5.2 CLASSIFICATION OF GAS TURBINES :

Gas turbines are generally classified as follows.

1. According to the path of working fluid.

   Ex : (a) Open cycle Gas Turbine.

   (b) Closed cycle Gas Turbine.

   (c) Semi-closed cycle Gas Turbine.

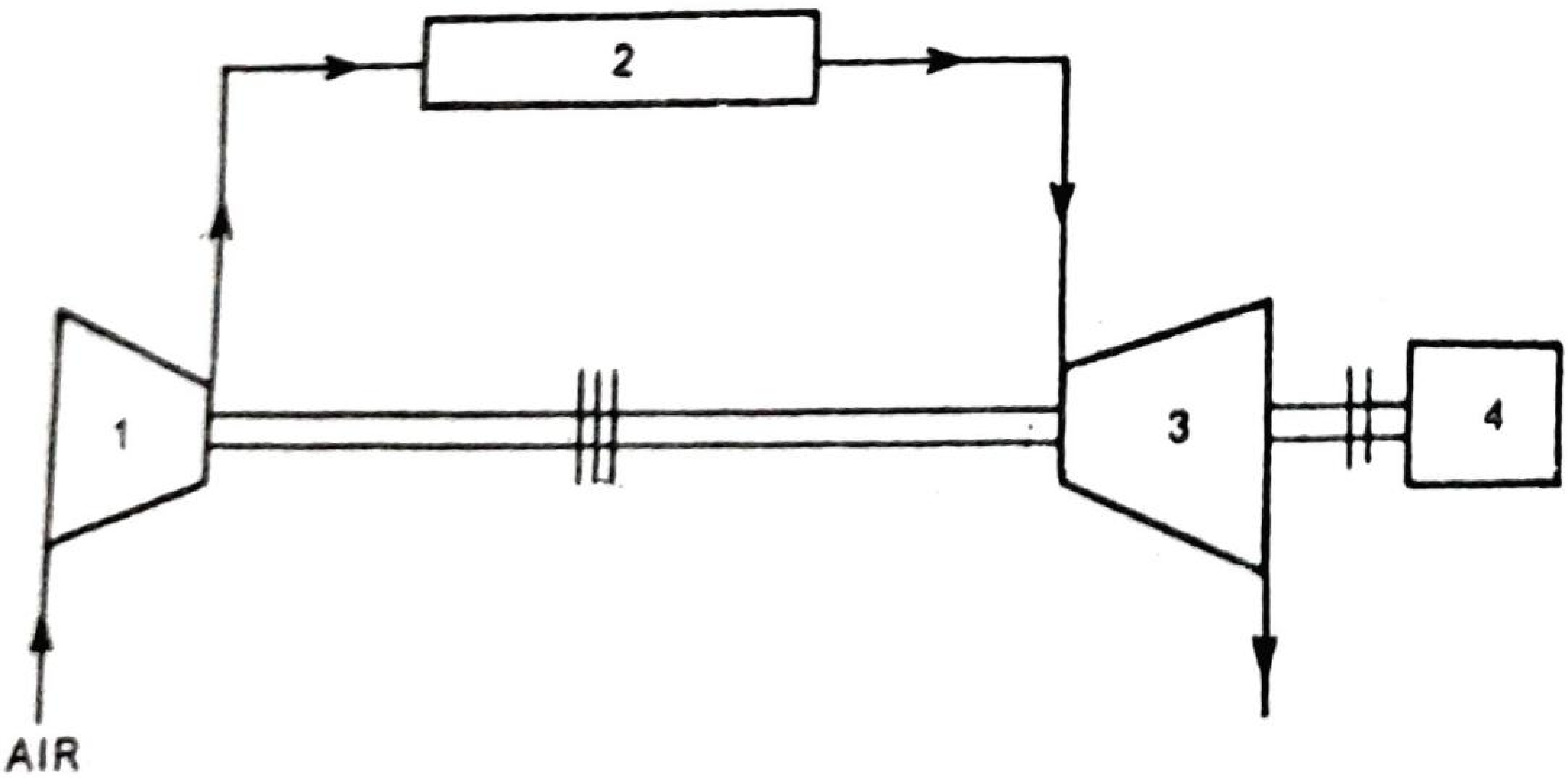
2. According to the process of heat absorption.

   Ex : (a) Constant pressure or continuous combustion type gas turbine.

   (b) Constant volume or explosion type gas turbine.

5.3 OPEN CYCLE GAS TURBINE :

The schematic diagram of an open cycle gas turbine is shown in Fig. 5.1.



1. Compressor 2. Combustion Chamber 3. Turbine 4. Generator

Fig. 5.1 Slightly Dark

Air is drawn in from atmosphere by the rotary compressor (1) and is compressed adiabatically. It is then delivered to combustion chamber (2). In combustion chamber fuel is burnt and the hot gases formed mixup with compressed air. The air gets heated up and its mass increases. A jet of these hot gases flow over the blades of a turbine (3) and expand over them adiabatically producing work (power) at the output shaft. The gases are exhausted out into atmosphere. The output shaft may be coupled to an electrical generator (4) for electric power generation, it may be coupled to a propeller shaft of an air craft.

An open cycle gas turbine is also called a continuous combustion gas turbine as the combustion of fuel is continuous. It works on Brayton cycle (Fig. 5.2 (a) and 5.2 (b)).

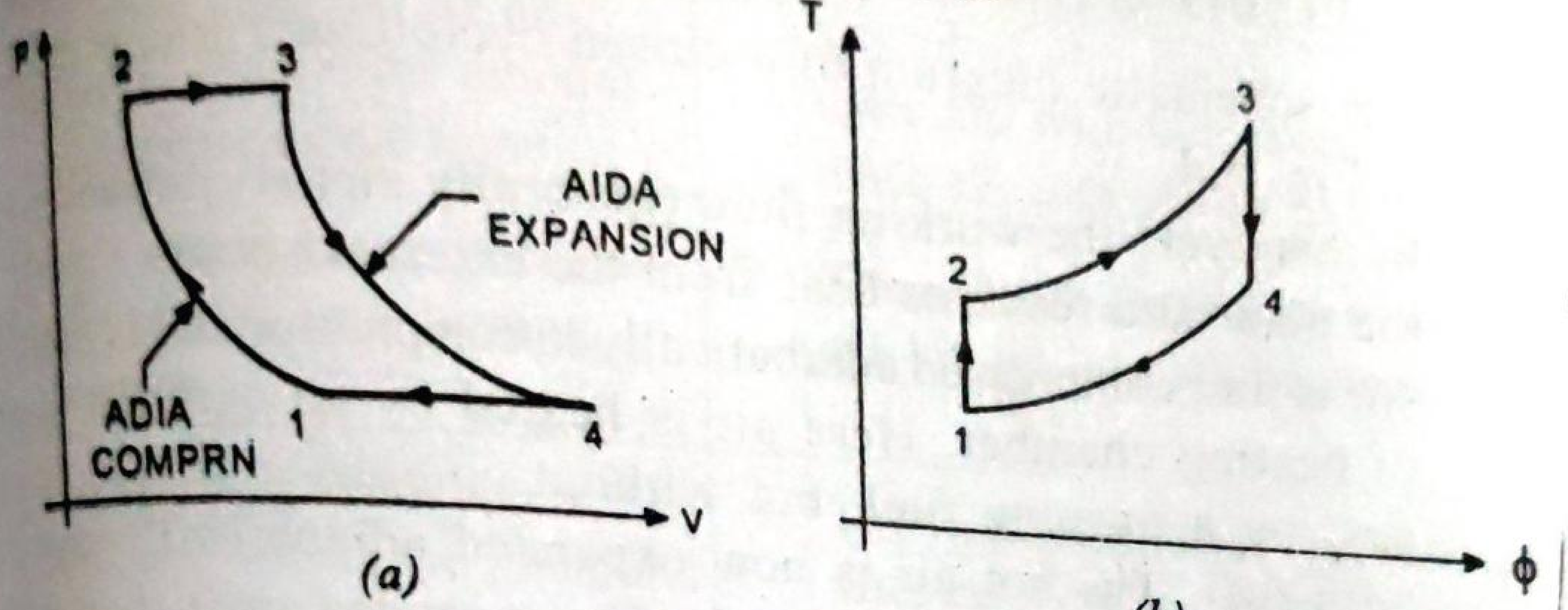
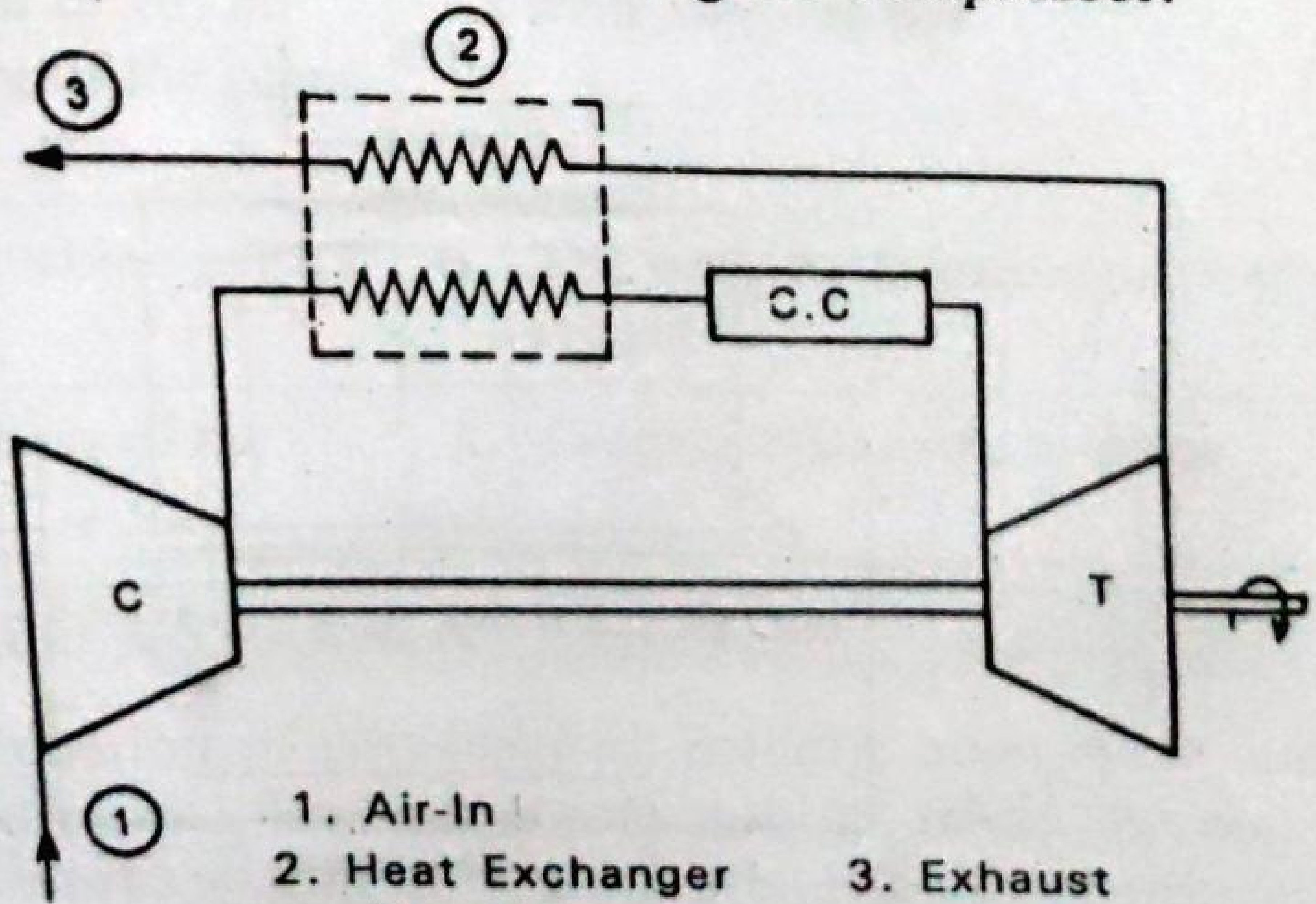


Fig. 5.2

Note : 1. Here the process 4 – 1 has no practical importance as the gases are exhausted into atmosphere at point 4, and fresh air is sucked by compressor at point 1.

2. Turbine shaft is also coupled to compressor shaft so that no other source is required to drive the compressor. But a portion of power developed by turbine is utilised in driving the compressor.



1. Air-In
2. Heat Exchanger 3. Exhaust

Fig. 5.3

A heat exchanger may also be employed in an open cycle as shown in Fig. 5.3.

Here the exhaust gases from turbine are not let out to atmosphere. They are passed through heat exchanger. In this heat exchanger, heat from hot gases is transferred to compressed air before entering the combustion chamber. Thus, by pre-heating the air, the heat of exhaust gases is utilised to some extent and overall efficiency of the plant is increased. Fuel consumption per unit mass of air is reduced.

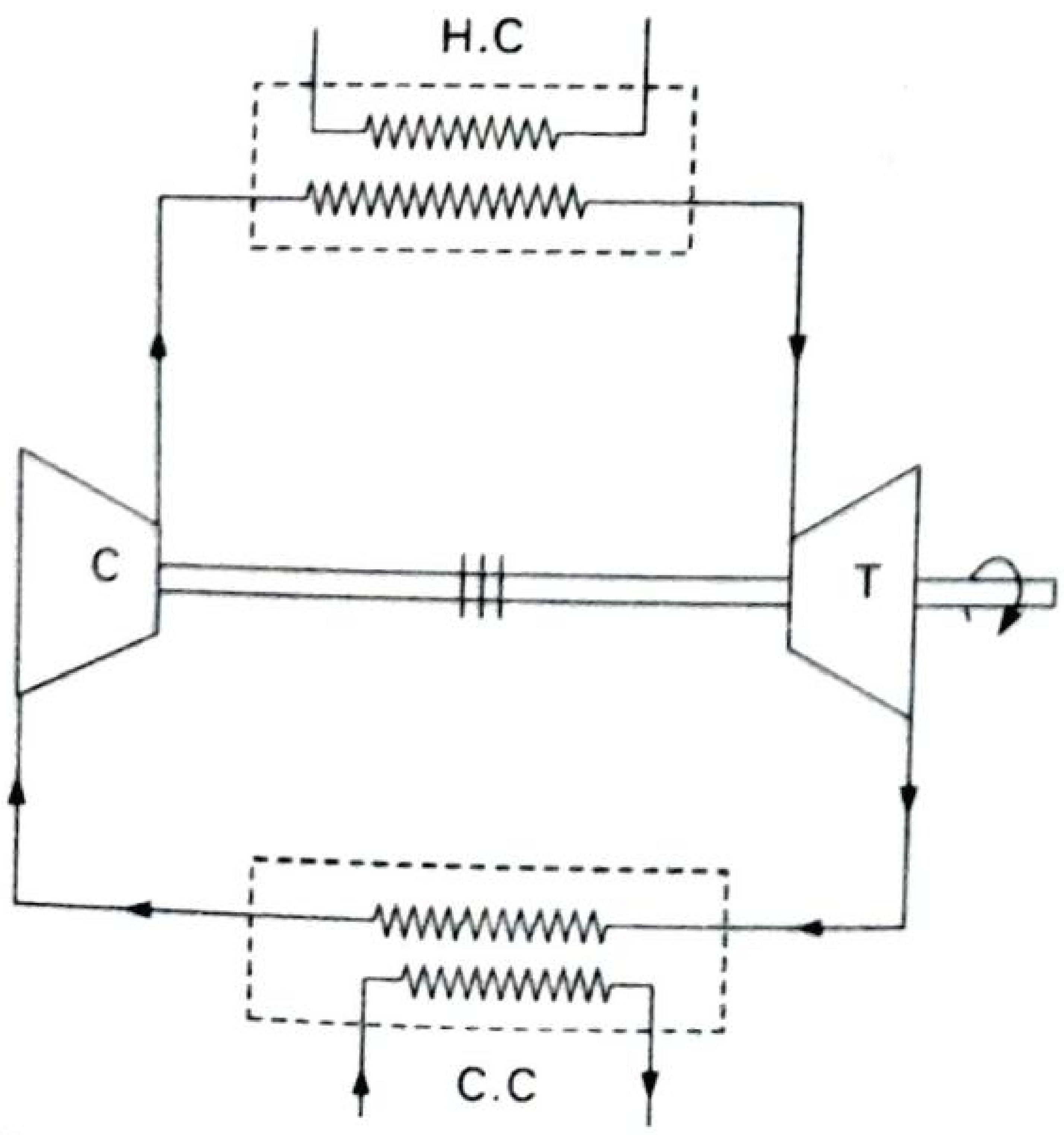
5.4 CLOSED CYCLE GAS TURBINE : (Oct.2012)

The schematic diagram of a closed cycle Gas Turbine is shown in Fig. 5.4.

In this cycle the working fluid (generally air) is confined within the plant and receives heat from the external source.

Air is first compressed adiabatically in compressor and is delivered of heating chamber. Here air is heated by an external source, say, by a burning fuel, but without coming in direct contact with fuel. The hot air is now expanded adiabatically over the turbine blades producing power. The expanded air is then passed through a cooling chamber where it is cooled by circulating water to original temperature. Afterwards, air passes to compressor and the cycle is repeated. It is to be noted that through out the cycle of operation, air is circulated inside the plant itself and air alone circulates through the compressor and turbine.

The ciosed cycle gas turbine works on Brayton cycle shown in Figs. 5.4 (a) and 5.4 (b).



C - Compressor T - Turbine H.C - Heating Chamber C.C - Cooling Chamber

Fig. 5.4

5.5 COMPARISON OF CLOSED CYCLE WITH OPEN CYCLE GAS TURBINE :

OR

ADVANTAGES OF CLOSED CYCLE GAS TURBINE :

S.No.	Closed Cycle Gas Turbines		Open Cycle Turbines
1.	Compressed air is heated in a heating chamber by an external source; the amount of gas remains the same.	1.	Compressed air is heated in a combustion chamber and gets mixedup with hot gases; the mass of gases and air increases.
2.	The exhaust gases from the turbine pass into cooling chamber.	2.	The exhaust gases from turbine are let out into atmosphere.
3.	The working fluid (air) is confined within the plant and is circulated continuously.	3.	The working fluid is replaced after each cycle of operations.
4.	Any fluid with better thermo-dynamic properties can be used as it will not mix with the products of combustion.	4.	Only air is used as the working fluid.
5.	Turbine blades do not suffer corrosion and no carbon deposits form on them; no internal cleaning of the plant is required.	5.	Frequent cleaning of the plant is necessary; turbine blades wear away earlier.
6.	The weight of turbine per kW power is high.	6.	The weight of turbine per kW is less.
7.	Thermal efficiency of the plant is higher.	7.	Thermal efficiency is lower.

5.6 SEMI-CLOSED CYCLE GAS TURBINE

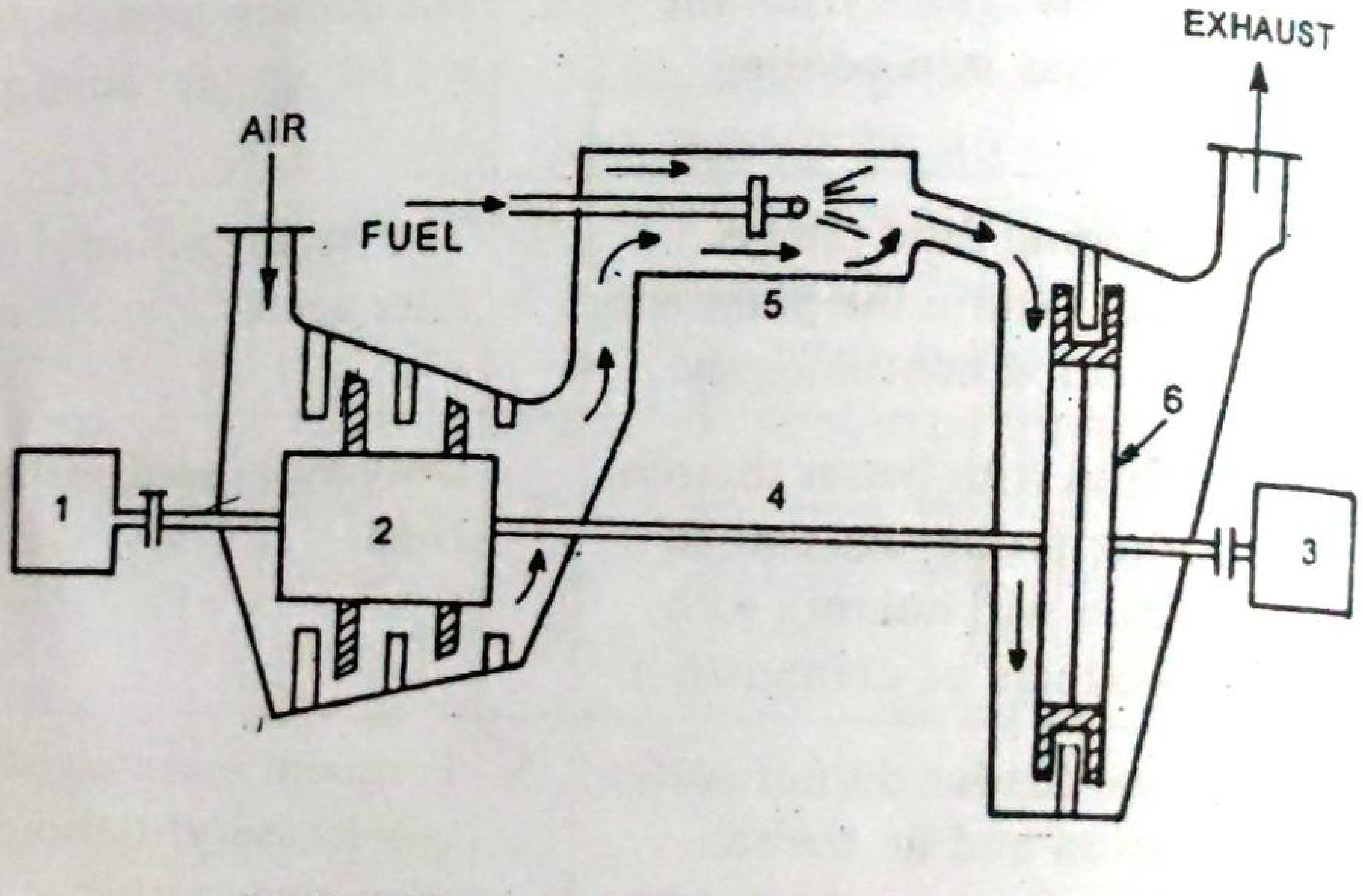
This is a combination of two turbines namely, open cycle and closed cycle turbines. The open cycle turbine drives the main generator and works within pressure limits of atmospheric and 16 bar. The closed cycle unit drives the compressor and works within the pressure limits of 2 bar and 16 bar approximately.

This type of turbine is not used on commercial basis.

5.7 CONSTANT PRESSURE GAS TURBINE :

This is a turbine in which fuel is burnt and air is heated at constant pressure is a combustion chamber. Almost all of the modern gas turbines belong to this class only.

Air is drawn from atmosphere and is compressed in a multi stage compressor (Fig. 5.5). The compression ratio varies from 4:1 to 18:1. The compressed air passes into a combustion chamber where fuel is injected into it. A portion of this air is burning the fuel and rest of the air gets mixed up with the products of combustion thus reducing the temperature of products.



1. Motor 2. Multistage Rotary Compressor 3. Generator
4. Coupling Shaft 5. Combustion Chamber 6. Turbine (Runner)

Fig. 5.5 Constant Pressure Gas Turbine

The mixture of air and combustion products enters the turbine forming a jet to impinge on turbine blades. As the gases expand over the blades the pressure energy is converted into kinetic energy. The K.E is absorbed by the turbine rotor and thus power is developed. The expanded gases are exhausted into atmosphere.

The speed of turbine can be controlled by regulating the fuel supply. The turbine shaft may be coupled to compressor to drive it. Or else a separate electric motor is used to drive the compressor.

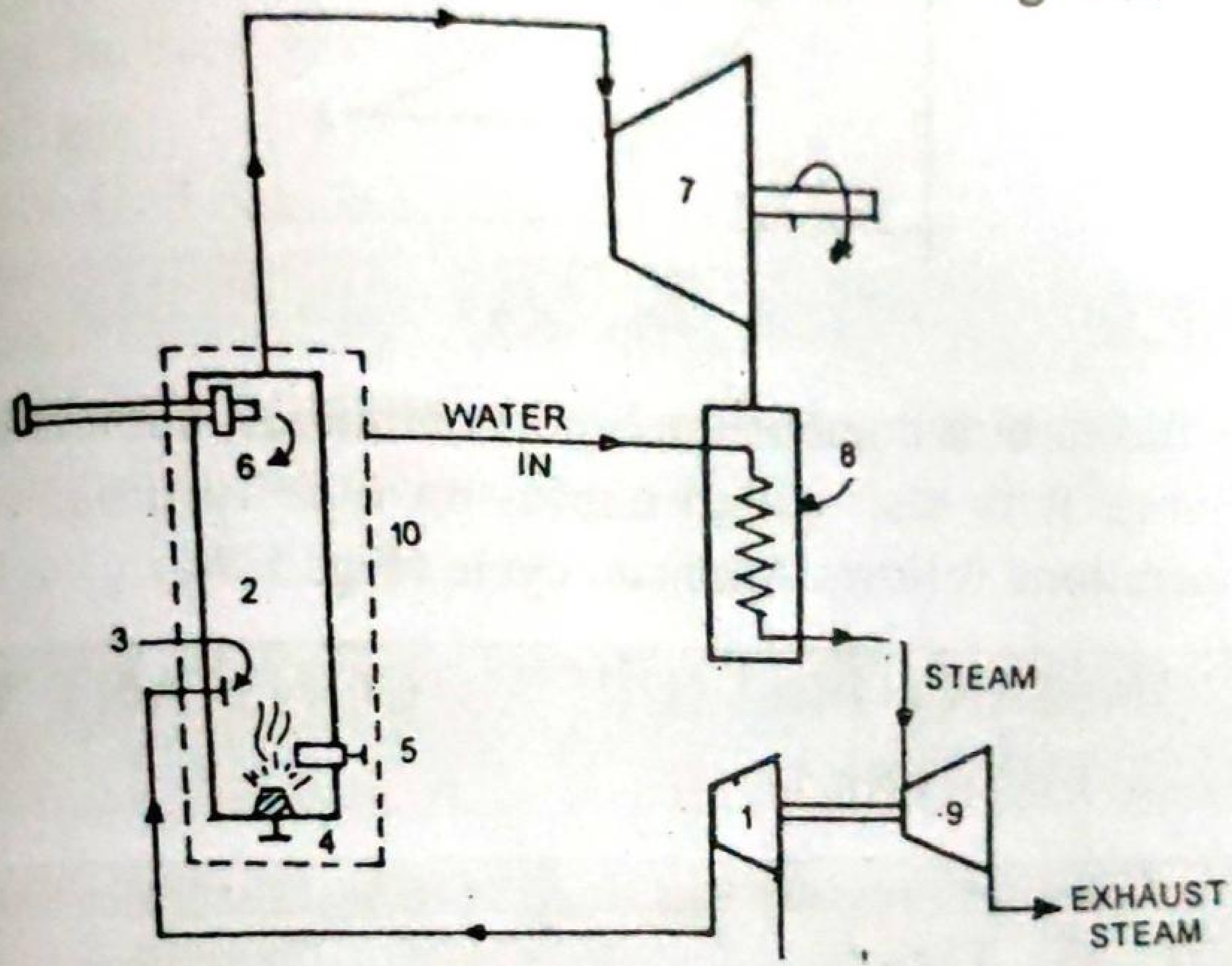
Note : 1. The p-V diagram and T-ϕ diagram for the cycle are shown in figs. 5.2 (a) and 5.2 (b).

2. The student, however, may draw only a line diagram of the cycle as shown in Fig. 5.1.

5.8 CONSTANT VOLUME GAS TURBINE :

This is a turbine in which fuel is burnt and air is heated at constant volume in a combustion chamber.

Basic elements of the turbine are shown in Fig. 5.6.



1. Air Compressor 2. Combustion Chamber 3. Air Valve
4. Fuel Injector 5. Spark Plug 6. Nozzle Valve
7. Gas Turbine 8. Heater 9. Steam Turbine 10. Water Jacket

Fig. 5.6 Constant Volume Gas Turbine

Air under pressure (2 to 3 bar) is supplied to combustion chamber (2) by an air compressor (1). Its quantity is regulated by air valve (3). Fuel is injected through an injector (4) into the combustion chamber and is ignited by means of a spark plug (5). The pressure of mixture of air fuel rises from 10 to 14 bar at constant volume. At this instant nozzle valve (6) opens and the combustion products pass through it into the turbine (7). When they pass through nozzle valve pressure energy is converted into kinetic energy which is absorbed by turbine rotor as the gases expand over turbine rotor as the gases expand over turbine blades. Thus mechanical energy is produced and the turbine develops power rotating its output shaft. The hot expanded gases are exhausted into a heater (8) where water is evaporated by the heat in exhaust gases. Steam produced in the heater is discharged into a steam turbine (9) to which the air compressor is coupled. Thus whole of the power developed by gas turbine may be made use of to run the generator etc. Combustion chamber may be cooled by water jacket (10) in which water is circulated.

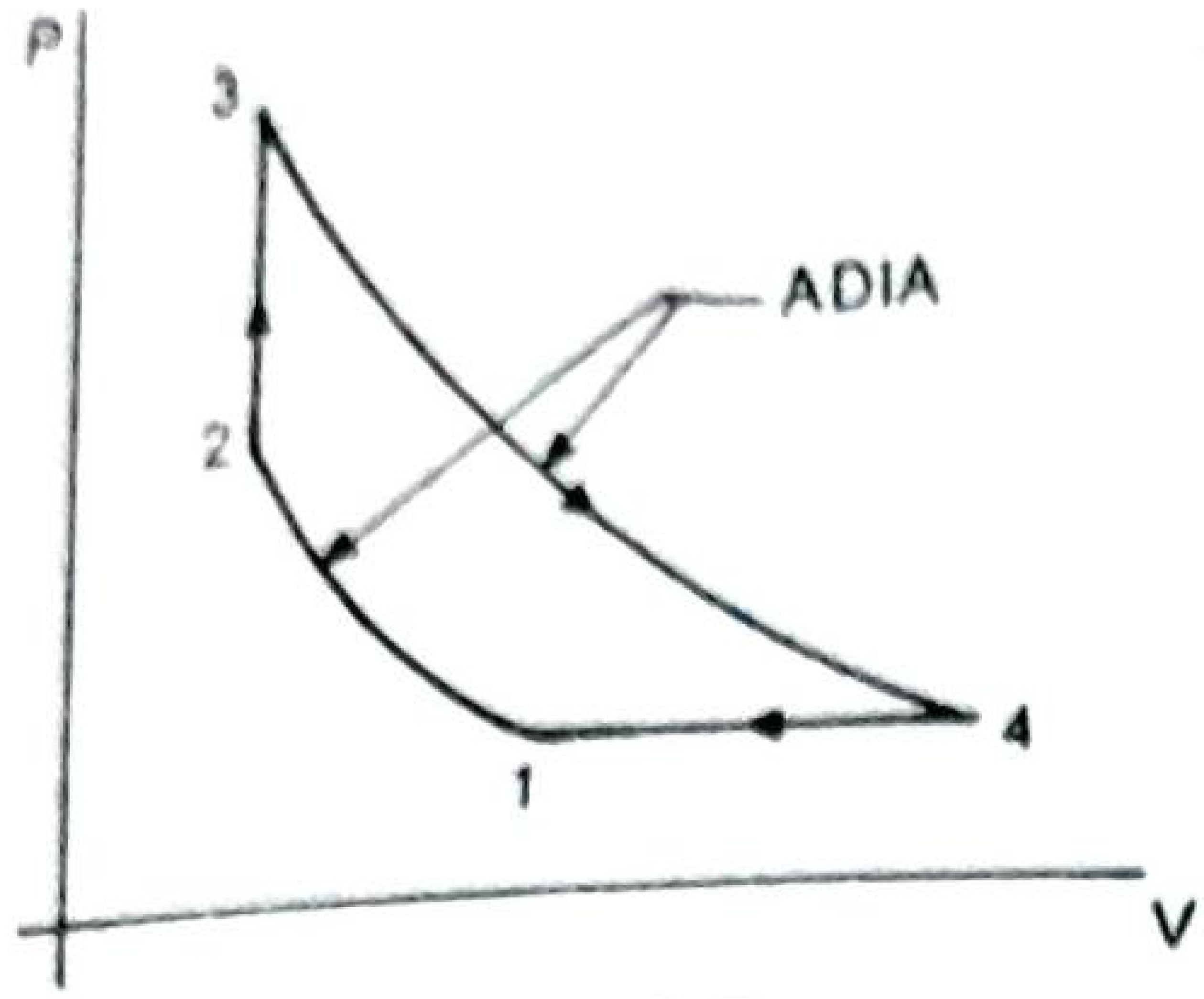


Fig. 5.7

In this turbine combustion is not continuous, but it is intermittent. Hence it is also called explosion type turbine. Its cycle of operations follows Atkinson cycle (Fig. 5.7).

5.9 CONSTANT PRESSURE Vs CONSTANT VOLUME GAS TURBINE :

S.No.	Constant Pressure Gas Turbine		Constant Volume Gas Turbines
1.	Combustion of fuel and heating of air is at constant pressure.	1.	Combustion of fuel and heating of air is at constant volume.
2.	Combustion of fuel is continuous, so the rotation of turbine is smoother.	2.	Combustion is not continuous but it is intermittent; rotation of turbine shaft is not so smooth.
3.	High combustion temperature is reduced by supplying excess amount of air.	3.	High combustion temperature is reduced by providing water jacket around combustion chamber.
4.	The unit is relatively simple.	4.	The unit is not simpler because of steam generator etc.
5.	There is no need of condenser.	5.	Condenser may be employed to condense steam.
6.	Cycle of operations follows reversed Joule's cycle or Brayton Cycle.	6.	Cycle of operations follows Atkinson's cycle.
7.	Most commonly built type of turbine.	7.	It is rarely built.