EW

@ENGINEERINGWALLAH

UNIT II
Introduction to Thermal Engineering

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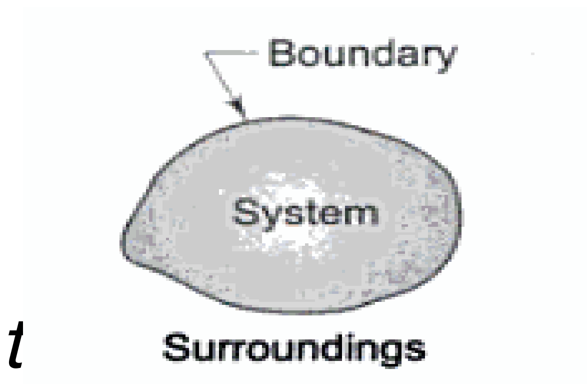
Thermodynamics System

A thermodynamics system is defined as a quantity of matter or a

region in space upon which attention is concentrated in the

analysis of a problem.



Surrounding

every thing external to the system is called t

surrounding or the environment.

Boundary

the system is separated from the surroundings by the system

boundary

Types of Thermodynamics System

1. **Closed System**

i. *"A system is called a closed system when only energy transfer takes place across the boundary but no mass mass transfer takes place"*

ii. It is also known as non flow syste

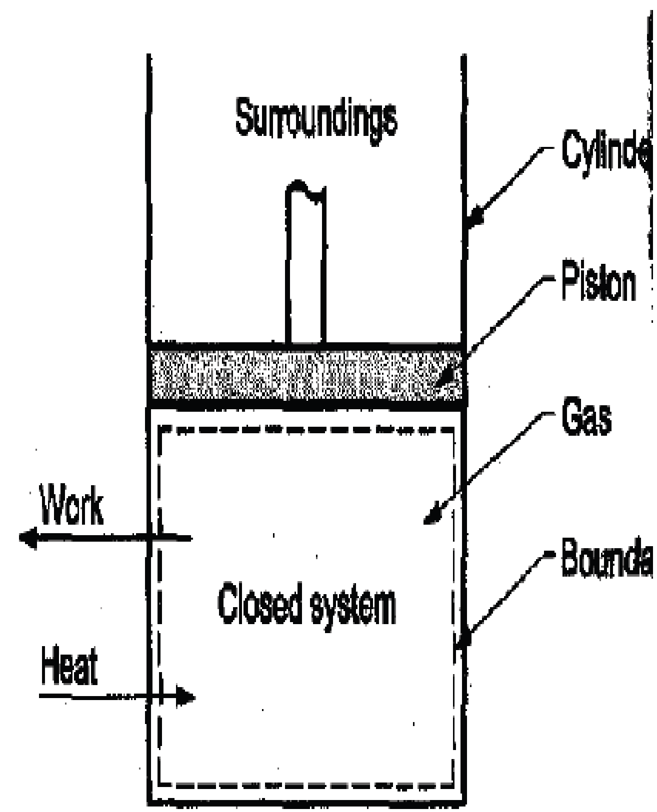
iii. Closed system is of fixed mass

General Example : greenhouse

Engg Example : A piston in cylinde

Other Example : i) pressure cooker

Closed Systems



2. **Open System**

i. *"A system is called as open system when energy transfer as well as mass transfer takes place across the boundary"*

ii. It is also known as flow system

General Example : ocean

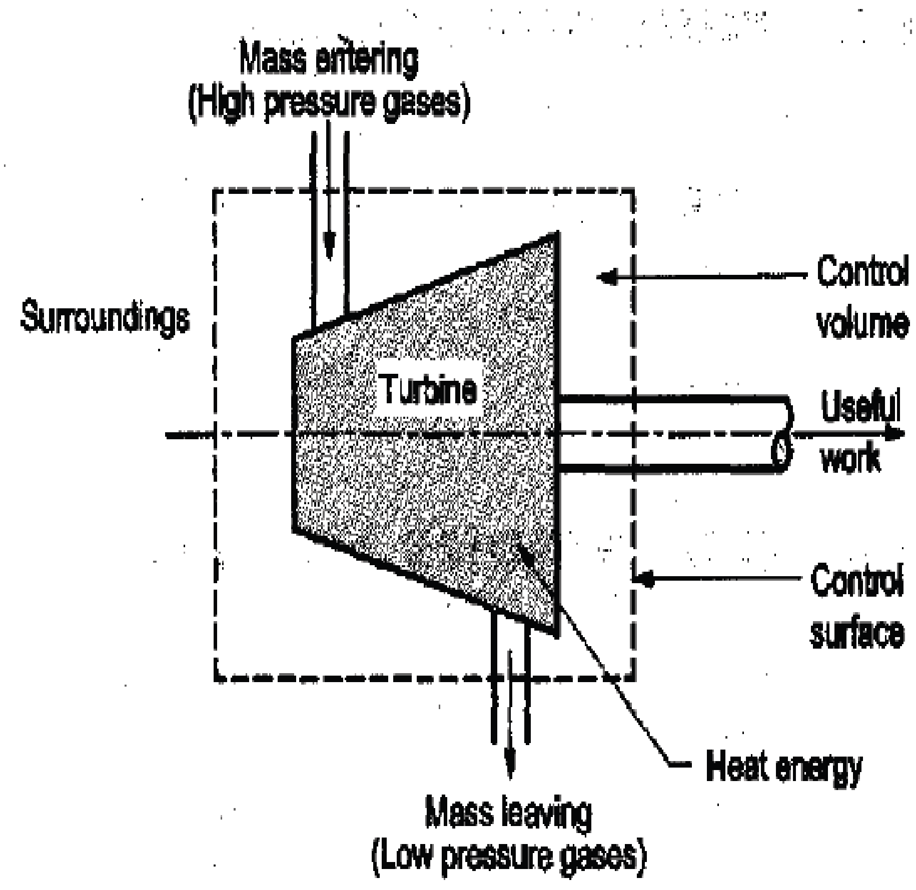
Engg Example: i) turbine

ii) air compressor

Other Example : i) IC engine

ii) turbine

Open Systems



3. Isolated system

i. *"A system is called as Isolated system when there is no energy transfer and mass transfer takes place across the boundary*

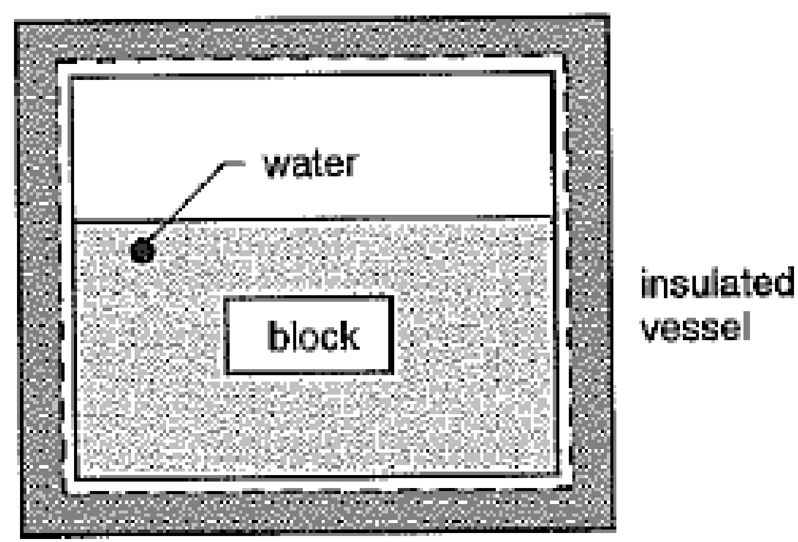
ii. It is of fixed mass and energy

iii. It is completely Isolated from surrounding

General Example : i)thermal flask

Engg Example: i) Insulated container

ii) enclosed vessel containing gas



Thermodynamic Properties

Intensive Properties

i. *“Properties which doesn’t depends on the total mass in the system are known as Intensive Properties”*

ii. For e.g. a) temp

b) pressure

c) velocity

Extensive Properties

i. *“Properties which depends on the total mass in the system are known as Intensive Properties”*

ii. For e.g. a) volume

b) energy

c) enthalpy

THERMODYNAMICS

Defn

Thermodynamics is the science of energy transfer and its effect on the physical properties of substances

Examples of energy transfer

i. Generator : mech to electrical
ii. Electrical motor : electrical to mech
iii. Fuel cell : chem to electrical
iv. Refrigerator : electrical to cooling effect

Applications

i. Thermodynamic laws and principles are found in all fields of energy technology.
ii. In steam and nuclear power plants, internal combustion engines, gas turbines ,
iii. air conditioning ,refrigeration , gas dynamics , jet propulsion , compressors ,
iv. chemical process plants and direct energy conversion devices.

Thermodynamic Laws

Zeroth law of thermodynamics

"If two systems are in thermal equilibrium with a third system,
then they are in thermal equilibrium with each other"

<u>Explanation</u>

i. Consider three bodies X, Y, Z
ii. If X and Z are brought in good contact, then energy in the form of heat is transfer from higher temp body to lower temp body
iii. After some time bodies X and Z are in thermal equilibrium
iv. Now if Y and Z brought in good contact then after some time these are also in thermal equilibrium
v. Hence bodies X,Y,Z are in thermal equilibrium

First Law of Thermodynamics

The statement of First Law of Thermodynamics in different forms can be stated as follow

Statement 1

"When system undergoes a cyclic change, then the algebraic sum of work deliver to the surrounding is directly proportional to the algebraic sum of heat taken from the surrounding"

Statement 2

"Energy can neither be created nor be destroyed only one form of energy can converted into other form"

Statement 3

"No machine which is capable of producing work without expenditure of energy"

Limitations of first law

i. I st law of thermodynamics states that, when a closed system undergoes a cyclic process then the cyclic integral of the work is proportional to the cyclic integral of the heat
ii. Also I st law of thermodynamics deals with principle of conservation of energy
iii. According to I st law, the energy transfer can take place in either direction and it doesn’t specify the direction of energy transfer
iv. The Limitations of I st law of thermodynamics can understood with the help of following examples

Example 1

i. When an ice cream is kept open to atmosphere, it absorbs heat and get melted
ii. But liquid ice cream doesn’t solidify without doing any work (without refrigeration)

Example 2

i. When we kept a cup of tea in a cooler room, it will cool off
ii. That is heat is transfer from hot system to cooler system
iii. But reverse of the process is not possible
iv. Because tea will not heated up in the cold surrounding

Example 3

i. Water flows from higher level to lower level
ii. But water cant flow from lower level to higher level without some external work

Example 4

i. Two gases mixed spontaneously when placed in an Isolated system
ii. But the mixed gases cant be separated without some external work

Limitations of first law

i. The process can proceed in particular direction only i.e. heat transfer from hot system to cold system

ii. The work is completely converted into heat but heat cant completely converted into work

iii. I st law provides a necessary but not sufficient condn for process to takes place

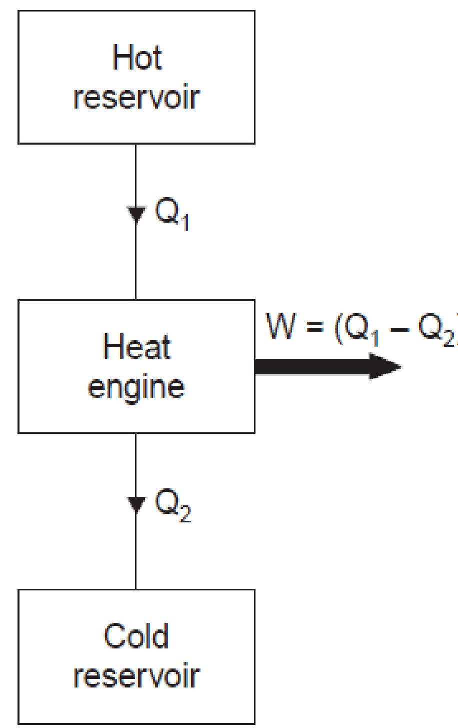
iv. heat transfer takes place in particular direction only.

Second Law of Thermodynamics

There are two statements of second law of thermodynamics

1. <u>**Kelvin-Planck Statement**</u>

"It is impossible to construct a heat engine operating on a cycle whose sole effect is the transfer of heat from a single heat reservoir and its conversion into equal amount of work"



(a)
Heat engine

i. *Consider an engine which receives hea High temp heat reservoir at T1*

ii. *It rejects heat Q2 to low temp heat reservoir and does the work*

$$W = Q1 - Q2$$

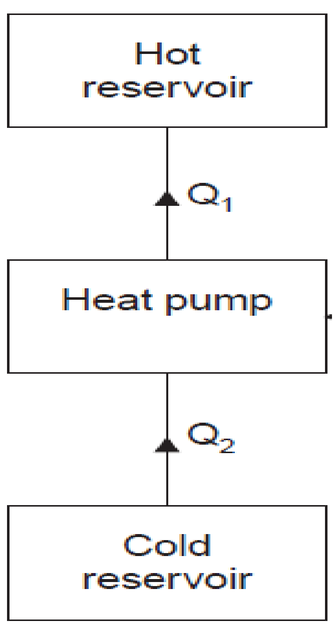
2. Clausius Statement

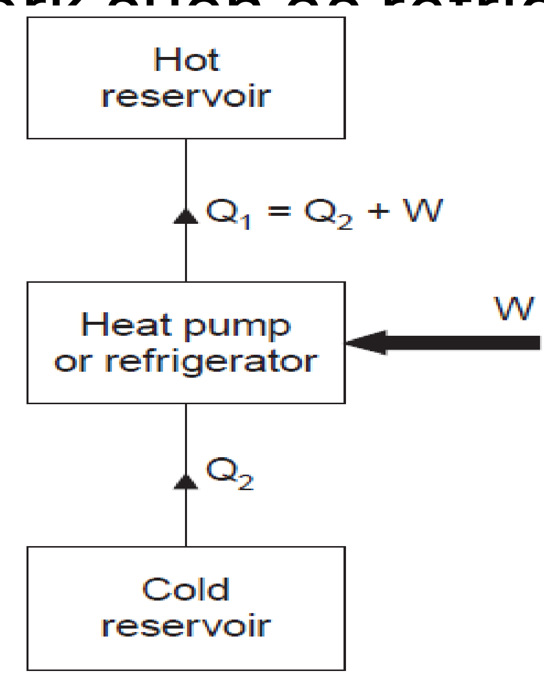
"It is impossible to construct a device operating on a cycle whose sole effect is the transfer of heat from a low temp heat reservoir to a higher temp heat reservoir"

Though the heat cant flow from a body at lower temp to a body at

higher temp, however such transfer of heat can achieved in

practice with the help of external work such as refrigerator





Definitions

1. **Heat or Thermal Reservoir**

i. *"A Heat or Thermal Reservoir is defined as the source of infinite heat energy, which is capable of absorbing or rejecting an unlimited quantity of heat without any change in its temperature"*

ii. For examples

large budies of water such as lakes

the atmosphere

2. **Heat Source**

i. *"A heat reservoir which supplies heat to a system is known as Heat Source"*

ii. It is also known as high temperature reservoir

3. **Heat Sink**

i. *"A heat reservoir which absorbs heat from the system is known as Heat Sink*

ii. It is also known as low temperature reservoir

4. **Heat Engine**

i. *"Heat engine is a thermodynamic system or device operating in a cycle to which net heat is transferred and from which net work is delivered"*

OR

ii. *Heat engine is the device which can produce the work continuously at the expense of heat input*

iii. For example : **steam engine, steam turbine**

i. *Consider an engine which receives heat Q1 from High temp heat reservoir at T1*

ii. *It rejects heat Q2 to low temp heat reservoir and does the work*

$$W = Q1 - Q2$$

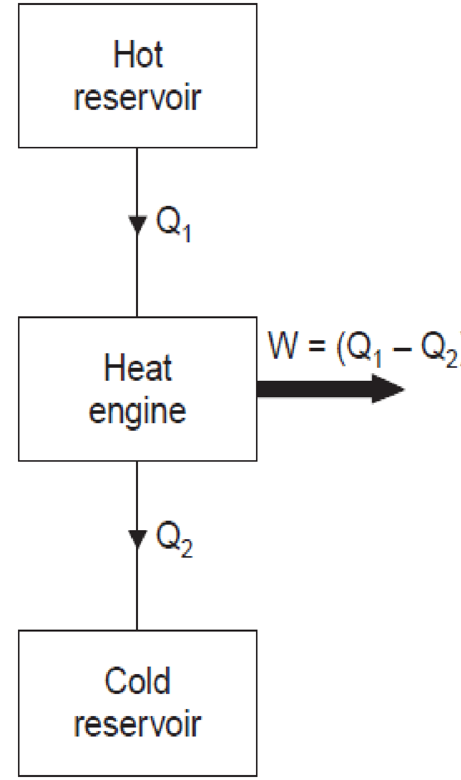
efficiency of heat engine

$$\eta = \frac{\text{Net work output of the cycle}}{\text{Total heat input to the cycle}}$$

$$= \frac{W_{\text{net}}}{Q_1}$$

$$\eta = \frac{W_{\text{net}}}{Q_1} = \frac{W_T - W_P}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

$$\eta = 1 - \frac{Q_2}{Q_1}$$



(a)
Heat engine

He

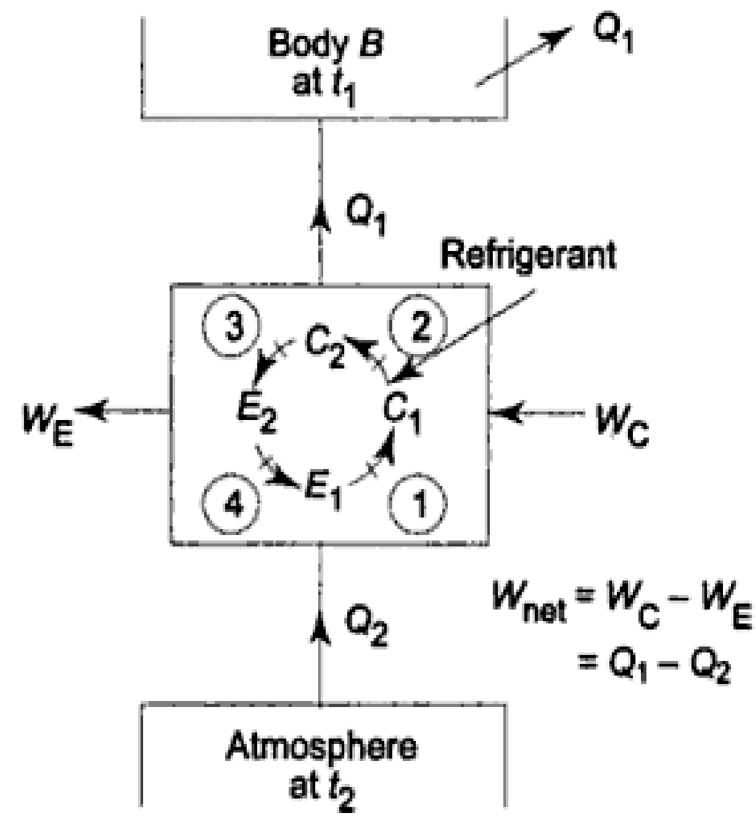
5. <u>Heat Pump</u>

i. *If the objective of the system is to deliver heat energy at higher temp. T_1, then the temp. T_2 corresponds to ambient temp.*

ii. *Such a device is known as* **Heat Pump**

$$\text{COP} = \frac{Q_1}{W}$$

$$[\text{COP}]_{\text{H.P.}} = \frac{Q_1}{Q_1 - Q_2}$$

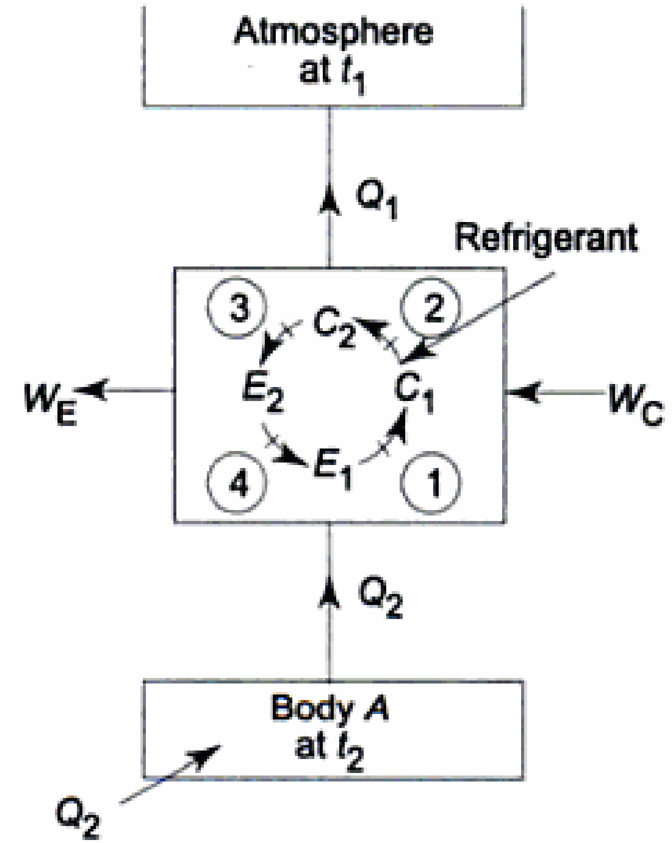


6. ***Refrigerator***

i. *A refrigerator is a device operating on a cycle which removes heat from body at low temperature and supply it to body at high temperature on the expense of external work supplied"*

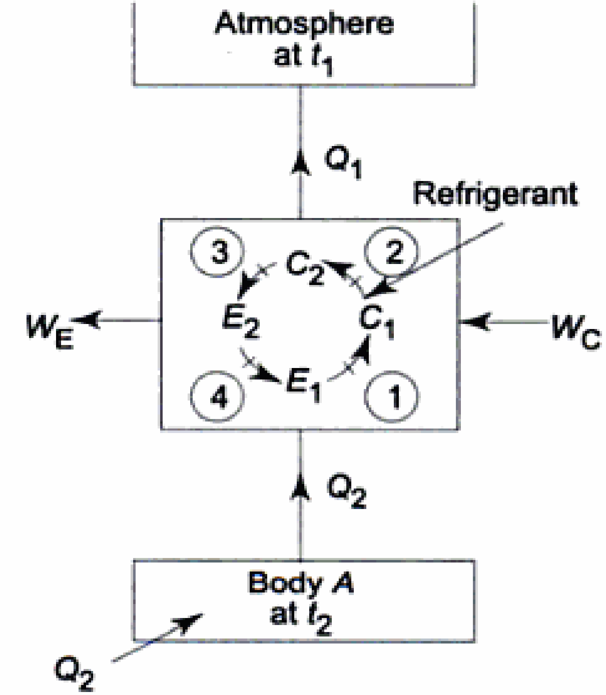
$$\mathrm{COP} = \frac{\text{Desired effect}}{\text{Work input}} = \frac{Q_2}{W}$$

$$[\mathrm{COP}]_{\mathrm{ref}} = \frac{Q_2}{Q_1 - Q_2}$$



6. **<u>Coefficient of Performance</u>**

the efficiency of Refrigerators and heat pump is expressed in terms of coefficient of performance

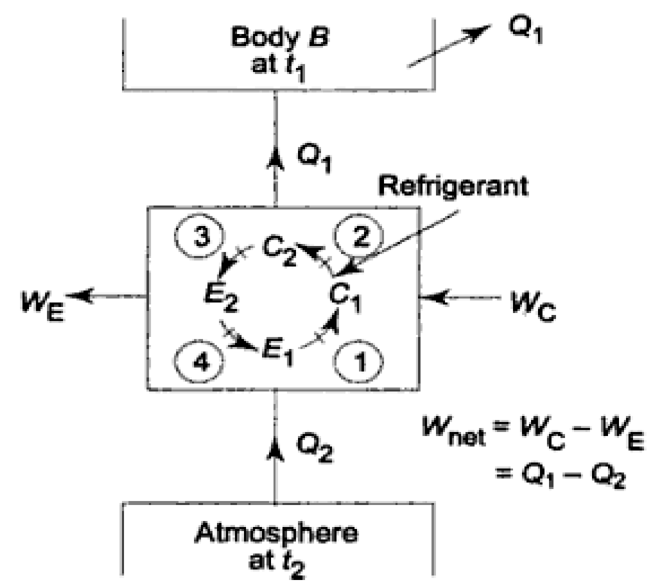


From Ist law $W = Q_1 - Q_2$

$$COP = \frac{\text{Desired effect}}{\text{Work input}} = \frac{Q_2}{W}$$

$$[COP]_{ref} = \frac{Q_2}{Q_1 - Q_2} \quad \text{........} \quad 1$$

For Heat Pump



$$COP = \frac{Q_1}{W}$$

$$[COP]_{H.P.} = \frac{Q_1}{Q_1 - Q_2} \quad \text{......} \; 2$$

From 1 and 2

$$[COP]_{H.P.} = [COP]_{ref} + 1$$

8. **Perpetual Motion Machines**

i. *Any machine or device that violates either Ist law or second law of thermodynamics is known as perpetual Motion Machines*

ii. *These are of two kinds*

1. **Perpetual Motion Machines of first kind (P M M I)**
   i. *A machine or device that violates Ist law of thermodynamics is known as perpetual Motion Machines of first kind (P M M I)*
   ii. These machines give continuous work without receiving energy from other system
   iii. It is impossible to construct P M M I

2. **Perpetual Motion Machines of first kind (P M M II)**
   i. *A machine or device that violates second law of thermodynamics is known as perpetual Motion Machines of second kind (P M M II)*
   ii. It is the machine which gives 100% efficiency

Heat Engine	Heat Pump	Refrigerator
It is a work developing device	It is a work absorbing device	It is a work absorbing device
It obeys Kelvin Plank's statement of second law of thermodynamics.	It obeys Clausius statement of second law of thermodynamics.	It obeys Clausius statement of second law of thermodynamics.
Its performance is measured in terms of "Efficiency" $\eta = W / Q1$	Its performance is measured in terms of "Coefficient of Performance" COP = Q1 / W	Its performance is measured in terms of "Coefficient of Performance" COP = Q2 / W
Efficiency is always less than 100%	COP is always greater than 1	COP is always greater than 1

Heat Transfer

Heat transfer is the science that seeks to predict the rate of heat energy transfer that take place between material bodies as a result of a temperature difference.

Application of Heat Transfer

1) Automobile
2) Milk chillers and dairy industries
3) Ice plant
4) IC engines
5) Steam and Gas Turbines power plants
6) Food Industries
8) Refrigeration and air conditioning
8) Medicine preservation
9) Solar power plant
10) Electronic cooling
11) Electric vehicles

Modes of Heat Transfer:

1) Conduction
2) Convection
3) Radiation

Conduction

i. Conduction is the mode of transfer of heat from one part of a substance to another part of the same substance, or from one substance to another which are in physical contact with each other without appreciable displacement of molecules forming the substance.
ii. Heat transfer takes place due to vibratory motion from one electron to another.

Convection

i. Convection is the heat transfer due to the bulk movement of molecules within fluids such as gases and liquids.
ii. Convection is the mode of transfer of heat in which physical circulation of molecules takes place.

Radiation

Radiation is the mode of transfer of heat through space by means of thermal radiations or electromagnetic waves.

Fourier's law of heat conduction

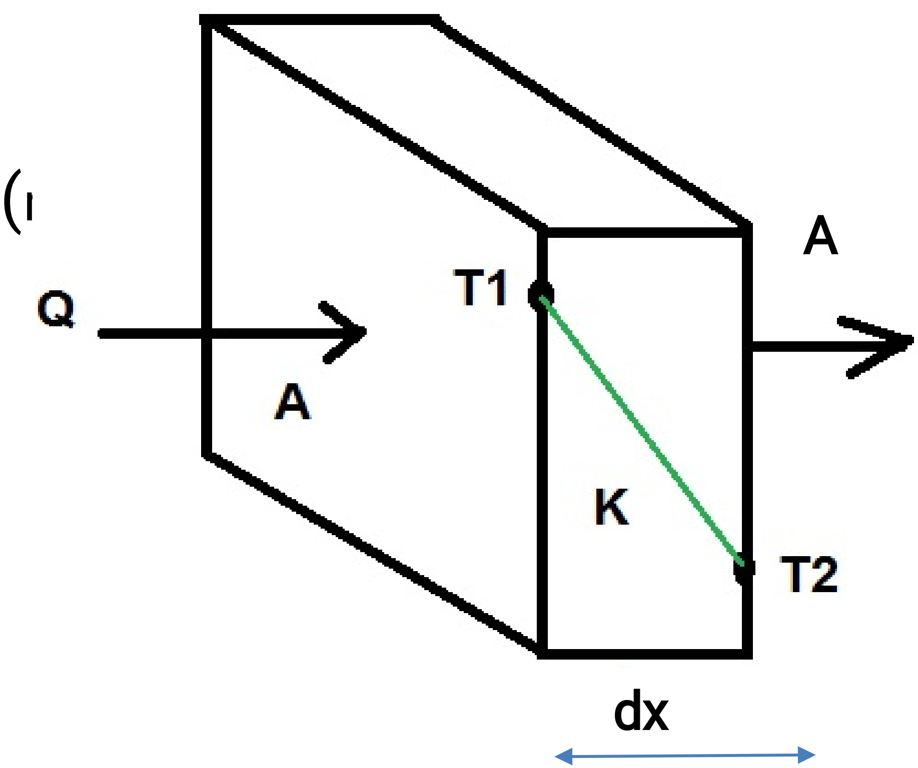
It states that the rate of heat transfer is directly proportional to the area in the direction of heat flow and temperature gradient present in that direction.

$$Q \propto A \, dT / dx$$

$$Q = - K A \, dT / dx$$

Where

Q = rate of heat transfer (w)
K = thermal conductivity (w/mk)
A = area in the direction of heat flow (ı
dT = temp difference (k)
dx = thickness of the surface (m)



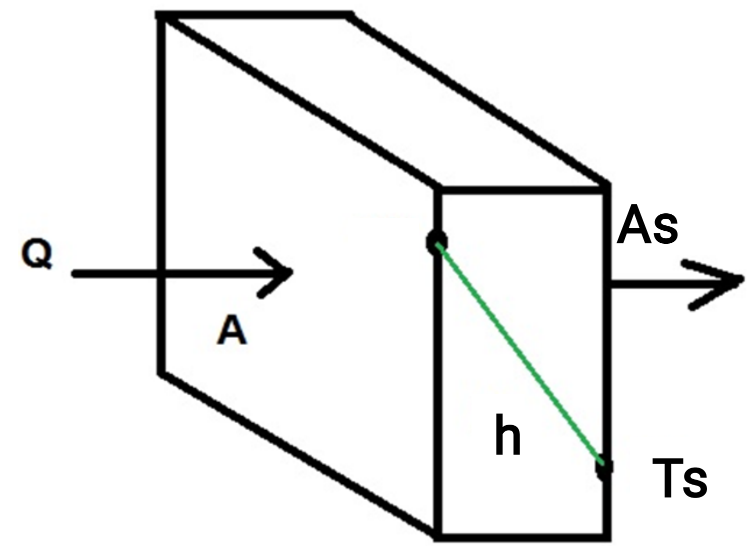
Newton's Law of Cooing

It states that the rate of heat transfer is directly proportional to the surface area and the difference in the temperatures between the surface and fluid

$$Q \,\alpha\, A_s (T_s - T_f)$$

$$Q = h\, A_s (T_s - T_f)$$

Fluid
Tf



where

Q = rate of heat transfer (w)
h = convective heat transfer coefficient (w/m^2k)
A_s = surface area (m^2)
$(T_s - T_f)$ = temp difference between the surface and fluid

Stefan Boltzmann's Law

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

$$Q \, \alpha \, A \, T^4$$

$$Q = \sigma A T^4 \quad \textit{for black surface}$$

$$Q = \sigma \varepsilon A T^4 \quad \textit{for gray surface}$$

where

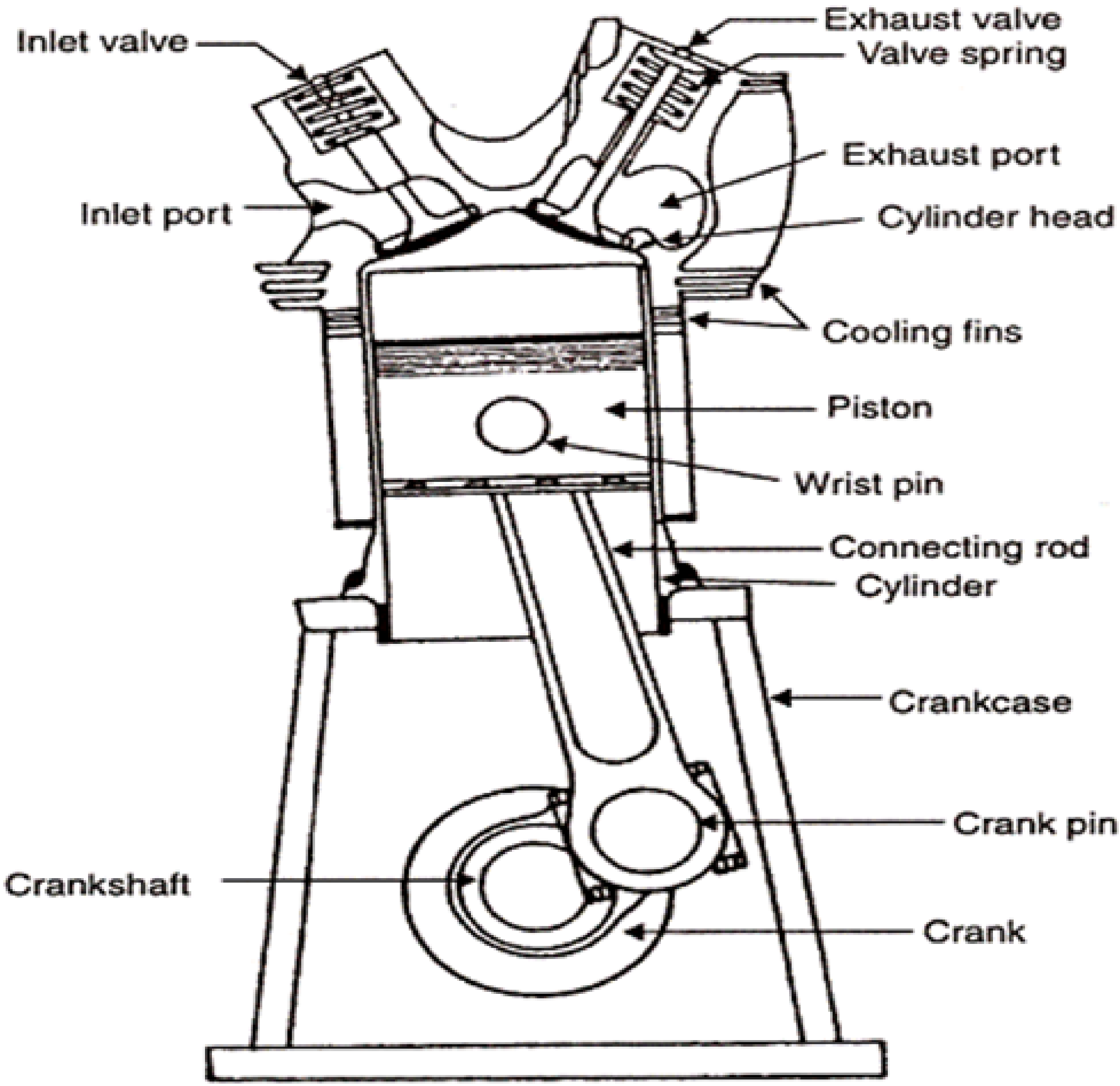
Q = rate of heat transfer (w) / *emissive power*

A = surface area (m^2)

σ = Stefan Boltzmann's constant = 5.67×10^{-8} W/m^2K^4

Thermodynamics	Heat Transfer
It is the branch of science which deals with energy transfer and its effect on the system.	It deals with the rate of Heat Transfer
Energy transfer in thermodynamics is based on various laws such as: Zeroth law, 1^{st} law, 2^{nd} law and 3^{rd} law of thermodynamics.	Heat transfer between system and surrounding is based on three modes of heat transfer such as: Conduction, Convection and Radiation.
Thermodynamics give information about conversion of heat into work.	Heat transfer provides information about the rate of heat transfer.
It provides state point properties of the system	It provides temperature distribution inside the material.
Application of thermodynamics: Heat engine, Heat pump, refrigerator	Application of Heat transfer: Heat exchangers, condenser, evaporator

Components of I C engine



Components of I C engine

1. <u>Cylinder</u>

i. In cylinder the piston reciprocates to develop power
ii. It has to withstand very high pressure upto 75 bar and temp upto 2400 C
iii. The combustion is take place inside the cylinder
iv. It is air cooled or water cooled
v. It is made of cast iron or alloy steel

2. <u>Piston</u>

i. It is made of cast steel
ii. It compressed the air fuel mixture during the compression stroke
iii. It is used to transmit the gas force to the connecting rod and then crank during compression stroke

3. **Piston pin**

i. It is made of hardened steel

ii. It is used to connect piston to the end of connecting rod

4. **connecting rod**

i. It is a rod of circular or rectangular cross section

ii. Its small end is connected to the piston and large end is connected to the crank

iii. It converts reciprocating motion of piston into rotary motion of crankshaft

5. **Crank and crankshaft**

i. Crank is the integral part of the crankshaft

ii. Crankshaft is supported in main bearings and carries the balancing weights

6. **Spark plug**

It is used to provide high intensity spark for combustion of air fuel mixture in petrol engines

7. **Engine bearings**

i. Crankshaft is supported in main bearings

ii. Bearing provides smooth motion to the crankshaft and reduce friction

8. **Suction valve**

It is the passage which carries the charge from carburetor to the engine

9. **Exhaust valve**

it is the passage which carries the exhaust gases to the atm

Terminology used in I C engine

1. **Bore**

Bore is the inside diameter of the cylinder

2. **Piston stroke**

It is the distance travelled the piston from TDC to BDC

3. **TDC**

i. In case of vertical engines when the piston is at the top most position then the crank position is known as TDC

ii. In case of horizontal engines it is known as IDC

4. **BDC**

i. In case of vertical engines when the piston is at the bottom most position then the crank position is known as BDC

ii. In case of horizontal engines it is known as ODC

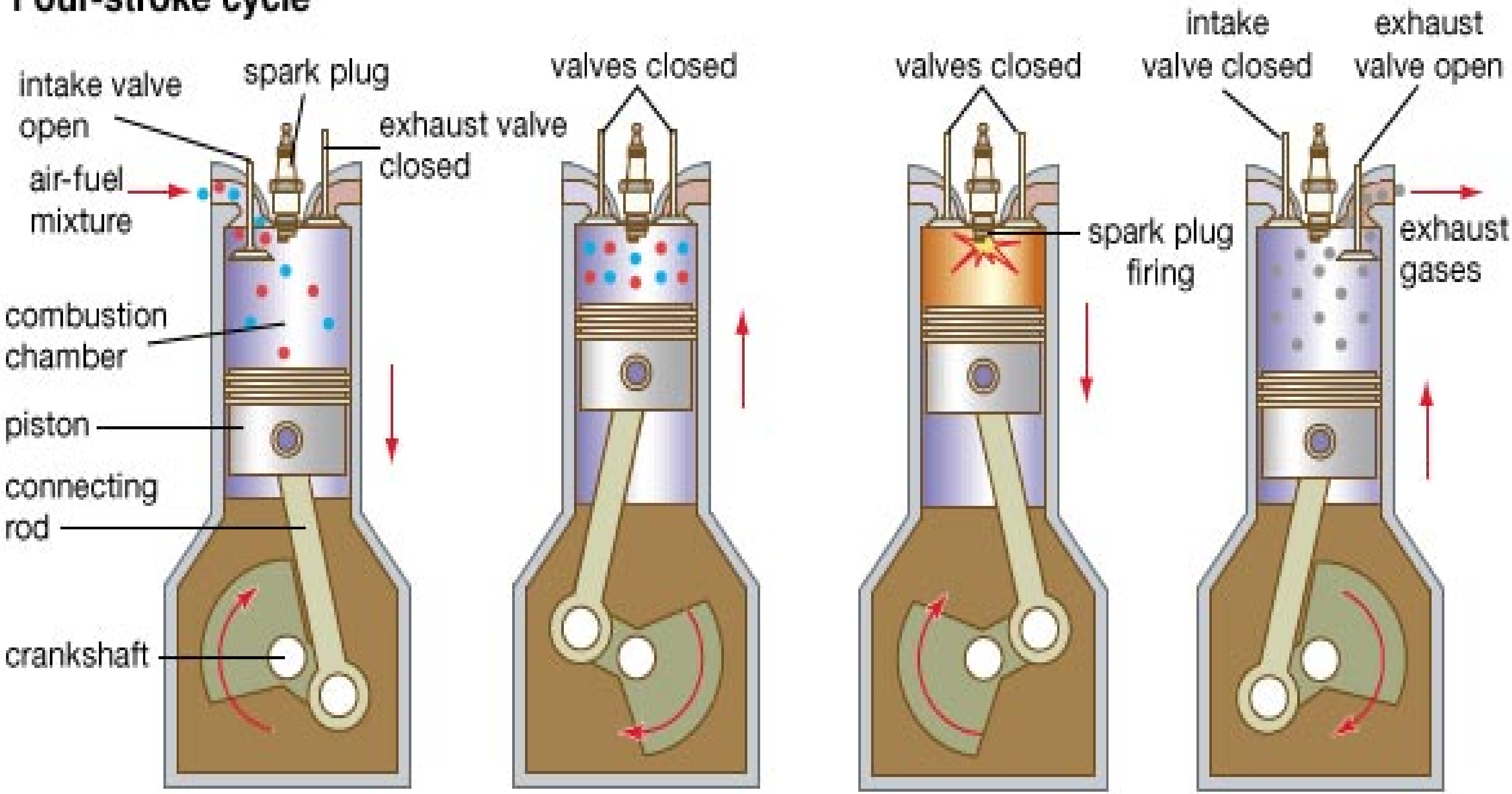
Four Stroke Cycle Engines

Four Stroke Petrol Engine (SI Engine)

i. The working of four stroke spark ignition engine is based on the Otto cycle
ii. The working fuel used for these engines is petrol or gas
iii. Four strokes are completed in two revolutions of the crankshaft
iv. The compression ratio used in these engines varies from 5 to 10

1. **Suction Stroke**
    i. During this stroke inlet valve remains open and exhaust valve remains closed
    ii. Piston moves from TDC TO BDC
    iii. The air fuel mixture is inducted during this stroke

Four-stroke cycle



intake Air-fuel mixture is drawn in.

compression Air-fuel mixture is compressed.

power Explosion forces piston down.

exhaust Piston pushes out burned gases.

2. **Compression Stroke**

   i. During this stroke both inlet and exhaust valve remain closed
   ii. Piston moves from BDC to TDC
   iii. The air sucked during compression stoke is compressed
   iv. During the process, pressure and temp. of the mixture increases
   v. Just before the end of compression stroke, the mixture is ignited with the help of spark plug

3. **Expansion or power stroke**

   i. During this stroke both inlet and exhaust valve remain closed
   ii. The product of combustion exerts pressure on the Piston hence it moves from TDC TO BDC
   iii. power is developed during expansion of gases
   iv. Hence this stroke is also known as power stroke
   v. During this stroke pressure and temp decreases

4. **<u>Exhaust stroke</u>**

   i. At the end of the expansion stroke the exhaust valve opens but inlet valve remains closed
   ii. During this stroke piston moves from BDC to TDC
   iii. Hot gases inside the cylinder are exhausted through exhaust valve

<u>Four Stroke Diesel Engine (CI Engine)</u>

i. The working of four stroke spark ignition engine is based on the diesel cycle

ii. The working fuel used for these engines is <u>diesel</u>

iii. Four strokes are completed in two revolutions of the crankshaft

iv. The compression ratio used in these engines varies from 14 to 20

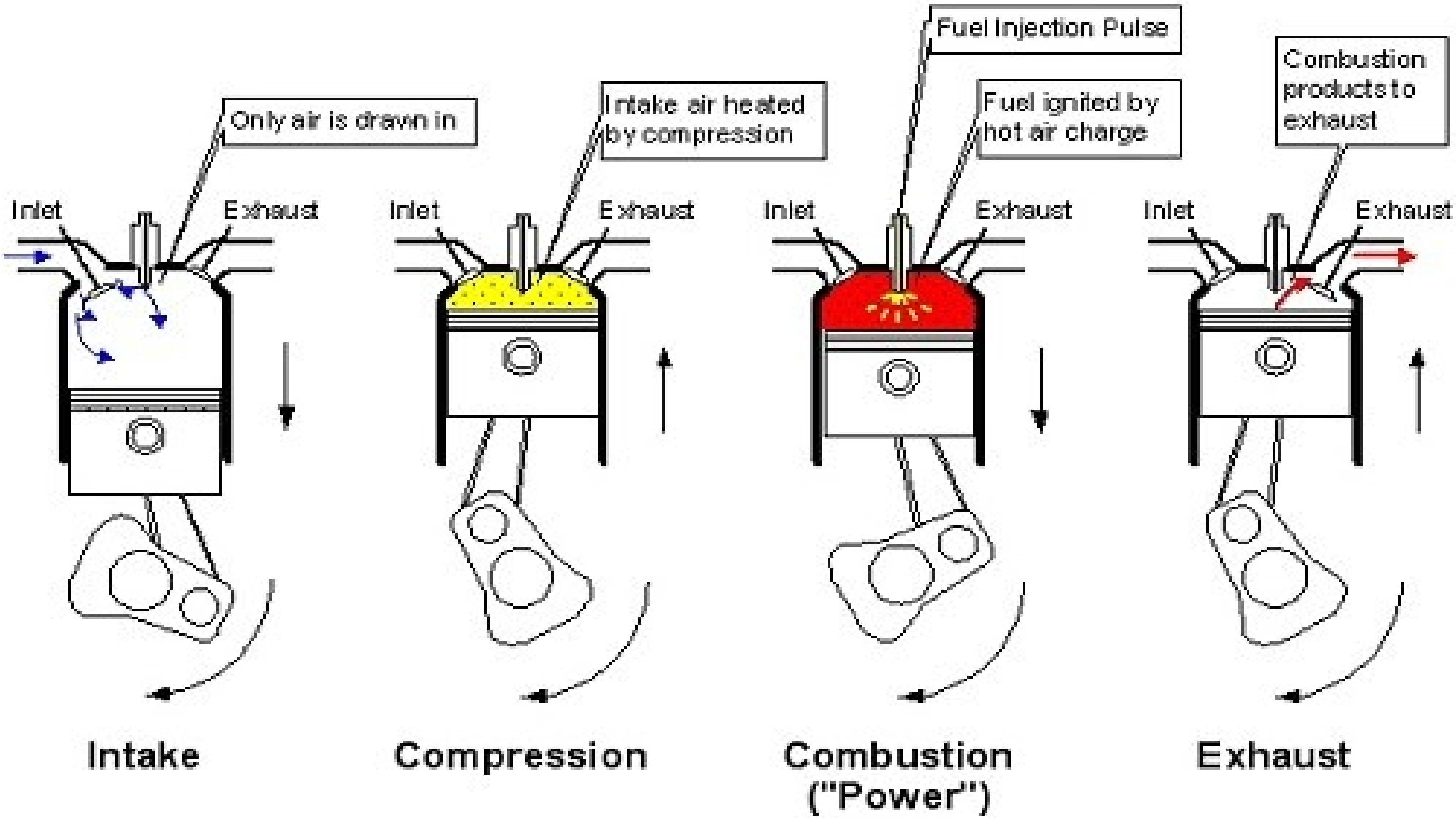
1. <u>Suction Stroke</u>

i. During this stroke inlet valve remains open and exhaust valve remains closed

ii. Piston moves from TDC TO BDC

iii. **only air** is inducted during this stroke

4-stroke Compression-ignition (Diesel) Engine Cycle



2. **<u>Compression Stroke</u>**

   i. During this stroke both inlet and exhaust valve remain closed
   ii. Piston moves from BDC to TDC
   iii. The air sucked during compression stoke is compressed

3. **<u>Expansion or power stroke</u>**

   i. During this stroke both inlet and exhaust valve remain closed
   ii. The product of combustion exerts pressure on the Piston hence it moves from TDC TO BDC
   iii. power is developed during expansion of gases
   iv. Hence this stroke is also known as power stroke
   v. During this stroke pressure and temp decreases

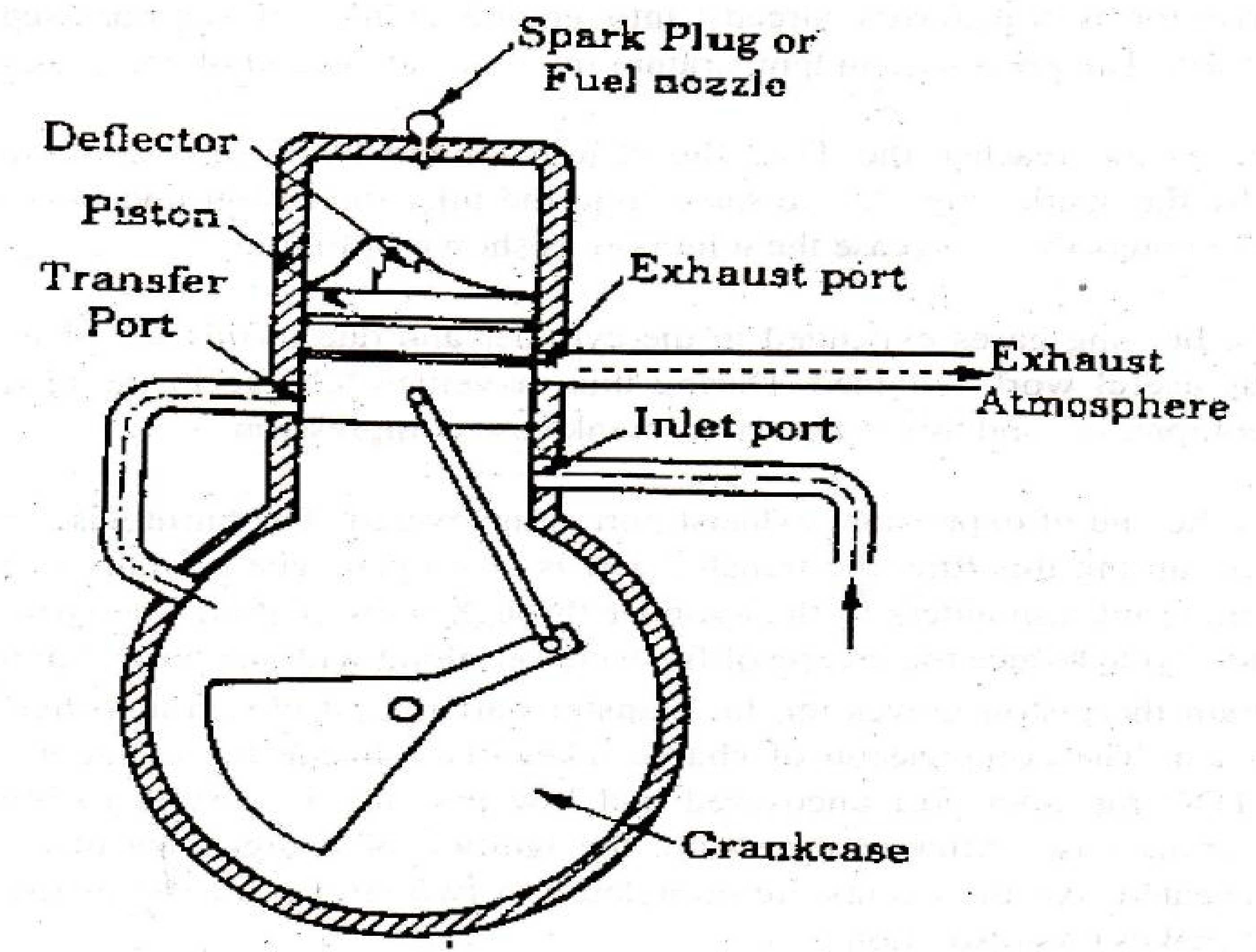
4. **Exhaust stroke**

i. At the end of the expansion stroke the exhaust valve opens but inlet valve remains closed
ii. During this stroke piston moves from BDC to TDC
iii. As diesel engine uses very high CR, the temp. of the air at the end of compression stroke is very high
iv. This temp is sufficient to self ignite the mixture
v. Hence in this spark plug isnt required
vi. Hot gases inside the cylinder are exhausted through exhaust valve

Sr. No.		Petrol (S.I.) Engines	Diesel (C.I.) Engines
1	Basic cycle	Work on otto cycle	Work on diesel cycle
2	Working fuel used	Petrol	diesel
		Advantages	Disadvantages
1	Initial cost	low	high
2	Compression ratio	Varies from 5-10	Varies from 14-20
3	starting	Easy because of low CR	Difficult because of high CR
4	weight	lighter	Heavier
5	opern	silent	noisy
6	Rotation speed	High	Low

Sr. No.		Petrol (S.I.) Engines	Diesel (C.I.) Engines
		Disadvantages	Advantages
1	Thermal efficiency	Low because of low CR	High because of high CR
2	Compression ratio	low	high
3	for ignition	Spark plug required	Not required
	Example	motor cycles , scooter , cars etc.	bus , trucks etc.

Two stroke SI engines



First stroke (suction and compression)

- Initially the piston is at BDC the arrangement of the ports is such that the piston performs two operations simultaneously.
- When piston starts rising from BDC it closes the transfer port and exhaust port and the already existing charge is compressed.
- At that time , vacuum is created in the crank case which is gas tight.
- As soon as inlet port is uncovered the fresh air is sucked in the crank case and charging is continued until the crank case is filled.
- At the end of this stroke piston reaches TDC.

Second stroke (expansion and exhaust)

- During this the spark ignites the air fuel mixture and power is produced. But with power waste gases also produced.
- When piston starts moving from TDC it uncover the exhaust port and through exhaust port waste gases are passed to the surrounding At that time , vacuum is created in the crank case which is gas tight.
- Further movement of the piston towards BDC uncovers the transfer port and free charge is enter in the combustion chamber.

Sr. No.	Two stroke engines	Four stroke engines
1	Cycle complete in 1 revolution	Cycle complete in 2 revolution
2	Power stroke is obtained in every revolution	Power stroke is obtained in every two revolution
3	Ports are presents	Contains valves
4	Piston have dome shape	Piston is flat
	Advantages	Disadvantages
1	More power produce	Less power produce
2	Initial cost is low	Initial cost is high
3	Starting is easy	Starting is difficult

Sr. No.	Two stroke engines	Four stroke engines
	Disadvantages	Advantages
1	Low thermal efficiency	High thermal efficiency
2	Low volumetric efficiency	High volumetric efficiency
3	Consume more lubricating oil	Consumes less amount of lubricating oil
4	Produce more noise	Produces less noise
	Applications	
	Used in scooters, mopeds	Cars, buses, trucks

Boiler

boiler is a closed vessel in which water is converted into steam by the application of heat

Essential requirements of good boiler

i. It should be capable of quick starting
ii. light weight
iii. Occupy less space
iv. Should produce maxi quantity of steam with mini fuel consumption

Classification

1. **Position of water and hot gases**

Water tube	Fire rube or smoke tube
Water inside the tube and Hot gases outside the tube	Hot gases inside the tube and water outside the tube
Examples	Examples
1. Babcock and wilcock boiler	1. Lancashire boiler
2. Benson boiler	2. Cochran boiler
3. La mont boiler	3. Locomotive boiler
4. Loeffler boiler	4. Cornish boiler

2. **Position of the furnace**

Internally fired	Externally fired
Furnace is located inside the boiler shell tubes	Furnace is located outside the boiler shell tubes

3. **Axis of the shell**

Horizontal boilers	Vertical boilers
The axis of the shell is horizontal	The axis of the shell is vertical

4. **Pressure of steam**

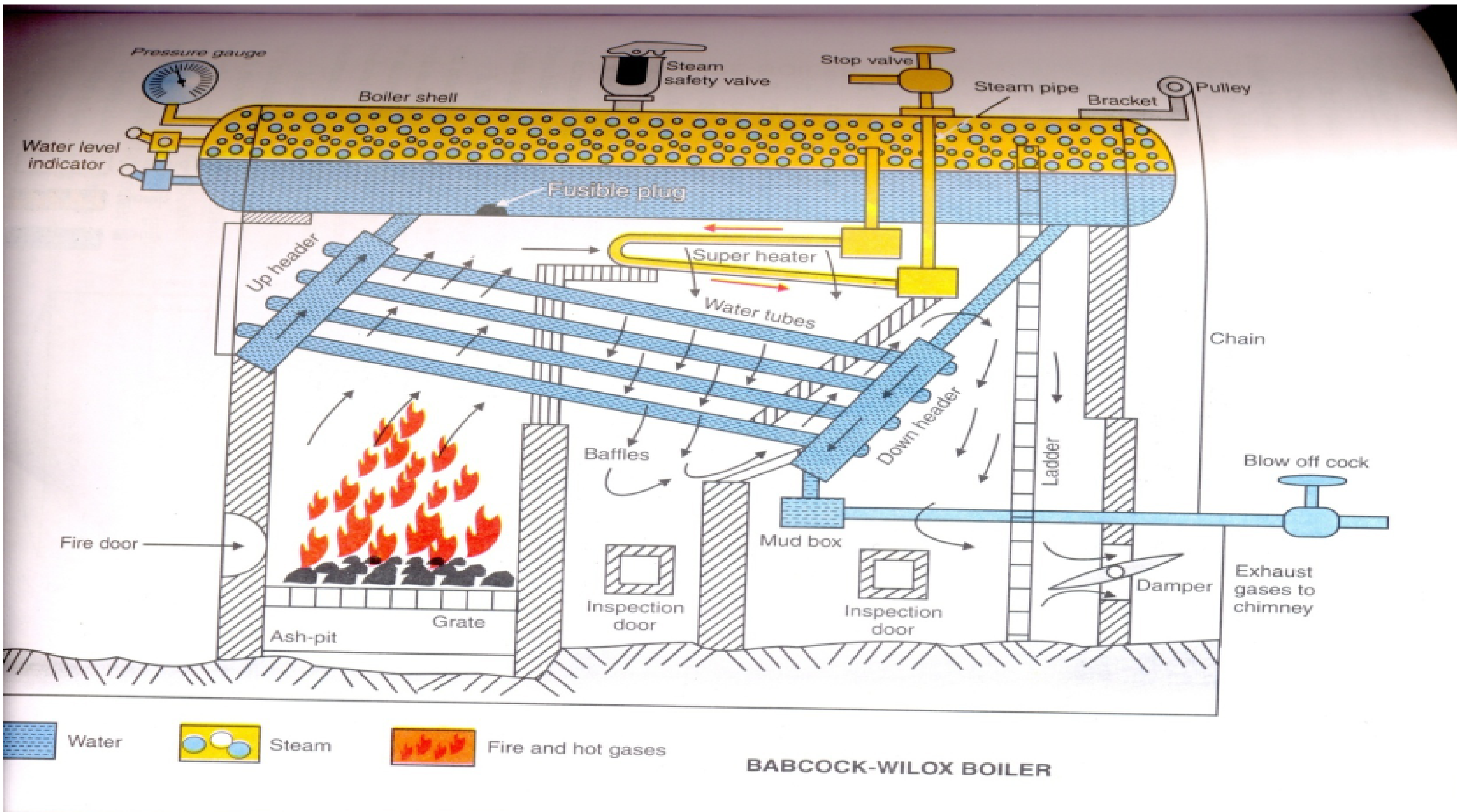
High pressure boilers	Low pressure boilers
It produces steam at the pressure of 80 bar or above	It produces steam at the pressure below 80 bar

5. **Nomber of tubes**

Single tube	Multi tube
There is only water tibe or fire tube	There are mor than two water tube or fire tube

6. **From use**

Stationary boiler	Mobile boiler
They do move from place to another	They move from place to another



<u>Components of boiler</u>

1. **Boiler shell**
   i. **It is cylindrical in shape**
   ii. **This stores water for heating**

2. **Furnace**
   i. it is the place where the fuel is burnt
   ii. The hot flue gases travel from furnace to the chimney

3. **Boiler mountings**
   These are mounted on the boiler for its proper and safe working

   A. **Safety valves**
      <u>Location</u> It is generally mounted on the top of the shell
      <u>Function</u> It is used to release excess steam when the pressure of the boiler is more than the rated pressure

B. **Water level indicator**

<u>Location</u> Normally two water level indicators are fitted at the front end of boiler

<u>Function</u> It indicates the level of water inside the boiler

C. **Pressure gauge**

<u>Location</u> it is mounted on the front top of the shell

<u>Function</u> it measures the pressure exerted inside the boiler

D. **Fusible plug**

<u>Location</u> it is mounted over the combustion chamber

<u>Function</u> it is used to protect the boiler because of overheating for low water level

E. **Steam stop valve**

<u>Location</u> it is mounted on the boiler and connected to the steam pipe

4. <u>Boiler accessories</u>

These are auxillary parts required to increase the efficiency of the boiler

A. Superheater

i. It is used to increase the temp of steam above its saturation temp
ii. It is located in the path of the hot flue gases

B. Economiser

In economiser the waste heat of flue gases is stored for heating the feed water

C. Air preheater

It is used to increase the temp of air before it enters the furnace

D. Steam seperator

i. It removes the water particles from the steam

ii. It is located near the turbines

Mountings	Accessories
These are mounted on the boiler	These are the auxillary part of boiler
These are provided for safe working of boiler	These are provided to increase the efficiency
Mountings are necessary without mountings boiler cant function	Accessories are nt must but its use is desirable boiler can function without accessories
Safety valves **Water level indicator** **Pressure gauge** **Fusible plug** **Steam stop valve**	**Superheater** **Economiser** **Air preheater** **Steam seperator**

Water tube boiler

<u>Introduction</u>

it is stationary horizontal, externally fired water tube boiler

<u>Working</u>

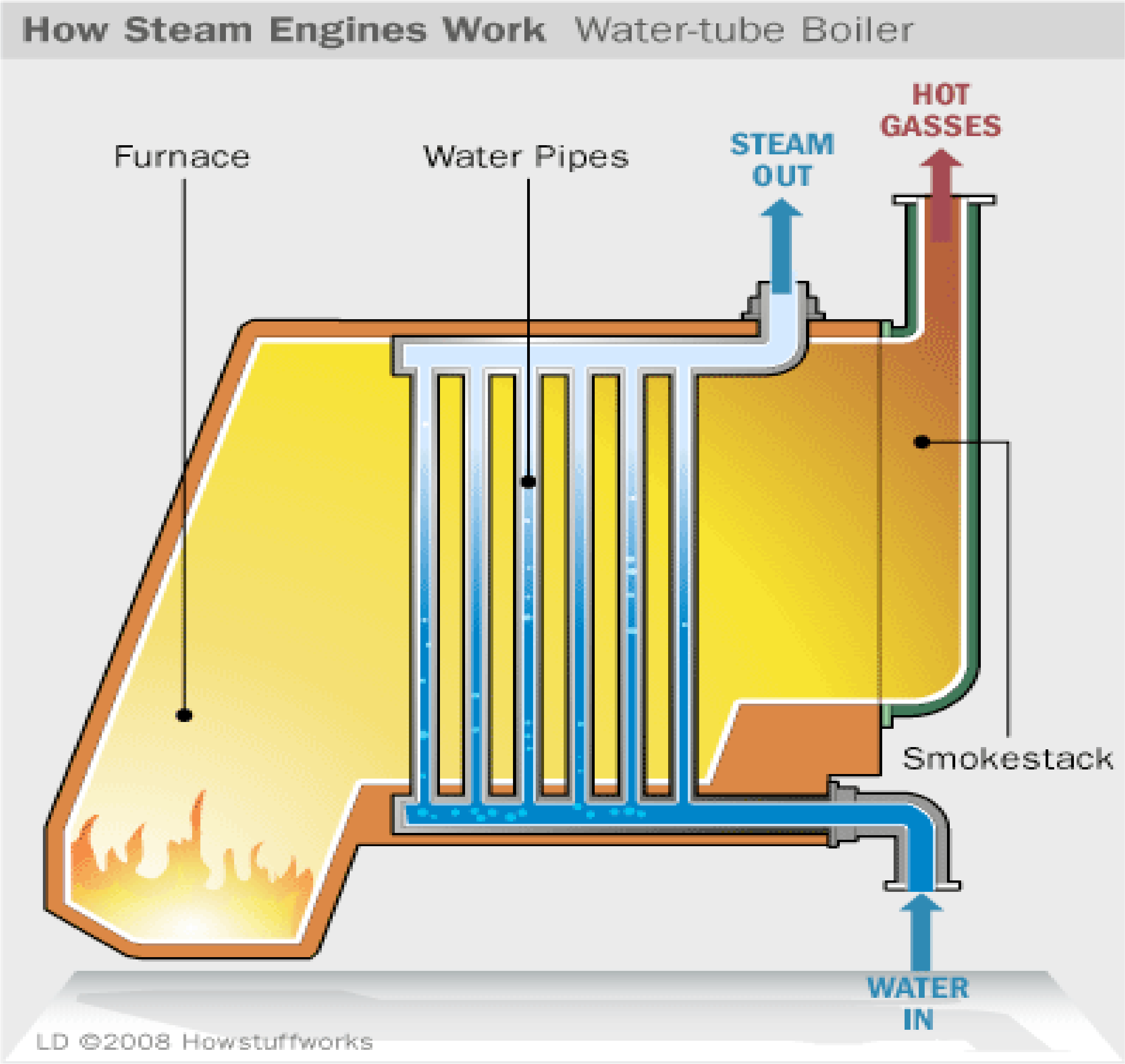
i. coal is entered into the grate through the fire door and is burnt
ii. The hot gases rise upward and pass across the left side portion of the water tubes
iii. The baffle deflects the flue gases
iv. Hence flue gases travel over the water tubes
v. The flue gases finally escape to the atm through chimney
vi. Now because of hot flue gases passing over the water tubes, the water inside the tube get heated

<u>Applications</u>

i. <u>Locomotives</u>
ii. <u>rockets</u>

Water tube Boilers

Internally fired



Fire tube boilers

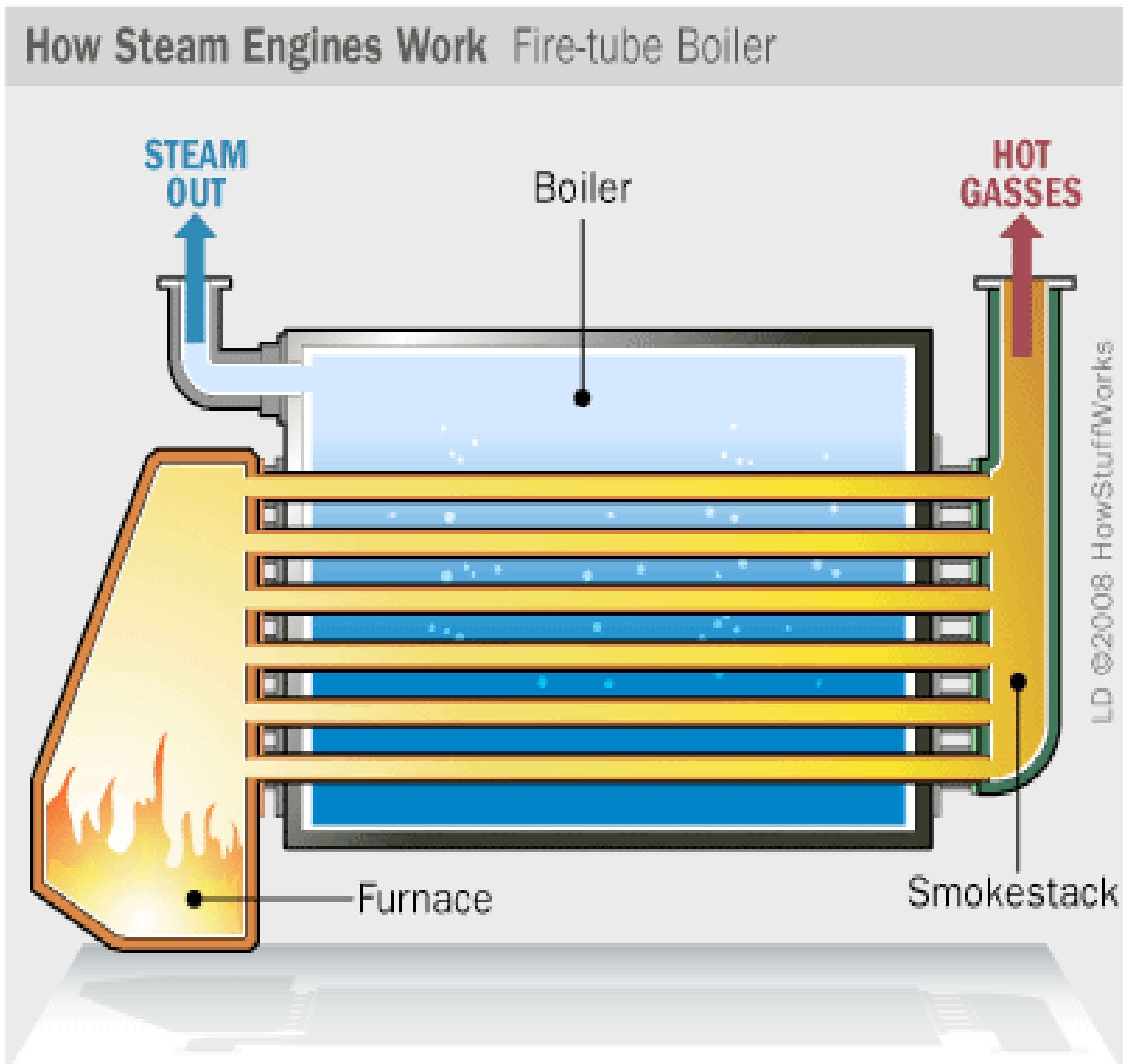
Introduction

In fire tube boilers hot gases are inside the tube and water is outside the tube

Working

i. A water tube boiler is a type of boiler in which hot gases from fire pass through one or more tubes surrounded by water
ii. The fuel is burnt in firebox to produce hot combustion gases
iii. The hot gases from the furnace are entered in the tubes
iv. Because of hot gases, the water which is outside the tubes get heated and converted into steam
v. This steam is passed through the superheater to dry the steam or superheat the steam

Fire tube
Externally fired



Sr no	particulars	Water tube	Fire tube
1	Position of water and hot gases	Water inside the tube and hot gases outside the tube	Hot gases inside the tube and water outside the tube
2	Mode of firing	Externally fired	Internally fired
		<u>Advantages</u>	<u>Disadvantages</u>
1	construction	simple	complicated
2	Space require	less	more
3	Maintenance cost	less	more
4	Rate of steam production	higher	lower
5	suitability	Suitable for large plants	Not suitable for large plants
6	Operating pressure	Can work under high pressure as high as 250 bar	Operating pressure limited to 25 bar

Sr no	particulars	Water tube	Fire tube
		<u>**Disadvantages**</u>	<u>**Advantages**</u>
1	Initial cost	high	less
2	Chance of explosion	more	less
3	Treatment of water	necessary	Not necessary
4	cleaning	easy	difficult
	Types	i. Babcock and wilcox ii. La mont iii. benson	i. Cornish ii. Lancashire iii. Locomotive
	Applications	i. Sugar industry ii. Textile industry iii. Food processing plant	i. Locomotives ii. Textile industry