

UNIT-1

COAL BASED - THERMAL PLANTS

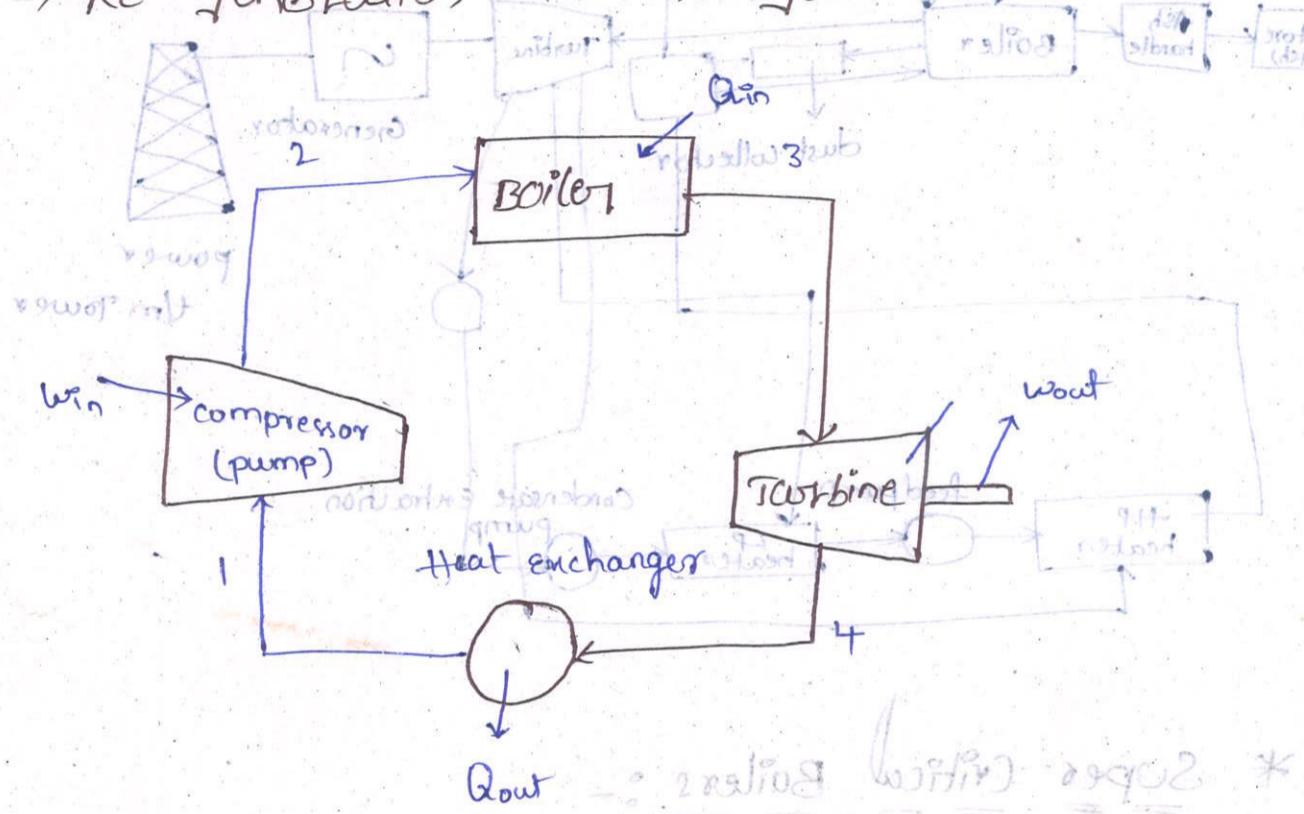
=/ Basic Rankine cycle & its modifications :-

Types of Cycles:-

=/ Ideal Rankine Cycle

=/ Re-heat Rankine cycle

=/ Re-generation Rankine Cycle



A scottish civil engineer, physicist and mathematician.

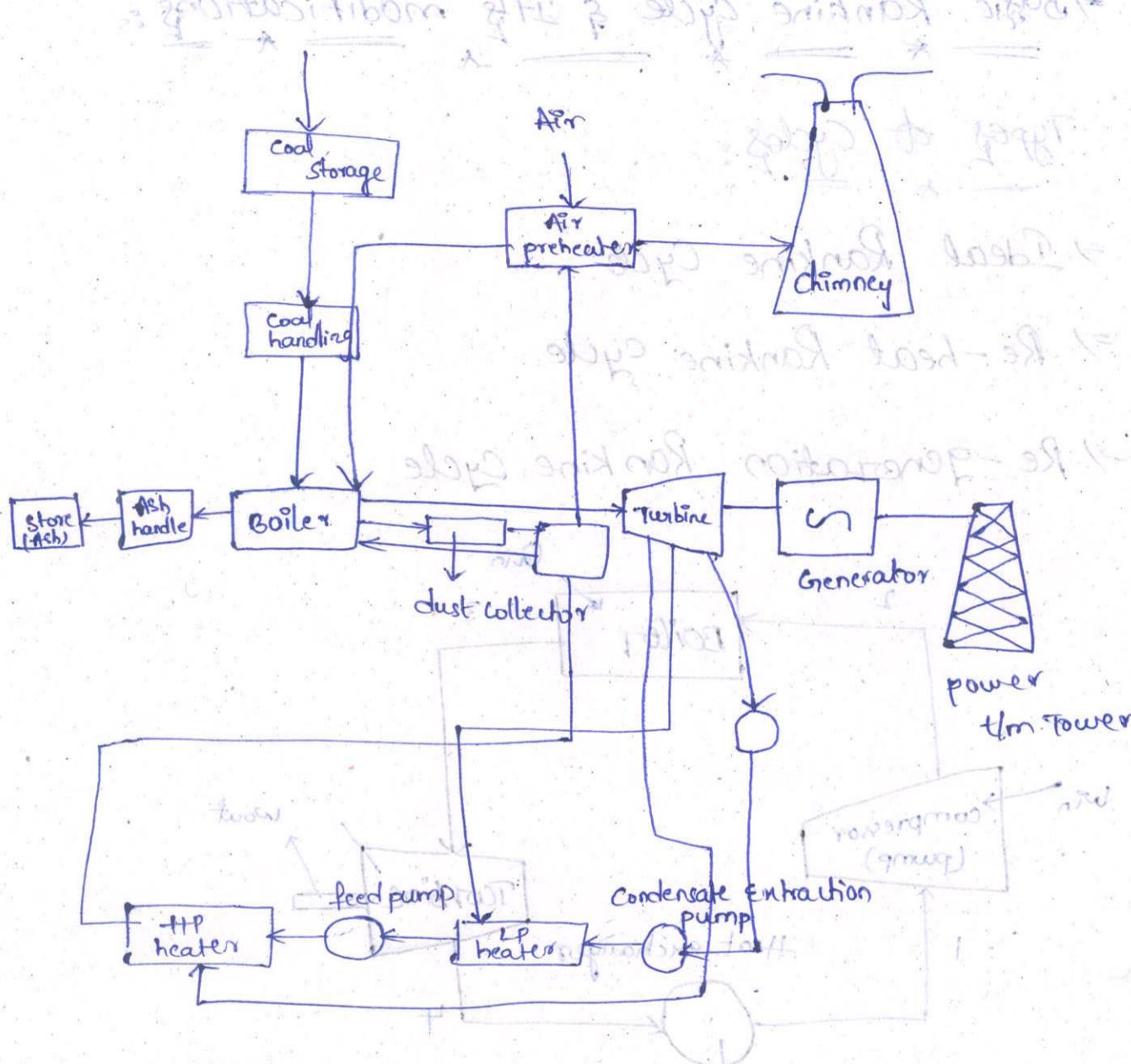
He was a founding contributor, with Rudolf Clausius and William Thomson, to the science of thermodynamics particularly focusing on the first of the three thermodynamic laws.

The Rankine cycle is a cycle that converts heat into work.

Q1, Q2, w1, wout

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* Layout of modern Coal power plant:-



* Super Critical Boilers :-

→ The term "super critical" refers to main steam operating conditions, being above the critical pressure of water (221. bar).

→ Above the critical pressure, there is no distinction between steam and water, i.e. above 221. bar, water is a fluid.

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* Subcritical & supercritical pressure range :-

* Subcritical : Below 221 bar - a

* super critical : 221 bar - a and above

Benefits of supercritical technology :-

1. Higher cycle efficiency means

→ primarily less fuel consumption

less fuel consumption

less per MW infrastructure investments

less emission

less auxiliary power consumption

less water consumption.

2. Operational flexibility

Better temp.

control and load change flexibility

FBC boilers :-

* In 1921, the first fluidized bed being used successfully in Germany.

* The fuels burnt in these boilers include coal, washery rejects, rice husk, wood chips & other agricultural wastes.

* The fluidized bed boilers include coal, washery

0.5 T/hr to over 100 T/hr.

* Fluidized bed combustion has emerged as a feasible 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
pollutants such as SO_x and NO_x.

there are three basic types of fluidised
bed combustion boilers:-

1. Atmospheric classic fluidised bed combustion
System (AFBC)

2. Atmospheric circulating (fast) fluidised bed
Combustion system (CFBC)

3. pressurised fluidised bed Combustion system
(PFBC).

• low pressure bed bubble drift at 10% of

maximum of filter area

• low bubble height or travel drift at

• 3 times lower dust load & higher production

• low bubble height or travel drift at

Turbines :-

A ~~turbine~~ ^{is a} ~~rotary~~ ^{fast} mechanical device that extracts energy from a fast moving flow of water, steam, gas, air, or other fluid and converts it into useful work.

A turbine is a ~~rotor machine~~ with at least one moving part called a ~~rotor assembly~~, which is a shaft ~~spinning~~ with blades attached.

Moving fluid acts on the blades so that they move and impart rotational energy to the rotor.

Types :-

1. water turbine
2. steam turbine
3. Gas turbine
4. wind turbine.

Although the same principles apply to all turbines, their specific designs differ sufficiently to merit separate descriptions.

Working principle :-

→ When the fluid strikes the blades of the turbine, the blades are displaced, which produces rotational energy.

→ When the turbine shaft is directly coupled to an electric generator, mechanical energy is converted

into electrical energy.

→ This electrical power is known as hydroelectric plant.

* Condensers :-

→ heat exchangers are used to transfer heat.

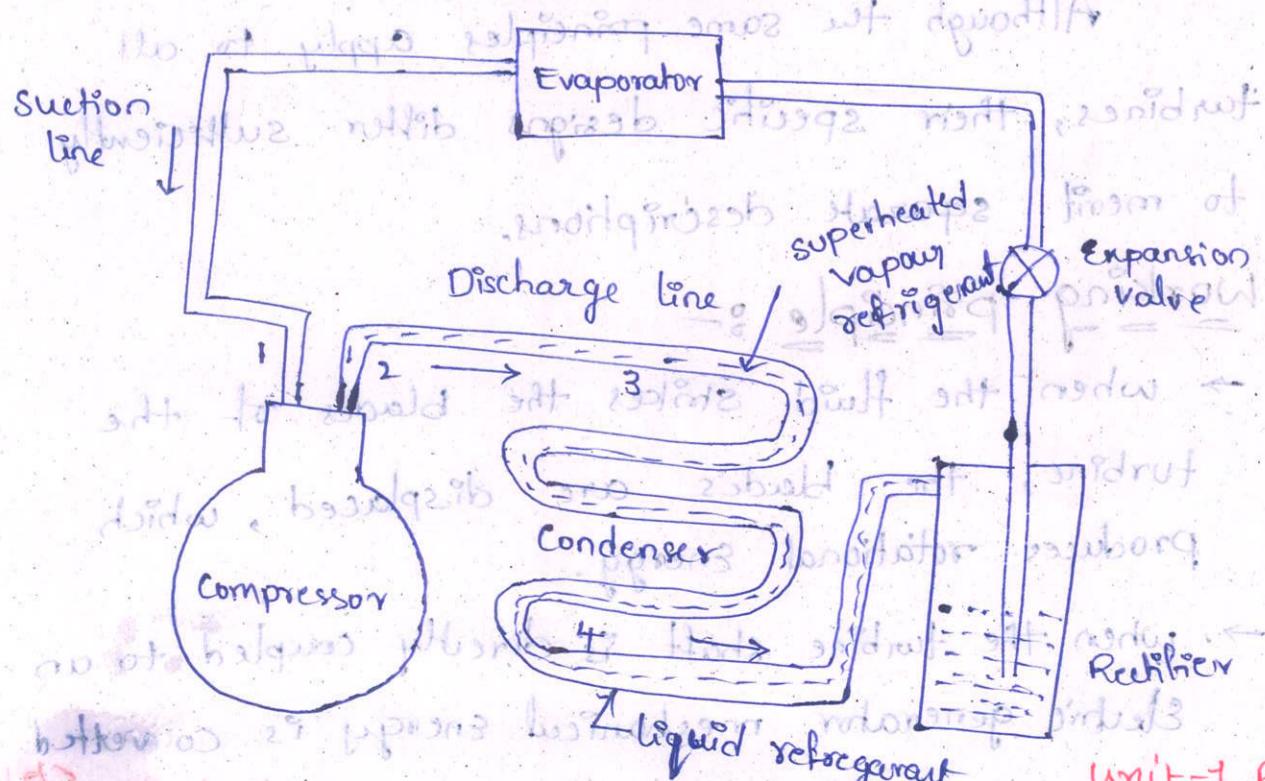
Some processes like heating, cooling, condensation, boiling or evaporation.

→ Different heat exchangers are named according to their application.

→ Heat exchanger is used for boiling purposes are called boilers. Heat exchangers being used to condense are known as condensers.

→ The condenser accept all the hot, high pressure refrigerant usually a superheat gas from the compressor.

Working of Condenser :-



In a typical refrigerant condenser, the refrigerant enters the condenser in a superheated state. It is first de-superheated and then condensed by rejecting heat to an external medium.

The refrigerant may leave the condenser as a saturated or a sub-cooled liquid, depending upon the temperature of the external medium and designed of the condenser.

* Steam and heating rates :-

Steam is the gaseous phase of water. It

utilizes heat during the process and carries large quantities of heat later. Hence, it could

be used as a working substance for heat engines. Steam is generated in boilers at

constant pressure. Generally,

* Heat Rate :-

Heat rate = $\frac{\text{Heat output}}{\text{Time}}$

Generator O/P = $11 \text{ kwh} = 1860 \text{ kcal}$ (in 1000 kg steam)

Losses in the GE = 20 kcal

O/P to the generator = 880 kcal

Turbine exhaust = 1185 kcal

Heat O/P to the turbine = 2065 kcal

Boiler O/P = 2065 kcal

Boiler losses = 331 kcal

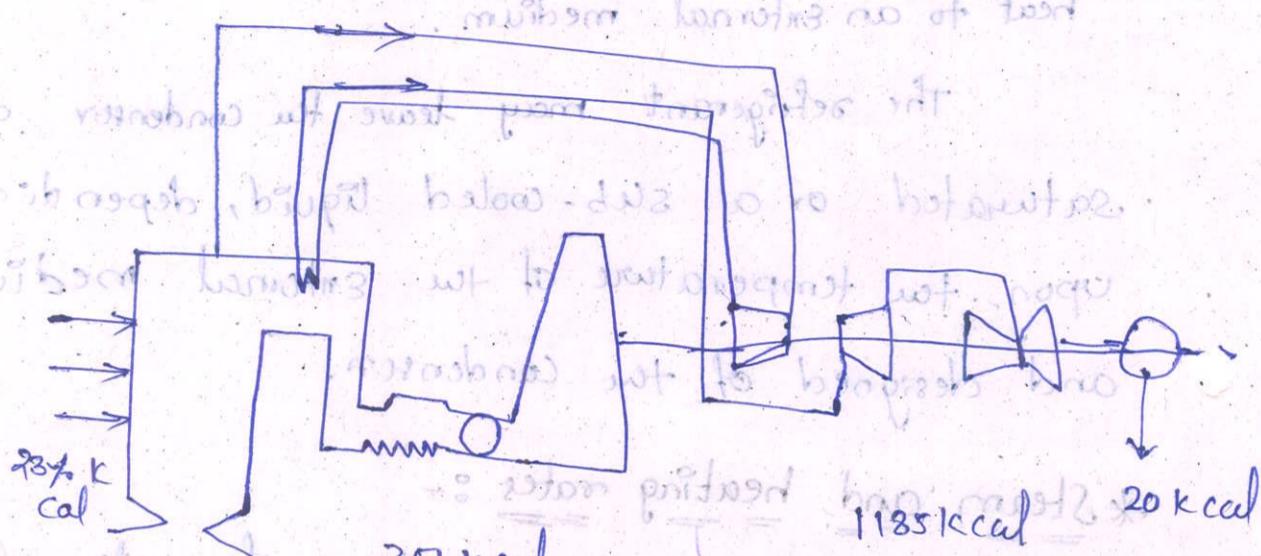
Total O/P to the Boiler = 2396 kcal

O/P heat Energy to the Boiler = 2396 kcal (unit heat rate)

If the heat value of coal is 4000 kcal/kg .

$$2396 \text{ kJ/kg} / 4000 \text{ kcal/kg} = 0.599 \text{ kg of coal}$$

Efficiency of boiler = 2065 kcal .



Efficiency of boiler = $2065 \text{ kcal}/2396 \text{ kJ/kg}$

Turbine heat rate = 2065 kcal/kWh

Unit heat rate = 2396 kcal/kWh

*Subsystems of thermal power plant

→ A thermal power plant converts the heat energy of coal into electrical energy; coal is burnt in a boiler which converts water into steam. The expansion of steam in turbine produces mechanical power which drives the alternator coupled to the turbine.

Thermal power plants contribute maximum to the generation of power for any country.

→ Thermal power plants constitute 75.43% of the total installed captive and non-captive power generation in

→ In thermal generating stations coal, oil, natural gas etc. are employed as primary sources of energy.

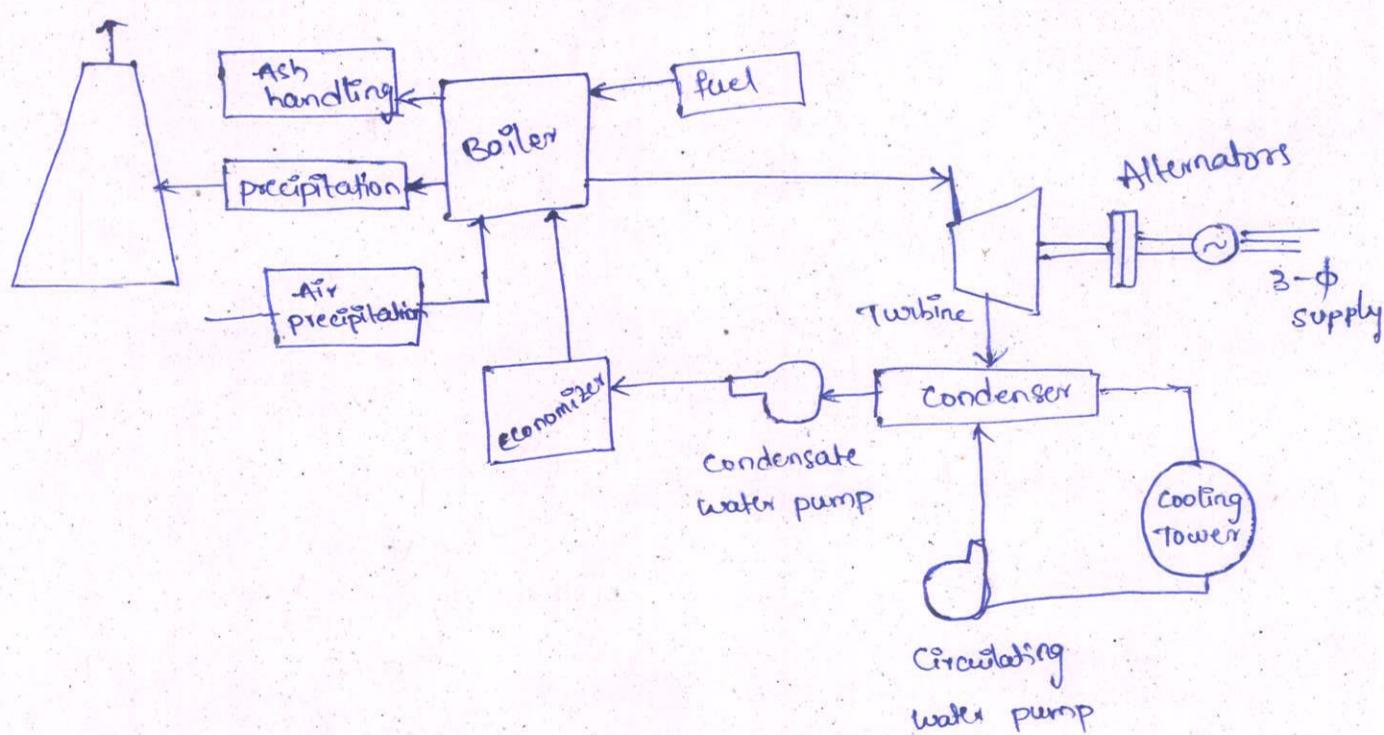
Working principle

* Firstly the water is taken into the boiler from a water source. The boiler is heated with the help of coal.

* Increase in temp helps in the transformation of water into steam.

* The steam generated in the boiler is sent through a steam turbine.

* A generator is connected to the steam turbine. When the turbine turns, electricity is generated and given as output by the generator, which is then supplied to the consumers through high-voltage power lines.



replication, λ , μ , ν initial protein, homologous \rightarrow

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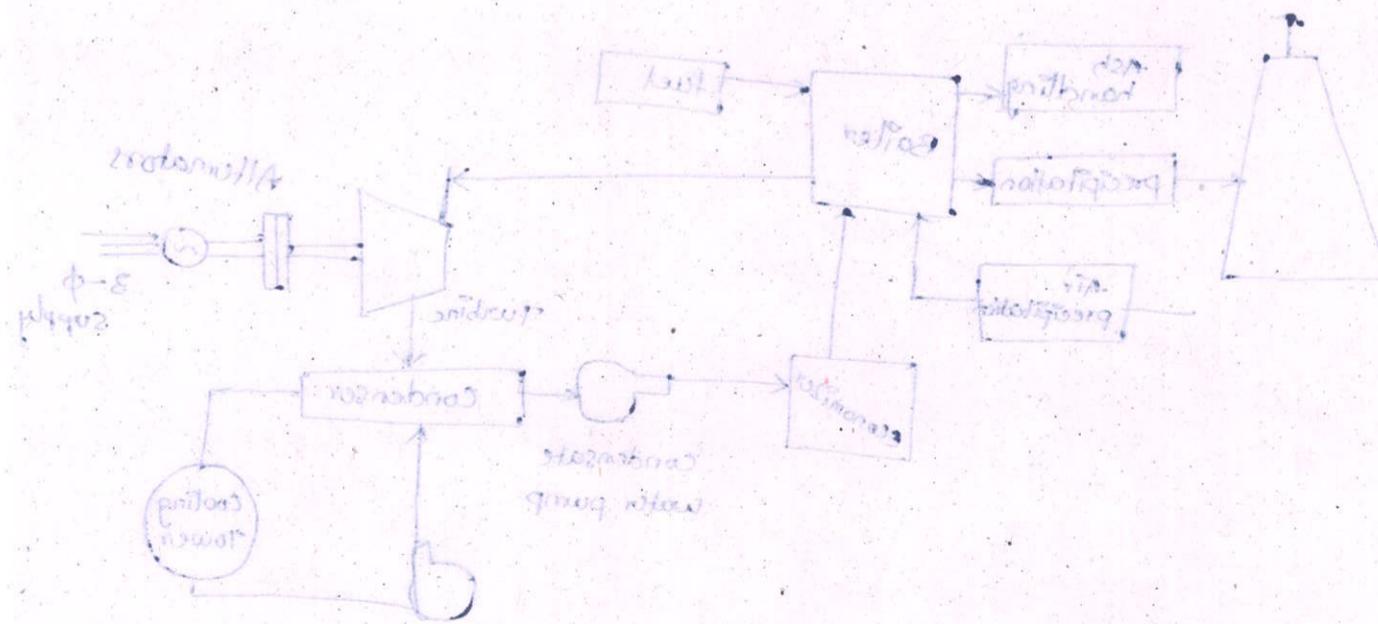
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* Fuel and ash handling

ash disposal:-

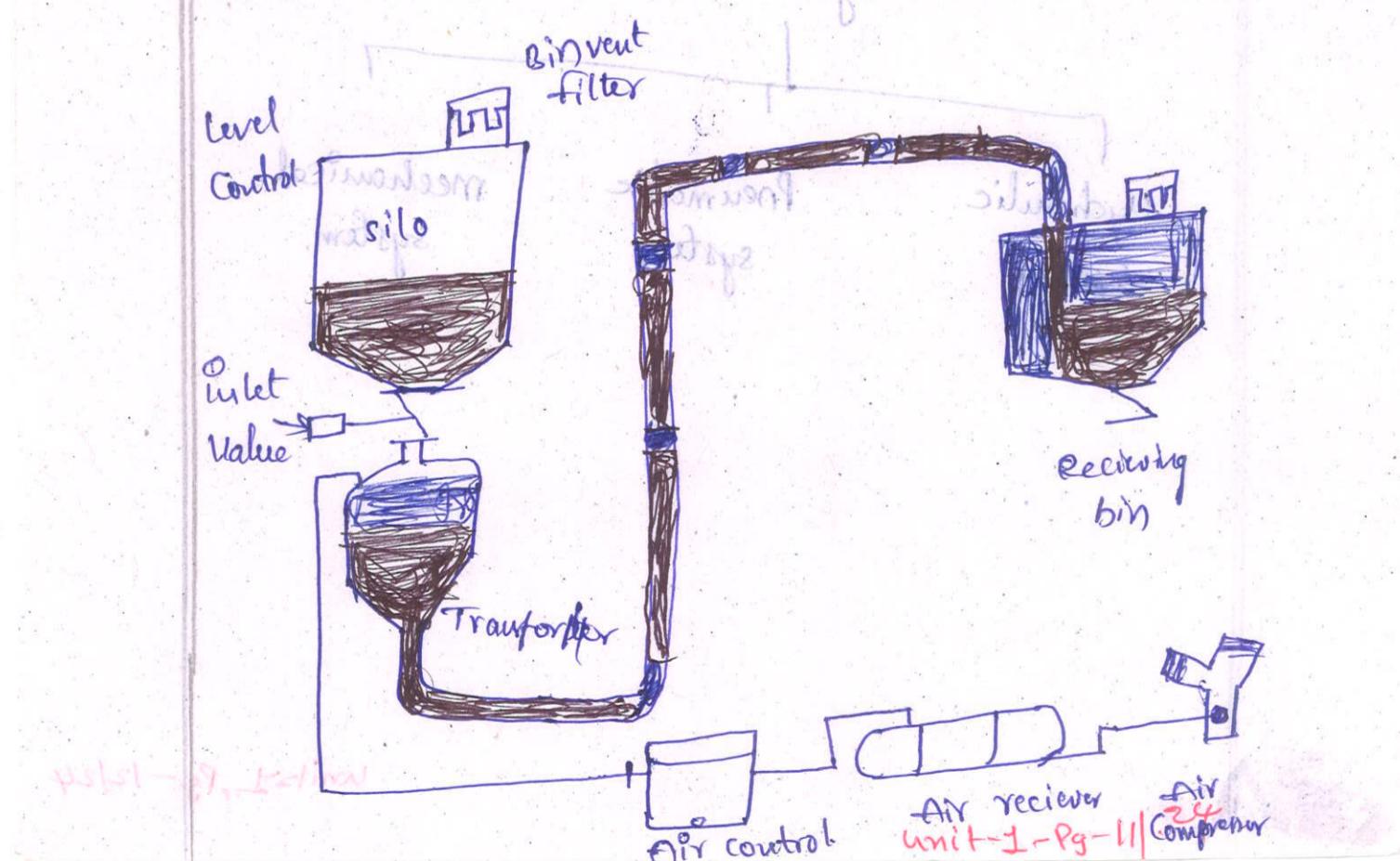
* A large quantity of ash is produced in steam power plants using coal.

* Ash produced is about 10 to 20% of the total coal burnt in the furnace.

* Handling of ash is a problem because ash coming out of the furnace is too hot, it is dusty and irritating to handle and accompanied by some poisonous gases.

ash handling equipments

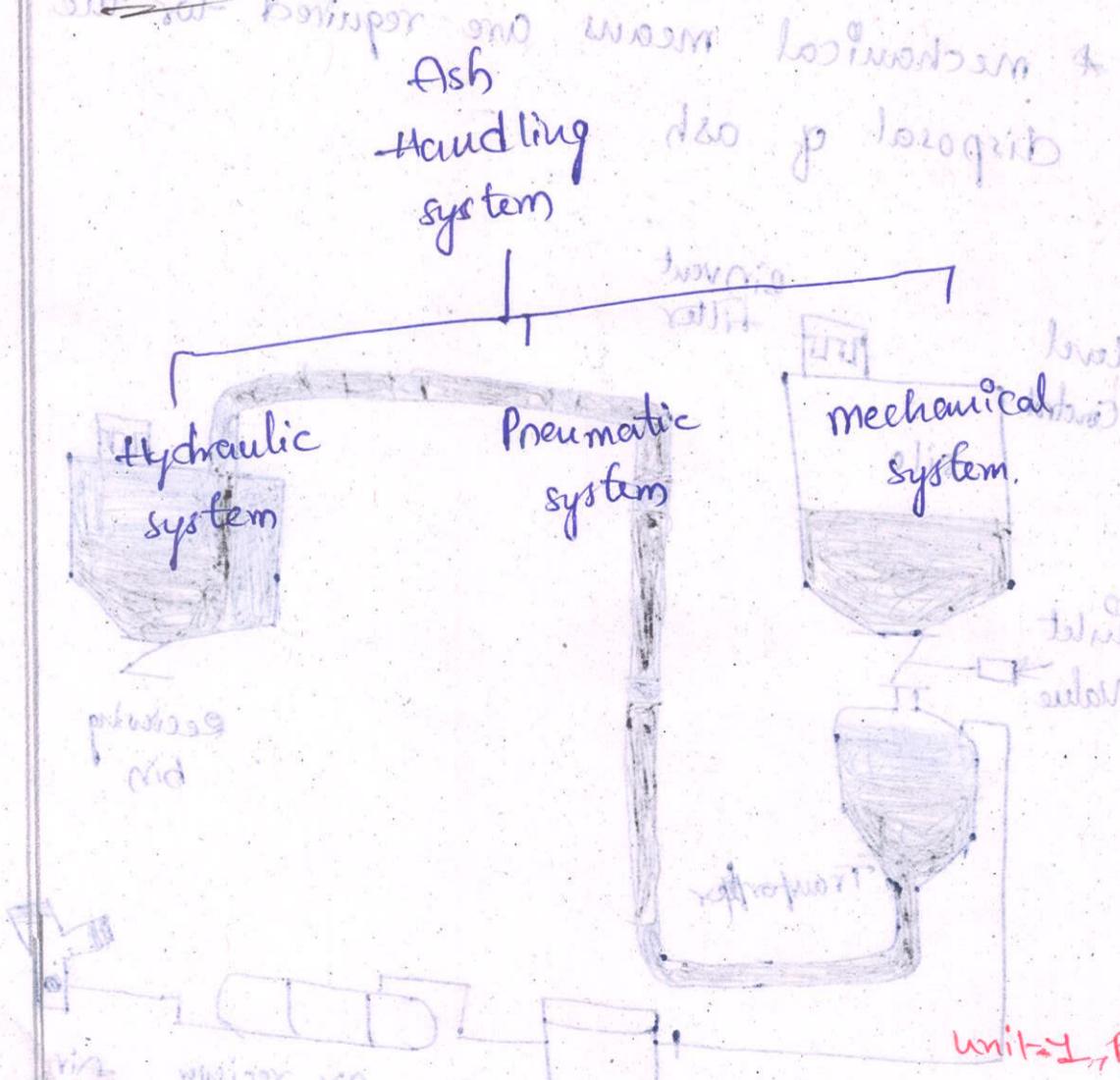
* Mechanical means are required for the disposal of ash



Handling equipment should perform the following functions:

- * Capital investment, operating and maintenance charges of the equipment should be low.
- * It should be able to handle large quantities of ash.
- * clinkers, soot, dust etc. create troubles, the equipment should be able to handle them smoothly.
- * The equipment should be corrosion & water resistant.

flow chart



Hydraulic system

* Ash from the furnace grates falls into a system of water possessing high velocity & is carried to the sumps.

* It is generally used in large power plants

pneumatic system

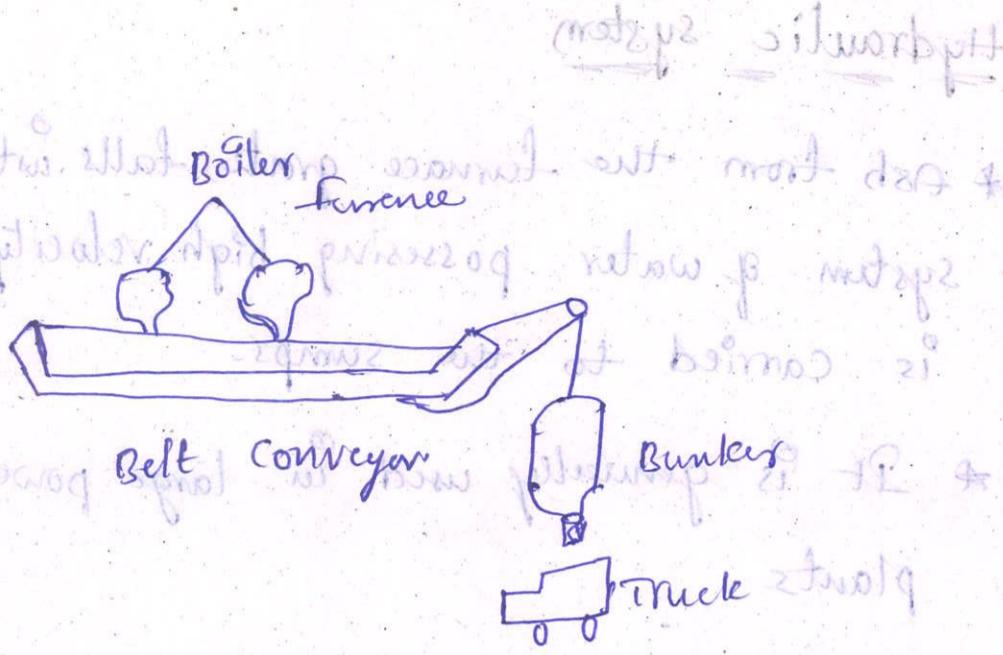
* In this system ash from the boiler furnace outlet falls into a crusher, where larger ash particles are crushed to small sizes.

* The ash is then carried by a high velocity air or steam to the point of delivery.

mechanical ash handling system

* In this system ash cooled by water seal falls on the belt conveyor and is carried out continuously to the bunker.

* The ash is then removed to the dumping site from the ash bunker with help of trucks.



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metals pd below out metals int. v. L.

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metals out

* Binary Cycle and Cogeneration Systems

* The model cycle for vapour power cycle is the Ranting cycle which is composed of four usually reversible processes.

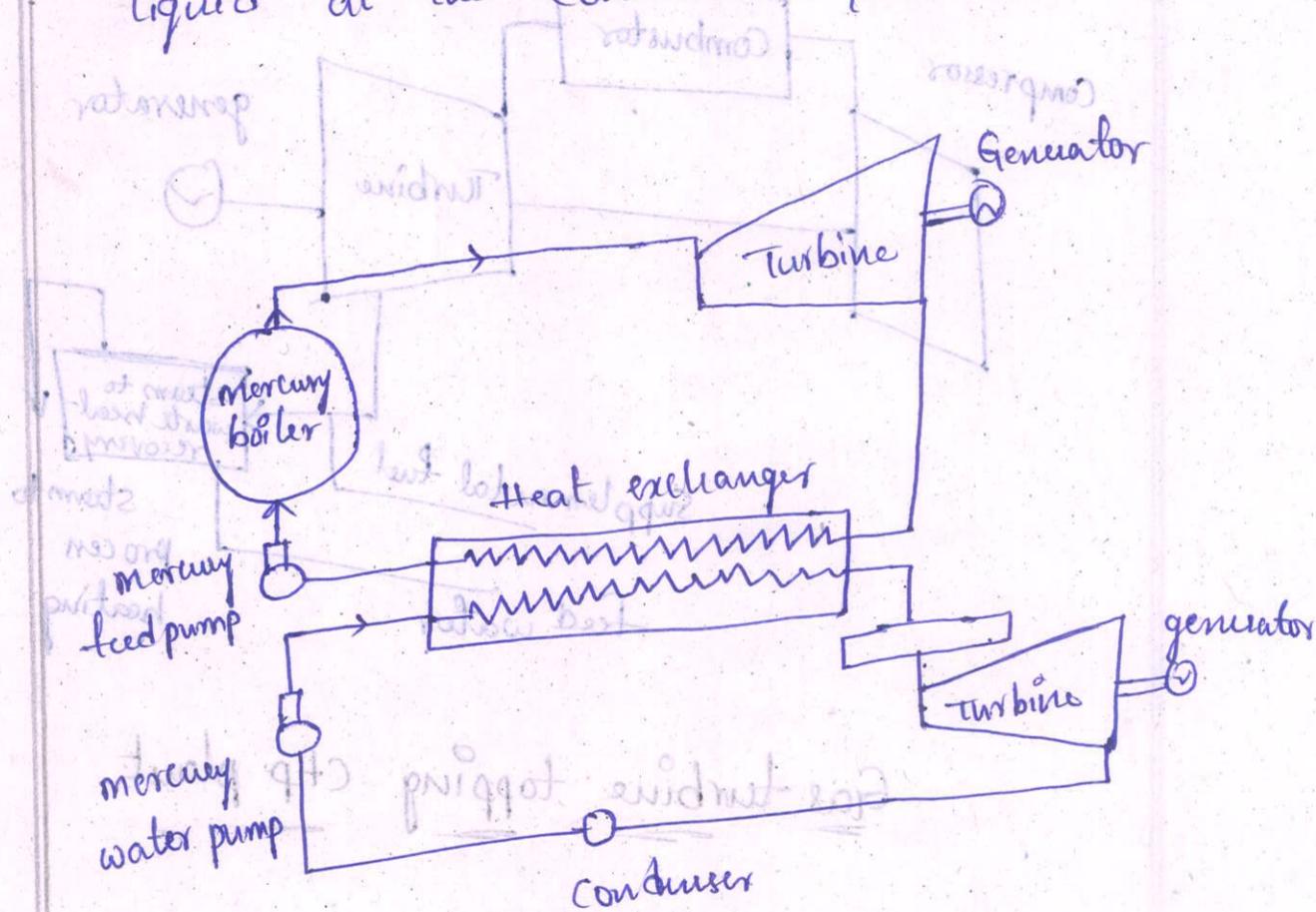
* Constant - pressure heat addition in a boiler

* Isentropic expansion in a turbine

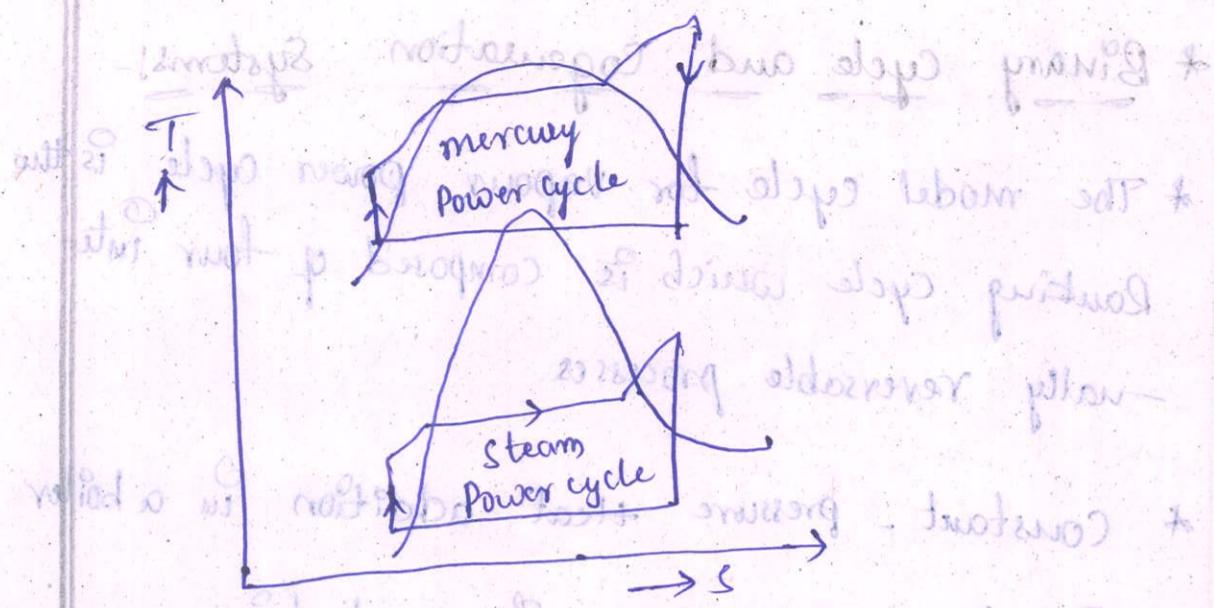
* Constant - pressure heat rejection in a condenser.

* Isentropic compression into a pump

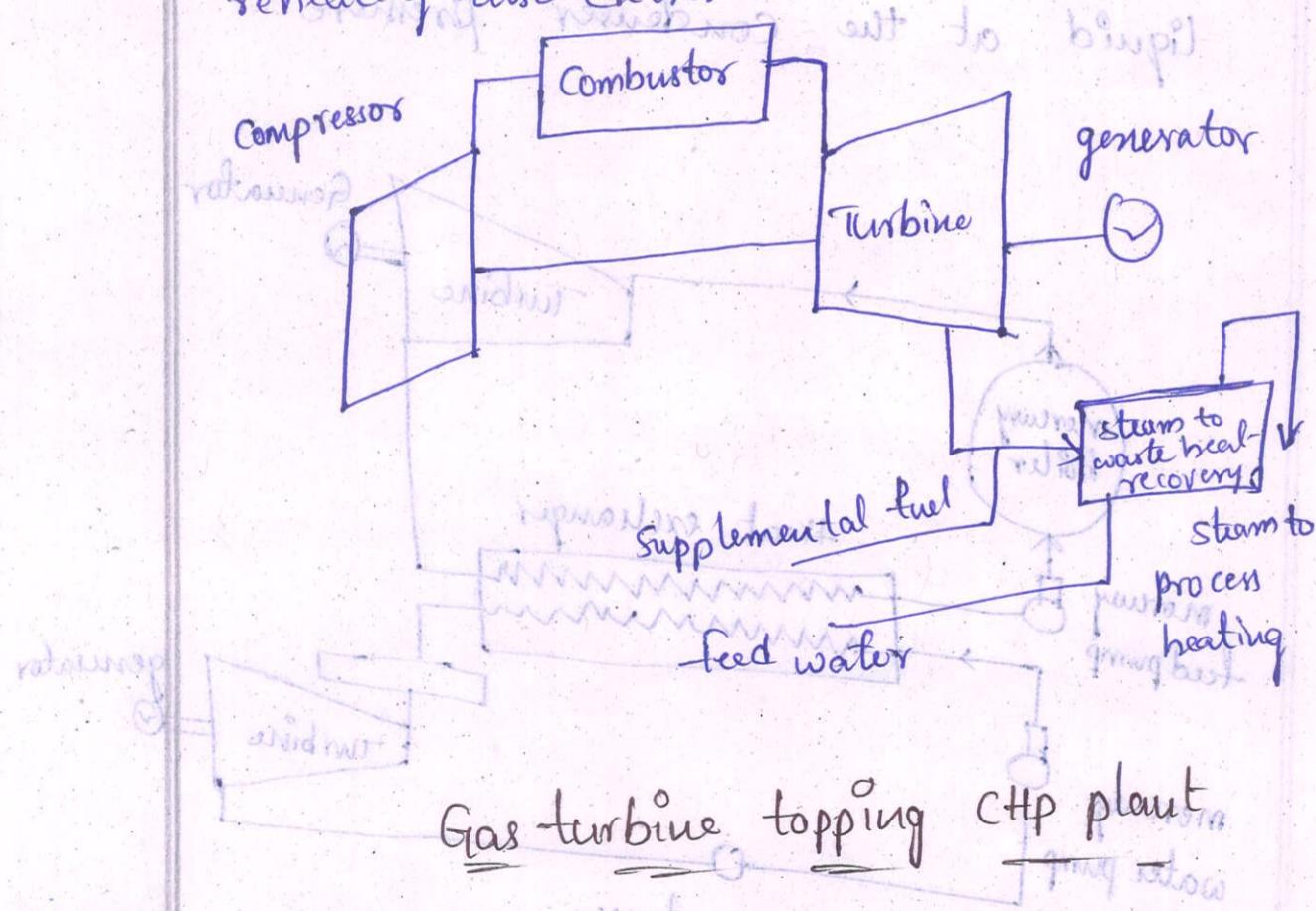
* steam leaves the condenser as a saturated liquid at the condenser pressure

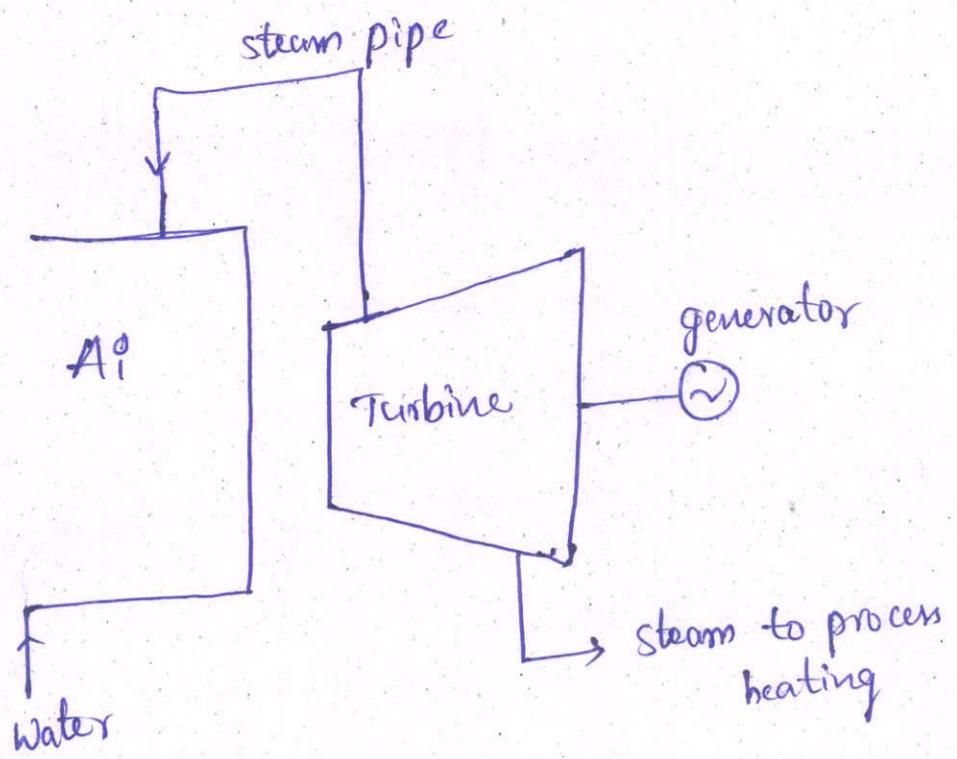


layout of Binary Vapour cycle

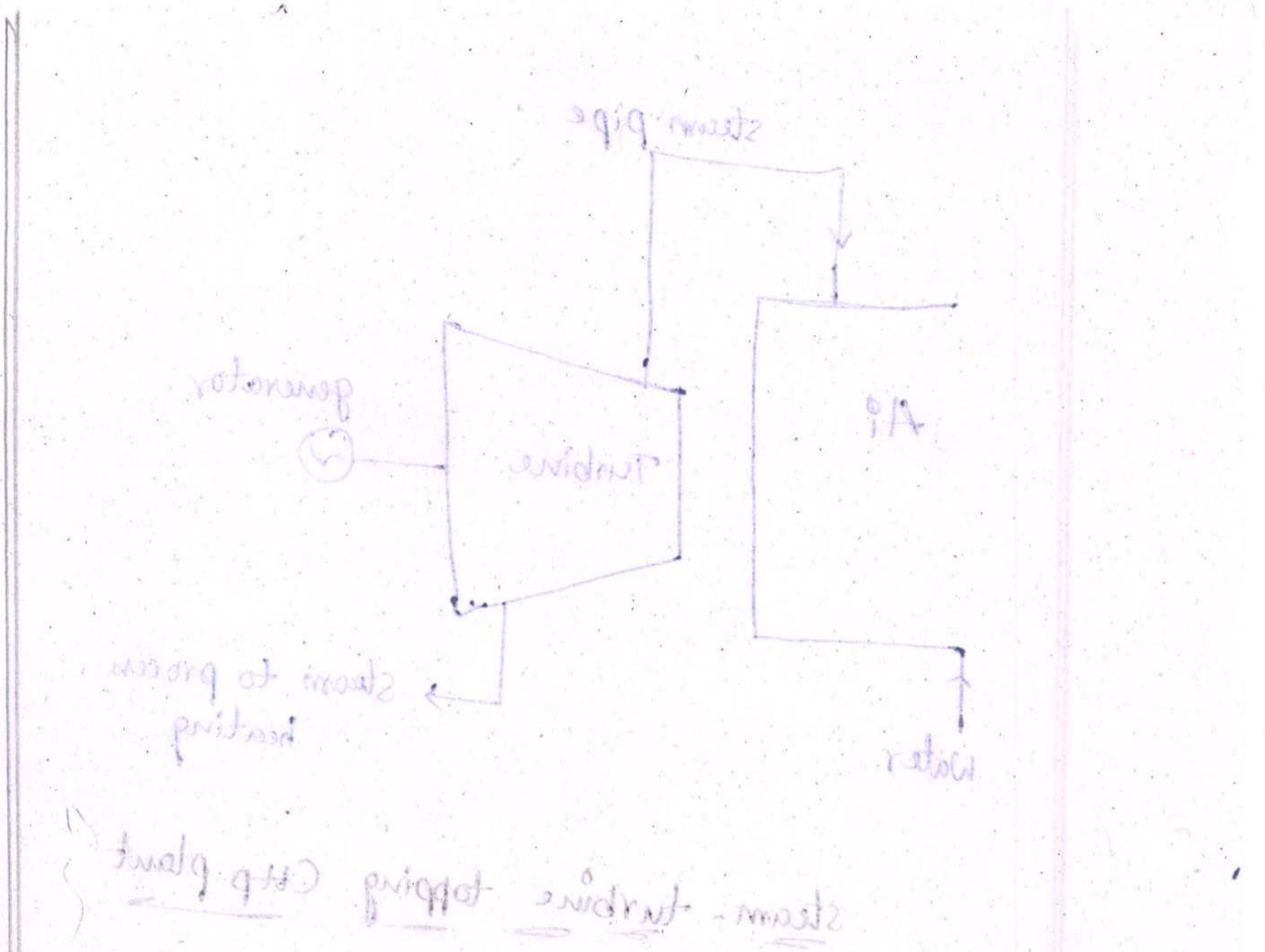


As the number of stages is increased, the expansion and reheat process approach an isothermal process at maximum temperature. reheating also decreases.



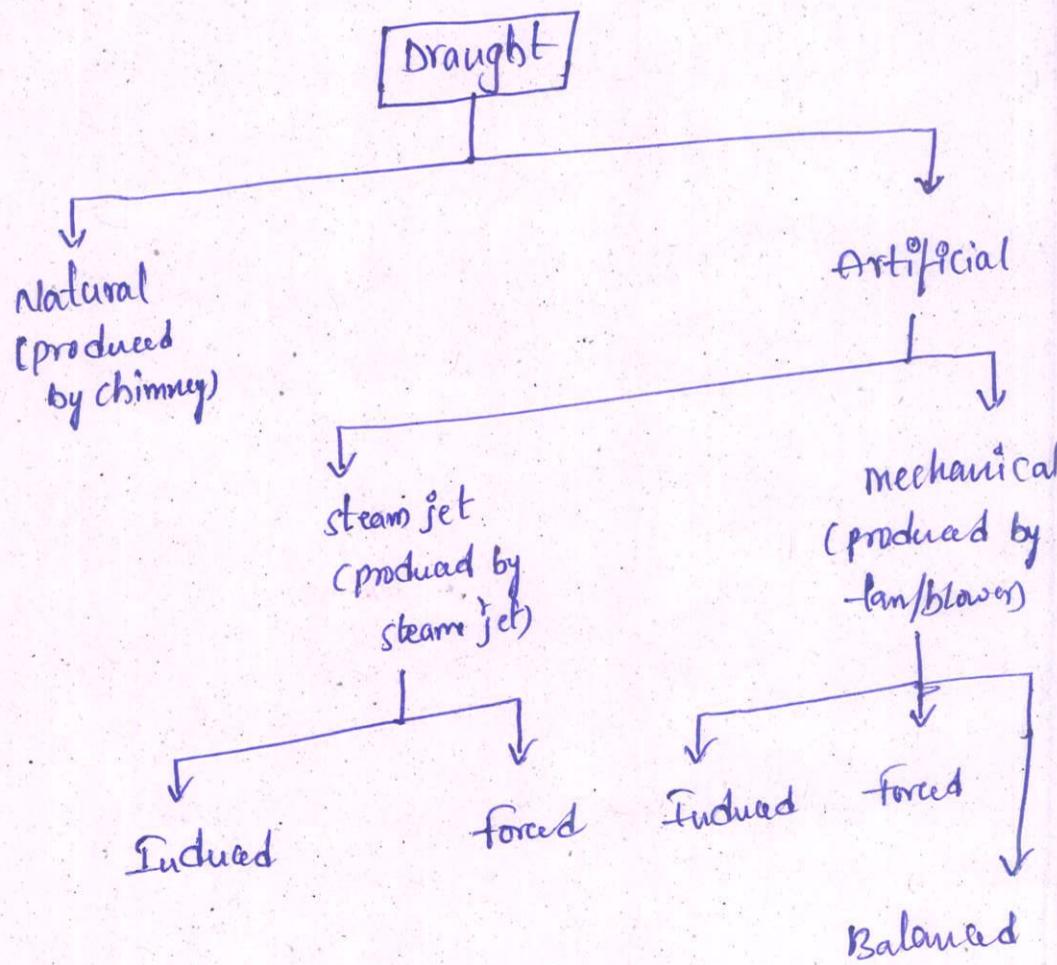


steam - turbine topping CHP plant



Draught System :-

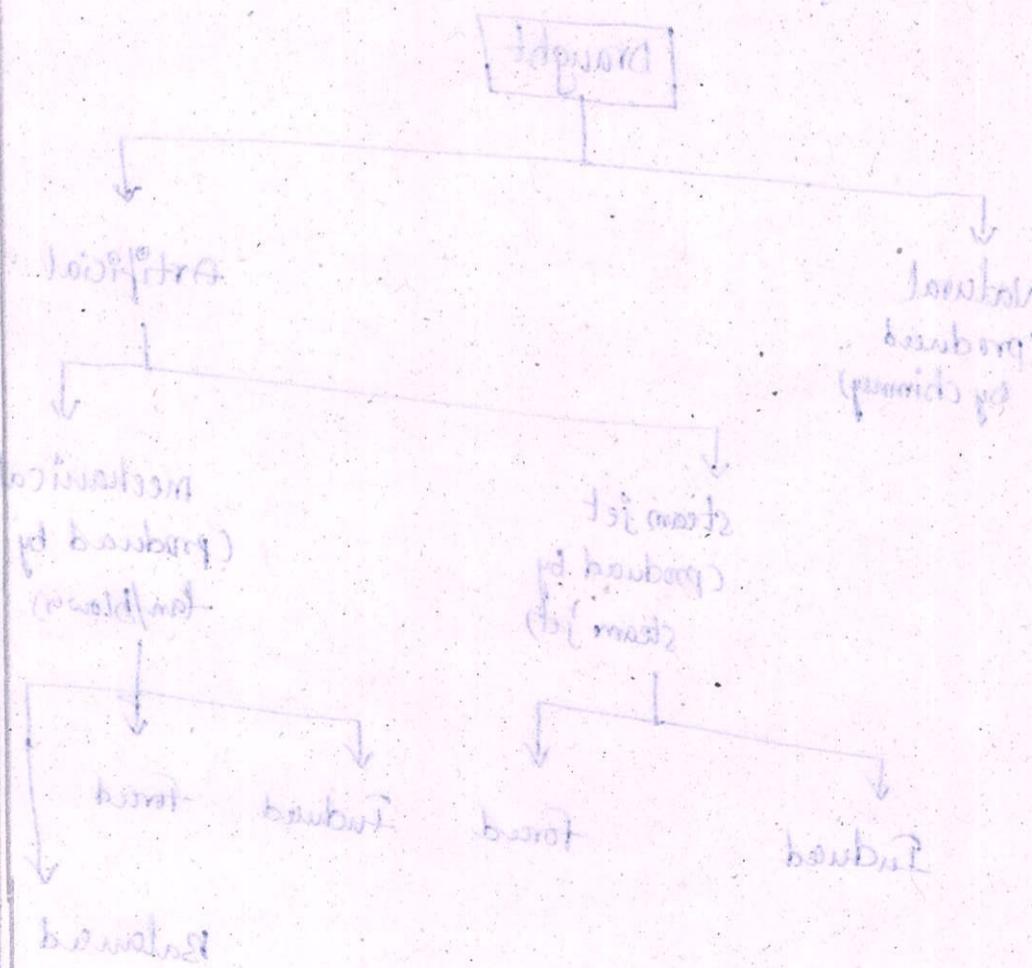
- * Boiler draught may be defined as the small difference b/w the pressure of outside air and that of gases within a furnace or chimney at the grate level, which causes flow of air hot flue gases to take place through boiler.
- * The draught is necessary to force air through the fuel bed/grate to aid in proper combustion of fuel and to remove the products of combustion of flue gases to the atmosphere after they have given their heat to water being evaporated in boiler.



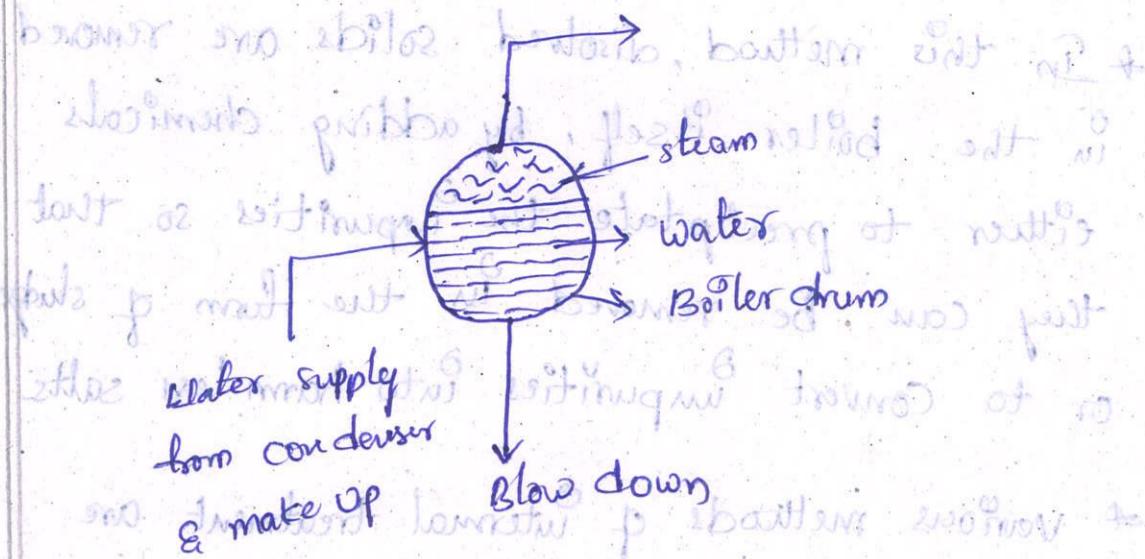
Natural draught

without flue gas

- * Natural draught is obtained naturally by the use of a chimney.
- * Chimney is a conical shape vertical tubular steel or masonry or concrete structure having a large height of 100 ft.
- * The flue gases after transferring their heat in the boiler are guided by chimney to a considerable height in the atmosphere.
- * As chimney has a large height and is the only outlet from boiler, it remains filled by hot flue gases.



Blow down system



* External water treatment system :-

* When the quantity of make up water is large and it contains considerable suspended and dissolved impurities, then external water treatment is used. In this method of treatment raw water is taken to a tank where reagents are mixed.

* Various methods are

1. Mechanical

* sedimentation

* Coagulation

* Direct filtration.

2. Thermal

* Distillation

* Deaeration

3. Chemical

* Zeolite process

* Determination

Internal water treatment systems

* In this method, dissolved solids are removed in the boiler itself, by adding chemicals either to precipitate the impurities so that they can be removed in the form of sludge or to convert impurities into harmless salts.

* Various methods of internal treatment are

1. Sodium carbonate treatment

2. phosphate treatment

3. sodium aluminate

4. colloidal treatment

↳ Blow down system

Colloidal treatment :-

* It is used in low pressure boilers to prevent scale formation by adding organic substances like tannin, starches, lignin,

* Coating of these substances is formed over scale forming precipitates

* It results in formation of non-sticky &

loose deposits similar to sludge which can be removed by blow down

feed water treatment

* Different impurities found in feed water

1. undissolved and suspended materials

a) chlorides

b) Iron

c) magnesium

d) colour

2. Dissolved salts and minerals

a) calcium and magnesium salts

3. Dissolved gases

a) oxygen

b) carbon dioxide

c) other material

a) free mineral acid

b) oil.

Effect of impurities:-

1. scale formation

2. corrosion

3. priming, foaming and carryover

4. caustic embrittlement

Artificial draught

- * When the draught is produced by some external agency i.e. mechanical fan/blower or by steam jet itself, it is artificial draught.
- * In modern commercial boilers, more value of draught is required to increase the heat transfer co-efficient and hence the thermal efficiency.
- * So, artificial draught is must to use to overcome the flow resistance offered by large flue passages.

Draught losses:-

- * Loss due to the frictional resistance offered by flue gas passage to the flow of flue gases.
- * Loss due to friction head in grate, economizer, super heater etc.
- * Loss due to bends in gas flow circuit, which also offer flow resistance.
- * Loss due to flow resistance offered by chimney.