UNIT-II NOTES ….SME

Thermodynamics

Thermodynamic is branch of physical science which deals with energy interaction (transfer of Heat and work) and its effect properties of substance.

It is originated from Greek words therme (heat) and dynamic ,effort to convert heat into power .

Thermodynamic, basically depends on four laws – Zeroth ,first, second and third law of thermodynamic.

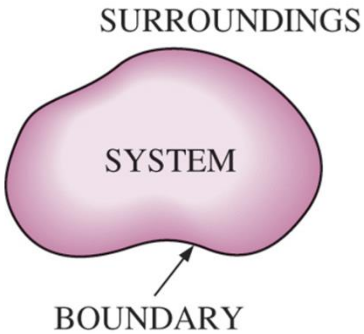
Thermodynamic *Systems*

System: A region in a space, upon which attention is focused for understanding the concept of transfer and conversion of energies like heat and work.

Boundary: It is the surface which encloses/surrounds or separates the system from the surroundings. Boundary may be real or imaginary.

Surrounding – region which lies outside the system boundary is known as surrounding.

System +Surrounding = Universe



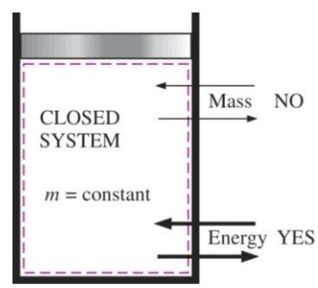
Types of Thermodynamic *Systems*

1) Closed system

2) Open system

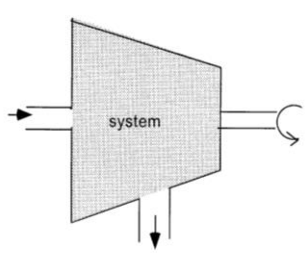
3) Isolated system

1)Closed system- : A system in which only energy transfer takes place across the boundary but no mass transfer takes place and mass of the system remains constant such system is called as closed system. E.g. hot water stored in tank ,cylinder with movable piston.



2) Open system : A system in which both mass and energy transfer takes place across the boundary, such system is called as open system.

e.g. I.C. Engine, air compressor, gas turbine.

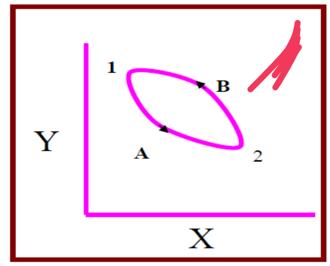


Example of an open (flow) system: a steam turbine

3) Isolated system:

A system in which neither energy nor mass transfer takes place across boundary..e.g. Thermos flask.

The First Law of Thermodynamics



Statement 1

The first law of thermodynamics, also known as Law of Conservation of Energy, states that energy can neither be created nor destroyed; energy can only be transferred or changed from one form to another.

Statement 2

When a closed system execute a complete cycle

the sum of heat intraction is equal to some of work interactions.

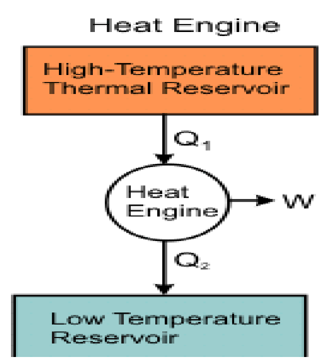
$\sum Q = \sum W$

Second law of thermodynamics

Kelvin-Planck statement of second law

It is impossible to construct a device (engine) operating in a cyclic process whose sole effect is the conversion of all the heat energy in to an equivalent amount of work.

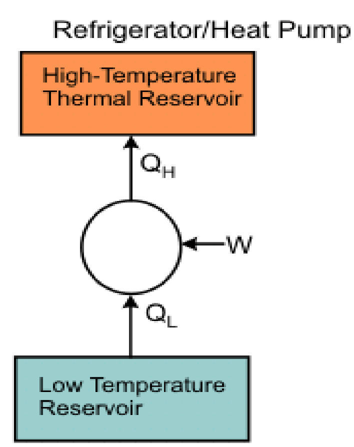
That means some amount of heat is loss to low temperature Reservoir.



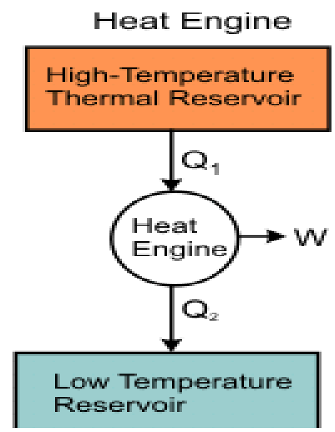
Clausius' statement of second law

It is impossible to transfer heat in a cyclic process from low temperature to high temperature without work from external source.

Examples:Refrigerator,Heat Pump



1. Heat engine-



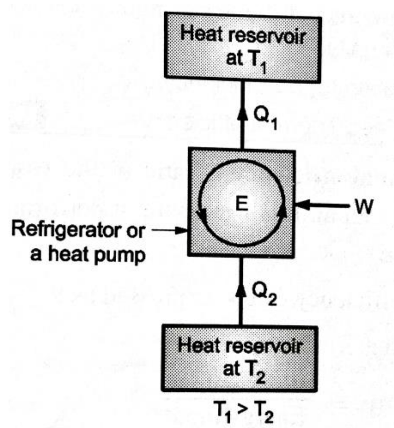
A device which can produce the work contineously at the expence of heat input is called a heat engine i.e.T1>T2

$$\text{Thermal Efficiency} = \frac{Desired\ output}{Energy\ input}$$

$$\text{ThemalEfficiency} = \frac{w}{Q1} = \frac{Q1 - Q2}{Q1}$$

$$\text{ThemalEfficiency} = \frac{T1 - T2}{T1}$$

2. Heat pump-



Heat pump is a device operating on cyle which removes heat form body at lower temperature T_2(Heat sink) and reject it to a body at high temperature T_1(Heat source) on expence of external work supplied. If the objective of the system is to delive heat energy at high temperatue,

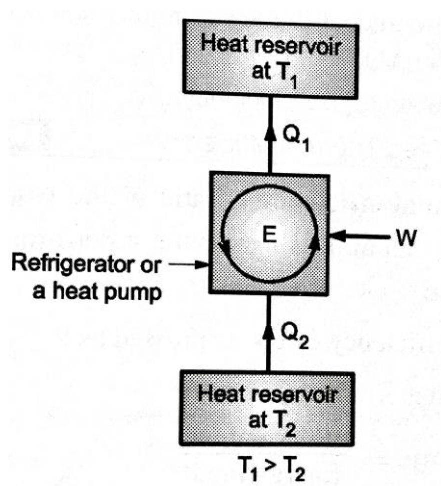
Coefficient of Performance$(COP)_{\text{Heat pump}}$

$$\text{(COP)HP} = \frac{Desired\ effect}{Energy\ input}$$

$$\text{(COP)HP} = \frac{Q1}{W}$$

$$\text{(COP)HP} = \frac{Q1}{Q1 - Q2} = \frac{T1}{T1 - T2}$$

3.Refrigrator-



Refrigerator is a device operating on cyle which removes heat for body at lower temperature T2(Heat sink) and reject it to a body at high temperature T1(Heat source) on the expence of external work supplied. If the objective of the system is to produce cooling effect at low temperatue,

Coefficient of Performance$(COP)_{\text{Heat pump}}$

$$(\mathrm{COP})\mathrm{RF} = \frac{Desired\ effect}{Energy\ input}$$

$$(\mathrm{COP})\mathrm{RF} = \frac{Q2}{W}$$

$$(\mathrm{COP})\mathrm{HP} = \frac{Q2}{Q1 - Q2} = \frac{T2}{T1 - T2}$$

Heat Transfer-

Heat Transfer occurs due to difference in Temperature between two systems. During HT the Heat energy always flows from Higher temperature to Lower temperature systems. The transfer of Heat energy stops once both the systems reach their equality of temperature. The driving force of transfer of heat energy is temperature difference and the rate of heat transfer increases with the increase in temperature gradient/ difference. Engineering Applications need to know the rate of heat transfer and temperature distribution under steady and transient conditions, for designing the various components.

Application Areas of Heat Transfer :

1. Design of Heat Exchangers, ducts in Refrigeration & AC
2. Design of Cylinders, radiators, etc in IC Engines
3. Design of Combustion Chambers and cooling of blades for Gas Turbines
4. Design of Motors, Generators, Transformers
5. Design of Boilers, Condensers, Cooling Towers, Heat Exchangers in Thermal and Nuclear Power Plant
6. Design of Solar Collectors, Furnaces, Space Vehicles and components of Chemical process plants

Modes of Heat Transfer

1. Conduction
2. Convection
3. Radiation

Conduction is defined as the transfer of heat from one part of the substance to another part of the same substance without appreciable motion of molecules. It takes place in Solids, Liquids and gas.

Convection : The process of heat Convection is due to the capacity of moving matter to carry heat energy.

The transfer of heat by convection takes place between a solid surface and the adjacent liquid or layer that is in motion. In case the fluid is at rest then the transfer of heat between the solid surface and the layer of fluid is purely by conduction.

Radiation is the process of heat transfer due to the electromagnetic radiation emitted in a wavelength band between 0.1 micron to 100 micron solely as a result of the temperature of a surface.

The transfer of heat energy of radiation does not require the presence of any material medium as in case of heat transfer by conduction or convection.

Example : Transfer of Heat from furnace to boiler to the water flowing in the tubes.

Here, Heat is dissipated by flue gases to metal surface of tube both by radiation and convection. Heat is transferred by conduction across the thickness of tube to its inner surface; further it is transferred by convection and radiation to water in the tubes.

Heat is a form of energy in transit for which the driving force is the temperature difference.

Heat Transfer Rate : The amount of heat energy transferred during a process over a given period of time is denoted by Q. The amount of heat transferred per unit time is called heat transfer rate Q^* (J/sec or Watts)

$$Q^* = \int_0^t Q.dt$$

The rate of Heat Transfer per unit area normal to the direction of heat transfer is called the Heat Flux Rate q^* .

$q^* = Q^* / A$ (W/m^2) ......where A is heat transfer area.

Fourier's Law of Heat Conduction

The rate of heat flow through a simple homogeneous solid is directly proportional to the area measured normal to the direction of heat flow and the temperature gradient in the direction of heat flow.

$Q \;\alpha\; A.\, dT / dx$

$Q = - K.\, A.\, dT / dx$ $\quad \boxed{Q = -\frac{K.\,A}{x}\,(T1 - T2)}$

Heat Flux $q = Q/A = - K.\, dT/dx$ $\quad \boxed{q = -\frac{K}{x}(T1 - T2)}$

Where, K is called Coefficient of thermal conductivity of material.

$$K = \frac{Q\ (W).dX\ (m)}{A(\ sq.m).dT\ (°C\ \ or\ \ K\ )} = \frac{W}{mK} \quad or \quad \frac{W}{m°C}$$

Thermal Conductivity is the ability of material to conduct heat through it. It is the amount of heat flow rate per unit area normal to the direction of heat flow through unit thickness of the material per unit temperature difference.

Convection

The process of heat transfer between the solid surface and a fluid flowing past the surface is called Convection.

Sr.No.	**Forced Convection**	**Free / Natural Convection**
1	Movement of molecules occurs due to external force or by using external means like pump, compressor, blower , etc.	Movement of molecules is due to density difference.
2	Applications are in Heat Exchangers like condenser, evaporator, boilers, radiators, etc	Cooling human body, hot still air flow over roads surface, etc.

Coefficient of Convective Heat Transfer or Film Conductance (h)

$$= \frac{Thermal\ \ conductivity\ \ \ of\ film\ Kf}{Film\ thickness\ \ \delta}$$

The value of δ decreases, with increase in fluid velocity. Hence, the convective heat transfer by forced convection is more than the heat transfer by natural convection.

Value of Kf is lower for gases as compared to the liquids.

Newton's Law of Cooling : (applies to Convective Heat Transfer)

The rate of convective heat transfer between a surface and the fluid is known as Newton's law of cooling. It states that the rate of heat transfer is proportional to the surface area perpendicular to heat flow direction and the difference between the wall surface temperature T_w and the fluid temperature, T_∞ in the direction perpendicular to heat flow direction.

$$\boxed{Q = h.\ A.\ (T_w - T_\infty\ )}$$

$$Q = \frac{(Tw - T\infty\ )}{\left(\frac{1}{h\ .\ A}\right)} \quad ;$$

where $\left(\frac{1}{h\ .\ A}\right)$ *is called Convective resistance*

Radiation:

Radiation is the process of heat transfer due to the electromagnetic radiation emitted in a wavelength band between 0.1 micron to 100 micron solely as a result of the temperature of a surface. The transfer of heat energy of radiation does not require the presence of any material medium as in case of heat transfer by conduction or convection.Two bodies at different temperatures; the hotter body sends radiations to colder body, & vice versa. As a result the hotter body is cooled and the colder body is heated.

The intensity of radiations emitted by a body depends on the nature of the body and its temperature. Out of total radiations falling on the body, a part of it is reflected at the surface (reflectivity ρ), a part is absorbed while travelling along the depth of the body (absorbtivity α) and the remainder energy is transmitted through the body (transmissivity Υ). Therefore, $\rho + \alpha + \Upsilon = 1$.

A body which absorbs entire radiations is called a Black Body . So, $= \Upsilon = 0$ and $\alpha = 1$.

A black body is also a best radiator.

Opaque body , usually solid ; either absorbs or reflect the entire radiant energy falling on it. $\Upsilon = 0$ and $\rho + \alpha = 1$.

In certain materials like Glass and Gases, the entire radiant energy falling on them is transmitted.

$\rho = \alpha = 0$ and $\Upsilon = 1$. Such body is called White Body.

For diathermanous bodies, $\alpha = \Upsilon = 0$ and $\rho = 1$. Diathermanous body is a body which transmits all the incident radiation without absorbing or reflecting. Air, up to certain extent can be considered as the diathermanous body because it transmits all the radiation <u>without heating itself</u>.

The emissive power of any surface is defined as the energy emitted by the surface per unit area per unit time. Its unit is W/m^2 .

Emissivity ( ) is defined as the ratio of emissive power of any surface to the emissive power of a black surface at the same temperature. Its value ranges from 0 to 1. For black body =1.

Stefan- Boltzmann Law of Radiation

This law states that the emissive power of a black body is directly proportional to fourth power of its absolute temperature.

$q \propto T^4$

$Q \propto A.T^4$ or $\boxed{Q = \sigma.A.T^4}$

q= emissive power or heat flux (W/m^2)

Q= rate of heat energy radiated (W)

= Stefan-Boltzmann’s constant = 5.67 X 10^{-8} W/m^2 . K^4

This equation holds good only for Black Body.

Grey Body – A body having emissivity less than one and it is same for all wavelength. Its absoptivity is equal to emissivity.

For grey body $Q= .\sigma.A.T^4$

If a large grey body of surface area A at temperature T1, is kept in infinite surroundings at temperature T2 (where T1>T2). The exchange of energy by **radiation** from a solid to its surroundings or Heat transfer between two large grey bodies with higher & lower temp respectively, then Heat Transfer Q is -

$$\boxed{Q = \varepsilon.\sigma.A.(T1^4 - T2^4)}$$ in watt

Internal Combustion Engines

Introduction of I.C. Engine

Heat Engines - A machine or device which derives heat from the combustion of fuel and converts part of this energy into mechanical work is called a heat engine.

Heat engines may be classified into two main classes as follows:

1. External combustion engines
2. Internal combustion engines

Internal Combustion Engines – In this case, combustion of fuel with oxygen of the air occurs within the cylinder of the engine. The internal combustion engines group includes engines employing mixtures of combustible gases and air, known as gas engines, those using lighter liquid fuel or spirit known as petrol engines and those using heavier liquid fuels, known as oil, compression ignition or diesel engines.

The important applications of I.C. engines are: (i) Road vehicles, locomotives, ships and aircraft, (ii) Portable standby units for power generation in case of scarcity of electric power, (iii) Extensively used in farm tractors, lawn movers, concrete mixing devices and motor boats.

Classification of I.C. Engines

The internal combustion engines may be classified in the following ways:

1. According to the type of fuel used

a) Petrol engines, b) Diesel engines, and c) Gas engines.

2. According to the method of igniting the fuel

a) Spark ignition engines, and b) Compression ignition engines.

3. According to the number of strokes per cycle

a) Four stroke cycle engines, and b) Two stroke cycle engines.

4. According to the cycle of operation
a) Otto cycle engines, b) Diesel cycle engines, and c) Dual cycle engines.

5. According to the speed of the engine
a) Slow speed engines, b) Medium speed engines, and c) High speed engines.

6. According to the cooling system
a) Air-cooled engines, and b) Water-cooled engines.

7. According to the method of fuel injection
a) Carburettor engines, and b) Air injection engines.

8. According to the number of cylinders
a) Single cylinder engines, and b) Multi-cylinder engines

The basic idea of internal combustion engine is shown in Fig. (Basic idea of I.C. engine). The cylinder which is closed at one end is filled with a mixture of fuel and air. As the crankshaft turns it pushes cylinder. The piston is forced up and compresses the mixture in the top of the cylinder. The mixture is set alight and, as it burns, it creates a gas pressure on the piston, forcing it down the cylinder. This motion is shown by arrow '1'. The piston pushes on the rod which pushes on the crank. The crank is given rotary (turning) motion as shown by the arrow '2'. The flywheel fitted on the end of the crankshaft stroes energy and keeps the crank turning steadily.

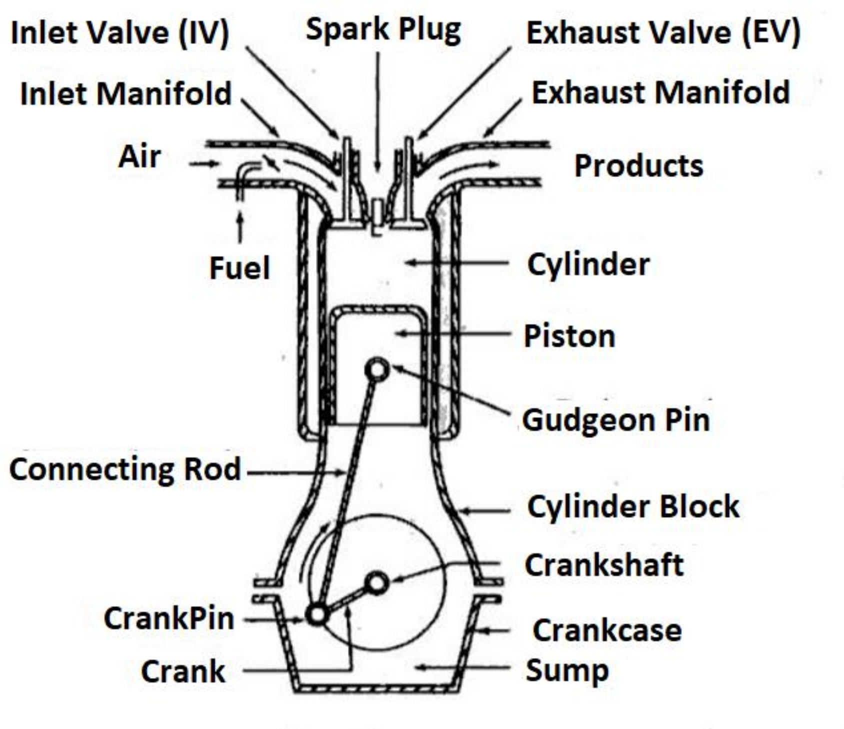


Fig. Internal Combustion Engin

What is 4 Stroke Engine?

Any mechanical device which is capable of converting chemical energy of the fuel into mechanical energy is called an engine.Also in four stroke engine, the chemical energy is converted into mechanical energy in which the piston does four times movement to produce a power stroke (2 times from TDC to BDC and 2 times from BDC to TDC).

Types of Four Stroke Engine
The four stroke engine are of two types and these are

1. Petrol engine/ gasoline engine: when petrol is used as a fuel in four stroke engine then it is called as four stroke petrol engine. The construction of petrol engine is slightly different from the diesel engine. In petrol engine there is a spark plug for the combustion of the fuel. And air-fuel mixture is sucked in the cylinder.

2. Diesel engine: When the fuel used in the four stroke engine is diesel than it is called as diesel engine. In diesel engine there is fuel injector for the injection of the fuel within the cylinder. During suction, only air is sucked within the cylinder. Hot compressed Air is used for the burning of the fuel in this type of four stroke engine.

Four Stroke SI/Petrol Engine Working

The various strokes in four stroke Spark Ignition(SI) engine are

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

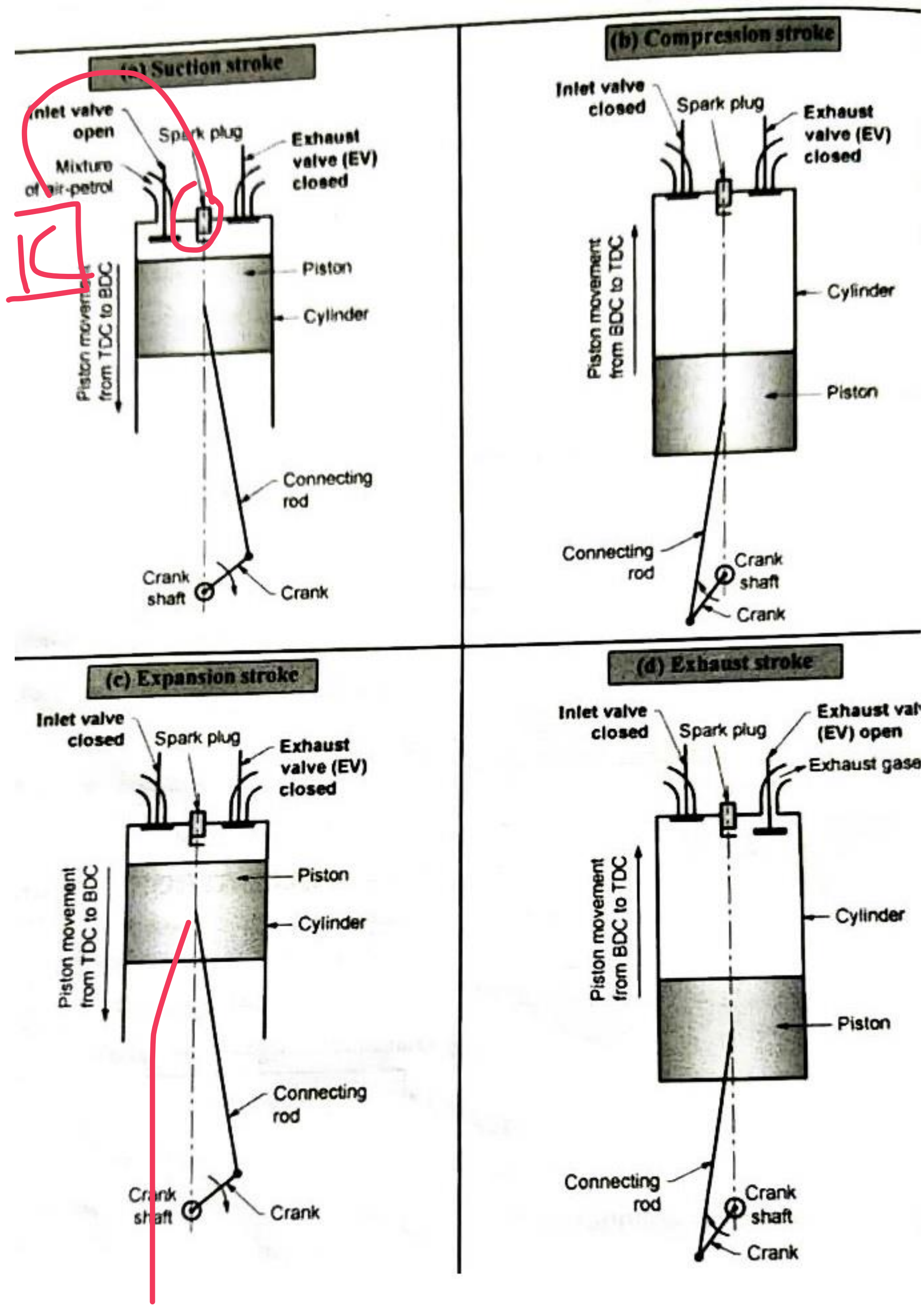
Working Principle-

1. Suction stroke

In suction stroke what happens, first the piston moves from TDC to BDC. As the piston moves the inlet valve opens and the air fuel mixture enters into the cylinder. The exhaust valve remains closed during this stroke.

2. Compression stroke

In compression stroke, the piston moves from BDC to TDC. The inlet and exhaust valve remains closed during this stroke. As the piston moves upward(from BDC to TDC) the compression of air- fuel takes place. The compression processes completes when piston reaches to the TDC. The compression is done to increase the temperature of the air or air-fuel mixture. The temperature is increased so that it can easily catch fire during



3. Expansion/Power Stroke

The air-fuel mixture is ignited by the spark plug. Due to the ignition the burning process starts. The burning of the air-fuel mixture creates a very high pressure burnt gases. This high pressure burnt gases exerts a thrust on the top face of the piston and it starts to move downward from TDC to BDC. This is the power stroke of the engine. In this stroke we get power which is utilized to run the vehicle. The intake and exhaust valve remains closed during this stroke.

4. Exhaust Stroke

In this stroke the piston moves upward i.e. from TDC to BDC. As the piston moves upward the exhaust valve opens and all the burnt gases left after power stroke starts escaping out of the cylinder. The burnt gases escape out in the environment through exhaust Valve. When the piston reaches at TDC the exhaust process completes.

Four Stroke CI/Diesel Engine Working

The various strokes in four stroke Compression Ignition (CI) engine are

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

1. Suction stroke

In suction stroke what happens, first the piston moves from TDC to BDC. As the piston moves the inlet valve opens and the only air enters into the cylinder. The exhaust valve remains closed during this stroke.

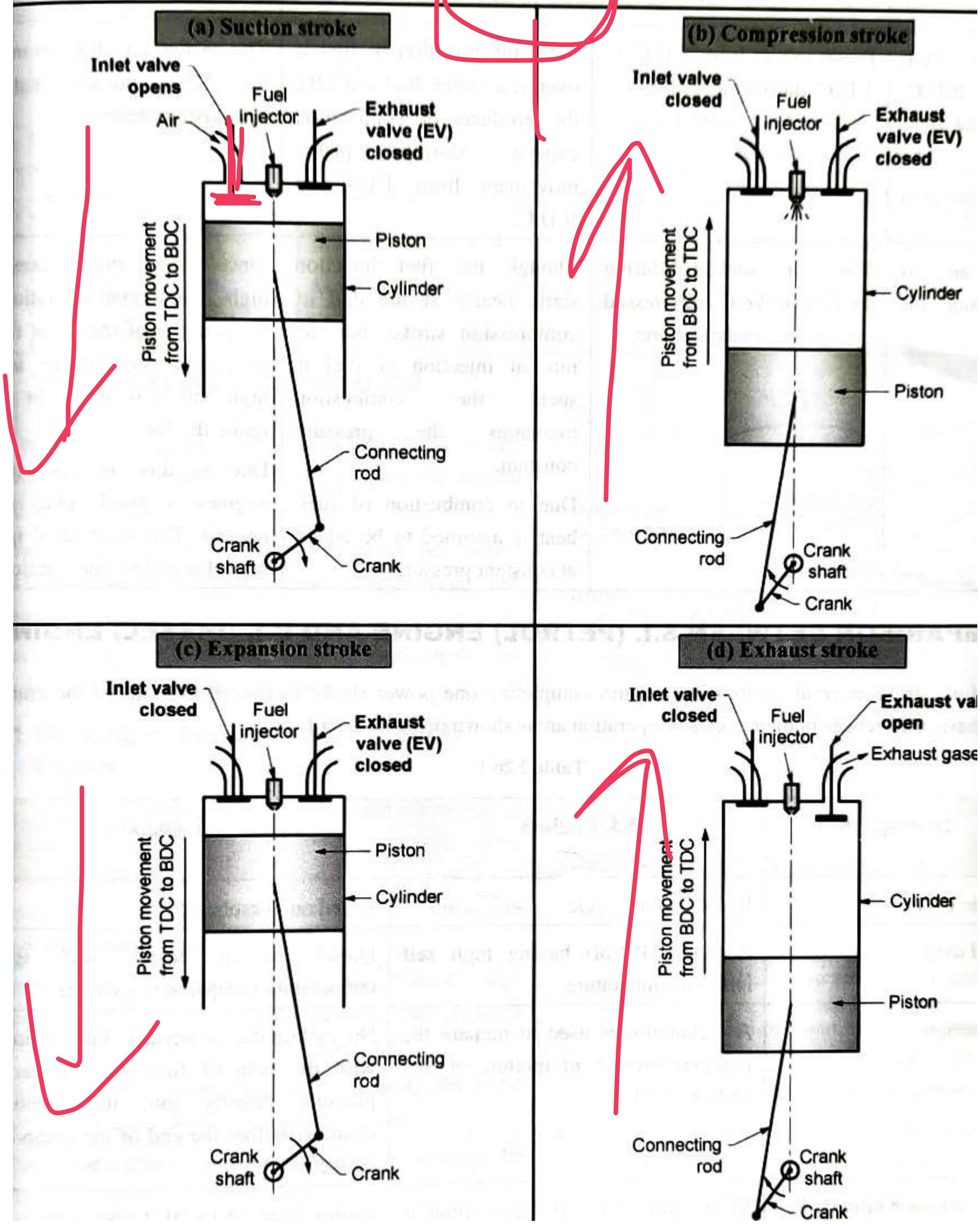
2. Compression stroke

In compression stroke, the piston moves from BDC to TDC. The inlet and exhaust valve remains closed during this stroke. As the piston moves upward(from BDC to TDC) the compression air in case of diesel engine takes place. The compression processes completes when piston reaches to the TDC. The compression is done to increase the temperature of the air. The temperature is increased so that it can easily catch fire during spraying of diesel.

3.Expansion/Power Stroke

As the Piston approaches TDC the injection of the diesel in the form of spray by fuel injector takes place. As the diesel sprayed by the fuel injector come in contact with the hot compressed gases it catches fire and burning processes starts. Due to burning high pressure hot burnt gases originates and it puts a very high thrust on the top face of the piston. Due the thrust impact on the piston it starts to move in downward direction i.e. form TDC to BDC.

WORKING OF 4 STROKE DIESEL ENGINE



4.Exhaust Stroke

In this stroke the piston moves upward i.e. from TDC to BDC. As the piston moves upward the exhaust valve opens and all the burnt gases left after power stroke starts escaping out of the cylinder. The burnt gases escape out in the environment through exhaust Valve. When the piston reaches at TDC the exhaust process completes. And after this again all the four stroke repeat themselves.

Two Stroke Engine

When the piston moves from TDC to BDC or BDC to TDC then this movement of piston from TDC to BDC and vice versa is called one stroke.

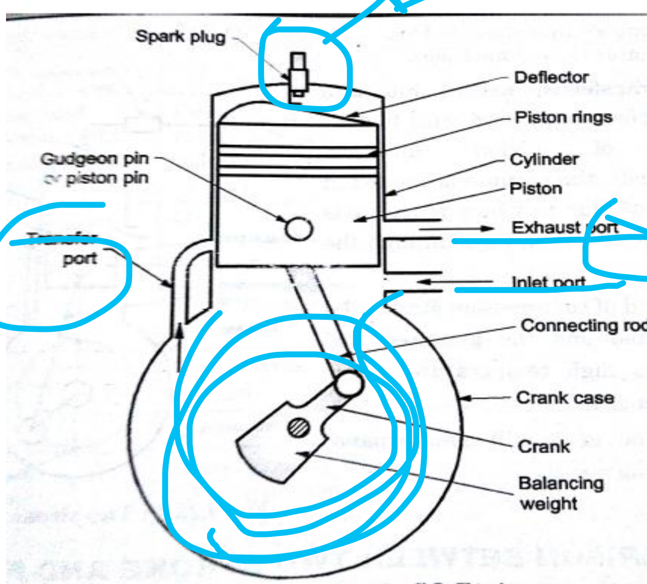


Fig Two stroke SI Engine/ Petrol engine

The two strokes of a two stroke engines are described as follows:

1. Upward stroke

- During upward stroke, the piston moves from BDC to TDC and compresses the charge (air-fuel mixture) in the combustion chamber of the cylinder.
- Because of the upward movement of the piston a partial vacuum is created in the crankcase and this allows the entry of the fresh charge into the crankcase through uncovered inlet port.
- The exhaust port and the inlet port remains covered when the piston at the TDC.
- The ignition of the fresh charge is takes place by the spark plug.

2. Downward stroke

- As soon as the combustion of the fresh charge takes place, a large amount of the hot gases is produced which exerts a very high pressure force on the top of the piston. Due to this high pressure force, the piston moves downward and rotates the crankshaft and does useful work.

- During this stroke the inlet port is covered by the piston and the new charge is compressed in the crankcase.
- Further downward movement of the piston uncovers first the exhaust port and the transfer port and the exhaust starts through the exhaust port.
- As soon as the transfer port opens, the charge through it is forced into the cylinder.
- The charge strikes the deflector on the piston crown, rises to the top of the cylinder and pushes out most of the exhaust gases.
- The piston is now at BDC position. The cylinder is completely filled with the fresh charge but it is somewhat diluted with the exhaust gases.
- Finally the cycle event is then repeated. We get two strokes for the single revolution of the crankshaft

Difference between Petrol Engine and Diesel Engine

SR.No.	Petrol Engine	Diesel Engine
1.	The petrol engine works on Otto cycle i.e. on constant volume.	The diesel engine works on diesel cycle i.e. on constant pressure.
2.	The air and petrol are mixed in the carburetor before they enter into the cylinder.	The fuel is fed into the cylinder by a fuel injector and is mixed with air inside the cylinder.
3.	The petrol engine compresses a mixture of air and petrol which is ignited by an electric spark.	The diesel engine compresses only a charge of air and ignition is done by the heat of compression.
4.	Compression ratio is low.	Compression ratio is higher in diesel engine.
5.	Less power is produced due to lower compression ratio.	Due to higher compression ratio more power is produced.
6.	Petrol engine is fitted with a spark plug	It is fitted with a fuel injector.
7.	Burns fuel that has high volatility.	Burns fuel that has low volatility.
8.	They are used in light vehicles which requires less power. Eg: car, jeep, motorcycle, scooters etc.	They are used in heavy vehicles which require high power. Eg: bushes, trucks, locomotive etc.
9.	Fuel consumption in petrol engine is high.	Fuel consumption in diesel engine is less.
10.	Lighter	Heavier
11	Lower initial cost.	Higher initial cost.
12.	Lower maintenance cost.	Higher maintenance cost.

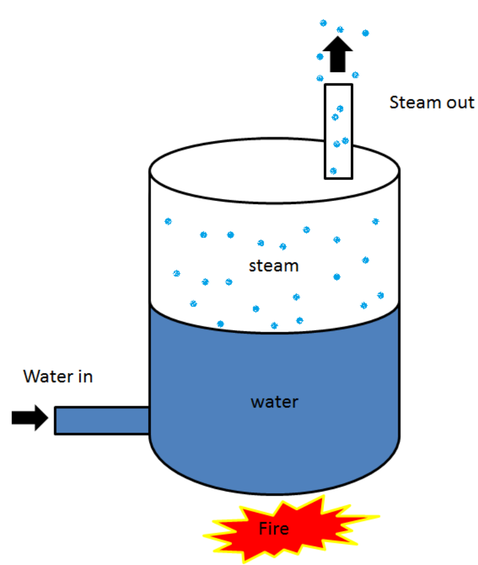
Difference between Four stroke engine and Two stroke engine

Sr.No.	Four stroke engine	
1.	It has one power stroke for every two revolutions of the crankshaft.	It has one power stroke for each revolution of the crankshaft.
2.	Heavy flywheel is required and engine runs	Lighter flywheel is required and engine runs

	unbalanced because turning moment on the bcrankshaft is not even due to one power stroke for every two revolutions of the crankshaft.	balanced because turning moment is more even due to one power stroke for each revolution of the crankshaft.
3.	Engine is heavy	Engine is light
4.	Engine design is complicated due to valve mechanism.	Engine design is simple due to absence of valve mechanism.
5.	More cost.	Less cost than 4 stroke.
6.	Less mechanical efficiency due to more friction on many parts.	More mechanical efficiency due to less friction on a few parts.
7.	More output due to full fresh charge intake and full burnt gases exhaust.	Less output due to mixing of fresh charge with the hot burnt gases.
8.	Engine runs cooler.	Engine runs hotter.
9.	Engine is water cooled.	Engine is air cooled.
10.	Less fuel consumption and complete burning of fuel.	More fuel consumption and fresh charge is mixed with exhaust gases.
11.	Engine requires more space.	Engine requires less space.
12.	Used in cars, buses, trucks etc.	Used in mopeds, scooters, motorcycles etc.

Steam Generator (Boiler)

A boiler is a closed vessel which is used to convert the water into high pressure steam. The high pressure steam so generated is used to generate power. The boiler works on the same principle as the water is heated in a closed vessel and due to heating, the water changes into steam. This steam steam possesses high pressure kinetic energy.The boiler contains water. The water is heated to its boiling temperature by the use of



heat from the furnace. Due to heating of water, it gets converted into high pressure steam. The steam generated is passed through the steam turbines. As the high pressure steam strikes the turbine, it rotates the turbine. A generator is attached to the turbine and the generator also starts to rotate with the turbine and produces electricity.

Classification of Boiler

1.. According to the Contents in the Tubes

(a) Fire Tube Boiler

(b) Water Tube Boiler

2. According to the Number of Tubes

(i). Single Tube Boilers

(ii). Multitubular Boiler

3. According to the Position of the Furnace

(i). Internally Fired Boilers

(ii). Externally Fired Boilers

4.According to the Methods of Circulation of Water and Steam

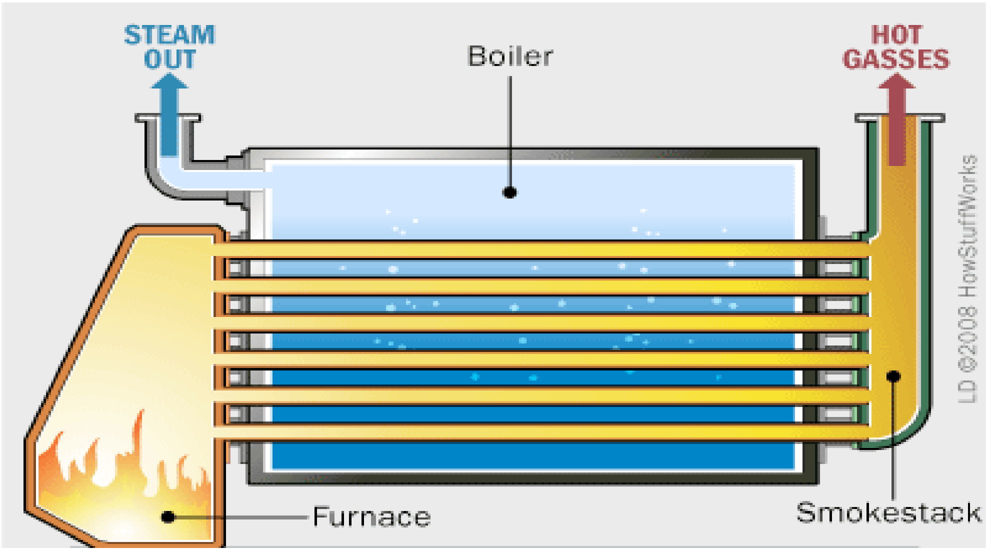
(i). Natural Circulation Boilers

(ii). Forced Circulation Boilers

(i) Fire Tube Boiler:

In fire tube boiler the fire or hot gas are present inside the tubes and water surrounds these fire tubes. Since fire is inside the tubes and hence it is named as fire tube boiler. The heat from the hot gases is conducted through the walls of the tube to the water.

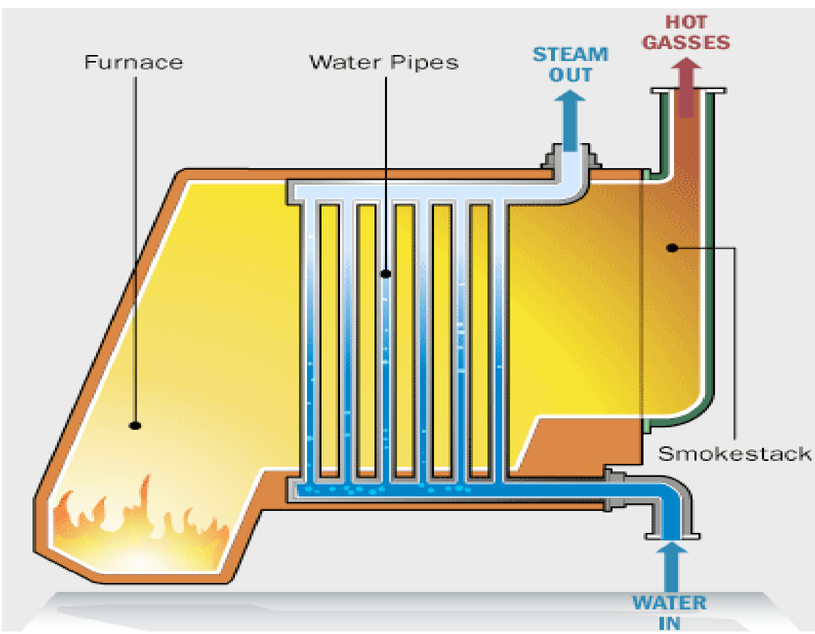
The examples of the fire tube boiler are: simple vertical boiler, Cochran boiler, Lancashire boiler, Cornish boiler, Locomotive boiler, Scotch marine boiler and Velcon boiler.



(ii). Water Tube Boiler:

In water tube boilers, the water is present inside the tubes and the fire or hot gases surrounds these water tubes.

The examples of water tube boilers are: Stirling boiler, Babcock and Wilcox boiler, Yarrow boiler and Loeffler boiler.



Difference Between Fire Tube Boiler and Water Tube Boiler

	Fire tube boiler	Water tube boiler
1.	In this boiler the hot flue gases is present inside the tubes and water surrounds them	The water is present inside the tubes and the hot flue gases surrounds them
2.	They are low pressure boilers. The operating pressure is about 25 bar.	They are high pressure boilers and the operating pressure is about 165 bar.
3.	The steam generation rate in fire tube boiler is low, i.e.9 tonne per hour.	Steam generation rate in water tube boiler is high i.e. 450 tonne per hour.
4.	For a given power the floor area required for steam generation is more i.e. 8 m^2 per tonne per hour.	The floor area required for the steam generation is less, i.e. 5 m^2 per tonne per hour.
5.	The transportation and erection in this type of boiler is difficult.	The transportation and erection is easy as its parts can be separated.
6.	The overall efficiency of this boiler is upto 75%.	The overall efficiency is upto 90% with the economizer.
7	Operating cost is low.	Operating cost is high.
8	Bursting chance is less in fire tube boiler.	Bursting chance in water tube boiler is more.
9.	Due to bursting, there is a greater risk to the damage to the boiler.	The bursting in this boiler does not produce any major destruction to the whole boiler.
10.	It can be operated with less skilled person.	A skilled person is required to operate this boiler.
11.	Low maintenance cost.	High maintenance cost.
12.	It is suitable for small power plant.	It is suitable for large power plant.

! ! Best Luck for Exam. ! !