ELEMENTS OF MECHANICAL ENGINEERING

PART – A

Unit - I

WELCOME TO

DEPARTMENT OF MECHANCAL ENGINEERING

Unit – I
Energy and Steam

Unit - I

Objectives:

1.1 Introduction - Energy

1.2 Forms of Energy

1.3 Sources of Energy

1.4 Energy Requirements & its Effect

1.0 Introduction

"Energy" – Derived from Greek Word – "Energia", means capacity for doing work.

It is Hard to define Energy. We use energy for everything we do.

What is Energy?

- How Cars Move on the road?
- How people move from Place to place?
- How radio plays a favorite Song?
- How this PPT works?

Scientists define energy as the ability/ capability to do work.

1.2 Forms of Energy

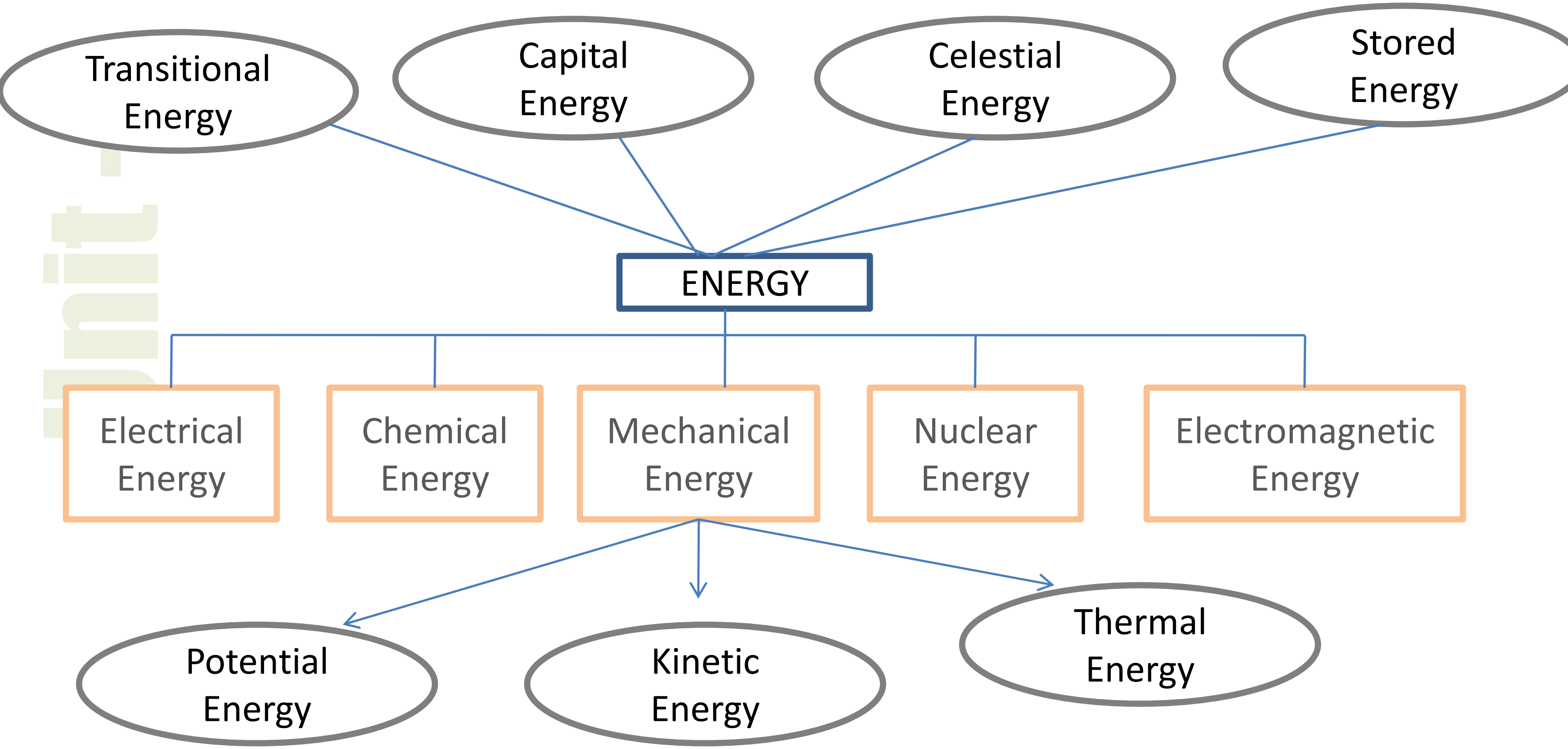

Fig. 1.1 Forms of Energy

Energy derived from motion is Transitional Energy

Ex: Wind & Hydel Energy

Energy derived from the fuels existing in the earth is capital energy

Ex: fossil fuels, nuclear Fuels

Energy from outer atmosphere/ space is celestial energy or income energy

Ex: Solar

Energy exists from existing masses is Stored energy

Ex: Flywheels, Tides

Energy is found in different forms such as Light, Heat, Sound & Motion. There are many forms of Energy. Broadly they can be put into two categories: Kinetic & Potential Energy

Kinetic Energy: is motion. It is the motion of waves, electrons, atoms, molecules, Substances & Objects.

Electrical Energy: is the movement of electrons. Ex: Lighting – electrons moving in the wire.

Radiant Energy: Electromagnetic energy that travels in transverse waves. Ex: visible light, Rays, Radio waves – Solar Energy

Thermal Energy: is the internal energy in the substance. Is the vibration & movement of atoms & molecules with in the substance. – Geo thermal energy

Potential Energy: is the stored energy and the energy of position.

Chemical Energy: energy stored in the bonds of atoms & molecules.- Bio-mass, Petroleum, natural gas.

Stored Mechanical Energy: energy stored in objects by application of force. Compressed springs & Rubber bands.

Nuclear Energy: energy stored in nucleus of atom.

Gravitational Energy: Energy of Position or Place.- Hydro Power

1.3 Sources of Energy

All the forms of energy obtained mainly by

a) Earth -- Fossil fuels, geo thermal, Nuclear Power

b) Sun -- Rain-Hydel power, Ocean Thermal power, Bo Fuels, Wave power, Heating of Earth – Wind Power

c) Gravitational force and effect – Tidal Power and Planetary motion

Fossil fuels: Preserved in the earth crust due to their accumulation over the period of time. – Coal, petroleum, natural gas etc.

Bio fuels: Bagasse, Rice & wood Husk.

1.4 Energy Requirements & its Effect

Worlds Annual Energy Production is 6000 mtoe against the requirement of 7000 mtoe

Mtoe-(Million ton oil equivalent)

Worldwide Consumption of total energy

ENERGY SOURCE	CONSUMPTION
COAL	32.5%
OIL	38.3%
GAS	19.0%
URANIUM	0.13%
HYDRO	2.0%
WOOD	6.6%
DUNG	1.2%
WASTE	0.3%

Unit – I
Energy and Steam

Objectives:

1.5 Classification of Energy Sources

1.6 Conventional and Nonconventional Energy Sources

1.7 Renewable and Nonrenewable Energy Sources

1.8 Conversion or Utilization of Energy Sources

- 1.8.1 Fossil Fuels
- 1.8.2 Hydel Energy
- 1.8.3 Solar Energy
  - a) Chemical Energy (Helio Chemical Process)
  - b) Electrical Energy (Helio Electric Process)
  - c) Thermal Energy (Helio Thermal Process)
- 1.8.4 Wind Energy
- 1.8.5 Tidal Energy
- 1.8.6 Ocean Thermal Energy
- 1.8.7 Geothermal Energy

1.5 Classification of Energy Sources.

BASIS	TYPES
Availability & Usage with respect to time and economical viability	Conventional and nonconventional energy sources
Possibility of renewability	Renewable and nonrenewable energy sources.

1.6 Conventional and Nonconventional Energy Sources

Conventional are the sources which are being used since long. i.e.

a) Fossil fuels – Solid/Liquid/Gaseous forms – coal/petroleum/natural gas

b) Hydel Sources – energy stored in water

c) Nuclear energy – Uranium

Nonconventional Energy Sources

The ever increase in rapid use of fuels has threatened exhausting of the source very soon. So the time has come for searching other source of energy which are inexhaustible to replace the conventional sources.

Solar Energy, wind, tidal, ocean thermal energy, bio energy, solid waste, hydrogen etc. These alternate inexhaustible sources of energy are called nonconventional energy sources.

Comparison of Conventional & nonconventional energy sources.

Conventional	Nonconventional
Widely used	Very high initial cost
Economical	Nonexhaustible
Hazardous to environment	Environment friendly
Reliable	Not reliable
Initial cost is low and energy transmission cost are high	Low energy transmission cost

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Energy and Steam

Reclassification

1.7 Renewable and Nonrenewable Energy Sources

Renewable energy is energy generated/ produced continuously from natural resources—such as sunlight, wind, rain, tides, and geothermal heat—which are renewable (naturally replenished/inexhaustible). Renewable energy technologies include solar power, wind power, hydroelectricity, micro hydro, biomass, solid waste, and hydrogen.

Nonrenewable sources which can be extracted from the earths crest due to their accumulation over the period of time and which are exhaustible such as fossil fuels, Nuclear fuels, Heat traps.

Renewable energy

Advantages	Disadvantages
Inexhaustible, Freely available, environment friendly, High initial & low maintenance cost, Utilization equipments yet to be designed and can be used on site with flexible design.	Intermittent nature of availability, Dependent on atmospheric conditions,time,latitude of space, regions, state of the art technology yet to be developed, costlier.

1.8 Conversion or Utilization of energy resources.

Conventional energy sources

1) Fossil Fuels – These are rich Hydrocarbons.

a) Coal: is a solid fossil fuel formed from ancient plants, including trees, ferns and mosses that grew in swamps and bogs or along coastal shore lines. Generations of these plants died and were gradually buried under layers of sediment. As sedimentary overburden increased, the organic material was subjected to increasing heat and pressure that causes the organic material to undergo a number of transitional states to form coal. Organic material are rich in carbon, hydrogen and oxygen. The successive stages of coal formation are Peat – Partially carbonized plant matter. Bituminous coal – Soft coal with higher carbon and low moisture. Anthracite – Hard coal with highest carbon with lowest moisture.

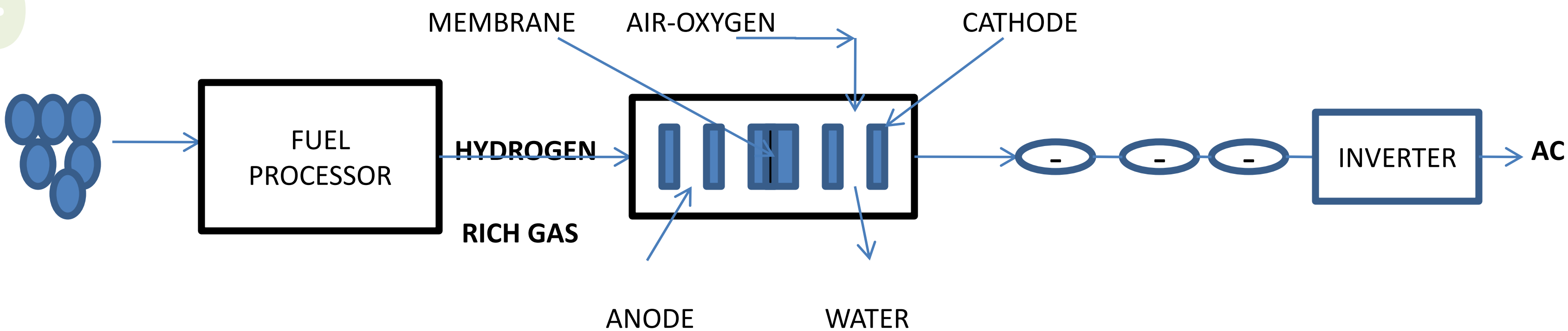
b) Petroleum: formed from ancient microscopic plants and bacteria that lived in the ocean and salt water seas. When these micro organisms died and settled to the seafloor, they mixed with sand, the slit to form organic rich mud. As layers are accumulated, the mud was gradually heated and slowly compressed into shale, chemically transforming into petroleum.

c) Natural Gas: formed by plankton-tiny water dwelling organisms, including algae and protozoan, that accumulate on the ocean floor as they died. These were slowly buried and compressed under layers of sediment. Over a years the pressure and heat generated by overlying sediments convert this organic material into natural gas. Gas forms a layer over the petroleum.

Conversion or Utilization of Energy Sources

Conventional:

1)Fossil Fuels: These are rich hydrocarbons. On combustion they produce heat, then is converted into mechanical energy in turbines. When prime movers are coupled to electrical generators in thermal power plants to produce electrical energy.



Unit – I

Energy and Steam

1) Source of energy– Coal

2) In fuel processor coal is converted into hydrogen rich gas.

3) Gas fed into Fuel cell system

4) In fuel cell the gas is channelized through anode on one side.

5) on other side oxygen is channelized through cathode.

6) polymer electrolyte membrane allows only positively charged ions to pass through cathode.

7) while Negatively charged electrons flow to the cathode, creates an Direct current.

8) The inverter converts the DC to AC.

9) Positively charged ions at cathode combine with oxygen to from water, which flows out of the cell.

Coal, oil, Gas, water, Nuclear power, Agricultural & Organic waste like Garbage, Animal dung, Paddy Husk, Nuclear power etc.

2) HYDEL SOURCE: Renewable source- Non polluting - Hydro energy is considered as an indirect source of solar energy.

Water- evaporated by solar heat – transported by winds – rain fall – hydrological cycle.

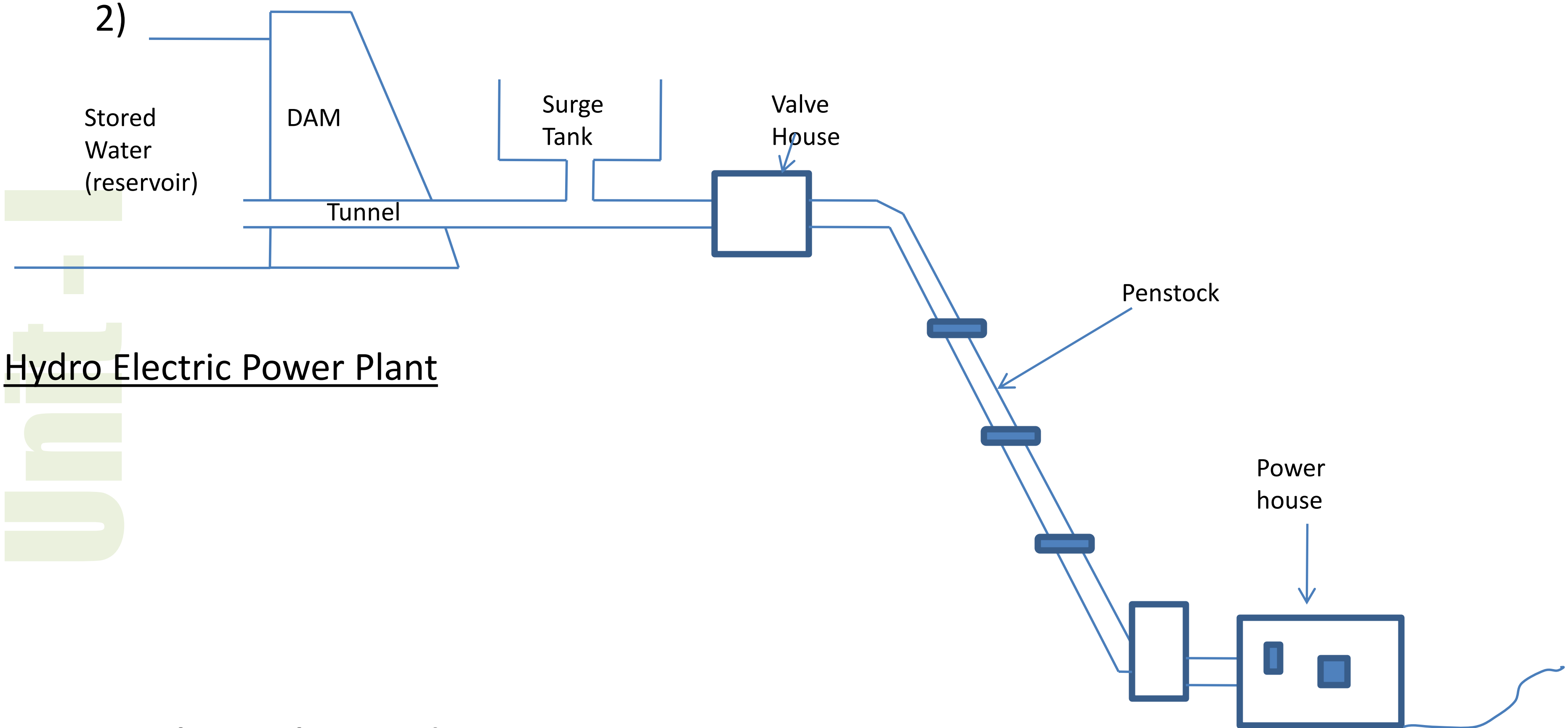
river water stored in higher levels by building dams.

water potential energy – mechanical energy – through turbines – electrical energy – generators.

Operating cost is low.

Problems – Construction of dam alters ecology – up/down stream regions, submerge of agricultural lands.

2)

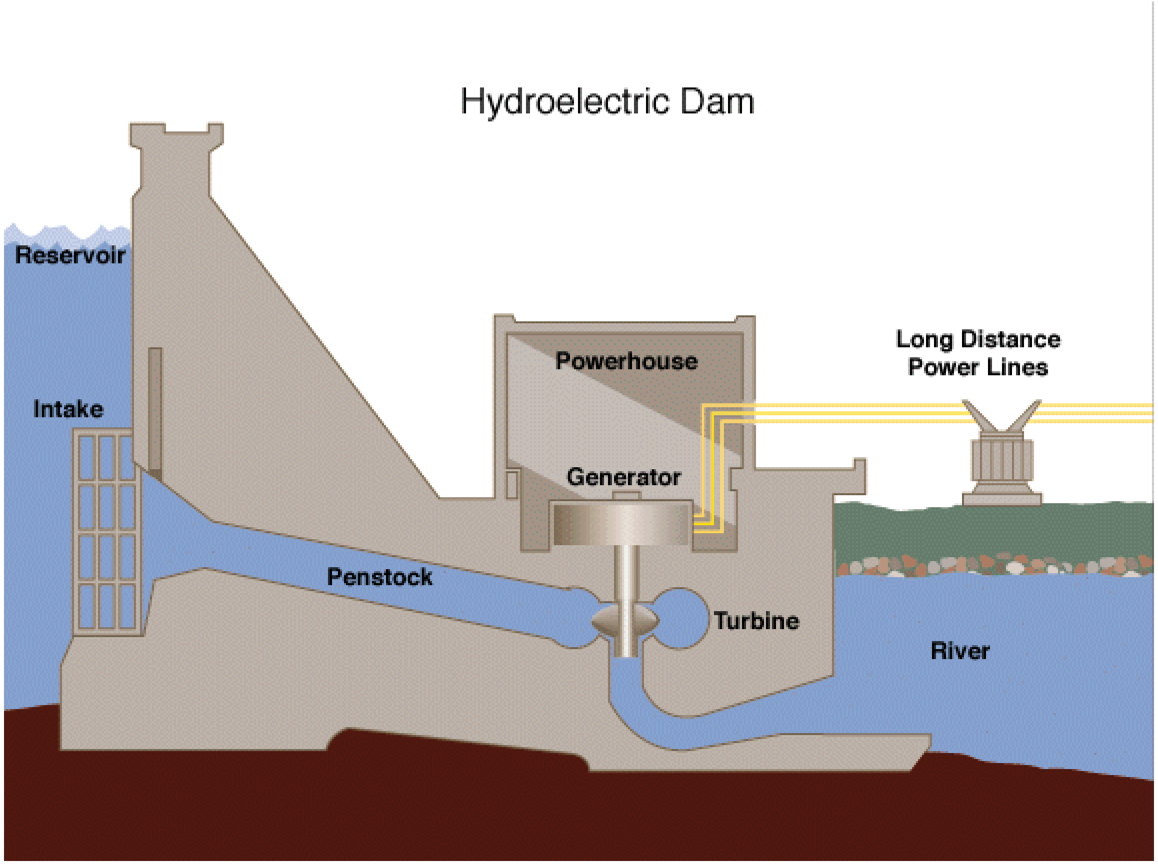


Hydro Electric Power Plant

Penstock – A large diameter pipe – carries water.

Surge tank prevents sudden pressure rise in penstock.

(Depends on the load on the turbine/close of inlet valve)


Hydroelectric Dam
Reservoir
Intake
Powerhouse
Generator
Long Distance
Power Lines
Penstock
Turbine
River

Unit – I

Energy and Steam

Non Conventional Sources: renewable energy -Solar, wind, tidal, ocean, geo thermal

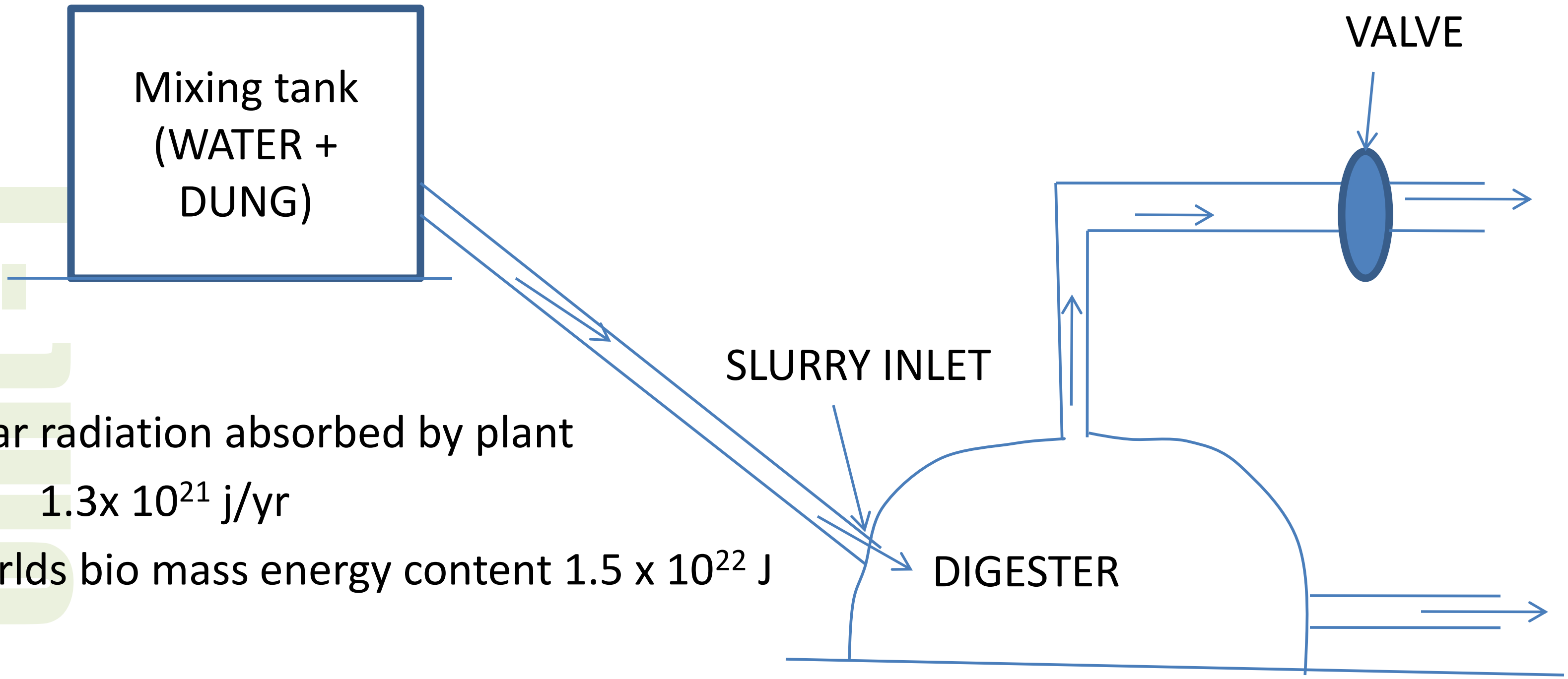
Solar Energy: The radiant energy in the Sun is transmitted to the earth through space in quanta of energy called photons – in the form of electromagnetic radiation.

99% - narrow band of visible spectrum between ultraviolet & infrared rays.

Three process of solar energy conversion.

1) Helio chemical process (Chemical energy): is photosynthesis process – is a biological conversion of solar energy into chemical energy called bio energy which will be stored in plants. This stored energy can be converted into useful energy by combustion or converted as a storable fuel.

Bio Gas plant: The mixture of dung & water is pored into mixing chamber – liquid slurry – led to underground digester chamber (Bricks, masonry, Concrete) – anaerobic digestion in the absence of oxygen – pyrolysis takes place to form bio gas.



Solar radiation absorbed by plant

- 1.3×10^{21} j/yr

Worlds bio mass energy content 1.5×10^{22} J

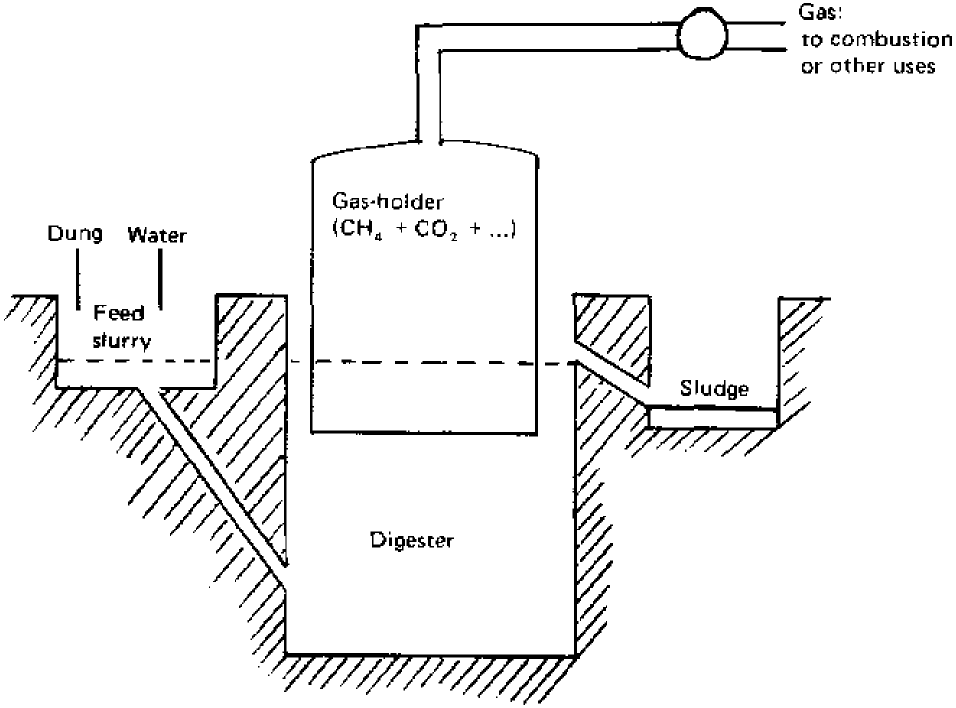
<u>BIO GAS PLANT</u>

Bio mass : traditional Solid mass – wood & agricultural waste – burn – energy

Non traditional – bio mass converted into – ethanol, methanol – liquid fuel

Fermented form- anaerobic ally to get gaseous fuel – 55 to 65% methane, 30-40% co2 rest impurities – H_2,H_2S, N_2

Bio mass- sources - Concentrated waste (Municipal solids, wood husk, industrial waste)



The biogas plant consists of two components: a digester (or fermentation tank) and a gas holder. The digester is a cube-shaped or cylindrical waterproof container with an inlet into which the fermentable mixture is introduced in the form of a liquid slurry. The gas holder is normally an airproof steel container that, by floating like a ball on the fermentation mix, cuts off air to the digester (anaerobiosis) and collects the gas generated.

Unit – I
Energy and Steam

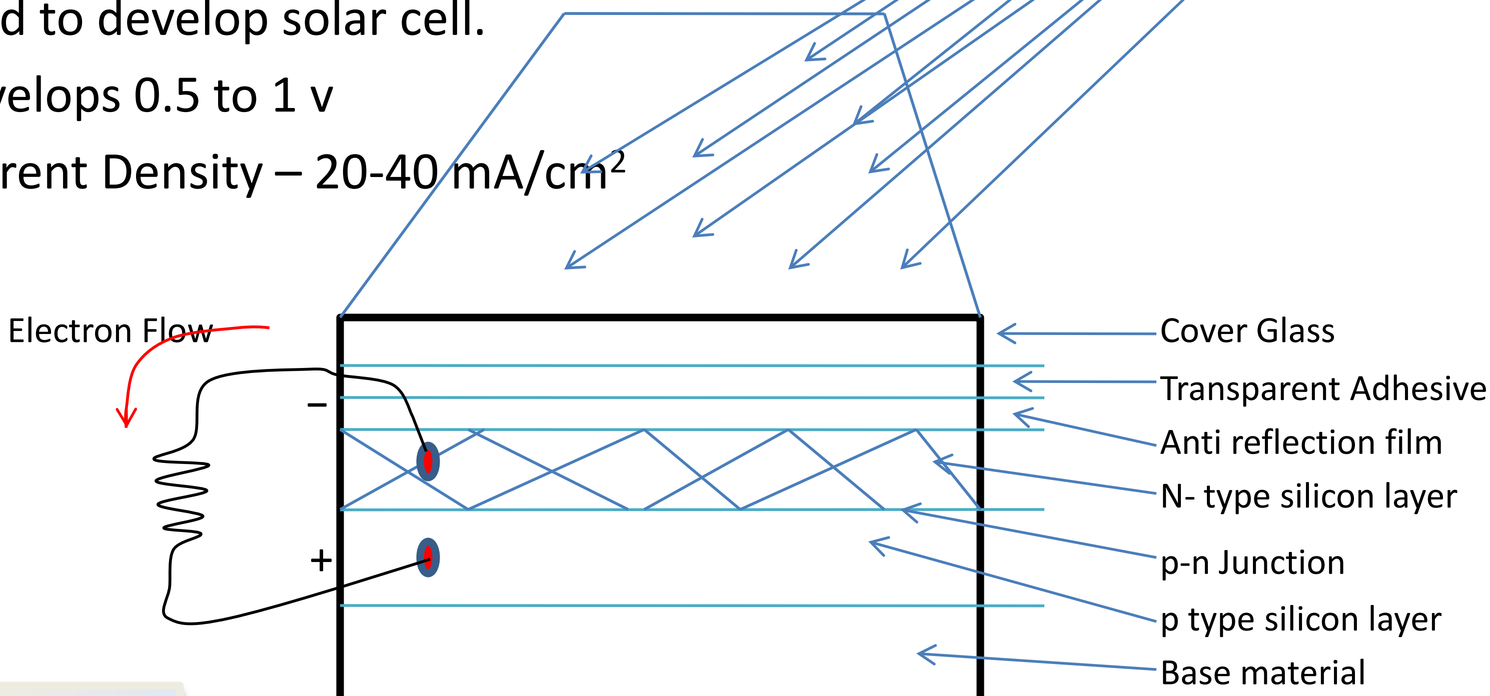
Helio electrical Process: Solar energy converted into electrical energy.

(Silicon, germanium, cadmium sulphide, gallium arsenide)

Principle of photovoltaic effect – sunlight photons absorbed by semiconductors they create free electrons (insulators-no free electrons)– silicon - p-n junction- diffuse of electrons – exposed – p +vely charged & n –vely charged – when load applied – charge difference will drive current – used to develop solar cell.

Develops 0.5 to 1 v

Current Density – 20-40 mA/cm^2

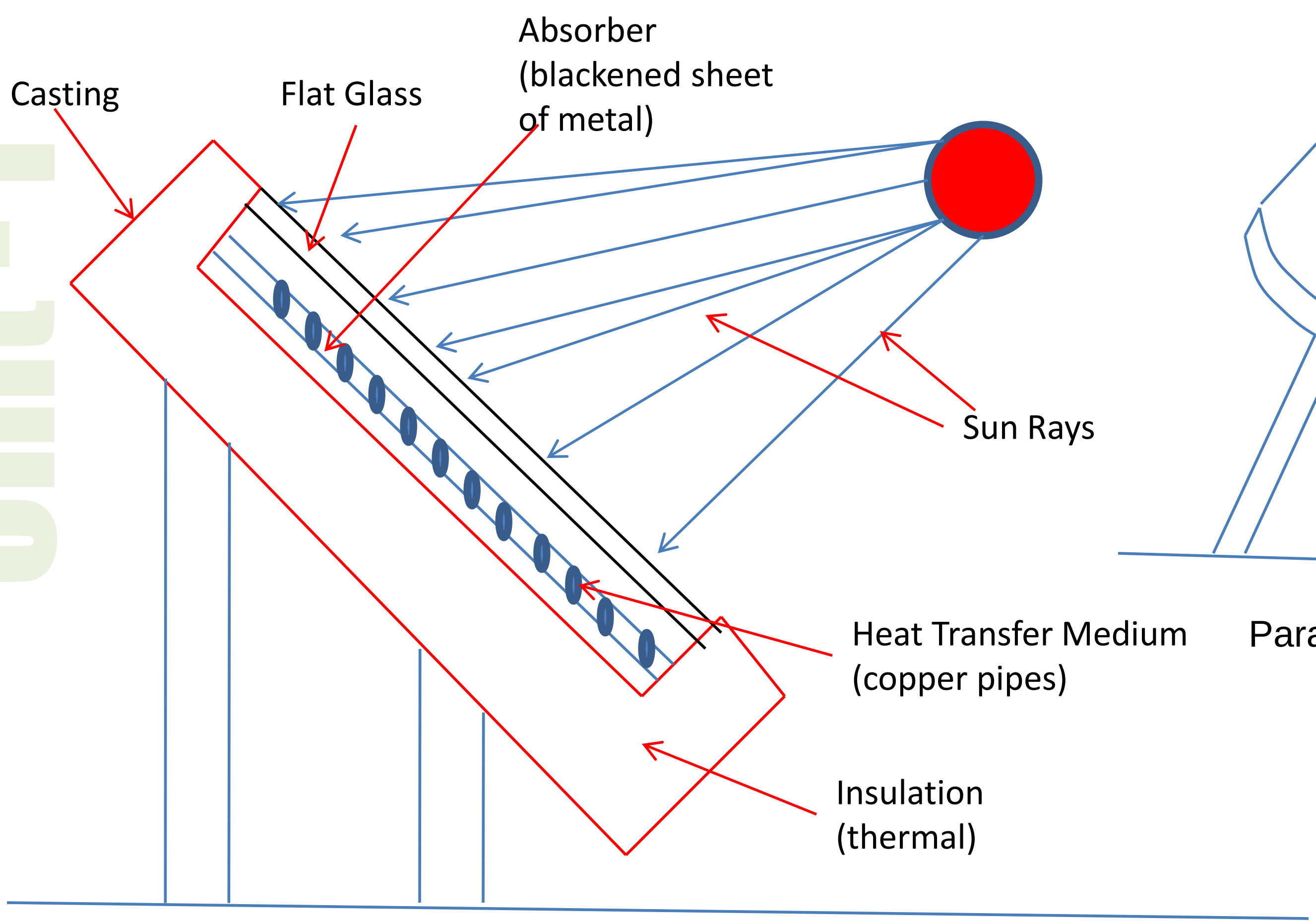


Photovoltaics (PV) or Solar Cells as they are often called, are semiconductor devices that convert sunlight into direct current (DC) electricity. Groups of PV cells are electrically configured into modules and arrays, which can be used to charge batteries, operate motors, and to power any number of electrical loads. With the appropriate power conversion equipment, PV systems can produce alternating current (AC) compatible with any conventional appliances, and can operate in parallel with, and interconnected to, the utility grid.

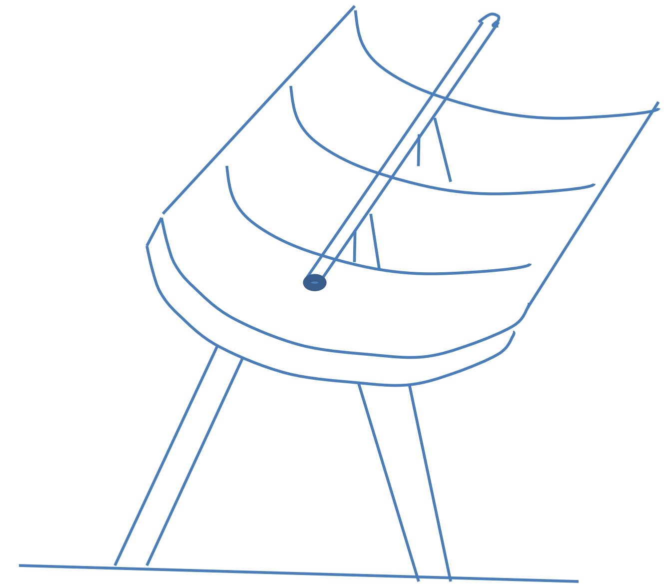
Unit – I

Energy and Steam

1) Helio Thermal process(Thermal energy): South at 20^0 Angle

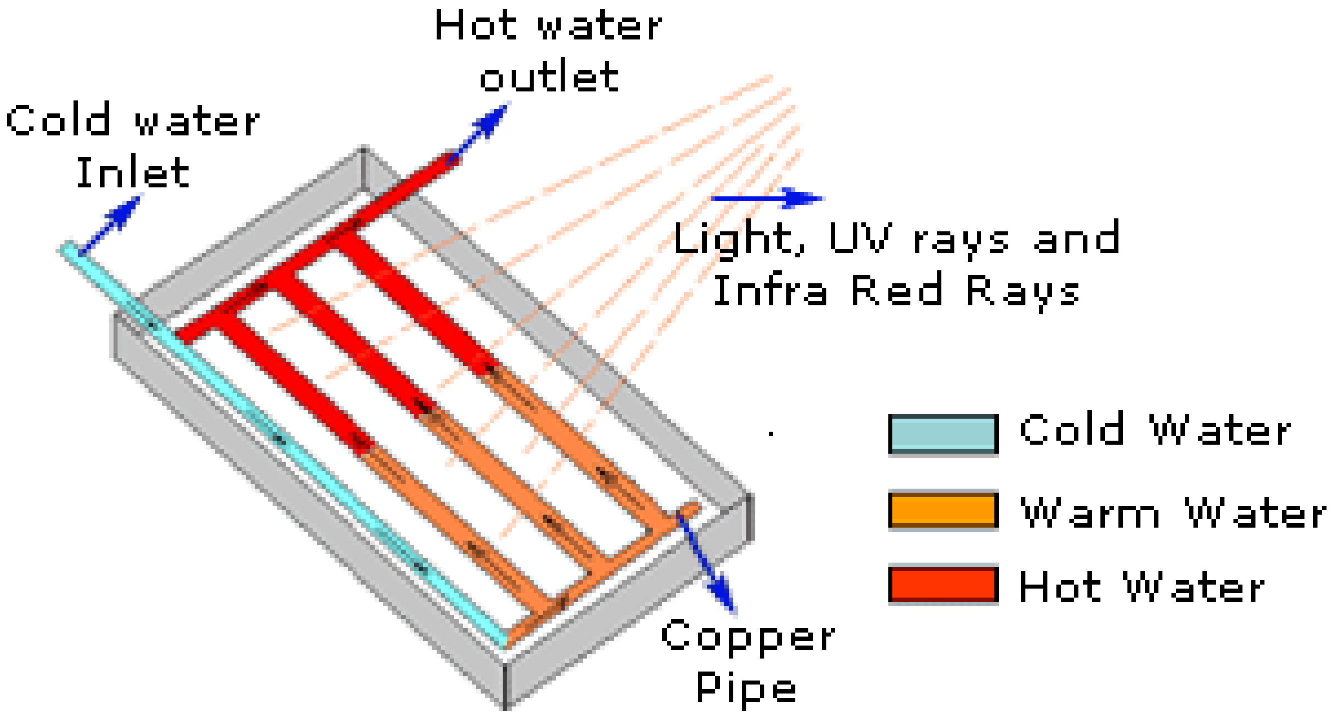


Flat plate collector



Parabolic Focusing collector

Flat Plate Collector



Flat plate collector data

Application	
Domestic Use	House, Apartments & Bungalows
Commercial	Hotels, Lodges, Marriage Halls, Hospitals, Schools & Colleges, Hostels
Tank	Copper / SS
Insulation	Glasswool
Outerbody	Aluminium sheet, powder coated
Electrical Backup	2 KW heating element and thermostat
Collector Plate	
Absorber Material	Copper
Absorber Coating	Solchrome Black
Absorber Bonding	Tig Welding
Back insulation	Rockwool / 50 mm Thick/ 48kg/m cube Density
Side insulation	PUF
Back sheet	Aluminium
Absorber Area	$2m^2$
Top cover (Glass)	4 mm Tempered Glass
Pressure Rating	$1\ kg/cm^2$
Header & riser pipes	Copper
Reflective surface	Aluminum foil

Energy and Steam

1) Helio Thermal process(Thermal energy):

Radiant Solar Energy

– Available Quantity 10^{16} W Demand 10^{13} W

– Radiation absorbed per year 3.8 x 10^{24} Joules / year

-- Collection -- Flat Plate or Focused collector

– covert into thermal energy

- Insulation – to minimize conduction & convection losses.

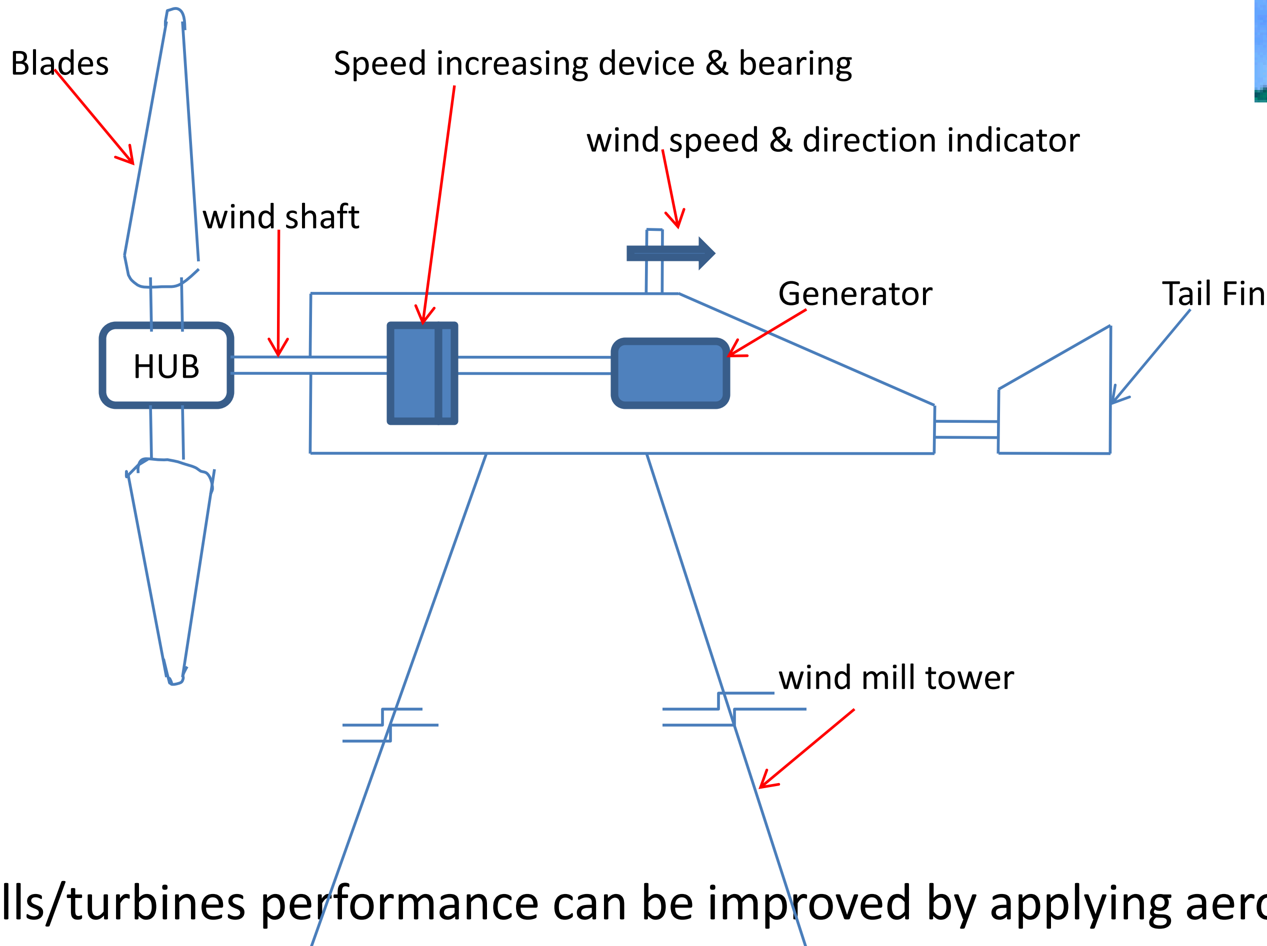
Process: Solar rays – absorbed – glass passes short wave length radiation– blackened flat sheets surface for high absorptiveness & low emissivity's - copper, steel aluminum of 1 to 2 mm thick, tubes 10 to 15 mm Dia - (non concentrated) operating temperature is below 90^0 C –

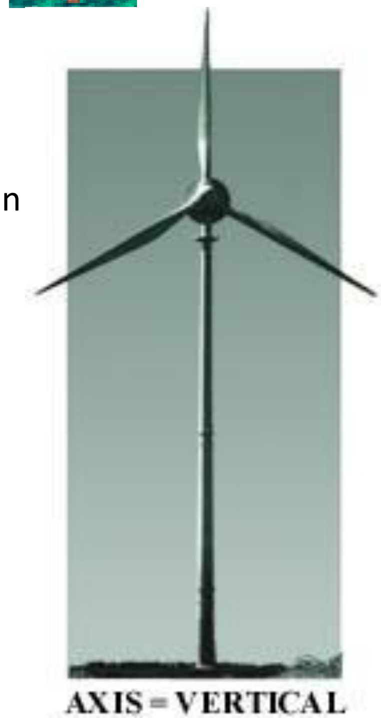
-- water heater, cooker, drying, seasoning woods

– parabolic reflectors i.e. mirrors/lenses – focusing collector – require tracking system to follow the path – above 100^0 C – line focusing/point focusing (Dish antenna).

Unit – I
Energy and Steam

1) Wind Energy – wind mill





Wind mills/turbines performance can be improved by applying aerodynamic principles.

1) Wind energy:

is the kinetic energy contained in the force of the winds blowing on earth surface.

Causes: 1) the circulation of air in atmosphere is caused by the non uniform heating of earths surface. The air in warm area expands & becomes less dense. It is forced upward by cool denser air causing wind. At night this process is reverse.

2) rotation of the earth with respect to atmosphere and its motion around sun. Difference of Pressure in two places.

wind speed increases with height. Wind energy available is 1.6×10^7 MW

Indian potential – 20,000 MW

Kinetic Energy / unit volume $= E = \frac{1}{2} \rho V^2$

ρ = Density of Air V = Average linear Speed.

Rotational motion of the wheel can be either translated into rotary motion to generate electricity or reciprocating motion to drive pump.

Energy and Steam

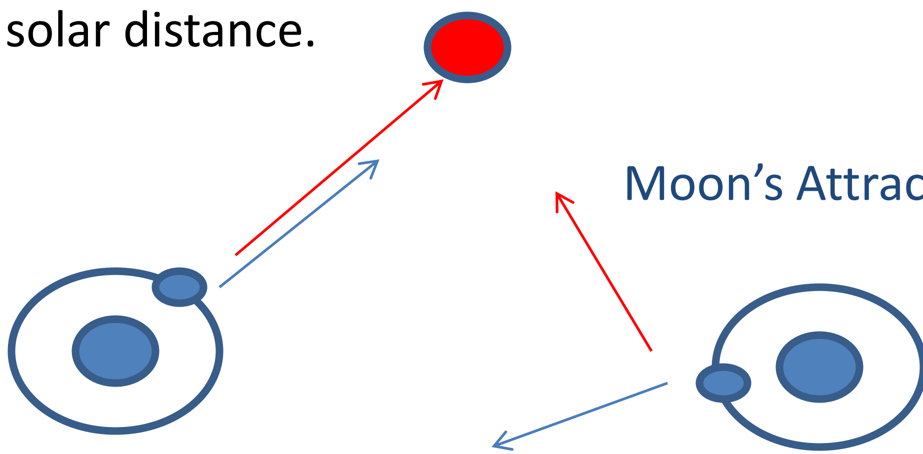
1) Tidal energy: From oceans – taped from coastal water – dam – entrap at high tide – release at low tide – generate power using turbines.

Occurrence of tide is due to a balance of forces, mainly gravitational force of moon & son and also on centrifugal force on water due to earths rotation.

Rotation of moon creates rise and fall in tides.

Tidal range R = Water elevation at high side – water elevation at low side

R is maximum at new (Sun, Earth & moon fall in line) & full moon called spring & Half moon they act at right angle – is neap tide. Varies from location & solar distance.



Sun's Attraction

Moon's Attraction

Spring Tide

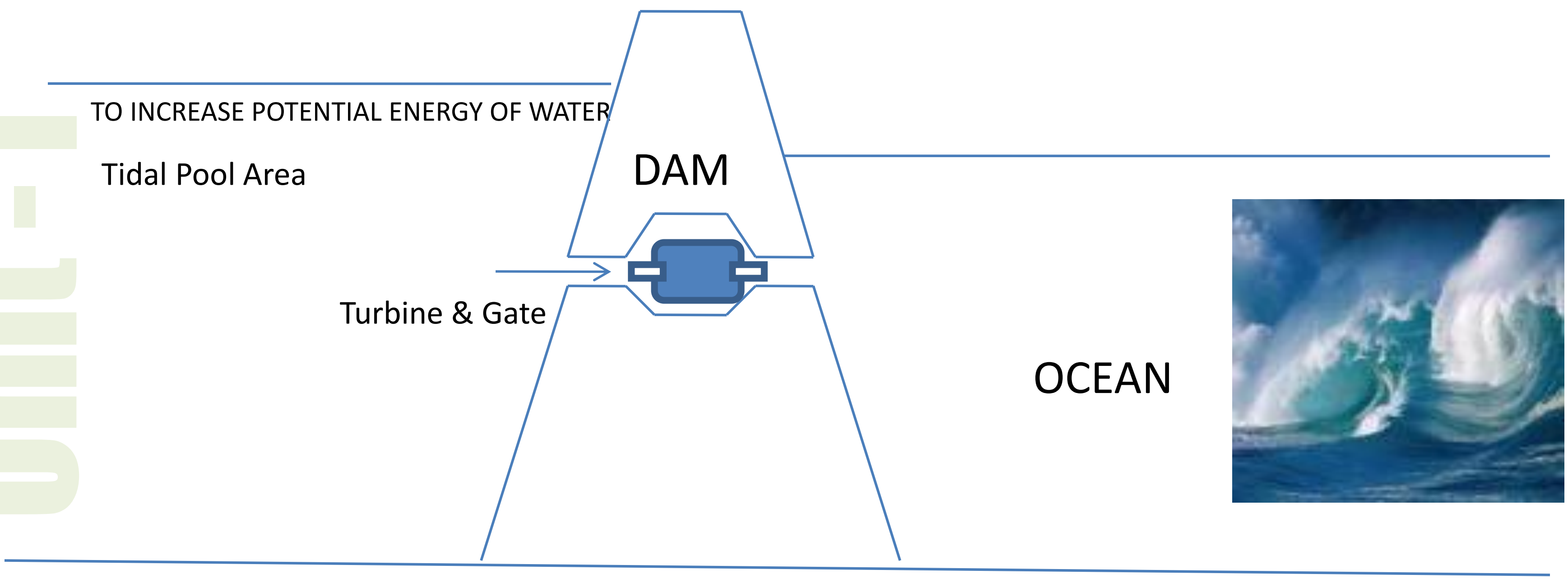
Neap Tide.

Raise & fall above mean sea level called – flood(high tide)

Raise & fall below mean sea level called – ebb (low tide)

Unit – I
Energy and Steam

1) Tidal energy:



Consists of – Dam built across the tidal reach to create pool in which water can be stored. Inside the dam reversible water turbines and flood gates are installed. During occurrence of high and low tides the gates open & close respectively.

Tide cycle – low tide to high tide and back to low tide.– time 12.5 hours – pool is filled & emptied.

Advantages:

Totally independent of rain

Uniform power supply due to definite tide cycle

Amount of land required is less.

Disadvantages:

High transmission cost

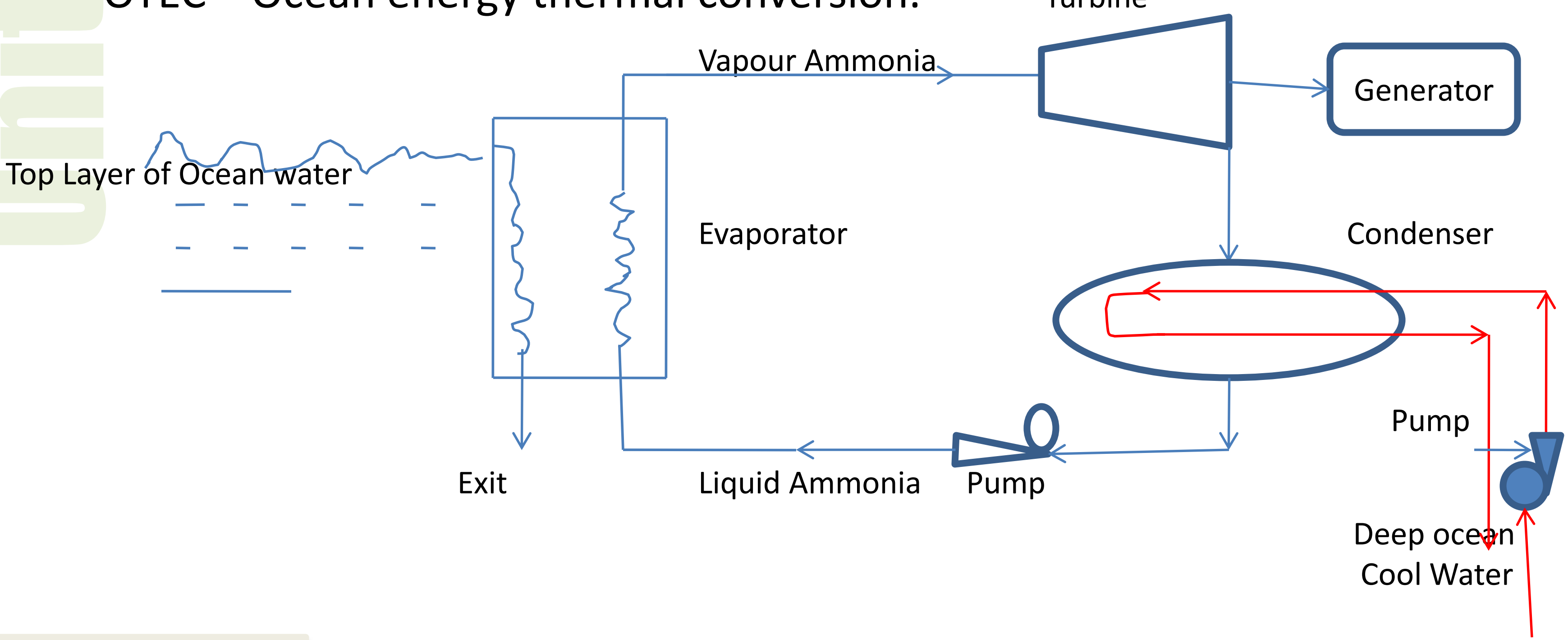
Entire potential energy cannot be harnessed

Hence generation of power is less.

Ocean Thermal Energy

The solar heating of upper layer of ocean water(27 to 29°C) combined with earth's rotation produces large convection currents while the deep water (5 to 7°C @ 1 to 1.5 km) remains cold. The difference in these two temperatures could be used to generate mechanical energy which will be converted into Electrical Energy.

OTEC – Ocean energy thermal conversion.



This works on the principle of Closed cycle system.

1) A low boiling point liquid – ammonia – in evaporator as working fluid.

2) The top layer of heated ocean water passed on Evaporator

3) This evaporates ammonia

4) Evaporated Ammonia flows to turbine at high Pressure (Approx- 10 bar), it expands & propels the turbine.

5) Then turbine rotates the coupled electrical generator to produce the electrical energy.

6) The low pressure exit ammonia vapor passes through condenser, to have a conversion of liquid ammonia.

7) Liquid ammonia pumped back to evaporator to repeat the cycle.

8) For condensation of ammonia the cold water pumped from bottom layer of ocean.

Dis Adv: 1) Low Efficiency, system needs extremely large power plant equipments and components.

2) High capital, installation & maintenance cost, hence the unit power cost is high.

GEO THERMAL ENERGY:

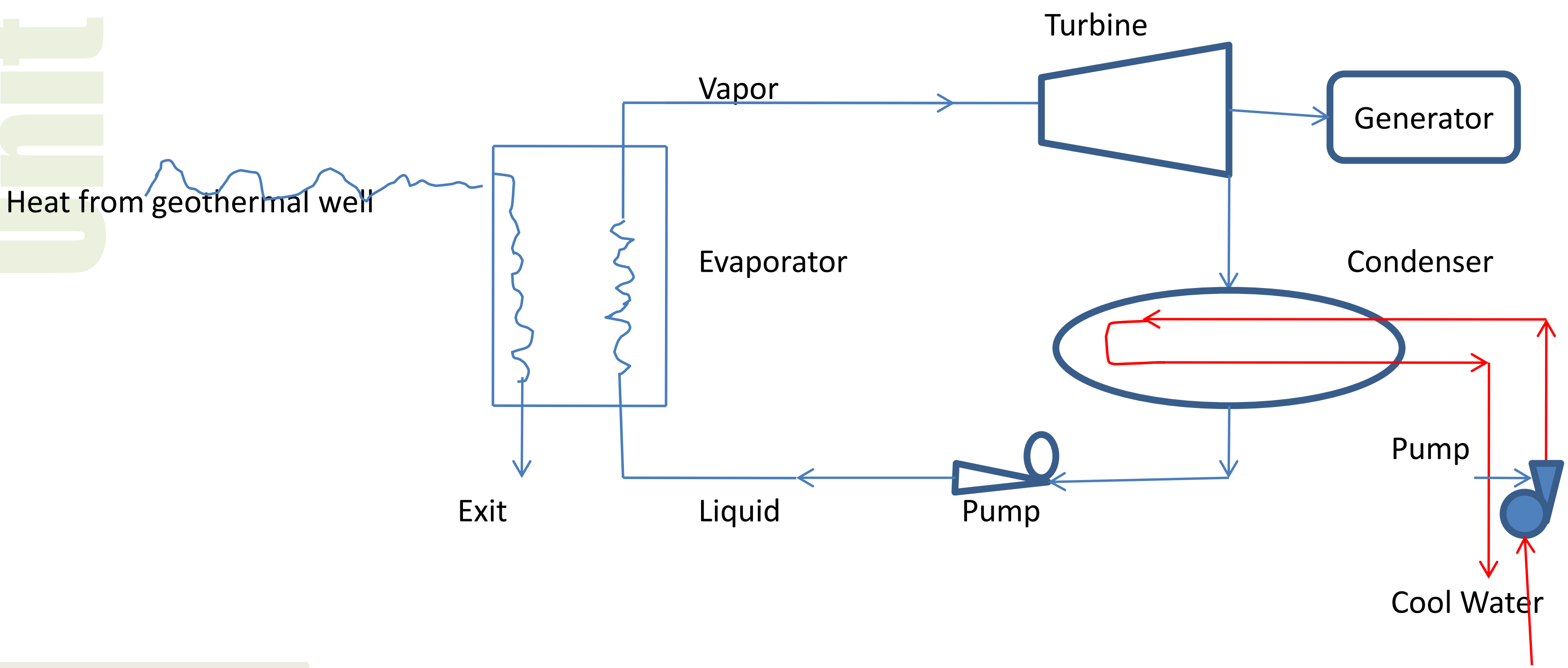
This is the thermal energy that occurs naturally within the earth. Molten interior of the earth contains vast quantities of thermal energy. This is formed due to decay of radioactive material. this energy manifests through steam, hot water and hot rock, and is released naturally in the form of fumaroles(hot gas & vapor), geysers (super heated steam), hot springs (steam type water) & volcanic eruptions (molten rock).

The temperature of earth increases rapidly with depth. Thermal gradients can rise by over 80^0C for each 1000m penetration in thin crest region. 25^0 to 35^0C for geologically stable areas.

Geothermal energy can be mined by drilling down into a hot underground layer of rock containing hot water. Is not strictly a renewable, since heat is drawn from the well, the temperature of rock falls, once the well is exhausted it would take thousands of years to restore the natural heat flows from surrounding rock. This process is slow because rock is very poor conductor of heat.

Geothermal Energy:

steam from the geothermal well can be used to run the steam turbine or the heat transferred to another fluid which vaporizes at much lower temperature then the water and the vapor can be used to run the turbine. (Temperatures may be about 4000^0C. At Tuscany in Italy about 26,000 kg of steam is available per hour at a pressure varying from 4 to 16 bar)



The four commonly used systems to harness the geothermal energy are

1) Dry steam system
2) Wet steam system
3) Hot dry rock system
4) Molten rock chamber system.

NUCLEAR ENERGY

It is the chemical energy released during the splitting or fusing of atomic nuclei. The atom consists of small massive, +vely charged core nucleus surrounded by electrons. It is composed of neutrons & protons bonded together by strong nuclear forces. Protons carry +ve charge. Neutrons carry no electric charge.

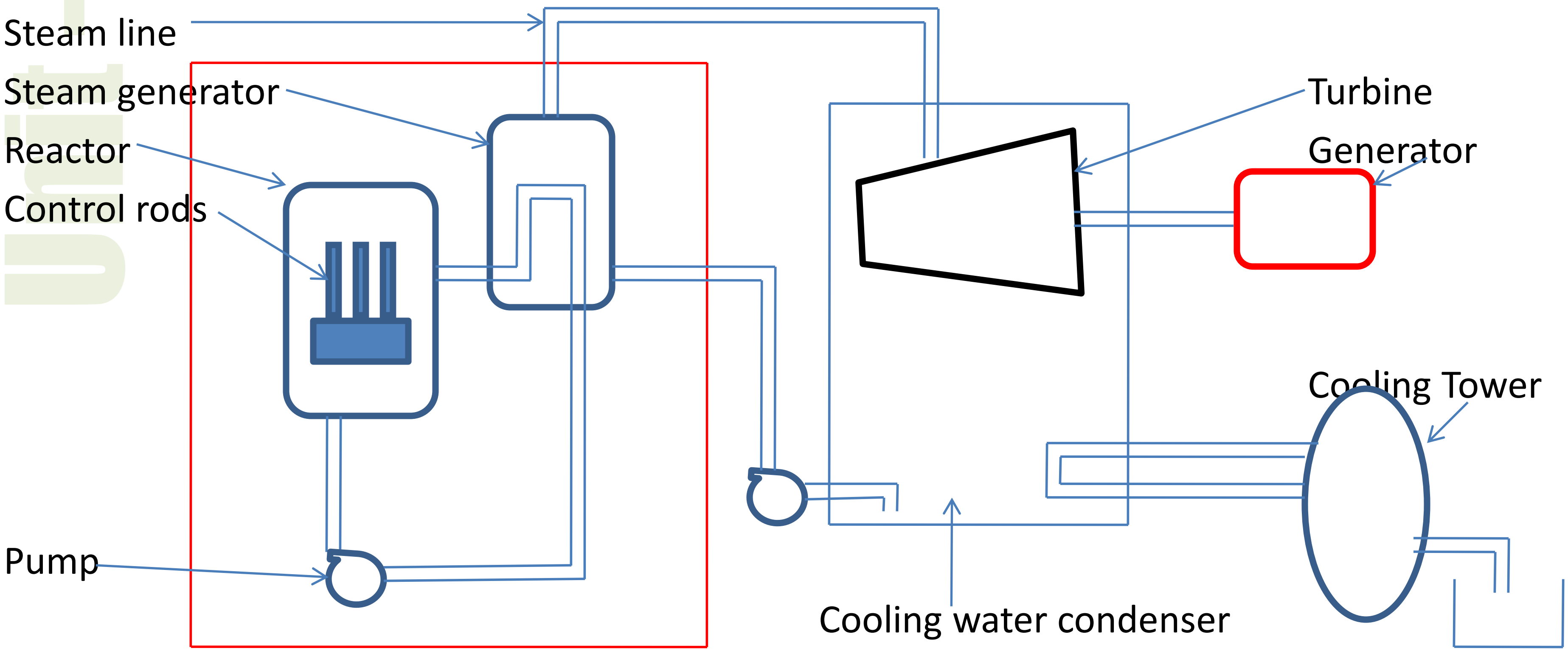
A nuclear reaction involves changes in the structure of the nucleus. As a result of such changes, the nucleus gains/losses one or more neutrons/protons and release useful amount of energy. The nuclear energy measured in millions of electron volts(MeV) and will be released by fusion and fission nuclear reactions.

Most of nuclear power plants are based on the fission of the nucleus of Uranium-235 atoms.

Nuclear power plant.

It consists of Nuclear reactor (device where nuclear chain reactions are initiated, controlled and also sustained at a steady rate), steam generator, cooling water condenser, cooling tower, turbine & generator.

Control rods of reactor are used to control the splitting of Uranium atoms.



Unit – I
Energy and Steam

1) Reactor & Steam generator housed in structure.
2) Nuclear reaction produces enormous amount of heat, which is transformed into steam generator where steam is produced by reaction of heat with cooling water.
3) The steam is led to turbine through steam line and it drive the turbine and generator will produce the power.

Unit – I
STEAM

Objectives:

- Preamble
- Formation of steam
- Properties of Steam
- Types of steam
- Properties of Steam – Specific Volume, Enthalpy, Internal Energy etc.
- Simple numerical problems.

Unit – I

STEAM

Preamble:

Steam is a gaseous phase of water. A perfect gas does not change its phase during thermodynamic process. Pure substance is a homogenous substance retains its chemical composition even though it undergoes a change in phase during a thermodynamic process. Water is a pure substance which exist in three different phases.

Solid Phase – ICE – freeze water

Liquid phase – Water – melt of ice

Gaseous phase – Steam – vaporization of water

It retains the same chemical composition.

Ice melt – Solid to liquid phase – water formation.

Water heated- above boiling point – evaporating – liquid to gaseous phase.

Vapourisation.

Steam exists in different states or Types or conditions like Wet steam, dry steam, Superheated steam, Supersaturated steam.

Unit – I

STEAM

Formation at constant pressure.

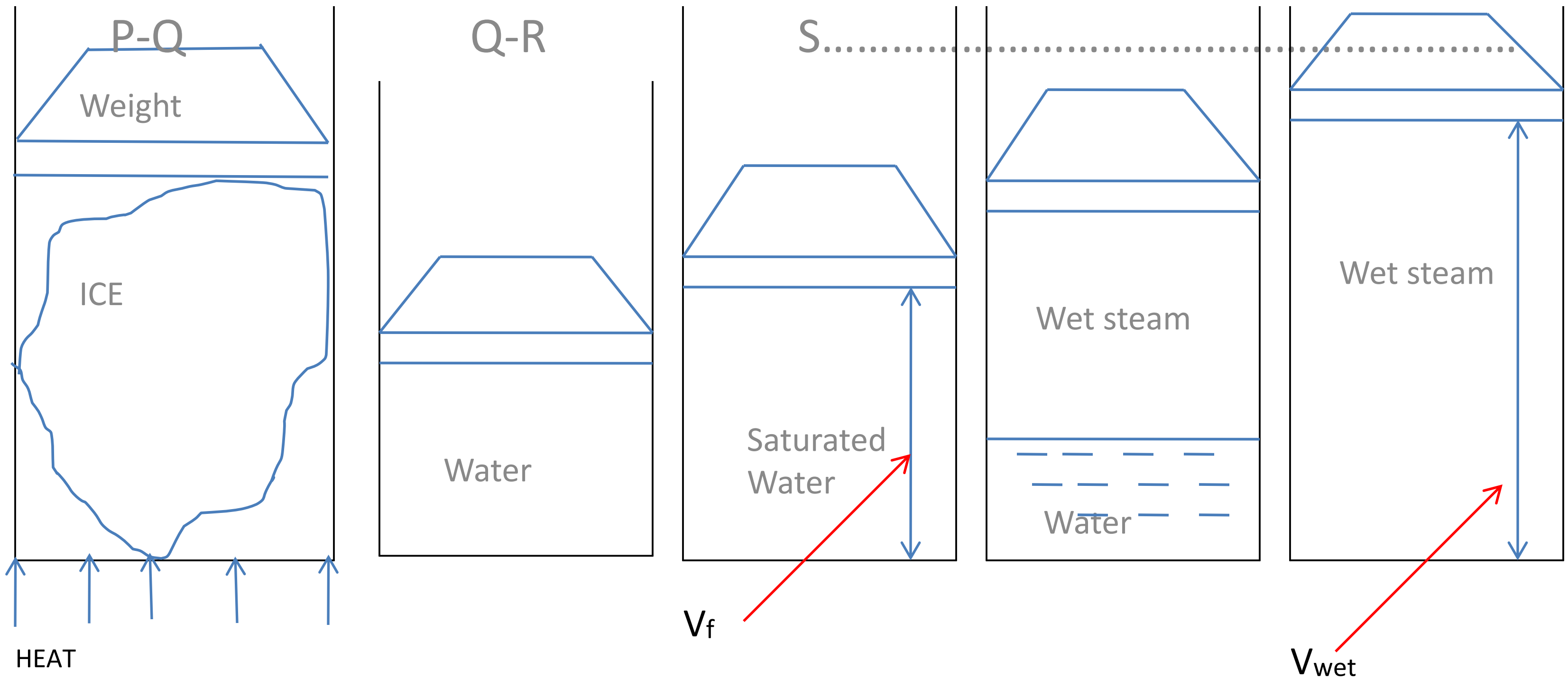
Steam generators – boilers – water – atmospheric pressure & Temp – heat – formation of steam.

continuous generation of steam – increase in pressure – fed to turbines at constant pressure.

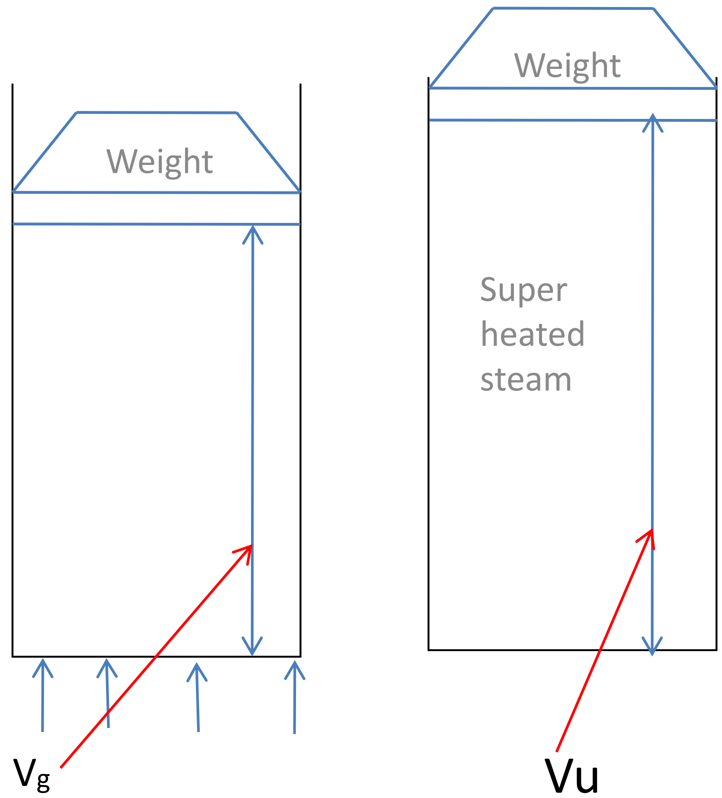
Properties of Steam

Pressure, Temperature, Specific volume, enthalpy and internal energy.

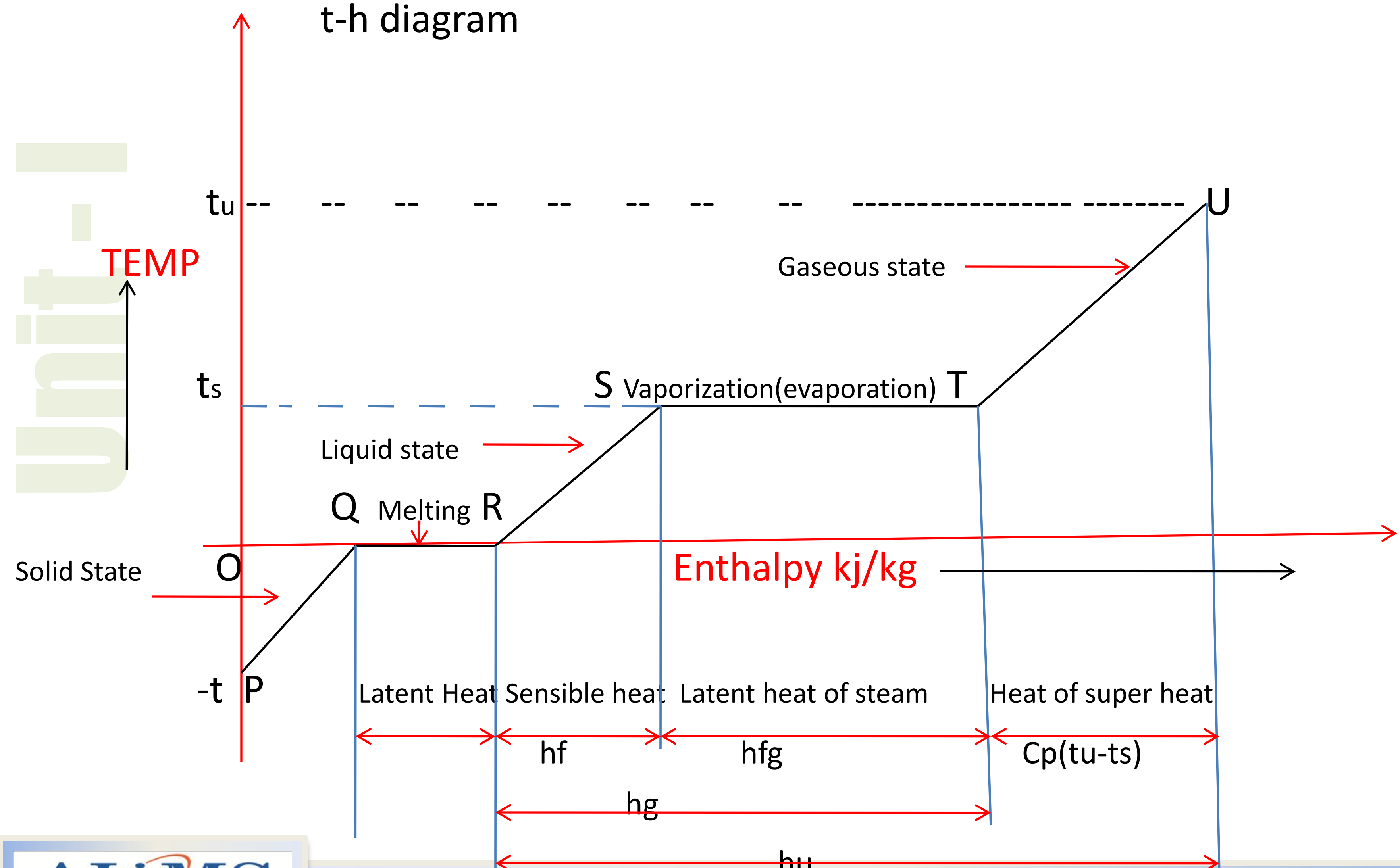
Formation of steam at constant pressure



Unit – I
STEAM



Temperature – Enthalpy diagram for formation of steam at constant pressure



STEAM

Formation at constant pressure.

1) 1 kg of ICE – Absolute pressure P bar – (Gauge + atmospheric) – temp t^0C below freezing point – heat – t-h diagram – p to q temp - $-t^0C$ till o^0C freezing temp.

2) Heat – melting – same temp – ice to water from Q to R . The amount of heat added during this period Q to R is called Latent heat of fusion/ice.

Latent Heat: is the amount of heat at constant temp to convert 1 kg of ice to water at given pressure.

3) Heat – Boiling point $t_s{}^0C$ – Saturation temp - is the temp at which the water starts boiling – Pressure is called saturation pressure -↑ Pressure↑ Temperature – amount of heat added R-S is sensible heat/enthalpy of saturated water/ total heat of water↑. Volume of water called Specific volume of standard water v_f.

4) Heat – beyond S water starts evaporate- convert of steam – same temp – steam in contact with water is called wet steam or saturated steam.

5) Heat – entire water concerted into steam – heat supplied from 0^0C is called enthalpy of wet steam –volume is specific volume of wet steam.

Formation at constant pressure.

6)Heat – final particles of wet stream get evaporated at point T is called dry steam or dry saturated steam – volume – specific volume of dry steam. The amount of heat added during S to T is called Latent heat of vaporization of steam or latent heat of steam. Heat supplied from 0^0C is called enthalpy of dry steam.

7) Heating above point T – super heating – Super heated steam – behave like a perfect gas(obeys gas laws – boyle's & charle's law) – temp from T to U called Degree of super heat. Amount of heat during T to U called heat of super heat = $Cp(t_u – t_s)$. Cp- mean specific heat. The total heat supplied from 0^oC is called enthalpy of superheated steam – volume is specific volume of super heated steam.

Dryness fraction of saturated steam

ratio of mass of dry steam m_g to the mass of total wet steam (m_g+m_f)

m_f = mass of water vapor.

$$x = \frac{m_g}{m_{g+} m_f}$$

Quality of steam.

Quality of steam = $x \times 100$

Wetness fraction: is the ratio of the mass of water vapor to the mass of total wet steam.

wetness fraction = $\frac{m_f}{m_g + m_f} = (1 - x)$

Priming: is the representation of wetness fraction in percentage.

Note = quality + priming = 100%

Priming = $(1 - x) \times 100$

STEAM

Density of steam ρ , Kg/m^3

is the mass of the steam per unit of volume of steam at the given pressure & temperature. It is the reciprocal of the specific volume.

$$\rho = \frac{1}{v}$$

Internal latent heat (Internal energy of steam) (U), kj/kg

Is the energy required to change the phase. It is the actual heat energy stored in the steam above 0^{o}C. It is calculated by subtracting the external work of evaporation from the enthalpy.

External work of evaporation (E), kj/kg

it is the fraction of the latent heat of vaporization which does the an external work in moving the piston at constant pressure due to increase in volume.

work done = pressure x volume

= Pv

Enthalpy (h), kj/kg

It is the total amount of heat received by 1 kg of water from 0^0C at constant pressure to convert it to the desired form of steam. It is the sum of internal energy & work done at constant pressure process, which is equal to the change of enthalpy.

Let U = Internal energy,

h = Enthalpy (heat received)

Q = Heat Supplied

P = Pressure

v = Volume

dU = Change in internal energy

dh = Change in enthalpy

dQ = Change in heat supplied

dP = Change in Pressue

dv = Change in volume

By definition - Enthalpy = internal energy + Work done

$$h = U + Pv$$

STEAM

Energy balance equation based on first law of thermodynamics,

$dQ = dU + d(Pv)$

$= dU + v\,dP + P\,dv$

$= dU + d(Pv) - v\,dP$

$= d(U + Pv) - v\,dP$

For constant pressure process, $dP = 0$

$dQ = d(U + Pv)$

$\mathbf{dQ = dh}$

STEAM BOILERS

Steam Boilers

A **boiler** or **steam generator** is a device used to create steam by applying heat energy to water. The function is to evaporate water into steam at required constant pressure and to supply type of steam. Steam boilers are used in driving steam turbines, marines, locomotives and industries like textile, paper, sugar, tyre, chemical etc.

It is a closed vessel with water. By heating water above atmospheric pressure, the steam will be generated at the desired pressure & temperature.

Classification:

Basis	Types
According to position of water & hot gas carrying tubes.	Water tube Boilers and fire tube boilers
According to Location of Furnace	Externally & internally fired boilers
According to use	Stationary, portable, locomotive, marine
According to direction of axis	Horizontal, Vertical & Inclined axis
Height of circulation	High & Low end boilers
Pressure of steam	Low & High Pressure
Method of water circulation	Natural & Forced Circulation

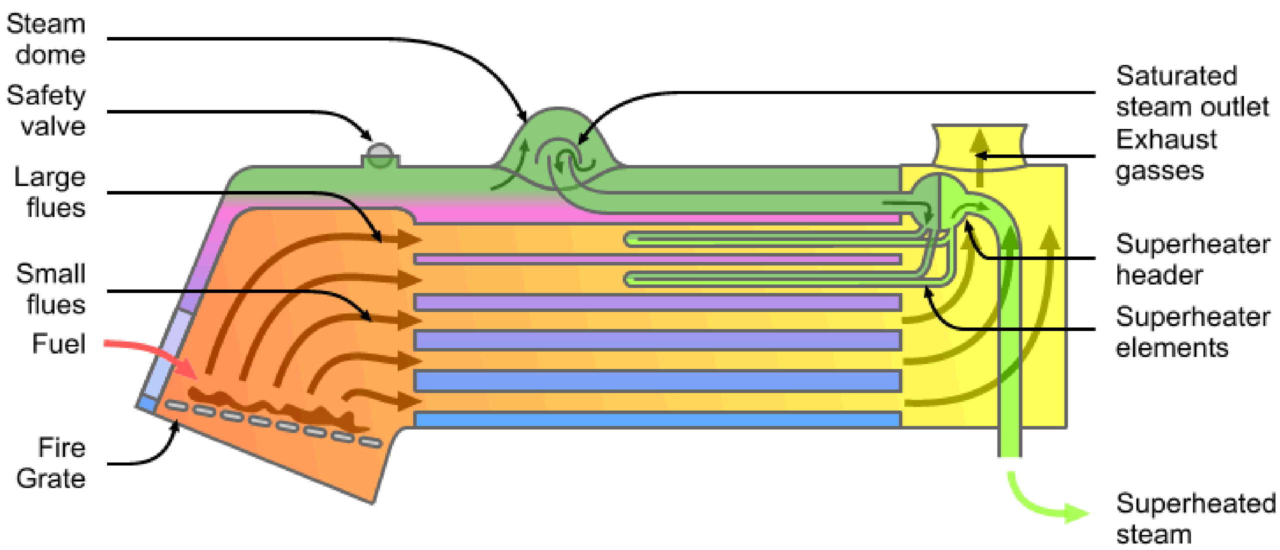
Steam Boilers

A **boiler** or **steam generator** is a device used to create steam by applying heat energy to water.

A **fire-tube boiler** is a type of boiler in which hot gases from the fire pass through one or more tubes within the boiler. It is one of the two major types of boilers, the other being the water-tube boiler. A fire tube boiler can be either horizontal or vertical. A fire-tube boiler is sometimes called a "smoke-tube boiler" or "shell boiler" or sometimes just "fire pipe".

This type of boiler was used on virtually all steam locomotives in the horizontal "locomotive" form. It is also typical of early marine applications and small vessels, such as the small riverboat. Today, they find extensive use in the stationary engineering field, typically for low pressure steam use such as heating a building.

Lancashire, Locomotive, Cornish, Gallaway, Scotch marine boilers.



Hot flue gases pass through one or more tubes, which are surrounded by water.

STEAM BOILERS

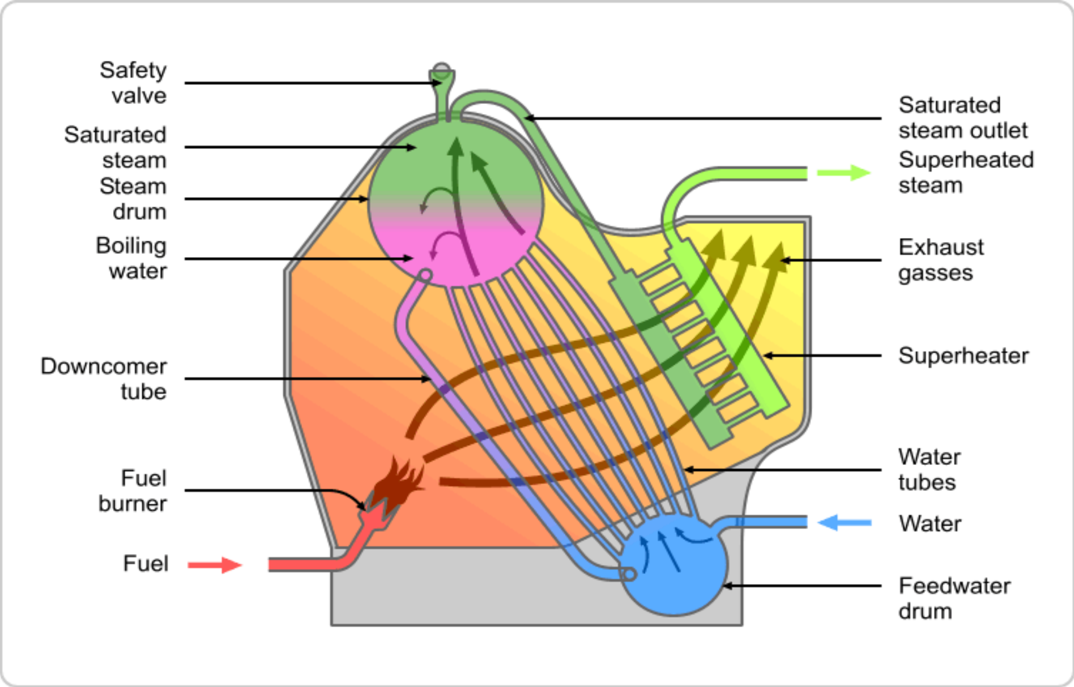
A **water-tube boiler** is a type of boiler in which water circulates in tubes heated externally by the fire. Water-tube boilers are used for high-pressure boilers. Fuel is burned inside the furnace, creating hot gas which heats up water in the steam-generating tubes. In smaller boilers, additional generating tubes are separate in the furnace, while larger utility boilers rely on the water-filled tubes that make up the walls of the furnace to generate steam.

The heated water then rises into the steam drum. Here, saturated steam is drawn off the top of the drum. In some services, the steam will re enter the furnace in through a super heater in order to become superheated. Superheated steam is used in driving turbines.

Cool water at the bottom of the steam drum returns to the feed water drum via large-bore 'down comer tubes', where it helps pre-heat the feed water supply. To increase the economy of the boiler, the exhaust gasses are also used to pre-heat the air blown into the furnace and warm the feed water supply. Such water-tube boilers in thermal power station are also called *steam generating units*.

A significant advantage of the water tube boiler is that there is less chance of a catastrophic failure: There is not a large volume of water in the boiler nor are there large mechanical elements subject to failure.

Unit – I
STEAM



Water circulates through the tubes.

Hot flue gases surround them externally

Tubes are slightly inclined to produce a syphonic flow of water.

Bobcock & wilcox, stirling,yarrow,La-mont,simple vertical, Benson, Loefffier Boiler Etc..

Lancashire boiler

is a land type or stationary, horizontal, straight tube, internally fired, natural circulation, fire tube boiler.

Size: 7 to 9 m length

2 to 3 m Diameter

8 to 9 tonne/hr – steam generation

15 bar – Pressure.

Construction: Cylindrical shell – two large conical flue tubes of same diameter (0.4 times of boiler shell dia) – ¾ th of shell volume filled with water – water submerges the flue tubes – space above water level is steam space.

Front end of flue tube – Larger Dia – accommodate furnace grates – brick bridge is provided at the end of the gate to prevent entry of unburnt fuel & ash particles – tapered & small dia at back end – ash pit – the flue gas flow in the enclosed chamber of brick work first through the main flue tube and then enter bottom flue (brick work)– then side flue before exiting thro the rare exit passage & chimney.

Mountings & accessories: Stop valve, safety valve, Pressure gauge, water gauge, etc.,

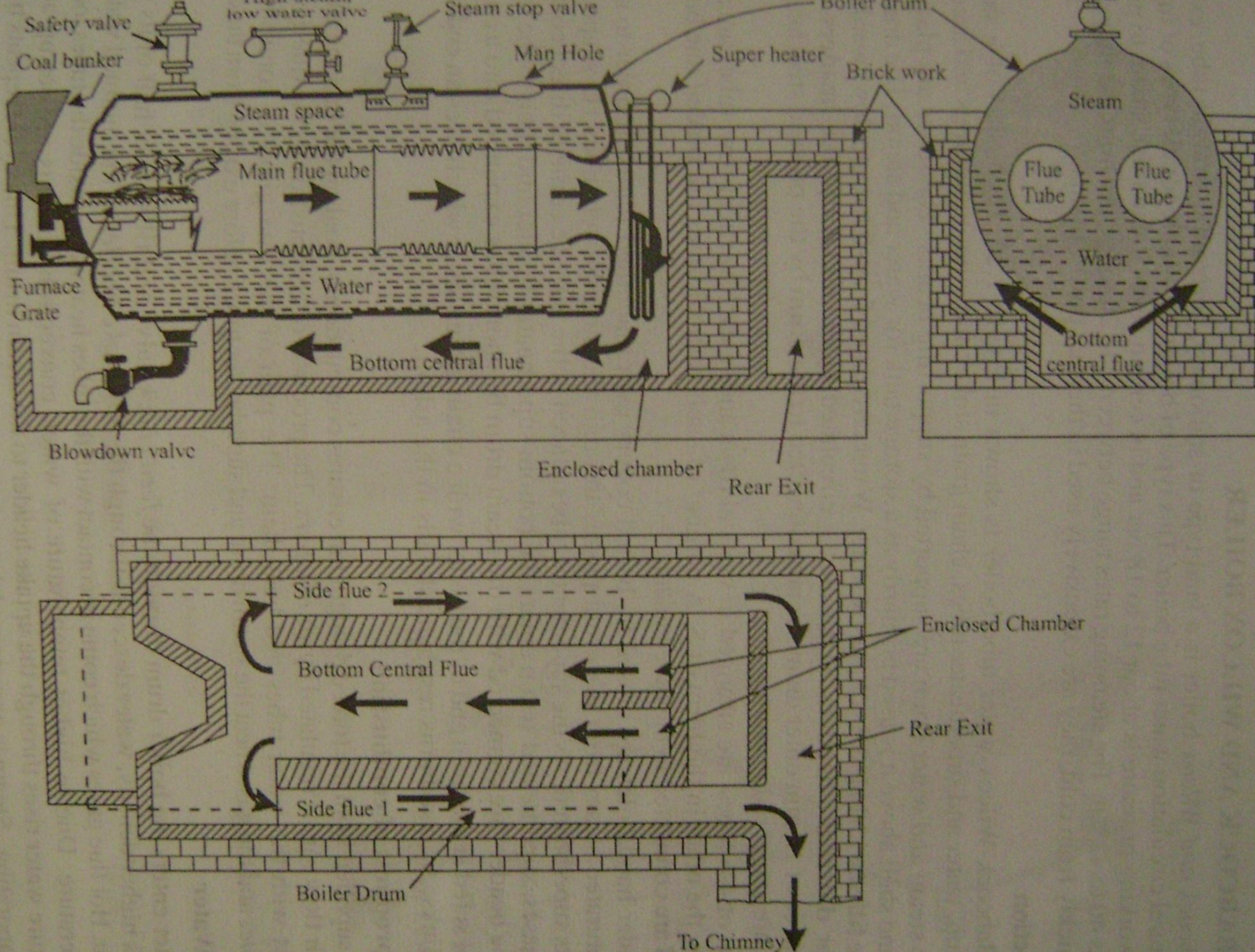


Fig 1.22 : Lancashire Boiler

STEAM BOILERS

Lancashire boiler: Pump of water- economizer-nonreturn feed check valve.

Combustion Process:

1) Flue Gas formation – combustion of fuel – formation of gas – gas flow through furnace tubes/main flue tubes from front to rear end.

2) this is the 1st run of flue gases, through which heat (83%) is transferred to water.

3) At rear end flue gas deflected by enclosed chamber & enter bottom central flue tube. – 2nd run – water in bottom portion get heated (9.5% of total heat) and temp of water is increased.

4) In front end it is diverted to side flue tubes – 3rd run – hot flue gases (7.5% heat) in contact with two sides of boiler shell.

5) after 3rd run gases reunite again at rear end and enter the chimney.

6) steam formed due to this heat transfer and it occupies steam space. Again this steam is passed through U tubes of super heater, placed at rear end of shell, which gets heat from hot flue gas leaving the main flue tube. Superheated steam is formed in super heater.

Lancashire boiler

Adv:

1) Economical, easy to operate, clean & inspect.
2) Low maintenance cost
3) Load fluctuations can be easily met de to large water storage
4) efficiency is up to 80 to 85% due to superheater & economizer.

Dis Adv:

1) Slow steam generation- 9000 KG/Hr
2) Occupies more space – 40 m2 for 5000 kg/hr Capacity.
3) Maintenance of brick work
4) The grate area is limited to small diameter of fire tubes.
5) Low pressure boiler – Up to 20 bar.

BABCOCK AND WILCOX BOILER

It is a stationary, horizontal straight tube, externally fired, natural circulation water tube boiler. This is suitable for all types of fuels. The normal working pressure is about 12 to 18 bar, in certain cases it can rise steam to pressures as high as 40 to 42 bar.

The steaming rate – range 2 to 20 tonne per hour.

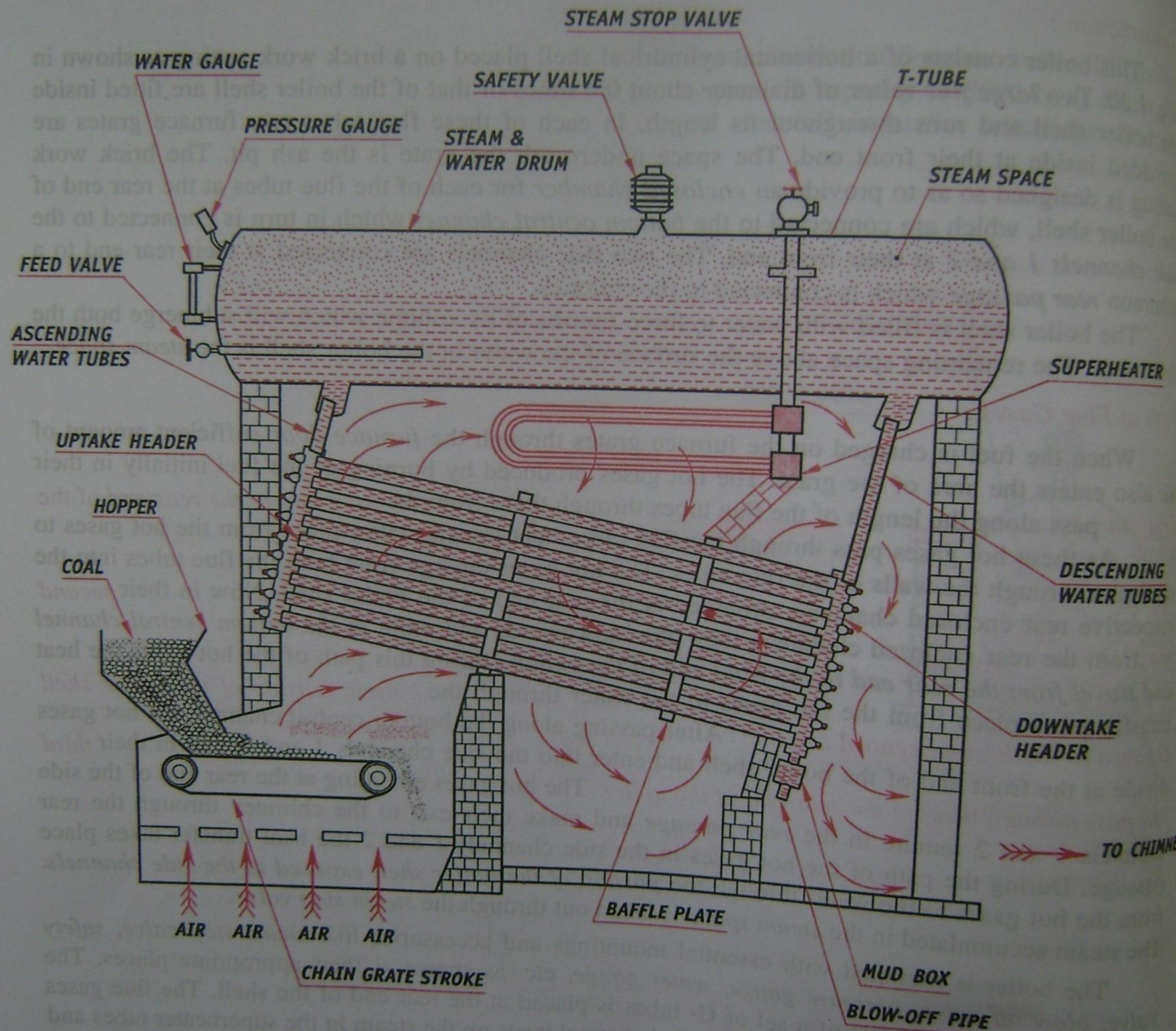
Construction: Components are steam & water steel drum, inclined water (15^0)and super heater tubes, chain grate stoker and other mounting & accessories.

Steam and water drum supported by supporting beams.

Tubes are placed in the furnace.

Half of the drum is filled by water and the same level has to be maintained.

Water circulated downwards by down take headers. Hot water circulated by means of uptake headers. Inclined tubes of 10 mm outer diameter are connected to drum by the pressed steel headers and the tubes are staggered in pairs.



Babcock & Wilcox Boiler
Fig. 1.21

Construction :

BABCOCK AND WILCOX BOILER

A set of 4-5 tubes are arranged in vertical rows & in each vertical row, tubes are arranged one below the other in the form of S. a number of such vertical tubes are placed one behind the other and are connected to the tube headers.

Saturated steam from drum passes through U shaped super heater tubes, where steam get superheated. As the super heater tubes placed in furnace come in direct contact with the flue gases, superheated steam enters the bottom superheater header and then to the main stop valve. Coal is fed at the front end of the boiler with a chain grate stoker which uses an endless chain made of links. As coal burns ash falls in ash pit.

Combustion: Air supplied by fan for combustion of coal. Air flow will be regulated by air dampers. The products of combustion or the flue gases come in contact with water tubes and heat them. The path of flue gas is controlled by baffle plates, which will heat steal drum & super heater tubes before Exiting from chimney.

BABCOCK AND WILCOX BOILER

Path of water: Water – thro feed check valve – drum – fills half of its volume – descends thro down take header to inclined tube – hot gas heat the water inside the tube – increase in temperature – high temp water rises through uptake header to the steam drum. Cycle repeats till steam starts evaporating. Then steam is passed thro super heater header where it get superheated.

Comparison

Water tube boilers	Fire tube boilers
Water circulates thro tubes & hot flue gases surrounded them externally.	Flue gases pass thro tubes which are surrounded by water.
Quick steam generation	Slow steam generation
Large power plants – marine-evaporating capacity – 50,000 kg/hr Steam pressure range – 21 Mpa (area of heating surface)	Low power plants – locomotives – 9000 kg/hr – 2MPa
Any type of fuel can be used (Furnace can be altered)	Only coal is suitable
Soft water is necessary	not
Bursting of water tube is less serious	Fire tube is disastrous
Reliable and high initial cost	Not reliable with low initial cost
High heat transfer rate- less thermal stress – easy maintenance – low deposit of sediment – occupies less space – easy to transport & install	low heat transfer rate- high thermal stress – difficult maintenance – high deposit of sediment – occupies more space – inconvenient to transport & install

STEAM BOILERS

Boiler Mountings: are the external fittings which are required to ensure safe operation of boiler.

1)water level indicator: the function is to indicate the level of water inside the oiler drum at any given instant. Two water level indicators are fitted at the front of the boiler drum. TO MAINTAIN CONSTANT LEVEL OF WATER.

2) Pressure gauge: is to indicate the steam pressure inside the drum in bar or kgf/cm^2 or kN/m^2 gauge pressure. One or more gauge fitted to the super heater header to indicate the super heated steam pressure at any given instant.

3) Steam stop valve or junction valve: stop valve smaller in size, junction valve are larger in size. Mounted on top most portion of drum is unction valve. The valve connected to steam pipe to regulate the flow of steam is stop valve.

4) feed check valve: regulates the flow of feed water under pressure o the boiler drum. It is a one way valve. No water flows back from boiler. It consists of two valves together. One to allow water & one to prevent back flow by using pneumatic pressure.

Boiler Mountings:

5) Blow down valve or blow off clock : is to remove the sludge or sediments collected at the bottom of the boiler drum from time to time.

6) safety valves: is to protect the excessive steam pressure inside the boiler drum exceeding the design pressure. When pressure is increased then the rated pressure, it automatically opens and discharges the steam to atmosphere till it retains normal working pressure. This situation arises whenever furnace temp increases causing excessive heat transfer or when sudden drop in steam demand. Two types of safety valves are a) Spring Loaded Safety Valve b) dead weight safety valve.

Boiler Accessories:

are the appliances which ensure the improved efficiency of the boiler. These may be installed inside r outside the boiler.

1) Economizer: is to recover a portion of heat of the exhaust gases before the flue gases enter the chimney and discharged to atmosphere. Placed between boiler exit and entry of chimney. Feed water – absorbs heat – from exhaust gas. By decreasing fuel consumption – increase boiler efficiency.

Boiler Accessories:

Super heater: is to increase the temp of steam above its saturation temp.

Air pre heater: is to recover the heat of a portion of exhaust flue gases before the flue gases enter the chimney. Placed between economizer and chimney. Air is passed over the pre-heater tubes containing flue gases. Due to higher air temp combustion of fuel becomes rapid and consumes less fuel and increases the efficiency of the boiler.

Feed water pump: is to pump water at high pressure to water space of boiler drum. Rotary & Reciprocating pumps are used.

Pressure reducing valve: is to maintain constant pressure on the delivery side of the valve with the fluctuating boiler pressure.

Steam Trap: is to drain off water resulting from the partial condensation of steam in the steam pipe lines without allowing the steam to escape through it.

Steam separator: is to separate the water particles in suspension that are carried by the steam coming from the boiler.