Water Management & Trouble Shooting in Thermal Power Plants

Welcome to Power Sector Professionals

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Covering points

1. Role of Chemistry in Thermal Plant
2. Pre treatment of Water Treatment Plants
3. Technologies for DM Water Production
4. Ion Exchange Based DM Plant (No design aspects)
5. Ion Exchange Properties and illustrations
6. Trouble Shooting in DM Plant
7. Case Studies in DM Plant Area

Role of Chemistry in Thermal Plants

Chemistry: Vital role in the operation of thermal power plants from feed to exit. It's crucial for managing water quality, preventing corrosion, scaling and efficiency of the plant.

Main aspects of Chemistry in Thermal Power Plants:

Water quality management:

- **PT Plant & DM Plant:** $1^0/2^0/3^0$ treatment followed by Resin/ Membrane based Plant.
- **Feedwater Treatment:** Required water to prevent scaling and corrosion in boilers and turbines. This involves removing impurities incl. oxygen and suspended solids etc.
- **Boiler Water Chemistry:** Maintaining the correct pH and controlling the concentration of dissolved substances in boiler water to prevent corrosion and scale formation.
- **Condenser Chemistry:** Specific chemical treatments are used to control these issues and maintain efficient heat transfer.

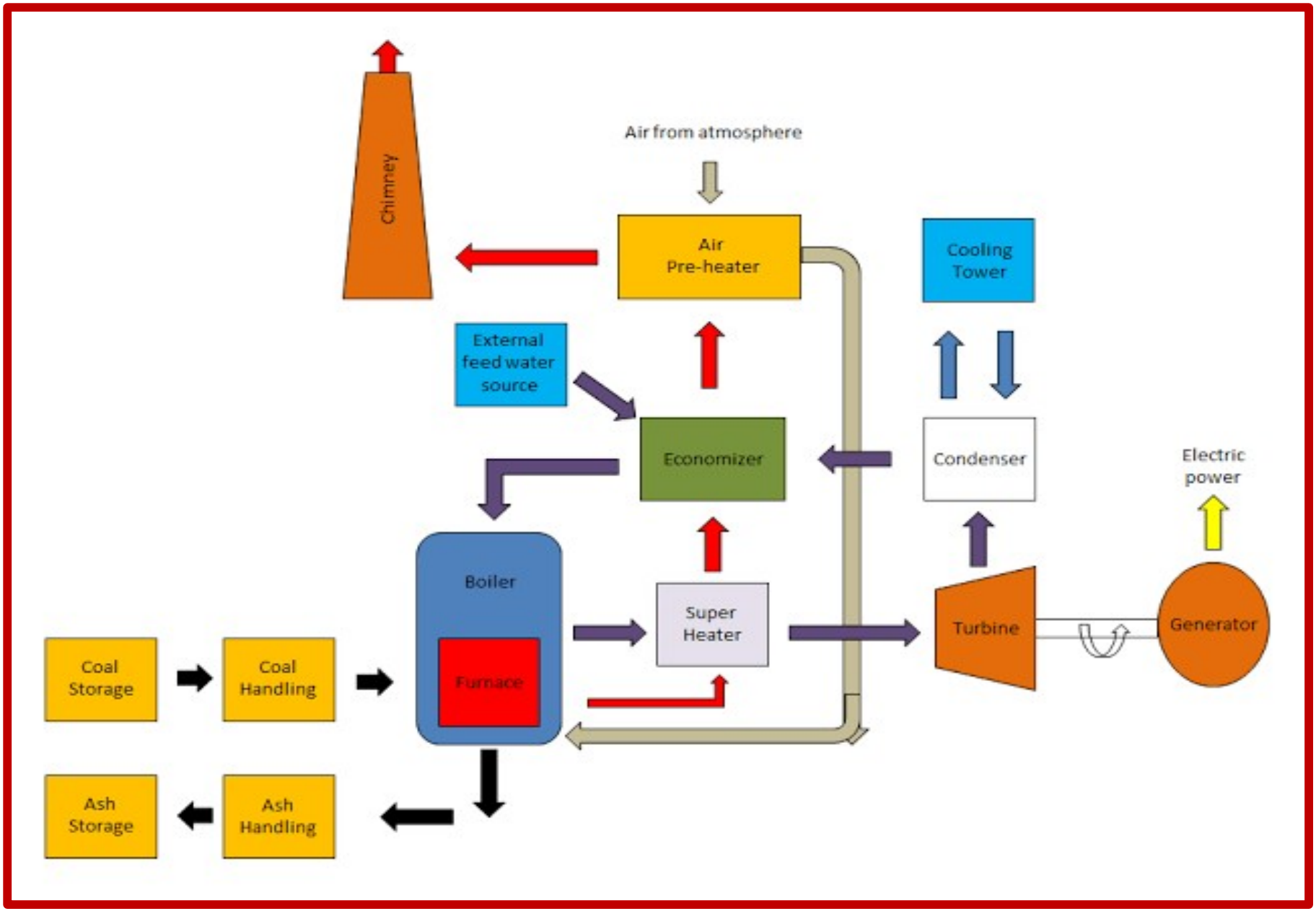
Coal quality & Biomass testing: To optimize fuel cost and efficiency of unit, coal quality (proximate & ultimate analysis) is tested from source to feeding in boiler.

Emission Control: Maintaining parameters like sulfur dioxide, nitrogen oxides, and particulate matter within specified limits of Pollution Boards. Chemical processes, such as flue gas desulfurization (FGD) are employed now.

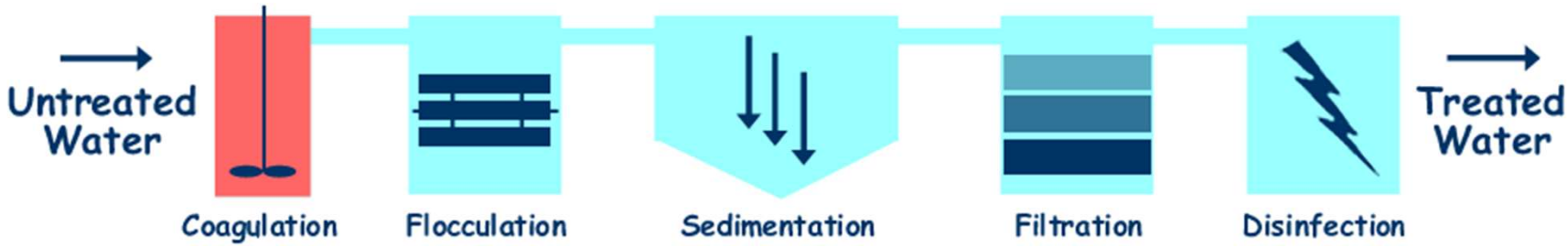
Ash Management: Nearly 35% ash is produced from coal combustion and utilized for in construction or cement production. Testing of ash and constituents is required routinely.

Others: Oil & Lubricants, STP quality/ Testing of CW Treatment Chemicals/ ClO2/ Limestone for FGD etc.

Chemistry in Thermal Plants- Feed to Exit



Fundamentals of Pre-Water Treatment:

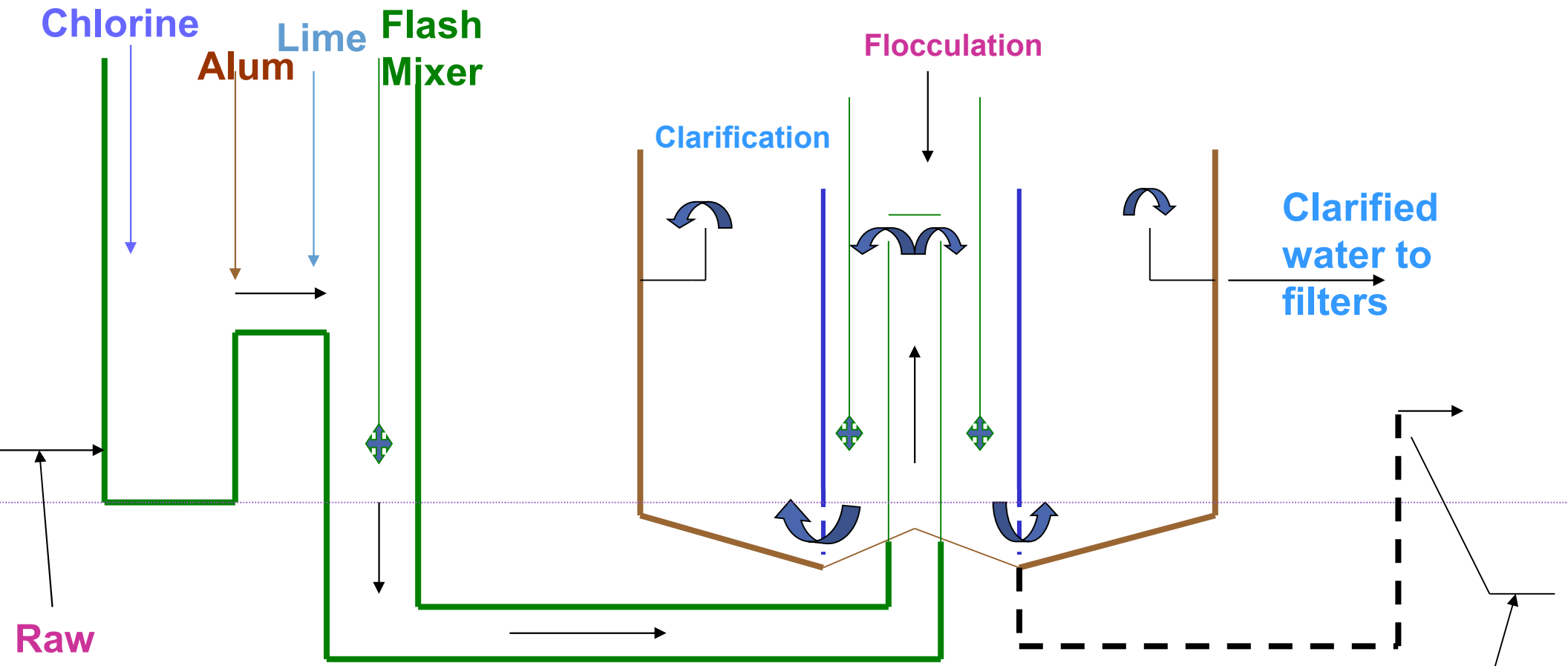


In pretreatment of water insoluble/suspended impurities and living organisms are removed from raw water. Pretreatment of water includes the following processes:

- Coagulation
- Flocculation
- Sedimentation
- Filtration &
- Disinfection

Clari-flocculator

- A high-energy, rapid-mix to properly disperse the coagulant and promote particle collisions is needed to achieve good coagulation. Over-mixing does not affect coagulation, but insufficient mixing will leave this step incomplete. Coagulants should be added where sufficient mixing will occur. Proper contact time in the rapid-mix chamber is typically 1 to 3 minutes.

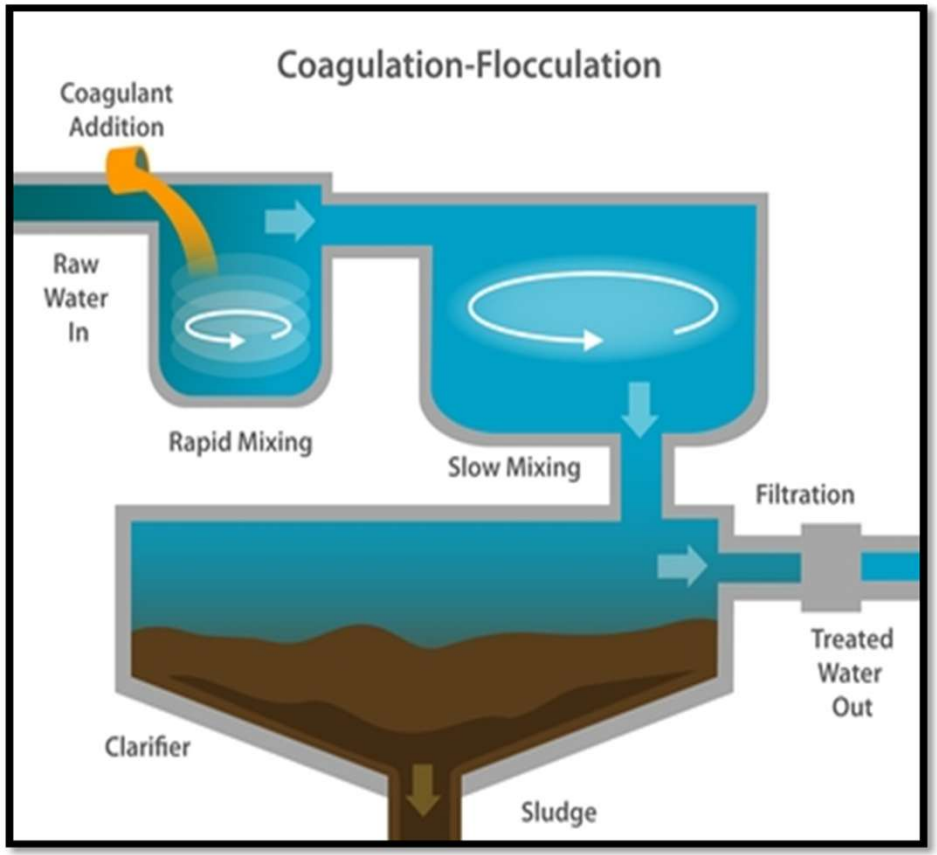


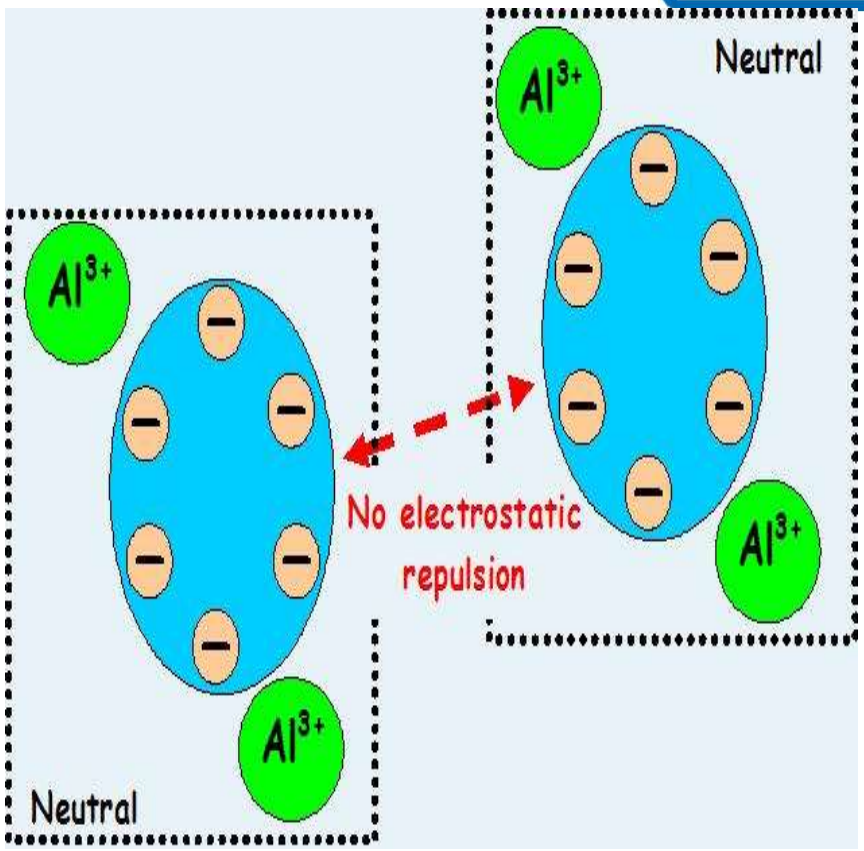
Water quality at Clarifier outlet

Turbidity - <20 NTU pH - 5.5 to 8.0

Residual Chlorine - 0.2-0.5 ppm

Process of coagulation





- Coagulation is the process of destabilization by charge neutralization by the addition of coagulants. Once neutralized, particles no longer repel each other and can be brought together . Coagulation is necessary for the removal of colloidal sized suspended matter.
- In this process the negative charge on particles is neutralized, usually by addition of positive charges such as those provided by alum. The neutralization of particles allows them to clump together forming larger particles which are easier to settle.

Process of coagulation & Flocculation

- Common coagulant chemicals used are alum, ferric sulfate, ferric chloride, ferrous sulfate, and sodium aluminate. The first four will lower the alkalinity and pH of the solution while the sodium aluminate will add alkalinity and raise the pH.
- Following the first step of coagulation, a second process called flocculation occurs.
- Flocculation is the process of bringing together the destabilized or “
- Coagulated” particles to form a larger agglomeration, or “floc”.
- Flocculation, a gentle mixing stage, increases the particle size from submicroscopic micro-floc to visible suspended particles.
- Jar test is done for raw water (with different coagulant concentrations)

$$Al_2(SO_4)_3 + 3\,Ca(HCO_3)_2 \text{ ----------> } 2\,Al(OH)_3 + 3CaSO_4 + 6\,CO_2$$

Alum already in the water

Disinfection

Disinfection: Killing of Pathogenic Bacteria in Water.

- Chlorination/ Chlorine dosing
- Chlorine Dioxide(ClO2) dosing
- Ozone
- UV
- Sodium Hypochlorite

Residual chlorine is needed in distribution system after water / wastewater treatment. In addition to disinfection, chlorine also has the functions like: taste and odor control as an oxidizing agent, oxidation of Fe^{2+} and Mn^{2+} in groundwater, ammonium removal in domestic waste treatment slime, biofouling control etc.

Chemical reaction: $Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$

- HOCl is a weak acid with Ka = 4.5×10^{-4} ($HOCl == H^+ + OCl^-$)
- HOCl and OCl^- are free available chlorine which are very effective in killing bacteria
- Small amount of ammonium (NH_4^+) in water is desired. But excessive amount of ammonium (NH_4^+) in water is undesirable because it consume excess demand of Cl_2.

Considering the hazardous nature of Chlorine, safety measures like Chlorine leak Absorption system is must to absorb any fugitive chlorine.

Chlorine Dioxide (ClO2) as an effective disinfectant

- 2.5 times more powerful and highly effective oxidizer
- Not affected by pH, active in wide range of pH
- Won't react with many organic contaminants - including ammonia compounds
- Excellent biofilm removal - rapidly penetrates and oxidizes biofilms
- Can destroy odors caused by microorganisms and organics
- It is much less hazardous than Chlorine.

1) Chlorine Method - Chlorine + Sodium Chlorite

$$NaClO_2 + Cl_2 \rightarrow 2ClO_2 + 2NaCl$$

2) Acid activation - HCl + Sodium Chlorite

$$5NaClO_2 + 4HCl \rightarrow 4ClO_2 + 5NaCl + 2H_2O$$

Note: Sodium chlorite($NaClO_2$) is the precursor to generate chlorine dioxide

Clarified water frequency for quality parameters

S.N.	Parameter	UOM	Testing frequency
1	pH at 25°C	--	Once/day
2	Sp. Conductivity at 25°C	µS/cm	Once/day
3	Turbidity	NTU	Once/day
4	Total Dissolved Solids (TDS)	mg/l	Once/day
5	Ca-Hardness	ppm $CaCO_3$	Once/day
6	Mg-Hardness	ppm $CaCO_3$	Once/day
7	Total-Hardness	ppm $CaCO_3$	Once/day
8	FRC/ Residual ClO2	ppm	Once/Shift
9	Sodium, Potassium	ppm	Once/week
10	P-Alkalinity, M-Alkalinity	ppm	Once/day
11	Equivalent Mineral Acidity (EMA)	ppm	Once/day
12	Chloride	ppm Cl^-	Once/day
13	Sulphate	ppm	Once/day
14	Reactive Silica	ppm SiO_2	Once/day
15	Colloidal Silica	ppm SiO_2	Quarterly
16	Organics ($KMnO_4$ No.)	ppm	Once/week
17	Chemical Oxygen Demand (COD)	ppm	Once/week
18	Total Suspended Solids (TSS)	ppm	Once/week
19	Total Iron	ppm Fe	Once/week
20	Equivalent Mineral Acidity (EMA)	ppm	Once/day
21	Total Organic Carbon (TOC)	ppm	Once/week

Demineralization (DM Water Production) Technologies

1. Ion Exchange Demineralization (Traditional DM Plant)

This is the classic DM water process and is widely used in power plants and industries.
Process:

Cation Exchange Resin – removes positively charged ions (Ca^{2+}, Mg^{2+}, Na^{+}, etc.) and replaces them with H^{+}.

Degasser (optional) – removes CO_2 formed during treatment.

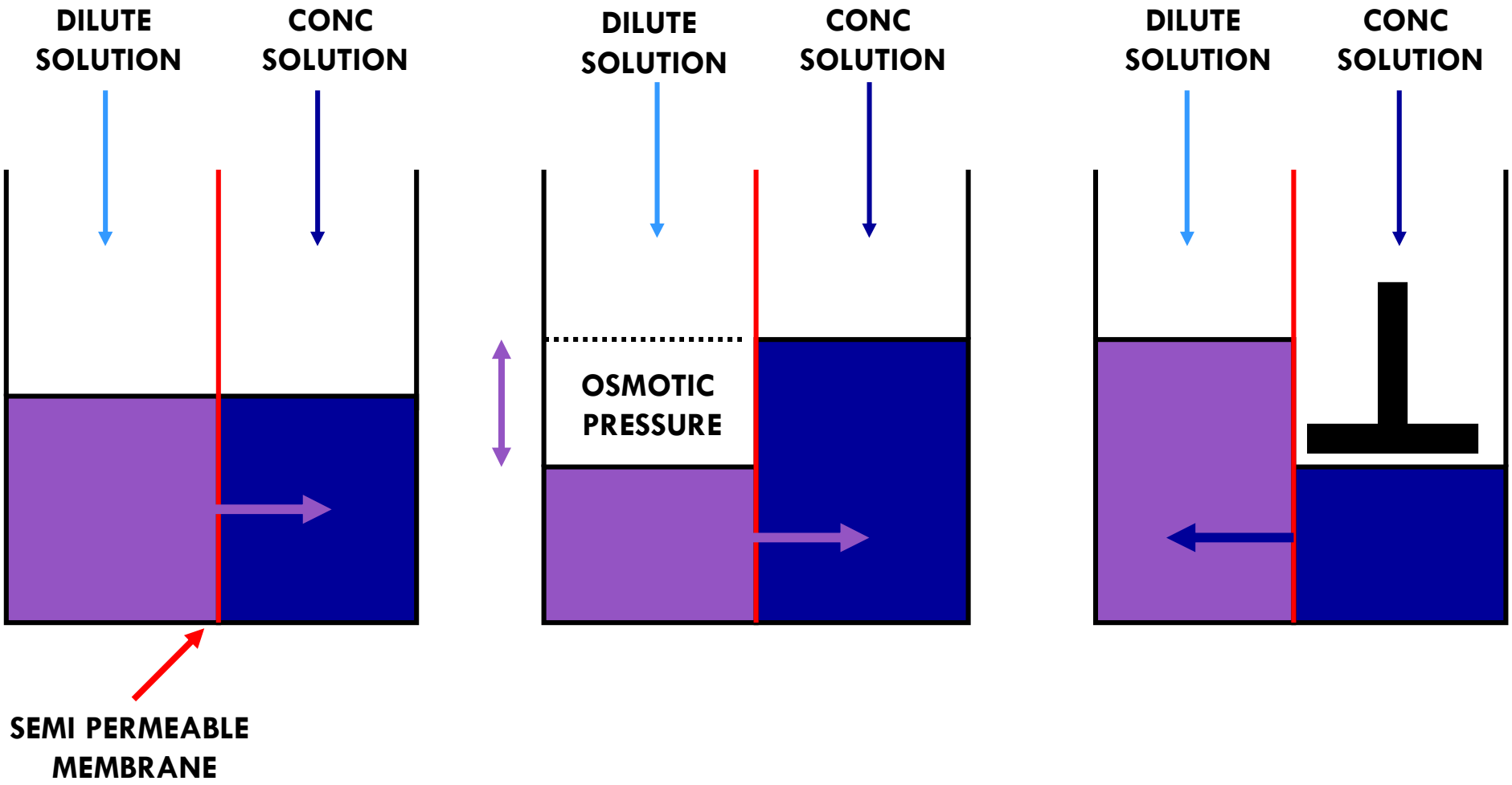
Anion Exchange Resin – removes negatively charged ions (Cl^{-}, SO_4^{2-}, NO_3^{-}, etc.) and replaces them with OH^{-}.

Mixed Bed Polisher – final polishing step for very high purity water.

Typical product quality: Conductivity: 0.1–10 µS/cm

Suitable for boiler feed water and process water.

2. Reverse osmosis Principle Based- RO Plant with MB



R.O Plant parameters with utilization of CW effluents

S. N.	Unit	Parameters	Guaranteed Values
1	High Rate solid contact rector clarifier	Turbidity	<10NTU
2	Dual media filter	Turbidity	<2NTU
3	Ultra-filtration Outlet	SDI	<3
		Turbidity, BOD, Organic matter.	BDL
4	Micron cartridge filter Outlet	SDI	<3
		pH	6.5-7
		Chlorine	NIL
		Turbidity	BDL
5	RO Permeate	TDS	<150ppm
6	Degasser Tower	CO_2	<5ppm

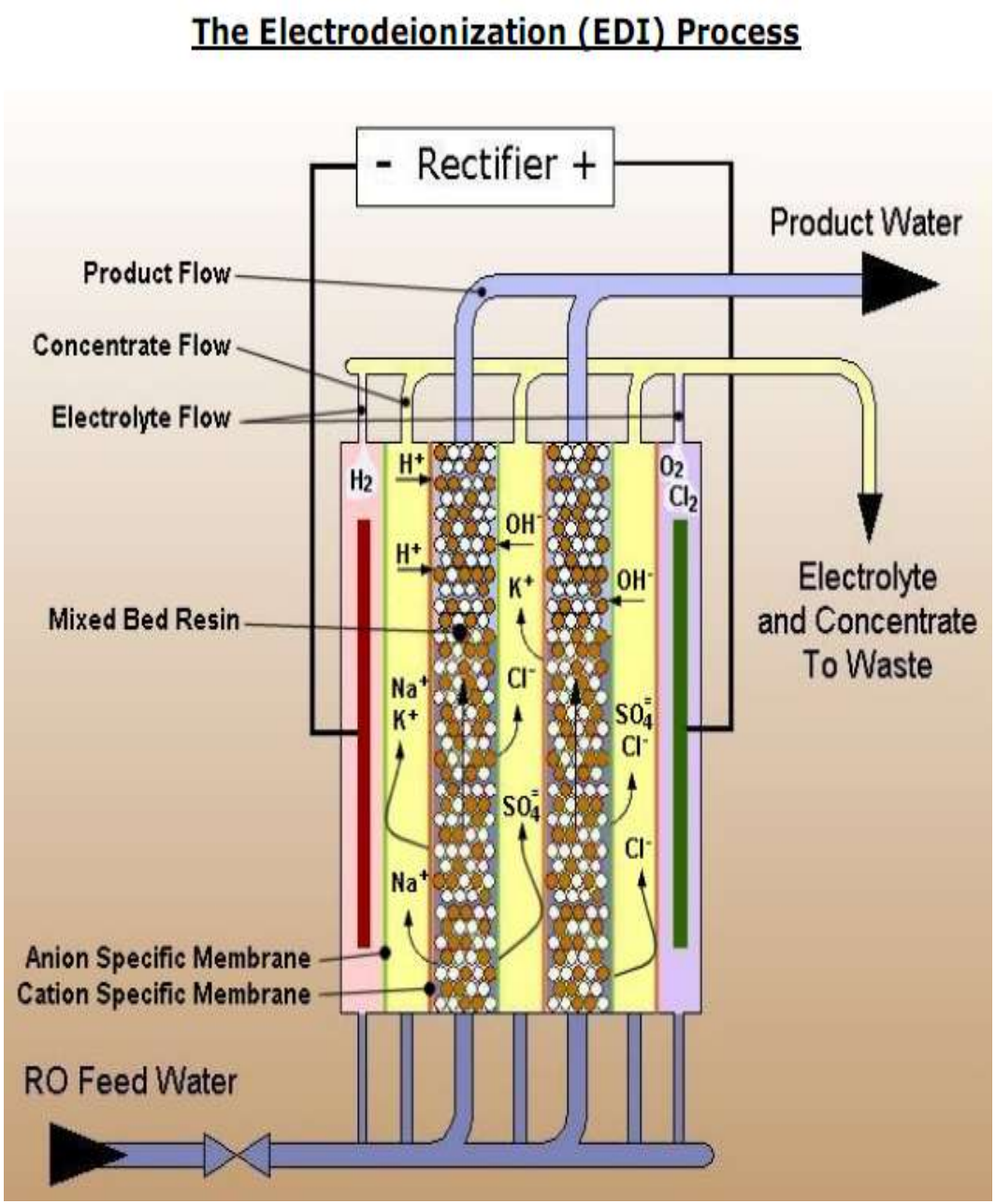
Electro-deionization(EDI)

- Electro-deionization (EDI) is usually considered a water treatment technology that utilizes an electrode to ionize water molecules and separate dissolved ions (impurities) from water.
- It differs from other water purification technologies in that it is done without the use of chemical treatments and is usually a tertiary treatment to reverse osmosis (RO).
- EDI module is driven by electrical energy from an outside power supply, more specifically it is an electrolytic cell.
- Each EDI module consists of five primary components: Ion exchange resin (in MB form), two ion exchange selective membranes (cation & anion) and two electrodes.

Electro-deionization(EDI) Process

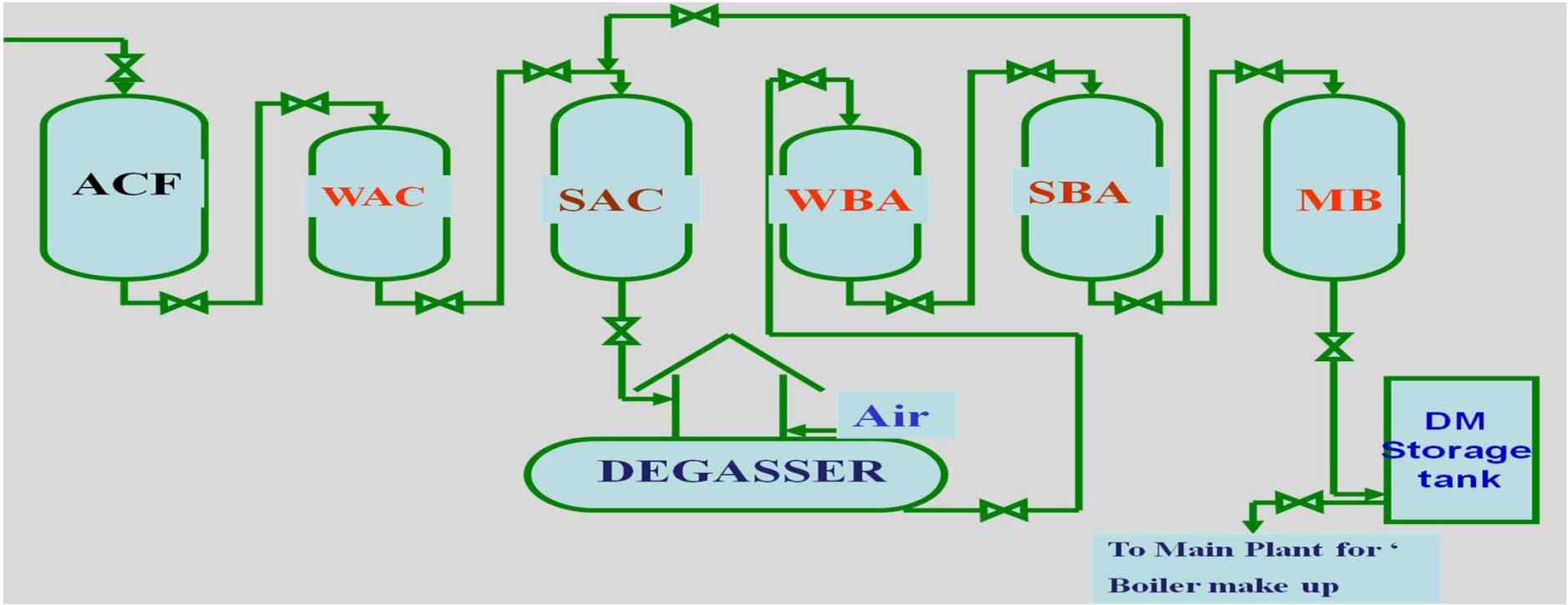
As water flows through the EDI module and power is applied, there are three processes occurring simultaneously:

1. The deionization process where the water is purified by ion exchange in diluting chambers (giving the product water);
2. Ion migration where the ions are removed from the resin through concentrating chambers (going as waste, may be recycled);
3. Continuous regeneration of the resin. The electricity causes a small percentage of water molecules to split into hydrogen and hydroxide ions which continuously regenerate the resin bed: $H_2O \rightarrow H^+ + OH^-$.



DM PLANT (IER Based):

- **Ion exchange is the reversible interchange of ions between a solid (ion exchange material) and a liquid in which there is no permanent change in the structure of the solid. Ion exchange is used in water treatment and also provides a method of separation for many processes involving other liquids**



COMMON DM PLANT SCHEME

ACTIVATED CARBON FILTER (ACF)

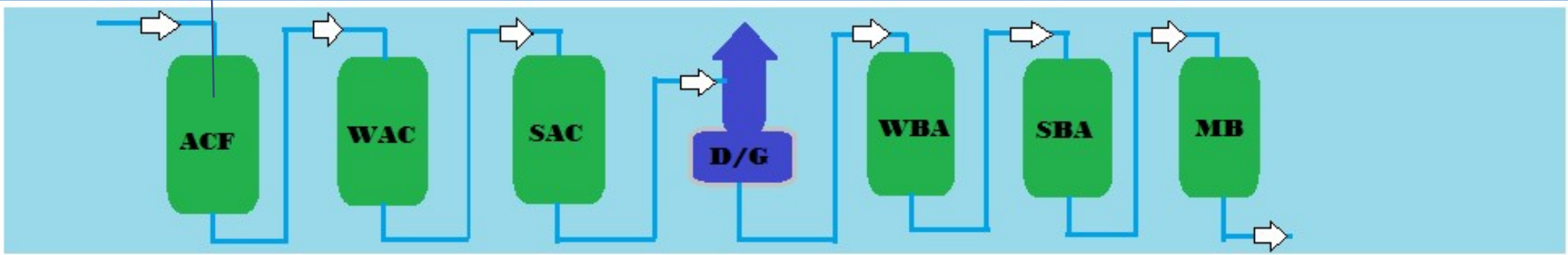
Acts on principle of adsorption which is a surface active phenomenon .

It removes residual turbidity (<2 NTU) of water to its 1/10 level.

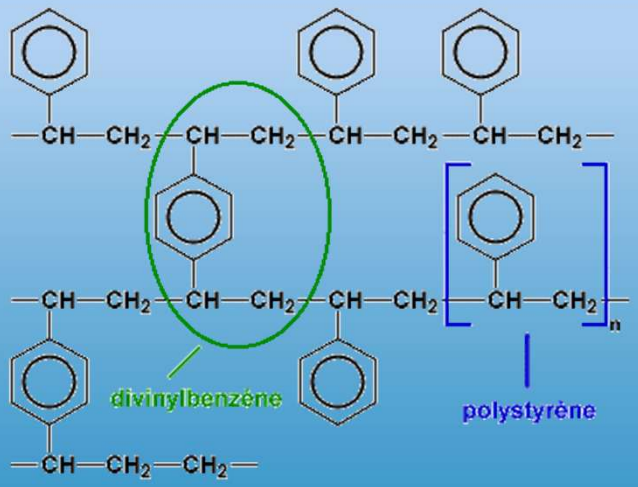
It removes organic molecules to control color and odor.

It removes free residual chlorine present in filtered water(0.5 ppm →Nil)

ACTIVATED CARBON



TYPES OF RESIN



SAC: Strong Acid Cation
WAC: Weak Acid Cation
SBA: Strong Base Anion
WBA: Weak Base Anion

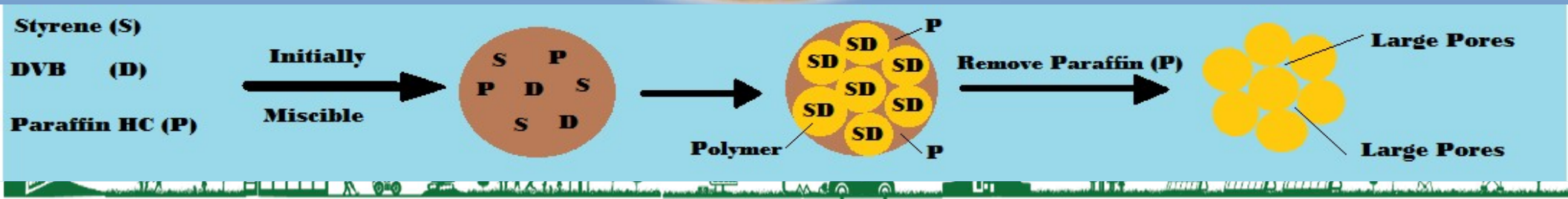
(R)

R-SO3H
Sulphonic Acid
(SAC)

CH3
|
R-CH2-NH+ OH
|
CH3
Tertiary Ammonium
(WBA)

R-CH2CHCH3
|
COOH
Carboxylic Acid
(WAC)

CH3
|
R-CH2-N-CH3 OH
|
CH3
Quarternary Ammonium
(SBA)

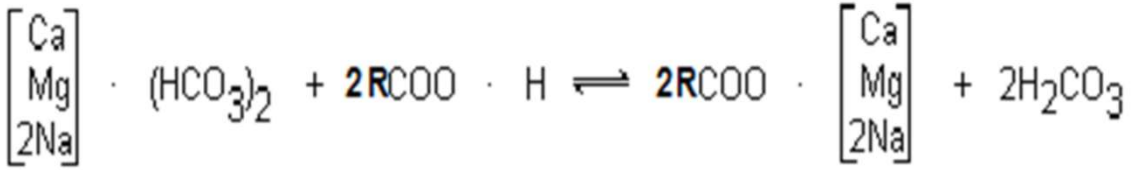


WEAK ACID CATION (WAC)

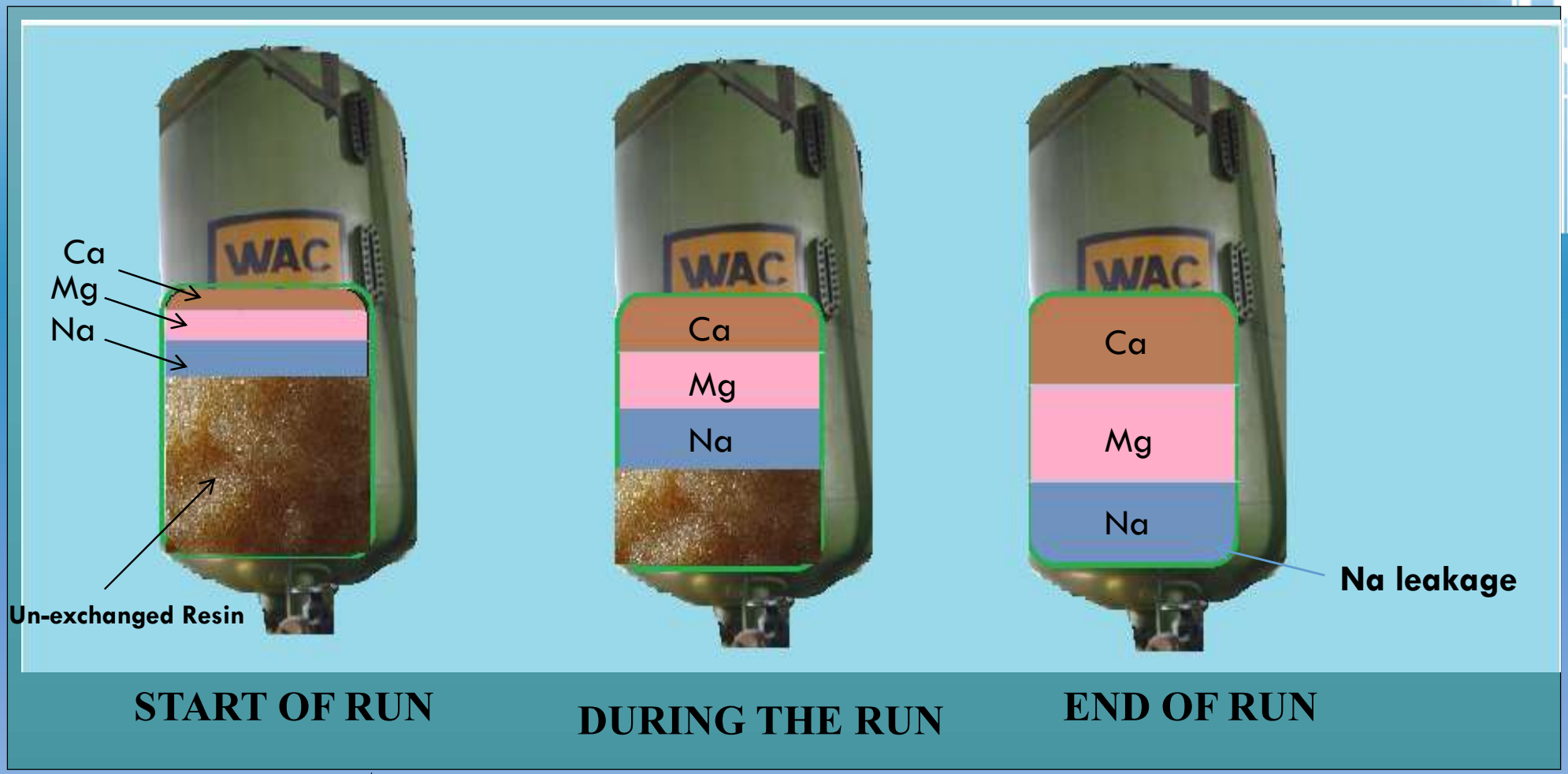
Weak acid cation exchange resins derive their exchange activity from a carboxylic group (-COOH). When operated in the hydrogen form, WAC resins remove cations that are associated with alkalinity, producing carbonic acid as shown:

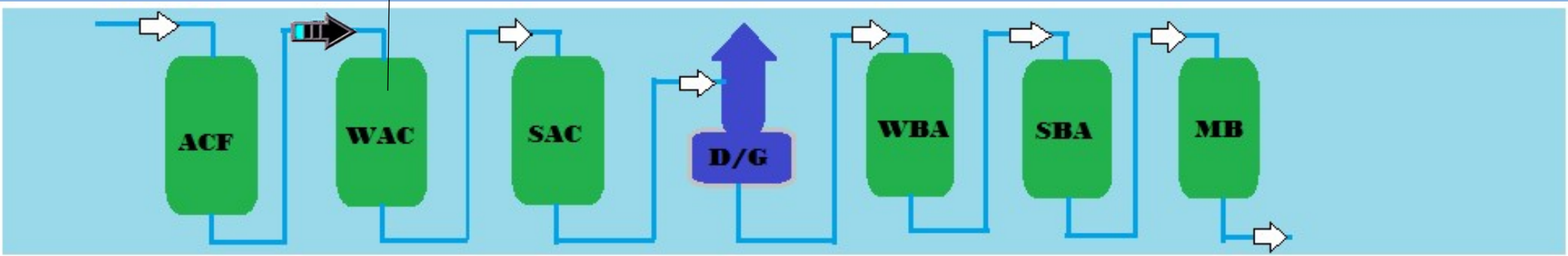
These reactions are also reversible and permit the return of the exhausted WAC resin to the regenerated form. Their primary asset is their high regeneration efficiency in comparison with SAC resins. This high efficiency reduces the amount of acid required to regenerate the resin, thereby reducing the waste acid and minimizing disposal problems.

Weak acid cation resins are used primarily for softening and dealkalization of high-hardness, high-alkalinity waters, frequently in conjunction with SAC sodium cycle polishing systems. In full demineralization systems, the use of WAC and SAC resins in combination provides the economy of the more efficient WAC resin along with the full exchange capabilities of the SAC resin.



CATION EXCHANGE MECHANISM



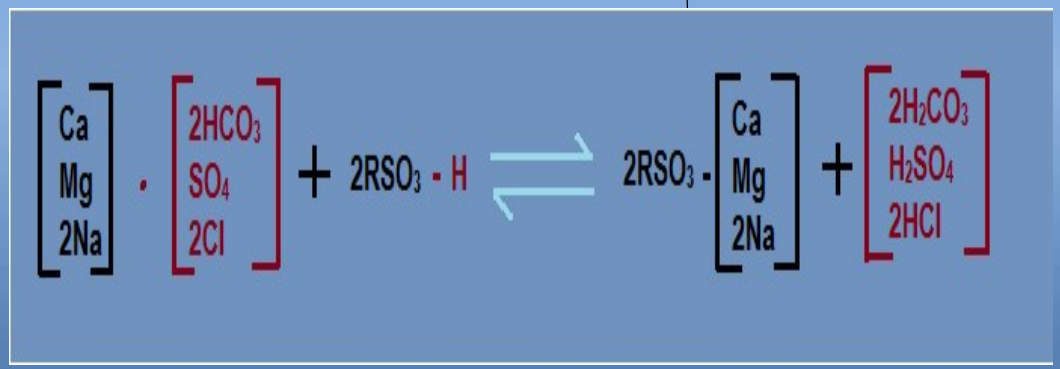


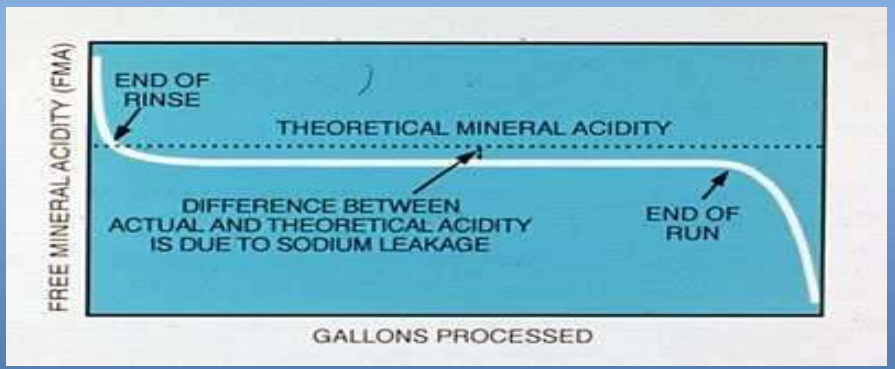
STRONG ACID CATION (SAC)

SAC resins can neutralize strong bases and convert neutral salts into their corresponding acids. SAC resins derive their functionality from sulfonic acid groups (HSO_3^-). When used in demineralization, SAC resins remove nearly all raw water cations, replacing them with hydrogen ions, as shown below:

Strong acid cation exchangers function well at all pH ranges. A measure of the total concentration of the strong acids in the cation effluent is the free mineral acidity (FMA). In a typical service run, the FMA content is stable most of the time. If cation exchange were 100% efficient, the FMA from the exchanger would be equal to the theoretical mineral acidity (TMA) of the water. The FMA is usually slightly lower than the TMA because a small amount of sodium leaks through the cation exchanger.

The amount of sodium leakage depends on the regenerant level, the flow rate, and the proportion of sodium to the other cations in the raw water. In general, sodium leakage increases as the ratio of sodium to total cations increases. The exchange reaction is reversible. When its capacity is exhausted, the resin can be regenerated with an excess of mineral acid.

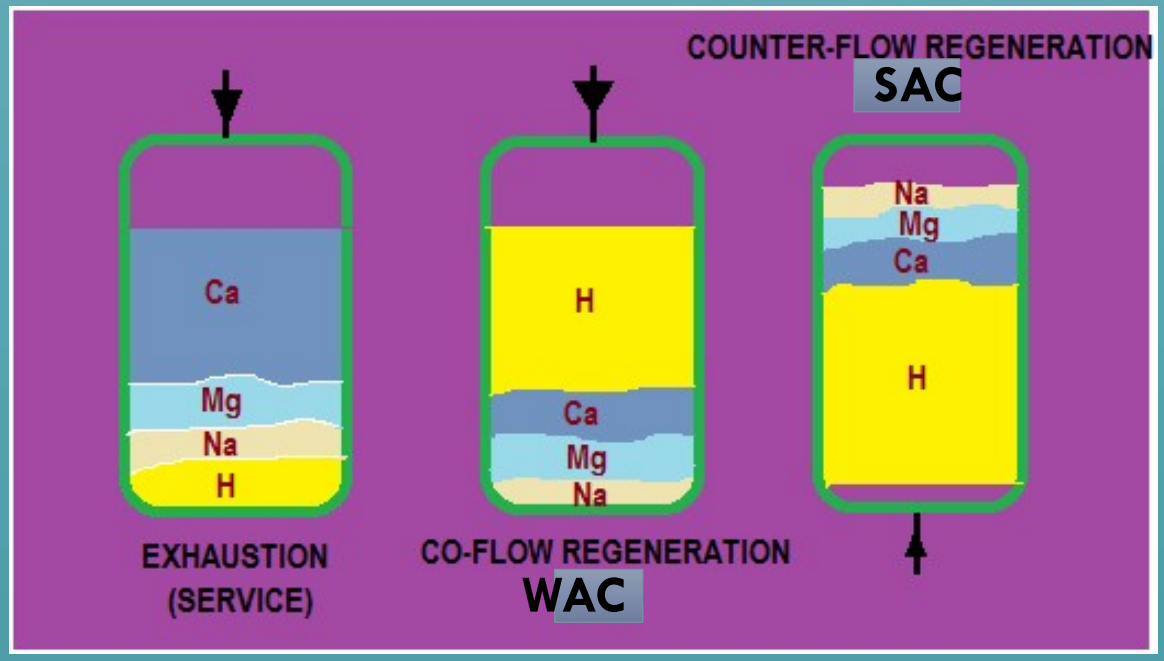




EXHAUSTED CATION RESIN REGENERATION

Thoroughfare Counter-flow Regeneration

The regeneration efficiency of WAC is very high compared to the strong acid resin. Therefore it is possible to utilize the regenerant acid strength from the strong acid unit to regenerate the weak acid unit.

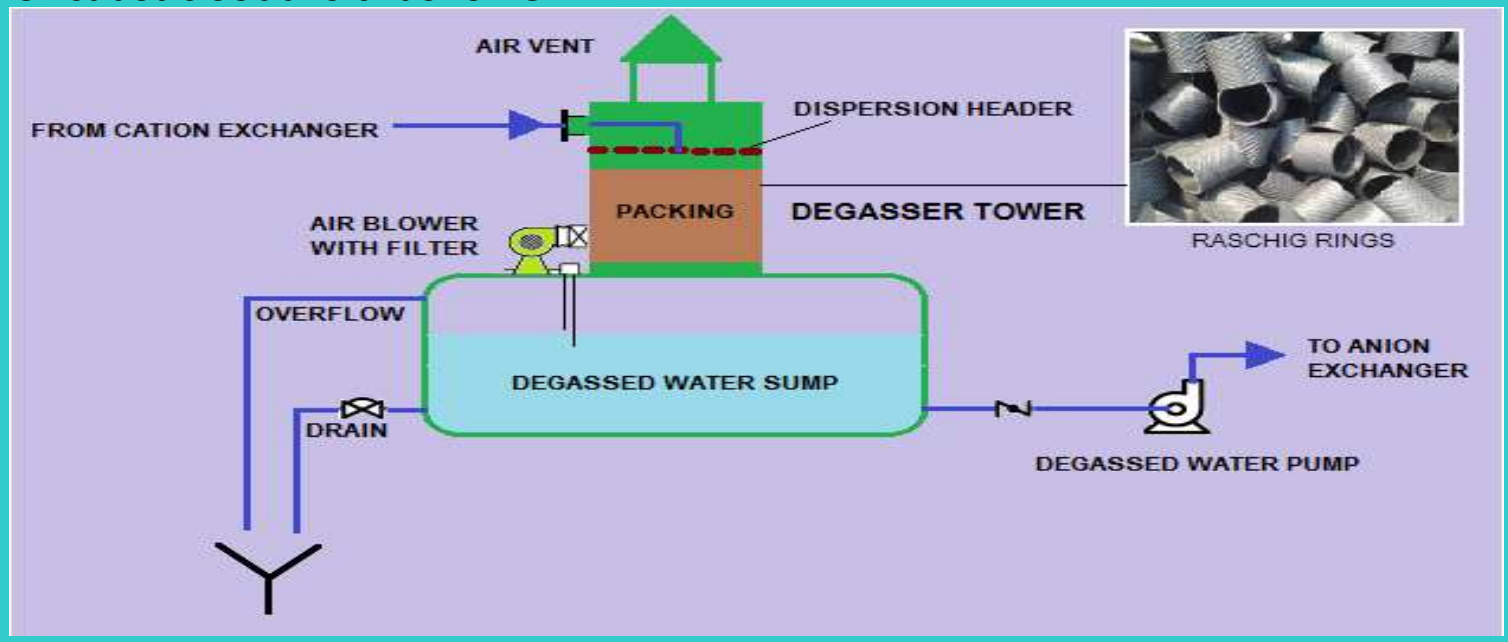


DEGASIFIER DESIGN

In water demineralization, a degasifier, or degasser, is often used to remove dissolved carbon dioxide after cation exchange. The most common degassers are of the so-called forced draft or atmospheric type. Under mechanical scrubbing the gas tends to move into the air because the partial pressure of CO_2 in air is much below the equilibrium pressure.

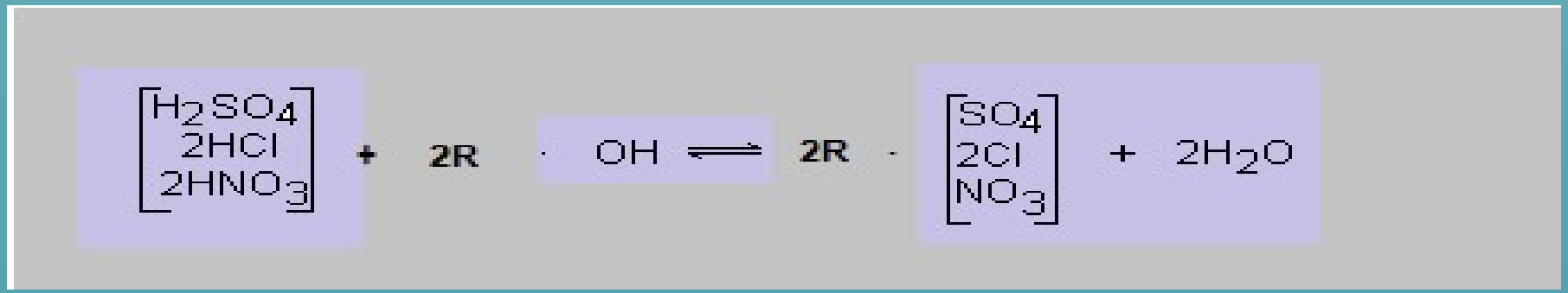
The residual CO_2 after an atmospheric degasifier is typically 10 mg/L as CO_2. Therefore, such degassers are used when the bicarbonate concentration plus free carbon dioxide in the feed water to separate column demineralization systems is at least 0.6 to 0.8 meq/L.

Using a degasser to remove CO_2 reduces the ionic load on the strong base anion resin, and the consumption of caustic soda is thus lower.



WEAK BASE ANION EXCHANGER

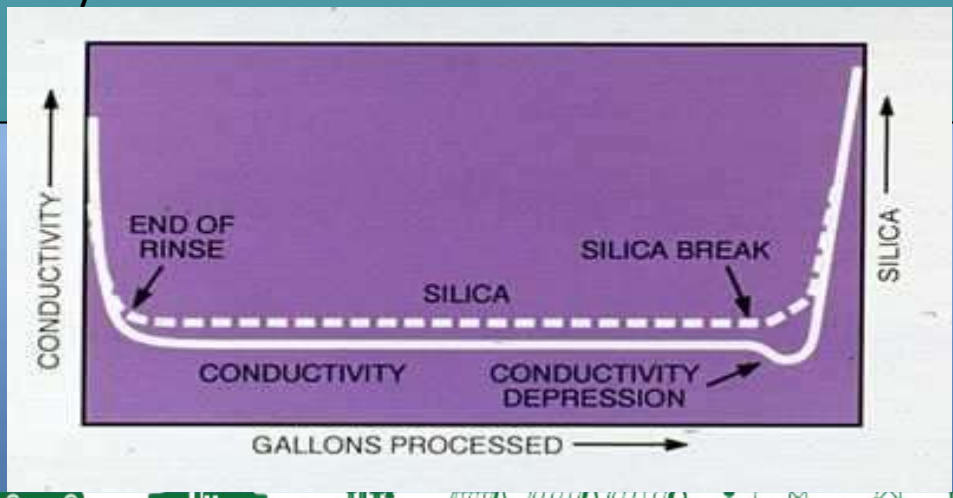
Weak base resin functionality originates in primary (R-NH_2), secondary (R-NHR'), or tertiary (R-NR'_2) amine groups. WBA resins readily re-move sulfuric, nitric, and hydrochloric acids, as represented by the following reaction:



STRONG BASE ANION EXCHANGER

- SBA resins derive their functionality from quaternary ammonium functional groups. When in the hydroxide form, SBA resins remove all commonly encountered anions as shown below:
- As with the cation resins, these reactions are reversible, allowing for the regeneration of the resin with a strong alkali, such as caustic soda, to return the resin to the hydroxide form
- Demineralization using strong anion resins removes silica as well as other dissolved solids. Effluent silica and conductivity are important parameters to monitor during a demineralizer service run. When silica breakthrough occurs at the end of a service run, the treated water silica level increases sharply. Often, the conductivity of the water decreases momentarily, then rises rapidly. This temporary drop in conductivity is easily explained. During the normal service run, most of the effluent conductivity is attributed to the small level of sodium hydroxide produced in the anion exchanger.
- When silica breakthrough occurs, the hydroxide is no longer available, and the sodium from the cation exchanger is converted to sodium silicate, which is much less conductive than sodium hydroxide. As anion resin exhaustion progresses, the more conductive mineral ions break through, causing a subsequent increase in conductivity.

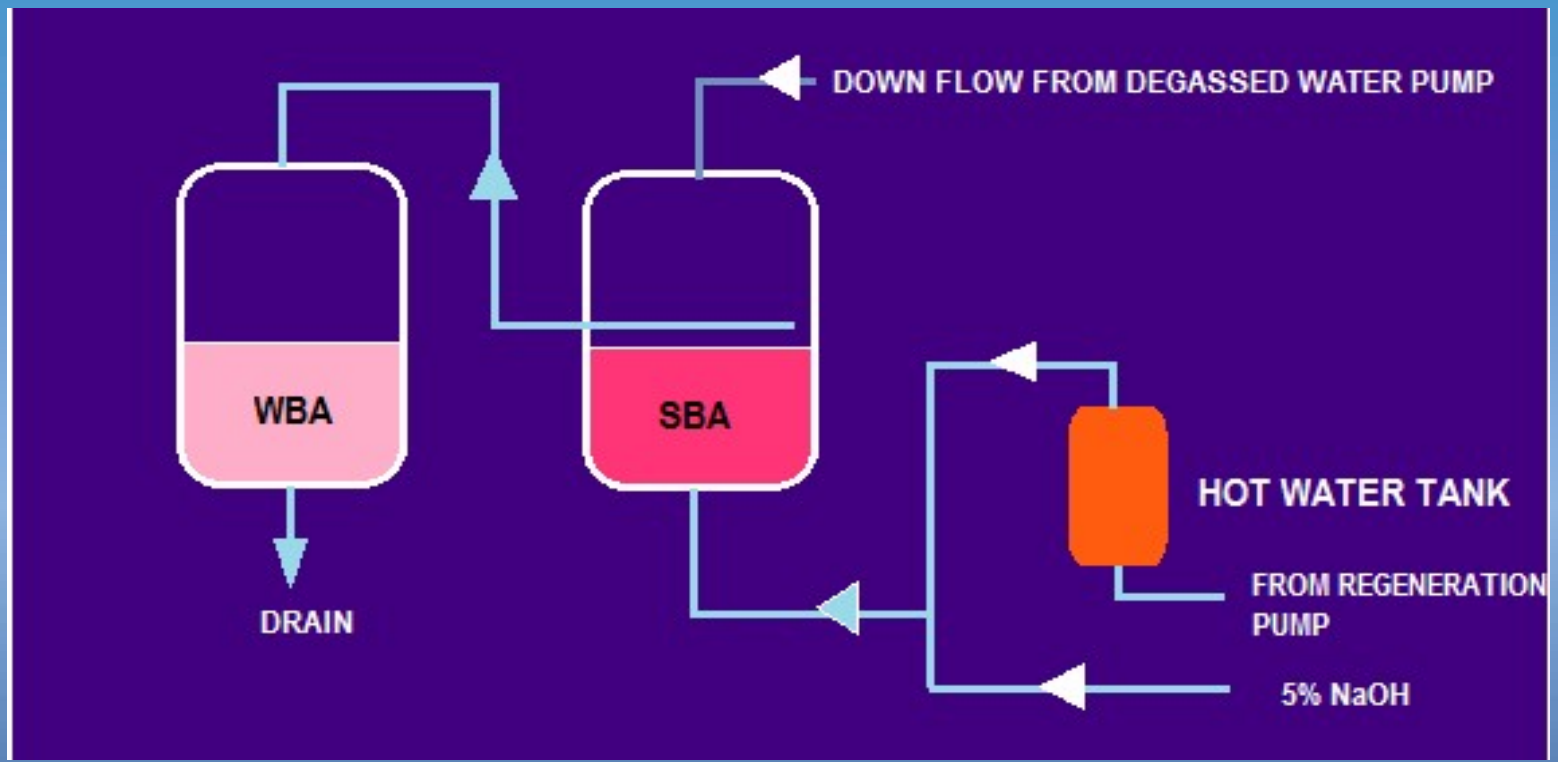
$$\begin{bmatrix} H_2SO_4 \\ 2HCl \\ 2H_2SiO_3 \\ 2H_2CO_3 \end{bmatrix} + 2R - OH \rightleftharpoons 2R \cdot \begin{bmatrix} SO_4 \\ 2Cl \\ 2HSiO_3 \\ 2HCO_3 \end{bmatrix} + 2H_2O$$



EXHAUSTED ANION RESIN REGENERATION

Strong base anion exchangers are regenerated with a 5% sodium hydroxide solution. As with cation regeneration, the relatively high concentration of hydroxide drives the regeneration reaction. To improve the removal of silica from the resin bed, the regenerant caustic is usually heated to 120°F or to the temperature specified by the resin manufacturer.

The regeneration efficiency of WBA is very high compared to the strong base resin. Therefore, it is possible to utilize the regenerant alkali strength from the strong base unit to regenerate the weak base unit through Thoroughfare Counter-flow Regeneration.

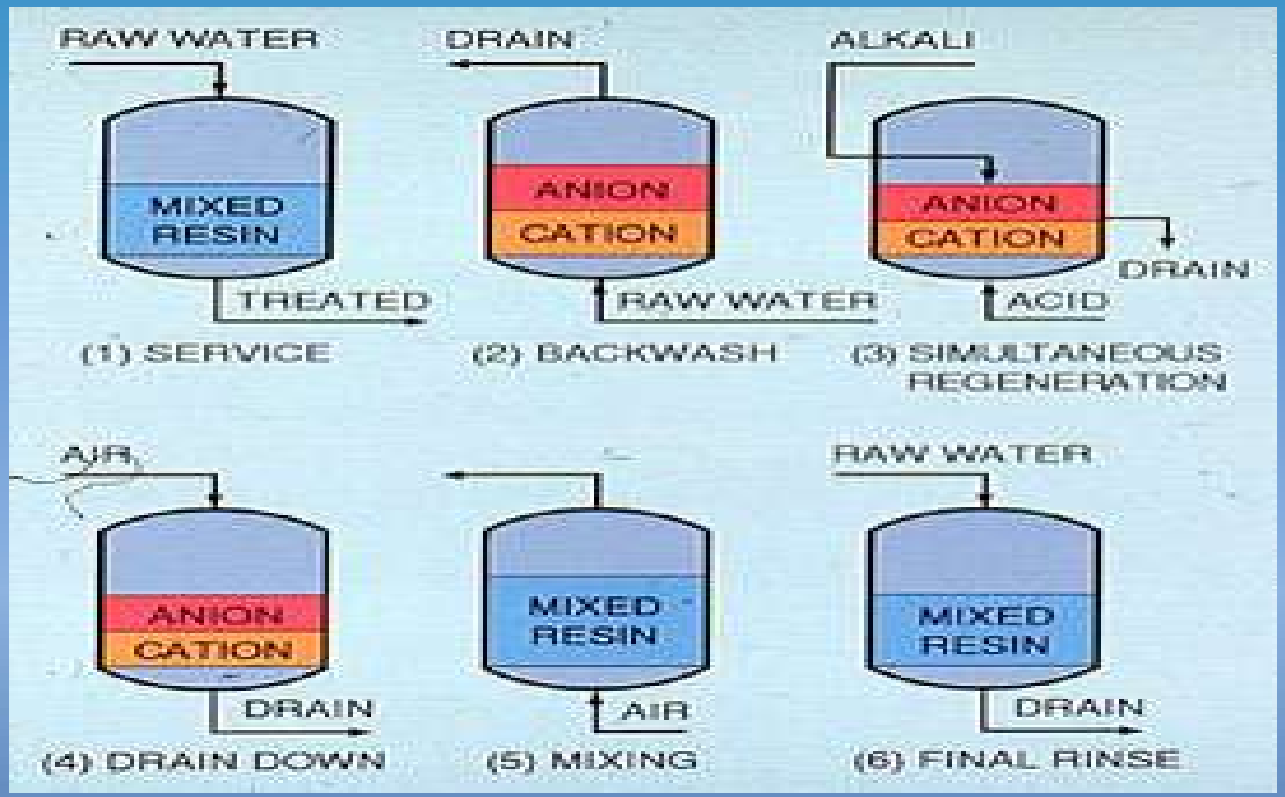


MIXED BED EXCHANGER & REGENERATION

A mixed bed exchanger has both cation and anion resin mixed together in a single vessel. As water flows through the resin bed, the ion exchange process is repeated many times, "polishing" the water to a very high purity.

During regeneration, the resin is separated into distinct cation and anion fractions as shown in Figures

1. **SERVICE**
2. **BACKWASH**
3. **SIMULTANEOUS REGENERATION**
4. **DRAIN DOWN**
5. **MIXING WITH AIR**
6. **FINAL RINSE**



RESIN REPORT-SPECIMEN

A. RESIN ANALYSIS (STAGE-2)

S.N.	Sample Description	Total exchange capacity as gm of $CaCO_3$/lit of resin	Salt splitting capacity as gm of $CaCO_3$/lit of resin	WRC (%age)	Density gm/ml.
1	WBA-I	63.0		58.7	0.7155
2	WBA-II	59.0		59.9	0.7249
3	SBA-I	50.5	42.1	52.8	0.6942
4	SBA-II	50.9	42.3	52.5	0.6829
5	WAC-I	127.7		52.8	0.7493
6	WAC-II	138.0		51.9	0.7462
7	SAC-I	74.3	72.2	58.2	0.7799
8	SAC-II	72.6	71.3	59.1	0.7809
9	MBSAC-I	80.8	80.2	58.3	0.7758
10	MBSAC-II	80.9	80.7	56.3	0.7743
11	MBSBA-I	49.1	41.7	54.3	0.7057
12	MBSBA-II	51.0	40.3	53.9	0.7064

TEC/SSC for new SAC resin = approx. 100 gm $CaCO_3$ / lit of resin.
SBA resin = approx. 60-58 gm $CaCO_3$ / lit of resin

B. CPU RESIN ANALYSIS (STAGE-2)

S.N.	Sample Description	Total exchange capacity as gm of $CaCO_3$/lit of resin	Salt splitting capacity as gm of $CaCO_3$/lit of resin	WRC (%age)	Density gm/ml.
1	CPUSAC LOT 1	79.3	78.7	57.9	0.7625
2	CPUSAC LOT 2	79.0	78.6	57.8	0.7559
5	CPUSAC LOT 5	79.9	76.9	56.3	0.7578
6	CPUSAC LOT 6	79.7	76.0	57.9	0.7685
7	CPUSAC LOT 7	79.5	77.5	57.8	0.7652
8	CPUSBA LOT 1	42.4	35.0	54.3	0.7047
9	CPUSBA LOT 2	42.1	35.1	53.9	0.7024
12	CPUSBA LOT 5	43.2	37.5	54.7	0.7044
13	CPUSBA LOT 6	42.4	36.9	54.3	0.7027
14	CPUSBA LOT 7	42.1	36.6	53.9	0.7084

TEC/SSC for new SAC resin = approx. 100 gm $CaCO_3$ / lit of resin.
SBA resin = approx. 60-58 gm $CaCO_3$ / lit of resin
WBA resin = approx. 84 gm $CaCO_3$ / lit of resin

C. ACTIVATED CARBON ANALYSIS

S.N	Sample particular	Iodine adsorption Value mg/gm
1	ACF-I	561.7
2	ACF-II	571.5

DM Water Parameters

Water quality at different stages of Demineralization process:-

Feed water to DM plant: Turbidity - < 2 NTU

ACF: Residual Cl_2 – Nil; Turbidity - < 0.5 NTU

Cation Exchanger O/L: Na - <2 ppm

Degasser O/L: Dissolved CO_2 - <5 ppm

Anion Exchanger O/L : Silica - < 200 ppb, conductivity - < 10 ms/cm, pH - 6.8 - 7.2

Mixed bed O/L (DM WATER):

Silica - < 20 ppb, Conductivity - < 0.1 µs/cm, pH = 6.8 - 7.2

KEY ASPECTS OF EFFICIENT DM PLANT OPERATION

1. REGULAR CALCULATION OF OBR TO PREVENT ANY REGENERATION FAILURE.
2. MAINTAINING DESIGN FLOW FOR EACH REGENERATION STEPS.
3. REGULAR FOLLOW UP WITH MAINTENANCE GROUP FOR TIMELY ATTENDING OF VALVES.
4. EMPHASIS ON AUTO MODE OPERATION.(PLC BASED OPERATION)
5. HEALTHINESS OF ONLINE ANALYSERS FOR DM WATER QUALITY MONITORING.
6. REGULAR CHECKING OF P&I OF DM PLANT OPERATION.
7. PERIODIC OPEN BACKWASH ACTIVITY TO REMOVE RESIN FINES PARTICULARLY IF REPREATED FAILURE OF VESSEL OUTLET STRAINER HAPPENS.

CHEMICAL TREATMENT METHODS

There are various formulations and procedures for chemically cleaning the fouled ion exchange resins. The following table summarizes foulants and the cleaning solvent.

SN	Foulant	Cleaning Chemicals
1	Organics	2% NaOH + 10% NaCl at 50±2 Deg C for type 1 SBA and 40±2 Deg C for type 2 SBA
2	Oil and grease	Surfactant/ detergent
3	Iron	HCl 8% (2BV, higher concentration w/w) with 8-16 hrs. soaking period
4	Silica	Caustic soda or alkaline brine treatment
5	Biological Growth	Hypochlorite treatment with low concentration 0.2 %. Per acetic acid (CH3COOOH) for bacteria

5.2 DM Plant (ACF, CATION, DG, ANION, MB, DMST)

Table 3:				
S.N.	**PARAMETER**	**UOM**	**Test Frequency**	**REMARKS**
I	**ACF Outlet**			
1	Turbidity	NTU	Once/shift	
2	FRC/ Residual ClO2	ppm	Once/shift	
II	**Cation Exchanger**			
1	Sodium	ppm	Online: Continuous	Either (1) or (2), as per design
2	Conductivity Ratio			
3	FMA	ppm	Once/shift	
III	**Degasser**			
1	Free CO2	ppm	Once/shift	
2	Blower Discharge Pressure	mm WC	Once/shift	
IV	**Anion Exchanger**			
1	pH at 25 deg C	---	Online-Continuous, Offline-Twice/shift	
2	Sp Conductivity at 25 ^{O}C	µs/cm		
3	Reactive Silica	ppm as SiO2		

V	**Mixed Bed**			
1	pH at 25 deg C	---	Online- Continuous, Offline- Once/shift	
2	Sp Conductivity at 25 ^{O}C	µs/cm		Common header conductivity is to be monitored online continuously.
3	Reactive Silica	ppm as SiO2		
4	Colloidal Silica	ppm as SiO2	Offline- quarterly	
VI	**DM Storage tank**			
1	pH at 25 deg C	---	Online- Continuous, Offline- Once/Day	
2	Sp Conductivity at 25 ^{O}C (in make-up water line)	us/cm		
3	Reactive Silica	ppm as SiO2		
4	Colloidal Silica	ppm as SiO2	Offline- quarterly	
VII	**DM Make-up pump (suction/discharge header)**			
1	Sp Conductivity at 25 ^{O}C	µs/cm	Online- Continuous	
VIII	**OBR (Totalised flow)**			
1	ACF	M3	Once/Shift	
2	Cation	M3	Once/Shift	
3	Anion	M3	Once/Shift	
4	MB	M3	Once/Shift	

RESIN TESTING FREQUENCY:

Table 5A: Resin testing				
S.N.	**Resin type**	**Parameters to be tested**	**Testing Frequency**	**Remarks**
1.	**WAC** (Weak Acid Cation)	Total Exchange Capacity Water Retention Capacity Density	Once/Year	Activated carbon and Resins testing to be done at CC-NETRA/ Govt./NABL-accredited third party labs/ ACF/Resin supplier's lab.
2.	**SAC** (Strong Acid Cation)	▪ Total Exchange Capacity Salt Splitting Capacity Water Retention Capacity Density	Once/Year	
3.	**WBA** (Weak Base Anion)	▪ Total Exchange Capacity Water Retention Capacity Density	Once/Year	
4.	**SBA** (Strong Base Anion)	▪ Total Exchange Capacity Salt Splitting Capacity Water Retention Capacity Density	Once/Year	
5.	**ACTIVATED CARBON**	• Iodine value	Once/Year	

Note:
Following parameters are to be tested for Cation/Anion resins in case station is having problems with OBR reduction:
Operating Capacity
Particle size distribution

ION EXCHANGE RESINS PROPERTIES

Graphic representation of granulometry

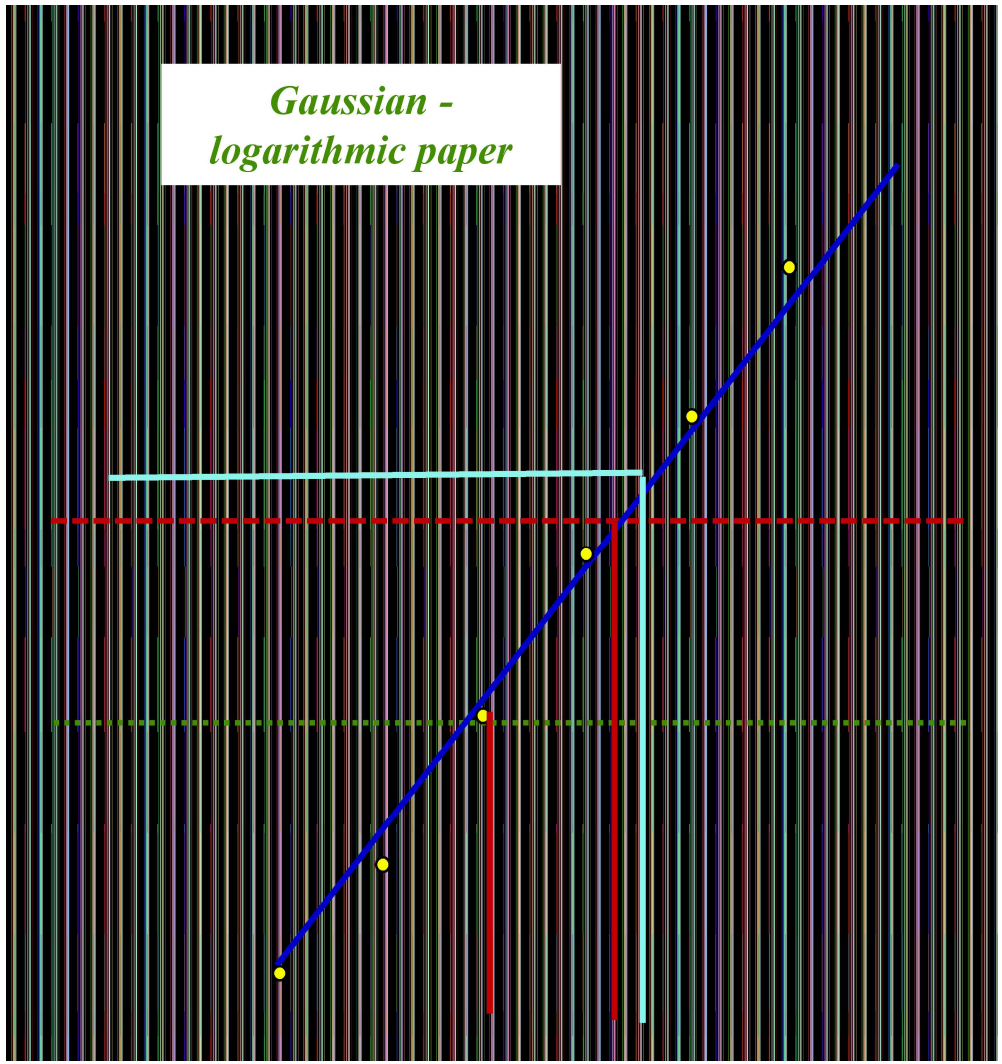
Uniformity coefficient

d_{60} / d_{10} =

690/475

= 1.45

% passing through sieve (volume)



Mean diameter
670 μm

Effective size
490 μm

Sieve opening μm

The particle size distribution can be plotted on a graphing paper, called probability paper, with a Gaussian y-scale and a logarithmic x-scale. On such a peper, a "normal" distribution prints as a straight line.
Mean diameter, effective size and uniformity coefficient values can be obtained from the graph. The steeper the line, the smaller is the uniformity coefficient.

Influence of particle size

Fine resin

fast exchange
high capacity

Coarse resin

low pressure drop
no nozzle clogging

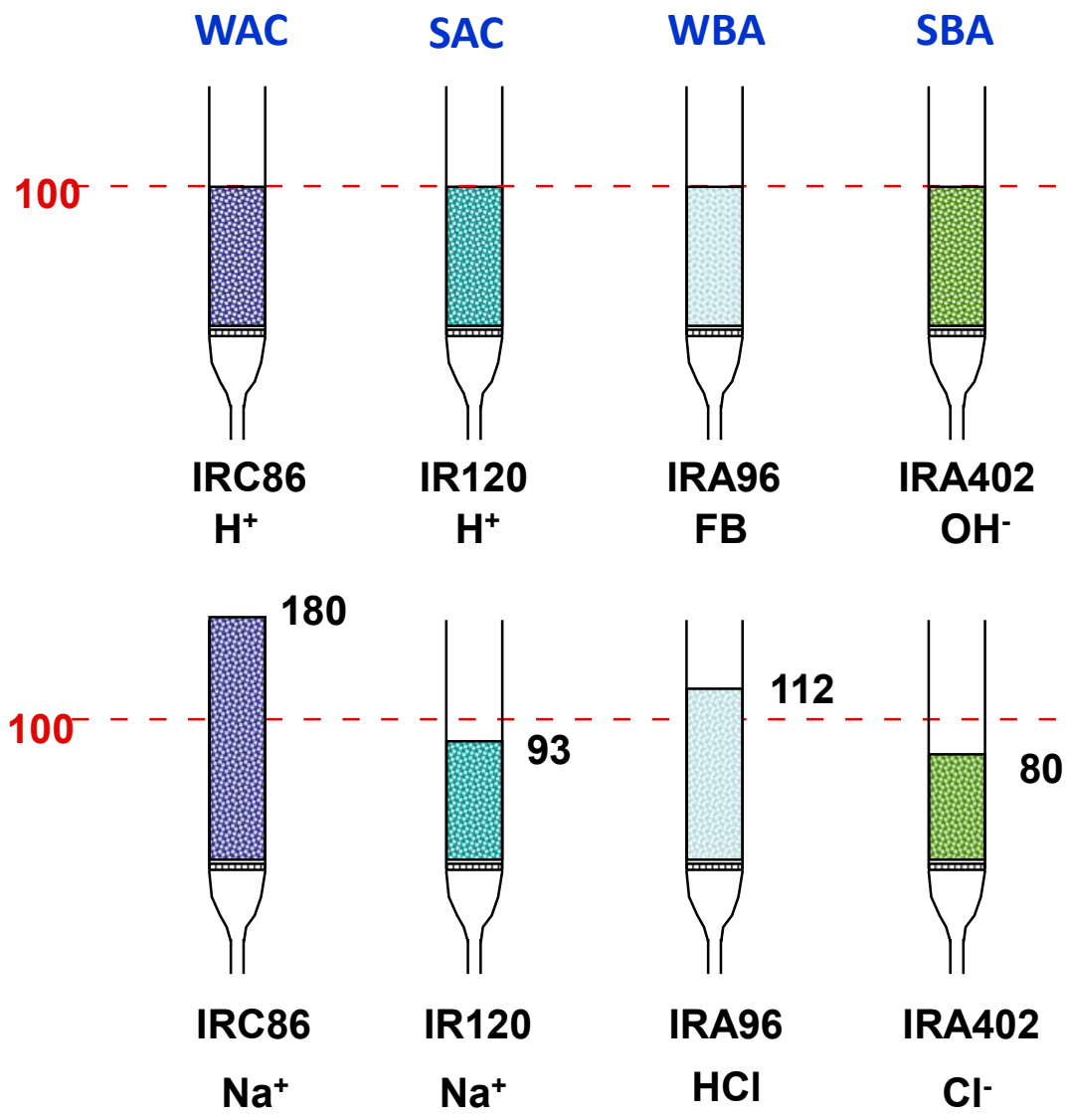
Bead size is important

- for mixed beds
- for stratified beds
- for fluidised beds
- for backwashing
- for chromatography

•The choice of particle size is a *compromise* : fine resins deliver a higher capacity, but cause high head loss, and excess fines may produce nozzle clogging. Coarse beads on the other hand are frequently more sensitive to osmotic stress and have slower kinetics, thus giving a lower operating capacity.

•For all applications requiring separation of different resins in the same column, such as stratified or mixed bed units, selection of the right particle size is of utmost importance.

Change of volume vs. ionic form



Reason: Due to hydration of ions and nature of electrolyte

Ion Exchange Capacity (TEC)

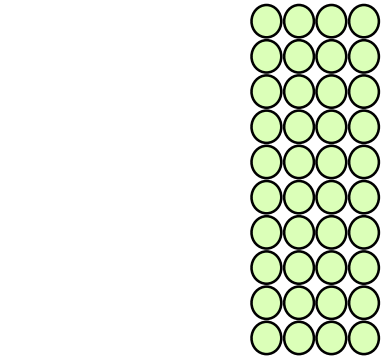
Total capacity

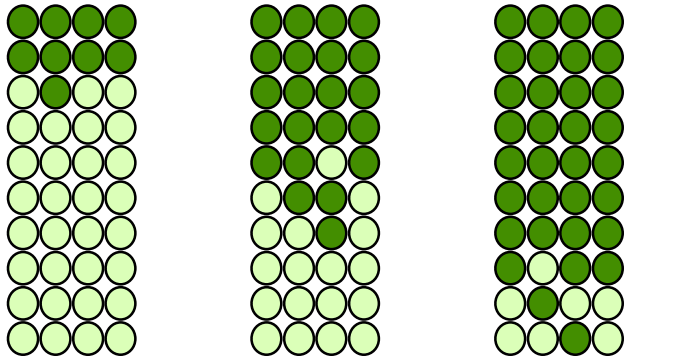
-Number of active groups

-Number of exchangeable ions

Operating capacity or *Useful* capacity

-Number of exchangeable ions *during a cycle*





Beginning

End of run

Factors affecting TEC

- **Regenerant level**
- **Flow rate**
- **Composition of feed**
- **Temperature**
- **Bed depth**

Why the Operating Capacity is smaller than Total Exchange Capacity??

Moisture holding capacity (water retention)

Moisture is related to *porosity*

- High moisture
  - fast exchange
  - good adsorption properties
  - low total capacity
- Low moisture
  - high total capacity
  - difficult to regenerate
  - no removal of big ions
  - tendency to fouling

- About half the weight of all ion exchange resins is water, unless they have been dried or the water has been replaced with an organic solvent. The water surrounds the active groups (hydration water) and fills the voids in the resin matrix. Obviously, a resin with high moisture has less dry matter, therefore less active groups and less capacity; but on the other hand, such a resin may provide easier access for large ions into its structure.
- Usually, low moisture resins have a slower exchange rate and are more susceptible to fouling than high moisture resins.

Specific gravity (true wet particle density)

Important for

- Mixed bed separation
- Stratified beds
- Fluidised beds
- Backwashing

Resin type	Range	Typical
S A C	1.17 to 1.38	(1.28)
W A C	1.13 to 1.20	(1.17)
S B A	1.07 to 1.12	(1.09)
W B A	1.02 to 1.10	(1.04)

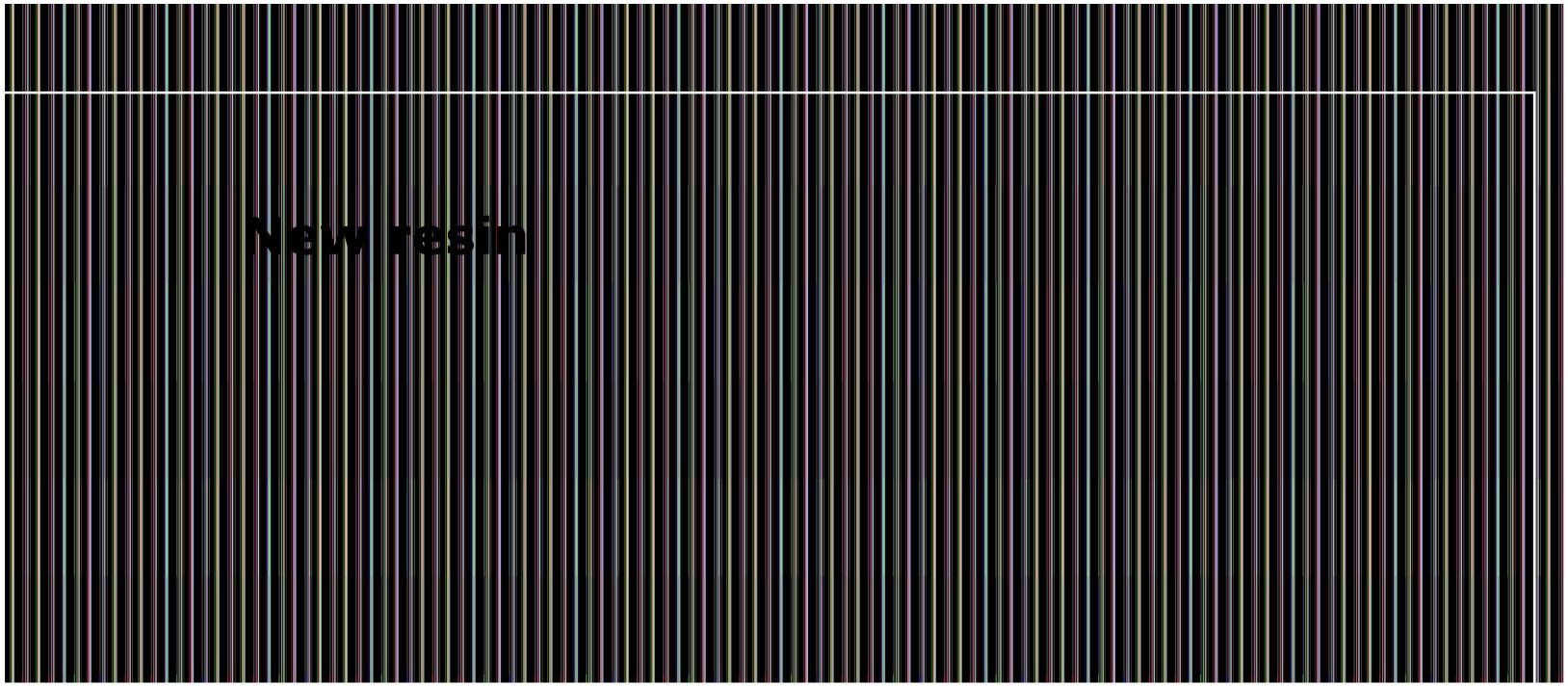
Although not an item for routine testing, specific gravity is an important parameter for successful plant operation. It is critical for all processes involving mixing or separation* of 2 or 3 resins in the same column, and for adjustment of resin backwash flow rate. It is due to their different swelling behaviour (densities as well) in caustic solution.

Measurement of the specific gravity is made with a pykno-metre.

Measurement : pyknometric

*** Can you guess which Weak or Strong Resin will rise and which will settle?**

Degradation : what happens



A close view of chemical resin degradation in the resin :

- During oxidation, the matrix of the resin breaks down. In the case of cation exchangers, no significant loss of active groups occurs.
- Pure capacity loss can occur when active groups disappear without change of the polymer matrix.
- Resin fouling is due to the adsorption of foreign molecules that are not eluted during regeneration and accumulate in the structure.

Example 1

Strong acid cation exchange resin

	New	Used
Capacity eq/L (Na)	2.05	1.75
Capacity eq/kg (Na)	4.60	4.38
Moisture holding %	47.9	49.5
Optical aspect		
Perfect beads %	92	65
Whole beads %	97	75
Broken beads %	3	25

Issue: Fines, so topping is required after removal of fines.

Example 2: Another SAC

		New	Used
Capacity eq/L (Na)	>2.00	0.90	
Capacity eq/kg (Na)	>4.50	4.62	
Moisture holding %	44-48	77.4	

Strong oxidation : no cure

This is a much more pronounced example of the same type :

- Dry weight capacity is untouched (higher than minimum spec.)
- Volume capacity is low by more than 50%
- Moisture is very high.

Conclusions

- Physical damage : de-crosslinking
- Chemical damage : large capacity loss

Recovery Treatment : None. The resin is severely oxidised, and must be changed.

Remark

- After investigation, it appeared that resin was oxidised with HNO3.

Example 3: Another SAC

Imac C 12 (sugar)	New	Used
Capacity eq/L (Na)	>2.05	1.91
Capacity eq/kg (Na)	>4.50	3.29
Aspect	Amber	Black
Moisture holding %	43-49	34.4

Issue: Fouling. Do the fouling treatment for cation.

Example 3: SAC (cont.)

Conclusions

Volume capacity still OK

Dry weight cap and moisture low

This is a typical fouling case

Recovery Treatment : HCl

Characteristics after treatment:

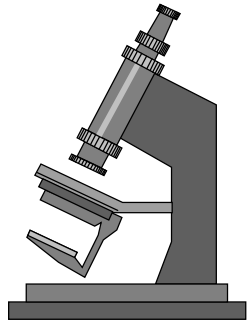
Volume cap	1.97 eq/L (Na)
Dry weight cap	4.45 eq/kg (Na)
Moisture holding	44 % (Na)

Properties essentially restored

- This sample has lost little of its volume capacity, but a large portion of its dry weight capacity. Moisture holding is unusually low.
- Low moisture indicate that the resin beads contain foreign material instead of the normal water content. This is what we call *fouling*. In the sugar industry, where Imac C 12 is used to remove large quantities of calcium from sugar juices, calcium can precipitate in and around the beads. In addition, the resin removes also proteins from the sugar solution, and these are frequently difficult to eluate. The black colour of the resin was a sign for such organic fouling.
- After hydrochloric acid treatment, tested in the laboratory, the resin recovered practically all of its initial properties.
- We recommended the customer to carry out a similar treatment in the industrial column.

Summary

	Vol cap eq/L	Dry wt cap eq/kg	Moisture % H2O	Problem
❶	↘	→	↗	Decrosslinking Oxidation
❷	↘	↘	→	Capacity Loss
❸	→	↘	↘	Fouling



A good resin analysis gives useful information on the probable plant problem

Thank You