Thermodynamics

Thermodynamics

Basic Concepts

- 1. Thermodynamics Terminology
  - Closed and Open Systems
  - Thermodynamic Equilibrium
  - Processes
  - Zeroth Law of Thermodynamics
  - The State Postulate
  - Property of Systems
  - Other Properties
  - Dimensions and Units
  - The Pure Substance
  - P-V-T Behavior of A Pure Substance
  - Tables of Thermodynamics Properties
  - T – V Diagram
  - P – V Diagram
  - Saturated Liquid-Vapor Mixture

Basic Concepts

- Thermodynamics can be defined as the science of energy. Energy can be viewed as the ability to cause changes.

- A **thermodynamic system**, or simply a **system**, is defined as a quantity of matter or a region in space chosen for study.

- The mass or region outside the system is called the **surroundings**. The real or imaginary surface that separates the system from its surroundings is called the **boundary**.

- **Boundary** neither contains matter nor occupies a volume in space. The thickness of a boundary is mathematically zero.

- Properties on the boundary is shared by both the system and the local environment.

- The systems may considered to be **closed** or **open**, depending on whether a fixed mass or a fixed volume in space is chosen for study.

Basic Concepts

Systems
- **Closed (control mass)**
- **Open (control volume**

- A **closed system** consists of a fixed amount of mass, an no mass can cross its boundary. That is, no mass can enter or leave a closed system. But energy, in the form of heat and work, can cross the boundary, and the volume of a closed system can change. If a special case, even energy is not allowed to cross the boundary, that system is called an isolated system.

- An **open system**, as it is often called, is a properly selected region in space. It usually encloses a device that involves mass flow such as a compressor, turbine or nozzle. Flow through these devices is best studied by selecting the region within the device as the control volume. Both **mass and energy can cross** the **boundary** of a control volume, which is called a **control surface**.

- **The thermodynamics relations (equations) that are applicable to closed and open systems are different , because the term of advection of energy in the open systems. We must recognize the type of system we have before we start analyzing it.**

Properties and State

- Considering a system that is not undergoing any change. At this point, all the **properties can be measured or calculated** throughout the entire system, which gives us a set of properties that completely describe the condition, or the **state** of the system.

- A **state** is defined or described by its **properties**. **The State Postulate**

  *The **state** of a **simple compressible system** (no field forces) is completely specified by **two independent, intensive properties***

- Thermodynamic properties do not depend on the history of the system.

Properties
- Temperature
- Pressure
- Density
- Internal energy
- Enthalpy
- Entropy
- Exergy

No Properties
- Mass flow,
- Work,
- Heat,
- Entropy transfer,
- Entropy generation

Basic Concepts

Properties
- **Extrinsic**
- **Intrinsic**

- **Extrinsic** Independent of the nature of the substance
- **Intrinsic** dependent on the nature of the substance

Extrinsic
- Translational Velocity
- Rotational Energy
- Potential Energy
- Electric Field

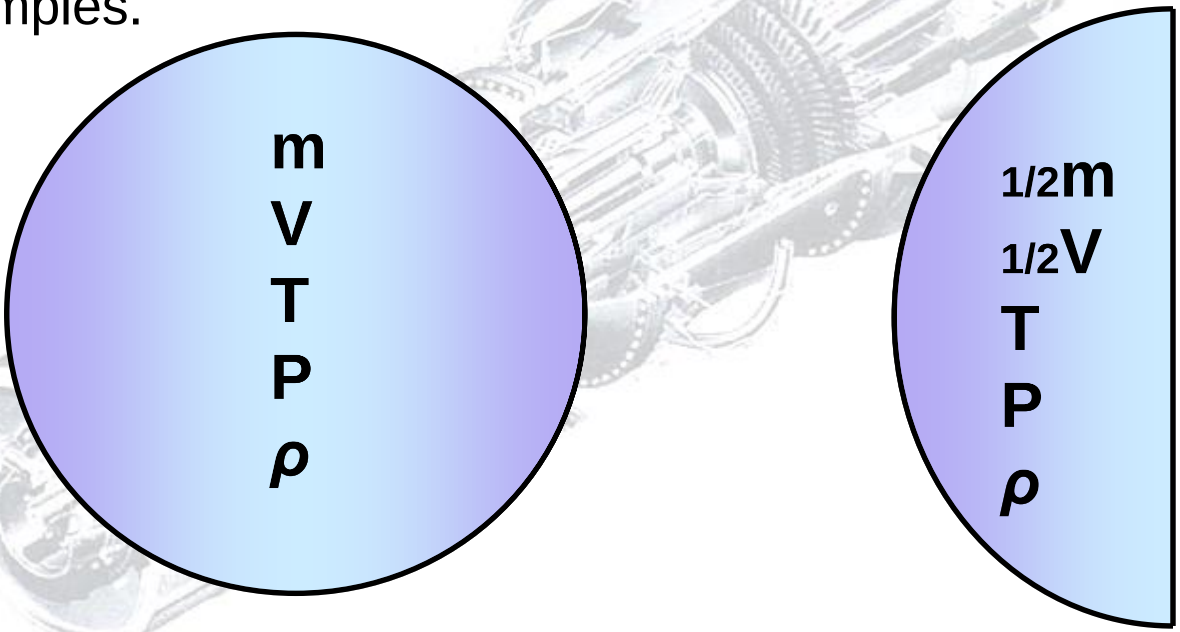
Intrinsic
- Temperature
- Pressure
- Density
- Viscosity

Basic Concepts

Properties { **Intensive** / **Extensive** }

- **Intensive** properties are those that are independent of the size of a system, such as temperature, pressure, and density.

- **Extensive** properties are those whose values depend on the size, or extent of the system. Mass m, volume *V*, and total energy are some examples.



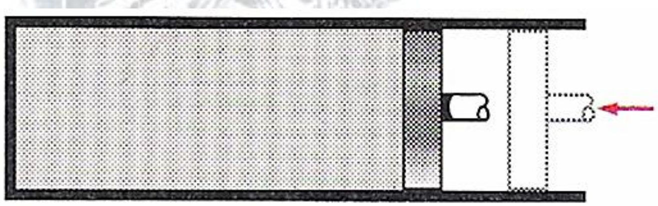
– An extensive property divides by the mass of the system is call a specific property. Specific properties is an intensive property.

Processes

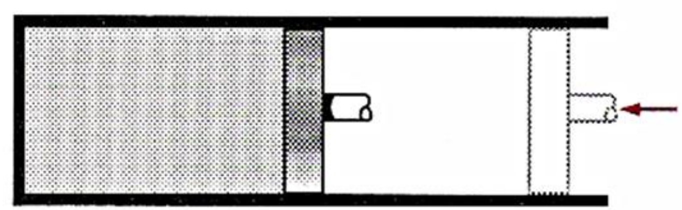
- Any change that a system undergoes from one equilibrium state to another is called a **process**, and the series of states through which a system passes during a process is called the **path** of the process.

- To describe a process completely, one should specify **the initial and final states** of the process, as well as the **path it follows**, and the **interactions with the surroundings** (the history).

- When a process proceeds in such manner that the system remains infinitesimally close to an equilibrium state at all the times, it is called a **quasi-static**, or **quasi-equilibrium** process. (properties no undergoing large gradients in the process)



(*a*) Slow compression
(quasi-equilibrium)



(*b*) Very fast compression
(non-quasi-equilibrium)

Special processes

Process

- **Isothermal** is a process during which the temperature T remains constant.
- **Isobaric** is a process during which the pressure P remains constant
- **Isochoric (or isometric, or isovolumetric)** is a process during which the specific volume v remains constant.
- **Adiabatic** is when there is not heat transfer across the boundary of the system.
- **Isentropic process**, when the process is adiabatic and reversible.

Cycle

- A system is said to have undergone a **cycle** if it returns to its initial state at the end of the process.

$$\oint \delta b = 0$$

cyclic integral of a property is zero

Basic Concepts

Thermodynamic Equilibrium

- Thermodynamics deals with equilibrium states. The word equilibrium implies a state of balance. In a equilibrium state, there are no unbalanced potentials (or driving forces) within the system.

Types of Thermodynamics Equilibrium

Thermal, if the temperature is the same through the entire system. (A system that involves changes with time is not in equilibrium).

Mechanical, is related to pressure, if a system does not undergoing changes in pressure at any point of the system with time.

Phase, if a system involves two phases, the mass of each phases reaches an equilibrium and stays there.

Chemical equilibrium if its chemical composition does not change with time, i.e not chemical reactions occur.

Basic Concepts

The Pure Substance

- A substance that has a fixed chemical composition throughout is called a **pure substance**.
- A mixture of two or more phases of a pure substance is still a pure substance as long as the chemical composition of all phases is the same. Phases of a pure substance are **solid, liquid, and gas**. The molecular spacing is small in solids and relative large in gas. The molecular structure in solid look as an arrange pattern that is repeated throughout of solid. In the gas phase, the molecular order is nonexistent.

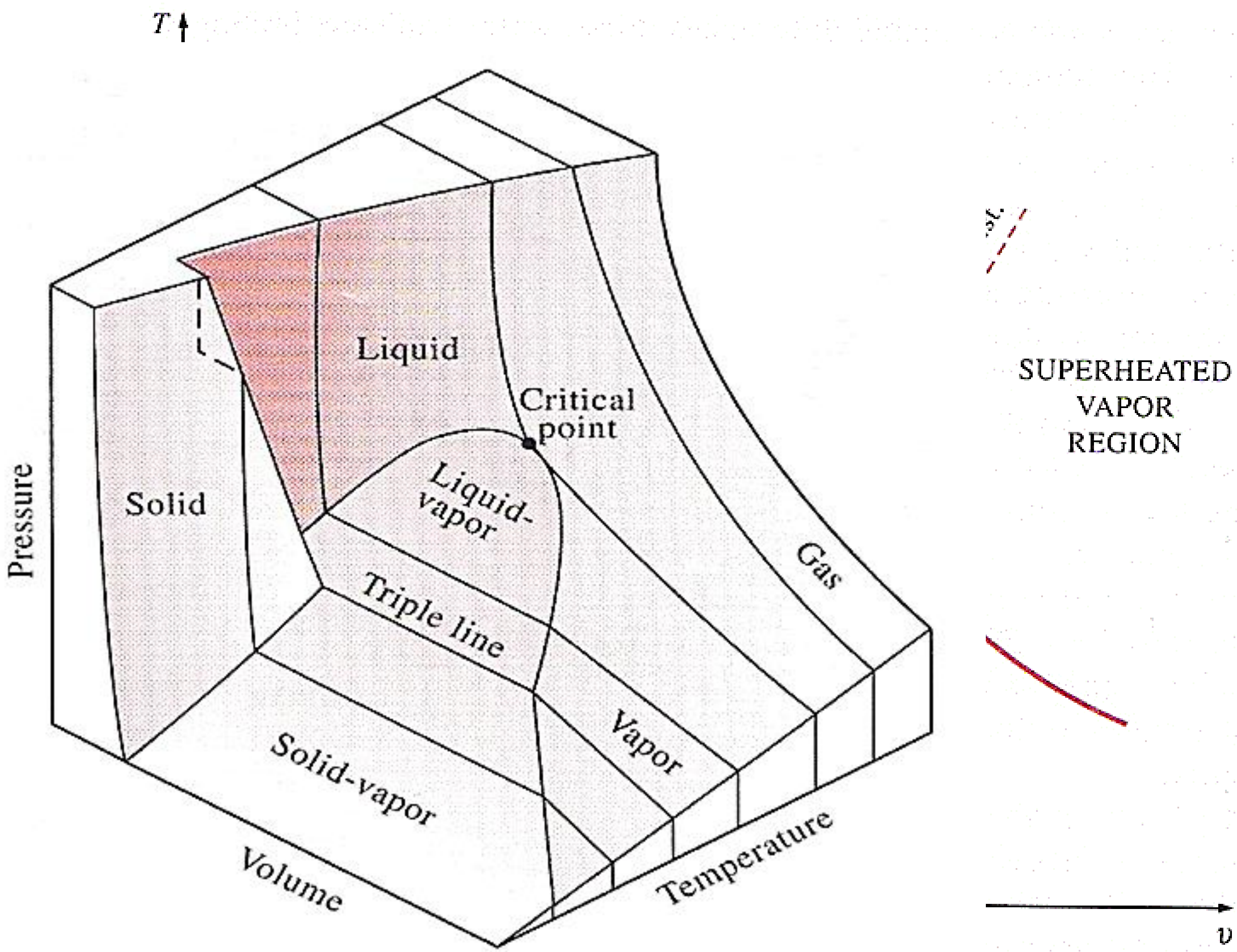
P-V-T Behavior of a Pure Substance

- Remember, the state of a simple compressible substance is fixed by any two independent, intensive properties. (e.g. $P = f(T,v)$, $T = f(P,v)$, etc)

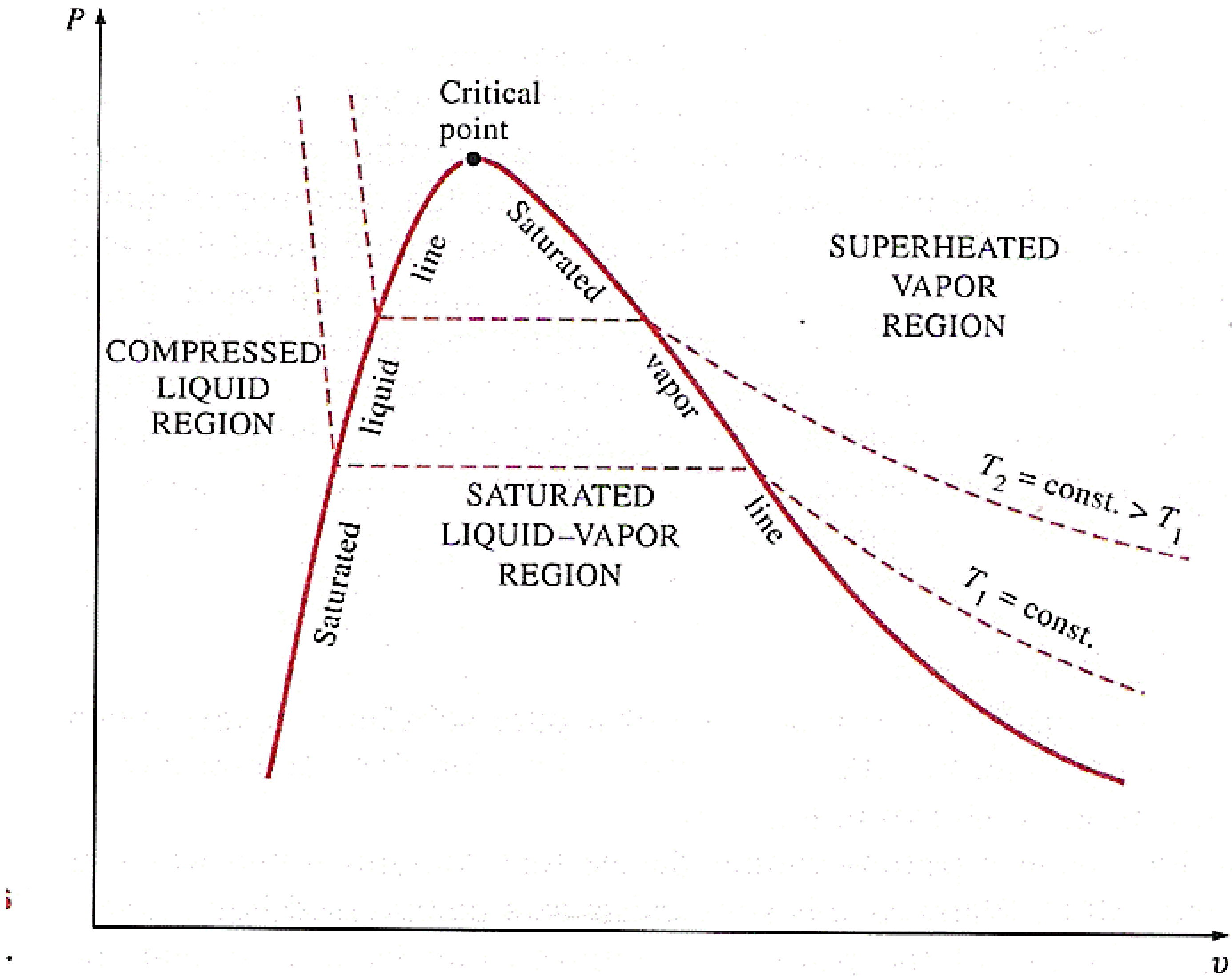
Tables of Thermodynamics Properties

- For most substances, the relationship among thermodynamic properties are too complex to be expressed by simple equations. Therefore, properties are frequently presented in form of tables. Some properties can be measured, but other cannot be measured directly and are calculated by using the relations that relate them to measurable properties.

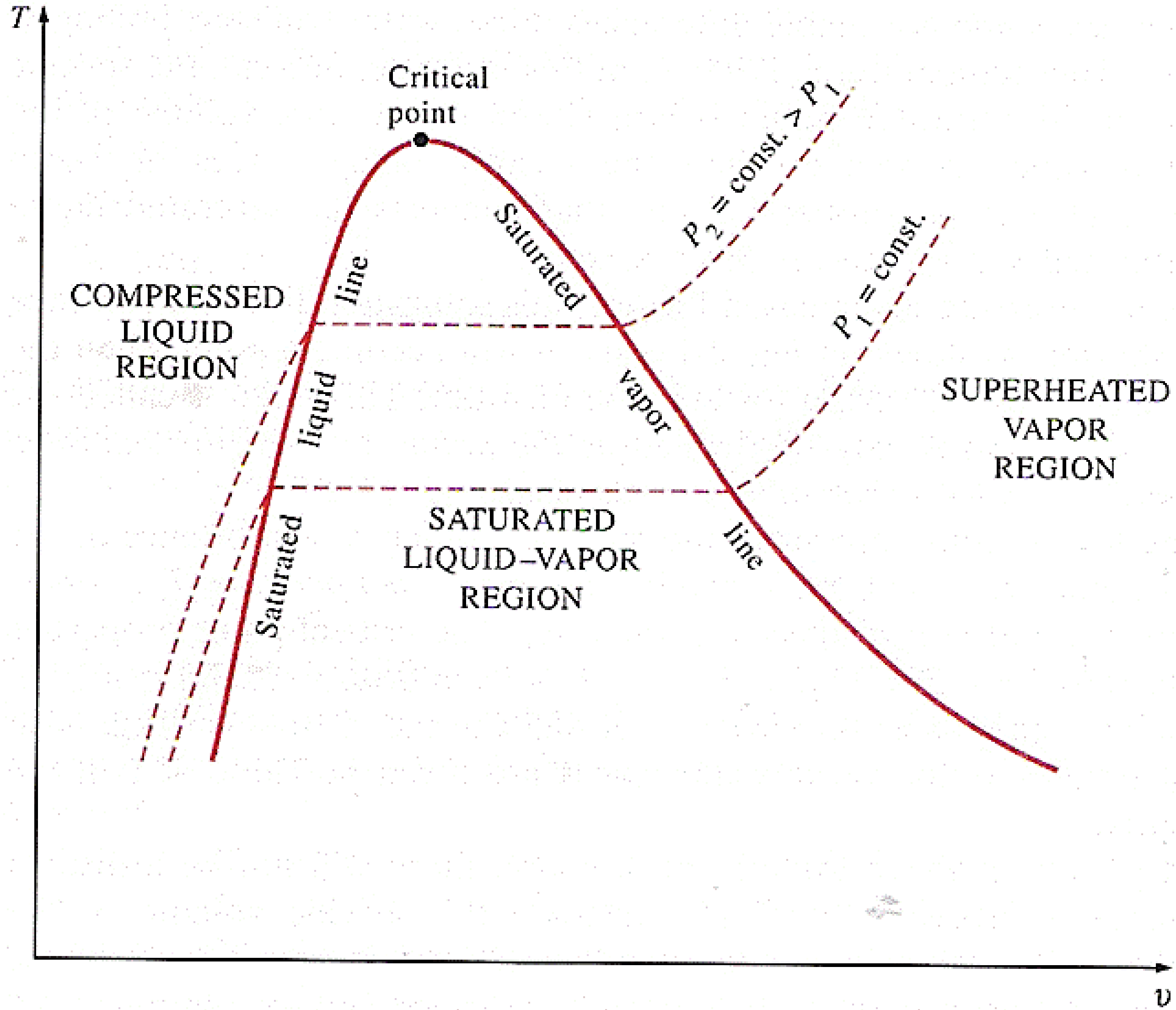
T – v Diagram


T
Liquid
Critical point
Solid
Liquid-vapor
Pressure
Triple line
Gas
Vapor
Solid-vapor
Volume
Temperature
SUPERHEATED VAPOR REGION
v

P – v Diagram


P
Critical point
Saturated liquid line
Saturated vapor line
COMPRESSED LIQUID REGION
SUPERHEATED VAPOR REGION
SATURATED LIQUID–VAPOR REGION
T2 = const. > T1
T1 = const.
v

T – s Diagram


T
Critical point
P_2 = const. > P_1
P_1 = const.
Saturated liquid line
Saturated vapor line
COMPRESSED LIQUID REGION
SATURATED LIQUID–VAPOR REGION
SUPERHEATED VAPOR REGION
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Basic Concepts
Gases

7.1 Equation of State:

Equation of states any equation that relates the Pressure, Temperature, and specific volume of a substance:

- Ideal Gas Equation of State: $$P v = R T$$
  - Where R is called the gas constant
- The gas constant is different for each gas and is determined from
  - $\boldsymbol{R = R_u / M}$
- Where R_u is the universal gas constant
- Ru is constant for all substances, and its value is:

$\boldsymbol{R_u}$ = 82.06 cm^3 atm/ ^{o}K g-mole

$\boldsymbol{R_u}$ = 83.15 cm^3 bar/ ^{o}K g-mole

$\boldsymbol{R_u}$ = 0.8478 kg m/ ^{o}K g-mole

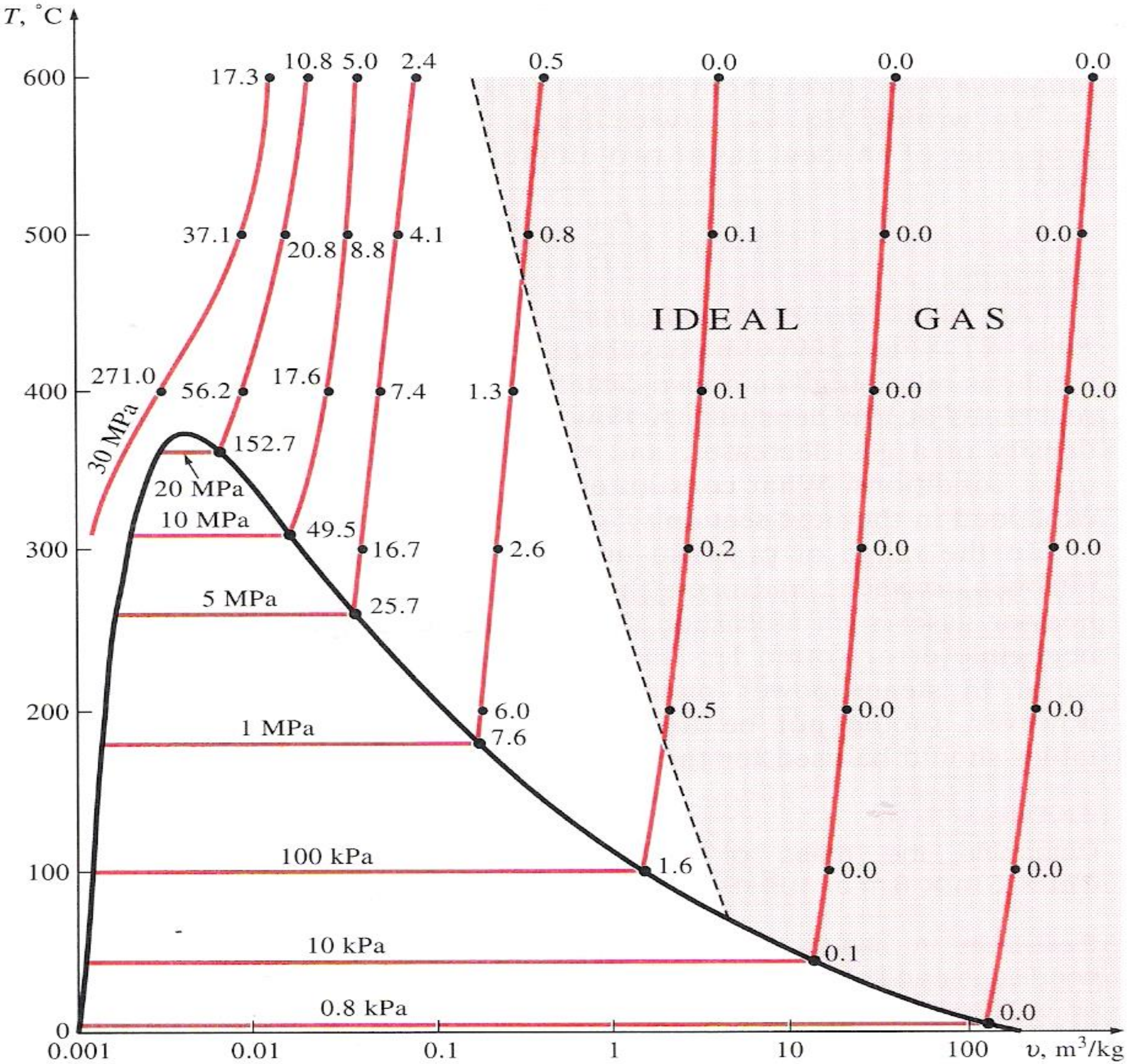
$\boldsymbol{R_u}$ = 8.314 kJ / kmole K.

$\boldsymbol{R_u}$ = 1.9859 Btu/^{o}R lb-mole

$\boldsymbol{R_u}$ = 10.73 psia ft^3/ lbmol R

$\boldsymbol{R_u}$ = 1545.3 ft lb-f/ ^{o}R lb-mole.

Basic Concepts
Gases

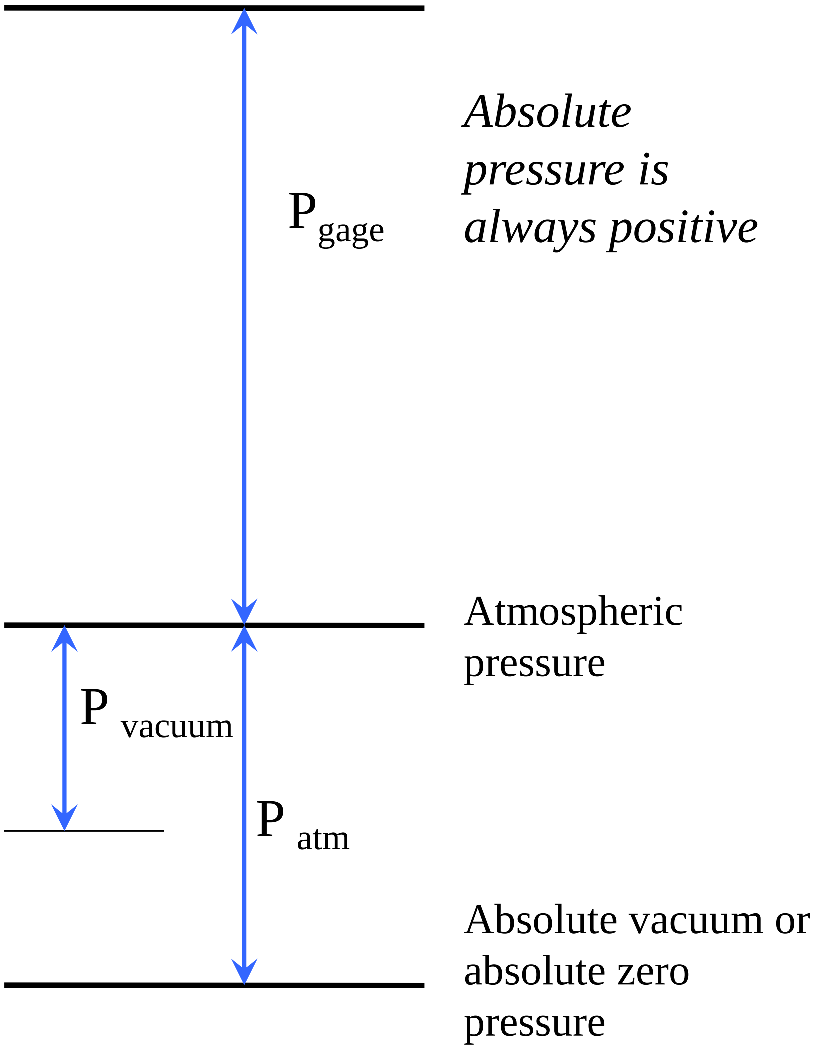


Basic Concepts

Pressure: is the force exerted by a fluid per unit area.

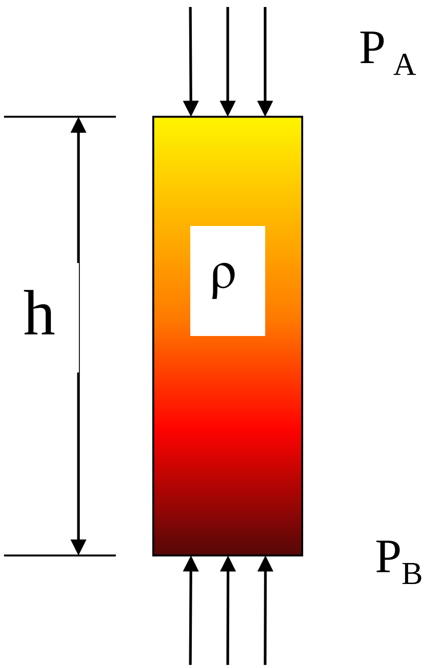
Units of Pressure: (force by unit of area)

- **SI** Pascal: $1Pa = 1\ N/m^2$
- **English System** $1\ Psi = 1\ lb/\ in^2$
  - The pressure unit pascal is too small for pressures encountered in practices: kilopascal (10^3 pascal) and megapascal (10^6 Pa) are commonly used.
- **Other common units are**:
- $1\ bar = 10^5\ Pa = 0.1\ MPa = 100\ kPa$
- $1\ atm = 101{,}325\ Pa = 1.01325\ bars = 14.7\ psi = 2116.8\ lb/ft^2 = 760\ mmHg$
  - **Absolute Pressure:** It is the pressure measured relative to absolute vacuum as shown in the figure:



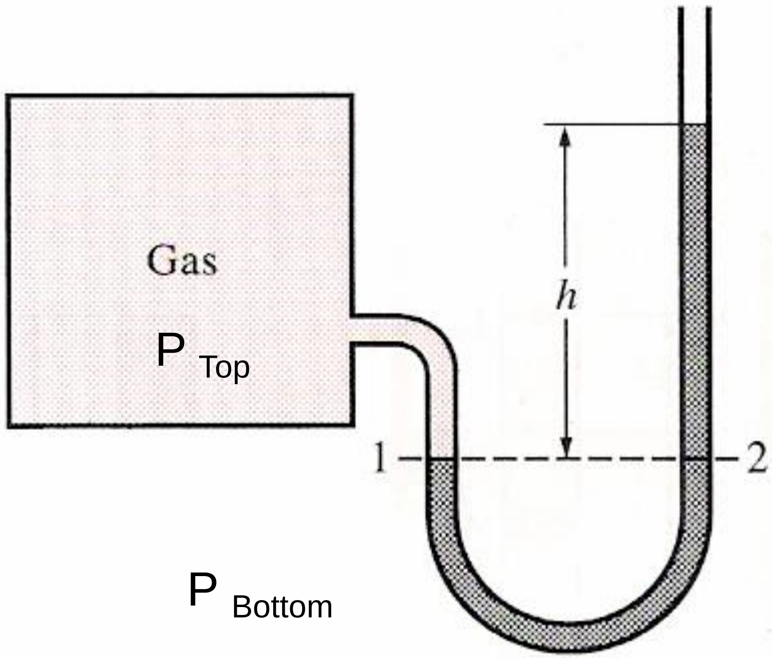
Basic Concepts

Manometer: Pressure depends on the column of the height of a column of liquid



$$F_B - F_A - W = 0$$

$$P_B = P_A + \rho g h$$



Pressure changes is considered negigible for gases

$P_{Bottom} \approx P_{top}$

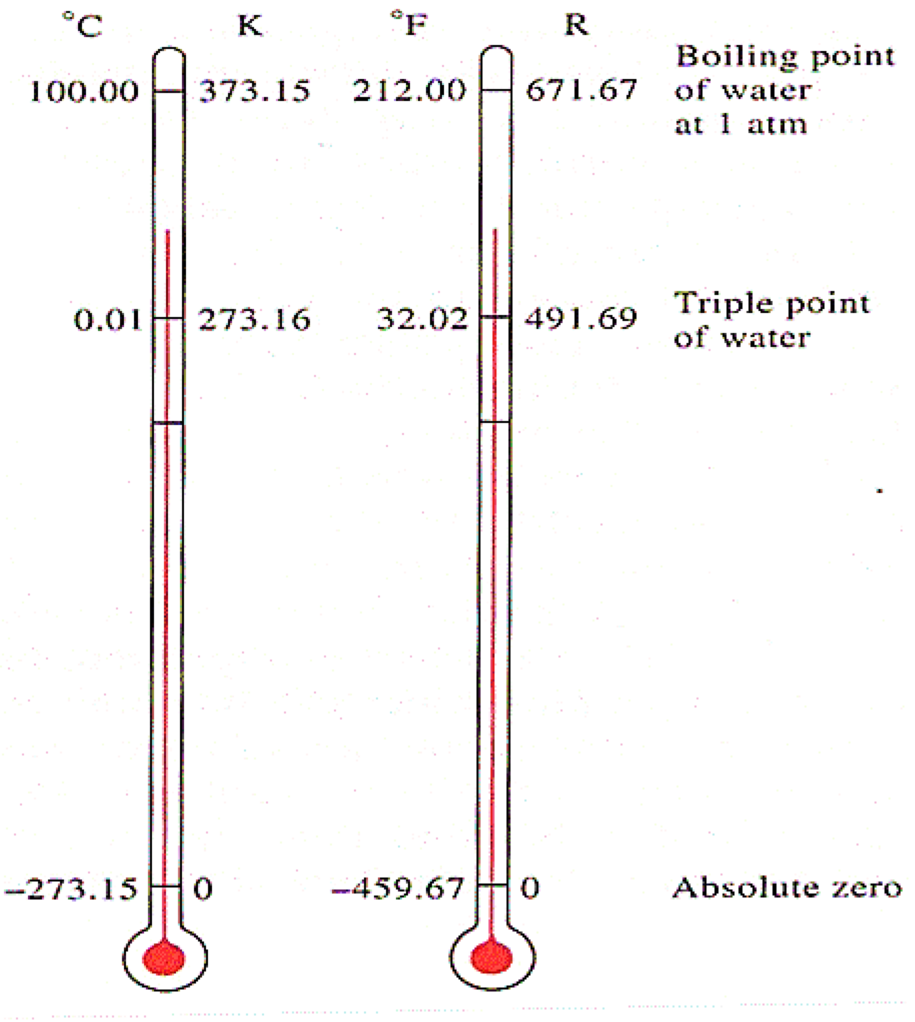
$$P_{Bottom} = P_{top} + \rho g h$$

$\rho g h$ (h=1) = 1.271kg/m^3 *9.81m/s^2*1m/1000 = 0.0124

$\rho g h$ (h=100) = 1.271kg/m3 *9.81m/s2*100m/1000 = 1.24

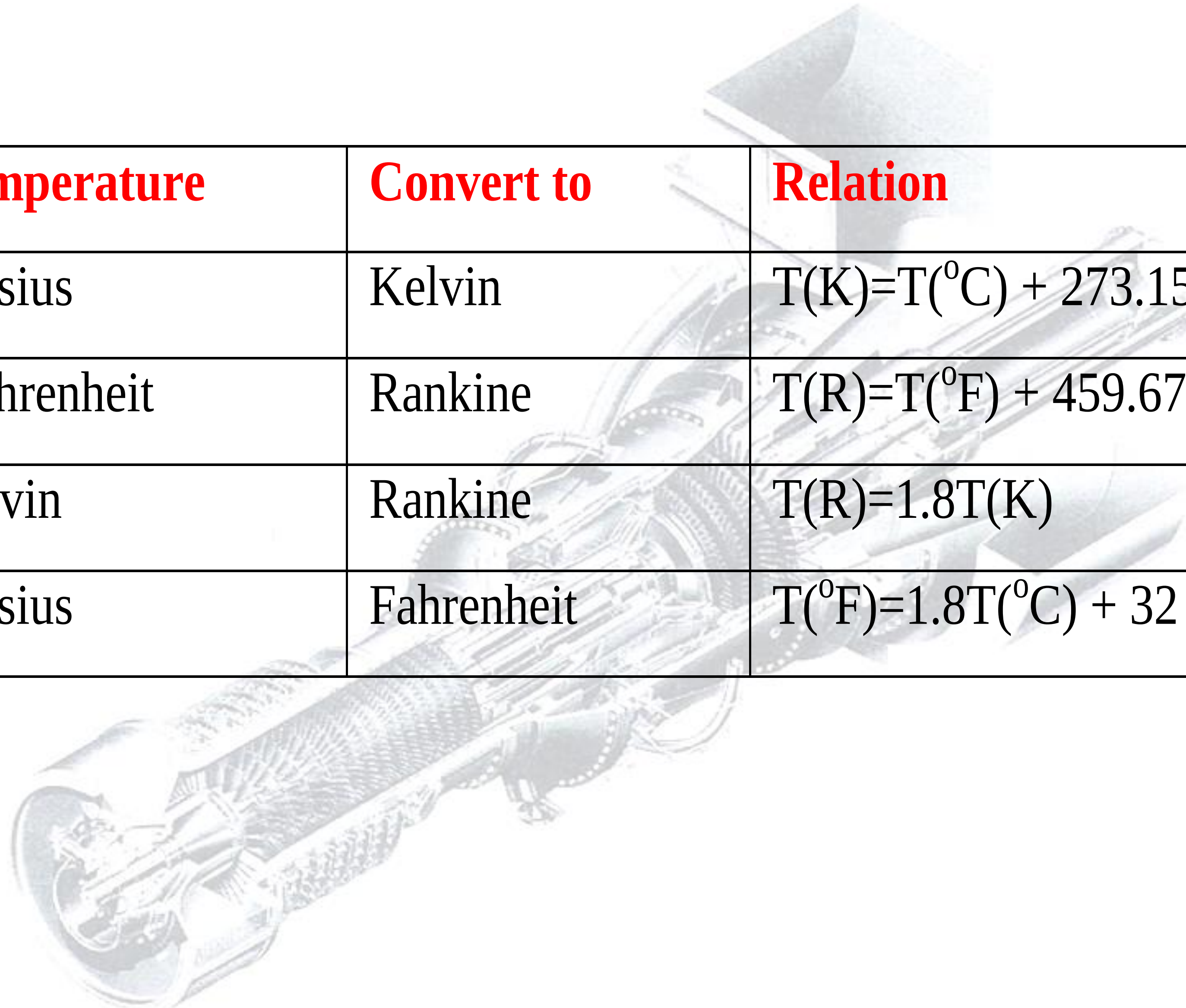
Temperature

- **Temperature scales** is a common basis for temperature measurements.
- **Celsius scale** (centigrade scale) ice and steams (P_{atm}) points are assigned the values of 0 and100 ºC, respectively.
- **Fahrenheit scale** the corresponding values on the Fahrenheit scale are 32 and 212ºF.
- **Kelvin scale** the lowest temperature on the Kelvin scale is 0 K. (Thermodynamic scale in SI)
- **Rankine scale** is the thermodynamic scale in English system.



Basic Concepts

Temperature	Convert to	Relation
Celsius	Kelvin	$T(K)=T(^oC) + 273.15$
Farhrenheit	Rankine	$T(R)=T(^oF) + 459.67$
Kelvin	Rankine	$T(R)=1.8T(K)$
Celsius	Fahrenheit	$T(^oF)=1.8T(^oC) + 32$



Dimensions and Units

Any physical quantity can be characterized by **dimensions**. The arbitrary magnitudes assigned to the dimensions are called **units**. Some basic dimensions such as mass m, length L, time t, and temperature T are selected as **Primary** or **Fundamental Dimensions,** while others such as velocity V, energy E, and volume V are expressed in terms of the primary dimensions and are called **secondary dimensions**, or **derived dimensions**.

Fundamental Dimension	SI Units	English System
Length	Meter (m)	Foot (f)
Mass	Kilogram (kg)	Pound mass (lbm)
Time	Second (s)	Second (s)
Temperature	Kelvin (K)	Rankine (R)
Electric current	Ampere (A)	Ampere (A)
Amount of light	Candela (c)	
Amount of matter	Mole (m)	

Dimensional Homogenity

In engineering, all equations must be dimensionally homogeneous. That is, every term in an equation must have the same units.

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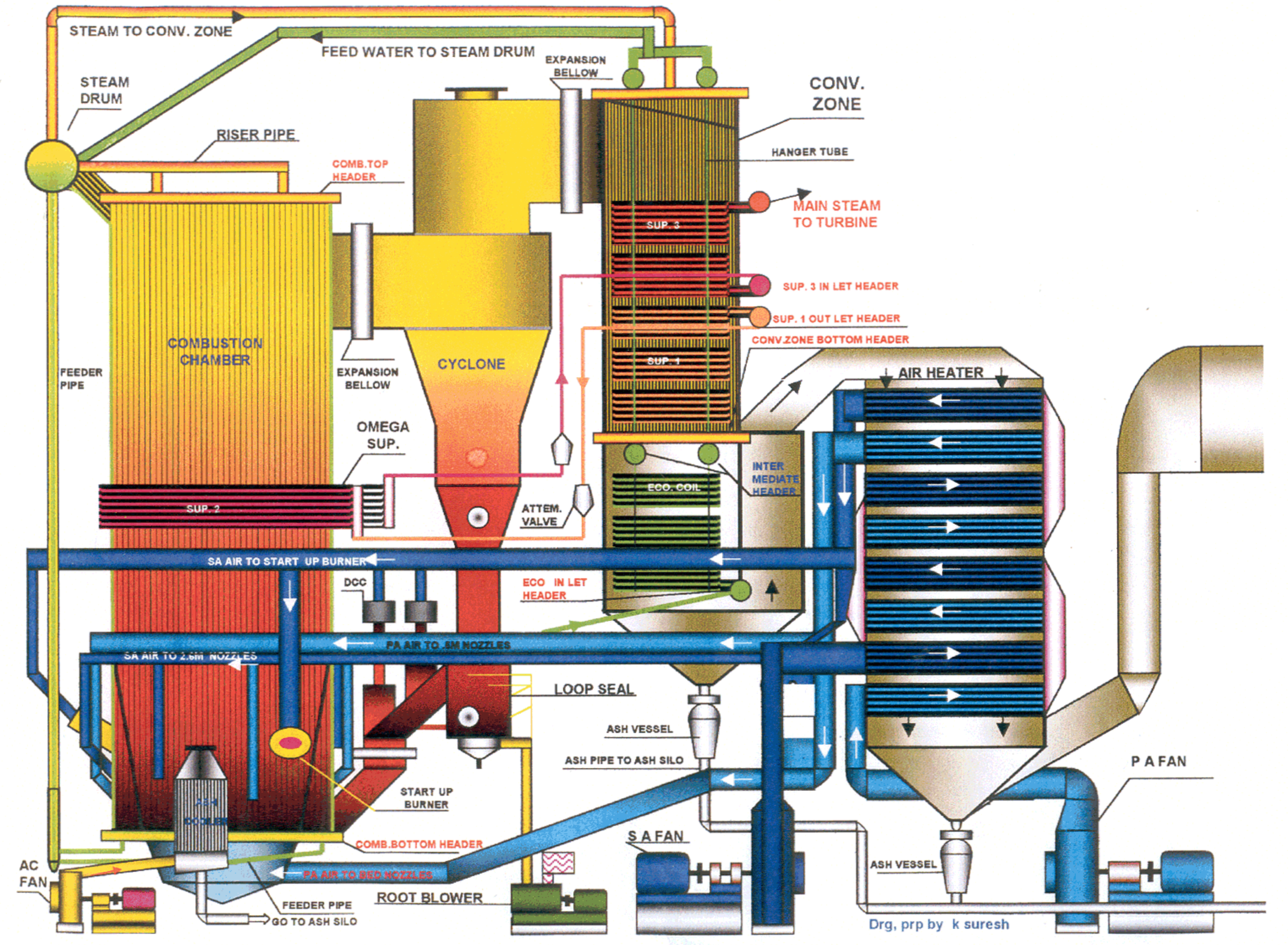

STEAM TO CONV. ZONE
FEED WATER TO STEAM DRUM
STEAM DRUM
RISER PIPE
COMB.TOP HEADER
EXPANSION BELLOW
CONV. ZONE
HANGER TUBE
MAIN STEAM TO TURBINE
SUP. 3
SUP. 3 IN LET HEADER
SUP. 1 OUT LET HEADER
CONV.ZONE BOTTOM HEADER
SUP. 1
AIR HEATER
COMBUSTION CHAMBER
FEEDER PIPE
EXPANSION BELLOW
CYCLONE
OMEGA SUP.
INTER MEDIATE HEADER
ECO. COIL
SUP. 2
ATTEM. VALVE
SA AIR TO START UP BURNER
DCC
ECO IN LET HEADER
PA AIR TO .6M NOZZLES
SA AIR TO 2.6M NOZZLES
LOOP SEAL
ASH VESSEL
ASH PIPE TO ASH SILO
P A FAN
START UP BURNER
ASH COOLER
COMB.BOTTOM HEADER
S A FAN
AC FAN
PA AIR TO BED NOZZLES
ASH VESSEL
FEEDER PIPE
ROOT BLOWER
GO TO ASH SILO
Drg, prp by k suresh