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B.E.

Eighth Semester Examination, May-2008

POWER PLANT ENGINEERING

Note : Attempt any five questions.

Q. 1. (a) The run-off data at a particular site for 12 weeks is tabulated below. Draw the mass curve and find the size of reservoir and possible rate of flow which would be available after the reservoir has been built.

Week :	1	2	3	4	5	6	7	8	9	10	11	12
Weekly from m^3/s :	6000	5000	4000	2000	1000	500	1000	4000	8000	5000	2000	1000

Ans.

Week (a)	Weekly flow in m^3/sec.	Weekly flow in day sec-metre	Cumulative flow in day-sec-metres
1	6000	42000	42000
2	5000	35000	77000
3	4000	28000	105000
4	2000	14000	119000
5	1000	7000	12000
6	500	3500	129500
7	1000	7000	136500
8	4000	28000	164500
9	8000	56000	220500
10	5000	35000	255500
11	2000	14000	269500
12	1000	7000	276500

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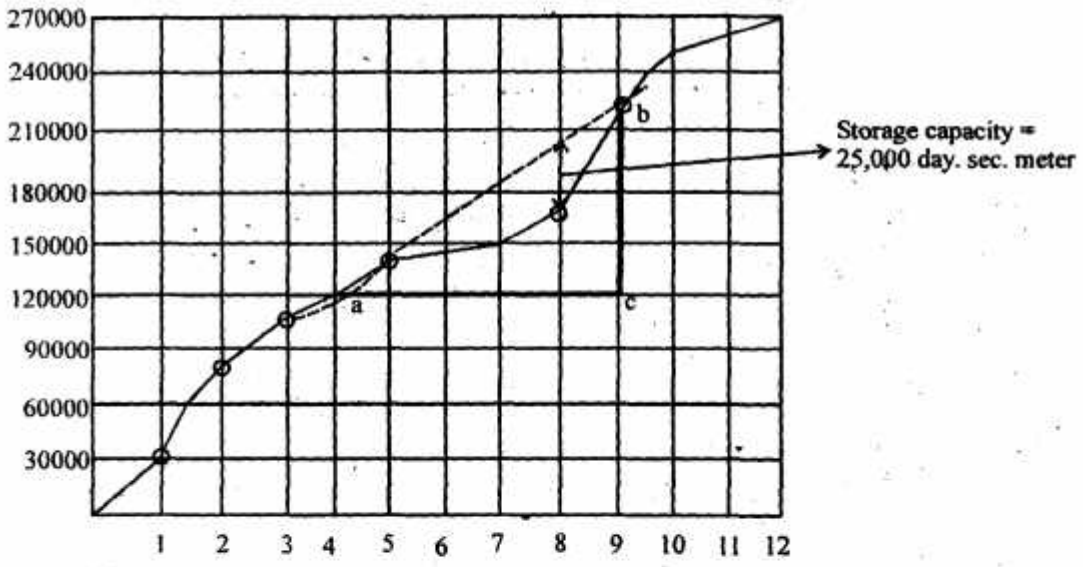

$$\text{Flow rate} = \frac{bc}{ac} = 1800\,m^3/\text{sec.}$$

Q. 1. (b) Explain Run-off river power plant. How its performance is increased by introducing a pontage in the plant?

Ans. Runn-off river plant :

Such plants are many in number in Europe and all major rivers have series of such plants along their course of flow. The reason for not having such plant in India is typical monsoon which brings rain or flow only for 4 months. Against this, European rivers have more or less uniform distributed flow throughout the years which is the prime requirement of runn-off plant.

There are two types of Run-off Poundage :

This type of plant does not store water and uses the water as it comes. This plant ash no control over the river flow. Therefore, water is wasted during low load and high flood conditions. During day seasons, the ·ity of the plant goes down due to the low flow rate of the water. The utility of these plants is very less red with other plants due to non-uniformly of supply and lack of assurance for continuous constant

Run-off River Plant with Poundage :

ıe usefulness of the run-off river plant is increased by incorporating a point in the plant. The pond s to store water during off peak hours and uses during peak hours of the same day. The poundage

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capacity is decided to take the fluctuating load based on 24-hours basis. Poundage increases the steam capacity for a short period, a hour or week depending on the capacity of the pond.

Q. 2. Draw a general layout of modern thermal power plants and explain the working of different circuit. (Fuel, Air, Steam-water, Cooling etc.)

Ans. General Layout of Modern Thermal Power Plant :

General layout of thermal power plant consist of mainly circuits as shown in fig.

The four main circuits are :

1. Cool and ash circuit
2. Air and gas circuit
3. Feed water and steam flow circuit
4. Cooling water circuit

A thermal power station using steam as working fluid works basically on Rankine cycle. Steam is generated in a boiler, expanded in the prime mover and condensed and fed into the boiler again with the help of pump. However, in practice, there are numerous modifications and improvements in this cycle with the cum of affecting heat economy and to increase thermal efficiency of plant.

1. Coal and ash circuit :

In this circuit, coal from the storage fed to boiler through coal handling equipment for the generation of steam. Ash produce due to the combustion of coal is removed to ashes storage through ash handling system.

2. Air and gas circuit :

Air is supplied to the combustion chamber of boiler either through F.D. or I.D.for or by using both. The dust from the air is removed before supplying to combustion chamber. The exhaust gases carrying sufficient quantity of heat and ash are passed through air heater where the exhaust heat of gases is given to air and them it is passed through dust collectors where most of dust is removed before exhausting the gases to the atmosphere through chimney.

3. Feed water and steam circuit :

The steam generated in the boiler is fed to steam prime mover to develop power. The steam coming out of prime mover is condensed in the condenser and them fed to the boiler with the help of pump. The condensate is heated in feed heater using steam tapped from different points of turbine. The feed heater may be of mixed types or indirect heating.

Some of steam and water is lost passing through different components of system, therefore, feed water is supplied from external sources to compensate this loss. The feed water supplied from external source is passed through purifying plant to reduce the dissolved salts to an acceptable level. The purification is necessary to avoid the scaling of boiler tubes.

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4. Cooling water circuit :

The quantity of cooling water required to condense the steam is considerably large and it is taken either from lake, river or sea. The cooling water is taken from upper side of river it is passed through condenser and heated water is discharged to the power side of river. Such system of cooling water supply is possible if adequate cooling water is available through out year. This system is known as open system. When adequate water is not available, then the water coming out from the condenser is cooled either in cooling pond or cooling tower

Q. 3. A gas turbine power plant consists of two stage compressor and single stage turbine with regenerator. The air is taken into the compressor at 20°C and 1 bar. The maximum temperature of the cycle is limited to 700°C and maximum pressure ratio is 6. The effectiveness of regenerator is 0.7. Assuming following data, find the air-fuel ratio used, thermal efficiency of the cycle and specific fuel consumption. Take Air flow rate 200 kg/s, Isentropic efficiency of both compressor 082, Isentropic efficiency of turbine 0.92, combustion efficiency 0.96, Mechanical efficiency. 96, Generation efficiency 0.95, Cv of the fuel 880 kcal/kg, Cp = 0.24 kcal/kg-k and γ (gamma) 1.4 for air and gases. Assume perfect inter cooling, and negligible loss of heat and pressure in the system.

Ans. Formulas used are,

P_i (Pressure in intercooler) $= \sqrt{P_1 P_2}$

$$T_2' = T_1\left[\frac{P_i}{P_i}\right]^{\frac{\gamma-1}{\gamma}}$$

$$\eta_c = \frac{T_2' - T_1}{T_2 - T_1}$$

$$T_4' = T_3\left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}}$$

$$T_7' = T_6\left[\frac{P_1}{P_2}\right]^{\frac{\gamma-1}{\gamma}}$$

$$\eta_t = \frac{T_6 - T_7}{T_6 - T_7'}$$

$$\text{Thermal efficiency} = \frac{(T_6 - T_7) - [(T_4 - T_3) + (T_2 - T_1)]}{[T_6 - T_5]}$$

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$$= \frac{\text{Work done per kg of air}}{\text{Heat supplied per kg of air}}$$

Q. 4. Explain the working of nuclear power plant having following reactors :

(a) PWR

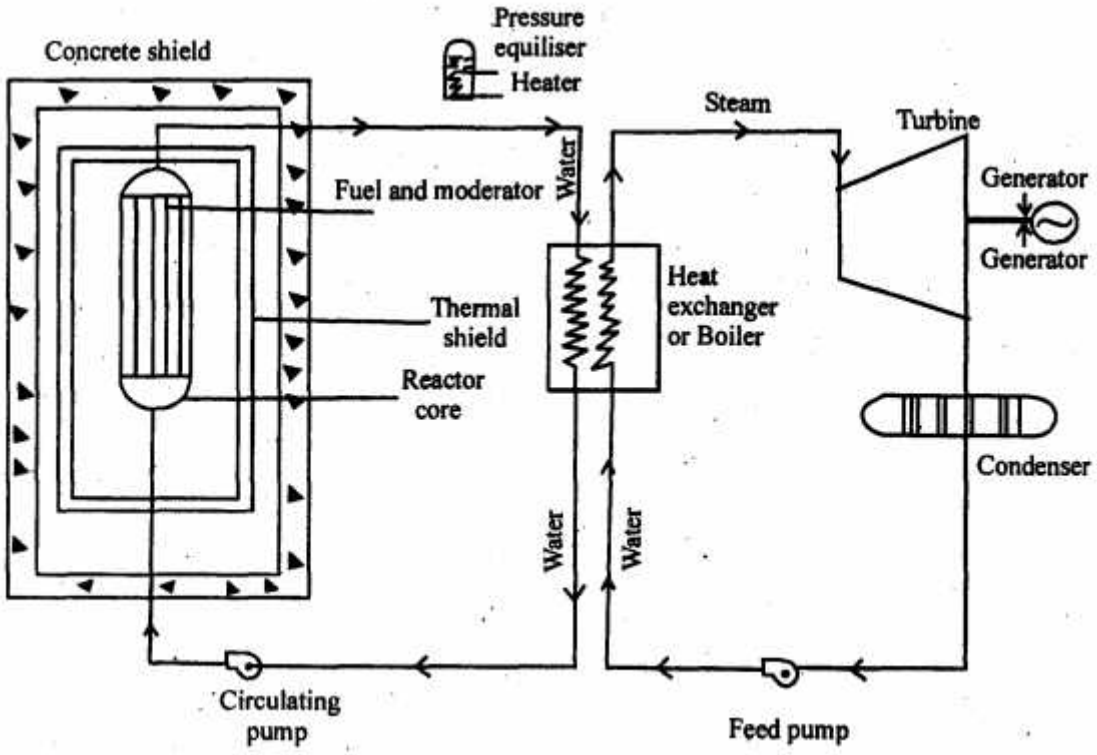
(b) Gas Cooled Reactor.

Ans. (a) PWR :

In simplest form, a pressurised water reactor is a light water cooled and moderated reactor. It uses enrich uranium as fuel.

The pressuring tank included in the circuit maintains the constant and only constant pressure in the circuit throughout the load range. Electric heating coil in pressuriser boils the water to form the steam which is collected in dome as shown in fig., and pressurises the entire coolant circuit before starting reactor. To reduce the pressure, water spray is used to condense the steam.

The fuel which is generally used in UO_2. The uranium oxide is highly resistant to irradiation damage and is very well adopted to high burns ups. It is also highly resistant to irradiation damage in the event of a break up in fuel cladding.



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The water becomes radioactive in passing through the reactors, therefore, entire primary circuit including steam generator (heat exchanger) must be shielded to protect the operating persons. The radioactive coolant does not make the steam radioactive in boiler. Bezant I is the first commercial nuclear station in Switzerland working on PWR.

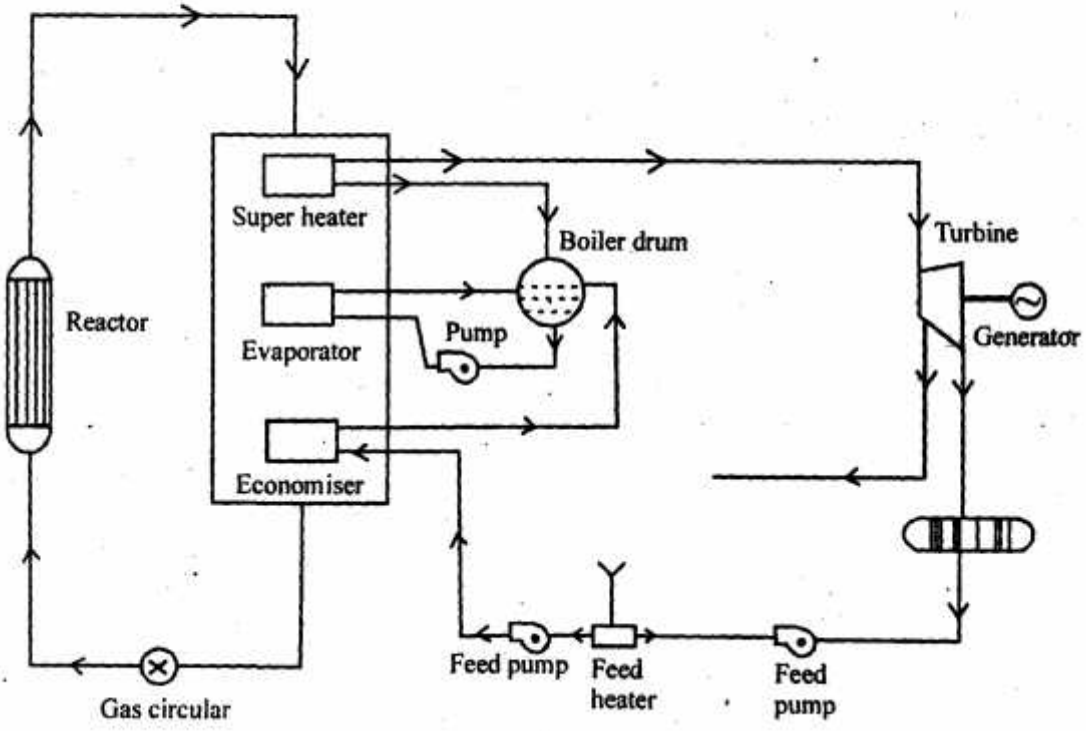
(b) Gas cooled reactor : .

The reactor is cooled by the gas and heat carried by the gas from the reactor is either used for generating steam in the secondary circuit like PWR or it can be directly used as the working fluid in gas turbine plant.

Indirect result :

The CO_2 gas is used as primary coolant which is in turn generates steam in secondary circuit as shown in fig. (a). The corresponding temperature enthalpy diagram is shown in fig. (b).

The inlet temperature of turbine is fixed by the reactor outlet temperature. The temperature potential causing heat transfer from gas to steam in the reactor is very small (5–15°C). Therefore, it is necessary to balance the power required to circulate the gas at higher velocities against the increased capital costs for extended heat transfer surface.



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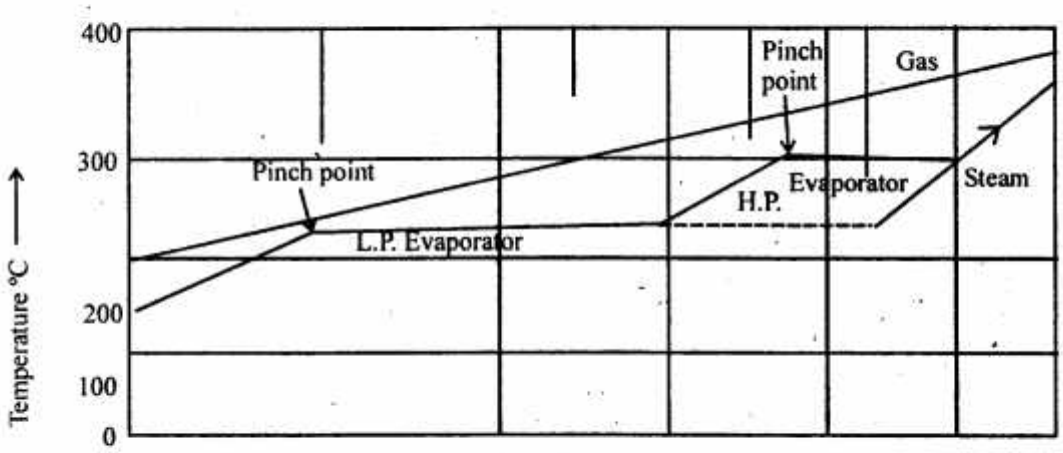
The choice of feed water temperature for given steam pressure affect the temperature of gas at the inlet of reactor. A "pinch point" occur where the feed water temperature reaches the saturation temperature and approaches to with in a few degree of the gas temperature at pinch point. Therefore the steam pressure in the cycle is limited to pressure corresponding the saturation pressure at "pinch point." If less heat is added in economiser and pinch point occur at lower gas temperature (shown in by dotted line), the steam is generated at lower pressure at the evaporation starts at lower saturation temperature.



The Hinkely point power station of 248 MW capacity with 26% efficiency at some set in England is an example of this type of power plant. The reactor consists of spherical pressure vessel made up of low carbon steel. The core is a twenty four sided prism in which the fuel rods are arranged between graphite bricks which has as a moderator and reflector. The reactor is surrounded by a concrete shield about 3 metre thick which acts as biological shield. The CO_2 gas is used as coolant, graphite as moderator and natural uranium as fuel.

Q. 5. (a) The following data relates to 10 MW power station. Cost of plant Rs. 1200kW, Interest 5%/annum, depreciation 5% cost of primary distribution Rs. 500,000, Interest 5%, cost of coal Rs. 4.4/kN, operating cost Rs. 500,000. Fixed and variable maintenance cost Rs. 20,000 and Rs. 30,000 per annum. Installed capacity 10,000 kW, maximum demand 9MW, Annual load factor 0.6, consumption of coal 255000kN. Find cost of power generation per kW per years cost per kWh generated, Total cost of generation/kWh.

Ans. Capital cost of plant

$$= 10 \times 1000 \times 1200$$

$$= \text{Rs.} 12 \times 10^6$$

$$\text{Interest} = \frac{5}{100} \times 12 \times 10^6$$

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$$= 60 \times 10^4 \text{ Rs.}$$

$$\text{Average load} = \text{Maximum demand} \times \text{Load factor}$$

$$= 10 \times 1000 \times 0.6$$

$$= 6 \times 10^3 \text{ kw}$$

$$\text{Energy supplied per year} = \text{Average load} \times 8760$$

$$= 6 \times 10^3 \times 8760 \text{ kw} - \text{hr}$$

$$= 52.56 \times 10^6 \text{ kw} - \text{hr}$$

$\therefore$ Interest charges per unit of energy

$$= \frac{5 \times 60 \times 10^4}{6 \times 10^3 \times 8760} \times 100$$

$$= 5.7 \text{ p / kw} - \text{hr}.$$

Q. 5. (b) Discuss load curve, Incremental rate theory, Diversity factor.

Ans. Load Factor : It is defined as the ratio of average load to the peak or maximum load determined by the consumer.

$$\therefore \quad \text{Load factor} = \frac{\text{Average load}}{\text{Maximum load}}$$

The load factor can also be given by

$$\text{Load factor} = \frac{\text{Factor energy consumption in 24 hours}}{\text{Peak load} \times 24}$$

The load factor is always less than unity.

Demand Factor :

It is defined as the ratio of maximum demand to connected load.

The demand factor for some numerical value is,

$$(F_d) = \frac{620}{1440} = 0.43 \text{ (day time)}$$

$$= \frac{780}{1440} = 0.54 \text{ (evening time).}$$

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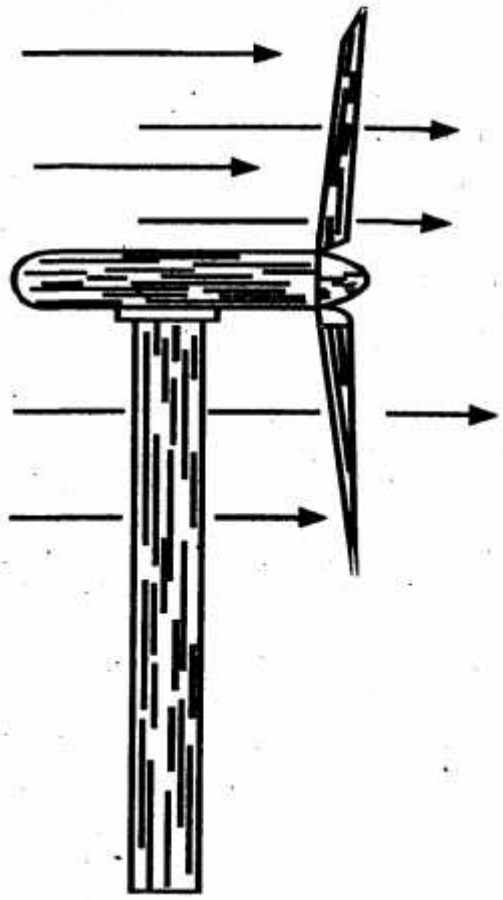
The maximum value of demand factor is unity.

Diversity Factor :

It is defined as the ratio of average load to peak load. The needs of the consumers are their maximum demands and their energy consumptions during a day. It is always necessary to provide the generating capacity equal to their maximum, demands to fulfil their needs and the energy supplied should be charged as minimum as possible.

Q. 6. (a) Draw a neat sketch of any one wind electric generating power plant. Explain how does it work.

Ans. Horizontal Axis Two Blades Wind Mill :



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In this arrangement, rotor drive a generator through a set up gear box. The components are mounted on a bed plate which is mounted on a pintle at the top of tower. The two blade rotor is usually designed to be oriented down ward of tower. The arrangement of all components used in horizontal axis wind mill is shown in fig.

When the machine is operating, its rotor blades are continuously flexed by unsteady aerodynamic, gravitational and inertial loads. If the blades are makeup of metal, flexing reduces their fatigue life. The tower is also subjected to unsteady load and dynamic between components of machine-tower system can cause serious damage. For example : If the vibrational modes of rotor happens to couple with one of natural made of vibration of tower the system may shake itself to pieces.

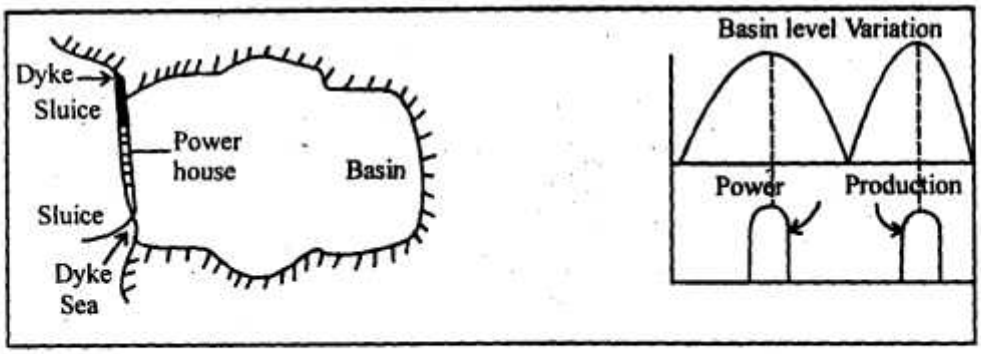
All modern wind turbine generators have just two rotor blades. Rotors with two blades would have slightly higher power coefficient, but because of high cost of blade (10 lakh Rs per blade), rotors with more than 2 blades are not cost effective. The most effective way to get more, torque out of a rotor disc is simply to lenghten its blades. The area of rotor disc increases with square of its diameter, so a fairly small increase in blade length can result in large torque.

Q. 6. (b) Name the components of Tidal power plant. Explain any one tidal power plant installed in India after mentioning the details of location, capacity etc.

Ans. Working of Different Tidal Power Plant :

Single Basin One Way Cycle :

This is the simplest form of tidal power plant. In this system, a basin is allowed to get filled during flood tick and during the ebb tide, the water flows from the basin to the sea passing through turbine and generates power. The power is available for a short duration during ebb tide.



This fig., shows the diagrammatic representation of a dom at the mouth of basin and power generation during the falling tide.

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Example :

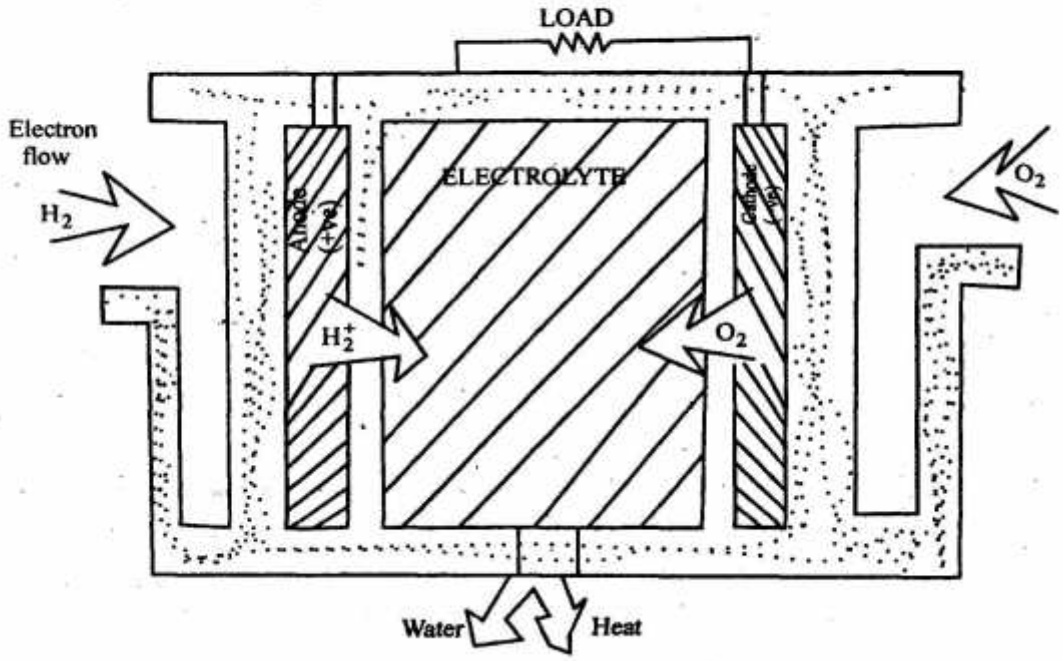
Gulf of Combay :

The tidal range in Gulf of Combay is quite large (10.8 mm) which qualifies this estuary for setting TPP. There are 2 possible sites on western bank : Sonari Geek and Bhavnagar creek and two sites on eastern bank : Dhadar River out fall and Kim River outfall into the Gulf. The most promising site is sonari creek, but in this case, embankments will have to built for a considerable length along both banks so as to prevent water spreading on both banks. The major problem in gulf of combay is high silt index (5000 ppm) which may cause high erosion of barrage.

Q. 7. (a) What is a fuel cell? Describe a hydrogen oxygen cell.

Ans. Fuel Cell :

Fuel cell are efficient & quiet, operate on a variety of hydrogen and carbon fuels, produces almost no objectionable emissions. The concept has been proven in numerous small scale applications. The recent infusion of power cost from fossil fuels may convert this promising device into a major source of electric power generation.



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The working of fuel cell is explained here with reference to hydrogen-oxygen fuel cell using aqueous electrolyte. The fuel cell consist of an anode, a cathode and an electrolyte. Hydrogen fuel is fed into he anode side of cell.

Positive H_2 ion moves from the anode-side and enter the electrolyte through porous cell walls. The anode is left with a negative charge. Air is fed into the cathode side. O_2 ions enter the electrolyte leaving the cathode with a positive charge. Excess anode electrons flow to the cathode creating a current flow. H_2 and O_2 ions combine in the electrolyte to form water which leaves the cell as steam.

The reaction takes place at electrodes are given below :

1. Hydrogen electrode (anode)

$$2H_2 = 4H$$

$$4H + 4OH = 4H_2O + 4e$$

2. Oxygen electrode (cathode)

$$O_2 = 2O$$

$$2O + 2H_2O + 4e = 4OH$$

3. Overall cell reaction

$$2H_2 + O_2 = 2H_2O$$

The above reaction indicate that H_2 molecules break up into H_2 atoms at the anode and they combine with OH ion its form water and free electron at anode. The formed free electrons travel to cathode, through the external circuit as shown in fig. At the cathode, O_2 molecules break up into two O_2 atoms and these atoms combine with 4 electrons arriving external circuit and two molecules of water (out of 4 molecules produced at the anode to form 4OH ions). The OH ions migrate toward the anode and are consumed there. The electrolyte remains invariant. It is a prime requirement that the composition of electrolyte should not change as the cell operates.

Q. 7. (b) Describe with the help of neat line diagram, the working of thermionic power generation.

Ans. Thermionic Conversion System :

As we have seen the main reason for low thermal efficiency of thermoelectric generators is the conduction heat transfer from the high temperature source to low temperature source. All attempts mode to reduce Q_c by increasing the value of Z have so far failed. In this connection, thermionic converters can be regarded as a kind of thermo-electric generators in which the hot and cold "junctions." are separated by a vacuum preventing the transfer of heat by way of conduction. The electric current is maintained in the circuit of the converter by electric emission.

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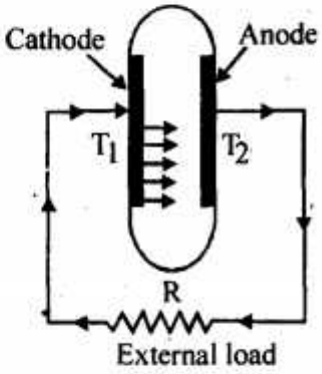
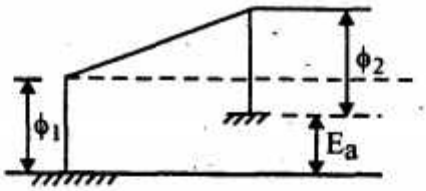
Principal :

The operational principle of thermionic converter is based on ability of heated metals to emit electrons from their surfaces. As it know from elementary physics, any metal has free electrons whose emission from surface of metal is opposed by a potential barrier equal to difference between the emerges of an electron outside and inside the metal. In order to overcome this barrier and conduct the electron from metal into surroundings, a certain amount of work must be spent referred to as the work function. This differs from substances to substance and it ranges from 1eV to 10eV.

The schematic diagram of thermionic converter is known in fig. (a) and distribution of potential work functions is shown in fig. (b). The two metallic surfaces are separated by vacuum and maintained the temperatures T_1 and T_2 $(T_1 >> T_2)$. As $T_1 >> T_2$ more electrons will be emitted by surface –1 than surface–2 as a result, the surface –2 will be negatively charged and potential difference will appear between the 2 plates. If the circuit is completely by inserting an external resistance R, an electric current will flow through circuit.



(a)



(b)

The emission of electron from surface-1 is regarded as evaporations of electron from surface of emitter and accumulation of electrons on surface-2 is regarded as condensation of electrons.

According to Richardson's equation, the maximum emission of ion current from surface is given by,

$$J_1 = BT_1^2(e)^{-\left(\phi_1^{1kT_1}\right)}$$

Where ϕ_1 is the electron work function, B is constant $\left(120A/cm^2 - K^2\right)$ and k is Boltzmann's constant.

For various materials, the work function ϕ varies from 1 to 5eV.

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If the electrons escaping from surface–1 accumulate on surface–2, the problem becomes more difficult. That is because, as the surface–2 becomes more and more negatively charged due to accumulation of electrons, it becomes more difficult for electrons emitted from surface–1 to reach surface–2 since, in addition to work function ϕ_1, the electron have to overcome a space barrier due to potential difference between the plates. Let us denote this potential by E_α.

Therefore, the electrons emission current from surface–1 considering the space resistance is given by

$$J_1 = BT_1^2(e)^{\left[-(\phi_2+E_\alpha)/KT_1\right]}$$

Similarly, the electrons emission current from surface–2 is given by

$$J_2 = BT_2^2(e)^{\left[-\phi_2/KT_2\right]}$$

It is clear from fig. (b) that electrons emitted by the anode have to overcome a space charge barrier equal to ϕ_2.

Therefore, the net current density flow is given by

$$J = J_1 - J_2$$

$$= BT_1^2(e)^{\left(-(\phi_2-E_\alpha)/KT_1\right)} - BT_2^2(e)^{-(\phi_2/KT)}$$

The current flows through circuit of a thermionic converter is given by

$$I = J.A$$

And out put is given by

$$W = IE_\alpha$$

Where A is area of the anode and cathode.

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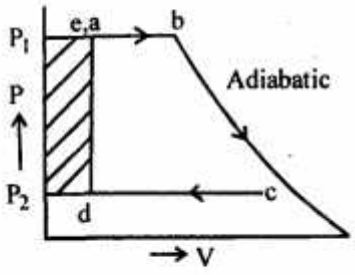
Q. 8. Discuss the following :

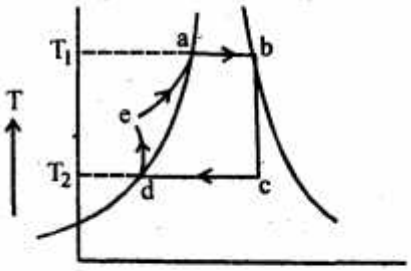
(a) Thermodynamic cycles used in power plants,

(b) Waste disposal in Nuclear power plants.

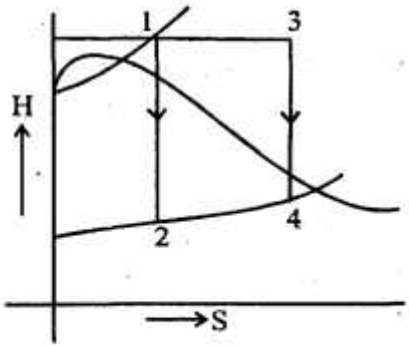
Ans. (a) Thermodynamic cycles used in Power Plants :



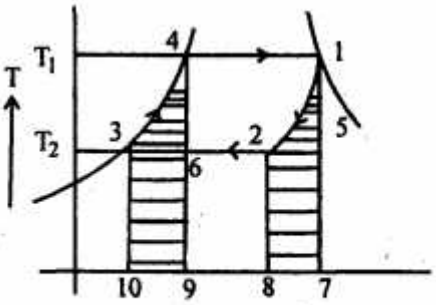
(i) Rankine cycle on P-V diagram



(ii) Ranking cycle on T-S diagram



(iii) Re-heat cycle



(iv) Regeneration cycle

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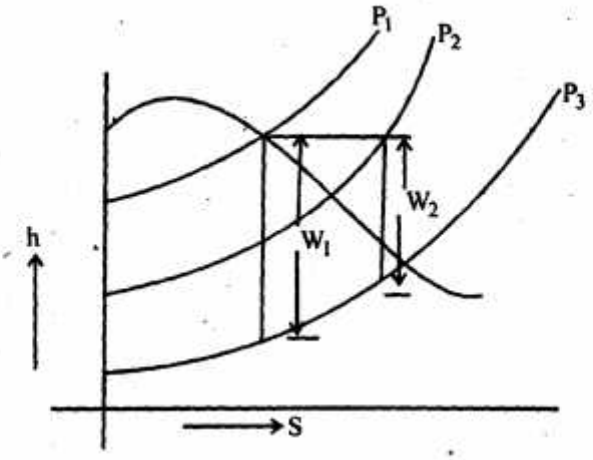

(v) Binary vapour cycle

Ans. (b) Waste Disposal in Nuclear Power Plants :

Disposal of low level solid waste :

The nuclear waste of this category is cast in cement is steel drum. The safety of the method list in the vast dilution of activity as it diverse at the bottom of ocean. Radiologically, the disposal of waste in this category to sea seems to be the best option to avoid risks due to unnecessary handling and storage.

Disposal of medium level solid waste :

These wastes are mainly contaminated with neutron activation product isotopes. They are incorporated into cement cylinders as current is non-combustible and provides shielding against external exposure. Another ability of cement is resistance to touching by the ground water.

Disposal of high level solid waste :

This is the solution remaining after useful fuel is dissolved in nitric acid and U^{235} and Pu^{239} are extracted. The remaining liquid is stored on the site in special steel tanks in concrete vaults. They are water cooled and then taken to the storage area.

Geological formation :

Geological formations considered for the location of waste cylinders are rock salt, argillaceous sediments and hard rocks.

Disposals in salt domes is used in USA and Germany as salt has some special qualities for stage of high level waste.

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(i) It is powerful absorber of radio active emission.

(ii) Its plasticity provides a barrier between repository and the biosphere.

(iii) It has good thermal conductivity which helps to keep temperature with in acceptable limit.

(iv) Big cavities and tunnels can be easily made.

The waste drums are covered with salt. When the cavity is full, the mine is filled completely with salt and the site is sealed.

2. Argillaceous Sediments :

These are used for final disposal in Italy, Belgium and USA. In Belgium, bore holes are provided at 160m to 250m depth in a 100m thick bed of clay. It is necessary to study the ground water flow to find out the suitability of geology for final disposal. The analysis of sediments has confined the high plasticity, high ion exchange capacity and low permeability required for safe storage.

3. Hard Rock :

A variety of igneous, metamorphic and sedimentary rocks can be classified as hard rocks. It is considered as a potential disposal media. The essential requirement for considering hard rocks for waste disposal is that :

(i) There should be no ground water flow through repository.

(ii) The rock area (300m depth) should be reasonably free from seismic activity and should not be adjacent to major civil engineering development like dams. It is internationally accepted that the most promising solution is storage in geological formation.