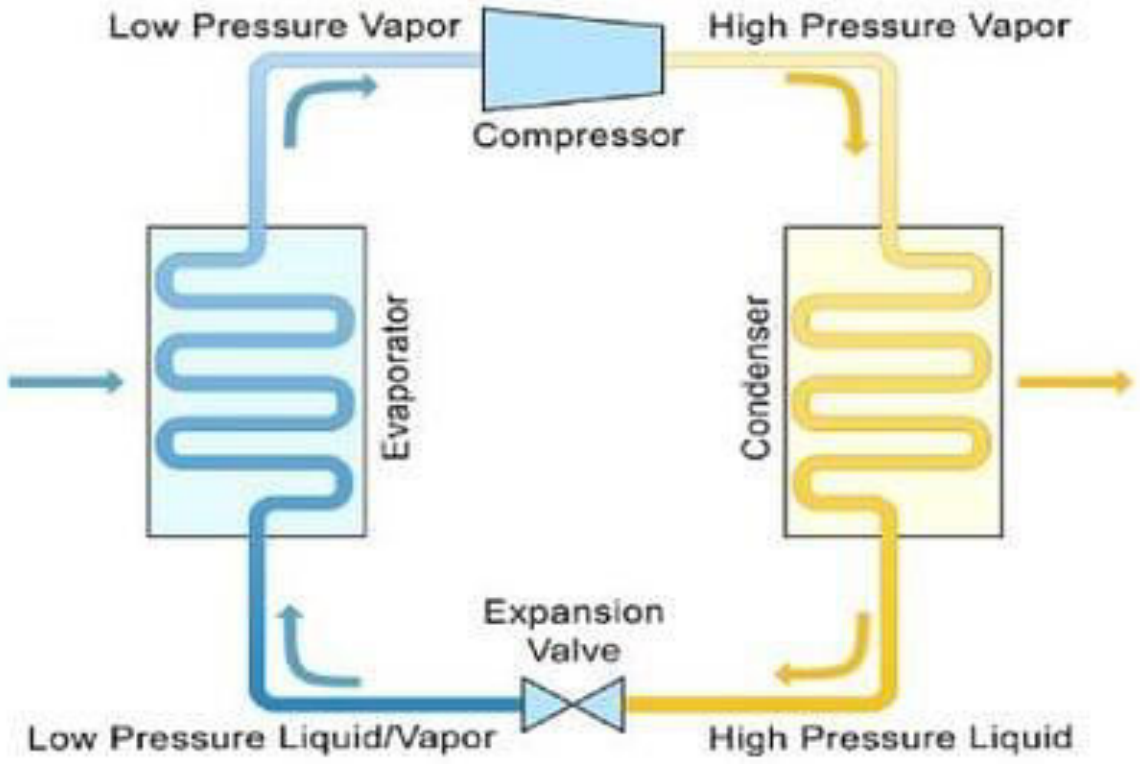
ME 161
Introduction to Mechanical Engineering

Refrigeration and air-conditioning

Please go through class notes and reference materials discussed in the class. This is just a guideline for those who missed the classes

Refrigeration system components



Types of Air Conditioners

- Central air conditioning system
- Split type air conditioner
- Portable air conditioner
- Window air conditioner
- Cassette air conditioner
- Evaporative air conditioner

- **Air-conditioning** means control of temperature, humidity, purity and movement of air. The working conditions and comfort for human beings is improved by air-conditioning. The temperature is brought down during summer and increased during winter without causing any discomfort. There are 6 major parts to the system. The Compressor, The Condenser, The Receiver/Dryer or Accumulator, The Thermal Expansion Valve or Orifice Tube,The Evaporator, The Refrigerant
- **Refrigeration** may be defined as the process of removing heat from a substance under controlled conditions and reducing and maintaining the temperature of a body below the temperature of its surroundings by the aid of external work.
- **Coefficient of Performance of a Refrigerator : COP**
  The performance of a refrigeration system is expressed by a factor known as Coefficient of Performance (COP). The COP of a refrigeration system is defined as the ratio of amount of heat absorbed or extracted in a system to the amount of work supplied. COP=Amount of heat absorbed/Amount of work supplied. $COP_r = Qc/W$

- **Refrigerants**. The refrigerant is a heat carrying medium which during their cycle in the refrigeration system absorb heat from a low temperature system and reject the heat to a high temperature system.

- **Unit of Refrigeration: Tons of refrigeration**
  In a refrigeration system, the rate at which the heat is absorbed in a cycle from the interior space to be cooled is called refrigerating effect. The capacity of a refrigeration system is expressed in Tons of refrigeration which is the unit of refrigeration. A ton of refrigeration is defined as the quantity of heat absorbed to convert one ton of water at 0°C to one ton of ice at the same temperature in 24 hours.
- In S.I. System,1 Ton of Refrigeration = 210 kJ/min = 3.5 kW,
- In FPS system200 Btu/min
- In MKS system 50 kcal/min

Types of compressors

- Reciprocating compressors.
- Rotary vane compressors.
- Scroll compressors.
- Screw compressors.
- Centrifugal compressors.

Types of Condenser

- Air cooled
- Water cooled
- Evaporative

Too much humidity cause

- A stuffy nose, itchy and watery eyes, sneezing, difficulty breathing, skin rashes,
- A diminished immune system and resistance to respiratory allergies and infection

Benefits of dehumidification

- A better indoor ‘smell’
- Protected clothes and fabrics
- Protected Property.
- Everything is fresher
- Less cleaning time
- Lower energy costs

Evaporator Purpose

- There are two purposes of evaporators:
  - Cooling
  - Dehumidification

Evaporator Capacity

- Factors that effect evaporator capacity:
  - Surface Area
  - Temperature Difference
  - Refrigerant Velocity
  - Conductibility (How fast heat moves through metal)
  - Metal thickness
  - Air Volume

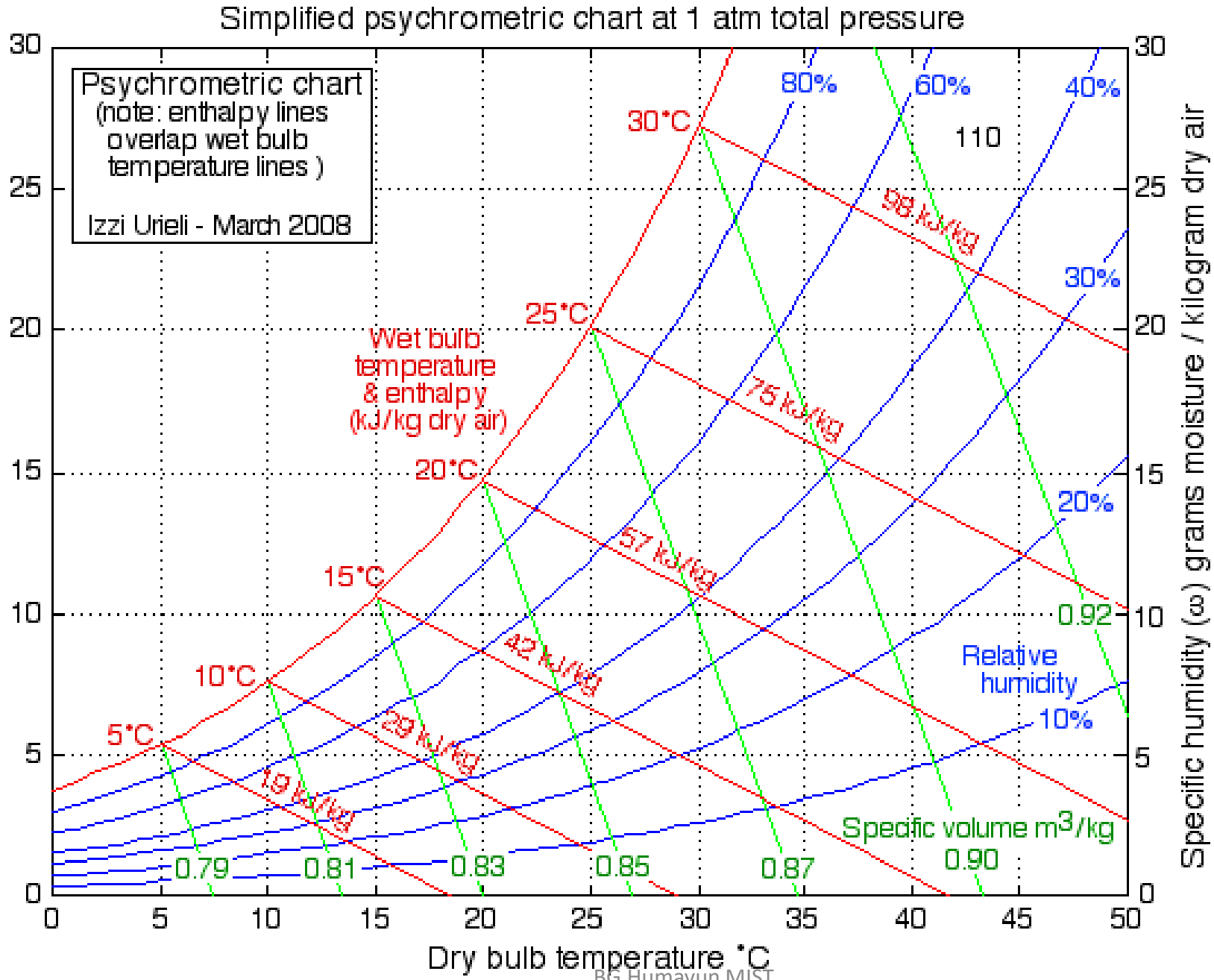
Laws of thermodynamics

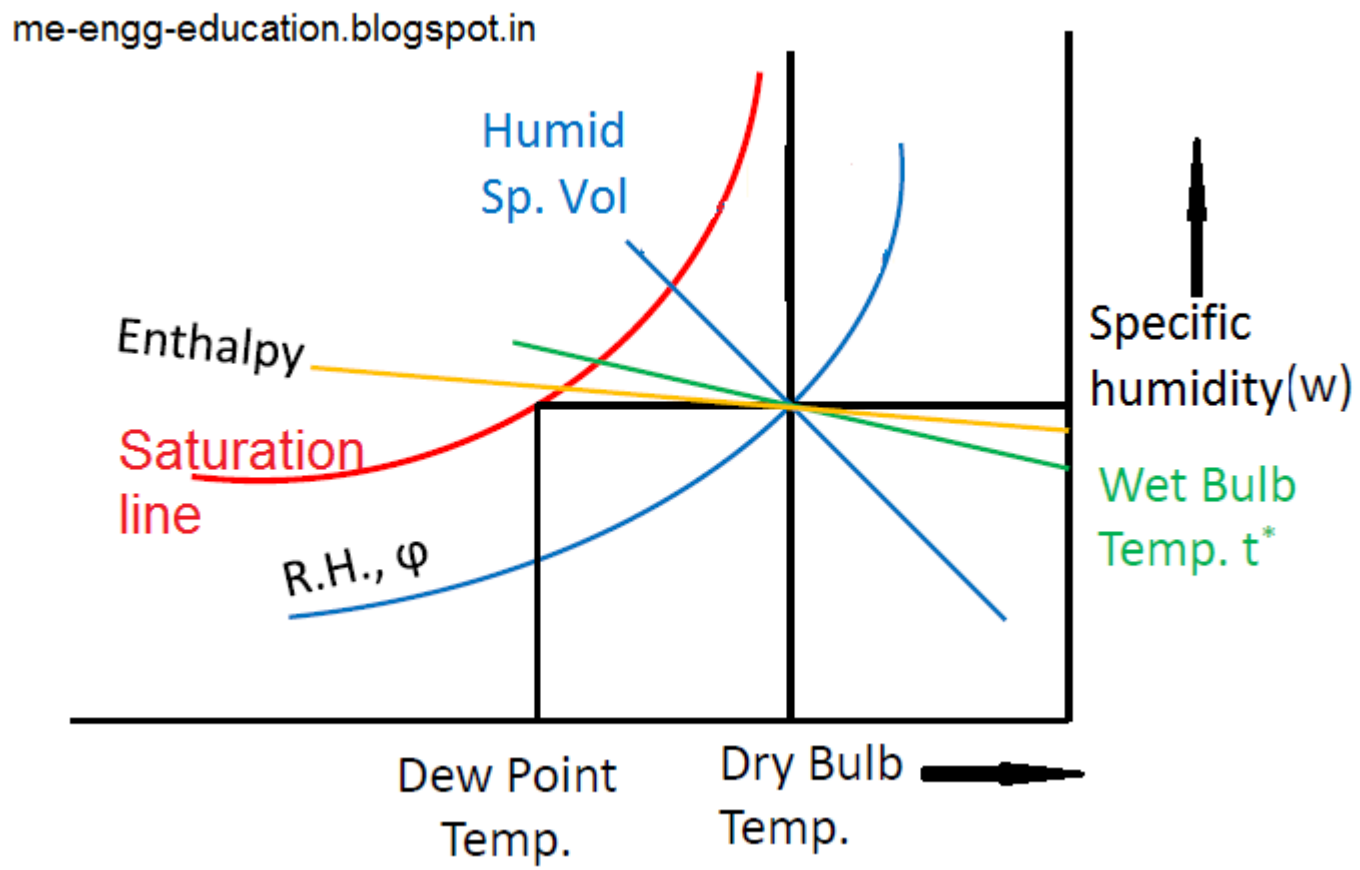
- The zeroth law of thermodynamics defines thermal equilibrium and forms a basis for the definition of temperature: If two systems are each in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.

- The first law of thermodynamics states that, when energy passes into or out of a system (as work, heat, or matter), the system's internal energy changes in accordance with the law of conservation of energy.

- The second law of thermodynamics states that in a natural thermodynamic process, the sum of the entropies of the interacting thermodynamic systems never decreases.

- The third law of thermodynamics states that a system's entropy approaches a constant value as the temperature approaches absolute zero. The entropy of a system at absolute zero is typically close to zero.

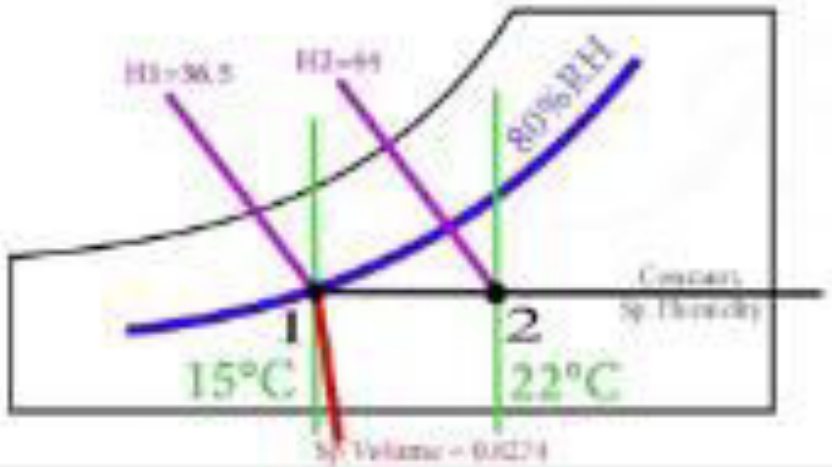

Simplified psychrometric chart at 1 atm total pressure
Psychrometric chart
(note: enthalpy lines
overlap wet bulb
temperature lines)
Izzi Urieli - March 2008
Wet bulb
temperature
& enthalpy
(kJ/kg dry air)
30°C
25°C
20°C
15°C
10°C
5°C
110
98 kJ/kg
75 kJ/kg
57 kJ/kg
42 kJ/kg
29 kJ/kg
19 kJ/kg
80%
60%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


me-engg-education.blogspot.in
Humid
Sp. Vol
Enthalpy
Saturation
line
R.H., φ
Specific
humidity(w)
Wet Bulb
Temp. t*
Dew Point
Temp.
Dry Bulb
Temp.

Psychrometric Chart

Ex. 2 : In winter air-conditioning system, 100 m^3 of air per minute at 15° C DBT and 80% relative humidity is heated until its DBT is 22 °C with constant specific humidity. Find heat added to the air per minute

Given – 1. Initial Condition: 15°C DBT & 80% RH
2. Final Condition: 22°C DBT at Const. Sp Humidity



Answer - From Psychrometric chart,

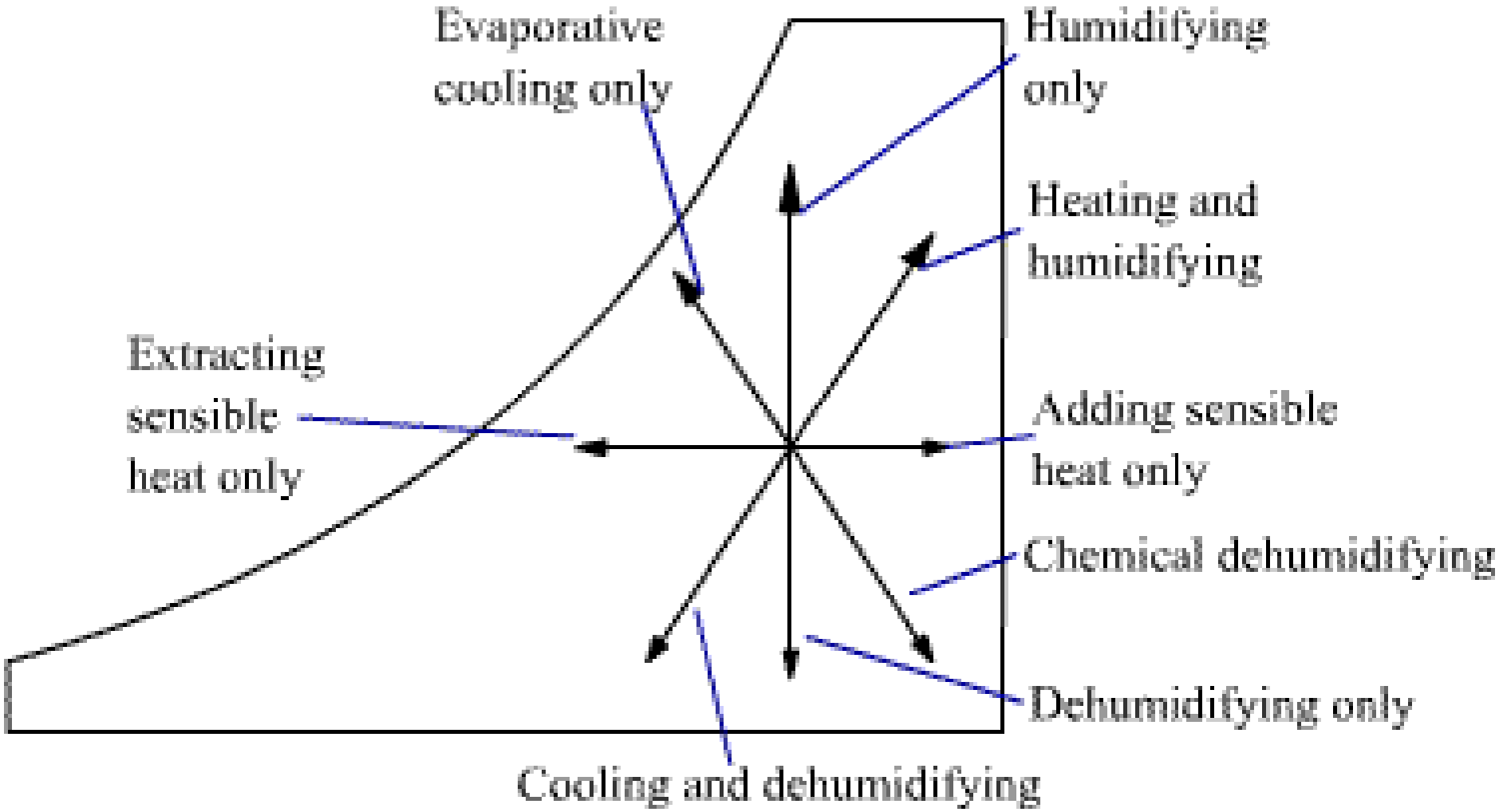
1) H1 = 36.5 kJ/kg
2) H2 = 44 kJ/kg
3) Sp. Volume = 0.8274 m^3/kg

$$ma = \frac{\text{Volume}}{\text{Sp. Volume}} = \frac{100}{0.8274} = 120.860 \text{ kg/min}$$

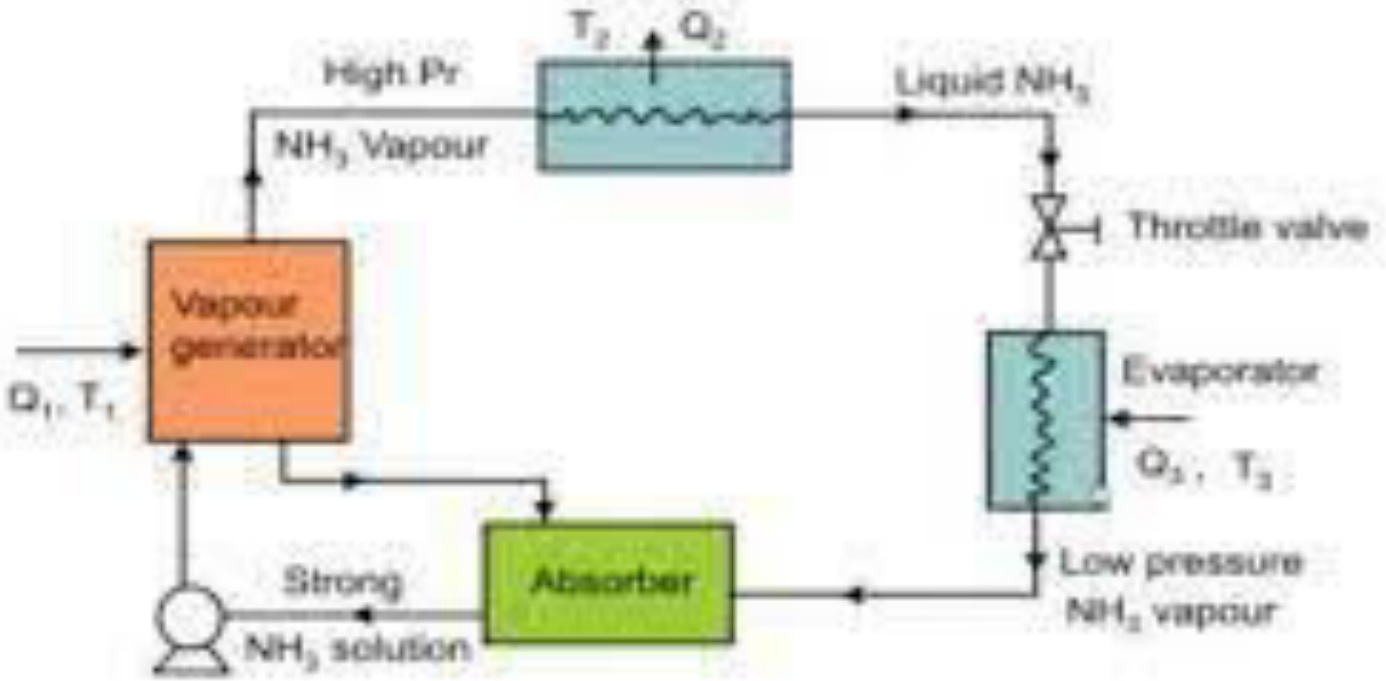
Heat added to the air per minute,
= ma (H1- H2) kJ/kg
= 120.860 (44 - 36.5)
= 906.4539 kJ

1:50

YouTube/Infotech


Evaporative
cooling only
Humidifying
only
Heating and
humidifying
Extracting
sensible
heat only
Adding sensible
heat only
Chemical dehumidifying
Dehumidifying only
Cooling and dehumidifying

Simple vapour absorption system



Simple Vapour Absorption System

- The VARS refrigeration system uses two working fluids for refrigeration i.e. refrigerant and absorbent. In the NH3–H_2O refrigeration system, ammonia (NH_3) is used as a refrigerant while the water (H_2O) is used as an absorbent.
- The purpose of the **absorber** is to absorb the low-pressure refrigerant vapours in the solution of the refrigerant and absorbent. Here the refrigerant vapours are absorbed to form a stronger solution.
- The weaker solution from the generator and the low-pressure refrigerant vapours from the evaporator enters the absorber.
- **Generator** is used to heat the strong solution by use of heating coils, solar energy or waste heat. As the refrigerant has a lower boiling point than the absorbent, the refrigerant inside the solution gets vapourised leaving the solution weaker.
- **Expansion valve** is located between the condenser & evaporator. Here the high-pressure liquid refrigerant is converted into a mixture of low-pressure refrigerant (liquid + vapour).

Advantages:

- It can utilize solar energy or any waste heat from the furnace or turbine for the heating the generator.
- The refrigerant won't produce the greenhouse effect.
- The moving component is a pump which consumes less power than the compressor.
- It has a quieter operation.
- It can handle huge refrigeration loads.

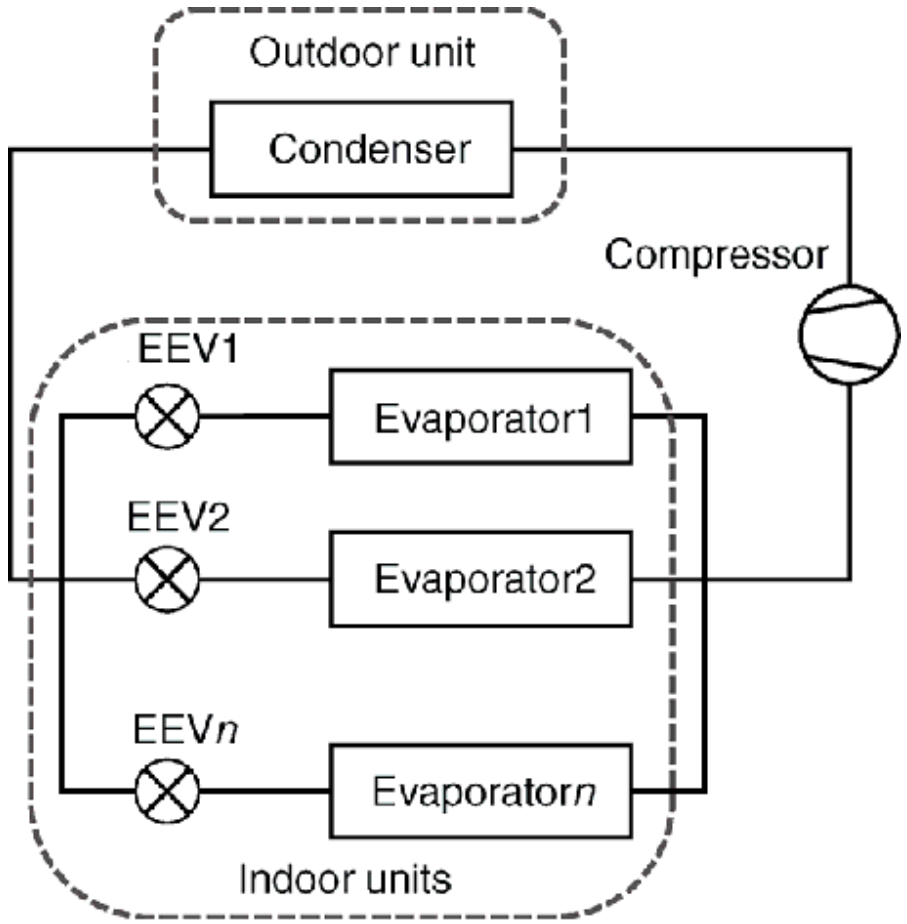
Disadvantages:

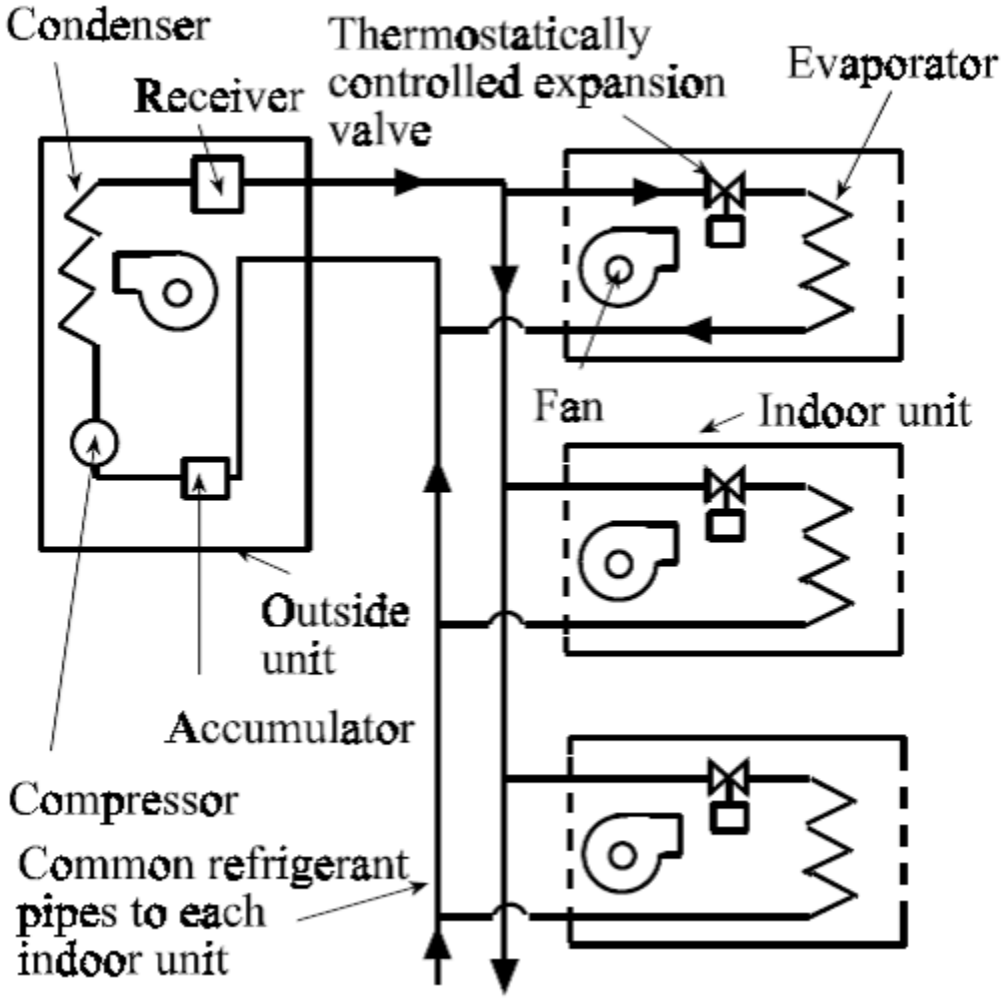
- It uses more components than the VCR system.
- It has a bulky setup.
- Lower coefficient of performance (COP).
- The Li-Br absorbent is corrosive in nature.
- Higher initial cost.

Applications:

- Large-capacity refrigeration in bigger plants.
- Suitable for larger air conditioning .
- Used in places having electricity problems for refrigeration and air conditioning.

VRF Air-conditioning System



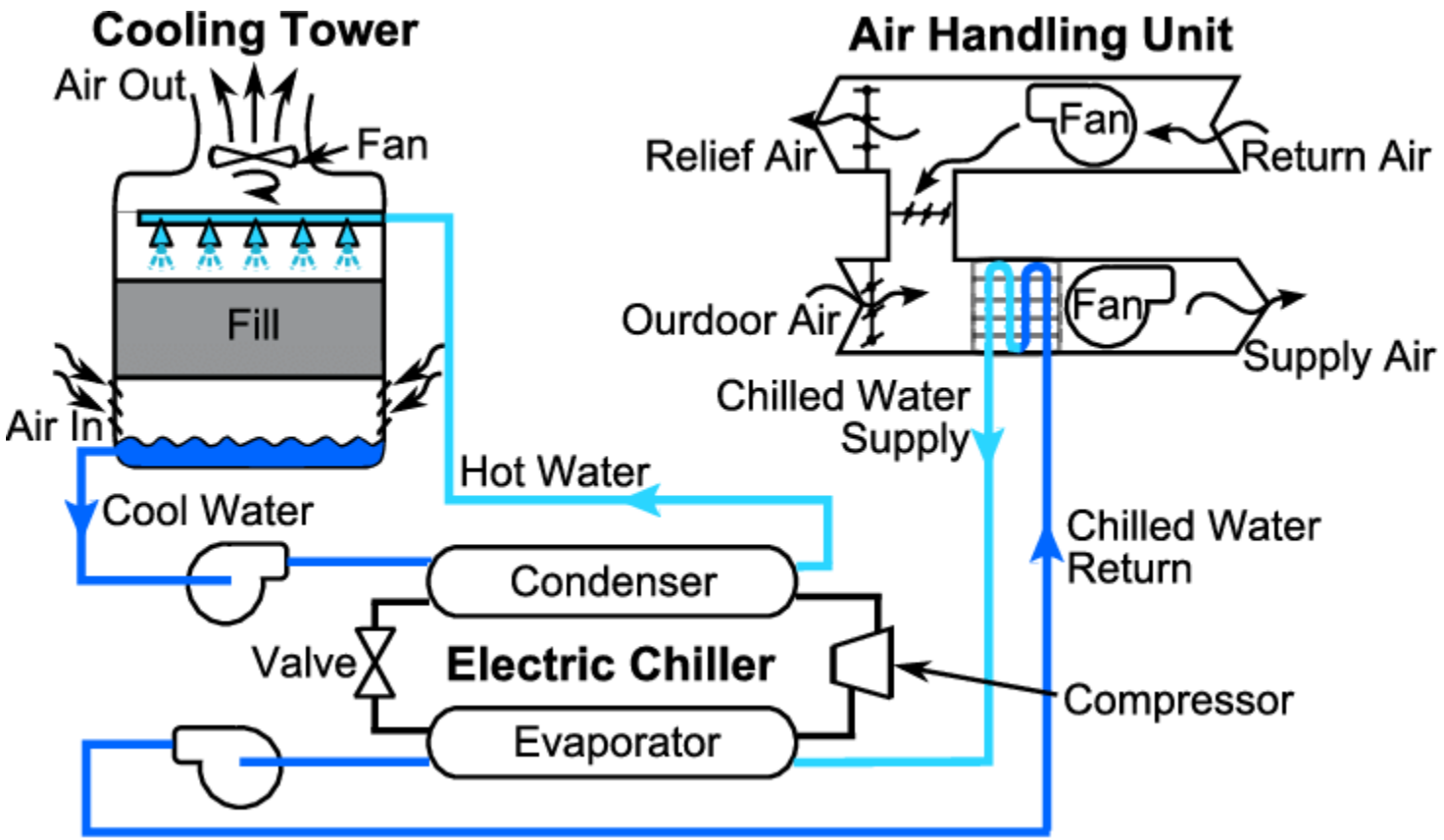


Key benefits of VRF air conditioning systems:

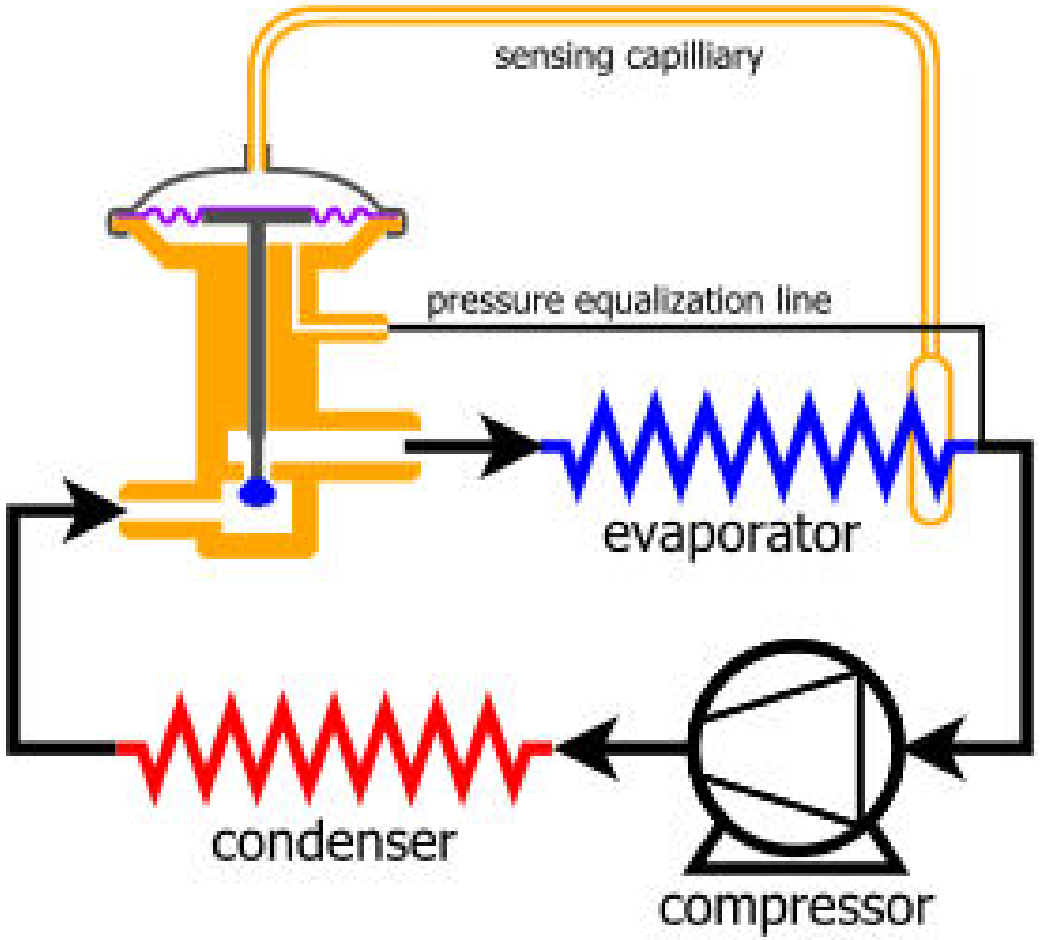
- Highly energy efficient
- Precise temperature control
- Simultaneous heating & cooling
- Heat recovery
- Zoned comfort
- Flexible & modular designs
- Simpler to install
- Sophisticated, easy to use and controls

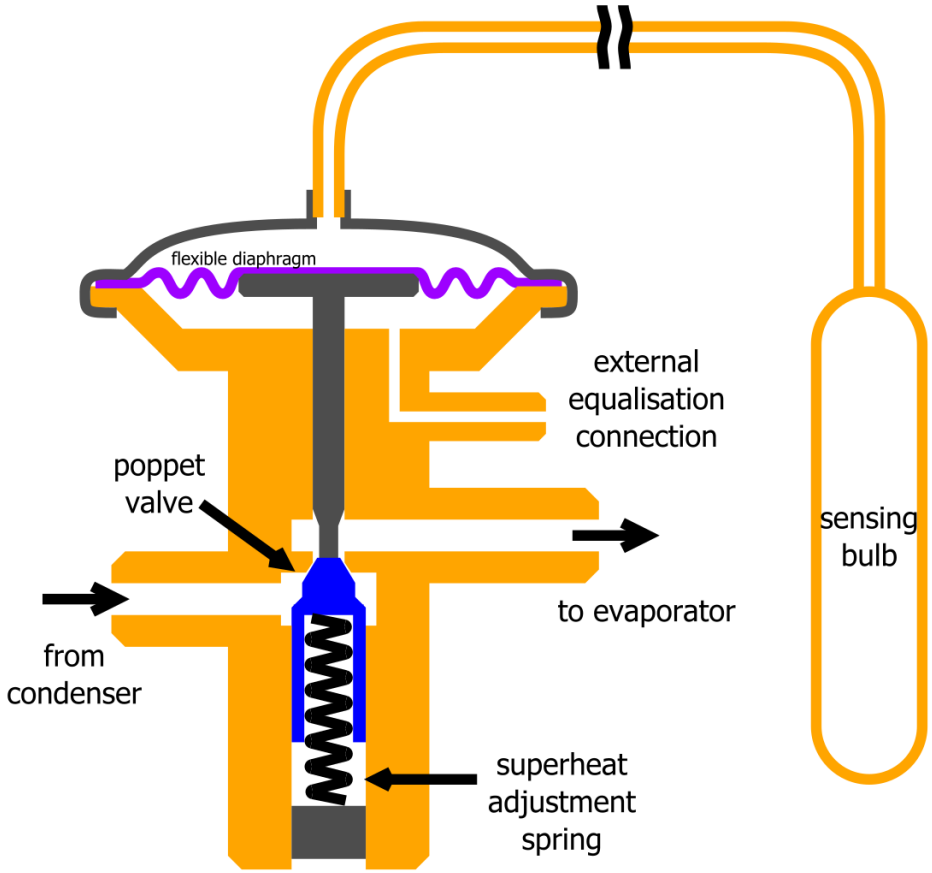
VRF models are used in many commercial and residential applications as follows:

Hospitals , Hotels, Airports, Offices in high-rise office buildings, Commercial buildings such as shopping malls.


Cooling Tower
Air Out
Fan
Fill
Air In
Cool Water
Hot Water
Condenser
Valve
Electric Chiller
Evaporator
Air Handling Unit
Relief Air
Fan
Return Air
Ourdoor Air
Fan
Supply Air
Chilled Water
Supply
Chilled Water
Return
Compressor

How does expansion valve work in refrigeration system





Properties of a good refrigerant

Desirable Properties of a Good Refrigerant

1) Thermodynamic Properties :-

a) Boiling Point :- It should have Low Boiling Point.

b) Freezing Point :- It should be below the Evaporator temperature.

c) Evaporative Pressure :- It should be above Atmospheric pressure.

d) Condensing Pressure :- It should have LOW Condensing pressure.

e) Latent Heat of Vapourisation :- It should have HIGH Latent heat of Vaporisation.

f) Critical Temperature & Pressure :- It should be above the condensing Temperature & Pressure.

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2) Chemical Properties :-

a) Toxicity :- It should not be Poisonous or injurious . It should not be non-irritating to eyes.

b) Corrosiveness :- It should not be corrosive & should not have any effect on materials used in equipment.

c) Leak Detection :- It should have less tendency to leak & if it is leaking it should be easily detectable.

d) Flammability :- It should not be Inflammable.

e) Miscibility with Oil :- It should be immiscible with oil & should not have any effect on the properties of Oil used for Lubrication.

f) Effect on Foodstuff :- It should not affect on food articles Or make them poisonous or unportable.

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3) Physical Properties :-

a) Specific Volume :- It should be LOW in Vapour state.

b) Viscosity :- It should have LOW viscosity.

c) Thermal Conductivity :- It should have HIGH Thermal Conductivity.

d) Di-Electric Strength :- It should have High strength.

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Terminology

Refrigerator- machine used to extract heat from body at low temperature to high temperature.

Refrigerant- It is liquid capable of absorbing heat from the other substance.

Capacity of Refrigerator- It is the rate at which heat can be removed from the cold body. Unit- ton of refrigeration

One ton of refrigeration is defined as the quantity of heat required to freeze one ton of water at 0° C in 24 hours. Value is 3.5 kJ/sec.

Coefficient of Performance- Ratio of heat absorbed to the workdone.

COP- Heat absorbed/ Work done

Refrigerant effect- Ratio between heat removed and the time taken. Heat removed/ time taken.