UNIT 5 COMBINED OPERATIONS, INSTRUMENTATION AND CONTROL

PART-A
SHORT QUESTIONS WITH SOLUTIONS

Q1. What do you understand by "Interconnected System"?

Answer :

Interconnected system is the system in which the number of various power stations such as hydro, thermal, nuclear etc., are worked together to supply the power in order to fulfill the customers requirements. The power stations in interconnected system can be operated with more reliability and economy. In this system, by creating the appropriate administration and technical setup, the optimal utilization of resources can be obtained. Simultaneously, the reliability assurance and continuous supply of power to the system can be achieved. The instantaneous pace of interconnection between power systems increases the safety, probity and continuity of power supply. This can be achieved to the maximum extent if interconnected system is equipped with the sound mechanism which monitors and controls the different devices.

Q2. Define the following,

(i) Base load

(ii) Peak load.

Answer :

(i) **Base Load**

The load which is constant throughout the whole day on the power plant is known as base load. The plants which serve the base load continuously are known as base load plants. In these plants, loads are economically distributed to various systems in order to achieve overall economy.

(ii) **Peak Load**

Peak load is the load which has the peak values over and above the base load of power plants. The run-off river plants with pondage and pumped storage plants are used as peak load plants. These plants store the water during off peak time and supply for peak hours.

Q3. Write a short note on load curve. **Model Paper-II, Q1(e)**

Answer :

Load Curves

A graph obtained between the load consumption and time is called as load curve. It is also defined as the curve representing the load demand with respect to time. The curve is referred as daily, monthly and annually load curve, when the time is represented in hours, days and months represented. However, a general daily load curve is shown in figure.

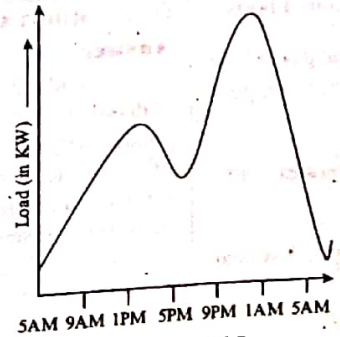


Figure: Daily Load Curve

Q4. What is the need of combining run-off river plant with steam plant?

Answer :

Need of Combined Run-off and Steam Plants

The run-off river plants are those hydro plants which take the water directly from the river. If the quantity of water available for these plants is not uniform throughout the year. Thus, it is not possible to use run-off river plant to supply the variable load. Therefore, steam power plants are needed to be mixed with run-off river plants. The use of combined run-off and steam plants prevails coordinating the fluctuation of run-of and power demand during the year.

The combination of run-off river plant with steam plant is to supply the load with greater reliability whenever it is required. The selection of plants as the base load and peak load depends mainly on the weather. During the rainy season, run-off river plants are used as base load whereas thermal plant as peak load. Thermal plants are used as base load during dry season and run-off river plant used as peak load.

Q5. Write the advantages of a pumped storage power plant in an interconnected system.

Answer :

Advantages of Pumped Storage Power Plant

(i) In pumped storage plants, thermal plant are loaded economically as they transport peak load and energy from peak to peak-off periods.

(ii) It decreases the wastage of availability of off peak-energy.

(iii) The pumped storage plant stores the energy over the year, when there is minimum load on the system.

(iv) It facilitates the standby power to the system.

Q6. Write a short note on coordination of hydro-electric and gas turbine power plants?

Answer :

Co-ordination of Hydro-electric and Gas Turbine Plants

In combined operation of hydro-electric and gas turbine plant, the gas turbine plant is generally used as a peak load plant.

The plant is most economical, when it operates, under the following conditions.

(a) If only a small part of total energy is supplied as peak loads.

(b) If the total load factor is less than 15%.

Q7. List out the various functions of instruments in power plant.

Model Paper-IV, Q1(e)

Answer :

Various functions of instruments in power plants are as follows,

1. Operating guidance.
2. Performance calculations.
3. Maintenance and repair guidance.
4. Economical supervision.
5. Cost allocation.

Q8. List out the techniques for measuring water purity.

April/May-17, Set-3, Q1(e)

OR

How measurement of water purity is done?

Answer : April-18, Set-4, Q1(e) | Model Paper-I, Q(e)

Techniques for Measuring Water Purity

Water purity is measured using various methods, these techniques are designed in such a way that they can measure only particular type of contaminants. Few of the water purity measuring techniques are,

1. Resistivity or Conductivity meter
2. Total organic carbon (TDC)
3. Turbidimetry (Passing light through water)
4. using special electrodes for dissolved gases.

Q9. What is the need of measurement of water purity in power plants.

Answer :

Need of Measurement of Water Purity in Power Plants

In power plants, excessive impurity concentration results in corrosion, priming and scaling of the boiler tubes. Generally, sea or river water is used as cooling water for condenser and this water is contaminated by dye-works, sewage waste etc. Thus, mostly the impurities enter into the feed water circuit through the faulty pipes present in condenser. In some cases, excessive impurity concentration in high pressure boilers also leads to the failure of metallic components in power plants. Hence, measurement of water purity in power plants is important to maintain the impurity concentration within the safe limits.

Q10. Write a short note on conductivity of water.

Answer :

Conductivity test is performed to determine the amount of dissolved salts in feed water, steam and condensate. Electrical conductivity of water with salt concentration is more than that of pure water because of more ions (i.e., salts dissociate into positive and negative ions). Thus measuring the conductivity of water is essential to know the salt content of feed water. Excessive salt concentration in feed water results in the formation of impure steam in boiler which causes scaling and corrosion in boiler tubes. Thus, it is necessary to maintain the conductivity of water within the safe limits.

Q11. What is pH value? Explain its significance for the feed water used in power plants.

Answer : April/May-16, Set-2, Q7(a)

The pH is a measure of acidity or basicity of a solution. As the temperature is measured on scale of a thermometer, the value of pH is measured on a pH scale.

The pH value has a great impact on feedwater of power plants. If the feedwater has low pH i.e., if the pH is below 7, the water becomes acidic and corrosion takes place in the metallic equipments of the plants. Similarly, if the feedwater has high pH i.e., if it is above 7, scales are formed due to the basicity of water. To prevent corrosion and scale forming in power plant equipments, the pH value is controlled by various chemical treatments and thereby the pH of feedwater is maintained at a minimum value of about 10.5.

Thus, the analysis of any water is incomplete without attaining the pH value.

Q12. What is the purpose of gas analysis?

Answer :

Gas analysis is performed to determine the concentration of each individual constituent present in a gas mixture. Generally, in steam power plants gas analysis is performed on exhaust gases, to determine and maintain the concentration levels of CO_2 and O_2 gases as less as possible. It is also possible to improve the efficiency of the steam generation through constant recording and analysing of the constituents of exhaust gases.

Q13. What are the different methods used for nuclear radiation detection?

Answer : Model Paper-III, Q1(e)

For nuclear radiation detection in power plants, the following two methods are generally used. They are,

1. **Detection by Gamma Activity of the Fission Products**

In this method, the gamma activity of coolant is measured to detect the presence of nuclear fission products in coolant.

2. **Detection by Radio Active Gaseous Fission Products Produced**

During fission process in nuclear power plants a number of radioactive gaseous products are produced and combines with the coolant. Thus, the coolant is examined to detect the type of radio active elements in gaseous products.

PART-B

ESSAY QUESTIONS WITH SOLUTIONS

5.1 COMBINED OPERATIONS OF DIFFERENT POWER PLANTS

5.1.1 Introduction – Advantages of Combined Working, Load Division between Power Stations

Q14. Explain the advantages associated with combined working of power plants.

April-15, Set-2, Q6(a)

OR

State the advantages of combined power plants.

April/May-17, Set-2, Q1(e)

Answer :

Advantages Associated with Combined Working of Power Plants

In interconnected system, the reliability of supply to the customer is more compared to an isolated system with a single power station.

1. The total cost of energy required per unit of a combined system is low.
2. The capital investment needed for combined system is minimum.
3. The expenditure required for supervision, operation and maintenance is minimum in integrated system.
4. This system provides the effectual use of transmission line facilities at higher voltages.
5. The interconnection of various power plants decreases the amount of capacity that is generated and required to be installed.
6. There is a reduction in spinning reserve required as compared to single power plant.
7. As more number of stations are combined in interconnected system, the power can be supplied from the other station to the customer if power fails at any of the stations. Therefore, it is not necessary to shutdown the complete system.
8. The stability limit of the system is high.
9. Overall cost is reduced.

Q15. What is the purpose of inter connection in the load distribution? Differentiate base and peak load plants.

Answer :

Purpose of Interconnections

The main objective of interconnection is to obtain the overall economy of the combined system which can be achieved by distributing the total load among the interconnected system.

Difference between Base Load and Peak Load Plants

	Base-load Power Plant		Peak-load Power Plant
1.	Base-load plants operate through out the year	1.	Peak-load plants are operated during peak demand hours only, primarily for taking care of a power system.
2.	They have high plant load factor.	2.	The have low plant load factor.
3.	Operating costs plays a significant role in base-load power plants because the plant working base on load should have low operating on cost as they are heavily loaded.	3.	Since, peak-load plants are used for only small fraction of time, the fuel cost is not major.
4.	If operating costs are maintained, it has high capital.	4.	In peak-load plants, minimum capital cost is maintained.
5.	It takes high start-up time.	5.	It takes low start-up time.
6.	It has low and fast maintenance requirements.	6.	It has high maintenance requirements.
7.	Thermal nuclear and hydraulic power plants are considered as base-load power plant.	7.	Gas turbines, steam and diesel power plants are considered as peak-load power plants.

Q16. What are the requirements of plant supplying the base load and peak load?

Answer :

Requirements of Plant Supplying the Base Load

The various requirements of a plant supplying the base load are as follows,

(i) The operating cost of the plant should be minimum.
(ii) The load should be continuous throughout the period.
(iii) The capital cost of the plant should be less.
(iv) The cost required for maintenance should be low.
(v) The location of plant should be provided closer to the load centre.
(vi) The number of operators should be minimum.
(vii) The additional components and repairing facilities should be available easily.

Requirements of a Plant Supplying the Peak Load

The requirements of a plant supplying the peak load are stated as follows,

(i) The operating cost required to supply the peak load should be minimum.
(ii) Peak loads are required to have less capital cost.
(iii) The power plant should have the capability to run at cold conditions within a shorter period of time.
(iv) The power plant must be able to hold the peak load for short duration in the special cases.
(v) The plant should react instantly to the load variation.

Q17. Write short notes on load distribution between power plants.

Answer :

Load Distribution between Power Stations

The load distribution between different power stations are discussed as follows:

In combined system, various power stations such as hydro, nuclear, diesel and steam power plants are adopted to generate the power. These power plants distribute the load curve into two types as base load and peak load. The interconnected system (in which different power stations are worked together to supply the power) does not require to connect the power stations of the same kind. If the base load is supplied by one power station then it is not essential to supply the peak load to the same power station. It should be supplied to the other power station. The power stations are selected as base load and peak load plants based on their characteristics and ability to meet the requirements. The load distribution should be performed such that the better overall economy of the system can be achieved.

Generally, the base load is supplied by steam power plant whereas peak load is supplied by hydro-electric power plant. Among all the power plants, hydro-electric power plant is mostly suitable for supplying both base and peak loads. In load division, if the hydro-electric power plant is specifically selected for supplying the base load then steam or diesel is adopted to supply the peak load.

5.1.2 Storage Type Hydro-electric Plant in Combination with Steam Plant, Run-of-River Plant in Combination with Steam Plant

Q18. Explain the working of storage type hydroelectric plant in combination with steam plant.

OR

Discuss the working of hydro-electric plants having ample storage with steam power plant.

Answer :

April-15, Set-1, Q6(a)

The hydro power plant carries the load instantly and follows the variations of peak demands successfully as compared to thermal power plant. These plants can also take the loads steadily and permit the thermal plants to shutdown, without effecting the system requirements. The reliability of hydro power plant is high and it increases for the combined operation of hydro and steam power plant.

During normal or heavy run-off periods there is an increase in the application of hydro power due to water storage, while steam plants are useful at the time of drought. The combined operation of steam and hydro plant is most advantageous as it reduces the minimum cost required for the operation. Since, the initial cost of steam power plant is less than the thermal plant. Steam power plants are used at any point of the load duration curve, but at low load factors it is more expensive to use as peak load stations.

When there is enough run-off specifically in a monsoon period it is suitable to use hydro plant as base load and thermal plant as peak load as shown in figure (1).

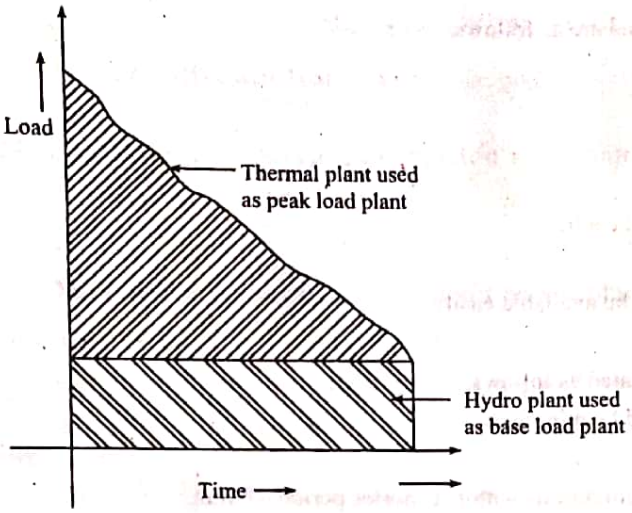


Figure (1): Use of Plants During Monsoon Period in Interconnected System

During the drought period, hydro plant is used as peak load and thermal plant as base load as shown in figure (2).

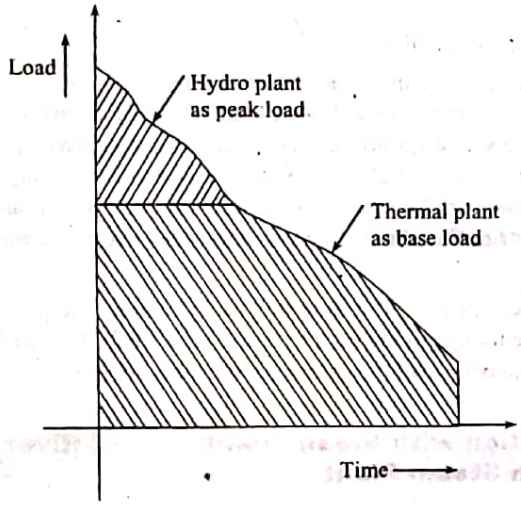


Figure (2): Use of Plants During Drought Period in Interconnected System

Q19. Discuss the following:

(i) Predominant hydro

(ii) Predominant thermal

(iii) Hydro and thermal equally predominant.

Answer :

(i) Predominant Hydro

In power plants, few hydro power stations (run-off river plants) are used as base load plant while the other plants are used as peak load plants. In some countries, where the water is extracted from melted snow thereby maximum quantity of water is available in early summer, when the power demand is less. During winter season, the water available is insufficient as the rivers are frozen.

Hence, it is difficult to coincide the maximum demand with maximum run-off, as result thermal plants are needed to mix with hydro plants. Therefore, during the minimum run-off period the combined hydro and thermal power stations increases the efficiency of the power station.

(ii) Predominant Thermal

Hydro power plants are developed to operate even at minimum annual load factor which is more beneficial. This is due to reason that, the cost of water storage increases the capital investment cost. But, the capital cost is independent of annual load factor. Usually, capital cost is minimum for low annual load factor and it is maximum for high annual load factor. One more benefit of developing hydro plants is to decrease the spillage during maximum run-off period. This can be achieved by operating the plant for prolong period which economises the cost of fuel.

(iii) Hydro and Thermal Equally Predominant

In an interconnected operation of hydro and thermal power plant, the firm capacity which is the total capacity of hydro plant must be taken into consideration. A complete review should be made on the plants all over the year, as the firm capacity of hydro plant depends on the kind of weather i.e., summer or winter. The minimum cost for power supply can be calculated by the ratio of hydro power to total peak demand. This ratio is specifically suitable for the fields where there is more cost of hydro power development and less cost of fuel. The economic power ratio ranges from 0.25 to 0.4 for the fields where the fuel is cheap and hydro power development is not high. The ratio varies from 0.8 to 0.9 is applicable to the fields where the fuel is more expensive and favourable hydro power plant sites are more.

In an interconnected system, the economic balance between hydro and steam power station depends on the following factors such as,

1. Nature of load curve
2. Run-off and its seasonal variation
3. Cost of fuel
4. Availability of condensing water etc.

Q20. Explain the factors used in combining the hydro and thermal power plants.

(OR)

How would you make an economic analysis of the combined operation of the hydro and steam power plants?

Answer :

The factors which are basically used for mixing the hydro and thermal power plants are explained as follows,

1. Fuel Consumption

In thermal power plants, the consumption of fuel at no-load requires 7% of full-load consumption of fuel. If these plants are used as peak loads then, it is essential to keep some of the components as hot even when they are not working. Hence, thermal plants work more economically as base load plant compared to peak load plants.

2. Introduction of Hydro Plant into a Predominantly Thermal System

In an interconnected system, the introduced hydro plant has the following main effects on total fuel consumption of system and overall generating cost,

(i) It saves the fuel required to increase the temperature of boiler.

(ii) As the hydro plant follows more closely and it changes frequently with variation in demand. Thus, the quantity of operation of peak zone can be improved.

(iii) In contrast to thermal plant, hydro plant as peak load plant works economically even at 15% annual load factor.

3. Installed Capacity of Hydro and Thermal Plant

The capacity of hydro and thermal power plant depends upon the spare capacity. Generally, the lowest total installed capacity of combined hydro and thermal plant must be equal to the peak load required with the possibility of sufficient contribution of alternatives. In case of thermal power plant, if the maximum continuous rating is taken as firm capacity then spare capacity is considered as 10% additional to this capacity. As the hydro plants are more reliable, the spare capacity of these plants are usually low as compared to thermal power plant. In an interconnected system, the percentage of spare capacity which is sufficiently taken ranges from 5 to 10% of the firm hydro power capacity.

4. Grouping of Thermal Plant

The plant which works at the lowest cost per kWh generated should be placed below in the load duration curve. The machines are arranged in the increasing order of their unit fuel cost in order to decrease the overall costs of fuel consumption rate and power generation.

Q21. Explain the working of run-of-river plant in combination with steam plant.

Answer : April/May-17, Set-2, Q6(a) | April/May-17, Set-4, Q6(b)

The run-off river plants are those hydro plants which take the water directly from the river. If the quantity of water available for these plants is not uniform throughout the year. Thus, it is not possible to use run-off river plant to supply the variable load. Therefore, steam power plants are needed to be mixed with run-off river plants. The use of combined run-off and steam plants prevails coordinating the fluctuation of run-of and power demand during the year. The combination of run-off river plant with steam plant is to supply the load with greater reliability whenever it is required. The selection of plants as the base load and peak load depends mainly on the weather. During the rainy season, run-off river plants are used as base load whereas thermal plant as peak load. Thermal plants are used as base load during dry season and run-off river plant used as peak load.

Method for Adopting a Run-off River Plant in combination with Steam Plant

The method to adopt a run-off river plant with steam power plant is as follows,

(i) Initially plot the load duration curve for system and compute the values of load factor as well as average load.

(ii) Represent the power available curve which can be obtained by plotting the power available by run-off river plant.

(iii) The average power is known as prime rate of power (or) prime hydra steam rate which is calculated from the load curve. This power must be supplied to both hydro and steam power plants.

(iv) From the power curve, calculate the minimum power that can be supplied with hydro power station. Usually 97% of the time, the minimum power can be taken as minimum hydro power rate from power duration curve.

(v) Now, calculate the maximum steam power rate. It is defined as the rate of power which is to be supplied by steam plant is hydrostation is supplying the power at minimum hydro power rate.

Mathematically,

Maximum steam power rate = [Prime hydro steam rate] – [Minimum hydro power rate]

(vi) The next step is to determine the ratio of minimum hydro power and prime hydro steam rate which is denoted by 'x'.

Mathematically,

$$x = \frac{\text{Minimum hydro power}}{\text{Prime hydro steam rate}}$$

(vii) Finally, by studying the load duration curve, the values of total energy required during the year and prime-hydro steam rate can be computed.

Q22. Compare the principle of operation of combined cycle power plant with the cogeneration unit along with their limitations.

Answer : April-18, Set-2, Q6(a)

Combined Cycle Power Plant

Operating Principle

In combined cycle power plant gas turbine combines with steam turbine. Main objective of such power plant is to make use of exhaust heat of gas turbine to generate heat to drive steam turbine. Thereby to produce additional electricity.

Novel principle of combined cycle involves, allowing gases at high temperatures to expand in the gas turbine in order to produce mechanical output which inturn used to generate electricity. Hot gases leaving the turbine are passed through a steam generator before exhausted to atmosphere. The water entering the steam generator, absorbs heat of exhaust gases and gets converted into stream which is expanded in steam turbine to produce additional electricity.

For figure refer Unit-II, Q56, Figure: Combined Cycle without Reheat of Exhaust.

Limitations

1. Efficiency of the plant decreases, when there is drop in barometric pressure or when there is raise in ambient temperature.
2. Part-load efficiency ranges from average to moderate.
3. Not much compatible with fuels of low quality.

Cogeneration Unit

Operating Principle

Objective of cogeneration unit is to generate both mechanical and heat energy from a single primary source of energy. Mechanical energy produced is used to drive the generator which in turn develops electricity, Combined cycle power plant is a type of cogeneration unit. Other cogeneration systems includes, diesel engine with waste heat recovery boiler and cooling water heat exchanger, extraction – condensing turbine, back-pressure turbine, gas turbine with heat recovery boiler etc.

Principle of diesel engine cogeneration unit involves, allowing air-fuel mixture to burn in engine so as to develop mechanical output. Hot exhaust gases leaving the engine is allowed to pass through waste heat recovery boiler before exhausted to atmosphere. Feed water passes through provisions provided to cool engine jacket before entering the boiler. In boiler, feed water gets converted into steam as a result of heat transfer from engine exhaust gases. Thus, generated steam used for industrial or domestic applications.

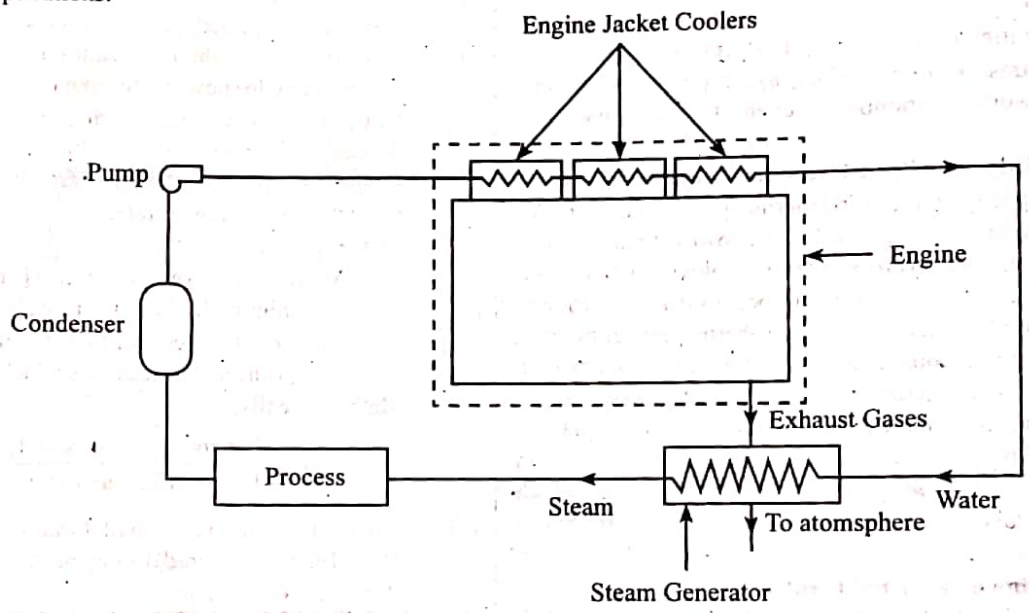


Figure: Diesel Engine Cogeneration Unit

Limitations

Limitations of diesel engine cogeneration unit are,

1. Steam obtained is of low temperature.
2. Overall efficiency is low.
3. There exists need of frequent maintenance.

Q23. Draw the schematic diagram of magneto hydrodynamic direct energy conversion power generation unit along with their auxiliary components and discuss the principle.

Answer : April-18, Set-3, Q6(a)

Principle of MHD Power Generation

The principle of MHD power generation is based on Faraday's law of electromagnetic induction. It states that, when an electric conductor passes through a magnetic field a voltage is developed in the conductor. The MHD power generator consists of a gaseous conductor i.e., an ionised gas, or conducting fluid which generates current when passes through a magnetic field with high velocity. The electrodes are placed in the path of current to extract it. The power developed by MHD generator is DC and it is converted into AC by an inverter.

Consider an electric conductor, that is moving through the magnetic field. Then, the emf and current are produced and also the conductor is subjected to a retarding force, as stated by faraday's law of electromagnetic induction.

∴ The emf induced,

E = Velocity of conducting medium × Magnetic field intensity

$$E = u \times B$$

The current density,

J = Electrical conductivity × emf induced

$$J = \sigma \times E$$

$$\therefore \quad J = \sigma u B$$

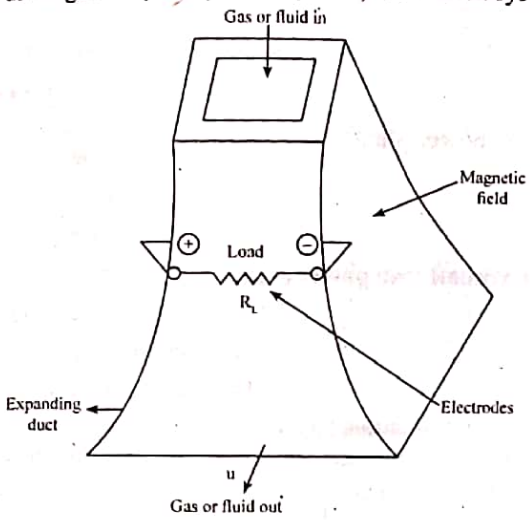
Retarding force,

$$F = J \times B$$

$$= \sigma u B \times B$$

$$\therefore \quad F = \sigma u B^2$$

Therefore, due to the electromagnetic induction principle, the movement of high velocity conducting fluid across a magnetic field is converted into electrical energy, hence, it is called as magneto hydrodynamic (MHD) conversion system.



Figure

5.1.3 Pump Storage Plant in Combination with Steam or Nuclear Power Plant, Co-ordination of Hydro-electric and Gas Turbine Stations, Co-ordination of Hydro-electric and Nuclear Power Stations, Co-ordination of Different Types of Power Plants

Q24. Explain the working of pump storage type plant in combination with steam plant.

Answer : April/May-17, Set-3, Q6(b)

In the combined system, if thermal power plants available are old and uneconomical then, they are usually suitable to take the peak loads. The development of pumped storage plants are necessary when these plants cannot take the peak loads. By using the pumped storage plant, the sudden or rapid peak loads can be supplied for the short period of duration. A pumped storage power plant requires suitable site at the tail race of hydro power plant. So that stored water from the tank can be pumped nearly to the upmost position and can be reused at the time of peak loads. The combined working of hydro power plant and pumped storage plant is beneficial as the exit water from the turbine can be reused again to the tail race.

In addition to this, pumped storage plant during the peak load time improves the load factor of power plant. If the reversible pump-turbine sets are incorporated in the pumped storage plant then the process becomes more effective and efficiency of such process increases to 73%.

Q25. Explain the pump storage plant in combination with steam and nuclear power plant.

Answer : April-18, Set-1, Q6(b)

In the combined system, if thermal power plants available are old and uneconomical then, they are usually suitable to take the peak loads. The development of pumped storage plants are necessary when these plants cannot take the peak loads. By using the pumped storage plant, the sudden or rapid peak loads can be supplied for the short period of duration. A pumped storage power plant requires suitable site at the tail race of hydro power plant. So that stored water from the tank can be pumped nearly to the upmost position and can be reused at the time of peak loads.

In addition to this, pumped storage plant during the peak load time improves the load factor of power plant. If the reversible pump-turbine sets are incorporated in the pumped storage plant then the process becomes more effective and efficiency of such process increases to 73%.

A combined pumped storage and steam power plant will results in the following advantages,

1. Loading of thermal power plants is more economical.
2. Reduction in wastage of off-peak energy of thermal power plants.
3. When the demand is high, the pumped storage system stores the energy by utilizing off-peak energy.

In Uttar Pradesh, a pumped storage plant in combination with nuclear power plant is started at Ramganga power station. During off peak hours, this nuclear power station near by the hydro site can result in cheap pumping energy to pumped storage plants. This combination is beneficial as nuclear station can be operated at high capacity factor and the locations where coal prices are high, this becomes a competitive to the conventional thermal power plant.

Q26. Explain the working principle of hydroelectric and gas turbine station.

Answer : [Model Paper-IV, Q6(b) | April/May-17, Set-1, Q6(a)]

Combined Operation of Hydroelectric and Gas Turbine Station

Hydro plant and Gas turbine plant are interconnected on the same grid to supply power to the centralized load very economically. By doing so, the sources available at both the stations are utilized to its maximum. Proper scheduling of hydrothermal station is necessary to minimize the total cost of generation. The cost of operation of hydro plant is low and its capital cost is high whereas the cost of operation of gas turbine plant is high and its capital cost is low. Thus, by proper

utilization of sources available at each station, most economical power can be generated for demanding load. Depending upon the sources available at both the stations, either hydro plant or gas turbine plant is used as base load station or peak load station. Normally, hydro plant is used as a peak load plant as it can take up peak load demand very fast whereas gas turbine plant is used as base load plant. As the operating cost of hydro plant is low, during the rainy season when the head of the water available in the reservoir is enough to generate power, hydro plant is loaded to supply power to the demanding load and thus minimize the amount of water getting wasted. During this operation gas turbine plant acts as a peak load plant. During the dry season, when the head of the water is reduced in the reservoir, the gas turbine plant is used as a base load plant and the hydro plant is reserved for the peak load period.

The total cost of generation of hydrothermal plant depends upon the cost of operation of gas turbine plant. Hence, by using hydro plant as a peak load station to supply peak load demand every time the cost of generation of hydro-electric and gas turbine plant can be minimized. During the operating time of hydro plant it must be noted that the water available should be utilized to its maximum extent.

As the hydro plants are multipurpose, certain factors like utilization of water for irrigation and navigation purpose should also be considered. Hence, discharge of water from plant and spillage should be minimum.

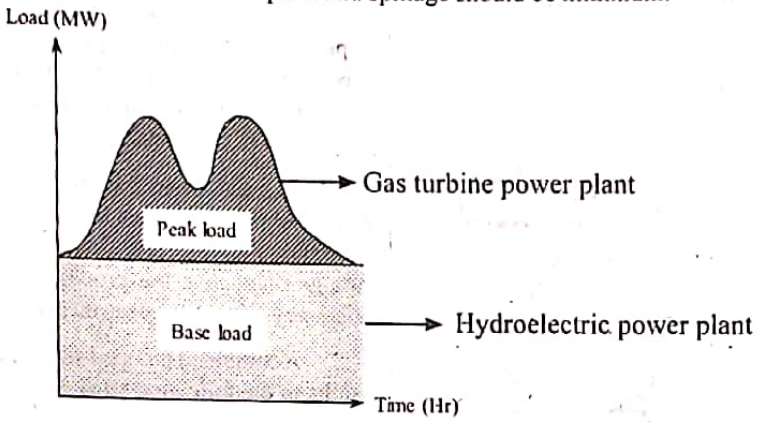


Figure (1)

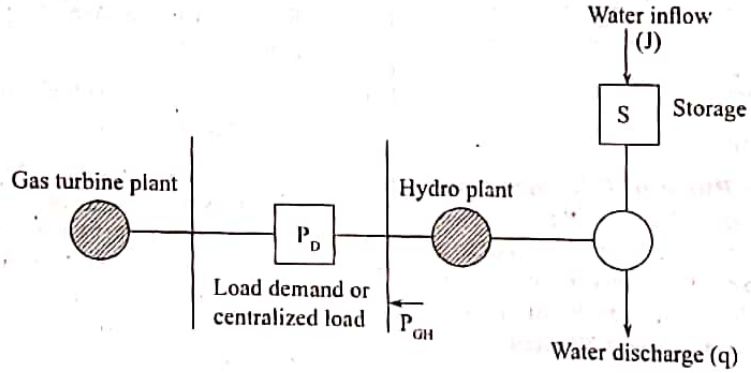


Figure (2) : Co-ordination of Hydro Electric and Gas Turbine Plant

Necessity of Two Different Plants on Same Grid

If a single plant is used to supply power during both base load and peak load period, then the capacity of that plant should be able to supply power to peak or more load whenever required. If the operating cost of this plant is very high, then supplying power during peak load period will be uneconomical as the peak load occurs on the plant for a short period in a year. To supply power economically for both peak load and base load period, two plants are interconnected on same grid. Two plants on the same grid can either be hydroplant and gas turbine plant or nuclear plant and thermal plant. While selecting two plants, it should be consider that one plant whose operating cost is low should supply power during the base load period and other should be reserved to supply peak load demand. The reserved plant should be capable of taking up the demanding load very fast. Hence, by interconnection of two plants, the cost of supplying power for base load and peak load period is reduced to economic value.

Using of gas turbine plants at peak loads is economical under the below conditions.

1. The energy supplied at peak load is less than the total energy.
2. When load factor is less than 15%.

Q27. Enlist the advantages of gas turbine plant over steam power plant.

Answer :

Advantages of Gas Turbine Power Plant over Steam Power Plant

The advantages of gas turbine power plant in contrast to steam power plant are as follows:

(i) The capital investment of gas turbine plant is significantly less when compared to steam power plant.

(ii) The time required for construction and installation of gas turbine plant is considerably less compared to steam plant.

(iii) The gas turbine power plants occupy less space compared to steam power plants.

(iv) The number of operators required to work with gas turbine power plant is less than steam plant.

(v) In comparison to steam power plants, gas turbines provide instantaneous reactions.

(vi) The gas turbine power plants require minimum amount of cooling water for the operation.

(vii) The gas turbine plant does not require heavy sub-structures.

Q28. Discuss the coordination of hydro-electric and nuclear power station in detail.

Answer :

In nuclear power station, nuclear reactors are used to generate the power. These reactors are mainly classified into two groups such as,

1. Thermal reactors
2. Fast reactors.

The reactors which are practically used for nuclear power stations are as follows,

(i) Gas cooled reactors

(ii) Boiling water reactors .

(iii) Pressurized water reactors.

The nuclear power station occupies more space as its size is large (usually about 150 MW). These power plants have to be worked with high load factors and the initial cost of the plant ranges from ₹. 2000 to ₹. 2500 per kW. The nuclear power plant is suitable to use as a base load plant as it is complicated to achieve the close and rapid fluctuations of the plant under variable load conditions.

If hydro power plants are combined with nuclear power plants then it is essential to use the nuclear power plants as base load plant and hydro plant as a peak load plant. As the hydro plants can easily supply the variable loads.

When hydro power plants are combined with nuclear power plants then the following factors have to be considered.

(i) The nuclear power plants should be located near to load centres.

(ii) In hydro power plant, the load centre should be provided at a long distance which require long transmission lines including the transmission liability.

(iii) Nuclear power plants have the following advantages when compared to steam stations used in combination with hydro-stations.

(iv) These plants can be used for many other applications as they do not require the conventional fuels.

(v) Nuclear power plants require very less quantity of fuel. Hence, the transportation cost is reduced.

Q29. Briefly discuss the coordination of different types of power plants.

Answer :

Coordination of Different Power Plants April-18, Set-4, Q6(b)

The different power plants used in the combined system are hydro, nuclear, thermal, gas and diesel. When in certain areas, different power plants are available then it is essential to arrange and use them properly at a lowest possible generating cost. To obtain the most economical operation of existing plants, the coordination of plants are essential.

It is difficult to arrange the different power stations as it is required to consider the following factors.

(i) The initial cost of the plant.

(ii) The cost of the fuel.

(iii) The cost required for operation and maintenance.

(iv) Availability of fuel

(v) The economics of base load and peak load operation.

(vi) The working properties of the plant

(vii) Transmission liabilities

(viii) Cost of incremental power.

All the above factors in interconnected system are considered for economical loading of various power stations. Based on the nature of load duration curve, availability of fuel and resources, the most optimum coordination can be obtained.

The figure shows the graphical representation of annual load duration curve for various power stations.

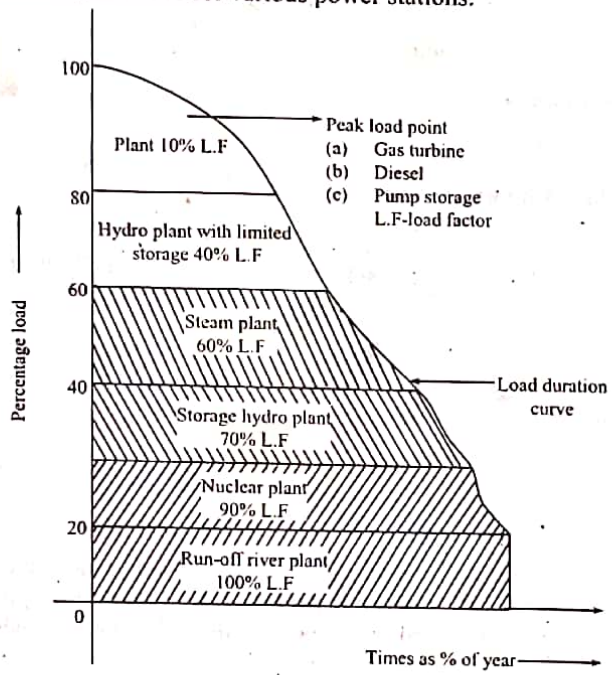


Figure: Annual Load Duration Curve for Different Power Stations

Q30. A load duration curve of a system is a straight line, the maximum and minimum loads being 100 MW and 20 MW respectively. The load is supplied by base load and peak load plants. The total cost of both is given as,

For base load plant:

Rs. 200/kW-year + 5 P/kWh

For peak load plant:

Rs. 50/kW-year + 10 P/kWh

For minimum overall cost, determine the load shared by peak load plant and annual load factor for both stations.

April-15, Set-1, Q6(b) | April-15, Set-2, Q6(b)

Answer : Model Paper-I, Q6(a)

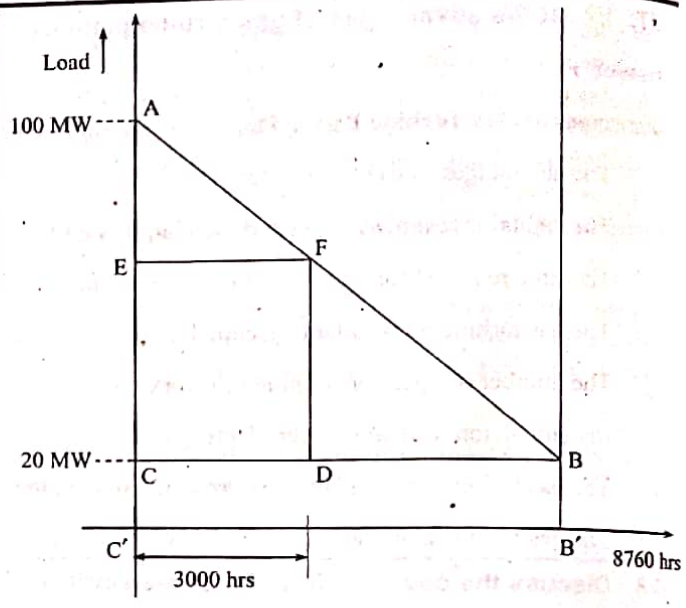
Given that,

Maximum demand = 100 MW

Minimum demand = 20 MW

C_1 = 200/kW-year + 5 P/kWh ... (1)

C_2 = 50/kW-year + 10 P/kWh ... (2)



Figure

(i) Load Shared by Peak Load Plant

From equations (1) and (2),

$A_1 = 200, \quad B_1 = 5P = 0.05$

$A_2 = 50, \quad B_2 = 10P = 0.1$

Time required to operate base load for minimum overall cost can be calculated as,

$$L = \frac{A_1 - A_2}{B_2 - B_1} = \frac{200 - 50}{0.1 - 0.05}$$

$L = 3000$ hrs

Let,

P_b – Peak load on base load plant

$P_{b'}$ – Peak load on peak load plant

∴ Peak load on peak load plant,

$P_{b'} = 100 - P_b$

From the figure, considering ΔABC and ΔAEF,

$$\frac{100 - P_b}{100 - 20} = \frac{3000}{8760}$$

$$P_b = 100 - (100 - 20) \times \frac{3000}{8760}$$

$P_b = 72.603$ MW

$P_{b'} = 100 - 72.603$

$P_{b'} = 27.397 \simeq 27.4$ MW

∴ Load shared by peak load plant, $P_{b'} = 27.4$ MW

(ii) Load Factor for Base Load Plant and Peak Load Plant

In case of base load plant, load factor can be determined by using,

$$(L.F)_b = \frac{\text{Average load}}{\text{Peak load}} \times \frac{8760}{8760}$$

$$= \frac{\text{Area } EFB'CC'}{P_b \times 8760}$$

$$= \frac{\text{Area } EFBCE + \text{Area } BB'CC'B}{P_b \times 8760}$$

$$= \frac{\text{Area of triangle} + \text{Area of rectangle}}{P_b \times 8760}$$

$$= \frac{\frac{1}{2} \times b \times h + l \times b}{P_b \times 8760}$$

$$= \frac{\frac{1}{2} \times (3000 + 8760)(72.603 - 20) + 8760 \times 20}{72.603 \times 8760}$$

$$= \frac{5880 \times 52.603 + 175200}{636002.280}$$

$$= \frac{309305.640 + 175200}{636002.280}$$

$\therefore (L.F)_b = 0.762$ (or) 76.2%

Load factor for peak load plant is given by,

$$(L.F)_p = \frac{\text{Area } AFEA}{P_b \times 8760} = \frac{\text{Area of triangle}}{P_b \times 8760}$$

$$= \frac{\frac{1}{2} \times b \times h}{P_b \times 8760} = \frac{\frac{1}{2} \times 3000 \times 27.4}{27.4 \times 8760}$$

$\therefore (L.F)_p = 0.171$ (or) 17.1%

Q31. The annual load duration curve of a station varies uniformly from 64000 kW to zero. The load is supplied by two stations whose cost equations are given as,

C_1 = ₹ (84000 + 84 kW + 0.0116 kWh)

C_2 = ₹ (50000 + 44 kW + 0.02985 kWh)

Find the minimum cost of generation in paise/kWh for the system.

Answer :

Given that,

Maximum demand = 64000 kW

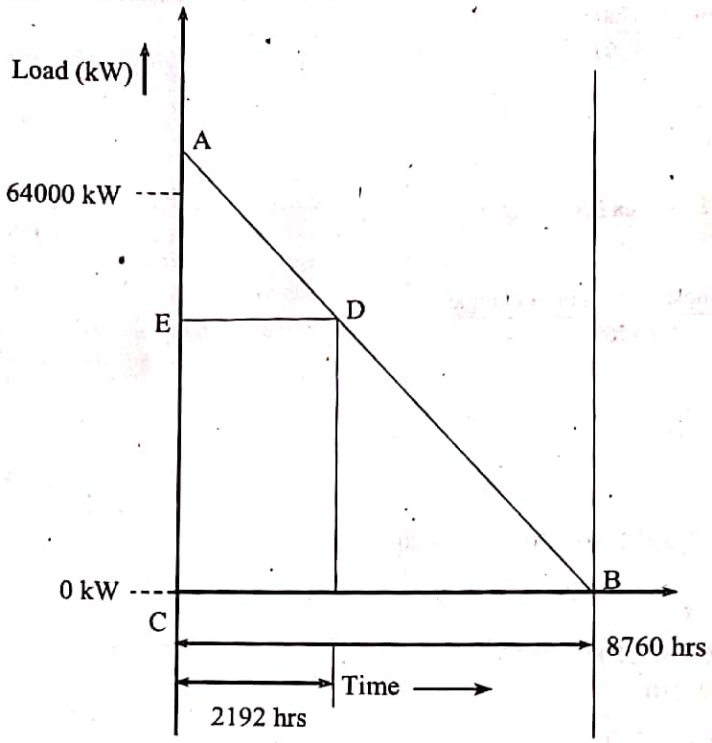
Minimum demand = 0 kW

Cost structure for station (1), ... (1)

$C_1 = 84000 + 84$ kW $+ 0.0116$ kWh

Cost structure for station (2), ... (2)

$C_2 = 50000 + 44$ kW $+ 0.0985$ kWh



Figure

From equation (1),

$A_1 = 84$, $B_1 = 0.0116$

$A_2 = 44$, $B_2 = 0.02985$

Time required to operate the base load for minimum cost is calculated as,

$$L = \frac{A_1 - A_2}{B_2 - B_1} = \frac{84 - 44}{0.02985 - 0.0116}$$

$L = 2191.781 \text{ hrs} \simeq 2192 \text{ hrs}$

From the figure, considering ΔADE and ΔABC,

$$\frac{64000}{8760} = \frac{P_b}{2192}$$

$$P_b = \frac{64000 \times 2192}{8760} = 16014.612 \text{ kW}$$

$$\therefore \quad P_b' = 64000 - 16014.612$$

$$= 47985.388 \text{ kW}$$

Power generated by base load plant in kWh is given by,

$$(P_b) = \frac{1}{2} \times b \times h \times P_b'$$

$$= \frac{1}{2} \times (8760 + 2192) \times 47985.388$$

$$(P_b) = 2627.679 \times 10^5 \text{ kWh}$$

Power generated by peak load plant in kWh is given by,

$$(P_p) = \frac{1}{2} \times b \times h$$

$$= \frac{1}{2} \times 2192 \times 16014.612$$

$$(P_p) = 175.520 \times 10^5 \text{ kWh}$$

$\therefore$ Total energy generated, $P = (P_b) + (P_p)$

$= 2627.679 \times 10^5 + 175.520 \times 10^5$

$P = 2803.199 \times 10^5$ kWh

On substituting the value of P_b' and (P_b) in equation (1),

$$C_1 = 84000 + 84 \times 47985.388 + 0.0116 \times 2627.679 \times 10^5$$

$$= 0.84 \times 10^5 + 40.307 \times 10^5 + 30.481 \times 10^5$$

$$= (0.84 + 40.307 + 30.481) \times 10^5$$

$$C_1 = 71.628 \times 10^5$$

Similarly, substituting the value of P_b and (P_p),

$$C_2 = 50000 + 44 \times 16014.612 + 0.02985 \times 175.520 \times 10^5$$

$$= 0.50 \times 10^5 + 7.046 \times 10^5 + 5.239 \times 10^5$$

$$= (0.50 + 7.046 + 5.239) \times 10^5$$

$$C_2 = 12.785 \times 10^5$$

Total cost,

$$C = C_1 + C_2$$

$$= 71.628 \times 10^5 + 12.785 \times 10^5$$

$$= ₹\ 84.413 \times 10^5$$

$\therefore$ Minimum cost of generation can be calculated as,

$$= \frac{\text{Total cost}}{\text{Total energy generated}} = \frac{84.413 \times 10^5}{2803.199 \times 10^5}$$

Minimum cost of generation = 0.03/kWh or 3 paise/kWh

Q32. The estimated cost of two power stations in rupees are given as follows,

C_1=12500 kW + 2.75 kWh

C_2=12500 kW + 3 kWh

These two stations operate in parallel and supply a load having annual load duration curve as straight line joining two points 0-hours – 100MW and 8760 hrs – 10 MW. Find,

(a) Minimum cost of generation

(b) Installed capacity of each station

(c) Annual load factor, capacity factor and use factor for each station. Assume plant II has 20% reserve.

(April-15, Set-3, Q6(b) | April-15, Set-4, Q6(a))

Answer :

Given that,

Cost structure for station (1), $C_1 = 12500$ kW + 2.75 kWh ... (1)

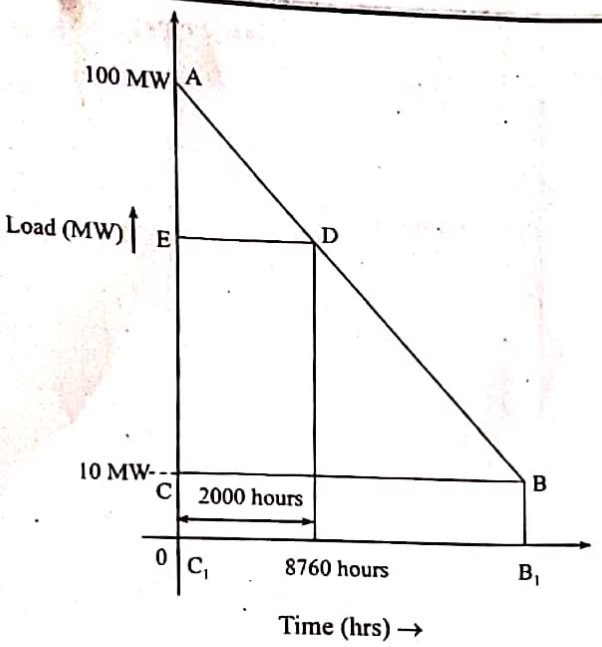
Cost structure for station (2), $C_2 = 12000$ kW + 3 kWh ... (2)

From equation (1),

$A_1 = 12500$, $B_1 = 2.75$

From equation (2),

$A_2 = 12000$, $B_2 = 3$



Figure

Time required to operate base load plant is given by,

$$L = \frac{A_1 - A_2}{B_2 - B_1}$$

$$= \frac{12500 - 12000}{3 - 2.75}$$

$$L = 2000 \text{ hrs}$$

From the figure, considering ΔABC and ΔADE,

$$\frac{100 - P_b}{100 - 10} = \frac{2000}{8760}$$

$$P_b = 100 - (100 - 10) \times \frac{2000}{8760}$$

$$P_b = 79.452 \text{ MW}$$

$$P_{b'} = 100 - P_b$$

$$= 100 - 79.452$$

$\therefore$ Peak load on peak plant $P_{b'} = 20.548$ MW

(a) Minimum Cost of Generation

Base Load Plant (or) Plant-I

Total units generated is given by,

$$= \text{Area } DEBCE + \text{Area } BB_1 CC_1 B$$

$$= \frac{1}{2} \times (2000 + 8760) \times (79.452 - 10) + 10 \times 8760$$

$$= 461251.760 \text{ MWh}$$

$$= 461.251 \times 10^6 \text{ kWh} \quad \ldots (2)$$

$$C_1 = 79.452 \times 10^3 \times 12500 + 461.251 \times 10^6 \times 2.75$$

$\therefore C_1 = ₹2261.590 \times 10^6$

Peak Load Plant (or) Plant-II

Total units generated,

$$= \text{Area } ADE$$

$$= \frac{1}{2} \times 2000 \times (100 - 79.452)$$

$$= 20548 \text{ MWh}$$

$$= 20.548 \times 10^6 \text{ kWh} \quad \ldots (3)$$

$$\therefore \quad C_2 = 20.548 \times 10^3 \times 12000 + 20.548 \times 10^6 \times 3$$

$$= ₹308.22 \times 10^6$$

Total generated units from plant-I and plant-II,

$$= 461.251 \times 10^6 + 20.548 \times 10^6$$

Total generated units $= 481.799 \times 10^6$ kWh

Now, total generating cost,

$$C = C_1 + C_2$$

$$= 2261.590 \times 10^6 + 308.22 \times 10^6$$

$$C = ₹2569.81 \times 10^6$$

$$\text{Average cost} = \frac{\text{Total generating cost}}{\text{Total generated units}}$$

$$= \frac{2569.81 \times 10^6}{481.799 \times 10^6}$$

$= ₹ 5.334$/kwh

(b) Installed Capacity of each Station

Installed capacity of base load plant = 79.452 MW

Installed capacity of peak load plant,

$$= 20.548 \times \left(\frac{100 + 20}{100}\right)$$

$$= 20.548 \times 1.2$$

($\because$ Reserve capacity for plant-II = 20%)

$= 24.658$ MW

(c) Annual Load Factor, Capacity Factor and Use Factor for each Station

Base Load Plant or Plant-I

Load factor is given by,

$$L.F = \frac{\text{Actual units generated}}{P_b \times 8760}$$

$$= \frac{\text{Area } DEBCE + \text{Area } BB_1 CC_1 B}{P_b \times 8760}$$

$$= \frac{\frac{1}{2}(2000 + 8760) \times (79.452 - 10) + (10 \times 8760)}{79.452 \times 8760}$$

$$L.F = \frac{373651.760 + 87600}{695999.520}$$

$= 0.663$ or 66.3%

∴ Load factor for base load plant = 66.3%

Capacity factor,

$$C.F = L.F = 0.663$$

Use factor is given by,

$$U.F = \frac{\text{Capacity factor}}{\text{Load factor}}$$

$$= \frac{C.F}{L.F} = \frac{0.663}{0.663}$$

∴ Use factor for based load plant = 1

Peak Load Plant or Plant-II

Load factor is given by,

$$L.F = \frac{\text{Actual units generated}}{P_b \times 8760}$$

$$= \frac{\text{Area } ADE}{P_b \times 8760}$$

$$= \frac{\frac{1}{2} \times 2000 \times (100 - 79.452)}{20.548 \times 8760}$$

$$L.F = 0.114 \text{ or } 11.4\%$$

∴ Load factor for peak load plant = 0.114 or 11.4%

Capacity factor is given by,

$$C.F = \frac{\text{Average load}}{\text{Actual plant capacity}}$$

$$= \frac{\text{Actual units generated}}{\text{Installed capacity of peak load plant} \times 8760}$$

$$= \frac{\text{Area } ADE}{24.658 \times 8760}$$

$$= \frac{\frac{1}{2} \times 2000 \times (100 - 79.452)}{24.658 \times 8760}$$

$$= 0.095 \text{ or } 9.5\%$$

∴ Capacity factor for plant - II = 0.095 or 9.5%

Use factor can be calculated as,

$$U.F = \frac{\text{Capacity factor}}{\text{Load factor}}$$

$$= \frac{C.F}{L.F} = \frac{0.095}{0.114}$$

$$U.F = 0.833 \text{ or } 83.3\%$$

∴ Use factor for plant - II = 0.833 or 83.3%

5.2 POWER PLANT INSTRUMENTATION AND CONTROL

5.2.1 Importance of Measurement and Instrumentation in Power Plant

Q33. Explain the importance of measurement and instrumentation in power plant.

Answer :

Plant instrumentation plays a significant role in power plant engineering. It is an essential requirement for the modern electric power plants. These instruments provide accurate information regarding the plant operation for safe, continuous and proper functioning of the system.

Power plant instruments used for the measurement are categorized into two groups,

(i) Mechanical instruments
(ii) Electrical instruments.

(i) Mechanical Instruments

Some of the mechanical instruments are,

1. Pressure measuring instruments
2. Temperature measuring instruments
3. Flow measuring instruments
4. Fuel measuring instruments
5. Gas analysis instruments
6. Speed measuring instruments
7. Level recorders
8. Steam calorimeters and fuel calorimeters
9. Atmospheric measuring instruments (barometer, thermometer etc.)
10. Gong alarms.

(ii) Electrical Instruments

Some of the electrical instruments are,

1. Ammeters
2. Wattmeters
3. Voltmeter
4. Power factor meters
5. Synchroscope
6. Reactive volt ampere meters
7. Ground detectors.

The instruments are also classified as,

1. Indicating instruments: These instruments are used only for operating guidance.
2. Recording Instruments: These type of instruments are used for operating supervision and for calculating the performance of the plant.
3. Indication and Recording Instruments: These instruments have the combine functions of indication and recording instruments.
4. Indicating and Integrating Instruments: These are used for providing operating guidance, calculation of plant performance and also used for cost allocation.
5. Indicating, Recording and Integrating Instruments: These type of instruments have the combine functions of indicating, recording and recording and integrating instruments.

Instruments indicate certain conditions established in the system visually which can be altered according to the process requirements. The information given by the instruments helps to achieve the best performance possible and provide details for the calculations so that the results can be recorded and compared timely. Information recorded from these instruments can also be used to inspect the internal condition of equipment and show when and where maintenance or repair is required.

Q34. What are the functions of instruments? List the steps involved in control process and mention the purpose of providing controls in power plants.

Answer :

The various functions of instruments performed in power plants are as follows:

1. Operating Guidance

They guide to function the plant efficiently and economically by providing constant information regarding the state of pressure, temperature, flow etc., to the operating manpower which helps in achieving the best performance through the plant.

2. Performance Calculations

They contribute by providing the data for calculations so that the performance of the plant is calculated in terms of plant working.

3. Maintenance and Repair Guidance

They are used to inspect the internal conditions of the equipment to provide information about the maintenance or repair if required.

4. Economical Supervision

It helps in the regulation of the plant economically.

5. Cost Allocation

Instruments help in dealing with the issues regarding accounting of costs and cost distributions.

The basic steps involved in control process are,

(i) Measuring the quantity being controlled.

(ii) Observing the measuring device indication.

(iii) Manipulation of the control device.

(iv) Change in the quantity of the unbalanced flow by the control device.

Controls are provided for the following reasons,

(i) Safety measures to prevent damages.

(ii) Convenience of operation

(iii) Overall operation efficiency

(iv) Reduction of operation cost.

Q35. Explain briefly the types of mechanical instruments.

Answer :

The two general classification of instruments are,

Mechanical Instruments

Mechanical instruments are of the following types,

1. Pressure measuring instruments
2. Temperature measuring instruments
3. Flow measuring instruments
4. Fuel measuring instruments
5. Gas analysing instruments
6. Speed measuring instruments
7. Level recorders
8. Gong alarms.

1. Pressure Measuring Instruments

Some of the pressure measuring instruments are,

(i) Standard Bourdon Tube Type, Steam Pressure Gauge

This type of gauge is used to measure the pressure at moderate and high intensity steams. The recording type instruments is placed on the panel boards in order to measure the pressure but the initial information is always taken from a standard short lead gauge which is mounted on the boiler.

(ii) Helical Tube or Diaphragm Type Low Steam Pressure

The low steam pressure gauges are used to measure bleeder pressures, exhaust pressures etc.

(iii) Vacuum Gauges and Manometers

Condenser vacuums and heater pressures are measured with the help of vacuum guages and manometers.

(iv) Draft

Draft gauges are used to acquire and retain the best furnace conditions, to inspect the operation of automatic combustion equipment, to examine the condition of the boiler setting and flues and also evaluates the performance of draft fans and chimneys.

2. Temperature Measuring Instruments

Following are the temperature measuring instruments:

(i) Glass Tube Mercury Thermometers

It consists of a bulb containing mercury attached to a glass tube which is used in flow lines, measuring condensate temperature, circulating water, feedwater, bearing oil etc. Mercury thermometers are generally used to read local readings but are also frequently used as a check on remote reading bulb and tube thermometers.

(ii) Gas Filled Bulb and Tube Thermometers

These are used to measure the temperature of gases and liquids upto 550°C. They are ideal for distance reading upto 100 meters from the bulb locations.

(iii) **Vapour Pressure Thermometer**

It is used for measuring temperature upto 270°C. The bulb of this thermometer partly consists of a liquid which is linked to a length of tubing. Compared to gas filled type thermometers the vapour pressure thermometers have limited applications in power plants.

(iv) **Electrical Resistance Thermometer**

Electrical resistance thermometers are used for the precise measurement of feedwater, condensate temperature and temperature of electrical machine windings.

(v) **Thermocouple Thermometer and Pyrometer**

These are used to measure high range temperatures of furnace flue gases, preheated air, superheated steams etc.

3. **Flow Measuring Instruments**

(i) **Steam Flow Meters**

They are used to measure the flow steams in individual boiler output, group boiler output, turbine supply auxiliary steam, industrial steam etc.

(ii) **Water Flow Meters**

It measures the flow of water such as flow of condensate, feed water pump discharge etc.

(iii) **Air Flow Meters**

It is in the form of differential draft gauge used for measuring the flow of air outside the gas loop.

4. **Fuel Measuring Instruments**

(i) **Coal**

Basically, coal is measured in batches and can also be measured by belt conveyors and few pulverized coal instruments which are continuous in process. A chain grate stroker with coal volume measuring meter is also useful in coal measurement.

(ii) **Gas Meter**

Gases can be measured either by positive displacement or differential head type.

(iii) **Oil Meters**

Oil meters are of positive displacement type only.

5. **Gas Analysing Instruments**

Orsat apparatus, CO_2 and O_2 instruments are some of the examples of gas analysers.

The CO_2 meter presently uses one of the following principles,

Chemical : It is a modification of Orsat apparatus

Electrical : It depends on the measurement of conductivity of flue gases

Mechanical : The density of the flue gas is balanced against air.

6. **Speed Measuring Instruments**

Speed measuring instruments are of the following types,

(i) Vibrating read tachometer
(ii) Electrical tachometer
(iii) Clock type tachometer
(iv) Centrifugal tachometer
(v) Stroboscope tachometer
(vi) Revolution counters.

7. **Level Recorders**

Level recorders are used for monitoring and recording water level in boilers, tanks, canals. It also measures the coal level in pulverized coal bins.

8. **Gong Alarms**

Gong alarms are alert indicators which indicates about the temperature prevailing in generators, transformer coils and in other various processes. The alarm is mounted on the main switch or panel board.

Q36. Classify electrical instruments and explain each of them briefly.

Answer :

An electrical instrument is a device used for measuring the electrical quantities like current, voltage, power, energy etc.

Following are the different types of electrical instruments used in power plants,

(i) **Ammeters**

Ammeters are instruments which measures current in an electric circuit. They are used in generator leads, feeder circuits, auxiliary power circuits and field circuits.

(ii) **Voltmeters**

They are used to measure voltage or potential difference. Voltmeters are also used to obtain desired voltage, inspect automatic voltage regulators, synchronize and detect grounds.

(iii) **Wattmeters**

It is an instrument used for measuring the electric power or the supply rate of electrical energy of circuits in watts. It is used to show power in generator or feeder circuits.

(iv) **Synchroscope**

They are used to measure and display the frequency differences and the phase angle between two power systems.

(v) **Reactive Volt Ampere Meters**

It is a meter which measures reactive power in an A.C electrical power system. Its power is measured in VARs (Volt - Ampere - Reactive).

(vi) **Power Factor Meters**

They are used to check excitation and load division in alternators leads. These meters are placed on bushbars when a synchronous condenser is used to maintain power factors.

(vii) **Ground Detector**

It is an instrument used to indicate the pressure of ground in an electric circuit. It is also known as ground indicator.

5.2.2 Measurement of Water Purity, Gas Analysis, O_2 and CO_2 Measurements

Q37. With the help of a neat sketch describe the method of measuring conductivity of water.

Answer :

The amount of salt in feedwater, steam and condensate is determined by the electrical conductivity of water. It is a process through which the capacity of water to conduct an electric current is evaluated .The conductivity of pure water is very low because it has mineral salts, acids or alkalies in it which splits into positive and negative ions. The conductivity of water increases with the increase in the amount of ions in the water.

The working and arrangement of an electric circuit measuring conductivity is shown in the figure.

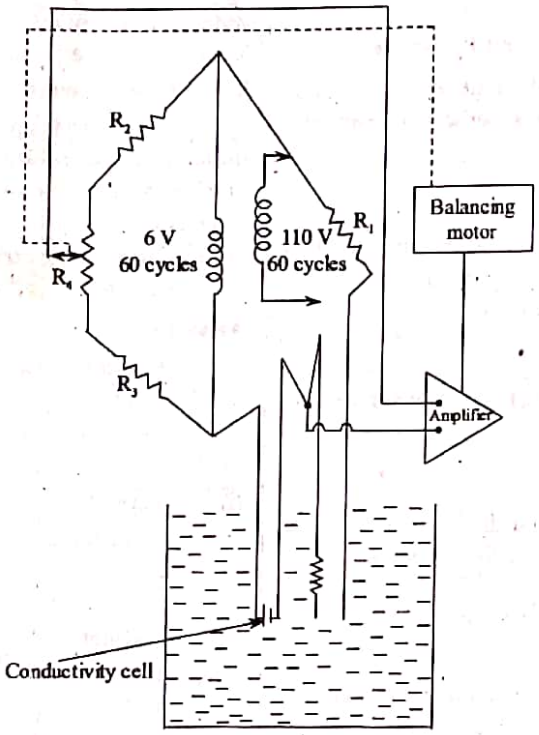


Figure: Electric Circuit

The conductivity meter used in the process is an electric measuring device. This method works on the principle of Wheatstone bridge which measures the conductivity of the circuit. As shown in the figure, the cell is immersed in the water sample with one leg of an unknown resistance R_x and the other leg of the temperature sensitive resistance R_t.

The function of R_t is to compensate the temperature if its temperature exceeds above 20°C. The unknown resistance R_x changes with the change in solution conductivity. The signals of the two resistances R_x and R_t is fed to the amplifier which amplifies and actuates the balancing motor. The balancing motor instantly moves the slider on R_4 where new position of balance is obtained. The arrangement also consists of an instrument pen which records the conductivity value. Thus, the conductivity of water is calibrated.

Q38. Why oxygen level in the water is maintained low. Draw the circuit used to measure the dissolved O_2 in the water and explain.

April-15, Set-4, Q7(b) | Model Paper-II, Q6(a)

OR

What is the use of dissolved oxygen recorders? Explain the working of the recorder with the help of a neat sketch.

Answer :

The important factor responsible for corrosion of boiler tubes and decrease in performance of the condenser is the presence of dissolved oxygen in feedwater. To eliminate or minimize this effect an oxygen recorder is employed in feedwater in order to record and indicate the amount of oxygen present in it.

The recorder measuring the amount of oxygen is described in the figure.

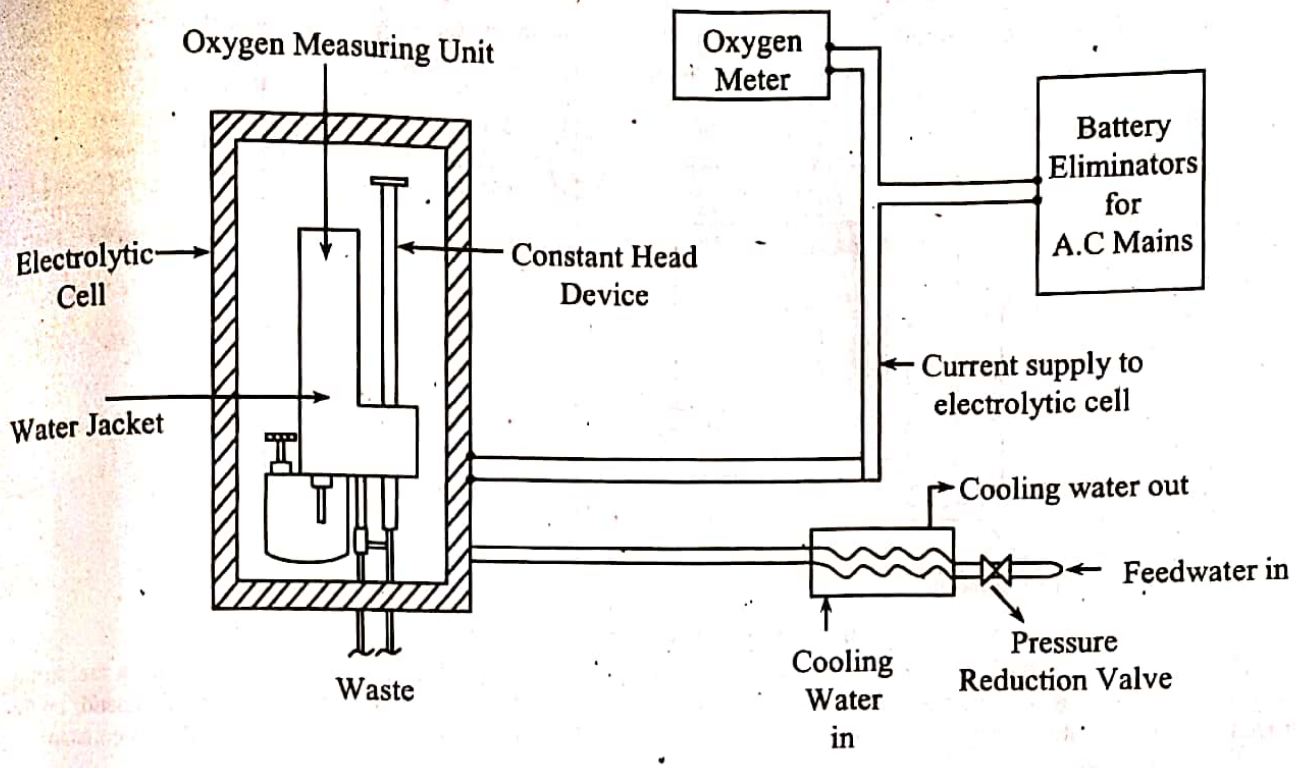


Figure: Dissolved Oxygen Recorder

In this process, the oxygen in feedwater is analyzed by passing the feedwater through a pressure reduction valve into a cooler where the water temperature is reduced to 20°C. An electrolytic cell consisting of a constant head device which maintains a constant water flow through an opening in a water jacket. The water jacket encloses a Katharometer, an instrument which detects a gas or measures the concentration of the gas in a mixture by measuring the changes in thermal conductivity.

The water when flows further it mixes with the H_2 – gas thereby dissolving the H_2 – gas and releasing the oxygen. The H_2 – gas produced in the electrolytic cell passes through one side of Katharometer and flows to the compensator whereas, the other side of katharometer is exposed to the gas in the chamber.

In a central metal block, Katharometer is made to form a Wheatstone bridge by placing and connecting the four-platinum spirals of Katharometer in cells. The two cells are open to the pure hydrogen and to the two gases from the contact chamber. The platinum spirals are heated with the help of an electric current and when the gas comes in contact with these spirals, they obtain the same temperature with no deflection of the galvanometer in the indicator. In the contact chamber, when two spirals are exposed to H_2 and the other two are exposed to H_2 and O_2 mixture, the temperatures of both the pairs will change and the deflection is obtained on the galvanometer.

In a contact chamber, oxygen in a mixture is proportional to the oxygen dissolved in water because the deflection is directly proportional to the oxygen in mixture and to the oxygen dissolved in water.

Thus, the galvanometer scale is measured and the amount of dissolved oxygen is recorded.

Q39. Describe the process for measuring the pH of the solution.

(OR)

Draw an electric circuit used to measure pH value of feed water and explain its working.

Answer : **[Model Paper-IV, Q6(a) | April/May-16, Set-2, Q7(b)]**

The circuit used for measuring the pH value is a combination of electrometer and potentiometer as shown in figure.

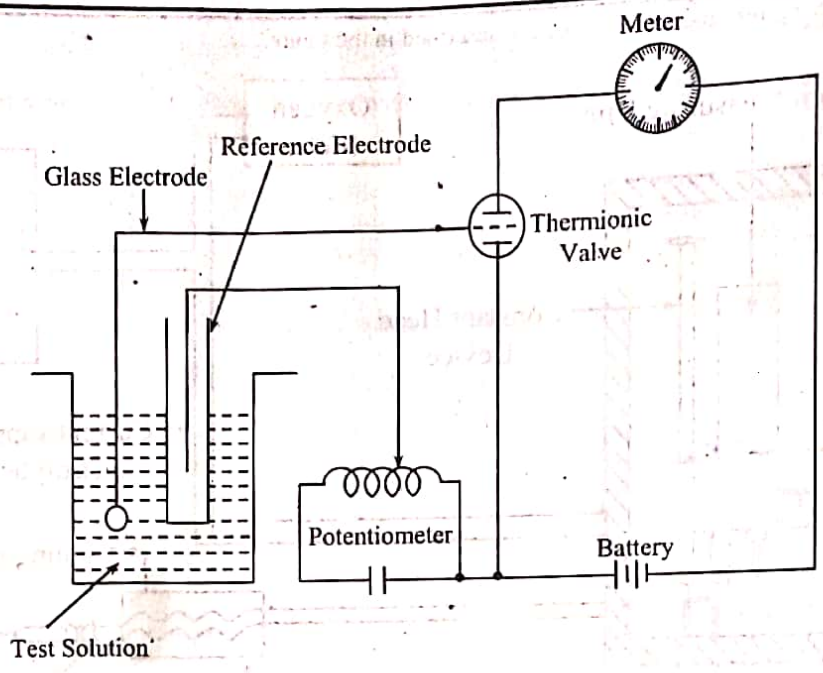


Figure: Electric Circuit Measuring pH Value

The pH meter consists of two elements for measuring the pH value of a solution. The two elements are a measuring element and a comparison element. The measuring element in this process is the glass electrode whose potential depends on the hydrogen ions concentration whereas, the comparison element is the reference electrode whose potential is always constant.

These two electrodes forms a galvanic system when connected electrically. Active concentration of the hydrogen ions of the solution and its pH value is obtained by measuring the e.m.f of the galvanic system.

In this circuit, the reference electrode is kept constant whereas the glass electrode is adjusted to a known voltage supplied by a potentiometric circuit.

When the voltages of both the electrodes are equal, then there is no voltage supply to the grid which is indicated by a sensitive meter. This makes the electrode voltage equal to the voltage indicated by the potentiometric dial.

Q40. Explain the magnetic wind method for the measurement of O_2 in the flue gases.

Answer : April/May-17, Set-4, Q6(a) | April-15, Set-1, Q7(a) | Model Paper-III, Q6(a)

Measurement of Oxygen

A paramagnetic oxygen analyser based on the magnetic wind type principle is used for measuring oxygen.

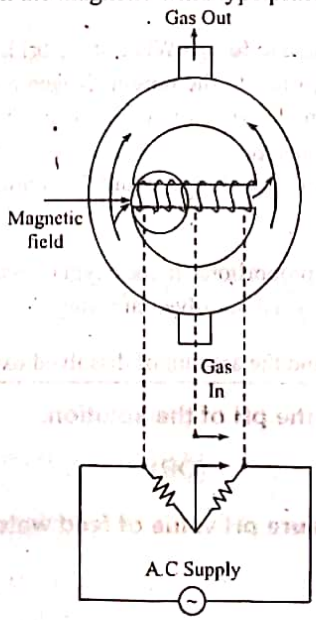


Figure: Paramagnetic Oxygen Analyser

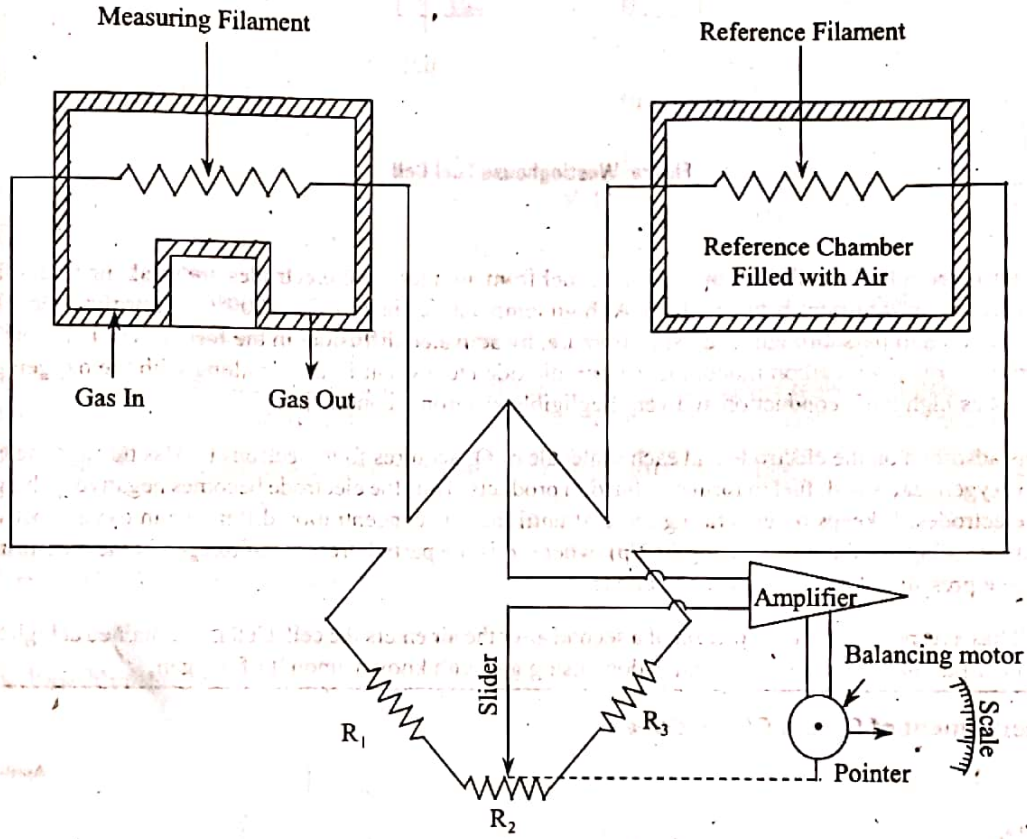
In this process, the gas is passed into the measuring cell through annulus with the help of a horizontal bypass tube. The bypass tube having two similar adjacent platinum windings outside are connected to the Wheatstone bridge circuit which is heated due to the voltage across the bridge. As shown in figure, one of the winding is cut by an intense magnetic field. When the flue gases enters the cell, O_2 is drawn into the bypass tube due to its paramagnetic properties. Oxygen is then heated by the winding to minimize the magnetic susceptibility of the gas. Further, the cool oxygen is passed into the tube replacing the hot gas which in turn passes into the annulus through the tube. A convection flow known as magnetic wind causes differential cooling of the windings. The change in resistance with temperature unbalances the bridge. This unbalanced e.m.f is then calibrated by a standard potentiometer recorder which depends on the O_2 content of the sample.

Q41. Draw the electric line diagram to measure CO_2 in the flue gases and explain the working.

Answer :

(April/May-17, Set-3, Q6(a) | April/May-16, Set-3, Q7(b) | April-15, Set-1, Q7(b))

Measurement of Carbon Dioxide



Figure

The electrical circuit used for the measurement of CO_2 content in gases consists of a hot wire thermal conductivity gas analysis cell. The circuit is composed of two chambers with a wire filament in each chamber. One chamber is filled with the gas whose conductivity is to be measured whereas the other chamber is filled with reference gas like air is passed and sealed in it.

A wheatstone bridge is formed by passing the platinum wire elements through the cells. The wire elements are heated under normal conditions by the bridge current. As a result, the temperature of filament increases in the measuring chamber due to decrease in thermal conductivity of gases passing around the filament. The change in temperature and resistance of the two platinum wire elements unbalances the bridge and gives an unbalanced voltage proportional to CO_2 percentage present in the flue gases. This unbalanced voltage in turn used for measuring the percentage of CO_2 in flue gases.

Q42. With a neat sketch explain the working of Westing house oxygen analyser.

Answer :

April-15, Set-2, Q7(a)

A westing house oxygen analyzer is a fuel cell oxygen analyzer. It generates electric current when it comes in contact with the oxygen and thus oxygen is analyzed.

It consists of two electrodes and an electrolyte.

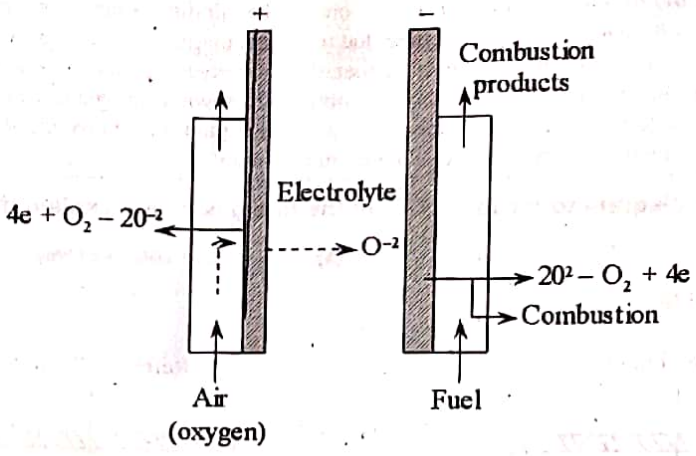


Figure: Westinghouse Fuel Cell

Working

Oxygen or air is fed into the cell from one side and fuel from another. Two electrodes are used, air enters from cathode side, and ceramic electrolyte is present between them. At high temperatures ie 400°C – 1000°C, electrolyte acts like a filter or a screen and allows oxygen to pass through its crystal structure, by activated diffusion, in the form of O^{2-} ions. Other gases like hydrogen, nitrogen, water vapour, carbon monoxide, carbon dioxide etc present in the air along with the oxygen gets blocked since the electrolyte has high ionic conduction and very negligible electronic conduction.

Oxygen gets adsorbed on the electrode and each molecule of O_2 acquires four electrons to pass through the electrolyte to another electrode. Oxygen reacts with fuel to form combustion products. Thus the electrode becomes negatively charged resulting in emf across the electrodes. It keeps on generating the emf until there is concentration difference in oxygen between the two electrodes. The output voltage is about 0.0557 log (0.2/p), where, P is the partial pressure of oxygen at the measuring electrode. Fuel helps to keep the pressure of oxygen low at the anode.

The fuel cell has a response time of a fraction of a second after the air enters the cell. Cell is maintained at high temperatures and it requires air flow rate of 4 + t^3/hr. Calibration is done using gas with known amount of oxygen.

Q43. How measurement of O_2 and CO_2 is done?

Answer :

April-18, Set-3, Q1(e)

Measurement of O_2

For answer refer Unit-V, Q40.

Measurement of CO_2

For answer refer Unit-V, Q41.

5.2.3 Measurement of Smoke and Dust, Measurement of Moisture in Carbon Dioxide Circuit

Q44. With a neat sketch explain the working of photo cell type smoke meter.

(April/May-17, Set-1, Q6(b) | April-15, Set-3, Q7(a)

OR

With a neat sketch, explain the working of smoke measurement system.

Answer :

Photocell Type Smoke Meter

April-18, Set-1, Q6(a) | Model Paper-I, Q6(b)

A smoke detector is a device that detects smoke and gives an alarm or a visual signal to indicate the smoke in the atmosphere.

A block diagram of a smoke detector is shown in figure.

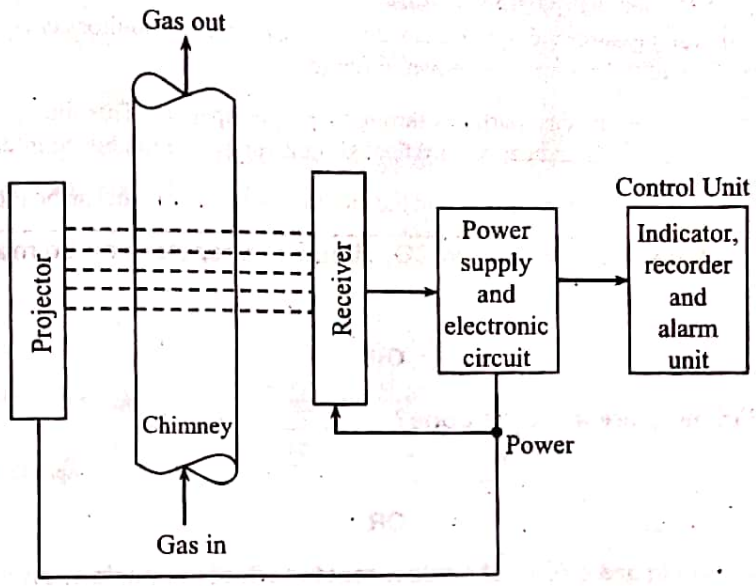


Figure: Smoke Meter

In a photocell type of smoke detector, the projector emits a light source through the chimney. The receiver consisting of a photocell is fixed opposite to the projector. The projector and the receiver are supplied with a controlled power. An indicator, recorder and an alarm are a part of a control unit. When the smoke enters the chimney, the smoke particles deflect some of the light rays which on reaching the photocell activates and generates a signal in the photocell circuit.

The variation in the signal which is a measure of smoke in the flue gas is further passed by the electronic circuit to the control unit where the smoke is indicated, recorded and displayed. The final reading is then recorded and measured in percentage.

Q45. With a neat sketch explain the working of reflected light dust monitor. April-15, Set-4, Q7(a)

OR

How measurement of dust is done? April-18, Set-2, Q1(e)

Answer :

Reflected Light Dust Monitor

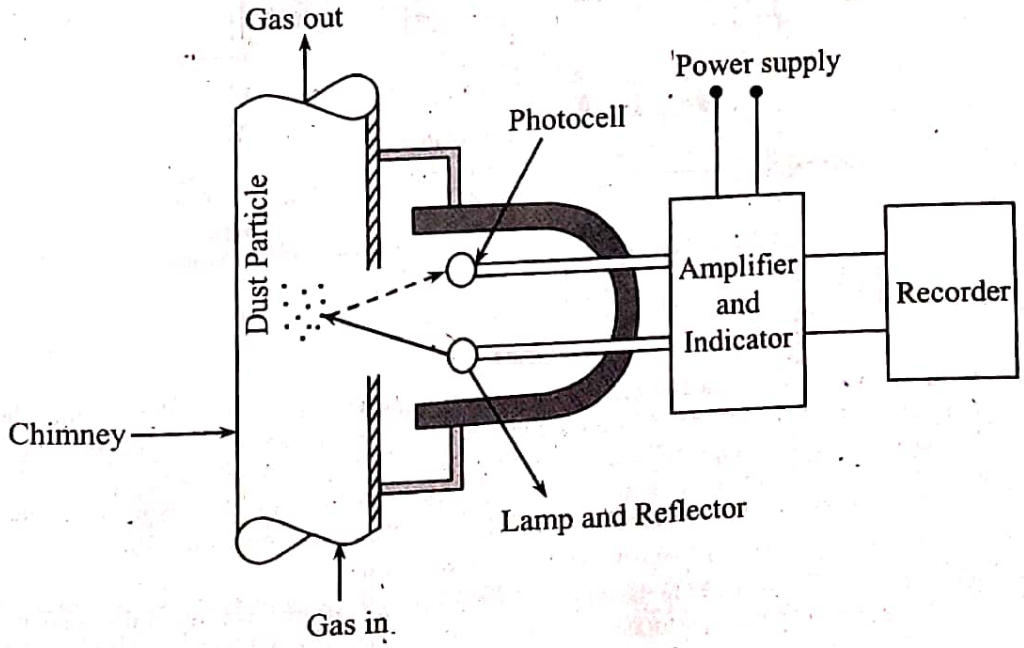


Figure: Reflected Light Dust Monitor

It is used to measure the dust released from the exhaust.

A reflected light dust monitor measures the light reflected from the dust. The monitor consists of a photocell receiver and a lamp with reflector on either sides of the chimney as shown in figure.

The lamp emits a beam of light to the dust particles through a proper opening. This light gets reflected back by the dust particles and reflects on to the photocell. The indication of reflected light varies due to change in dust quantity in the gas.

When the quantity of dust remains constant throughout the monitor, then instrument can be measured based on the weights.

Q46. With a neat sketch explain how moisture in CO_2 circuit of a reactor can be measured.

April-15, Set-2, Q7(b)

OR

How measurement of moisture in CO_2 is done?

April-18, Set-1, Q1(e) | Model Paper-III, Q6(b)

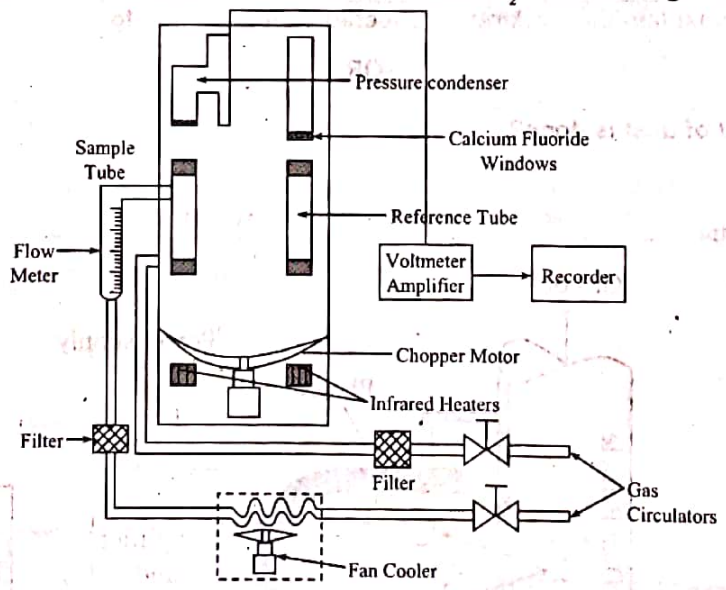
OR

Explain how the moisture in gas circuit of nuclear reactor effect the performance of the reactor. Describe the arrangement used for the measurement of moisture in CO_2 circuit.

Answer :

The nuclear reactors with moisture content in the gas circuit leads to corrosion of the circuit and pressure vessels. It effects the working of fuel element considerably and reduces the efficient working of the reactor circuit. Therefore, to enhance the performance of the reactor, it is required to control the CO_2 moisture content constantly, to detect and avoid any kind of leakage of boiler tubes and alert the operator with the help of an alarm.

An infrared gas analyser is used to detect and measure moisture in CO_2 as shown in figure below,



Figure

In this process, the analyser is connected to the gas circulators to provide gas flow to the system. The function of the comparator system of the analyser is to examine the difference in infrared radiation intensity passing through the reference tube consisting of dry carbondioxide and the sample tube of the reactor. Two nichrome heaters acting as infrared sources are used for the infrared radiation and an electrical fan is provided to chop the infrared radiations. It is chop to regulate uniform discrete amounts of infrared radiation to the two calcium fluoride coated windows. These windows retain the pressure depending on the moisture content in the gas which is then compared with the pressure condenser.

A pulsed pressure differential is provided to the diaphragm for unequal infrared heating of the condenser. The electrical signal of the analyser is obtained by placing a perforated plate close to the diaphragm which completes the condenser.

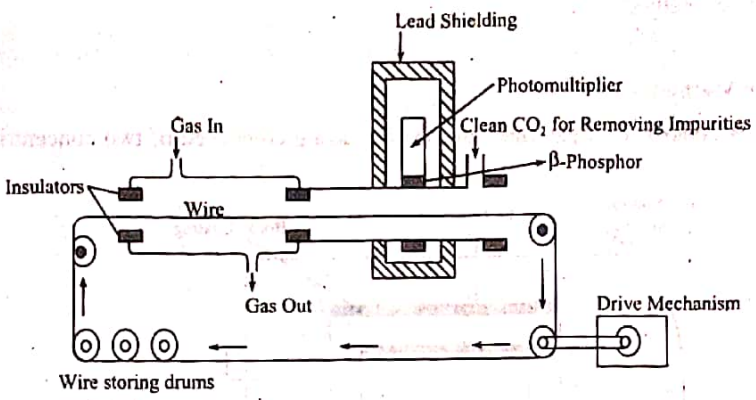
This signal is further passed to the amplifier where it is amplified and the output is recorded by the recorder.

Q47. Explain the working and arrangement of precipitator chamber and detection system with the help of a neat sketch.

Answer :

Precipitator Chamber

It consists of a metal cylinder and a thin metal wire passing through the centre of the cylinder. The wire is being insulated from the cylinder. A precipitator chamber and detection system is shown in figure.



Figure

The cylinder of this chamber is maintained at a potential of 4 kV positive. The gas is allowed to flow for 25 seconds into the precipitation chamber from the sample channels. The daughter products like rubidium and caesium produced by this action gets accumulated on the wire as they are positively charged. Further, the wire is quickly moved out of a precipitation chamber and passed into a hole of phosphor and photomultiplier system. The rate-meter is operated by using a beta-sensitive phosphor and by amplifying the photo multiplier output. The β-active materials existing on wire is detected by determining the integrated count over a period which is similar to the gas sampling period. The wire from the precipitation chamber moves over a system of pulleys and again enters into the chamber after a certain time and complete decay of deposited active products takes place in the chamber.

A gas sampling circuit arrangement is shown in figure (2).

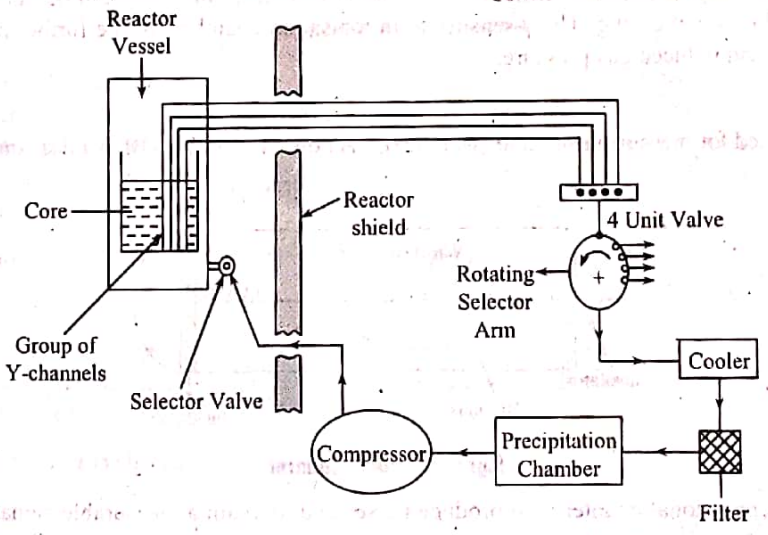


Figure (2): Gas Sampling Circuit

A cooled reactor consists of various fuel channels which makes the process uneconomical and difficult in monitoring each channel for the presence of fission products. This is prevented by providing a small pipe at the top of each channel to take the gas sample from each channel. These pipes are further connected together in groups after bringing them out of the reactor and lead shielding.

The mixed gas sample from this group of pipes is passed to the selector valve. The function of the selector valve is to control the groups and select a group of channels sequentially and pass the gas sample to the compressor. The gas is allowed to pass into a precipitate chamber through a compressor. The gas from this chamber is again passed to the main gas circuit or pressure vessel to maintain the pressure of the gas circuit.

5.2.4 Nuclear Measurements

Q48. What are the different methods used for the measurement of neutron flux? Explain them with the help of neat sketches.

Answer :

The methods used for the measurement of neutron flux are,

1. Ionisation chamber method
2. Pulse counter.

1. Ionisation Chamber Method

An ionisation chamber consists of a gas-tight aluminium casing composed of two concentric aluminium electrodes as show in figure (1).

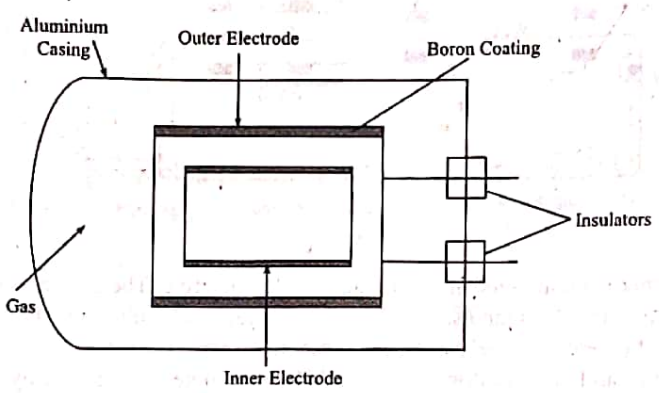


Figure (1): Ionisation Chamber

The internal and external surfaces of the outer electrode and the external surface of the inner electrode is coated with boron. The casing is filled either with hydrogen or argon gas. The sensitivity of neutron depends on the amount of boron coated on the electrodes, the amount of boron enhanced with isotope boron 10 and the gas pressure inside the casing. In this method, due to the presence of large γ-rays it becomes difficult to measure the neutron flux. This can be minimized by using a suitable gas like hydrogen in the aluminium casing. The γ-sensitivity in ionisation chamber can be further minimized by using coated electrodes, enriched boron and reduced gas pressure.

2. Pulse Counter

A pulse counter is used for measuring small neutron fluxes. A boron trifluoride (BF_3) pulse counter is shown in figure (2).

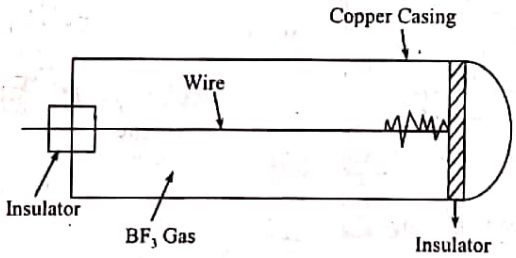


Figure (2): Pulse Counter

The principle of a proportional counter is to produce pulses and to attain a measurable signal from pulse amplification technique. This counter consists of a copper tube acting as an electrode and an insulated wire at the centre of the tube which acts as another electrode. The tube is filled with BF_3 gas and the wire is maintained at a high voltage to establish secondary ionisation to get a large pulse.

Q49. What do you mean by dosimeter? Draw a block diagram of a dosimeter and explain its working.

Model Paper-II, Q6(b)

OR

Explain with a neat line diagram the circuit to analyses the gas for nuclear radiation.

April/May-17, Set-2, Q6(b)

Answer :

A dosimeter is an instrument used for measuring the radiation intensity. They are mainly of two types,

(i) Survey dosimeter

(ii) Personal dosimeter.

Survey Dosimeter

A survey dosimeter consists of the following parts,

(a) Ionisation chamber

(b) Amplifier

(c) Ammeter

(d) Power supply.

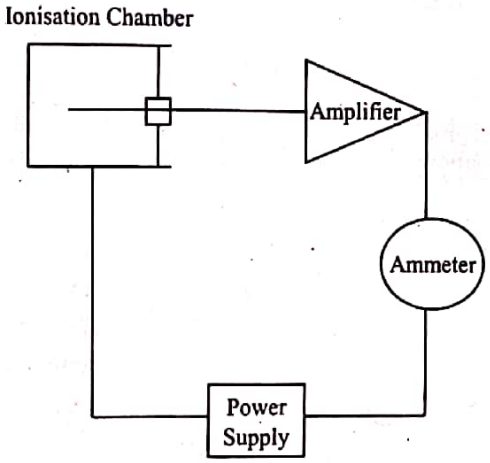


Figure: Survey Dosimeter

In survey dosimeter, the current of ionisation chamber is proportional to the intensity of incident gamma-radiation. The current from ionisation chamber is passed on to the amplifier where it is amplified and the readings are then calibrated by the ammeter. The readings are measured in terms of dose rate units as Roentgents (R) per hour which is a measurement unit for the exposure of X-rays and γ-rays. The readings evaluated from survey dosimeter gives the information about the feasibility of the time limit to work in a room without facing any health hazard.

Q50. Explain the principle and arrangement of a fountain pen dosimeter.

Answer :

A fountain pen dosimeter is used to measure the radiation doses received by the worker. It is based on the principle of gold leaf electroscope i.e., when the electroscope is charged, because of the electrostatic repulsion, the thin movable gold foil diverges and makes an angle of divergence.

A fountain pen dosimeter is shown in figure.

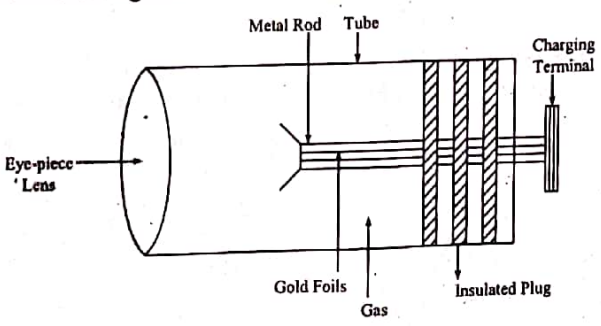


Figure: Fountain Pen Dosimeter

This dosimeter is an insulated tube, filled with gas and earthed. One end of the pen is closed by an eye-piece from where the divergence of the gold foils can be observed whereas the other end consists of an insulated plug. From a metal rod, two gold foils are passed through the insulated plug keeping a part of them outside the tube in the charging terminal. The tube is charged by a high voltage battery and the metal rod is charged. The gold foils with like charges diverge making an angle proportional to the potential. Radiations of beta particles and gamma rays penetrates the tube wall and ionises the gas molecules present inside the tube. Further, the gold foils are discharged by the ions for making an angle of divergence. This change in angle of divergence is read from the scale and the amount of ionising radiation is calibrated. .