Episode 23 Getting Down with Anion 2

Why dealkalize water?

Boiler Feed Water Pretreatment

- Ion Exchange to prevent scale formation and control corrosion.
    - Bicarbonate alkalinity and calcium magnesium hardness, when combined, will form calcium carbonate which will scale up industrial, commercial, and residential boilers.
    - For industrial boilers you will want low hardness and alkalinity. This is accomplished by treating makeup with a softener and dealkalizer.
    - **Reducing alkalinity and hardness reduces the amount of boiler blow down so you don't have to use as many chemicals for scale and corrosion control.**
    - There is a second benefit **– if you don't take bicarbonate alkalinity out from the boiler feed water, that alkalinity will flash off with the steam as carbon dioxide (CO_2).** When that steam condenses it is typically brought back to the boiler as condensate. The CO_2 in the steam will condense as carbonic acid dropping the pH to an acidic, corrosive condition.
    - How does a water treatment guy combat that carbonic acid that forms? More chemicals. They feed neutralizing amines to the boiler feed water, which also flash over with the steam to neutralize the carbonic acid when it forms in the condensate. The benefit from that is corrosion control. Without it, you're going to corrode the piping, so you're going to see copper and iron coming back in the condensate. And ultimately that's going to go back into boiler feed water and back into the boiler, and you're going to have copper and iron deposits in the boiler, which we want to avoid. Copper will cause pitting on boiler tubes and may ultimately lead to tube failure.

Alkalinity Removal

- Strong base anion resin in the chloride form and regenerated with NaCl will remove alkalinity
- Examples when using SBA are nitrate, TOC, arsenic, and uranium removal
- **Removal of alkalinity will depress pH below a neutral condition and cause corrosion.**
- pH adjustment of the finished water will be necessary when applying SBA in chloride form
- Without the hardness component (calcium & magnesium) the likelihood of forming scale even if the alkalinity is present is very low.
- **Having alkalinity in the water puts you in the pH range of 7, or higher.** The higher the alkalinity, the less corrosion you're going to have in your system. If you have a softened water with alkalinity, scale and corrosion will be minimized.
- Strong base anion resin (SBA) used for nitrate removal will remove alkalinity and could potentially form calcium carbonate scale on the resin and on wetted surfaces including valves. However, **there is no need to soften water before a nitrate system until hardness exceeds 10 grains even if alkalinity is high**. There won't be enough hardness to form scale

- What happens when a customer has high hardness, 12-14 grains, and nitrates above allowable limits and this customer doesn't want to buy a softener? How does the hardness affect the anion resin?
    - As discussed above, **calcium carbonate scale will deposit on the resin and wetted surfaces and impede flow.**
    - **Drain lines may clog with the built-up scale.**
    - **High heat areas such as water heaters or boilers will scale.**

SBA resin in the chloride form will not remove or reduce chlorides. They exchange chloride for alkalinity and contaminants (nitrate, TOC, etc.)

- Anion resin used in the home is regenerated with NaCl (salt).
- As water passes through any anion resin in the chloride form it is exchanging chloride for anions which have a greater affinity for the SBA - nitrate, sulfate, etc.
- When the resin is exhausted it is regenerated with 10% NaCl. The resin is overwhelmed by the high concentration of chlorides and the nitrates, sulfates etc. are exchanged off as the chloride goes back on the SBA exchange sites.
- If you have 450 ppm of chloride coming in, it's going to increase to a much higher level, equivalent to the amount of sulfate, nitrate anions that you take out of the water.
- Adding sodium carbonate into the brine tanks may reduce chloride but it's not a real strong science so it's not recommended.
- Membrane technology – Reverse Osmosis is the only practical way to reduce chlorides in residential water.
- This same problem will occur if you are trying to reduce sulfates – SO4.
- Demineralization: A strong acid cation (SAC) in hydrogen (H) form followed by a strong base anion (SBA) resin in hydroxide (OH) form following will remove all ions including chloride but acid and caustic will be necessary for regeneration. This is not practical for home use.
- Mixed bed resin: A mixed bed composed of SBA in hydroxide form and SAC in H form will also remove all ions including chlorides however, as with demineralization it is not practical for home use.

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Removing Alkalinity and Hardness with Weak Acid Cation Resin in Industrial Water

- Weak acid cation (WAC) resin in the hydrogen form can be used in facilities which can handle acids as the WAC must be regenerated with hydrochloric or sulfuric acid.
- The WAC resin removes temporary hardness, which is the hardness associated with bicarbonate alkalinity, Ca $(HCO_3)_2$.
- The hydrogen ion (H^+) exchanged for the Calcium and Magnesium temporary hardness reacts with the alkalinity to form carbonic acid.
    - WAC-H + Ca $(HCO_3)_2$ -> WAC-Ca^{+2} + H_2CO_3
- The WAC resin will not remove permanent hardness, $CaSO_4$, $MgSO_4$.
- **In water with more alkalinity than hardness it will take out all the hardness because all of the hardness is temporary hardness.**
- **If the water has alkalinity lower than hardness it will only take out the hardness equal to the alkalinity (temporary), but none of the hardness salts (Permanent).** Residual hardness will go into the process or boiler if not removed by a trailing sodium cycle softener.
    - WAC-H -> SAC-Na will remove all hardness
    - In the WAC process alkalinity is removed when the treated water is processed with a forced draft or vacuum decarbonator. In this case the carbonic acid formed is stripped as CO_2 by the decarbonator.
    - HCO_3 -> H_2O + CO_2

With a decarbonator the stream will be dealkalized by feeding it through the top of the decarbonator tower, down through packing rings to form water droplets. The forced draft air coming up from the bottom strips out the CO_2 thereby reducing the alkalinity

When to use Strong Base Anion (SBA) vs. Weak Acid Cation (WAC)

- Use SBA if the facility can't accommodate acid.
- WAC should be used to soften and dealkalize if there is a positive ratio of hardness to alkalinity and acid for regeneration is allowed. Capacity of the WAC is easy to calculate by hand or computer programs.
- Don't be intimidated by using another type of resin, as it just requires a different set of equipment designed to handle acid conditions. The major benefit when using a WAC resin is you get softening and dealkalization with one resin. This approach is used by municipal and industrial plants to soften and dealkalize raw water.

Strong Base Anion Resin Capacity – Calculating Kilograins per Cubic Foot (KGr/ft^3)

- Range is between 4 and 10 Kgr/ft^3 or 4,000 and 10,000 grains/ft^3. There are dealkalization capacity curves on specification sheets but it's necessary to have a water analysis.

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- The capacity of A300E or any type 2 anion resin for dealkalization is based on the percent of alkalinity of all the anions in the water. To determine you would need to know sulfate, alkalinity, nitrate, and chloride.
    - For example, using a capacity curve, if you have 100 ppm total anions and 60 ppm is alkalinity, that's probably going to give you about 8,000 grains per cubic foot.
    - In an industrial environment if you add a little caustic to the brine you will get higher capacity. There are separate curves shown on the spec sheets for this. The caustic addition to the NaCl increases capacity about 10-15%.
    - Adding extra salt doesn't get you extra capacity – e.g., typically 5 pounds per cubic foot per regeneration is adequate. Bumping it up to 10 pounds does not increase capacity. Ditto for caustic. Adding more than a 0.25 pound of caustic per cubic foot will not increase capacity.
    - The caustic is fed separately from the brine into the NaCl dilution water with a chemical feed pump.
    - It is important to note that softened water should be used for brine make up. Otherwise, you will form calcium carbonate in the brine. This is especially important if you are using caustic.

Purolite Resin System Modeling

https://www.purolite.com/purolite-resin-system-modelingsoftware

- PRSM is a suite of calculation programs used to design equipment including water softeners, nitrate removal systems, arsenic systems, boron removal systems, and demineralization. Dealkalizer and mixed bed programs are in the works.
- This suite does not include PFAS but Purolite has a proprietary program which is available.
- Modeling your application with PRSM is based on cost performance and enables you to determine the best resin choice for an application. You can pick 2 different products to determine which one is better in terms of $/gallons of treated water.
    - For example – In the softening program you can compare standard cation, like C100E to SST6000E. The SST is more expensive on a cost per cubic foot basis. but the SST typically demonstrates higher performance. The evaluation is based on regenerant water and wastewater cost. The difference might be minimal on a residence, but considerable on larger commercial systems.
- Purolite provides PRSM program training and is highly recommended when you first start using the programs.