6TH SEM./MECH./DME/MECH(PROD.)/MECH(MAINT)/ MECH(IND.INT)MECH(SAND)/2022(S)
TH-3 Power Station Engineering

Full Marks: 80 Time- 3 Hrs

Answer any five Questions including Q No.1& 2
Figures in the right hand margin indicates marks

1. Answer **All** questions 2 x 10

a. Classify power plant.
b. Define specific steam consumptions.
c. What is an Air Pre-heater? State its field of use.
d. What is Nuclear Reactor?
e. What is the function of surge tank in Hydro electric power plant?
f. Draw P-V & T-S diagram of Rankine cycle.
g. Define Draught.
h. Write name of fuels used in Gas Turbine power station?
i. What is the function of cooling tower?
j. What is the function of steam condenser?

2. Answer **Any Six** Questions 6 x 5

a. Write the difference between Jet condenser and Surface condenser.
b. State merits and demerits of Gas turbine station.
c. State the criteria for selection of site for a Hydel power plant.
d. Explain the working principle of ESP.
e. Explain fuel storage and supply system in a diesel power plant.
f. Differentiate between Captive and Central power plant.
g Differentiate between boiler mountings and accessories.

3 Describe layout of steam power station. 10

4 Explain the working of PWR with neat sketch. 10

5 Explain the working of diesel power plant. 10

6 A simple Rankine cycle works between pressure 28 bar and 0.06 bar.The initial condition of steam being dry saturated. Calculate the cycle efficiency,work ratio & SSC. 10

7 Define compounding. Explain pressure & velocity compounding with neat sketch. 10

6thSEM MECHANICAL
TH-3 Power Station Engineering

1.a)Classify power plant.

Ans- Power plant are 2types

i)conventional power plant

They include the generation of electricity from conventional sources of energy.these resources are infinite & exhaustible. Once consumed,these resources can not be replaced by other.

EX: Coal,timber,petroleum,lignite etc.

ii)Non-conventional power plant

The non-conventional sources of energy are being continuously produced in nature and are not exhaustible.

EX: Wood,geothermal energy, wind energy etc.

b)Define specific steam consumption.

Ans-It is defind as the steam consumed by a heat engine (tubine or steam engine)per unit output of power.

It is typically measured in kg/kJ.

$$(kg/kwh) = \frac{\text{Steam production (kg/hr)}}{\text{Power(KW)}}$$

c)What is an air pre-heater?.State its field of use.

Ans-The main function of an air pre-heater is to extract the excess heat from the flue gases in the boiler. As we know, combustion requires air, fuel, and fire to take place. Air pre-heaters help significantly in feeding the hot air and increasing the combustion efficiency for the operation in steam boilers.

An air pre-heater is placed between the economizer and the chimney and it extracts heat from the flue gases and transfers to air which is entering the furnace. The portion of the heat that otherwise would pass up the chimney to waste. Air Pre-heaters are basically heat-exchangers installed in the exit flus gas duct of the boiler. The purpose of the air preheater is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the useful heat lost in the flue gas.

d)What is Nuclear Reactor?

Ans-Nuclear reactors are the heart of a nuclear power plant. They contain and control nuclear chain reactions that produce heat through a physical process called fission. That heat is used to make steam that spins a turbine to create electricity. A nuclear reactor is a system that contains and controls sustained nuclear chain reactions. Reactors are used for generating

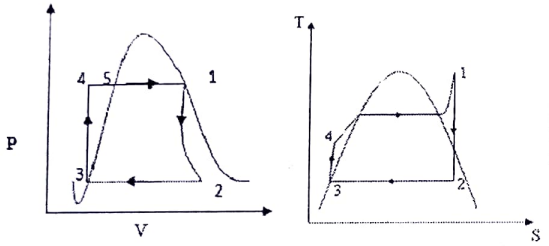
electricity, moving aircraft carriers and submarines, producing medical isotopes for imaging and cancer treatment, and for conducting research.

e)What is function of surge tank in Hydro electric power plant?

Ans-Surge tanks are applied in hydropower plants with long water conduits to reduce pressure forces during the acceleration of the large water masses. They are constructed as intermittent water reservoirs close to the turbines, either with open access to atmospheric air or as a closed volume filled with pressurized air. A surge tank (or surge drum or surge pool) is a standpipe or storage reservoir at the downstream end of a closed aqueduct, feeder, dam, barrage pipe to absorb sudden rises of pressure, as well as to quickly provide extra water during a brief drop in pressure.

f)Draw P-V & T-S diagram of Rankine cycle.

Ans-



g)Define Draught.

Ans-Draught is defined as the difference between absolute gas pressure at any point in a gas flow passage and the ambient (same elevation) atmospheric pressure. Draught is achieved by small pressure difference which causes the flow of air or gas to take place. It is measured in milimetre (mm) or water.

h) Write name of fuels used in Gas Turbine power station?

Ans- While gas turbines are often advertised as having fuel flexibility, about 90 percent of gas turbines worldwide operate on natural gas or liquefied natural gas (LNG) because of its purity and ease of combustion. Only about 400 GE gas turbines globally operate on crude, naphtha or heavy fuel oil.

Explanation: Natural gases,petrol,diesel etc can be used as fuels in gas turbines. Gas turbines requires liquids with high specific heat as fuels.

i)What is the function of cooling tower?

Ans- A cooling tower is designed to remove heat from a building or facility by spraying water down through the tower to exchange heat into the inside of the building. Air comes in from the sides of the tower and passes through the falling water. The primary use of large, industrial cooling towers is to remove the heat absorbed in the circulating cooling water systems used in power plants, petroleum refineries, petrochemical plants, natural gas

processing plants, food processing plants, semi-conductor plants, and for other industrial facilities.

j)What is the function of steam condenser?

Ans- A surface condenser or steam condenser is a water-cooled shell and tube heat exchanger used to condensate the exhaust steam from the steam turbine in thermal power stations: the steam is converted from gaseous to liquid state at a pressure level below atmospheric pressure. In thermal power plants, the purpose of a surface condenser is to condense the exhaust steam from a steam turbine to obtain maximum efficiency, and also to convert the turbine exhaust steam into pure water (referred to as steam condensate) so that it may be reused in the steam generator or boiler as boiler feed water.

2.a) Write the difference between Jet condenser and Surface condenser .

Ans-

Jet Condensers	Surface Condensers
Cooling water and steam are mixed up	Cooling water & steam aren't mixed up
Low manufacturing cost	High manufacturing cost
Requires small floor space	Requires large floor space
The condensate cannot be used as feed water to boiler unless it is free from impurities	The condensate can be used as feed water to boiler as it is not mixed with cooling water
More power is required for air pump	Less power is required for air pump
Less power is required for water pump	More power is required for water pump
Requires less quantity of cooling water	Requires large quantity of cooling water
Less suitable for high capacity plants due to low vacuum efficiency	More suitable for high capacity plants as vacuum efficiency is high
Lower upkeep	Higher upkeep

b) State the merits & demerits of Gas turbine station.

Ans- Merits of gas turbine station

1.They are small in size, weigh less and have low initial cost per unit output.
2.They are easy to install within short periods.
3.They are quick-starting and smooth running.
4. They offer flexibility by supplying electricity for power generation as well as by supplying compressed air for process needs.
5.They are capable of using a range of liquid and gaseous fuels including synthetic fuels.
6.They are subjected (put) to fewer environmental restrictions than other prime mover.
7. Water consumption is less compared to steam power plant.

Demerits of gas turbine station

1. An electric motor or an I.C. engine is necessary for starting the plant. The starting motor must bring the compressor well towards the operating speed. So, starting is not simple as in the case of other power plants.

2. Gas turbine plants have less vibrations when compared with reciprocating engines of the same speed. However the high frequency noise from the compressor is objectionable.
3. High temperatures impose severe restriction on the servicing conditions of the plant.
4. Overall efficiency is low since two-thirds of the total power output is used for driving the compressor.
5. The blades of the turbine require special cooling methods due to the severity of operating temperatures and pressures. In practice, the temperatures at the entry of the turbine are as high as 1100°C - 1260°C. Hence they should be made of special metals and alloys.
6. They are incompatible with solid fuels.

c) State the criteria for selection of site for Hydel power plant.

Ans- The key characteristics for the selection of the site for the hydroelectric power plant are that the site should accommodate a large catchment area, steep gradients for a good potential head, high average annual rainfall throughout the year, a suitable location for the building of storage or reservoir dams. It is an important point for site selection of hydroelectric power plant. Water head is directly related to the cost of generation of electric power. If effective head is increased,water storage has to be reduced as well as capital cost of the plant is reduced.

The selection of the site for a power plant depends upon many factors such as cost of transmission of energy, cost of fuel, cost of land and taxes, requirement of space, availability of site for water power, storage space for fuel, transport facilities, availability of cooling water, nature of load.

d)Explain the working principle of ESP.

Ans- An electrostatic precipitator (ESP) removes particles from a gas stream by using electrical energy to charge particles either positively or negatively. The charged particles are then attracted to collector plates carrying the opposite charge. An ESP works on the principle of the corona discharge effect. A high DC voltage is applied across the two plates or electrodes. The negatively charged plate attracts the dust particles which are further attracted by the positively charged electrode by the process of Ionisation

The working principle of electrostatic precipitators is quite simples.
It has two sets of electrodes; one is positives, and the other is negative.
Negatives electrodes are in the form of a rod or wire mesh.
Positive electrodes are in the form of plates.
Positive plates and negatives electrodes are placed vertically alternately one after another in the electrostatic precipitator.
Negative electrodes are connected to a negatives terminal of the high voltage dc source, and positive plates are connected to the positives terminal of the dc source.

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The positive terminal of the dc source can be grounded to achieve strong negativity in negative energy.

e)Explain fuel storage and supply system in a diesel power plant.

Ans- It consists of fuel tank for the storage of fuel, fuel filters and pumps to transfer and inject the fuel. The fuel oil may be supplied at the plant site by trucks, rail, road, tank, cars, etc. It consists of pipe for the supply of air and exhaust of the gases. The function of the diesel fuel system is to inject a precise amount of atomized and pressurized fuel into each engine cylinder at the proper time. Combustion in a diesel engine occurs when this rush of fuel is mixed with hot compressed air. The basic types of fuel injection systems are single-point fuel injection, multi-point fuel injection, sequential fuel injection, and direct injection.

f)Differentiate between Captive & Central power plant.

Ans- (i) The electrical energy available from central power stations is meant for general sale to the customers who wish to purchase it. Example NTPC, Kaniha , Talcher.
In case of captive power stations, these are run by manufacturing companies for their own use and the output is not available for general sale. Example CPP of NALCO.
(ii) Generally central power stations are condensing type i.e., the exhaust steam is discharged into a condenser instead of into the atmosphere. Normally most of captive power stations are non-condensing type because a large quantity of steam (low pressure) is required for different manufacturing operations.
(iii) Capacity or amount of power generation of central power stations are much higher than the captive power stations.
(iv) The operating conditions i.e., pressure and temperature etc . are much higher in case of central power stations than captive power stations. (v) The plant load factor (PLF) of central power stations are higher than the captive stations as there is no restrictions to generate power.

g) Differentiate between boiler mounting and accessories.

Ans-

Boiler Mountings	Boiler Accessories
It amplify the safety of a boiler	It amplify the efficiency of a boiler
Mountings are necessary for changeable the boiler.	Accessories are not necessary but their use is enviable.
Commonly they are mount on boiler shell.	They are not located on boiler shell.
Mountings are installed from simple working and control of a boiler. eg. Waterlevel, Indicator, Pressure gauge.	Accessories are install to amplify efficiency of a boiler. eg. : Super heater, Economiser.

3. Describe layout of steam power station.

LAYOUT OF STEAM POWER PLANT:

The layout of steam power plant has the following circuits:

1. Fuel (Coal) and ash circuit
2. Air and flue gas circuit
3. Feed water and steam flow circuit
4. Cooling water flow circuit.

Coal and Ash Circuit:

- Coal from mines is delivered by ships, rails or trucks to the power station.
- Coal received at coal yard.
- Coal is sized by crushers, breakers etc.,
- The sized coal is stored in coal storage.
- From stock yard, the coal is transferred to the boiler furnace by means of conveyors, elevators etc.,
- The coal is burnt in the boiler and ash is formed.

AIR AND FLUE GAS CIRCUIT:

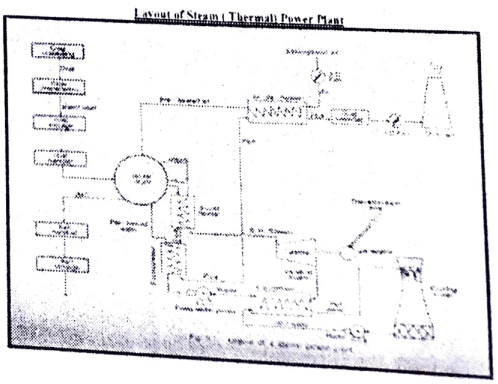
- Air is taken from the atmosphere by the action of FD fan.
- It is passed through an air pre heater
- The air is preheated by the flue gases in the pre heater.
- This preheated air is supplied to the furnace to aid the combustion of fuel.
- Due to the combustion of fuel the flue gases are formed.
- The flue gases from the furnace pass over the boiler tubes and super heater tubes.
- Then the flue gases pass through economiser to heat the feed water.

Water and Steam Circuit:

- The water is preheated by the flue gases in the economiser.
- This preheated water is then supplied to the boiler drum.
- It is superheated by the flue gases.
- The turbine drives generator to produce electric power.
- The expanded steam is t hen passed through the condenser.
- In the condenser, steam i s condensed into water there circulated.

COOLING WATER CIRCUIT:

- The exhaust steam from t he turbine is condensed in the condenser.
- In the condenser, the cold water is circulated to condense the steam into water.
- The steam is condensed b y losing its latent heat to the circulating the col d water.
- Hence the cold water get s heated.
- This hot water is then ta ken to a cooling tower.
- In cooling tower the water is sprayed in the form of droplets through nozzzles.
- The atmospheric air ente rs the cooling tower from the openings provided at the bottom of the tower.
- This cold water is again circulated through the pump, condenser and the cooling
- Some amount of water may be lost during circulation.
- Hence make up water is added to the pond by means of a pump



4. Explain the working of PWR with neat sketch.

Ans. Pressurised Water Reactor (PWR) :

A pressurised water reactor, in its simplest form, is a light water cooled and moderated thermal reactor having an unusual core design, using both natural and highly enriched fuel. The principal parts of the reactor are :

(i) Pressure vessel
(ii) Fuel elements
(iii) Pressurizer
(iv) Reactor thermal shields
(v) Control rods
(vi) Reactor containment

The components of the secondary system of PWR is similar to normal thermal power plant. It includes (i) Turbine (ii) Condenser (iii) Feed pump (iv) Heat exchagner etc.

As shown in figure, in a PWR, there are two circuits of water, one primary circuit which passses through the fuel core and is radioactive. The primary circuit then produces steam in a secondary circuit which consists of heat exchanger i.e., boiler and turbine. The pressure in the primary circuit should be high so that the boiling of water takes place at high pressure. A pressuring tank keeps the water at about 100 bar so that it will not boil. Electric heating coils in the pressuriser boil some of the water to form steam that collects in the dome. As more steam is formed in the dome by boiling, its pressure rises and pressurises the entire circuit. The pressure may be reduced by providing cooling coils or spraying water on the steam. A PWR can produce only saturated steam. For producing super heated steam, a separate furnace may be provided to heat the steam produced in the reactor. Here water is used as both coolant as well as moderator.

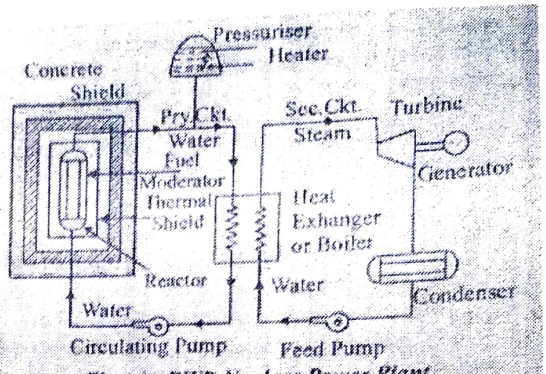


Fig (a) : PWR Nuclear Power Plant

Advantages :

(i) Water used in reactor as coolant, moderator and reflector is cheap in first cost and available in plenty.
(ii) Fuel consumption is less.
(iii) The reactor is compact and higher power density (65 kW/litre) due to use of enriched fuel.
(iv) Small number of control rods are needed (60 control rod/1000 MW).
(v) Safe and stable operation.
(vi) There is a complete freedom to inspect and maintain the secondry circuit i.e., the turbine, condenser, feed heaters etc. during opetation.
(vii) The secondary circuit may be optimized for higher efficiency.
(viii) High power demand co-efficient i.e., when power demand is moe, it responds quickly to supply the same.
(ix) Fission products remain contained in the reactor and are not circulated.

Disadvantages :

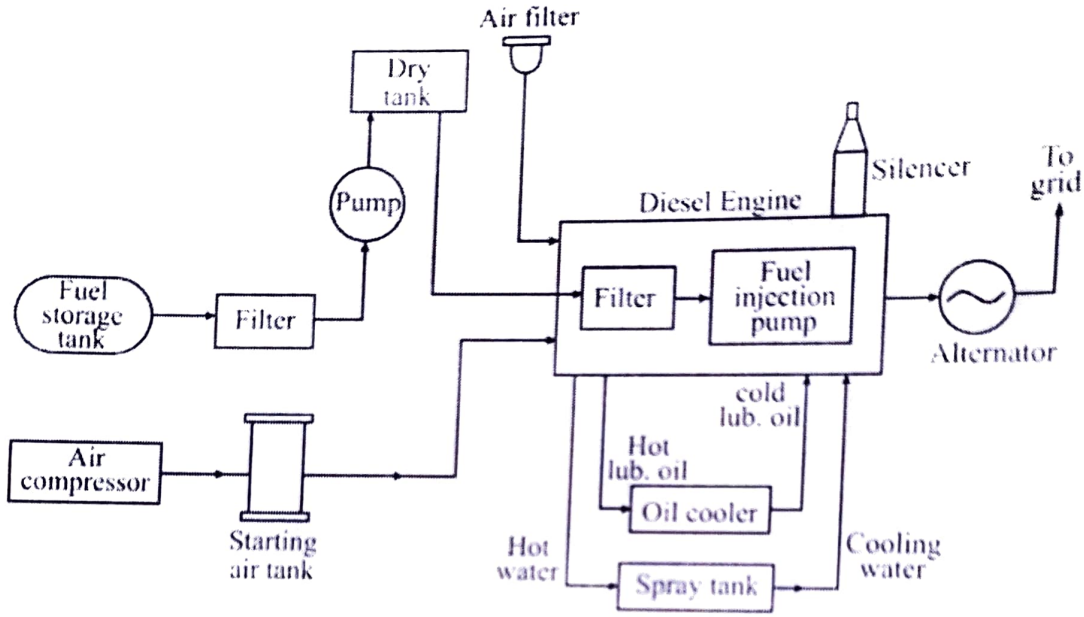
(i) High capital cost due to primary circuit requires strong pressure vessel to withstand high pressure.
(ii) The efficiency of plant is quite low (20%) due to low pressure (60 to 70bar) in the secondry circuit.
(iii) Fuel suffers radiation dainge and its reprocessing is difficult.
(iv) Fuel element fabrication is expensive.
(v) It is necessary to shut down the reactor for fuel charging which requires a couple of months' time.
(vi) It suffers from severe corrosion problems.

5. Explain the working of diesel power plant.

An electric power generating station in which the chemical energy of diesel is converted into electrical energy is known as **diesel power plant**. In other words, the diesel power plant is a power generating plant in which diesel engine is used as the prime mover for the generation of electrical energy.

Schematic Diagram and Working of Diesel Power Plant

The schematic arrangement of a typical diesel power plant is shown in the figure given below.



In a diesel power plant, the diesel engine is used as the prime mover to drive an alternator. The diesel (fuel oil) burns inside the engine and the products of this combustion acts as the working agent to produce mechanical energy. The diesel engine drives an electric generator which converts the mechanical energy into electrical energy.

Due to high cost of diesel, the diesel power plants are only used to produce small power. The diesel power plants are used at such places where demand of power is less and sufficient quantity of coal and water is not available. The diesel power plants are also used as standby sets for supplying power to important points such as hospitals, cinema halls, telephone exchanges, etc.

Advantages of Diesel Power Plant

The primary advantages of a diesel power plant are given as follows –

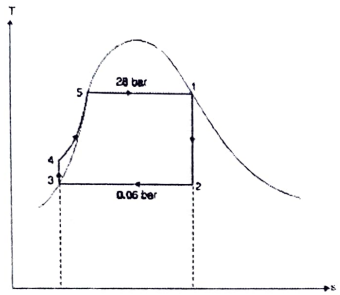
- The layout of a diesel power plant is quite simple.
- A diesel power plant requires less space because the number and size of its auxiliary equipment is small.
- A diesel power plant can be started quickly and it can pick up the load in a short time.
- A diesel power plant requires less water for cooling.
- For the same capacity, the overall cost of a diesel power plant is much less than that of a thermal power plant.
- For the same capacity, the thermal efficiency of a diesel power plant is higher than that of a thermal power plant.
- A diesel power plant requires less staff for the operation.
- A diesel power plant can be installed at any place.
- A diesel power plant does not have any standby losses.

Disadvantages of Diesel Power Plant

Following are some disadvantages of a diesel power plant –

- As the diesel (fuel oil) is costly, thus the diesel power plant has high running cost.
- The diesel power plant can only be used to generate small power.

6. A simple Rankine cycle works between pressure 28 bar and 0.06 bar. The initial condition of steam being dry saturated. Calculate the cycle efficiency,work ratio & SSC.



From steam tables,

At 28 bar : $h_1 = 2802$ kJ/kg, $s_1 = 6.2104$ kJ/kg K

At 0.06 bar : $h_{f2} = h_{f3} = 151.5$ kJ/kg,

$h_{fg2} = 2415.9$ kJ/kg,

$s_{f2} = 0.521$ kJ/kg K,

$s_{fg2} = 7.809$ kJ/kg K

$v_f = 0.001\ m^3/kg$

Considering turbine process 1-2, we have :

$s_1 = s_2$

$s_{f2} = 0.521$ kJ/kg K,

$s_{fg2} = 7.809$ kJ/kg K

$v_f = 0.001\ m^3/kg$

Considering turbine process 1-2, we have :

$s_1 = s_2$

$6.2104 = s_{f2} + x_2\, s_{fg2} = 0.521 + x_2 \times 7.809$

$$x_2 = \frac{6.2104 - 0.521}{7.809} = 0.728$$

$$h_2 = h_{f_2} + x_2\, h_{fg_2}$$

$= 151.5 + 0.728 \times 2415.9 = 1910.27$ kJ/kg

$\therefore$ Turbine work, $W_{turbine} = h_1 - h_2 = 2802 - 1910.27 = 891.73$ kJ/kg

Pump work, $W_{pump} = h_{f4} - h_{f3} = v_f (p_1 - p_2)$

$$= \frac{0.001\,(28 - 0.06) \times 10^5}{1000} = 2.79 \text{ kJ/kg}$$

$[\because h_{f_4} = h_{f_3} + 2.79 = 151.5 + 2.79 = 154.29$ kJ/kg]

$\therefore$ Net work, $W_{net} = W_{turbine} - W_{pump}$

$= 891.73 - 2.79 = 888.94$ kJ/kg

$$\text{Cycle efficiency} = \frac{W_{net}}{Q_1} = \frac{888.94}{h_1 - h_{f_4}}$$

$$= \frac{888.94}{2802 - 154.29} = 0.3357 \text{ or } 33.57\%.$$

$$\text{Work ratio} = \frac{W_{net}}{W_{turbine}} = \frac{888.94}{891.73} = 0.997.$$

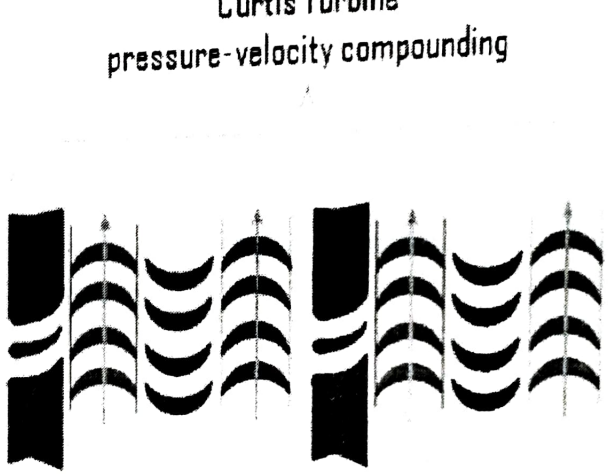
Specific steam consumption $= \frac{3600}{W_{net}} = \frac{3600}{888.94} = 4.049$ kg/kWh

7. Define compounding. Explain pressure & velocity compounding with neat sketch.

Compounding of steam turbines is the method in which energy from the steam is extracted in a number of stages rather than a single stage in a turbine. In all turbines the rotating blade velocity is proportional to the steam velocity passing over the blade.

Pressure-Velocity Compounding – Curtis Turbine

Impulse stages may be either pressure-compounded, velocity-compounded, or **pressure-velocity compounded**. **Pressure-velocity compounding** is a **combination** of the above two types of compounding. In fact, a series of velocity-compounded impulse stages is called a pressure-velocity compounded turbine. Each stage consists of rings of fixed and moving blades. Each set of rings of moving blades is separated by a single ring of fixed nozzles. In each stage, there is one ring of fixed nozzles and 3-4 rings of moving blades (with fixed blades between them). Each stage acts as a velocity compounded impulse turbine.



Curtis Turbine – pressure-velocity compounding

The steam coming from the steam generator is passed to the first ring of fixed nozzles, which gets **partially expanded**. The pressure partially decreases, and the velocity rises correspondingly. It then passes over the 3-4 rings of moving blades (with fixed blades between them), where nearly all of its velocity is absorbed. From the last ring of the stage, it exhausts into the next nozzle ring and is again partially expanded.

This has the advantage of allowing a bigger pressure drop in each stage and, consequently, fewer stages are necessary, resulting in a shorter turbine for a given pressure drop. We may see that the pressure is constant during each stage; the turbine is, therefore, an impulse turbine. The method of pressure-velocity compounding is used in the **Curtis turbine**.