WINTER – 19 EXAMINATION

Subject Name: Power Plant Engineering **Model Answer** **Subject Code: 22566**

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q.N.	Answer	Marking Scheme
Q.1 (A)	a)	Types of Power Plant 1. Nuclear power plant 2. Thermal power plant 3. Wind power plant 4. Geothermal power plant 5. Diesel power plant 6. Hydroelectric power plant 7. Tidal power plant	Any four 2M
	b)	Following are the two types of FBC boiler 1) Bubbling Fluidized Bed Combustion (BFBC) 2) Circulating Fluidized Bed Combustion (CFBC).	1M each
	c)	**Advantages of Steam Power Plant – (four points – 2 marks)** 1) The fuel used is quite cheap. 2) It can be installed at any place irrespective of the existence of coal. The coal can be transported to the site of the plant by rail or road. 3) Economical in initial cost compared to hydro plants 4) Running costs are less compared to gas plants or diesel plants 5) Steam plants can withstand for overload for certain extent	2M
	d)	Waste heat is the heat which is not used and exhausted out as a waste product. In thermal power plant large quantity of heat at lower thermal potential (70^0c) is discharged to the atmosphere. If we recover this heat, there will be reduction in fuel consumption, lower harmful emissions and improvement in production efficiency.	2M

	e)	List of nuclear fuel 1. Uranium-235 2. Plutonium-239 3. Uranium – 233 4. Thorium	½ M EACH
	f)	i. Fixed Cost – It is the capital invested in the installation of complete plant. It includes the cost of land, building, equipments, transmission and distribution lines, cost of planning and designing the plant sub-stations and many others. ii. Depreciation cost – It is the amount to get aside per year from the income of the plant to meet the depreciation caused due to wear and tear of the equipments	1M each
	g)	Limitations of Diesel Power Plant 1. The plant has high running charges as the fuel used is costly. 2. The [plant can only generate small power. 3. The maintenance charges are generally high. 4. The cost of lubrication is generally high. 5. The plant does not work satisfactorily under overload conditions for a longer period. 6. Noisier in operation.	Any four 2M
Q.2	a)	Classification of hydroelectric power plants- 1. According to the availability of head • High head power plants • Medium head power plants • Low head power plants 2. According to the nature of load • Base load plants • Peak load plants 3. According to quantity of water available • *Run-off river power plants without pondage.* • *Run-off river power plants with pondage* • *Reservoir power plants.* • *Pump storage plants* • *Mini and micro Hydel plants*	4M

<table>
<tr><td></td><td>b)</td><td>Following procedure is adopted to do maintenance of major components of high pressure boiler

<u>General Maintenance</u>

Even though the boiler has electrical and mechanical devices that make it automatic or semi-automatic in operation, these devices require systematic and periodic maintenance. Any "automatic" features do not relieve the operator from responsibility, but rather free him from certain repetitive chores, providing him with time to devote to upkeep and maintenance.

<u>Shift Maintenance</u>

Shift maintenance should include checking the boiler water level in the gauge glass and the boiler steam pressure on the gauge. Operate the intermittent blow down valve to remove any accumulated solids in the mud drum. The valves on the water column and gauge glass should be operated to make sure these connections are clear. Monitor water chemistry to adjust the chemical feed treatment and continuous blow down as required, to remain within water treatment guidelines established by the Owner's water treatment consultant.

<u>Daily Maintenance</u>

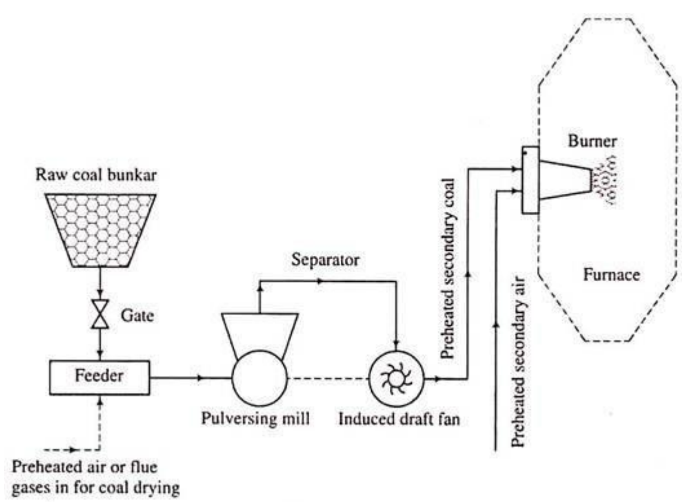
Daily Maintenance should include a check of the burner operation, including fuel pressure, atomizing air or steam pressure, visual appearance, etc. Clean the observation ports during periods of low fire or shutdown. Test the boiler level alarms and low water cutoff. Maintain a daily schedule of soot blowing.

<u>Monthly Maintenance</u>

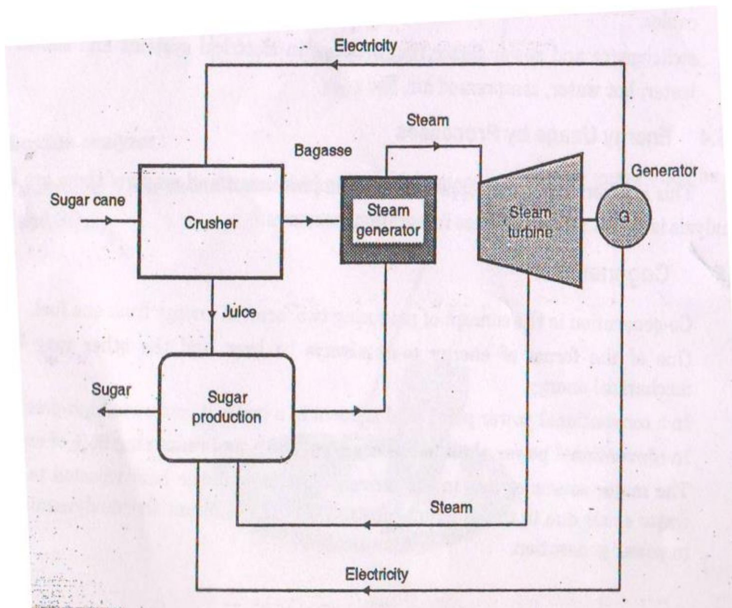
Follow the recommendations of you authorized inspector pertaining to safety valve inspection and testing. The frequency of testing, either by the use of the lifting lever or by raising the steam pressure, should be based on the recommendation of your authorized inspector. Test the boiler safety valves in accordance with the manufacturer's instructions to be absolutely sure that the valves have not corroded shut.

<u>Annual Maintenance</u>

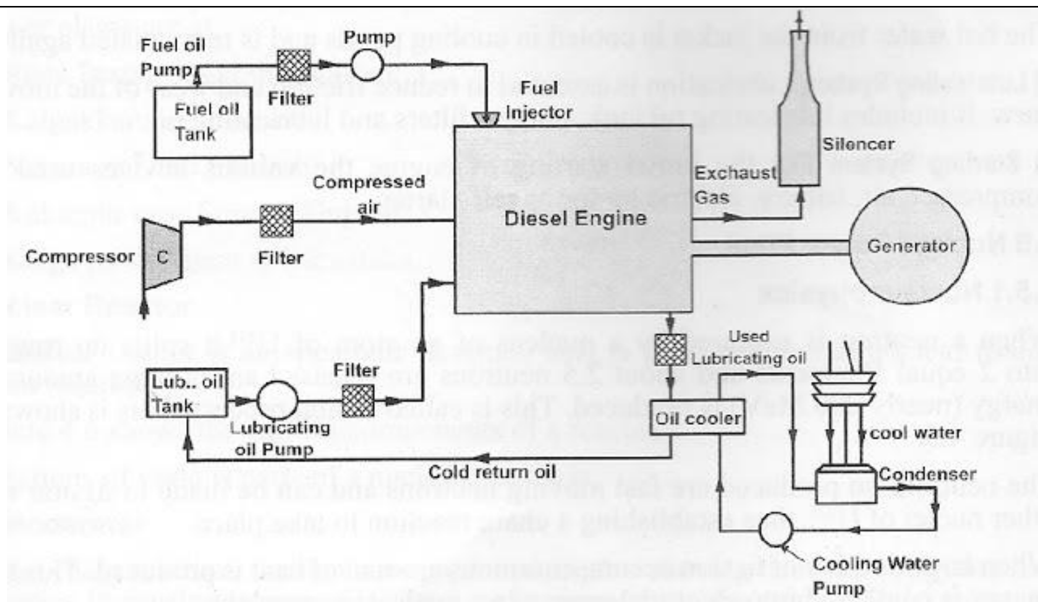
Clean both the heating and heated sides of the boiler. Remove all man way and hand hole covers. Open all bottom blow down and drain valves. Hose the inside of the boiler with clean water under high pressure. Use a hand scraper to remove accumulated sludge and scale. Start near the top and work toward the bottom. After cleaning tube exteriors, inspect the tube surfaces for signs of overheating, such as bulging, blackened surfaces in the tubes, etc.</td><td>4M</td></tr>
<tr><td></td><td>c)</td><td>Layout of solid fuel handling system used in steam power plant -



Unit system</td><td>4M</td></tr>
</table>

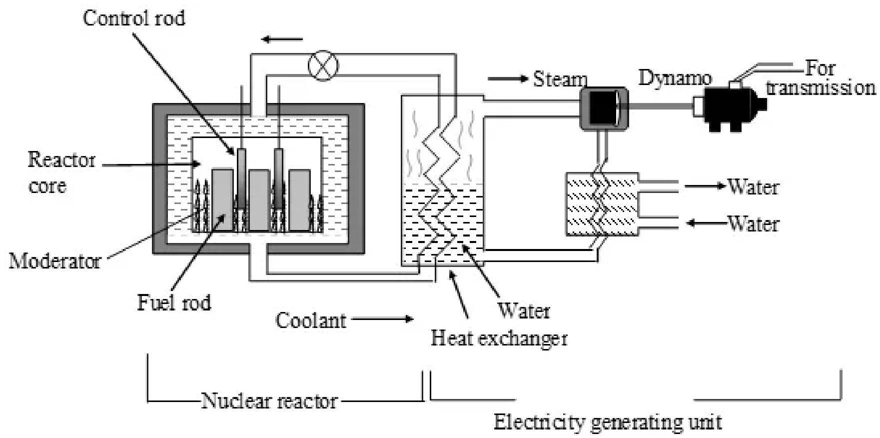
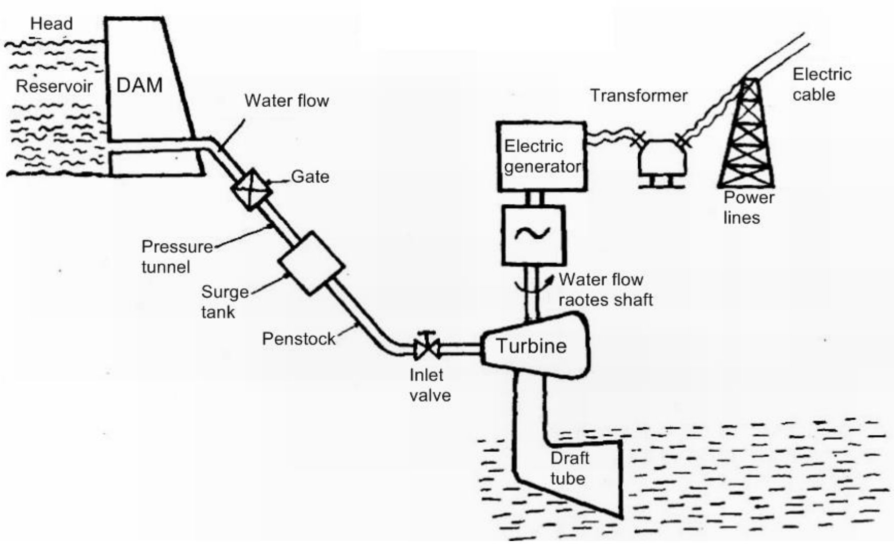
<table>
<tr>
<td></td>
<td>d)</td>
<td>
Co-generation is procedure for generating electric power and useful heat in a single installation. The useful heat may be in the form of steam, hot water, or hot air. In the cogeneration system, a mechanical work is converted into electrical energy in an electric generator and the discharged heat, which would otherwise be dispersed to the environment, is utilized in an industrial process or in other ways. The net result is an overall increase in the efficiency of fuel utilization.
In sugar factory juice is extracted from cane and bagasse is burned to generate steam. The steam is sent to steam turbine to generate electricity. Extracted steam and low pressure steam from turbine is used in the process of sugar manufacturing


</td>
<td>2M

2M</td>
</tr>
<tr>
<td>Q.3</td>
<td>a)</td>
<td>


Diesel Engine Power Plant
</td>
<td>4M</td>
</tr>
</table>

	b)	**Advantages of Gas Power Plant**- 1) Less vibrations hence perfect balancing is possible 2) Mechanical efficiency is high up to 90% 3) Continues power developing hence torque characteristics are better 4) Work developed per kg of air is more 5) Less weight per HP 6) Lubrication and ignition is simple 7) Specific fuel consumption is constant 8) Installation and maintenance costs are less	ANY FOUR 4M
	c)	**Trigeneration Concept:** Trigeneration is the simultaneous process of cooling, heating and power generation from only one fuel input. Trigeneration is the process by which some of heat produced by co-generation plant is used to generate chilled water for air conditioning or refrigeration. Thermal power plants are used to produce electricity. The byproduct is waste heat, which is then directed to absorption chillers and boilers for space cooling, hot water and related purposes. Because of trigeneration we have, • High efficiency production of electricity and heat • Reduced fuel and energy costs • Lower electrical usage during peak summer demand • Engine heat can be used to produce steam of hot water for onsite use • Significant reductions in greenhouse gas emissions No harmful chemical pollutants since water is used as the refrigerant Opportunities in thermal power plants: In thermal power plants the high pressure vapour produced by a boiler is expanded in the turbine generates electricity and the heat is then available as low pressure steam. This steam is then utilized for heating and cooling. Also exhaust gases (flue gas) from boiler after producing steam is utilized in trigeneration.	3M 1M
	d)	Nuclear power plant A nuclear reactor is a special apparatus used to perform nuclear fission. Since the nuclear fission is radioactive, the reactor is covered by a protective shield. Splitting up of nuclei of heavy atoms is called as nuclear fission, during which huge amount of energy is released. Nuclear fission is done by bombarding slow moving neutrons on the nuclei of heavy element. As the nuclei break up, it releases energy as well as more neutrons which further cause fission of neighboring atoms. Hence, it is a chain reaction and it must be controlled, otherwise it may result in explosion. The heat energy released then passed through heat exchanger, the primary coolant transfers heat t**o the secondary coolant (water)and** water from the secondary loop is converted into steam. The primary system and secondary system are closed loop, and they are never allowed to mix up with each other. Thus, heat exchanger helps in keeping secondary system free from radioactive stuff. This generated steam is passed through a steam turbine, which runs due to pressure of the steam. As the steam is passed through the turbine blades, the pressure of steam gradually decreases and it expands in volume. The steam turbine is coupled to an alternator through a rotating shaft thus generating electrical energy.	2M

		Thus in Nuclear power plant energy transforms in the following way Nuclear energy of fuel –- Heat energy of steam --- Kinetic energy of Turbine --- Kinetic energy in alternator to Electrical energy.  Fig : Nuclear Power Plant	2M FOR SKETCH
Q.4	a)	A hydro electric power plant consists of the following: 1. Reservoir: used to store water during rainy season. This water is used to run the hydraulic turbine 2. Dam: It is a structure of considerable height built across the river. It provides working head of water for power plant 3. Gate: It is provided for controlling of flow of water from reservoir to turbine 4. Waterway and penstock: Waterway carries water from the dm to the power house. It includes canal and penstock or tunnel 5. Hydraulic turbine: These are used to convert the kinetic energy of water into mechanical energy 6. Electric Generator: The mechanical energy from turbine is converted to electrical energy.  Hydroelectric Power Plant	2M 2M FOR SKETCH

	b)	Advantages of Nuclear power plant: 1) Low greenhouse gas emission, 2) Powerful and Efficient 3) Reliable and clean electricity 4) Cheap Electricity 5) Low Fuel Cost 6) Easy Transportation Limitations of Nuclear power plant 1) Radioactive Waste 2) Nuclear Accidents 3) Initial cost of the project, 4) Major Impact on Human Life	ANY FOUR 2M ANY FOUR 2M
	c)	Factors considered for selection of type of power plant 1. Cost of Transmission of Energy: 2. Cost of Fuel: 3. Cost of Land and Taxes: 4. Requirement of Space: 5. Availability of Site for Water Power: 6. Storage Space for Fuel: 7. Transportation Facilities: 8. Availability of Cooling Water: 9. Disposal of Ash: 10. Pollution and Noise: 11. Nature of Load: 12. Reliability of Supply:	ANY EIGHT 4M
	d)	World and National scenario of demand and supply of energy: World energy consumption is the total energy produced and used by the entire human civilization. Typically measured per year, it involves all energy harnessed from every energy source applied towards humanity's endeavors across every single industrial and technological sector, across every country. It does not include energy from food, and the extent to which direct biomass burning has been accounted for is poorly documented. Being the power source metric of civilization, world energy consumption has deep implications for humanity's socio-economic-political sphere. World total primary energy consumption by fuel in 2018 Coal (27%) Natural Gas (24%)	4M

Hydro (renewables) (7%)

Nuclear (4%)

Oil (34%)

Others (renewables) (4%)

Demand of energy in India

During the fiscal year 2017-18, the utility energy availability was 1,205 billion KWh, a short fall relative to requirements of 8 billion KWh (-0.7%). Peak load met was 160,752 MW, 3,314 MW (-2%) below requirements. In the 2018 Load Generation Balance report, India's Central Electricity Authority anticipated energy surplus and peak surplus to be 4.6% and 2.5%, respectively, for the 2018–19 fiscal year It stated that power would be made available to the few states expected to face shortages from regions with a surplus, through regional transmission links From calendar year 2015 onwards, power generation in India has been less of a problem than power distribution.

Supply

India has recorded rapid growth in electricity generation since 1985, increasing from 179 TW-hr in 1985 to 1,057 TW-hr in 2012.The majority of the increase came from coal-fired plants and non-conventional renewable energy sources (RES), with the contribution from natural gas, oil, and hydro plants decreasing in 2012-2017. The gross utility electricity generation (excluding imports from Bhutan) was 1,372 billion kWh in 2018-19, representing 5.53% annual growth compared to 2017-2018.The contribution from renewable energy sources was nearly 17% of the total. In the year 2018-19, more than 50% is contributed by the renewable energy sources to the total incremental electricity generation.

	e)	Q4 (e)	04 M

Q4 (e) Plant Capacity $= 60 \times 2 + 30$

$= 150$ MW

$$\text{Avg. Load} = \frac{\text{Energy Produced / year}}{8760}$$

$$= \frac{700 \times 10^6}{8760} = 79.90 \text{ MW} \quad \text{— (1)}$$

$$\text{Plant Load factor} = \frac{79.90}{150} = 0.5326$$

$$= 53.26\% \quad \text{— (1)}$$

$$\text{Plant use factor} = \frac{\text{Actual Energy Produced}}{\text{max. possible energy that can be produced}}$$

max. possible energy that can be produced

$$= (60 \times 2 \times 7000) + (30 \times 1500)$$

$$= 840{,}000 + 45000$$

$$= 8{,}85{,}000 \text{ MWh}$$

$$= 885 \times 10^6 \text{ kWh} \quad \text{— (1)}$$

$$\therefore \text{Plant use factor} = \frac{700 \times 10^6}{885 \times 10^6}$$

$$= 0.79 \quad \text{— (1)}$$

Q.5 a)

Lamont Boiler:

Principle:

This boiler works on basic principle of forced convection. If the water is circulate by a pump inside the tube, the heat transfer rate from gas to the water is increases. It is the basic principle of it.

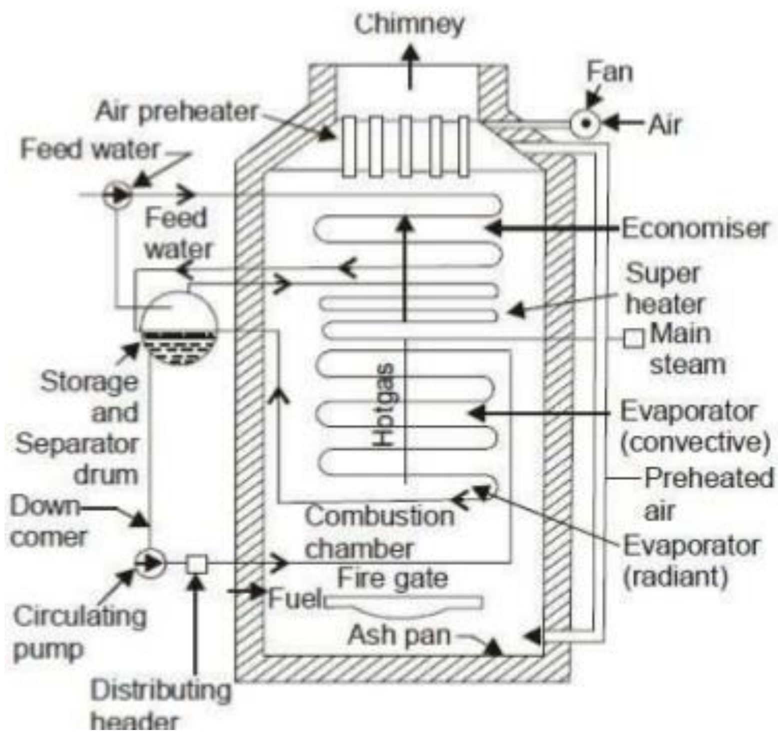
Construction: (2M)

This boiler is the first force circulation boiler. This boiler consist various part which are as follow.

Economizer:

Economizer use to preheat the water by using remaining heat of the combustion gases. It

		increases the boiler efficiency. The feed water first supplied to the economizer before entering to the boiler. Centrifugal pump: The Lamont boiler is a force convection boiler. So a centrifugal pump is used to circulate water inside the boiler. This pump is driven by a steam turbine. The steam for the turbine is taken by the boiler. Evaporator tube: The evaporator tube or can say water tubes are situated at furnace wall which increase the heating surface of boiler. This is also at the up side and down side of the furnace and other equipment. The main function of these tubes to evaporate water into steam. This also cools down the furnace wall. Grate: The space in the furnace where the fuel is burn is called grate. It is bottom side of furnace. Furnace: In the Lamont boiler vertical furnace is used. The main function of Furnace is to burn the fuel. Super heater: The steam generated by the evaporator tube is saturated steam. If it directly used in steam turbine can cause the corrosion. So the saturated steam sends to the super heater where it can increase the temperature of steam. Water steam separator drum: The steam separator is situated outside from the boiler. The mixture of water and steam from the evaporator tube send to the steam separator where it separate the steam and send it to super heater. The remaining water again sends to the economizer. Air preheater: It's main function to preheat air before entering into furnace. **Working:** Lamont boiler is a forced circulation, internally fired water tube boiler. The fuel is burn inside the boiler and the water is circulating by a centrifugal pump through evaporator tubes. The working of this boiler is as follow. A feed pump forces the water into the economizer where the temperature of water increases. This water forced into the evaporator tube by using a centrifugal pump driven by steam turbine. Water passes 10 – 15 times into the evaporator tube. The mixture of saturated steam and water is formed inside the tube. This mixture sends to the steam separator drum which is outside the boiler. Steam from the separator sends to the super heater, where the saturated steam converts into superheated steam. The water again sends to the economizer where it again passes by the evaporator tubes. The air from the air preheater enter into the furnace where fuel burn. The flue gases first	2M

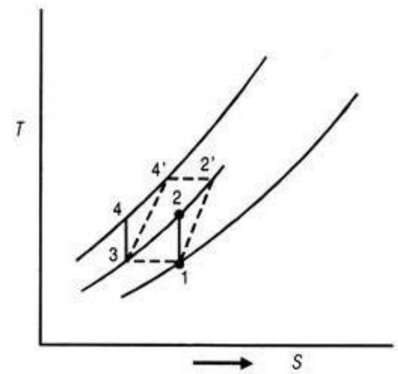
		heat the evaporator tube then passes by the super heater. These gases from the super heater again use to preheat the air into air preheater before exhaust into atmosphere. This working pressure of this boiler is above 170 bar and have the steam generation capacity of about 50000 kg/hour at temperature 773 ^{0}K .  Lamont Boiler	2M
	b)	**Intercooling Method to improve the thermal efficiency of gas turbine plant:** Net work of the gas turbine cycle can be increased either by reducing the compressor work or increasing the turbine work.. If the compression is achieved in two or more stages, the air delivered by the 1st stage of the compressor, is cooled, on its way to the next stage. This cooling of air in between the two stages is called intercooling. When the air is cooled to the temperature of air entering any stage, intercooling is called perfect intercooling. 1- 2 Isentropic compression in first stage 2- 3 Intercooling between the stages 3-4 Isentropic compression in the second stage 1-5 Isentropic compression without intercooling Vertical distance between 3-4 is less than the vertical distance 2-5 and therefore, [(1-2) + (3-4)] < (1-5) ∴ The compression work is reduced while the turbine work remains same when other data remains same. ∴ Network = $W_t – W_{ci}$ = Constant – reduces W_c	4M

> $W_t - W_c$

Where $W_c = h_5 - h_1$

W_{ci} = Compression work with intercooling.

When the intercooling is perfect and when the intermediate pressure is the geometric mean ($P_2 = \sqrt{p_1 \times p_3}$) then the compression work is minimum. 2M



c) In a Pressurised Water Reactor (PWR), ordinary (light) water is utilized to remove the heat produced inside the reactor core by nuclear fission. This water also slows down (or moderates) neutrons (constituents of atom nuclei that are released in the nuclear fission process). Slowing down neutrons is necessary to sustain the nuclear chain reaction (neutrons have to be moderated to be able to break down the fissile atom nuclei). 4M

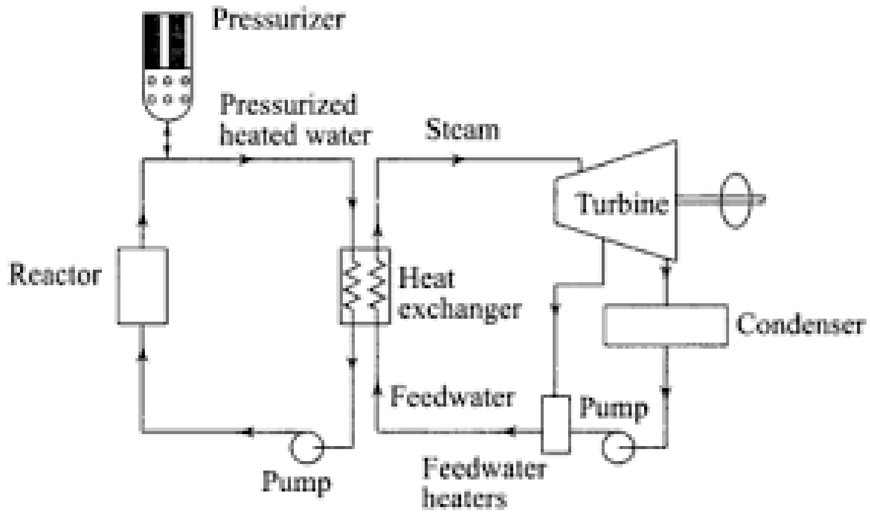
The heat produced inside the reactor core is transferred to the turbine through the steam generators. Only heat is exchanged between the reactor cooling circuit (primary circuit) and the steam circuit used to feed the turbine (secondary circuit). No exchange of cooling water takes place.

The primary water is pumped through the reactor core and the primary side of the steam generators, in four parallel closed loops, by coolant pumps powered by electric motors. Each loop is equipped with a steam generator and a coolant pump. The reactor operating pressure and temperature are such that the cooling water does not evaporate and remains in the liquid state, which increases its cooling effectiveness.

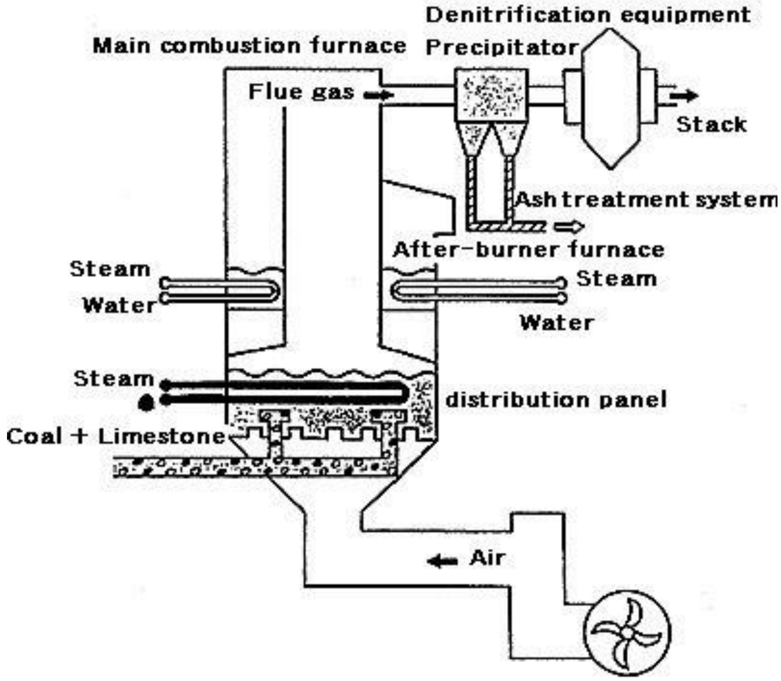
A pressuriser connected to one of the coolant loops is used to control the pressure in the primary circuit.

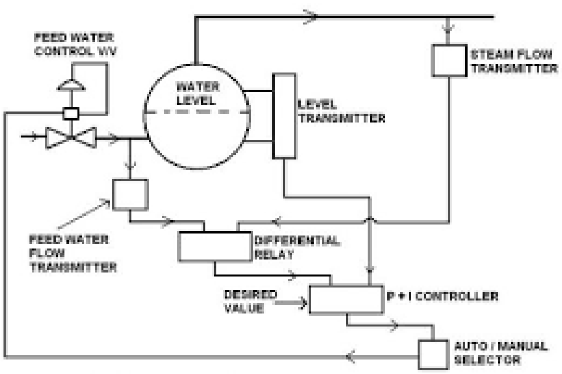
Feed water entering the secondary side of the steam generators absorbs the heat transferred from the primary side and evaporates to produce saturated steam. The steam is dried in the steam generators then delivered to the turbine.

After exiting the turbine, the steam is condensed and returns as feed water to the steam generators. The generator, driven by the turbine, generates electricity.

<table>
<tr><td></td><td></td><td>

Pressurised Water Reactor (PWR)</td><td>2M</td></tr>
<tr><td>Q.6</td><td>a)</td><td>In Fluidized Bed Combustion Boiler technology When air or gas is passed through an inert bed of solid particles such as sand supported on a fine mesh or grid, the air initially will seek a path of least resistance and pass upward through the sand. With further increase in the velocity, the air bubbles through the bed and the particles attain a state of high turbulence. Under such conditions, the bed assumes the appearance of a fluid and exhibits the properties associated with a fluid and hence the name “Fluidized Bed combustion”.
MECHANISM OF FLUIDISED BED COMBUSTION
If the sand, in a fluidized state, is heated to the ignition temperature of the fuel and the fuel is injected continuously into the bed, the fuel will burn rapidly and the bed attains a uniform temperature due to effective mixing. This, in short is fluidized bed combustion.
While it is essential that temperature of bed should be at least equal to ignition temperature of fuel and it should never be allowed to approach ash fusion temperature (1050°C TO 1150°C) to avoid melting of ash. This is achieved by extracting heat from the bed by conductive and convective heat transfer through tubes immersed in the bed.
If velocity is too low, fluidization will not occur and if the gas velocity becomes too high, the particles will be entrained in the gas stream and lost. Hence to sustain stable operation of the bed, it must be ensured that gas velocity is maintained between minimum fluidization velocity and particle entrainment velocity.
Combustion temperature Excess air level and Superficial gas residence time are the principal factors that influence combustion efficiency of a FBC boiler. Combustion efficiency of Fluidized Bed Combustion (FBC) Boiler is 90% or greater.</td><td>4M</td></tr>
</table>

<table>
<tr><td></td><td></td><td>

Fluidized Bed Combustion (FBC) boiler</td><td>2M</td></tr>
<tr><td></td><td>b)</td><td>

Boiler Feed Water Control System

The mass of the water flow and the steam flow must be regulated so mass water flow equals the mass steam flow to maintain drum level. The feed water control regulates the mass water flow to the boiler. The effects of the input control actions interact, since firing rate also affects steam temperature and feed water flow affects the steam pressure, which is the final arbiter of firing rate demand.

Economic feasibility of a power plant requires smooth and uninterrupted plant operation in spite of varying electrical power demand. It has been observed from operation experiences of a power plant that one of frequent causes of shutdowns is by violation of safety limits on the water level.

The Steam Drum level control is also an influencing factor of overall safety of the power plant as it is closely related to Main Heat Transport coolant inventory and sustained heat removal through natural circulation. Steam drum level control at multiple loop configurations has been</td><td>2M

4M</td></tr>
</table>

		proposed to enhance the safety margin. For proper control of drum level single parameter control is not sufficient, and three element Steam Drum Level Controller has been conventionally used for most of the boilers where controlling parameters are Drum level, steam flow and feed water flow. In this paper we will discuss on some the critical issues on drum level measurement and control, design aspects and installation requirements for safe and trouble-free operation.	
	c)	Q6 (c) $\text{Load factor} = \frac{\text{Avg. Load}}{\text{Peak Load}}$ $0.45 = \frac{\text{Avg. Load}}{50}$ $\text{Avg. load} = 50 \times 0.45 = 22.5\ MW$ — (2) $\text{Demand factor} = \frac{\text{Maximum demand}}{\text{Connected load}}$ $= \frac{50}{(20+17+10+9)}$ $= \frac{50}{56} = 0.892$ — (2) $\text{Diversity factor} = \frac{\text{Sum of Individual max. demands}}{\text{Simultaneous max. demand}}$ $= \frac{56}{50} = 1.12$ — (2)	