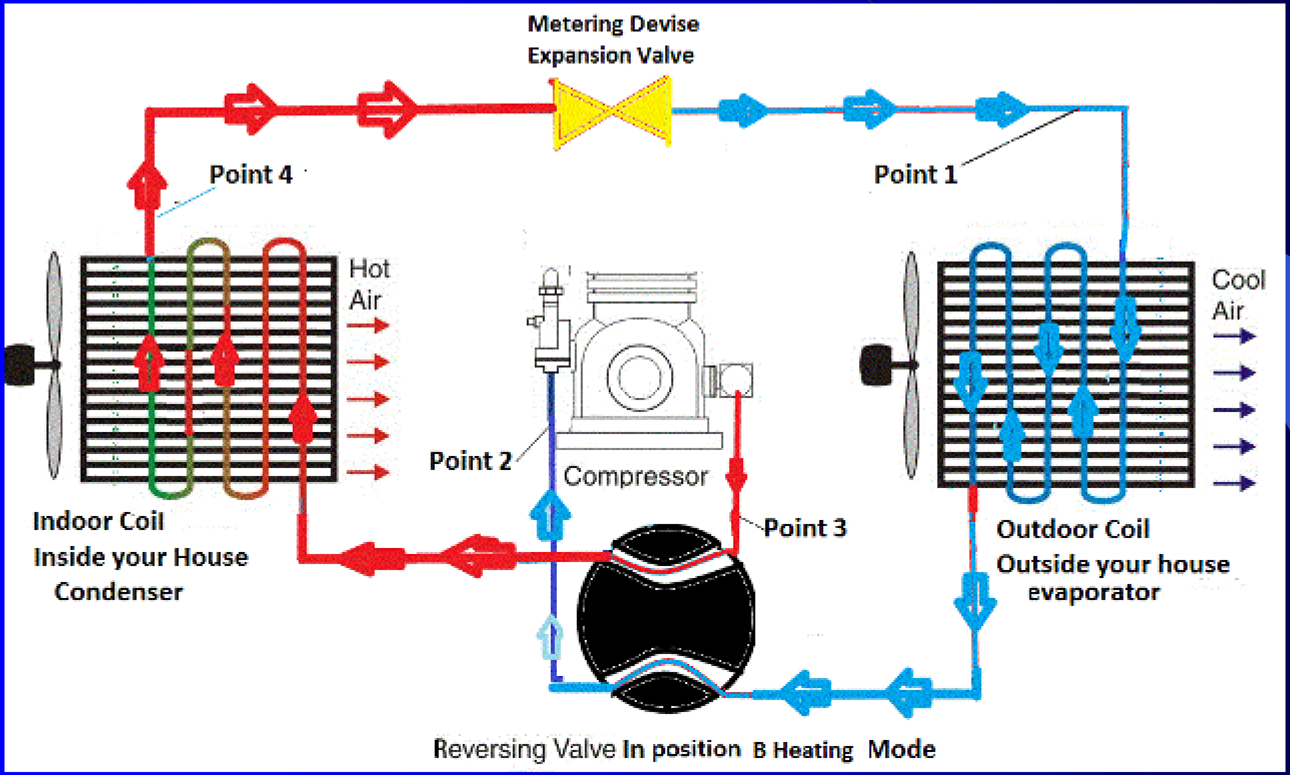
HVAC Training

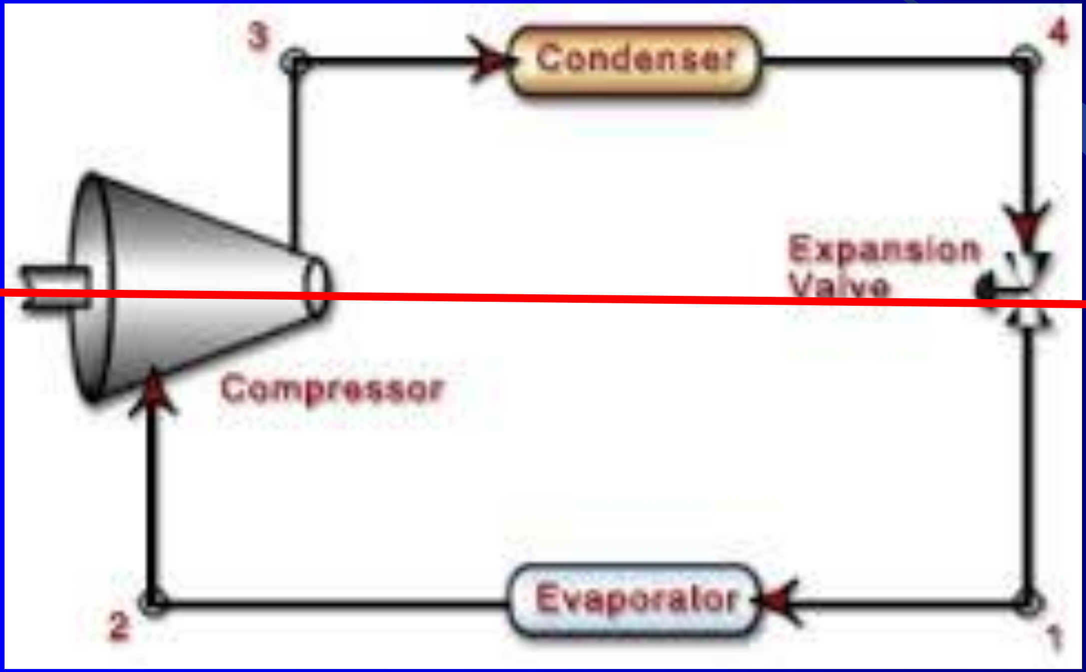
Psychrometric

Revision : 1
Date : Jun/2002
Owner : CS Chuah, Enthalpy Engineering Sdn Bhd

HVAC System - Introduction



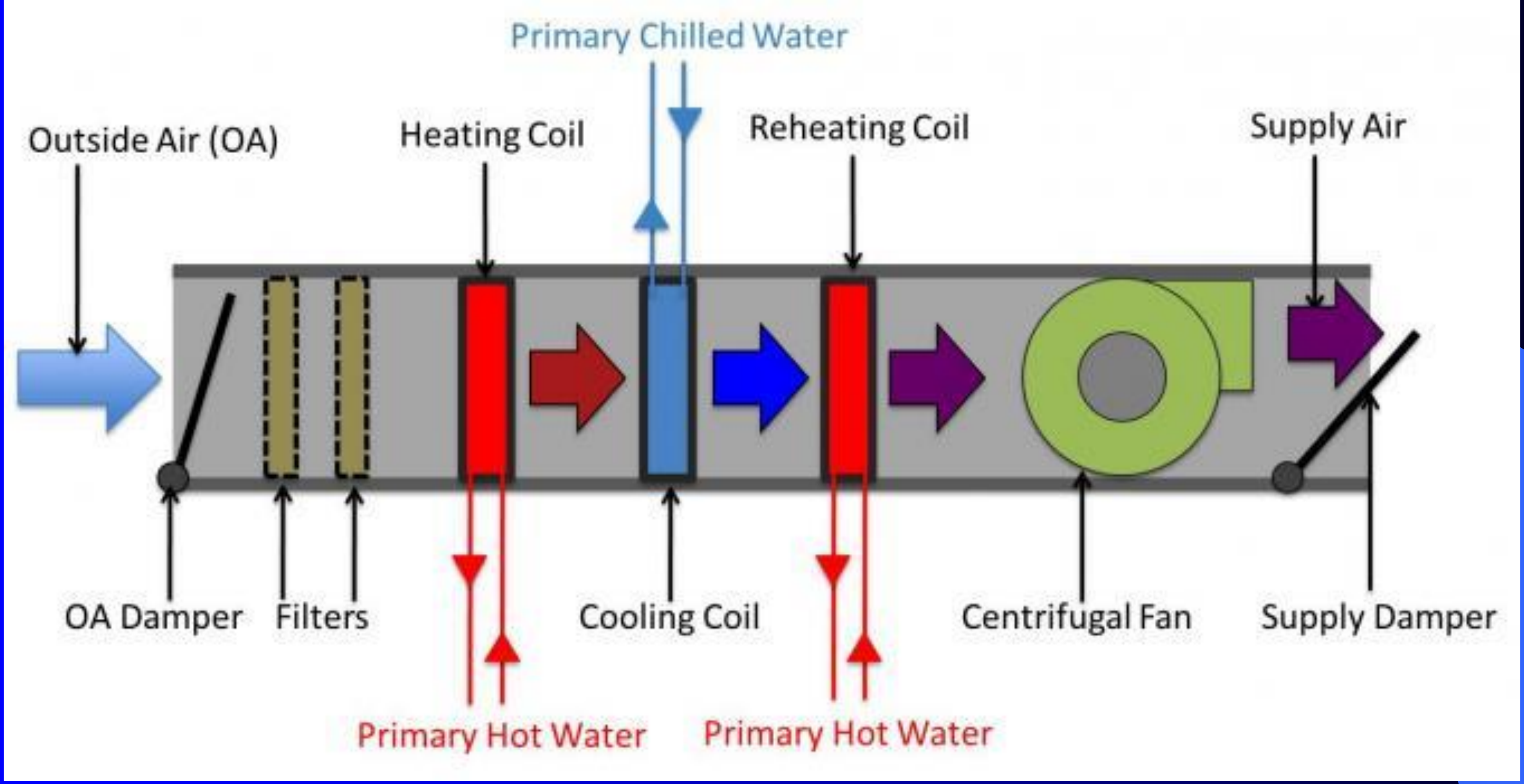
HVAC System – Refrigerant Cycle – Heat Pump



Hi
Pressure
side

Low
Pressure
side

HVAC System – Air Side



Content

- Introduction
- Air properties
- Psychromeric processes
- Psychrometric processes – work examples
- Psychrometric processes in air-cond. equipment
- RH and Temp. control
- RH and Temp. control – work examples
- Test.

Introduction

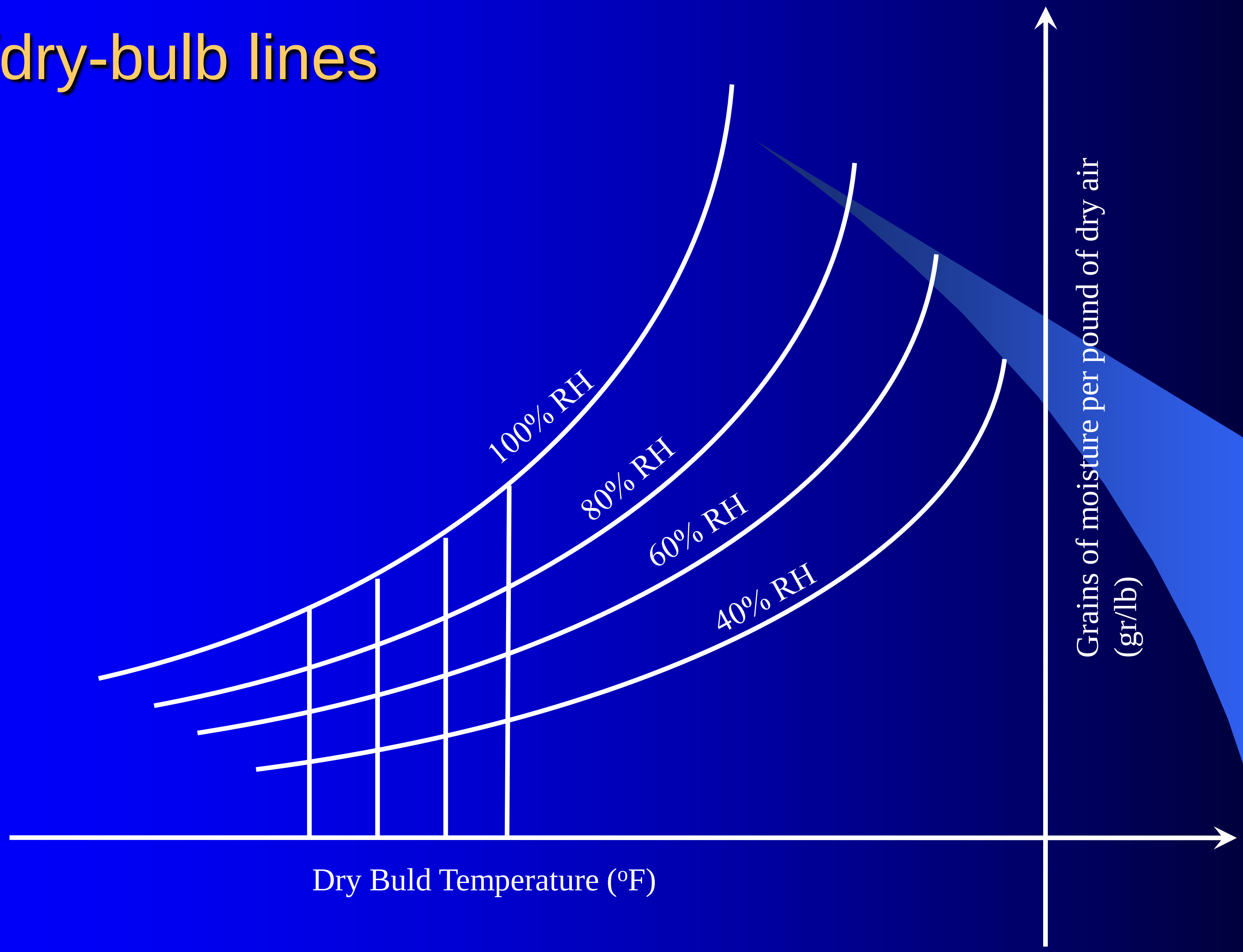
Psychrometry or hygrometry is the study of how the properties of moist air can change as a result of air conditioning processes

The psychrometric chart (as in next page) is a useful design tool for air conditioning engineers. The chart presents a number of properties of moist air:

- dry-bulb temperature
- sling wet-bulb temperature
- moisture content
- specific enthalpy
- specific volume
- relative humidity (RH)
- Dew-point.

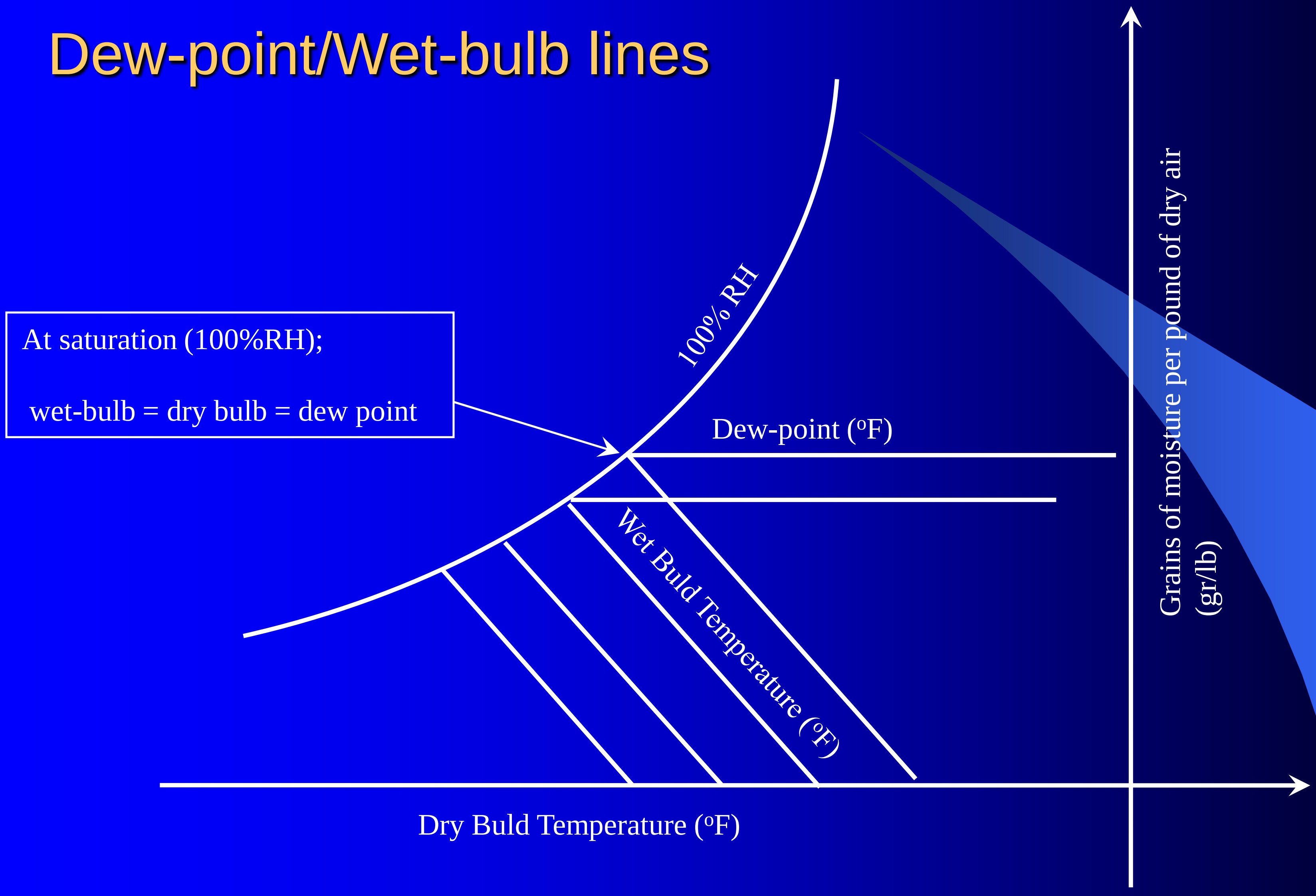
Introduction

RH/dry-bulb lines



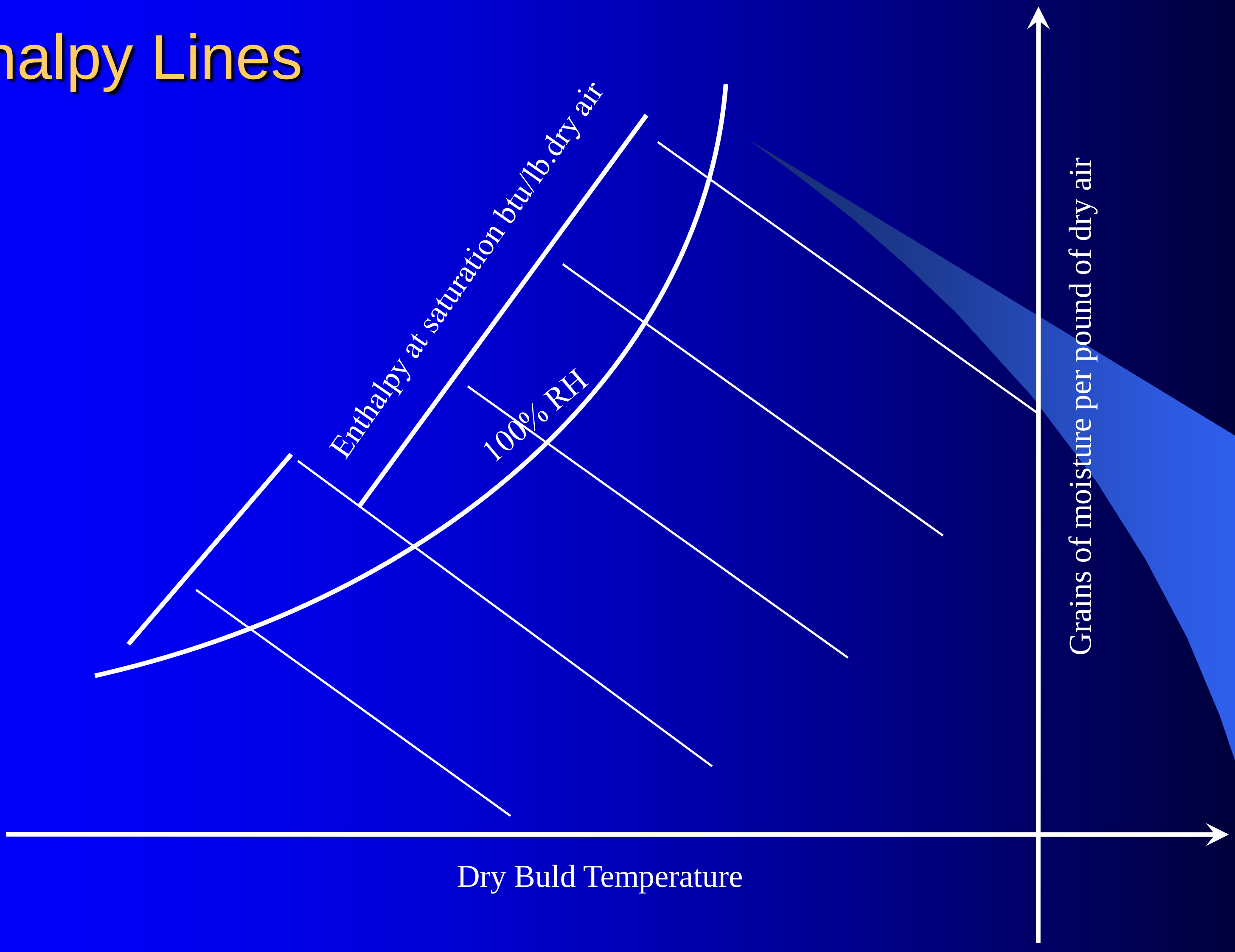
Introduction

Dew-point/Wet-bulb lines



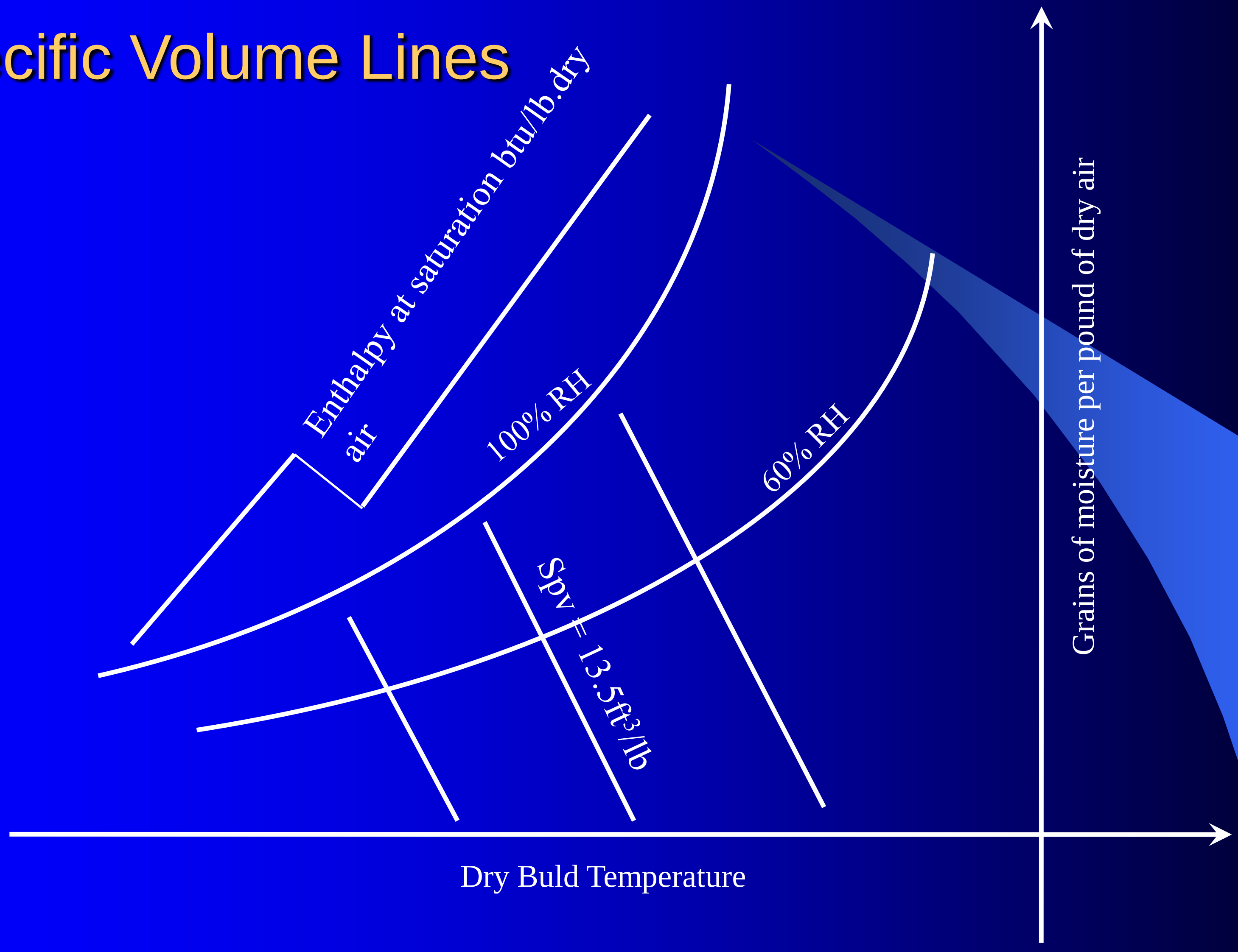
Introduction

Enthalpy Lines



Introduction

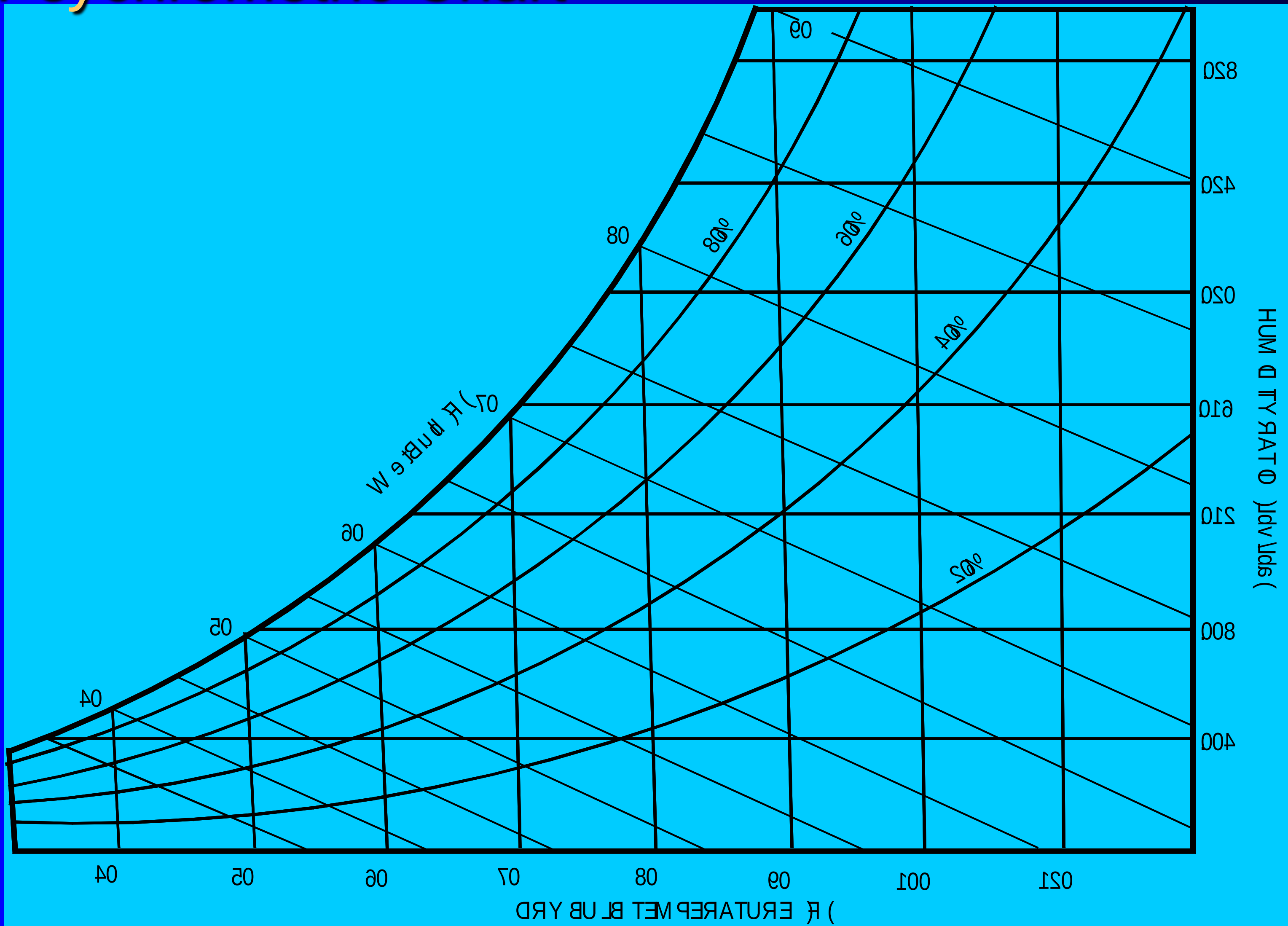
Specific Volume Lines



Enthalpy

Introduction

Psychrometric Chart



Air Properties

- dry-bulb temperature

The dry-bulb temperature of air is measured by a thermometer which is freely exposed to the air but is shielded from radiation and moisture. Unit in ^{o}F Db

- wet-bulb temperature

The Wet-bulb Temperature of air is measured by a thermometer whose bulb is covered by a muslin sleeve which is kept moist with distilled and clean water, freely exposed to the air and free from radiation. Unit in ^{o}F Wb

Air Properties

Enthalpy

- <u>moisture content</u>

Specific/absolute humidity, moisture content or humidity ration of air is the ratio of the mass of water to the mass of dry air in a given volume of moist air. Unit in gr/lb or lb/lb (moisture/air)

- <u>specific enthalpy</u>

Specific enthalpy has the same dimension as [energy/mass]. The SI unit of specific enthalpy is btu/lb. Other units are: kJ/kg, erg/g, cal/g.

Air Properties

- specific volume

The specific volume of a system is the volume occupied by unit mass of the system. Unit ft^3/lb.

- relative humidity (RH)

Relative humidity or percentage saturation is defined as the ratio of the specific humidity of air to the specific humidity of saturated air at the same temperature. Unit in % or integer.

- Dew-point (RH)

Dew-point is a temperature point where air will fully saturated (100%RH) at this point dew point = dry-bulb = wet-bulb temperature. Being used as a measurement of absolute humidity. Unit in ^{o}F.

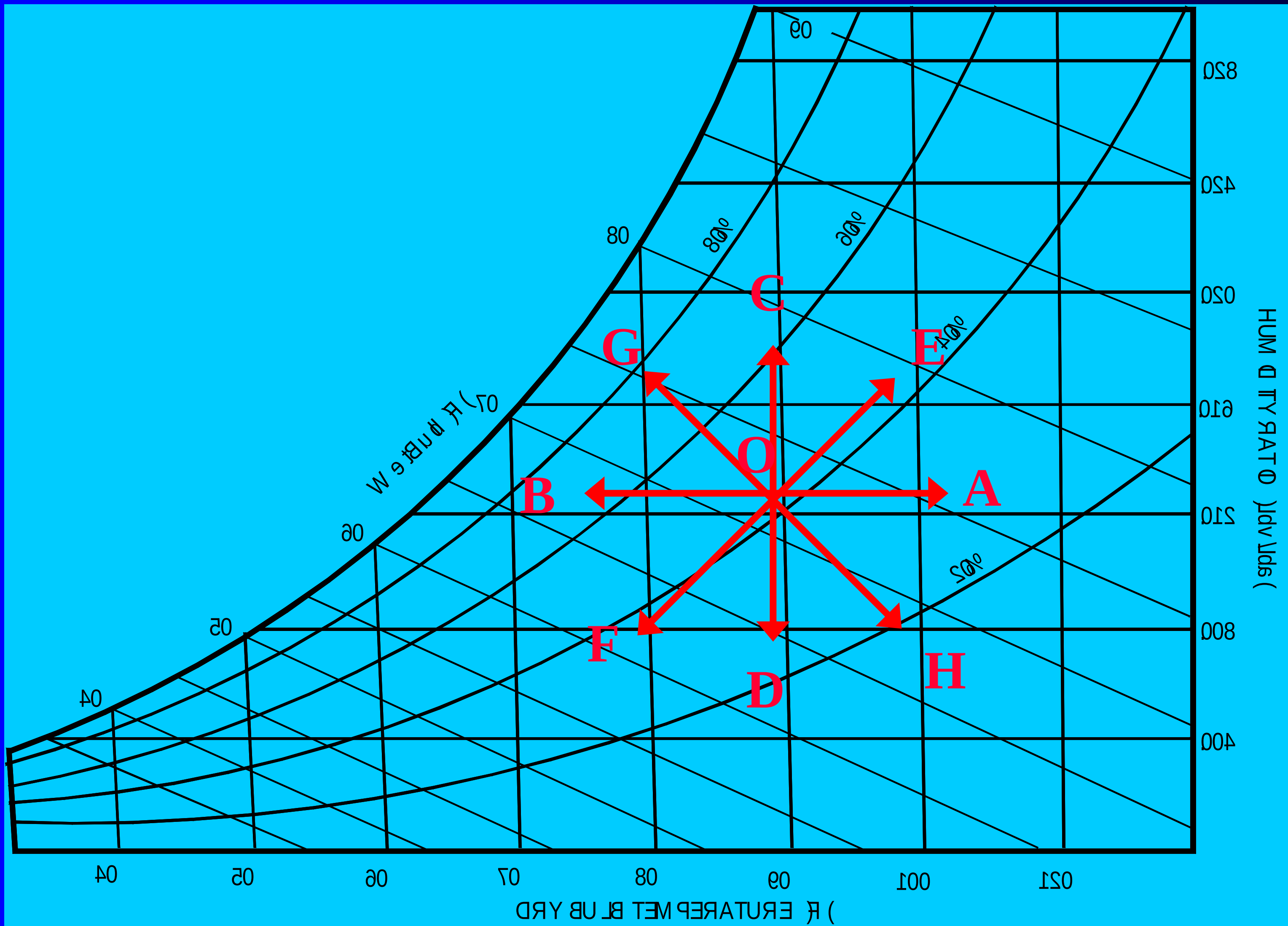
Psychrometric processes

8 basics thermodynamic processes by which the air properties can be altered as below (refer chart next page);

- Sensible cooling - OA
- Sensible heating - OB
- Humidifying - OC
- Dehumidifying - OD
- Heating & humidifying - OE
- Cooling & dehumidifying - OF
- Cooling & humidifying - OG
- Heating & dehumidifying - OH

Enthalpy

Psychrometric processes



Psychrometric processes

- Two primary processes being identified for heat transfer calculation through psychromatric chart i.e. Sensible heat and latent heat.

1. Sensible heat process – heating or cooling.

A heat transfer process that changes ONLY the dry-bulb temperature of air properties (WITHOUT humidity ratio changes). A horizontal line in psychometric chart, as per B-O-A in previous chart.

$$Q_{sensible}\ (\text{btu/hr}) = 1.08 \times CFM \times \Delta Tdb$$

ΔTdb : changes of dry-bulb temp. (point 1 to point2)

Psychrometric processes

2. Latent heat process – humidification or dehumidification

A heat transfer process that add or remove water vapor from air through humidifying or dehumidifying process. It changes the properties of humidity ratio and NOT the dry-bulb temp.). A vertical line in psychometric chart, as per D-O-C in previous chart.

Q_{latent} (btu/hr) = 0.69 x CFM x ΔW

ΔW : changes of humidity ratio (point1 to point2)

Psychrometric processes

- The total heat transfer (add or remove) by having air porporties being move from one point to another can be quantified by sensible heat + latent heat.

$$Q_{TOTAL} = H_{SESIBLE} + H_{LATENT}$$

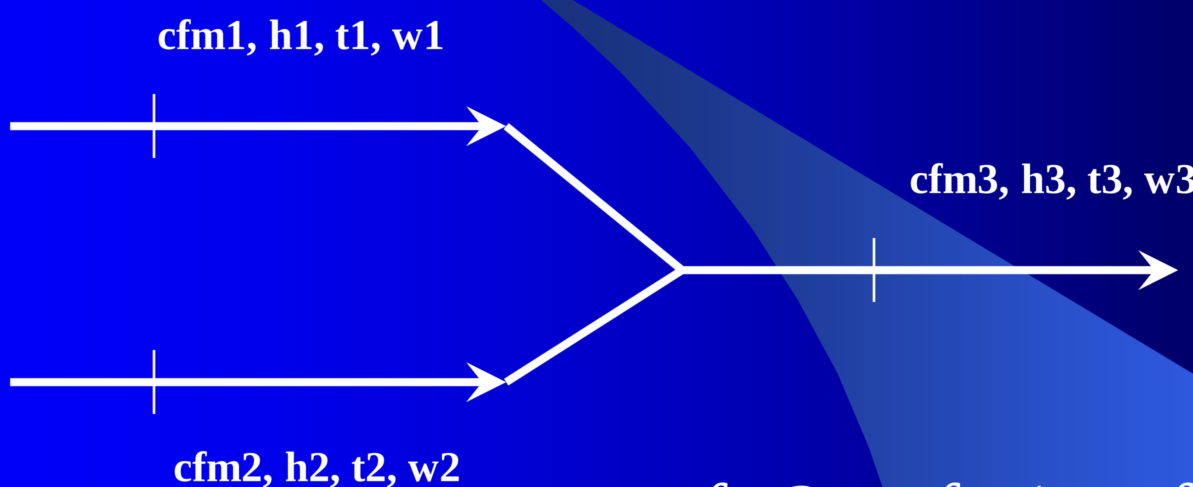
Or $$Q_{TOTAL}\ (btu/hr) = 4.5 \times CFM \times \Delta h$$

Δh : Specific enthalpy changes (point1 to point2)

Psychrometric processes

- The air mixing process

Te air mixing process is where 2 streams of air with diferent properties being mixed and form a third stream. This process occurred particularly in mixing outside air with return air from room.



cfm3 = cfm1 + cfm2

Psychrometric processes

- mixed air dry-bulb temp.

$$T3 = \frac{cfm1.t1 + cfm2.t2}{cfm3}$$

- Mixed air humidity ratio.

$$W3 = \frac{cfm1.w1 + cfm2.w2}{cfm3}$$

- Mixed air specific enthalpy.

$$h3 = \frac{cfm1.h1 + cfm2.h2}{cfm3}$$

Psychrometric processes

- Sensible heat factor (SHF)

The ration of the sensible heat transfer to the total heat transfer is termed as sensible heat factors.

$$SHF = \frac{Qs}{Qs + QL}$$

- The SHF is important to cooling coil selection, this is to design a coil that able to transfer room latent and sensible load accordingly.

Psychrometric process – work examples

1. Find the properties of air at 80^{o}F DB and 50% RH.
   a) specific volume (ans: SpV = 13.85ft3/lb dry air)
   b) specific enthalpy (ans: h = 31.4btu/lb dry air)
   c) dew-point (ans: dew point = 59.8^{o}F)

2. Air initially at 70^{o}F and 55%RH is heated to 100^{o}F (DB). Find the WB, DP and RH of air at 100^{o}F (DB) and the heat added per lb. of air, if the moisture kept constant. (ans: WB=69.5^{o}F, DP=52.6^{o}F & RH=20%)

Psychrometric process – work examples

3. Air is heated from state 1, t=^{70oF} and RH=57% to state 2, t=85^{o}F and WB=70oF. Determine the heat added, the RH at state2 and the change in moisture content. (ans : heat added = 7.45btu/lb; moisture content added = 0.0034lb/lb dry air)

4. An air stream of 8,000 cfm of return air at 74^{o}F DB 50%RH being mixed with 2,000 of fresh air at 90^{o}F DB 65%RH. Determine the mixed air properties of

   a) Temperature (DB) (ans : temp = 77.2^{o}F)

   b) Moisture contain (ans : 80.8gr/lb dry air)

   c) RH% (ans : RH = 59%)

   d) Specific enthalpy (ans : 31.4 btu/lb dry air)

Psychrometric process – work examples

- Psychrometric process in air-conditioning equipment
  - Reheat coil.
  - Coil process line
  - Coil apparatus dew point
  - Coil contact and bypass factor.

- RH and temp control.

Psychrometric process in air-cond. equipment.

- **Reheat coil**

A coil that reheat the cooled air before delivery to space. This is particularly required to achieved supply air to low dew-point at the same-time supply at a comfortable temperature.

- **Coil process line**

A line can be drawn on the psychromatric chart representing the change in condition of air passes over the cooling and dehumidifying coil. It normally being drawn in straight line between entering point and leaving point.

Capacity of coil is defined as sensible, latent and total heat load which being expressed in term of refrigerant load, tons, 1RT = 12000 btu/hr.

Psychrometric process in air-cond. equipment.

- **Coil apparatus dew-point**

A point where SHF line crosses the saturation line of psychrometric chart. As such, this effective surface temperature is considered to be the dew-point of the coil or being called by apparatus dew-point.

- **Coil contact and bypass factor**

When air passes across the outside surface f a coil, only part of the air actually contacts the surface and is cooled – Thus called contact factro (CF) and Bypass Factor (BPF)

Psychrometric process in air-cond. equipment.

Contact factor (CF) can be defined as the proportion of air passing through the coil that touches the cooling surface and is thus cooled.

Bypass Factor (BPF) is defined as the proportion of air that does not touch the surface, and is therefore not cooled.

For a one-row coil with eight fins pr inchi, BPF is about 0.56. The BPF for a coil n rows deep can be estimated approximately;

BPF (n row coil) = 0.56^n

Example : BPF (2 row coil) = 0.56^2 = 0.31

BPF (4 row coil) = 0.56^4 = 0.1

The BPF also vary with air velocity through the coil, higher BFP with higher air velocity.

CF + BPF =1

Psychrometric process in air-cond. equipment.

O : out-door air properties

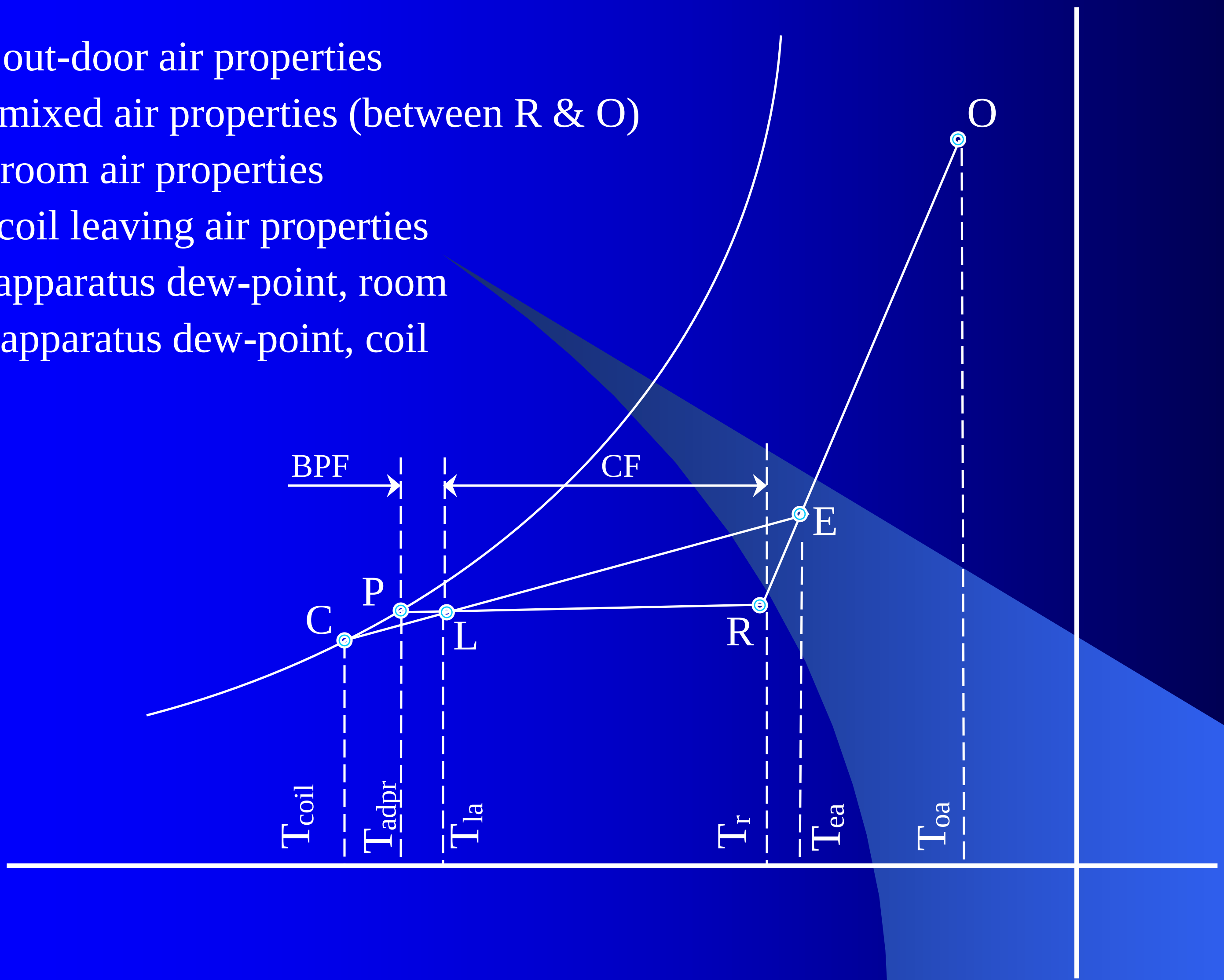
E : mixed air properties (between R & O)

R : room air properties

L : coil leaving air properties

P : apparatus dew-point, room

C : apparatus dew-point, coil

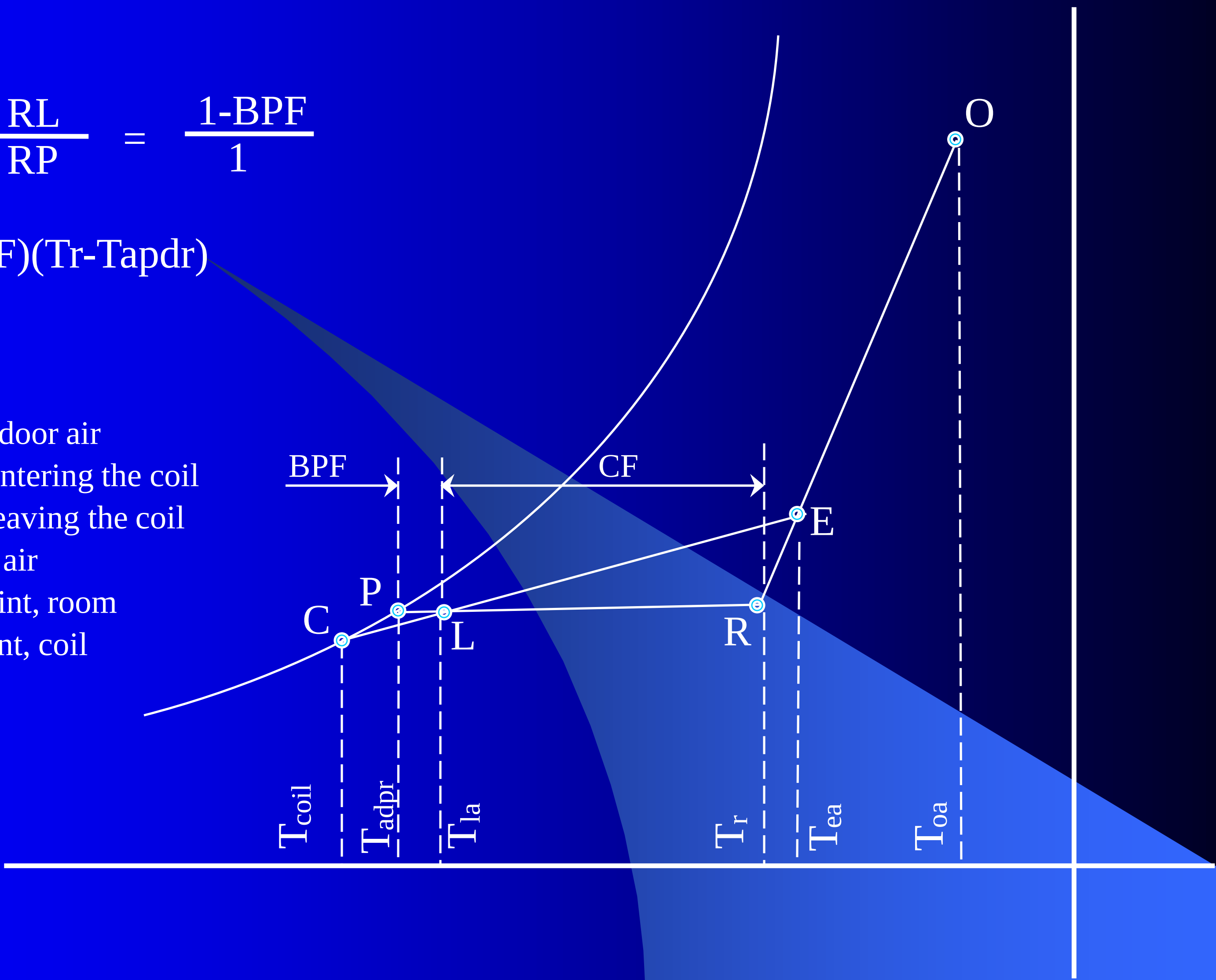


Psychrometric process in air-cond. equipment.

$$\frac{Tr - Tla}{Tr - Tapdr} = \frac{RL}{RP} = \frac{1\text{-}BPF}{1}$$

$$Tla = Tr - (1\text{-}BPF)(Tr\text{-}Tapdr)$$

Toa : Temperature of out-door air
Tea : Temperature of air entering the coil
Tla : Temperature of air leaving the coil
Tr : Temperature of room air
Tapdr : apparatus dew-point, room
Tcoil : apparatus dew-point, coil



Psychrometric process in air-cond. equipment.

1. Room air kept at 76ºF DB, 50% RH, SHF line of 0.80. What is the apparatus dew point (room). (ans : apperatus dew point ~ 52ºF)

2. Give OA at 95oFDB, 84ºFWB; Room at 76ºFDB, 50%RH, air entering coil at 83.^{2oFDB}, 71.3ºFWB and air leaving coil at 60ºFDB, 57.5ºFWB.

   Locate these points on the psychrometric chart, determine the room apparatus dew-point and coil apparatus dew-point. (ans : Tapdr = 56ºF, Tcoil = 41ºF)

Psychrometric process in air-cond. equipment.

1. Room air kept at 76°F DB, 50% RH, SHF line of 0.80. What is the apparatus dew point (room). (ans : apparatus dew point ~ 52°F)

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Psychrometric process in air-cond. equipment.

1. Given Out-door Air : 95°FDB, 84°FWB
   Room design cond. : 76°FDB, 50%RH
   Room Sensible Heat : 135000 Btu/hr
   Room Latent Heat : 40000 Btu/hr
   Out-side air required : 1500 cfm

   A four-row DX coil with BPF of 0.10 will be used.
   Determine the following;
   a) The room apparatus dew-point. (ans : 51.1°F)
   b) The temp. of air leaving coil. (ans : 53.59°F)
   c) The return air CFM (ans : 4080cfm)
   d) The temp. of air entering coil. (ans : 81°F)
   e) The coil apparatus temperature. (ans : 48.8°F)
   f) Coil operating temperature*. (ans. 41.8°F)

*temperature of refrigerant usually 5°F-7°F of lower than coil apparatus dew point.

RH and Temp. Control

- **Standard temperature control, no RH control.**
  - 74 +/- 3 ºFDB
  - 40% - 65% RH even no RH control provided

- **Example of relative humidity (RH) control requirement.**

- Museums	**- 70 DB/35-50%RH**
- Computer rooms	**- 72 DB/50%RH**
- Hospitals	**- 72 DB/50-60%RH**
- Clean-room	**- 68 DB/40-45%RH**

- **Example of specific humidity control requirement.**
  - Pharmaceutical “dry room” - 72 DB/5-15 gr/lb

Psychrometric process in air-cond. equipment.

- **Temperature/RH control method**

  1. Chilled water/refrigeration cooling with reheat.

  - used for 68°FDB/35% RH as minimum

  - most semiconductor/biotech/pharmaceutical RH control application can be met.

  2. Desiccant dehumidification system with re-cooling.

  - pharmaceutical "dry rooms"

  - 68°FDB/5-15 gr/lb specific humidity

  3. Discharge temperature control.

  - cooling coil discharge temperature related to customers room control requirement.

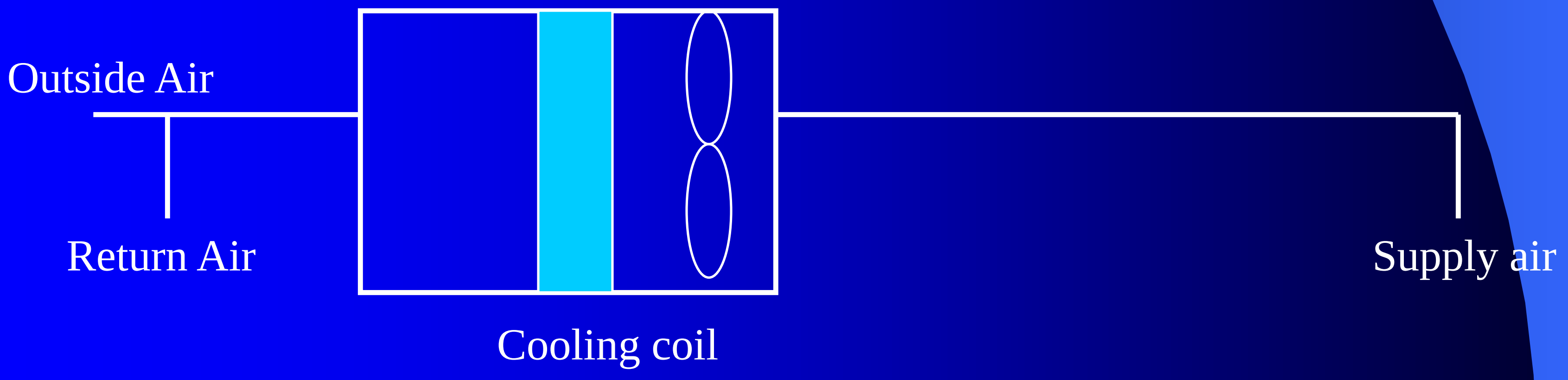
  - example :

  72 DB/50%RH : 51°F discharge temp. required

  70 DB/50%RH : 49°F discharge temp. required

RH and Temp. control – work example

Dehumidification/humidification example.	
Outside air	**Outside air**
	93ºFDB
	80ºFWB
Indoor air condition	**78ºFDB/55%RH**
Outside air	**2100CFM**
Bypass factor	**0.10**
Room sensible load	**77,854 btu/hr**
Room latent load	**26,050 btu/hr**



RH and Temp. control – work example

Enthalpy

Room Sensible heat factor

RSH= 77854 btu/hr, RLH = 26050 btu/hr

RSHF = (77854)/(77854+26050) = 0.75

Construct line AR in psychrometric chart, get the Tadpr = 56.4 (refer next page)

Given Tr = 78°F, BF = 0.10

$$\frac{Tr - Tla}{Tr - Tapdr} = \frac{RL}{RP} = \frac{1\text{-}BPF}{1}$$

Tla = Tr – (1-BPF)(Tr-Tapdr)

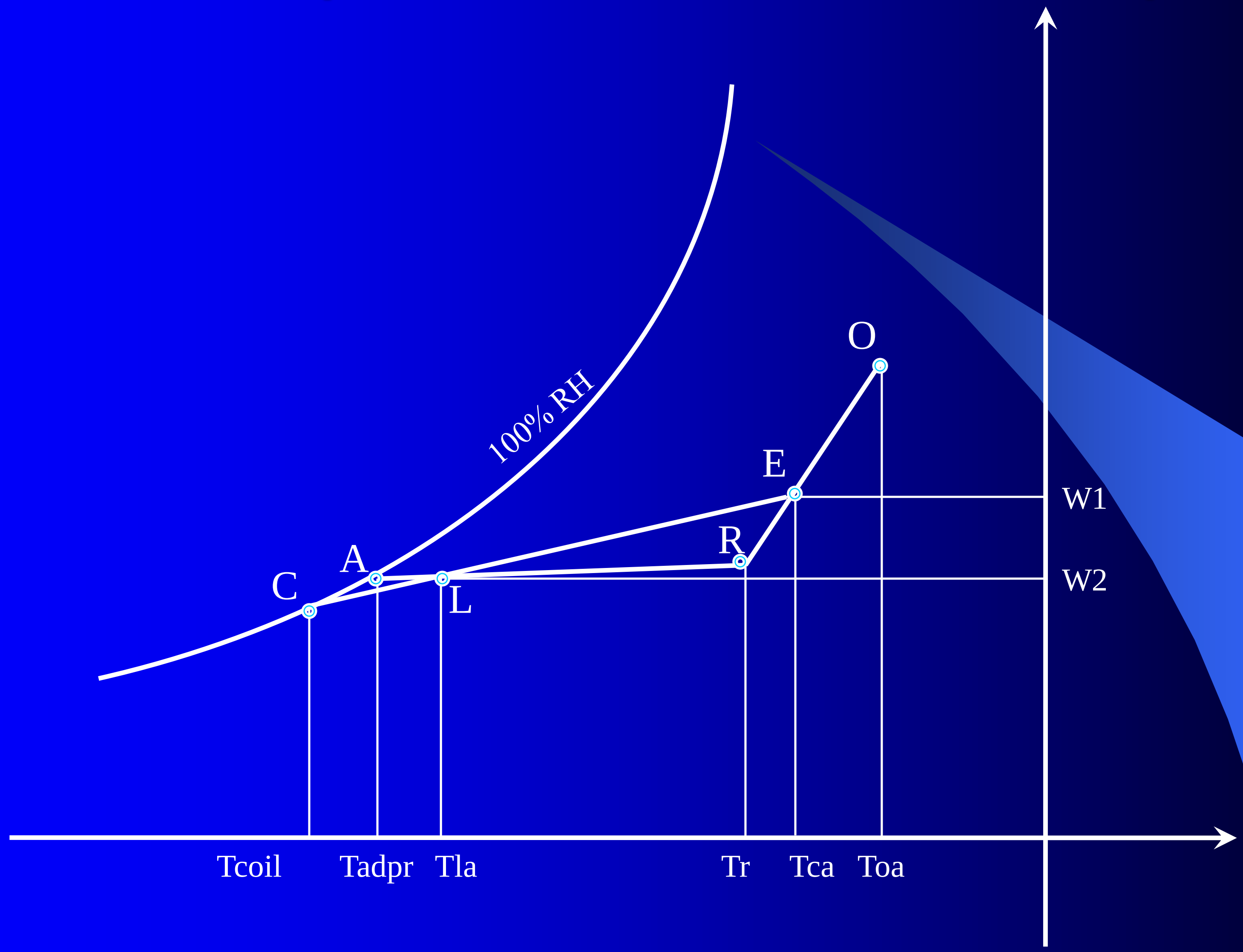
Tla = 78 – (0.90)(78-56.4) = 58.56°F

Hence the room supply air CFM;

CFMsa = RSH /[(1.08)(Tr – Tsa)]

CFMsa = 77854 /[(1.08)(78 – 58.56)] = 3708

RH and Temp. control – work example



RH and Temp. control – work example

Enthalpy

$CFM_{ra} = CFM_{sa} – CFM_{oa}$ = 3708-2100 = 1608

Temperature of mixed air Tca;

Tca = [(Toa X CFMoa)+(Tr X CFMra)] / [CFMsa]

Tca = [(93 X 2100)+(78 X 1608)] / [3708] = 86.5°F

Construct line EC in psychrometric chart, cutting through point “L”

From chart Tcoil = 54.5°F

From chart W1=110gr/lb; W2=69gr/lb, Spv = 14.1cuft/lb

Moisture removed/hr = Msa (ΔW) (60/7000)

= (3708/14.1)(110-69)(60/7000)

= 92.4 lb/hr.

Test

Q1. The weather reports reads. 80°F db & 40%RH, what is the wb temp.?

Q2. The air leaving a cooling coil is at 52°Fdb and 43°Fwb. What is its humidity ration and enthalpy?

Q3. Water pipes with surface temp at 50°F runs through an environment at 70°F, what is the maximum RH can be maintained without condensation at pipe surface?

Q4. An air-cond. unit has a cooling coil that cools and dehumidifies 20000cfm of air from 82°F db and 50% RH to 64°F db and 61°F wb. Find the sensible, latent and total load capacity of the cooling coil and amount of moisture condensed.

Q5.Calculate the sensible heat required to raise the dry-bulb temperature of 7400CFM of air at 30°Fdb/29°Fwb to 77°Fdb.

Test

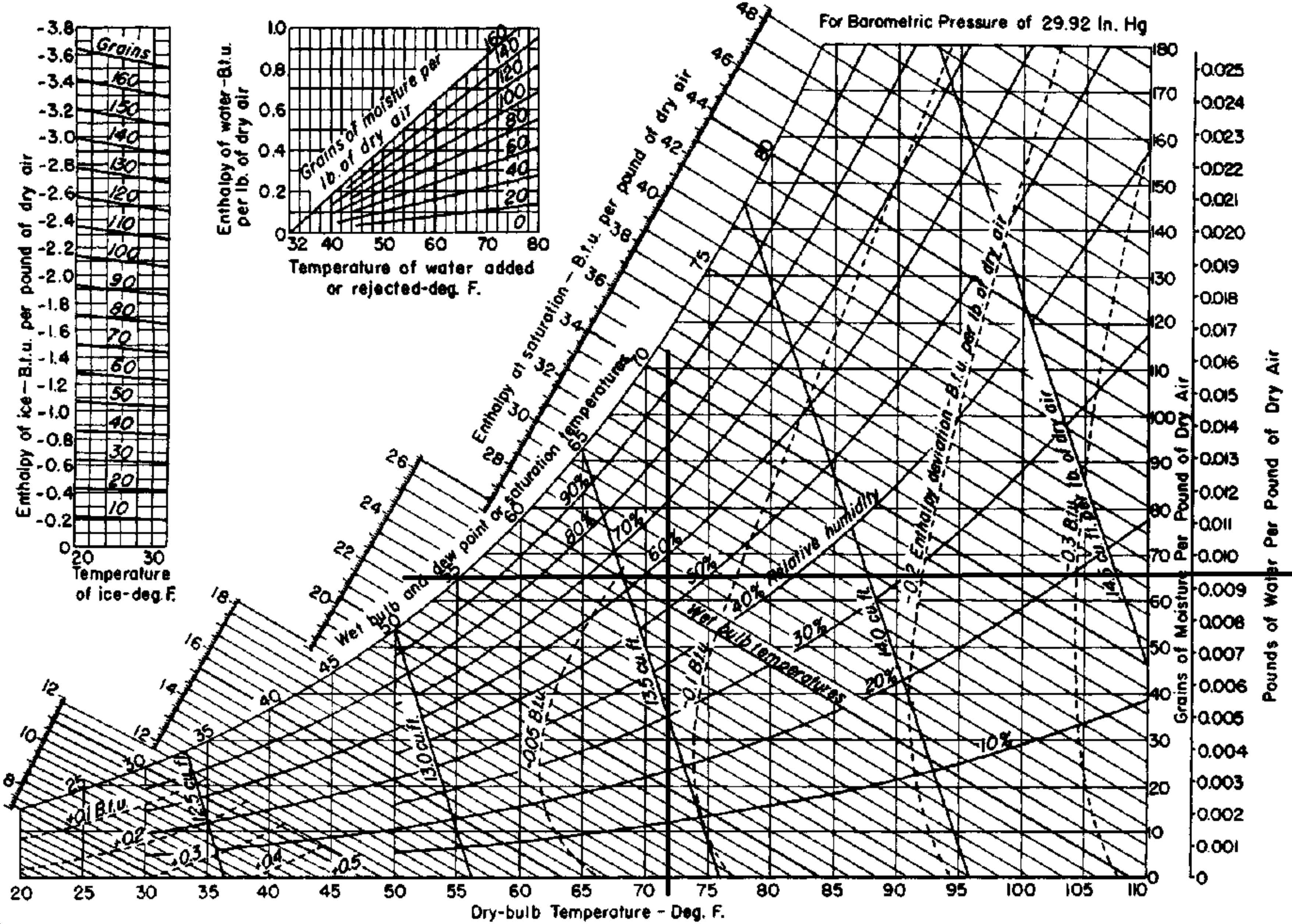
Q6. A hall is to be designed for comfort air-conditioning using the following data:

Out-door air conditions	: 90°Fdb, 79°Fwb
In-door design conditions	: 77°Fdb, 50%rh
Sensible heat load in the hall	: 191,250 btu/hr
Latent heat load in the hall	: 41,000 btu/hr
Total infiltration air	: 740CFM
Apparatus dew-point temperature of cooling air.	: 50°F

If 60% of the total air is recalculated from the hall, and is mixed with the conditioned air (fresh air) after the cooling coil. Find the following;

A) The condition of air leaving the cooling coil before mixing with the recalculated air.
B) The condition of air before entering the hall.
C) The weight of fresh air entering the hall in lb/min
D) The weight of total air passing through the hall in lb/min.
E) The by pass factor of the cooling coil.
F) The refrigeration load in tons of refrigerant on cooling coil.

Enthalpy



For Barometric Pressure of 29.92 In. Hg
Dry-bulb Temperature - Deg. F.
Grains of Moisture Per Pound of Dry Air
Pounds of Water Per Pound of Dry Air
Enthalpy at saturation - B.t.u. per pound of dry air
Wet bulb and dew point or saturation temperatures
Wet bulb temperatures
Relative humidity
Enthalpy deviation - B.t.u. per lb. of dry air
Enthalpy of ice - B.t.u. per pound of dry air
Temperature of ice-deg. F.
Grains
Enthalpy of water - B.t.u. per lb. of dry air
Grains of moisture per lb. of dry air
Temperature of water added or rejected-deg. F.
13.0 cu. ft.
13.5 cu. ft.
14.0 cu. ft.
14.5 cu. ft. per lb. of dry air
12.5 cu. ft.