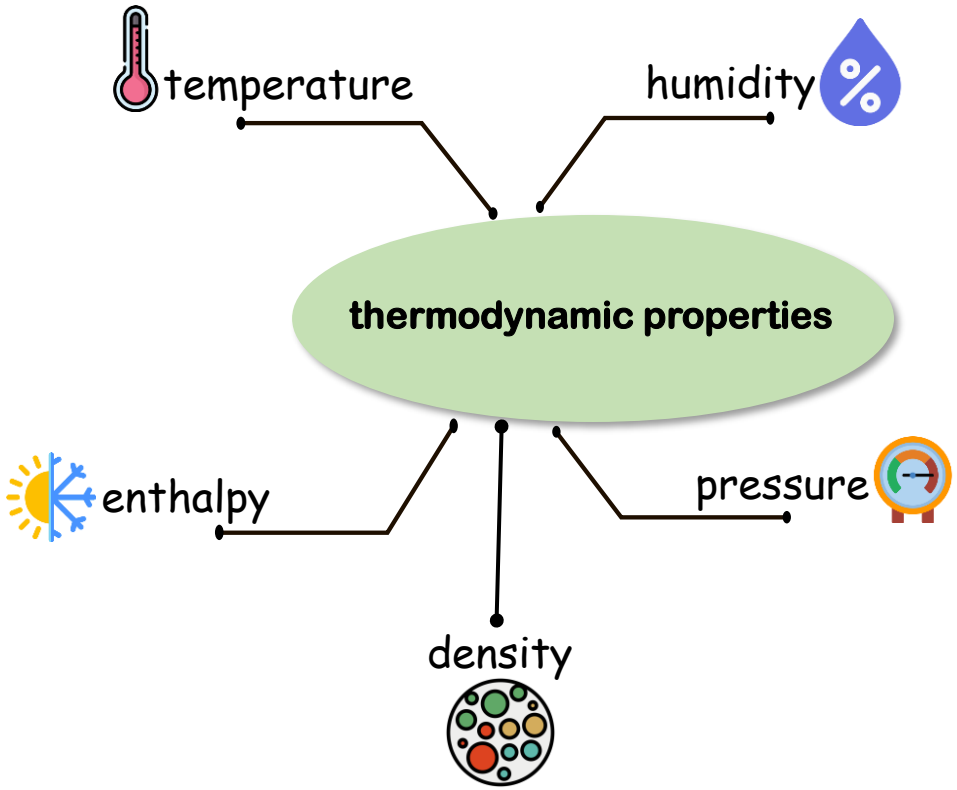
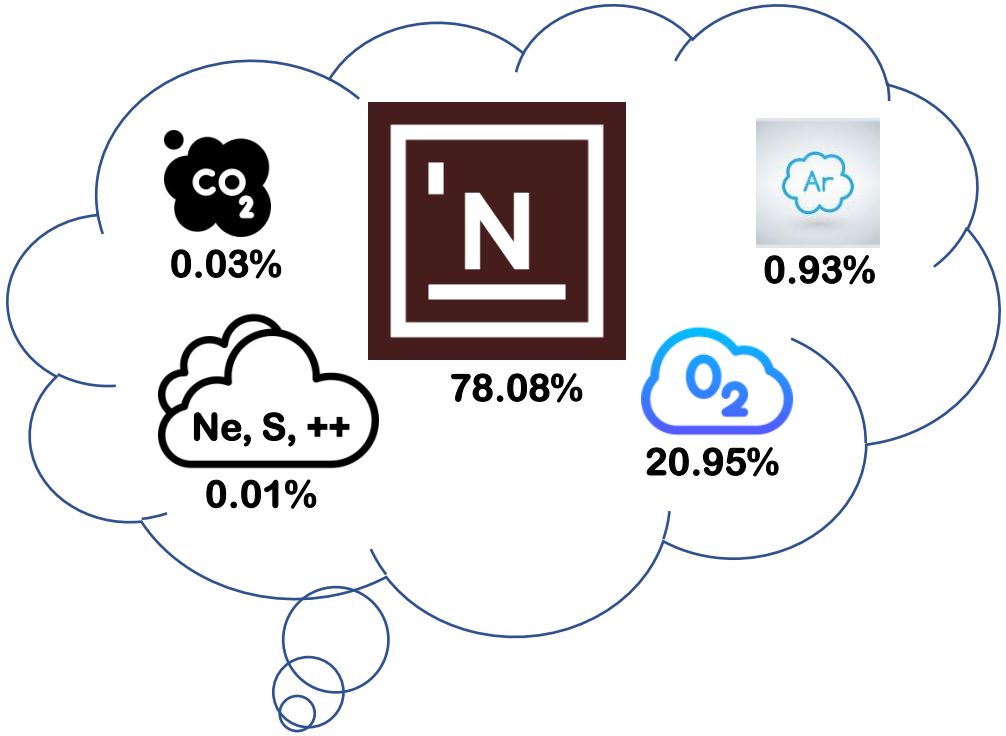
psychrometry

study of the thermodynamic properties of moist air (atmospheric air)



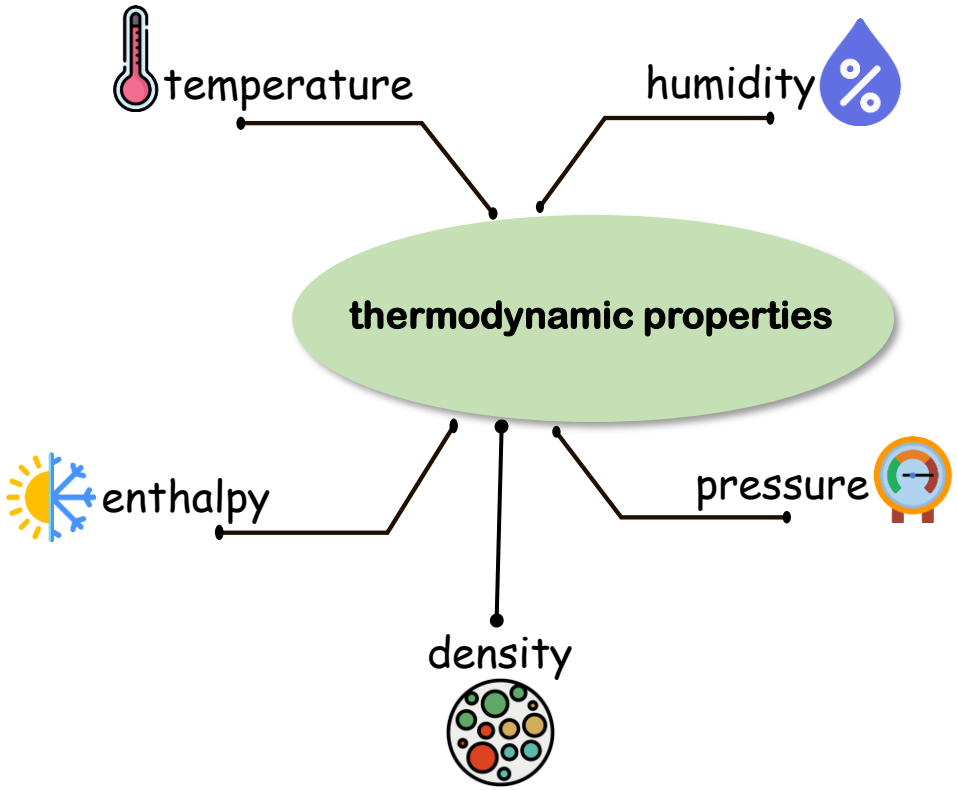
dry air + water vapor(moisture)

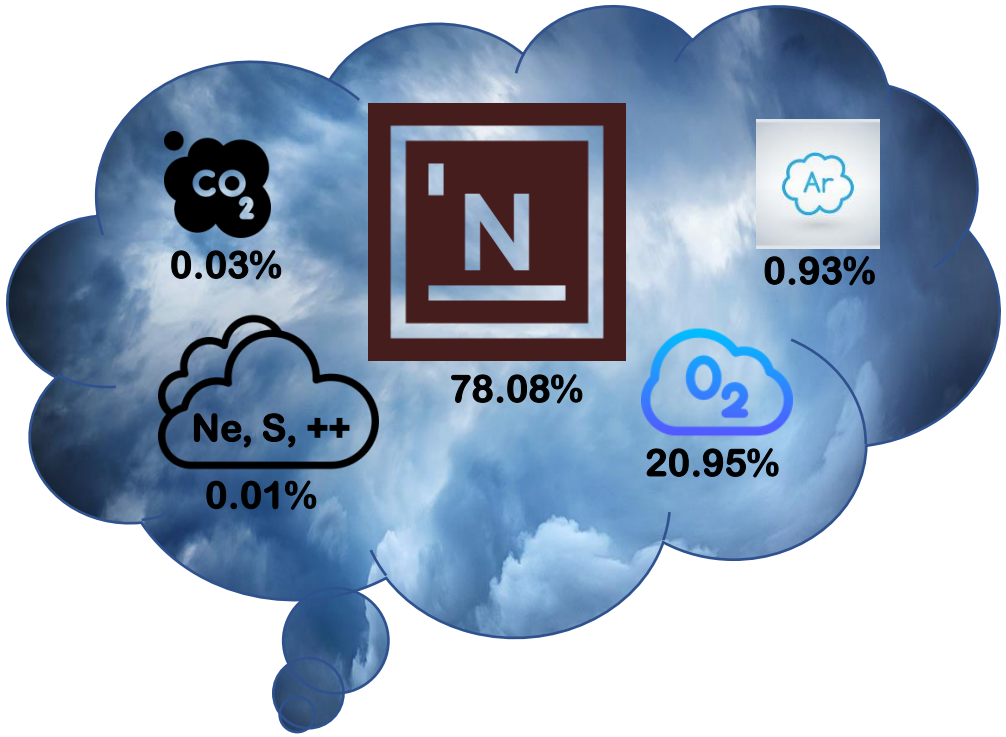


psychrometry

study of the thermodynamic properties of moist air (atmospheric air)

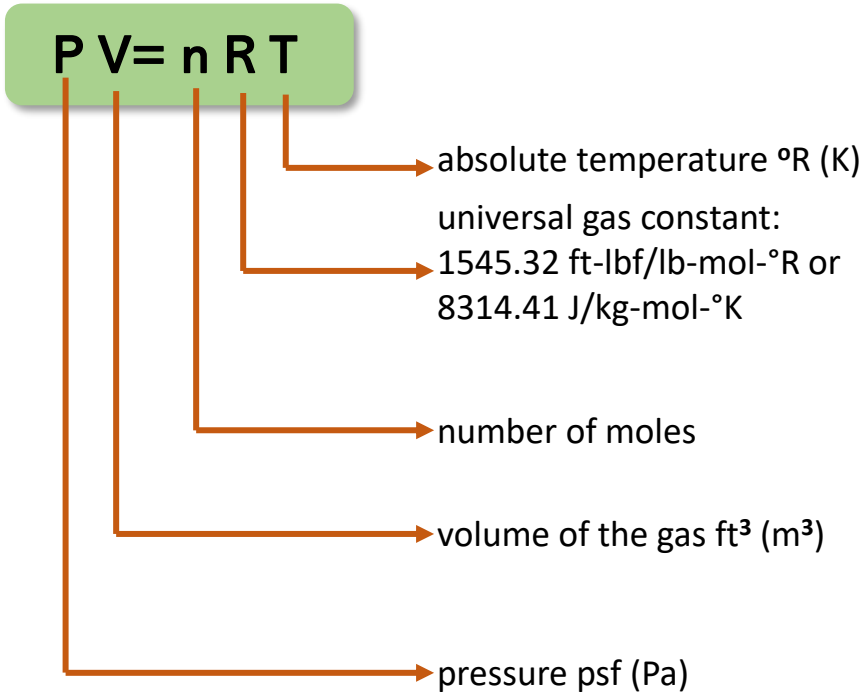
dry air + water vapor(moisture)





psychrometry

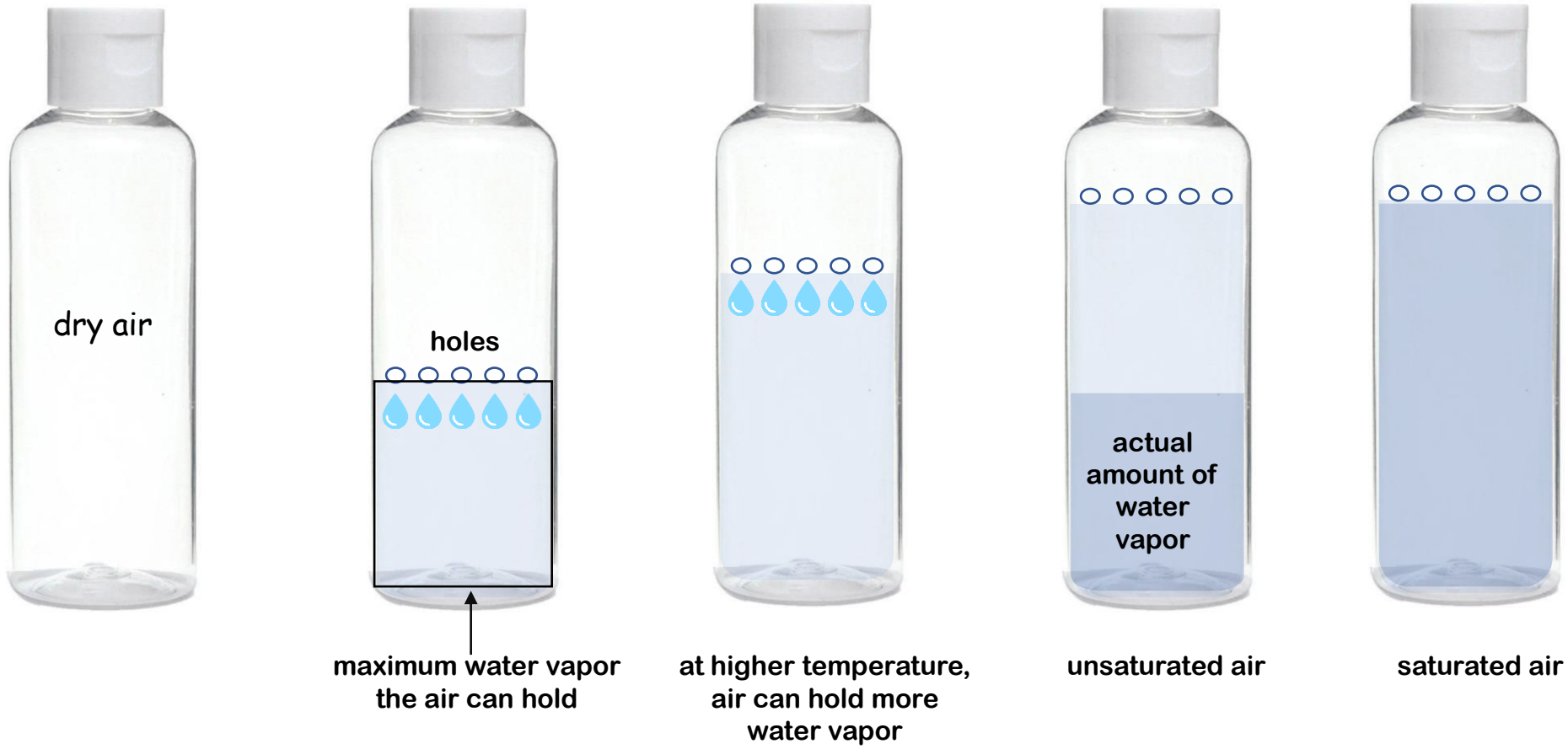
Ideal Gas Equation



psychrometry

humidity

air has the ability to hold water



maximum water vapor the air can hold

at higher temperature, air can hold more water vapor

unsaturated air

saturated air

humidity

humidity ratio

$$humidity\ ratio = \frac{mass\ of\ water\ vapor}{mass\ of\ dry\ air}$$

$$W = \frac{m_v}{m_a}$$

$$W = \frac{0.6219 P_v}{P_T - P_v}$$

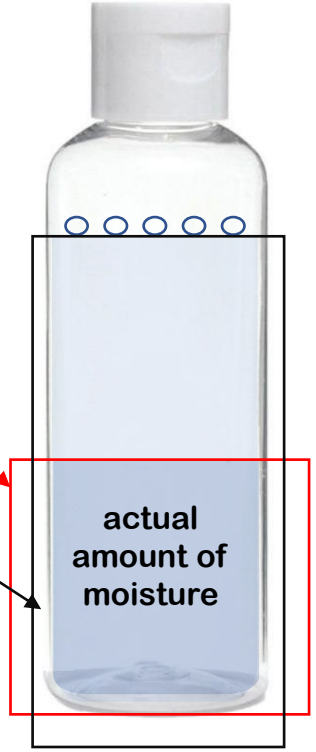
humidity

humidity ratio

relative humidity

$$Relative\ Humidity = \frac{actual\ moisture\ in\ the\ air}{maximum\ moisture\ air\ can\ hold} x\ 100\%$$

$$\boldsymbol{\Phi} = \frac{m_v}{m_{vs}} \quad \boldsymbol{\Phi} = \frac{P_v}{P_{vs}} \quad \boldsymbol{\Phi} = \frac{WP_a}{0.6219P_{vs}}$$



example:
At 25°C,
max. moisture holding capacity= 60g
actual moisture present in air= 30g

$$RH = \frac{30}{60} * 100\%$$
$$RH = 50\%$$

humidity

humidity ratio

relative humidity

$$Relative\ Humidity = \frac{actual\ moisture\ in\ the\ air}{maximum\ moisture\ air\ can\ hold}\ x\ 100\%$$

T= 25^{O}C

max. moisture holding capacity= **60g**

actual moisture present in air= 30g

$$RH = \frac{30}{60} * 100\%$$

$$RH = 50\%$$

T= 40^{O}C

max. moisture holding capacity=**80g**

actual moisture present in air= 30g

$$RH = \frac{30}{80} * 100\%$$

$$RH = 37.5\%$$

humidity

humidity ratio

relative humidity

degree of saturation

$$\text{degree of saturation} = \frac{\text{humidity ratio}}{\text{humidity ratio of saturated air}} \quad \text{at same T and P}$$

$$\mu = \frac{W}{W_s}$$

humidity

- humidity ratio
- relative humidity
- degree of saturation
- absolute humidity

Absolute Humidity is the total mass of water vapor present in unit **volume** of moist air

moist air

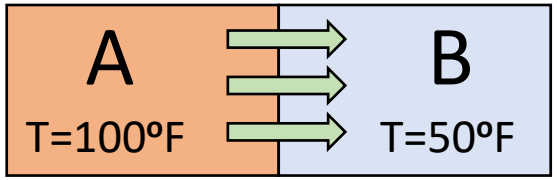
$$absolute\ humidity = \frac{mass\ of\ water\ vapor}{volume\ of\ moist\ air}$$

total volume of moist air= **$2m^3$**
mass of moisture present= **60g**

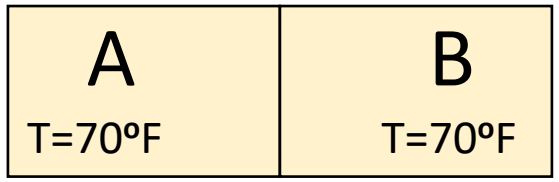
$$AH = \frac{60g}{2m^3}$$
$$AH = 30g/m^3$$

temperature

Temperature is the measure of hotness or coldness of a body



- ✓ heat flows due to the difference in temperature



- ✓ no heat flow once the temperature of both bodies become same
- ✓ thermal equilibrium is achieved (same T for both)

Units of temperature

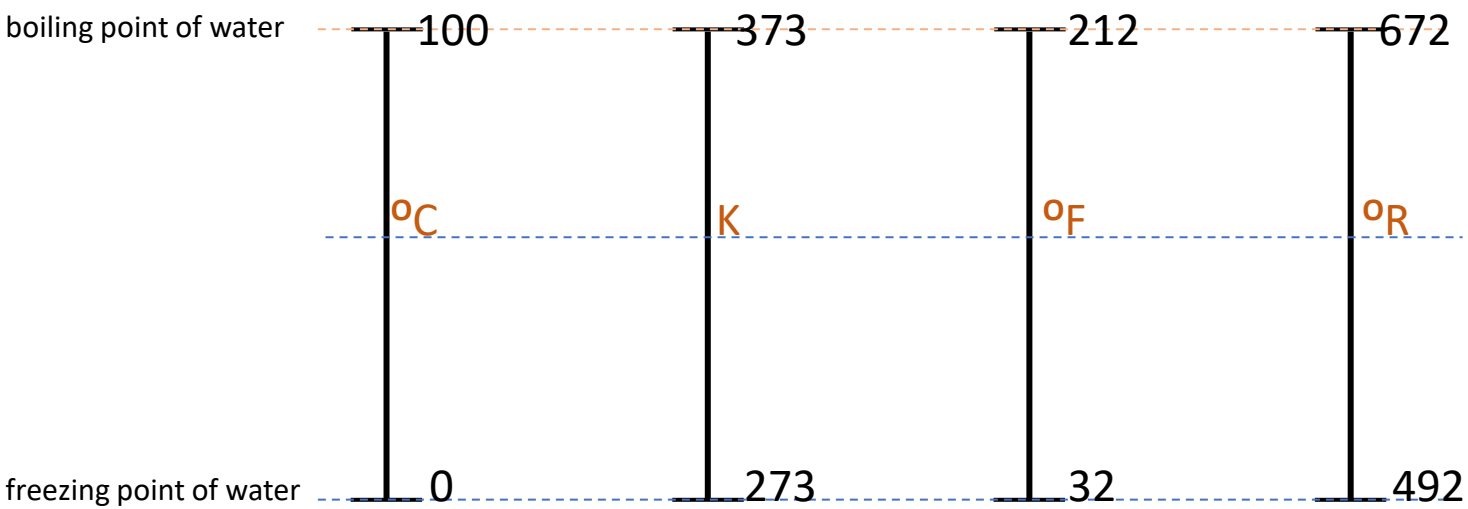
Kelvin(K) → International Unit (SI)
Celsius (ºC)
Fahrenheit (ºF)
Rankine (ºR)

temperature

Units of temperature

Kelvin(K)
Celsius (ºC)
Fahrenheit (ºF)
Rankine (ºR)

conversion of units



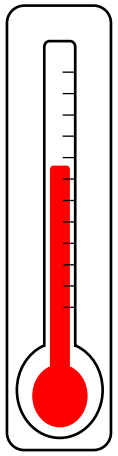
celsius　　kelvin　　fahrenheit　　rankine

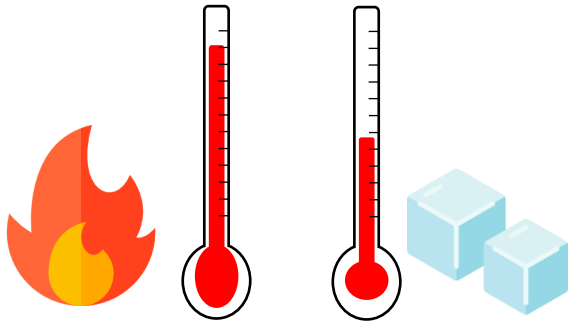
$$\frac{C-0}{100-0}=\frac{K-273}{373-273}=\frac{F-32}{212-32}=\frac{R-492}{672-492}$$

temperature

Dry Bulb Temperature 1

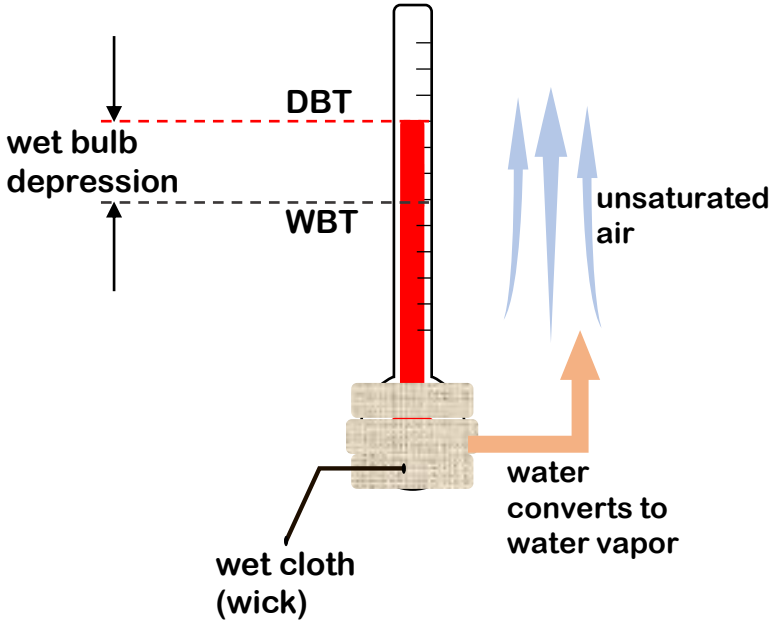
- ✓ **The dry-bulb temperature (DBT)** is the temperature of air measured by a thermometer freely exposed to the air, but isolated from radiation and moisture
- ✓ DBT is the temperature that is usually thought of as air temperature
- ✓ It shows the amount of heat content in the air

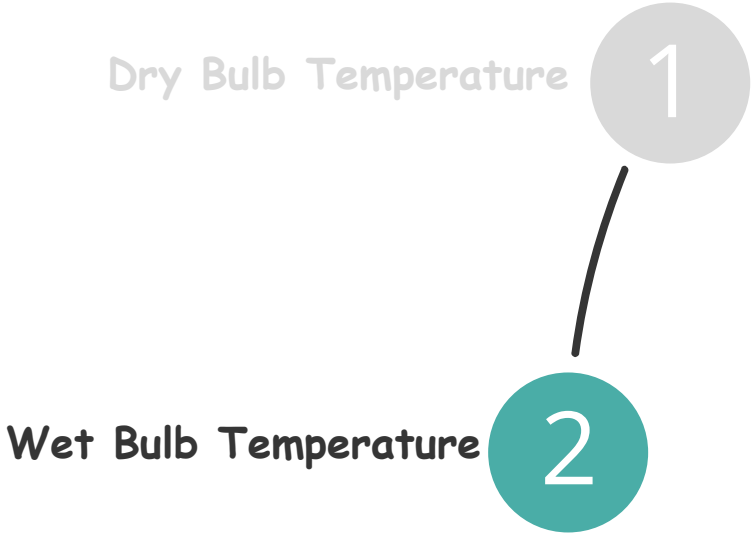




temperature

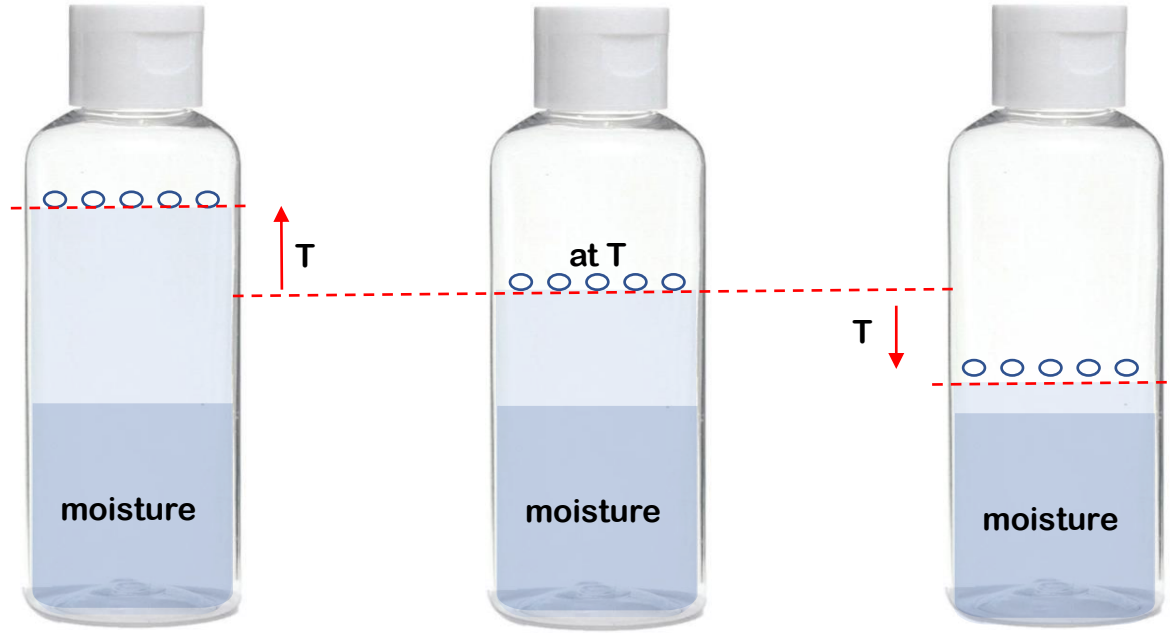
- ✓ **The wet-bulb temperature (WBT)** is the lowest temperature to which air can be cooled by the evaporation of water into the air at a constant pressure
- ✓ when the air is fully saturated (RH=100%), then DBT=WBT





temperature

- ✓ **The dew-point temperature (DPT)** is the temperature to which air must be cooled to become saturated with water vapor it contains
- ✓ On cooling further, the water vapor will condense to form liquid water (dew)



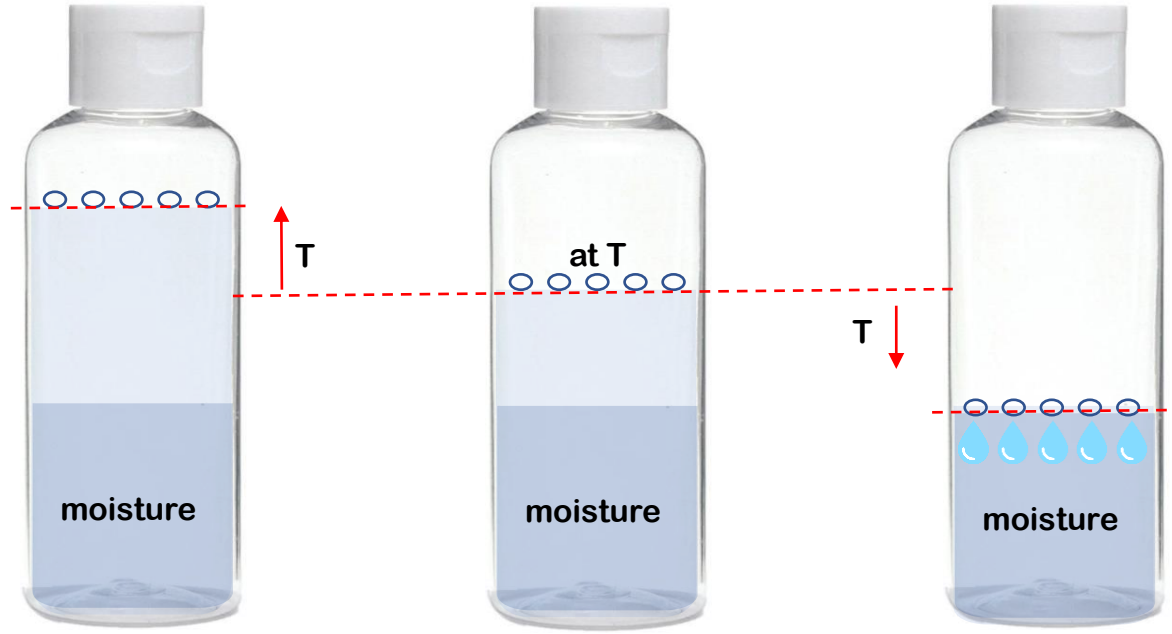
Dry Bulb Temperature 1

Wet Bulb Temperature 2

Dew point Temperature 3

temperature

- ✓ **The dew-point temperature (DPT)** is the temperature to which air must be cooled to become saturated with water vapor it contains
- ✓ On cooling further, the water vapor will condense to form liquid water (dew)



Dry Bulb Temperature 1

Wet Bulb Temperature 2

Dew point Temperature 3

specific volume

It is the volume of air per unit mass of dry air

It is measured in ft^3/lb

$$specific\ volume = \frac{volume\ of\ air}{mass\ of\ dry\ air}$$

$$specific\ volume\ of\ dry\ air = \frac{volume\ of\ dry\ air}{mass\ of\ dry\ air}$$

$$specific\ volume\ of\ moist\ air = \frac{volume\ of\ moist\ air}{mass\ of\ dry\ air}$$

$$specific\ volume\ of\ saturated\ air = \frac{volume\ of\ moist\ air\ at\ saturation}{mass\ of\ dry\ air}$$

specific enthalpy

Enthalpy is the sum of internal energy and pressure-volume energy of air

- **H=U+PV**
- **H=mCpΔT (at constant pressure)**

Specific Enthalpy is the sum of internal energy and pressure-volume energy of air per unit mass of **dry air**

- **h=CpΔT**
- it is measured in kJ/kg or Btu/lb

- ✓ @ zero K: enthalpy is zero
- ✓ enthalpy increases with temperature

for air: $h_{moist\_air}=h_{dry\_air}+W.h_{vapor}$

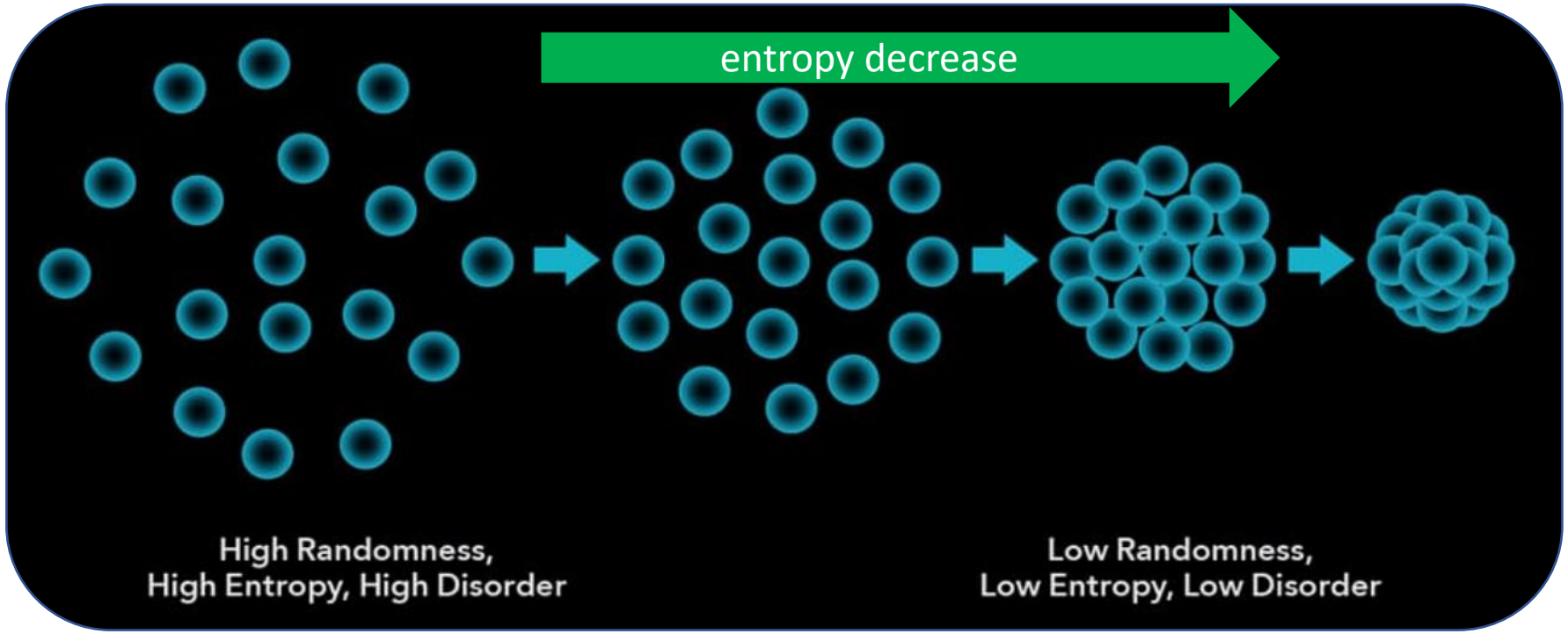
$h_{dry\ air}=C_pT$
C_p=specific heat of dry air
C_p=0.240 Btu/lb

$h_{vapor}=h_g+C_{pv}T$
h_g=sp. enthalpy of saturated vapor
@ 0°F: h_g=1061 Btu/lb
C_{pv}=specific heat of vapor
C_{pv}=0.444 Btu/lb

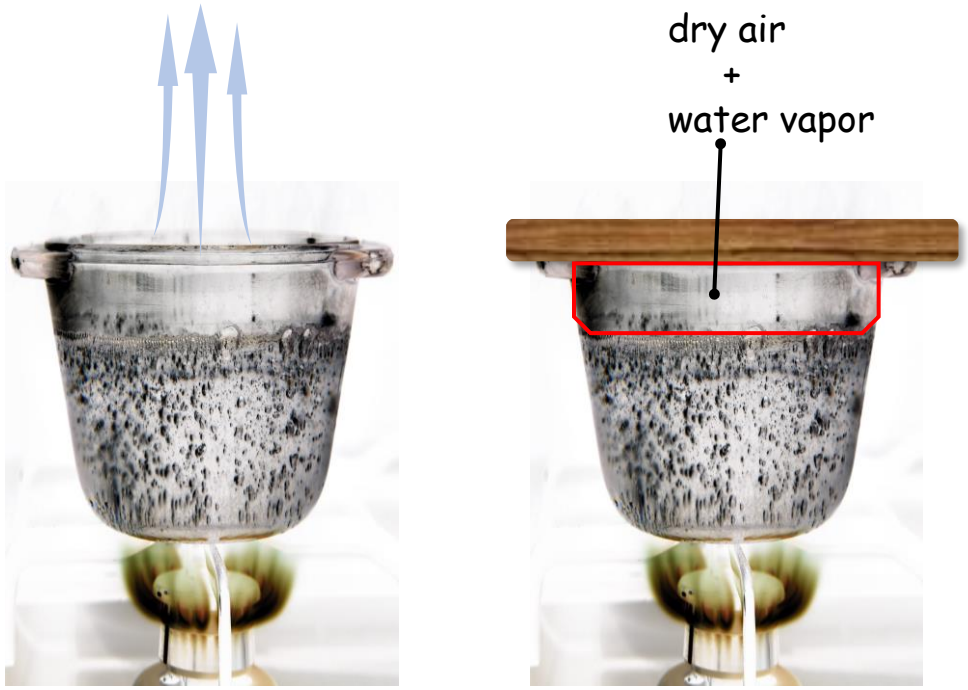
h=[0.24T+W(1061+0.444T)]Btu/lb

specific entropy

- ✓ **Entropy** is measure of the molecular disorder or randomness of a system
- ✓ It the measure of a system's thermal energy per unit temperature that is unavailable for doing useful work
- ✓ **Specific Entropy**= (total entropy of the system/mass of the system)
- ✓ It is measured in Btu/lb-^{O}F



vapor pressure



when air is unsaturated

- evaporation>condensation
- P_{w_vapor}=partial pressure of water vapor

when air is saturated

- evaporation=condensation
- $P_{w\_vapor}=P_{max}$

→ VAPOR PRESSURE

density

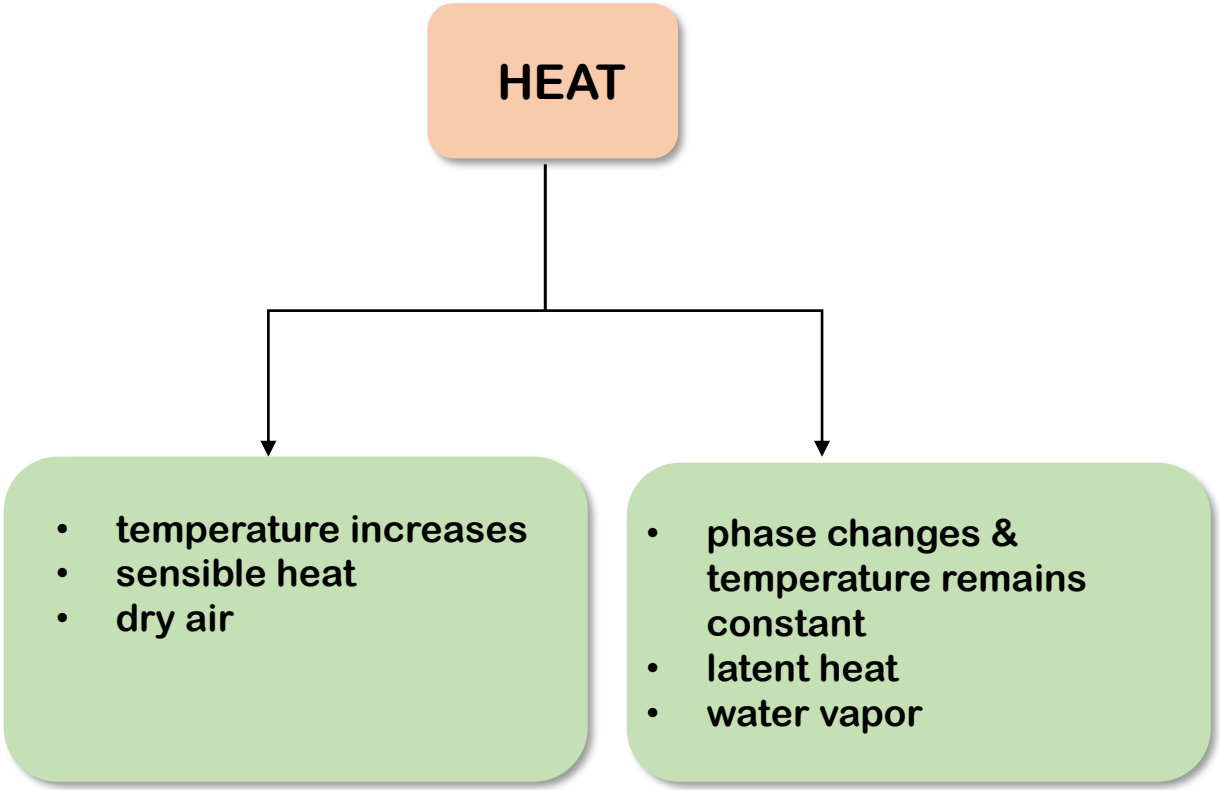
It is the mass of unit volume of air

$$Density\ of\ air = \frac{Mass\ of\ air}{Volume\ of\ air}$$

At STP:

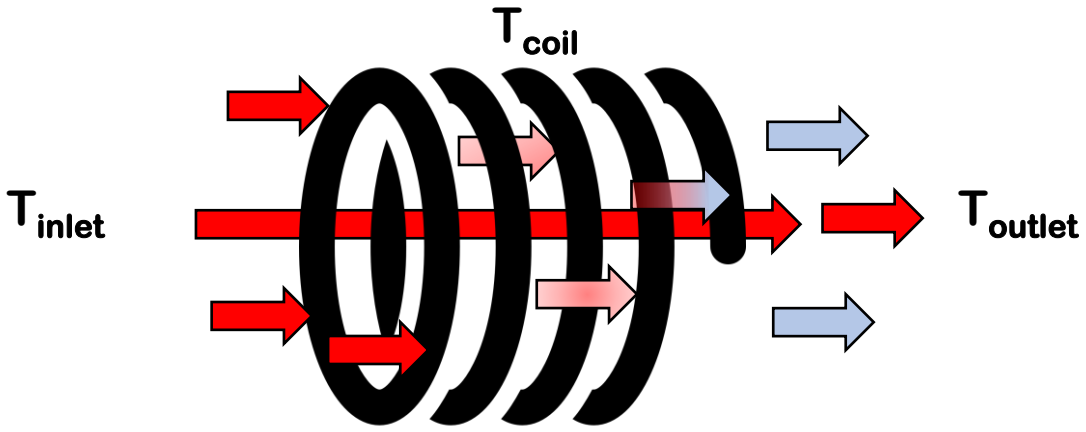
- In Metric units: $\boldsymbol{\rho}_{\mathbf{air}}$=1.225 kg/m³
- In Imperial units: $\boldsymbol{\rho}_{\mathbf{air}}$=0.0765 lb/ft³

heat


HEAT
• temperature increases
• sensible heat
• dry air
• phase changes & temperature remains constant
• latent heat
• water vapor

bypass factor

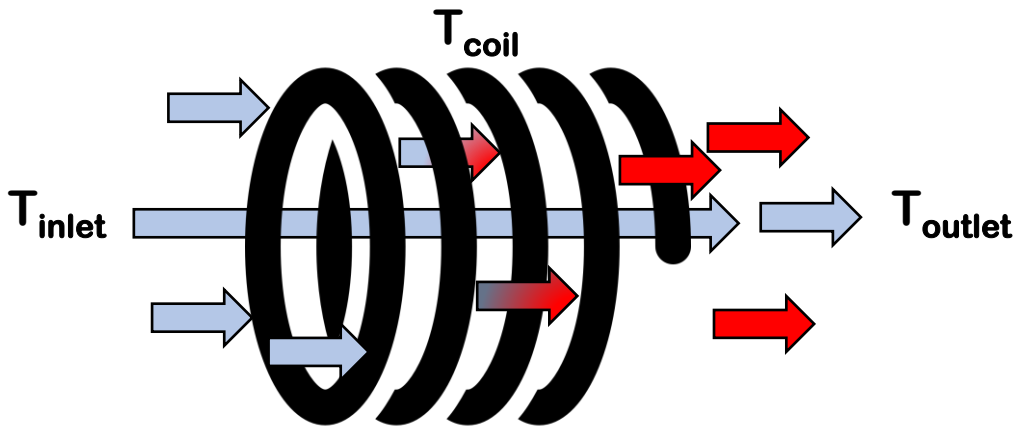
$T_{in} > T_{out} > T_{coil}$



cooling coil

$$BPF = \frac{T_{out} - T_{coil}}{T_{in} - T_{coil}}$$

$T_{coil} > T_{out} > T_{in}$

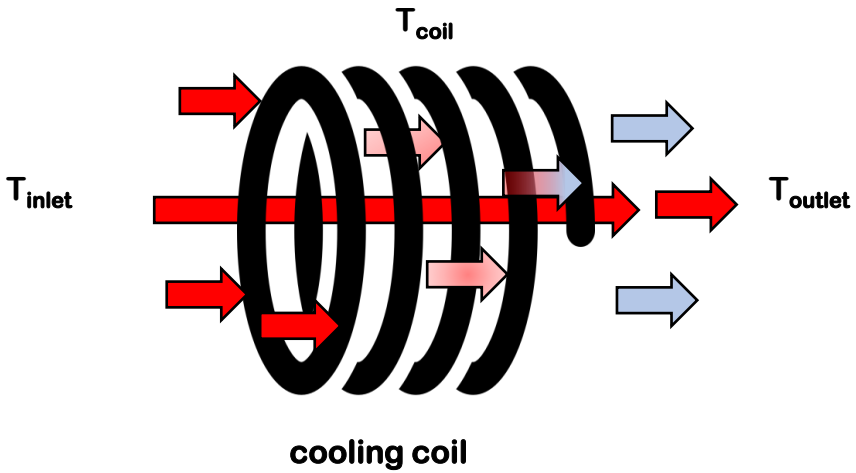


heating coil

$$BPF = \frac{T_{coil} - T_{out}}{T_{coil} - T_{in}}$$

contact factor

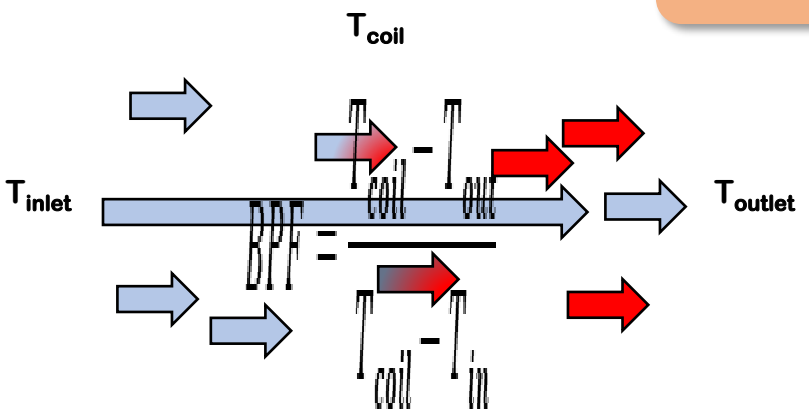
$T_{in} > T_{out} > T_{coil}$



cooling coil

$$BPF = \frac{T_{out} - T_{coil}}{T_{in} - T_{coil}}$$

$T_{coil} > T_{out} > T_{in}$

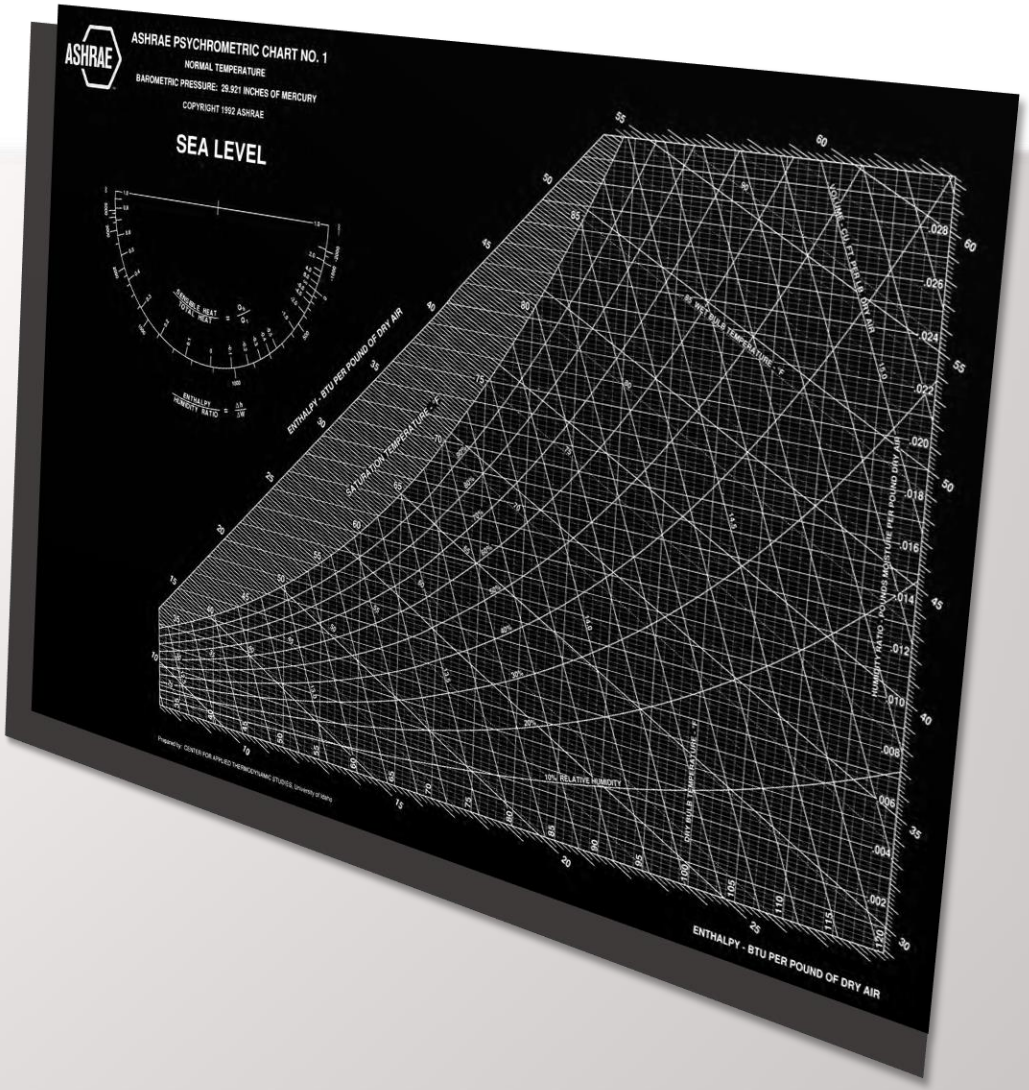


heating coil

$$BPF = \frac{T_{coil} - T_{out}}{T_{coil} - T_{in}}$$

Contact Factor= 1- bypass Factor

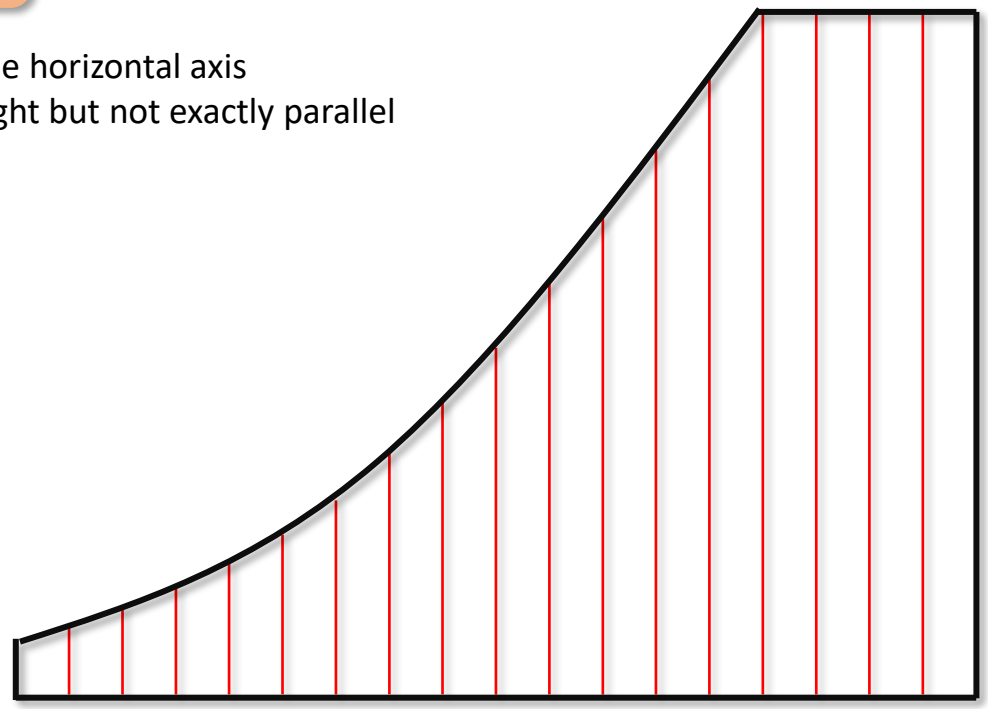
PSYCHROMETRIC CHART



psychrometric chart

Dry Bulb Temperature (DBT)

- Dry bulb temperature is plotted along the horizontal axis
- The dry bulb temperature lines are straight but not exactly parallel and incline slightly to the left

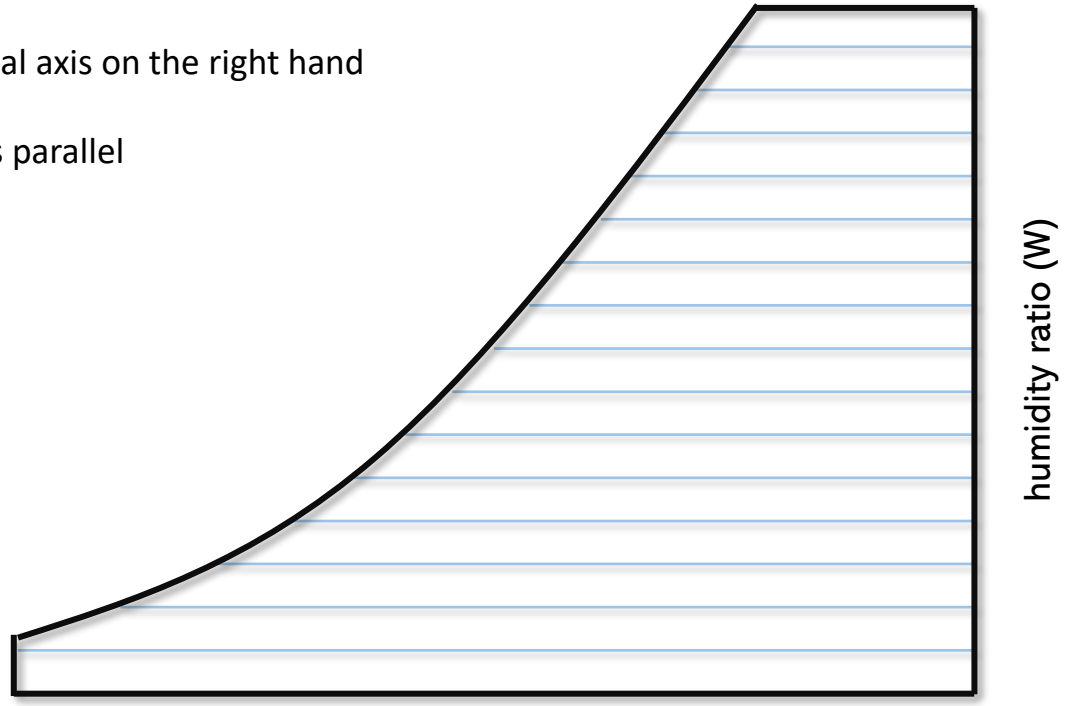


dry bulb temperature

psychrometric chart

humidity ratio (W)

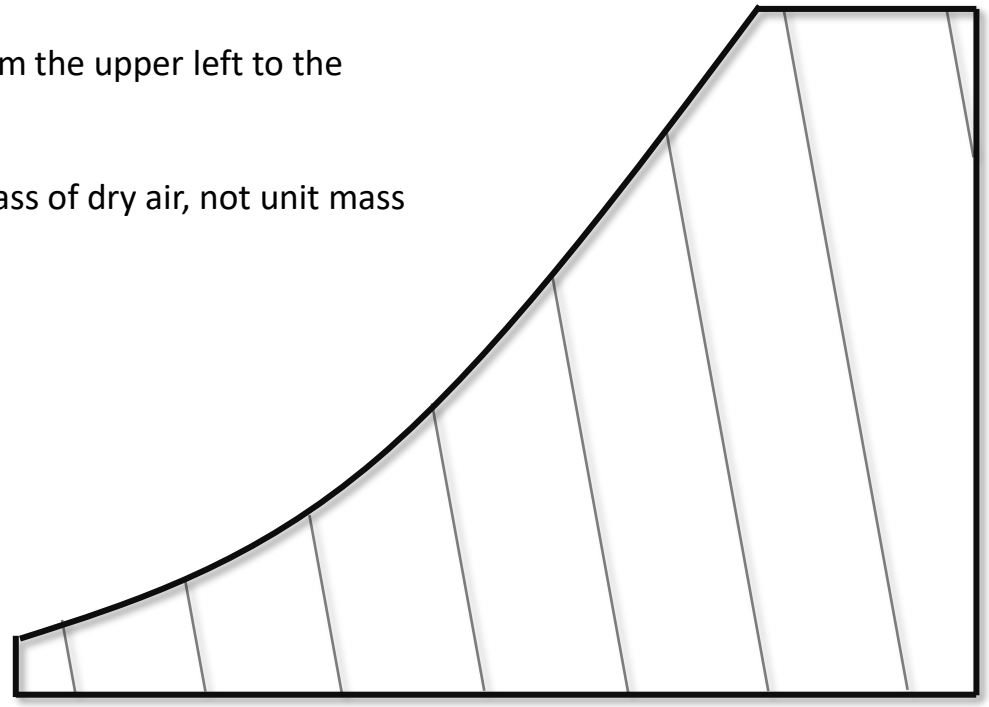
- Humidity ratio is plotted along the vertical axis on the right hand side of the chart
- The scale is uniform with horizontal lines parallel



psychrometric chart

specific volume (v)

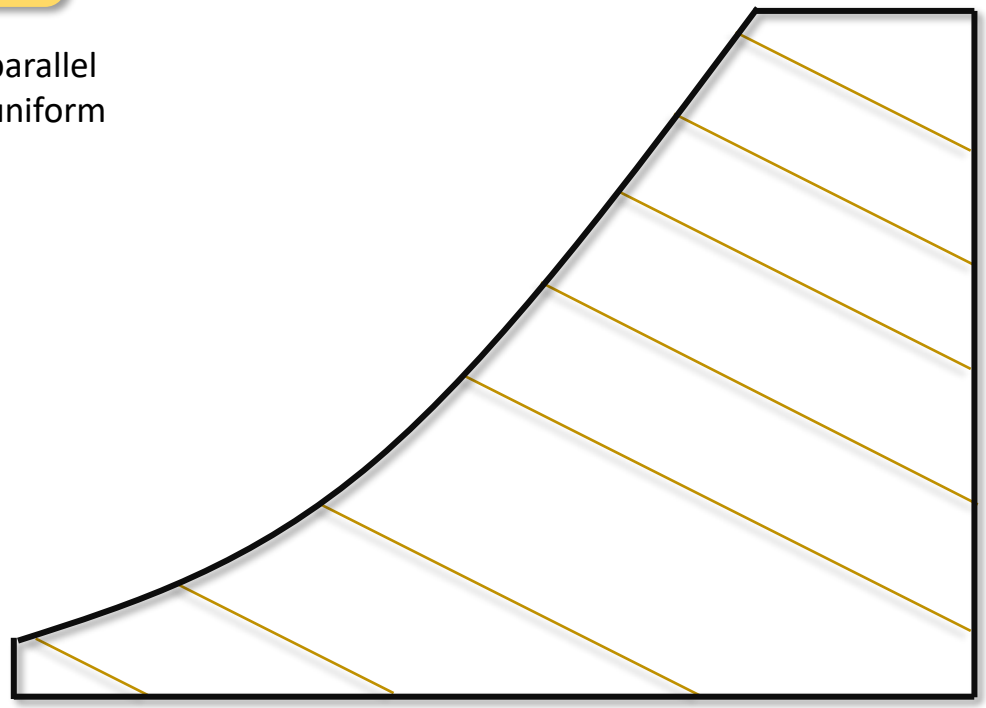
- specific volume lines appear inclined from the upper left to the lower right
- these lines are not parallel
- specific volume scale is based on unit mass of dry air, not unit mass of moist air



psychrometric chart

Wet Bulb Temperature (WBT)

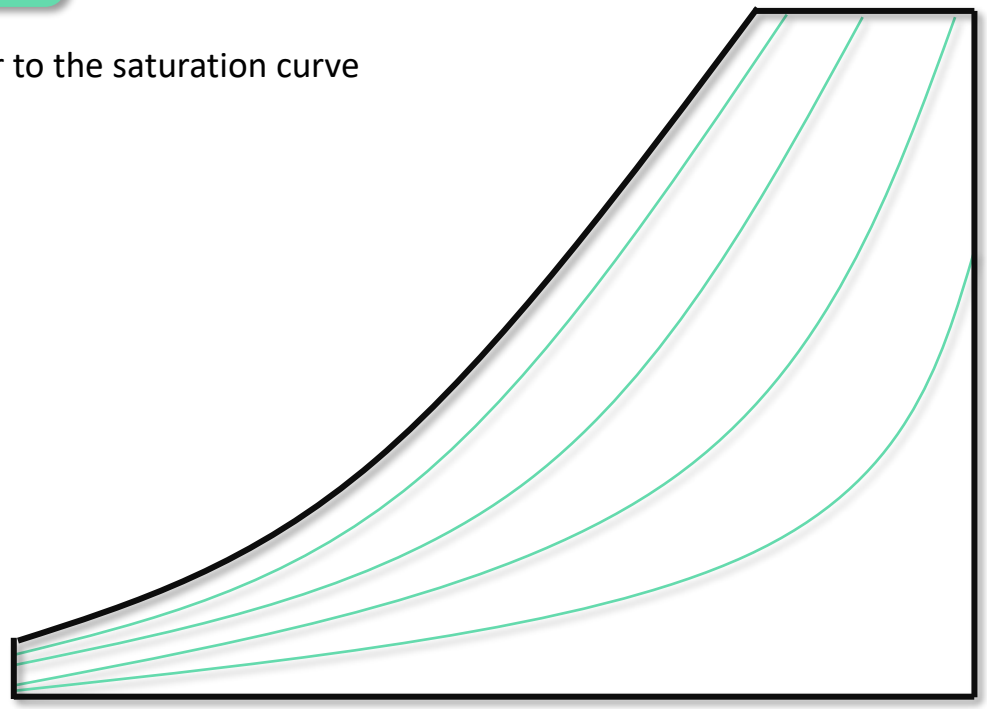
- the wet bulb temperature lines are not parallel
- The spacing of the wet bulb lines is not uniform



psychrometric chart

Relative Humidity (Φ)

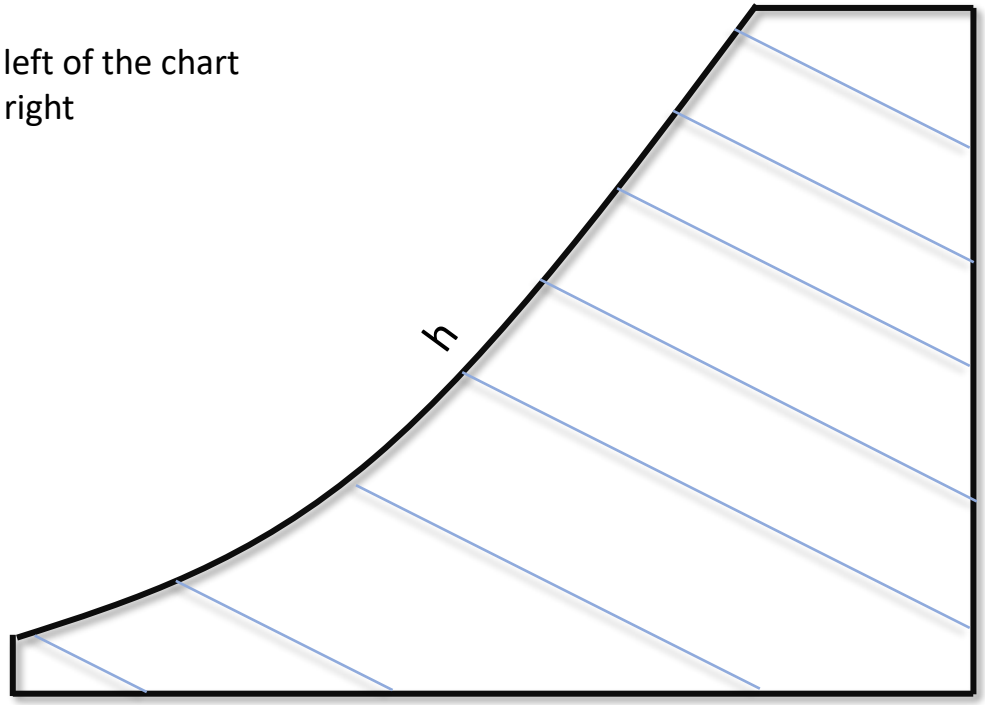
- relative humidity lines are shapes similar to the saturation curve
- they appear at regular intervals



psychrometric chart

Enthalpy (h)

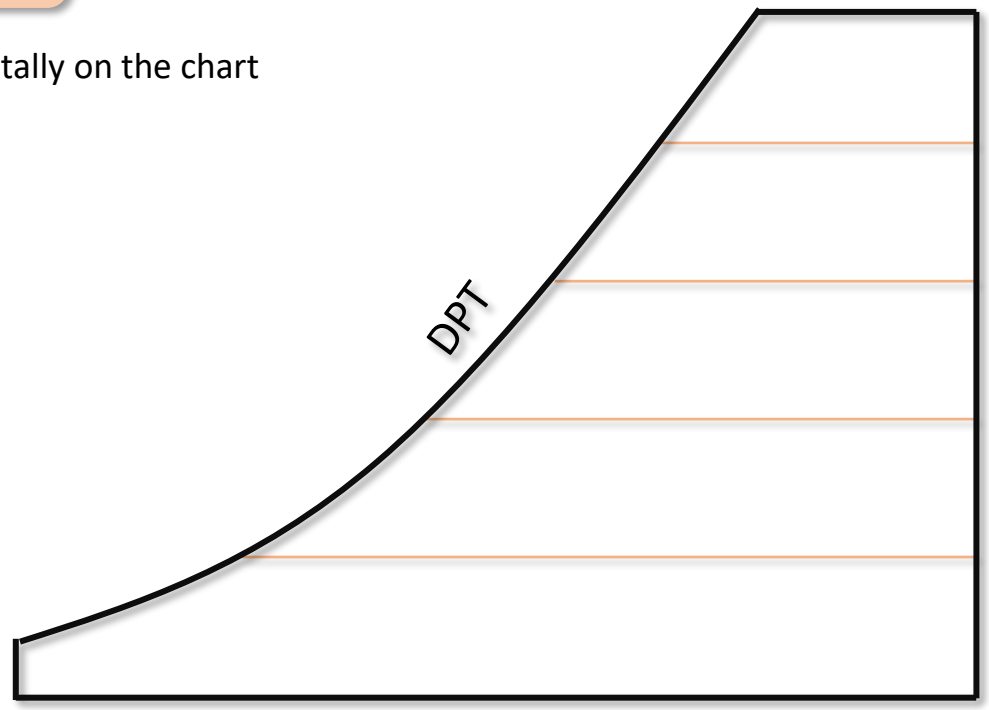
- enthalpy scale is drawn obliquely on the left of the chart
- enthalpy lines inclined downward left to right



psychrometric chart

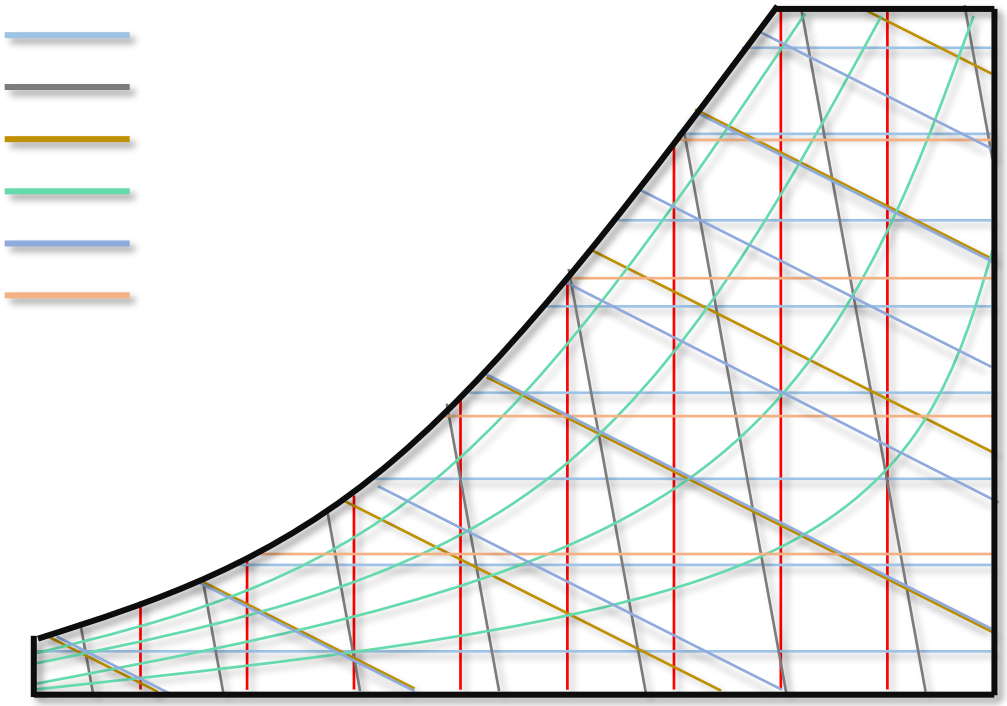
Dew Point Temperature (DPT)

- dew point temperature is drawn horizontally on the chart

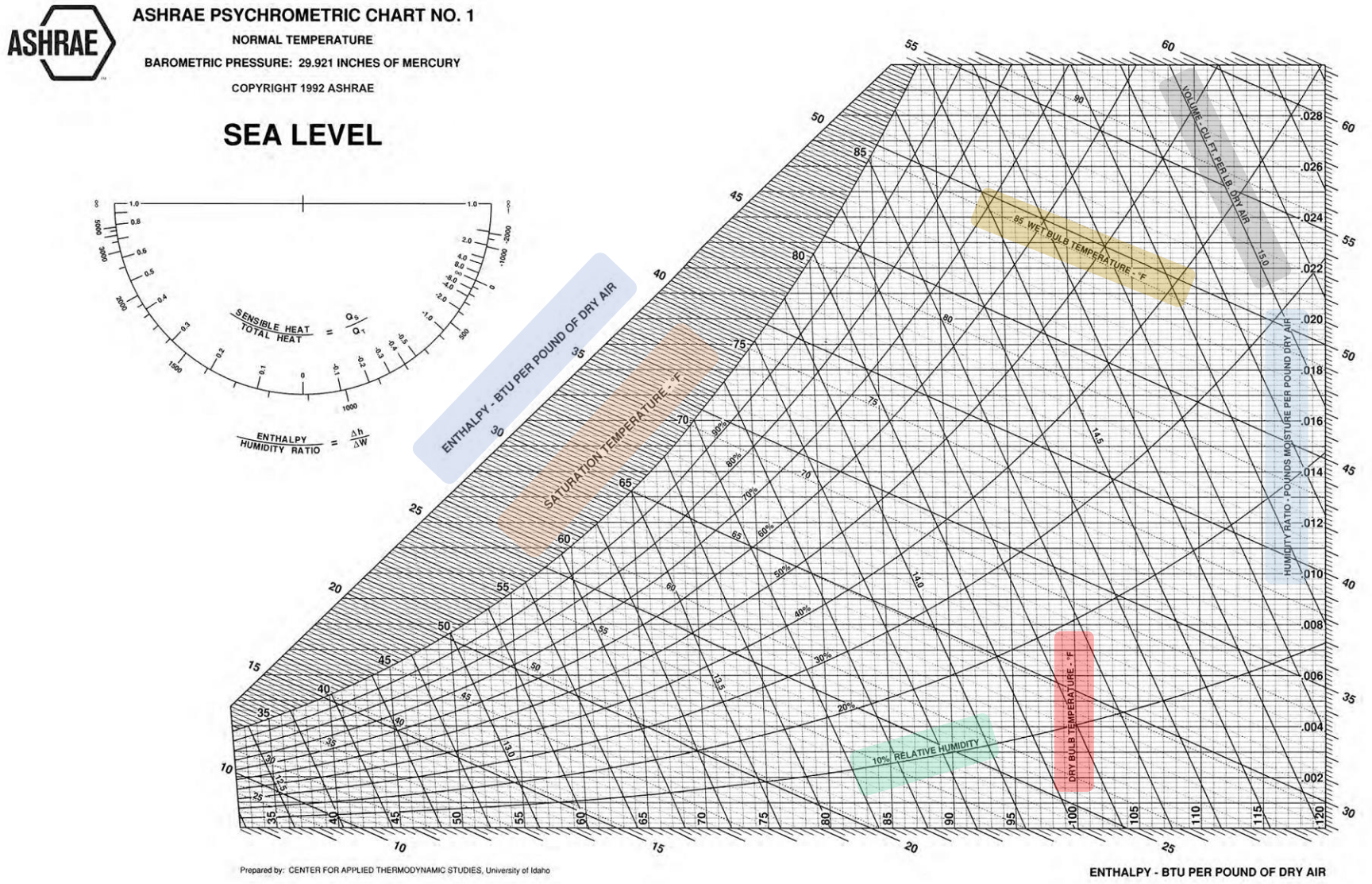


psychrometric chart

- ✓ dry bulb temperature
- ✓ humidity ratio
- ✓ specific volume
- ✓ wet bulb temperature
- ✓ relative humidity
- ✓ enthalpy
- ✓ dew point temperature



psychrometric chart



psychrometric chart

The air leaves a cooling coil is at 70°F T_d and 60°F T_w

dry bulb temperature (T_d)=70°F

wet bulb temperature (T_w)=60°F

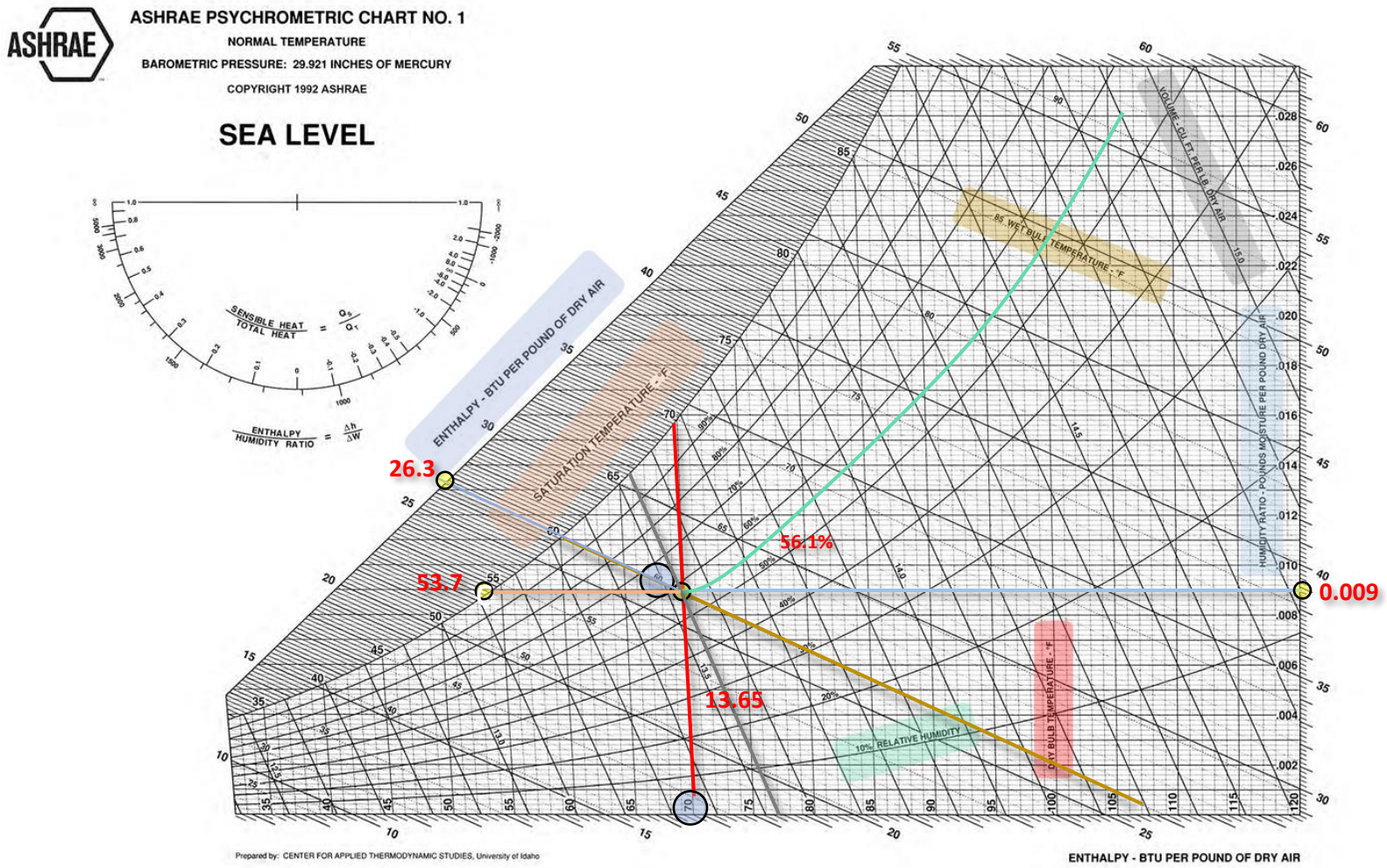
humidity ratio
W=0.009

relative humidity
ϕ=56.1%

specific enthalpy
h=26.3 Btu/lb

specific volume
v=13.65 ft³/lb

dew point temperature
T_{dp}=53.7°F



psychrometric chart

The air leaves a cooling coil is at 70°F T_d and 60°F T_w

dry bulb temperature (T_d)=70°F

wet bulb temperature (T_w)=60°F

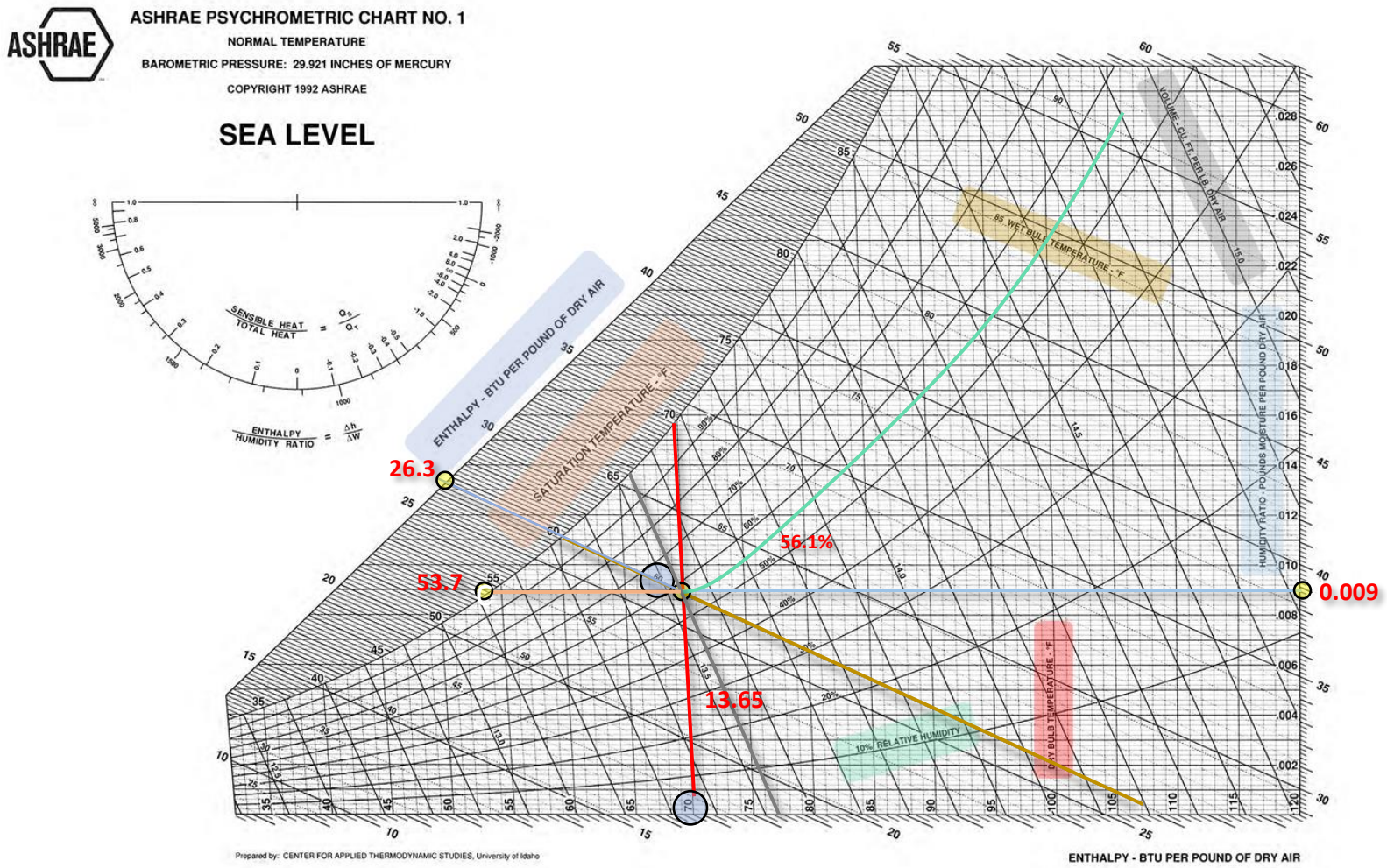
humidity ratio
W=0.009

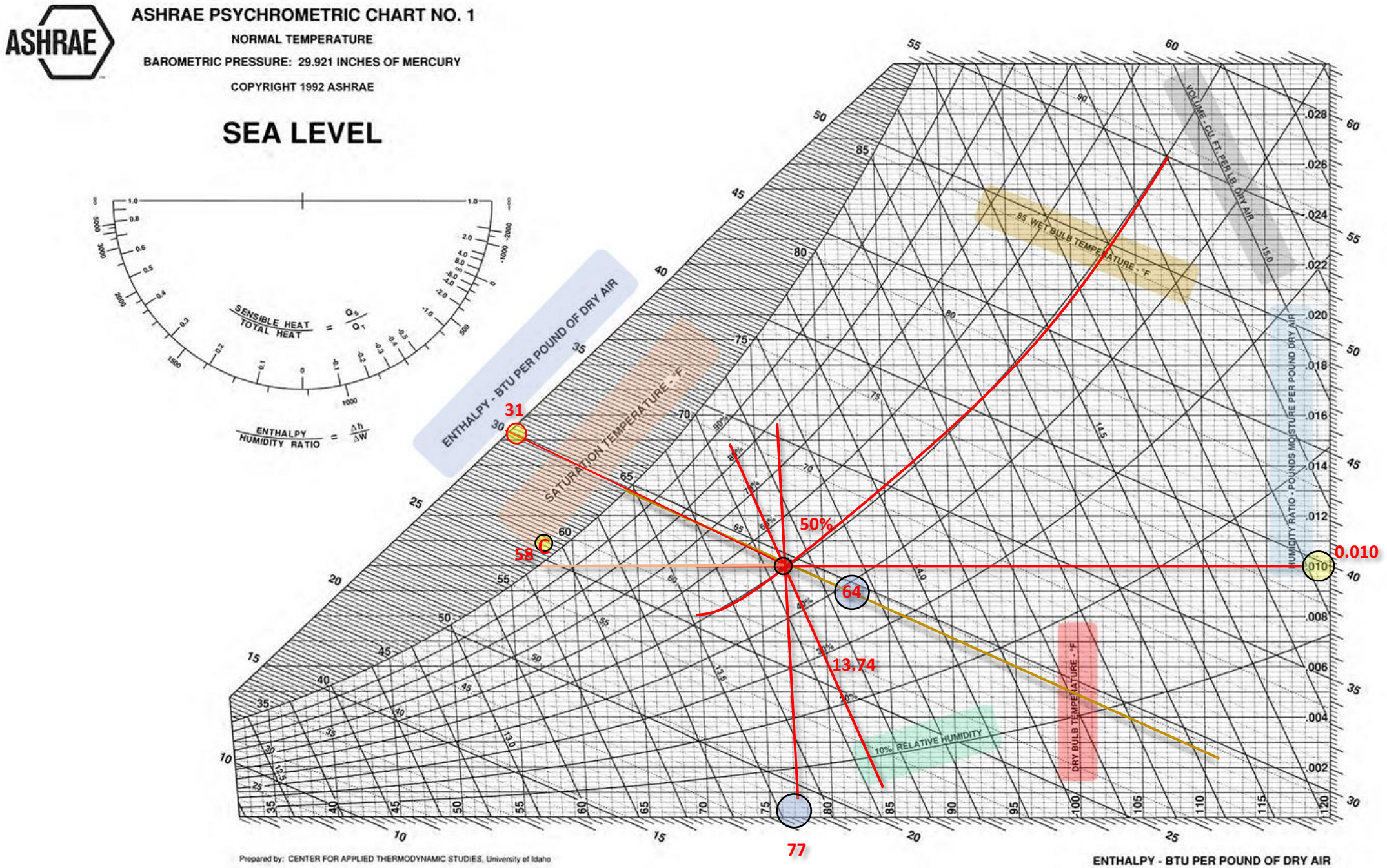
relative humidity
ϕ=56.1%

specific enthalpy
h=26.3 Btu/lb

specific volume
v=13.65 ft³/lb

dew point temperature
T_{dp}=53.7°F




ASHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE: 29.921 INCHES OF MERCURY
COPYRIGHT 1992 ASHRAE
SEA LEVEL
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
85 WET BULB TEMPERATURE - °F
VOLUME - CU. FT. PER LB. DRY AIR
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
DRY BULB TEMPERATURE - °F
10% RELATIVE HUMIDITY
31
58
C
50%
64
13.74
77
0.010
Prepared by: CENTER FOR APPLIED THERMODYNAMIC STUDIES, University of Idaho
ENTHALPY - BTU PER POUND OF DRY AIR