# Lecture 7: Steam Turbines – Feedwater System

**Course:** MECH-422 – Power Plants

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BUITEMS – DEPARTMENT OF MECHANICAL ENGINEERING

# Turbines

# What is a Turbine ?

-A Turbine is a device which converts the heat energy of steam into the kinetic energy & then to rotational energy.

-The Motive Power in a steam turbine is obtained by the rate of change in momentum of a high velocity jet of steam impinging on a curved blade which is free to rotate.

-The basic cycle for the steam turbine power plant is the Rankine cycle. The modern Power plant uses the rankine cycle modified to include superheating, regenerative feed water heating & reheating.

# Impulse & Reaction Turbine

1. **Based on Blading Design**

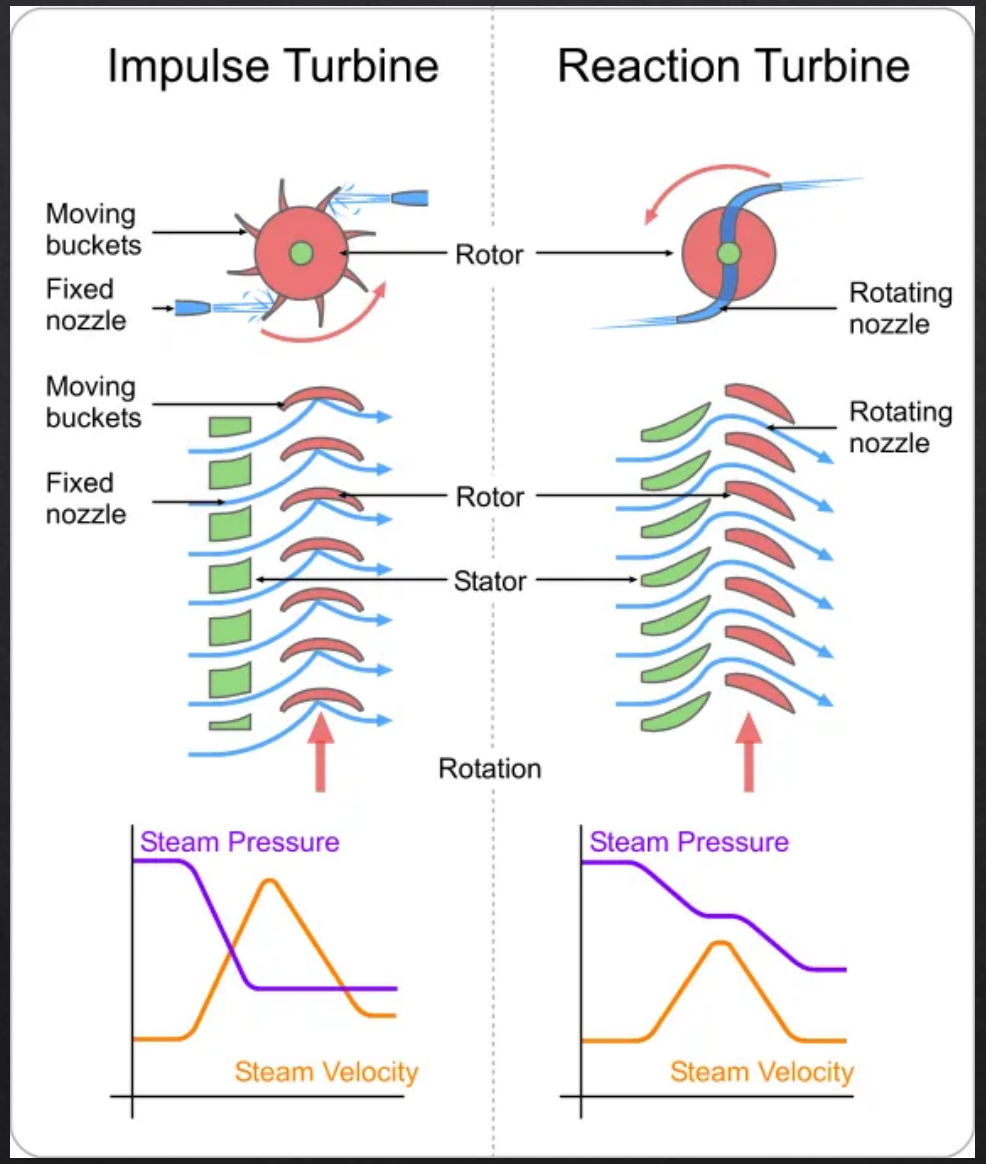
   a) Impulse turbine

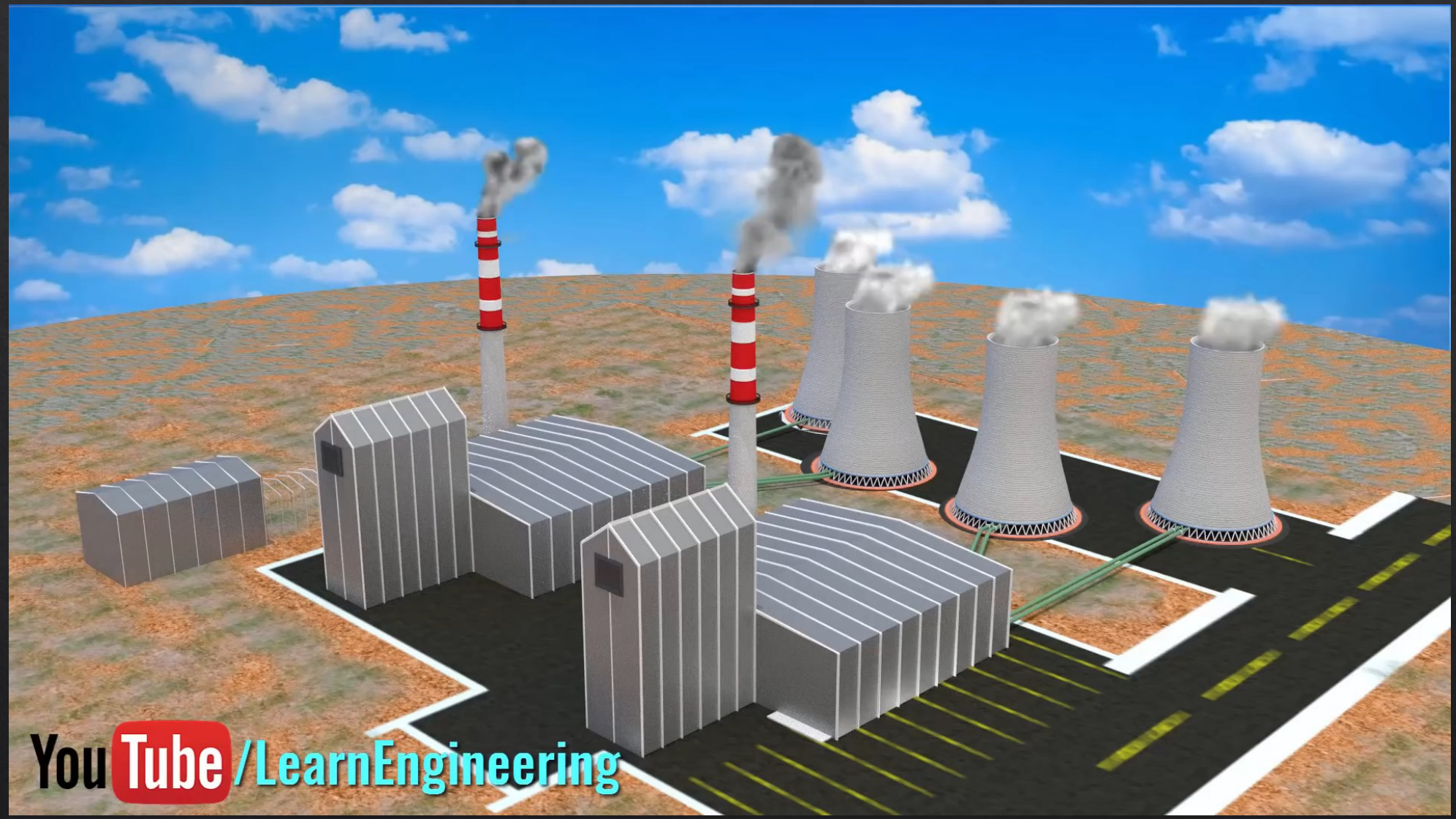
   **There is no pressure drop across moving blades. Steam energy is transferred to the rotor entirely by the steam jets striking the moving blades.**

   b. Reaction turbine

   **Steam expands in both the stationary & moving blades. Moving blades also act as nozzles. High axial thrust is produced.**

   c) Combination of Impulse & Reaction turbine


Impulse Turbine
Reaction Turbine
Moving buckets
Fixed nozzle
Rotor
Rotating nozzle
Moving buckets
Fixed nozzle
Rotor
Stator
Rotating nozzle
Rotation
Steam Pressure
Steam Velocity
Steam Pressure
Steam Velocity

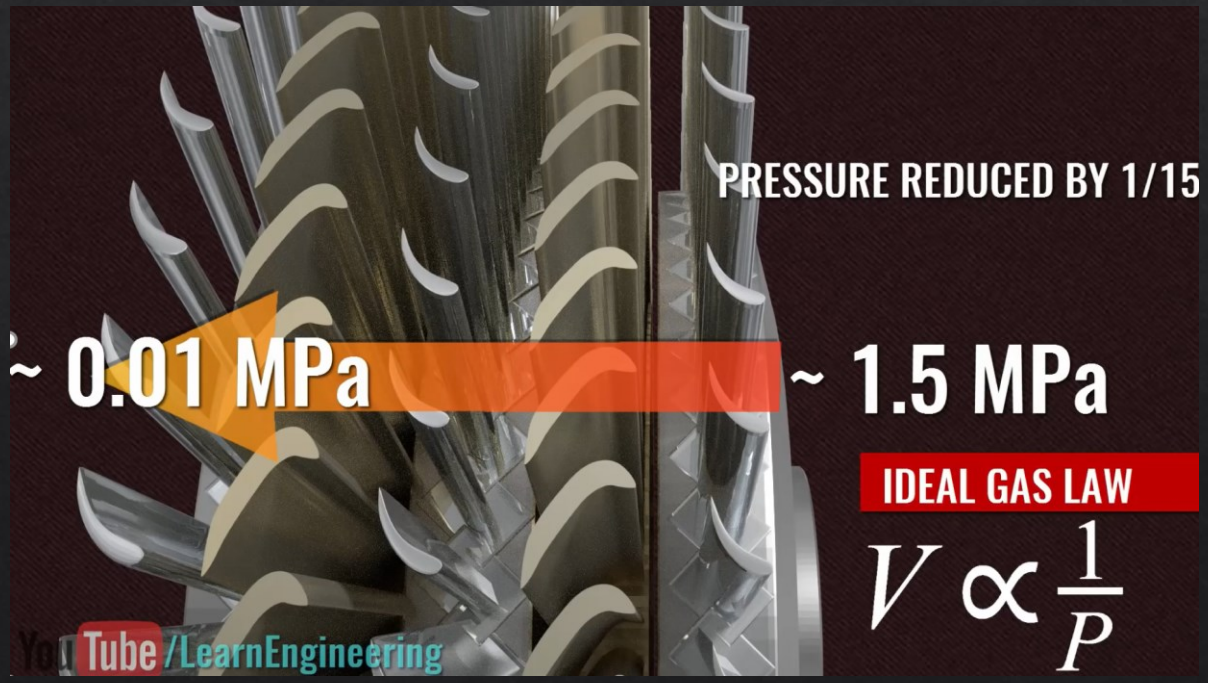





https://www.youtube.com/watch?v=SPg7hOxFItI

## DEGREE OF REACTION

$$D.O.R = \frac{\Delta E_{Pressure} + \Delta E_{Temperature}}{\Delta E_{Total}} = \frac{\Delta Enthalpy}{\Delta E_{Total}}$$



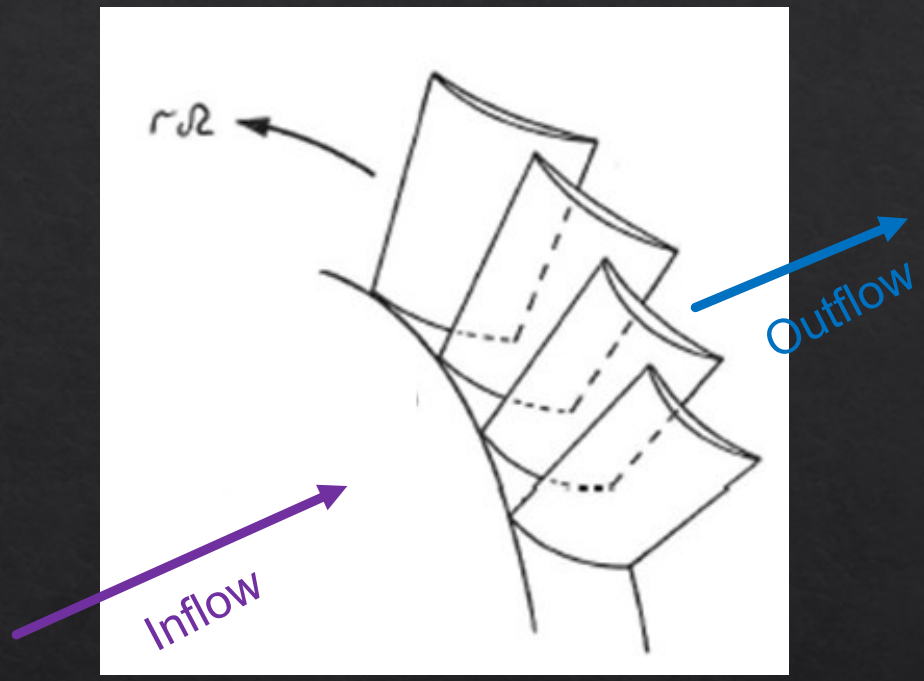
| S.no | Impulse Turbine | Reaction Turbine |
|---|---|---|
| 1. | In an impulse turbine, the steam flows through the nozzle and strike on the moving blades. | In the reaction turbine, first, the steam flows through the guide mechanism and then flows through the moving blades. |
| 2. | Steam strikes on the buckets with kinetic energy. | The steam glides over the moving blades with both pressure and kinetic energy. |
| 3. | During the flow of steam through moving blades, its pressure remains constant. | During the flow of steam through moving blades its pressure reduces. |
| 4. | The steam may or may not be admitted to the whole circumference. | The steam must be admitted over the whole circumference. |
| 5. | The blades of impulse turbine are symmetrical. | The blades of reaction turbine are not symmetrical. |
| 6. | While gliding over the blades the relative velocity of steam remains constant. | In reaction turbine, while gliding over the blades the relative velocity of steam increases. |
| 7. | For the same power developed, the number of stages required is less. | For the same power developed, the number of stages required is more. |
| 8. | The direction of steam flow is radial to the direction of turbine wheel. | The direction of steam flow is radial and axial to the turbine wheel. |
| 9. | It requires less maintenance work. | It requires more maintenance work. |
| 10. | It is suitable for low discharge. | It is suitable for medium and high discharge. |
| 11. | Pelton Wheel is the example of impulse turbine. | Francis turbine, Kaplan turbine etc. are the examples of reaction turbine. |

# Euler Theory: Clue for Generation of Torque

Torque exerted by flow on A blade row = shaft output torque = $\tau$

= Rate of change  of Angular momentum of fluid

# Flow Kinematics in the Meridional Plane

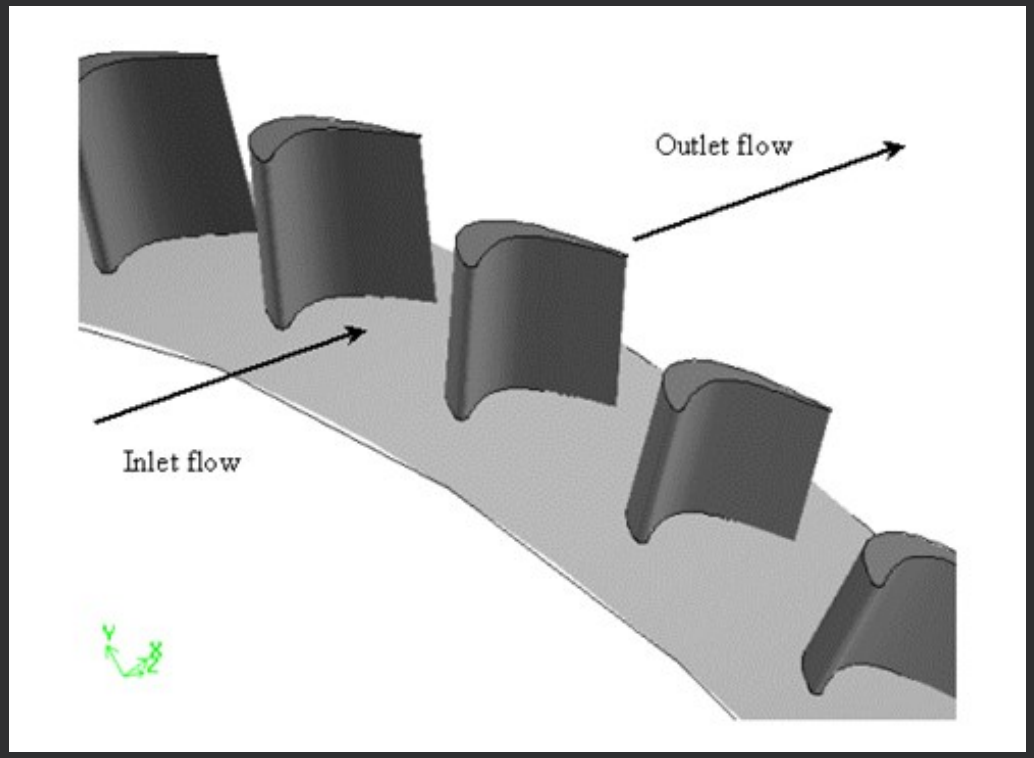



The momentum balance is considered in a plane constructed through axis of rotation and radial axis.

This Plane is called Meridional Plane.

Euler Differential Turbine Equation.

$$d\tau = d\{\dot{m} V_\theta r\}$$


Outlet flow
Inlet flow

# CONSTRUCTIONAL FEATURES

- **CASING :** Made of cast steel except condensing stage which is made of cast iron. It is mounted on the front-end bearing pedestal. Expansion of casing is towards front end.

- **ROTOR :** Machined from a forged blank of alloy steel. Rotor is a single forging incorporating the thrust bearing collars. It is supported on two pressure lubricated journal bearings. Expansion of rotor is towards rear end.

- **CONTROL STAGE :** Consists of moving blades & nozzles. Nozzles are machined from solid blanks. The moving blades are machined from solid bar stock & have inverted tee roots. Tee roots are inserted into groves in the turbine rotor & caulked with brass strip.

# LOSSES

1. **External Losses**
   - ESV & strainer losses
   - Governing losses (throttling losses)
   - Leaving Energy Losses (Latent heat of exhaust steam in condenser)
   - Radiation Loss to the surroundings
2. **Internal Losses**

   **a) Blade losses**

   i) **Primary Losses:**

   Friction loss due to profile surface finish

   ii) **Secondary Losses:**

   - Impingement loss

# Losses in Turbine (contd.)

b) **Inter stage Tip Leakages:**

Steam throttles in the inter stage seals without doing work

c) **Residual velocity Losses:**

Kinetic energy of the leaving steam of one stage will be carried over to the next stage. As the axial clearances increase between the stages (or stage groups) part of the kinetic energy will be lost.

# Feedwater System

# INTRODUCTION

- Producing quality steam depends on properly managed water treatment to control steam purity, deposits and corrosion.
- Boiler performance, efficiency, and service life are direct products of selecting and controlling feed water used in the boiler.
- Most of the components in the feed water are soluble. However, under heat and pressure most of the soluble components come out of solution as particulate solids, in crystallized forms and as amorphous particles.
- When solubility of a specific component in water is exceeded, scale or deposits will develop
- The boiler water must be sufficiently free of deposit forming solids to allow rapid and efficient heat transfer and it must not be corrosive to the boiler metal.

# CAUSE OF IMPURITIES IN BOILER WATER

- Deposits and corrosion result in efficiency losses
- Deposits act as insulators and slows down heat transfer. Large amounts of deposits throughout the boiler could reduce the heat transfer to reduce the boiler efficiency and further result in tube failures.

**Hardness salts:**

- The most important chemicals contained in water that influences the formation of deposits in the boilers are the salts of calcium and magnesium, which are known as hardness salts.

# CAUSE OF IMPURITIES IN BOILER WATER

**Temporary hardness:**

- Calcium and magnesium bicarbonate dissolve in water to form an alkaline solution and these salts are known as alkaline hardness. They decompose upon heating, releasing carbon dioxide and forming a soft sludge, which settles out. These are called temporary hardness that can be removed by boiling.

**Permanent hardness:**

- Calcium and magnesium sulphates, chlorides and nitrates, etc. when dissolved in water are chemically neutral and are known as non-alkaline hardness. These are called permanent hardness and form hard scales on boiler surfaces, which are difficult to remove.

**Silica:**

- The presence of silica in boiler water can rise to formation of hard silicate scales. It can also associate with calcium and magnesium salts, forming calcium and magnesium silicates of very low thermal conductivity.
- Silica can give rise to deposits on steam turbine blades (carried over either in droplets of water in steam, or in volatile form in steam at higher pressures)

# WATER TREATMENT TYPES

There are two major types of boiler water treatment :

- ✓ Internal water treatment
- ✓ External water treatment
  - Softening
  - Demineralisation

# INTERNAL WATER TREATMENT

- Internal treatment is carried out by adding chemicals to boiler to prevent the formation of scale by converting the scale-forming compounds to free-flowing sludges, which can be removed by blowdown.
- Different waters require different chemicals. Sodium carbonate, sodium aluminate, sodium phosphate, sodium sulphite and compounds of vegetable or inorganic origin are all used for this purpose

# EXTERNAL WATER TREATMENT

- External treatment is used to remove suspended solids, dissolved solids (particularly the calcium and magnesium ions which are a major cause of scale formation) and dissolved gases (oxygen and carbon dioxide).
- The external treatment processes available are **ion exchange; demineralization; reverse osmosis and de-aeration**.
- Before any of these are used, it is necessary to remove suspended solids and color from the raw water, because these may foul the resins used in the subsequent treatment sections.
- Methods of pre-treatment include simple sedimentation in settling tanks or settling in clarifiers with the aid of coagulants and flocculants. Pressure sand filters, with spray aeration to remove carbon dioxide and iron, may be used to remove metal salts from bore well water.

# EXTERNAL WATER TREATMENT

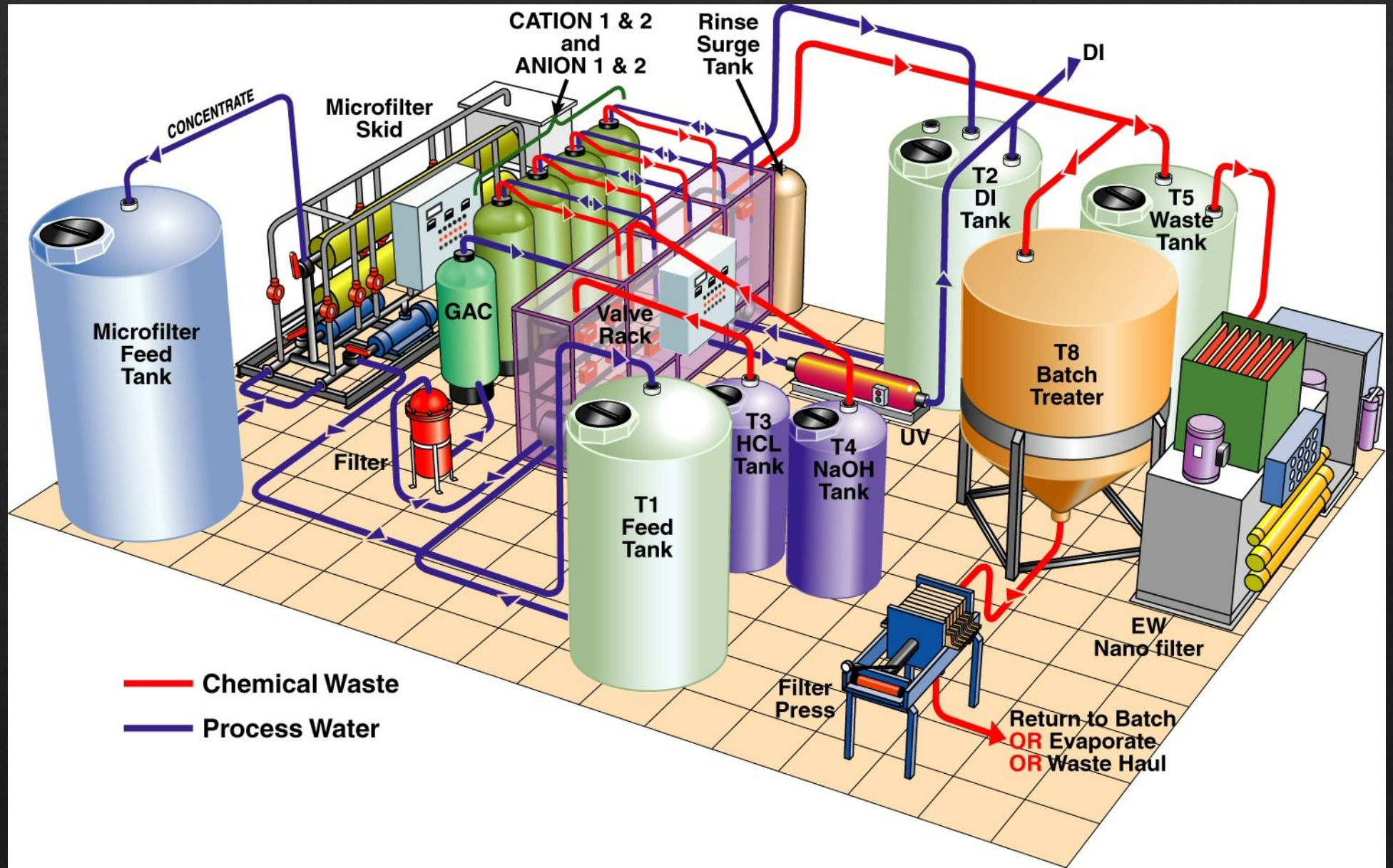
- The first stage of treatment is to remove hardness salt and possibly non-hardness salts.

**Sofening:**

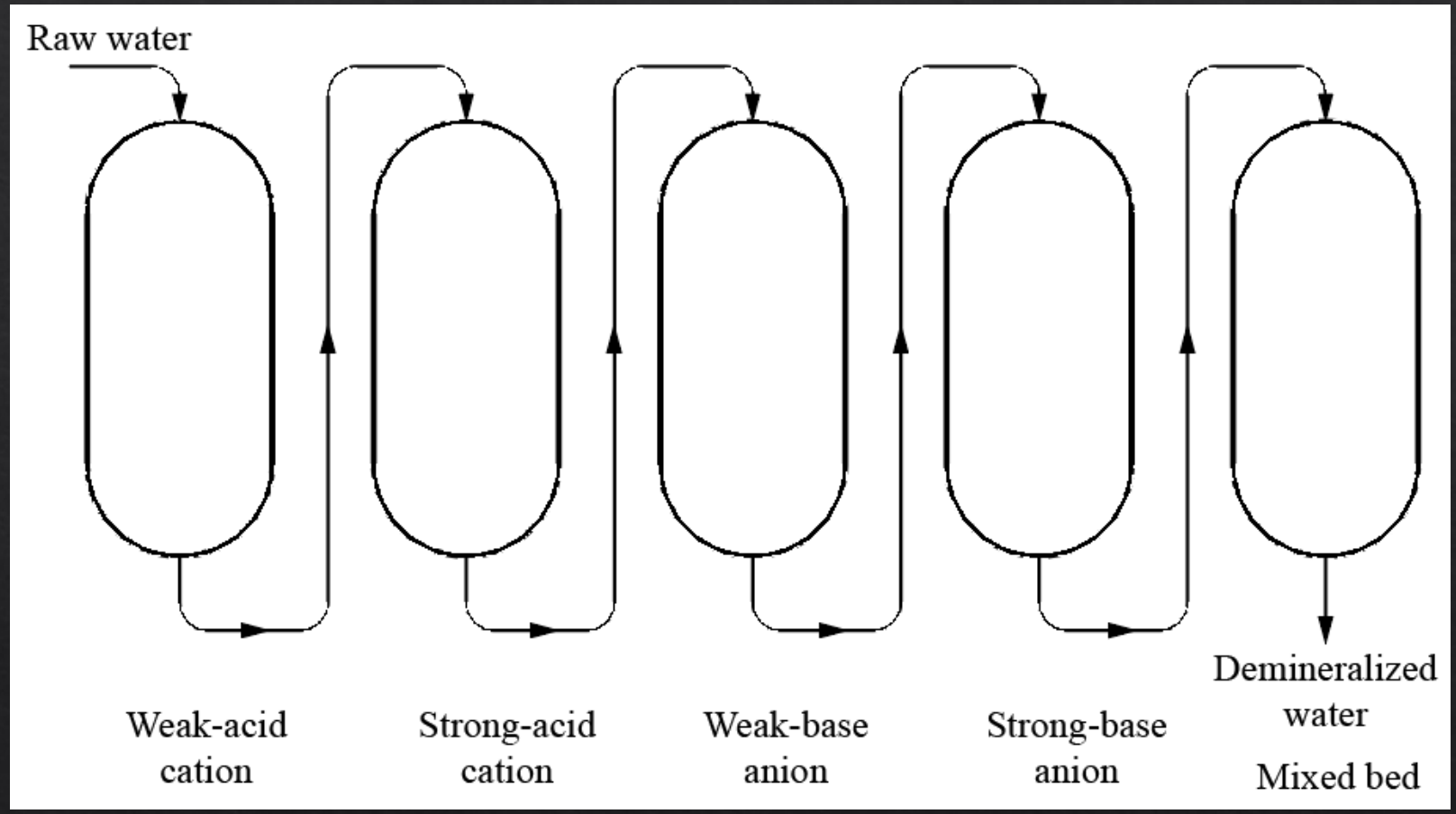
- Removal of only hardness salts is called softening

**De-mineralization:**

- Total removal of salts from solution is called demineralization.


CATION 1 & 2
and
ANION 1 & 2
Rinse
Surge
Tank
DI
CONCENTRATE
Microfilter
Skid
T2
DI
Tank
T5
Waste
Tank
Microfilter
Feed
Tank
GAC
Valve
Rack
T8
Batch
Treater
T3
HCL
Tank
T4
NaOH
Tank
UV
Filter
T1
Feed
Tank
EW
Nano filter
Filter
Press
Return to Batch
OR Evaporate
OR Waste Haul
Chemical Waste
Process Water

# Feedwater System




Schematic of a typical water demineralization plant

# End of Lecture!