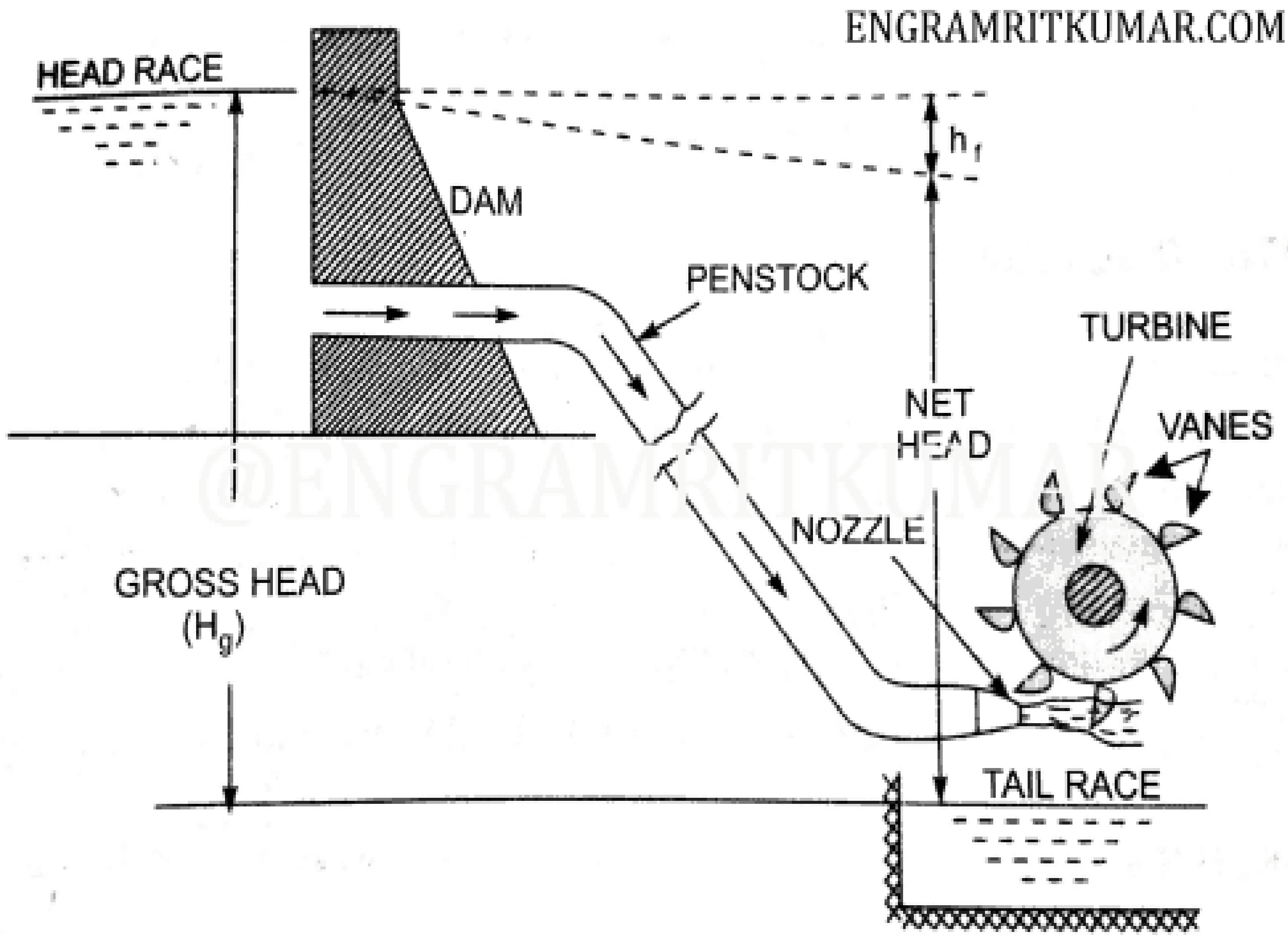
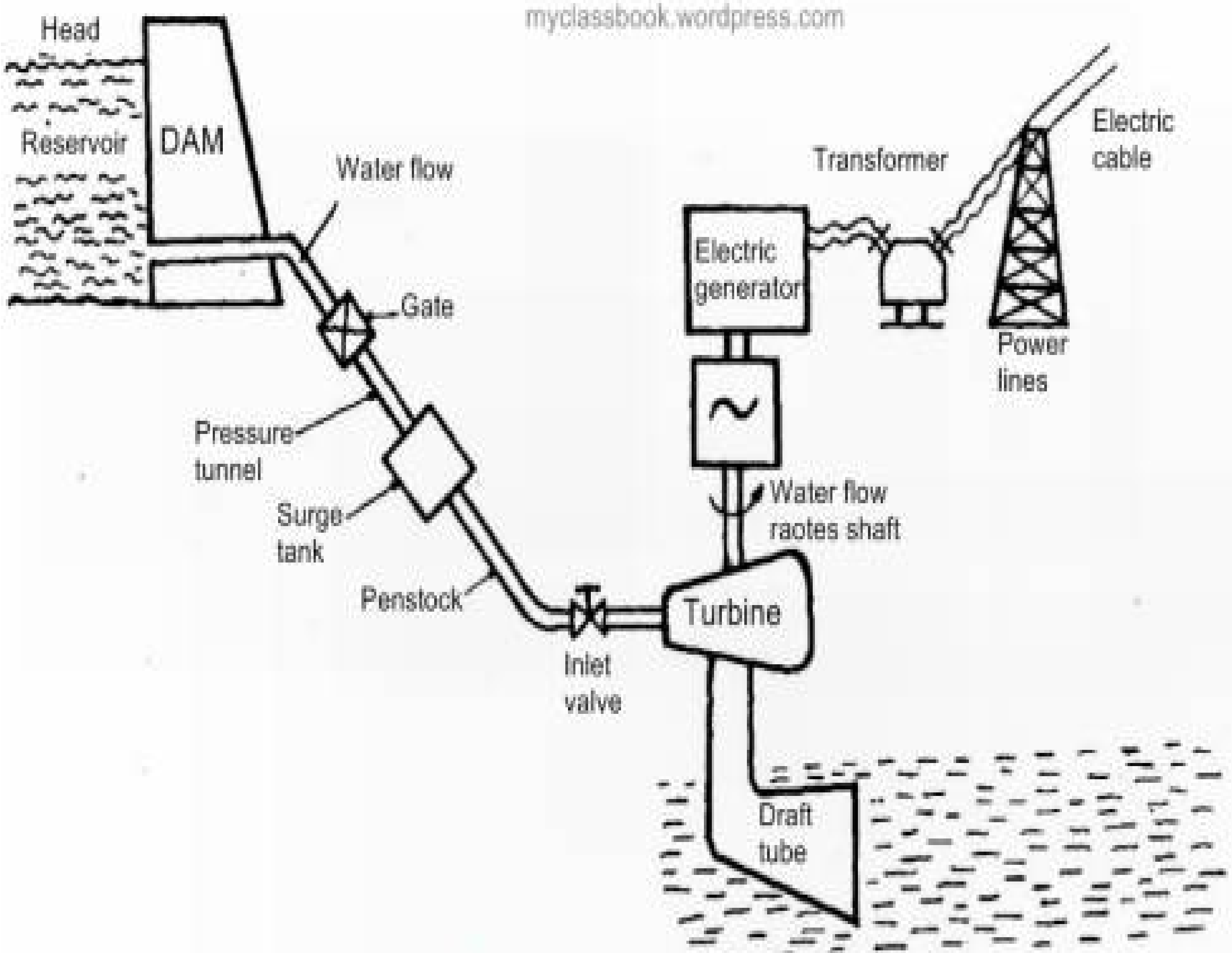
MODULE III



Layout of a hydroelectric power plant.



Layout of hydro electric power plant

CLASSIFICATION OF WATER TURBINE

Water turbines are classified into

1. **According to the energy available at the inlet**
   a)impulse turbine b)reaction turbine

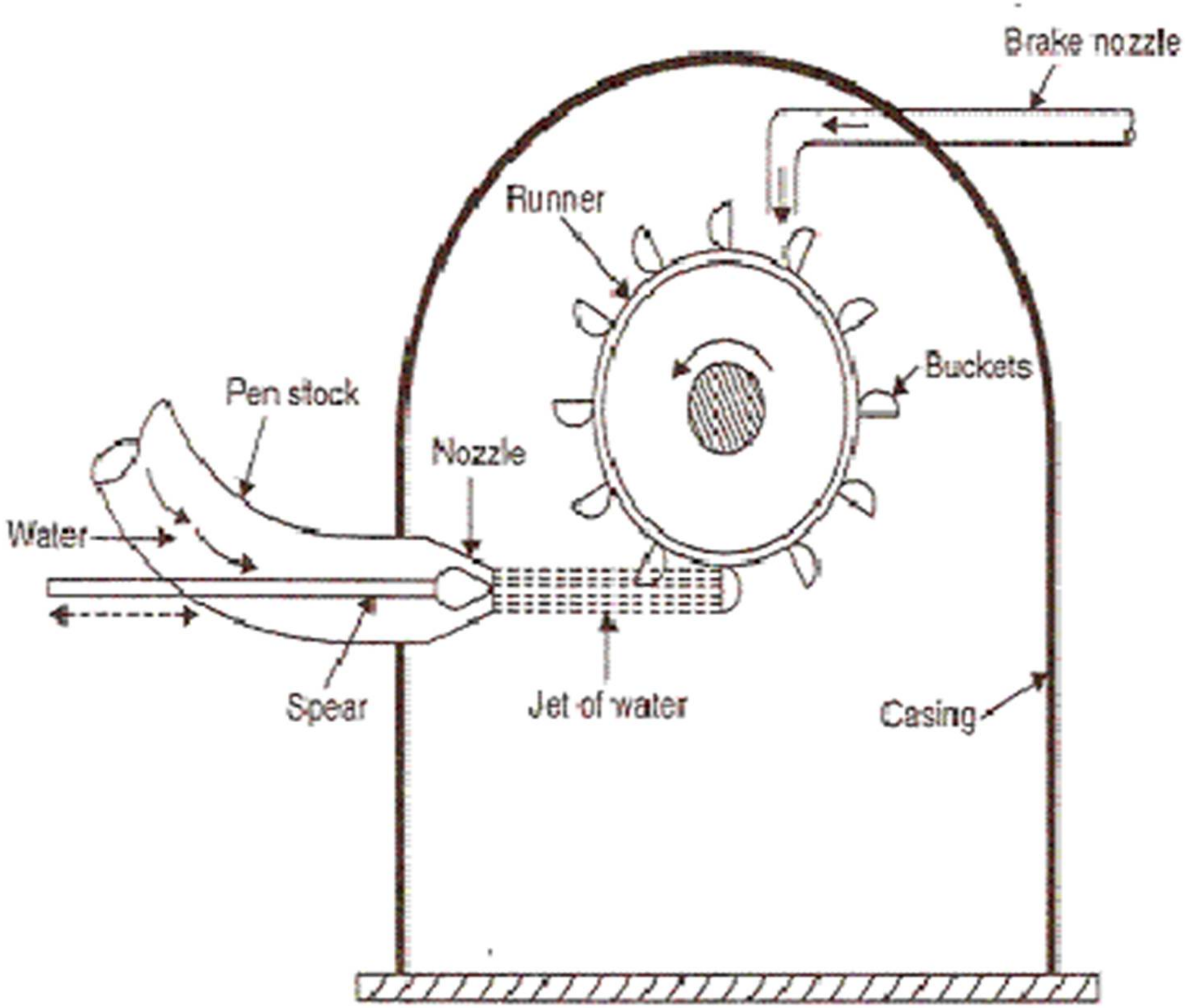
2. **According To The Direction of Flow through runner**
   a) Tangential flow turbine b) Axial flow turbine b)Radial flow turbine

3. **According to the name of originator**
   a) Pelton turbine or Pelton wheel b) francis turbine c) kaplan turbine d) mixed floe turbine

4. **According to the head available at the inlet**
   a) High head turbine b)Medium head turbine
   c)Low head turbine

5. **According to the specific speed of the turbine**
   a) High specific speed turbine b)Medium specific speed turbine
   c)Low specific speed turbine

PELTON WHEEL



Working

- The water stored at high head is made to flow through the penstock and reaches the nozzle of the Pelton turbine.

- The nozzle increases the K.E. of the water and directs the water in the form of jet.

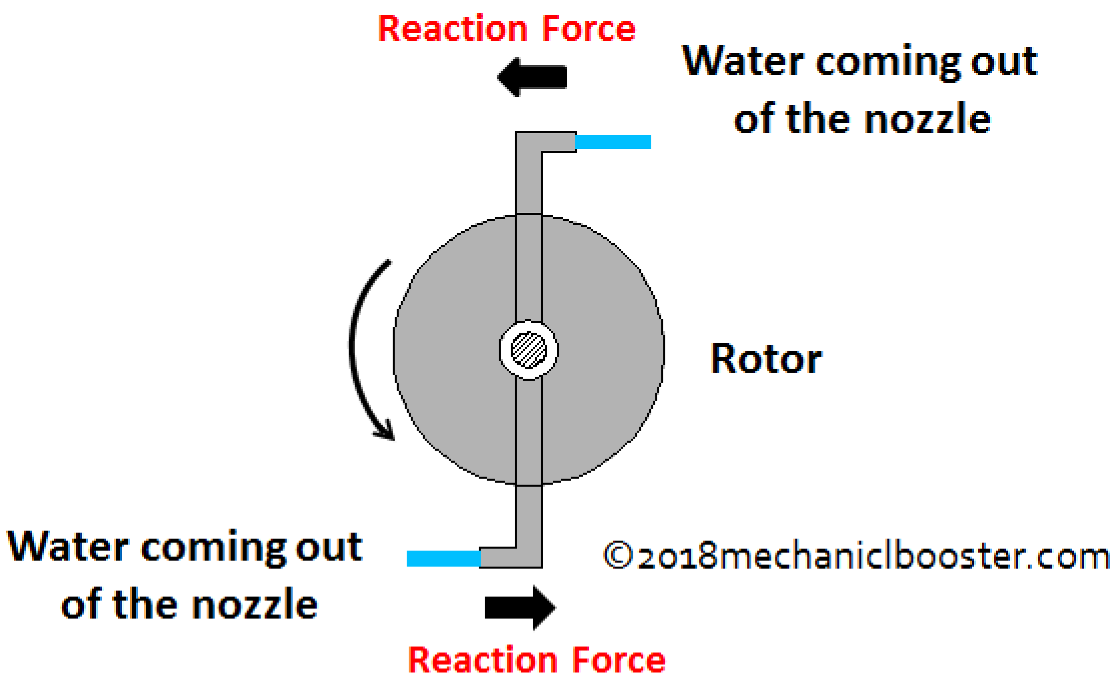
- The jet of water from the nozzle strikes the buckets (vanes) of the runner. This made the runner to rotate at very high speed.

- 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 the runner which converts the mechanical energy (i.e. rotational energy) of the runner into electrical energy.

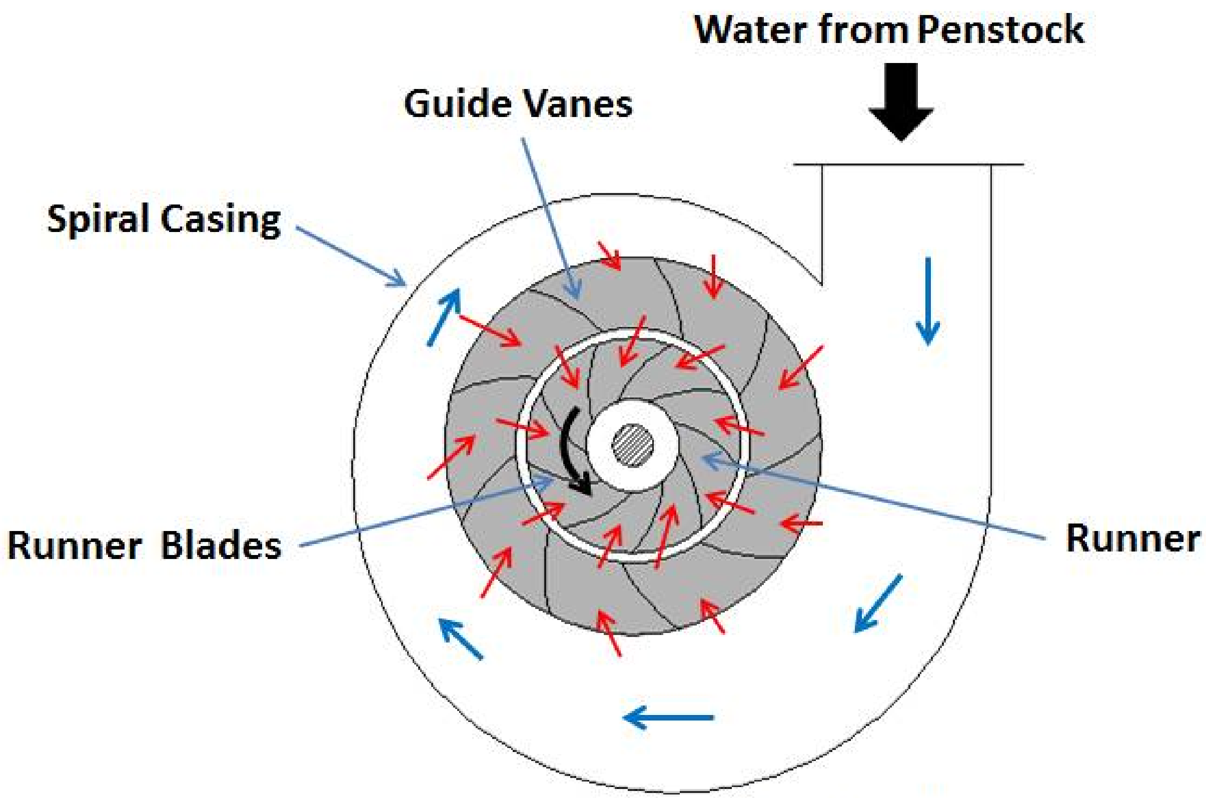
- **CONSTRUCTION DETAILS OF PELTON TURBINE:** Components of the Pelton turbine:-
- **Nozzle**: – the amount of water striking the vanes (buckets) of the runner is controlled by providing a spear (flow regulating arrangement) in the nozzle.
- **Spear**: – the spear is a conical needle which is operated either by a hand wheel or automatically in an axial direction depending upon the size of the unit.
- **Runner with bucket:** – runner of Pelton wheel consists of a circular disc on the periphery of which a number of buckets evenly spaced are fixed.
- **Casing:** – casing is to prevent the splashing of the water and to discharge water to tail race. It is made up of cast iron or steel plate.
- **Breaking jet:** – when the nozzle is completely closed by moving the spear in the forward direction the amount of water striking the runner reduce to zero.
- But the runner due to inertia goes on revolving for a long time. To stop the runner in a short time, a small nozzle is providing which directs the jet of water on the back of vanes. This jet of water is called breaking jet.

REACTION TURBINE



- The working of the reaction turbine can be well understand by taking a rotor having moving nozzles and water of high pressure is coming out of the nozzle. As the water leaves the nozzle, a reaction force is experienced by the nozzle. This reaction force rotates the rotor at very high speed.

- In the same way in reaction turbine, a reaction force is generated by the fluid moving on the runner blades. The reaction force produced on the runner blades makes the runner to rotate. Fluid after moving over the runner blades enters into draft tube and finally to the trail race.



Reaction Turbine

- **Spiral casing**

  It is a spiral casing, with uniformly decreasing cross-section area, along the circumference. Its decreasing cross-section area makes sure that we have a uniform velocity of the water striking the runner blades, as we have openings for water flow in-to the runner blades from the very starting of the casing, so pressure would decrease as it travels along the casing. So we reduce its cross-section area along its circumference to make pressure uniform, thus uniform momentum or velocity striking the runner blades.

- **Guide vanes**

  Guide vanes are installed in the spiral casing, their most important function is to make sure that water striking the runner blades must have a direction along length of the axis of turbine otherwise the flow would be highly swirling as it moves through spiral casing, making it in-efficient to rotate runner blades. The angle of these guide vanes is adjustable in modern turbines, and we can adjust the water flow rate by varying the angle of these guide vanes according to the load on the turbine.

- **Runner blades**

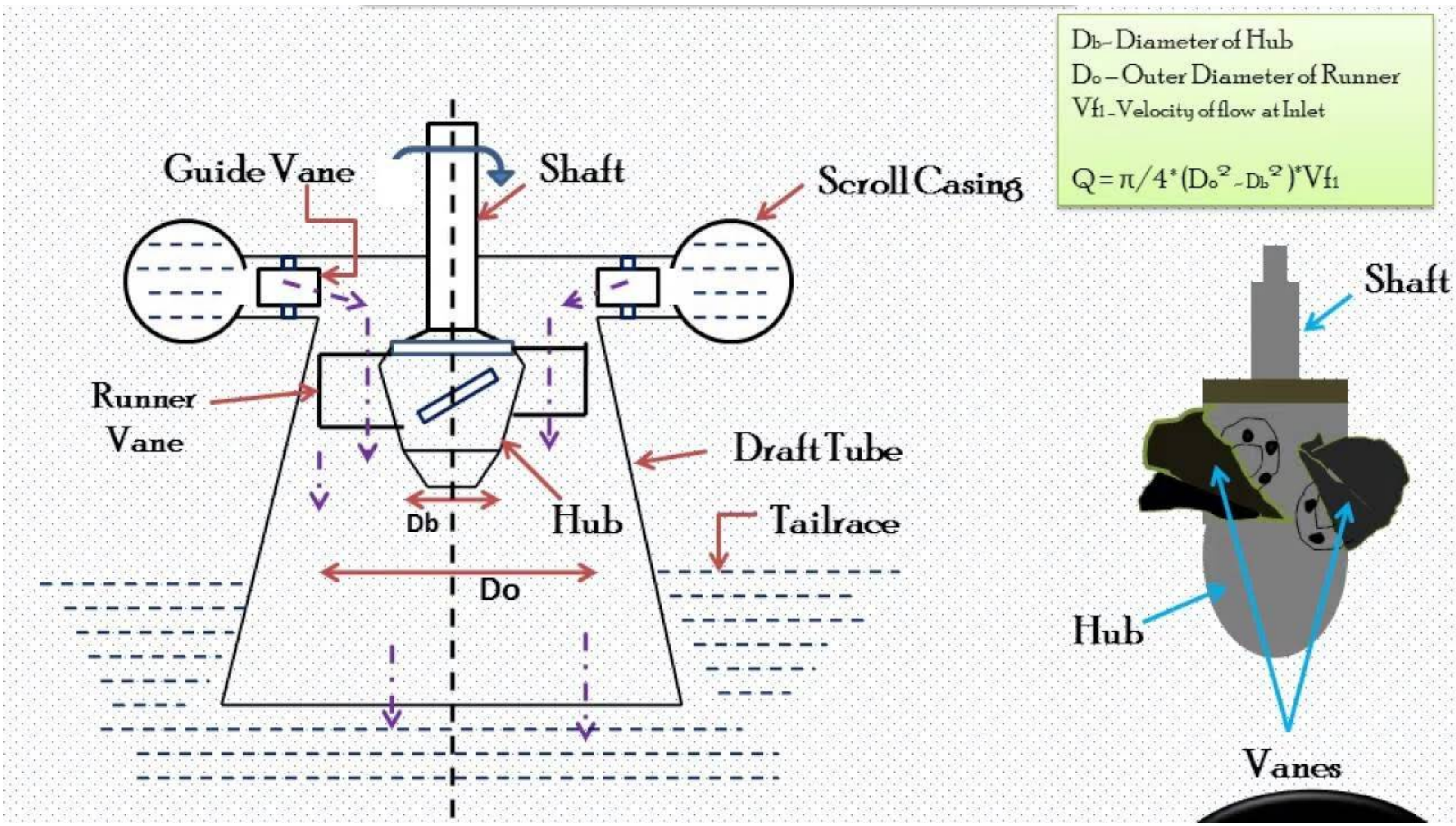
  Runner blades are said to be heart of a reaction turbine. It is the shape of the runner blades which uses the pressure energy of water to run turbine. Their design plays a major role in deciding the efficiency of a turbine. In modern turbines these blades can pitch about their axis, thus can vary the pressure force acting on them according to the load and available pressure.

- **Draft tube**

  Draft tube connects the runner exit to the tail race. Its cross-section area increases along its length, as the water coming out of runner blades is at considerably low pressure, so its expanding cross-section area help it to recover the pressure as it flows towards tail race.

Impulse Turbine	Reaction Turbine
1. All the available energy of the fluid is converted into kinetic energy by an efficient nozzle that forms a free jet.	1. Only a portion of the fluid energy is transformed into kinetic energy before the fluid enters the turbine runner.
2. The jet is unconfined and at atmospheric pressure throughout the action of water on the runner, and during its subsequent flow to the tail race.	2. Water enters the runner with an excess pressure, and then both the velocity and pressure change as water passes through the runner.
3. Blades are only in action when they are in front of the nozzle.	3. Blades are in action all the time.
4. Water may be allowed to enter a part or whole of the wheel circumference.	4. Water is admitted over the circumference of the wheel.
5. The wheel does not run full and air has free access to the buckets.	5. Water completely fills the vane passages throughout the operation of the turbine.
6. Casing has no hydraulic function to perform; it only serves to prevent splashing and to guide the water to the tail race.	6. Pressure at inlet to the turbine is much higher than the pressure at outlet ; unit has to be sealed from atmospheric conditions and, therefore, casing is absolutely essential.
7. Unit is installed above the tail race.	7. Unit is kept entirely submerged in water below the tail race.
8. Flow regulation is possible without loss.	8. Flow regulation is always accompanied by loss.
9. When water glides over the moving blades, its relative velocity either remains constant or reduces slightly due to friction.	9. Since there is continuous drop in pressure during flow through the blade passages, the relative velocity does increase.

KAPALAN TURBINE



Main Parts of a Kaplan Turbine

Scroll Casing:

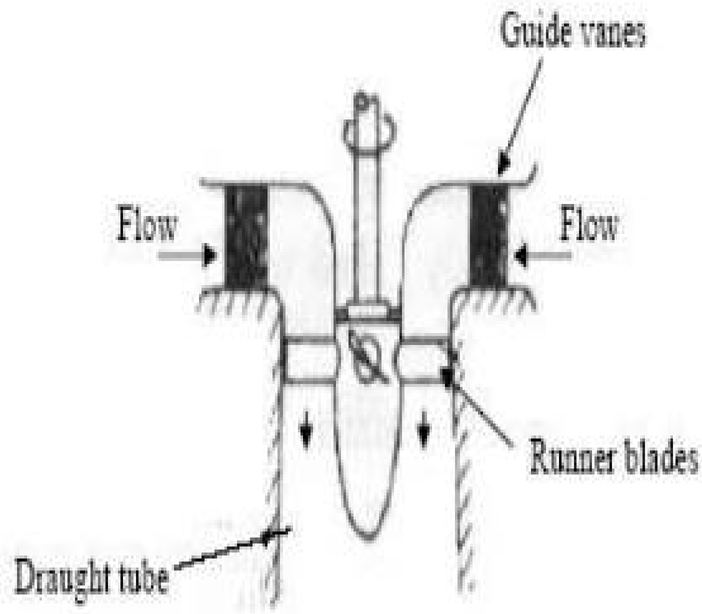
It is the Casing in which guides the water and control the water passage.

Guide Vanes:

It is the blade in which guides the water and control the water passage.

Draft Tube:

After passing through the runner the water is discharged to the tail race through a gradually expanding tube



Runner:

It is connected to the shaft of the generator.

Hub:

It is the part of the runner in which blades are mounted.

Working

The water from the pen-stock enters into the scroll casing. The water moves into the scroll casing and the guide vanes directs the water from the casing to the blades of the runner. The vanes are adjustable and can adjust itself according to the requirement of flow rate. As the water moves over the blades it starts rotating due to reaction force of the water. The blades in the Kaplan turbine is also adjustable. From the runner blades, the water enters into the draft tube where its pressure energy and kinetic energy decreases. Actually here the K.E. is gets converted into pressure energy results in increased pressure of the water. Finally the water discharged to the trail race. The rotation of the turbine is used to rotate the shaft of generator for electricity production and for some other mechanical work.

SPECIFIC SPEED OF TURBINE

The specific speed value for a turbine is the speed of a geometrically similar turbine which would produce unit power (one kilowatt) under unit head (one meter). The specific speed of a turbine is given by the manufacturer (along with other ratings) and will always refer to the point of maximum efficiency.

The Formula of Specific speed for turbine is as:

$$n_s = n\frac{\sqrt{P}}{H^{\frac{5}{4}}}$$

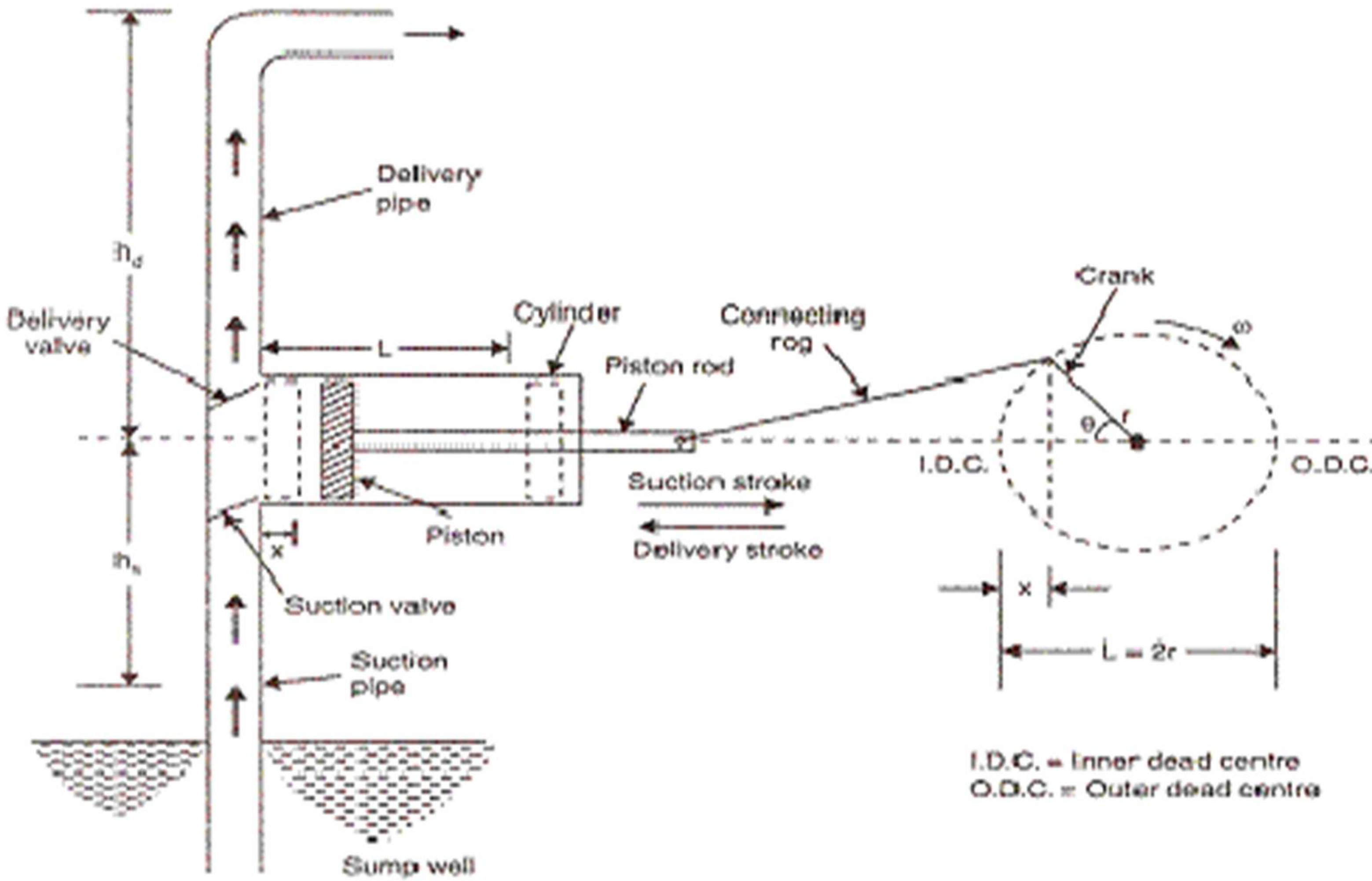
Where: n_s = specific speed

n= revolution per minute

P=Power (K.W)

H= head (m)

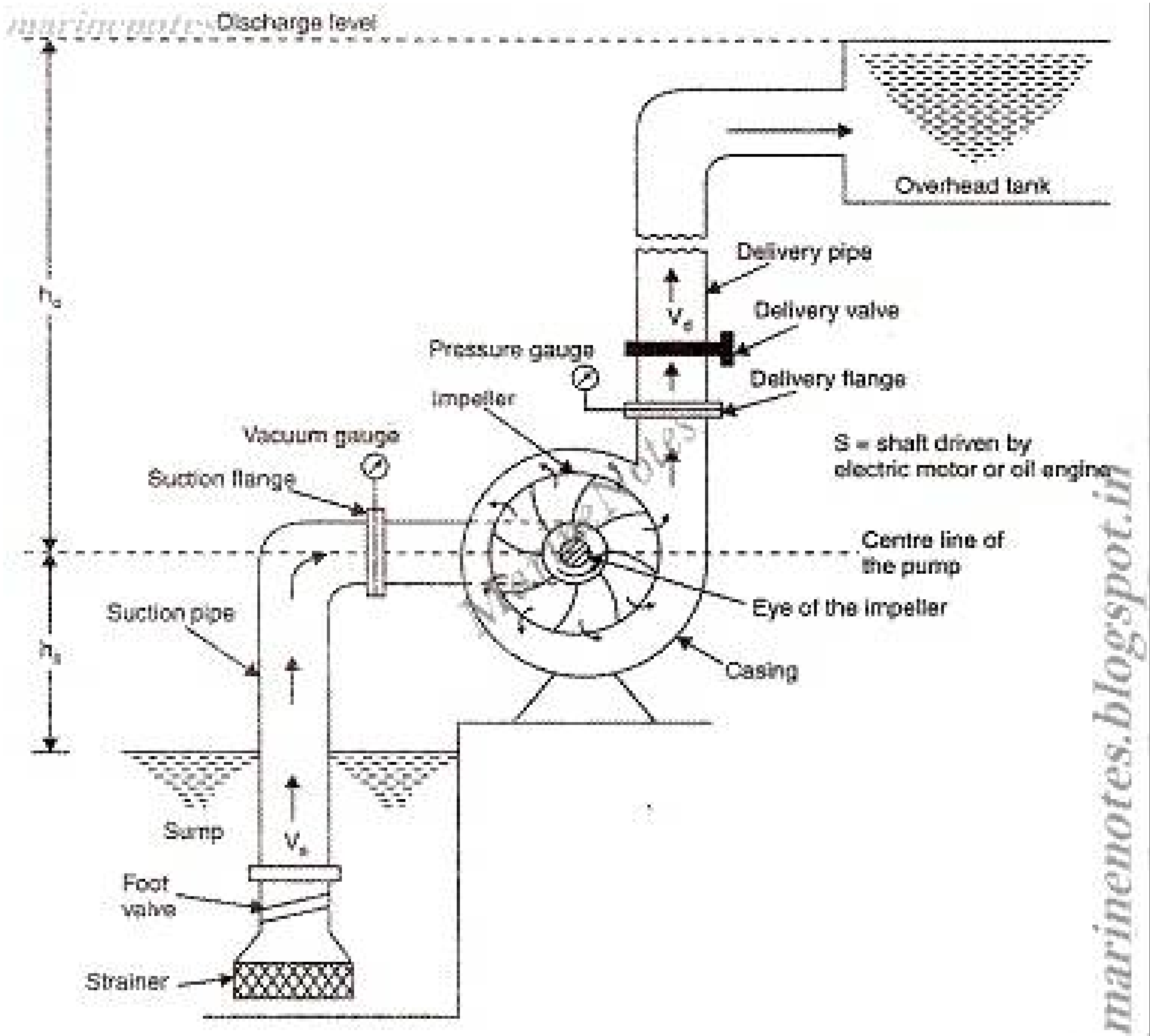
RECIPROCATING PUMP



WORKING OF RECIPROCATING PUMP

- Operation of reciprocating motion is done by the power source (i.e. electric motor or i.c engine, etc). Power source gives rotary motion to crank; with the help of connecting rod we translate reciprocating motion to piston in the cylinder (i.e. intermediate link between connecting rod and piston). When crank moves from inner dead centre to outer dead centre vacuum will create in the cylinder. When piston moves outer dead centre to inner dead centre and piston force the water at outlet or delivery value.

CENTRIFUGAL PUMP



Working

- As the electric motor starts rotating, it also rotates the impeller. The rotation of the impeller creates suction at the suction pipe. Due to suction created the water from the sump starts coming to the casing through the eye of the impeller.
- From the eye of the impeller, due to the centrifugal force acting on the water, the water starts moving radially outward and towards the outer of casing.
- Since the impeller is rotating at high velocity it also rotates the water around it in the casing. The area of the casing increasing gradually in the direction of rotation, so the velocity of the water keeps on decreasing and the pressure increases, at the outlet of the pump, the pressure is maximum.
- Now form the outlet of the pump, the water goes to its desired location through delivery pipe.

SPECIFIC SPEED OF PUMP

- Pump Specific Speed, NS is a method of characterizing a pump duty by head, flow rate and rotational speed. Pump specific speed may be used to determine an appropriate pump design for a given application when choosing between axial, radial or multistage centrifugal designs or positive displacement pumps.

$$n_s = \frac{n(Q)^{0.5}}{H^{0.75}}$$

Where:

n_s = specific speed

n = rotative speed, in revolutions per minute

Q = total pump flow rate, in cubic meters per second (US gallons per minute)

H = head per stage, in meters (feet)

MODULE IV

Heat engine is a machine for converting heat, developed by burning fuel into useful work. It can be said that heat engine is equipment which generates thermal energy and transforms it into mechanical energy.

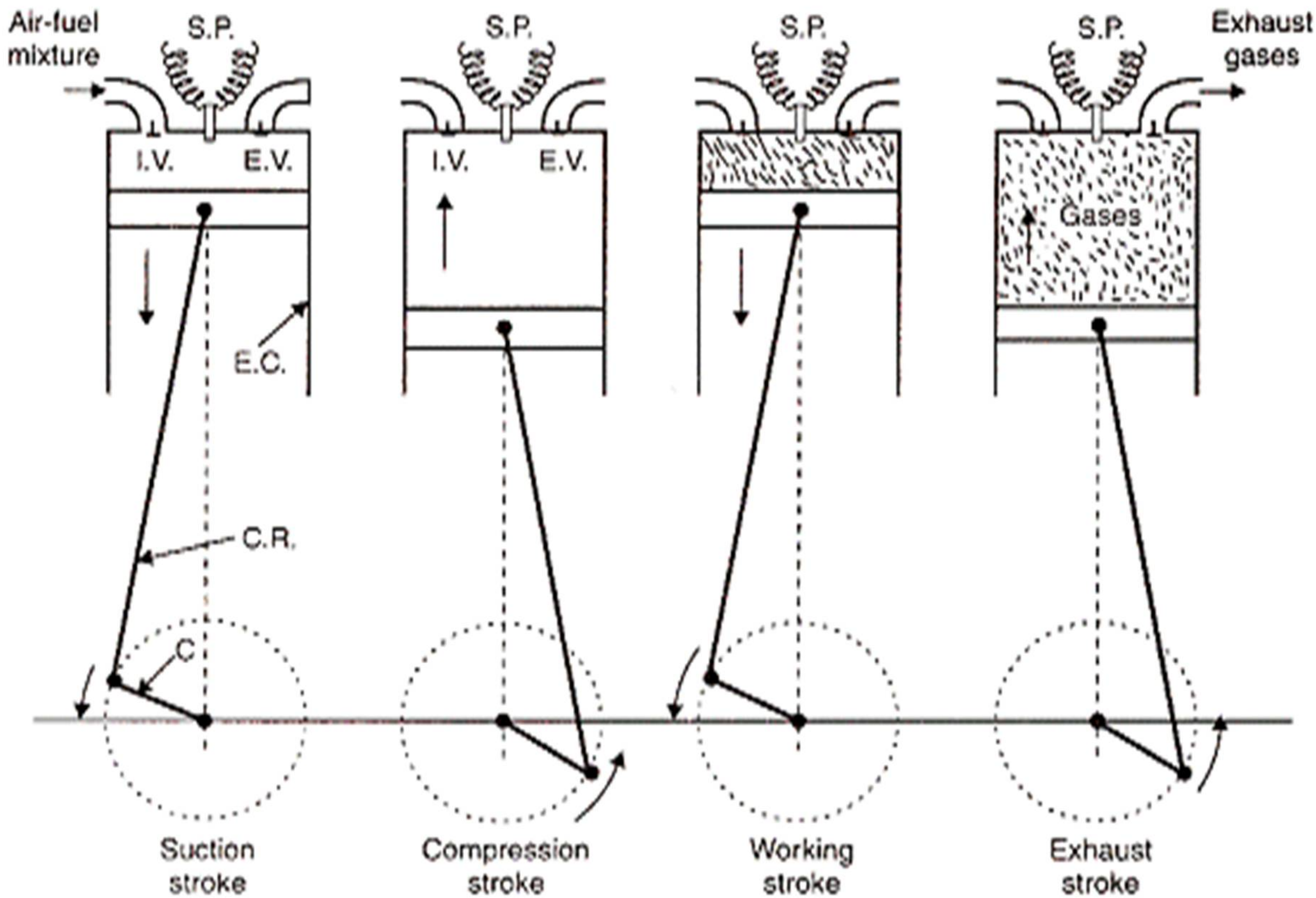
CLASSIFICATION OF HEAT ENGINES

1. Based on combustion of fuel:
   a)External combustion engine
   b)Internal combustion engine.
2. Based on fuel used
   a) Diesel engine b)Petrol engine c)Gas engine
3. Based ignition of fuel
   a)Spark ignition engine
   b)Compression ignition engine
4. Based on working cycle
   a)Four stroke cycle engine
   b)Two stroke cycle engine

FOUR STROKE PETROL ENGINE

In four stroke petrol engines the four events namely

1. Suction stroke
2. Compression stroke
3. Power stroke
4. Exhaust stroke



I.V = Intel valve, E.V. = Exhaust valve, E.C. = Engine cylinder, C.R. = Connecting rod
C = Crank, S.P. = Spark plug.

SUCTION STROKE

During suction stroke inlet valve opens and the piston moves downward. Then the mixture of air and fuel are drawn inside the cylinder. The exhaust valve remains in closed position during this stroke. The pressure in the engine cylinder is less than atmospheric pressure during this stroke

COMPRESSION STROKE

During this stroke the piston moves upward. Both valves are in closed position. The mixture of air and fuel taken in the cylinder is compressed by the upward movement of the piston. At the end of the compression stroke the mixture is ignited by a spark plug.

POWER STROKE

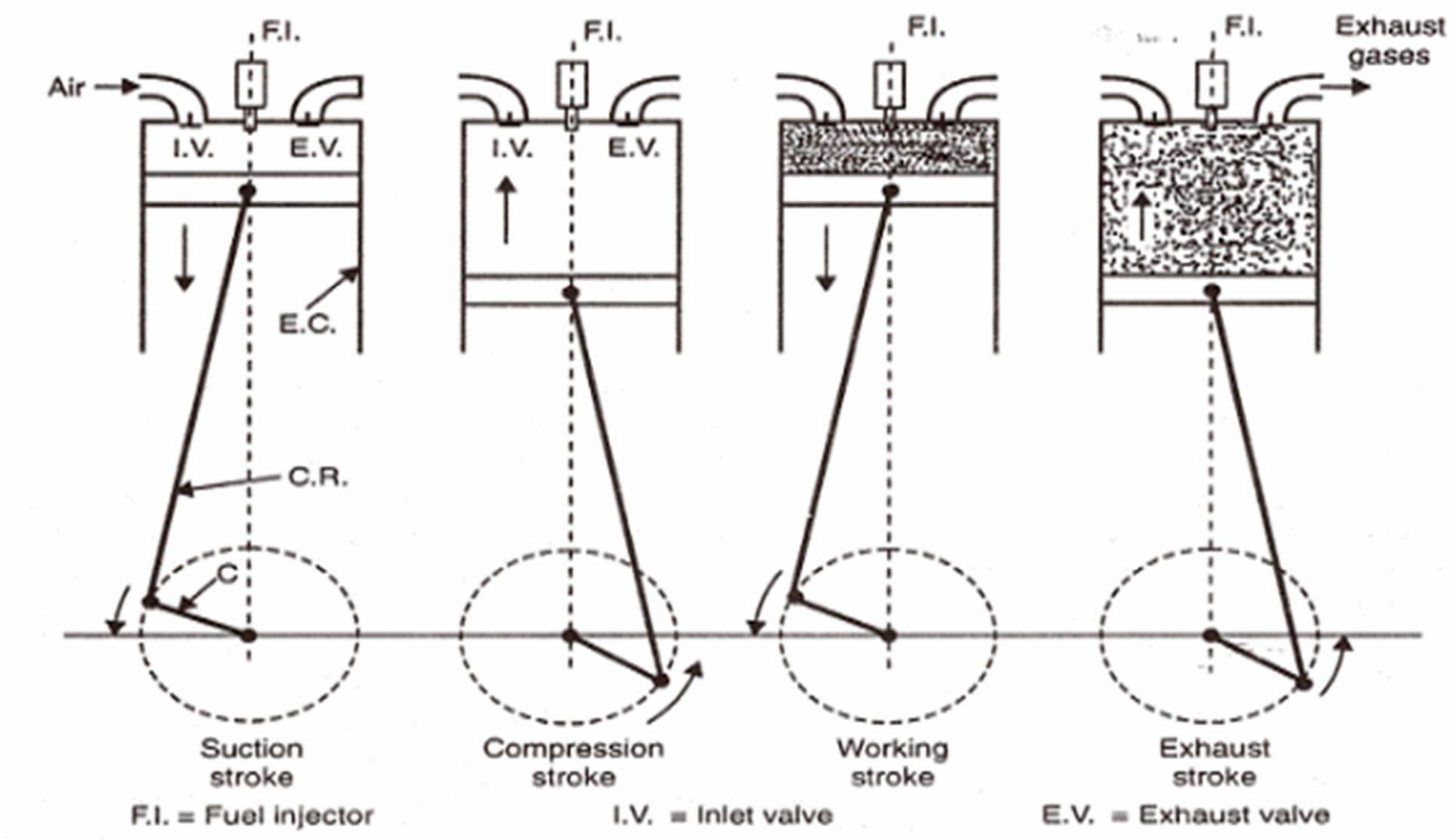
After ignition from spark plug, large amount of heat is generated, causing very high pressure in the cylinder which pushes the piston downward. The downward movement of the piston at this instant is called power stroke. The connecting rod transmits the power from piston to the crank shaft and crank shaft rotates. Mechanical work can be taped at the rotating crank shaft. Both valves remain closed during power stroke.

EXHAUST STROKE

During this stroke piston moves upward. Exhaust valve opens and exhaust gases go out through exhaust valves opening. All the burnt gases go out of the engine and the cylinder becomes ready to receive the fresh charge. During this stroke inlet valve remains closed.

Thus it is found that out of four strokes, there is only one power stroke and three idle strokes in four stroke cycle engine. The power stroke supplies necessary momentum for useful work.

FOUR STROKE DIESEL ENGINE



SUCTION STROKE

During suction stroke inlet valve opens and the piston moves downward. Only air is drawn inside the cylinder. The exhaust valve remains in closed position during this stroke. The pressure in the engine cylinder is less than atmospheric pressure during this stroke

COMPRESSION STROKE

During this stroke the piston moves upward. Both valves are in closed position. The charge taken in the cylinder is compressed by the upward movement of piston. If only air is compressed, as in case of diesel engine, diesel is injected at the end of the compression stroke and ignition of fuel takes place due to high pressure and temperature of the compressed air.

POWER STROKE

After ignition of fuel from the injector, large amount of heat is generated, causing very high pressure in the cylinder which pushes the piston downward. The downward movement of the piston at this instant is called power stroke. The connecting rod transmits the power from piston to the crank shaft and crank shaft rotates. Mechanical work can be taped at the rotating crank shaft. Both valves remain closed during power stroke.

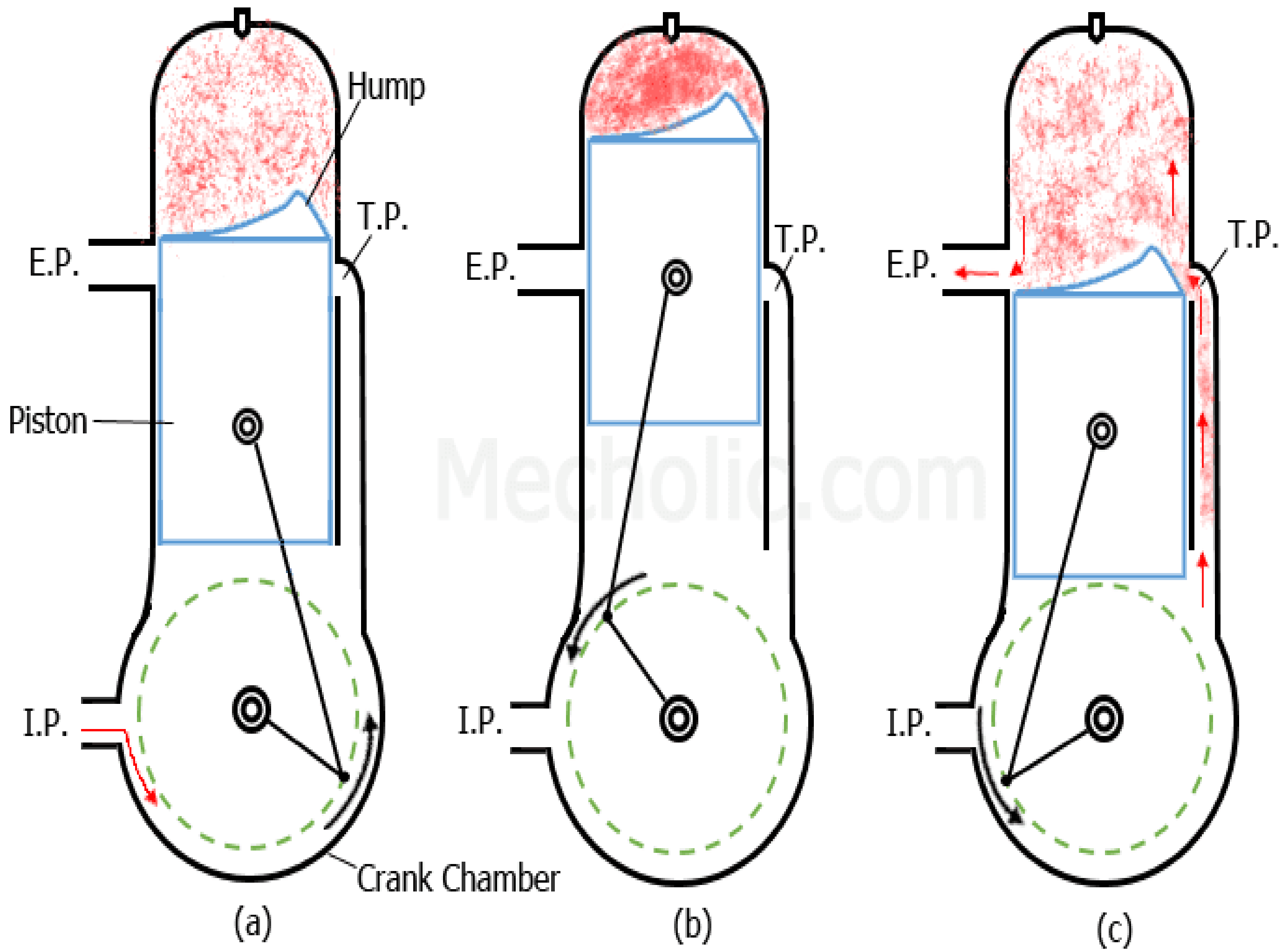
EXHAUST STROKE

During this stroke piston moves upward. Exhaust valve opens and exhaust gases go out through exhaust valves opening. All the burnt gases go out of the engine and the cylinder becomes ready to receive the fresh charge. During this stroke inlet valve remains closed.

Thus it is found that out of four strokes, there is only one power stroke and three idle strokes in four stroke cycle engine. The power stroke supplies necessary momentum for useful work.

TWO STROKE PETROL ENGINE

In two stroke cycle engines, the whole sequence of events i.e., suction, compression, power and exhaust are completed in two strokes of the piston i.e. one revolution of the crankshaft. There is no valve in this type of engine. Gas movement takes place through holes called ports in the cylinder. The crankcase of the engine is air tight in which the crankshaft rotates.



I.P. = Inlet port T.p. = Transfer port E.P. = Exhaust port

Upward stroke of the piston (Suction + Compression)

When the piston moves upward it covers two of the ports, the exhaust port and transfer port, which are normally almost opposite to each other. This traps the charge of air- fuel mixture drawn already in to the cylinder. Further upward movement of the piston compresses the charge and also uncovers the suction port. Now fresh mixture is drawn through this port into the crankcase. Just before the end of this stroke, the mixture in the cylinder is ignited by a spark plug. Thus, during this stroke both suction and compression events are completed.

DOWNWARD STROKE (POWER + EXHAUST)

Burning of the fuel rises the temperature and pressure of the gases which forces the piston to move down the cylinder. When the piston moves down, it closes the suction port, trapping the fresh charge drawn into the crankcase during the previous upward stroke. Further downward movement of the piston uncovers first the exhaust port and then the transfer port. Now fresh charge in the crankcase moves in to the cylinder through the transfer port driving out the burnt gases through the exhaust port. Special shaped piston crown deflect the incoming mixture up around the cylinder so that it can help in driving out the exhaust gases . During the downward stroke of the piston power and exhaust events are completed.

COMPARISON BETWEEN TWO STROKE AND FOUR STROKE ENGINES

Four stroke engine	Two stroke engine
1. One power stroke for every two revolutions of the crankshaft.	One power stroke for each revolution of the crankshaft.
2. There are inlet and exhaust valves in the engine.	There are inlet and exhaust ports instead of valves.
3. Crankcase is not fully closed and air tight.	Crankcase is fully closed and air tight.
4. Top of the piston compresses the charge.	Both sides of the piston compress the charge.
5. Size of the flywheel is comparatively larger.	Size of the flywheel is comparatively smaller.
6. Fuel is fully consumed.	Fuel is not fully consumed.
7. Weight of engine per hp is high.	Weight of engine per hp is comparatively low.
8. Thermal efficiency is high.	Thermal efficiency is comparatively low.
9. Removal or exhaust gases easy.	Removal of exhaust gases comparatively difficult.
10. Torque produced is even.	Torque produced is less even.

Comparison of Petrol and Diesel Engines

PETROL ENGINE

1. Works on Otto Cycle
2. Fuel-air mixture is admitted during suction stroke
3. Spark ignition
4. Low compression ratios (6 to 10)
5. Lower engine efficiency
6. Higher fuel consumption
7. Lower engine vibrations and noise
8. High running cost
9. Light duty application

DIESEL ENGINE

1. Works on Diesel Cycle
2. Fuel is injected at the end of compression stroke
3. Compression ignition
4. High compression ratios (10 to 20)
5. Higher engine efficiency
6. Lower fuel consumption
7. Higher engine vibrations and noise
8. Low running cost
9. Heavy duty application

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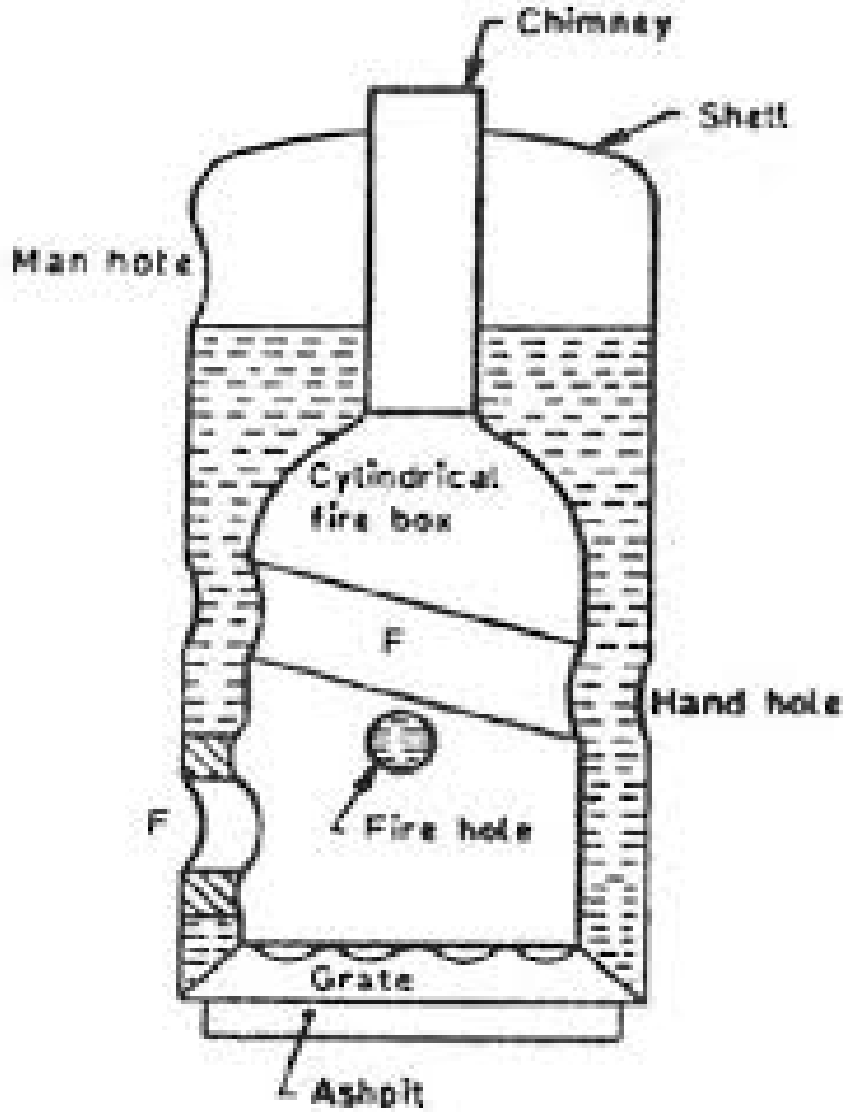
STEAM GENERATOR OR BOILER

- A steam generator or a boiler is defined as a closed vessel in which water is converted into steam by burning of fuel in presence of air at desired temperature, pressure and at desired mass flow rate.
- In case of boiler, any type of fuel burn in presence of air and form flue gases which are at very high temperature (hot fluid). The feed water at atmospheric pressure and temperature enters the system from other side (cold fluid). Because of exchange of heat between hot and cold fluid, the cold fluid (water) temperature raises and it form steam.

STEAM GENERATOR OR BOILER

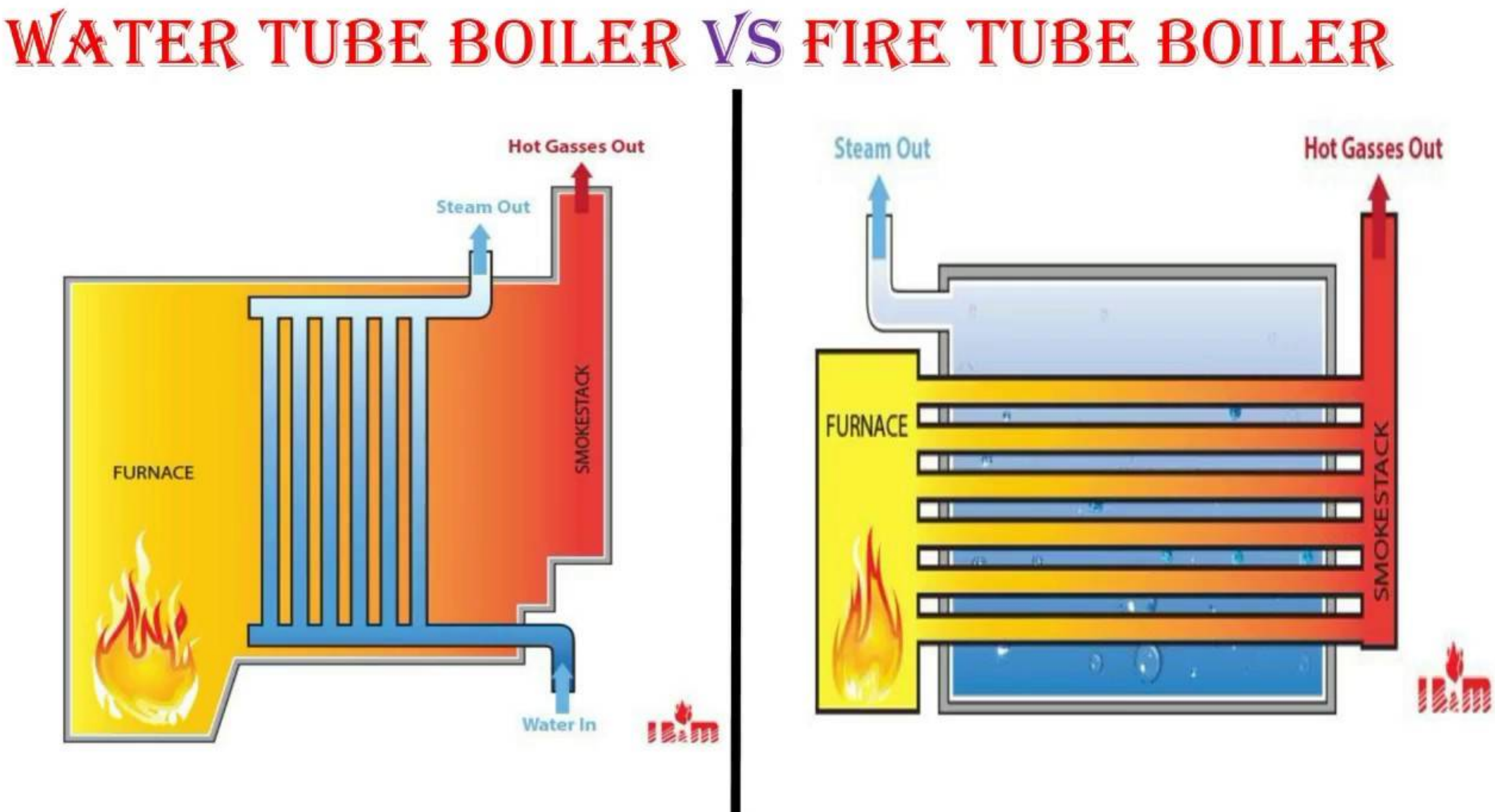


FUNCTIONS OF A BOILER

The steam generated is employed for the following purposes

1. Used in steam turbines to develop electrical energy
2. Used to run steam engines
3. In the textile industries, sugar mills or in chemical industries as a cogeneration plant
4. Heating the buildings in cold weather
5. Producing hot water for hot water supply

FIRE TUBE & WATER TUBE BOILERS



FIRE TUBE BOILER

- A fire-tube boiler is a type of boiler in which hot gases pass from a fire through one or more tubes running through a sealed container of water. The heat of the gases is transferred through the walls of the tubes by thermal conduction, heating the water and ultimately creating steam.

WATER TUBE BOILER

A high pressure water tube boiler is a type of boiler in which water circulates in tubes heated externally by the fire. Fuel is burned inside the furnace, creating hot gas which heats water in the steam-generating tubes.

TYPES OF FIRE TUBE BOILERS

- Cornish boiler
- Lancashire boiler
- Locomotive boiler
- Scotch marine boiler
- Admiralty-type direct tube boiler
- Horizontal return tubular boiler
- Immersion fired boiler
- Vertical fire-tube boiler

TYPES OF WATER TUBE BOILER

The Water tube boilers are divided into two types based on whether the tubes are horizontal or bent as

1. **Horizontal straight water tube boilers**

- Longitudinal drum
- Cross-drum.

2. Bent tube boilers

- Two drum
- Three drum
- Low head three drum
- four drum.

S.No	Fire tube boiler	Water tube boiler
1	In Fire-tube boilers hot flue gases pass through tubes and water surrounds them.	In Water-tube boilers water passes through tubes and hot flue gasses surround them.
2	These are operated at low pressures up to 20 bar.	The working pressure is high enough, up to 250 bar in super critical boilers.
3	The rate of steam generation and quality of steam are very low, therefore, not suitable for power generation.	The rate of steam generation and quality of steam are better and suitable for power generation.
4	Load fluctuations cannot be handled.	Load fluctuations can be easily handled.
5	It requires more floor area for a given output.	It requires less floor area for a given output
6	These are bulky and difficult to transport.	These are light in weight, hence transportation is not a problem.
7	Overall efficiency is up to 75%.	Overall efficiency with an economizer is up to 90%.
8	Water doesn't circulate in a definite direction.	Direction of water circulated is well defined.
9	The drum size is large and damage caused by bursting is large.	If any water tube is damaged, it can be easily replaced or repaired.
10	It requires more floor area for a given output.	It requires less floor area for a given output

STEAM TURBINE

A steam turbine is a device that converts the thermal energy of steam into mechanical energy by turning the blades of a rotor.

Applications:

As prime movers in all thermal and nuclear power plants to produce electricity, large ships, pumps and fans at petrochemical plants.

CLASSIFICATION THE STEAM TURBINES

Steam turbines are classified into

1. **According To The Mode Of Steam Action**
   a)impulse turbine b)reaction turbine

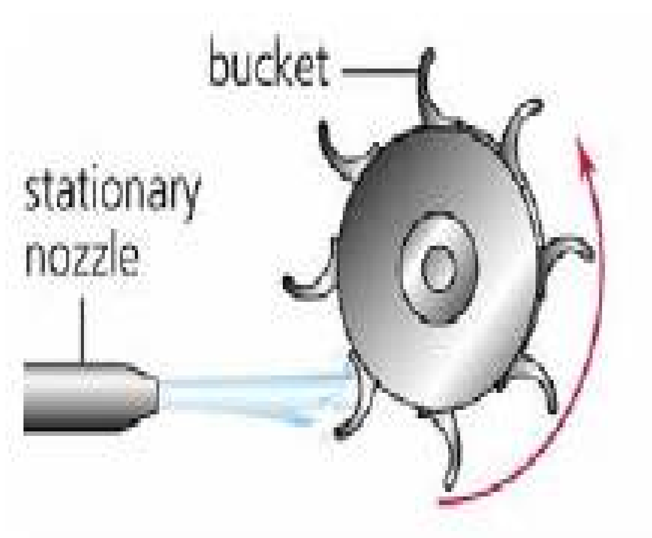
2. **According To The Direction of Steam Flow**
   a)Axial flow turbine b)Radial flow turbine

3. **According To Exhaust Condition Of Steam**
   a) Condensing turbine b) Non condensing turbine

4. **According To The Pressure Of Steam**
   a) High pressure turbine b)Medium pressure turbine
   c)Low pressure turbine

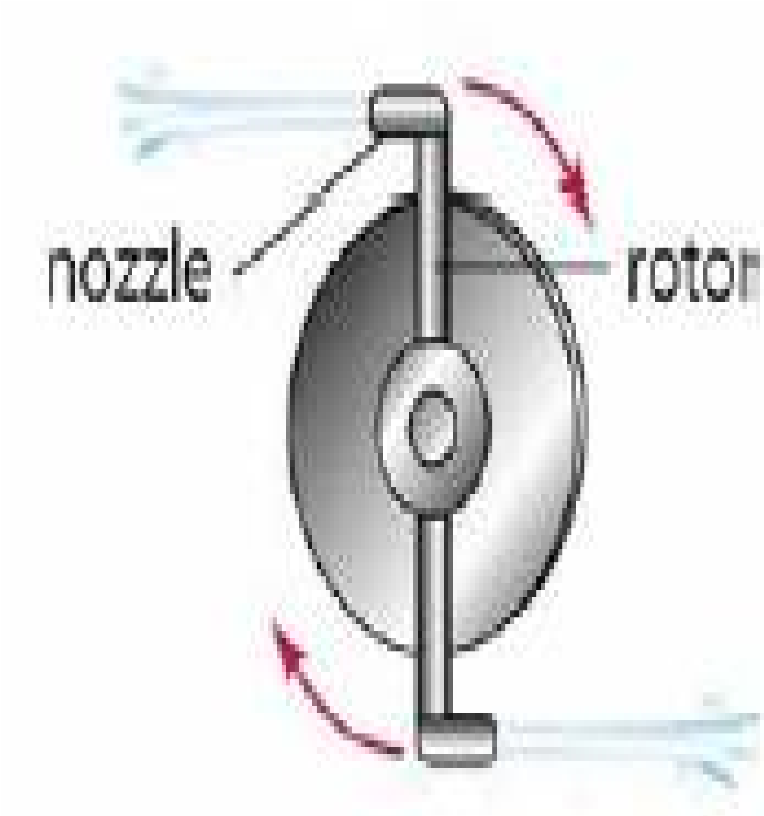
5. **According To The Number Of Stages**
   a) Single stage turbine b) Multi stage turbine

IMPULSE TURBINES



- In impulse turbines, high-velocity steam from fixed nozzles impacts the blades, and this impulse drives the blades forward, causing the rotor to turn.
- The main feature of these turbines is that the heat drop per stage can be quite large, allowing for large blades and a smaller number of stages.

REACTION TURBINES



- In reaction turbines, high-velocity steam from nozzles striking blades also produces impulse, but the steam jet runs into the blades and the main force turning the rotor is the reactive force produced by the expansion of steam flowing off the rotor blades themselves.
- The main feature of this type of turbine is that in contrast to the impulse turbine, the heat drop per stage is lessened, so the blades become smaller and the number of stages increases.