Chapter – 8
Feed Water Treatment

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8.1 Introduction

- Water treatment removes impurities from water outside the boiler in order to minimize scaling.
- Scaling and corrosion are mostly faced problem in boiler due to poorly treated water.
- It may downgrade plant efficiency and create severe risk to safety.
- So safe and efficient performance from boiler, proper treatment of feed water should be employed every time.

8.2 Necessity of feed water treatment

- Water contains more minerals hence scaling in tubes of boiler, condenser and in turbine blades takes place.
- To avoid scaling, increase steam rate, control water pollution and safe working of plant it is required.

8.3 Impurities Present in feed water

- They may be categorized in following categories:

1. Dissolved : dissolved gases, inorganic salts.
2. Suspended: inorganic clay and sand, organic vegetables, and animal material.
3. Colloidal : Finally divided clay and silica, organic water products, colouring matter, amino acid.
4. Microscopic

8.4 Impurities Present in feed water

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8.4 Effect of Impurities in feed water

1. Melting Point:

- A substance containing soluble impurities usually melts at a lower temperature than the pure compound.
- Smaller the range of melting temperature, higher the purity of the sample.

2. Boiling Point:

- It can also be changed by adding impurities in the water. Impurities includes salt, sugar, and other dissolved molecules.

8.4 Effect of Impurities in feed water

3. Effects of water impurities on human health:

- Nervous system damage
- Speech and language impairment
- Decrease muscular and bone growth. Etc.

4. Effects of water impurities on plant growth:

- Each plant will be watered with sugar, salt, bleach or water.
- Conclusion that plant watered with sugar grew most, while the plant watered with water grew little less.

8.5 pH of water

- It measure acidic and basic of water
- The range goes from 0 -14, with 7 being neutral.
- pH less than 7 indicates acidity and greater indicate base.
- It is really a measure of the relative amount of free hydrogen and hydroxyl ions in water.

8.5.1 Role of pH in corrosion

- It plays important role to control the corrosion of metals.
- The acidic and basic value of pH may cause corrosion.
- Water in contact with iron dissolves small quantity of iron into solution, water quickly becomes saturated with iron from this dissolving metal stops.
- Water dissolves in water oxides produces ferrous hydroxide [$Fe^{++} + 2OH^- \rightarrow Fe(OH)_2$]
- When this ferrous hydroxide comes in contact with oxygen and hydrogen, produces ferric hydroxide. [$4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3$]
- This is insoluble in water in water, allows production of more ions in the solution.

8.5.2 Role of pH in scale formation

- It can destroy the metal, hence it is very important factor.
- The presence of material like calcium carbonate ($CaCO_3$) in water can cause scale formation.
- pH and calcium hardness are interrelated as at same level rise in concentration level of alkalinity causes precipitation of $CaCO_3$.

8.6 Water Treatment Systems

- They are two types:

1. Internal Water Treatment System
2. External Water Treatment System

8.6.1 Internal water treatment

- It constitute when boiler operate at low or moderate pressure.
- When large amounts of condensed steam are used for feed water or good quality raw water is available.
- The dissolved solids in the water are removed in the boiler itself by chemical treatment then the method is internal treatment.
- It is carried out to prevent scale formation and nullify the effects of external treatment.

8.6.1 Internal water treatment

1. Sodium Carbonate (Soda Ash) Treatment:

- In low pressure boiler, scale formation can be avoided by adding of Na_2CO_3 (sodium carbonate) to boiler.
- This system of cleaning destroys sulphate hardness.
- The only disadvantage is it forms CO_2 which goes with steam and dissolves in the condensate, it form carbonic acid.
- This lower pH and accelerates the rate of oxygen corrosion.

8.6.1 Internal water treatment

2. Phosphate Treatment:

- It is used in high pressure boilers by adding sodium phosphate to avoid scale formation.
- The common phosphates used are:
- Trisodium phosphate (highly alkaline) used when alkalinity of boiler water is low.
- Disodium phosphate (moderate alkaline) used when alkalinity of boiler water is adequate.
- Monosodium phosphate (slightly alkaline) used when alkalinity of boiler water is too high.

8.6.1 Internal water treatment

3. Sodium Aluminate Treatment:

- The scale formation can be avoided by addition of $NaAlO_2$ to boiler.
- The by products $Al(OH)_3$ and $Mg(OH)_2$ produced inside the boiler can be removed by blow down operation.

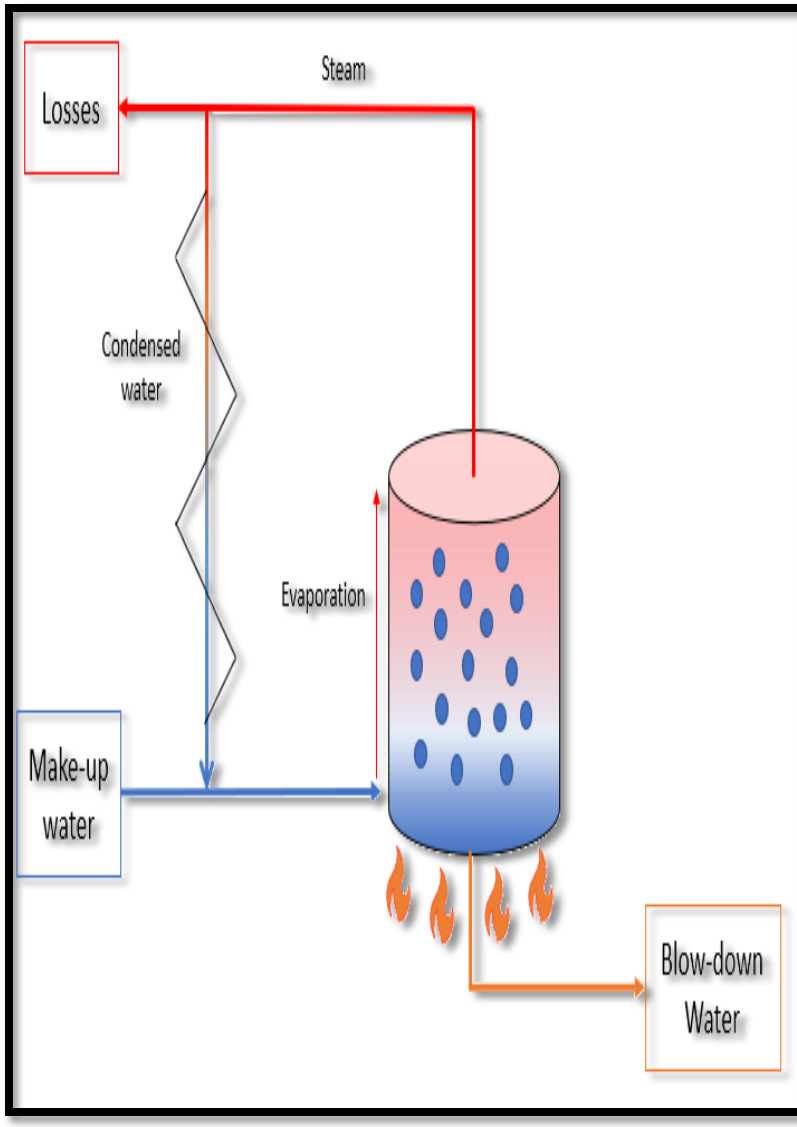
4. Colloidal Treatment:

- It is used in low pressure boiler by adding organic substances like tanin, lignis, starch, kerosene etc.
- These substance get coated over scale formation precipitates.
- Other non sticky and loose deposits similar to sludge can be removed by blow down process.

8.6.1 Internal water treatment

5. Blow down system:

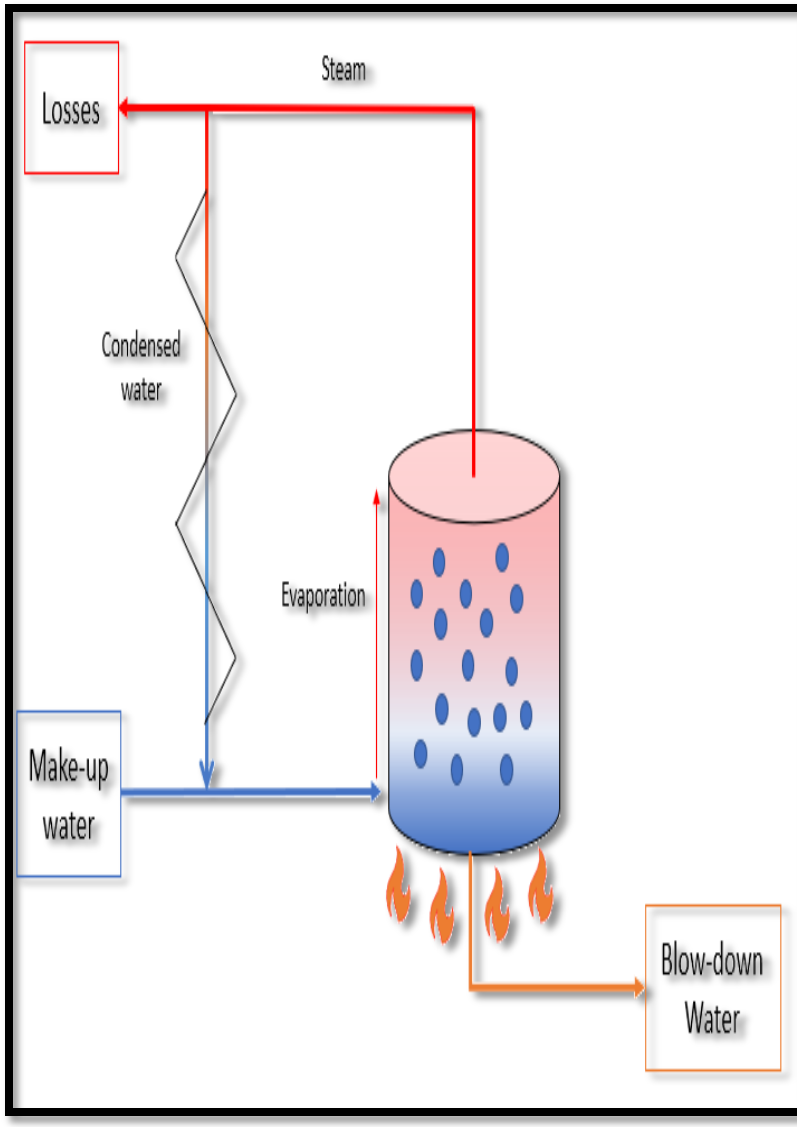
- During boiler operations, the water is heated and evaporated to get a stream.
- The concentration of dissolved solids therefore increases the boiler.
- In the same time, its facts that the water needs more energy to be evaporated increases the energy consumption.
- To prevent the scaling and control the energy consumption, the water contained in the boiler is discharged and replaced with feed water.
- This operation is called the blow down.



8.6.1 Internal water treatment

5. Blow down system:

- Depending on the boiler design, the blow down operation can be operated manually or continuously.
- Usually, most of the industrial systems can operate both. Manual blow down allows to discharge the water when the water quality becomes closed to the limits of operation.
- **Benefits of blow down water treatment include:**
- less maintenance,
- lower fouling and corrosion,
- reduction of chemicals used,
- more stable water quality.



8.6.2 External water treatment

- This system becomes essential when make up water is in large quantity and contains considerable suspended and dissolved solid materials.
- The solid suspended material is removed by mechanical means.
- The dissolved solid are removed with the use of chemical treatment.
- The dissolved gases are removed by thermal treatment.

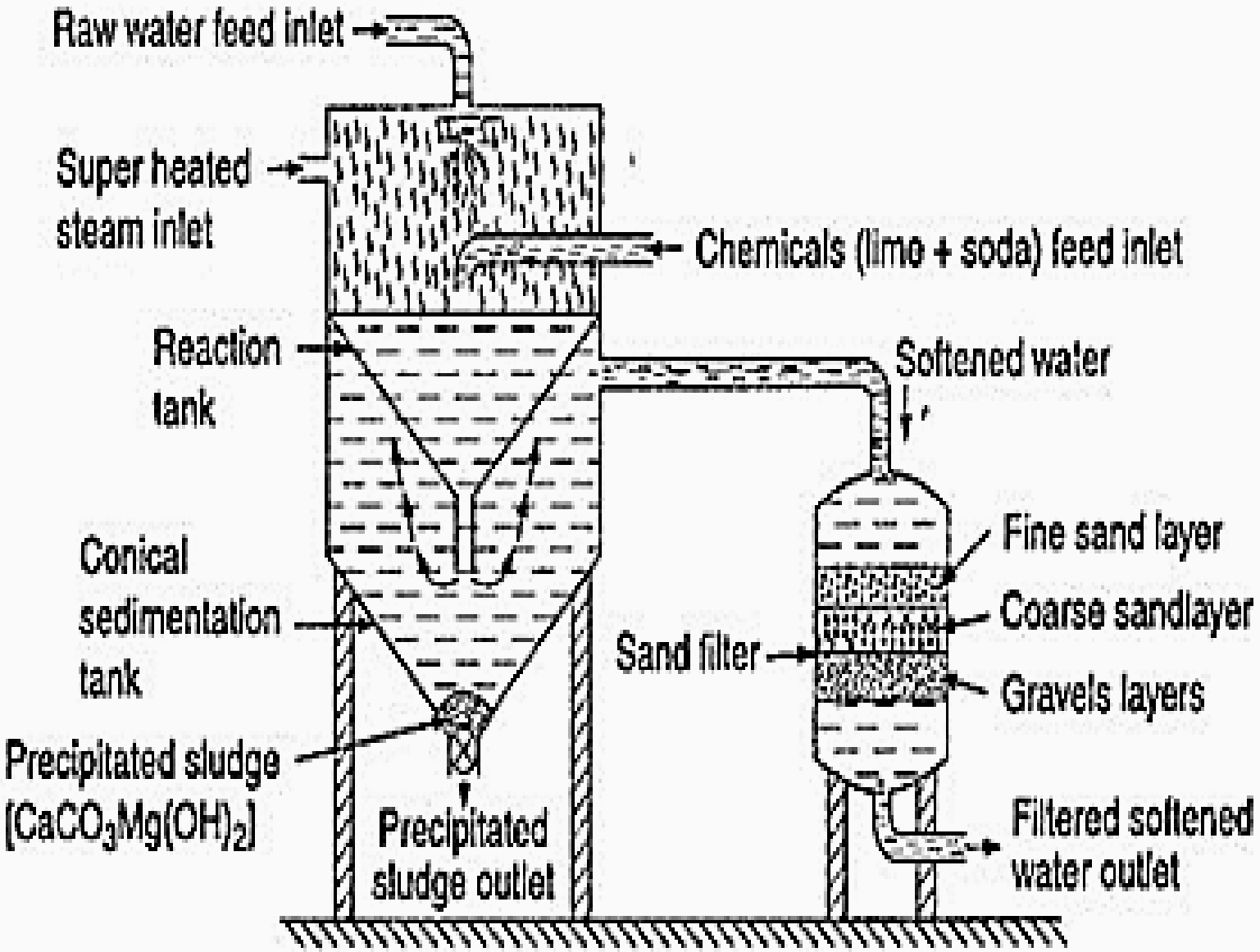
8.6.2 External water treatment

- The solid suspended material is removed by mechanical treatment (includes sedimentation, coagulation and filtration).
- Sedimentation water to stands quietly for some time, solid matter settles down and removed.
- Coagulation adding of aluminium sulphate, sodium aluminate or ferrous sulphate to impure water which removes minute colloidal suspensions.
- Filtration consist of passing the water through filters, it may be gravity or pressure type filters.

Hot Lime Soda Process

- Lime Soda process is a method of softening hard water.
- This process is now obsolete but was very useful for the treatment of large volumes of hard water.
- In this process Calcium and Magnesium ions are precipitated by the addition of lime (Ca (OH)2) and soda ash (Na2CO3).
- By this process soluble magnesium and calcium salts are removed as calcium carbonate and magnesium hydroxide precipitated.
- After removal of this precipitated, we obtain soft water.
- Both temporary water hardness and permanent water hardness are removed by this lime softening water softener systems.
- Before water treatment calculate the amount of temporary and permanent water hardness, and then estimate the amount of lime and soda ash and added control with careful.

Hot Lime Soda Process



Hot Lime Soda Process

- In case of temporary water hardness the following reactions are take places:
- $Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$
- $Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + MgCO_3 + 2H_2O$
- $MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCO_3$
- In case of permanent water hardness the following reactions are take places:
- $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$
- $MgSO_4 + Na_2CO_3 \rightarrow MgCO_3 + Na_2SO_4$
- $MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCO_3$

Hot Lime Soda Process

- **Advantages:**
- Silica is effectively removed from water.
- It is more economical.
- Size of settling tank is reduced as the precipitate is larger in size and settles more quickly.
- Capable of treating large quantity of water in relatively small unit.
- **Dis-Advantages:**
- Only limited to low hardness water.
- Controlling is difficult.
- Softened water must be filtered before use to avoid to carry the precipitate with water.

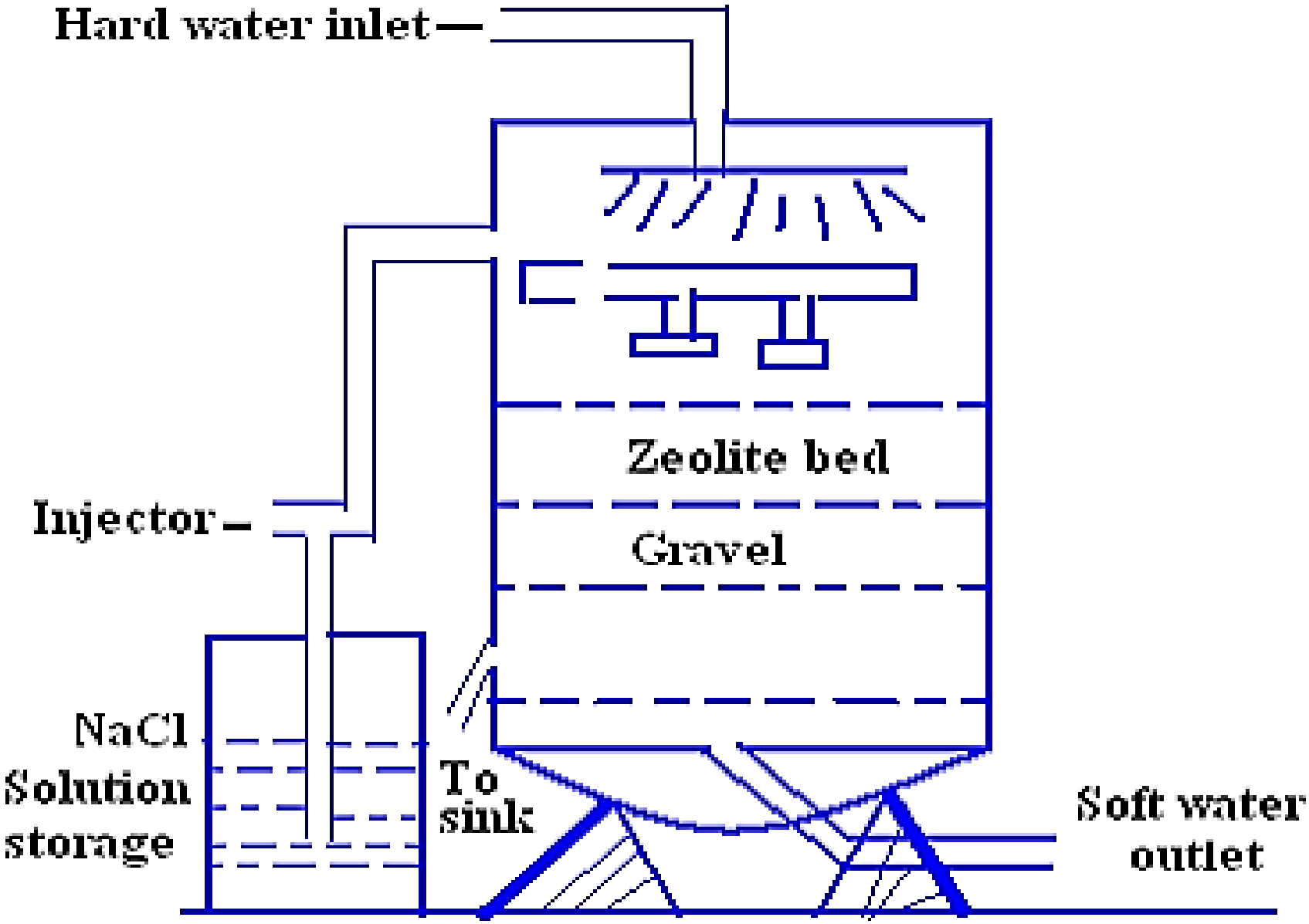
Zeolite Process

- Zeolite is hydrated sodium alumino silicate.
- Zeolites are also known as permutits.
- Zeolite is capable of exchanging reversibly its sodium ions for hardness-producing ions in water.
- Chemical Structure : $Na_2O.Al_2O_3.xSiO_2.yH_2O$,where X=2-10 and Y=2-6.
- Types of Zeolite Zeolites are of two types:
- 1. Natural zeolite : Natural zeolite are non-porous, for example, natrolite ,$Na_2O.Al_2O_3.xSiO_2.yH_2O$.
- 2. Synthetic zeolite : Synthetic zeolite are porous and posses get structure.

Zeolite Process

- For softening of water by zeolite process,hard water is percolated at a specified rate through a bed of zeolite, kept in a cylinder.
- The hardness causing ions(Ca2+ ,Mg2+ ,etc.) are retained by the zeolite as CaZe and MgZe ; while the outgoing water contains sodium salts.
- For softening of water by zeolite process, hard water is percolated at a specified rate through a bed of zeolite. Zeolite holds sodium ion loosely and can be represented as Na_2Z, where Z represents insoluble radical frame work.

Zeolite Process



Zeolite Process

Reactions:

- $Ca(HCO_3)_2 + Na_2Z = CaZ + 2NaHCO_3$
- $Mg(HCO_3)_2 + Na_2Z = MgZ + 2NaHCO_3$
- $CaSO_4 + Na_2Z = CaZ + Na_2SO_4$
- $CaCl_2 + Na_2Z = CaZ + 2NaCl$
- $MgSO_4 + Na_2Z = MgZ + Na_2SO_4$
- $MgCl_2 + Na_2Z = MgZ + 2NaCl$

Zeolite Process

- After some time, when the zeolite is completely changed into calcium and magnesium zeolites, then it gets exhausted (saturated with Ca^{+2} and Mg^{+2} ions) and it ceases to soften water. It can be regenerated and reused by treating it with a 10% brine (sodium chloride) solution.
- $CaZ + 2NaCl = Na_2Z + CaCl_2$
- $MgZ + 2NaCl = Na_2Z + MgCl_2$

Zeolite Process

- **Merits of ion-exchange process:**
- The process can be used to soften highly acidic or alkaline water.
- It produces water of very low hardness (say 2ppm).
- It is very good for treating water for use in high-pressure boiler.
- **Demerits of ion-exchange process:**
- The equipment is costly and more expensive chemicals are needed.
- If water contains turbidity, then the output of the process is reduced
- Turbidity must be below 10 ppm. If it is more, it has to be removed first by coagulation and filtration.

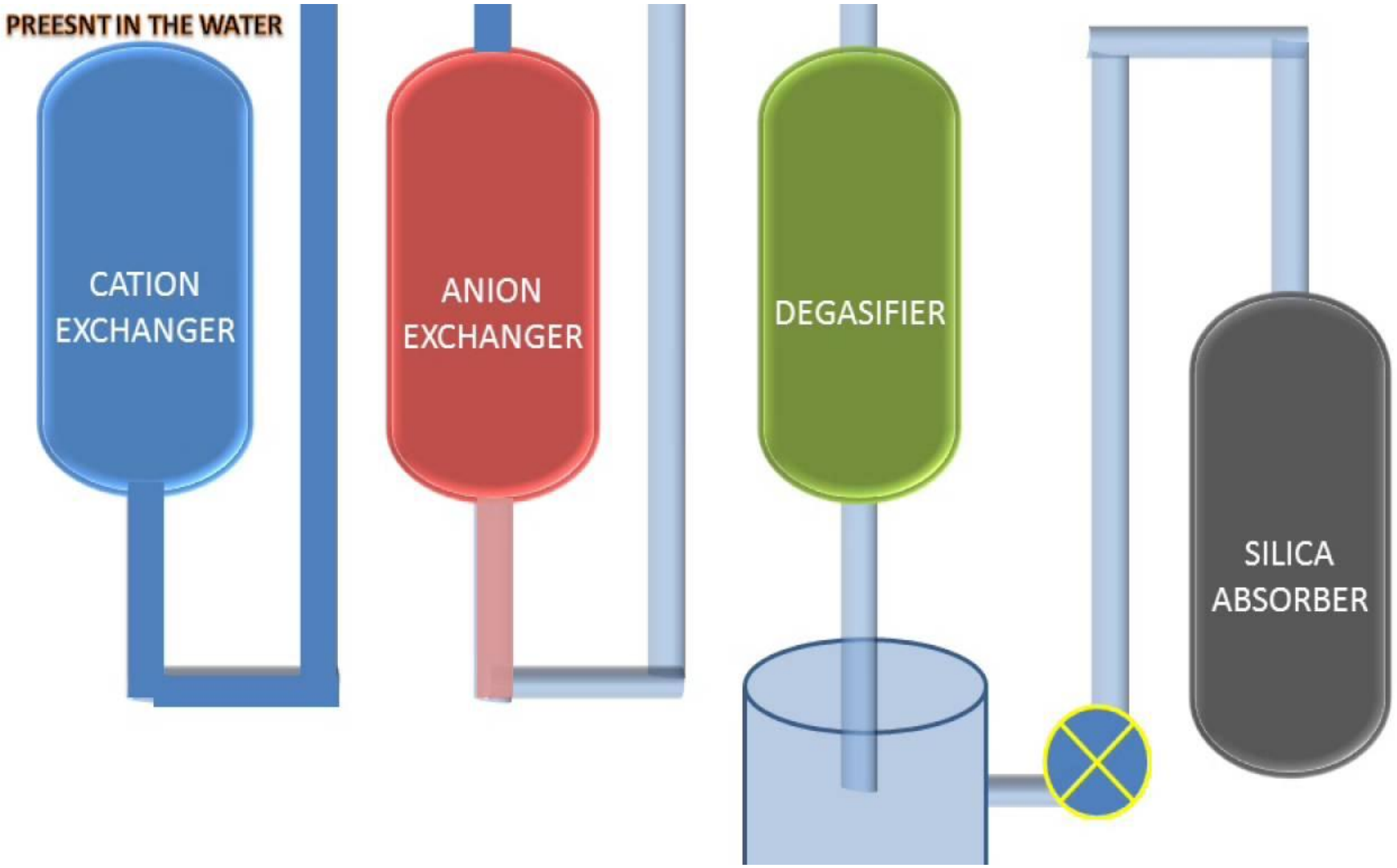
Zeolite Process

- **Merits of Zeolite Process:**
- It removes the hardness almost completely (about 10 ppm hardness only).
- The process automatically adjust itself for variation in hardness of incoming water.
- This process does not involve any type of precipitation, thus, no problem of sludge formation occurs.
- **Demerits of Zeolite Process:**
- The outgoing water (treated water) contains more sodium salts.
- This method only replaces Ca^{+2} and Mg^{+2} ions by Na^{+} ions.
- High turbidity water cannot be softened efficiently by zeolite process.

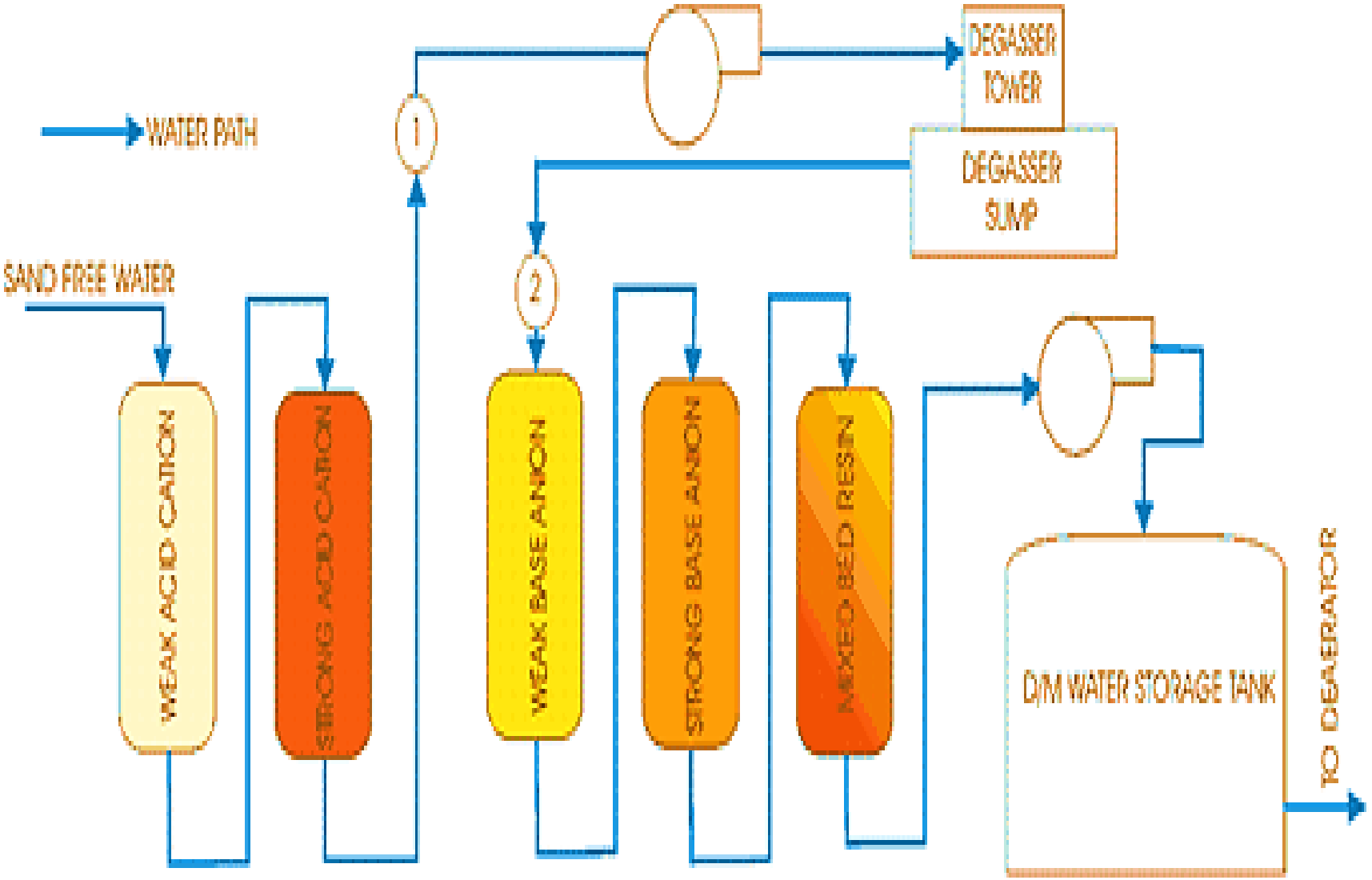
Demineralization Plant or Iron Exchange Process

- Demineralization is the removal of essentially all inorganic salts.
- In ion exchange demineralization hydrogen Cation exchange converts dissolved salts to their corresponding acids, and basic anion exchange removes these acids.
- **Purposes:**
- Removal of ionic substances
- Reduction of conductivity
- Control of pH

Demineralization Plant or Iron Exchange Process



Demineralization Plant or Iron Exchange Process



Demineralization Plant or Iron Exchange Process

- Raw water is first passed through a weak acid cation exchanger to remove the bicarbonates.
- Water coming out contains dilute carbonic acid, hydrochloric acid, and sulphuric acid.
- Water coming out of catexer is passed through the anexer.
- In anexer, anions such as chlorides, sulphates, and nitrates are removed from water with certain resinous material (RCO3).
- Reaction occurred in anexer, using (RCO3) anions such as chlorides, sulphates and nitrates are eliminated from water: 2HCL + RCO3 = RCL2 + H2CO3
- The water coming out of anexer and catexer is practically free from dissolved salts.

Demineralization Plant or Iron Exchange Process

- Further the reactivation of anexer can be done allowing the circulation of NaOH or Na2CO3, the reaction occurs as: RCl2+Na2CO3 = RCO3 + 2 NaCl
- Water from the anexer is allowed to flow through a degasifier tower packed with porcelain.
- Water flows down by gravity distributing all over the tower over large area and at the bottom of the tower the air is blown.
- Which allowed to react with water by which CO2 is liberated which passes away from top of the tower.
- The resultant water consist CO2 of 2 to 5 ppm and is collected in sump.

Demineralization Plant or Iron Exchange Process

- Finally at last the resultant water is passed through strong base anion resin tower to reduce silica content upto 0.02ppm
- Reaction will be $R4NOH + H2SiO3 = R4NHSiO3 + H2O$

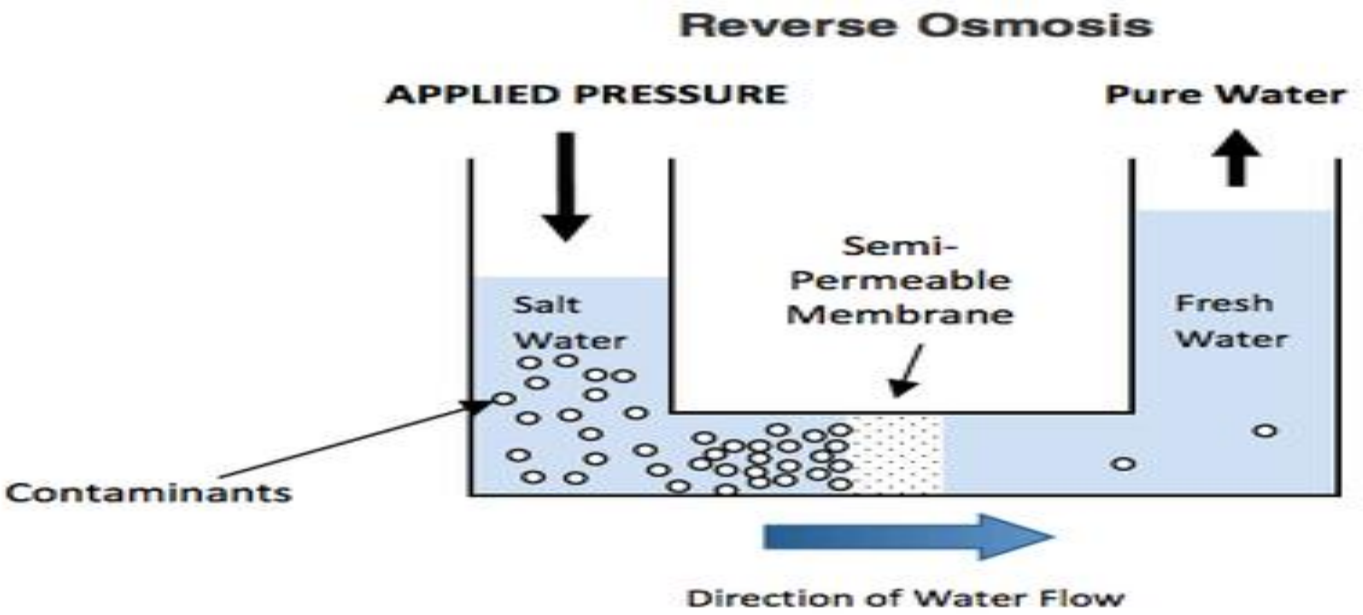
Demineralization Plant or Iron Exchange Process

- **Advantages:**
- It is very efficient as the resultant water is pure in quality not linking to the flow quality and quantity.
- It wastes less water and has a lower capital cost than reverse osmosis.
- **Dis-Advantages:**
- It uses heavy chemicals and also it discharges them.
- It has down time of regenerations.

Reverse Osmosis Process

- Reverse Osmosis, commonly referred to as RO, is a process where you demineralize or deionize water by pushing it under pressure through a semi-permeable Reverse Osmosis Membrane.
- Osmosis is a naturally occurring phenomenon and one of the most important processes in nature.
- It is a process where a weaker saline solution will tend to migrate to a strong saline solution.

Reverse Osmosis Process



- A solution that is less concentrated will have a natural tendency to migrate to a solution with a higher concentration.
- A semi-permeable membrane is a membrane that will allow some atoms or molecules to pass but not others.
- A simple example is a screen door. It allows air molecules to pass through but not pests or anything larger than the holes in the screen door.

Reverse Osmosis Process

- Reverse Osmosis is the process of Osmosis in reverse.
- Osmosis occurs naturally without energy required, to reverse the process of osmosis you need to apply energy to the more saline solution.
- A reverse osmosis membrane is a semi-permeable membrane that allows the passage of water molecules but not the majority of dissolved salts, organics, bacteria and pyrogens.
- However, you need to 'push' the water through the reverse osmosis membrane by applying pressure that is greater than the naturally occurring osmotic pressure.

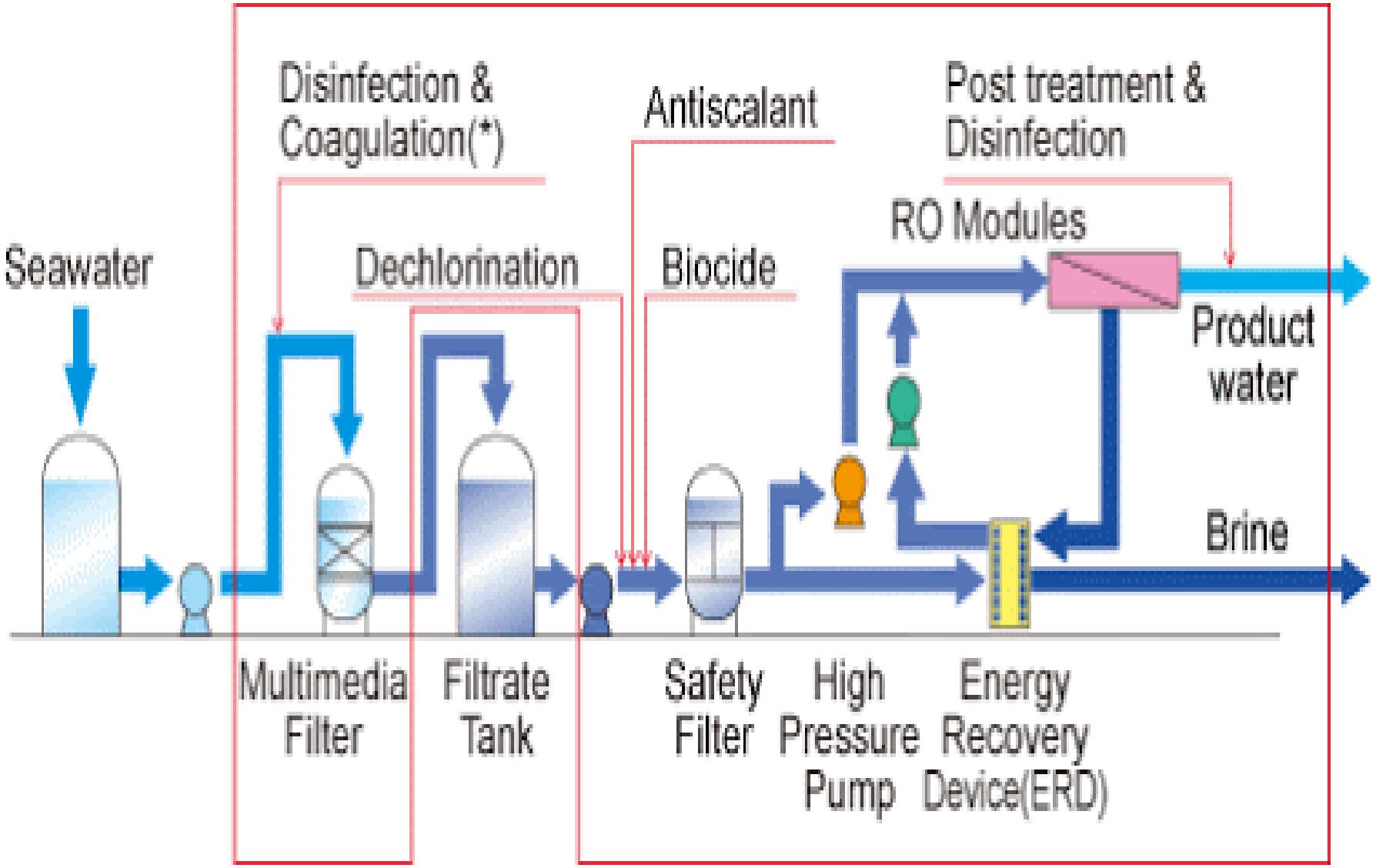
Reverse Osmosis Process

- When pressure is applied to the concentrated solution, the water molecules are forced through the semi-permeable membrane and the contaminants are not allowed through.
- Reverse Osmosis works by using a high pressure pump to increase the pressure on the salt side of the RO and force the water across the semi-permeable RO membrane, leaving almost all (around 95% to 99%) of dissolved salts behind in the reject stream.

Sea Water Treatment Using Reverse Osmosis

- The desalinated water that is demineralized or deionized, is called permeate (or product) water.
- The water stream that carries the concentrated contaminants that did not pass through the RO membrane is called the reject (or concentrate) stream.
- It is important to understand that an RO system employs cross filtration rather than standard filtration where the contaminants are collected within the filter media.
- With cross filtration, the solution passes through the filter, or crosses the filter, with two outlets: The filtered water goes one way and the contaminated water goes another way.

Sea Water Treatment Using Reverse Osmosis



R O Process

- **Advantages:**
- Very high space / production capacity ratio 25000 to 60000 liters /day /m2.
- More efficient in removing salts.
- Low maintenance, non metallic used in construction.
- Remove organic and inorganic contaminants.
- **Dis-Advantages:**
- Membranes are sensitive to abuse.
- Initial cost is high.

De-aeration

- A deaerator is a device that removes oxygen and other dissolved gases from liquids.
- Deaerator are commonly used to remove dissolved gases in feed water for steam-generating boilers.
- Dissolved oxygen in feed water will cause serious corrosion damage in a boiler by attaching to the walls of metal piping and other equipment and forming oxides (like rust).
- Dissolved carbon dioxide combines with water to form carbonic acid that may cause further corrosion.
- Most deaerator are designed to remove oxygen down to levels of 7 ppb by weight or less, as well as essentially eliminating carbon dioxide.

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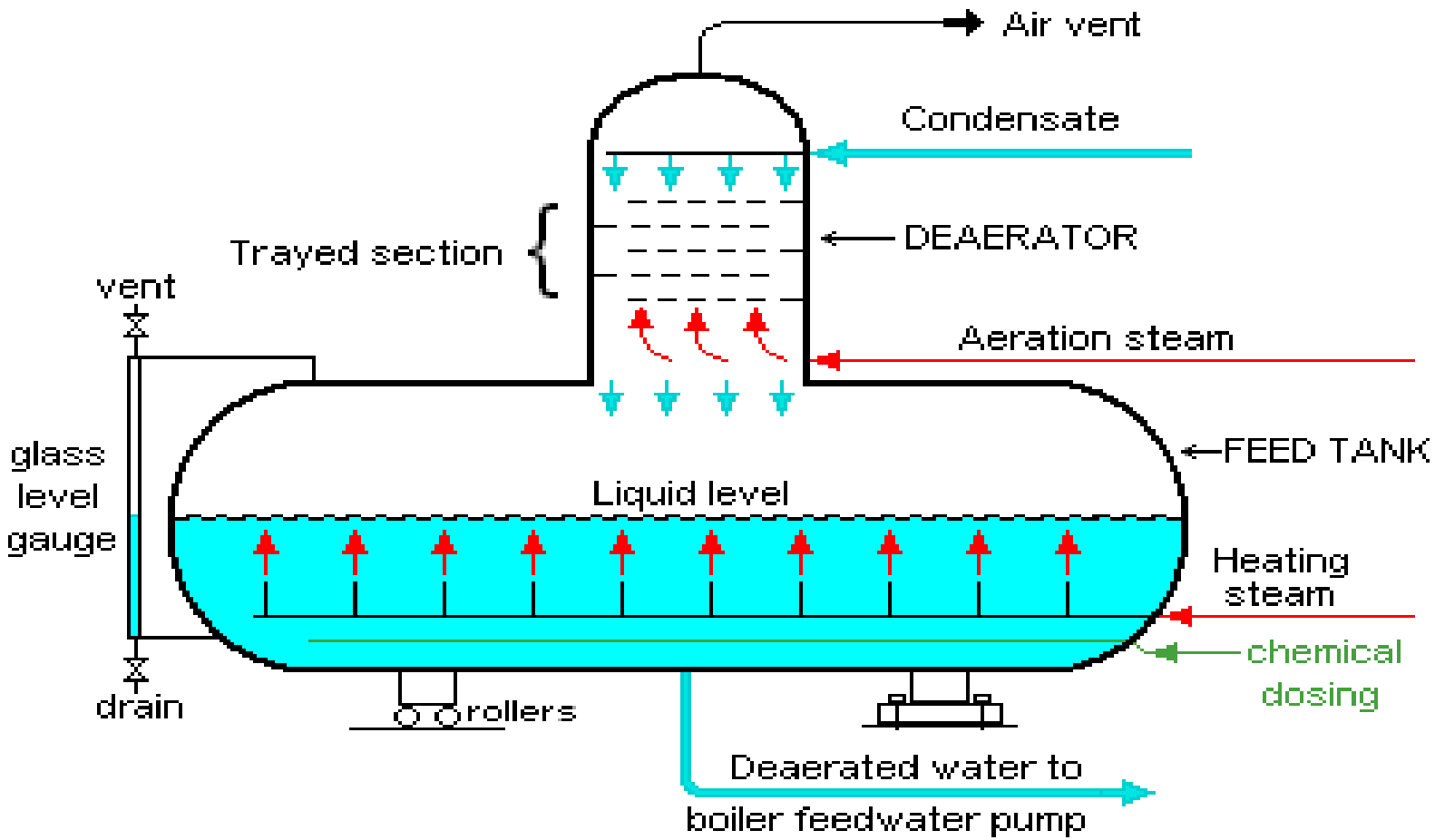
Air vent
Condensate
DEAERATOR
Trayed section
vent
Aeration steam
FEED TANK
glass
level
gauge
Liquid level
Heating
steam
chemical
dosing
drain
rollers
Deaerated water to
boiler feedwater pump
Internal steam distributor piping
Internal perforated pipe (water distributor)
Perforated trays
Low pressure steam
Boiler feed water (Recycled condensate and makeup water)