KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University)
(Established Under Section 3 of UGC Act 1956)
Pollachi Main Road, Eachanari (Po),
COIMBATORE – 21

FACULTY OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

SUBJECT NAME: POWER PLANT ENGINEERING **SUBJECT CODE : 14BEMEE18**

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INTENDED OUTCOMES:

- To understand the components and operations of steam power plants and hydel power plants
- To understand the components and operations of Nuclear power plant and Gas turbine plants

UNIT I INTRODUCTION TO POWER PLANTS AND BOILERS

Layout of Steam, Hydel, Diesel, MHD, Nuclear and Gas Turbine Power Plants – Combined Power Cycles – Comparison and Selection, Load Duration Curves.
Steam Boilers and Cycles – High Pressure and Super Critical Boilers – Fluidised Bed Boilers

UNIT II STEAM POWER PLANT

Fuel and Ash Handling, Combustion Equipment for burning coal, Mechanical Stokers, Pulveriser, Electrostatic Precipitator, Draught – different types, Surface Condenser Types, Cooling Towers

UNIT III NUCLEAR AND HYDEL POWER PLANTS

Nuclear Energy – Fission, Fusion Reaction, Types of Reactors, pressurized water reactor, Boiling Water Reactor, Waste Disposal and safety.
Hydel Power Plant – Essential Elements, Selection of Turbines, Governing of Turbines– Micro Hydel developments.

UNIT IV DIESEL AND GAS TURBINE POWER PLANT

Types of Diesel Plants, Components, Selection of Engine Type, Applications Gas Turbine Power Plant – Fuels – Gas Turbine Material – Open and Closed Cycles – Reheating – Regeneration and Intercooling – Combined Cycle.

UNIT V OTHER POWER PLANTS AND ECONOMICS OF POWER PLANTS

Geo thermal –OTEC – Tidel – Pumped storage – Solar thermal central receiver system.
Cost of Electric Energy – Fixed and operating Costs – Energy Rates – Types of Tariffs – Economics of load sharing, comparison of economics of various power plants.

TEXT BOOKS:

S.NO	AUTHOR(S) NAME	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1	Arora S.C and Domkundwar S	A course in Power Plant Engineering	Dhanpatrai Publishers, New Delhi.	1984

REFERENCES:

S.NO	AUTHOR(S) NAME	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1	Nag P.K	Power plant Engineering	Tata McGraw–Hill, New Delhi.	2007
2	Rajput R.K	Power Plant Engineering	Laxmi Publications, Chennai.	2005
3	Morse Frederick T	Power Plant Engineering	Prentice Hall of India, New Delhi.	1998

WEBSITES :

1. www.igcar.gov.in
2. ga.water.usgs.gov
3. www.mapsofindia.com
4. www.solarpaces.org

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FACULTY OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

LESSON PLAN

Subject Name : POWER PLANT ENGINEERING Subject Code : 14BEMEE18

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – I INTRODUCTION TO POWER PLANTS & BOILERS			
1.	1	**Fundamentals**: Steam – types, properties and applications. Fuels – Calorific value	**WEBSITE**
2.	1	Generator working principle, Fleming's rule, renewable and non renewable resources	
3.	1	Nuclear energy, fission and fusion reactions	
4.	1	Layout of Steam Power Plants	T [1]:5.1-5.9
5.	1	Layout of Hydel Power Plants	T [1]:3.1-3.8
6.	1	Layout of Diesel Power Plants	T [1]:23.6-23.16
7.	1	Layout of MHD Power Plants	R [1]:856-863
8.	1	Layout of Nuclear Power Plants	T [1]:28.24-28.38
9.	1	Layout of Gas Turbine Power Plants, Combined Power Cycles Comparison and Selection of power plants, Load Duration Curves	T [1]:24.1-24.9, T [1]:25.5-25.12, R [1]:2-9
10.	1	Steam Boilers and Cycles, High Pressure and Super Critical Boilers – Fluidized Bed Boilers	T [1]:13.1-13.3, 13.13-13.14, 15.2-15.8
11.	1	Video lecture: videos based on working of steam, hydel and Diesel power plants	**VIDEOS**
12.	1	Discussion of previous year questions	KAHE ESE Questions
Total No. of Hours Planned for Unit - I			**12**
Sl. No.	**No. of Periods**	**Topics to be Covered**	**Support Materials**
UNIT – II STEAM POWER PLANT			
13.	1	Fuel handling system	T [1]:7.2-7.11

14.	1	Ash Handling system	T [1]:9.2-9.9
15.	1	Combustion Equipment for burning coal, Mechanical Stokers	T [1]:8.2-8.8
16.	1	Pulveriser	T [1]:8.13-8.19
17.	1	Electrostatic Precipitator	T [1]:9.16-9.23
18.	1	Draught – different types	T [1]:12.4-12.9
19.	1	Surface Condenser Types, Cooling Towers	T [1]:17.4-17.9, 18.10-18.20
20.	1	Video lecture: Videos based on fuel handling and ash handling systems	**VIDEOS**
21.	1	Discussion of previous year questions	KAHE ESE Questions
Total No. of Hours Planned for Unit - II			**09**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – III NUCLEAR AND HYDEL POWER PLANTS			
22.	1	Nuclear Energy – Fission	T [1]:27.2-27.7, 27.14-27.18
23.	1	Nuclear Energy Fusion Reaction	T [1]:27.14
24.	1	Types of Reactors, pressurized water reactor	T [1]:28.6-28.8
25.	1	Boiling Water Reactor	T [1]:28.8-28.10
26.	1	Waste Disposal and safety	T [1]:30.6-30.12
27.	1	Hydel Power Plant – Essential Elements, Selection of Turbines	T [1]:4.2-4.25, 4.43-4.48
28.	1	Difference between Impulse & reaction turbine, Micro Hydel developments, Governing of Turbines	T [1]:4.48-4.52
29.	1	Video lecture: Videos based on Nuclear fission, fusion process and Nuclear power plants	**VIDEOS**
30.	1	Discussion of previous year questions	KAHE ESE Questions
Total No. of Hours Planned for Unit - III			**09**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – IV DIESEL AND GAS TURBINE POWER PLANT			
31.	1	Types of Diesel Plants, Components	T [1]:23.3-23.10

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
32.	1	Selection of Engine Type, Applications	T [1]:23.4-23.5
33.	1	Gas Turbine Power Plant	T [1]: 24.2-24.9
34.	1	Fuels – Gas turbine material	T [1]:24.18-24.24
35.	1	Open and Closed Cycles	T [1]:24.9-24.14
36.	1	Reheating – Regeneration Intercooling	T [1]:22.3-22.16
37.	1	Combined Cycle	T [1]:22.3-22.16
38.	1	Video lecture: Videos based on Brayton cycle, Intecooling	**VIDEOS**
39.	1	Discussion of previous year questions	KAHE ESE Questions
Total No. of Hours Planned for Unit - IV			**09**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – V OTHER POWER PLANTS AND ECONOMICS OF POWER PLANTS			
40.	1	Geo thermal power plant	T [1]: 31.3-31.9,
41.	1	OTEC power plant	R [1]:917-918
42.	1	Tidel power plant, Pumped storage system	T [1]:31.9-31.14, R [1]:816-818
43.	1	Solar thermal central receiver system	R [1]:899-905
44.	1	Cost of Electric Energy – Fixed and operating Costs	T [1]:34.2-34.4, R [1]:10-17
45.	1	Energy Rates – Types of Tariffs,	T [1]:34.12-34.14
46.	1	Economics of load sharing	T [1]:34.12-34.14
47.	1	Video lecture: Videos based on Geo thermal and OTEC power plants	**VIDEOS**
48.	1	Discussion of previous year questions	KAHE ESE Questions
Total No. of Hours Planned for Unit - V			**09**

TEXT BOOKS

T [1] - Arora S.C and S. Domkundwar, 1984, A course in Power Plant Engineering, Dhanpatrai Publishers

REFERENCES

R [1] - Nag P.K, 2007, Power plant Engineering, Tata McGraw-Hill
R [2] - Rajput R. K, 2005, Power Plant Engineering, Laxmi Publications
R [3] - Morse Frederick T, 1998, Power Plant Engineering, Prentice Hall of India

WEBSITES

5. www.solarpaces.org
6. www.igcar.gov.in
7. ga.water.usgs.gov
8. www.mapsofindia.com

JOURNALS

J [1] - Omidali Akbari et al. Evaluation of supply boiler repowering of an existing natural gas-fired steam power plant. Applied Thermal Engineering. Volume 124, September 2017, Pages 897-910.

J [2] - Robertas et al. Investigation of warm gas clean-up of biofuel flue and producer gas using electrostatic precipitator. Energy. Volume 143, 15 January 2018, Pages 943–949.

J [3] - Paul et al. Effects of Boiling Water Reactor Medium on the Fatigue Life of Austenitic Stainless Steels. Journal of Pressure Vessel Technology. Volume 138, Issue 3, 22 February 2016, 6 pages.

J [4] - Ibrahim et al. Statistical analysis and optimum performance of the gas turbine power plant. International Journal of Automotive and Mechanical Engineering; Kuantan Vol. 13, (Jun 2016): 3215-3225.

J [5] - Soo-Hwang et al. Performance prediction of a prototype tidal power turbine by using a suitable numerical model. Renewable Energy. Volume 113, December 2017, Pages 293-302.

TOTAL NUMBER OF COURSE HOURS : 48 Hrs

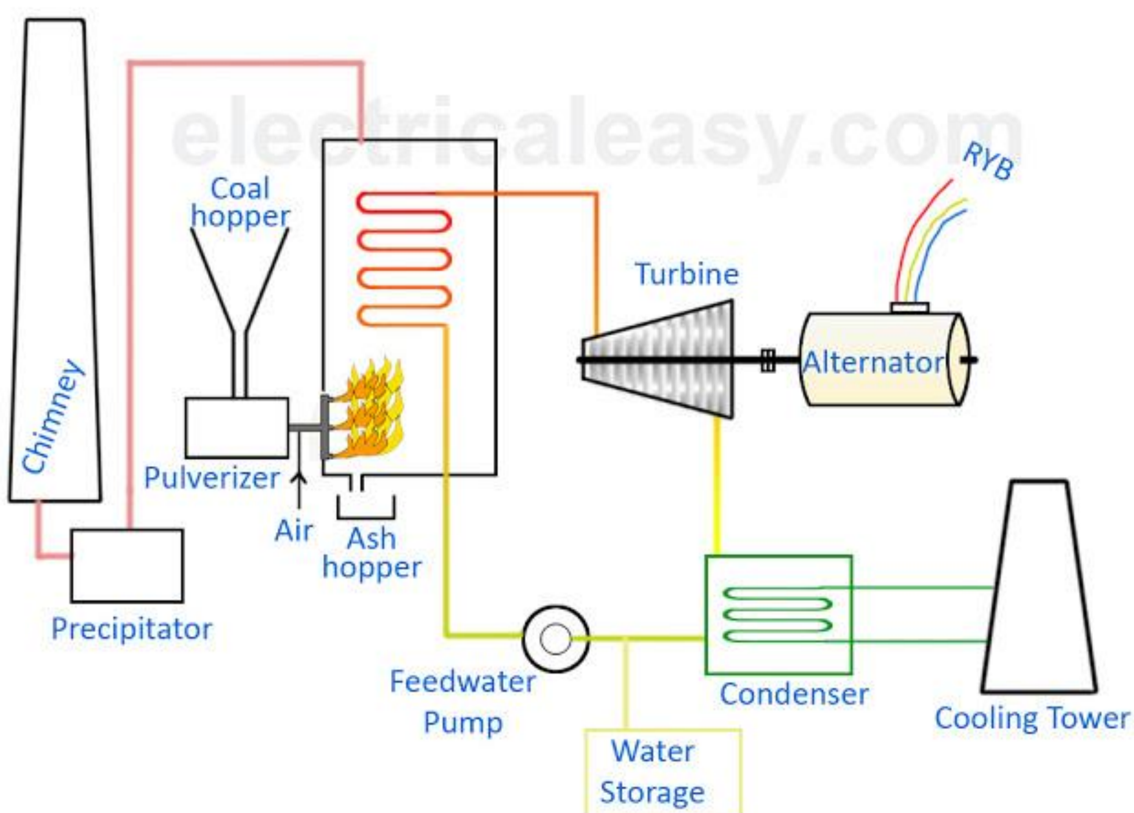
Unit – I

INTRODUCTION TO POWER PLANTS & BOILERS

LECTURE NOTES

STEAM POWER PLANT:

A thermal power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankine cycle. The greatest variation in the design of thermal power stations is due to the different fuel sources. Some prefer to use the term *energy center* because such facilities convert forms of heat energy into electricity. Some thermal power plants also deliver heat energy for industrial purposes, for district heating, or for desalination of water as well as delivering electrical power. A large proportion of CO_2 is produced by the worlds fossil fired thermal power plants; efforts to reduce these outputs are various and widespread.



-Coal andAshCircuit

-AirandGasCircuit

- Feed Water and Steam Circuit

- Cooling Water Circuit

Coal and Ash Circuit

Coal and Ash circuit in a thermal power plant layout mainly takes care of feeding the boiler with coal from the storage for combustion. The ash that is generated during combustion is collected at the back of the boiler and removed to the ash storage by scrap conveyors. The combustion in the Coal and Ash circuit is controlled by regulating the speed and the quality of coal entering the grate and the damper openings.

Air and Gas Circuit

Air from the atmosphere is directed into the furnace through the air preheated by the action of a forced draught fan or induced draught fan. The dust from the air is removed before it enters the combustion chamber of the thermal power plant layout. The exhaust gases from the combustion heat the air, which goes through a heat exchanger and is finally let off into the environment.

Feed Water and Steam Circuit

The steam produced in the boiler is supplied to the turbines to generate power. The steam that is expelled by the prime mover in the thermal power plant layout is then condensed in a condenser for re-use in the boiler. The condensed water is forced through a pump into the feed water heaters where it is heated using the steam from different points in the turbine. To make up for the lost steam and water while passing through the various components of the thermal power plant layout, feed water is supplied through external sources. Feed water is purified in a purifying plant to reduce the dissolve salts that could scale the boiler tubes.

Cooling Water Circuit

The quantity of cooling water required to cool the steam in a thermal power plant layout is significantly high and hence it is supplied from a natural water source like a lake or a river. After passing through screens that remove particles that can plug the condenser tubes in a thermal power plant layout, it is passed through the condenser where the steam is condensed. The water is finally discharged back into the water source after cooling. Cooling water circuit can also be a closed system where the cooled water is sent through cooling towers for re-use in the power plant. The cooling water circulation in the condenser of a thermal power plant layout helps in maintaining a low pressure in the condenser all throughout.

COMBINED POWER CYCLES:

In electric power generation a **combined cycle** is an assembly of heat engines that work in tandem off the same source of heat, converting it into mechanical energy, which in turn usually drives electrical generators. The principle is that the exhaust of one heat engine is used as the heat source for another, thus extracting more useful energy from the heat, increasing the system's overall efficiency. This works because heat engines are only able to use a portion of the energy their fuel generates (usually less than 50%).

The remaining heat (e.g., hot exhaust fumes) from combustion is generally wasted. Combining two or more thermodynamic cycles results in improved overall efficiency, reducing fuel costs. In stationary power plants, a successful, common combination is the Brayton cycle (in the form of a turbine burning natural gas or synthesis gas from coal) and the Rankine cycle (in the form of a steam power plant). Multiple stage turbine or steam cylinders are also common.

LOAD DURATION CURVE:

A **load duration curve** (LDC) is used in electric power generation to illustrate the relationship between generating capacity requirements and capacity utilization.

A LDC is similar to a load curve but the demand data is ordered in descending order of magnitude, rather than chronologically. The LDC curve shows the capacity utilization requirements for each increment of load. The height of each slice is a measure of capacity, and the width of each slice is a measure of the utilization rate or capacity factor. The product of the two is a measure of electrical energy (e.g. kilowatthours).

HIGH PRESSURE BOILERS:

A **boiler** is a closed vessel in which water or other fluid is heated. The heated or vaporized fluid exits the boiler for use in various processes or heating applications.

Most boilers produce steam to be used at saturation temperature; that is, saturated steam. Superheated steam boilers vaporize the water and then further heat the steam in a *superheater*. This provides steam at much higher temperature, but can decrease the overall thermal efficiency of the steam generating plant because the higher steam temperature requires a higher flue gas exhaust temperature. There are several ways to circumvent this problem, typically by providing an *economizer* that heats the feed water, a combustion air heater in the hot flue gas exhaust path, or both. There are advantages to superheated steam that may, and often will, increase overall efficiency of both steam generation and its utilisation: gains in input temperature to a turbine should outweigh any cost in additional boiler complication and expense. There may also be practical limitations in using *wet* steam, as entrained condensation droplets will damage turbine blades.

Superheated steam presents unique safety concerns because, if any system component fails and allows steam to escape, the high pressure and temperature can cause serious, instantaneous harm to anyone in its path. Since the escaping steam will initially be completely superheated vapor, detection can be difficult, although the intense heat and sound from such a leak clearly indicates its presence.

Superheater operation is similar to that of the coils on an air conditioning unit, although for a different purpose. The steam piping is directed through the flue gas path in the boiler furnace. The temperature in this area is typically between 1,300–1,600 degrees Celsius. Some superheaters are radiant type; that is, they absorb heat by radiation. Others are convection type, absorbing heat from a fluid. Some are a combination of the two types. Through either method, the extreme heat in the flue gas path will also heat the superheater steam piping and the steam within. While the temperature of the steam in the superheater rises, the pressure of the steam does not: the turbine or moving pistons offer a *continuously expanding space* and the pressure remains the same as that of the boiler. Almost all steam superheater system designs remove droplets entrained in the steam to prevent damage to the turbine blading and associated piping.

SUPERCRITICAL BOILER:

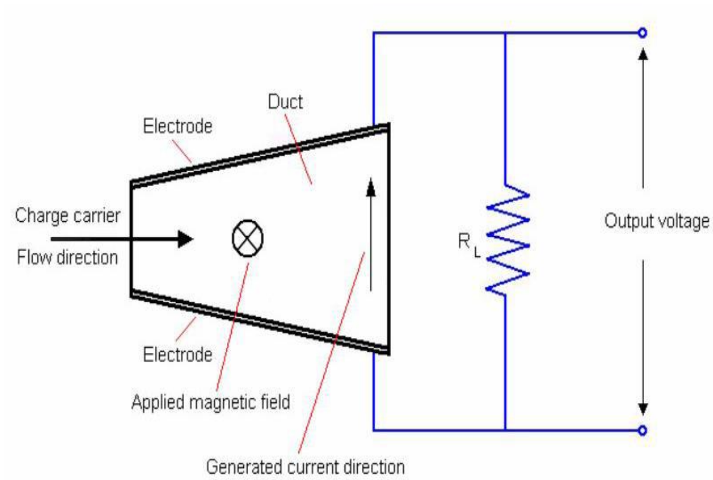
Supercritical steam generators (also known as Benson boilers) are frequently used for the production of electric power. They operate at "supercritical pressure". In contrast to a "subcritical boiler", a supercritical steam generator operates at such a high pressure (over 3,200 psi/22.06 MPa or 220.6 bar) that actual boiling ceases to occur, and the boiler has no water - steam separation. There is no generation of steam bubbles within the water, because the pressure is above the "critical pressure" at which steam bubbles can form. It passes below the critical point as it does work in the high pressure turbine and enters the generator's condenser. This is more efficient, resulting in slightly less fuel use. The term "boiler" should not be used for a supercritical pressure steam generator, as no "boiling" actually occurs in this device.

FLUIDIZED BED BOILERS:

The major portion of the coal available in India is of low quality, high ash content and low calorific value. The traditional grate fuel firing systems have got limitations and are techno-economically unviable to meet the challenges of future. Fluidized bed combustion has emerged as a viable alternative and has significant advantages over conventional firing system and offers multiple benefits – compact boiler design, fuel flexibility, higher combustion efficiency and reduced emission of noxious pollutants such as SOx and NOx. The fuels burnt in these boilers include coal, washery rejects, rice husk, bagasse & other agricultural wastes. The fluidized bed boilers have a wide capacity range- 0.5 T/hr to over 100 T/hr.

MAGNETOHYDRODYNAMIC POWER GENERATION (MHD)

The magnetohydrodynamic power generator[8] is a device that generates electric power by means of the interaction of a moving fluid (usually a ionized gas or plasma) and a magnetic field. As all direct conversion processes the MHD generators can also convert thermal energy directly into electricity without moving parts. In this way the static energy converters, with no moving mechanical part, can improve the dynamic conversion, working at temperature more higher than conventional processes. The typical configuration of MHD generator is shown in Figure.



In the MHD system, the kinetic energy of the gas is converted directly to electric energy as it is allowed to expand. When a high velocity gas flows into convergent-divergent duct and passes through the magnetic field an e.m.f is induced, mutual perpendicular to the magnetic field direction and to the direction of the gas flow. Electrodes in opposite side walls of the MHD flow channel provide an interface to an external circuit. Electrons pass from the fluid at one wall to an electrode, to an external load, to the electrode on the opposite wall, and then back to the fluid, completing a circuit.

In the MHD generator the advantage of having no moving parts allows to work at higher temperatures than a conventional energy conversion. It is possible to work with temperature around 3000K, and a these temperature the maximum theoretical efficiency would be near 90%.

MULTIPLE CHOICE QUESTIONS

Questions	Opt1	Opt2	Opt3	Opt4	Answer
Out of the following which one is not a unconventional source of energy?	Tidal power	Geothermal energy	Nuclear energy	Wind power	Nuclear energy
A thermal power station is a power plant in which the ______ is steam driven	water mover	dams	prime mover	head race	prime mover
In thermal power plant ____ is heated, turns into steam and spins a steam turbine which drives an electrical generator	kerosene	oil	Water	mercury	Water
________in a thermal power plant layout mainly takes care of feeding the boiler with coal from the storage for combustion	Coal and Ash circuit	Air and Gas Circuit	Feed Water and Steam Circuit	Cooling Water Circuit	Coal and Ash circuit
Hydroelectric power plants convert the hydraulic _______ from water into electrical energy	potential energy	kinetic energy	mechanical energy	electrical energy	potential energy
_______ are structures built over rivers to stop the water flow and form a reservoir	Water mover	Dams	Prime mover	Head race	Dams
The height of water in the dam is called _____	surge tanks	penstocks	spillway	head race	head race
A ______ as the name suggests could be called as a way for spilling of water from dams	Surge tanks	Penstocks	spillway	head race	spillway
______ are pipes which carry water from the reservoir to the turbines inside power station	Surge tanks	Penstocks	spillway	head race	Penstocks
________ are tanks connected to the water conductor system	Surge tanks	Penstocks	spillway	head race	Surge tanks
Power station contains a _______ coupled to a generator	compressor	turbine	engine	motor	turbine

Diesel power plants produce power from a ______	diesel engine	motor	compressor	turbine	diesel engine
______ power is the use of sustained Nuclear fission to generate heat and do useful work	Diesel	Hydel	Steam	Nuclear	Nuclear
Nuclear power provides about ____ of the world's energy	26%	6%	16%	60%	6%
A ______ is used in electric power generation to illustrate the relationship between generating capacity requirements and capacity utilization	mass duration curve	valve duration curve	semi duration curve	load duration curve	load duration curve
In thermal power the ash that is generated during combustion is collected at the back of the boiler and removed to the ash storage by ______	scrap conveyors	solar conveyors	spring conveyors	screw conveyors	scrap conveyors
The ______ in the Coal and Ash circuit is controlled by regulating the speed and the quality of coal entering the grate	conduction	convection	conjuction	combustion	combustion
In thermal power plant the air from the atmosphere is directed into the furnace through the air preheated by the action of a ______	forced draught fan	stoker	induced draught fan	Tunnel	forced draught fan
Dams are also used for controlling ____	tunnels	waves	storms	floods	floods
Superheated steam boilers vaporize the water and then further heat the steam in a ______	superheater	stoker	Draught	Tunnel	superheater
The ____ piping is directed through the flue gas path in the boiler furnace	water	kerosene	oil	steam	steam
_____ conveyors can be fed by a continuous slot hopper or bunker beneath the stockpile to reclaim material	Superheater	Stoker	Draught	Tunnel	Tunnel

A mechanical ______ is a device which feeds coal into the firebox of a boiler	superheater	stoker	Draught	Tunnel	stoker
_____ is obtained by forcing air into the furnace by means of a fan and ductwork	superheater	stoker	Draught	Tunnel	Draught
Forced draught furnaces usually have a _____ pressure	positive	negative	balance	zero	positive
_____ draught is obtained through use of both induced and forced draught	positive	negative	balanced	zero	Balanced
The _____ turbine itself is a device to convert the heat in steam to mechanical power	water	kerosene	oil	steam	steam

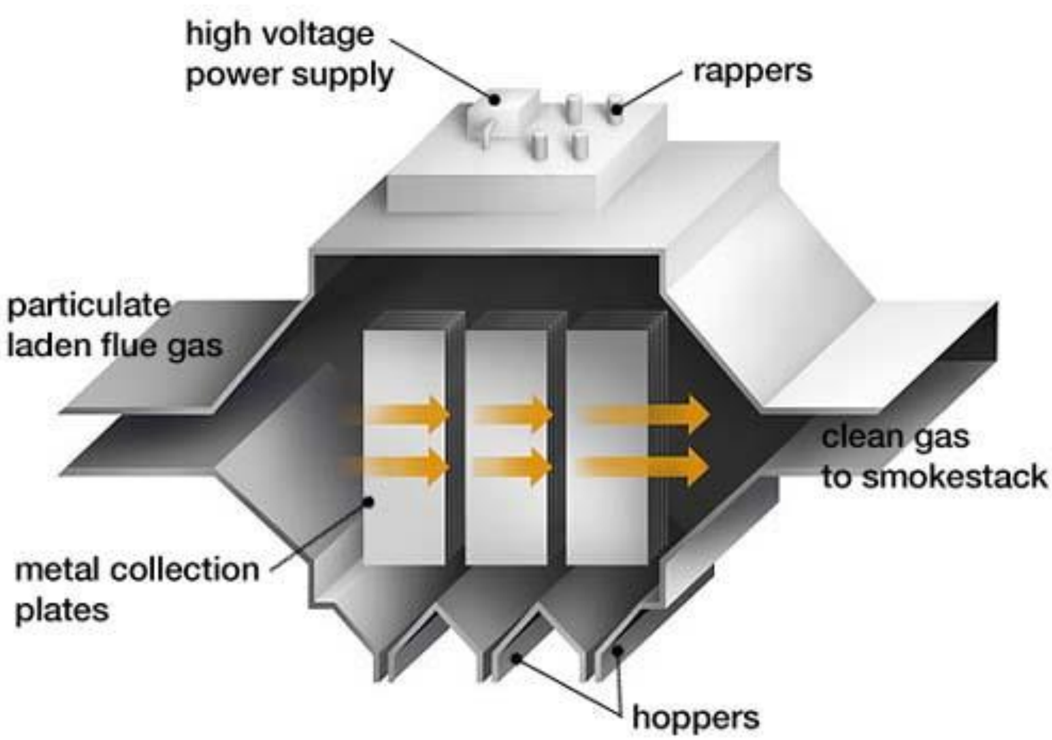
Unit – II

STEAM POWER PLANT

LECTURE NOTES

ELECTROSTATIC PRECIPITATOR

The electrostatic precipitators are extensively used in removal of fly ash from electric utility boiler emissions. The use of this collector is growing rapidly because of the new strict air quality codes. An electrostatic precipitator can be designed to run at any desired efficiency for use as a primary collector or as a supplementary unit to a cyclone collector. It is often considered worthwhile to retain an existing cyclone as a primary collector in cases where collection efficiencies must be upgraded especially where there is large amount of unburnt carbon in fly ash(about 15%) because the presence of large quantities of carbon in the gas can adversely affect the collection efficiency of a precipitator.



The dust laden gas is passed between oppositely charged conductors and it becomes ionized as the voltage applies between the conductors is sufficiently large. As the dust laden ad is passed through these highly charged electrodes, both negative and positive ions are formed, the later being as high as 80%. The ionized gas is further passed through the collecting units which consist of a set of vertical metal plates. Alternate plates are positively charged and earthed. As the alternate plates are earthed, high intensity electrostatic field exerts a force on positively charged dust particles and drives them toward the grounded plates. The deposited dust particles are removed from the plates by giving the shaking motion to the plates with the help of cam driven by external means. The dust removed from the plates with the help of shaking motion is collected in the dust hoppers. Care should be taken that the dust collector in the hopper should not be entrained in the clean gas.The advantages and disadvantages of this collector are listed below:

ADVANTAGES:

This is more effective to remove very small particles like smoke, mist and fly ash. Its range of dust removal is sufficiently large (0.01 micron to 1.00 micron). The small dust particles below 10 microns cannot be removed with the help of mechanical separators and wet scrubbers cannot be used if sufficient water is now available. Under these circumstances, this type is very effective.

- This is also most effective for high dust loaded gas (as high as 100 grams per cu. meter)
- The draught loss of this system is the least of all forms(1 cm of water)
- It provides ease of operation.
- The dust is collected in dry form and can be removed either dry or wet.

DISADVANTAGES:

- The direct current is not available with the modern plants, therefore considerable electrical equipment is necessary to convert low voltage (400 V) A.C to high voltage (60000 V) D.C. This increases the capital cost of the equipment as high as 40 to 60 cents per 1000 kg of rated installed steam generating capacity.

- The running charges are also considerably high as the amount of power required for charging is considerably large.
- The space required is larger than the wet system.
- The efficiency of the collector is not maintained if the gas velocity exceeds that for which the plant is designed. The dust carried with the gases increases with an increase of gas velocity.
- Because of closeness of the charged plates and high potential used, it is necessary to protect the entire collector from sparking by providing a fine mesh before the ionizing chamber. This is necessary because even a smallest piece of paper might cause sparking when it would be carried across adjacent plates or wires.

DRAUGHT:

Most boilers now depend on mechanical draught equipment rather than natural draught. This is because natural draught is subject to outside air conditions and temperature of flue gases leaving the furnace, as well as the chimney height. All these factors make proper draught hard to attain and therefore make mechanical draught equipment much more economical.

There are three types of mechanical draught:

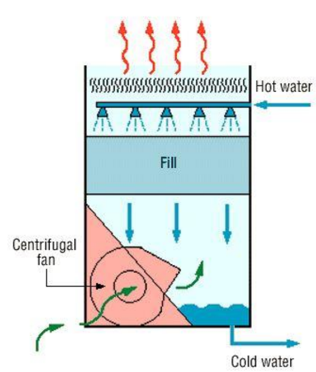
***Induced draught*:** This is obtained one of three ways, the first being the "stack effect" of a heated chimney, in which the flue gas is less dense than the ambient air surrounding the boiler. The denser column of ambient air forces combustion air into and through the boiler. The second method is through use of a steam jet. The steam jet oriented in the direction of flue gas flow induces flue gasses into the stack and allows for a greater flue gas velocity increasing the overall draught in the furnace. This method was common on steam driven locomotives which could not have tall chimneys. The third method is by simply using an induced draught fan (ID fan) which removes flue gases from the furnace and forces the exhaust gas up the stack. Almost all induced draught furnaces operate with a slightly negative pressure.

Forced draught: Draught is obtained by forcing air into the furnace by means of a fan (FD fan) and ductwork. Air is often passed through an air heater; which, as the name suggests, heats the air going into the furnace in order to increase the overall efficiency of the boiler. Dampers are used to control the quantity of air admitted to the furnace. Forced draught furnaces usually have a positive pressure.

Balanced draught: Balanced draught is obtained through use of both induced and forced draught. This is more common with larger boilers where the flue gases have to travel a long distance through many boiler passes. The induced draught fan works in conjunction with the forced draught fan allowing the furnace pressure to be maintained slightly below atmospheric.

FORCED DRAUGHT

In a forced draught counter flow cooling tower, the water is cooled by air that is forced through the falling water and out through the top of the tower.



A mechanical draft tower with a blower type fan at the intake. The fan forces air into the tower, creating high entering and low exiting air velocities. The low exiting velocity is much more susceptible to recirculation. With the fan on the air intake, the fan is more susceptible to complications due to freezing conditions. Another disadvantage is that a forced draft design typically requires more motor horsepower than an equivalent induced draft design. The forced draft benefit is its ability to work with high static pressure. They can be installed in more confined spaces and even in some indoor situations. This fan/fill geometry is also known as blow-through.

SURFACE CONDERSER:

Surface condenser is the commonly used term for a water-cooled shell and tube heat exchanger installed on the exhaust steam from a steam turbine in thermal power stations These condensers are heat exchangers which convert steam from its gaseous to its liquid state at a pressure below atmospheric pressure. Where cooling water is in short supply, an air-cooled condenser is often used. An air-cooled condenser is however significantly more expensive and cannot achieve as low a steam turbine exhaust pressure as a water cooled surface condenser.

Surface condensers are also used in applications and industries other than the condensing of steam turbine exhaust in power plants.

In thermal power plants, the primary purpose of a surface condenser is to condense the exhaust steam from a steam turbine to obtain maximum efficiency and also to convert the turbine exhaust steam into pure water (referred to as steam condensate) so that it may be reused in the steam generator or boiler as boiler feed water.

The steam turbine itself is a device to convert the heat in steam to mechanical power. The difference between the heat of steam per unit weight at the inlet to the turbine and the heat of steam per unit weight at the outlet to the turbine represents the heat which is converted to mechanical power. Therefore, the more the conversion of heat per pound or kilogram of steam to mechanical power in the turbine, the better is its efficiency. By condensing the exhaust steam of a turbine at a pressure below atmospheric pressure, the steam pressure drop between the inlet and exhaust of the turbine is increased, which increases the amount of heat available for conversion to mechanical power. Most of the heat liberated due to condensation of the exhaust steam is carried away by the cooling medium (water or air) used by the surface condenser

COOLING TOWERS:

Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or in the case of "Close Circuit Dry Cooling Towers" rely solely on air to cool the working fluid to near the dry-bulb air temperature. Common applications include cooling the circulating water used in oil refineries, chemical plants, power stations and building cooling. The towers vary in size from small roof-top units to very large hyperboloid structures that can be up to 200 metres tall and 100 metres in diameter, or rectangular structures that can be over 40 metres tall and 80 metres long. Smaller towers are normally factory-built, while larger ones are constructed on site. They are often associated with nuclear power plants in popular culture, although cooling towers are constructed on many types of buildings.

Industrial cooling towers

Industrial cooling towers can be used to remove heat from various sources such as machinery or heated process material. The primary use of large, industrial cooling towers is to remove the heat absorbed in the circulating cooling water systems used in power plants, petroleum refineries, petrochemical plants, natural gas processing plants, food processing plants, semi-conductor plants, and for other industrial facilities such as in condensers of distillation columns, for cooling liquid in crystallization, etc.[2] The circulation rate of cooling water in a typical 700 MW coal-fired power plant with a cooling tower amounts to about 71,600 cubic metres an hour (315,000 U.S. gallons per minute)[3] and the circulating water requires a supply water make-up rate of perhaps 5 percent (i.e., 3,600 cubic metres an hour).

If that same plant had no cooling tower and used **once-through cooling** water, it would require about 100,000 cubic metres an hour [4] and that amount of water would have to be continuously returned to the ocean, lake or river from which it was obtained and continuously re-supplied to the plant. Furthermore, discharging large amounts of hot water may raise the temperature of the receiving river or lake to an unacceptable level for the local ecosystem. Elevated water temperatures can kill fish and other aquatic organisms. (See *thermal pollution.*) A cooling tower serves to dissipate the heat into the atmosphere instead and wind and air diffusion spreads the heat over a much larger area than hot water can distribute heat in a body of water. Some coal-fired and nuclear power plants located in coastal areas do make use of once-through ocean water. But even there, the offshore discharge water outlet requires very careful design to avoid environmental problems.

Petroleum refineries also have very large cooling tower systems. A typical large refinery processing 40,000 metric tonnes of crude oil per day (300,000 barrels (48,000 m^3) per day) circulates about 80,000 cubic metres of water per hour through its cooling tower system.

The world's tallest cooling tower is the 200 metre tall cooling tower of Niederaussem Power Station.

ASH HANDLING SYSTEMS:

Ash Handling Systems is the none / un combusted portion or residue, after taking combustion of any solid fuel. Solid fuel is usually coal. And any coal contains some non combustible portion which is called ash. Content of that coal.

There are different types of ashes.

1. Bottom ash
2. fly ash

Bottom ash is the residue which remains in the solid form at the bottom and fly ash is the light particle which goes out along with exhaust gases, and usually they are collected in chimneys.

Taking their so formed ash away from the Plant / Boiler is called – "ASH HANDLING SYSTEM" This is done in either

1. Mechanical conveying
2. Pneumatic conveying

Mechanical system requires conveyors, and Pneumatic system requires – compressed air to carry out the ash.

1. Ash Handling Systems
   Bulk Material Handling Systems
   Conveyors And Material Handling Equipments
   Process Equipments And Storage Equipments
   Portable Handling Equipments
   Rotary Equipments
2. Pneumatic Conveying Systems
   Magnetic Equipments
   Vibratory Equipments
   Spares
   Overhead Bag Handling Systems

COMBUSTION EQUIPMENTS:

Combustion control options range from electro / mechanical through to full microprocessor control systems to match both application and customer needs.

Cochran supply an extensive range of fuel handling equipment to complement and help ensure that the optimum performance from the combustion and control equipment is maintained. Fuel handling equipment includes gas boosters, oil pumping and heating stations, fuel metering and instrumentation packages are available to match individual installation requirements.

MULTIPLE CHOICE QUESTIONS

Questions	Opt1	Opt2	Opt3	Opt4	Answer
Standard frequency usually for electric supply is	50 Hz	60 Hz	50 to 60 Hz	50 to 55 Hz	50 Hz
In power station practice "spinning reserve" is	reserve generating capacity that is in operation but not in service	reserve generating capacity that is connected to bus and ready to take the load	reserve generating capacity that is available for service but not in operation	capacity of the part of the plant that remains under maintenance	reserve generating capacity that is connected to bus and ready to take the load
Bagasse is	low quality coal	a fuel consisting of wood	fibrous portion of sugarcane left after extracting the juice	a kind of rice straw	a fuel consisting of wood
Low grade fuels have	low moisture content	low ash content	low calorific value	low carbon content	low ash content
Which variety of coal has lowest calorific value?	Steam-coal	Bituminous coal	Lignite	Anthracite	Bituminous coal
In a steam locomotive the engine is	Single cylinder	Vertical	Condensing	Non-condensing	Non-condensing
The boilers using lignite as fuel do not use	under feed stoker	traveling grate stoker	spreader stoker	all of the above	under feed stoker
In a steam turbine cycle, the lowest pressure occurs in	turbine inlet	boiler	condenser	super heater	condenser
Steam pressure in modem thermal plants of 100 MW and above capacity may be exacted to be	10 kg/cm^2	50 kg/cm^2	up to 100kg/cm^2	more than 100 kg/cm^2	more than 100 kg/cm^2

The overall efficiency of a boiler in a thermal power plant is of the order of	10%	25 to 30%	40 to 50%	70 to 80%	70 to 80%
Chemical composition of coal is given by	Proximate analysis	Ultimate analysis	Orast analysis	All of the above	Ultimate analysis
Which coal will have highest ash content ?	Bituminous coal	Grade I steam coal	Coking coal	Lignite	Lignite
Ash content of most of the Indian coals is around	1%	5%	10%	20%	20%
Ash content of coal can be reduced by	slow burning	washing	pulverizing	mixing with high grade coal	washing
A 100 MW thermal power-plant will consume nearly how many tonnes of coal in one hour ?	50 tonnes	150 tonnes	1500 tonnes	15,000 tonnes	50 tonnes
The steam consumption per kWh of electricity generated in a modem power plant is of the order of	1-2 kgs	2-4 kgs	5-7 kgs	10-12 kgs	5-7 kgs
For low head and high discharge, the hydraulic turbine used is	Kaplan turbine	Francis turbine	Pelton whe	Jonual turbine	Kaplan turbine
Soot is virtually nothing but	ash	cinder	gas	carbon	carbon
In pumped storage	Power is produced by means of pumps	Water is stored by pumping to high pressures	Downstream water is pumped up-stream during off load periods	Water is re circulated through turbine	Water is stored by pumping to high pressures

If the air standard efficiency of. a thermodynamic cycle is given as η= 1 - (k (r-1)) / (rk-1) where r = compression ratio, k = Cp/ Cv the cycle is	Lenoir cycle	Brayton cycle	Atkinson cycle	None of the above	Lenoir cycle
A graphical representation between discharge and time is known as	Monograph	Hectograph	Topograph	Hydrograph	Hydrograph
Cost of operation of which plant is least ?	Gas turbine plant	Thermal power plant	Nuclear power plant	Hydroelectric plant	Hydroelectric plant
In a hydro-electric plant a conduct system for taking water from the intake works to the turbine is known as	Dam	Reservoir	Penstock	Surge tank	Penstock
A Pelton wheel is	Inward flow impulse turbine	Outward flow impulse turbine	Inward flow reaction turbine	Axial flow impulse turbine	Axial flow impulse turbine
Running away speed of a Pelton wheel is	Actual operating speed on no load	Full load speed	No load speed when governor mechanism fails	90% greater than the normal speed	No load speed when governor mechanism fails
Spouting velocity is	Ideal velocity of jet	50% of ideal velocity of jet	Actual velocity of jet	Velocity of jet under specified conditions	Ideal velocity of jet
Outward radial flow turbines	are impulses turbines	are reaction turbines	are partly impulse partly reaction turbines	may be impulse or reaction turbines	may be impulse or reaction turbines

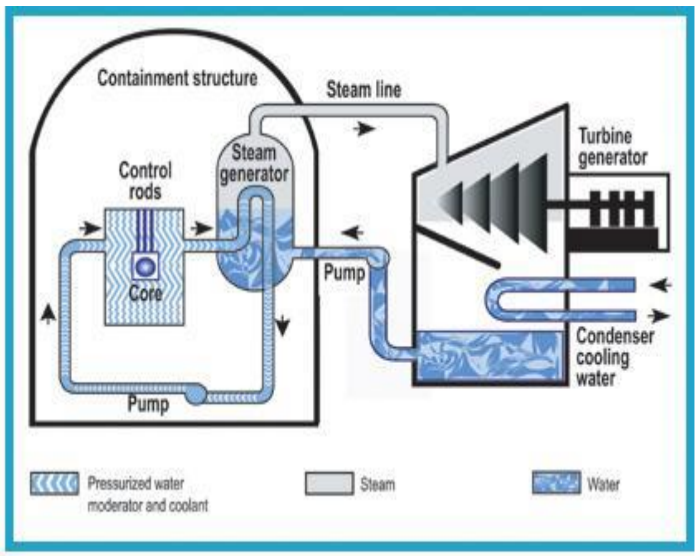
A Francis turbine is	Inward flow reaction turbine	Inward flow impulse turbine	Outward flow reaction turbine	Outward flow impulse turbine	Inward flow reaction turbine
A Kaplan turbine is	a high head mixed flow turbine	an impulse turbine, inward flow type	an reaction turbine, outward flow type	low head axial flow turbine	low head axial flow turbine
In turbulent flow	the fluid particles move in orderly manner	momentum transfer is on molecular scale only	shear stresses are generally larger than in laminar flow	cohesion is more effective than momentum transfer in causing shear stress	shear stresses are generally larger than in laminar flow
Heating value of diesel oil is the range	1000-1200 kcal/kg	2000-5000 kcal/kg	5000-9000 kcal/kg	9500-11000 kcal/kg	9500-11000 kcal/kg
Which of the following relation is correct ?	Weight of oxygen = 0.32 weight of air	Weight of oxygen = 0.32 weight of air	Weight of air = 0.23 weight of oxygen	Weight of air =2.33 x weight of oxygen	Weight of oxygen = 0.32 weight of air
How many kg of air are required for the combustion of one kg of diesel fuel ?	1 kg	1.3 kg	4 kg	15 kg	15 kg
Due to burning of 1 kg of pure carbon with a minimum quantity of air required, the percentage of carbon dioxide in the exhaust gas would be	10%	19%	29%	39%	29%
Diesel engine fuels are rated by	Octane number	H.U.C.R.	Cetane number	CRF number	Cetane number
The formula for cetane is	$C_{16} H_{34}$	$C_{12}H_{32}$	$C_{10} H_{32}$	C_8H_{16}	$C_{16} H_{34}$

Unit – III

NUCLEAR AND HYDEL POWER PLANTS

LECTURE NOTES

NUCLEAR POWER



Nuclear power is the use of sustained Nuclear fission to generate heat and do useful work. Nuclear Electric Plants, Nuclear Ships and Submarines use controlled nuclear energy to heat water and produce steam, while in space, nuclear energy decays naturally in a radioisotope thermoelectric generator. Scientists are experimenting with fusion energy for future generation, but these experiments do not currently generate useful energy.

Nuclear power provides about 6% of the world's energy and 13–14% of the world's electricity, with the U.S., France, and Japan together accounting for about 50% of nuclear generated electricity. Also, more than 150 naval vessels using nuclear propulsion have been built.

Just as many conventional thermal power stations generate electricity by harnessing the thermal energy released from burning fossil fuels, nuclear power plants convert the energy released from the nucleus of an atom, typically via nuclear fission.

NUCLEAR REACTOR TECHNOLOGY

When a relatively large fissile atomic nucleus (usually uranium-235 or plutonium-239) absorbs a neutron, a fission of the atom often results. Fission splits the atom into two or more smaller nuclei with kinetic energy (known as fission products) and also releases gamma radiation and free neutrons. A portion of these neutrons may later be absorbed by other fissile atoms and create more fissions, which release more neutrons, and so on.

This nuclear chain reaction can be controlled by using neutron poisons and neutron moderators to change the portion of neutrons that will go on to cause more fissions. Nuclear reactors generally have automatic and manual systems to shut the fission reaction down if unsafe conditions are detected.

Three nuclear powered ships, (top to bottom) nuclear cruisers USS Bainbridge and USS Long Beach with *USS Enterprise* the first nuclear powered aircraft carrier in 1964. Crew members are spelling out Einstein's mass-energy equivalence formula $E = mc^2$ on the flight deck.

There are many different reactor designs, utilizing different fuels and coolants and incorporating different control schemes. Some of these designs have been engineered to meet a specific need. Reactors for nuclear submarines and large naval ships, for example, commonly use highly enriched uranium as a fuel. This fuel choice increases the reactor's power density and extends the usable life of the nuclear fuel load, but is more expensive and a greater risk to nuclear proliferation than some of the other nuclear fuels.

A number of new designs for nuclear power generation, collectively known as the Generation IV reactors, are the subject of active research and may be used for practical power generation in the future. Many of these new designs specifically attempt to make fission reactors cleaner, safer and/or less of a risk to the proliferation of nuclear weapons. Passively safe plants (such as the ESBWR) are available to be builtand other designs that are believed to be nearly fool-proof are being pursued. Fusion reactors, which may be viable in the future, diminish or eliminate many of the risks associated with nuclear fission. There are trades to be made between safety, economic and technical properties of different reactor designs for particular applications. Historically these decisions were often made in private by scientists, regulators and engineers, but this may be considered problematic, and since Chernobyl and Three Mile Island, many involved now consider informed consent and morality should be primary considerations.

Cooling system

A cooling system removes heat from the reactor core and transports it to another area of the plant, where the thermal energy can be harnessed to produce electricity or to do other useful work. Typically the hot coolant will be used as a heat source for a boiler, and the pressurized steam from that boiler will power one or more steam turbine driven electrical generators.

Flexibility of nuclear power plants

It is often claimed that nuclear stations are inflexible in their output, implying that other forms of energy would be required to meet peak demand. While that is true for the vast majority of reactors, this is no longer true of at least some modern designs. Nuclear plants are routinely used in load following mode on a large scale in France. Unit A at the German Biblis Nuclear Power Plant is designed to in- and decrease his output 15 % per minute between 40 and 100 % of it's nominal power. Boiling water reactors normally have load-following capability, implemented by varying the recirculation water flow.

PWR

A nuclear reactor produces and controls the release of energy from splitting the atoms of elements such as uranium and plutonium. In a nuclear power reactor, the energy released from continuous fission of the atoms in the fuel as heat is used to make steam. The steam is used to drive the turbines which produce electricity (as in most fossil fuel plants).

In a PWR the primary coolant (water) is pumped under high pressure to the reactor core where it is heated by the energy generated by the fission of atoms. The heated water then flows to a steam generator where it transfers its thermal energy to a secondary system where steam is generated and flows to turbines which, in turn, spins an electric generator. In a PWR, there are two separate coolant loops (primary and secondary), which are both filled with demineralized/deionized water.

NUCLEAR FISSION:

In nuclear physics and nuclear chemistry, nuclear fission is a nuclear reaction in which the nucleus of an atom splits into smaller parts (lighter nuclei), often producing free neutrons and photons (in the form of gamma rays). The two nuclei produced are most often of comparable size, typically with a mass ratio around 3:2 for common fissile isotopes.[1][2] Most fissions are binary fissions, but occasionally (2 to 4 times per 1000 events), three positively-charged fragments are produced in a ternary fission. The smallest of these ranges in size from a proton to an argon nucleus.

Fission is usually an energetic nuclear reaction induced by a neutron, although it is occasionally seen as a form of spontaneous radioactive decay, especially in very high-mass-number isotopes. The unpredictable composition of the products (which vary in a broad probabilistic and somewhat chaotic manner) distinguishes fission from purely quantum-tunnelling processes such as proton emission, alpha decay and cluster decay, which give the same products every time.

Fission of heavy elements is an exothermic reaction which can release large amounts of energy both as electromagnetic radiation and as kinetic energy of the fragments (heating the bulk material where fission takes place). In order for fission to produce energy, the total binding energy of the resulting elements must be less than that of the starting element. Fission is a form of nuclear transmutation because the resulting fragments are not the same element as the original atom.

NUCLEAR FUSION:

In nuclear physics, nuclear chemistry and astrophysics nuclear fusion is the process by which two or more atomic nuclei join together, or "fuse", to form a single heavier nucleus. This is usually accompanied by the release or absorption of large quantities of energy. Large-scale thermonuclear fusion processes, involving many nuclei fusing at once, must occur in matter at very high densities and temperatures.

The fusion of two nuclei with lower masses than iron (which, along with nickel, has the largest binding energy per nucleon) generally releases energy while the fusion of nuclei heavier than iron absorbs energy. The opposite is true for the reverse process, nuclear fission.

In the simplest case of hydrogen fusion, two protons must be brought close enough for the weak nuclear force to convert either of the identical protons into a neutron, thus forming the hydrogen isotope deuterium. In more complex cases of heavy ion fusion involving two or more nucleons, the reaction mechanism is different, but the same result occurs— smaller nuclei are combined into larger nuclei.

Nuclear fusion occurs naturally in all active stars. Synthetic fusion as a result of human actions has also been achieved, although this has not yet been completely controlled as a source of nuclear power (see: fusion power). In the laboratory, successful nuclear physics experiments have been carried out that involve the fusion of many different varieties of nuclei, but the energy output has been negligible in these studies. In fact, the amount of energy put into the process has always exceeded the energy output.

Uncontrolled nuclear fusion has been carried out many times in nuclear weapons testing, which results in a deliberate explosion. These explosions have always used the heavy isotopes of hydrogen, deuterium (H-2) and tritium (H-3), and never the much more common isotope of hydrogen (H-1), sometimes called "protium".

Building upon the nuclear transmutation experiments by Ernest Rutherford, carried out several years earlier, the fusion of the light nuclei (hydrogen isotopes) was first accomplished by Mark Oliphant in 1932. Then, the steps of the main cycle of nuclear fusion in stars were first worked out by Hans Bethe throughout the remainder of that decade.

Research into fusion for military purposes began in the early 1940s as part of the Manhattan Project, but this was not accomplished until 1951 (see the Greenhouse Item nuclear test), and nuclear fusion on a large scale in an explosion was first carried out on November 1, 1952, in the Ivy Mike hydrogen bomb test. Research into developing controlled thermonuclear fusion for civil purposes also began in the 1950s, and it continues to this day.

WASTE DISPOSAL TECHNIQUES IN NUCLEAR POWER PLANT:

Types of radioactive waste

Although not significantly radioactive, *uranium mill tailings* are waste. They are byproduct material from the rough processing of uranium-bearing ore. They are sometimes wastes, from the section of the U.S. Atomic Energy Act that defines them. Uranium mill tailings typically also contain chemically hazardous heavy metals such as lead and arsenic. Vast mounds of uranium mill tailings are left at many old mining sites, especially in Colorado, New Mexico, and Utah.

Low level waste (LLW) is generated from hospitals and industry, as well as the nuclear fuel cycle. It comprises paper, rags, tools, clothing, filters, etc., which contain small amounts of mostly short-lived radioactivity. Commonly, LLW is designated as such as a precautionary measure if it originated from any region of an 'Active Area', which frequently includes offices with only a remote possibility of being contaminated with radioactive materials. Such LLW typically exhibits no higher radioactivity than one would expect from the same material disposed of in a non-active area, such as a normal office block. Some high activity LLW requires shielding during handling and transport but most LLW is suitable for shallow land burial. To reduce its volume, it is often compacted or incinerated before disposal. Low level waste is divided into four classes, class A, B, C and GTCC, which means "Greater Than Class C".

Intermediate level waste (ILW) contains higher amounts of radioactivity and in some cases requires shielding. ILW includes resins, chemical sludge and metal reactor fuel cladding, as well as contaminated materials from reactor decommissioning. It may be solidified in concrete or bitumen for disposal. As a general rule, short-lived waste (mainly non-fuel materials from reactors) is buried in shallow repositories, while long-lived waste (from fuel and fuel-reprocessing) is deposited in deep underground facilities. U.S. regulations do not define this category of waste; the term is used in Europe and elsewhere.

Spent Fuel Flasks are transported by railway in the United Kingdom. Each flask is constructed of 14 in (360 mm) thick solid steel and weighs in excess of 50 tons

High level waste (HLW) is produced by nuclear reactors. It contains fission products and transuranic elements generated in the reactor core. It is highly radioactive and often thermally hot. HLW accounts for over 95% of the total radioactivity produced in the process of nuclear electricity generation. The amount of HLW worldwide is currently increasing by about 12,000 metric tons every year, which is the equivalent to about 100 double-decker buses or a two-story structure with a footprint the size of a basketball court. A 1000-MWe nuclear power plant produces about 27 tonnes of spent nuclear fuel (unreprocessed) every year.

Transuranic waste (TRUW) as defined by U.S. regulations is, without regard to form or origin, waste that is contaminated with alpha-emitting transuranic radionuclides with half-lives greater than 20 years, and concentrations greater than 100 nCi/g (3.7 MBq/kg), excluding High Level Waste. Elements that have an atomic number greater than uranium are called transuranic ("beyond uranium"). Because of their long half-lives, TRUW is disposed more cautiously than either low level or intermediate level waste. In the US it arises mainly from weapons production, and consists of clothing, tools, rags, residues, debris and other items contaminated with small amounts of radioactive elements (mainly plutonium).

The Government is using latest technology for disposing the nuclear waste generated during operation of nuclear power plants. The details are as follows:

(i) The low and intermediate level radioactive waste generated during operation and maintenance of nuclear power plants is segregated, its volume reduced using various technologies and solidified. This solid/solidified waste is packaged in suitable containers to facilitate handling, transport and disposal.

(ii) Disposal of low and intermediate level waste is carried out in specially constructed structures such as stone lined trenches, reinforced concrete trenches and tile holes. These disposal structures are located both above and underground in access-controlled areas. Disposal system is designed based on multi barrier principle for ensuring effective containment of the radioactivity.

The areas where the disposal structures are located are kept under constant surveillance with the help of bore-wells laid out in a planned manner. The underground soil and water samples from these bore wells are routinely monitored to confirm effective confinement of radioactivity present in the disposed waste.

(iii) Gaseous waste is treated at the source of generation. The techniques used are adsorption on activated charcoal and filtration by high efficiency particulate air filters. The treated gases are then diluted with exhaust air and discharged through a tall stack with monitoring.

(iv) Liquid waste streams are treated by various techniques, such as filtration, adsorption, chemical treatment, thermal and solar evaporation, ion exchange, reverse osmosis etc. The concentrate from treatment of liquid waste are immobilized in inert materials like cement, polymer etc.

The nuclear waste handling, treatment, storage and disposal is carried out as per the well laid down procedures and guidelines stipulated by the Atomic Energy Regulatory Board (AERB).

MULTIPLE CHOICE QUESTIONS

Questions	Opt1	Opt2	Opt3	Opt4	Answer
For the same maximum pressure and heat input the most efficiency cycle is	Brayton cycle	Otto cycle	Diesel cycle	Dual cycle	Brayton cycle
For the same temperature limits and heat input, the most efficient cycle is	Carnot cycle	Otto cycle	Diesel cycle	Brayton cycle	Carnot cycle
An air filter is used in	nuclear power plants	steam power plants	diesel engine power plants	hydro-power plants	diesel engine power plants
Which of the following is not a part of diesel engine power plant?	Cooling tower	Penstock	Oil pump	Strainer	Penstock
Of the total heat supplied to a diesel engine plant, which one has the highest proportion ?	Useful output	Heat lost to cooling water	Heat lost in exhaust gases	Heat loss in friction radiation, etc	Useful output
Supercharging of a diesel engine means	overloading the engine for peak load	operating the engine with age	operating engine at higher altitudes	supplying pressurized air during suction	supplying pressurized air during suction
Which power plant cannot have single units of 100 MW capacity?	Steam power plant	Nuclear power plant	Hydroelectric power plant	Diesel engine power plant	Diesel engine power plant
In a thermal power plant, heat from the flue gases is recovered in	chimney	de-super heater	economizer	condenser	economizer
Which of the following is not a fire tube boiler ?	Cochron boiler	Lancashire boiler	Locomotive boiler	Babcock and Wilcox boiler	Babcock and Wilcox boiler
In a super-heater	pressure rises, temperature drops	pressure rises, temperature remains constant	pressure remains constant and temperature rises	both pressure and temperature remains constant	pressure remains constant and temperature rises

Bagasse is	a variety of coal	a fuel consisting of wood etc	fibrous portion of sugarcane left after extracting the juice	a kind of rice straw	fibrous portion of sugarcane left after extracting the juice
Which of the following is not an accessory for a boiler ?	Feed water pump	Condenser	Economizer	Air pre-heater	Condenser
A compound pressure gauge indicates	fluctuating pressures	pressures above atmospheric pressure	pressures below atmospheric pressure	pressures above and below atmospheric pressure	pressures above and below atmospheric pressure
For the same cylinder size and rpm which engine will produce more power ?	Gas engine	Petrol engine	Diesel engine	Super-charged engine	Super-charged engine
The internal combustion engines never work on	Diesel cycle	Rankine cycle	Otto cycle	Dual combustion cycle	Rankine cycle
A Joule cycle consists of	two isothermal and two adiabatic proces	two adiabatic and two constant pressure processes	two isothermal and two constant volume processes	two constant volume and two constant pressure processes	two adiabatic and two constant pressure processes
In ideal diesel cycle the working substance is	air	diesel	mixture of air and diesel	any combustible gas	air
The efficiency of an otto cycle will approach that of Carnot cycle when	engine is operated at high rpm	engine is run at high load	constant volume processes are replaced by isothermal processes	adiabatic processes are replaced by isothermal processes	constant volume processes are replaced by isothermal processes
Which power plant normally operates at high speeds?	Diesel engine plant	Petrol engine plant	Steam turbine plant	Hydro-electric power plant	Steam turbine plant

Which instrument can be used to measure the flow of a liquid through a pipe	Pitot tube	Venturimeter	Pressure gauge	Orifice	Venturimeter
A pitot tube is used to measure	energy of liquid	pressure of liquid	energy and pressure of liquid	energy, pressure and discharge of liquid	pressure of liquid
A rotameter is used to measure	velocity of fluids	viscosity of fluids	density of fluids	discharge of fluids	discharge of fluids
Vacuum can be measured by	venturimeter	pitot tube	U tube manometer	rotameter	U tube manometer
A binary vapor cycle	uses a fluid at two pressures in the cycle	uses fluid in liquid and vapor form	uses two different vapors as working fluid	uses same fluid twice	uses two different vapors as working fluid
In a steam power plant water is used for cooling purposes in	boiler	economizer	condenser	super-heaters	condenser
Which steam will have least enthalpy	wet steam at 10 kg/cm^2	dry and saturated steam at 10 kg/s cm^2	super-heated steam at 10 kg/cm^2	dry and saturated steam at 100 kg/s cm^2	wet steam at 10 kg/cm^2
In which part of the steam power plant the pressure of steam is less than the atmospheric pressure ?	Condenser	Boiler	Turbine	Super beater	Condenser
In a thermal power plant a cooling tower cools	steam from boiler	steam from turbine	water from economizer	water from condenser	water from condenser

Unit – IV

DIESEL AND GAS TURBINE POWER PLANT

LECTURE NOTES

GAS TURBINES POWER PLANT:

Gas turbines operate on an *open cycle*, as shown in Fig. Fresh air at ambient conditions is drawn into the compressor, where its temperature and pressure are raised.

The high pressure air enters into the combustion chamber, where the fuel is burned at constant pressure.

The high temperature gases then enter the turbine, and expand to the atmospheric pressure.

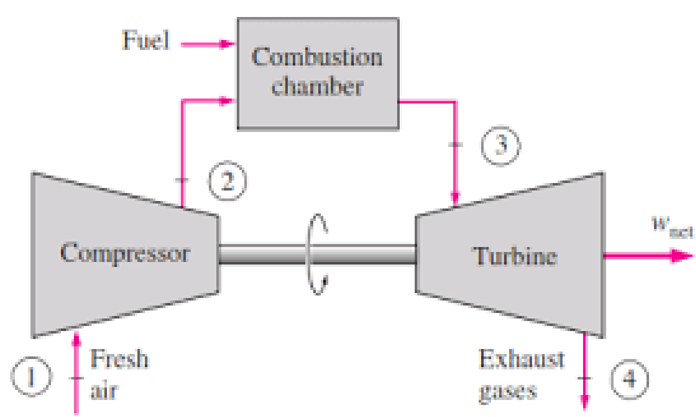
The exhaust gases leaving the turbine are not recirculated, causing the cycle to be classified as an open cycle. The open gas-turbine cycle described above can be modeled as a *closed cycle*, as shown in Fig., by utilizing the air-standard assumptions. Here the compression and expansion processes remain the same, but the combustion process is replaced by a constant-pressure heat-addition process from an external source, and the exhaust process is replaced by a constant pressure heat-rejection process to the ambient air. The ideal cycle that the working fluid undergoes in this closed loop is the **Brayton cycle,** which is made up of four internally reversible processes:

1-2 Isentropic compression (in a compressor)

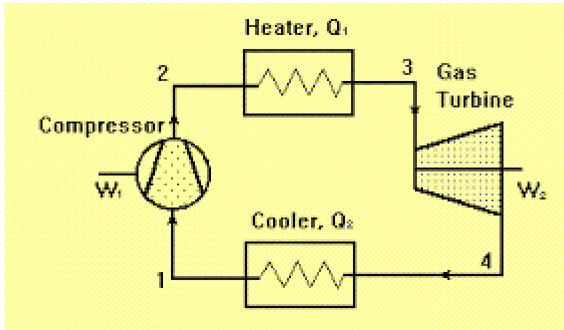
2-3 Constant-pressure heat addition

3-4 Isentropic expansion (in a turbine)

4-1 Constant-pressure heat rejection



OPEN CYCLE GAS TURBINE



CLOSED CYCLE GAS TURBINE

LAYOUT OF HYDEL POWER PLANT:

Hydroelectric power plants convert the hydraulic potential energy from water into electrical energy. Such plants are suitable were water with suitable head are available. The layout covered in this article is just a simple one and only cover the important parts of hydroelectric plant.The different parts of a hydroelectric power plant are

(1)Dam:

Dams are structures built over rivers to stop the water flow and form a reservoir.The reservoir stores the water flowing down the river. This water is diverted to turbines in power stations. The dams collect water during the rainy season and stores it, thus allowing for a steady flow through the turbines throughout the year. Dams are also used for controlling floods and irrigation. The dams should be water-tight and should be able to withstand the pressure exerted by the water on it. There are different types of dams such as arch dams, gravity dams and buttress dams. The height of water in the dam is called head race.

(2)Spillway

A spillway as the name suggests could be called as a way for spilling of water from dams. It is used to provide for the release of flood water from a dam. It is used to prevent over toping of the dams which could result in damage or failure of dams. Spillways could be controlled type or uncontrolled type. The uncontrolled types start releasing water upon water rising above a particular level. But in case of the controlled type, regulation of flow is possible.

(3) Penstock and Tunnel

Penstocks are pipes which carry water from the reservoir to the turbines inside power station. They are usually made of steel and are equipped with gate systems.Water under high pressure flows through the penstock. A tunnel serves the same purpose as a penstock. It is used when an obstruction is present between the dam and power station such as a mountain.

(4) Surge Tank

Surge tanks are tanks connected to the water conductor system. It serves the purpose of reducing water hammering in pipes which can cause damage to pipes. The sudden surges of water in penstock is taken by the surge tank, and when the water requirements increase, it supplies the collected water thereby regulating water flow and pressure inside the penstock.

(5) Power Station

Power station contains a turbine coupled to a generator. The water brought to the power station rotates the vanes of the turbine producing torque and rotation of turbine shaft. This rotational torque is transfered to the generator and is converted into electricity. The used water is released through the tail race. The difference between head race and tail race is called gross head and by subtracting the frictional losses we get the net head available to the turbine for generation of electricity.

MAJOR COMPONENTS OF DIESEL POWER PLANT

The major components of the plant are:

a) Engine

Engine is the heart of a diesel power plant. Engine is directly connected through a gearbox to the generator. Generally two-stroke engines are used for power generation. Now a days, advanced super & turbo charged high speed engines are available for power production.

b) Air supply system

Air inlet is arranged outside the engine room. Air from the atmosphere is filtered by air filter and conveyed to the inlet manifold of engine. In large plants supercharger/turbocharger is used for increasing the pressure of input air which increases the power output.

c) Exhaust System

This includes the silencers and connecting ducts. The heat content of the exhaust gas is utilized in a turbine in a turbocharger to compress the air input to the engine.

d) Fuel System

Fuel is stored in a tank from where it flows to the fuel pump through a filter. Fuel is injected to the engine as per the load requirement.

e) Cooling system

This system includes water circulating pumps, cooling towers, water filter etc. Cooling water is circulated through the engine block to keep the temperature of the engine in the safe range.

f) Lubricating system

Lubrication system includes the air pumps, oil tanks, filters, coolers and pipe lines. Lubricant is given to reduce friction of moving parts and reduce the wear and tear of the engine parts.

g) Starting System

There are three commonly used starting systems, they are;

1) A petrol driven auxiliary engine,
2) Use of electric motors,
3)Use of compressed air from an air compressor at a pressure of 20 Kg/cm

h) Governing system

The function of a governing system is to maintain the speed of the engine constant irrespective of load on the plant. This is done by varying fuel supply to the engine according to load.

ADVANTAGES:

1. More efficient than thermal plant
2. Design, Layout etc are simple and cheap
3. Part load efficiency is very high

4. It can be started quickly
5. Simple & easy maintenance
6. No problem with fuel & dust handling
7. It can be located in the heart of town
8. Less cooling water required.

DISADVANTAGES:

1. There is a limitation for size of a diesel engine
2. Life of plant is comparatively less
3. Noise pollution is very high
4. Repair cost is very high
5. High lubrication cost

MULTIPLE CHOICE QUESTIONS

Questions	Opt1	Opt2	Opt3	Opt4	Answer
Suspended solids can be removed from water by	settling	coagulation	filtration	any of the above	any of the above
Dissolved solids in water can be removed/reduced by	distillation	demineralization	softening	any of the above	any of the above
Small domestic electric power generators are usually of capacity around	10 kVA	5 kVA	1 kVA	100 VA	1 kVA
Producer gas is a by product from	fertilizer plants	steel plants	paper plants	sugar mills	steel plants
Sour crude	is corrosive when heated	evolves significant amounts of hydrogen sulphide on distillation	produces light fractions which require sweetening	all of the above	all of the above
Dam: Hydro plant::	Chimney : Gases	Coal: Steam plant	Gas turbine: Steam turbine	Reactor: Nuclear plant	Reactor: Nuclear plant
Bulb turbines are	high speed turbines	high pressure turbines	low head turbines	high head turbines	low head turbines
A frauds turbine is	Inward flow reaction turbine	Inward flow impulse turbine	Outward flow reaction turbine	Outward flow impulse turbine	Inward flow reaction turbine

In hydro power plants	Initial cost is high and operating cost is low	Initial cost as well as operating costs are high	Initial cost is low and operating cost is high	Initial cost as well as operating cost is low	Initial cost is high and operating cost is low
In which of the following power plant the availability of power is least reliable ?	Solar power plant	Wind energy	Tidal power plant	Geothermal power plant	Wind energy
Geothermal energy is	a renewable energy resource	alternative energy source	inexhaustible energy source	any of the above	any of the above
The disadvantage of renewable sources of energy is	lack of decidability	availability in low energy densities	intermittency	all of the above	all of the above
In the Geysers steam is continuously vented through fissures in the ground. These vents are called	vent holes	pot holes	fumaroles	sun spots	fumaroles
Geologists believe that below the earth's crust, the molten mass exists in the form of	magma	vent	hot cell	liquation	magma
In hydrothermal source of geothermal energy	hot water or steam is available	hot gases are available	molten lava is available	none of the above	hot water or steam is available

In axial flow turbines	only part of the available head is converted into velocity before the water enters the wheel	water is admitted over part of the circumference	it is possible that the wheel may run full	it is possible to regulate the flow	it is possible that the wheel may run full
In hydrothermal systems when steam, water and dissolved solids are available as source of energy, the entrained solids are removed by	filters	centrifugal separators	strainers	none of the above	centrifugal separators
Presence of sand in geopressurized water is likely to cause problems of	erosion	heat exchange	water circulation	all of the above	erosion
Presence of non-condensable gases in geopressurized water causes	corrosion of parts	pollution	flow problems	all of the above	all of the above
When geothermal energy is available in the form of saline water, power is developed using	flashed-steam system	binary-cycle system	total flow system	any of the above	any of the above
Petrothermal systems are composed of hot dry rock with	no underground water	large underground water	petrochemicals	dense gases	no underground water
In petrothermal systems of geothermal energy there is hot dry rock but no underground water. In such systems energy is obtained by	circulating compressed air	pumping water	creating water wells	none of the above	pumping water
Reflecting mirrors used for exploiting solar energy are called	diffusers	ponds	heliostats	mantle	heliostats
Which of the following area is preferred for solar thermal electric plants ?	mountain tops	hot arid zones	coastal areas	high rainfall zones	hot arid zones
In solar thermal conversion systems the solar heat is transferred to	water-steam	liquid metals	molten salts	any of the above	any of the above

Photovoltaic solar energy conversion system makes use of	fuel cell	solar cell	solar pond	none of the above	solar cell
Solar cells are made of	silicon	germanium	silver	aluminium	silicon
The voltage of a single solar cell is	0.5 V	1 V	1.1 V	5 W	0.5 V
The output of a solar cell is of the order of	0.1 W	0.5 W	1 W	5 W	1 W

Unit – V

OTHER POWER PLANTS AND ECONOMICS OF POWER PLANTS

LECTURE NOTES

OCEAN THERMAL ENERGY CONVERSION

Ocean thermal energy conversion (*OTEC*)uses the difference between cooler deep and warmer shallow or surface ocean waters to run a heat engine and produce useful work, usually in the form of electricity.

A heat engine gives greater efficiency and power when run with a large temperature difference. In the oceans the temperature difference between surface and deep water is greatest in the tropics, although still a modest 20ºC to 25ºC. It is therefore in the tropics that OTEC offers the greatest possibilities. OTEC has the potential to offer global amounts of energy that are 10 to 100 times greater than other ocean energy options such as wave power. OTEC plants can operate continuously providing a base load supply for an electrical power generation system.

The main technical challenge of OTEC is to generate significant amounts of power efficiently from small temperature differences. It is still considered an emerging technology. Early OTEC systems were of 1 to 3% thermal efficiency, well below the theoretical maximum for this temperature difference of between 6 and 7%.[2] Current designs are expected to be closer to the maximum. The first operational system was built in Cuba in 1930 and generated 22 kW. Modern designs allow performance approaching the theoretical maximum Carnot efficiency and the largest built in 1999 by the USA generated 250 kW .

The most commonly used heat cycle for OTEC is the Rankine cycle using a low-pressure turbine. Systems may be either closed-cycle or open-cycle. Closed-cycle engines use working fluids that are typically thought of as refrigerants such as ammonia or R-134a. Open-cycle engines use vapour from the seawater itself as the working fluid.

OTEC can also supply quantities of cold water as a by-product . This can be used for air conditioning and refrigeration and the fertile deep ocean water can feed biological technologies. Another by-product is fresh water distilled from the sea.

CYCLE TYPES

Cold seawater is an integral part of each of the three types of OTEC systems: closed-cycle, open-cycle, and hybrid. To operate, the cold seawater must be brought to the surface. The primary approaches are active pumping and desalination. Desalinating seawater near the sea floor lowers its density, which causes it to rise to the surface.

The alternative to costly pipes to bring condensing cold water to the surface is to pump vaporized low boiling point fluid into the depths to be condensed, thus reducing pumping volumes and reducing technical and environmental problems and lowering costs.

CLOSED CYCLE:

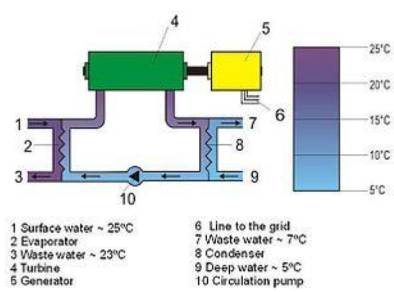


Diagram of a closed cycle OTEC plant

Closed-cycle systems use fluid with a low boiling point, such as ammonia, to power a turbine to generate electricity. Warm surface seawater is pumped through a heat exchanger to vaporize the fluid. The expanding vapor turns the turbo-generator. Cold water, pumped through a second heat exchanger, condenses the vapor into a liquid, which is then recycled through the system.

In 1979, the Natural Energy Laboratory and several private-sector partners developed the "mini OTEC" experiment, which achieved the first successful at-sea production of net electrical power from closed-cycle OTEC.[12] The mini OTEC vessel was moored 1.5 miles (2 km) off the Hawaiian coast and produced enough net electricity to illuminate the ship's light bulbs and run its computers and television.

OPEN CYCLE:

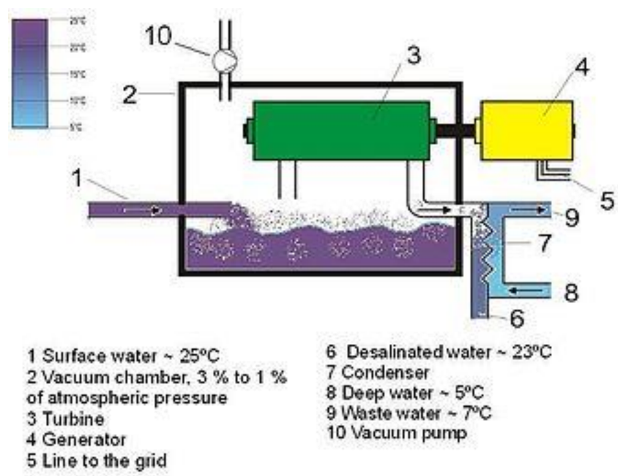


Diagram of an open cycle OTEC plant

Open-cycle OTEC uses warm surface water directly to make electricity. Placing warm seawater in a low-pressure container causes it to boil. The expanding steam drives a low-pressure turbine attached to an electrical generator. The steam, which has left its salt and other contaminants in the low-pressure container, is pure fresh water. It is condensed into a liquid by exposure to cold temperatures from deep-ocean water. This method produces desalinized fresh water, suitable for drinking water or irrigation.

PUMPED STORAGE:

Pumped-storage hydroelectricity is a type of hydroelectric power generation used by some power plants for load balancing. The method stores energy in the form of water, pumped from a lower elevation reservoir to a higher elevation. Low-cost off-peak electric power is used to run the pumps. During periods of high electrical demand, the stored water is released through turbines. Although the losses of the pumping process makes the plant a net consumer of energy overall, the system increases revenue by selling more electricity during periods of peak demand, when electricity prices are highest. Pumped storage is the largest-capacity form of grid energy storage now available.

GREEN ENERGY AND VARIOUS GREEN ENERGY SOURCES FOR GENERATING ELECTRICITY

Renewable energy is generally defined as **energy** that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat.

Types of green energy

Research into renewable, non-polluting energy sources is advancing at such a fast pace, it's hard to keep track of the many types of green energy that are now in development. Here are 6 of the most common types of green energy:

Solar Power - The most prevalent type of renewable energy, solar power is typically produced using photovoltaic cells, which capture sunlight and turn it into electricity. Solar energy is also used to heat buildings and water, provide natural lighting and cook food. Solar technologies have become inexpensive enough to power everything from small hand-held gadgets to entire neighborhoods.

Wind Power - Air flow on the earth's surface can be used to push turbines, with stronger winds producing more energy. High-altitude sites and areas just offshore tend to provide the best conditions for capturing the strongest winds. According to a 2009 study, a network of land-based, 2.5-megawatt wind turbines in rural areas operating at just 20% of their rated capacity could supply 40 times the current worldwide consumption of energy.

Hydropower - Also called hydroelectric power, hydropower is generated by the Earth's water cycle, including evaporation, rainfall, tides and the force of water running through a dam. Hydropower depends on high precipitation levels to produce significant amounts of energy.

Geothermal Energy - Just under the earth's crust are massive amounts of thermal energy, which originates from both the original formation of the planet and the radioactive decay of minerals. Geothermal energy in the form of hot springs has been used by humans for millennia for bathing, and now it's being used to generate electricity. In North America alone, there's enough energy stored underground to produce 10 times as much electricity as coal currently does.

Biomass - Recently-living natural materials like wood waste, sawdust and combustible agricultural wastes can be converted into energy with far fewer greenhouse gas emissions than petroleum-based fuel sources. That's because these materials, known as biomass, contain stored energy from the sun.

Biofuels - Rather than burning biomass to produce energy, sometimes these renewable organic materials are transformed into fuel. Notable examples include ethanol and biodiesel. Biofuels provided 2.7% of the world's fuels for road transport in 2010, and have the potential to meet more than 25% of world demand for transportation fuels by 2050.

GEOTHERMAL ENERGY POWER GENERATION:

Dry Steam Power Plant (Vapour Dominated System). Dry steam power plants draw from underground resources of steam. The steam is piped directly from underground wells to the power plant, where it is directed into a turbine/generator unit. There are only two known underground resources of steam in the United States: The Geysers in northern California and Yellowstone National Park in Wyoming, where there's a well-known geyser called Old Faithful. Since Yellowstone is protected from development, the only dry steam plants in the country are at The Geysers.

Power plants using dry steam systems were the first type of geothermal power generation plants built. They use the steam from the geothermal reservoir as it comes from wells, and route it directly through turbine/generator units to produce electricity. It is the rarest form of geothermal energy but the most suitable generation and the most developed of all geothermal resources or system.

Fig. 2.34 shows a schematic diagram of a dry steam power system also called vapour dominated system. Dry steam from the turbine at perhaps 200°C is used. It is near saturated at the bottom of the wall and may have a shut-off pressure up to 35 bar. Pressure drops through the well cause it to slightly superheated at the well head. An example of a dry steam generation operation is at the Geysers in northern California.

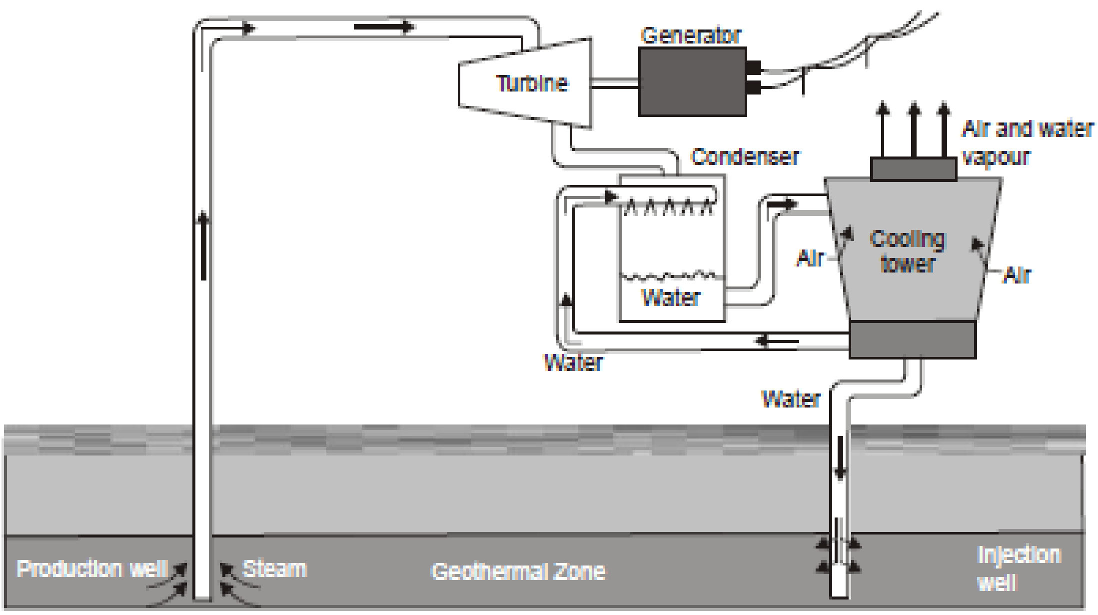


Fig. 2.34. Schematic of the Dry Steam Power Plant.

Flash Steam Power Plant (Liquid Domain System). Flash steam power plants are the most common. They use geothermal reservoirs of water with temperatures greater than 182°C. This very hot water flows up through wells in the ground under its own pressure. As it flows upward, the pressure decreases and some of the hot water boils into steam. The steam is then separated from the water and used to power a turbine/generator. Any leftover water and condensed steam are injected back into the reservoir, making this a sustainable resource.

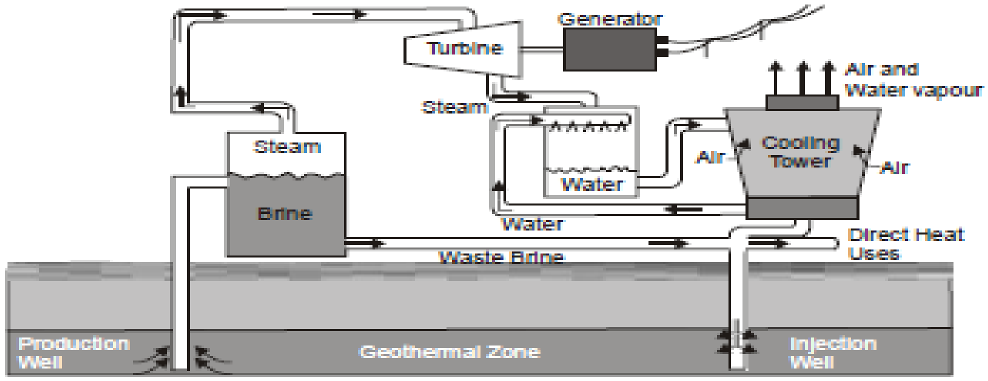


Fig. 2.35. Schematic of the Flash Steam Power Plant.

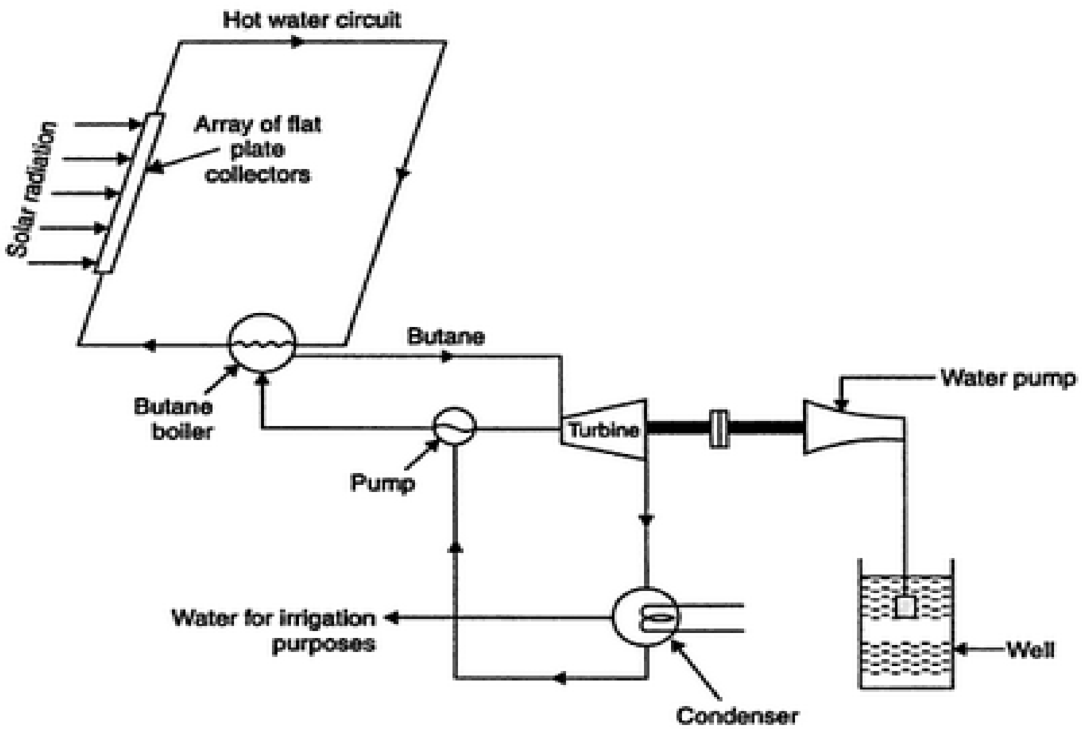
Flash-steam power plants built in the 1980s tapped into reservoirs of water with temperatures greater than 182°C. The hot water flows up through wells in the ground under its own pressure. As it

SOLAR POWER PLANT

The surface of the earth receives from the sun about 10^{14} kW of solar energy which is approximately five order of magnitude greater than currently being consumed from all resources. It is evident that sun will last for 10^{11} years. Even though the sun light is filtered by the atmosphere one square metre of the land exposed to direct sun light receives the energy equivalent of about 1 H.P or 1 kW. However, this vast amount of solar energy reaching earth is not easily convertible and certainly is not "free".

There are two obvious obstacles to harnessing solar energy. *Firstly* it is not constantly available on earth. Thus some form of storage is needed to sustain a solar power system through the night and during periods when local weather conditions obscure the sun. *Second* the solar energy is diffused. Although the total amount of energy is enormous, the collection and conservation of solar energy into useful forms must be carried out over a large area which entails a large capital investment for the conversion apparatus.

Fig. 7.14 shows a schematic diagram of a low temperature solar power plant. In this system an array of flat plate collectors is used to heat water to about 70°C and then this heat is used to boil butane in a heat exchanger. The high pressure butane vapour thus obtained runs a butane turbine which in term operates a hydraulic pump. The pump pumps the water from well which is used for irrigation purposes. The exhaust butane vapour (from butane turbine) is condensed with the help of water which is pumped by the pump and the condensate is returned to the heat exchanger (or boiler).



MULTIPLE CHOICE QUESTIONS

Questions	Opt1	Opt2	Opt3	Opt4	Answer
Baryon is one of the class of heavy elementary particles that includes	hyperons	neutrons	protons	all of the above	all of the above
Isotopes of uranium	U_{235}	U_{234}	U_{238}	all of the above	all of the above
Beaufort scale is used to measure	beta and gamma radiations	with speed	isolation	depth of sea	with speed
Beaufort scale is graded from 0 to	10	12	22	100	12
API gravity is expressed in terms of	gm/cc	dimensionless numbers	degrees	none of the above	degrees
Argillaceous rocks have	high clay content	high moisture content	low moisture content	low mineral content	high clay content
ASTM coal classification is based on	proximate analysis	ultimate analysis	orsat analysis	none of the above	proximate analysis
One barrel is nearly	0.96 cubic meter	0.44 cubic meter	0.16 cubic meter	0.013 cubic meter	0.16 cubic meter
Activated carbon is used for	absorption, of gases	paints and varnishes as coloring agent	production of carbon steels	purification of water	absorption, of gases
Solid or liquid panicles of microscopic size which are suspended in air or another gas form what is known as	aerosol	hyperon	geognosy	eluvium	aerosol
Air curtains find applications in	air conditioned spaces	green houses	nuclear power pants	solar energy systems	air conditioned spaces

The percentage of carbon in anthracites is generally	more than 90%	around 75%	between 50% and 70%	below 50%	more than 90%
Fluidized bed combustion helps to reduce	boiler size	pollution	both (A) and (B)	All the above	both (A) and (B)
In a boiler, the carry over of slugs of water into the piping due to dirty water is termed as	beating	foaming	seal ping	pitting	foaming
In geothermal power plants waste water is	re circulated after cooling in cooling towers	discharged into sea	discharged back to earth	evaporated in ponds	discharged back to earth
Grade of the coal is the same as	ultimate analysis	proximate analysis	orsat analysis	rank	rank
API gravity of water is taken as	zero	1	10	100	10
Liquids lighter than water (such as petroleum oils) have APT gravities numerically	less than 1.0	greater than 1.0	greater than 10	around 100	greater than 10
All of the following arc hard coals except	Anthracite	Lignite	Bituminous	Semi bituminous	Lignite
All of the following are heavy metals except	Mercury	Sodium	Chromium	Cadmium	Sodium
Which of the following is heavy oil ?	Gasoline	Kerosene oil	Diesel oil	Bunker oil	Bunker oil
Deuterium oxide is used in nuclear reactors as	fuel	moderator	shield	regulator	moderator
Heliochemical process is the process by which	solar energy is utilized through photosynthesis	neutron energy is converted into thermal energy	geothermal energy is converted Into electrical energy	wind energy is converted into electrical energy	solar energy is utilized through photosynthesis

Fixed carbon in case of bituminous coals is less than	70%	50%	35%	15%	70%
Humacite is the name associated with	lignites	radioactive minerals	bitumens	refrigerants	bitumens
In case of humic coals, hydrogen percentage varies from	4 to 6 percent	10 to 15 percent	16 to 20 percent	20 to 30 percent	4 to 6 percent