LECTURE NOTES

ON

POWER STATION ENGINEERING

6th SEMESTER

DEPARTMENT OF MECHANICAL ENGINEERING

GOVERNMENT POLYTECHNIC

SONEPUR-767017

PREPARED BY:
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TH.3 POWER STATION ENGINEERING

Name of the Course: Diploma in MECHANICAL ENGINEERING			
Course code		Semester	6th
Total Periods	80	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 electric and mechanical equipment and system are used in a power plant should have the awareness subject on 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 expansion 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

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 Diagram of combined 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

2.4 Explain the Regenerative cycle and reheat cycle and Cogeneration

2.5 Boilers: Simple Problems

2.6 List of thermal power stations in the state with their capacities

2.7 Boiler Accessories: Operation of Air pre heater, Operation of Economizer, Operation of Superheater, principle 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, condensate 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 generators 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 applications of gas turbine power plants.

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

LEARNING RESOURCES: [illegible]

S. No.	Name of Authors	Title of the Book	Name of the Publisher
[illegible]	R.K. Rajput	Power Plant Engineering	Laxmi Publication
[illegible]	P.K. NAG	Power Plant Engineering	TMH
[illegible]	Nagpal G.R.	Power plant Engineering	Khanna Publisher
[illegible]	[illegible]	Power Plant Engineering	S.K. KATARIA &SONS

Introduction :-

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

→ At the centre of nearly all power stations is a generator, a rotating machine that converts mechanical energy into electrical energy by creating relative motion b/w a magnetic field & a conductor.

Energy :-

→ Energy is defined as it is the capacity to do 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, such as Mechanical, thermal, electrical, solar, wind etc.

→ POWER :- It can be defined as it is the rate at which energy is used with respect to time. It can state that a power plant is a unit that are producing & delivering a form of mechanical & electrical energy.

Energy as Energy :-

There are various types of energy such as -

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

(2) Energy stored in water that is Hydraulic Energy.
(3) Energy stored in wind
(4) Nuclear Energy
(5) Wind power Energy
(6) Solar Energy
(7) Tidal power Energy
(8) Geothermal energy
(9) Thermoelectric 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 unit for its own use & the unit is not available for general sale.

(3) Fuel :-

→ Generally fuels are the substance which are used in generating the heat energy by combustion.

→ The principle combustible 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, kerosene)

(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 (vegetables). Different types of coals are

1. Peat
2. Lignite or brown coal
3. Bituminous.
4. Semi bituminous.
5. Anthracite.

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 sweden.

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

3. Bituminous coal :-
→ 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 type → ① Coking
② Non-coking

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

5. Anthracite :-

→ It is very hard coal it has a shining black lustre.
→ It ignites slowly unless the fuel bed temp. is high.
→ It is non-caking it has fixed percentage of carbon.
→ It burns either with very short blue flames or without flames.
→ The calorific value of this fuel is 33500 KJ/kg. & such is very suitable for steam generators.

* Coke :-

1- It is the solid residue left after the destructive distillation of wood or certain kinds of coals.
2- It is mainly used in blast furnace to produce heat & at the same time.
3- It consists of carbon, Sulphur, small quantity of ash & P.

* Energy stored in water :-

→ The energy carried 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.
→ Hydraulic plants are already increase in order, although the number of this type built is quite small.
→ Water power is quite cheaper where water is available in abundance.
→ Although the capital cost of hydroelectric powerplant is higher as compare to other type of power plants.

• Nuclear energy (nuclear power) :-

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

→ Complete fission of 1kg of uranium contains an energy equivalent to 3000 tons of coal or 2000 tons of oil.

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

• Wind power :-

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

→ The existence of intermittency & variability of operation have limited the use of wind mills.

→ In India the wind velocity along coast line has a range 10-16 m/s & a survey on wind power has revealed that wind power is capable of exploitation for pumping water from wells & for generating small amount of electric energy.

→ Modern windmills are known to work on velocities as low as 3-4 m/s while max efficiency is obtained at 10-16 m/s.

Characteristics of wind power / energy :-

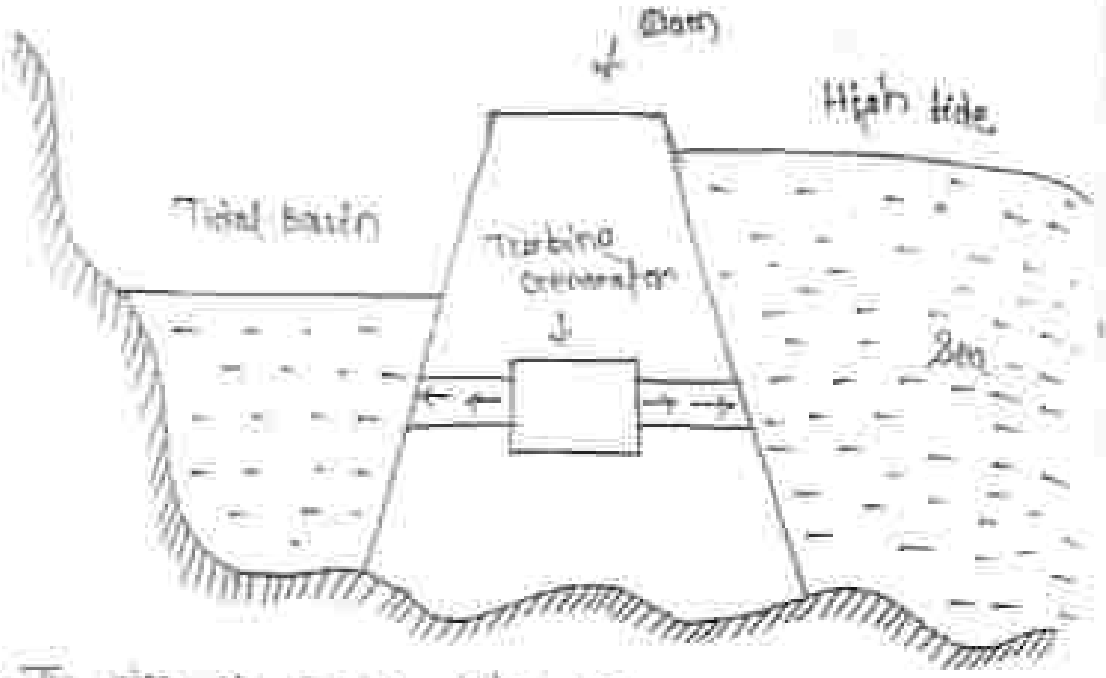
① The wind turbines & compressors are required in wind energy system.

② It is a renewable source of energy.

③ Wind power systems are non-polluting.

④ Wind power systems, with a long life, costs can be competitive with conventional electricity.

• Tidal power energy :-



1→ The rise of sea at tides offers a means for storing water till the time is discharging the water at sea.

2→ The use of tides for electric power generation is parted in a few favourably situated sites where the height of tide is large enough to justify the construction of a large tidal hydroelectric plant.

3→ To harness the tides, a dam should 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 gates are opened automatically after the tank has received the turbine is operated & the dam water is discharging to the tidal basin then the gate is closed.

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

* Geothermal power :-

→ In many places on the earth natural steam escapes from fissures, vents. Such natural steam vents suggest the possibility of heat in geothermal areas.

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

* Thermoelectric power :-

When the two ends of a loop of two dissimilar metals are held at different temperatures, an electromotive force is developed & the current flowing into the loop be heated by suitable material can also be used for power generation. This method involves low initial cost & negligible operating cost.

* Solar power :-

(1) It is wise to be utilized solar energy for generation of steam has been done in some countries.

(2) It is mainly result of the source of energy is, of course, that it is available only during the daytime, so that it is necessary to collect some large reserve of energy such as a storage battery must be drawn upon at night.

(3) Also the set is handicapped in times of cloudy weather.

(4) Nevertheless there are some locations in the world where strong solar radiation is received very regularly, such locations often most interest to the other power plant builders.

(5) In addition, solar energy has only have been applied that is the plant hence by the reflector.

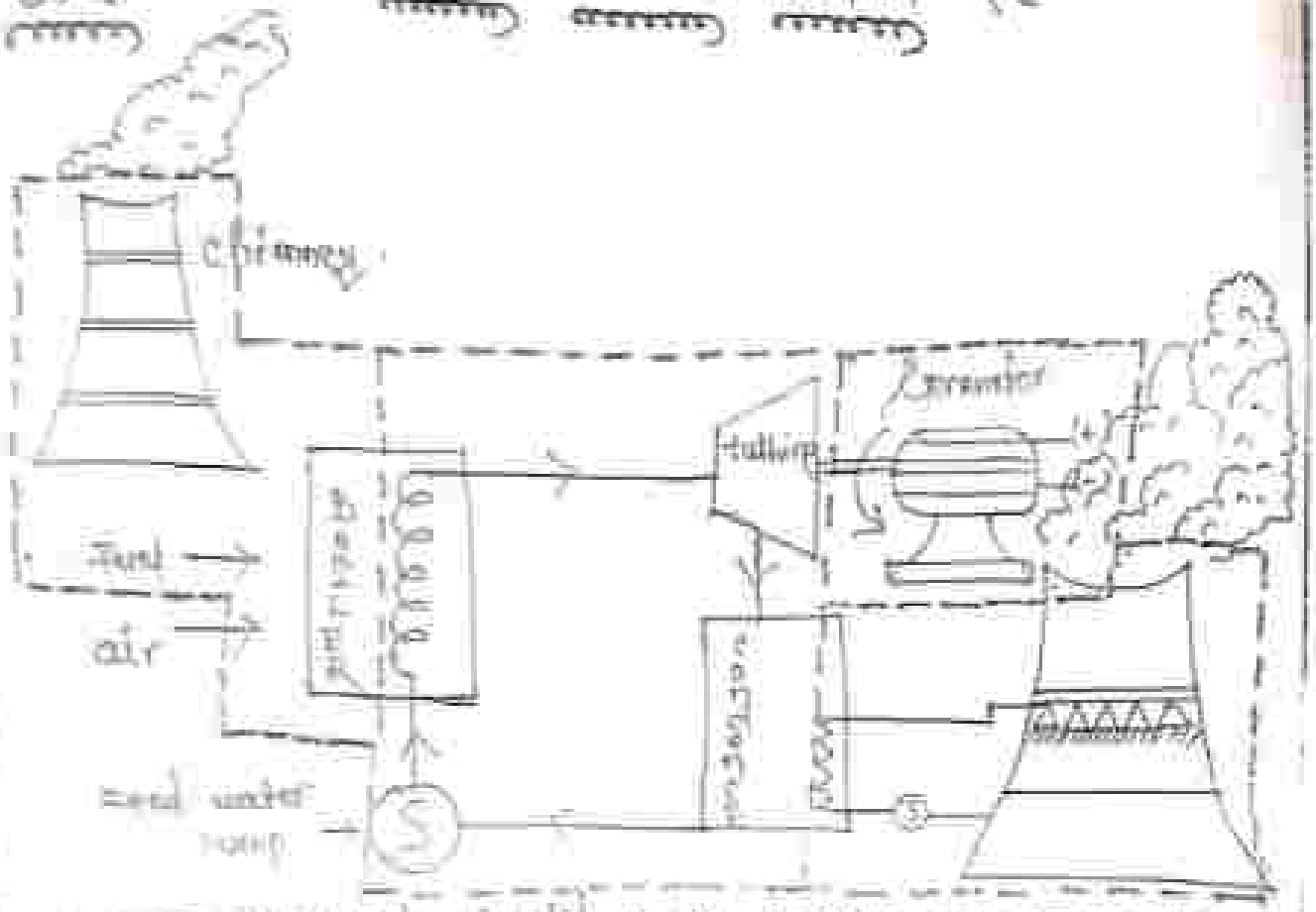
(6) Heat device concentrate the solar rays to the focal point which is characterized by a high degree of it which can be

utilised to hot water & generate steam.

(7) Cond' for utilisation of solar energy in India are found to be ideal for nearly 8 months of the year, sunshine for uninterrupted during the day. While in the other 4th months cloudy weather.

(8) Thus a combination of solar energy with water power can provide a workable plant for most places in India.

STEAM POWER PLANT



→ A steam power plant consist of the following main components

① Boiler
② steam turbine
③ Condenser
④ the 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 divided into 4 major subsystems identified as subsystem A, B, C & D.

Subsystem A → It consists of a furnace & chimney. Air & fuel supply heat energy to the boiler. The heat energy may be obtained by burning of coal, fuel.

nuclear reaction or by solar energy.

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

→ In this subsystem 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. It also 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 defined as it is the ratio of net work output to the heat i/p

→ Mathematically, $\eta_{th} = \frac{W_{net}}{Q_{in}}$

(10) Back work ratio :-

→ It is the ratio bet' the pump work & turbine work.

$$\text{Back work ratio} = \frac{W_p}{W_t}$$

(11) Work ratio :-

→ It is defined as it is the ratio bet' net work output & the turbine work.

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

$$= \frac{W_t - W_p}{W_t} = 1 - \frac{W_p}{W_t} = 1 - \text{back work.}$$

(12) Specific steam consumption :-

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

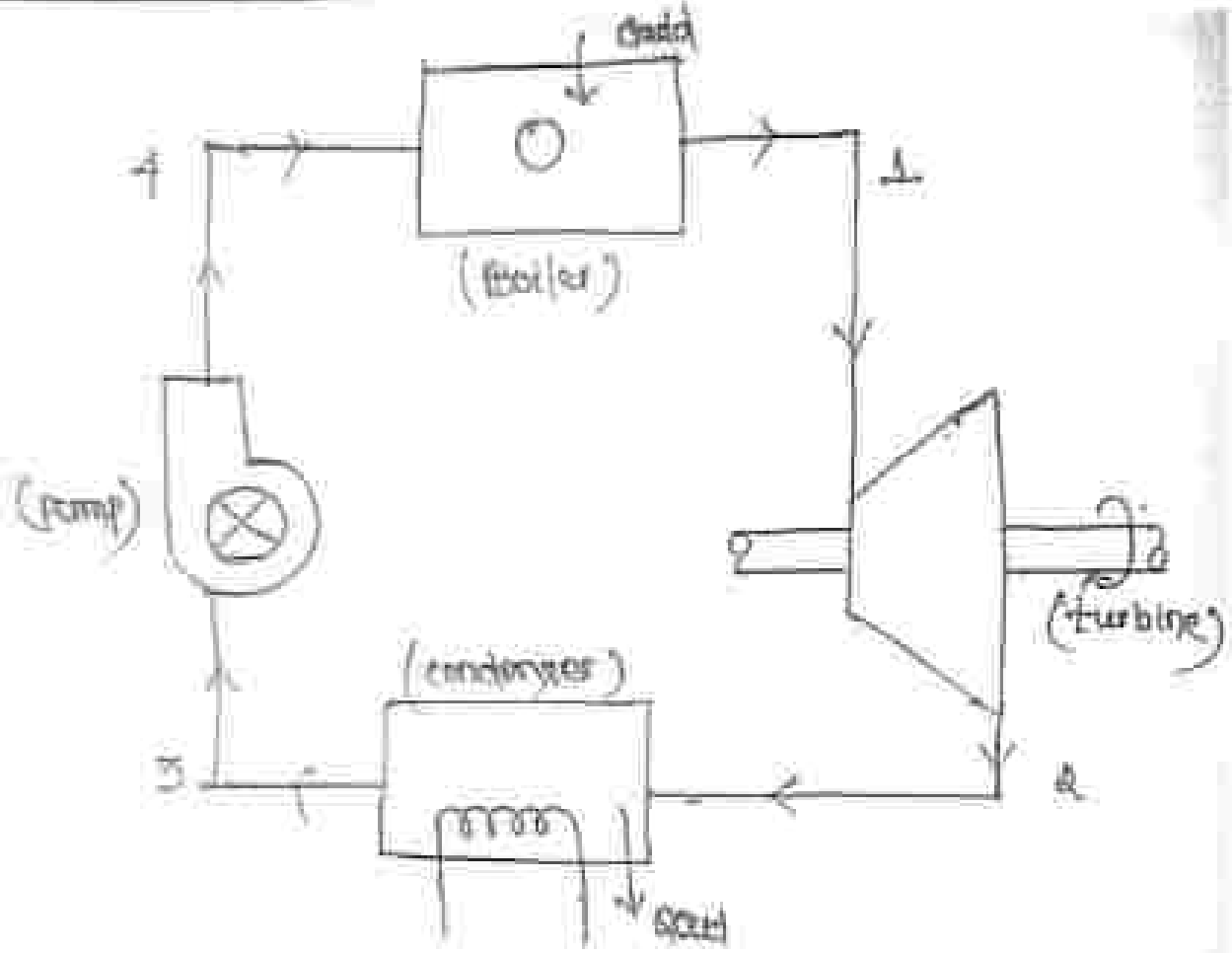
→ It is denoted by (SSC) & it is expressed as

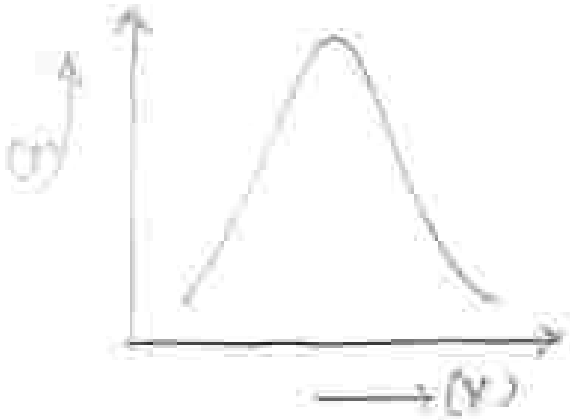
$$SSC = \frac{\text{Mass of steam in kg/hour}}{\text{Power o/p in kW.}}$$

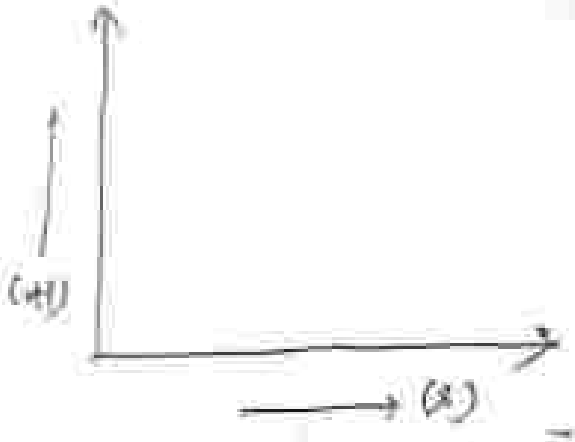
→ Rankine Cycle :-

→ The steam power plant is actually operated by rankine cycle. The rankine vapour cycle is more practical than the other cycle. It consist of 4 major components are 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 fated into the turbine where it gets expanding.


Coal
4
1
(Boiler)
(Pump)
(Turbine)
(condenser)
3
2
Cold


(V)


(H)
(S)

at entropy the steam loses its temp & pressure. The low pressure steam then enters into the condenser. 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 exit of condenser.

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

→ The above diagram indicates the schematic arrangement of rankine cycle with fig & its T-S 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 $W_{in} = h_4 - h_3$.

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/kg K

→ at state-2 :- $P_2 = ?$

$s_1 = s_2$

$x_2 =$ kJ/kg

$h_{f2} =$ kJ/kg

$h_{fg2} =$ kJ/kg

$s_{f2} =$ kJ/kg K

$s_{fg2} =$ kJ/kg K

→ at state-3 :-

$h_3 = h_{f3}$

$v_{f3} = ?$

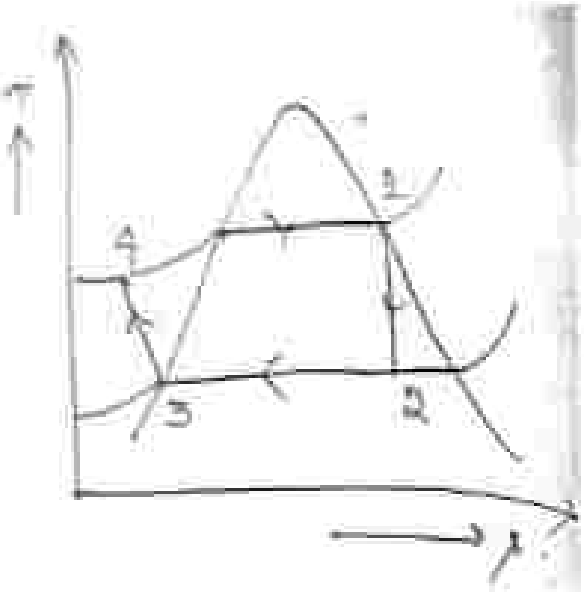
→ at state-4 :-

$w_p = h_4 - h_3$

$\Rightarrow h_4 = w_p + h_3$

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

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



$h_2 = h_f + x_2 h_{fg}$

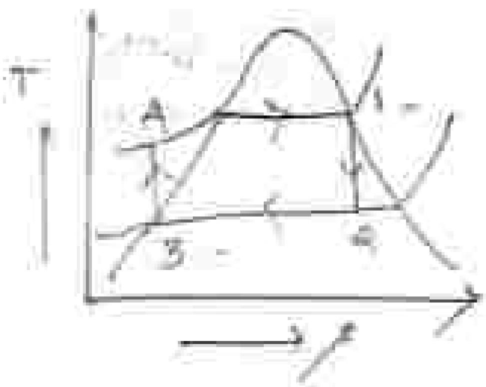
$s_1 = s_2 = (s_f + x_2 s_{fg}) = x$

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.

(Ans) 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

$h_1 = h_{g1} = 2784.3$ kJ/kg

$s_1 = s_{g1} = 5.8892$ kJ/kg K.

→ Then at state 2 :-

$P_2 = 0.1$ bar

$h_{f2} = 191.83$ kJ/kg

$h_{fg2} = 2392.8$ kJ/kg

$s_{f2} = 0.6493$ kJ/kg K.

$s_{fg2} = 7.5009$ kJ/kg K.

→ Then at state 3 :-

$P_3 = 0.1$ bar

$h_3 = h_{f3} = 191.83$ kJ/kg.

$v_{f3} = 0.001010$ m^3/kg.

→ Then at state 4 :-

$W_P = h_4 - h_3$

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

$= 0.001010\,(6000 - 10)$

$= 6.049$ kJ/kg

approx $= 6.05$ kJ/kg

$h_4 = W_P + h_3$

$= 6.05 + 191.83$

$= 197.88$ kJ/kg

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

$s_2 = (s_{f_2} + x\,s_{fg_2})$

$5.8898 = (0.6493 + x \times 7.5009)$

$\Rightarrow x = \dfrac{5.8898 - 0.6493}{7.5009}$

$\Rightarrow x = 0.6985$ (unit less)

$h_2 = 191.83 + x \times 2392.8$

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

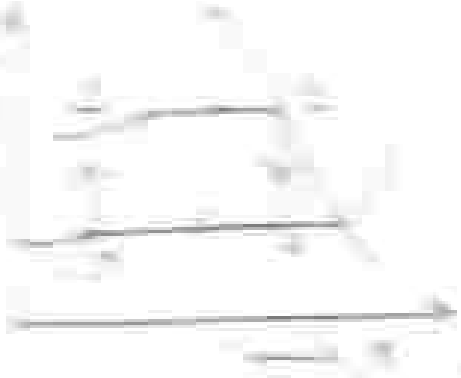
$\Rightarrow h_2 = 1863.20$ kJ/kg

efficiency of R.C. $= 1 - \dfrac{h_2 - h_3}{h_1 - h_4}$

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

$= 0.35\ \%$

$= 35\ \%$ Ans.



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

$h_2 = 137.82 + 0.7063 \times 2423.7$

$= 1849.6 \ kJ/kg$

At state 3: $p_3 = 0.05 \ bar$

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

$= 137.82 \ kJ/kg$

At state 4:

$W_p = h_4 - h_3$

$h_4 = W_p + h_3$

$= 4.014 + 137.82$

$= 141.834 \ kJ/kg$

$W_p = v_{f_3}(p_1 - p_2)$

$= 0.001005\,(4000 - 5)$

$= 4.014$

$=$ [illegible]

$\eta_{th} = 1 - \dfrac{h_2 - h_3}{h_1 - h_4}$

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

$= 0.355 \%$ $= 35 \%$

a) Reheat cycle

→ If the steam expands completely in a single stage then steam coming out from the turbine is very wet. The wet steam carries considerable moisture particle which are heavier than the vapour particles. They 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 done 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 its regains the inlet temp of the 1st stage of steam in a turbine.

→ This process is called reheating & the cycle is known as reheat cycle.

→ Due to reheating the wetness of the turbine increases, thus improving the thermal efficiency.

Working: The reheat cycle is designed to take advantage of higher boiler pressure by eliminating the problem of excessive moisture content in the exhaust.

The working of reheat cycle consist of a boiler, high pressure turbine, low pressure turbine, Condenser & a feed water pump. The above T-S diagram represents the steam enters at state-1 in the 1st stage of turbine & expands isentropically to the state-2.

At state 2 the quality of steam is either slightly dry or just wet & thus it is taken back to the boiler & reheated to the original superheated temp at 3.

steam then expanded power is further expanded in the low
pressure turbine in the process 5-6.
Then the cycle is returned at the starting
point.

Regenerative Cycle

→ In a simple rankine cycle, a significant amount of heat is added to the boiler 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 add^{n} 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 the 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.

→ The arrangement doesn't reduce the