The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

QUESTION BANK

CHAPTER 3 Components of Steam Power Plant

Program Name: Mechanical Engineering
Program Code: ME3k
Name of Subject & Code : Thermal Engineering (313310)
Semester : Third
Date & Time Slot: 02/06/2026

Q. NO.	QUESTION	DETAIL	MAPPING
1	Draw the layout of steam power plant and label the following components –i) Boiler ii) Turbine iii) Condenser iv) Generator v) Cooling tower vi) Chimney vii) Feed Pump viii) Coal Circuit	S 25 Q3 4M	CO 3.1 U
2	Classify the boilers according to - i) Relative position of flow of water and hot gases ii) Position of furnace.	S 25 Q1 2 M	CO 3.1 R
3	Give classification of Boiler.	W 24 Q3 D 4M	CO 3.1 R
4	Differentiate between water tube and fire tube boiler. (Any four points)	W-25 Q3 C 4M	CO 3.1 A
5	Explain with neat label sketch the construction and working of Lamont boiler.	S 25 Q6 A 6M W-25 Q5B 6M	CO 3.1 U
6	Explain Benson boiler with neat sketch	W 24 Q5 C 6M	CO 3.1 U
7	List any two applications of nozzle	W-25 2M	CO 3.2 A
8	Explain the working of impulse steam turbine with neat sketch. Also show pressure and velocity variation for the same.	W-25 Q6 B 6M	CO 3.2 U
9	Differentiate between Impulse turbine and Reaction turbine	W 24 Q6 A 6M	CO 3.2 A
10	Explain the method of velocity compounding of an impulse turbine for achieving rotor speed reduction.	S 25 Q3 4M	CO 3.2 U
11	Write basic function of condenser.	W 24 Q1 E 2M	CO 3.3 R
12	State the Dalton's law of partial pressure.	W-25 W 24 S 25 Q1 2M	CO 3.3 R
13	Suggest the non-mixing type and high capacity condenser for power plant. Draw its labeled sketch and explain its working in brief – [surface condenser]	S 25 Q3 4M	CO 3.3 A
14	Explain construction and working of surface condenser with neat sketch.	W 24 Q3 B 4M W 25 Q4 C 4M	CO 3.3 U
15	Explain construction and working of forced draught cooling tower with neat sketch.	W 24 Q3 C 4M W-25 Q2 C 4M	CO 3.4 U

02/06/2026

3/6/26

UNIT - 03 Components of Steam Power plant

Total Hrs=
Total Marks=

Question Pattern	Q1, Q3 & Q4	Q5 or Q6
	4M	12M	12M

3.1 - Components & layout of steam power plant.

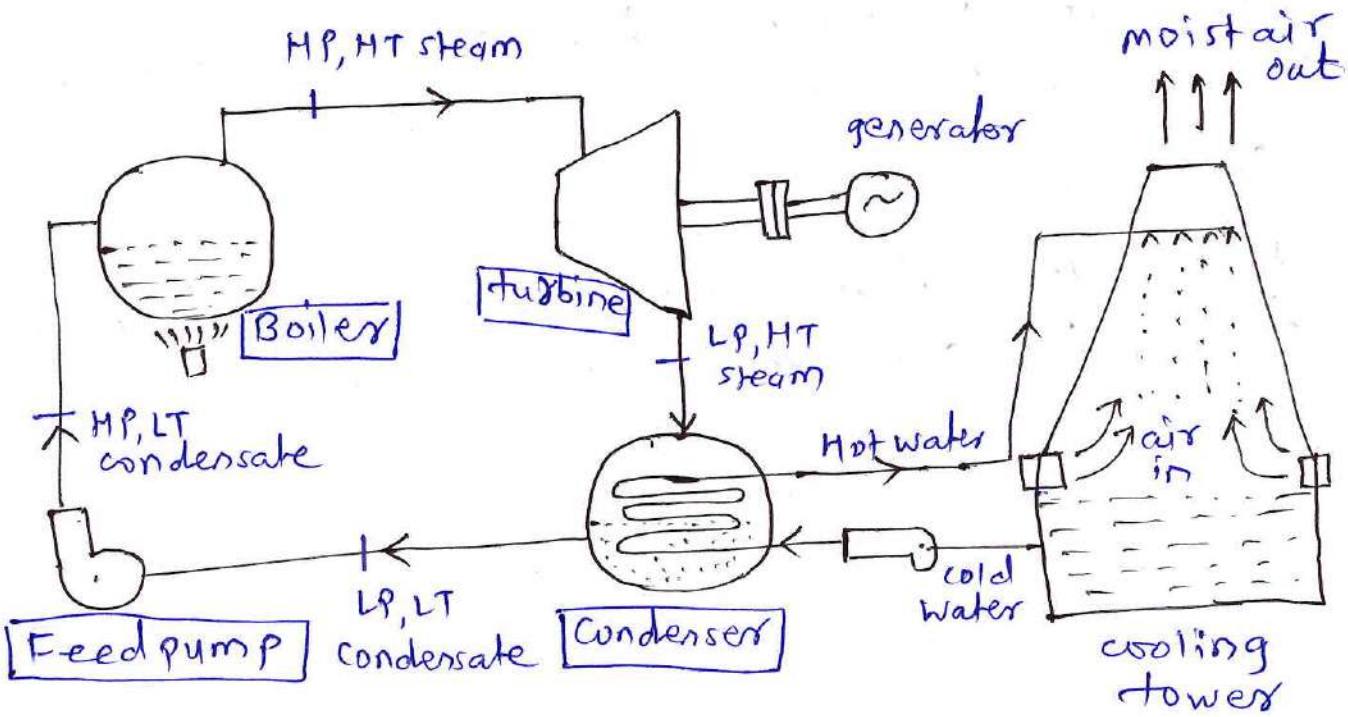


fig:- layout of steam power plant.

Components :- Boiler, turbine, condenser, feed pump, cooling tower, generator,

Working :-

1) Boiler :- water from feed pump is converted into pressurized steam by ~~supply~~ heat generated from burning of fuel.

2) steam turbine :- steam from boiler is expanded from boiler pressure to condenser pressure & thereby producing mechanical work.

turbine is connected to generator. for producing electrical energy.

3] Condenser :-

Low pressure steam from turbine is condensed into condensate by rejecting heat to cooling tower.

4] Feed pump :-

Condensate is pumped from condenser pressure to boiler pressure.

5] Cooling tower :-

Hot water from condenser is cooled in cooling tower by circulation of air.

Boiler :-

Definition as per IBR :-

IBR = Indian Boiler Regulation Act.

It Governs the manufacture, installation, operation & maintenance of the steam boilers.

Defination :-

A vessel containing greater than 25.0 lit of water, which is used to generate steam under pressure.

IBR tubes :-

Any boiler pipe system with a design pressure exceeding 3.5 kg/cm^2 falls under IBR tubes.

Function :-

Boiler is enclosed vessel that uses heat to convert water into hot water or pressurized steam for commercial, residential & industrial application.

Classification of Boiler

A] According to the content in the tube.

a] Fire tube boiler - Flue gases produced by combustion of fossil fuel passes through the tubes surrounded by water or steam

eg. Cochran Boiler,

b] water tube boiler :- water or steam flows through the tubes which is surrounded by flames or flue gases eg. Lamont Boiler.

B] According to position of furnace:-

a] Internally fired:- furnace is located inside of Boiler
eg. fire tube boiler

b] Externally fired:- furnace is located outside of Boiler
eg. water tube boiler.

C] According to axis of shell:-

a] Horizontal axis steam boiler:-
axis of shell is horizontal.
eg. Lancashire boiler.

b] Vertical axis steam boiler:-
axis of shell is vertical. eg. Cochran Boiler.

D] According to method of circulation:-

a] Natural circular boiler:-
circulation of water is by Natural convection currents, which are set-up during the heating of water. eg. Cochran boiler.

b] Forced circulation boiler:-
circulation of water is by forced circulation by Centrifugal pump. eg. Lamont boiler

E] According to use:-

a] stationery boiler - do not move from one place to another place as in steam power plant

b] mobile boiler:- move from one place to another Place eg. Locomotive.

* Difference between fire tube boiler & water tube boiler

Water tube boiler	Fire tube boiler
1] Water circulates through the tube surrounded by hot gases	1) Hot flue gases circulates through tubes surrounded by hot water.
Disadvantages	Advantages
2] High capital cost due to complex construction 3] High operating cost	2] low capital cost due to simple structure. 3] less operating cost
advantages	Disadvantages
4] High operating pressure upto 165 bar 5] High steam generation capacity.	4] low operating pressure upto 24.5 bar. 5] low steam generation capacity.
Application	Application
petroleum Companies. Power generation units Textile Industries	sugar industries chemical factories paper industry.

High pressure boiler:-

- if operating pressure in boiler is above 160 bar & high temperature, such boiler are called high pressure boiler.
- Generally used for power generation, chemical processing.

- High pressure boilers are generally water-tube
- High pressure boilers are forced circulating boiler

classified into 2 categories.

a] subcritical boiler:- operating pressure is between 160 bar to 222 bar.

b] super critical boiler:- operating pressure is above 222 bar.

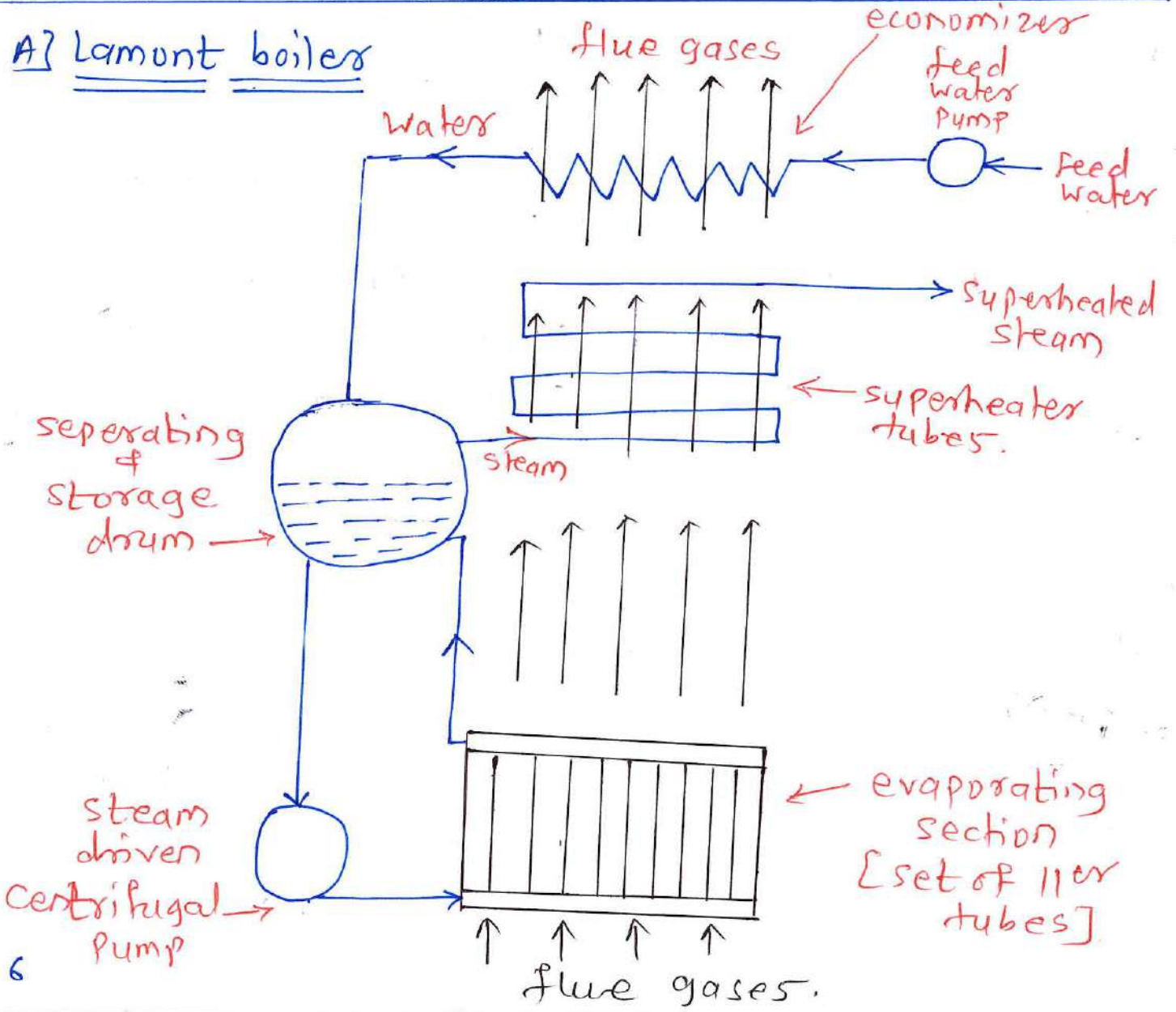
Examples:-

A] Lamont boiler

B] Benson boiler.

advantages- 1] high evaporation capacity.
2] Compact, less floor space.
3] Reduced overheating of parts

A] Lamont boiler



1] This boiler works on the principle of forced circulation maintain by a steam driven centrifugal pump.

2] water is supplied through an economiser to a seperating & storage drum, set externally to boiler

3] water from seperating & storage drum circulated through evaporation section by centrifugal pump

4] The mixture of water & steam is send back to drum, after heating into evaporating section.

5] large circulation of water prevents overheating of tubes.

6] In storage drum the vapours are seperated & drawn off through superheater for superheating

7] The superheated steam is sent to prime mover

8] The level of water in the drum is kept constant by supplying feed water equivalent to steam evaporated.

9] evaporating section, superheater & economiser are kept along the path of flue gases.

B] Benson Boiler:-

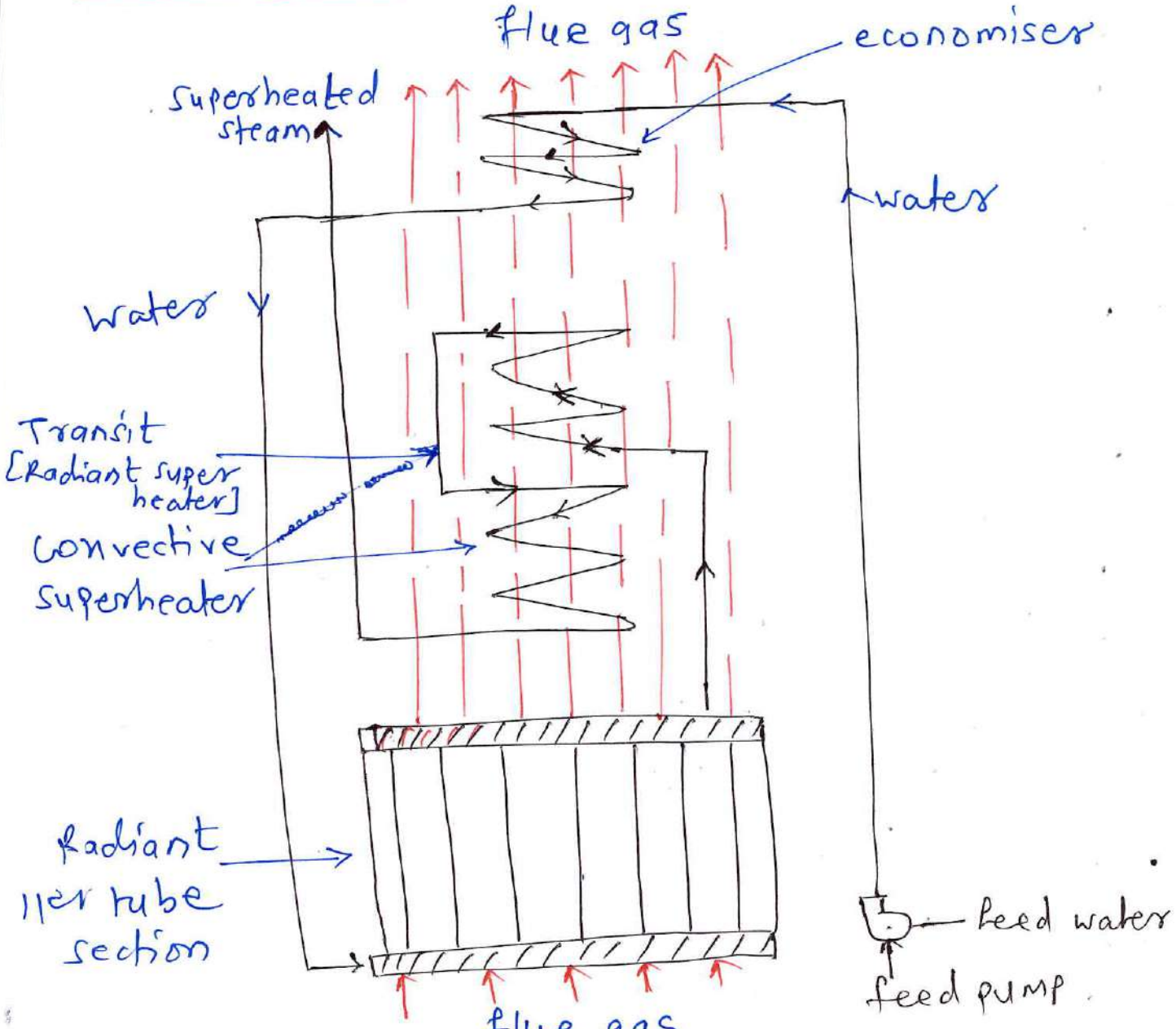


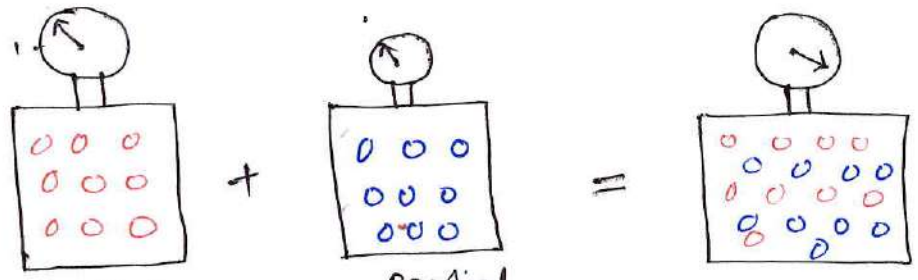
fig. Benson Boiler.

- Feed water enters at one end & discharges ~~at~~ superheated steam at the other end. The feed pump increases the pressure of water upto supercritical pressure [i.e. 225 bar] Thus, the water directly transform into a steam without boiling.
- The water passed through the economiser into the radiant evaporator where major portion of water is converted into steam
- The remaining water is evaporated in the convective evaporator absorbing heat from flue gas by convection
- The steam at supercritical pressure [225 bar] is passed through the superheater as shown in fig.

3.3 Steam Condensers :-

Dalton's law of partial pressure

Total pressure exerted by a mixture of non-reacting gases is equal to the sum of the partial pressures of the individual gases.



Partial Pressure 1 bar + Partial Pressure 1 bar = Total pressure 2 bar

& Volume $1 m^3$ + Volume $1 m^3$ = Total volume $1 m^3$

Total pressure [P] = Partial pressure [P_1] + Partial pressure [P_2]

$$\therefore \quad P = P_1 + P_2$$

Condenser :-

It is a closed vessel, where steam is condensed back into liquid again at constant pressure, after doing work in turbine.

function :-

1] Primary function :-

To maintain the low back pressure on the exhaust side of piston of steam engine or turbine. so that steam exepands to greater extends & more amount of mechanical work produced.

2] To supply the pure feed water to the hot well, from where, it is pumped back to the boiler.

classification of Condensers:-

- Condensers
  - 1] Jet Condensers
    - Low level
      - Parallel flow
      - counter flow
    - high level
    - Ejector
  - 2] Surface Condensers
    - surface condenser of single pass
    - Down flow type
    - Central flow type
    - Evaporative Condenser

1] Jet Condenser:-

Steam is condensed by direct mixing with cold water.

The temperature of condensate becomes same to the temperature of cold water leaving the condenser.

2] surface condenser:-

Exhaust steam & water do not comes in direct contact with each other

Steam passes over the surface of tubes, through which Constant supply of water is maintained.

It consists of a Horizontal cast iron cylinder vessel packed with tubes, through which the cooling water flows. The ends of the condenser are cut off by vertical perforated type plates into which

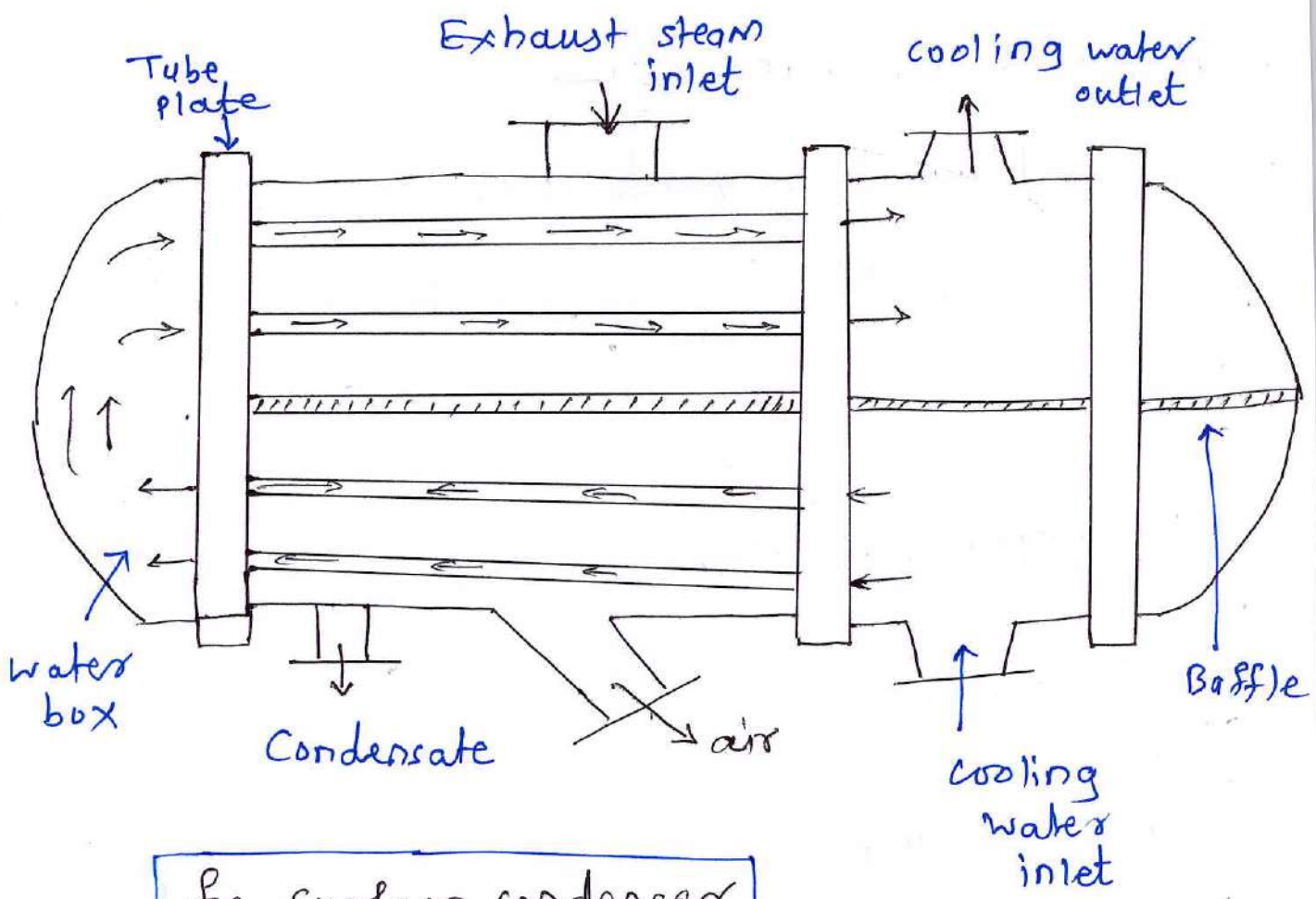


fig. surface condenser

The water tubes passes horizontally through the main Condensing space for the steam. The steam enters at the top & is forced to flow downwards over the the tubes due to the suction of extraction pump at the bottom.

The cooling water flows in the one direction through the lower half of the tubes & returns in opposite direction through the upper half as shown.

The steam loses its latent heat to the cooler tubes & condenses into a liquid, which is a pure & can be safely pumped back to the boiler to be reused.

Non condensable gases [air or leaked O_2) inevitably enter the system. air ejector or vaccum pump continuously extract these gases to maintain peak vaccum condition.

Sources of air leakages:-

1] Dissolved gases in feedwater:-

Air is naturally dissolved in the boilers feedwater. When steam is generated, these gases are carried along with the exhaust steam directly into the condenser.

2] Air-Extraction system:-

Defective air extraction pumps or leaking vacuum valves can allow air to bypass or enter the system.

3] Joints & flanges:-

improperly sealed pipe joint, casing flange or manhole acts as an entry point for atm. air.

4] Crack, corrosion in tubes, leads into entry of air into condenser.

Effects of air leakages:-

1] It reduces overall efficiency by increasing backpressure on the turbine

2] insulating barrier for heat transfer, so reduced rate of cooling

3] large size of condenser & vacuum pump.

4] maintainance & operating cost increases.

3.4 Cooling towers –

It is a device where waste heat is dissipated by evaporation of small portion of circulating water.

waste heat is associated with condenser cooling water circulated through condenser tubes.

Classification of cooling towers :-

A] According to draft method.

a] Natural draught cooling tower

b] ~~Forced~~ mechanical draught cooling tower.

i] Forced draught

ii] Induced draught

iii] Balanced draught

B] According to the direction of air & water flow.

a] Counter flow

b] Cross flow.

c] According to heat transfer type

a] wet

b] dry.

A] Construction & working of natural draught cooling tower.

→

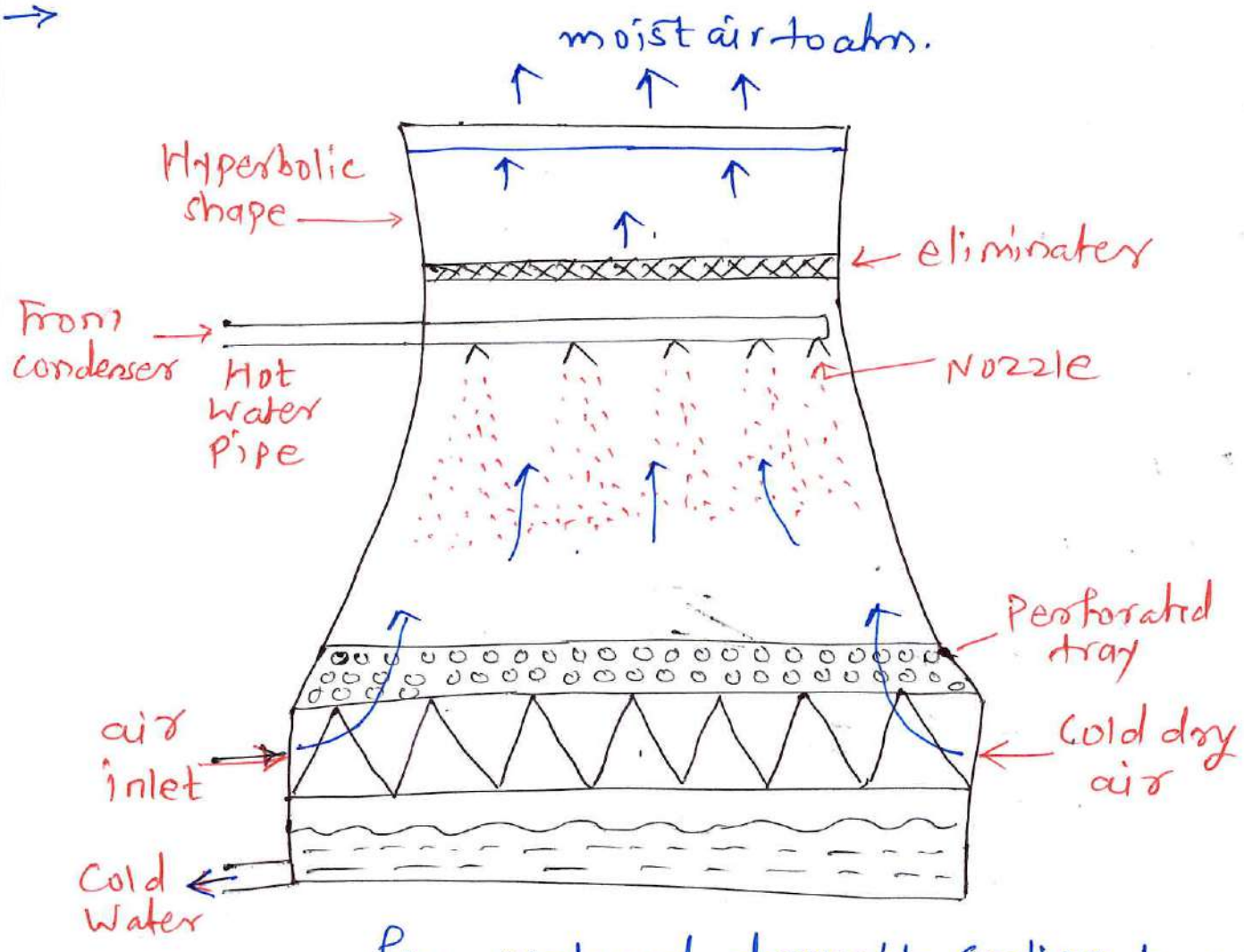


fig. Natural draught cooling tower.

Natural draught cooling tower works on the principle of buoyancy or stalk effect, ~~that is~~

circulation of air inside the cooling tower is done because of natural convection created by temperation & density differences between warm, moist air inside the tower & cooler ~~and~~ atmospheric air outside.

tower is generally in hyperbolic shape, which enhances structural stability & maximizes the natural draft effects.

warm air raises due to its lower density compared to the surrounding cooler air. This movement creates a natural convection current that draws in cool atmospheric air from base of the tower.

simultaneously, hot water is sprayed from top of the cooling tower.

Hot water droplets comes in contact cool air, evaporative cooling occurs, reducing water temperature.

Cooled water collected at the bottom & supplied to the condenser again.

Warm moist air raises naturally due to its lower density & exists from the top of tower.

advantages:- 1] No fans are required, reduce operating cost.

2] Low maintainance 3] suitable for large scale Industrial application.

disadvantages:- 1] large land area 2] high initial cost

3] requirement of very large land, due to tall structure area

Application:-

1] oil refineries

2] Thermal power plants

3] petrochemical & Natural gas processing plants.

B] forced draught cooling tower:-

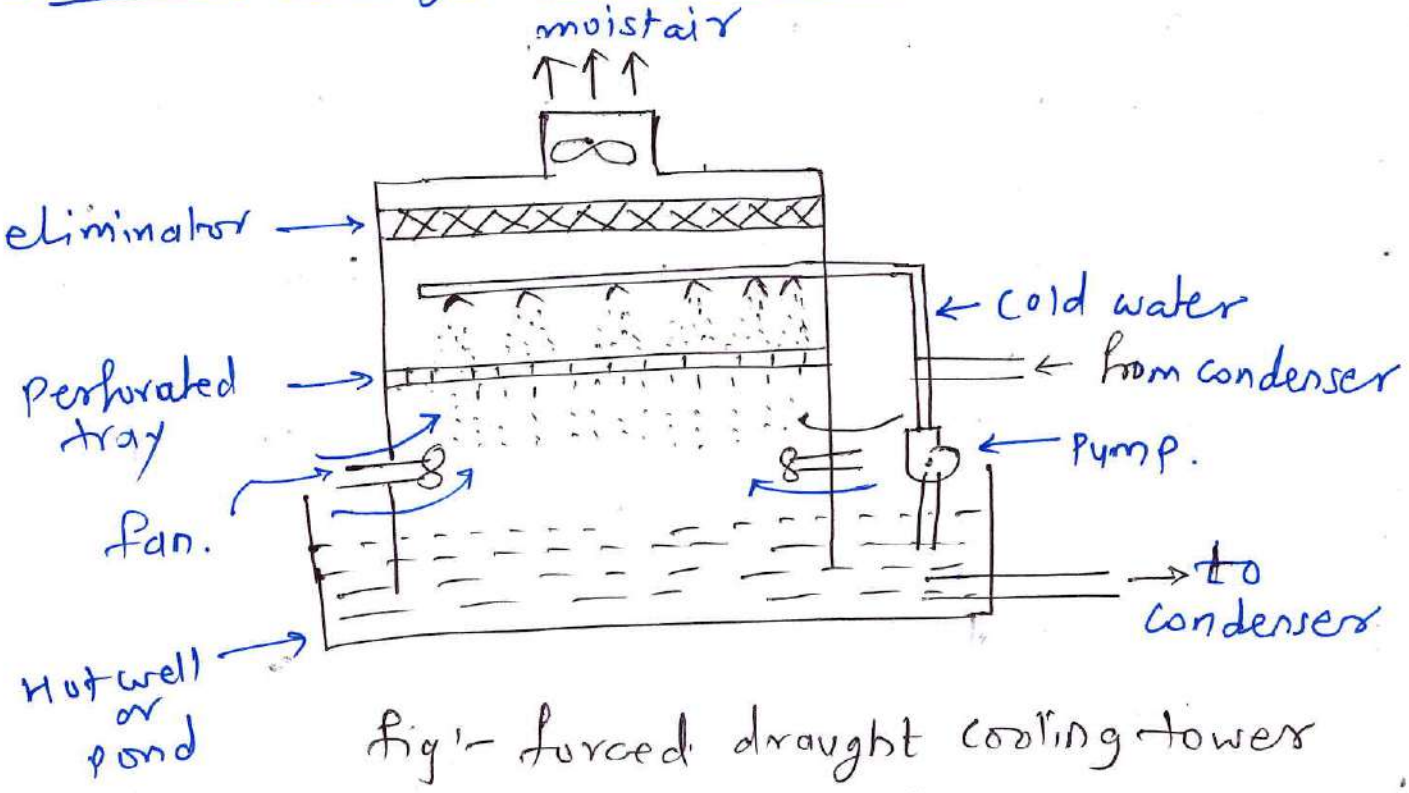


fig:- forced draught cooling tower

A Forced draught cooling tower is a type of mechanical draft cooling tower where fan or blower are used for air circulation through the cooling tower.

The fan or blowers are fitted at base of tower which forces air into the tower.

Hot water from condensers is sprayed at the top of tower which comes in contact of forced air from bottom.

Evaporative cooling of water takes place between air & water. Cooled water collected at bottom & moist air excape from the top of tower

c] Induced draught cooling tower:- fans or blower are fitted at top of tower as compared to forced draught

d) balanced draught:- fan & blowers both are fitted a

3.2 Steam Nozzles & turbines.

Steam Nozzles:→
it is a passage of varying cross-sectional area, which converts the Heat Energy of steam into Kinetic Energy, as the steam expands from the High pressure to lower pressure.

function:→ ① To convert the portion of Energy of steam into K.E.

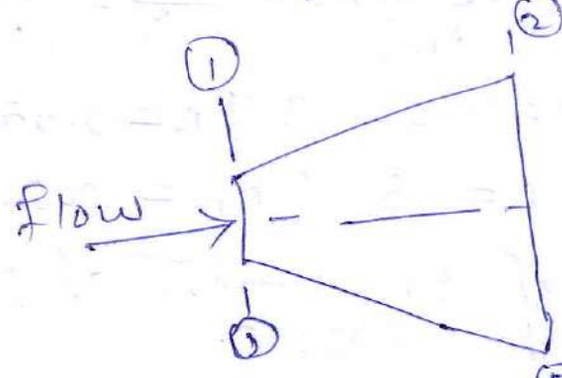
Applications:→ ① for jet propulsion.
② flow measurement of fluid
③ spray painting
④ Turbo-machines.

*** continuity equation:→**
The quantity of fluid flow per second flowing through a pipe at all sections is constant.
ie. flow rate is same throughout the pipe.

ie. $\dot{m}$ = constant

$\Rightarrow \rho A V$ = constant

where ρ = density of fluid
A = c/s area of Nozzle/pipe
V = velocity at given c/s.



at section ① - ①
$\dot{m} = \rho_1 A_1 V_1$

at section ② - ②
$\dot{m} = \rho_2 A_2 V_2$

$\therefore \boxed{\rho_1 A_1 V_1 = \rho_2 A_2 V_2}$

for incompressible fluid
$\rho_1 = \rho_2 = \rho$

$\therefore A_1 V_1 = A_2 V_2$

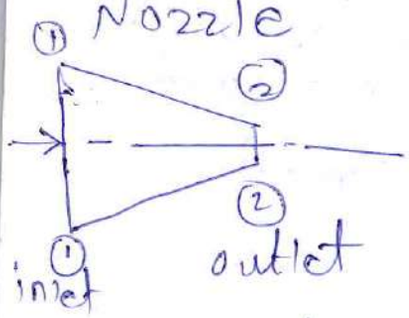
ie. AV = const $= \dot{m} \cdot \dot{V}_s$ $\quad \left[\dot{m} = \frac{AV}{\dot{V}_s}\right]$

$\dot{V}_s$ = sp. vol, m of flowing fluid.

* Types of Nozzles:-

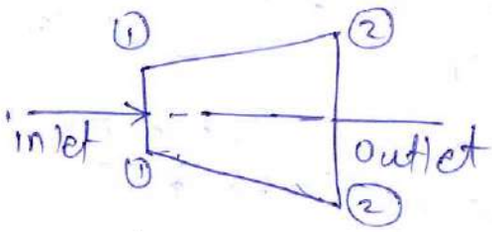
3-types

Convergent Nozzle



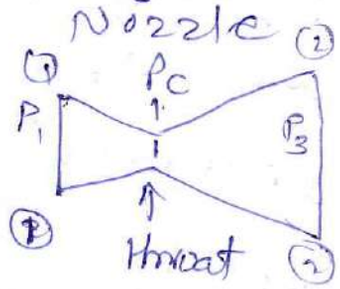
c/s area decreases from inlet to outlet

Divergent Nozzle



c/s area of Nozzle increases from inlet to outlet

convergent-divergent Nozzle



c/s area of Nozzle decreases from inlet to throat & then increases upto outlet.

critical pressure:- [P_c]

The pressure value at throat for the given inlet steam pressure, which gives maximum discharge through the Nozzle.

critical pressure ratio [R_{P_c}] :→

Ratio of critical pressure to the pressure of steam at inlet.

$$\text{critical pressure ratio } [R_{P_c}] = \frac{P_c}{P_1} = \left[\frac{2}{n+1}\right]^{\frac{n}{n-1}}$$

for saturated steam, $n = 1.135$, $\therefore R_{P_c} = 0.5774$

for superheat steam $n = 1.3$ $\therefore R_{P_c} = 0.5457$

where n = Index of expansion of steam through Nozzle.

* Mach Number :→

Ratio of actual velocity [V] to the sonic velocity [speed of sound through medium] [c]

∴ $M = \frac{V}{c}$, it is a dimensionless Number. [No unit]

Significance :→ if $M > 1$ ie. $V > c$, flow is supersonic

$M = 1$ ie $V = c$, flow is sonic

$M < 1$ ie $V < c$, flow is subsonic

~~$M \ll 1$ ie. $V \ll c$~~

$M >> 1$, ie $V >> c$. - flow is Hypersonic

Steam turbine

It is a prime mover, in which rotary motion is obtained by gradual change in momentum of steam.

"steam is expanded from a high pressure to low pressure either in nozzle or in blading. & the Kinetic Energy obtained is supplied to the rotary blade, where it is transformed into mechanical work."

classification

(1) According to working principle

A] Impulse turbine :→ jet with only K.E strikes on blade

B] Reaction turbine :→ jet with K.E + P.E strikes on blade.

2] According to Number of stages of expansion :-

(A) Single stage steam turbine

(B) Multistage steam turbine.

3] According to position of shaft:- (20)

A] Horizontal turbine:→ shaft axis is vertical

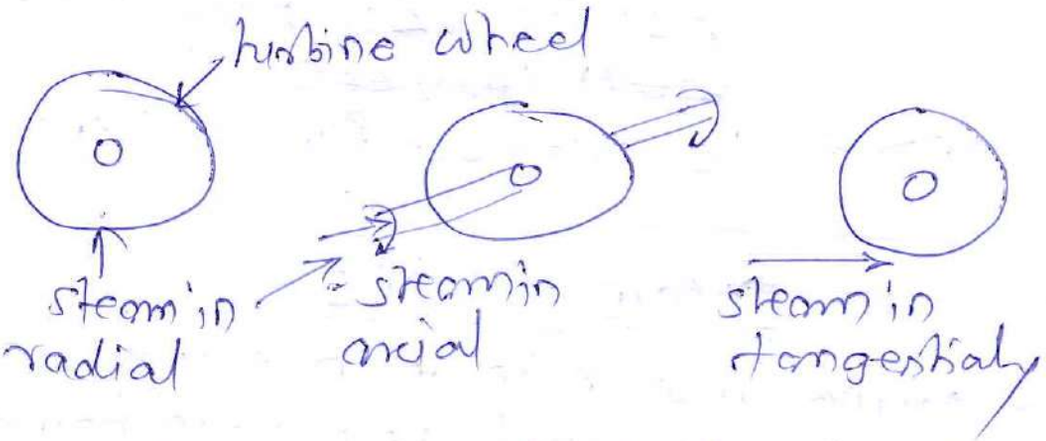
B] vertical turbine:→ —11— Horizontal

4] According to direction of steam flow:-

A] Axial flow:→ steam flow ~~radially~~ axially to turbine

B] Radial flow:→ —11— radialy —11—

C] Tangential flow:→ —11— tangentialy —11—



5] According to Method of governing:-

A] ~~A~~ Throttle

B] Nozzle

C] Bypass.

IMP Impulse turbine

construction:- consists 3 components

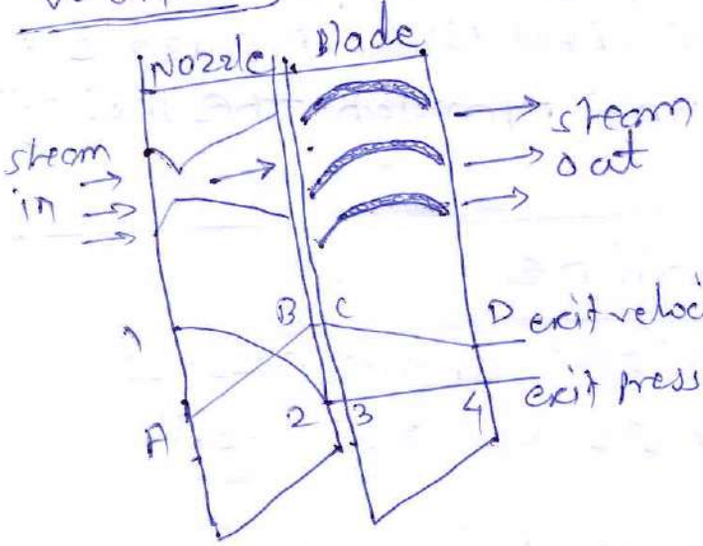
1] Nozzle:→ circular guide way, guides & regulates a steam flow in the designed direction & velocity.

2] Runner & Blade:→ it is a circular with peripheral mounted blades fixed on a Horizontal shaft.

The steam jet strikes on the blades which move in a direction of the jet. This movement of the ~~jet~~ blade makes the runner to rotate.

3] Casing:→ "air tight metallic case," which contains the turbine runner & blades. It controls the movement of steam from the blade to the condenser & does not permit it to move into the space. It acts as safegaard of runner against any accident.

Working:→



1234- pressure graph
ABCD- velocity graph

"Top portion shows a set of Nozzle, which is followed by moving blades."

fig Pressure velocity variation graph impulse turbine

As the name indicates power is developed by the impulsive force of high velocity steam jets.
These high velocity steam jets are obtained due to expansion of steam in the stationery Nozzles only. The steam is then passes through the moving blades with no further pressure drop, but a gradual decrease in velocity

After striking the high velocity steam jets over the curved blades mounted on the wheel the direction of Hence momentum of velocity jets is changed, which produces force on wheel. This force causes shaft to rotate.

The lower part of the diagram shows the approximate changes in pressure & velocity during the flow of steam through the turbine.

The pressure of steam jets is reduced in Nozzle & remains constant while passing through the moving blade.

The velocity of steam is increased in nozzle & is reduced while passing through the moving blade.

Reaction turbine.

"at inlet of turbine blade, steam possesses the pressure Energy as well as K.E."

Construction:→ ① casing:-
It is a air-tight Metallic case, which constitutes the guide mechanisms & turbine runner. The steam enters the fixed blades (Guide Mechanism) with ~~fixed~~ ~~blo~~ uniform velocity.

② Guide Mechanism:-
It consists of guide blades fixed to the casing.
~~The~~ to ① allow the steam to enter the runner without shock.
② Regulate the required quantity of steam.

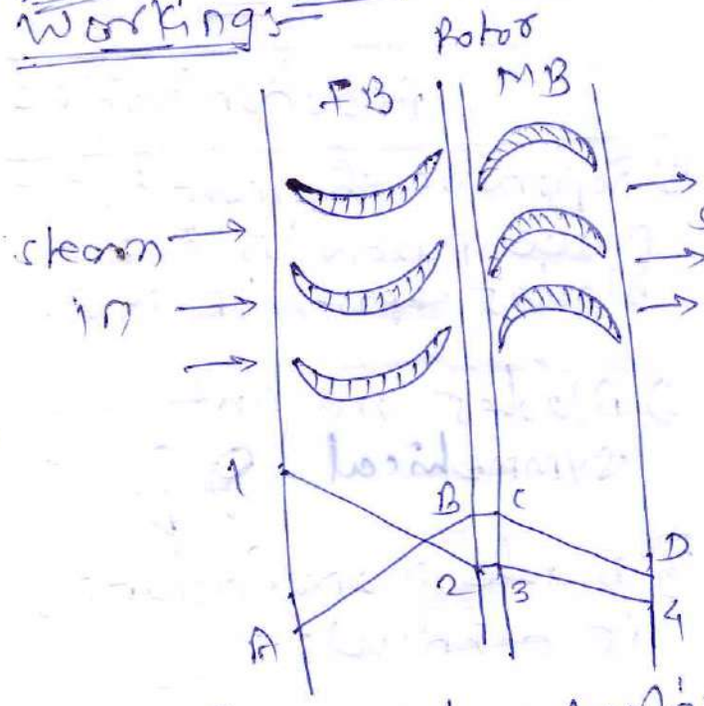
3] Turbine Runner:- similar to impulse turbine

4] draft tube:-

The steam, leaving the runner blade is allowed to flow into condenser through a tube called as draft tube.

5) if the draft tube is not provided in the turbine, then the steam will move freely & will cause steam eddies to set up.

Working:-



FB → fixed blade
MB → Moving blade

1-2-3-4 → pressure graph

A-B-C-D → velocity graph

fig. Reaction turbine pressure-velocity variation diagram.

1] Pressure drop takes place gradually, continuously over the FB & MB.

2] Top portion shows the arrangement of fixed & moving blades.

3] fixed blades alters the direction of steam as well as they allow steam to expand to have larger velocity.

4] As the steam passes through the MB, the K.E. obtained due to fall in pressure is absorbed by them.

Bottom of figure shows the velocity & pressure graph of steam flow through Nozzle.
pressure in reaction turbine reduced in FB & MB.
velocity of steam is increased in fixed blades & is decreased in moving blades.

JMP difference between Impulse turbine & Reaction turbine - any 4

Impulse turbine	Reaction turbine
① Expansion of steam takes place in nozzles only	① Expansion of steam takes place partly in fixed blades & partly in M B.
② The blades are symmetrical →	② Blades are not symmetrical →
③ Blade Manufacturing is easy	③ Blade Manufacturing is difficult.
④ low efficiency	④ High efficiency.
⑤ steam strikes blade with K.E only	⑤ steam strikes blade with K.E + P.E.
⑥ Suitable for low power requirements	⑥ Suitable for medium & large power requirements

✱ Compounding of Impulse steam turbine

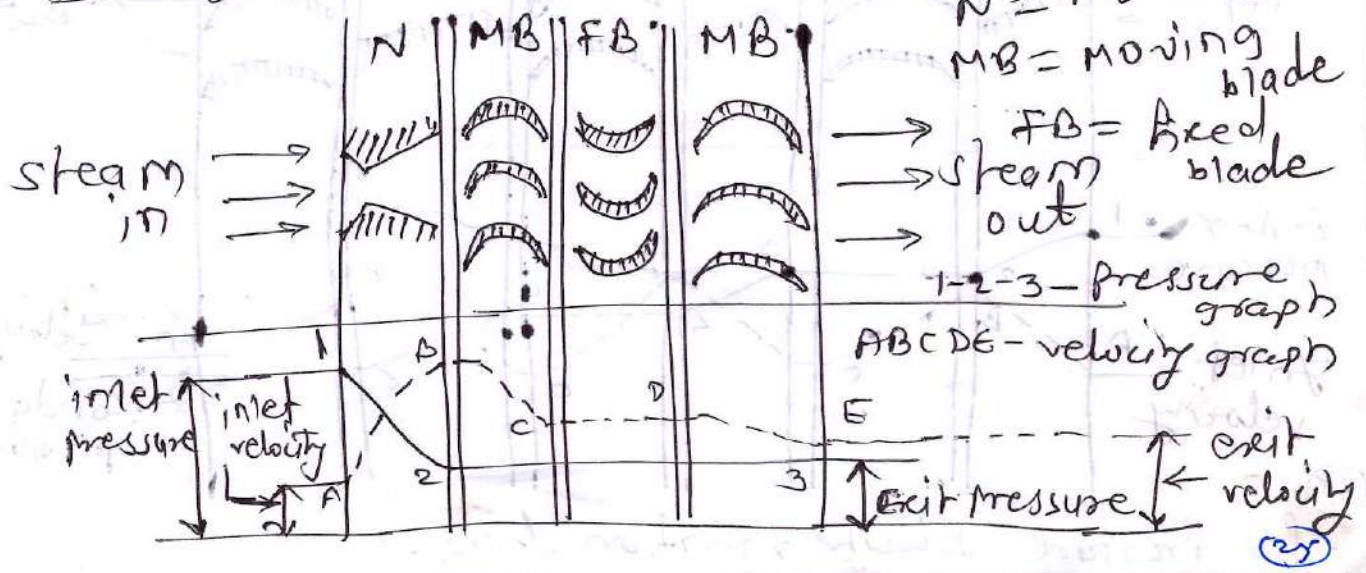
The compounding of impulse steam turbine means the methods to reduce the speeds of rotor shaft.

Necessity:→ if the steam from Boiler pressure to condenser pressure is expanded into a single stage, then the velocity of steam entering into the turbine will be extremely high. This will make the rotor to run at a very high speed, which is not useful from practical point of view. Hence it is become necessary to reduce the rotor speed by gearing as there is danger of failure of blades due to the excessive centrifugal stresses, when a single stage of blades are used.

✱ Methods or types of compounding

1. velocity compounding
2. pressure compounding
3. pressure-velocity compounding.

1. velocity compounding :- Pressure & velocity variation diagram.



steam is expanded into a nozzle from boiler pressure to condenser pressure. as a result of which velocity or K.E of steam is increases.

The gain in K.E. or velocity is compounded [used in] in two stages of moving blade rows as shown in above figure.

The function of fixed blade is to re-direct the steam flow without altering its velocity to the next row moving blades.

advantages:- ① only 2-3 stages are required so initial cost is less.

② space required is less ③ turbine Housing need not to be made stronger.

disadvantages:-

① friction losses are more due to high velocity of steam

② low efficiency due to increase in Number of stages.

2] Pressure compounding

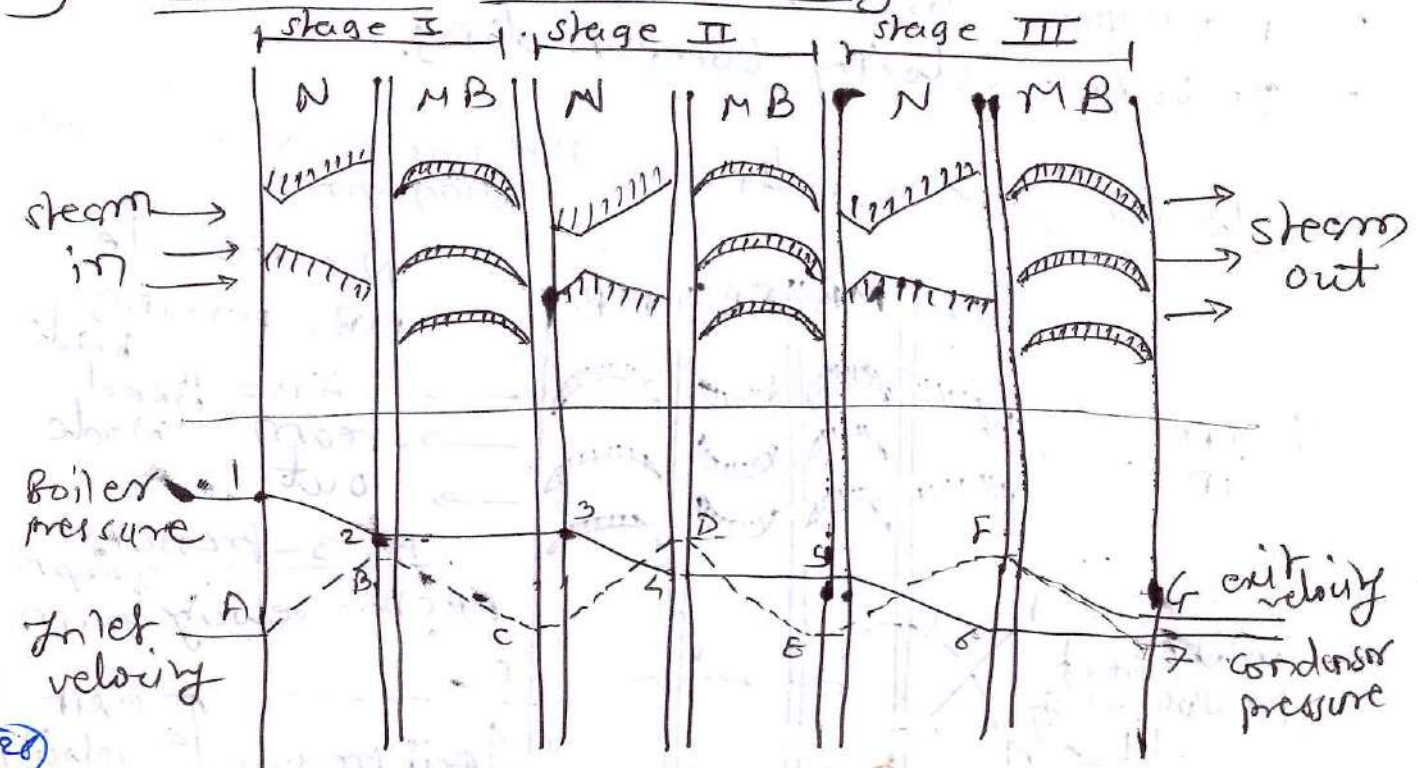


fig. pressure-velocity variation diag.

* Necessity of compounding :→

① To reduce speed of rotor blades to practical limits

② To reduce centrifugal force & Hence to prevent failure of loads.

③ To reduce velocity of steam leaving blades.

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* Regenerative feed heating & Bleeding :-

Bleeding :→ it is a process of draining steam from the turbine, at certain points during its expansion & using this for heating the feed water supplied to the ~~bl~~ boiler.

&

the process of heating the feed water is called as regenerative feed heating.

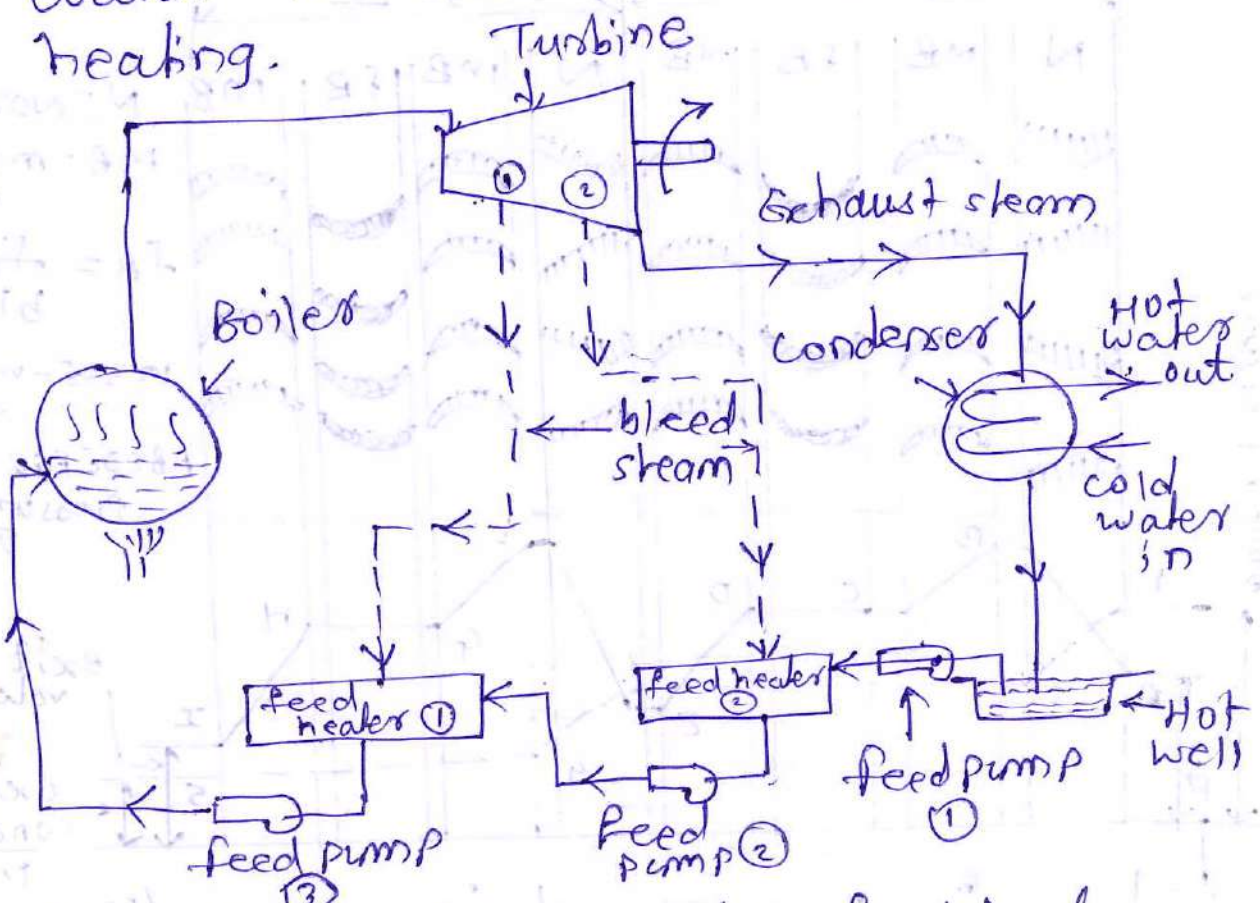

Fig. Bleeding & Regenerative feed heating

In pressure compounding, steam is partialy expanded in set of nozzles incorporated betn the rings of moving blades. The K.E. of steam thus obtained is absorbed by the moving blades.

Thus, the total pressure drop of steam does not take place in a single nozzle but it is devided among all the rows of fixed blades, working as nozzles.

3] Pressure-velocity compounding

This method is combination of pressure compounding & velocity compounding

The total pressure drop of steam is devided into number of stages & velocity obtained in each stage is also compunded.

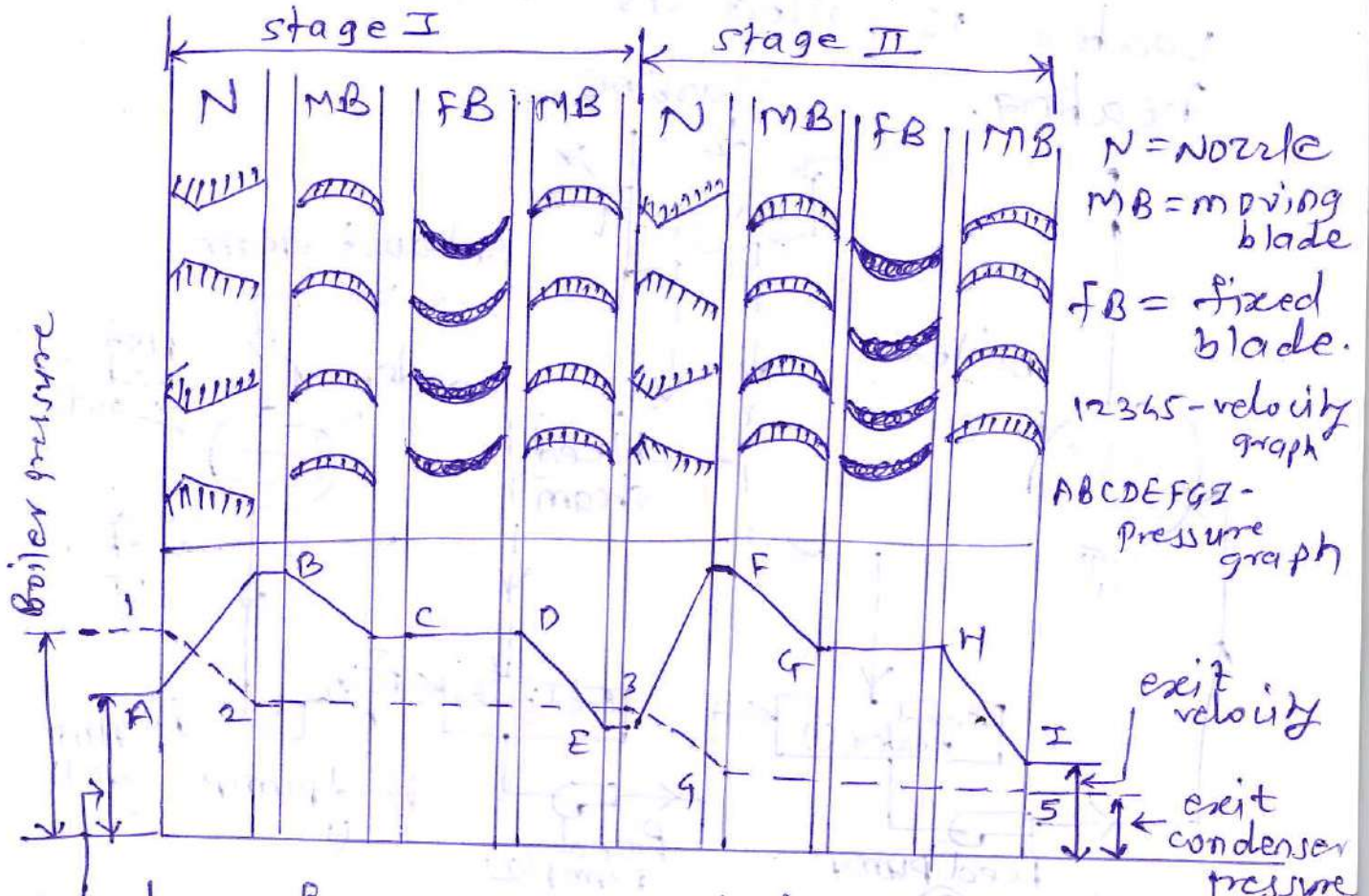

fig. Pressure-velocity compounding.

In this process small quantity of steam, at certain section of the turbine is drained from the turbine & is given to pipeline from hot well to boiler.

This steam is thus condensed due to relatively cold water & the heat so lost by steam is transferred to the feed water.

at section ①-① & ②-②, some of steam is extracted & passed into the feed heaters, from which, feed water is going to the Boiler

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~~Processing of steam turbine~~
~~in steam cycle~~

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