# Introduction

Prime movers:-

Prime mover is an engine or device which converts natural source of energy in to mechanical work.

In olden days man depends on his own physical strength and that of animal mainly horse, bullock therefore when mechanical systems were invented the unit of power was horse power.

Sources of energy:-

Prime movers use different sources of energy:

Fuels:-

When combustion of fuel takes place heat energy is released depends on its calorific value .

This heat energy is converted in to mechanical work by a device known as heat engine.

It is most widely used source of energy.

River water:-

It is another useful form of energy.

Water stored at high level possesses potential energy.

This potential energy is converted in to kinetic energy and ultimately in to mechanical work by a prime mover known as hydraulic turbine.

River water is also used to generate stream in boilers which in turn used to develop mechanical work using stream turbines and stream engines.

Atoms (Nuclear Energy) :-

Heat energy is released by the fusion and fission reaction of the atoms.

This heat energy is used to produce stream which in turn used to produce mechanical work using stream turbines.

Solar Energy:-

Solar energy is available freely and it is a non polluting source of energy.

Solar energy can be used to produce stream to run stream turbine.

Using solar photovoltaic cells one can produce electrical energy.

Wind Energy:-

Kinetic energy of wind is used to produce mechanical work using wind mills.

It is also freely available non polluting source of energy.

Classification of Prime movers:-

Prime movers are classified depends on the source of energy utilized by them.

Source of Energy used by Prime Movers:

(i) Non-thermal:

(ii) Thermal:

Further sub classification is as below:

(i) Non-thermal

(1) Water (hydraulic turbine)

(2) Tidel power (Tidel power plant)

(3) Wind (Wind mills)

Thermal

(1) Fuels (Heat Engines)

(2) Nuclear (Nuclear power plant)

(3) Geothermal (Geothermal power plant)

(4) Biogas (Biogas)

(5) Solar Energy

Further sub classification of Fuels is as bellows:-

(i) External combustion engine

(ii) Internal combustion engine

Both the engines can be sub classified is as below

(i) External combustion engine:-

(1) Steam Engines (Reciprocating)

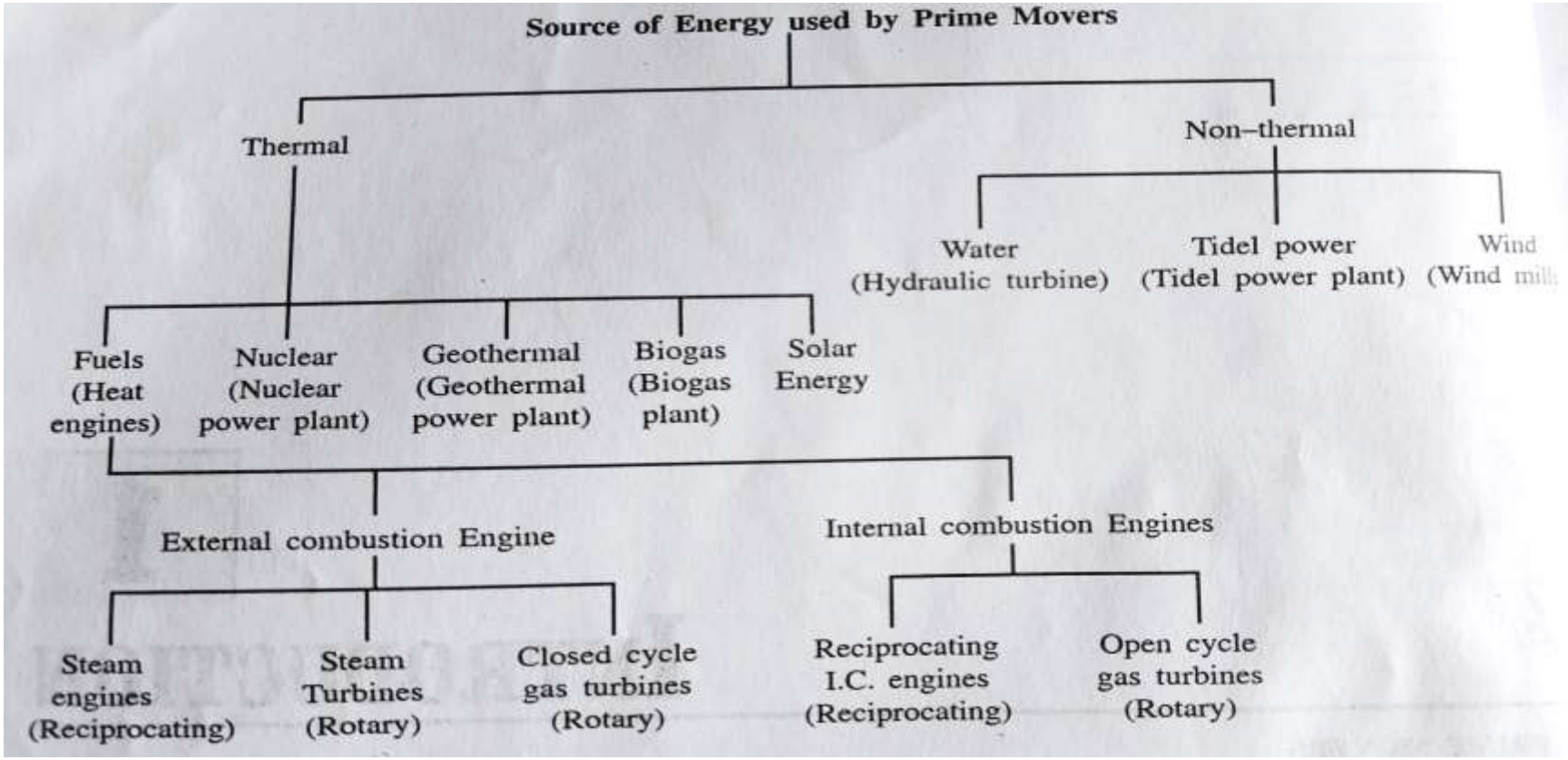
(2) Steam Turbines (Rotary)

(3) Closed Cycle Gas Turbines (Rotary)

(ii) Internal combustion engine:-

(1) Reciprocating I.C Engines (Reciprocating)

(2) Open cycle gas turbines (Rotary)


Source of Energy used by Prime Movers
Thermal
Non–thermal
Water
(Hydraulic turbine)
Tidel power
(Tidel power plant)
Wind
(Wind mill
Fuels
(Heat
engines)
Nuclear
(Nuclear
power plant)
Geothermal
(Geothermal
power plant)
Biogas
(Biogas
plant)
Solar
Energy
External combustion Engine
Internal combustion Engines
Steam
engines
(Reciprocating)
Steam
Turbines
(Rotary)
Closed cycle
gas turbines
(Rotary)
Reciprocating
I.C. engines
(Reciprocating)
Open cycle
gas turbines
(Rotary)

Force :-

Newton's second law of motion (F=ma) defines the force acting on a body. The unit of the force is Newton (N). When a force of 1 Newton is applied to 1 kg of mass, it produces acceleration of 1 $m/s^2$

The weight of body is the force with which the body is attracted to the center of the earth. It is a product of mass of the body and local gravitational acceleration (g).

W= mg

The value of the “g” at sea level is a 9.80663 $m/s^2$.

For all practical purposes it can be assumed as 9.81 $m/s^2$

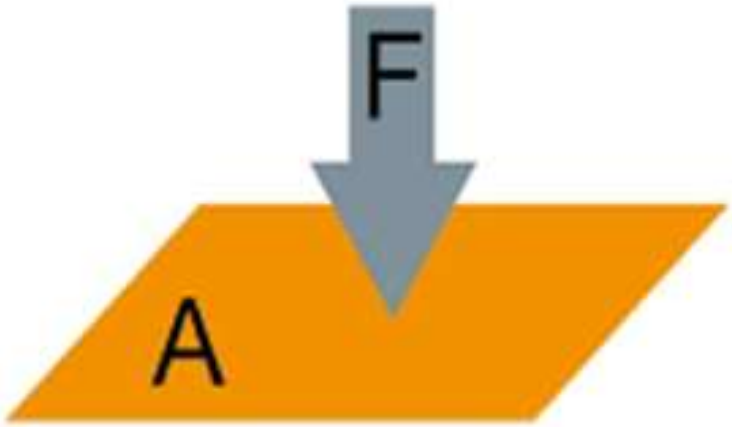
The weight of a body varies with elevation but the mass remains constant.

Mass:- The mass is defined as from the above definition as a ratio of the W/g. The unit of mass is Kg.

Pressure:-

Pressure is defined as the normal force exerted by a system against unit area of the bounding surface.

$$Pressure\ (p) = \frac{Force\ (F_n)}{Area(A)}$$



Pascal is very small unit and very often kilo-Pascal (kPa) and mega Pascal (MPa) is used.

The other unit of pressure through not belong to SI system of units are widely being used.

They are the “bar” and the “standard atmosphere”.

1 bar = $10^5$ Pa = 100 kPa = 0.1 Mpa

1atm = 101.325 kPa =1.01325 bar.

In SI system of units the unit of pressure is pascal.

One Pascal equals to force of one Newton acting on an area of 1 $m^2$.

Power:-

Rate of Energy transfer is known as Power. Its unit is watt (W).

It is a small unit and very often kilowatt (KW) and megawatt (MW) is used.

Energy:-

Energy is defined as a capacity to exert force through a distance.

It exits in many forms.

Engineering processes involves the conversion of energy from one form to another form.

The unit of energy is SI system of units is Nm or Joule (J).

The energy per unit mass is the specific energy. Its unit is J/kg.

Temperature :-

It is a quantitative measure of the degree of coldness or hotness of a system.

Its unit in SI system of unit  is Kelvin (K).

Other units of Temperature are Degree centigrade (˚C) and Degree Fahrenheit (˚F).

The relations between them are as under.

K= ˚C + 273.16, ˚C = 5/9 (˚F-32)

Heat:-

Heat is a form of energy that is transferred across the boundary of the system by a virtue of the temperature difference.

There are three mode of the heat transfer.
Conduction mode of heat transfer,

Convection mode of heat transfer,

Radiation mode of heat transfer.

Heat transfer is denoted by the symbol of Q.

If the heat is added to the system then it is taken as positive.

If the heat is rejected by the system it is taken as negative.

A process in which there is no heat transfer between system and surrounding is called adiabatic process.

Units of Heat:- The unit of heat in SI system is Joule (J). The rate of heat transfer is given in W or KW.

Specific Heat :-

The amount of heat required to raise the temperature of 1 kg of mass by 1˚C or 1˚K is termed as specific heat of the substance.

It is denoted by c. If the Q is amount of heat required in (J) , to raise the temperature of m kg of mass by Δt.K then specific heat can be written as $c = [Q/(m*\Delta t)]$ J/kg.K

Gases have two specific heats depends on the process in which heat transfer takes place.

specific heat at the constant pressure Cp

specific heat at the constant volume Cv.

Heat capacity at the constant pressure and constant volume can be denoted by the Cp and Cv respectively.

The product of mass and specific heat is called the heat capacity of the substance.

It is denoted by the C.

Latent Heat:-

Solid, liquid and vapour are the three phases in which matter can exist.

The amount of heat required to change the phase of 1 kg of substance at constant pressure and temperature is defined as the latent heat.

Amount of heat transfer to melt 1 kg of solid in to liquid is called latent heat of fusion.

Amount of heat transfer to vaporize 1 kg of liquid into vapour is called latent heat of vaporization.

Amount of heat transfer to convert 1 kg of solid in to vapour is called latent heat of sublimation.

Work:-

“Work is said to be done if a body is moving in the direction of the force”.

The action of force through a distance or torque through an angle is called mechanical work.

The magnitude of mechanical work is a product of the force and distance moved in the direction of force.

The symbol W is used for the work transfer. The unit of work is joule or Nm.

When work is done by a system it is taken positive ,while it is done on a system is taken as negative.

The rate of doing work by system or on the system is called the power, unit of which is J/s or Watt.

Work transfer:- Interaction between a closed system and its surrounding can be two types:

(i) By the work transfer (ii) By the heat transfer.

They are also referred as the energy interactions.

When these energy interactions take place system under goes a change of state and its properties will change.

Thermodynamic System:-

A thermodynamic system is defined as a quantity of matter or region in a space upon which attention is focused for the analysis of the problem.

Everything external to the system is called surrounding or the environment.

System boundry is a real or imaginary boundry which separates the system from surrounding.

It is generally denoted by dotted line.

System boundry may be fixed or moving.

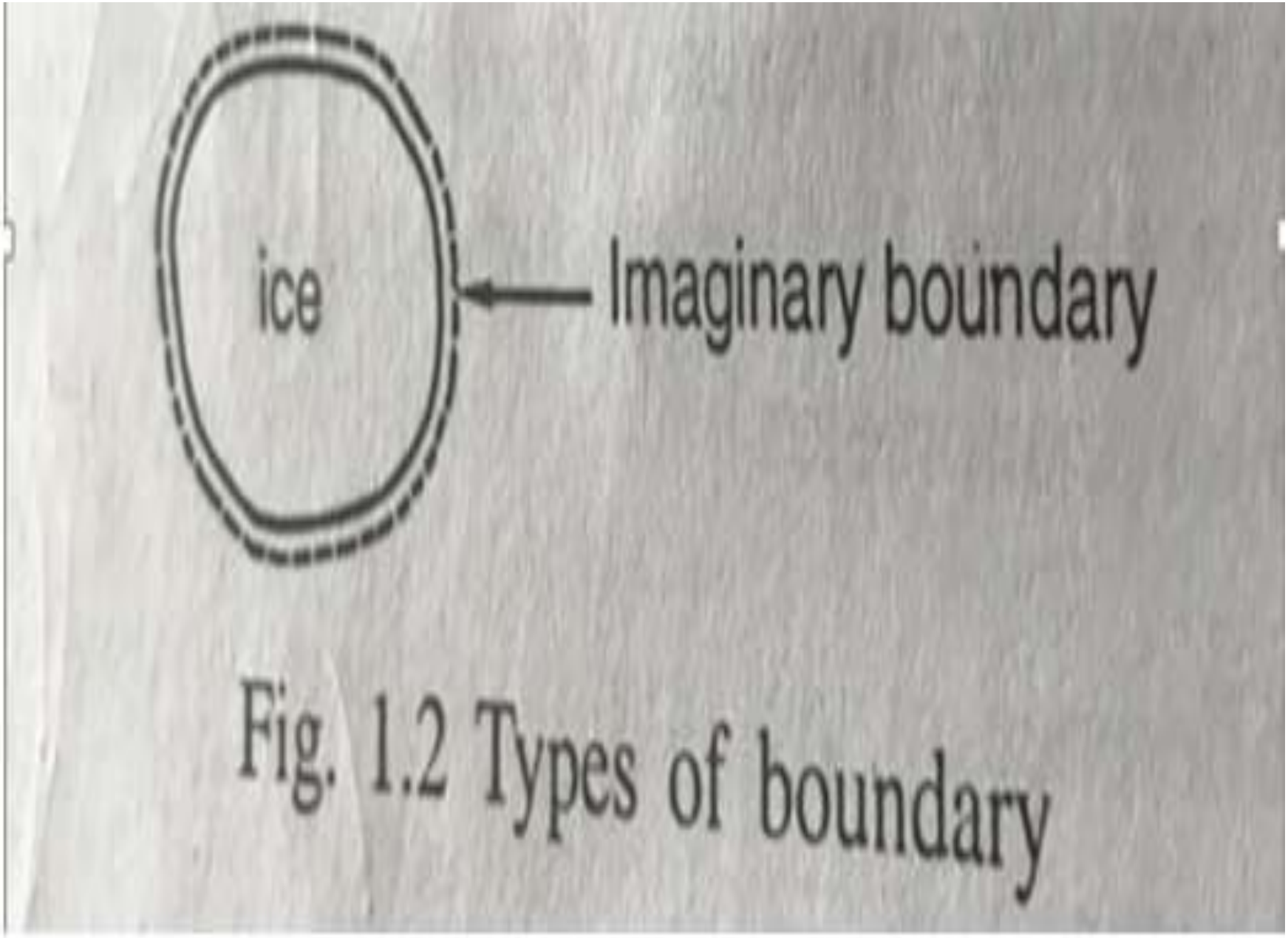


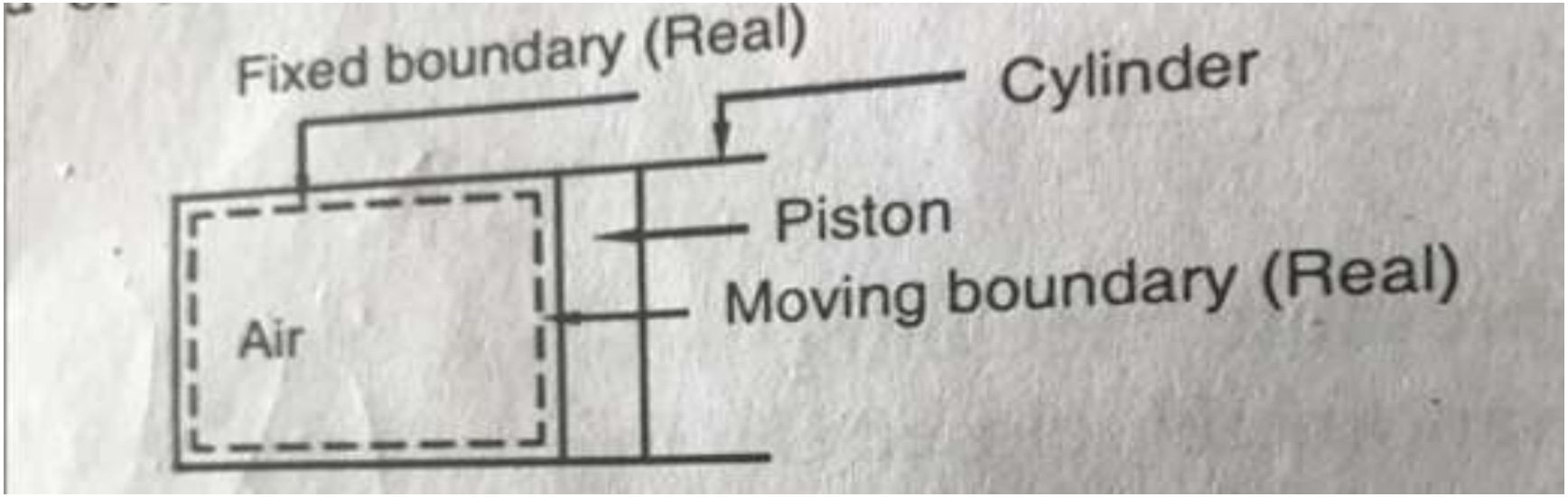

Fig. 1.2 Types of boundary

A system and its surrounding together form a universe. Systems can be classified in three categories (1) closed system (2) open system (3) isolated system.

Closed system is one in which there is no mass transfer across the boundry of the system thus it is a system of fixed mass.

Energy interaction can be there across the system boundry.

Example of closed system is air trapped in piston cylinder arrangement as shown in figure.



Open system is one in which both mass and energy cross the boundry of the system.

Most of the engineering applications are open system.

Examples of open system are gas turbine, Air compressor, pump, nozzle, etc.

In gas turbine, gas at high pressure, high temperature enters in to the turbine and leaves at lower pressure, lower temperature.

There are energy transfers across the system boundry.

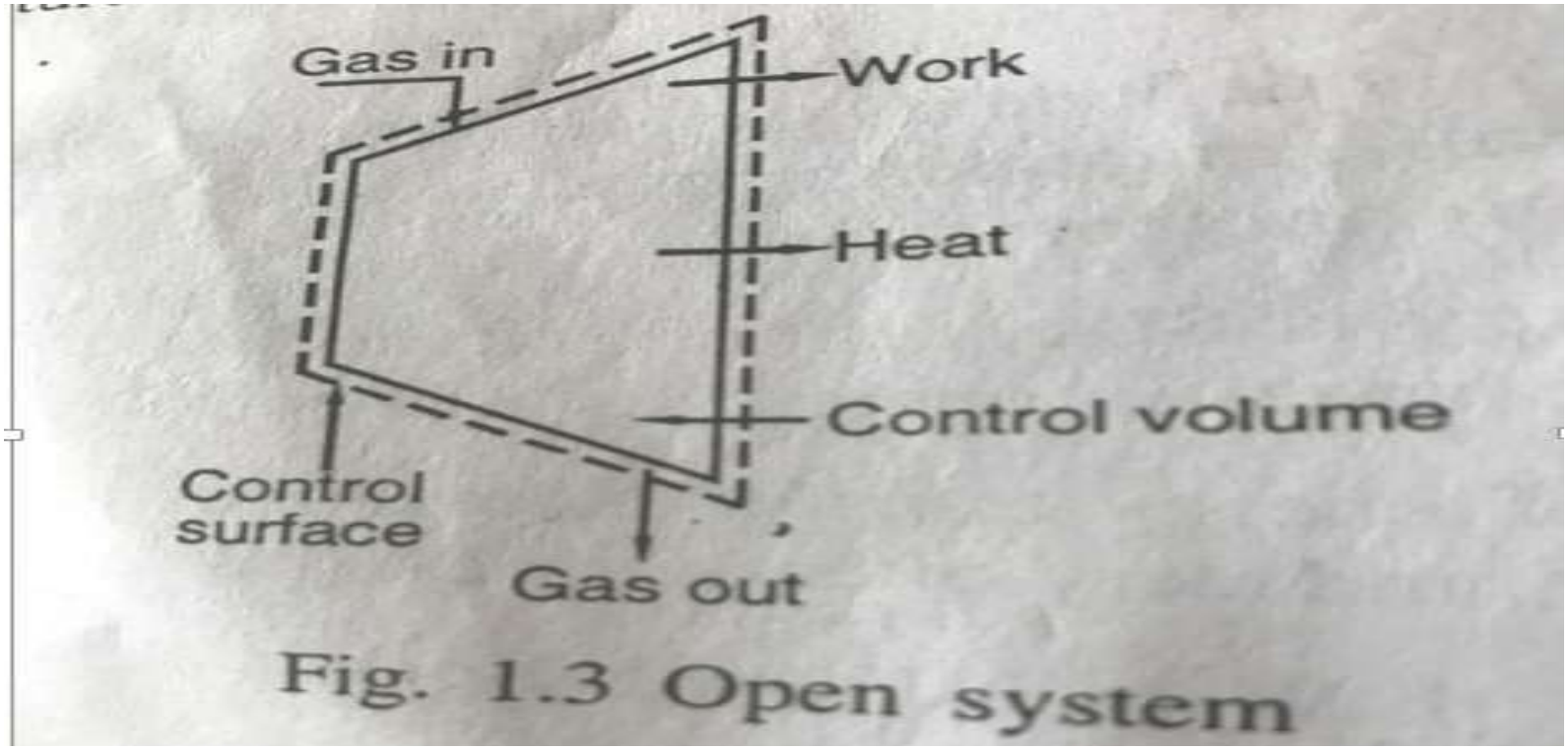



Fig. 1.3 Open system

The attention is focused on certain volume surrounding the gas turbine.

This volume is called control volume.

The bounded surface is known as control surface.

Mass and energy both cross the control surface. Thus there is no difference between open system and a control volume.

Isolated system is one in which neither mass nor energy crosses the boundry of the system.

Property, process, state, change of state, cycle :-

System have certain characteristics by which its physical condition can be described.

For example pressure, temperature, volume etc. Such characteristics are called properties of the system.

Properties are the coordinates to describe the state.

There are two types of properties,

Extensive properties are dependent of the mass of the system.

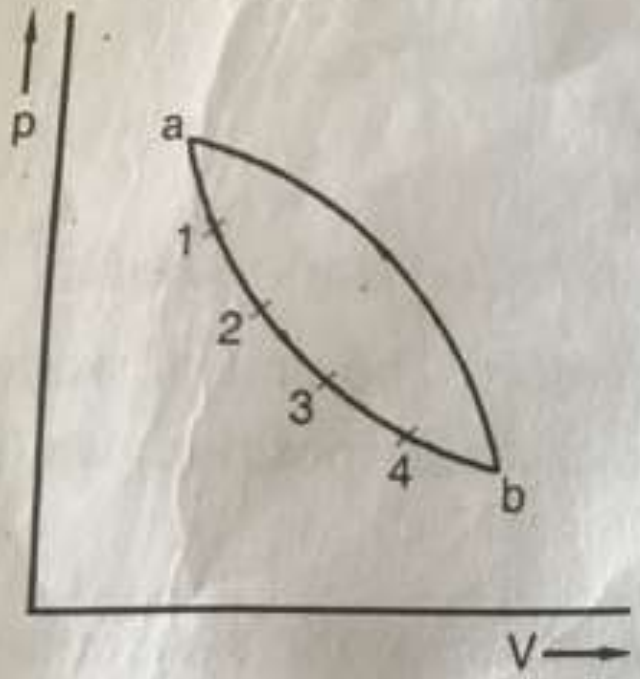
Examples are volume, energy etc.

Intensive properties are independent of the mass of the system.

Examples are pressure, temperature, density etc.

Extensive properties per unit mass known as specific extensive properties are intensive properties.

Examples are specific volume, specific energy etc.




| | |
|---|---|
| a-1 | change of state |
| a-b | path, process |
| a-b-a | cycle |

Fig. 1.4 A change of state, a process and a cycle

When all the system properties have definite values the system is said to be in a definite state.

In figure “a”, “1” etc. are different states of a system.

Any operation in which one or more of the system properties change is called a change of state.

In figure “a” to “1”, “1” to “2”, etc. are change of state.

Sequence of states passed through during a change of state is called the path of the change of state.

When path is complete specified the change of state is known as a process.

A series of the change of state such that the final state is identical with initial state is called cycle.

Enthalpy:-

The enthalpy of a substance is defined as

$H = U + PV$ .

Its unit is Kj.

It is an extensive property, Specific enthalpy is given by $h = u + pv$ and its unit is Kj/kg.

It is an intensive property of the system.

Zeros law of the thermodynamics:-

“When a body A is in thermal equilibrium with a body B and also with a body C ,then B and C must be in thermal equilibrium with each other .

First law of the thermodynamics:-

Close system under going a cycle, we can write the first law as follows:

(ΣW)cycle = (ΣQ)cycle

Which can also written as

$$\oint \boldsymbol{\delta} \mathrm{W} = \oint \boldsymbol{\delta} \mathrm{Q}$$

symbol of $\oint$ denote cyclic integration for the close path.

System under goes a change of state during which both the heat transfer and work transfer take place the net energy is to be store by the system.

If the W is the amount of work transfer and the Q is the amount of the heat transfer then the net energy is (Q – W) is store by the system.

This store energy is called internal energy of the system.

So we can write the first law of the thermodynamics for the process is as

$Q - W = \Delta E$

Where $\Delta E$ is the change in the energy of the system which is the property of the system.

So above equation can be written as

$Q = \Delta E + W$

Equation is generally written in the form

$Q = E + W$

Unit of the E must be same as that of Q and W and it is Joule or Kj.

From the sign convention of heat transfer and work transfer one can derive the sign convention of

E is the positive and internal energy of the system increases

E is the negative and internal energy of the system decreases.

If the system involves more than one heat transfer and work transfer the first law can be written as

$(Q1+Q2-Q3) = E+ (W1-W2)$

Thus in any process energy is conserved.

The 1 st law is also known as law of the consevation of energy.

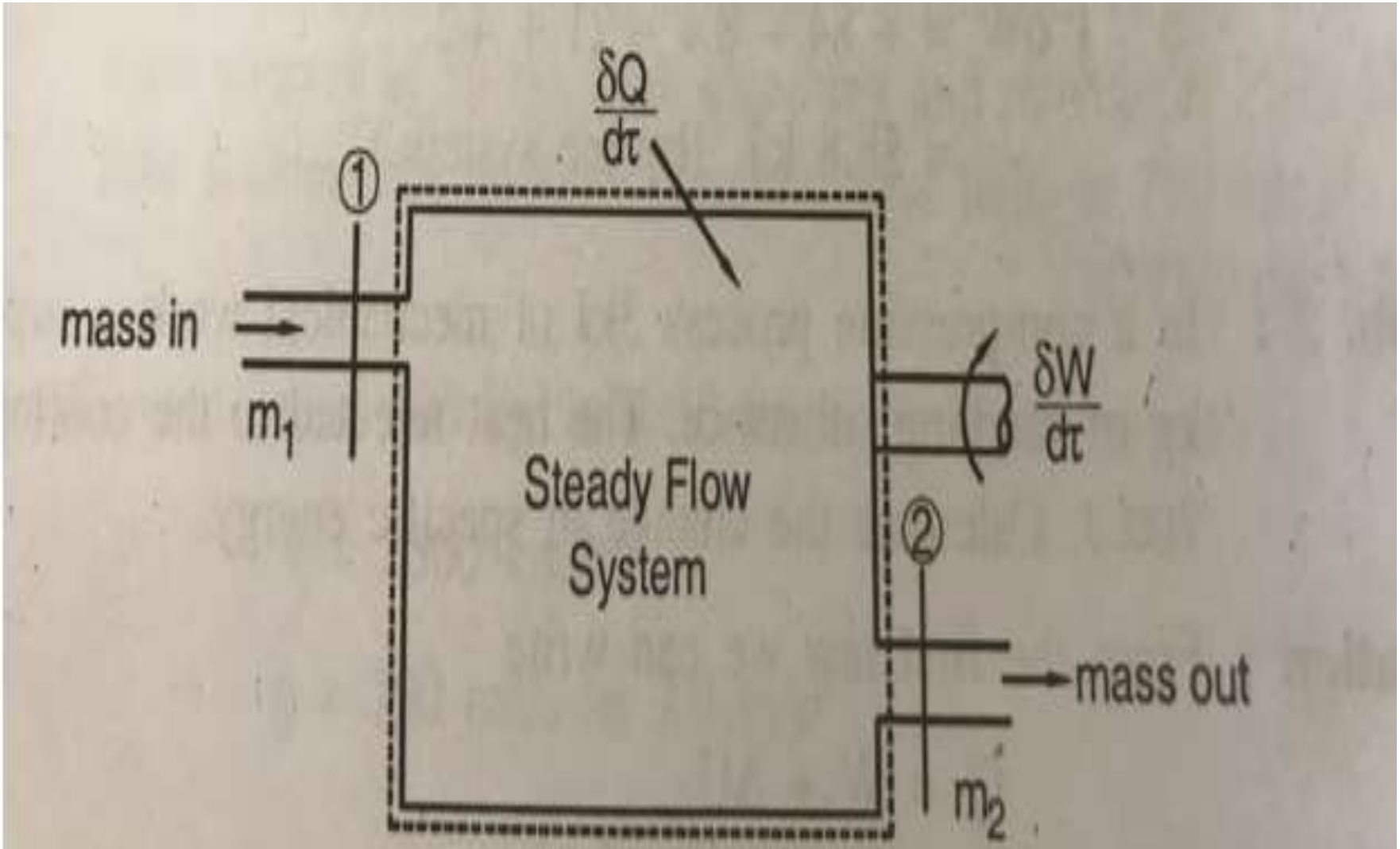



Fig. 1.12 An open system under goes a steady flow process

When open system executes a process such that there is no change in any property of the system with respect to time the process is called steady flow process.

Following quantities are defined subscript 1 and 2 corresponding to inlet and outlet section

$A_1, A_2$ – Cross section area $m^2$

$P_1, P_2$- Pressure(absolute) $N/m^2$

$M_1, M_2$- Mass flow rate kg/s

$V_1, V_2$- Specific volume $m^3/kg$

$U_1, U_2$- Specific internal energy J/kg

$C_1, C_2$- Velocity

$H_1, H_2$- Specific enthalpy j/kg

$Z_1, Z_2$- Elevation above the refference datum,m

$\Delta Q/d\tau$ = Net rate of heat transfer from the system j/s

$\Delta W/d\tau$ = Net rate of work transfer from the system j/s

First law applied to steady flow process can be written as follows which is known as Steady Flow Energy Equation (SFEE).

$m_1 \{ h_1 + (C_1^2)/2 + gz_1 \} + Q =$

$m_2 \{ h_2 + (C_2^2)/2 + gz_2 \} + W$

Unit of each term is J/s

For the unit mass flow rate:

$h_1 + (C_1^2)/2 + gz_1 + Q =$

$h_2 + (C_2^2)/2 + gz_2 + W$

Unit of each term is J/kg