PSYCHROMETRY

AIR CONDITIONING

- Treating or conditioning of air to alter its temperature and moisture content to suit specific requirements.
- **William H Carrier** – Father of Air Conditioning.
- Working substance – Atmospheric Air
- Atmospheric Air – **Dry Air + Water Vapor**

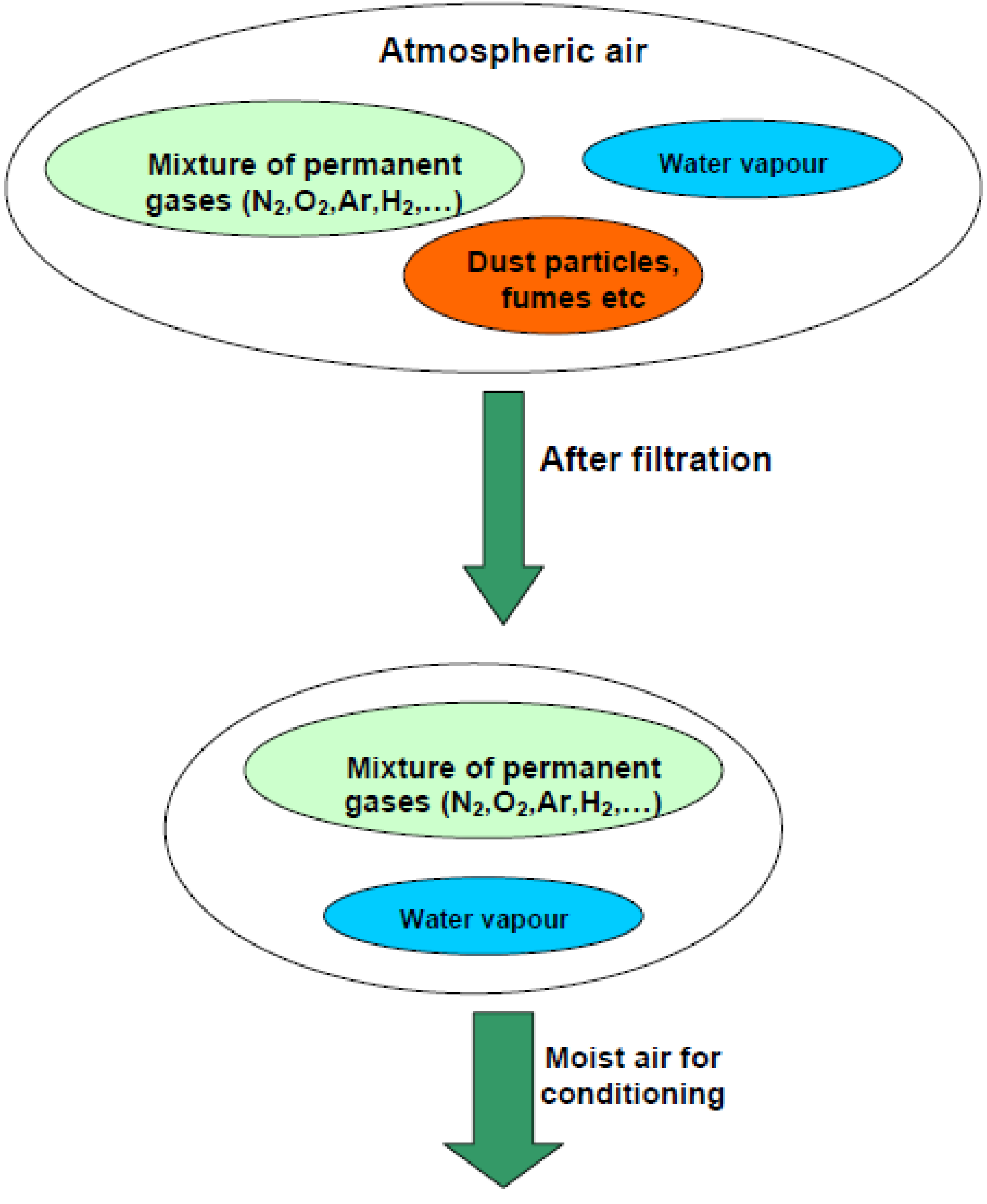
Composition of standard air

Constituent	Molecular weight	Mol fraction
Oxygen	32.000	0.2095
Nitrogen	28.016	0.7809
Argon	39.944	0.0093
Carbon dioxide	44.010	0.0003

- International joint committee in 1949.
- The molecular weight of **dry air** is found to be **28.966** and the gas constant R is **287.035 J/kg.K**.
- The mixture of dry air and water vapor is called as **moist air**.

- At a given temperature and pressure the dry air can only hold a certain maximum amount of moisture.
- When the moisture content is maximum, then the air is known as ***saturated air***.
- Any addition of moisture will drop out as free water.
- The molecular weight of **water vapour** is **18.015** and its gas constant is **461.52 J/kg.K**.

Atmospheric air



Psychrometry

- ***PSYCHROMETRY*** *is the study of the properties of mixtures of air and water vapor(Atmospheric Air).*
- *Atmospheric air makes up the environment in almost every type of air conditioning system.*
- *Hence a thorough understanding of the **properties of atmospheric air** and the ability to analyze various processes involving air is fundamental to air conditioning design.*

Psychrometric Properties

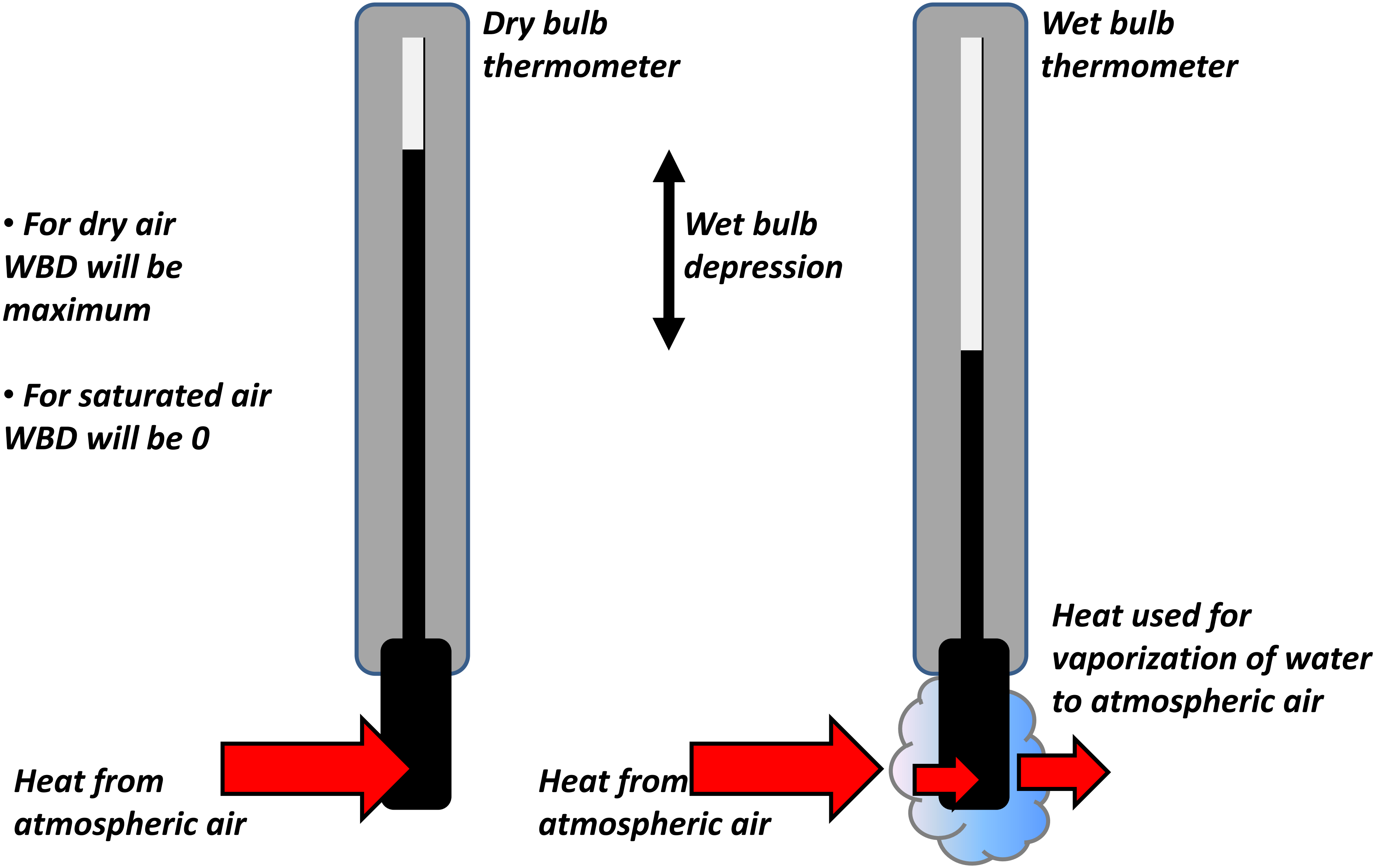
- **DRY BULB TEMPERATURE (DBT) -** It is the temperature of the moist air as measured by a standard thermometer or other temperature measuring instruments.
- **SATURATED VAPOUR PRESSURE (P_{SAT}) -** is the saturated partial pressure of water vapour at the dry bulb temperature.
- **WET BULB TEMPERATURE(WBT) -** Temperature of the moist air as measured by standard thermometer when its bulb is wound by a wet wick.

$$for\ dry\ air\ WBT << DBT$$

$$for\ saturated\ air\ WBT = DBT$$

DRY BULB AND WET BULB TEMPERATURES

- For dry air WBD will be maximum
- For saturated air WBD will be 0



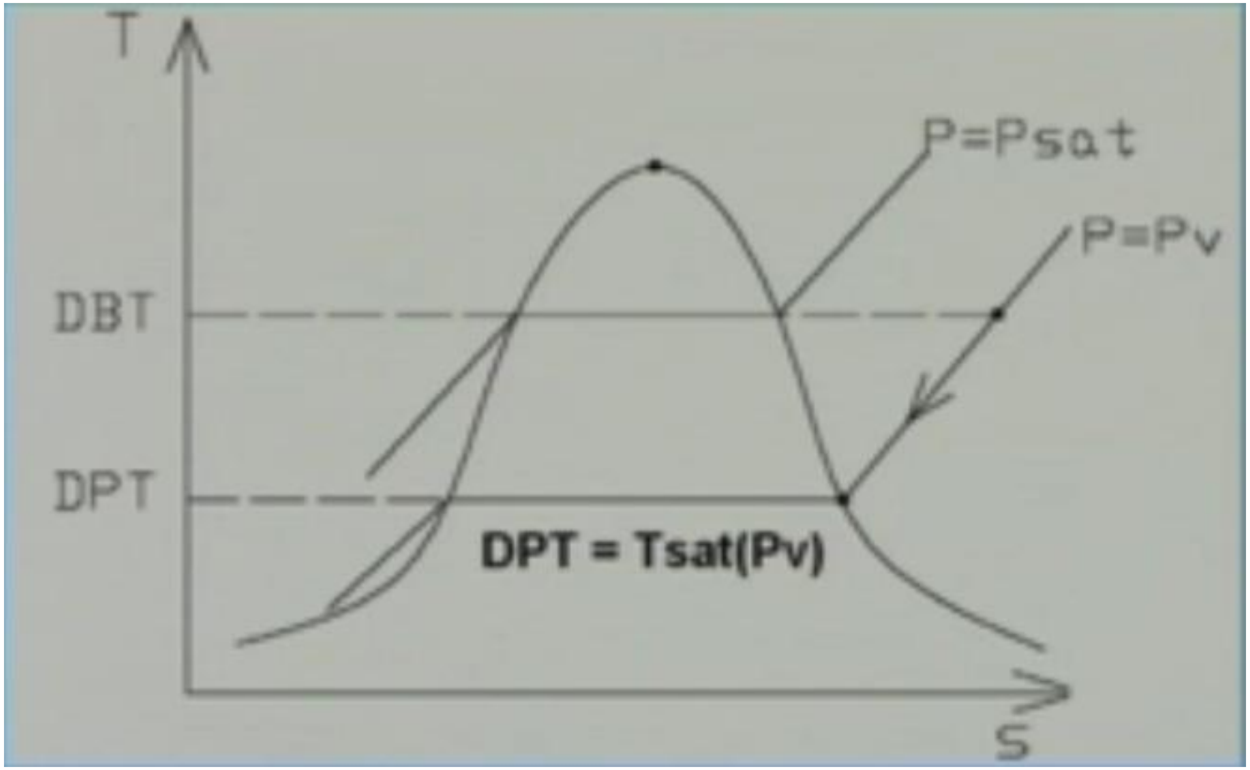
Note: If atmospheric air is saturated then vaporization won't take place so whole of the heat will be transmitted to the wet bulb. So in case of saturated air DBT = WBT

Dry-Bulb Thermometer

Wet-Bulb Thermometer

DEW POINT TEMPERATURE(DPT)

- If **unsaturated moist air** is cooled at constant pressure the temperature at which moisture in the air begins to condense is called DPT.
- The DPT is the saturation temperature corresponding to the vapour pressure of water vapour. So it can be obtained from steam tables.



Condensation Occurs At Dew Point

Fog Occurs When Air Is Saturated

Humidity Ratio(Specific Humidity)

…compares water vapor to dry air, by weight

- It is the mass of water vapour associated with each kilogram of dry air.

$$W = \frac{\text{kg of water vapour}}{\text{kg of dry air}} = \frac{p_v V / R_v T}{p_a V / R_a T} = \frac{p_v / R_v}{(p_t - p_v) / R_a}$$

$$W = 0.622 \frac{p_v}{p_t - p_v}$$

- $R_a = .287$ and $R_v = .462$
- $W = \frac{v_a}{v_v}$

Relative Humidity(Φ)

…describes the degree of saturation

$$\text{Relative Humidity} = \frac{\text{Amount of moisture that a given amount of air } \textbf{is holding at a given temp.}}{\text{Amount of moisture that a given amount of air } \textbf{can hold at same temp.}} = \frac{p_v}{p_{sat}}$$

- It is defined as the ratio of the mole fraction of water vapour in moist air to mole fraction of water vapour in saturated air at the same temperature and pressure.

Relative Humidity

…compares moisture content to saturation

50%

100%
(saturated)

Relative Humidity

- 50% RH means that the air contains half the amount of water vapor it can hold at that temp.
- RH increases as the temp. decreases.
- The maximum amount of moisture(saturation) that a given volume of air can hold varies with temp.
- The temp. at which RH becomes 100% is called DPT.

Degree of saturation (μ)

- The degree of saturation is the ratio of the humidity ratio W to the humidity ratio of a saturated mixture W_s at the same temperature and pressure.

$$\mu = \left|\frac{W}{W_s}\right|_{t,P} = \frac{p_v}{p_s}\left[\frac{1-\frac{p_s}{p_t}}{1-\frac{p_v}{p_t}}\right] = \emptyset\left[\frac{1-\frac{p_s}{p_t}}{1-\frac{p_v}{p_t}}\right]$$

Enthalpy of Moist Air

- It is the sum of the enthalpy of the dry air and the enthalpy of the water vapour.

$$h = h_a + Wh_g = c_p t + W(h_{fg} + c_{pw} t)$$

where c_p = specific heat of dry air at constant pressure, kJ/kg.K
c_{pw} = specific heat of water vapor, kJ/kg.K
t = Dry-bulb temperature of air-vapor mixture, °C
W = Humidity ratio, kg of water vapor/kg of dry air
h_a = enthalpy of dry air at temperature t, kJ/kg
h_g = enthalpy of water vapor[3] at temperature t, kJ/kg
h_{fg} = latent heat of vaporization at 0°C, kJ/kg

$$h = 1.022t + W\left[h_{fg.dp} + 2.3t_{dp}\right]$$

Where, $h_{fg.dp}$ = latent heat of vaporization at dew point temp.

t_{dp} = dew point temp

Humid specific heat

- It is the specific heat of humid(or moist) air per kg of dry air.
- From the equation for enthalpy of moist air, the humid specific heat of moist air can be written as:

$$c_{pm} = c_p + W.c_{pw}$$

where c_{pm}	=	humid specific heat, kJ/kg.K
c_p	=	specific heat of dry air, kJ/kg.K
c_{pw}	=	specific heat of water vapor, kJ/kg
W	=	humidity ratio, kg of water vapor/kg of dry air

- For all practical purposes the humid specific heat of moist air, c_{pm} can be taken as 1.0216 kJ/kg dry air.K

Specific volume

- The specific volume is defined as the number of cubic meters of moist air per kilogram of dry air.

$$v = \frac{R_a T}{p_a} = \frac{R_a T}{p_t - p_v} \qquad m^3/\text{kg dry air}$$

- The empirical relations for the vapor pressure of water in moist air:

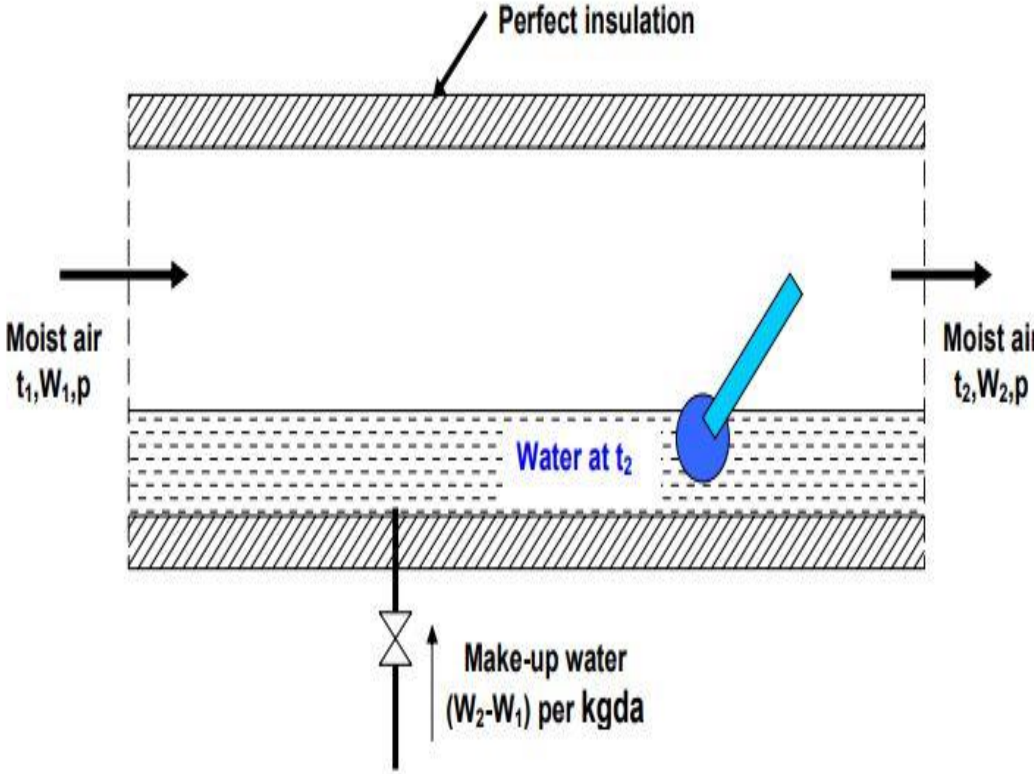
Carrier equation:

$$p_v = p'_v - \frac{1.8(p - p'_v)(t - t')}{2800 - 1.3(1.8t + 32)}$$

where t = dry bulb temperature, °C
t' = wet bulb temperature, °C
p = barometric pressure
p_v = vapor pressure
p_v' = saturation vapor pressure at wet-bulb temperature

Adiabatic saturation and Thermodynamic WBT

- **It is the temp at which air can be brought to saturation state adiabatically by evaporation of water into the flowing air.**



- An adiabatic saturator is a device in which air flows through an infinitely long duct containing water.
- The device is adiabatic as the walls of the chamber are thermally insulated.
- As the air comes in contact with water in the duct, there will be heat and mass transfer between water and air.
- Air at the exit would be fully saturated and its temperature is equal to that of water temperature.
- Make-up water to be provided to compensate for the amount of water evaporated into the air.
- After the adiabatic saturator has achieved a steady-state condition, the temperature indicated by the thermometer immersed in the water is the ***thermodynamic wet-bulb temperature***.

Problem 1

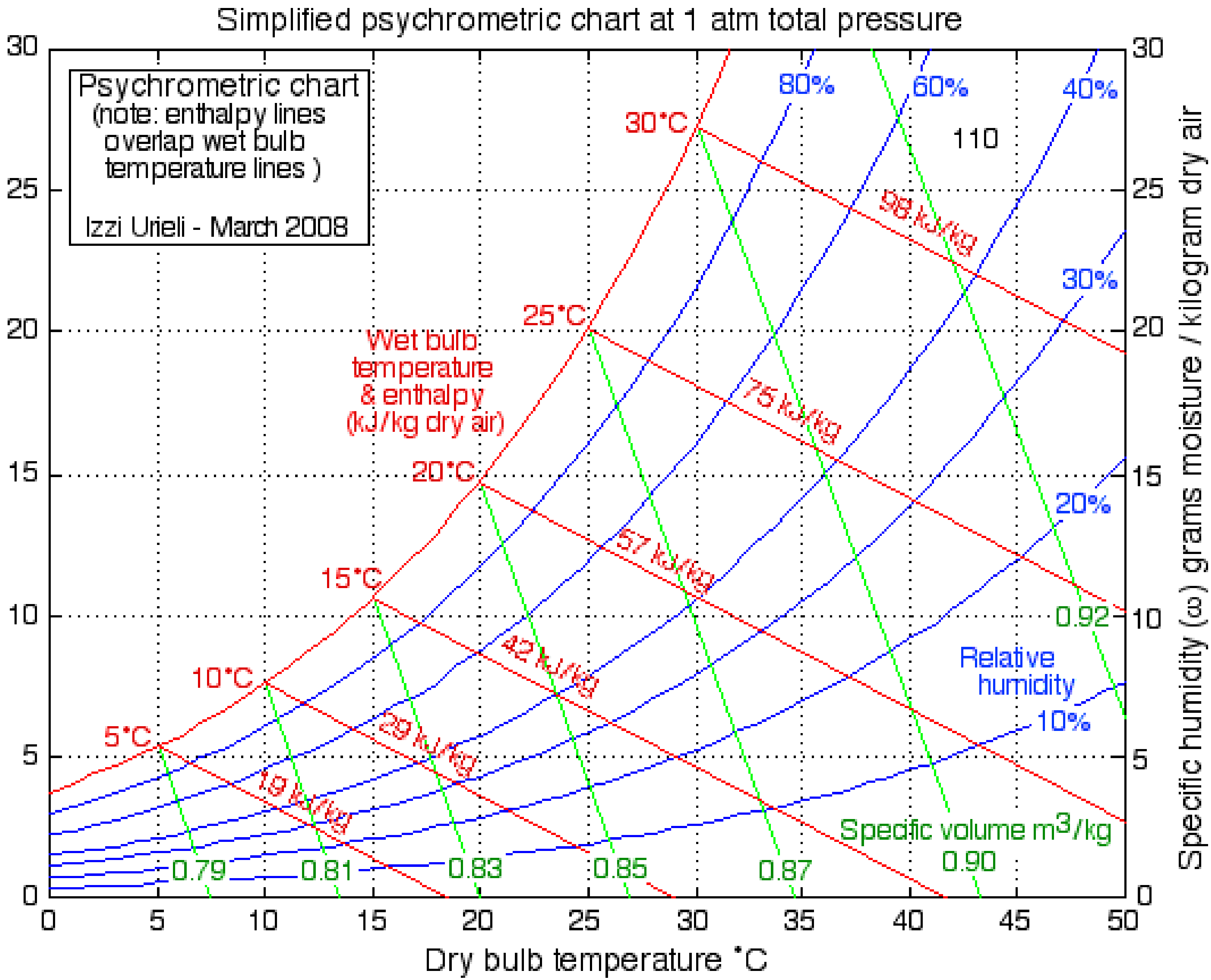
On a particular day the weather forecast states that the dry bulb temperature is 37^oC, while the relative humidity is 50% and the barometric pressure is 101.325 kPa. Find the humidity ratio, dew point temperature and enthalpy of moist air on this day.

Problem 2

Moist air at 1 atm. pressure has a dry bulb temperature of 32^oC and a wet bulb temperature of 26^oC. Calculate a) the partial pressure of water vapour, b) humidity ratio, c) relative humidity, d) dew point temperature, e) density of dry air in the mixture, f) density of water vapour in the mixture and g) enthalpy of moist air using perfect gas law model and Psychrometric equations.

The Psychrometric Chart

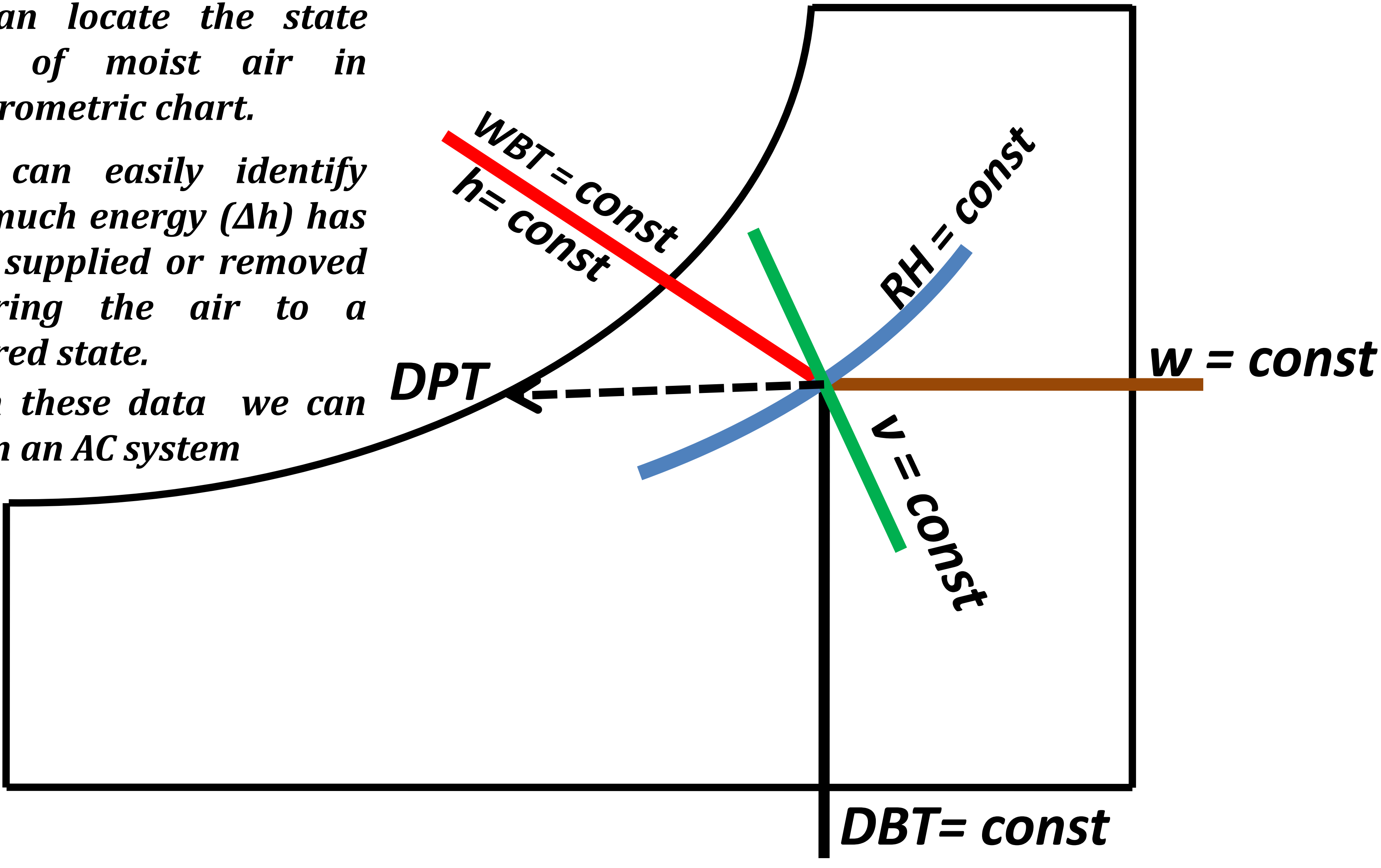
- **A Psychrometric chart graphically represents the thermodynamic properties of moist air.**
- **The chart is normally drawn for air at 1 atm. Pressure.**



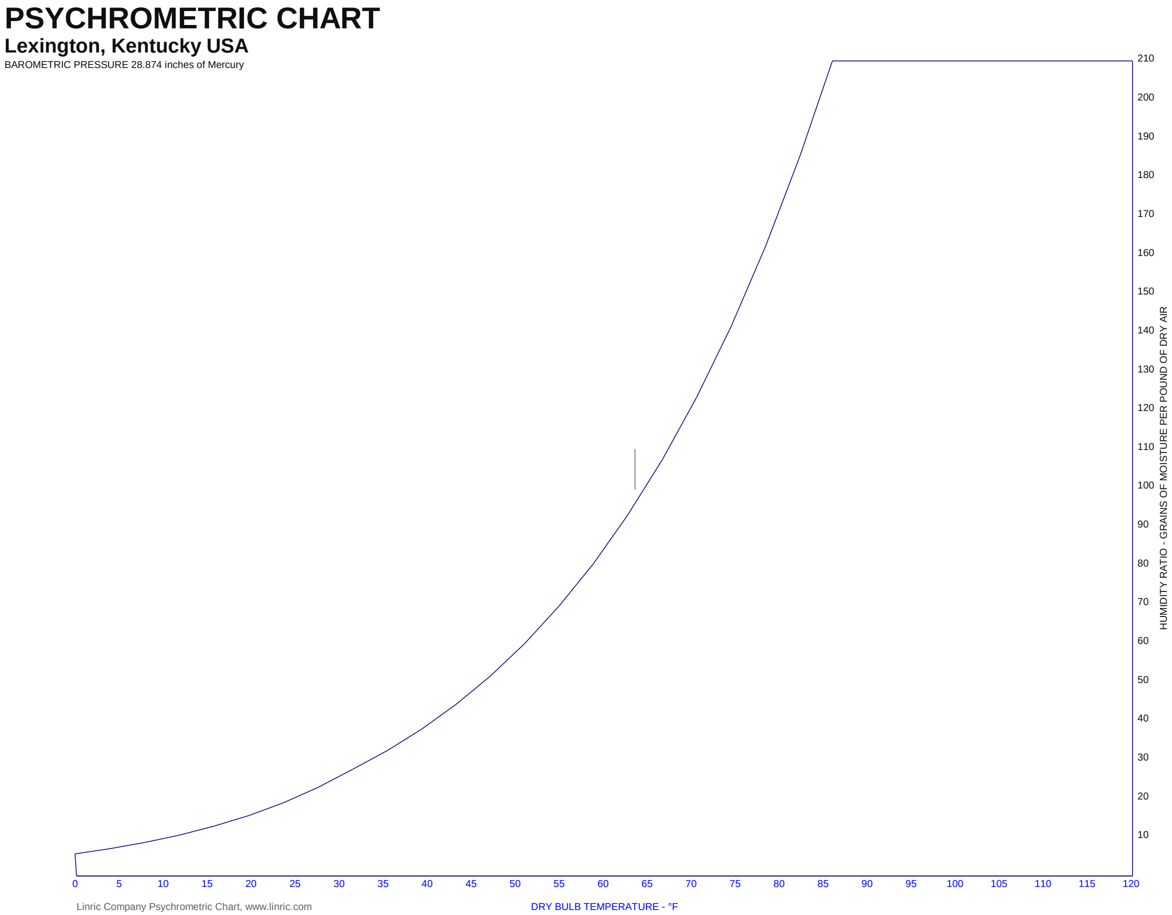
Simplified psychrometric chart at 1 atm total pressure
Psychrometric chart
(note: enthalpy lines overlap wet bulb temperature lines)
Izzi Urieli - March 2008
Wet bulb temperature & enthalpy (kJ/kg dry air)
5°C
10°C
15°C
20°C
25°C
30°C
19 kJ/kg
29 kJ/kg
42 kJ/kg
57 kJ/kg
75 kJ/kg
98 kJ/kg
110
80%
60%
40%
30%
20%
10%
Relative humidity
Specific volume m3/kg
0.79
0.81
0.83
0.85
0.87
0.90
0.92
Dry bulb temperature °C
Specific humidity (ω) grams moisture / kilogram dry air
0
5
10
15
20
25
30
35
40
45
50

PSYCHROMERTIC PROPERTY CURVES

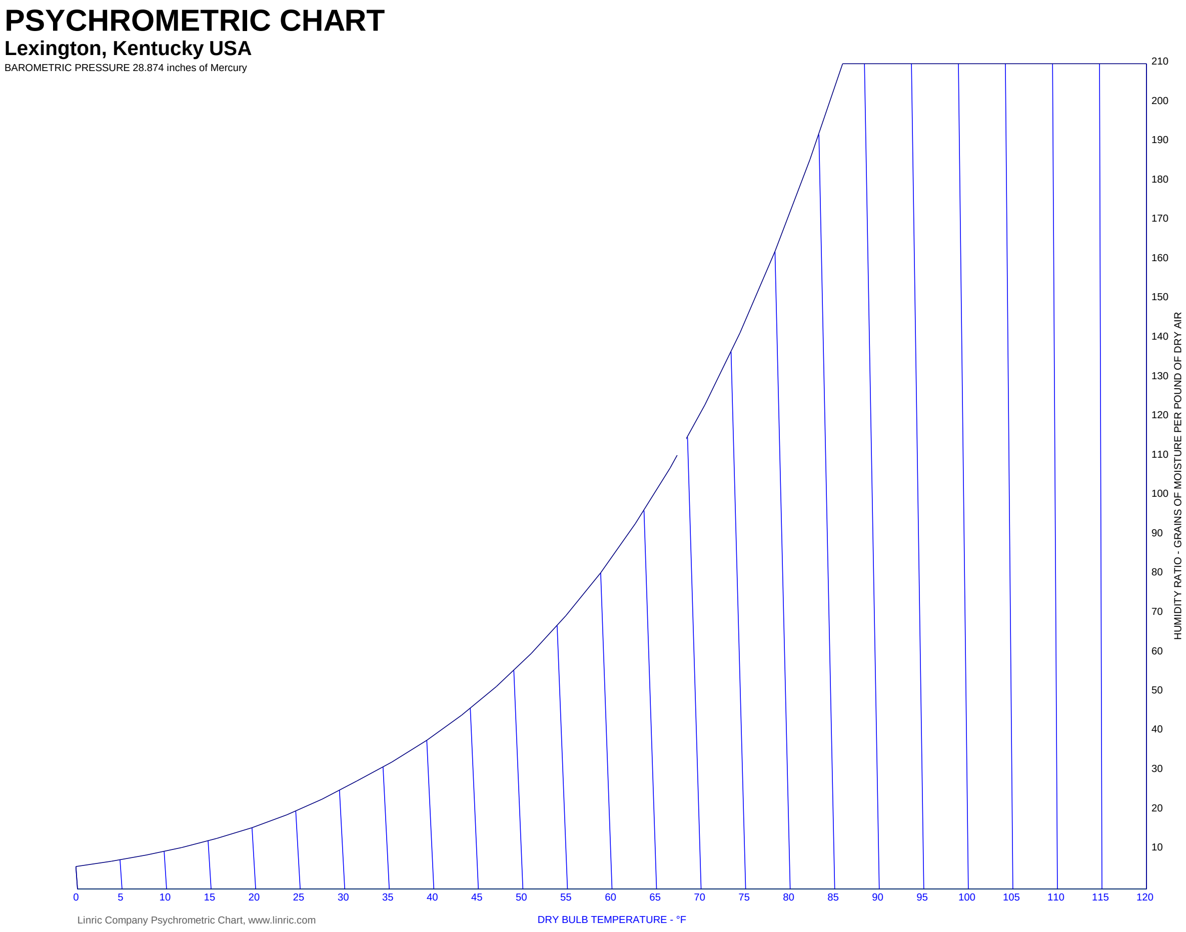
- *If we know any two Psychrometric properties we can locate the state point of moist air in Psychrometric chart.*
- *And can easily identify how much energy (Δh) has to be supplied or removed to bring the air to a required state.*
- *From these data we can design an AC system*



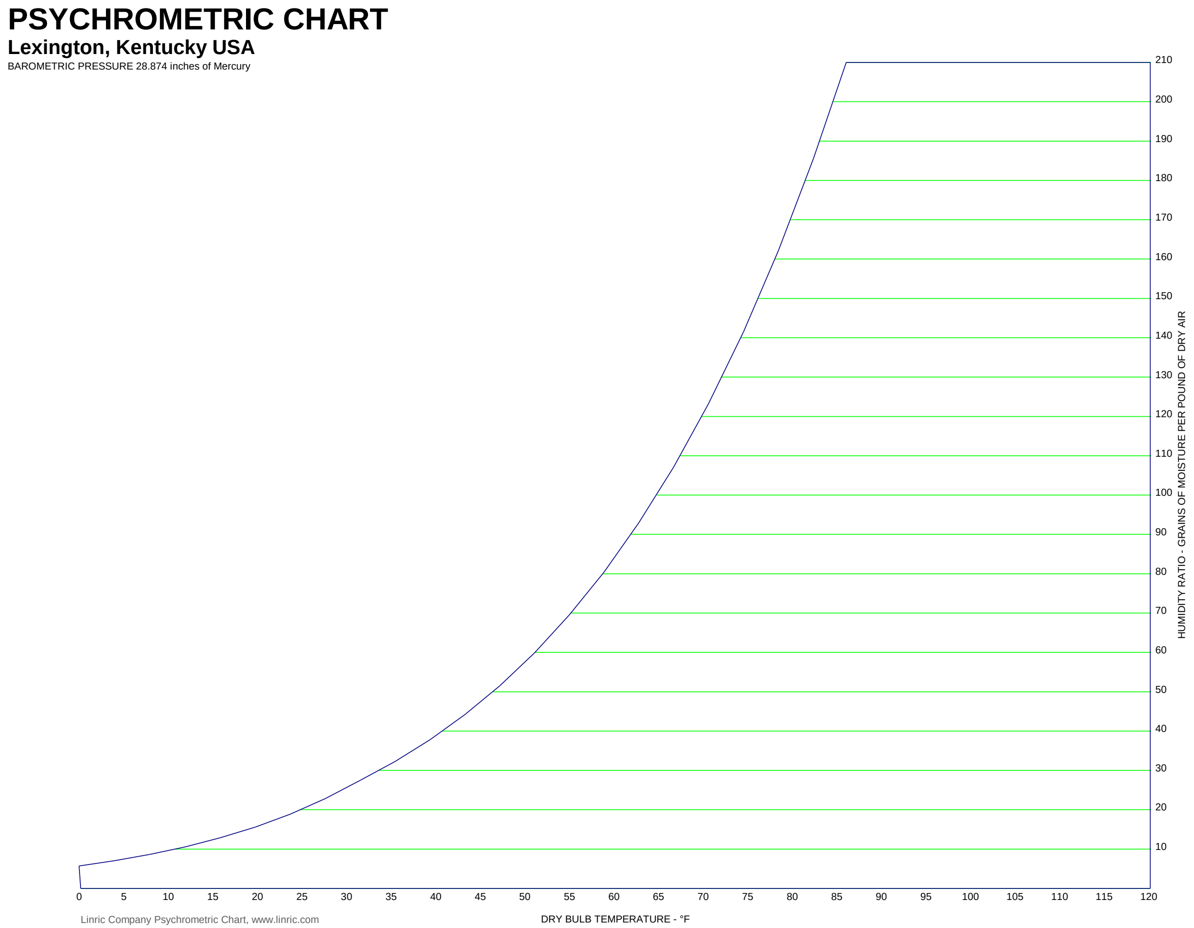
Saturation Line



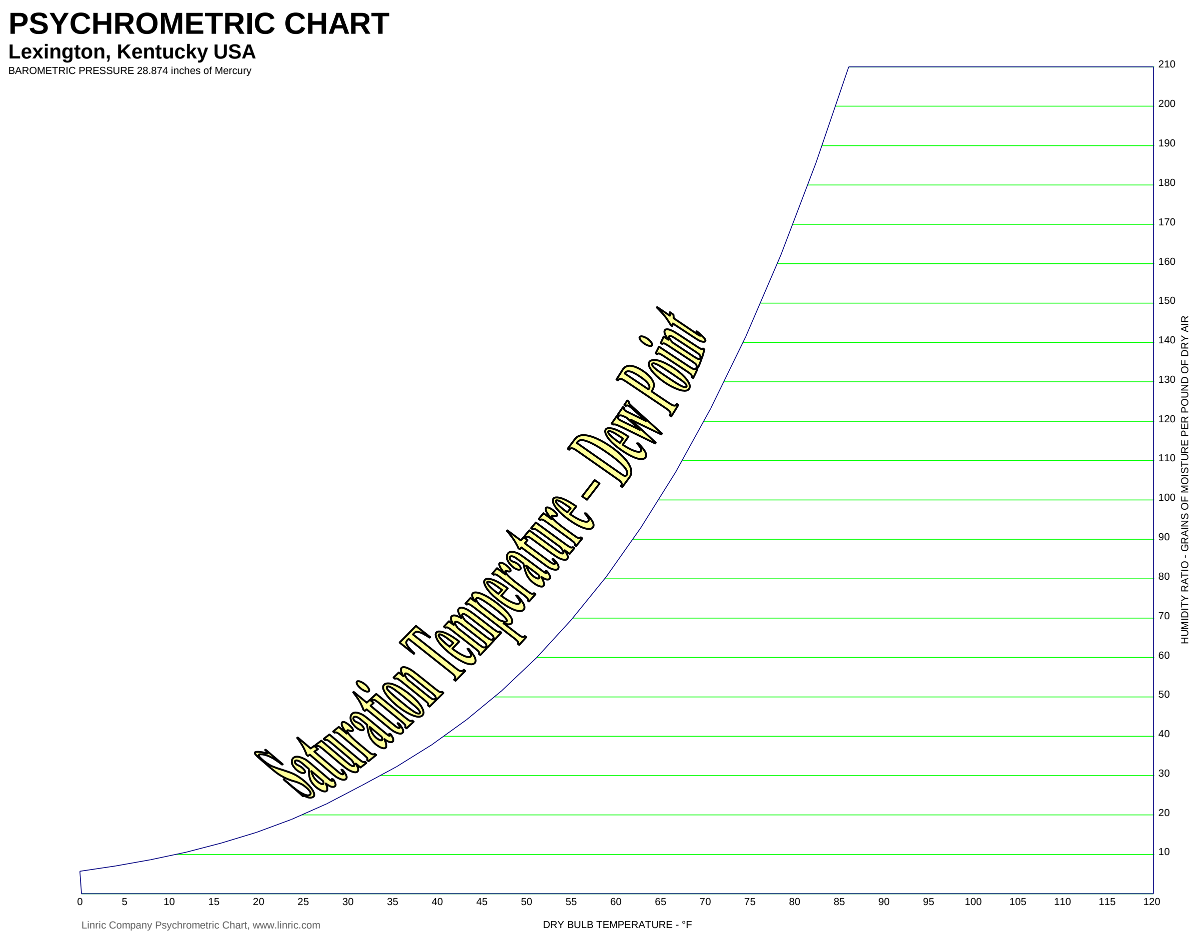
Constant Dry Bulb Temperature



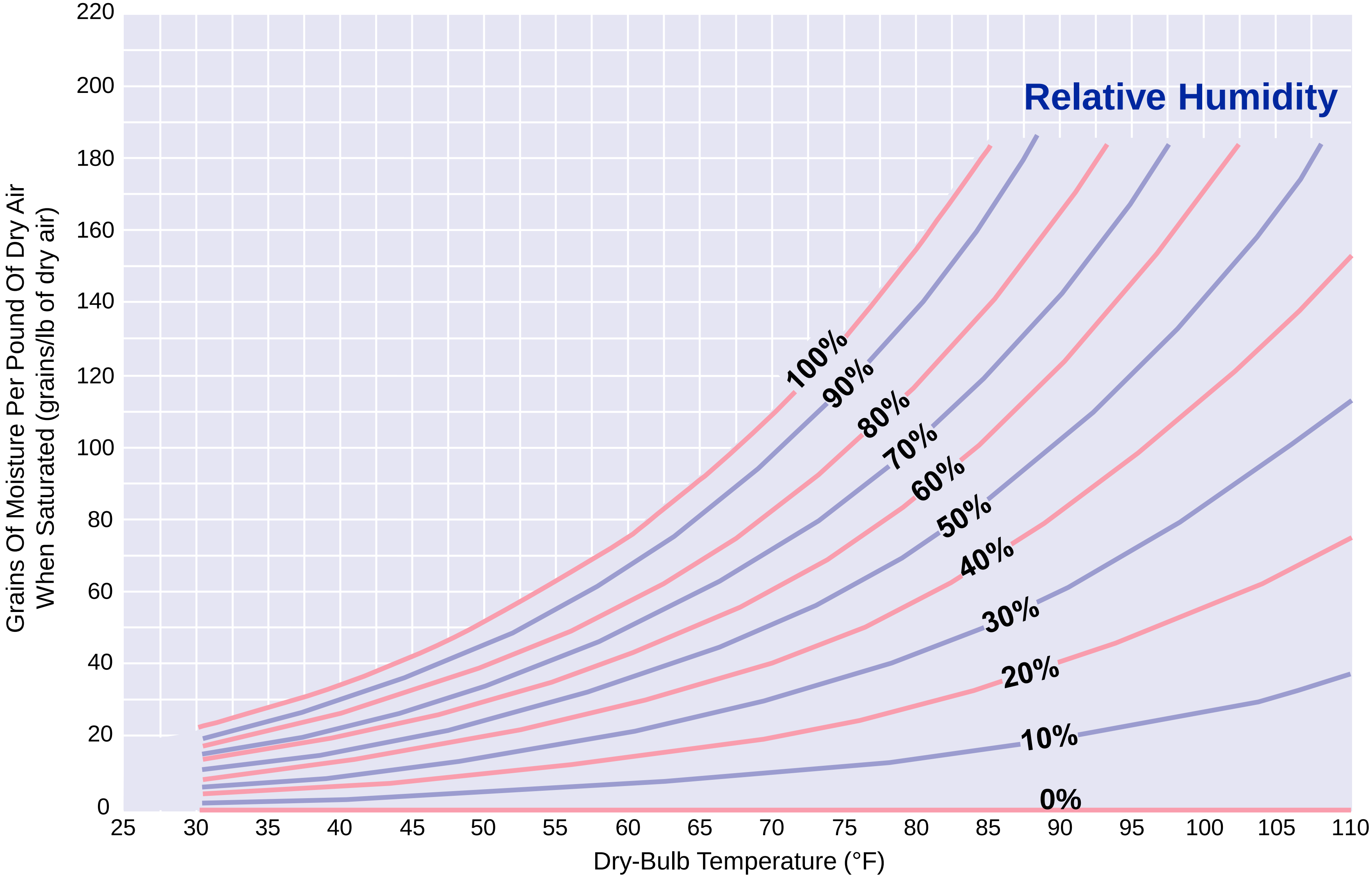
Constant Humidity Ratio & Pressure



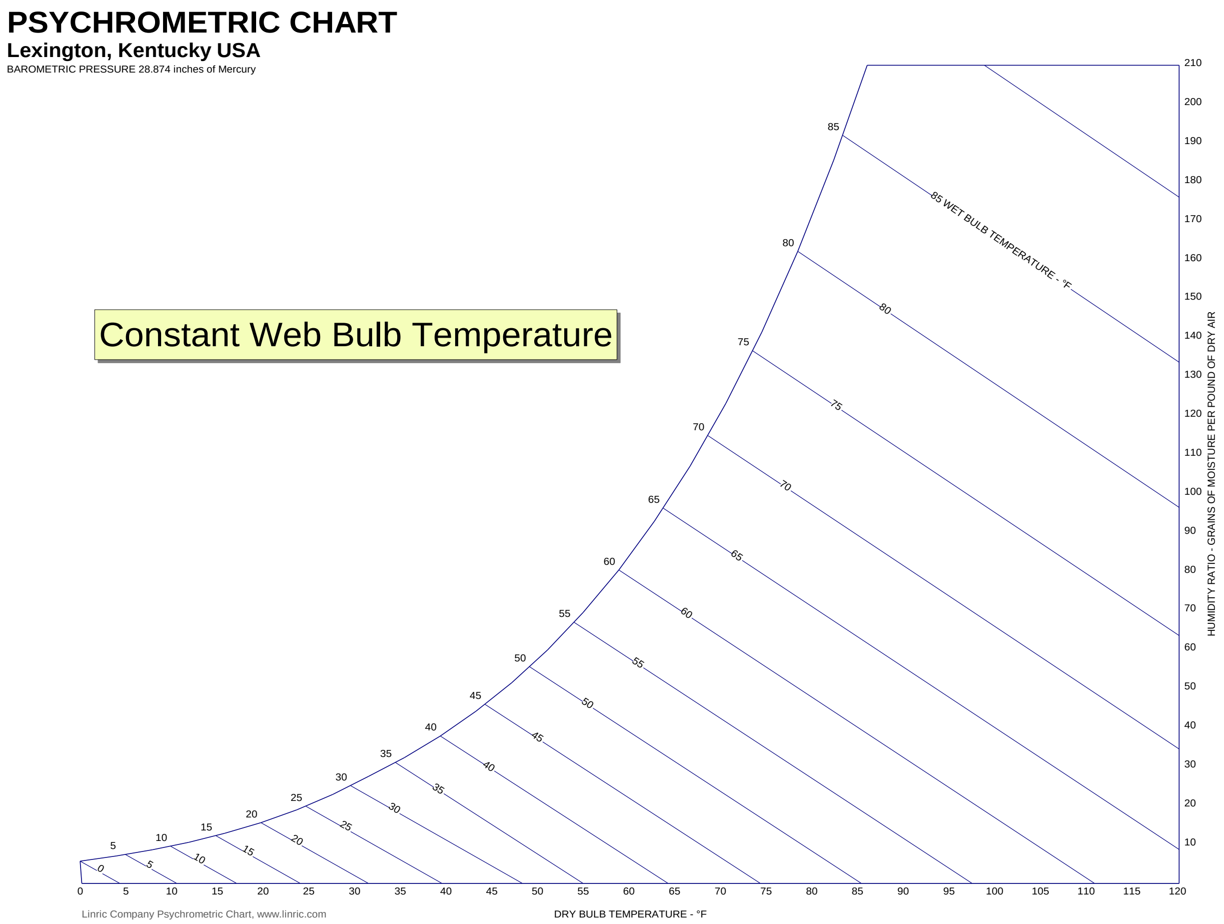
Dew Point temp.



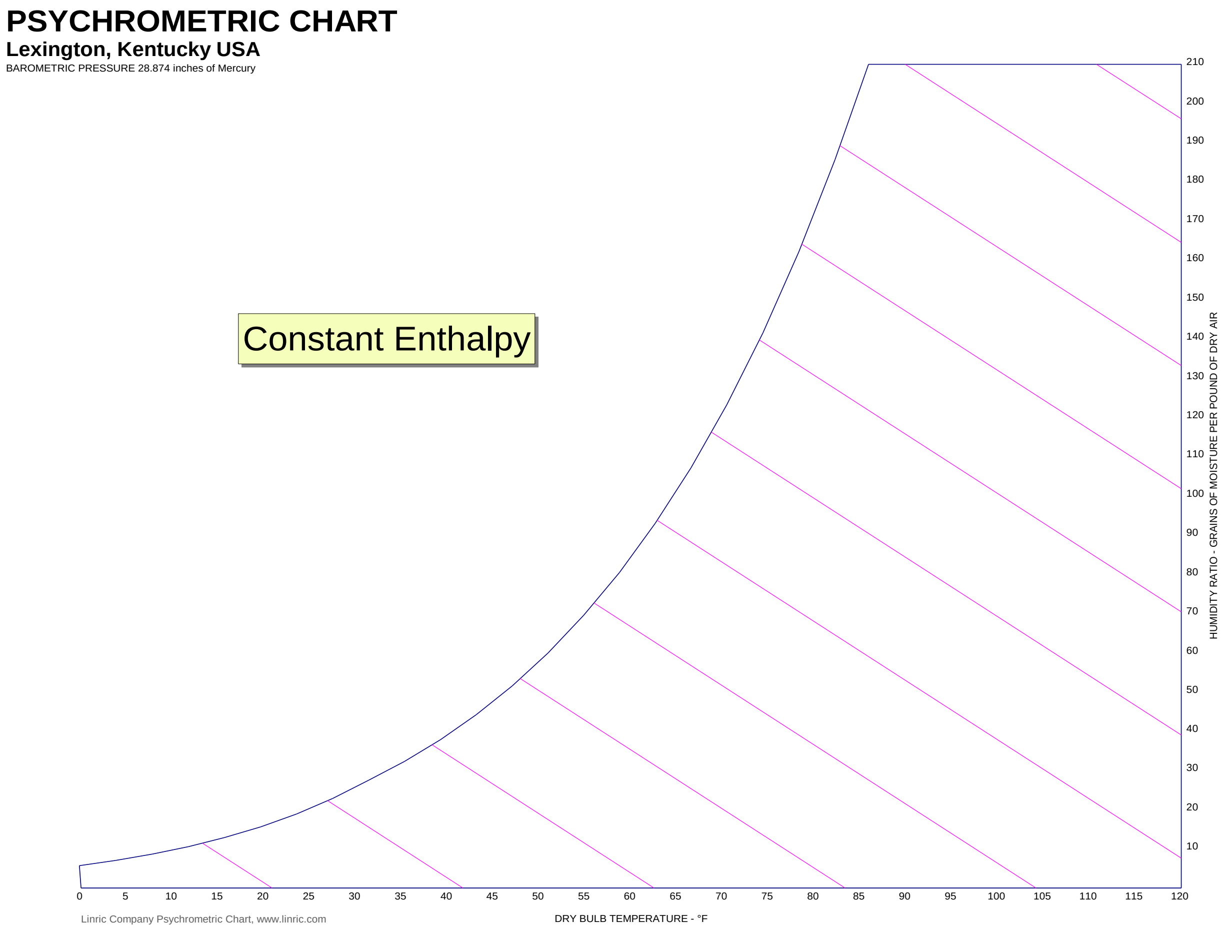
Constant Relative Humidity Curves



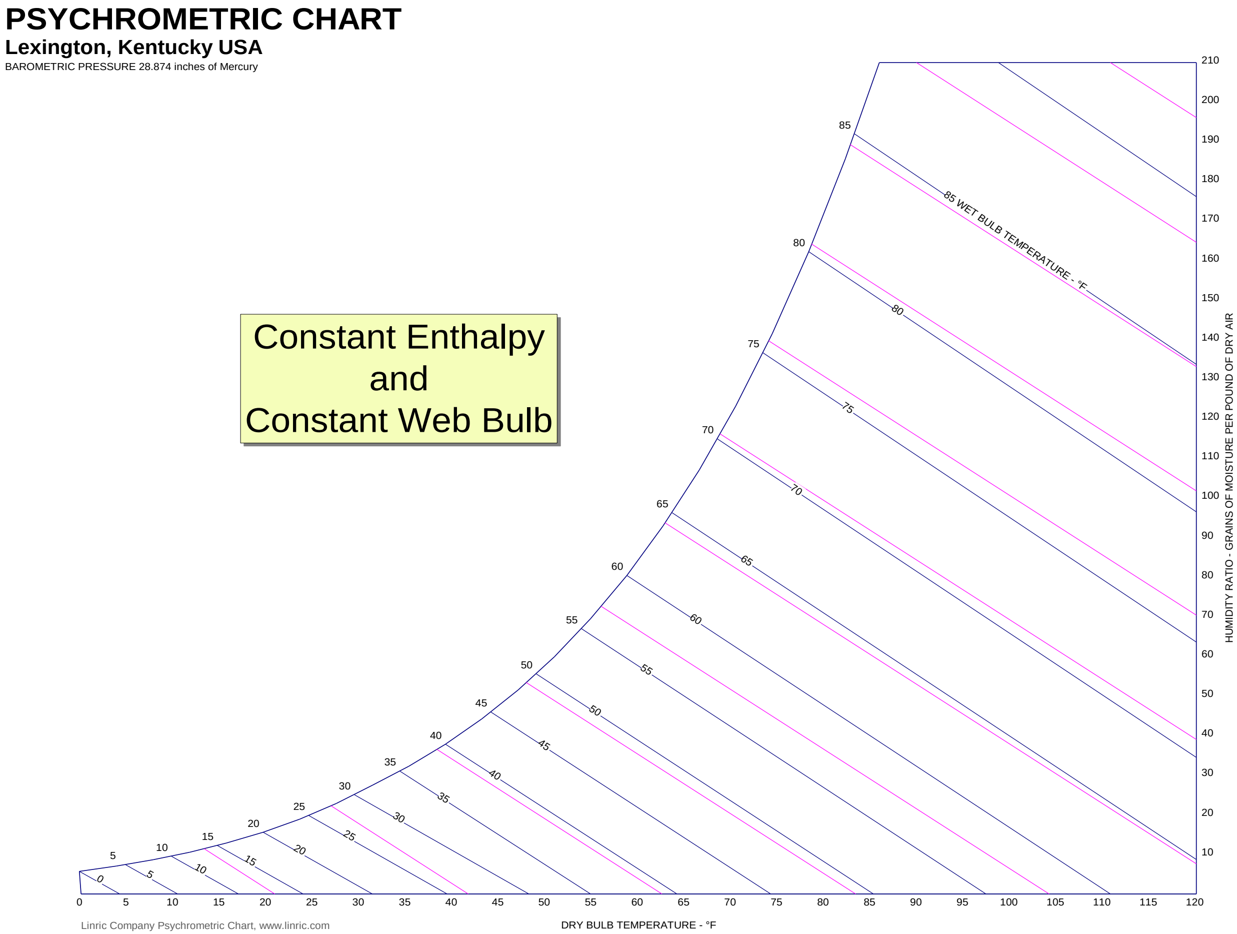
Constant Wet Bulb Temperature



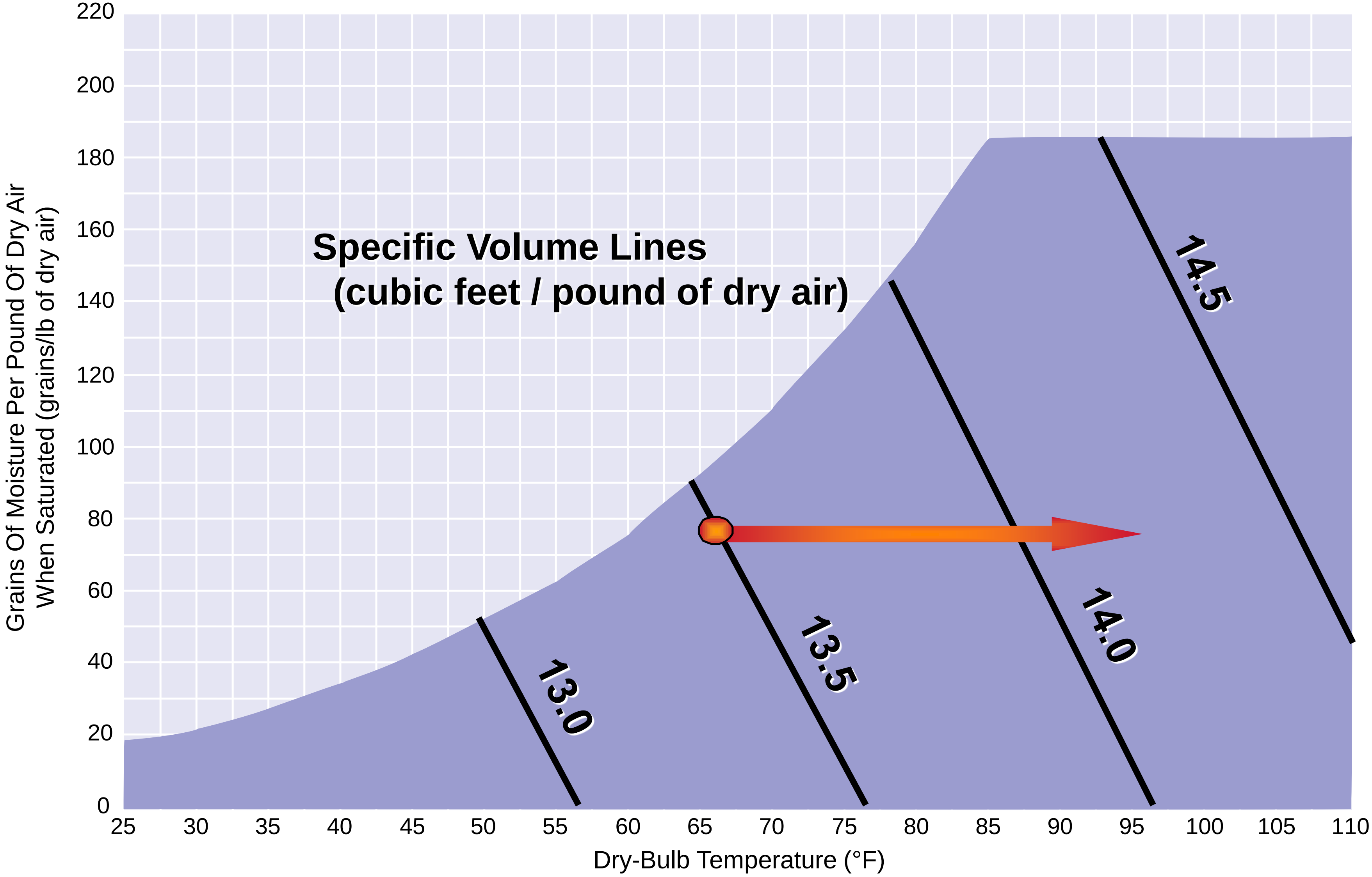
Constant Enthalpy



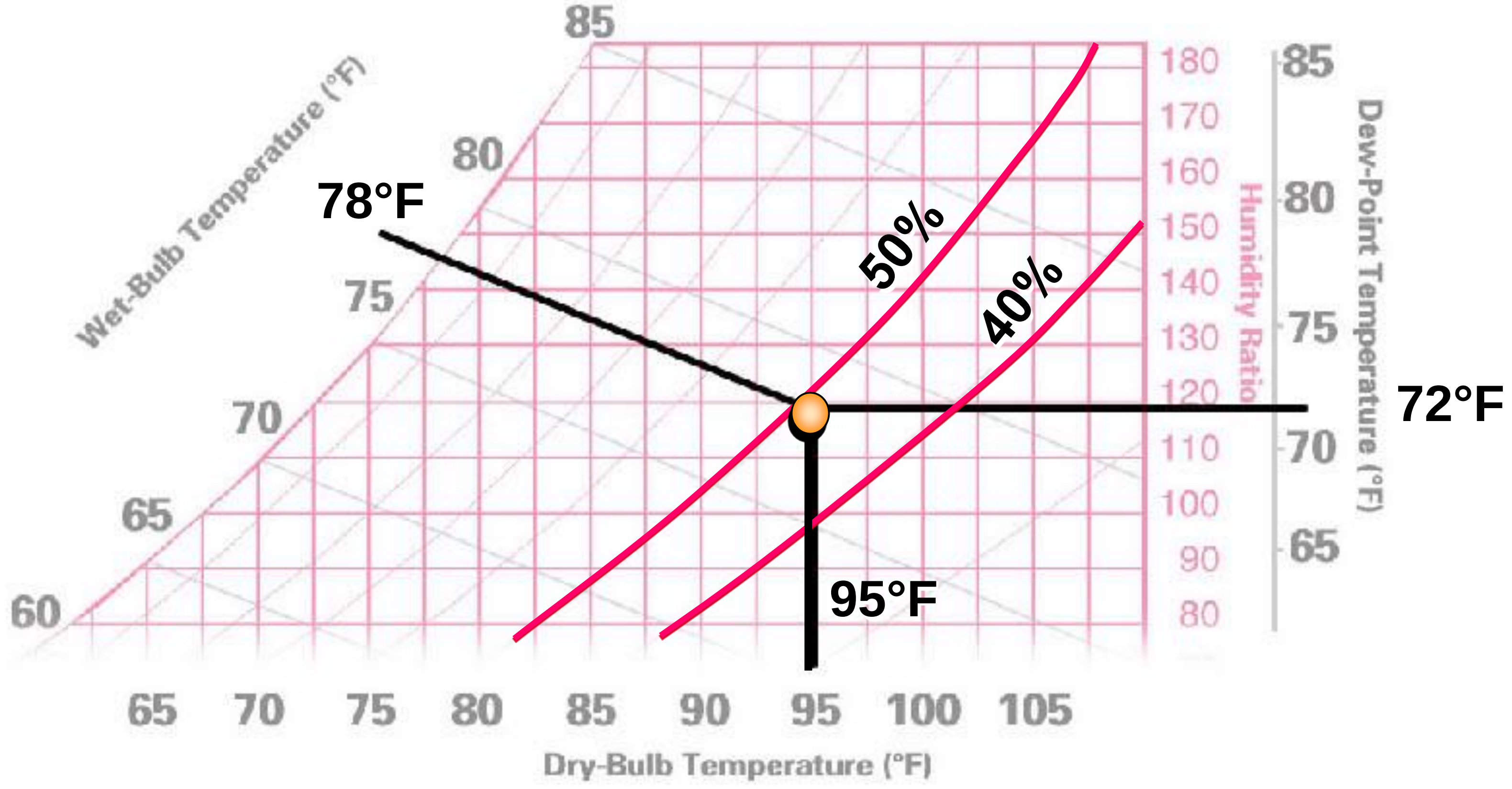
Constant Enthalpy and Web Bulb



A Final Property…Specific Volume



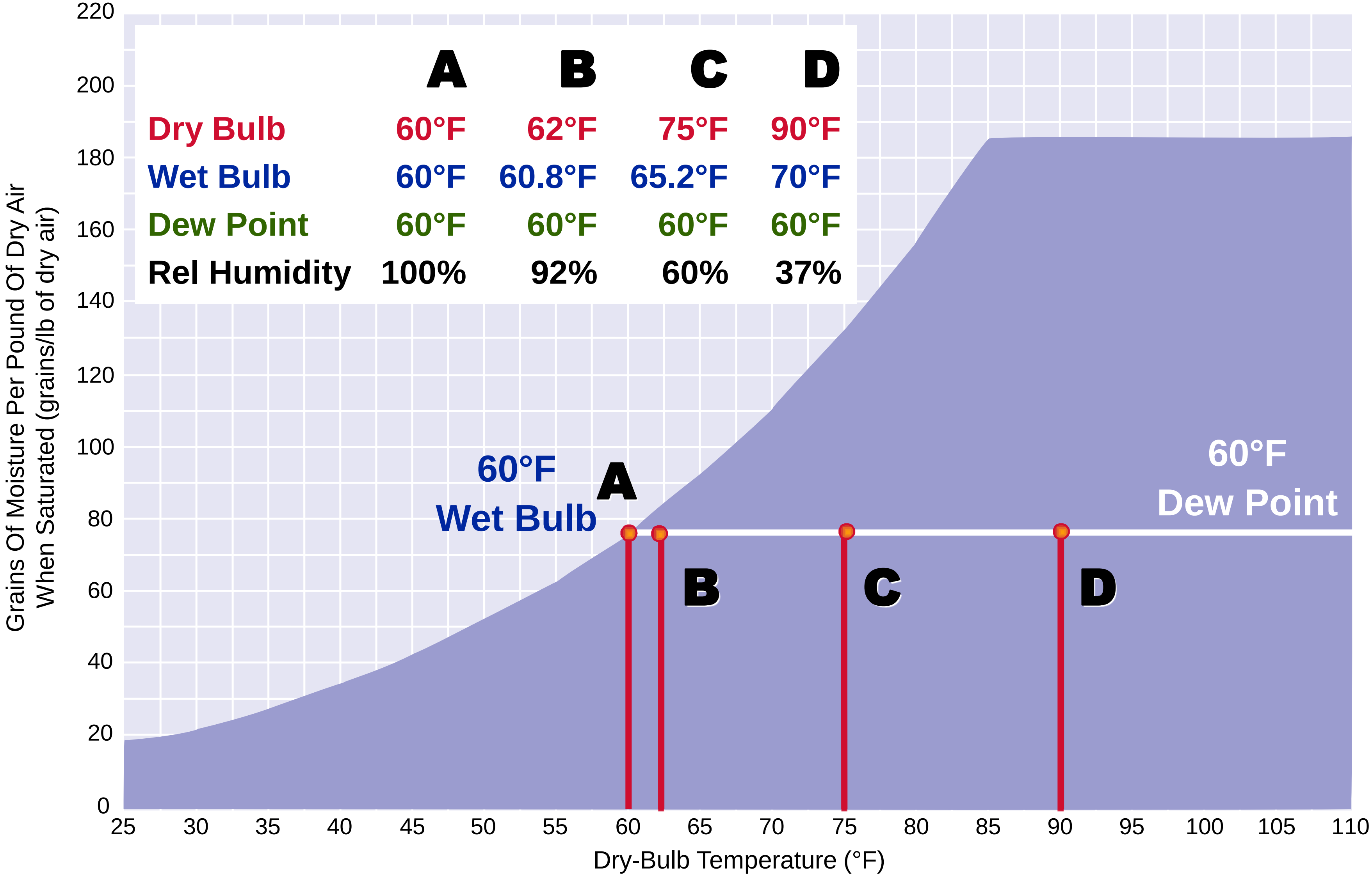
“X Marks The Spot”…



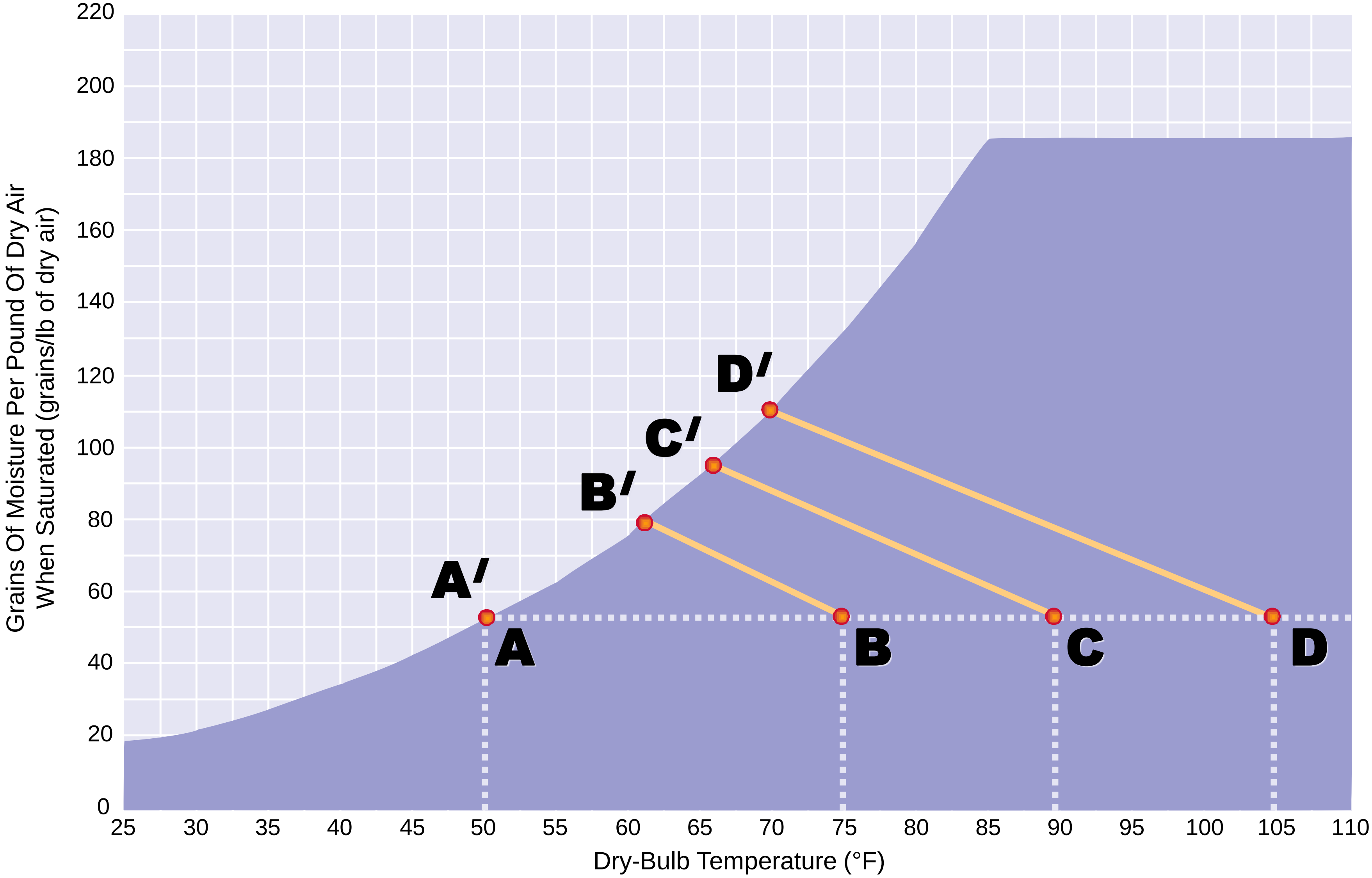
relationship between…

Dry Bulb, Wet Bulb And Dew Point

	A	B	C	D
Dry Bulb	60°F	62°F	75°F	90°F
Wet Bulb	60°F	60.8°F	65.2°F	70°F
Dew Point	60°F	60°F	60°F	60°F
Rel Humidity	100%	92%	60%	37%



Determining Wet-Bulb Lines

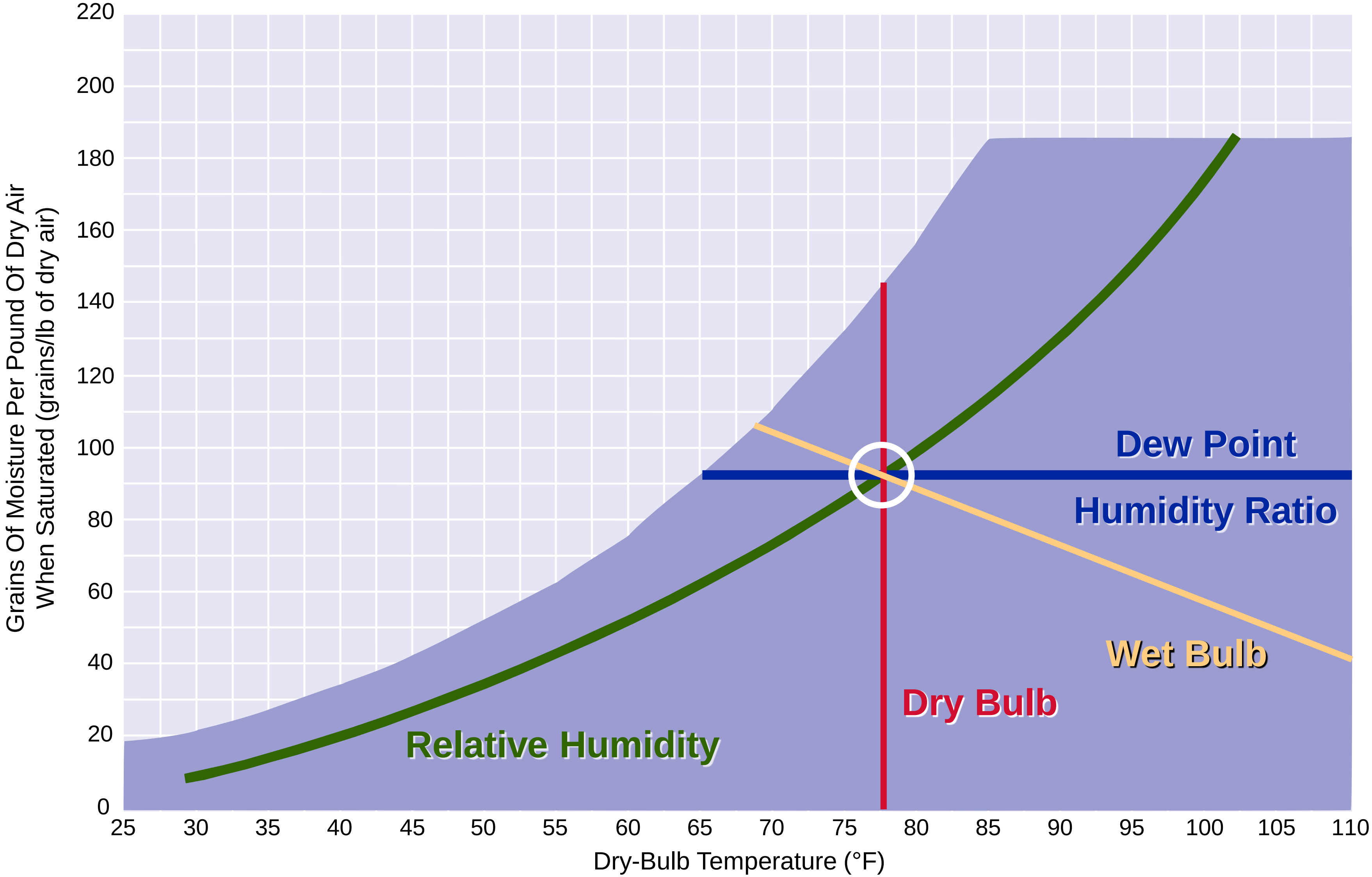


Knowing Two Properties
…lets you determine the remaining three

- Dry-bulb temperature
- Wet-bulb temperature
- Dew-point temperature
- Relative humidity
- Humidity ratio

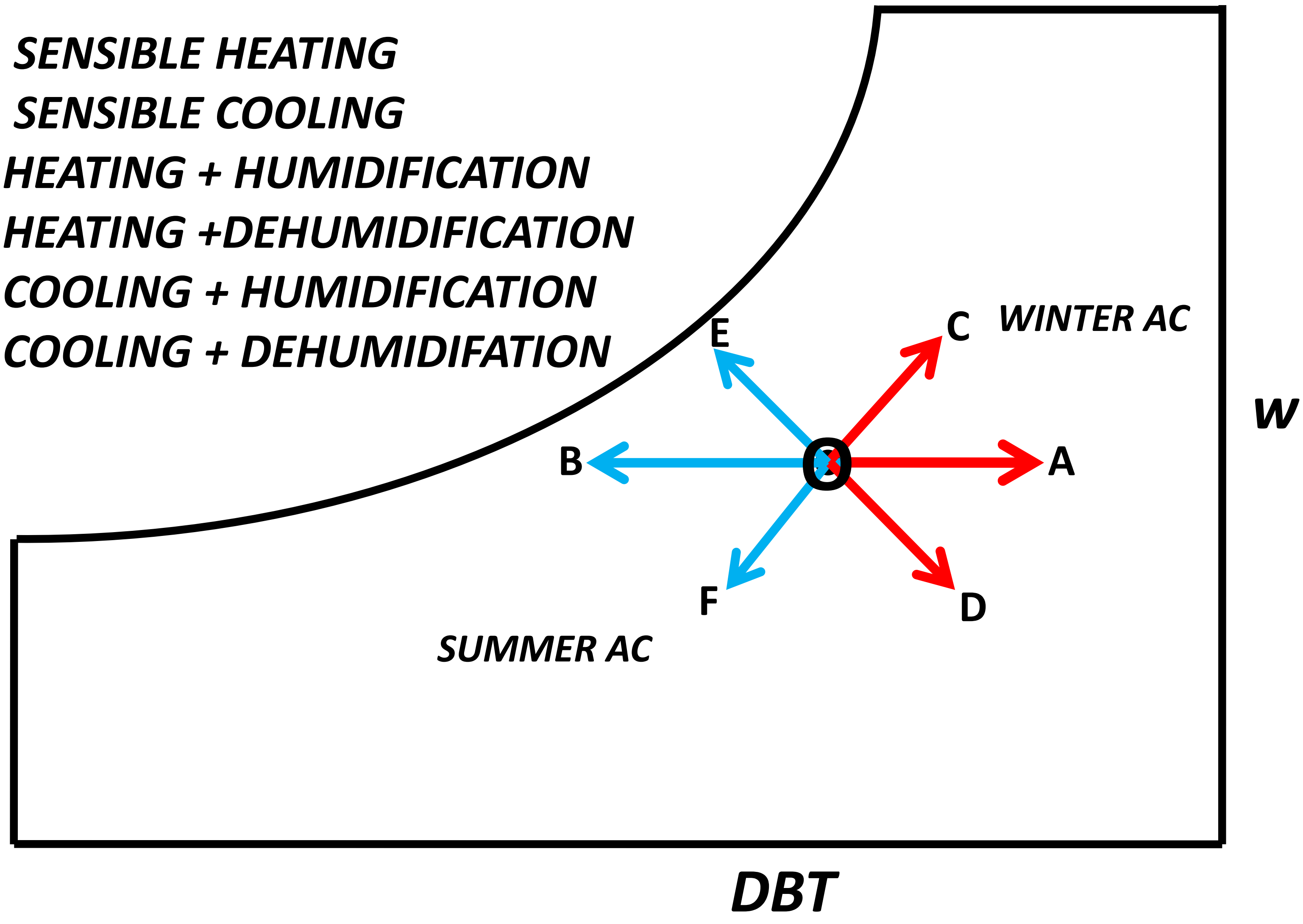
intersection of two known air properties…

Determines The Remaining Three



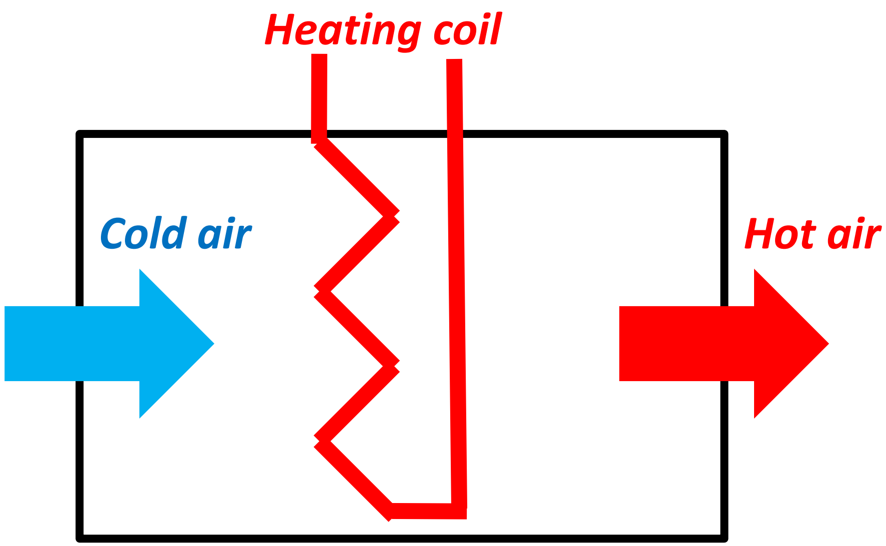
PSYCHROMERTIC PROCESSES

O-A	SENSIBLE HEATING
O-B	SENSIBLE COOLING
O-C	HEATING + HUMIDIFICATION
O-D	HEATING +DEHUMIDIFICATION
O-E	COOLING + HUMIDIFICATION
O-F	COOLING + DEHUMIDIFATION

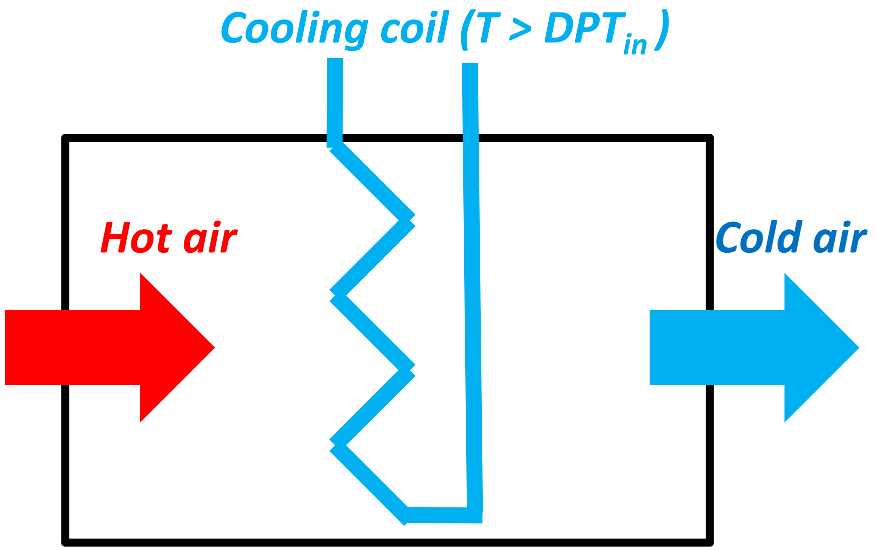


PSYCHROMETRIC PROCESSES

1. **SENSIBLE HEATING** – *During this process moisture content of the air remains constant. But its temperature increases as it flows over a heating coil.*
2. **SENSIBLE COOLING** – *During this process moisture content of the air remains constant . But its temperature decreases as it flows over a cooling coil. For the moisture to remain constant the surface of the cooling coil should be dry and $DBT_{in} > T_{surface} > DPT_{in}$ to avoid condensation of moisture.*

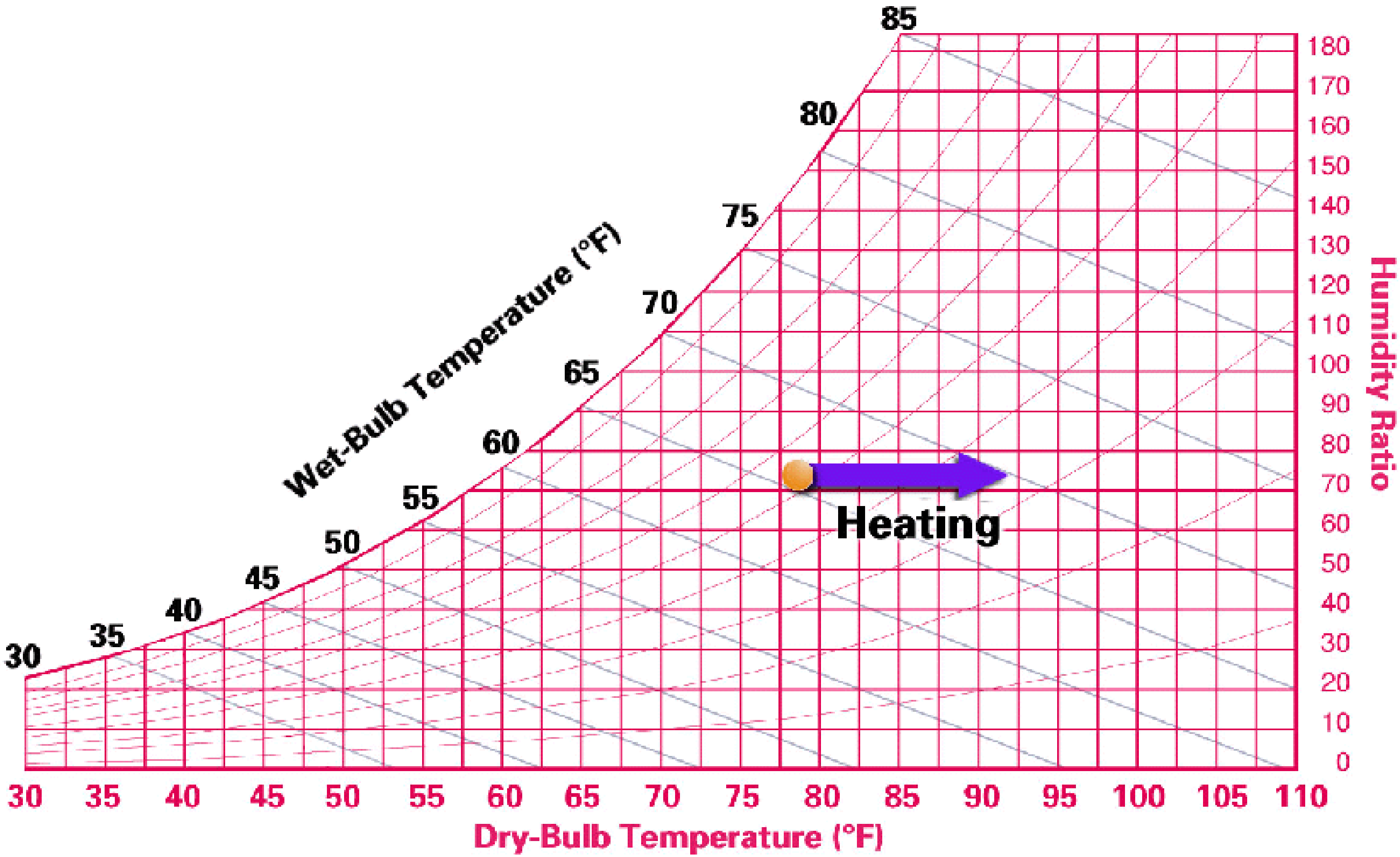


SENSIBLE HEATING

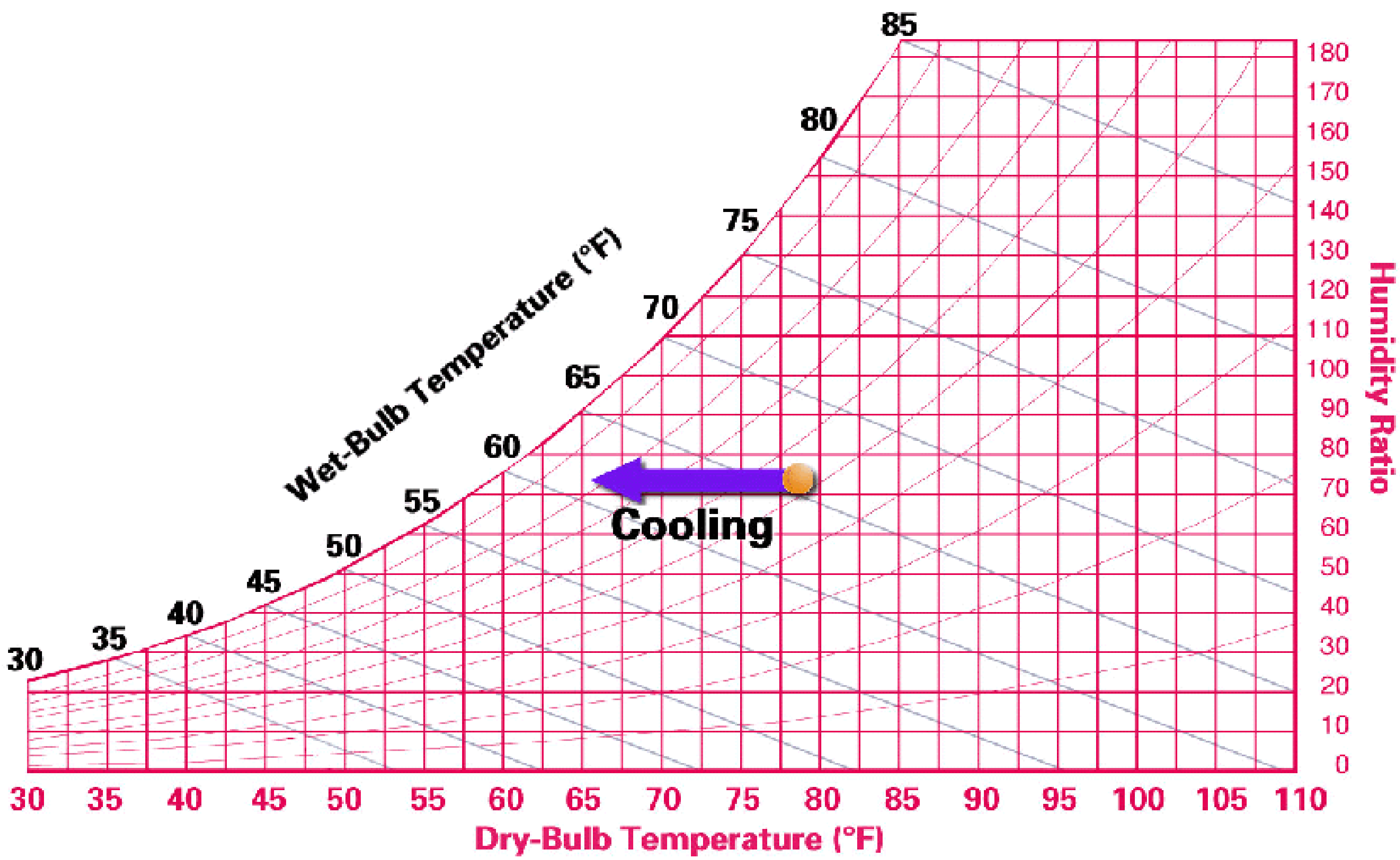


SENSIBLE COOLING

Effect Of Adding Sensible Heat

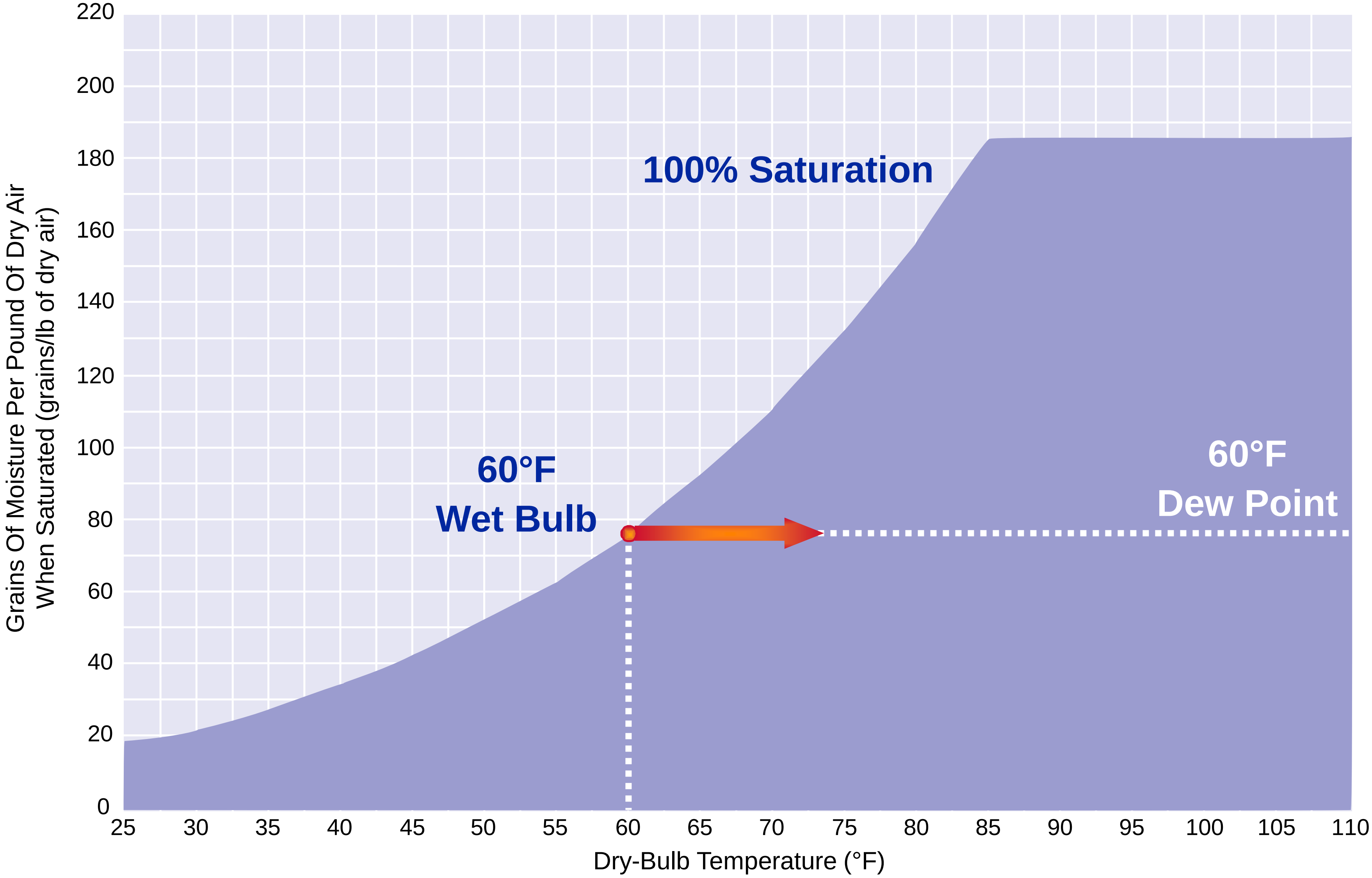


Effect Of Removing Sensible Heat

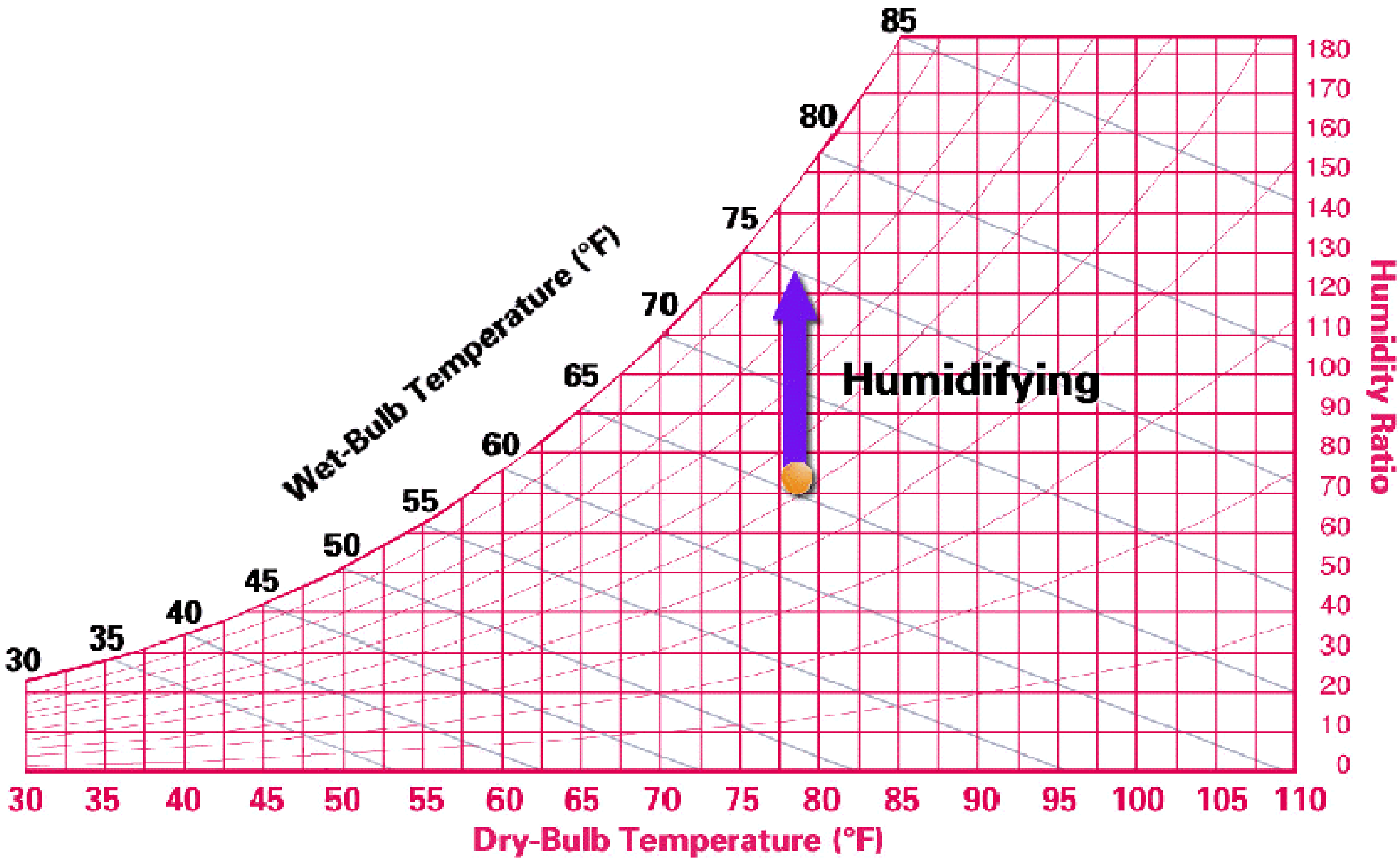


moisture content doesn’t change by…

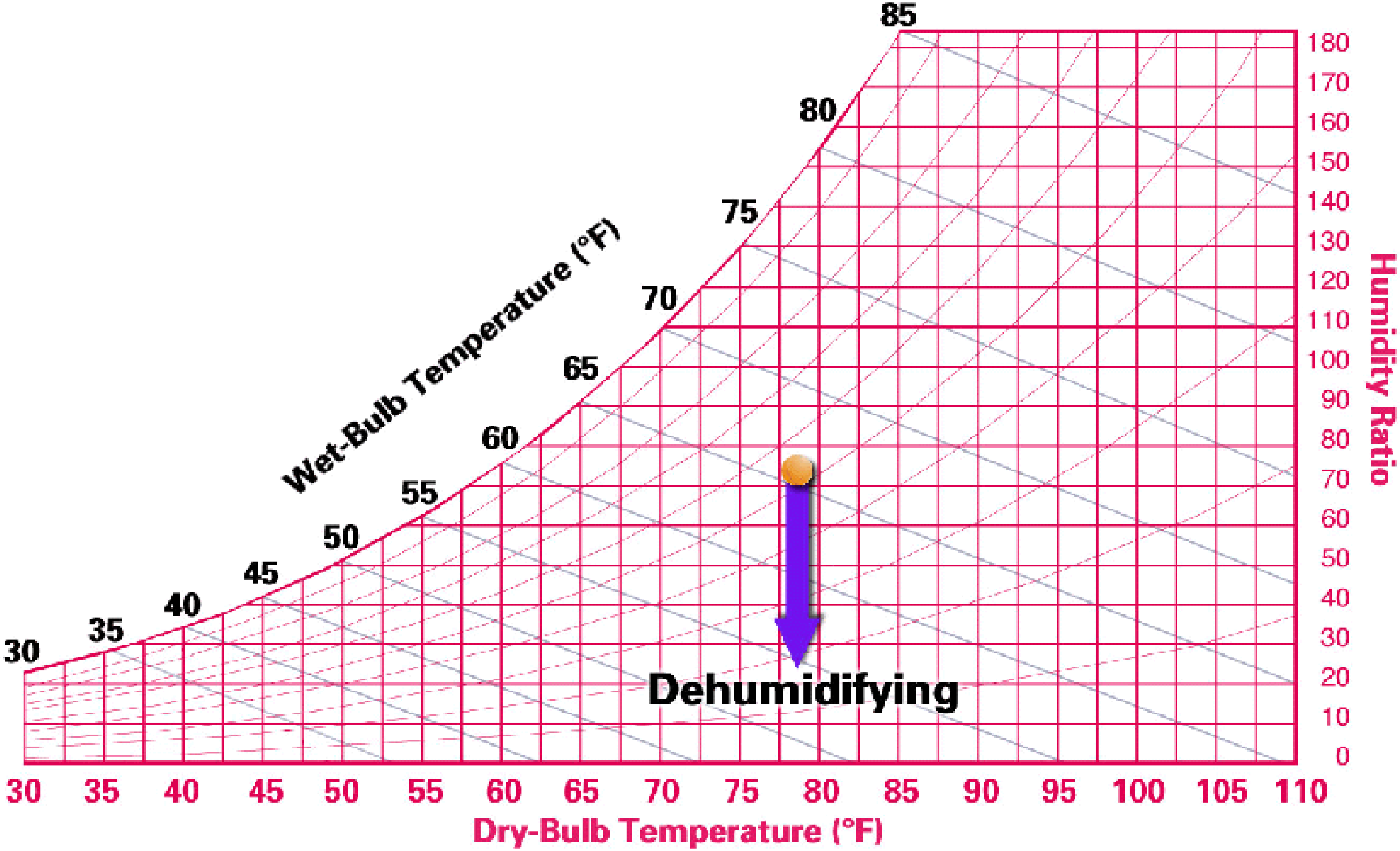
Adding/removing Sensible Heat



Effect Of Adding Moisture



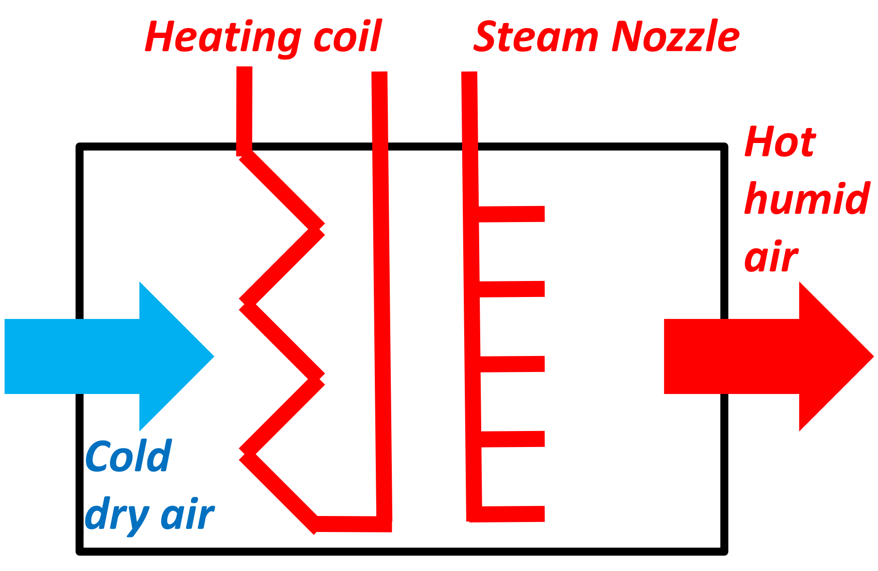
Effect Of Removing Moisture



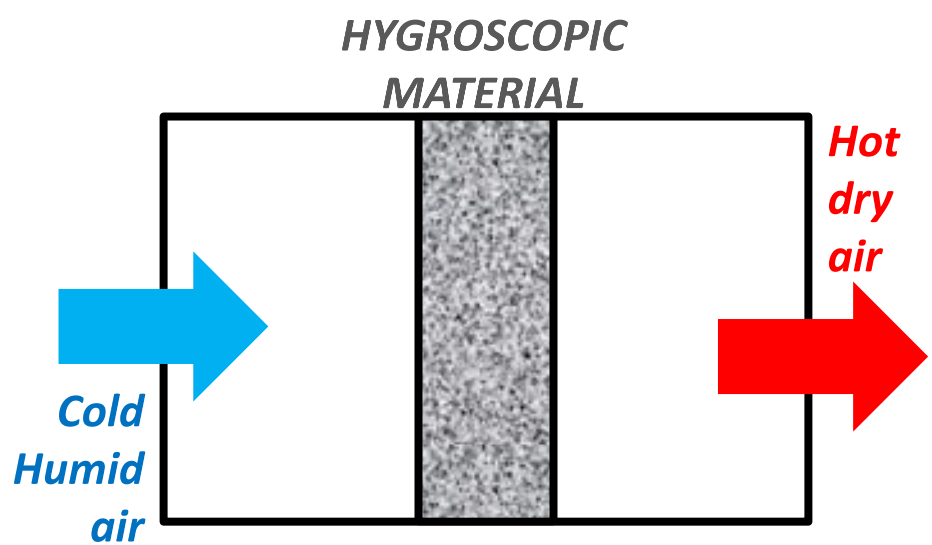
PSYCHROMETRIC PROCESSES

3. ***HEATING AND HUMIDIFICATION-*** *in this process air is first sensibly heated by a heating coil followed by spraying steam via steam nozzle.*

4. ***HEATING AND DEHUMIDIFICATION*** *- This process is achieved by using hygroscopic materials. Absorption of moisture by hygroscopic material(liquid/solid) is an exothermic reaction, as a result heat is released and temperature of air increases.*



HEATING AND HUMIDIFICATION

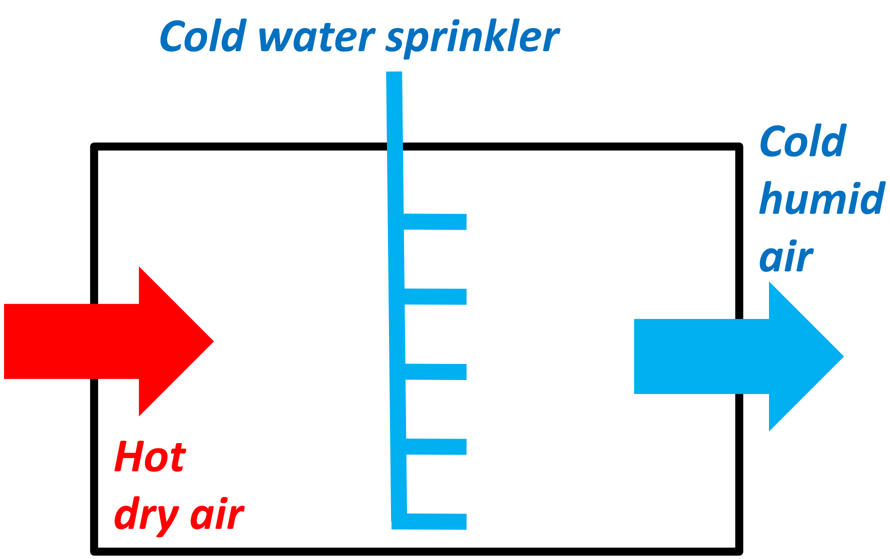


HEATING AND DEHUMIDIFICATION

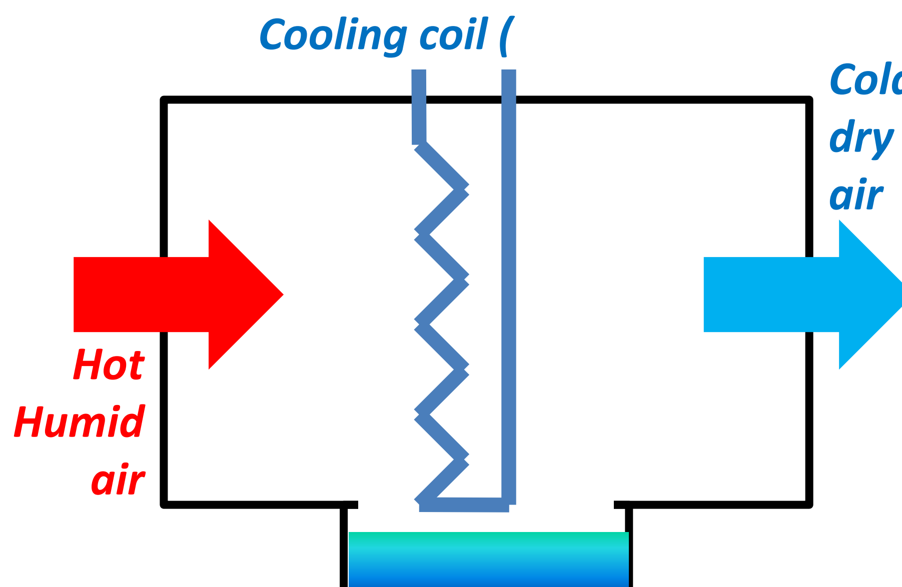
PSYCHROMETRIC PROCESSES

5. **COOLING AND HUMIDIFICATION-** *In this process air is cooled by spraying cold water into air stream.*

6. **COOLING AND DEHUMIDIFICATION** - *In this process air is cooled and moisture is removed when it flows over a cooling coil*



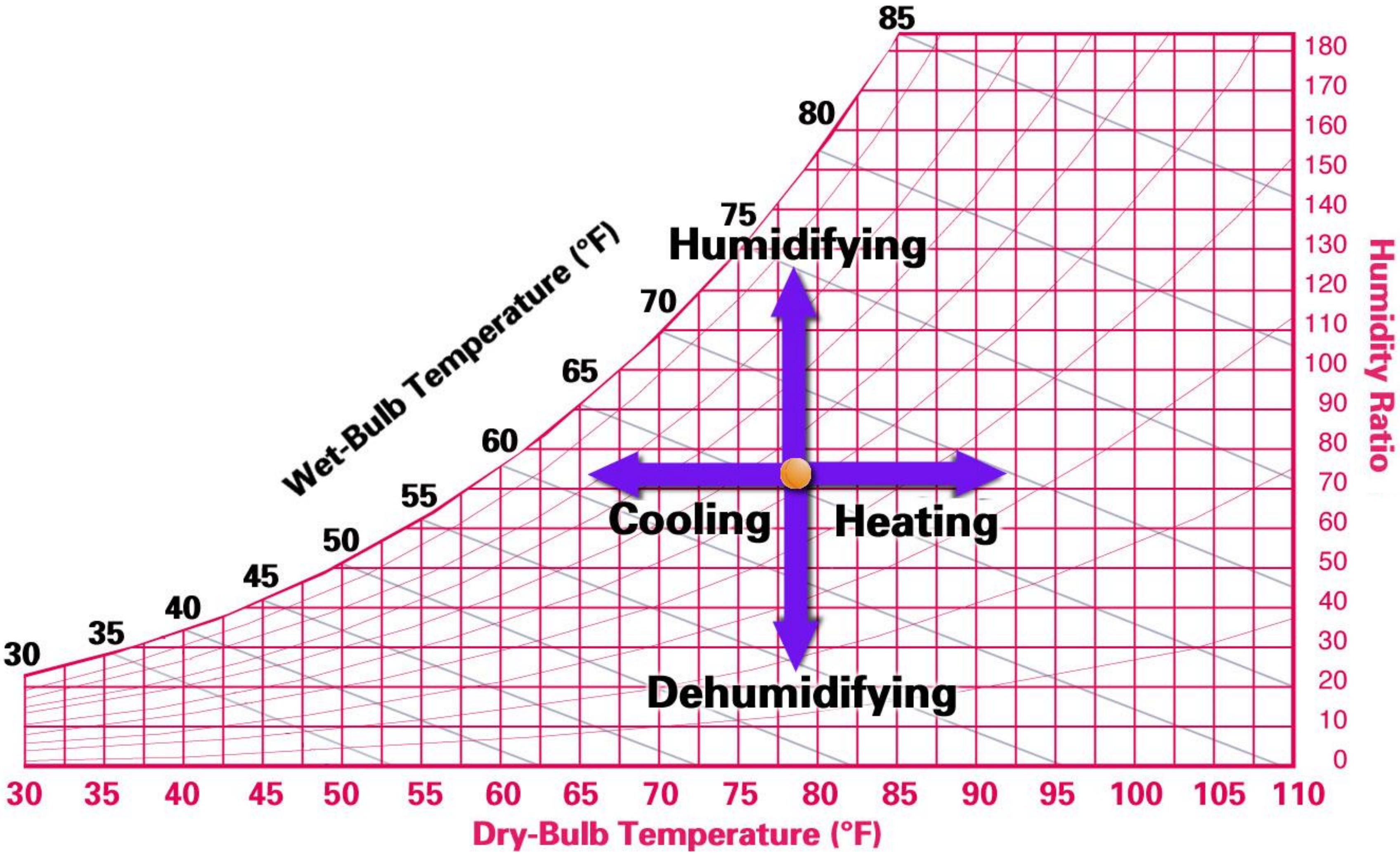
COOLING AND HUMIDIFICATION



COOLING AND DEHUMIDIFICATION

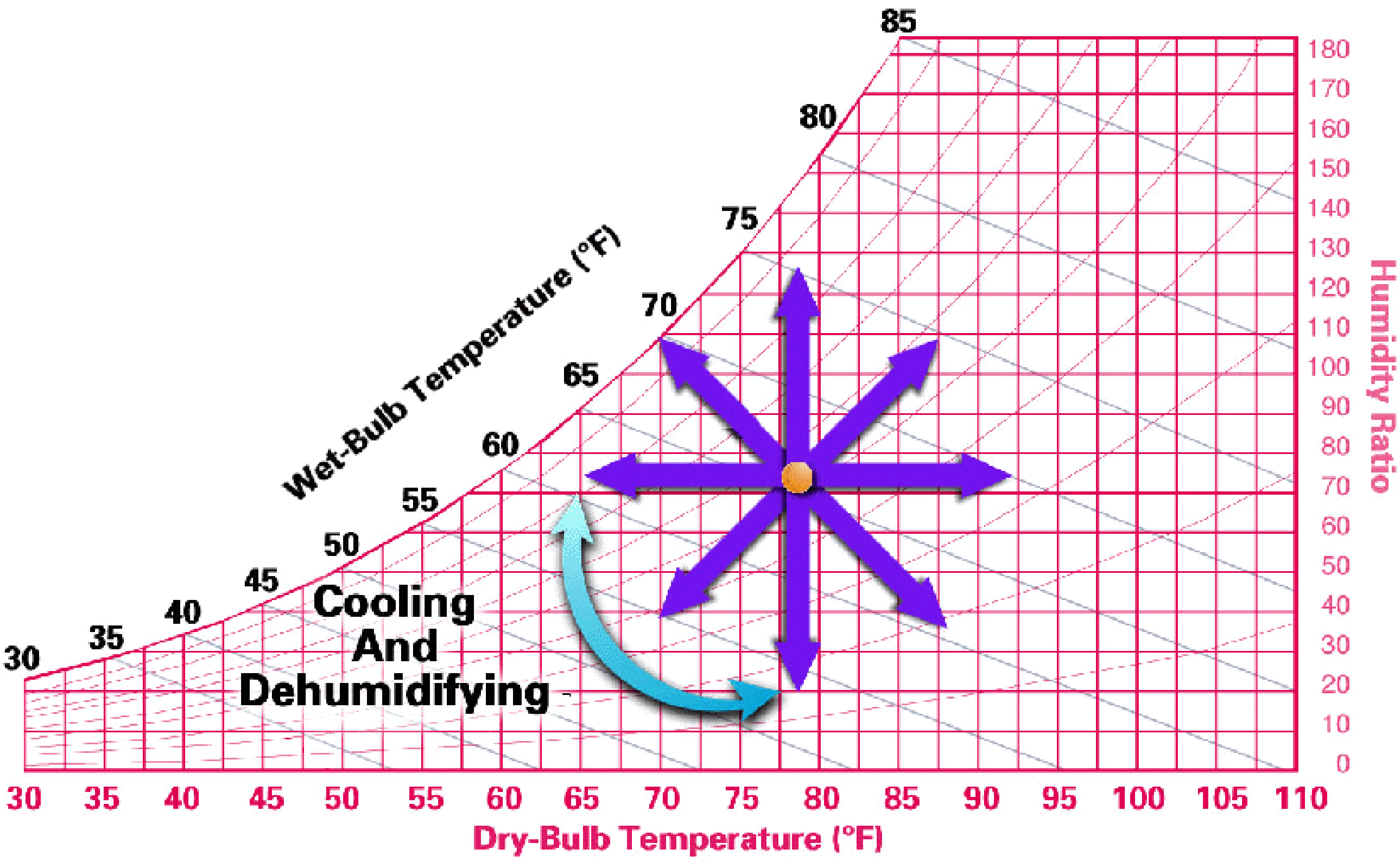
effect of changing…

Sensible Heat And Moisture Content



effect of changing…

Sensible Heat And Moisture Content



PSYCHROMETER

- Any instrument capable of measuring the psychrometric state of air is called a psychrometer.
- It comprises of two thermometers with the bulb of one covered by a moist wick.
- The two sensing bulbs are separated and shaded from each other so that the radiation heat transfer between them becomes negligible

Sling Psychrometer

- Widely used for measurements where the air velocity inside the room is small.
- Consists two thermometers mounted side by side and fitted in a frame with a handle for whirling the device through air.
- The required air circulation (≈ 3 to 5 m/s) over the sensing bulbs is obtained by whirling the psychrometer (≈ 300 RPM).
- Readings are taken when both the thermometers show steady-state readings.

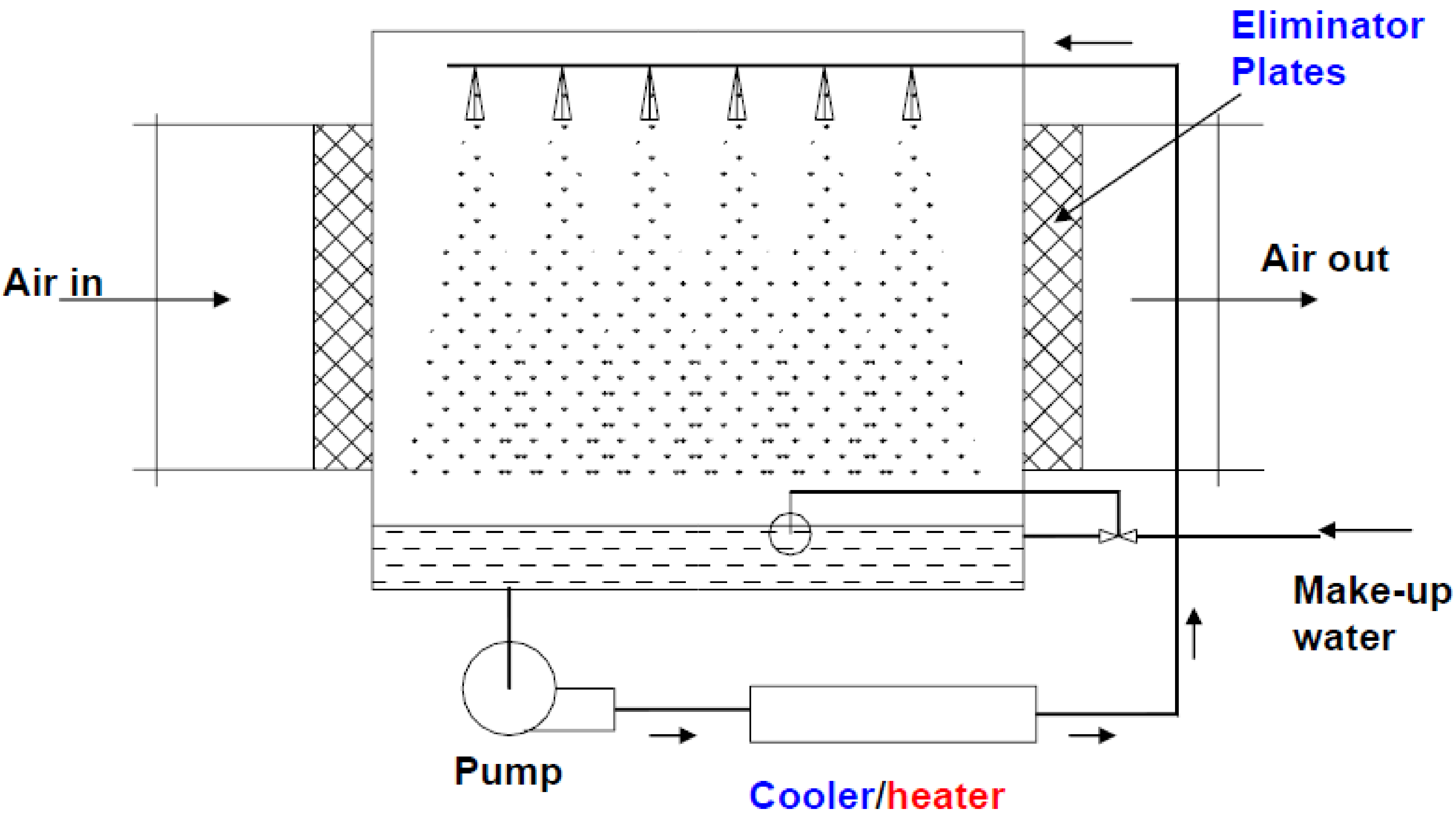
Aspirated Psychrometer

- The thermometers remain stationary, and a small fan, blower or syringe moves the air across the thermometer bulbs.
- The wicks made of cotton or cloth should be replaced frequently, and only distilled water should be used for wetting it.

Other types are:

1. Dunmore Electric Hygrometer
2. DPT meter
3. Hygrometer (Using horse's or human hair)

AIR WASHER


Eliminator
Plates
Air in
Air out
Make-up
water
Pump
Cooler/heater

- An air washer is a device for conditioning air.
- Air comes in direct contact with a spray of water - exchange of heat and mass (water vapour) between air and water.
- The outlet condition of air depends upon the temperature of water sprayed.
- Hence, by controlling the water temperature externally, it is possible to control the outlet conditions of air, which then can be used for air conditioning purposes.

- The mean temperature of water droplets in contact with air decides the direction of heat and mass transfer. Examples are:-
- Cooling and dehumidification: $t_w < t_{DPT}$. Here both latent and sensible heat transfers are from air to water. So water has to be externally cooled.
- Adiabatic saturation: $t_w = t_{WBT}$. Here the sensible heat transfer from air to water is exactly equal to latent heat transfer from water to air. Hence, no external cooling or heating of water is required. This the process that takes place in a perfectly insulated evaporative cooler.

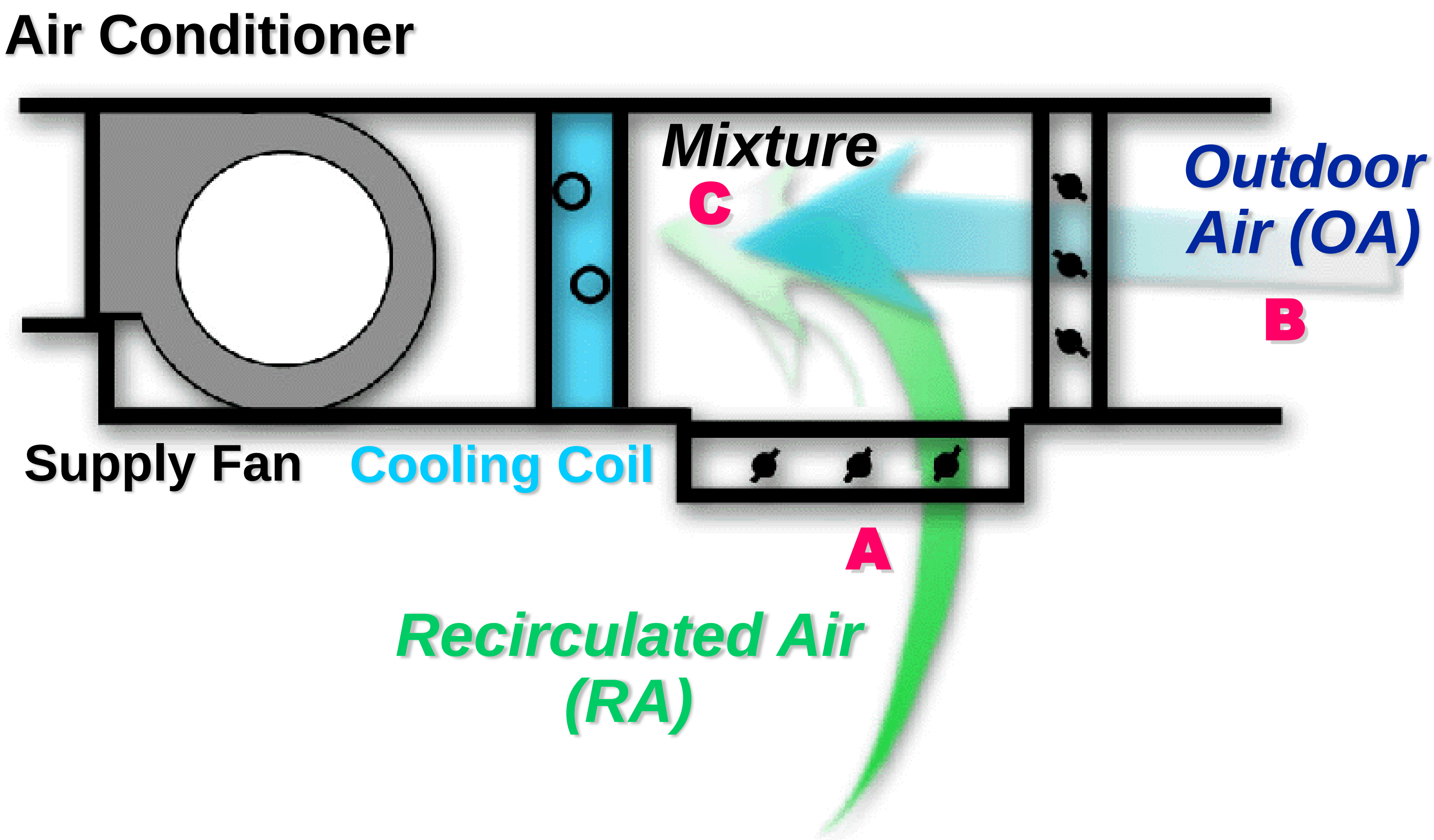
- <u>Cooling and humidification</u>: $t_{DPT} < t_w < t_{WBT}$. Here the sensible heat transfer is from air to water and latent heat transfer is from water to air, but the total heat transfer is from air to water, hence, water has to be cooled externally.
- <u>Cooling and humidification</u>: $t_{WBT} < t_w < t_{DBT}$. Here the sensible heat transfer is from air to water and latent heat transfer is from water to air, but the total heat transfer is from water to air, hence, water has to be heated externally. This is the process that takes place in a cooling tower.

- <u>Heating and humidification</u>: $t_w > t_{DBT}$. Here both sensible and latent heat transfers are from water to air, hence, water has to be heated externally.
- An air washer works as a year-round air conditioning system.
- It is not commonly used for comfort air conditioning applications due to concerns about health resulting from bacterial or fungal growth on the wetted surfaces.
- It can be used in industrial applications.

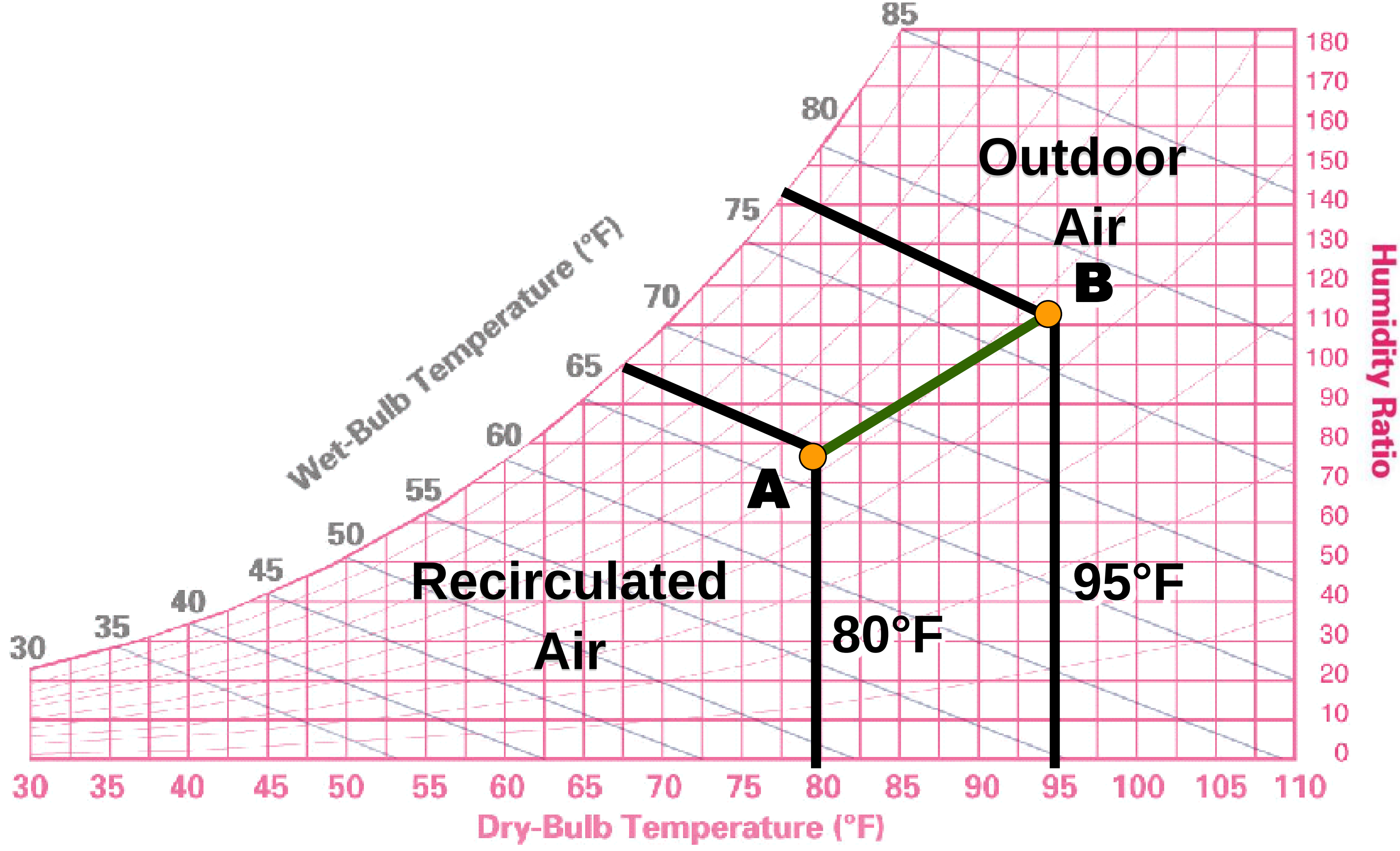
Psychrometry

Air Mixtures

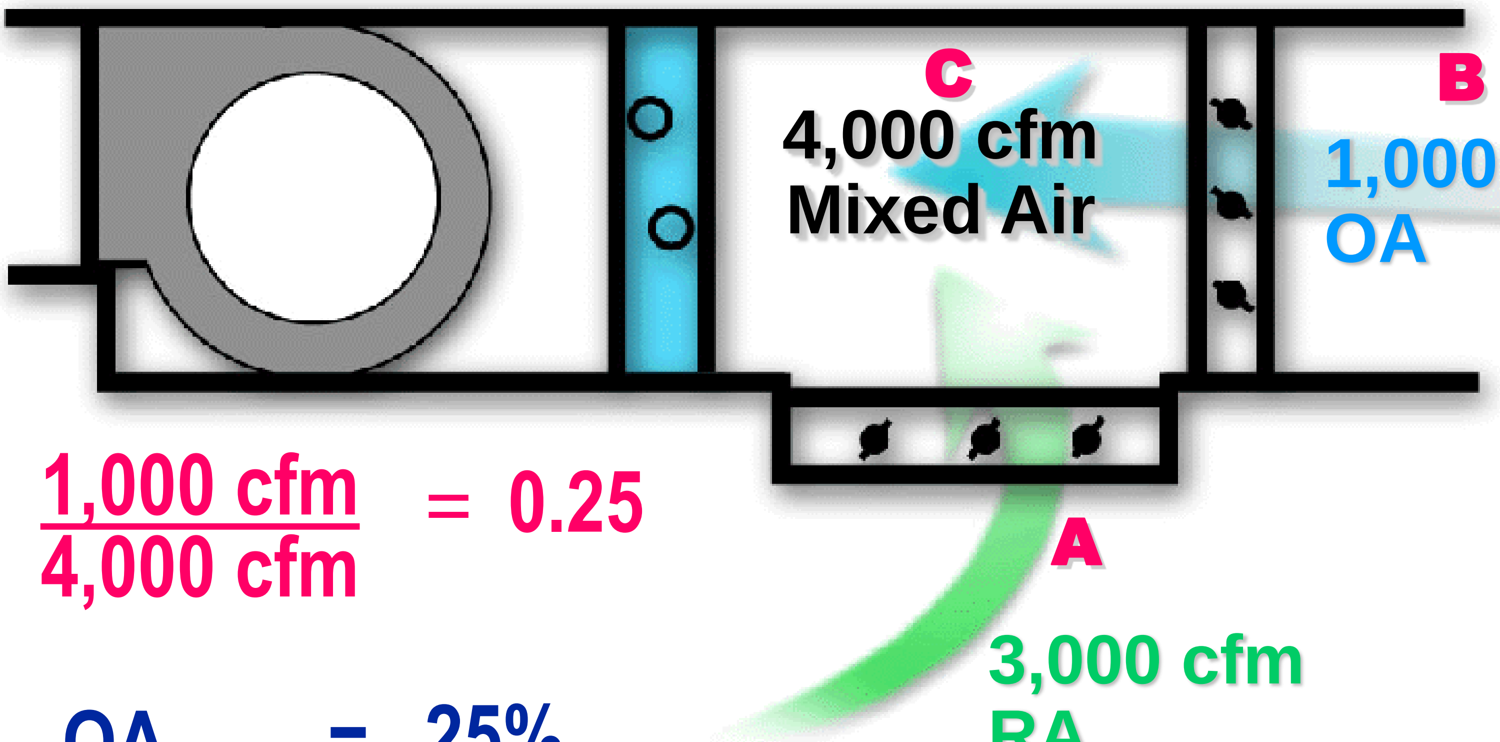
Determining Entering Air Conditions



Determining Entering Air Conditions



Determining Entering Air Conditions



$$\frac{1{,}000 \text{ cfm}}{4{,}000 \text{ cfm}} = 0.25$$

OA = 25%

RA = 75%

Mixture = 100%

Determining Entering Air Conditions

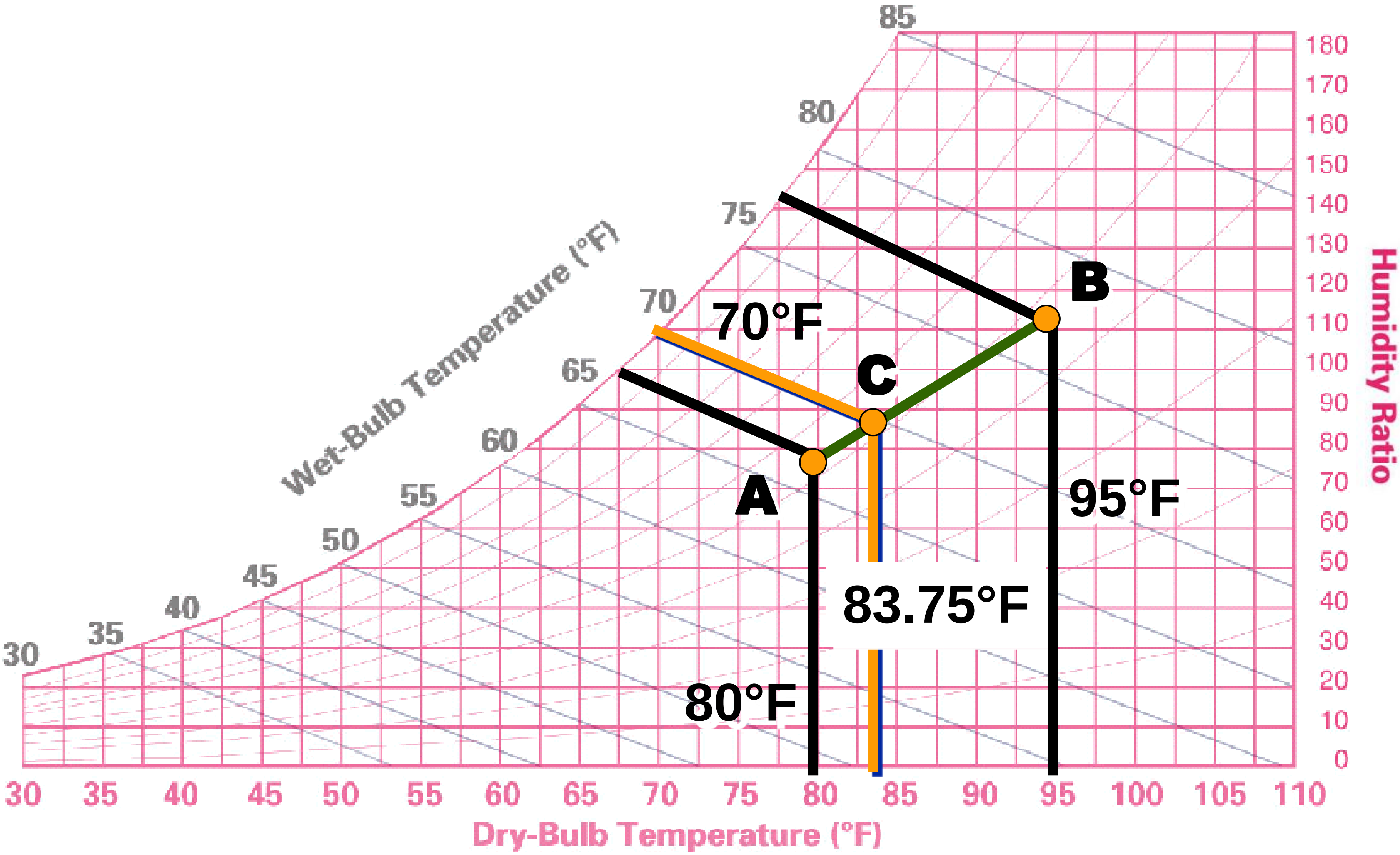
Mixed Air Temperature

$$95°F \times 0.25 = 23.75°F$$

$$\underline{80°F \times 0.75 = 60.00°F}$$

$$\text{Mixture} = 83.75°F$$

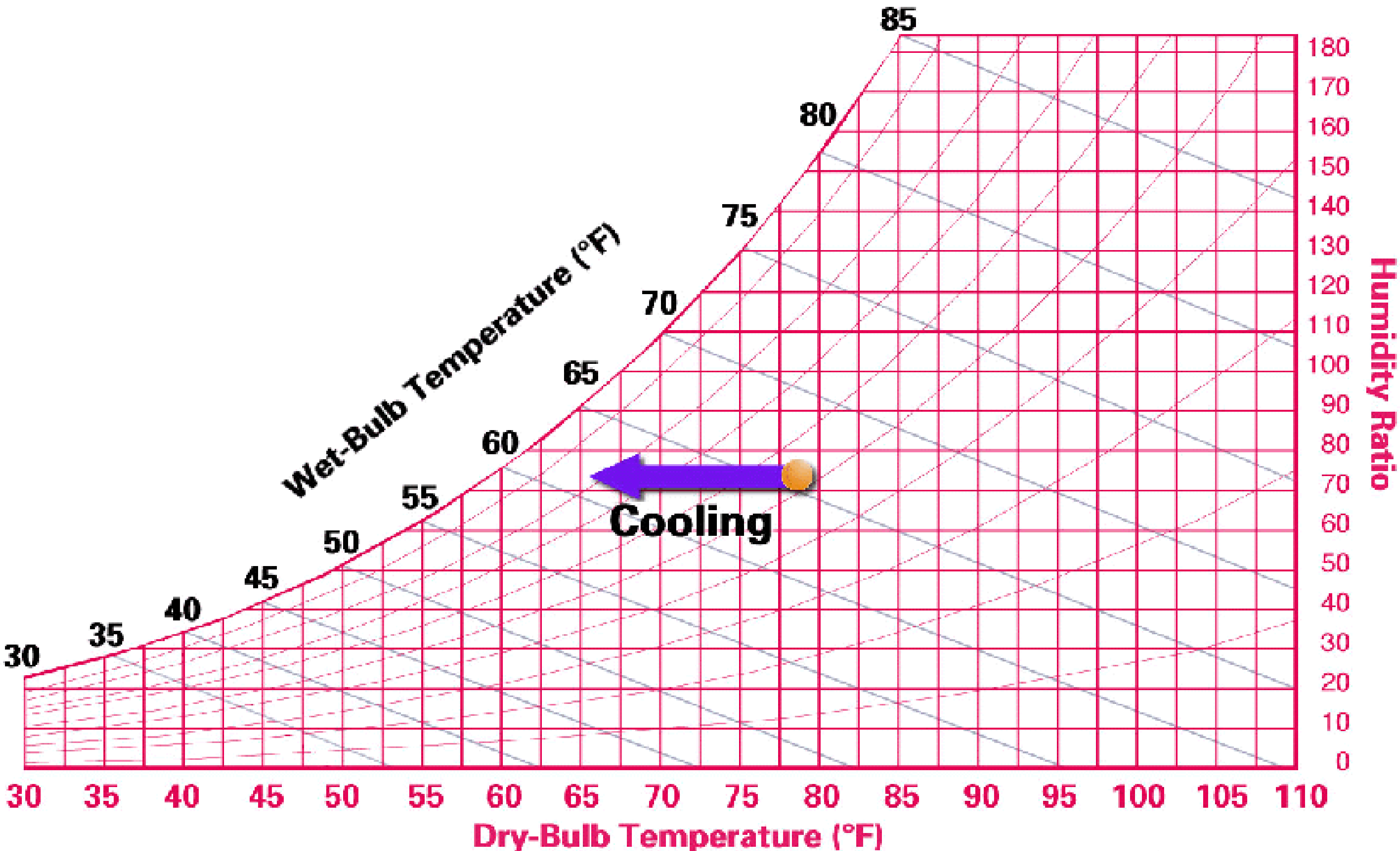
Determining Entering Air Conditions



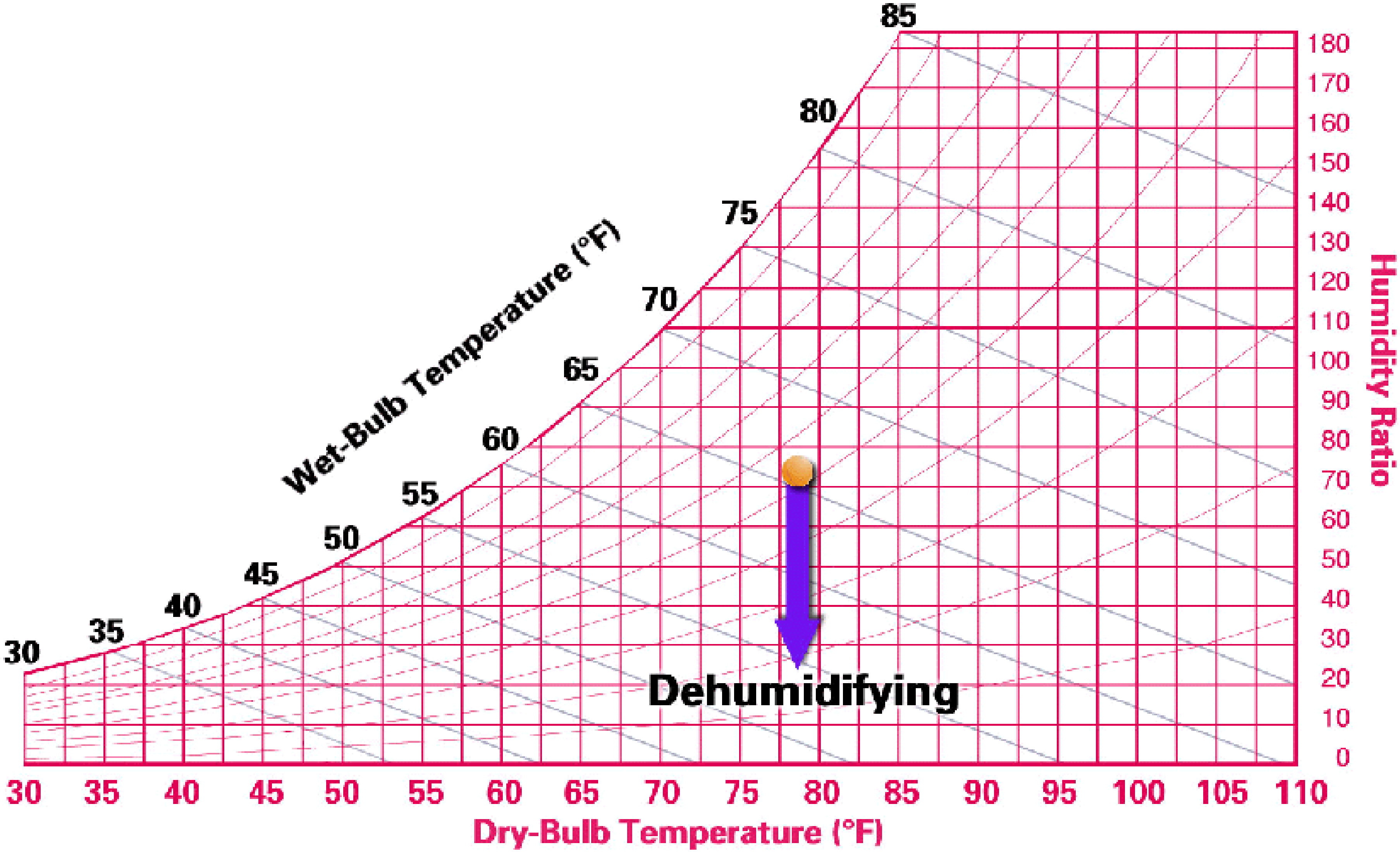
Psychrometry

Sensible Heat Ratio

Effect Of Removing Sensible Heat

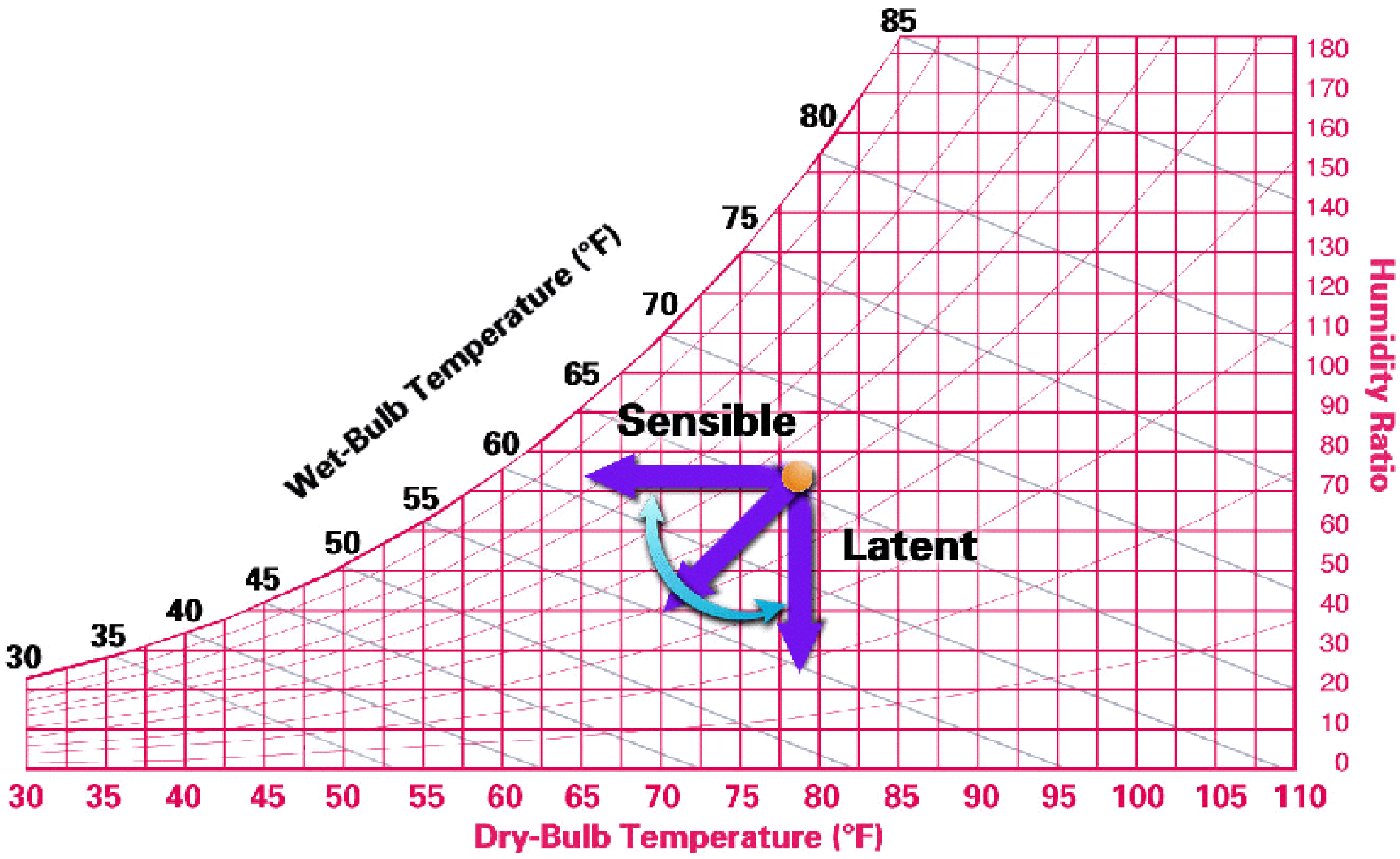


Effect Of Removing Latent Heat



effect of…

Removing Sensible And Latent Heat

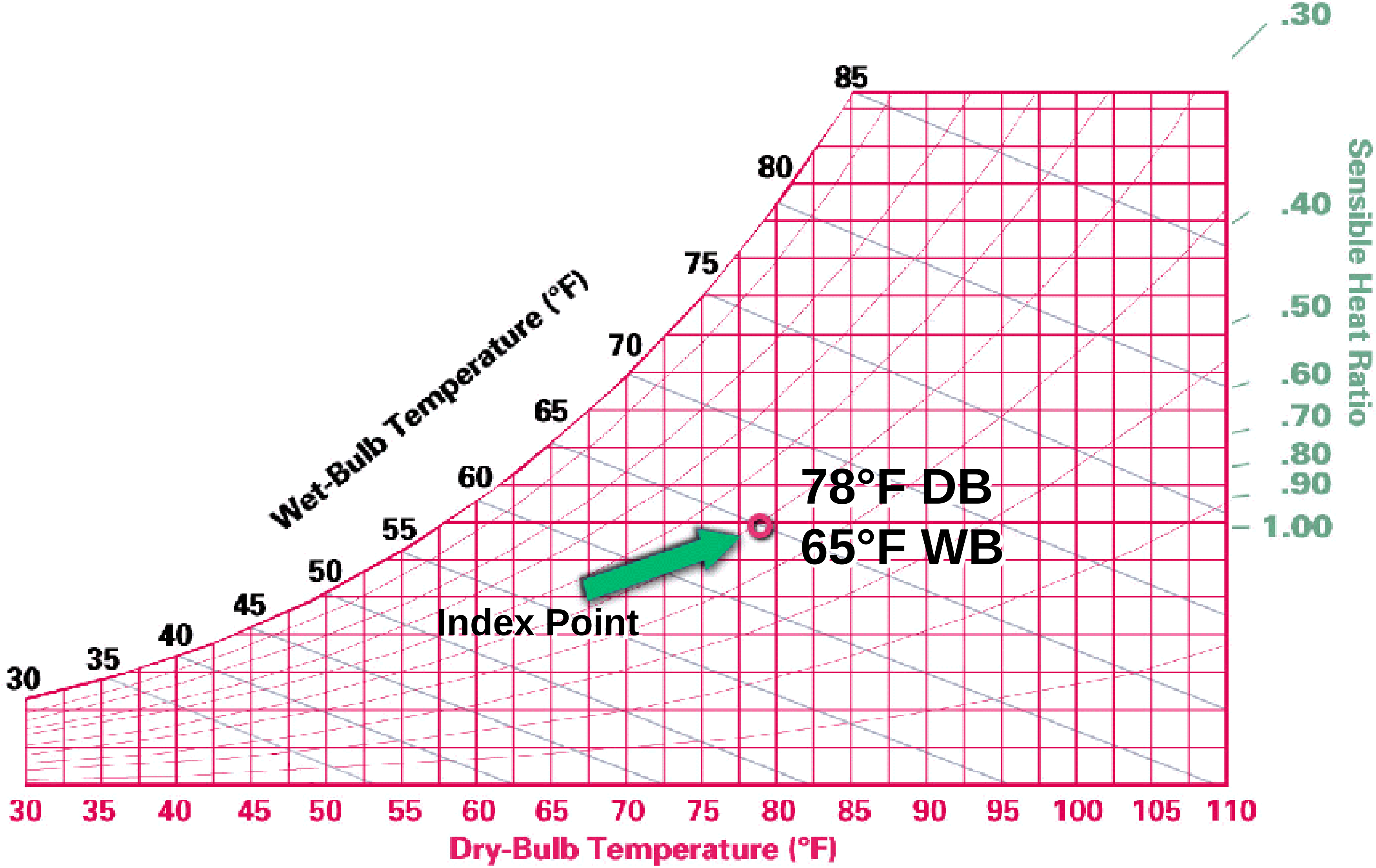


determining the…

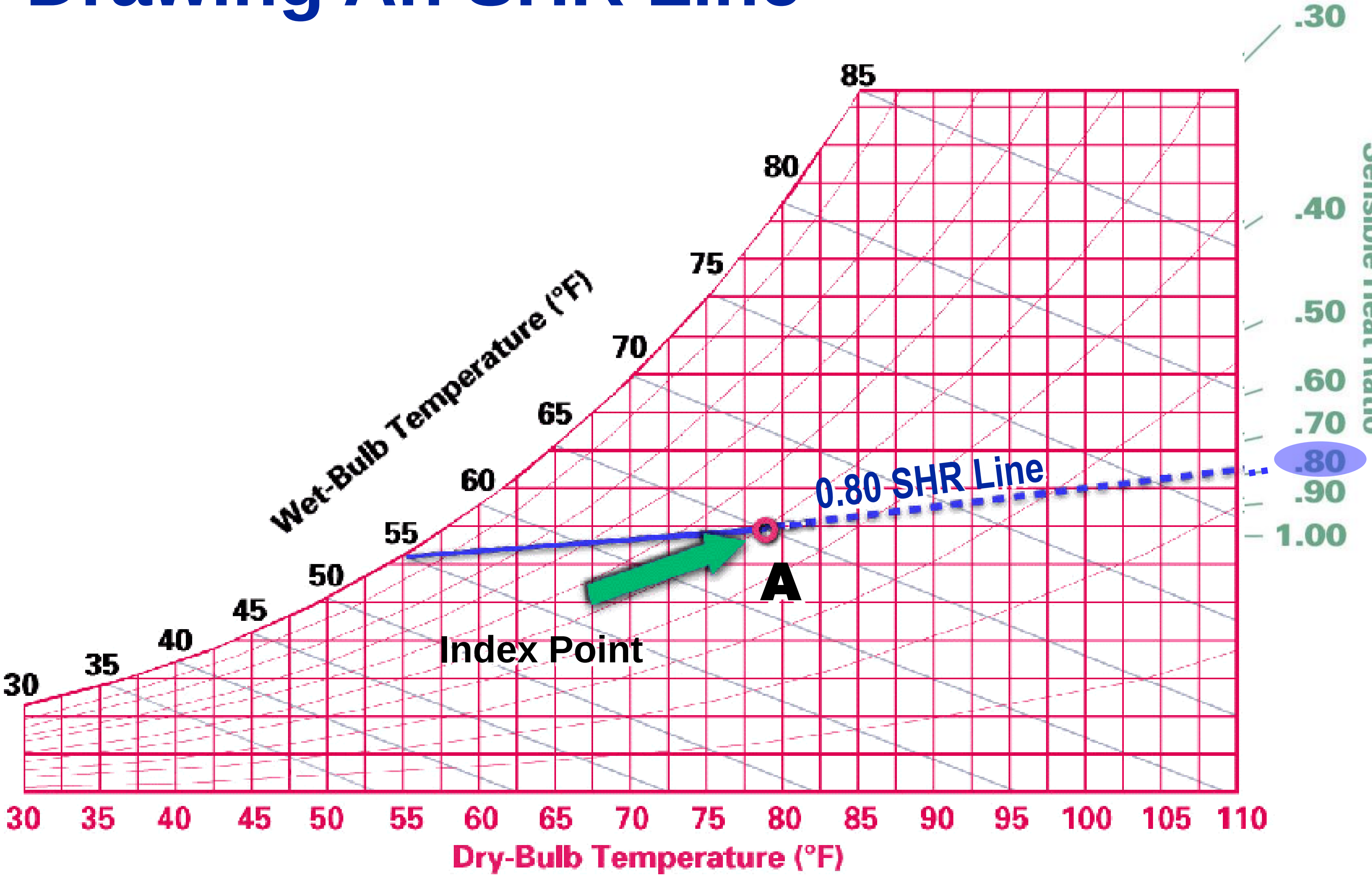
Sensible Heat Ratio (SHR)

$$\text{SHR} = \frac{\text{Sensible Heat Gain}}{\text{Sensible Heat Gain} + \text{Latent Heat Gain}}$$

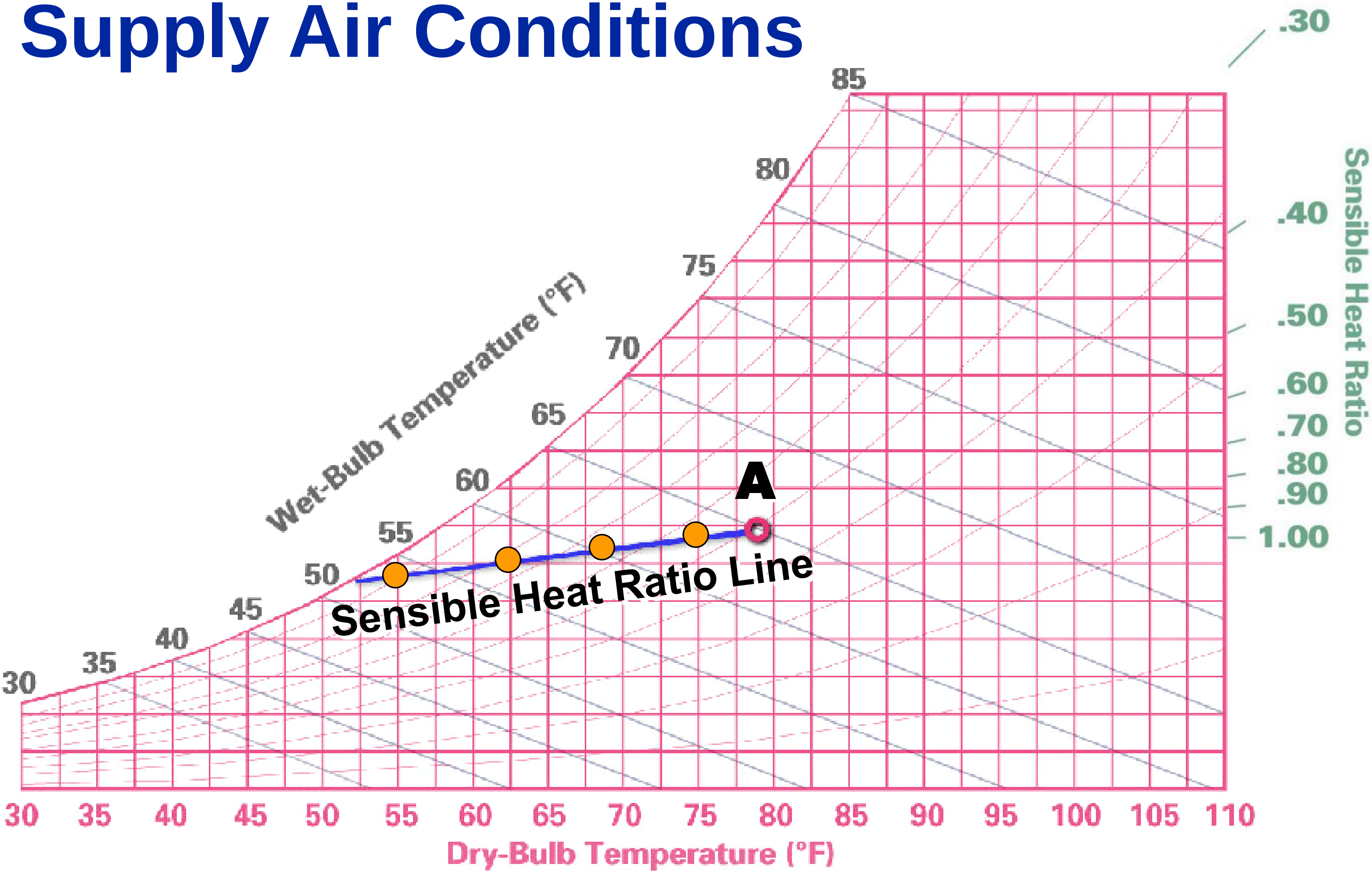
Sensible Heat Ratio Scale



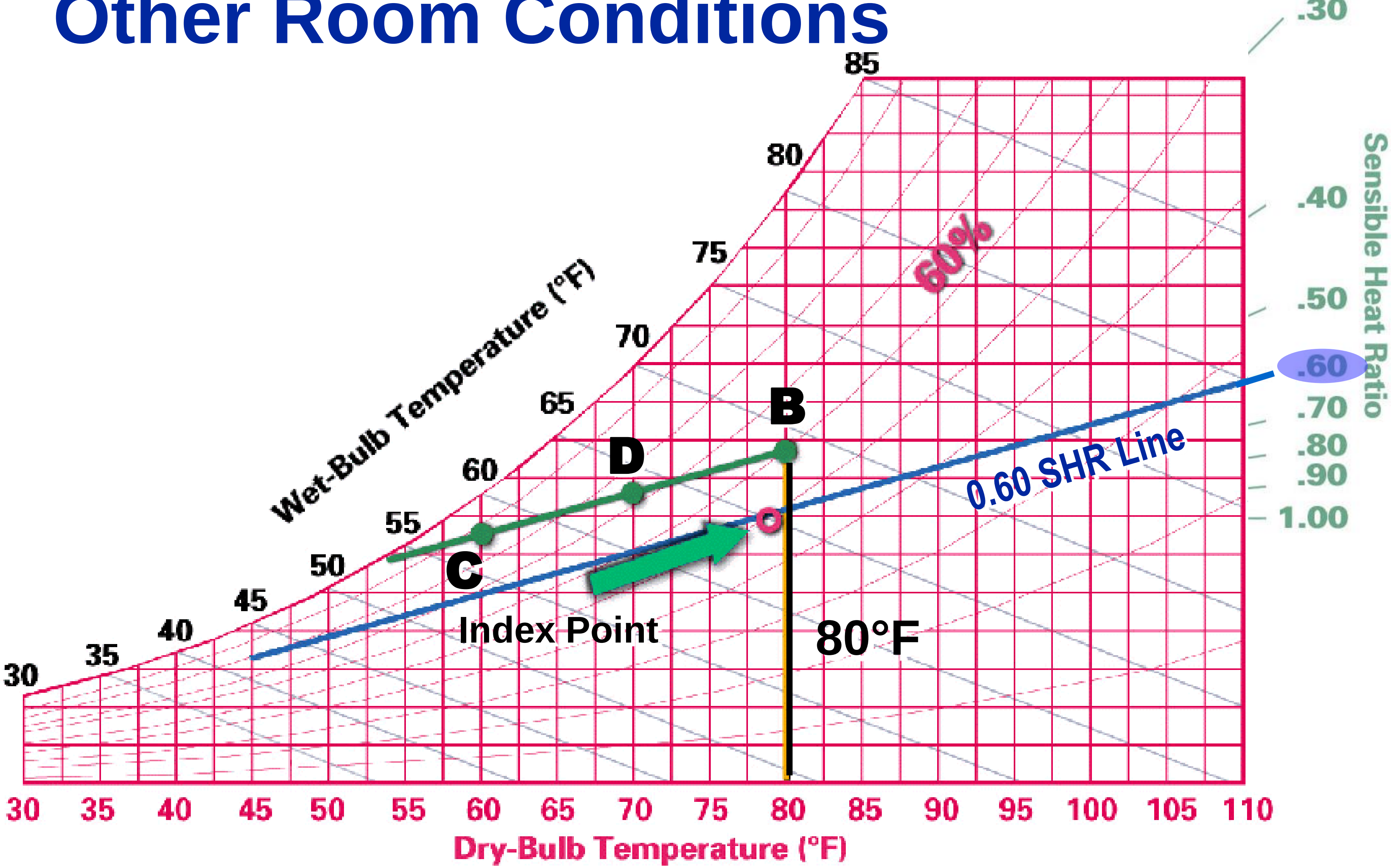
Drawing An SHR Line



Room SHR dictates…
Supply Air Conditions



drawing an SHR line for…
Other Room Conditions



Psychrometry

Air Quantity

Determining Supply Airflow

STEP 1: Calculate the sensible heat ratio (SHR)

80,000 kJ/hr sensible heat gain

20,000 kJ/hr latent heat gain

$$\text{SHR} = \frac{80{,}000 \text{ kJ/hr}}{100{,}000 \text{ kJ/hr}} = 0.80$$

Determining Supply Airflow

Design Conditions:

Room — 78°F DB, 50% RH

OA — 95°F DB, 78°F WB

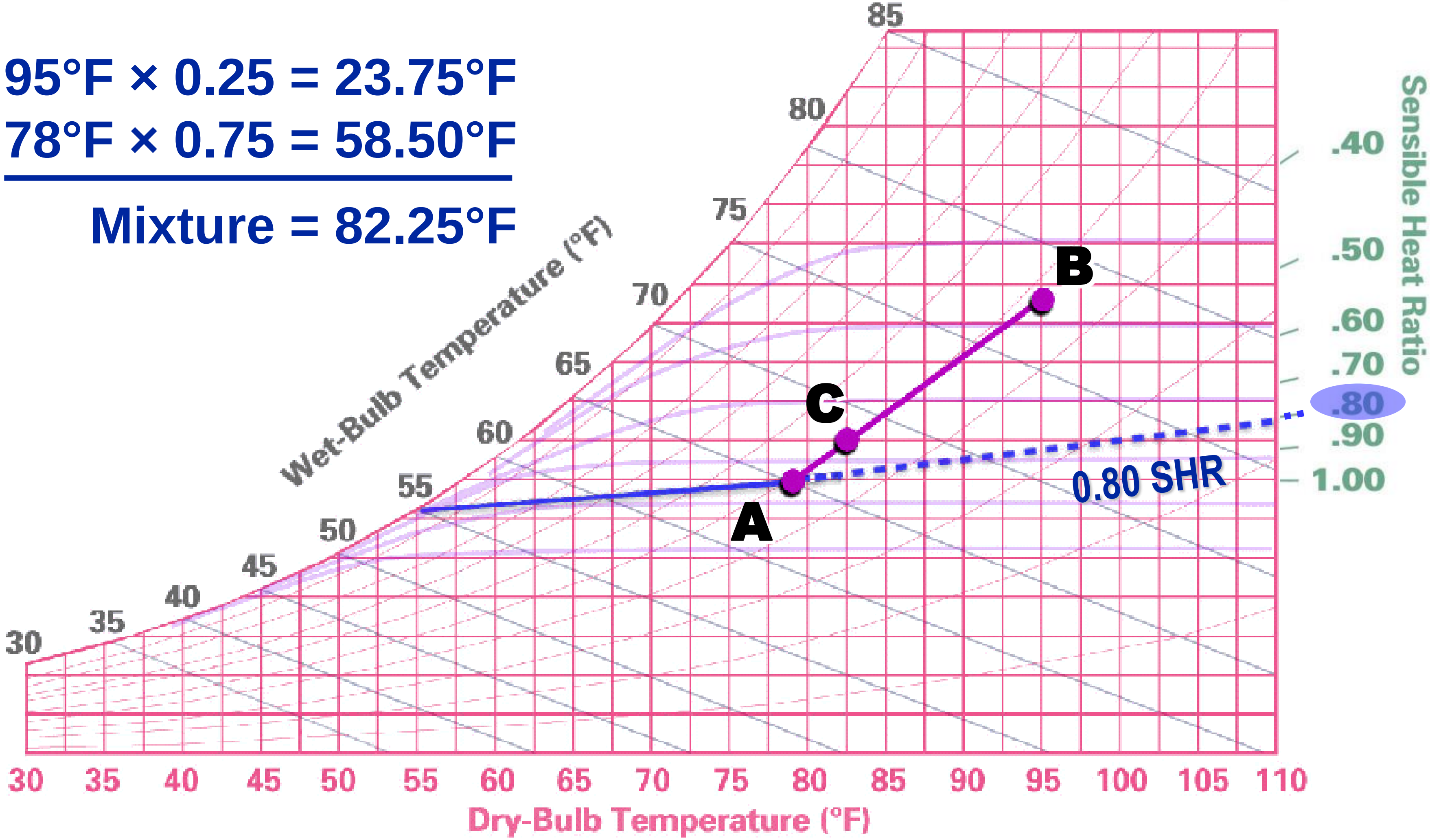
Ventilation — 25% OA

Determining Supply Airflow

STEP 2: Plot room, outdoor, and entering conditions

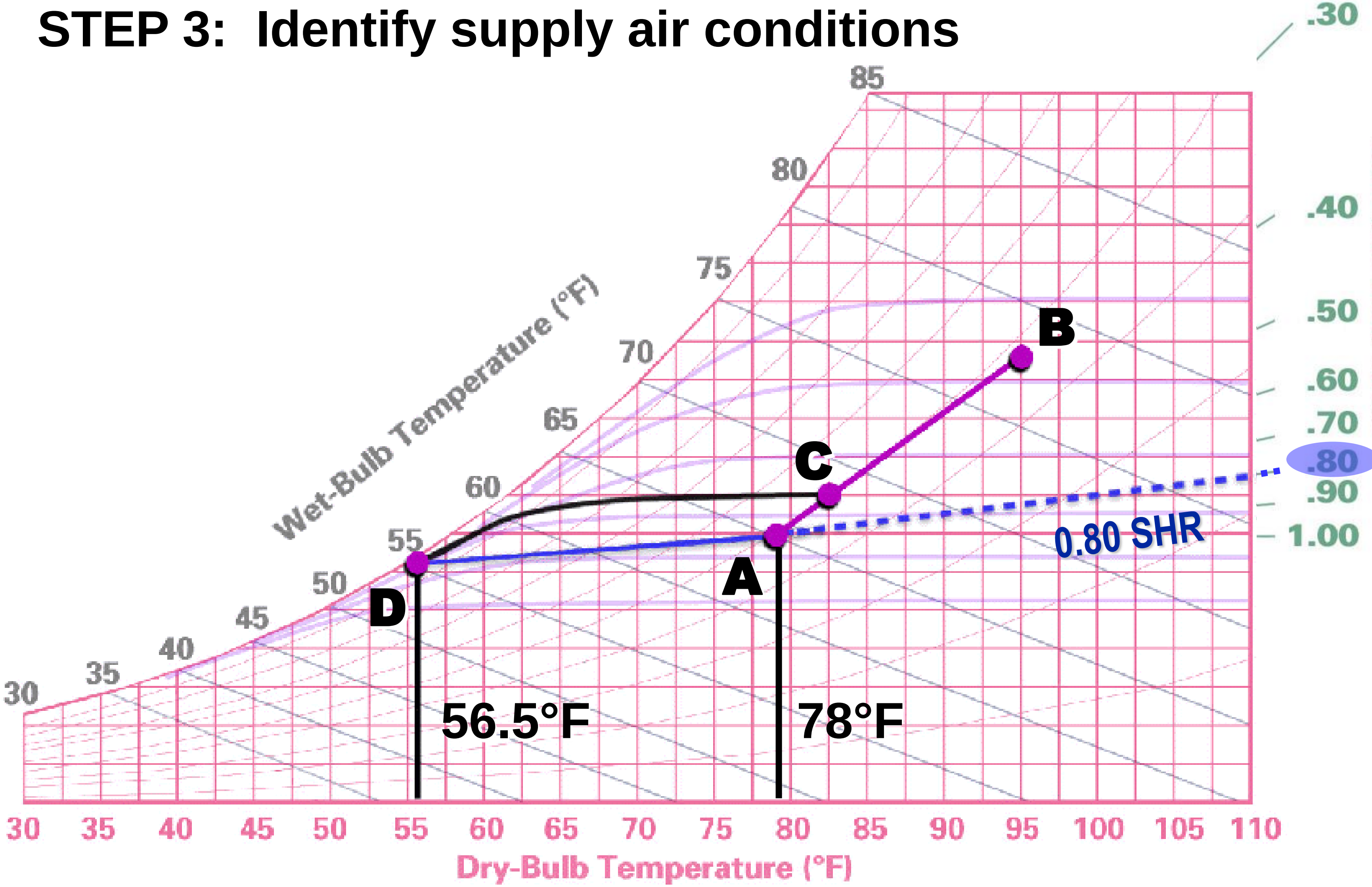
95°F × 0.25 = 23.75°F
78°F × 0.75 = 58.50°F

Mixture = 82.25°F



Determining Supply Airflow

STEP 3: Identify supply air conditions



Determining Supply Airflow

STEP 4: Solve the supply airflow equation

$$\frac{\text{Sensible Heat Gain}}{0.02044 \times (\text{Room DBT} - \text{Supply DBT})} = \text{Supply Airflow in CMM}$$

CMM = Cubic meter/minute(m^3/minute)

DBT in ^{0}C

Sensible Heat gain in kJ/s

DUCT DESIGN

The chief requirements are:

- It should convey specified rates of air flow to prescribed locations
- It should be economical in combined initial cost, fan operating cost and cost of building space
- It should not transmit or generate objectionable noise

Pre-requisites of duct design are:

- The required airflow rates from load calculations.
- The location of fans and air outlets are fixed initially.
- The duct layout is then made taking into account the space available and ease of construction.

General rules for duct design

- Air should be conveyed as directly as possible to save space, power and material.
- Sudden changes in directions should be avoided. When not possible to avoid sudden changes, turning vanes should be used to reduce pressure loss.
- Diverging sections should be gradual. Angle of divergence $\leq 20^o$

- Aspect ratio should be as close to 1.0 as possible. Normally, it should not exceed 4.
- Air velocities should be within permissible limits to reduce noise and vibration.
- Duct material should be as smooth as possible to reduce frictional losses.

Classification

- <u>Low pressure systems:</u> Velocity ≤ 10 m/s, static pressure ≤ 5 cm H_2O
- <u>Medium pressure systems:</u> Velocity ≤ 10 m/s, static pressure ≤ 15 cm H_2O
- <u>High pressure systems:</u> Velocity > 10 m/s, static pressure $15<p \leq 25$ cm H_2O

High velocities in the ducts results in:

- Smaller ducts and hence, lower initial cost and lower space requirement
- Higher pressure drop and hence larger fan power consumption
- Increased noise and hence a need for noise attenuation

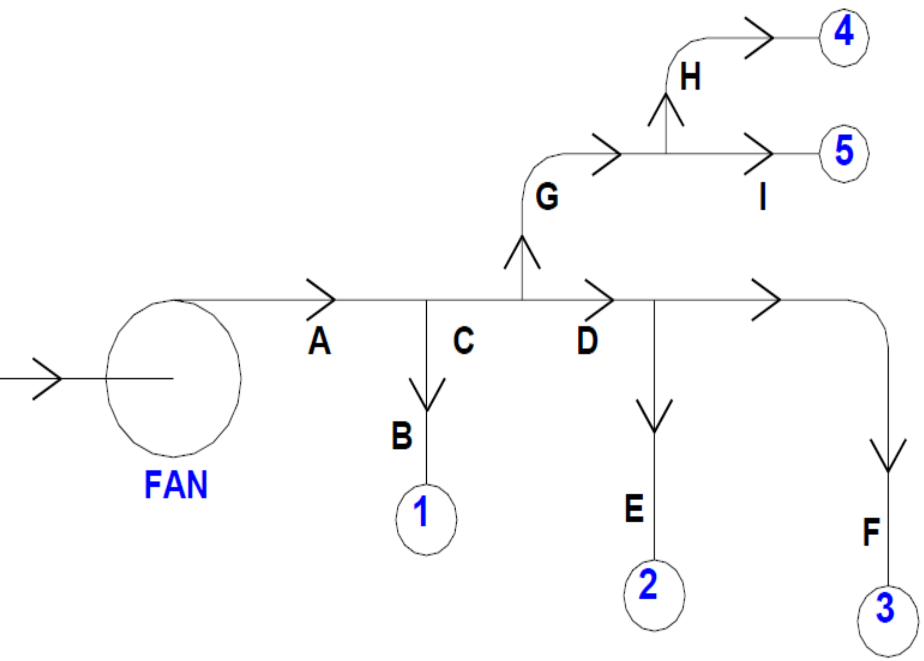
Typical recommended velocities are:

- **Residences: 3 m/s to 5 m/s**
- **Theatres: 4 to 6.5 m/s**
- **Restaurants: 7.5 m/s to 10 m/s**

➢ If nothing is specified, then a velocity of **5 to 8 m/s** is used for main ducts and a velocity of **4 to 6 m/s** is used for the branches.

➢ The allowable air velocities can be as high as **30 m/s in ships and aircrafts** to reduce the space requirement.

Duct Design Methods



- The run with the highest pressure drop is called as the **index run**.
- From load and Psychrometric calculations the required supply airflow rates are known.
- From the building layout and the location of the supply fan, the length of each duct run is known.

- The purpose of the duct design is to select suitable dimensions of duct for each run and then to select a fan, which can provide the required supply airflow rate to each conditioned zone.
- Most commonly used methods are:

1. Velocity method
2. Equal Friction (Constant pressure loss) Method
3. Static Regain method

Velocity method

- Here **the velocity decreases as the flow proceeds**.

The various steps involved are:

- ➢ Select suitable velocities in the main and branch ducts
- ➢ Find the diameters of main and branch ducts from airflow rates and velocities for circular ducts. For rectangular ducts, find the cross-sectional area from flow rate and velocity, and then by fixing the aspect ratio, find the two sides of the rectangular duct.

- From the velocities and duct dimensions obtained, find **the frictional pressure drop** for main and branch ducts.
- From the duct layout, dimensions and airflow rates, find **the dynamic pressure losses** for all the bends and fittings.
- Select a fan that can provide sufficient airflow for the index run.

- Balancing dampers have to be installed in each run.
- The damper in the index run is left completely open, while the other dampers are throttled to reduce the flow rate to the required design values.
- The application of this method requires **selection of suitable velocities** in different duct runs, which requires experience.

- Wrong selection of velocities can lead to very large ducts, which, occupy large building space and increases the cost, or very small ducts which lead to large pressure drop and hence necessitates the selection of a large fan leading to higher fan cost and running cost.
- The method is not very efficient as it requires partial closing of all the dampers except the one in the index run, so that the total pressure drop in each run will be same.

Equal friction method

- Here the **frictional pressure drop** per unit length in the main and branch ducts **($\Delta p_f/L$) are kept same**, i.e.,

$$\left(\frac{\Delta p_f}{L}\right)_A = \left(\frac{\Delta p_f}{L}\right)_B = \left(\frac{\Delta p_f}{L}\right)_C = \left(\frac{\Delta p_f}{L}\right)_D = \ldots$$

The stepwise procedure are as follows:

➢ Select a suitable frictional pressure drop per unit length (**$\Delta p_f/L$**) so that the combined initial and running costs are minimized.

- Then the equivalent diameter of the main duct (A) is obtained from the selected value of ($\Delta p_f/L$) and the airflow rate.

- Airflow rate in the main duct is equal to the sum total of airflow rates to all the conditioned zones.

- From the airflow rate and (**$\Delta p_f/L$**) the equivalent diameter of the main duct (**$D_{eq.}$**) can be obtained either from the friction chart or using the frictional pressure drop equation:

$$D_{eq,A} = \left(\frac{0.022243\, \dot{Q}_A^{\,1.852}}{\left(\frac{\Delta p_f}{L}\right)_A} \right)^{\left(1/4.973\right)}$$

- Since the frictional pressure drop per unit length is same for all the duct runs, the equivalent diameters of the other duct runs, are obtained from the equation:

$$\left(\frac{\dot{Q}^{1.852}}{D_{eq}^{4.973}}\right)_A = \left(\frac{\dot{Q}^{1.852}}{D_{eq}^{4.973}}\right)_B = \left(\frac{\dot{Q}^{1.852}}{D_{eq}^{4.973}}\right)_C = \ldots$$

- The velocity of air through each duct is obtained from the volumetric flow rate and the cross-sectional area.
- Next from the dimensions of the ducts in each run, the total frictional pressure drop of that run is obtained by multiplying the frictional pressure drop per unit length and the length

- Next the dynamic pressure losses in each duct run are obtained based on the type of bends or fittings used in that run.
- Next the total pressure drop in each duct run is obtained by summing up the frictional and dynamic losses of that run
- Next the fan is selected to suit the index run with the highest pressure loss. Dampers are installed in all the duct runs to balance the total pressure loss.

- This method usually yields a better design as most of the available pressure drop is dissipated as friction in the duct runs, rather than in the balancing dampers.
- Generally suitable when the ducts are not too long, and it can be used for both supply and return ducts.
- However, it requires partial closure of dampers in all but the index run, which may generate noise.
- If the ducts are too long then the total pressure drop will be high and due to dampering, ducts near the fan get over-pressurized.

Static Regain Method

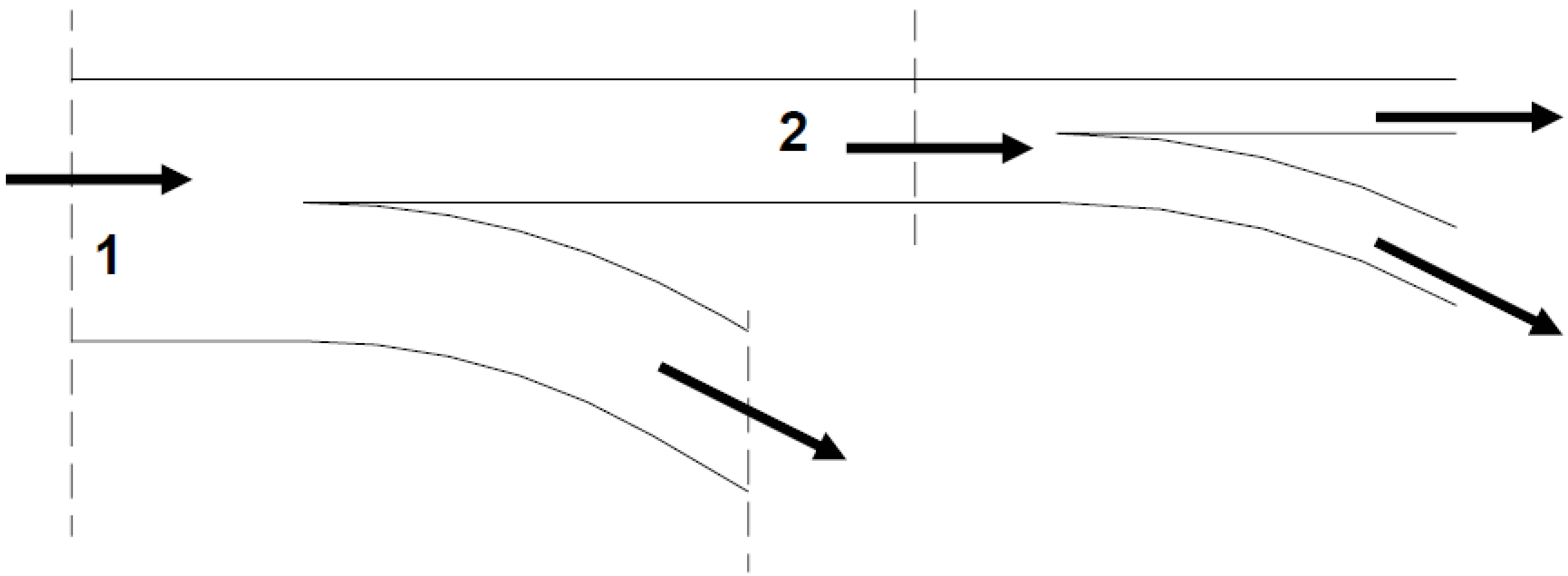
- Commonly used for high velocity systems with long duct runs, especially in large systems.
- The static pressure is maintained same before each terminal or branch.

The procedure followed is as given below:

- ➢ Velocity in the main duct leaving the fan is selected first.

- Velocities in each successive runs are reduced such that the gain in static pressure due to reduction in velocity pressure equals the frictional pressure drop in the next duct section. Thus the static pressure before each terminal or branch is maintained constant.

$p_{s,1} = p_{s,2}$



- If section 1 is the outlet of the fan, then its dimensions are known from the flow rate and velocity (initially selected).
- Since both the dimensions and velocity at section 2 are not known, a trial-and-error method has to be followed to get required dimensions of the section at 2.
- The procedure is followed in the direction of airflow, and the dimensions of the downstream ducts are obtained.
- The total pressure drop is obtained from the pressure drop in the longest run and a fan is accordingly selected.

- Static Regain method yields a more balanced system and does not call for unnecessary dampering.
- However, as velocity reduces in the direction of airflow, the duct size may increase in the airflow direction.
- Also the velocity at the exit of the longer duct runs may become too small for proper air distribution in the conditioned space.

AIR DISTRIBUTION SYSTEMS

Definitions

Intake. An opening through which air is *returned* or *exhausted* from the space.

Outlet. An opening through which air is *supplied* to the treated space.

Grille. A functional or decorative covering for an outlet or intake.

Resister. A grille provided with a damper.

Diffuser. An outlet grille (or appurtenance) designed to guide the direction of the air.

Throw. The horizontal or vertical axial distance that an air stream travels on leaving the outlet.

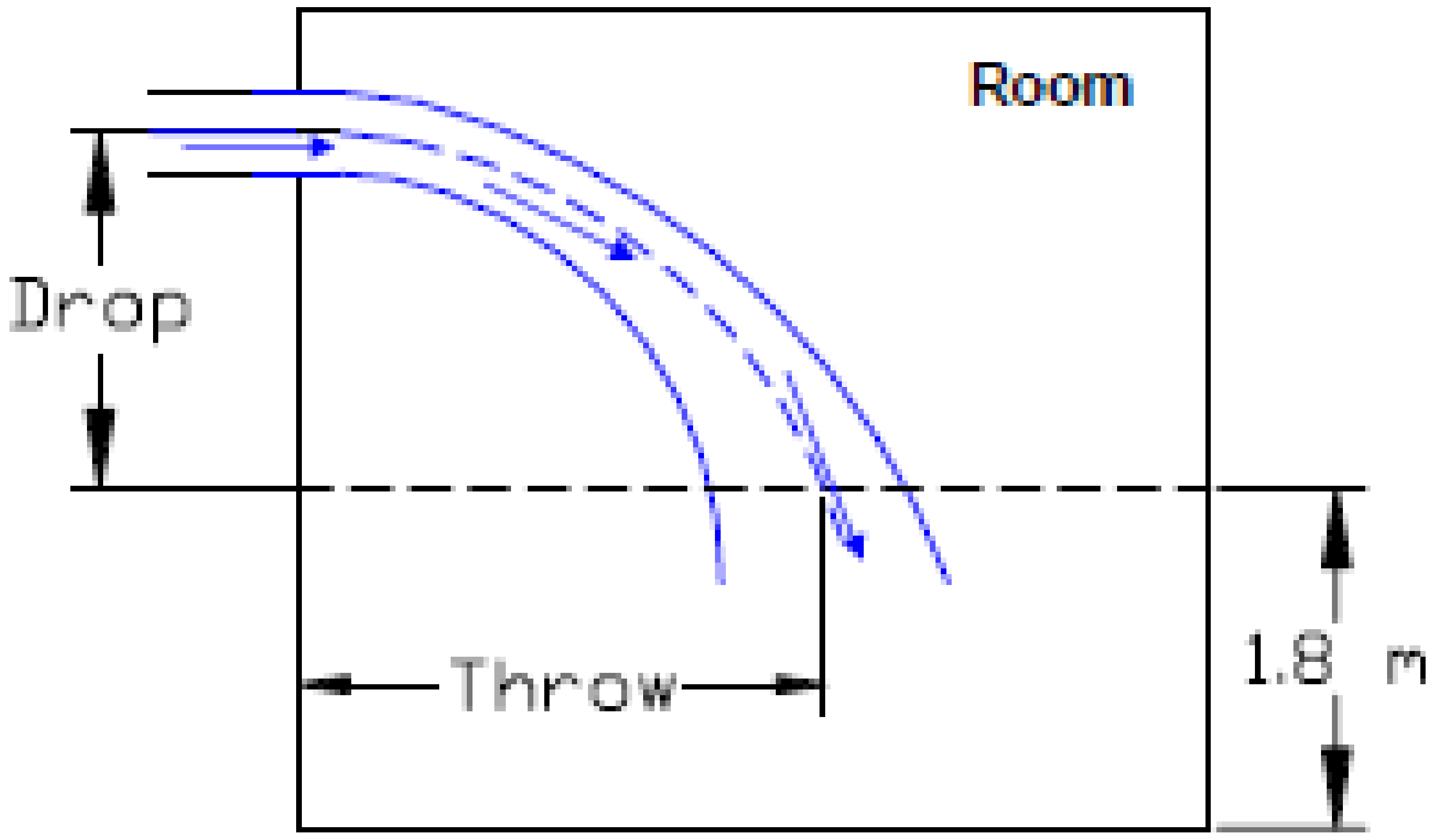
Drop. The vertical distance the lower edge of the air stream drops between the time it leaves the outlet and the time it reaches the end of its throw.

Primary air. The air coming out of the outlet.

Secondary air. The room air picked up by the primary air by entrainment.

Total air. The mixture of primary and secondary air.

Aspect ratio. Grille-dimension ratio, length to width.


Room
Drop
Throw
1.8 m

Principles of air distribution

1. Air should be distributed in the room so that the required temperature, humidity and air velocity are maintained in the occupied zone of about 1.8 m above the floor.
2. Air stratification, temperature difference, dead pockets, high drafts, stragnation layers, convection currents and spot ceiling or heating must be avoided.
3. There should be thorough mixing of the conditioned air discharged into the room through outlets with the air inside the room.
4. The temperature differential in the room should not be larger than 1°C.
5. The velocity should be in the range of 7 m/min to 17 m/min to avoid low or high drafts. Down flow and flow directed to the faces of people is preferred to the upward flow and flow directed to backs or sides of people.
6. The exhaust and inlet points must be so arranged that fresh air is available in all parts of the room.

Location of return duct opening

(i) There should not be short-circuiting of supply air and return air. The return air-opening should be complementary to the flow pattern established by the supply air.

(ii) The return air containing dirt, gases or odours should be removed without causing stratification in the conditioned space.

(iii) The recommended velocity of air at the inlet of the return air-opening should not exceed 80 m/min as they are nearer to the ear level to avoid undesirable noise. Whereas the velocity of air at the outlet of the supply grilles lies between 180 to 240 m/min.

- The *wall return* near the floor is *considered best.*
- A *ceiling return* should be *avoided* as there is possibility of short-circuiting.
- *Floor returns* should also be avoided as they act as duct collector. If used, a settling chamber should be provided.

Air-handling System

The air handling system consists:

1. **Air-distribution system.** It comprises various *inlets* for recirculated air and ducts for the supply air.
2. **Duct system.** It includes the *return duct, supply* duct and *air-conditioning apparatus* comprising *dampers, filters, coil or air washer.*
3. **Fan.** It provides necessary energy to move the air.

Figure shows schematic air-flow diagram for an air-conditioning system. It may be seen that in circulation of air a closed loop is formed. In this loop the point is room itself which can be considered at atmospheric pressure.

Through the inlets the air enters and it continues to drop in pressure until it reaches the fan. The fan raises the pressure, and this pressure thereafter starts dropping again until the air enters the space. Therefore, the pressure on the discharge side of the fan is positive and on suction side negative.