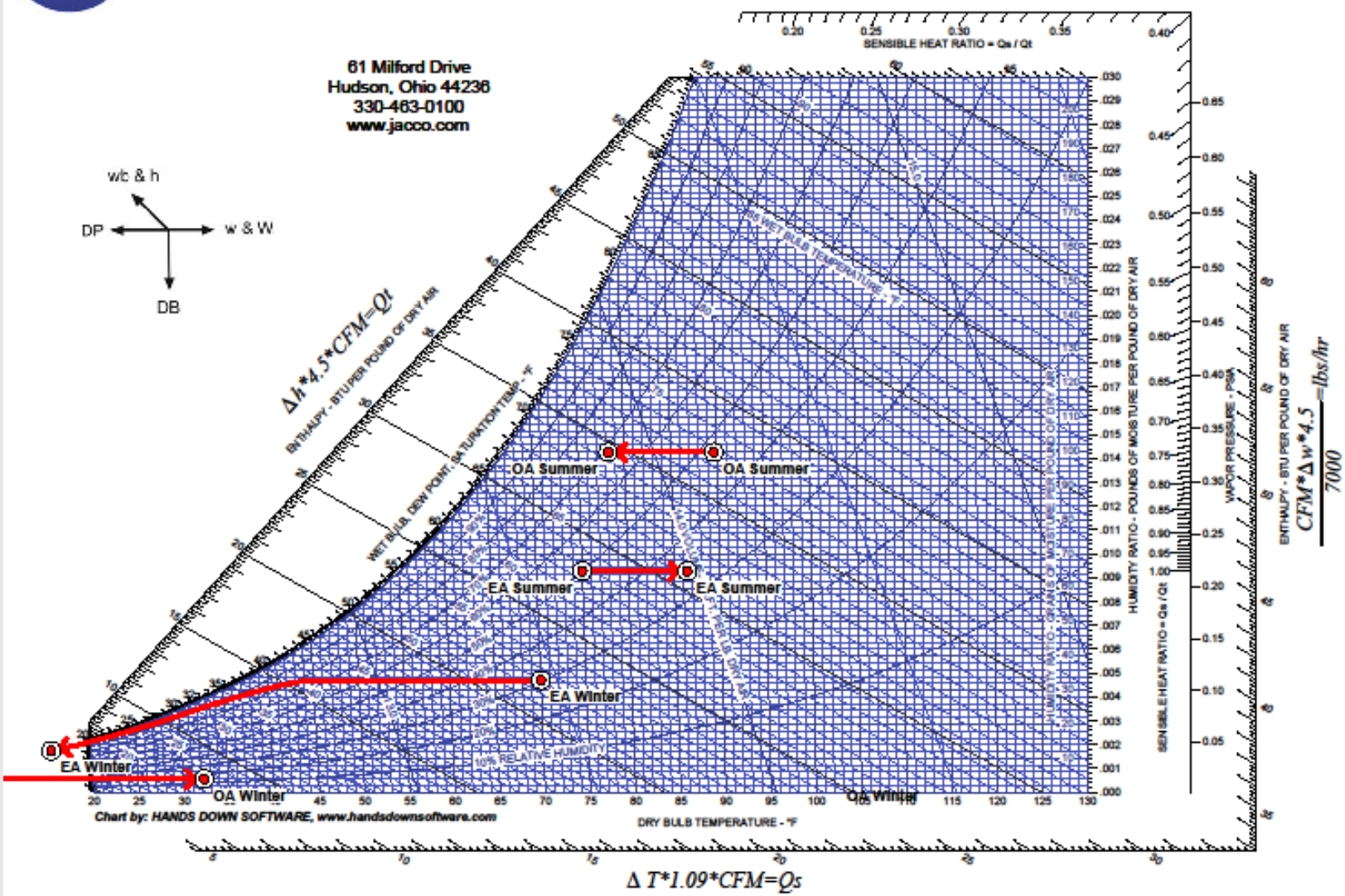
Applications – Heat Recovery

- Anything above 30% OA

Enthalpy Heat Wheel

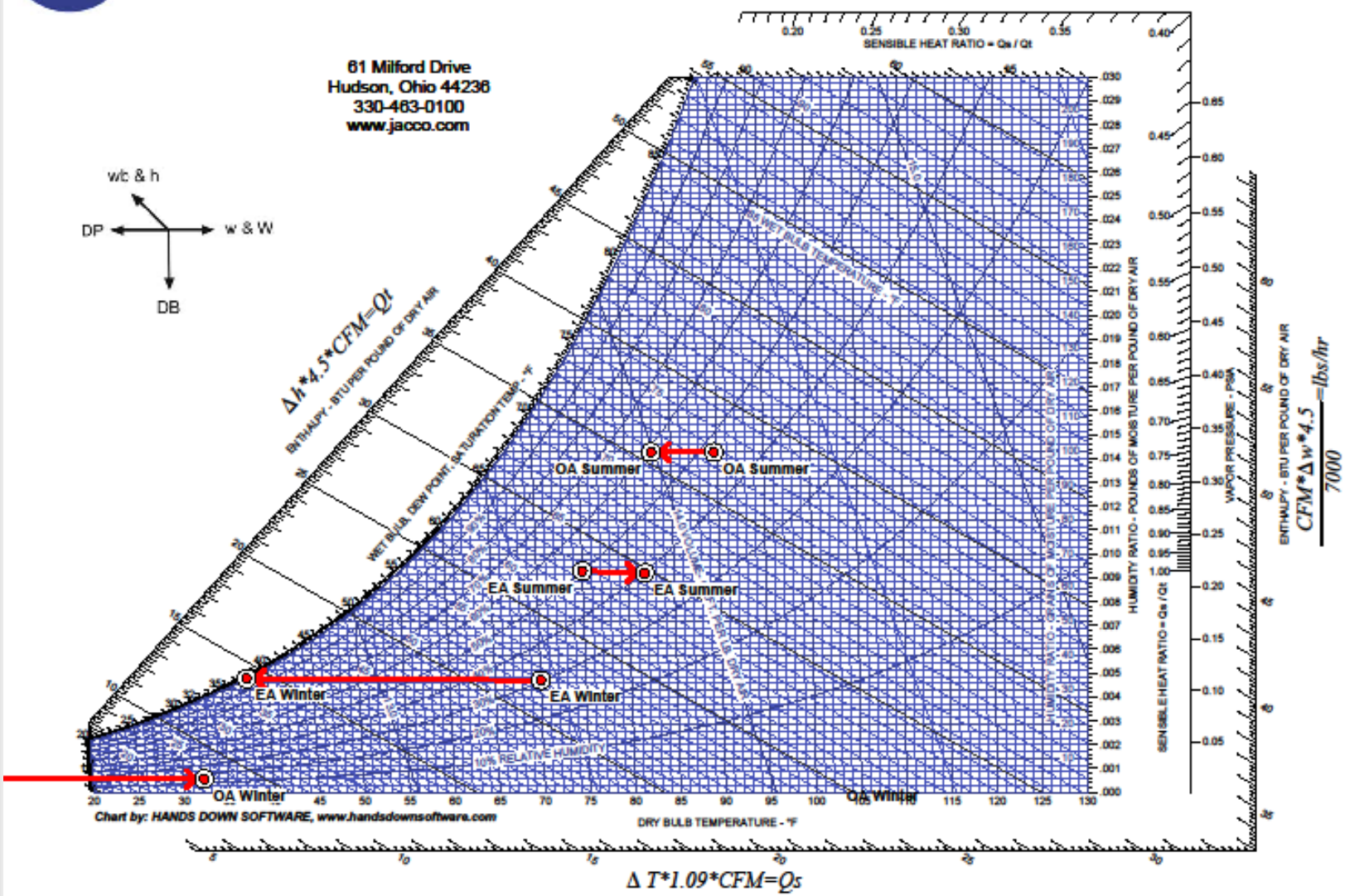


Sensible Heat Wheel



File Not Saved

Heat Pipe/Plate



File Not Saved

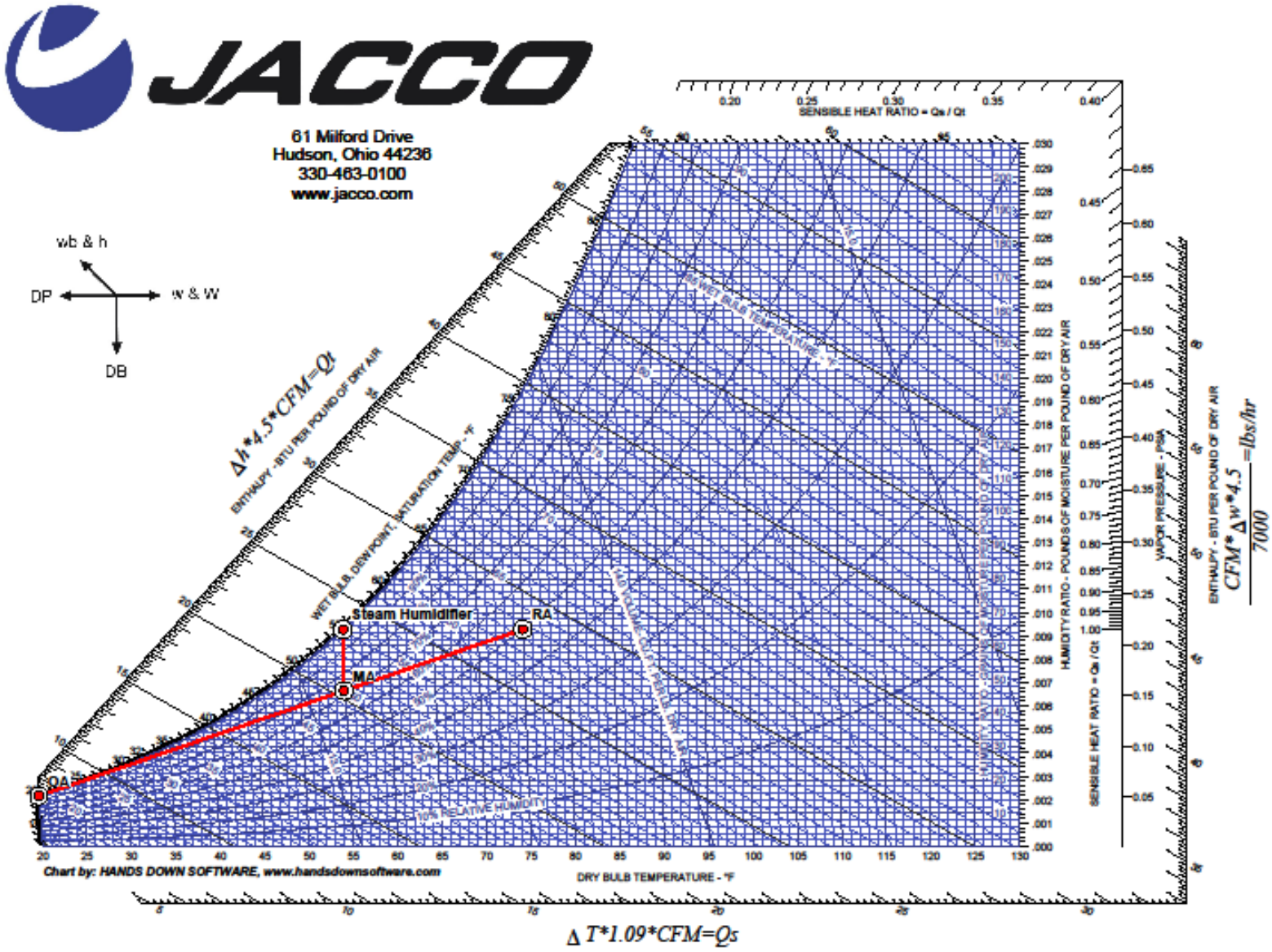
Applications – Humidification

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

JACCO

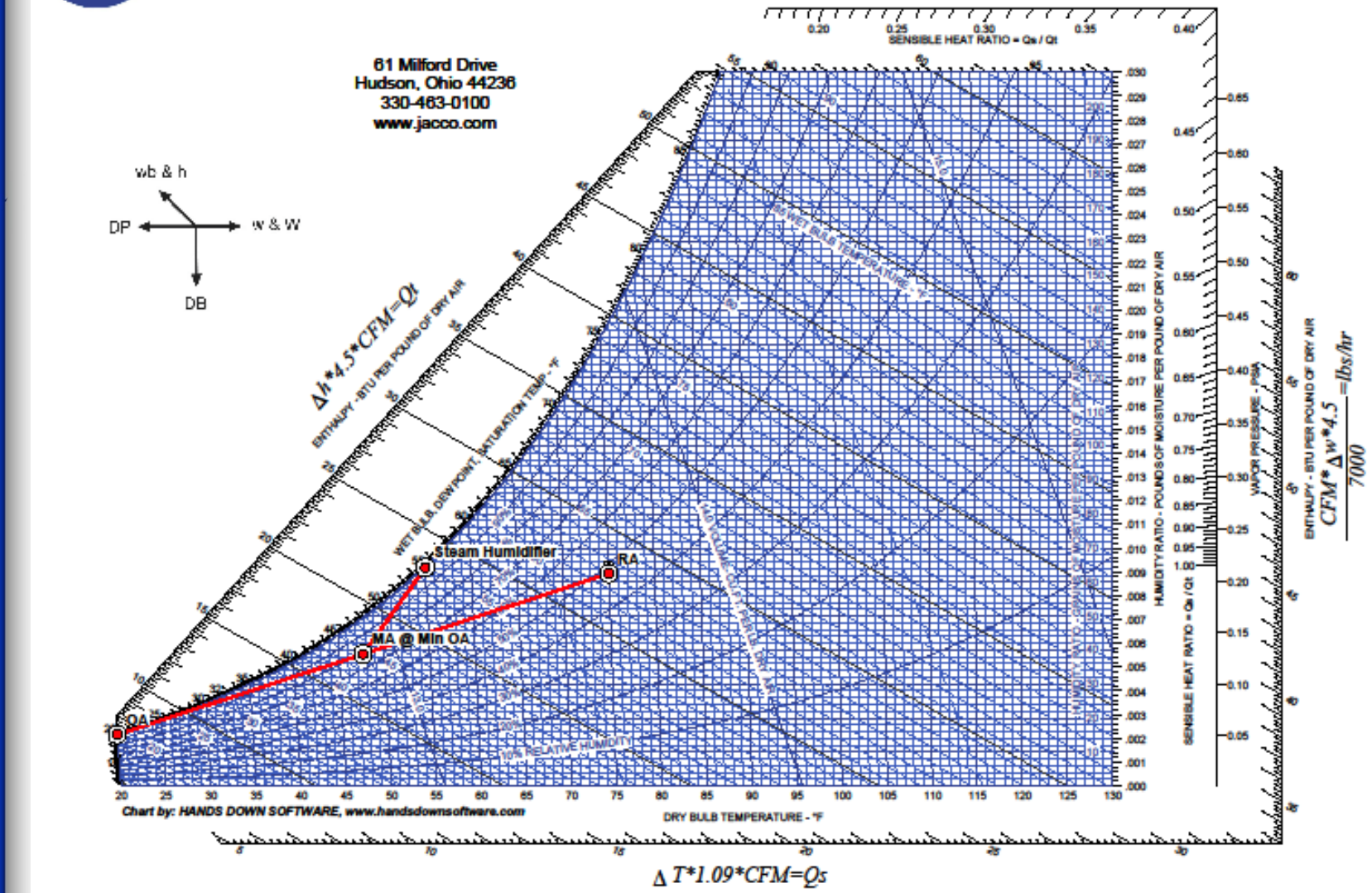
Steam Humidification

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



File Not Saved

JACCO

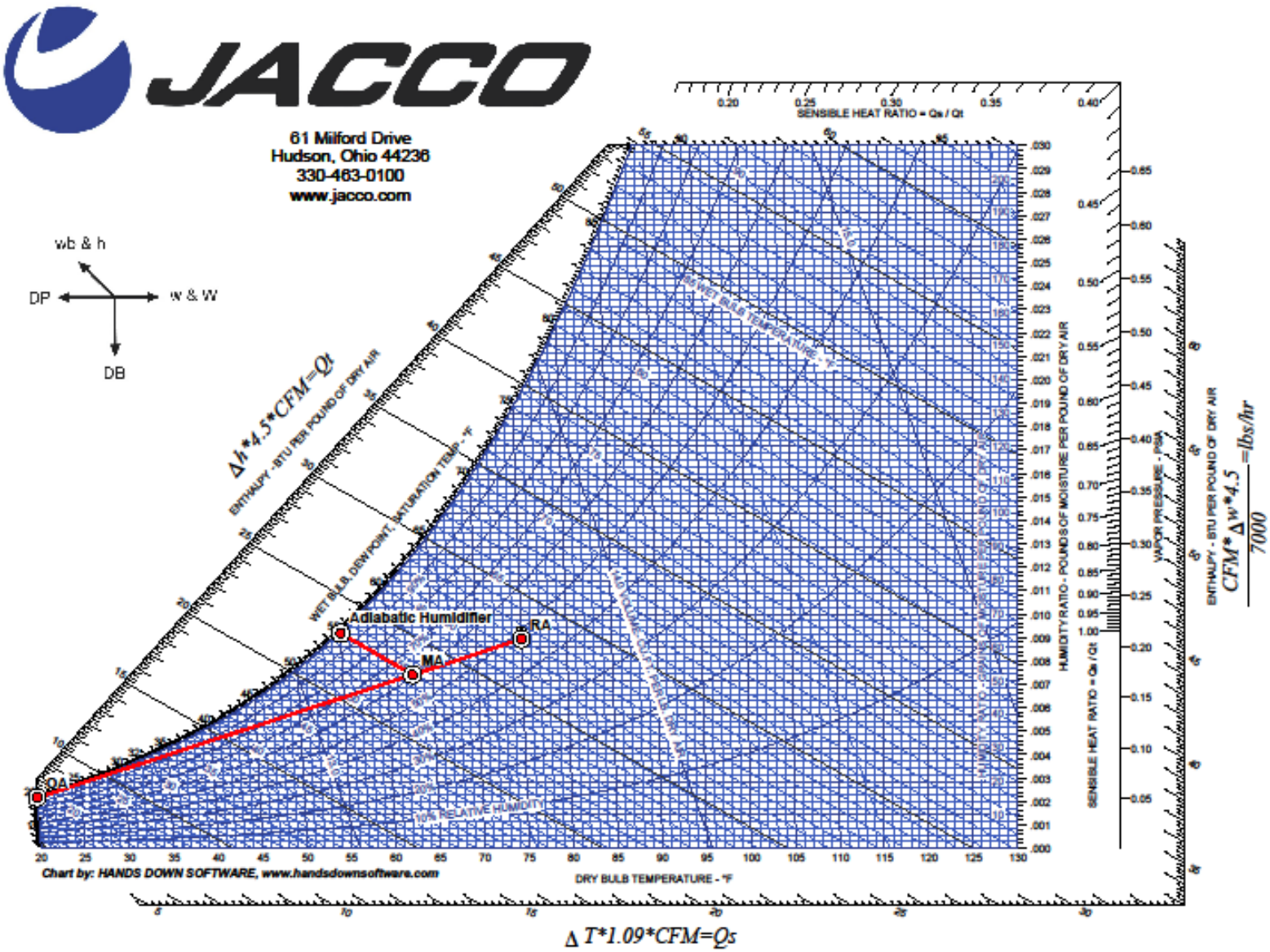


File Not Saved

Adiabatic Humidification

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

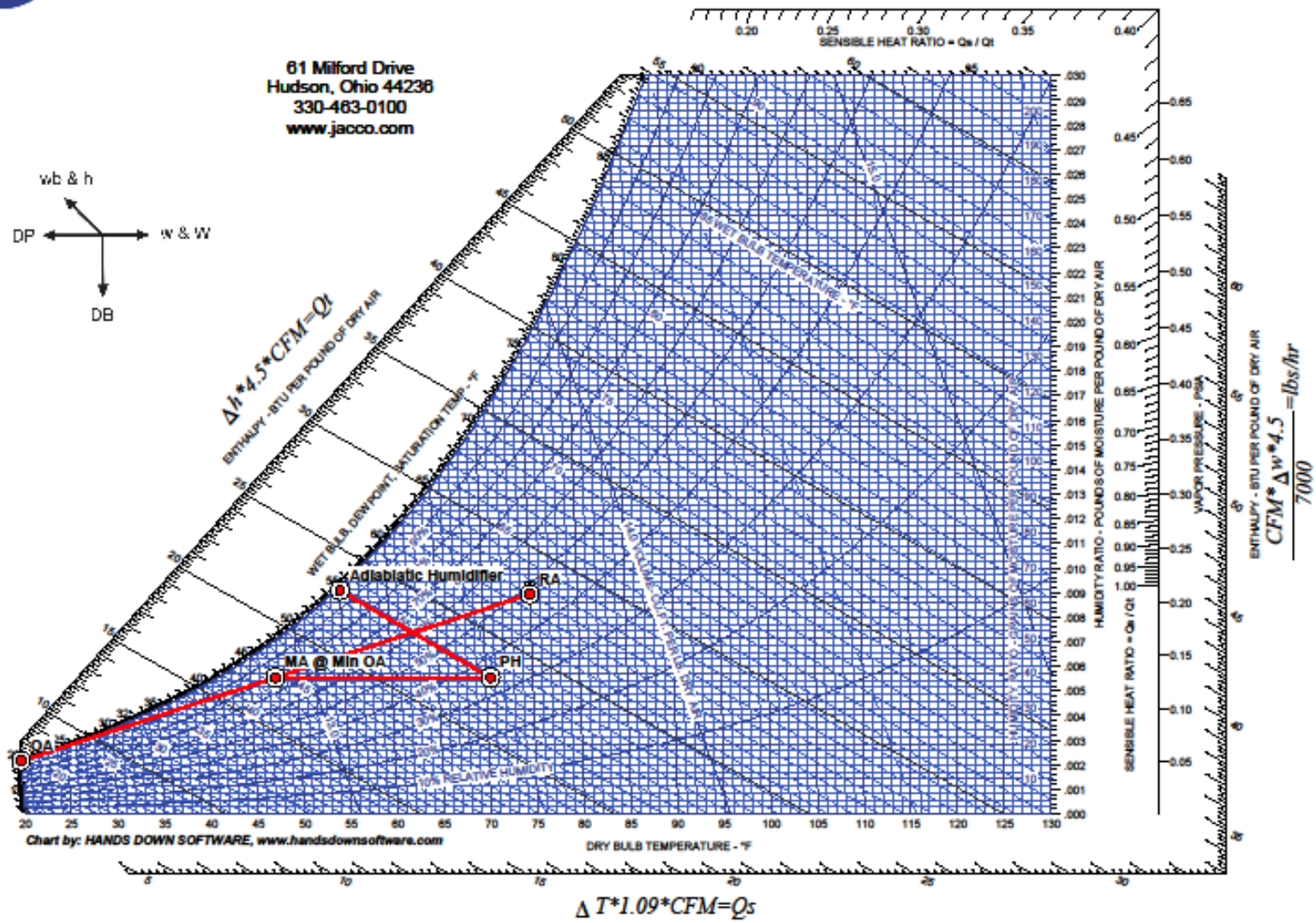
JACCO



File Not Saved

JACCO

61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com



Δ T*1.09*CFM=Qs

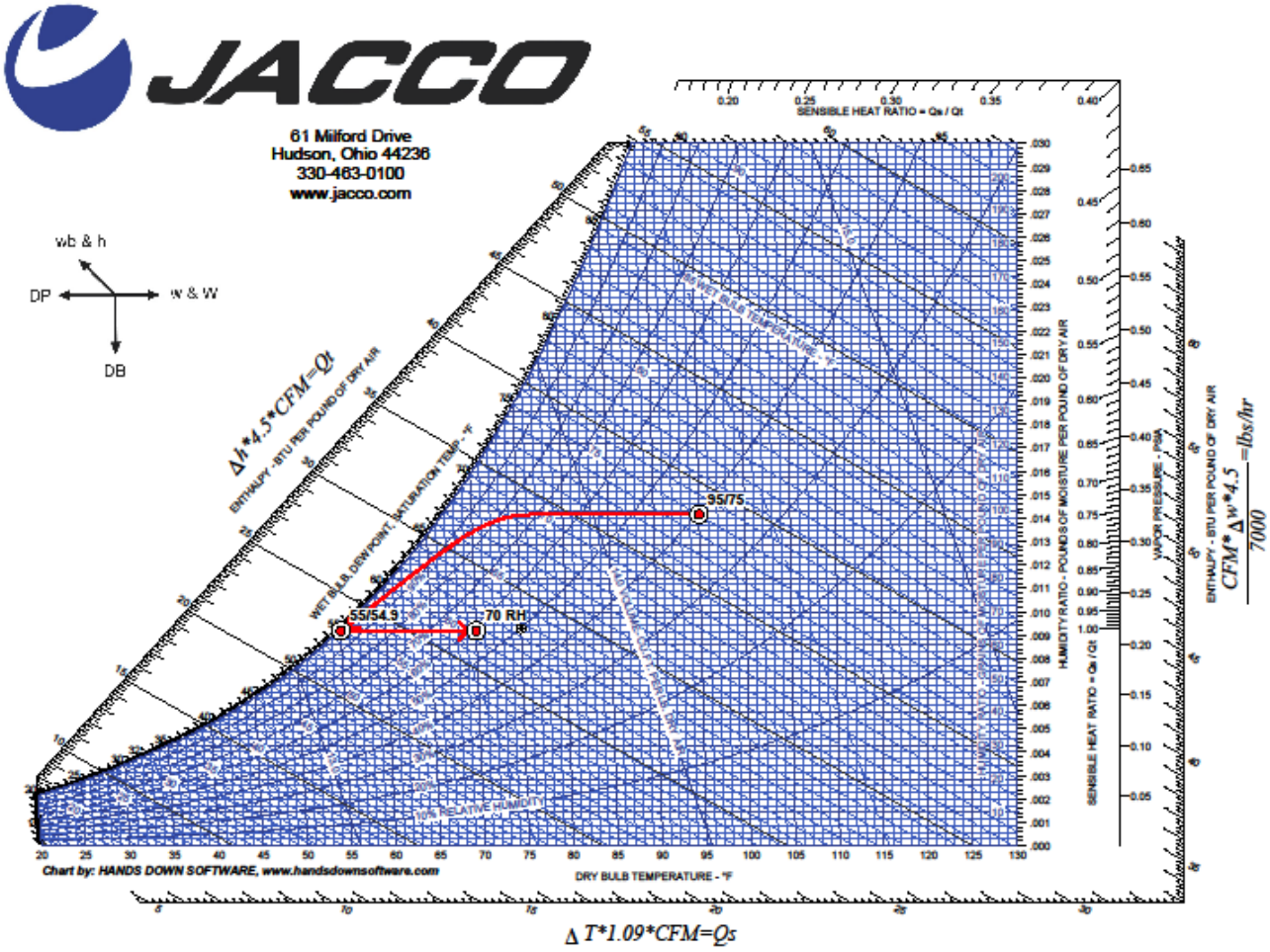
File Not Saved

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

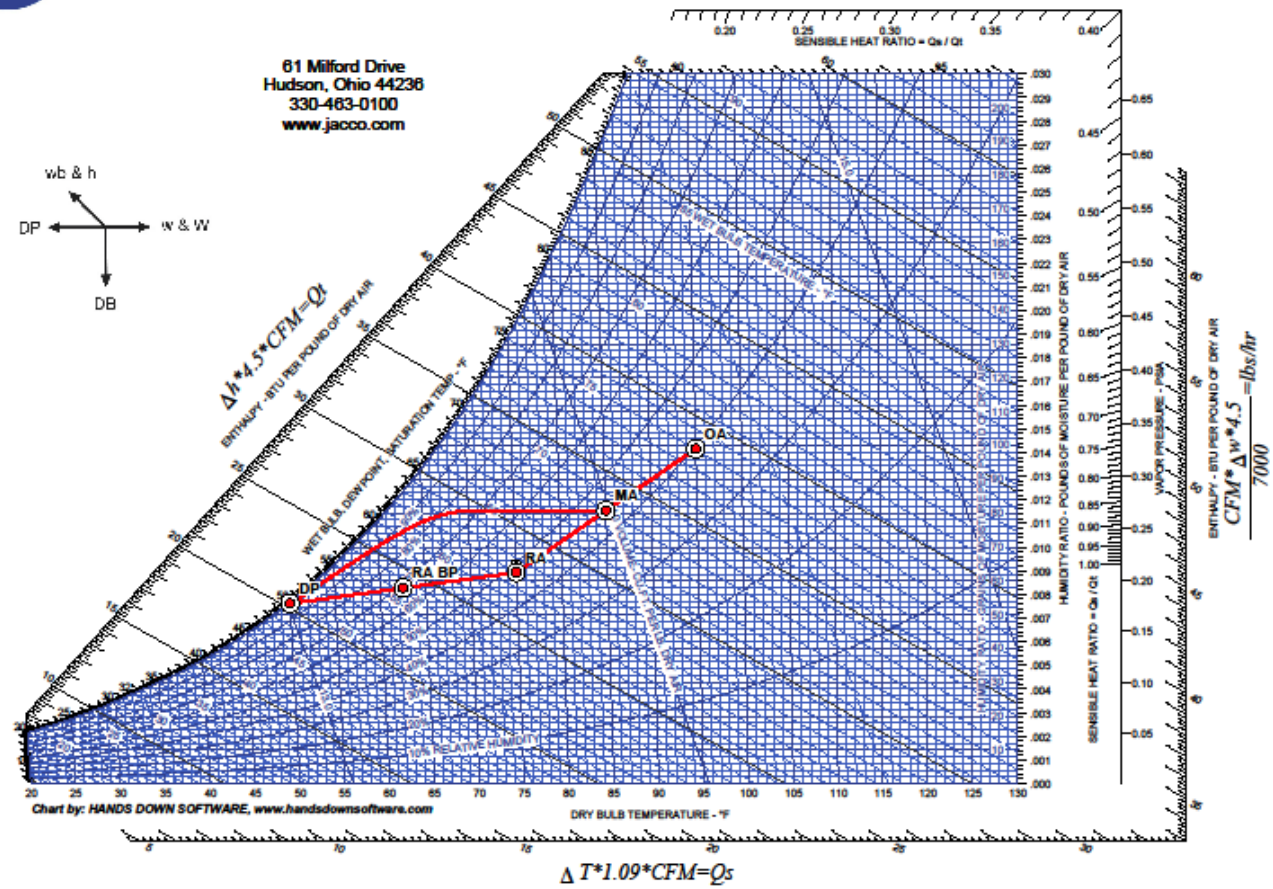
JACCO

Mechanical Dehumidification

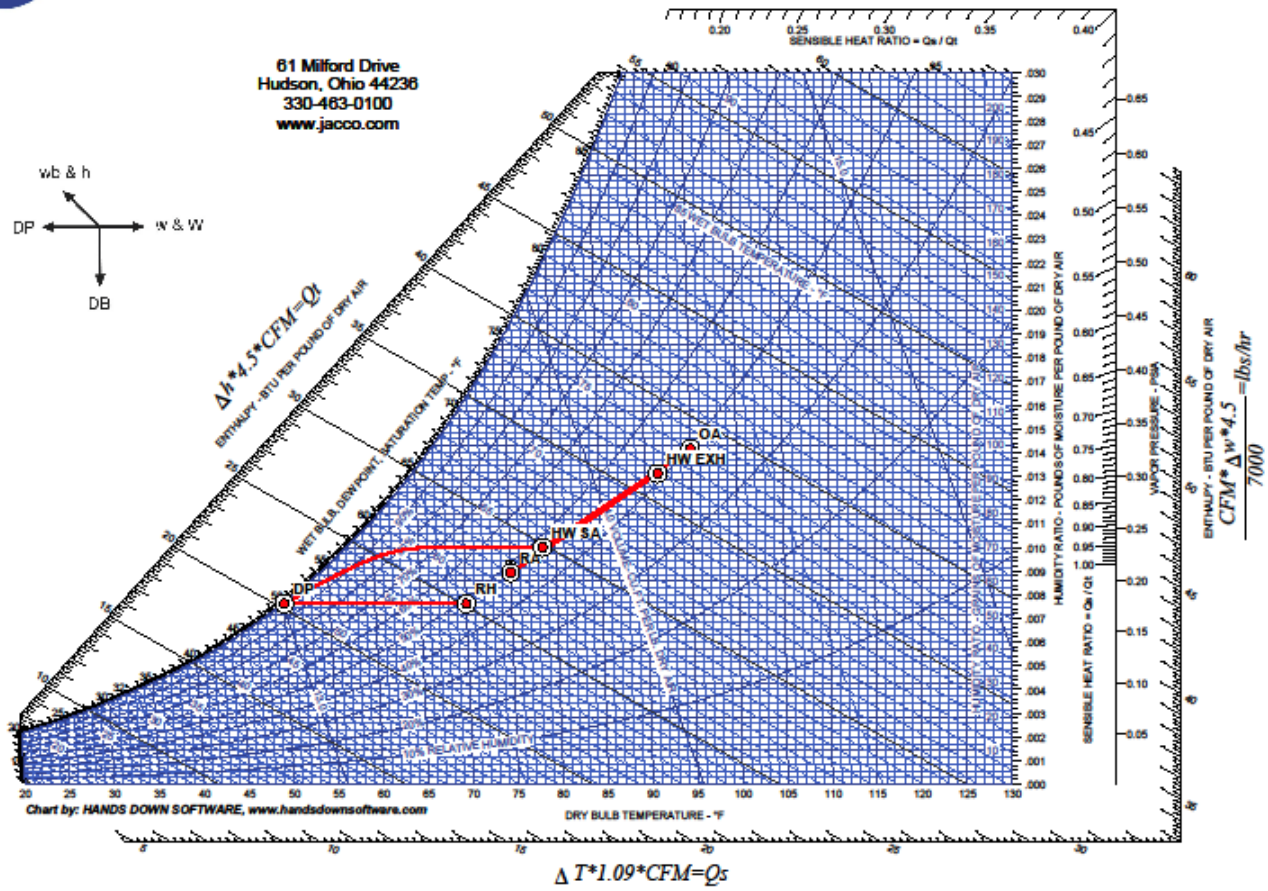


JACCO

Return Air Bypass

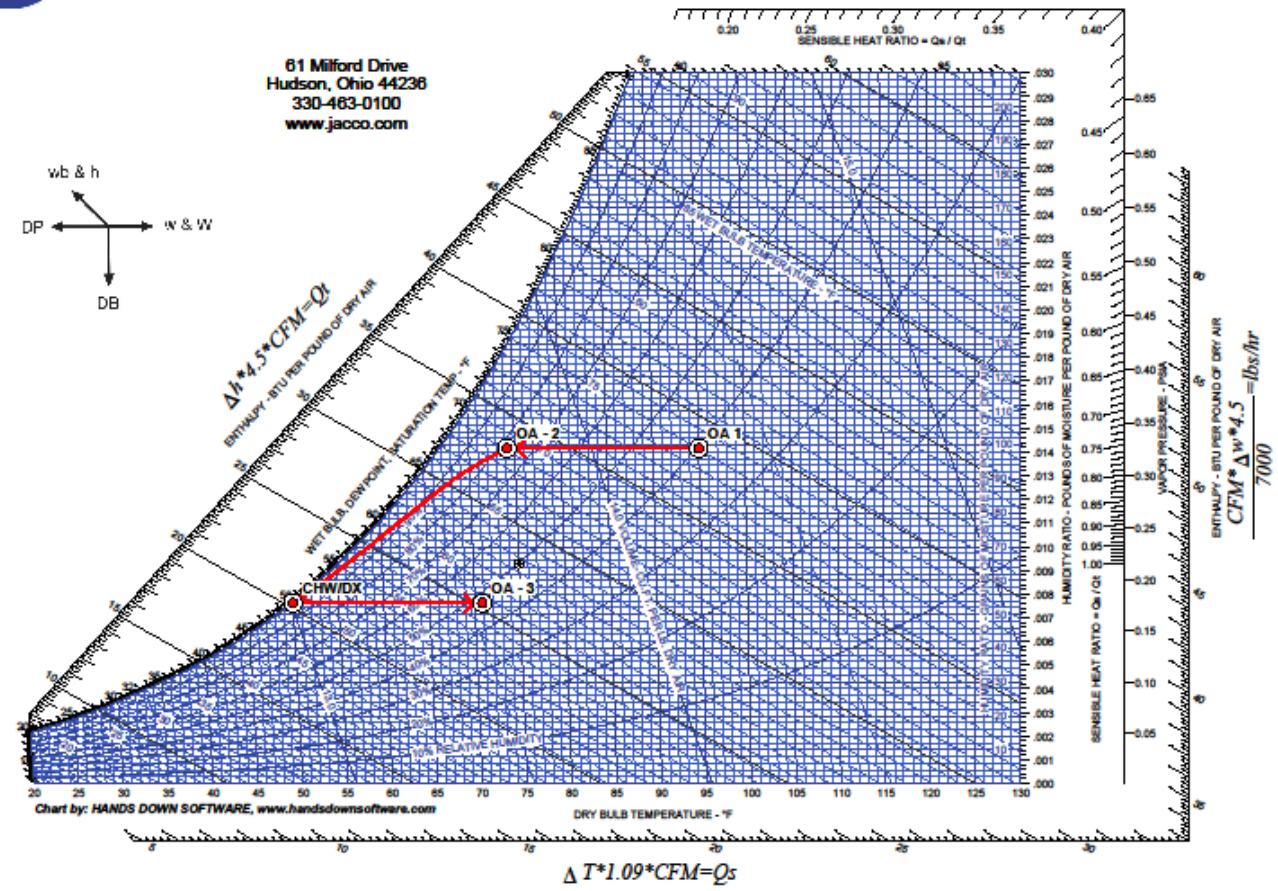


Heat Wheel

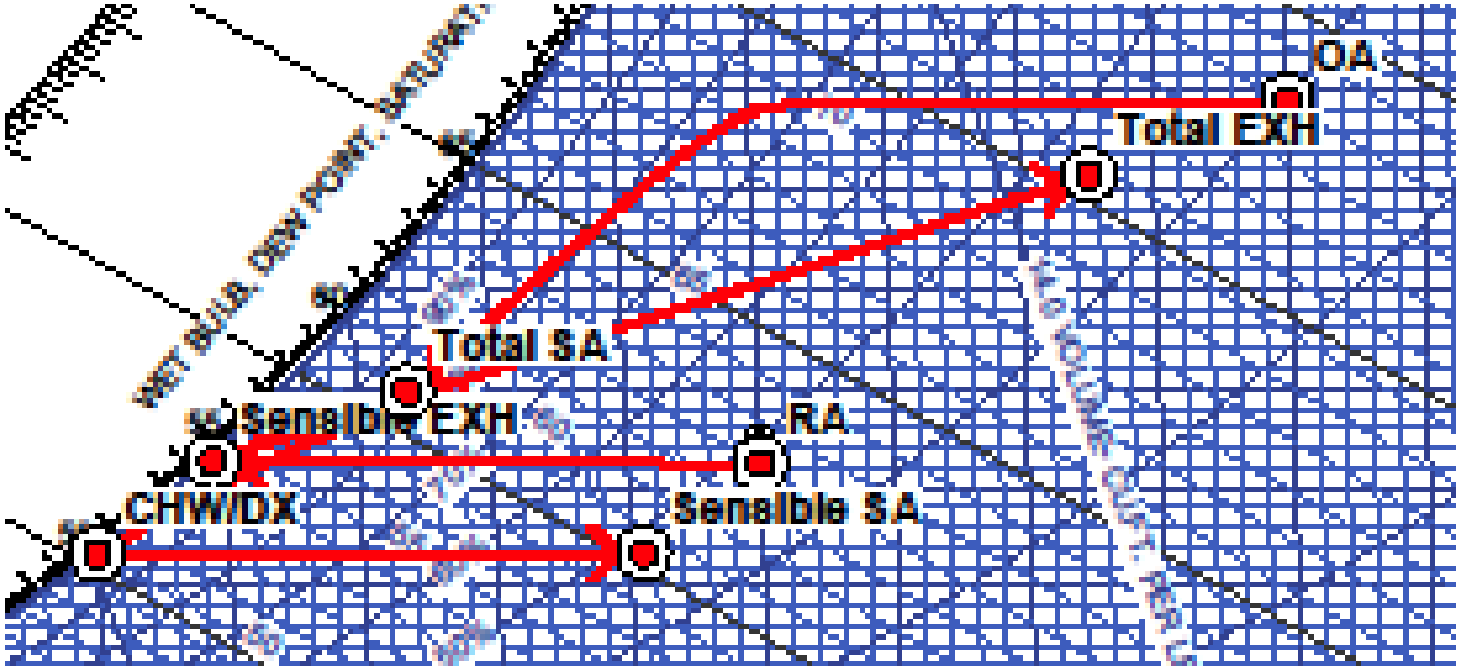


File Not Saved

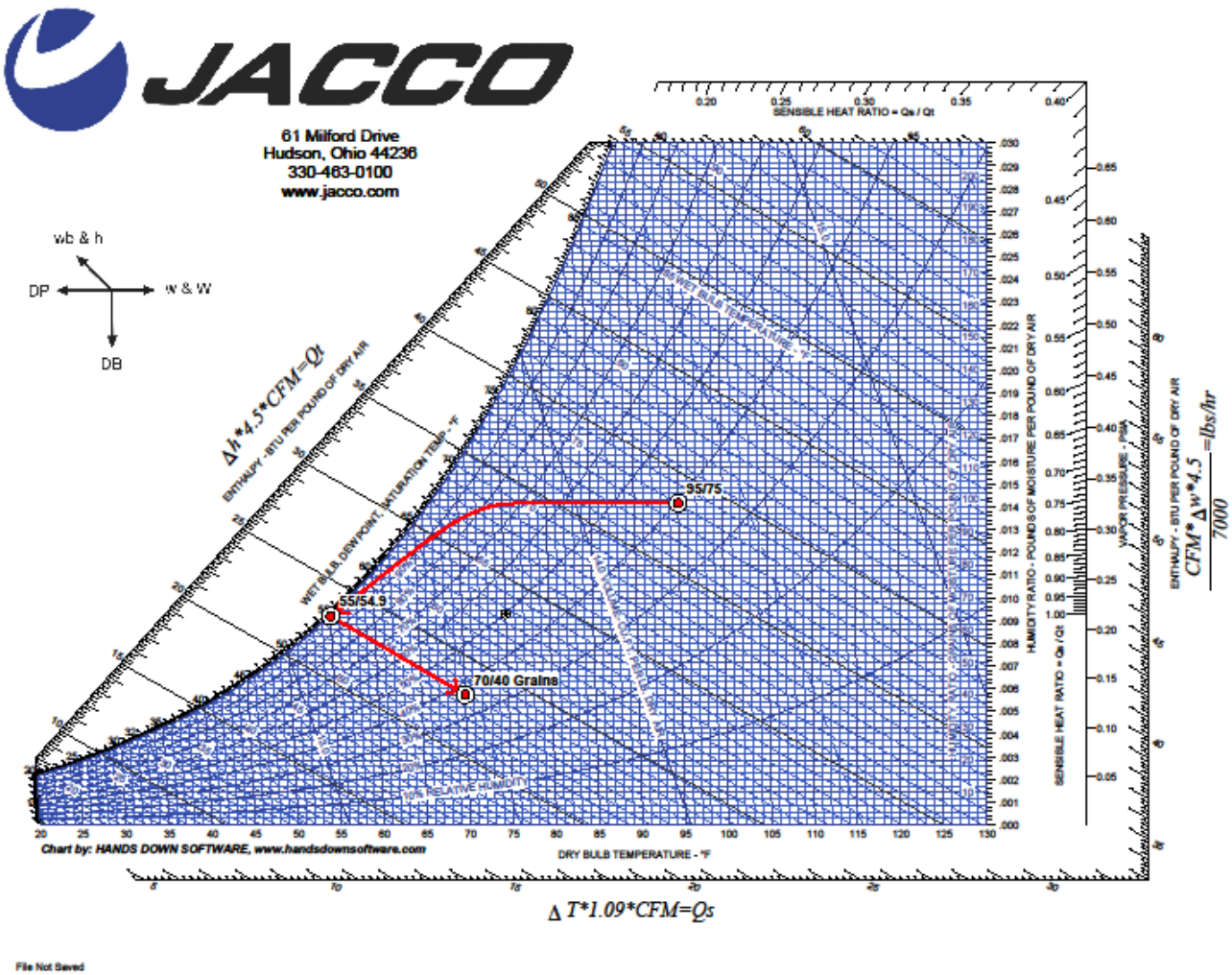
Single Pipe/Plate HX



Dual Wheel – Latent & Sensible

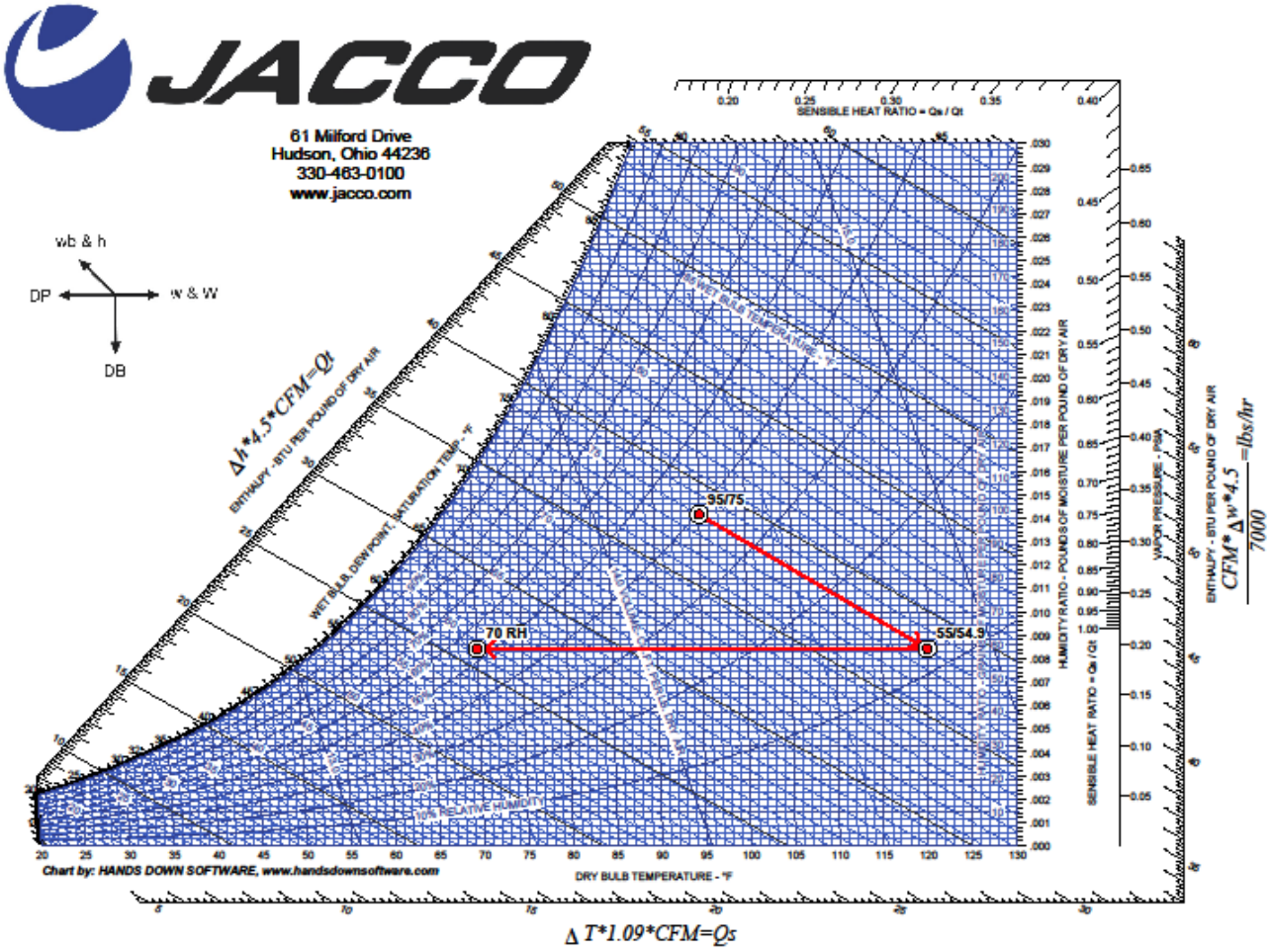


Desiccant Dehumidification Pre-Cool



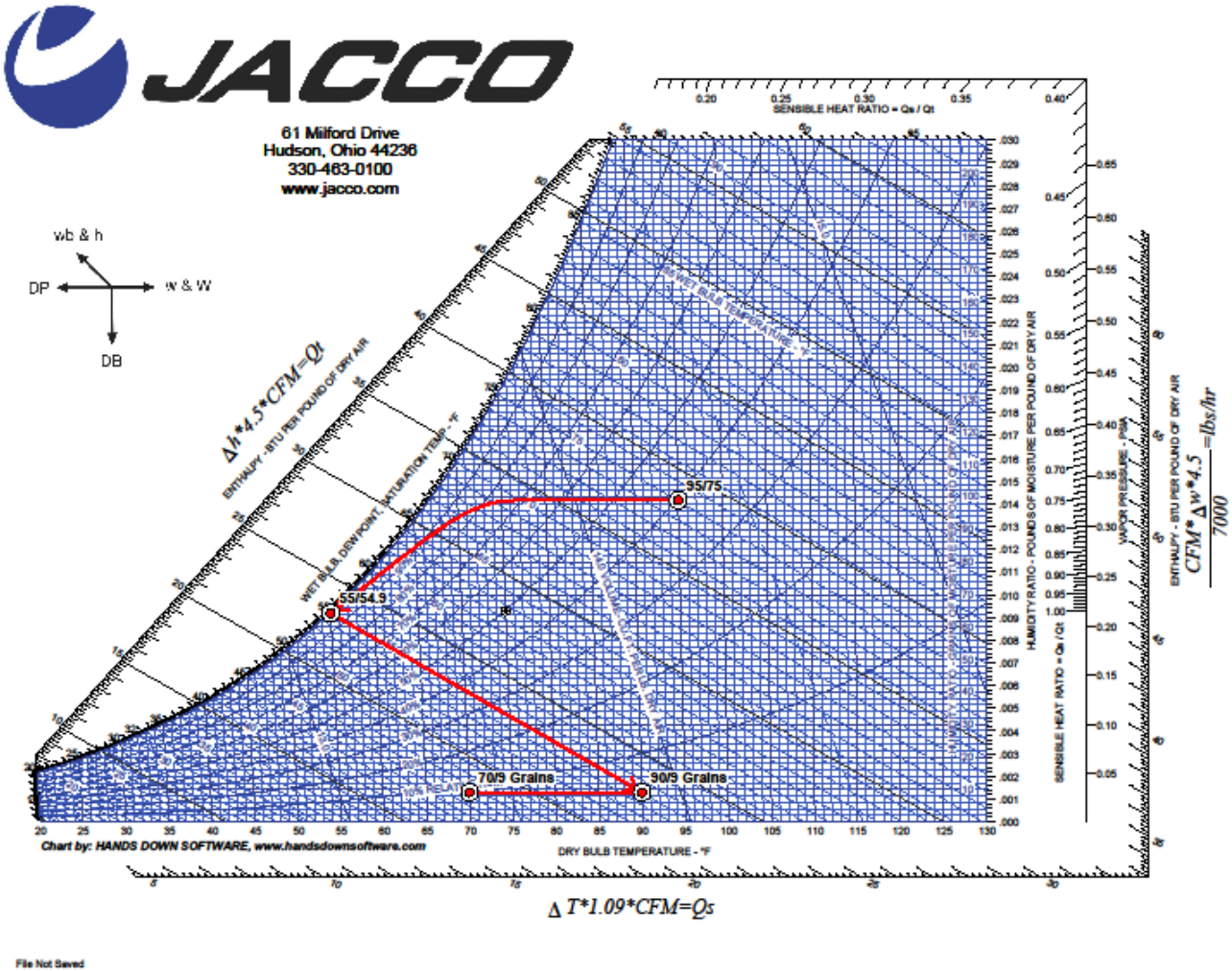
JACCO

Desiccant Dehumidification - Post-Cool



JACCO

Desiccant Dehumidification, Pre & Post-Cool



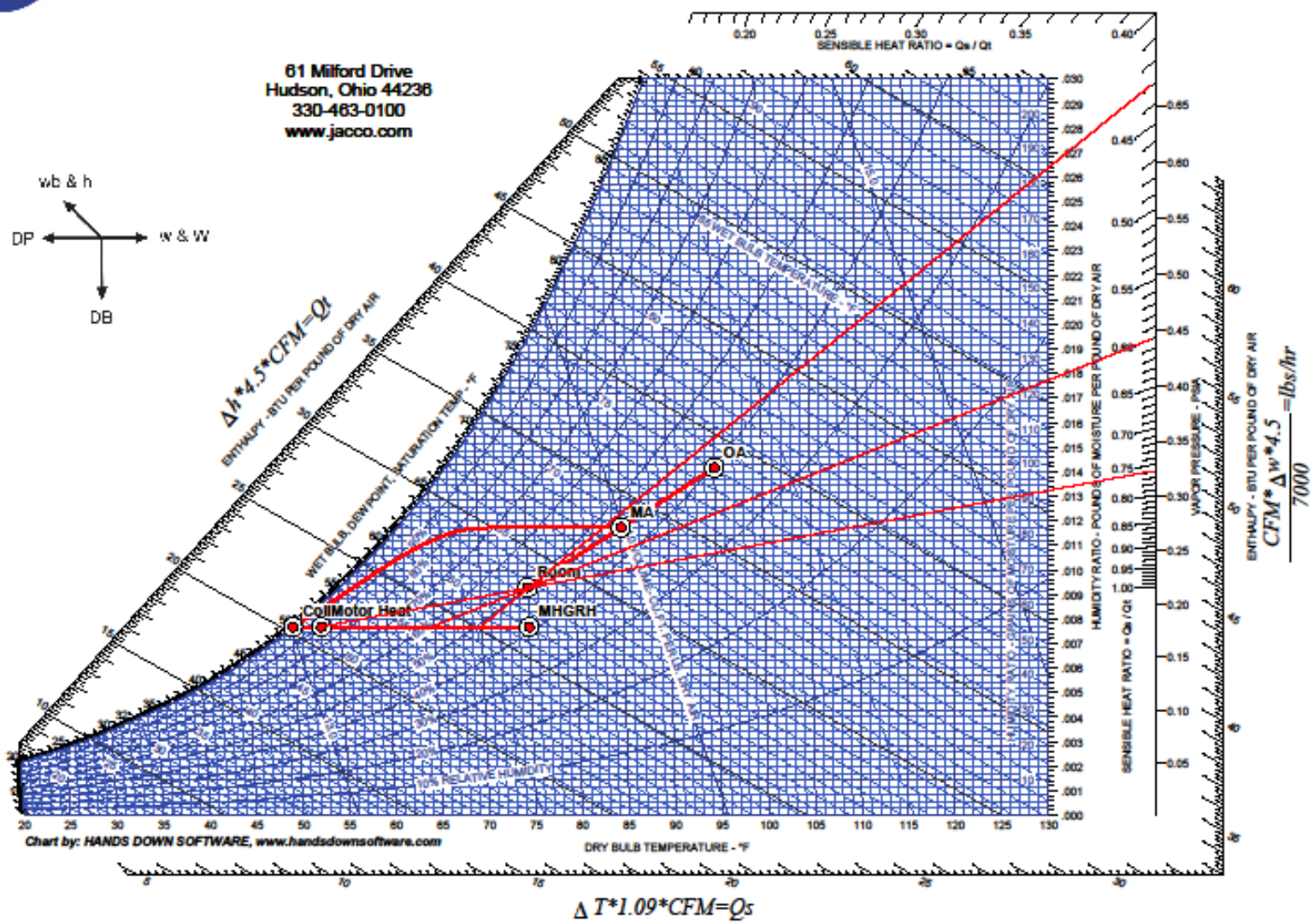
JACCO

Tight Temperature and Humidity Control

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

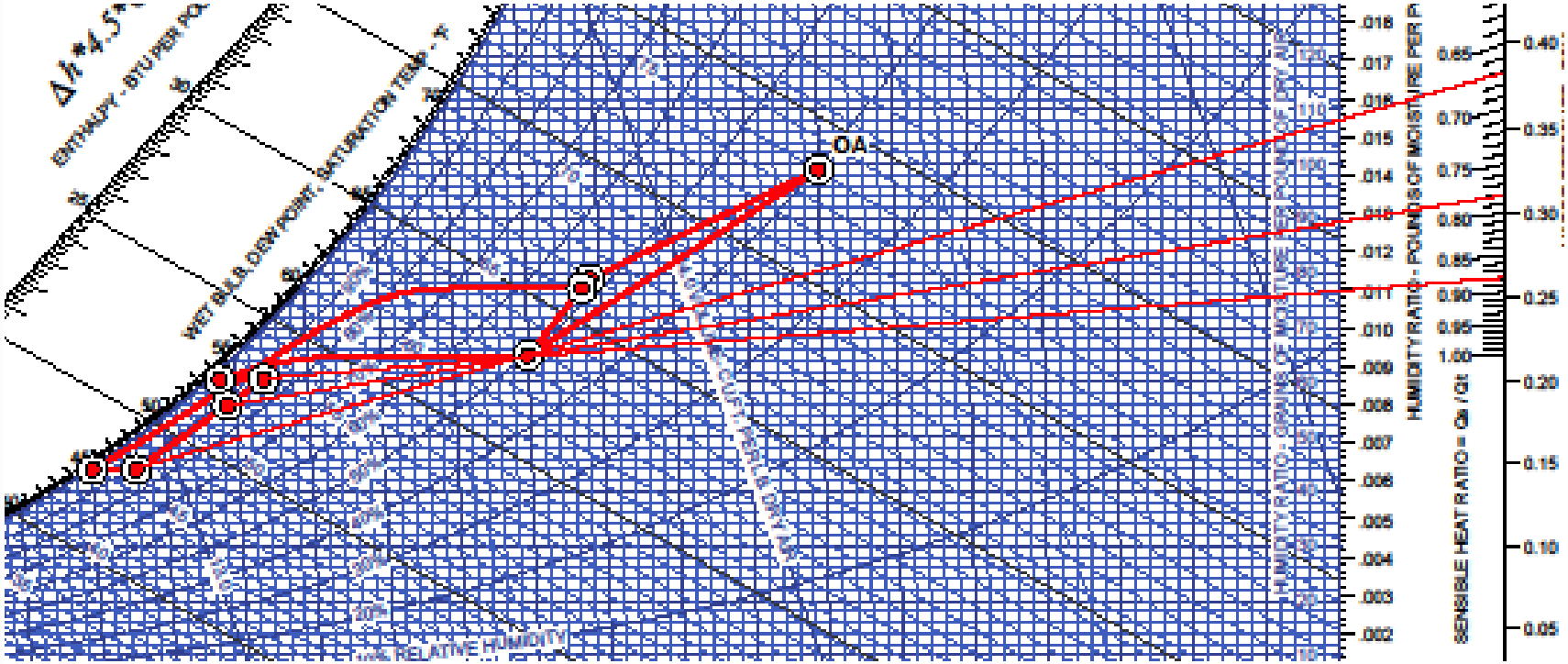
JACCO

JACCO



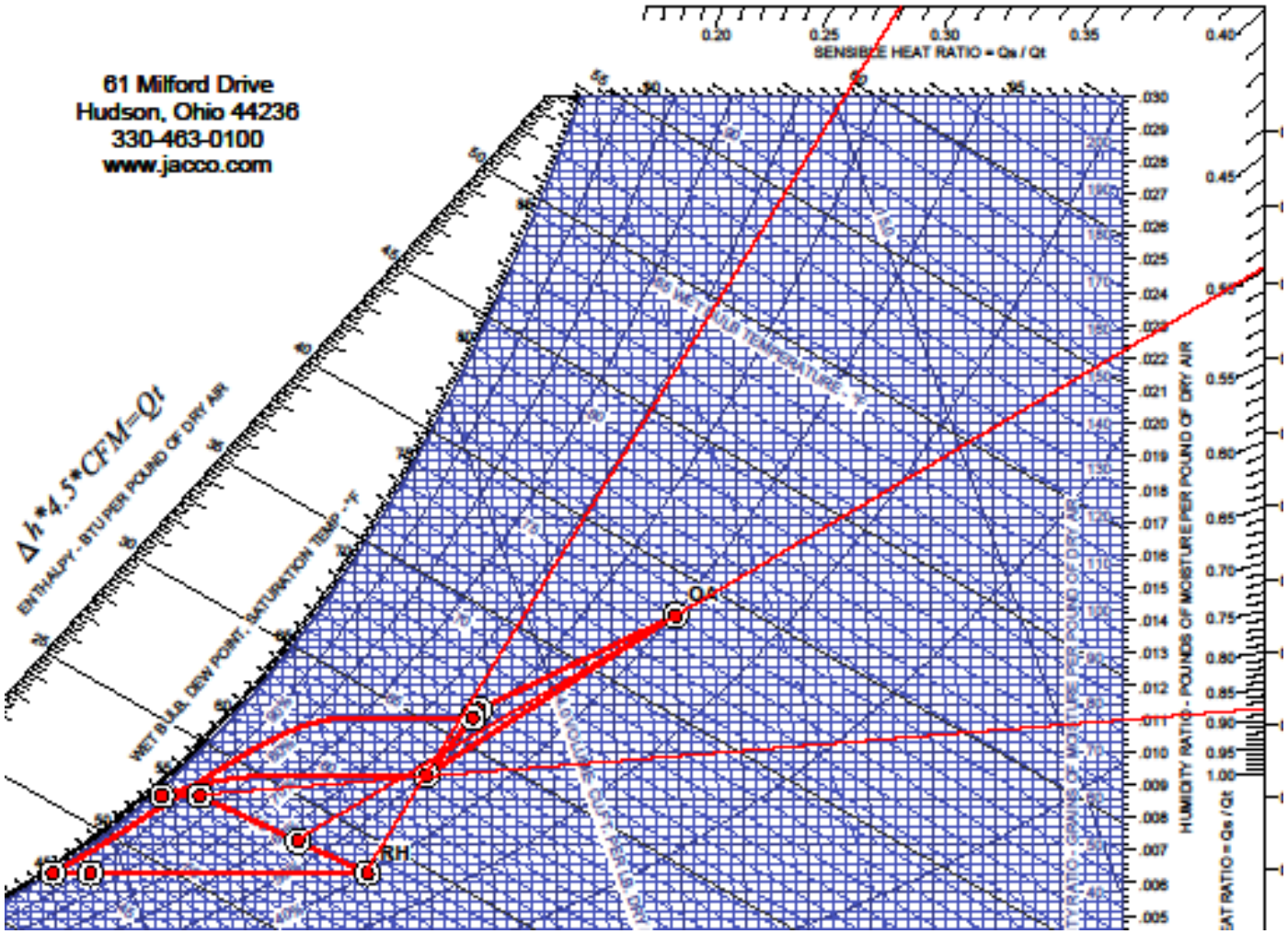
C:\Users\jacco\Desktop\Marketing - 2015 Seminars\Presentations\Psychrometrics\OOPS.hdd

Conquer & Divide for SHR



JACCO

Conquer & Divide for SHR



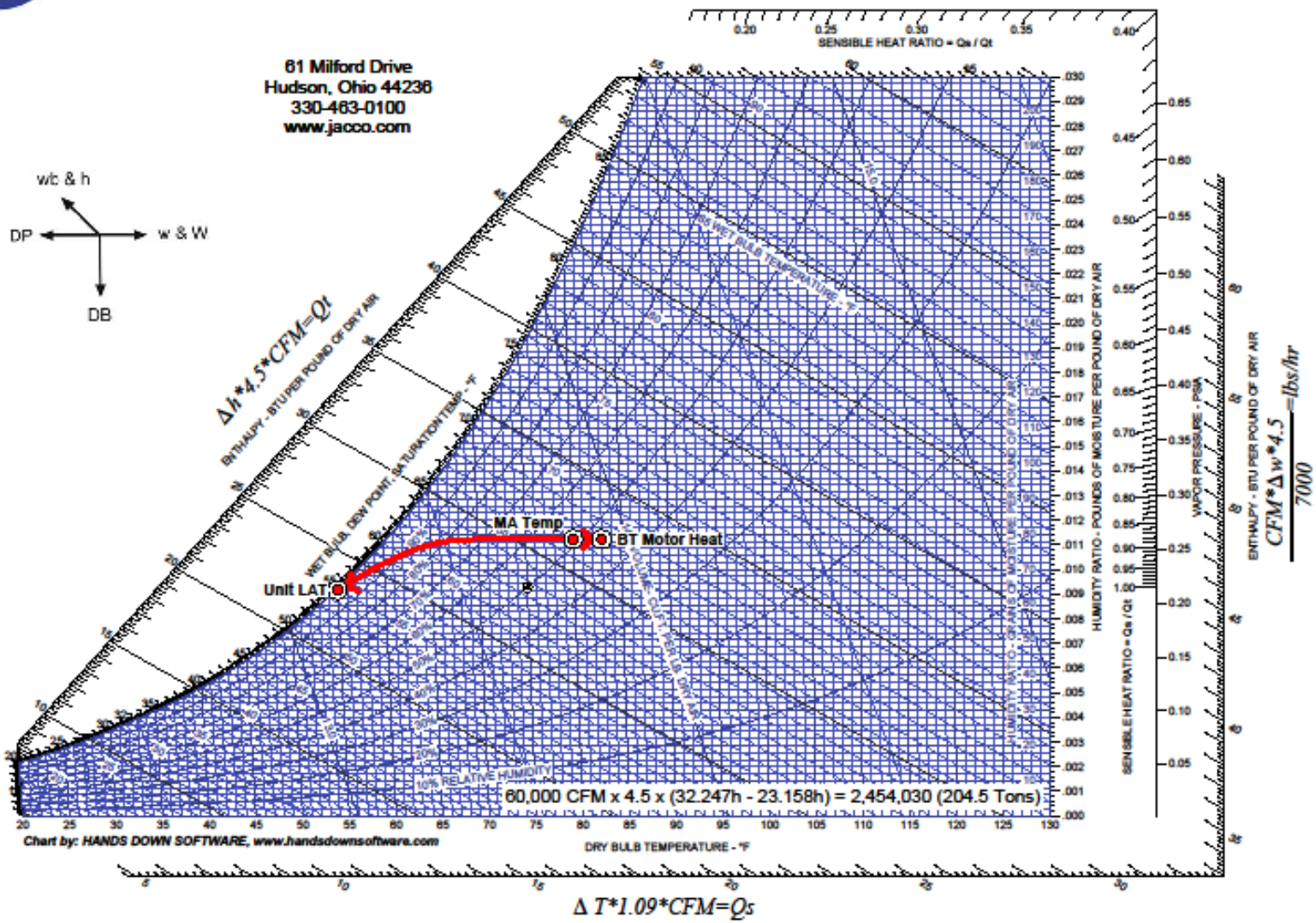
JACCO

Applications – Blow Through

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

JACCO

Blow Thru - 60,000 ft2 Bldg

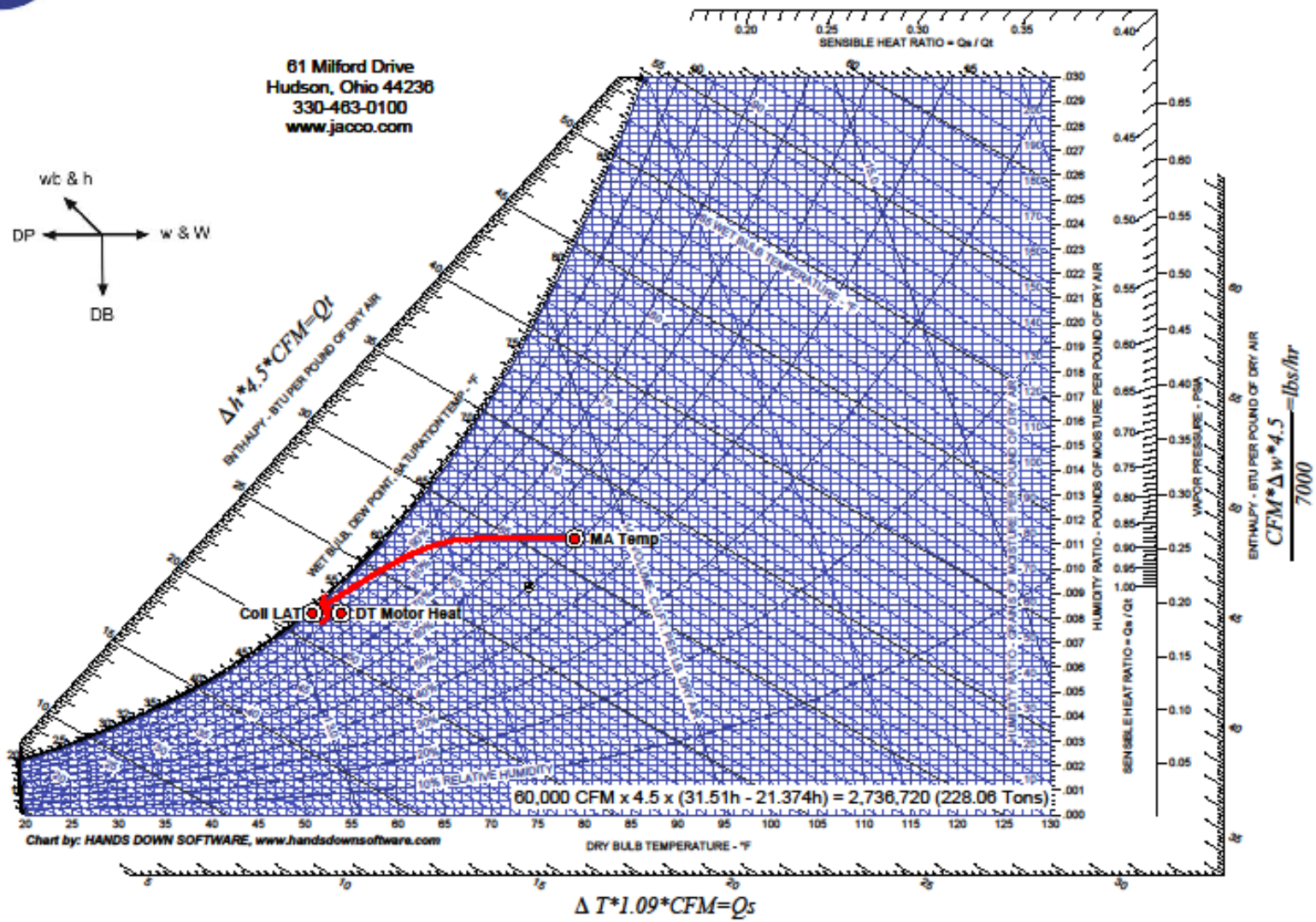


C:\Users\jerryc\Desktop\Marketing - 2015 Seminars\Presentations\Psychrometrics\11-22-15Blow Thru.hdd

Applications – Draw Through

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

Draw Thru - 60,000 ft2 Bldg

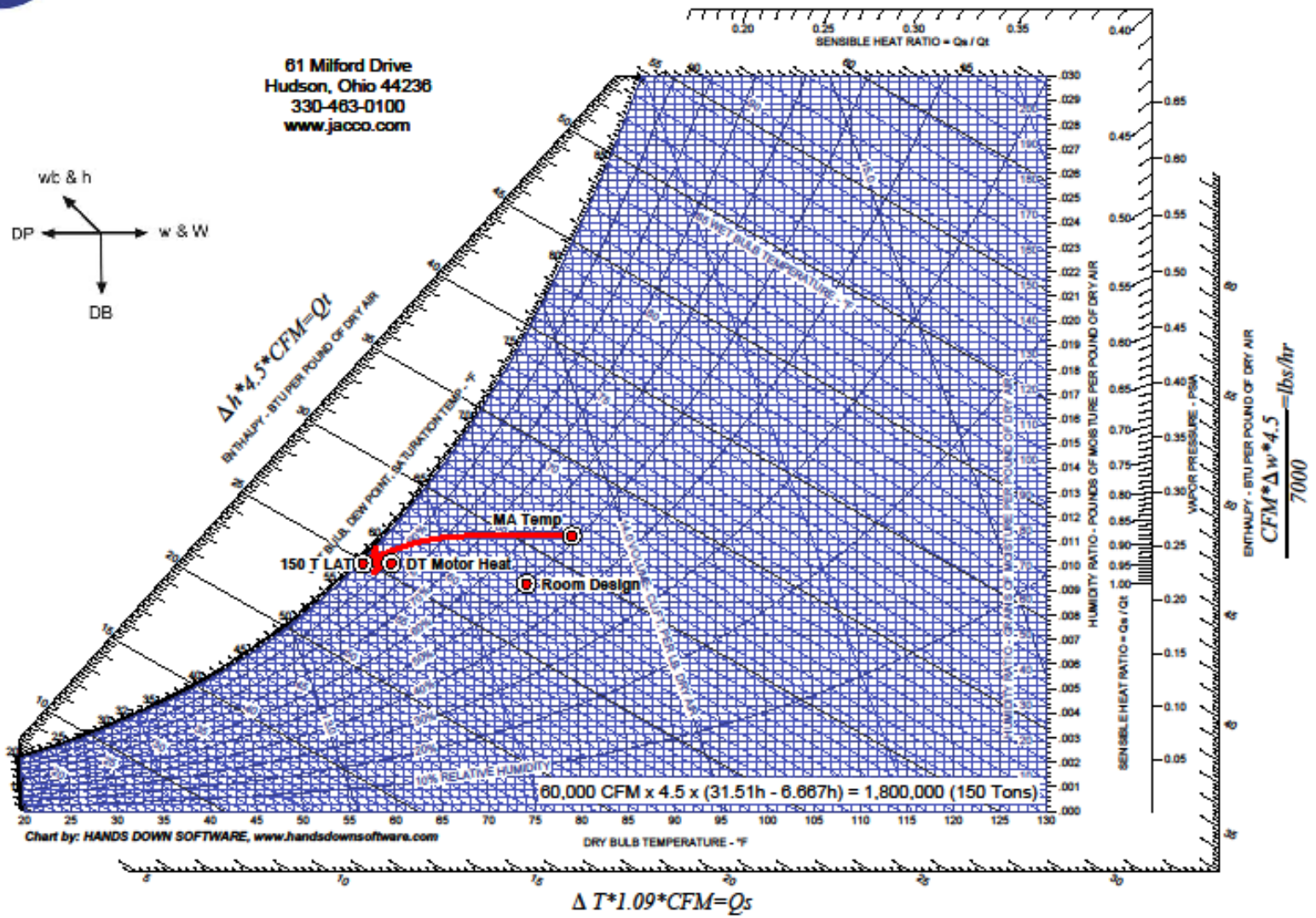


C:\Users\jerryc\Desktop\Marketing - 2015 Seminars\Presentations\Psychrometrics\11-22-15 Draw Thru.hdd

Applications – Draw Through

- 60,000 ft2 / 400 ft2 = 150 Tons
- Does this work?

150 Ton DT - 60,000 ft2 Bldg



C:\Users\jerryc\Desktop\Marketing - 2015 Seminars\Presentations\Psychrometrics\11-22-15 150T DT.hdd

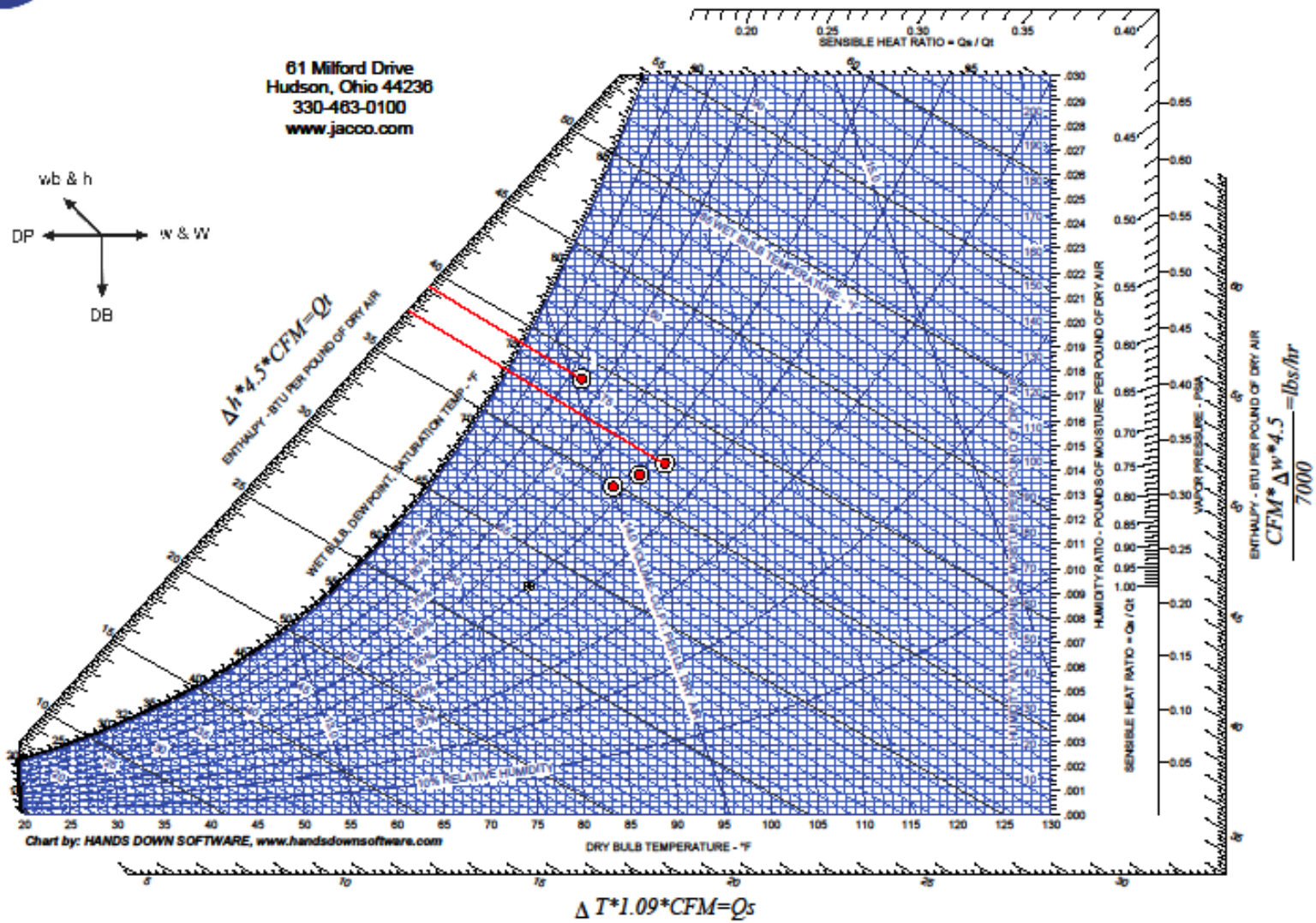
ASHRAE Data Sets

- 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.

JACCO

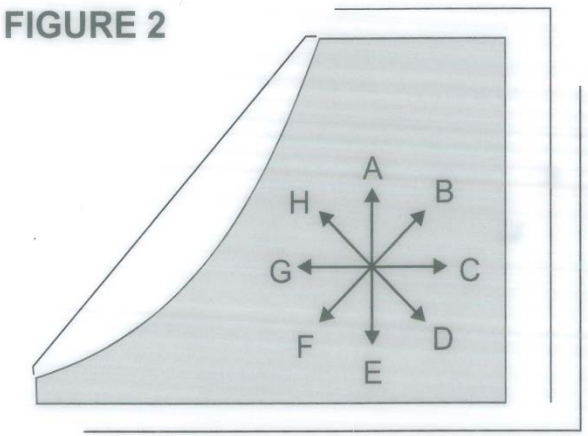
JACCO

61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com



File Not Saved

Psychrometric Cheat Sheet



A – Humidify Only

B – Heat & Humidify

C – Sensible Heat Only

D – Desiccant Dehumidify

E – Dehumidify Only

F – Cool & Dehumidify

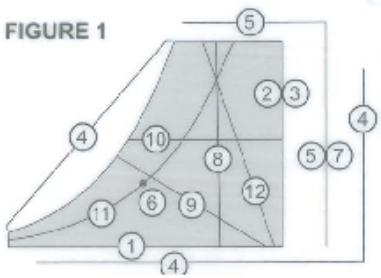
G – Sensible Cool Only

H – Evaporative Cool

JACCO

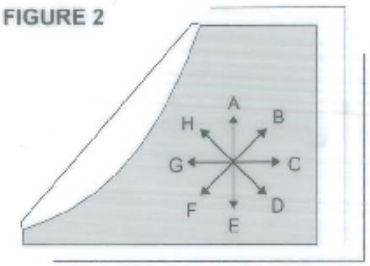
Psychrometric Cheat Sheet

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) = 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)

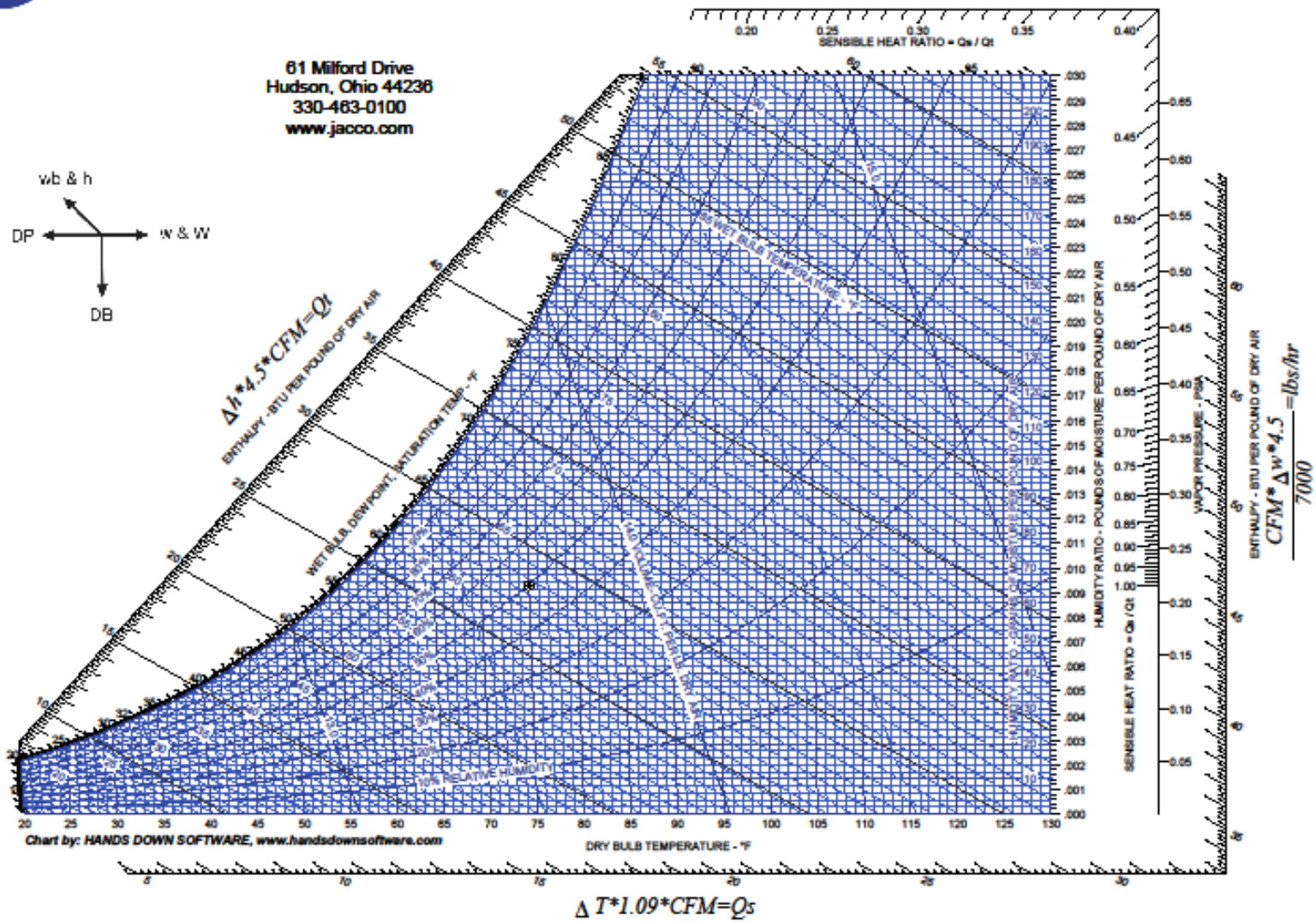
Definitions

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

JACCO

JACCO

61 Milford Drive
Hudson, Ohio 44236
330-463-0100
www.jacco.com



$\Delta h * 4.5 * CFM = Qt$

$\frac{CFM * \Delta w * 4.5}{7000} = lbs/hr$

$\Delta T * 1.09 * CFM = Qs$

File Not Saved

How Can Jacco Help You?

- Tight Temperature & Humidity Control
- Low SHR Applications with Aaon, 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, Seasons 4 & Energy Labs

JACCO

Thank You

Jerry Cohen
President
Jacco & Assoc.