Deionized Water (DI)

DEIONIZATION IN A "NUT SHELL"

City water is passed through dark amber colored, caviar sized plastic beads called cation ion exchange resin. The cation resin is in the "hydrogen" form (H+) and exchanges all the positively charged ions for hydrogen, thus converting all the impurities in the water into acids.

The acidic water from the cation is then passed through tan colored, caviar sized plastic beads called anion ion exchange resin. The anion is in the "hydroxyl" form (OH-) and exchanges all the negatively charged ions into the hydroxyl form, thus completing the conversion of all impurities into water (H+) + (OH-) ----> H_2O, thus providing pure *deionized water*.

DEIONIZATION IN "DETAIL"

Dissolved Solids - Ions

In nature solid inorganic substances dissolve in water and ionize into separate positive and negative components or "ions." These ions, whether positive or negatively charged, are known as electrolytes because they conduct electricity.

A good example of ionization is what happens to table salt when it is added to water. What was solid NaCl becomes the positively charged cation, sodium [Na+] and the negatively charged anion, chloride [Cl-]. The Greeks gave these disassociated electrically charged substances the name "ion" which means `to go about', which is exactly what they do. In water, the Na+ goes one way and the Cl- goes another.

Ions Commonly Found in City Water

Cations:
Sodium [Na+], Calcium [Ca++], Magnesium [Mg++], Potassium [K+], Iron [Fe+++], Manganese [Mn++] and Hydrogen [H+]

Anions:
Chlorides [Cl-], Sulfates [SO_4=], Nitrates [NO_3=], Carbonates [CO_3=], Silicates [SiO_2-] and Hydroxyl [OH-]

Ion Exchange Resins

Modern science has developed materials commonly called "ion exchange" resins. These resins take the form of little plastic beads made out of styrene cross-linked with divynalbenzene. Once formed, the beads are then either cooked in sulfuric acid to provide negatively charged sulfite sites to make **cation resin**, or processed in an ammonium salt solution to provide positively charged quaternary ammonium sites for

anion resin. It is the charged sites on these resin beads that give them their ion exchange properties. It has been estimated that a cation resin bead half a millimeter in diameter contains more than 280 billion exchange sites.

Cation Resin
The sulfite sited cation exchange resin is regenerated with an acid solution. In the acid form (H+), cation resin removes positively charged impurities such as calcium (Ca++), magnesium (Mg++), sodium (Na+) and potassium (K+). The impurities attach themselves to sites on the ion exchange resin, eluting off hydrogen (H+) from the acid regeneration. The resultant liquid is a mixture of acids caused by the association of the H+ hydrogen ion from the resin with all the anionic impurities still in the water.

Anion Resin
The resins with the quaternary ammonium sites are called anion resins and are regenerated with caustic soda solution to put them into the hydroxyl [OH-] state. The anion resin is then able to remove negatively charged impurities such as chloride (Cl-), sulfate (SO_4=) and carbonate (CO_3=). The impurities attach themselves to sites on the ion exchange resin, eluting off the hydroxyl radical (OH-).

Deionization
At this point all of the exchangeable anions and cations that were in the water are now held on the cation and anion resins exchange sites. The hydrogen ions [H+] eluted off of the cation resin combine with the hydroxyl ions [OH] eluted off of the anion resin to form pure water.

$$[H+] + [OH-] \rightarrow H_2O$$

This process continues until the resins have a majority of available exchange sites taken up with impurities. When this happens the resin is said to be exhausted. But after the cation resin is treated with acid and the anion is treated with caustic soda the deionizer is ready to operate again. The ability of ion exchange resins to be regenerated and used over and over again makes it a very practical and economical water purification tool.

Cation Regeneration
As soon as all the sites on the cation resin have given up their H+ ion and have taken up cationic impurities, the resin must be regenerated. To regenerate a cation resin column, a 10% hydrochloric acid (HCl) solution or a 4% sulfuric acid (H_2SO_4) solution is passed through the cation resin. The concentration of hydrogen ions in the acid solution provides the driving force to remove any other cations from the resin in favor or the hydrogen ion (H+).

Anion Regeneration
When the anion resin is loaded up with anionic impurities it is regenerated by passing a 4% caustic soda (NaOH or KOH) solution through it. The concentration of hydroxyl ions in the caustic soda solution provides the driving force to remove the anion impurities from the resin in favor of the hydroxyl [OH-] ion. The resin is once again ready to play its part in deionization.

Separate Bed Deionization
Separate bed or two-bed deionization refers to the fact that the cation resin and the anion resin are in separate tanks. Regeneration is relatively simple, and water quality is frequently around 200,000 ohms/cm^3 or 2 ppm.

Mixed Bed Deionization

In Mixed bed deionization the cation and the anion resins are mixed after regeneration and placed in the same vessel. The purpose of mixing the resins is to achieve a very high quality deionized water. When the resins are mixed, as the water passes through the resin bed it encounters a cation resin bead, then an anion resin bead, then cation, anion, cation, anion and so forth. The water is deionized then re-deionized continually resulting in an ultra high purity product.

The regeneration of a mixed bed resin complicated by the fact that the resins must first be separated into cation and anion columns, separately regenerated and rinsed, then mixed again. This process is more expensive and difficult than separate bed regeneration and mixed bed capacity is typically significantly lower than separate bed deionizers. But the product water from a properly regenerated mixed bed is the highest quality obtainable. Mixed bed deionization will frequently yield a water quality exceeding 18 megohms, less than 25 parts per billion.

Selecting a Deionizer System

It is important to select the proper deionizer for a specific need. In general the higher the quality of the deionized water required, the higher the cost. It is best to choose the most economical system that will meet your requirements.

Three Basic Deionizer Configurations:

1. **Two Bed Weak Base** systems produce high quality water for most applications. Weak base units typically produce deionized water over 20,000 ohms/cc with a pH under 7. Weak base units do not remove silica or carbon dioxide from the water.

2. **Two Bed Strong Base** systems produce high quality water over 50,000 ohms/cm3 with a pH over 7. Strong base units remove silica and carbon dioxide from the water.

3. **Mixed Bed** deionizers contain both cation and strong base anion resins mixed together in a single vessel. They produce the highest quality water typically from 200,000 to as high as 18,000,000 ohms/cc.

CAL-Water also offers multi-bed deionizer systems using any combination of cation, weak base, strong base and mixed bed units to meet specific volume and quality requirements.

Sizing A Deionizer

A water analysis is used to report each constituent contained in the water, usually in parts per million (ppm) or milligrams per liter mg/l.

All the constituents are then converted to equivalents of calcium carbonate [$CaCO_3$] as a common denominator. The exchangeable cations and anions are each totaled and the two should balance.

If silica [SiO_2] and carbon dioxide [CO_2] are to be removed they are also converted to $CaCO_3$ and one half of the silica and all of the carbon dioxide are added in with the anions.

The totals in ppm or mg/l are then converted to (G)rains (P)er (G)allon (GPG) because the capacities of the ion exchange resins are rated in grains exchange capacity.

ppm / 17.1 = GPG

7,000 grains equals one pound. If we dissolved one pound of table salt [NaCl] in one gallon water, it would contain 2750 grains of sodium (Na+) and 4250 grains of chloride (Cl-) for a total of 7,000 grains or one pound. Most water supplies contain from 2 to 40 grains of TEC AND TEA (Total Exchangeable Cations and Anions) or total dissolved solids.

Example: A service DI customer needs 10,000 gallons of deionized water over a one month period. The TEC are 30 GPG and the TEA plus silica and carbon dioxide are 33 GPG.

The service deionizer system must contain enough cation to remove 30 GPG X 10,000 = 300,000 grains, and anion resin to remove 33 GPG X 10,000 = 330,000 grains.

Since fully regenerated cation resin has a capacity of 30,000 grains per cubic foot, then 300,000/30,000 = 10 cubic feet of regenerated cation will be required for the month. This can be a single 10 cubic foot unit exchanged once a month or a 3.3 cubic foot unit exchanged 3 times a month.

Similarly, a fully regenerated strong base anion has approximately 17,000 grains capacity per cubic foot. The amount of anion resin required would be 330,000/17,000 = 20 cubic feet. Again it could be a single 20 cubic foot unit per month, or a 3.3 cubic foot unit exchanged 6 times a months.

In practice, the most cost effective system would be a set of 3.3 cubic foot deionizers made up of one cation and two strong base anions, exchanged three times a month.

Service Deionization - The Batch Process

The regeneration method used to regenerate resin from service deionizers by CAL-Water is known as the batch process. Resin from a number of portable exchange deionizers are dumped into a batch tank regeneration vessel. The resin is put through a computer-controlled regeneration in the batch tank then returned to the individual service units. It has been determined that, when properly operated, the batch method is the most cost effective method for service DI regenerations.

Deionizer Regeneration Chemicals

Cation Regenerant – HCl – H_2SO_4 – (Never HNO3)

Hydrochloric or Sulfuric Acid is used to regenerate Cation resin. Hydrochloric acid has the advantage of providing higher capacities than Sulfuric, but it is more expensive. Sulfuric acid also has the potential to cause calcium sulfate fouling of the cation resin. If sulfuric acid is to be used for cation regeneration, the water being deionized must be soft, or the sulfuric acid regeneration must proceed step wise, starting at a concentration below 2% and later being raised to 4%.

Never use nitric acid HNO_3 for cation deionizer regeneration. Combining a nitrate oxidizer with an organic cation resin can, and has, caused rapid exothermic reactions. (Explosions)

Anion Regenerant – NaOH – KOH – Soda Ash

Sodium Hydroxide is the regenerant of choice for most anion regenerations. While potassium hydroxide can be an excellent regenerant, it usually costs more than the

equally effective sodium hydroxide. Soda ash can be used weak base anion regenerations as long as the desired water quality can be achieved.

Regeneration In General

During any regeneration procedure, a chemical is being continuously diluted by water and fed into a resin bed. It is the total number of pounds of the chemical put through the bed that determines the capacity of the deionizer.

While the exact concentration of chemical can vary with little impact on the quality of the regeneration, maintaining the proper concentration is important because:

- If the strength it too high there will either be insufficient contact time or bed channeling.
- If the strength is too low there will not be sufficient driving force to do a complete regeneration.

It is always best to follow the resin manufactures guidelines as to regenerant concentration.

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