Unit No: 01

"Introduction to Energy Resources and it's Conversion"

Introduction :→

Defⁿ: Energy is nothing but a capacity to do the work.

The economic growth of country depends upon per capital energy consumption. The countries have to produce or generates more power than they consumes as there is large gap between demand and supply of energy. These energy forms available are mechanical, thermal, electrical, etc. The most usefull form of energy is electrical energy. The electrical power is easy to transmite and distribute, easily converted into other forms. Due to increased demand of power the the alternate methods and development in available form must be studied. (Joule is the unit of energy & Horsepower, Kilowatt-hour, KW, MW).

i) Renewable energy source

ii) Non-renewable energy source

- The renewable or nonconventional resources can be renewed or replenished over the period. There are solar energy, hydro energy, geothermal energy, tidal energy, wind energy.
- The non-renewable or conventional resources means it can't renewed or replenished. There are thermal power, Hydro-large, nuclear energy, diesel energy, etc.

Total power needed in india is 380000 MW whereas 280000 MW is generated using these resources out of this 70% of power is generated by non renewable resources & 30% of power is generated by Renewable resources.

Total Power	280000 MW	%
Thermal Power	195000 MW	69
Hydropower	42500 MW	15
Nuclear power	6000 MW	3
Non-Renewable	36500 MW	13

Thermal Power Plant :→

Principle: The use of oil, coal or gas is made to produce heat energy or thermal energy which is used to generate the electrical power. Depending upon use of energy (Input, These plants are coal themal power plant, gas turbine power plant, Diesel power plant.

The chemical energy of fuel converts into steam energy, the steam energy converts in to mechanical energy and finally in to electrical energy.

- Thermal power plant is widely used to generate electric power at large scale.
- Heat energy is generated by combustion of Fuel is utilise to generated high pressure & temperature steam in boiler.
- The steam is expanded in steam turbine to produce mechanical power which is finally converted into electr energy by generator.

Chemical energy → Heat energy → Mechanical energy → electrical energy

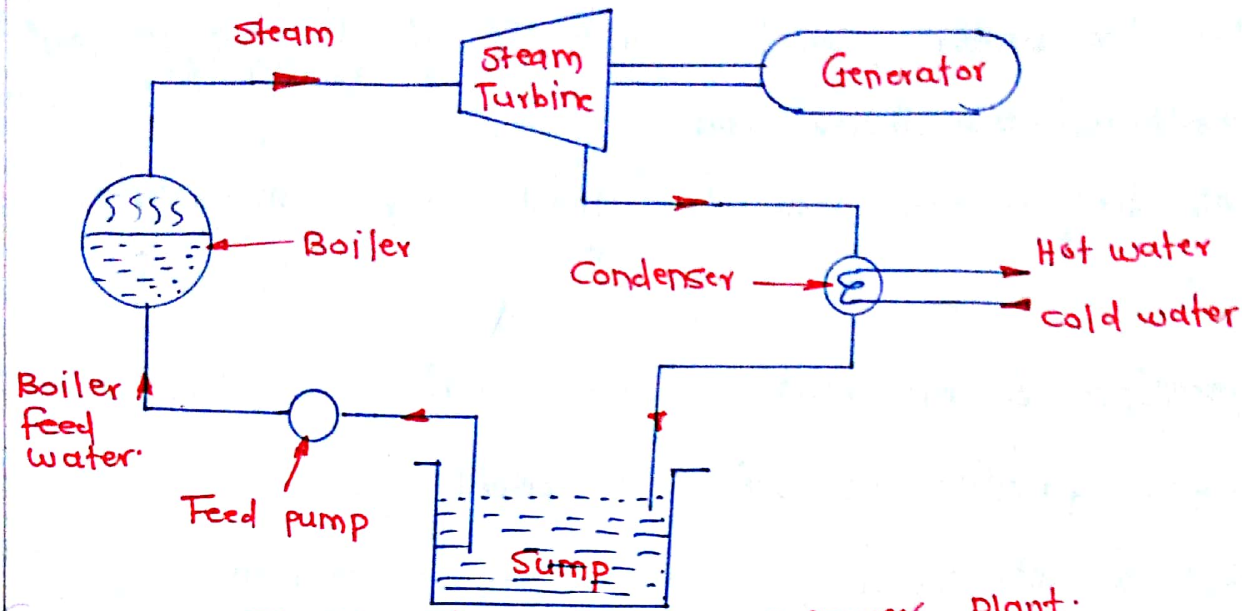

Fig: 1.1. Thermal (steam) power plant.

i) Boiler: Boiler is used to convert water in to super-heated steam.

ii) Steam turbine:- High pressure & high temp steam is expanded over the blades of steam turbine to produce shaft work.

iii) Generator: The shaft of turbine is coupled with shaft of generator, where the mechanical energy is converted into electrical power by electric generator.

iv) The exhausted steam from steam turbine is cooled and collected in condenser.

v) Feed Pump: The collected water from condenser is supplied back to boiler along with make up water.

Advantages:

i) Fuel used is cheaper

ii) Space required is less compared to other plants

iii) They can respond quickly with changes in load on the plant.

iv) Cost of power generation and it's initial cost is less compared to diesel plants.

v) Can be located near the load centre conveniently.

Disadvantages :-

i) Operation & maintenance cost is high.

ii) Large quantity of water is needed.

iii) Coal & ash handling poses a serious problem.

iv) Causes pollution.

v) Part load efficiency is low.

Applications :-

Thermal power station : Nashik – 630 MW. capacity.,
Chandrapur - 2 340 MW.,
Rajghat power station Delhi,
Panipat thermal power station - Punjab.

Hydropower Energy :-

Def. : Hydro power energy is the energy which is derived from the motion of water. or

Hydropower energy refers to the conversion of energy from flowing water into electricity.

Principle: The principle of hydroelectric power plant is that the potential energy of water stored at great heights in the dam is converted into kinetic energy by allowing water to flow at high speed. Then this K.E. of flowing water is used to generate electricity.

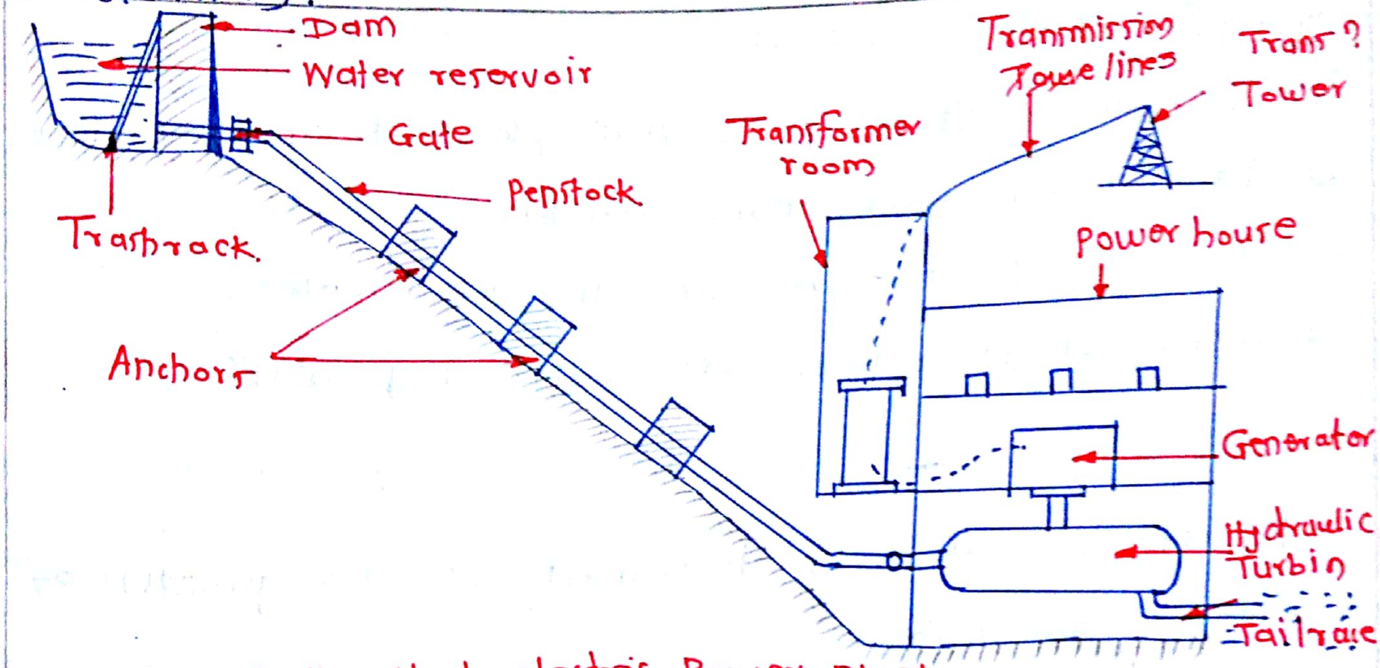

Fig.1.2. Hydroelectric Power Plant.

Working :→

- The basic requirement of hydroelectric plant is a reservoir where large amount of water is stored during rainy season & used in other seasons.
- During the operation the water is supplied to the turbine through the penstock which is located at much lower level than the height of water in the reservoir.
- Then the water is impinged on the turbine blades which drives the turbine shafts. As turbine shaft is coupled to generator shaft generator converts that mechanical work of turbine shaft in to electrici

Advantages :-

i) Water resource is easily available.

ii) No fuel is to burnt to generate the power.

iii) It's operation cost is less.

iv) Starting & stopping of this plant takes less time.

v) These plants are more reliable.

vi) These plants has no ash disposal problems.

vii) These plants require less supervising staff.

Disadvantages :-

i) Power generation is dependent on the quantity of water available.

ii) Time required for plant setup is more.

iii) Located away from the located (load) centres

iv) Transmission losses are more.

v) Require long transmission lines.

Energy Conversion :-

Potential energy → Kinetic energy → Mechanical energy rotation of turbine shaft → Electrical energy by generator.

Applications :-

i) Hydroelectric power plant Koyna - 1920 MW.

ii) Hydroelectric power plant Ghatghar - 250 MW.

iii) Hydroelectric power plant Bhatghar - 32 MW.

iv) Hydropower plant Dhudhganga Nagar - 24 MW.

Nuclear Energy :→

Def^n : The energy released during nuclear fission between an unstable atoms like uranium, plutonium, etc to generate electricity.

Nuclear Power Plant :→

Principle :→ Nuclear power plant utilizes nuclear energy produced by nuclear reactions for generation of steam. Nuclear power plant is similar to thermal power plant, only difference is that the boiler of steam power plant is replaced by nuclear reactor.

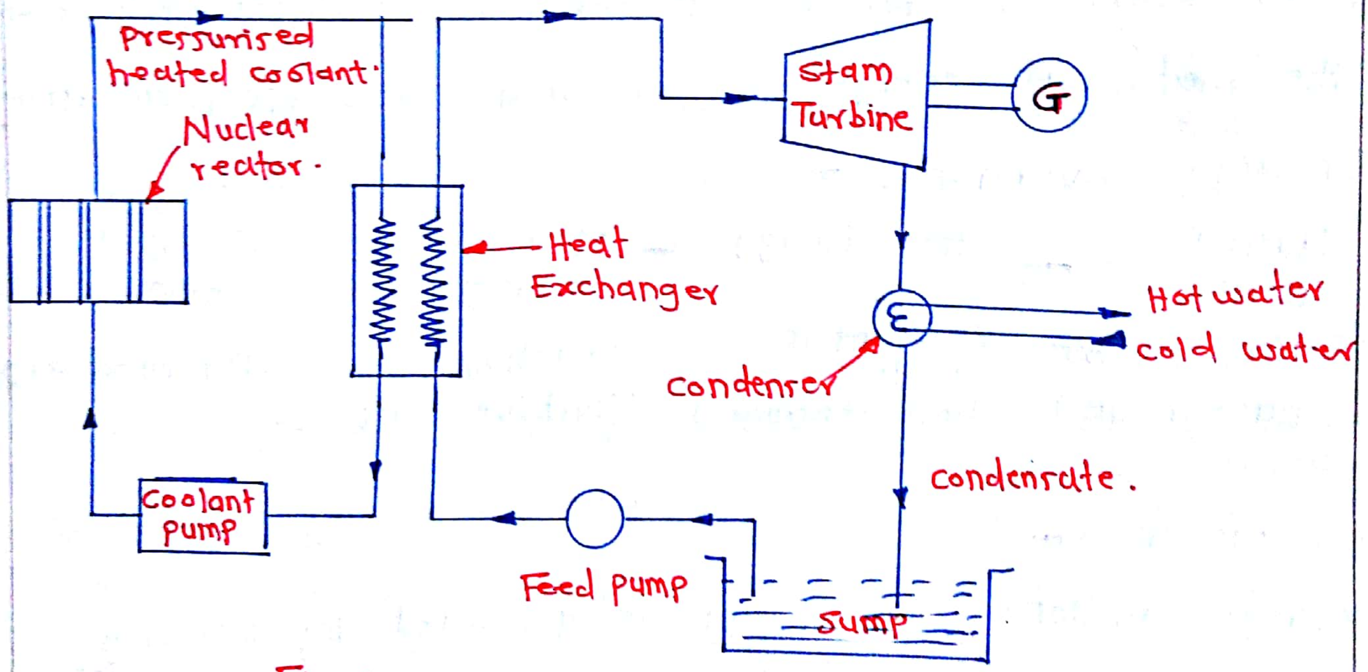

Fig. 1·3. Nuclear Power plant.

Working :→

i) The commonly used nuclear fuels are unstable atoms like Uranium (U^{235}), Thorium (Th^{232}) & Plutonium (Pu^{239}).

Fission reaction & fusion reaction.

ii) These unstable atoms liberate large amount of heat energy. The energy released by the complete fission of 1 kg of Uranium is equal to the heat energy obtained by burning 45000 tonnes of coal or 2200 tonnes of oil.

iii) In nuclear reactor, nuclear energy is produced & this energy is transffered to circulating coolant.

iv) Heat absorbed by the coolant is transffered to the water & steam is generated. This steam impacts on steam turbine producing mechanical energy.

v) As shaft of turbine is coupled to shaft of generator the mechanical energy is converted into electrical ~~energy~~.

Energy Conversion :→

Nuclear energy	→	Heat Energy	→	Mechanical Energy	→	Electrical Energy.
(Fission process in nuclear ele.)		(coolent is heated in Heat Exchanger.)		(Rotation of Turbine shaft		(By Generator)

Advantages :→

i) Large amount of energy is generated by burning small amount of fuel.

ii) Less space is required compared to Steam Power Plant

iii) It does not cause air pollution.

iv) Problem of large amount of fuel transportation & its storage facility is not needed.

v) Reduces demand of depleting resources like: coal, oil, gas.

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vi) No fossile fuel used.

vii) Performance & efficiency is high.

Disadvantages :→

i) It's capital cost is high

ii) It needs trained manpower.

iii) Nuclear reactor fuels are not easily available.

iv) It has problem of radioactive waste disposal.

v) High degree safety is needed for persons working on these plants against the nuclear radiation.

Applications :→

i) Nuclear power plant, Gujrat - 440 MW.

ii) Nuclear power plant, Tarapur - 1400 MW.

iii) Nuclear power plant, Rajasthan - 1180 MW.

iv) Nuclear Power Plant, Tamilnadu - 2000 MW.

Solar Energy :→

Def^n: Solar energy refers to capturing the energy emitted by the sun & Subsequently converting it into electricity. Solar energy is the most abundant, renewable source in the world. As the sun is expected to radiate at constant rate for billions of years, it may be considered as an inexhaustible source of energy.

Principle :→

- The energy produced & radiated by the sun or or sun radiations reaches to earth.

→ This energy is received in the form of radiations and it can be directly converted into other forms of energy like heat, electricity, ~~etc~~.

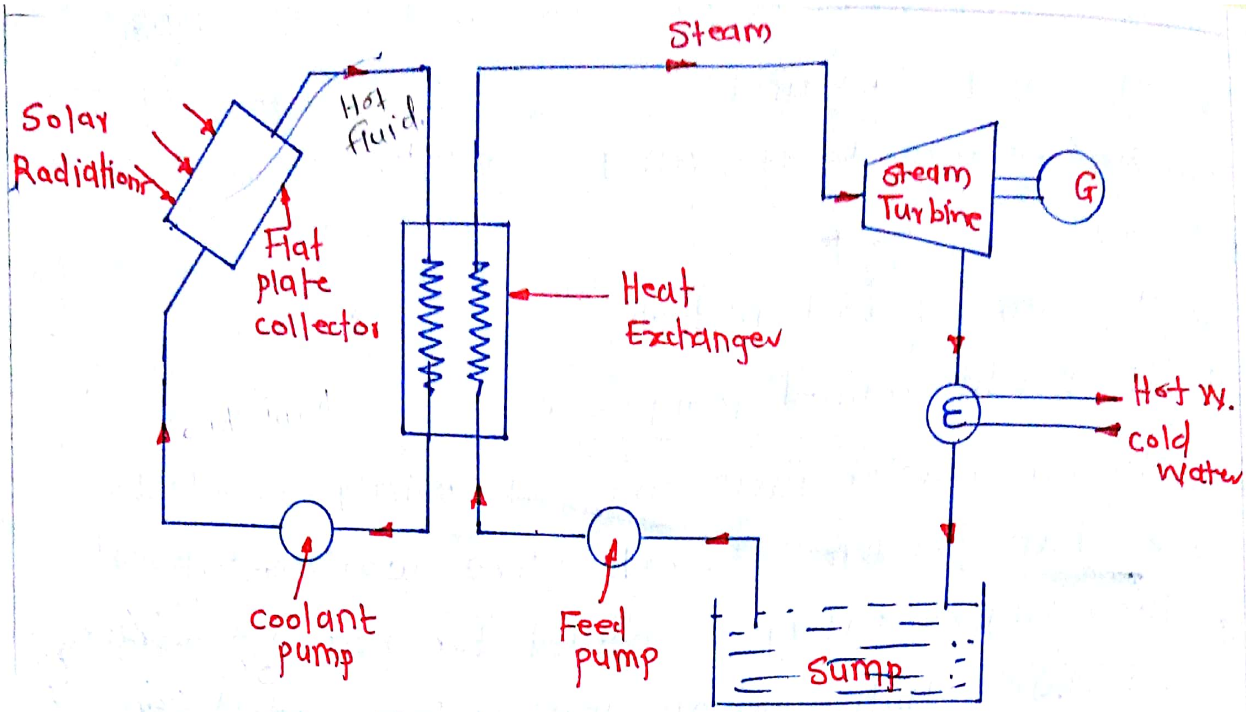


Fig. 1.4. Solar Power plant.

Working:—
The solar power plant utilizes the solar energy of sun rays & converted it into directly or indirectly electrical energy. Solar power plant may use PV cells for direct conversion & may use solar plates which transfer heat to water & generates steam.
Then this steam is expanded in turbine tends to rotate turbine shaft and mechanical work is produced. As the turbine shaft coupled to generator shaft. mechanical energy is converted into an electrical energy.

Energy conversion:

Solar Energy → Heat energy → Mechanical Energy → Electrical Energy.

① Solar concentrator type solar power plant

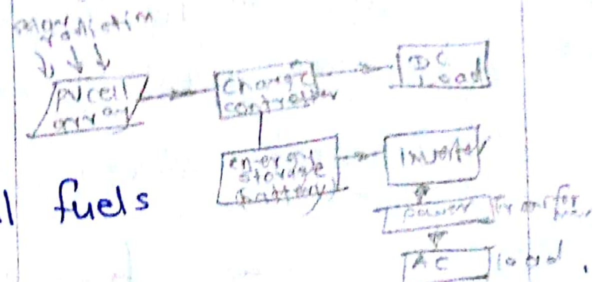
Advantages :-

i) Solar power is pollution free
ii) Reduces electricity bills
iii) Best solution for depleting fossil fuels
iv) Low maintenance cost
v) Diverse applications
vi) Solar energy is freely available.
vii) Low running cost.

Disadvantages :-

i) Initial cost of plant is high
ii) Weather Dependent Source.
iii) Solar energy storage is expensive
iv) Use lot of space.
v) The efficiency is low.
vi) It is Intermittent source because it is not available at night.

② Solar Photovoltaic (PV) cell Type solar power plant



Solar photovoltaic (PV) cells are used to convert the solar energy directly into an electrical energy. Since the power output of one cell is 3 W, the solar cell are connected in series or parallel to form a photovoltaic array to produce large power output. This power can be used either directly as DC power or AC power by using an inverter.

Applications :-

i) Solar water heating
ii) Solar drying of Agricultural products
iii) Solar power plant Sakri 125 MW.
iv) Solar power plant Badla Rajasthan 2255 MW.
v) Solar power plant Nandurbar
vi) Tata Solar (PV) plant Mulshi 3 MW.
vii) Solar power plant Karnool 1000 MW.

Wind Energy :-

Defn: Wind energy captures the natural wind in our environment & converts the air motion. Wind energy is the most mature & developed renewable energy.

- Electrical energy obtained from the wind with windmills or wind turbines.

Principle:→ The kinetic energy of wind is converted into mechanical energy of shaft by wind mills. Then mechanical energy is converted into electrical energy.

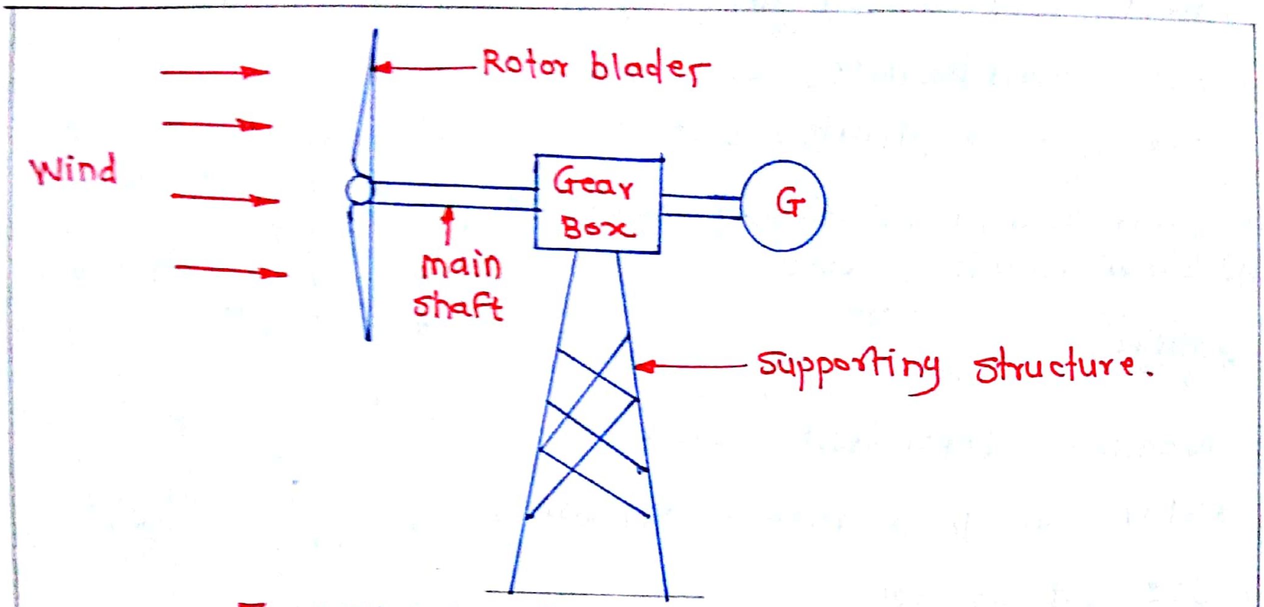


Fig. 1.5. Wind Power Plant.

Working:→

- In wind power plant, the rotor or blades of the mills rotates as the wind approaches during the operation
- This causes rotation of the shaft & therby rotation of gears generating mechanical energy.
- Finally the mechanical energy is converted into electrical energy.
- The wind power can be generated where wind velocities are more than 8 kmph.

Kinetic energy (Wind flow) → Mechanical Energy (Rotation of shaft) → Electrical Energy

Advantages:→

i) Wind is available at No cost.

ii) It has low running & maintenance cost.

iii) Wind energy is unexhaustible source of energy.
iv) It is clean and non-polluting source.
v) Wind power plant does not require fuel.

Disadvantages :→

i) Wind with required speed is not available all the times.
ii) It is location dependant which are away from cities.
iii) Wind supply is variable, unsteady so may impact on power generation.
iv) Storage of wind energy (electrical energy) is expensive.

Applications :→

The wind power can be used to run water pumps, charging of batteries or for generation of power.

i) Bramhanwel wind power plant 528 MW.
ii) Tuljapur (Siemens wind power plant) 126 MW.
iii) Suzlan energy Power plant 1064 MW.
iv) Dhalgoan (Sangli) - 278 MW.

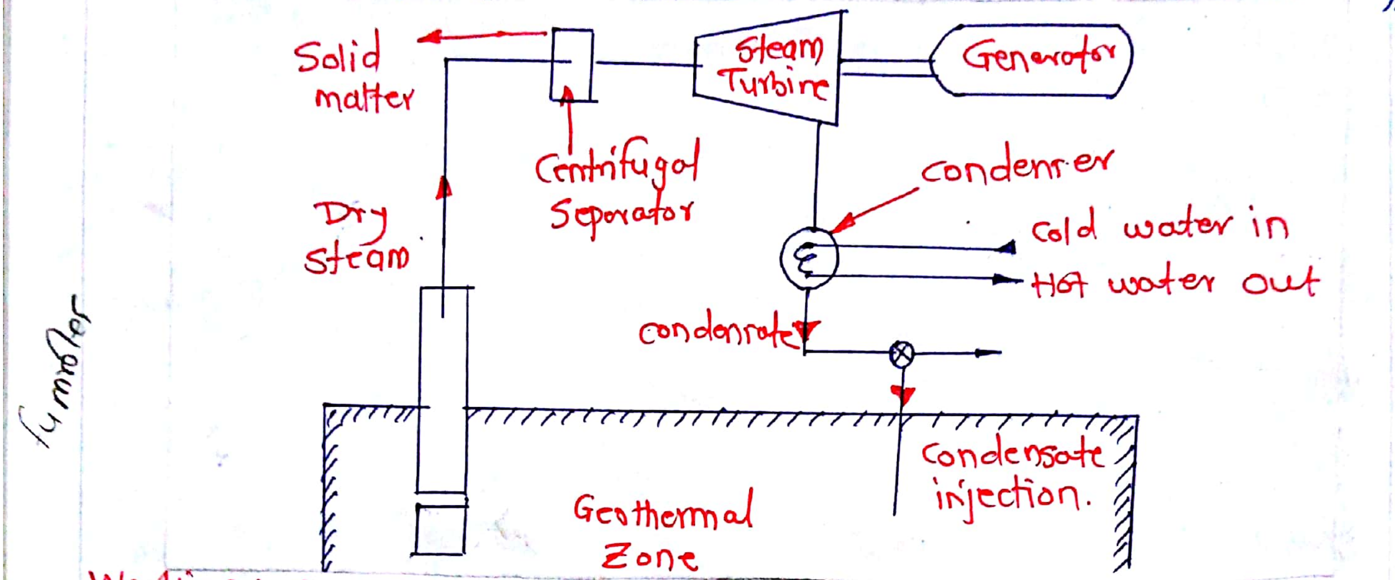
Geothermal Energy :→

Def : Geothermal energy refers to the production of energy using the internal heat of the earth's crust. It is generated & stored in the earth.

eg. A lava funtain is an example of amount of heat stored in the earth.

Geothermal power plant uses hydrothermal resources that have both water (hydro) & heat (thermal).

Principle :→ The core of earth is considerably hot, & also having reservoir of steam are created inside the earth. This hot steam is utilized to generate electricity.



Working :→

At a geothermal power plant, wells are drilled 1 or 2 miles deep into the earth to pump steam or hot water to the surface.
7 to 10 thousand feet deep

Hot water is pumped from deep underground through a well under high pressure. When the water reaches the earth surface, the pressure is dropped, which causes the water to turn into steam. The steam rotates the turbine which is connected to generator that produces electricity. The steam cools off in cooling tower & pumped back into the earth.

Advantages :→

1) Renewable energy Source
2) cost of fuel is negligible.
3) Less polluting compared to thermal power plant.
4) component required are less.
5) Less capital cost.

Disadvantages :→

i) Availability at certain regions only.

ii) Low efficiency

iii) Difficult to locate & bring in operation

iv) Steam carries lot of other particles requires filtration

Applications :→

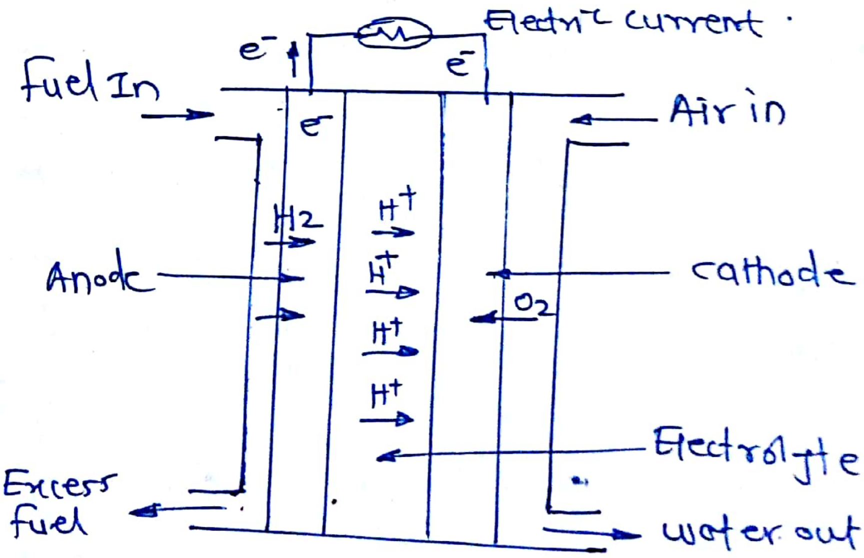
i) Geothermal power plant Jharkhand 107 MW.

ii) Geothermal Power plant Godavari 17 MW.

Hydrogen Energy :→

Hydrogen fuel is a zeroemission fuel, when burnt with oxygen. Hydrogen is a clean fuel. In a flame of pure hydrogen gas, burning in air, the hydrogen (H_2) reacts with oxygen (O_2) to form water (H_2O) & release energy.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + \text{Energy}.$$



Principle: The chemical energy of fuel is converted into electrical energy without combustion. The electrochemical energy combination observed in fuel cell.

Working :- Large tanks of liquid hydrogen will feed into thousands of Hydrogen fuel cells. These fuel cells are solid structures containing an electrolyte fluid, & two terminals much like batteries. The reactants flow into cells, in this case hydrogen & oxygen. The water flows out another port while the electricity is siphoned off the terminals & held in gigantic multi-ton batteries. The electricity resides in batteries until it is needed.

Advantages :-

i) It doesn't produce any harmful emission.
ii) It is environmental friendly & readily available.
iii) No greenhouse gases or other particulates are produced by the use of hydrogen fuel cells
iv) It is infinite source of energy
v) It's a renewable energy source & bountiful in supply
vi) It practically a clean energy source
vii) Hydrogen energy is non toxic
viii) It is more efficient than other sources of energy

Disadvantages :-

i) Hydrogen energy is expensive
ii) Storage complications means difficult to store
iii) Tricky to move around.
iv) It is highly inflammable.

Applications :- Hydrogen fuel cell used in satellites, NASA for space program
i) Automobile applications - car, in Houses for portable power material handling equipments. In Electrical system

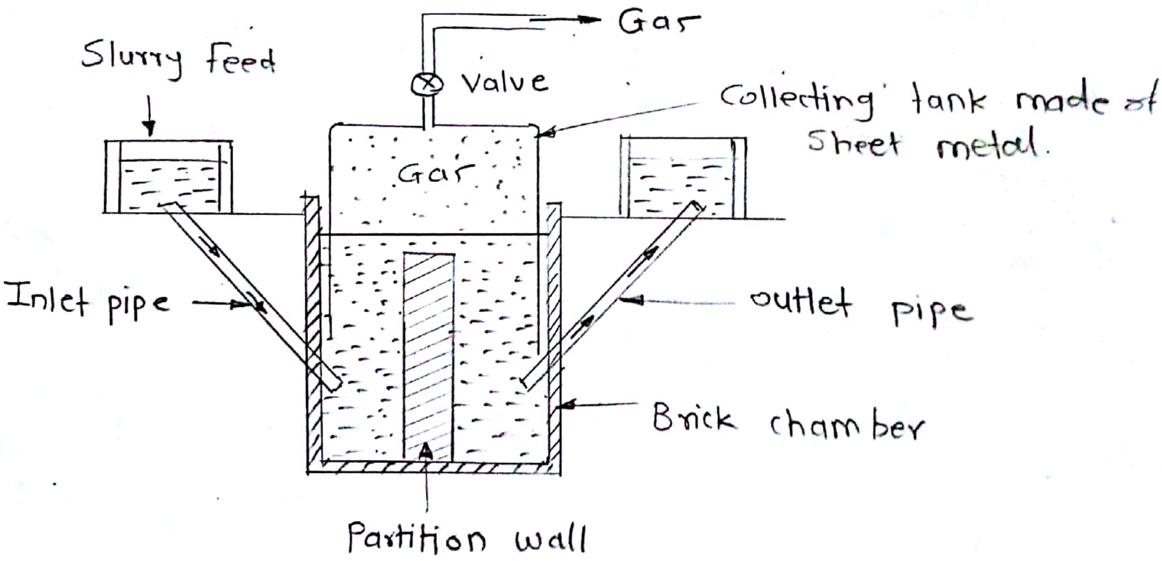
Biomass Energy :→

Defn: Biomass energy is a energy generated & produced by living or once living organisms. The most common biomass materials used for energy are plants such as corn & soy.

Biomass Power Plant :→

Principle :→

The organic matter (Biomass) energy is converted into liquid or gas fuel to get the heat energy. The conversion of Biomass into fuel is carried under decomposition process.



Working :

Biomass resources are of three categories solid mass (wood & agriculture residue), liquid fuel (ethanol, methanol).

The biogasses is used to generate electricity in power plant.

The brick chamber decomposes the Biomass like cowdung, forest & plant waste. it is mixed with water & slurry is formed. The gas after certain period is formed which is then collected to utilize as fuel through values. Also it can be used in liquid form.

Advantages :-

i) The use of waste materials reduce landfill disposal and makes space for everything else.

ii) Longer working life

iii) No corrosion problems & low cost of operation

Disadvantages :-

i) Agricultural waste will not be available if the basic crop is no longer grown

ii) Additional work is needed in areas such as harvesting methods

iii) Land used for energy crops may be in demand for other purposes such as farming, conservation, housing, resort, etc.

Applications :-

i) Akaltara (Chattisghar) 20 MW

ii) Malawali (Karnataka) 4.5 MW

iii) Samalkot mill (A.P.) 9 MW.

Tidal Energy :-

Defn: Tidal power or tidal energy is the form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity.

Tidal Power plant :-

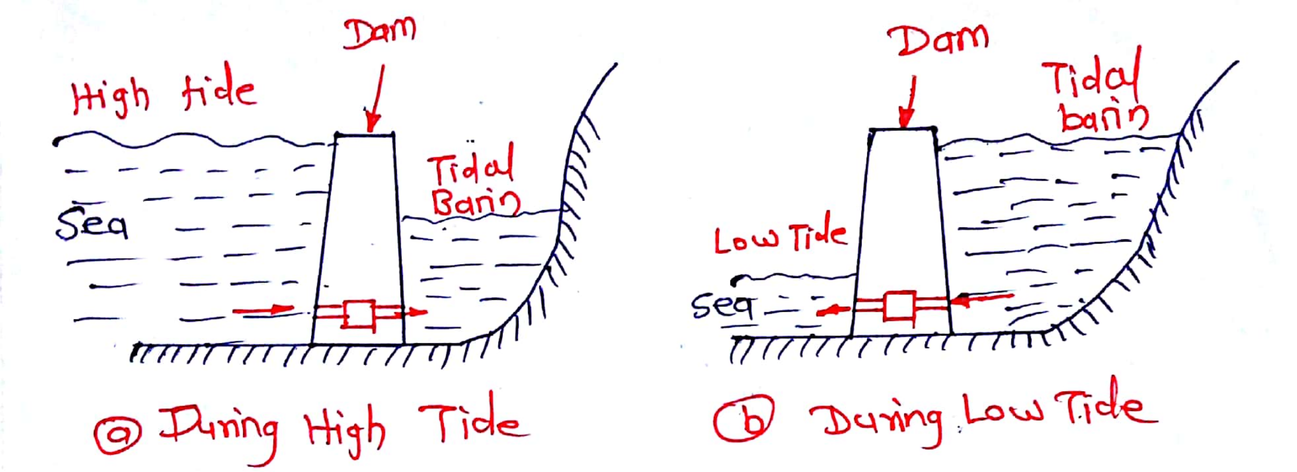


Fig: Tidal Power Plant.

Principle: Periodic rise & fall of water occured twice in each day, occurs due to gravitational forces of Moon & Sun on ocean water & are affected by spinning of earth around it's axis & relative positions of earth, moon & sun.

The ocean tides rise & fall the water level which carries K.E. converted in to mechanical energy then finally in to electrical energy.

Working:

A dam is constructed in a such a way that a basin gets seperated from the sea & a difference in the water level is obtained between basin &

sea. The potential energy of the water stored in the barn is used to drive the turbine which in turn generater electricity as it is direcly coupled to the generator.

Advantages :→

i) Tidal energy is environmental friendly & doesn't produces greenhouse gases.

ii) As 71% of earths surface is covered by water there is scope to generate this energy on large scale.

iii) Free from pollution.

iv) No rain dependancy.

v) Suitable to meet peak load demands.

vi) No extra land required.

Disadvantages :→

i) Intensity of sea wates are unpredictable & there can be damage to power generation.

ii) Influences aquatic life adversly & can disrupt migration of fish.

iii) Output power is not uniform.

iv) Corrosion of machine part due to salty water

v) Transmission cost is high for transmitting power.

Applications :→

i) Gulf of Kutch - 1200 MW

ii) Sundarban region of west Bengal 100 MW

iii) Gulf of Gujarat - 7000 MW.

Grades of Energy :→

Based on the amount of energy that can be converted into another form the quality of energy is decided. This is name as grades of energy. Due to limitations of conversion process some amount of energy will be lost during conversion.

According to the thermodynamic scenareo or amount of energy converted the grades are of following

Type :→ i) Low grade energy
ii) High grade energy.

i) Low Grade Energy :→

Def: The one form of energy is converted in to another form with less quantity as second form then it is called Low grade energy.

Ex: The thermal energy of coal fuel is converted into heat energy, mechanical & then electrical energy as final form

The amount of coal consumed or heat supply will be more as compared to it's output energy.

Heat energy (100 %) ⟶ Electrical (30 %)
(Thermal energy) Energy.

- The low grade energy are expensive
- Their efficiency is low
- Low grade energy is used for base load generation
- Available at cheaper rate.

Applications of low grade energy :-

- Thermal power plant
- Nuclear power plant
- Diesel power plant
- Process - Nuclear Fission , fuel combustion.

ii) High Grade Energy :-

Def: The energy that can be converted into almost all amount in another form can be called as high grade energy.

or

The energy that can be completely transformed into work without any loss i.e. fully utilizable.

Ex: The electrical form of energy is supplied to heat the water then almost all amount of electricity is converted into heat energy by electric heater.

Electrical Energy (100%) (Heater) ⟶ Thermal Energy (90%) (Heat energy)

- The high grade energy mean conversion into 100% other form which is impossible
- The efficiency of these energy conversion process is about 100%. (Practically above 90%)
- It is available in most usefull form.

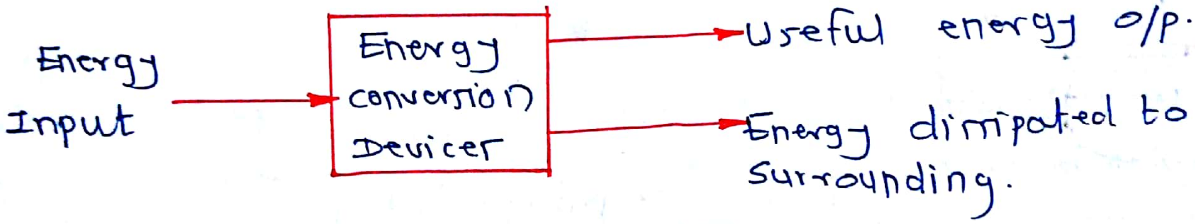
Applications of High grade energy :-

- Electrical energy
- Mechanical work
- Domestic & peak load applications.

Energy Conversion Devices :→

The energy can be transformed from one form to another and during this conversion all the energy that we put into a device comes out. However, all the energy that we put in may not come out in the desired form. Ex: we put electrical energy in to bulb & bulb produces light (which is desired form of energy) but we also get heat from the bulb. (Undesired form of energy).

When all forms of energy coming out of an energy conversion devices are added up it will be equal to the energy that is put in the device.



Pump :→

Pump is a mechanical device which converts mechanical energy into hydraulic energy.

Pump is a machine or mechanical equipment which is required to lift liqurd from low level to high level or to flow liqurd from low pressure area to high pressure area.

Pumps are broadly classified into two main categories : a) Dynamic / Rotodynamic Pump (Centrifugal pumps)
b) Positive displacement Pump (Reciprocating ")

Centrifugal Pump :→

Priciple: This pump uses centrifugal force to develop velocity in the liquid being handled. The velocity is then converted into pressure. As K·E decreses pressure energy increases. This pressure diff. drives the fluid. This device moves fluid by mechanical action.

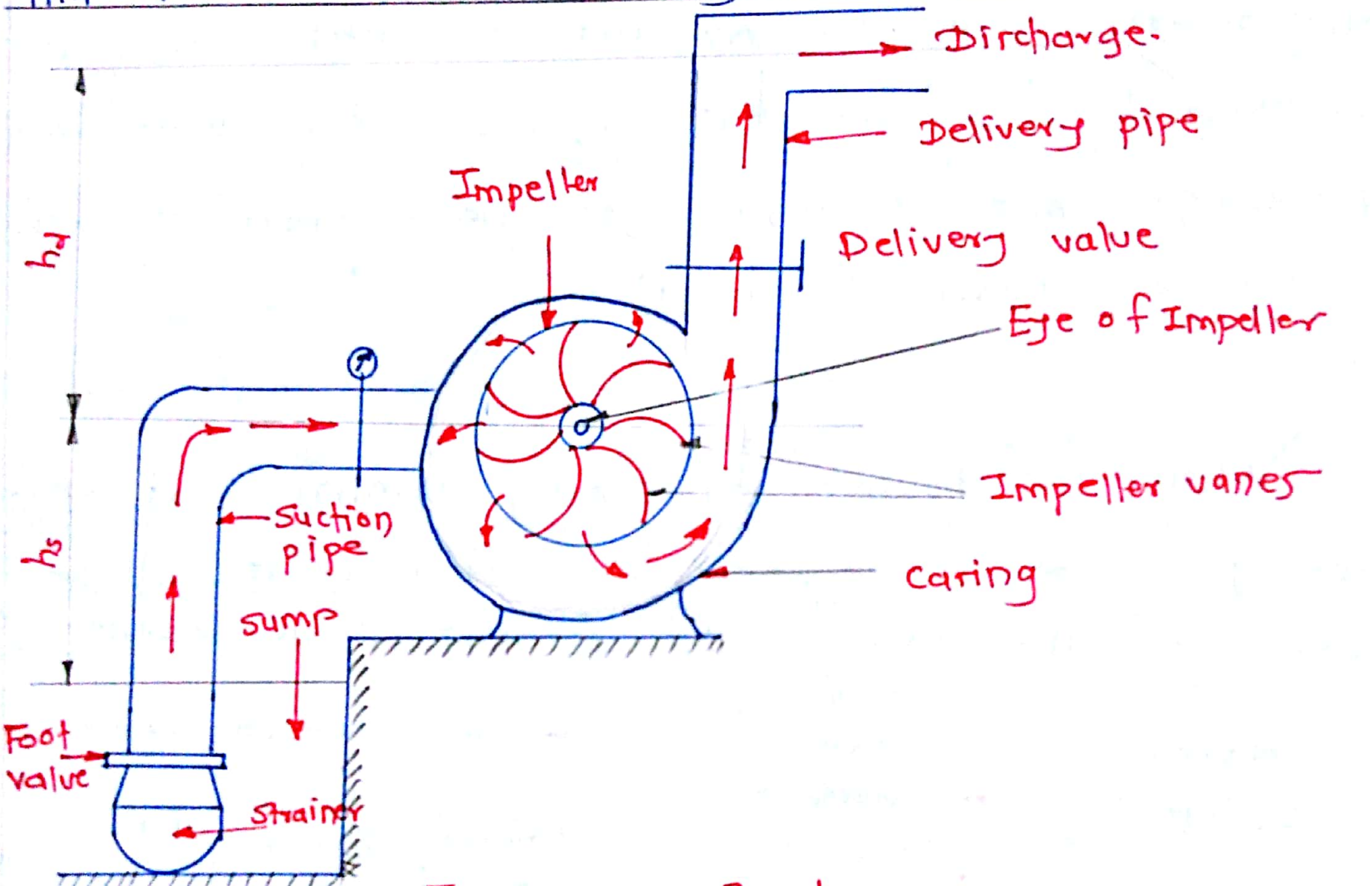


Fig. 1.10 Centrifugal Pump.

Working :→

- Initially the delivery valve is closed.
- Then the priming of the pump is carried out. Priming involves the filling the liquid in suction pipe & casing upto the level of delivery valve so that no air pockets are left in the system.
- The pump shaft & impeller is now rotated with the help of prime mover, like electric motor. The rotation of impeller inside a casing full of liquid

produces a forced vortex which is responsible in imparting the centrifugal head to the liquid. It creates a vaccum at the eye of impeller and causes liquid to rise into suction pipe from the sump.

• The speed of impeller should be sufficient to produce the centrifugal head such that it can initiate discharge from delivery pipe.

• Now the delivery valve is opened and the liquid is lifted & discharged through the delivery pipe due to it's high pressure.

Thus the liquid is continuously sucked from the sump to impeller eye & it is delivered from the casing of pump through the delivery pipe.

Function:-

i) It gives (delivers) flow volume & pressurise fluid.

ii) Combination of low to medium flow & pressure is used for different applications.

Advantages:-

i) Small in size

ii) Less capital cost

iii) Easy for maintainance.

iv) Deal with large volume

v) Able to work medium to low viscous fluid.

vi) Produce less friction.

Disadvantages:-

i) Extra priming for pump is required

ii) cannot be able to work high head.

iii) Cannot deal with high viscous fluid.

iv) Energy loss because of coupling that produce some magnetic resistance.

v) Low flow can lead to overheating of the pump.

Applications :→

i) Waste management, Agriculture & manufacturing :

- Waste water processing plant, gas processing, irrigation, flood protection.

ii) Pharmaceutical, chemical food industries :

- Paints, hydrocarbons, sugar refining food & beverage production.

iii) Various industries (Manufacturing, industrial, chemical, pharmaceutical, food production aerospace industry, etc.

Air Compressor :→

An air compressor is a device which compresses the atmospheric air to a higher pressure at the expense of external work supplied. either by electric motor or I.C. engine.

Principle: In an air compressor, air is compressed by pulling in atmospheric air, reducing it's volume & increasing it's pressure.

Classification:

i) Reciprocating air compressor

ii) Rotary air compressor.

Single Acting Compressor :→

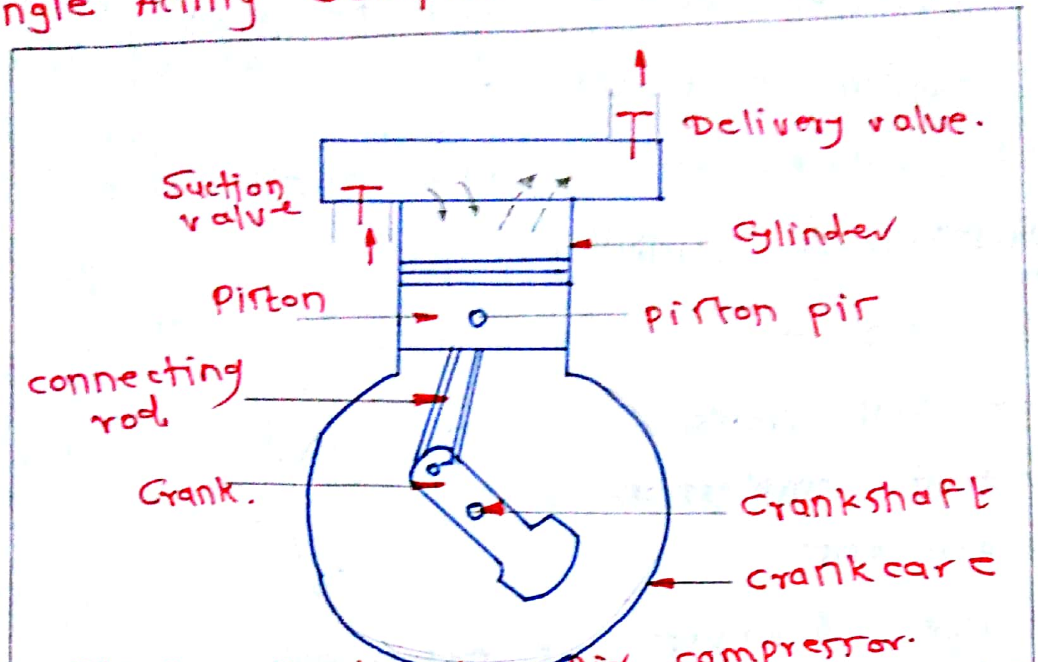


Fig: 1.11. Single acting Air compressor.

- As piston starts moving upward the inlet valve is closed and pressure starts increasing continuously. It increases till it exceeds the pressure of delivery side.
- The delivery valve opens & air enters into receiver during remaining upward motion of piston.
- At the end of delivery stroke small volume of pressure is left in clearance space. this high pressure air expands as piston starts moving.
- Inlet valve then opens as the pressure inside the cylinder falls below atmospheric pressure and air from atmosphere is taken in & cycle is repeated.

Advantages :→

i) Small size and weight

ii) Do not require separate cooling systems.

iii) Generally can be located close to point of use

iv) Simple maintenance procedures.

v) Used to produce high pressure gas

vi) High efficiency & flexibility.

Disadvantages :→

i) Relatively high noise

ii) High cost of compression

iii) High vibrations

iv) Piston rings & valves are extremely sensitive to the dirt present in fluid.

v) Part of work input is lost due to frictional resistance.

Applications :→

i) To operate pneumatic tools like drill, hamers, riveting machine, etc

ii) For spray painting

iii) In refrigeration & air conditioning industry.

iv) In gas turbine power plants

v) For conveying the materials like sand & concrete along a pipe line.

vi) In blast furnaces.

vii) In automobile service station.

viii) It is widely used in oil refineries, gas piplines, natural gas processing plants, chemical plants, etc

Turbine :→

Turbine is a mechanical rotary device which convert the pressure energy of fluid into mechanical work.

Ex: Hydraulic turbine : Pressure + K·E (Water) → Mechanical Energy

Steam turbine : Pressure + K·E (steam) → Mechanical Energy.

Classification :

According to nature of passing the fluid on turbine they are classified into two main categories:
(i) Impulse Turbine , (ii) Reaction Turbine.

In impulse turbine high pressure (hydraulic) energy is converted into kinetic energy by nozzle the jet is formed which strikes the blades converted into rotary energy of shaft. .

In reaction turbine some amount of available energy is converted into kinetic energy before the fluid enters runner. A reaction turbine is a type of turbine that develops torque by reacting to the pressure or weight of a fluid.

Principle : when the fluid strikes the blades of the turbine, the blades are displaced, which produces rotational energy.

Peton Turbine :→

It is a type of tangential flow impulse turbine used to generate electricity in the hydroelectric power plant.

Principle: The stram flow along the inner curve of the bucket and leave it in the direction oppoite to that of incoming jet. The high speed water jets running the pleton wheel turbine are obtained by expanding the high pressure water through nozzles to the atmospheric pressure.

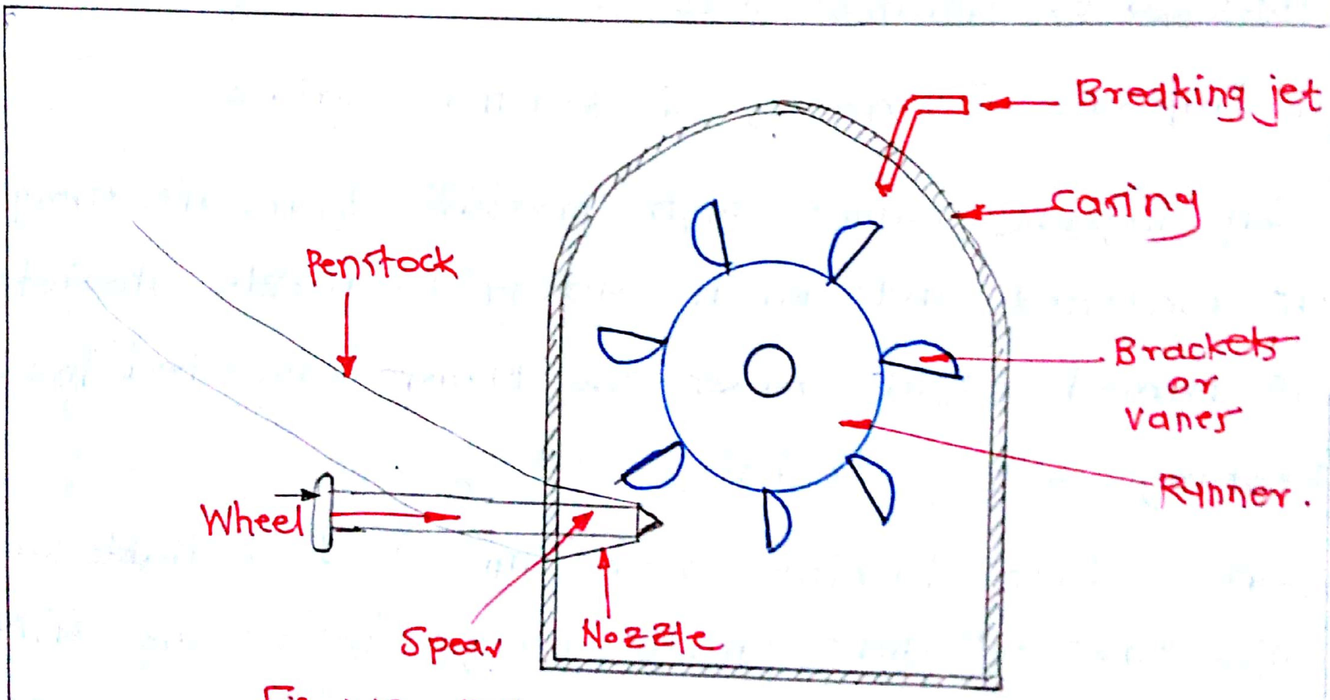


Fig. 1.12. Pelton Turbine.

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Working of pelton turbine:

- The water stored at high head is made to flow through the penstock & reaches the nozzle of the pelton turbine.
- The nozzle increases the K.E. of the water & direct the water in the form of jet.
- The jet of water from the nozzle strikes the buckets (vanes) of the runner. This made the runner to rotate at very high speed.
- The quantity of water striking the vanes or buckets is controlled by the spear present inside the nozzle
- The generator is attached to the shaft of runner which converts the mechanical energy (i.e. rotational energy) of the runner into electrical energy.

Applications:→

i) Pelton turbine is used in the hydroelectric power plant where the water available at high head (150m to 2000m).

ii) In hydroelectric power plant it is used. to drive the generator.

Advantages:→

i) It has simple construction.

ii) It is easy to maintain

iii) No cavitation problem

iv) It's overall efficiency is high

v) Intake & exhaust of water takes place at atm. pressure hence no draft tube is required.

vi) It can be both axial and radial flow

vii) It can work on low discharge.

Disadvantages:→

i) It requires high head for operation

ii) Turbine size is generally large

iii) It's efficiency decreases quickly with time

iv) Due to high head it is very difficult to control variations in operating head.

Wind mills :→

Wind mill is a structure that converts ~~the energy~~ of wind into rotational energy by means of vanes called sails or blades.

Principle:→ The basic principle of every windmill is to convert K.E. of wind into mechanical energy which is used to produce electricity.

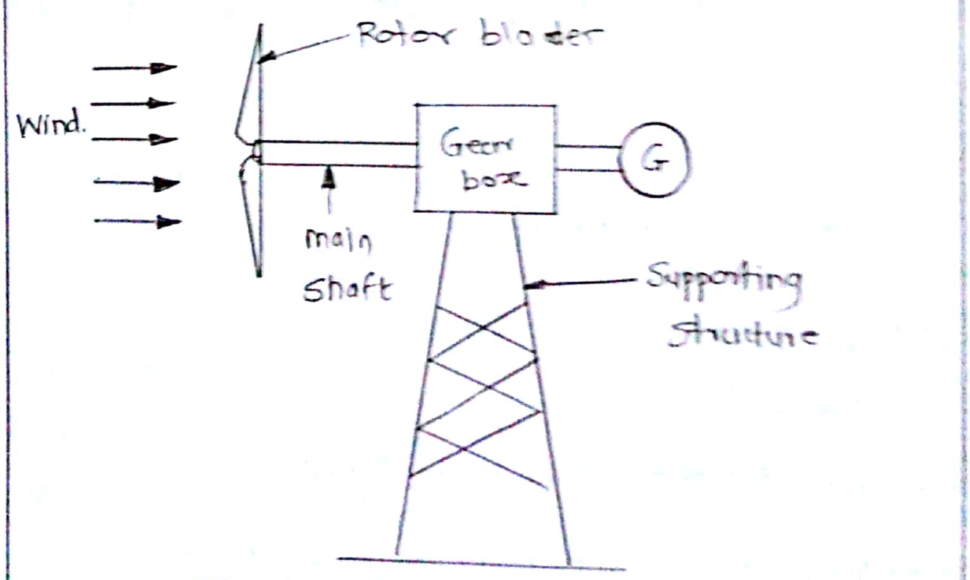

Fig. 1.13. Wind mills

Working :→

The wind can be utilized for the generation of electrical power with the help of wind turbine generators. The wind power can be generated where wind velocities are more than 8 kmph.

Wind turbine operate on a simple principle. The energy in the wind turns two or three propller-like blades around a rotor. The rotor is connected to main shaft, which spins the generator shaft to generate electricity.

Applications of wind mill :→

i) Wind mills can be used in many ways. These include

a) Grinding grain or spices

b) Pumping water

c) Sawing wood.

ii) Modern wind power machines are used to create electricity. (Power Generation)

iii) Charging of batteries.

Advantages :→

i) It's a clean fuel source.

ii) Non polluting source of energy like

iii) Wind turbine don't produce atmospheric emission that causes acid rain or greenhouse gasses

iv) Wind power plant does not require fuel

v) It has low running and maintanance cost.

vi) Wind energy is unexhaustible source of energy.

vii) Freely available.

Disadvantages:

i) Wind with required speed is not available all the time and at all the places.

ii) It is whether and location dependent.

iii) Storage of wind energy is expensive.

iv) Installation is expensive.

v) Noise disturbance,

Numericals on Efficiency Calculation of Thermal Steam Power Plant.

Formula:

★ For steam power plant input power is

* For mass flow rate:

Input Power (P_i) =

P_i = Mass flow rate of fuel (kg/s) x calorific value (J/kg)

$\therefore \boxed{P_i = \dot{m}_f \times C.V \quad (\text{Watt or } J/sec)}$

* For volume flow rate:

Input Power (P_i) =

P_i = Volume flow rate of fuel (m^3/s) x calorific value (J/m^3)

$\therefore \boxed{P_i = \dot{V}_f \times C.V \quad (\text{Watt or } J/sec)}$.

★ For Hydraulic Power Plant input power is,

P_i = Water power

$\boxed{P_i = \rho g Q H \quad (\text{Watt or } J/sec)}$

Where, ρ = Density of water in kg/m^3 = 1000 kg/m^3

g = Gravitational acceleration in m/s^2 = 9.81 m/sec^2

Q = Volume flow rate of water in m^3/s =

H = Available head of water (Height) in m.

Output Power (P_o):

$$\boxed{P_o = \frac{2\pi N T}{60} \ W}$$

Efficiency (η):

$$\boxed{\eta = \frac{P_o}{P_i} \times 100}$$

Torque (T):

T = Tangential force (N) x Radial Distance (m)

$$\boxed{T = F \times d. \ N\text{-}m}$$

calorific value is a characteristic for each substance. It is measured in units of energy per unit of the substance. (Kcal/kg or kJ/kg)

Numericals

Formula :

Power : Power is a rate of doing work or transferring heat. It is amount of energy transferred or converted per unit time

It is a scalar quantity.

The S.I unit of power is J/sec or watt. It is also expressed in KW, MW, etc.

→ 1 KW = 1000 W and 1 MW = 1000 KW.

Mathematically :

$$P = \frac{\text{Energy}}{\text{Time}} = \frac{E}{t}$$

or $P = \text{Force} \times \text{Velocity} = F \times V$

or $P = \text{Torque} \times \text{Angular velocity} = T \times \omega$

but $\omega = \frac{2\pi N}{60}$ rad/sec (N = No. of rev. r.p.m)

(T = Torque in N-m.

$$\therefore \boxed{P = \frac{2\pi NT}{60} \text{ Watt.}}$$

In Electrical, $P = \text{Voltage} \times \text{current} = V \times I.$

1) A steam power plant has coal consumption of 165 tonnes per hour. The calorific value of coal is 3500 Kcal/kg. If the power generation is 250 MW. Find overall eff. of the plant. Take. 1 kcal = 4.18 KJ.

→ Given:

$\dot{m}_f = 165 \text{ tonnes/hr} = \dfrac{165 \times 10^3 \text{ (kg)}}{3600 \text{ (sec)}}$

$= 45.8333 \text{ kg/sec.}$

• $C.V = 3500 \text{ kcal/kg}$

$= 3500 \times 4.18 \text{ KJ/kg.}$

$C.V = 14630 \text{ KJ/kg}$

$= 14630 \times 10^3 \text{ J/kg}$

output power $= P_o = 250 \text{ MW} = 250 \times 10^6 \text{ W.}$

→ $\eta = ?$

Input Power $= P_i = \dot{m}_f \times C.V.$

$= 45.8333 \times 14630 \times 10^3$

$\therefore \boxed{P_i = 670.5411 \times 10^6 \text{ Watts}}$

efficiency $\eta = \dfrac{P_o}{P_i} \times 100 = \dfrac{250 \times 10^6}{670.5411 \times 10^6} \times 100$

$\therefore \boxed{\eta = 37.283 \%}$

---

2) A small generating plant of 100 KW capacity uses gas of calorific value of 4000 KJ/m³. The volume of gas required per hour when the plant is running at full load condition is 450 m³/hr. Find a) Input power b) overall eff. of the plant.

→ Given:

$P_o = 100\ kW = 100 \times 10^3\ W$

$CV = 4000\ kJ/m^3 = 4000 \times 10^3\ J/m^3$

Volume flow rate $= \dot{V}_f = 450\ m^3/hr = \frac{450}{3600}\ m^3/sec$

$\therefore \dot{V}_f = 0.125\ m^3/sec$.

$P_i = ?$

$\eta = ?$

Input power

→ $P_i = \dot{V}_f \times C.V$

$P_i = 0.125\ (m^3/sec) \times 4000 \times 10^3\ (J/m^3)$

$\therefore \boxed{P_i = 500 \times 10^3\ J/sec}$ or Watts.

Efficiency,

$$\eta = \frac{P_o}{P_i} \times 100$$

$$= \frac{100 \times 10^3}{500 \times 10^3} \times 100$$

$\therefore \boxed{\eta = 20\ \%}$

Q3) A steam power plant has coal consumption of 16200 kg/hr with calorific value of coal as 17793.9 kJ/kg. If the speed of turbine is 1000 rpm. and generated torque is 477464.8293 N-m. Find a) Input power b) Output power c) efficiency.

→ Given:

$\dot{m}_f = 16200\ kg/hr = \frac{16200}{3600}\ \frac{kg}{sec}$.

$\dot{m}_f = 4.5\ kg/sec$

$C.V = 17793.9\ kJ/kg = 17793.9 \times 10^3\ J/kg$.

$N = 1000\ rpm$, $T = 477464.8293\ N\text{-}m$.

$P_i = ?$, $P_o = ?$ $\eta = ?$

→ Input Power (P_i)

$P_i = \dot{m}_f \times C.V.$

$= 4.5 \times 17793.9 \times 10^3$

$\therefore \boxed{P_i = 80.0725 \times 10^6 \text{ W.}}$

Output Power (P_o)

$P_o = \text{Torque} \times \text{Angular velocity}$

$= T \times \omega$

$= T \times \frac{2\pi N}{60}$

$= 477464.8293 \times \frac{2\pi \times 1000}{60}$

$\therefore \boxed{P_o = 50 \times 10^6 \text{ Watt.}}$

Efficiency (η)

$\eta = \frac{P_o}{P_i} \times 100$

$= \frac{50 \times 10^6}{80.0725 \times 10^6} \times 100$

$\therefore \boxed{\eta = 62.443 \%}$

4) A steam power plant has coal consumption of 16300 kg/hr with calorific value as 17793.9 KJ/kg. If the speed of steam turbine is 1100 rpm, radial distance is 1.5 m. and generated tangential force is 318309.8862 N. Find.

a) Generated torque b) Input and output power

c) Efficiency.

→ Given:

$\dot{m}_f = 16300 \text{ kg/hr} = \frac{16300}{3600} \text{ kg/sec} = 4.5277 \text{ kg/sec.}$

4. C.V. = 17793.9 KJ/kg = 17793.9×10^3 J/kg.

N = 1100 rpm, Radial distance $d = 1.5$ m,

Force F = 318309.8862 N.

Torque (T) = ?, $P_i = ?$, $P_o = ?$, $\eta = ?$

→ T = ~~Tangential~~ Tangential force × Radial distance

$= F \times d$

$\therefore T = 318309.8862 \times 1.5$

$\therefore \boxed{T = 477.4648 \times 10^3 \text{ N-m.}}$

Input power

$P_i = \dot{m}_f \times C.V. = 4.5277 \times 17793.9 \times 10^3$

$\boxed{P_i = 80.565 \times 10^6 \text{ Watts}}$

Output Power

$$P_o = \frac{2\pi NT}{60}$$

$$= \frac{2\pi \times 1100 \times 477.4648 \times 10^3}{60}$$

$\therefore \boxed{P_o = 55 \times 10^6 \text{ Watts.}}$

Efficiency $\eta = \frac{P_o}{P_i} \times 100$

$$= \frac{55 \times 10^6}{80.565 \times 10^6} \times 100$$

$\therefore \boxed{\eta = 68.26 \%}$

5) The coal consumption of thermal power plant is 100 Tonnes of coal / day. The calorific value of coal is 21000 kJ/kg. If the power generation ~~in one day~~ is 5000 KW. Find overall efficiency of the power plant.

→ Given:

$$\dot{m}_f = 100 \text{ tonnes/day} = \frac{100 \times 10^3 \text{ (kg)}}{24 \text{(hrs)} \times 3600 \text{ sec}}$$

$$\dot{m}_f = 1.1574 \text{ kg/sec}$$

$$C.V. = 21000 \text{ kJ/kg} = 21000 \times 10^3 \text{ J/kg}$$

Output power

$$P_o = 5000 \text{ kW} = 5000 \times 10^3 \text{ W.}$$

$$\eta = ?$$

$\frac{5000 \text{ kw}}{\text{Day}}$

→ Input power

$$P_i = \dot{m}_f \times C.V = 1.1574 \times 21000 \times 10^3$$

$\frac{5000}{24} \frac{\text{kw}}{\text{hr}}$

$$\boxed{P_i = 24.3054 \times 10^6 \text{ J/sec or Watt.}}$$

$\frac{5000}{24 \times 60} \frac{\text{kw}}{\text{min}}$

Efficiency,

$$\eta = \frac{\text{output power}}{\text{Input power}} \times 100 = \frac{P_o}{P_i} \times 100$$

or $\frac{5000}{24 \times 60 \times 60}$ kW

$$\therefore \eta = \frac{5000 \times 10^3}{24.3054 \times 10^6} \times 100$$

$$\therefore \boxed{\eta = 20.571 \%}$$

6) Determine power developed by wind mill if the wind speed is 20 m/s. and length of blade (radius) is 50 m. Take density of air as 1.23 kg/m3 and efficiency as 40 %.

→ Given:

$V = 20\ m/s$, $r = 50 m$, $\rho = 1.23\ kg/m^3$, $\eta = 40\%$.

$P_o = ?$

→ Input power of wind mill is

$$P_i = \frac{\pi}{2} \times r^2 \times V^3 \rho$$

$$P_i = \frac{\pi}{2} \times 50^2 \times 20^3 \times 1.23$$

$$\therefore \boxed{P_i = 38.6415 \times 10^6 \text{ Watts}}$$

Efficiency

$$\eta = \frac{P_o}{P_i} \times 100$$

$$\therefore P_o = \frac{\eta \times P_i}{100}$$

$$\therefore P_o = \frac{40 \times 38.6415 \times 10^6}{100}$$

$$\therefore P_o = 15.4566 \times 10^6 \text{ Watts}$$

$$\boxed{P_o = 15.4566 \text{ MW.}}$$

7) An impulse water turbine receive water from a penstock under a head of 100 m at the discharge of $1.2\ m^3/sec$. The power developed by turbine is 950 kW. Find input power and efficiency of turbine. Take $\rho_{water} = 1000\ kg/m^3$.

→ Given:

$H = 100 m$, $Q = 1.2\ m^3/se$, $P_o = 950\ kW = 950 \times 10^3\ W$,

$P_i = ?$, $\eta = ?$

→ Input power

$$P_i = \rho g Q H = 1000 \times 9.81 \times 1.2 \times 100 = 1.1772 \times 10^6\ W.$$

$$\therefore \boxed{P_i = 1.1772 \text{ MW.}}$$

Efficiency

$$\eta = \frac{P_o}{P_i} \times 100 = \frac{950 \times 10^3}{1.1772 \times 10^6} \times 100$$

$$\therefore \boxed{\eta = 80.7\ \%}$$

- Numericals on efficiency calculation of Thermal power plant:

1) A steam power plant has coal consumption of 165 Tons per Hour. Calorific value of coal is 3500 kcal/kg. If the power generation is 250 MW. find overall efficiency of the plant. Use relation 1 kcal = 4.18 kJ.

Given: Calorific value of coal = 3500 kcal/kg

Power output = 250 MW.

overall efficiency (η_o) = ?

$$\eta_{overall} = \frac{\text{output power}}{\text{input power or Energy Supplied.}}$$

Input Energy or power supplied = mass of coal × calorific value

$$= \frac{165 \times 1000}{3600} \times (3500 \times 4.18)$$

$$= 670541.667 \text{ kJ/s} = 670.541 \times 10^6 \text{ W.}$$

$$\therefore \eta_{overall} = \frac{250 \times 100}{67054.1667}$$

$$\eta_{overall} = 0.3728 = 37.28\%$$

2) A small generating plant of 100 kW capacity uses gas of calorific value of 4000 kJ/m³. The volume of gas required per hour when the plant is running at full load condition is 450 m³/hr. Find (a) Input power & (b) overall efficiency of the plant.

Given: Output Power = 100 kW.

Calorific value of gas = 4000 kJ/m^3

Amount of gas required = 450 m^3/hr.

Input Power = ?

Overall efficiency = ?

→ Input Power = mass of gas × calorific value.

$$= \frac{450}{3600} \times 4000$$

$$= 500 \text{ kJ/s} = 500 \text{ kW.}$$

$$\eta_{overall} = \frac{100}{500} = 0.2$$

$$\therefore \eta_{overall} = 20\%$$

3) A steam power plant has coal consumption of 18200 kg/hr with calorific value of coal as 17793.9 kJ/kg. If the speed of steam turbine is 1000 rpm and generated torque is 477464.8293 Nm. Find (a) Input power, (b) output power & (c) efficiency.

Given: Coal Consumption = 16200 kg/hr.

calorific value of coal = 177939 kJ/kg.

Speed of turbine (N) = 1000 rpm.

Torque generated (T) = 477464.8293 N-m.

Input power = ?

output power = ?

$\eta_{overall}$ = ?

→ Input power to shaft of turbine = mass rate of coal × Calorific value

$= \left[\frac{16200}{3600}\right] \times 17793.9$

$= 80072550.0$ W.

Output power by Turbine $= \frac{2\pi N T}{60}$ W.

$= \frac{2 \times \pi \times 1000 \times 477464.8293}{60}$

$= 50000000$ W.

$\eta_{overall} = \frac{\text{output power}}{\text{Input power}}$

$= 0.624$

$\therefore \eta_{overall} = 62.4\ \%$

4) A steam power plant has coal consumption of 16300 kg/hr with calorific value of coal as 17793.9 KJ/kg. If the speed of steam turbine is 1100 rpm. radial distance is 1.5 m and generated force is 318309.8862 N. Find (a) generated Torque, (b) Input power, (c) output power & (d) eff.

→ Given: Generated force = 318309.8862 N.

Coal Consumption = 16300 kg/hr.

Calorific value of coal = 17793.9 KJ/kg

N = 1100 rpm.

radial distance (r) = 1.5 m.

Generated torque = ?

Input Power = ? , output power = ? eff. ?

→ Torque = Force × distance

$= 318309.8862 \times 1.5$

$T = 477464.82$ N-m.

Input power = mass rate of coal × calorific value of coal

$= [16300/3600] \times 17793.3$

$= 80566825$ W.

output power $= \frac{2\pi NT}{60}$

$= \frac{2 \times \pi \times 1100 \times 477464.82}{60}$

$= 54999998.93$ W

$\eta_{overall} = \frac{\text{output power}}{\text{Input power}} = \frac{54999998.93}{80566825.0}$

$\eta_{overall} = 0.682 = 68.2\ \%$

5) Determine the power in the wind if the wind speed is 20 m/s and blade length is 50 m, air density $\rho = 1.23\ Kg/m^3$

Given: $\rho = 1.23\ Kg/m^3$

speed of air $N = 20$ m/s.

Length of blade = 52 m.

power in wind mill = ?

→ Power of wind mill $= \frac{1}{2} \times$ swept area $(\pi \times r^2)$ × air density × (velocity)^3

$= \frac{1}{2} \times [\pi \times (52)^2] \times 1.23 \times (20)^3$

Power of wind mill = 2089737.16 W.

6) In a wind mill the blade length is 63 m with the air density of 1.23 kg/m3. The speed of air available is 14 m/s. Determine the power generated by wind mill.

Given: Blade length = 63 m

density of air = 1.23 kg/m 3

speed of air = 14 m/s.

power of windmill = ?

→ Power of wind $= \frac{1}{2} \times \pi r^2 \times \rho \times v^3$

$$P = \frac{1}{2} \times \pi \times (63)^2 \times 1.23 \times (14)^3$$

$$P = 21042153.98 \text{ W.}$$

7) A wind turbine with rotor diameter ~~48~~ m operates under the velocity of wind 10 m/s. The rotor dia specified is 43 m. If the density of wind is 1.25 kg/m³. Detⁿ the power of the wind mill?

Given: rotor diameter d = 43 m ∴ r = 21.5 m.

velocity of wind v = 10 m/s.

density of wind ρ = 1.25 kg/m 3

→ power of wind mill $= \frac{1}{2} \times$ area of rotor $\times$ density of air $\times v^3$

$$= \frac{1}{2} \times \pi r^2 \times \rho \times v^3$$

$$= \frac{1}{2} \times \pi \times (21.5)^2 \times 1.25 \times (10)^3$$

$$\therefore \quad P = 907625.752 \text{ W.}$$

8) Numerical:

In steam power plant workdone by shaft is 1192 KJ/kg of steam. The heat supplied in boiler is 2344.5 KJ/kg. Det^n thermal efficiency of plant.

→

$$\eta_{thermal} = \frac{\text{Shaft work}}{\text{Heat Supplied}}$$

$$= \frac{W_s}{Q}$$

$$= \frac{1192}{2344.5}$$

$$\therefore \eta_{thermal} = 0.5084 = 50.84\%$$

9) In steam power plant turbine power is given as 11475 KJ/s. The rate of heat supplied in boiler is 43421500 J/sec. Determine thermal efficiency of power plant.

Given → Turbine power P = 11475 KJ/s.

Heat supplied Q = 43421500 J/sec.

→ $$\eta_{thermal} = \frac{\text{Power output}}{\text{Heat Supplied}}$$

$$= \frac{P}{Q} = \frac{11475}{43421500}$$

$$= \frac{\cancel{118750}}{}$$

$$= 0.2543$$

$$\eta_{thermal} = 25.43\%$$

10) A thermal power plant representr thermal cycle in which heat supplied to boiler 74115 KW and power output by turbine is 18760 KW. Find the thermal efficiency of power plant.

Given: Heat supplied $= Q = 74115$ KW.

power output $= P = 18760$ KW.

$\eta_{th} = ?$

$$\eta_{thermal} = \frac{\text{Power output}}{\text{Heat Supplied}}$$

$$= \frac{P}{Q}$$

$$= \frac{18760}{74115}$$

$$= 0.2513$$

$\therefore \eta_{thermal} = 25.13\%$

11) In steam power plant workdone by steam cycle is 745.698 kJ/kg and the heat supplied by the boiler is 2605000 J/kg. Det^n the thermal efficiency of power plant.

Given: Workdone in thermal plant $= 745.698$ kJ/kg.

Heat supplied $= 2605000$ J/kg.

$= 2605.00$ kJ/kg.

$\eta_{thermal} = ?$

$$\eta_{thermal} = \frac{\text{workdone by shaft}}{\text{Heat supplied.}}$$

$$= \frac{W_s}{Q}$$

$$= \frac{745.698}{2605.00}$$

$\eta_{th} = 0.2862$

$\eta_{th.} = 28.62\%$

12) During test on steam power plant the workdone by the turbine shaft is 575596 J/kg and heat supplied to steam generator is 2530 kJ/kg. Determine the efficiency of thermal power plant.

Given: Workdone by shaft = 575.596 KJ/kg.

Heat supplied to steam generator = 2530 KJ/kg

$\eta_{th} = ?$

$$\eta_{thermal} = \frac{\text{Workdone by shaft}}{\text{Heat supplied.}}$$

$$= \frac{W_S}{Q}$$

$$= \frac{575.596}{2530} = 0.2275$$

$\therefore \quad \eta_{thermal} = 22.75\%$

13) The steam power plant has the efficiency of 35.67% which operates on input heat supplied at 3742 KJ/kg. Determine the workdone by shaft.

Given: $\eta_{th} = 35.67\%$.

Heat supplied = 3742 KJ/kg , Workdone = ?

$$\eta_{thermal} = \frac{\text{Workdone by shaft}}{\text{Heat supplied.}}$$

$$\text{Workdone} = \eta_{thermal} \times \text{Heat Supplied.}$$

$$= 0.3567 \times 3742$$

$$W = 1335 \text{ kJ/kg.}$$

14) The thermal power plant runs on the workdone by shaft of 3600 KJ/kg. The efficiency of thermal power plant is 33.37 %. Determine the heat supplied to do the given work.

Given: $\eta_{thermal} = 33.37\ \%$

Workdone by shaft = 3600 KJ/kg.

Heat supplied = ?

$$\eta_{thermal} = \frac{\text{Workdone by shaft}}{\text{Heat supplied}}$$

$$= \frac{W_s}{Q}$$

$$\therefore Q = \frac{W_s}{\eta_{thermal}} = \frac{3600}{0.3367}$$

$$\therefore Q = 10786.56\ \text{KJ/kg}.$$

15) The thermal power station consumes the heat at rate of 2898.3 KJ/kg and it gives workdone of 927.3 KJ/kg. Calculate the efficiency of thermal power plant.

Given: Workdone by shaft = 927.3 KJ/kg

Heat supplied = 2898.3 KJ/kg.

$\eta_{thermal}$ = ?

$$\eta_{thermal} = \frac{\text{Workdone by shaft}}{\text{Heat supplied}}$$

$$= \frac{927.3}{2898.3}$$

$$= 0.3198$$

$$\therefore \eta_{thermal} = 31.98\ \%$$

★ Numericals on Turbine and Pump :→

16) The pelton turbine operates under a 40 m head and total discharge through wheel is 2.204 m^3/sec. It develops a power of 735 kW. Determine the mechanical efficiency of turbine.

Given: $h = 40\ m$

$q = 2.204\ m^3/s$

$P = 735\ kW.$

→ $$\eta_m = \frac{\text{shaft power}}{\text{water power}} = \frac{P}{wqh}$$

$$= \frac{735 \times 10^3}{9810 \times 2.204 \times 40}$$

$$\eta_m = 0.85 \quad \text{i.e. } 85\,\%$$

17) The pelton wheel is having semicircular bucket with 150 m head and consumes 50 litre/sec. of water. Determine power developed by turbine.

Given: $q = 50$ litre $= 50 \times 10^{-3}\ m^3$

$H = 150\ m$

$w = 9810$

$P = ?$

→ $$\text{Power } (P) = wqH$$

$$= 9810 \times 150 \times 50 \times 10^{-3}$$

$$= 73576\ W.$$

$$\therefore\ P = 735.76\ kW.$$

18) A centrifugal pump is required to lift 0.0125 m^3/s. of water from a well with depth 30 m. If rating of pump motor is 5 kW. Find out efficiency of pump: Take $\rho_{water} = 1000\ kg/m^3$

$P = wQH$

Given: $Q = 0.0125$ m3/sec. , shaft power = 5 KW.

$H = 30$ m

$\rho = 1000$ kg/m3

$W = 9810$

$\longrightarrow$ $P = 9810 \times 30 \times 0.0125$

$= 3.68 \times 10^3$ Nm/s

$\therefore \underline{\underline{P}} = 3.68 \times 10^3$ $\underline{\underline{KW.}}$

$$\eta_o = \frac{\text{Water power}}{\text{Shaft power}}$$

$$= \frac{3.68}{5}$$

$= 0.736$

$\therefore \eta_o = 73.6\ \%$

---

19) A centrifugal pump delivers 0.03 m^3/s of water to height of 20m. Calculate power of shaft. The loss of head in pipe is 23.81 m and efficiency is 0.72%.

Given: loss of head in pipe = 23.81 m

Head = 20 m.

Q = 0.03 m3/sec.

η = 72 %.

The power at shaft required to drive the pump

$$P = \frac{\text{water power}}{\eta_o}$$

Hydraulic power or water power = wQH.

$= 9810 \times 0.03 \times (20 + 23.81)$

$\because$ Since H = Head + loss of head

$= 20 + 23.81$

$\therefore$ Hydraulic power = 12.89 KW.

Shaft power $= \frac{12.89}{0.72} = 17.90$ KW .

20) A centrifugal pump is required to deliver 50 Liter of water/s to the height of 47 m. If the overall efficiency of pump is 70%. calculate the power required to drive the pump.

Given: $Q = 50 \text{ litre/s} = 50 \times 10^{-3} \text{ m}^3/\text{s}$

$H = 47 \text{ m}$

$\eta_o = 72\%$

$P_s = ?$

→ $P = \dfrac{WQH}{\eta_o} =$

$= \dfrac{9810 \times (50 \times 10^{-3}) \times 47}{0.7}$

$P = 32950 \text{ W}$

$\therefore P = 32.95 \text{ KW.}$

21) Calculate the power required to drive the single acting reciprocating pump for water of following specification. $Q = 4500 \text{ Lit./h}$, Head added to the flow is 10 m.

→ $P = WQH$

Watt horse power $P = \dfrac{9810 \times 10 \times 4500 \times 10^{-3}}{60 \times 60}$

$\therefore P = 12.26 \text{ hp.}$

22) A pelton wheel turbine runs at 1000 rpm with net head of 700 m and discharge through nozzle is 0.1 m3/sec. Determine the hydraulic efficiency of turbine. The jet velocity 117.2 m/s. and power developed is 667.57 KW.

Given: $H = 700 \text{ m}$

$Q = 0.1 \text{ m}^3/\text{s}$

$N = 1000 \text{ rpm}$

→ $\eta_{hydraulic} = \dfrac{\text{Power developed}}{\text{power available at input}}$

Power available at Nozzle P

$$P_i = \frac{1}{2} mV^2$$

$$m = \rho Q = 1000 \times 0.1 = 100 \text{ kg/s.}$$

$$P_i = \frac{1}{2} \times 100 \times (117.2)^2$$

$$P_i = \frac{1}{2} \times 100 \times$$

$$P_i = 686.79 \times 10^3 \text{ Nm/sec. or W.}$$

$$P_i = 686.79 \text{ KW.}$$

Now,

$$\eta_{hydraulic} = \frac{667.57}{686.79}$$

$$\eta_h = 0.972 = 97.2\ \%$$

23) The pelton wheel has power available at runner is 5039.48 KW. If hydraulic efficiency is 90.14%. Determine overall efficiency of turbine. The power at shaft is 4283.55KW.

Given: $\eta_m = 85\%$.

$P_i = 5039.48$ KW.

$\eta_h = 90.14\ \%$.

$\eta_o = ?$

$$\eta_{overall} = \eta_{mech.} \times \eta_{hydraulic.}$$

$$\eta_{mech} = \frac{\text{Shaft Power}}{\text{power available at runner or input}} = \frac{P_o}{P_i}$$

$$= \frac{4283.55}{5039.55}$$

$$\therefore \eta_{mech} = 0.85 = 85\ \%.$$

$$\therefore \eta_{overall} = 0.85 \times 0.9014 = 0.7662$$

$$\therefore \eta_{overall} = 76.62\ \%$$

Numericals on Turbine & Pumps

Formula for Turbine Problems

(overall) Mechanical efficiency (η_m)

$$\boxed{\eta_m = \frac{\text{Shaft Power}}{\text{Water Power}}}$$

In this case.

(mechanical work)

Output power is shaft power — P_o

Input power is water power (hydraulic power) — P_i

Input power (P_i)

$$P_i = \rho g Q H$$

$$\eta = \frac{P_o}{P_i} \times 100$$

$$P_o = \frac{2\pi N T}{60}$$

If necessary assume

$\rho = 1000$ kg/m3

$g = 9.81$ m/s^2

Q = volume flowrate in m^3/s

H = head in m.

Formula for pump.

overall Efficiency (η_o)

$$\boxed{\eta_o = \frac{\text{Water Power}}{\text{Shaft power}}}$$

In this case

output power is — Water power or hydraulic power — P_o

Input power is — shaft power — P_i

(mechanical work)

Input power (P_i)

$$P_i = \frac{2\pi N T}{60}$$

$$\eta = \frac{P_o}{P_i} \times 100$$

$$P_o = \rho g Q H.$$