LECTURE NOTES

ON

POWER STATION ENGINEERING

6th SEMESTER

DEPARTMENT OF MECHANICAL ENGINEERING

GOVERNMENT POLYTECHNIC

SONEPUR-767017

PREPARED BY:
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WORKSHOP SUPERINTENDENT

TH.3 POWER STATION ENGINEERING

Name of the Course: Diploma in MECHANICAL ENGINEERING			
Course code:		Semester	6th
Total Period:	60	Examination	3 hrs
Theory periods	4 P/W	Internal assessment	20
Maximum marks:	100	End Semester Examination:	80

A. RATIONALE:

Bulk powers used in industries and for domestic purposes are generated in power stations. A large number of diverse and specialized equipment and system are used in a power plant should have this important subject in mechanical engineering.

B. COURSE OBJECTIVES:

At the end of the course the students will be able to:

- Understand the generation of power by utilizing various energy sources.
- Understand the use of steam, its operation in thermal power stations.
- Understand the nuclear energy sources and power developed in nuclear power station.
- Understand the basics of diesel electric power station and hydroelectric power station.
- Understand the basics of gas turbine power station
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C.TOPIC WISE DISTRIBUTION OF PERIODS

Sl No.	Topic	Periods
1	INTRODUCTION	05
2	THERMAL POWER STATIONS	20
3	NUCLEAR POWER STATIONS	10
4	DIESEL ELECTRIC POWER STATIONS	10
5	HYDEL POWER STATIONS	10
6	GAS TURBINE POWER STATIONS	05

D.COURSE CONTENTS:

1.0 INTRODUCTION:

1.1 Describe sources of energy.
1.2 Explain concept of Central and Captive power station.
1.3 Classify power plants.
1.4 Importance of electrical power in day today life.
1.5 Overview of method of electrical power generation.

2.0 THERMAL POWER STATIONS:

2.1 Layout of steam power stations.
2.2 Steam power cycle. Explain Carnot vapour power cycle with P-V, T-s diagram and determine thermal efficiency
2.3 Explain Rankine cycle with P-V, T-S & H-s diagram and determine thermal efficiency, Work done, work ratio, and specific steam Consumption.
2.4 Solve Simple Problems.
2.5. List of thermal power stations in the state with their capacities.
2.6 Boiler Accessories: Operation of Air pre heater, Operation of Economiser, Operation Electrostatic precipitator and Operation of super heater. Need of boiler mountings and operation of boiler

2.7 Draught systems (Natural draught, Forced draught & balanced draught) with their advantages & disadvantages.
2.8 Steam prime movers: Advantages & disadvantages of steam turbine. Elements of steam turbine. governing of steam turbine. Performance of steam turbine: Explain Thermal efficiency. Stage efficiency and Gross efficiency
2.9 Steam condenser. Function of condenser, Classification of condenser. function of condenser auxiliaries such as hot well. condenser extraction pump, air extraction pump, and circulating pump.
2.10 Cooling Tower: Function and types of cooling tower, and spray ponds
2.11 Selection of site for thermal power stations.

3.0 NUCLEAR POWER STATIONS:

3.1 Classify nuclear fuel (Fissile & fertile material)
3.2 Explain fusion and fission reaction.
3.3 Explain working of nuclear power plants with block diagram
3.4 Explain the working and construction of nuclear reactor
3.5 Compare the nuclear and thermal plants.
3.6 Explain the disposal of nuclear waste.
3.7 Selection of site for nuclear power stations.
3.8 List of nuclear power stations.

4.0 DIESEL ELECTRIC POWER STATIONS:

4.1 State the advantages and disadvantages of diesel electric power stations.
4.2 Explain briefly different systems of diesel electric power stations: Fuel storage and fuel supply system, Fuel injection system, Air supply system, Exhaust system, cooling system, Lubrication system, starting system, governing system.
4.3 Selection of site for diesel electric power stations.
4.4 Performance and thermal efficiency of diesel electric power stations.

5.0 HYDEL POWER STATIONS:

5.1 State advantages and disadvantages of hydroelectric power plant.
5.2 Classify and explain the general arrangement of storage type hydroelectric project and explain its operation.
5.3 Selection of site of hydel power plant.
5.4 List of hydro power stations with their capacities and number of units in the state.
5.5 Types of turbines and generation used.
5.6 Simple problems.

6.0 GAS TURBINE POWER STATIONS

6.1 Selection of site for gas turbine stations.
6.2 Fuels for gas turbine
6.3 Elements of simple gas turbine power plants
6.4 Merits. demerits and application of gas turbine power plants.

Syllabus covered up to I.A-Chapters 1,2 &3

E.LEARNING RESOURCES:

Sl. No.	*Name of Authors*	*Title of the Book*	*Name of the Publisher*
1	R.K Rajput	Power Plant Engineering	Laxmi Publication
2	P.K.NAG	Power Plant Engineering	TMH
3	Nag pal G.R	Power plant Engineering	Khanna Publisher
4	P.C.SHARMA	Power Plant Engineering	S.K KATARIA &SONS

Introduction :-

→ Powerstation also referred as generating station or power plant is an industrial facility for the generation of electric power. power plant is also used to reffer to the engine in ships, aircraft & other large vehicles.

→ At the centre of nearly all power stations is a generator, a rotating m/c that converts mechanical energy into electrical energy by creating relative motion betn a magnetic field & a conducter.

Energy :-

→ Energy is defind as it is the capacity of doing work. As we already know that energy neither be created nor be destroyed only it can transforms from one form to another.

→ Energy Exists in various forms. for ex Mechanical, thermal, electrical, solar, wind etc.

→ POWER :- It can be defind as it is the rate of flow of energy with respect to time & can state that a powerplant is a unit built for production & delivery of a flow of mechanical & electrical energy.

Sources of Energy :-

There are various types of energy such as -

① Fuel — (a) solid :- coal
(b) liquid :- petrol, diesel, kirosine etc
(c) gasses :- LPG & CNG

② Energy stored in water that is Hydraulic Energy.

③ Neclear Energy.

④ Wind power Energy.

⑤ Solar Energy.

⑥ Tidal power Energy.

⑦ Geothermal energy

⑧ Thermo electric power.

TYPES OF POWER STATION :-

→ The power stations are classified into 2 types.

① central power station

② captive power station.

① central power station :-

→ The electrical energy available from these stations is for general sale to the customers who wish to purchase it.

② Captive power station :-

→ This type of power station is run by a manufacturing company for its own use & its O/P is not available for general use.

⊙ Fuel :-

→ Generally fuels are the substance which are used for generating the heat energy by conversion.

→ The principle conversible elements of each fuel are carbon & hydrogen.

→ The fuels are classified into 3 different types.

(a) solid fuel (coal, coke)

(b) liquid fuel (diesel, petrol, kirosin)

(c) gaseous fuel (LPG, CNG)

1. Solid fuels :-

→ Coal :- The main constituents of coal are carbon, hydrogen, oxygen, nitrogen, sulphur, moisture & ash. Coal passes through different stages during its formation from vegetation. Different stages of coals are

1. Peat
2. Lignite or brown coals
3. Bituminous.
4. Semi bituminous.
5. Anthraside.

1. Peat :- It is the 1st stage in the formation of coal.
→ It contains huge amount of moisture therefore it is dryed for about one to two months before it is put to use.
→ It is used as a domestic fuel in europe & power generation in Russia.

2. Lignite or brown coals :-
→ These are the intermediate stage betn the peat & coal.
→ These are associated with high moisture, high ash & low heat containts.
→ Lignites are usually amorphous in char. & impose transport difficulties as they break easily.

3. Bituminous coals :-
→ It burns with long yellow & smoking flames & has high percentage of volatile matter.
→ The calorific value of bituminous coal is 31350 kJ/kg.
→ It may be of two types ① Caking
② Noncaking

4. Semi bituminous coal :-
→ It burns with a very small amount of smoke.
→ It contains 15-20 % of volatile matter.
→ It is softer than anthraside.

5. Anthracite :-

→ It is very hard coal & has a shining black lustre.
→ It ignites slowly unless the furnesh temp. is high.
→ It is noncaking & has fixed percentage of carbon.
→ It burns either with very short blue flames or without flames.
→ The calorific value of this fuel is 35500 KJ/kg. & such is very suitable for steam generation.

• Coke :-

1- It is the solid residue left after the destructive distilation of wood or certain kinds of coals
2- It is mainly used in blast furnance to produce heat & at the same time
3- It consist of carbon, sulphur, small quantity of S, H & P.

• Energy stored in Water :-

→ The energy contain in flowing of water is a form of hydraulic energy or in the form of mechanical energy. It may exist as the kinetic energy or as potential energy of the water at some elevation w.r.t.o a lower datum level.
→ Hydraulic plants are slowly increase in order, although the no of new plants of this type built is quite small.
→ Water power is quite chiefe where water is available in abundance.
→ Although the capital cost of hydroelectric powerplant is higher as compare to other types of power plants.

• **Neuclar energy (neclear power) :-**

→ It is the large amount of energy that can be released from a small mass of active material.

→ Complete fission of 1 kg of uranium contains the energy equivalent of 4500 tones of coal or 2000 tones of oil.

→ The Neclear power is not only available in abundance but it is cheaper than the power generated by convenctional sources.

• **Wind power :-**

→ The man has been served by the power from winds for many centuries but total amount of energy generated in this manner is small.

→ The expence of installation & variability of operation have tended to limit. The use of wind mill.

→ In india the wind velocity along coast line has a range 10-16 kmph & a survey of wind power has revealed that wind power is capable of exploitation for pumping water from deep wells or for generating small amount of electric energy.

→ Modern wind mills are capable of working on velocities as low as 3-7 kmph while max^m efficiency is attained at 10-12 kmph.

Charecterstics of wind power / energy :-

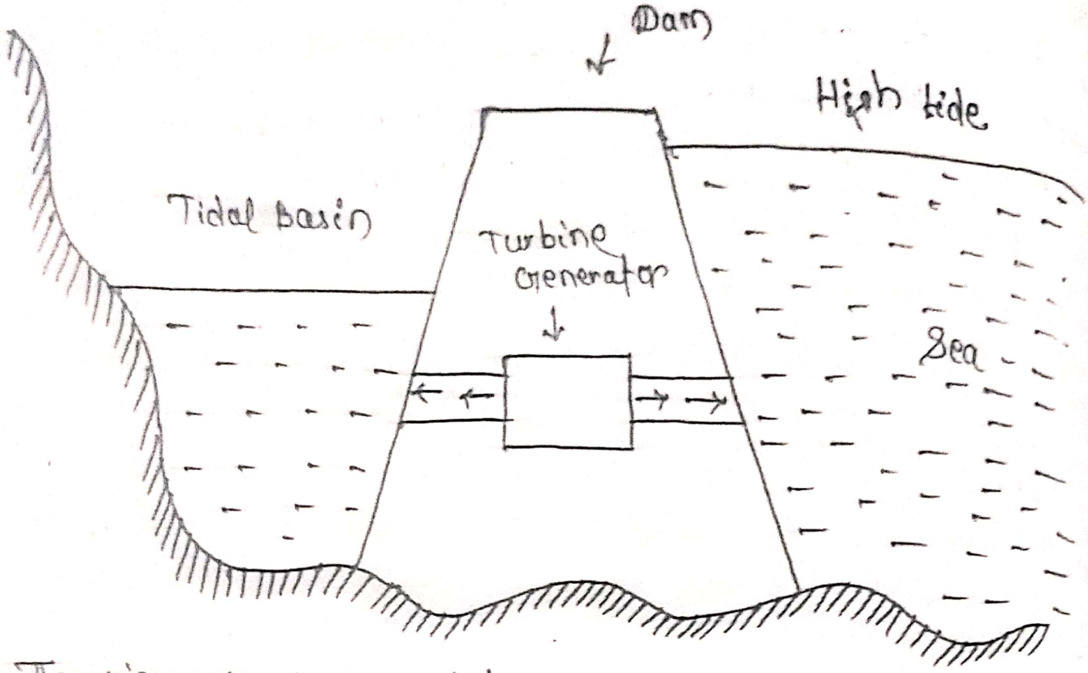
① No fuel provision & transport are required in wind energy system.

② It is a renewable source of energy.

③ Wind power systems are nonpolluting.

④ Wind power systems, upto a few kw, costs can be competative with convectional electricity.

• **Tidal power energy :-**



1 → The rise of fall of tides offers a means for storing water at the rise & discharging the water at fall.

2 → The use of tides for electric power generation is partical in a few favourably situated sites where the geography of an inlet of bay favours the construction of a large scale hydroelectric plant.

3 → To harness the tides, a dam would be built across the mouth of the bay in which large gates & low head hydraulic turbine would be installed.

4 → At the time of high tide the gets are opened automatically. After the tide has receeived the turbine is operated & then the water is discharging to the tidal basin then the gates are closed.

5 → With this type of arrangement the generation of electric power is not contineous.

- **Geothermal power :-**

→ In many places on the earth natural steam escapes from surface vents. such natural steam wells suggest the posibility of heat or geothermal energy.

→ There are probably many places where no natural steam vent or hot springs are sowing, deep drillings might tap a source of underground steam.

- **Thermoelectric power :-**

When the two ends of a loop of two dissimilars metals are held at different tempratures, an electromotive force is developed & the current closed into the loop. The method by slection of suitable material can also be used for power generation. This method involves low initial cost & neglisible operating cost.

- **Solar power :-**

(1) A lot of work to be utilized solar energy for generation of steam has been done in some countries.

(2) A serious fault of this source of energy is, of course that it is effective only during the daytime, so that if a contineous o/p is needed some large reserver of energy such as a storage battery must be drawn upon at night.

(3) Also the o/p is handicaped if there is clouding weather.

(4) Neverthless, there are some locations in the world where strong solar radiation is received very regularly, such locations offer more intrest to the solar power plant builders.

(5) For developing solar energy two ways have been explod that is the glass lence & the reflector.

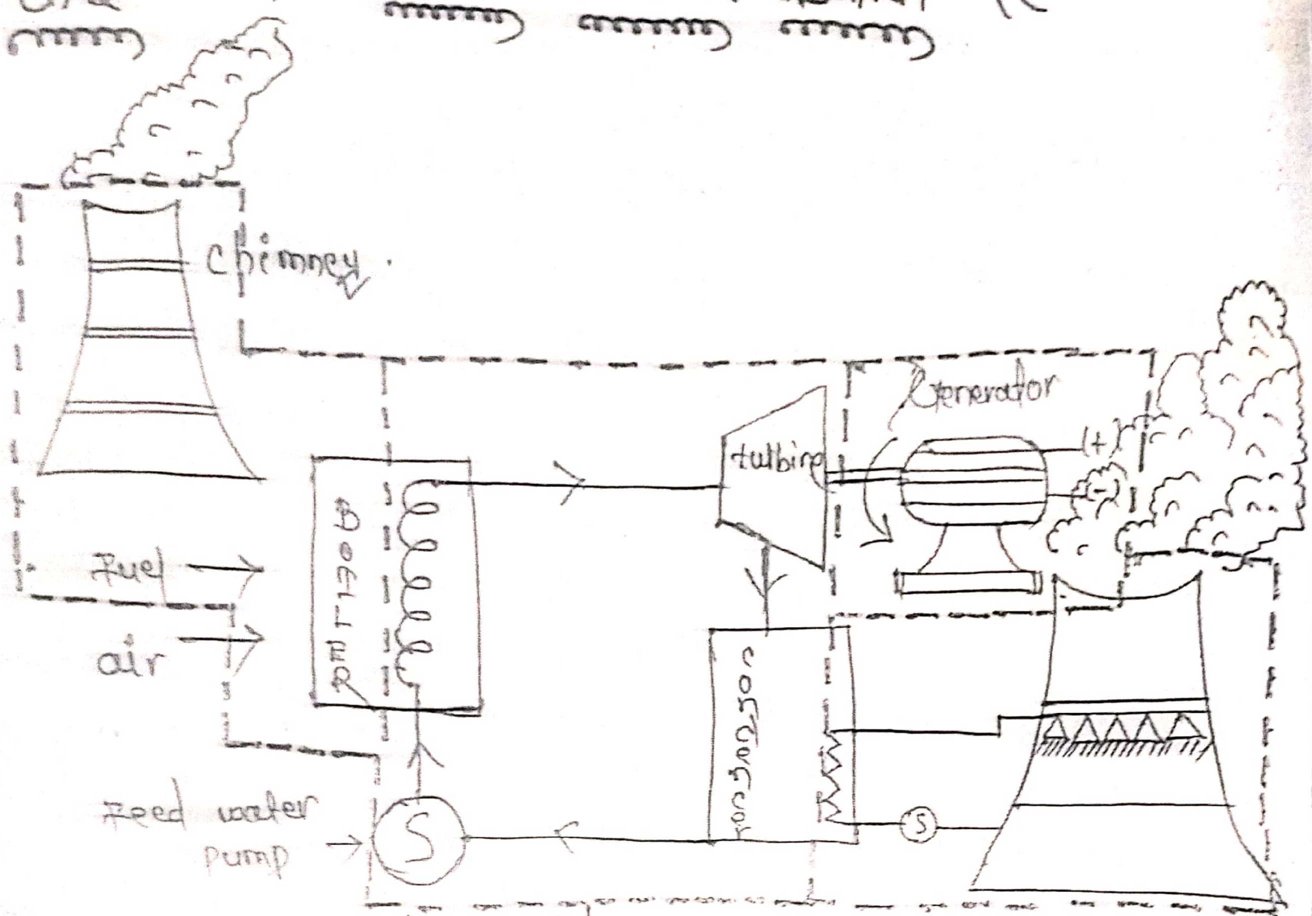
(6) These device concentrate the solar rays to the focal point which is charecterised by a high degree of it which can be

Utilised to boil water & generate steam.

7. Condn for utilization of solar energy in india are favorable since for nearly 6 months of the year, sun shine is uninterrupted during the day. While in the other six months cloudly weather.

8. Thus a coordination of solar energy with water power can provide a workable plant for most places in india.

ch-2 →» **STEAM POWER PLANT** «←



→ A steam power plant consist of the following main components

1. Boiler
2. steam turbine
3. condensor
4. ~~Fe~~ feed water pump.
5. Electric generator.
6. Cooling tower
7. Water circulating pump
8. Chimney

→ The above diagram represents the simplified cycle & the basic components of a steam power plant. To facilitate the thermodynamic analysis the whole plant can be devided into 4 major substations identified as subsystem A, B, C & D.

Subsystem A :- It consists of a furnesh & chimney. Its fun^c is to supply heat energy to the boiler. The heat energy may be obtained by burning of fossil fuel.

necluar reaction or by solar energy.

Subsystem B :- In subsystem B the working fluid passes through the series of 4 interconnected components & Power is generated in this cycle so that this cycle is reffered as steam cycle or power cycle.

→ In this sub system the heat energy is converted into the mechanical work. It consists of a boiler, a turbine, a condenser & a heat pump.

→ The steam generated in the boiler is passed to the turbine where it expands to a lower pressure thus power is generated.

→ The steam living the turbine is passed through the condenser where it condenses through the cooling water.

→ The cooling water is circulated in the condenser with the help of subsystem C.

→ The condensate is then recirculated to the boiler with the help of feed water pump.

Subsystem C :- It consist of the cooling tower & water recirculation pump. The circulated warm water from the condenser is sent to the cooling tower where its heat energy is rejected to the atmosphere.

Subsystem D :- The subsystem D pertains to generation of electrical energy & thus consist of a generator. The generated electricity is supplied to a power grid through the substations.

- **Performance parameters of steam power cycle :-**

1. **Thermal efficiency :-**

→ The thermal efficiency of steam power cycle is defind as it is the ratio betⁿ net work O/P & the heat I/P

→ Mathmatically $\eta_{ith} = \frac{W_{net}}{Q_{in}}$

② Back work ratio :-

→ It is the ratio betⁿ the pump work & turbine work

then $bwr = \frac{W_p}{W_t}$

③ Work ratio :-

→ It is defind as it is the ratio betⁿ net work output & the turbine work.

$$\text{work done} = \frac{W_{net}}{W_t}$$

$$= \frac{W_t - W_p}{W_t} = 1 - \frac{W_p}{W_T} = 1 - bwr.$$

④ specific steam consumption :-

→ It is the amount of steam required to produce one kwh of power or 3600 kJ of work is known as specific steam consumption (SSC) it is also called steam rat

→ It is denoated by (SSC) & it is expressed as

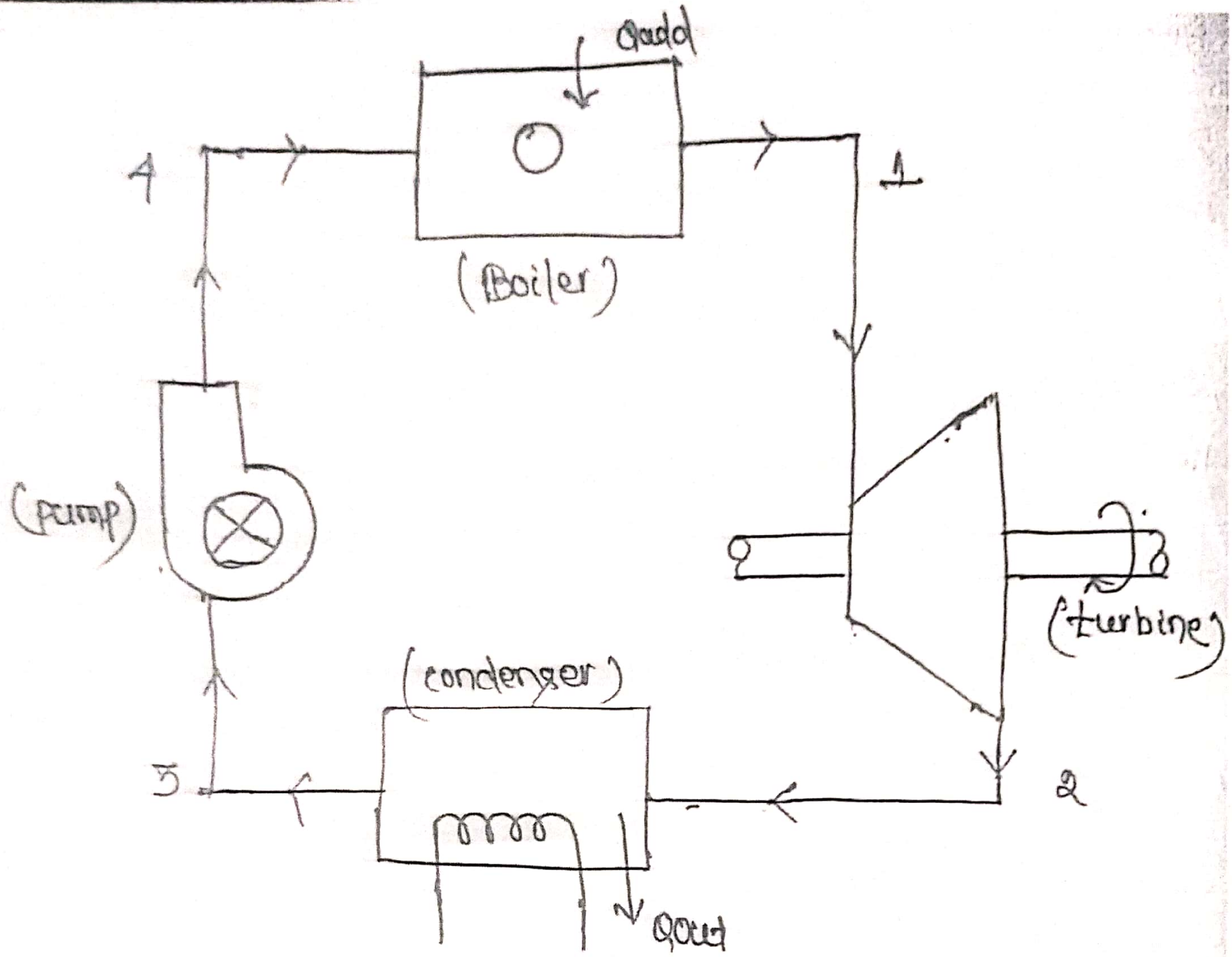
$$SSC = \frac{\text{Mass of steam in kJ/hour}}{\text{Power O/P in kW}}$$

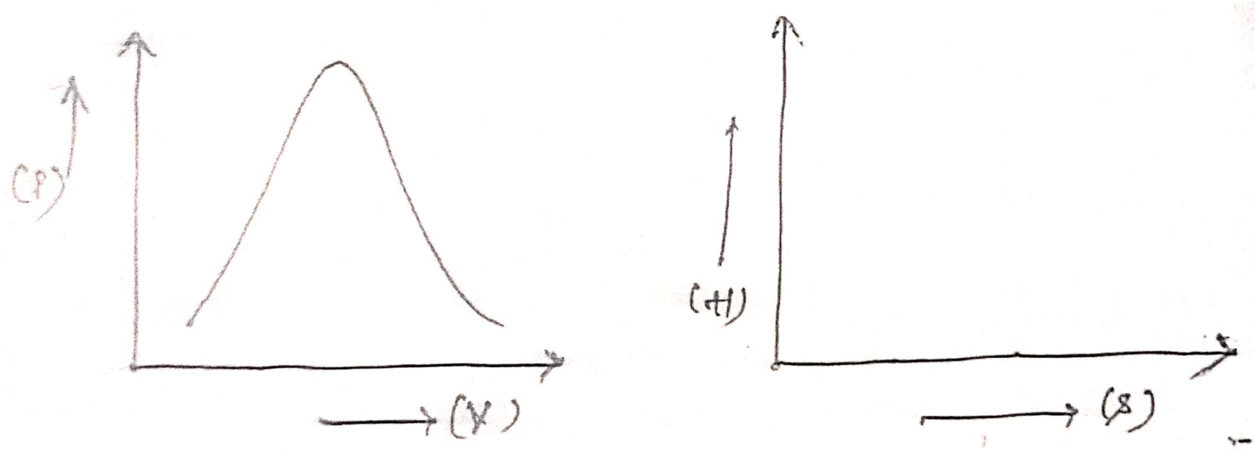
→ Rankine. Cycle :-

→ The steam power plant is actually operated by rankine cycle. The rankine vapour Cycle is more partical than the other cycle. It consist of 4 Major components for generating the power. The different components are a steam boiler known as steam generator, a steam turbine, a condenser & a pump.

→ Here in this cycle we are using a pump instead of a compressor operating in carnot Cycle.

→ The high pressure & temp saturated steam generating from the boiler is passes into the turbine where it gets expanding.


Qadd
4
1
(Boiler)
(pump)
(turbine)
(condenser)
3
2
Qout


(P)
(V)
(H)
(s)

at expansion the steam looses its temp & pressure. The low pressure steam then enters into the condensor. In the ~~steam is converted into the~~ condenser there is cooling water arrangement for condensing the low pressure steam. After that the steam is converted into the liquid form at the exist of condenser.

→ Then the condensate is allowed to flow through the pump where it compreses & increase the pressure.

→ The above diagram indicates the skimatic arrangement of rankine cycle with PV & Ts & Hs coordinates

→ The rankine cycle is operating in 4 different processes named as

Process 1-2 → Isentropic expansion process.

→ This process is known as isentropic expansion process

$W_t = h_1 - h_2$

process 2-3 → constant pressure heat rejection process.

→ Here $Q_{rej} = h_2 - h_3$

process 3-4 → Isentropic compression process

→ Here $W_p = h_4 - h_3$.

process 4-1 → constant pressure heat addition process.

→ Here $Q_{add} = h_1 - h_4$.

→ We know that $\eta_{th} = 1 - \frac{Q_{out}}{Q_{in}}$

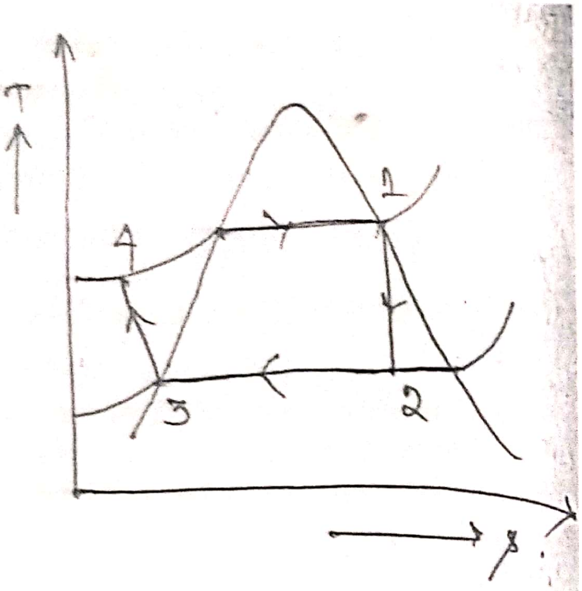
$= 1 - \frac{h_2 - h_3}{h_1 - h_4}$

→ Here at state-1 :-

$P_1 = ?$

$h_1 = h_{g1} = \ kJ/kg.$

$s_1 = s_{g1} = \ kJ/kgK$



→ at state-2 :-

$P_2 = ?$

$s_1 = s_2$

$h_{f2} = \ kJ/kg.$

$h_{fg2} = kJ/kg.$

$s_{f2} = kJ/kgK$

$s_{fg2} = kJ/kgK.$

$h_2 = h_f + x h_{fg}$

$s_1 = s_2 = (s_f + x\, s_{fg}) \Rightarrow x$

→ at state-3 :-

$h_3 = h_{f3}$

$v_{f3} = ?$

→ at state-4 :-

$W_P = h_4 - h_3$

$\Rightarrow h_4 = W_P - h_3$

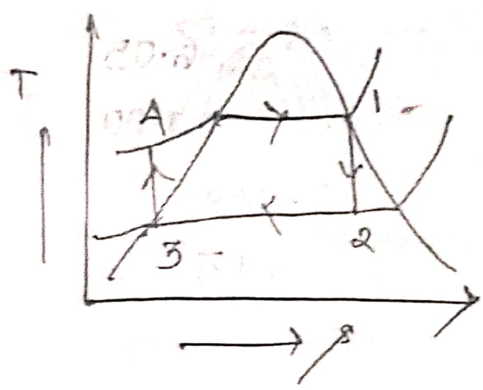
$W_P = v_{f3}(P_4 - P_3)$

$= v_{f3}(P_1 - P_2)$

Q) A steam power plant has boiler & Condenser pressure of 60 bar & 0.1 bar respectively. steam coming out of the boiler is dry & saturated. The plant operates on the rankine cycle. Calculate the thermal efficiency of the point.

Given) Here $p_1 = 60$ bar $= 60 \times 100$
$= 6000$

& $P_2 = 0.1$ bar
$= 0.1 \times 100 = 10$.



→ Here at state 1 :

$P_1 = 60$ bar

$h_1 = h_{g_1} = 2784.3$ kJ/kg

$s_1 = s_{g_1} = 5.8892$ kJ/kgK.

→ Then at state 2 :

$P_2 = 0.1$ bar

$h_{f_2} = 191.83$ kJ/kg

$h_{fg_2} = 2392.8$ kJ/kg

$s_{f_2} = 0.6493$ kJ/kgK.

$s_{fg_2} = 7.5009$ kJ/kgK.

→ Then at state 3 :

$P_3 = 0.1$ bar

$h_3 = h_{f_3} = 191.83$ kJ/kg.

$v_{f_3} = 0.001010$ m^3/kg.

→ Then at state 4 :-

$W_p = h_4 - h_3$

$W_p = v_{f3}(P_1 - P_2)$

$= 0.001010(6000-10)$

$= 6.049\ kJ/kg$

approx $= 6.05\ kJ/kg$

$h_4 = W_p - h_3$

$= 6.05 + 191.83$

$= 197.88\ kJ/kg$

then $h_2 = (h_{f2} + x\, h_{fg2})$

$S_2 = (S_{f2} + x\, S_{fg2})$

$5.8892 = (0.6493 + x \times 7.5009)$

$\Rightarrow x = \frac{5.8892 - 0.6493}{7.5009}$

$\Rightarrow x = 0.6985$ (unitless)

$h_2 = 191.83 + x \times 2392.8$

$\Rightarrow h_2 = 191.83 + (0.6985 \times 2392.8)$

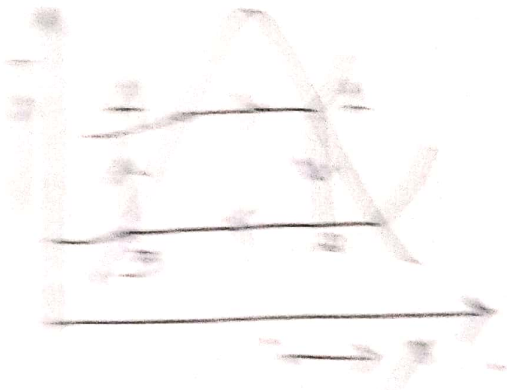
$\Rightarrow h_2 = 1863.20\ kJ/kg$

∴ efficiency of $\eta_{th} = 1 - \frac{h_2 - h_3}{h_1 - h_4}$

$= 1 - \frac{1863.20 - 191.83}{2784.3 - 197.88}$

$= 0.35\ \%$

$= 35\ \%$ Ans



[illegible]

$= 0{\cdot}7065$

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

$h_2 = 137.82 + 0.7053 \times 2423.7$

$= 1849.6 \ kJ/kg$

At state 3 : $P_2 = 0.05 \ bar$

$h_3 = h_{f_3}$ $\quad v_{f_3} = 0.001005 \ m^3/kg$

$= 137.82 \ kJ/kg$

At state 4 :

$W_P = h_4 - h_3$

$h_4 = W_P + h_3$

$= 4.014 + 137.82$

$= 141.834 \ kJ/kg$

$w_P = v_{f_3}(P_1 - P_2)$

$= 0.001005(4000 - 5)$

$= 4.014$

$= 4.014 \ kJ/kg$

$$\eta_{ith} = 1 - \frac{h_2 - h_3}{h_1 - h_4}$$

$$= 1 - \frac{1849.6 - 137.82}{2801.4 - 141.834}$$

$= 0.35 \ \% \quad = 35 \ \%$

Reheat cycle :

→ If the steam expands completely in a single stage then steam coming out from the turbine is very weight wet. The wet steam carries suspendent moisture particle which are heavier than the vapour particles, thus deposited on the blades & causing its erosion.

→ In order to increase the life of the turbine blades it is necessary to keep the steam dry during its expansion.

→ It is down by allowing the steam to expand to an intermediate pressure in a high pressure turbine, & then taking it out & sending back to the boiler where it is reheated at constant pressure, until it reaches the inlet temp. of the 1st stage as shown in skimatic diagram.

→ This process is called re heating & the cycle is known as reheat rankine cycle.

→ Due to reheating the work o/p of the turbine increases, thus improving the thermal efficiency.

Working : The reheat cycle is designed to take advantage of higher boiler pressure by eleminating the proplem of excessive moisture content in the exhaust &

The working of reheat cycle consist of a boiler, high pressure turbine, low pressure turbine, condenser & a heat water pump. The above skimatic diagram represents the steam enters at state - 1 in the 1st stage of turbine (Hp) & expands isentropically to the state - 2.

At state 2 the quality of steam is either slidely dry or just wet & thus it is taken back in the boiler & is reheated to the original superheated temp t_3.

*

then this reheated steam is further expanded in the low pressure turbine in the process 5-4.

Then the cycle is continued as the rankine cycle.

Regenerative Cycle :

→ In a simple rankine cycle is significant amount of heat is added for sensible heating of compressed liquid coming out the pump.

→ The mean temp at which sensible heat added is much lower than the source temp. thus the efficiency of the rankine cycle is much lower than that of carnot vapour power Cycle.

→ The efficiency of the rankine cycle can be improved by heating the feed water regeneratively.

Working : The mean temp of heat addⁿ in the rankine cycle can be improved by increasing the heat supplied at high temp such as increasing super heat, increasing boiler pressure & reheat.

→ The mean temp of the heat addition can also be increased by decreasing the amount of heat supplied at lower temps.

→ In actual practice the advantage of regenerative heating principle is used by extracting a part of expanded steam from the turbine & it is used for heating of feed water in separate feed water heaters,

→ This arrangement doesn't reduce the