# Basics of deionization

To design an effective system, dealers should know the application, desired purity and the existing impurities in the water.

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Deionization (DI), also referred to as demineralization, is an ion-exchange process wherein virtually all of the dissolved ions in the water can be removed, producing pure water.

Depending on the type and combination of equipment, DI can produce a purity from 100,000 ohms/cm to 18 million ohms/cm (or mega-ohms/cm).

## Types of resin

A deionizer uses two opposing charged resins (cationic and anionic). While the cationic resin removes the cations, the anionic resin removes the anions.

The cationic resin is typically made from styrene containing sulfonic acid groups, which are negatively charged. Although the resin is actually negatively charged, it is called a "cationic" resin, referring to the cations that it will exchange.

This resin typically comes in the hydrogen ion ($H^+$) form, meaning it is precharged with hydrogen ions on its exchange sites.

Anionic resin is typically made from styrene containing quaternary ammonium groups, which are positively charged. Despite its positive charge, it is called an "anionic" resin, referring to the anions that it will exchange.

This resin typically comes in the hydroxide ion ($OH^-$) form, meaning it is precharged with hydroxide ions on its exchange sites.

## Resin variations

- Cationic resin is referred to as strong acid or weak acid.
- Anionic resin is referred to as strong base or weak base.

The basic difference is the weakly ionized resin will exchange only the weak ions, where as a strongly ionized resin will exchange both weak and strong ions but at the expense of a reduced capacity.

The strong base anion comes in Type 1 or Type 2. Type 1 can remove silica and $CO_2$ better than Type 2 but at a reduced capacity.

There are other variations of resins to consider, with each providing its own advantages and disadvantages such as thermal, physical and chemical stability, oxidation and organic fouling resistance, kinetics and costs. One must choose the proper type of resin to fit the application.

## Dual and mixed-beds

Deionizers come in dual-beds or mixed-beds. In a dual-bed system, the cationic resin and the anionic resin are in separate vessels, where as in a mixed-bed the cationic and the anionic resins are mixed in a single vessel. This is also called a single-bed DI.

In a dual-bed DI (see Figure 1) water is passed through the cationic vessel where the cations in the water are exchanged

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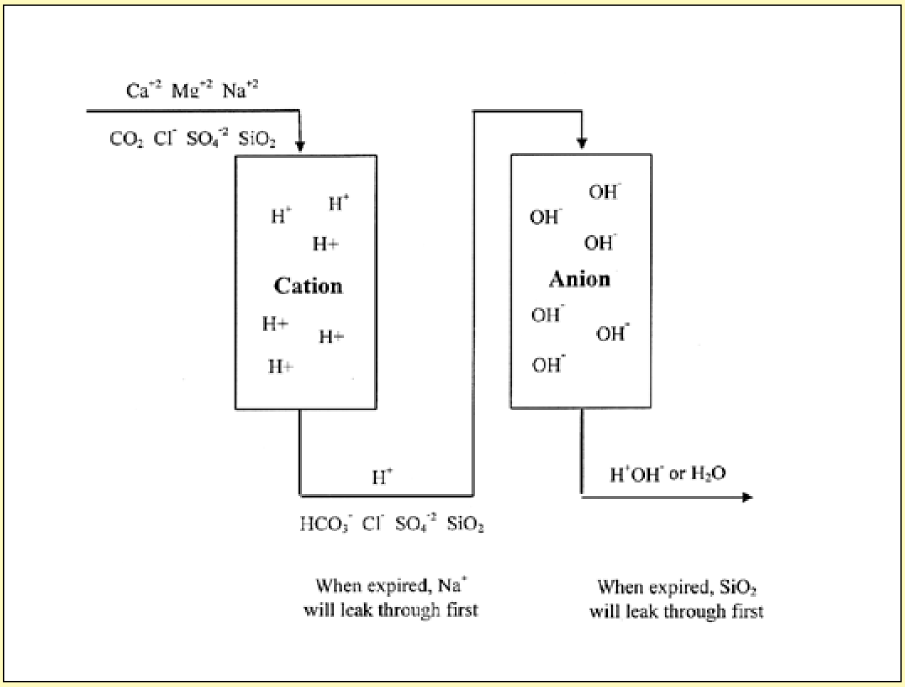


*Figure 1 – Typical dual-bed deionizer*

## Sizing the deionizer

Cationic resin is rated at about 20,000 grains per $ft^3$ at 2-gallons HCl regenerant per $ft^3$ of resin. Anionic resin is rated at about 12,000 grains per $ft^3$ at 1-gallon NaOH regenerant per $ft^3$ of resin

Despite the higher capacity of the cationic resin, dual-beds typically come with equal amount of cationic and anionic resin. In essence, the cationic vessels are oversized because they also supply the regenerant water for the anionic vessels.

Mixed-beds come with a 40/60 blend of cationic and anionic resin.

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with the hydrogen ions from the resin.

The cationic resin, having a greater affinity for the cations, releases the hydrogen ions while grabbing the cations. The released hydrogen ions form acid with the remaining anions in the water.

This water is then passed through the anionic vessel where the anions are now exchanged with the hydroxide ions from the resin. Similarly, the anionic resin, having a greater affinity for the anions, releases the hydroxide ions while grabbing the anions.

The released hydrogen ions ($H^+$) from the cationic vessel and hydroxide ions ($OH^-$) from the anionic vessel now combine to form HOH or $H_2O$.

Some of the ions will slip by and won't be exchanged. If the DI water can be passed through the dual-bed again, the deionizer will have another chance to remove the ions that slipped by.

Each time this pass is repeated, more ions are removed and exchanged, producing an even purer water. In a mixed-bed, the water passes through the cationic resin and the anionic resin repeatedly, virtually for an infinite time. The resulting water is usually ultrapure.

A mixed-bed can produce over 10M-ohm water, whereas a dual-bed typically produces only 50K-ohms to 100K-ohms water.

Another variation is a combination of dual-bed and mixed-bed, where the mixed-bed is used as a polisher. Such a set-up can produce ultrapure water up to 18 mega-ohm/cm.

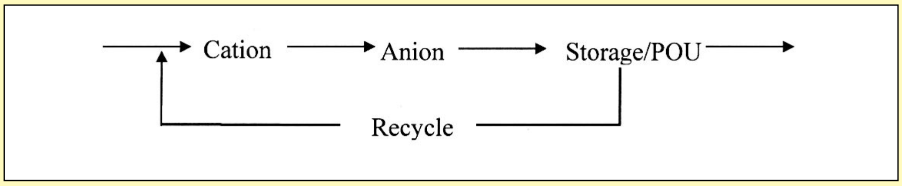


*Figure 2 – A fraction of the DI water is recirculated to the front of the deionizer to maintain the water's purity.*

## Recycling DI water

If the flow through the deionizer is temporarily halted, the water in the vessels will begin to take back the impure ions from the resin. When the flow is resumed, the first few gallons will usually be below specs.

To prevent this, the DI water can be recycled back at a fraction of the service flow rate to the front of the deionizer to keep the water moving and the purity up (See Figure 2).

This method is also used when DI water is stored after the deionizer. If the water is not used immediately, it will

## Non-ionic treatment

Deionizers do not remove non-ionic solids such as hydrophobic organic and some biological matters. Since these particles may be present in water, it would be prudent to add other equipment such as multi-media filters, activated carbon filters, RO and/or UV light to remove the non-ionic solids and to keep microbiological growth and fouling under control.

If the water contains significant amount of dissolved gasses like $CO_2$, removing them mechanically via degasifiers may be more cost efficient.

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absorb gasses like $CO_2$ and other air-borne particles, reducing the water's resistivity.

To prevent the water from falling below specs, it can also be recycled back to front of the deionizer for similar benefits.

### Expiration

Eventually the resins will expire, as all the hydrogen and/or hydroxide ions are expelled and all the exchange sites are filled with impure ions. Thereafter, the deionizer will no longer remove any subsequent impure ions, allowing them to leak through, reducing water purity.

The most common indicator of a deionizer expiration is a sudden and significant drop in the resistivity of the DI water.

There are other indicators. When the cationic resin expires, the first ion to leak through will be sodium ($Na^+$). When the anionic resin expires, the first ions to leak through will be silica ($SiO_2$) and/or carbonate alkalinity ($CO_3^{-2}$).

### Regeneration

To bring the water purity back to spec, the deionizer must be regenerated. Most deionizers are regenerated based on resistivity, while others are based on the ion leakage.

The cationic resin is regenerated with acid to replace the hydrogen ions. The preferred acid is hydrochloric acid (HCl), typically 20°Be (32 percent) at about 2-gallons per $ft^3$ of resin.

The anionic resin is regenerated with caustic to replace the hydroxide ions. The preferred caustic is a rayon or mercury grade sodium hydroxide (NaOH), typically 50°Be (50 percent) at about 1-gallon per $ft^3$ of resin.

A dual-bed can be regenerated in series or parallel:

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- *Series regeneration* means the cationic vessel is regenerated first and then supplies the water to regenerate the anionic vessel.

- *Parallel regeneration* means both the cationic and anionic vessels are regenerated simultaneously, reducing regeneration time and enabling the deionizer to be returned to service faster.

With a parallel regeneration, an alternate softwater or equivalent must be used to regenerate the anionic vessel to prevent fouling the anionic resin. An alternate softwater or equivalent must also be used to regenerate mixed-beds for the same reason.

In dual-beds the regenerants are typically introduced downflow through the resin beds and discharged through the risers. In a mixed-bed, the cation and anion resins are first stratified via backwash.

The cation resin — being heavier than the anion resin — will settle at the bottom half. The acid is introduced at the bottom, while the caustic is introduced at the top.

The regenerants meet at the interface collector at the middle of the tank where they are discharged. After regeneration, compressed air is introduced to re-mix the resins.

## Regenerant discharge

The resins have greater affinity toward the impure ions than the hydrogen and hydroxide ions. As such, the resins will release the hydrogen and hydroxide ions during the service cycle, to grab the impure ions.

In order to reverse this preference during regeneration, the deionizer is regenerated with excess regenerants (hydrogen and hydoxide ions) to force the impure ions off the resins.

Only a fraction of the regenerants is used. Most of the regenerants, along with the released impure ions, are discharged.

To prevent the discharge of spent acid and caustic to the sewer, they are typically routed to a neutralization tank where they neutralize each other. Further adjustment of the pH may be necessary to comply with the final discharge requirements of the local water district. ☐

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## Types of solids

Water dissolves minerals by dissociating the minerals to cations (+) and anions (-). For example, sodium chloride (NaCl), a table salt, will dissolve in water by dissociating to sodium ($Na^+$) cation and chloride ($Cl^-$) anion.

Dissociated ions, having ionic charges, are easily removed by DI.

Some gasses like carbon dioxide ($CO_2$) react with water to form carbonic acid ($HCO_3$), which dissociates to $2H^+$ and $CO_3^{-2}$. Likewise, these ions are easily removed by DI.

Other solids, when dissolved in water, do not dissociate to ions but they have enough density of charges that allow them to bridge with the water molecule. Examples are organic compounds like sugar, alcohol and solvents.

Although these compounds do not dissociate to ions, they impart some ionic charges and thus can be removed by DI.

Still other compounds like hydrophobic organics and some biological matters, when mixed in water, are non-ionic and thus cannot be removed by DI. These non-ionic compounds can be removed by equipment such as multi-media filters, activated carbon filters and reverse osmosis (RO).

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