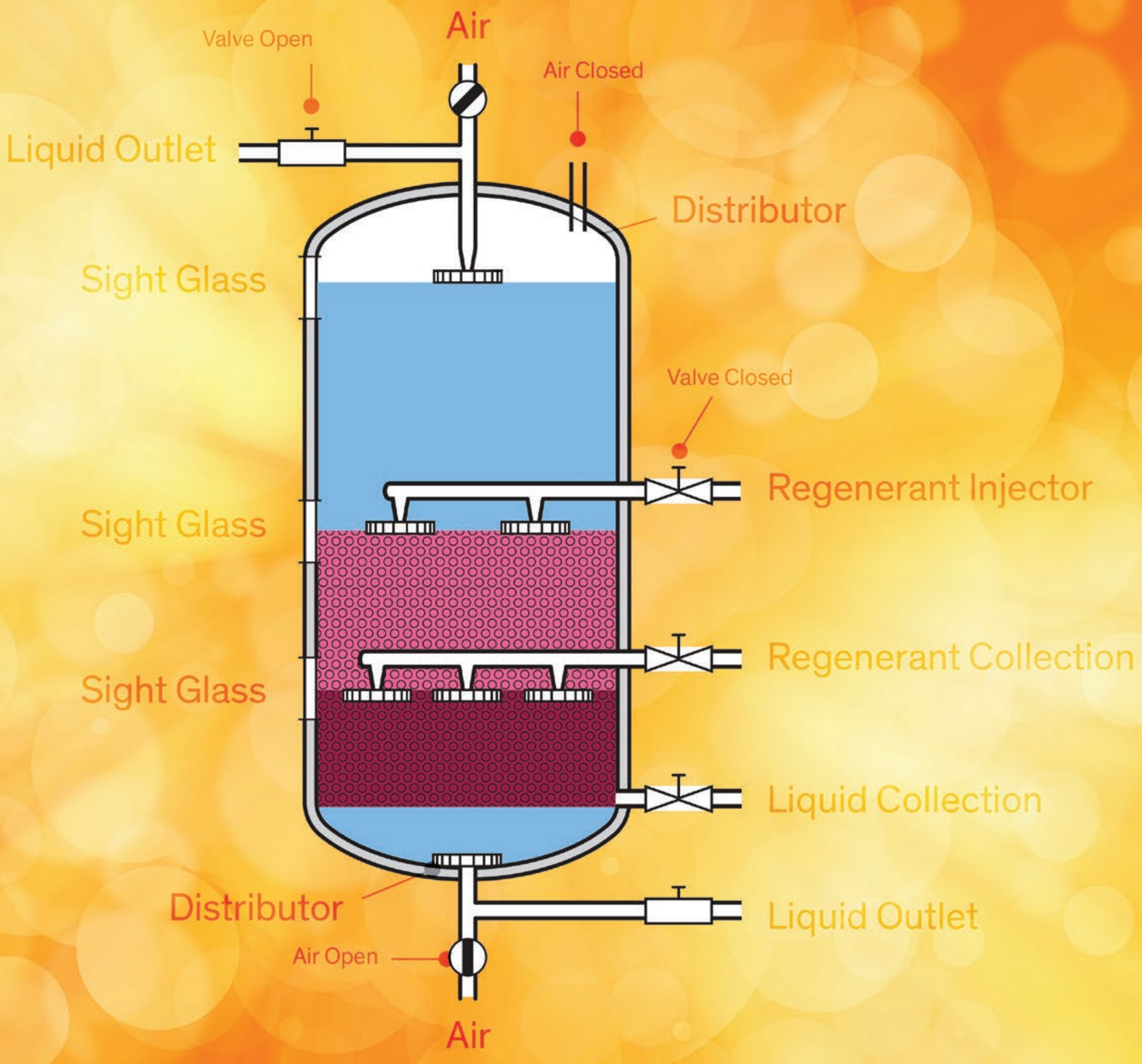
Water Solutions

Achieving Premium Performance with Uniform Particle Size Resins

AmberLite™ FP UPS Ion Exchange Resins for Sweetener Mixed Bed Polishing



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The Uniform Advantage

Pairing uniform particle size anion and cation resins for mixed bed polishing of sweetener feeds to replace typical Gaussian-distributed ion exchange resins offers several operational performance advantages.

These include:

- Reduced pressure drop
- Increased flowrates/product throughput
- More efficient regeneration profiles/reduced chemical usage
- Less fines/more efficient backwash fluidization
- Better utilization of existing equipment
- Overall operational cost reduction

Moving to uniform particle size mixed bed resins provides enhanced protection of chromatographic separation resins when staged before fractionation columns, and the ability to treat higher volumes with the same equipment footprint when staged as a final product polishing step.

AmberLite™ FP UPS Resins

DuPont consistently offers:

- **Reliability** – capital investment in worldwide production facilities to supply increasing global demand and offer leading quality, global service, and support.
- **Value** – products designed for applications that help lower operating costs and increase throughput, yield, and product quality.
- **Innovation** – R&D focused on delivering innovative products to maximize plant performance.

Advantages of Uniform Particle Size

Size and Distribution

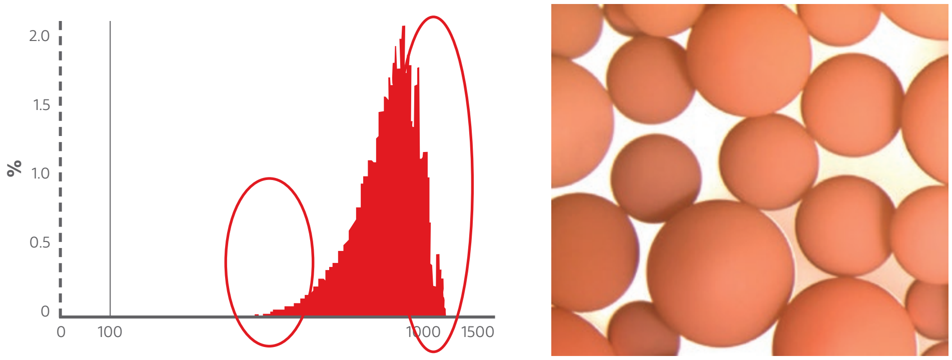
The technology for the manufacture of ion exchange resins has changed little since the development of the first synthetic styrene-divinylbenzene resins in the 1940s. The production of resins in a stirred reactor results in the formation of resin beads with a polydispersed particle size distribution. To overcome the disadvantages of a polydispersed bead distribution and to help provide products to meet increasingly demanding applications, these resins had to be graded and screened.

With our introduction of uniform particle size resins in the 1980s, improved resin performance has enabled exceptional application practices to be developed. Uniform particle size resins offer improved performance over conventional resins in a number of application areas, including high fructose corn syrup (HFCS) deashing, chromatography, and mixed bed polishing.

Figure 1 shows the difference in particle size distribution between AmberLite™ FPA22 OH Ion Exchange Resin, a Gaussian type, and AmberLite™ FPA22 UPS OH Ion Exchange Resin, a uniform particle size product. The AmberLite™ FPA22 UPS OH resin displays a high degree of bead size uniformity with 98% of the beads within a ± 50 µm of the mean diameter.

AmberLite™ FPA22 OH Strong Base Anion Resin

Total count	27455
Mean	760.8 microns
Standard deviation	157.5 microns
Coefficient of variance	22.02%
Harmonic mean	716.5 microns
Mode	833.7 microns
Skewness	-0.03
10%	531.3 microns
25%	648.6 microns
50%	773.6 microns
75%	881.3 microns
90%	970.4 microns
Percent of total	100.0%



AmberLite™ FPA22 UPS OH Strong Base Anion Resin

Total count	28347
Mean	652.7 microns
Standard deviation	37.5 microns
Coefficient of variance	5.75%
Harmonic mean	650.4 microns
Mode	659.1 microns
Skewness	0.24
10%	626.9 microns
25%	643.4 microns
50%	653.7 microns
75%	661.3 microns
90%	668.4 microns
Percent of total	100.0%

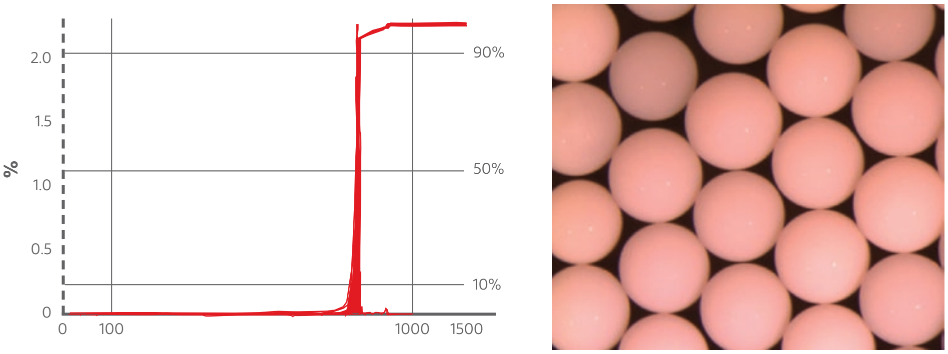


Figure 1: Comparison of particle size distribution and microphotographs for conventional (AmberLite™ FPA22 OH) and uniform (AmberLite™ FPA22 UPS OH) Ion Exchange Resins.

Advantages of Uniform Particle Size

Ion Exchange Kinetics

One of the major factors controlling ion exchange kinetics is the diffusion time required for the equilibrium of ions between liquid and solid phases. The transfer of ions is diffusion controlled and described by the Fick equation.* This equation summarizes the random motion that controls the net migration or flux of molecules in a system that has variability in concentration, temperature, pressure, etc. For a gradient in concentration, C, with respect to the distance in and out of a resin bead, x, the mass flux of solute per unit area, J, is given by Fick's first law:

$$J = -D \frac{dC}{dx}$$

For mixed bed polishing resins, the ionic load is presented to the resins in the form of a water/sugar solution.

By reducing overall bead size and tightening bead uniformity within the resin bed, the resin kinetics are improved in both the sweetening-on of the feed and the ionic loading of the resin. Similarly, the sweetening-off of the sugars from the resin bed and the regeneration of bound ionic materials are enhanced with the reduction of bead size and tightening of bead uniformity. The potential advantages of the small beads in a Gaussian distribution are not realized, due to the presence of kinetically slower larger beads. Figure 2 illustrates how resin particle size influences the mass transfer of materials in and out of a resin bead.

There are three basic steps to consider:

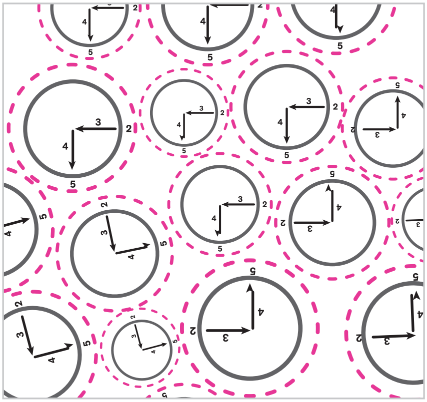
1. Ion/sugar transfer from the bulk of the solution to the static boundary layer (film) surrounding the resin bead. This process is independent of the size of the beads.

2. Ion/sugar transfer through the film to the bead surface. The rate of this film diffusion process is a function of 1/r (where r is the bead radius). With smaller resin beads, the total surface area is proportionately larger and the film diffusion rate is increased.

3. Ion/sugar transfer within the bead. The rate of this particle diffusion process is a function of $1/r^2$. In the regeneration phase, the increased ion concentration in the solution increases the diffusion rate through the film, and solute diffusion through the bead then becomes the limiting factor. Smaller resin beads have a shorter path within the solid phase and the particle diffusion rate is increased, Figure 2.

The overall kinetics are determined by the summation of the dwell times in and out of the beads, with the longest dwell times being impacted by the largest particle size beads.

Gaussian Particle Sized Beads



Uniform Particle Sized Beads

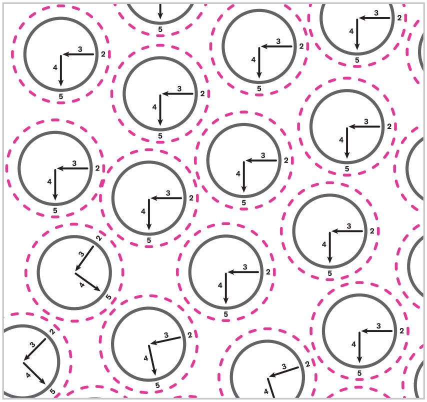


Figure 2: Mass transfer in and out of ion exchange resins.

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* *Fick, Ann. Phys Leipzig, 170 (1855) 59.*

Process Technology

Simplified Corn Sweetener Refining Process

A typical high fructose corn syrup (HFCS) process diagram is shown in Figure 3. Here, corn is milled down and enzymatically digested with α-amylase and glucoamylase to yield a slurry of dextrose and residual solids. This slurry is filtered, decolorized, and deashed to produce a liquid dextrose intermediate, from which crystalline dextrose can be prepared after chromatographic enrichment.

Further processing the deashed glucose, glucose isomerase converts 42 – 46% of the dextrose into fructose, and a second deashing step removes salts which are added as cofactors for the isomerase. A chromatographic separator (typically a simulated moving bed) is used to enrich the fructose to 75 – 95%. The enriched fructose is either crystallized or blended back with 42% fructose to yield 55% high fructose corn syrup.

As shown in Figure 3, mixed bed (MB) polishing operations applied in sweetener applications are typically staged as a secondary purification step. The process can be used after fructose deashing to protect the chromatography resins, and/or as a finishing step for 42% fructose, and after the blend step before finishing to 55% HFCS.

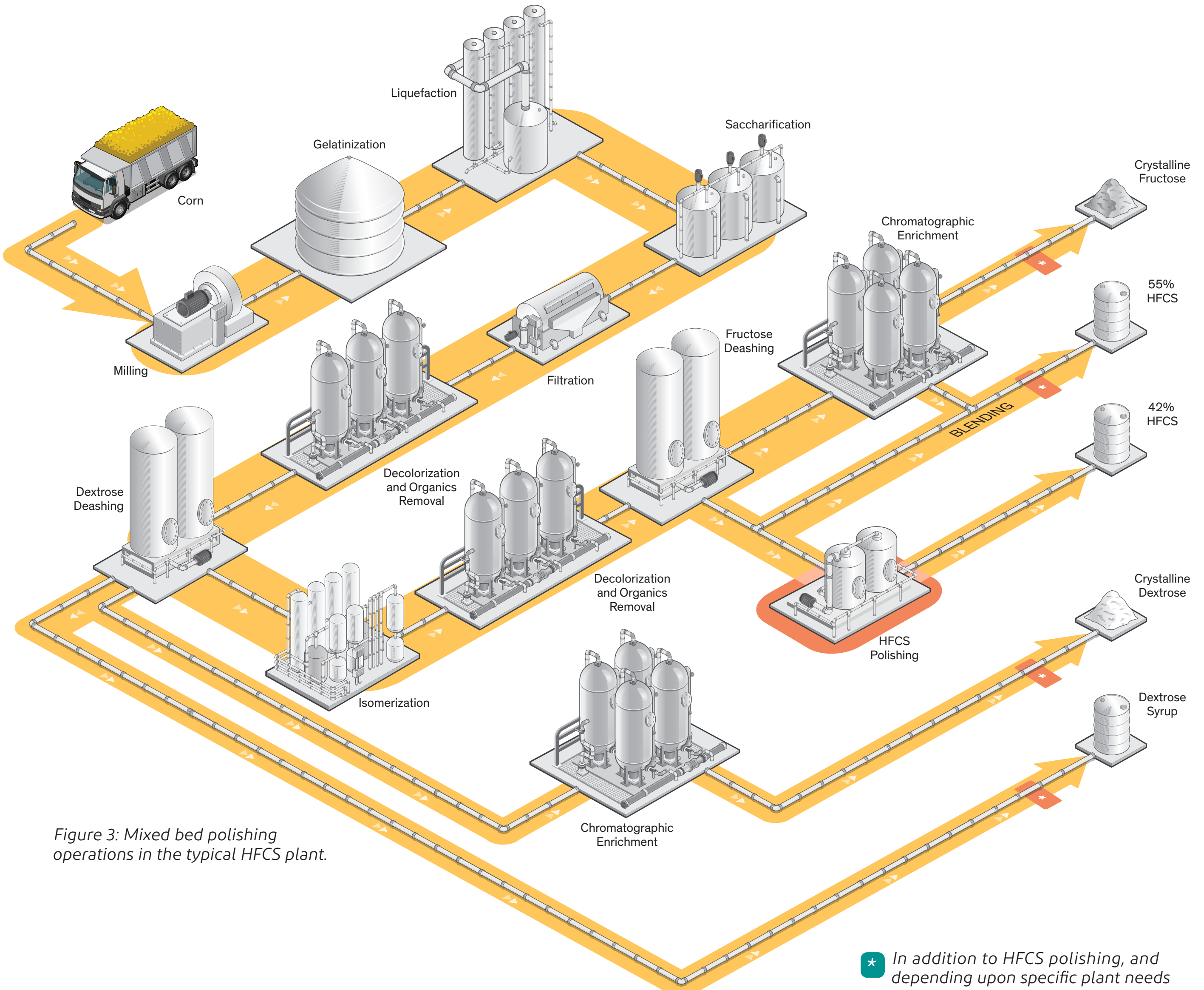


Figure 3: Mixed bed polishing operations in the typical HFCS plant.

* *In addition to HFCS polishing, and depending upon specific plant needs and final products being manufactured, mixed bed polishing can be employed at various stages to improve product quality.*

Process Technology

Mixed Bed Overview – How it Works

In a well-combined mixture of a macroporous strong acid cation resin and a macroporous N,N-dimethylethanolamine (DMEA), Type II strong base anion resin, syrup can be deashed to very low levels—below 0.5 μS/cm conductivity or in the 0.2 ppm ash (as NaCl) level. Figure 4 shows how beads of a mixed bed can split and hold an ionized salt, returning water to the feed.

In combination with very efficient deashing, a mixed bed polisher can reduce or eliminate hard-to-remove components, including color and color precursors such as 5-hydroxy-2-methyl furfural (HMF), 2-(2-hydroxyacetyl) furan (HAF), and proteins. Control and removal of organic color bodies, or organics that can produce color body formation upon storage of a sweetener, are critical for the quality and market value of the processed product. The anion side of the mixed bed also promotes the removal of organic acids and other solutes that may destabilize syrups upon storage (i.e., trace benzene sulfonic acid from cation resin degradation over time).

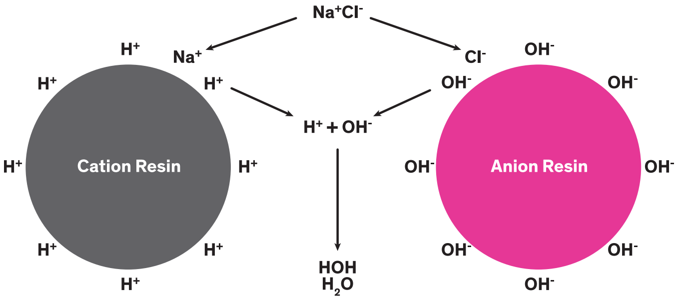


Figure 4: Salt splitting and retention of NaCl by mixed cation/anion resins.

Precautions and System Balance

Although Type II strong base anion resins do not produce as strong a bond as Type I anion resins, in mixed bed systems they regenerate more easily requiring less chemicals and time. One drawback of the Type II anion chemistry is the lower thermal stability as compared to either a Type I strong base anion or weak base anion chemistry. In water, the recommended upper temperature limit for a Type II anion resin in the hydroxide form is 35°C (95°F) during caustic regeneration; with an upper limit of 46°C (115°F) for the resin in syrup feed operation.

Care must be taken to match the ionic exchange capacity of the strong acid and strong base resins in a mixed bed polishing system, as the cation resins have a higher capacity per unit volume. Typically a volume-to-volume blend of 60% anion to 40% cation is employed, and this facilitates the resin blend to keep a stable pH for the processed syrup.

If the pH of the feed drops too low, fructose can convert to unwanted HMF, and if the feed has an elevated pH, fructose can convert to psicose, Figure 5. To limit the amount of fructose loss in a mixed bed operation, the velocity of the syrup is kept high enough to minimize the contact time with the anion without affecting the kinetics of the exchange on the resins. Utilizing uniform particle size resins typically yields lower pressure drop that allows the mixed bed systems to be run at high flowrates.

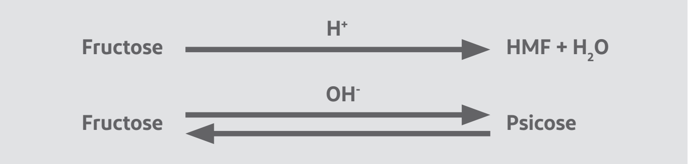


Figure 5: Potential fructose byproducts.

If the pH of the feed drops too low, dextrose can convert to mannose, and if the feed has an elevated pH, dextrose can convert to fructose, Figure 6.

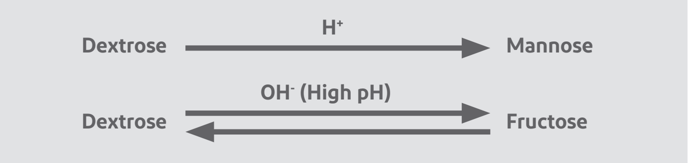


Figure 6: Potential dextrose byproducts.

Efficiency and Regeneration

Mixed bed polishing of sugar feed with Gaussian, macroporous resins is a well-established unit operation across the industry. Particle size, density, and size distribution can impact the effectiveness of a mixed bed polisher. A review of the history of macroporous type mixed bed resin performance shows inherent differences in settling velocity between the anion and cation resin particles. The key requirement in this mixed bed operation is the ability to both mix and separate the anion and cation resins employed in the system. The hydraulics of the system used to fluidize, lift, and settle the resin, combined with particle size and distribution and bead density, variably impact the efficiency of Gaussian systems.

Process Technology

In preparation for regeneration, the mixed bed is reclassified by bed expansion and fluidization, followed by well-controlled settling with cation resin on the bottom. The higher uniformity of both resins in a uniform particle size mixed bed contributes to superior control. The better the separation of the resin layers, with less resin mixing at the interface, the better the regeneration efficiency. If the cation and anion beads are not completely separated, cross contamination from the regenerant chemicals can occur as the wrong bead type interacts with the regenerant. Once back in operation the mis-regenerated beads can leak ions into the syrup stream being processed, resulting in poorer quality product and/or shorter production cycles, as well as less efficient utilization of regenerant chemicals.

General Process Flow

To produce a heat-stable product with consistent high quality and low ash, a bed of homogeneously mixed anion and cation exchange resins is used to polish the syrup. Equipment and controls for mixed bed systems are more complex than for typical deashing systems. A mixed bed requires a system plumbed with a set of four distributors at different heights, piping that allows for both co-current and counter-current liquids and air, and sight glasses at key locations to monitor the distributors, particularly the regenerant injector and collector ports.

Figure 7A shows a schematic of a mixed bed polisher system, as settled with the cation on the lower portion of the bed and anion portion layered above. Figure 7B is the legend for mixed bed schematic drawings in this publication. Of special note for mixed bed systems is the need to have enough freeboard space in the vessel to sufficiently expand the resin bed, in order to completely separate the anion from the cation resin in the fluidized state.

Since the resins are well mixed within a single column system during the syrup service, the regeneration of a cation/anion mixed bed is more complicated than the regeneration of a split bed system. As with a typical deashing operation, once the syrup reaches an operational specification, as monitored and measured by conductivity, pH, color or a combination thereof, the syrup feed is stopped and the bed is switched to a water feed to push out the remaining syrup.

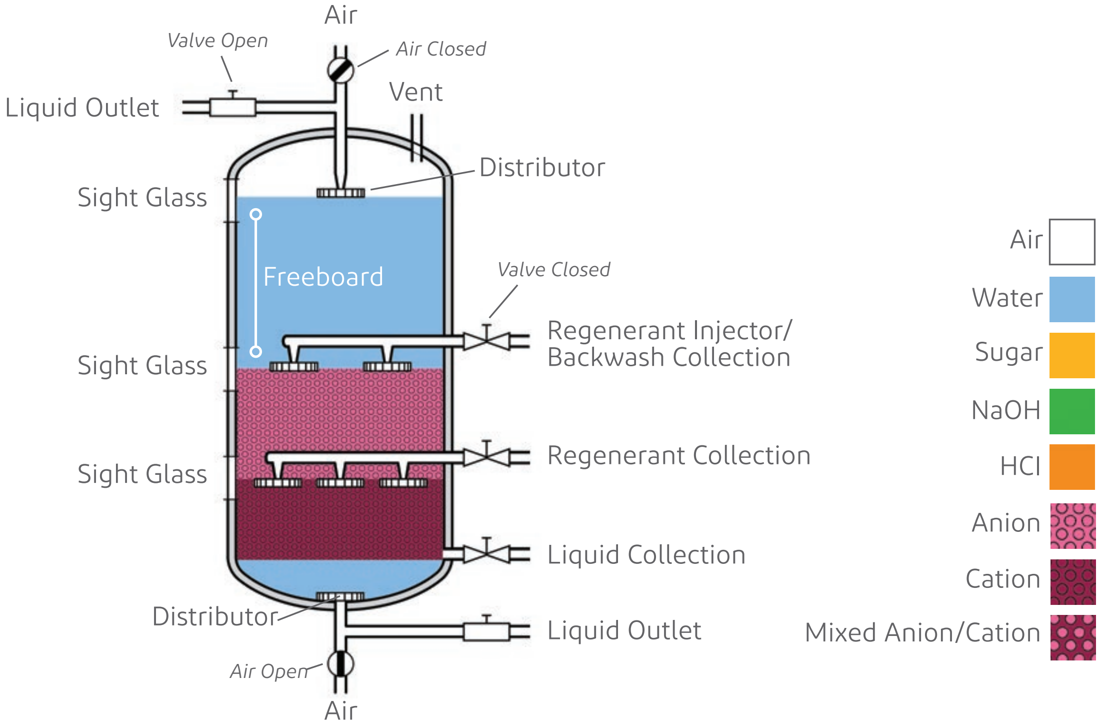


Figure 7: A: Schematic of a generic mixed bed polisher B: Legend for mixed bed column drawings.

Details of a Mixed Bed Polisher Operation

Operational Sequence for a Sweetener Mixed Bed Polisher

Bed Ready: Resins are fully regenerated, rinsed, mixed, and settled. Resin is packed in place with high-quality water and is ready to process syrup feeds, Figure 8.

Sweetening-On: Syrup is fed through the top distributor to displace the water in the freeboard space; water → sweetwater → processed syrup exits the bottom distributor. Typical feed concentrations are 30 – 55% dissolved solids (DS) with the feed pushing out the bulk water, mixing as sweetwater and finally as purified syrup, Figure 9.

Service Flow: Syrup is fed into the top distributor with syrup throughout, and the “processed” syrup exits the bottom distributor; syrup enters and higher quality syrup is produced, Figure 10.

Sweetening-Off: As with a typical deashing operation, once the resin reaches a low-level breakthrough of conductivity/pH/color to maintain quality, the syrup feed is stopped and the bed is switched to water feed to push the excess syrup through the interstitial void volume of the resin bed. Softened water or cooled condensate is fed through the top distributor to displace the syrup out of the piping, resin, and column. This is the reverse of sweetening-on, with water pumped in and syrup, sweetwater, and water out, Figure 11. On the initial displacement with water, a flow of full-strength syrup is exiting the bed. During this step, the output is taken as usable product. Then the residual feed in the column is diluted, producing a lower concentration of syrup “sweetwater” (possibly with salts and some contaminants); sweetwater may or may not be recycled depending on the operational practice. Finally, the dissolved solids/sugar concentration in the sweetwater drops below a fraction of a percent or so; this will be sent to waste or plant recycle. After the bulk of the sweetwater has eluted, the resin bed continues to be washed with water to remove residual sugar.

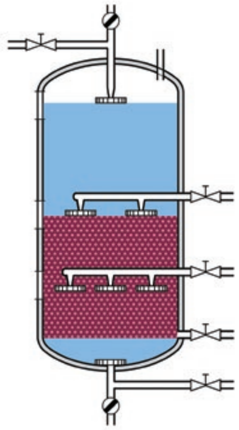


Figure 8: Bed Ready

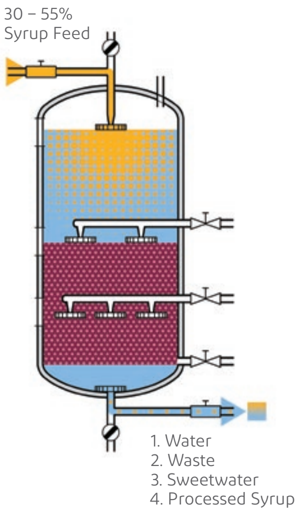


Figure 9: Sweetening-On

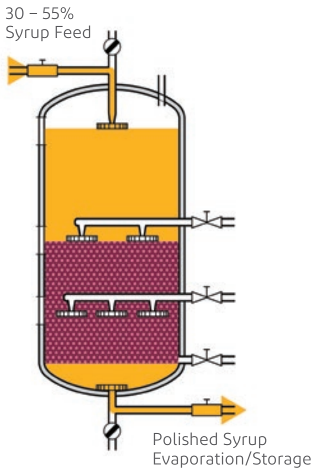


Figure 10: Service Flow

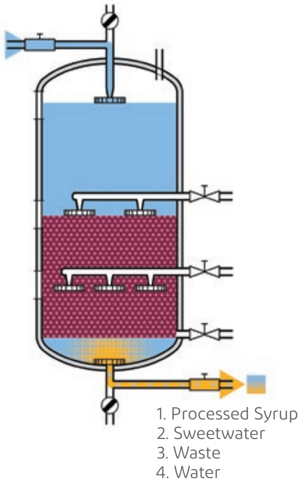


Figure 11: Sweetening-Off

Details of a Mixed Bed Polisher Operation

Blowdown (mixed resin): Pressurized air is fed through the top distributor. The water in the freeboard space between the top feed distributor and the backwash collector is displaced by pushing the water down through the resin bed, Figure 12.

Backwash: Process water is passed upflow from the bottom of the vessel through the bed of mixed anion and cation resin to achieve fluidization. The resin bed rises into the freeboard space of the vessel, Figure 13. At this point the very fine particulates from the feed or broken resin fines can be backwashed out of the bed through the top distributor (refer to the specific resin product data sheets to determine the appropriate flowrate).

Separation (partial): Once the upflow process water completely fluidizes the resin, the mixed beads will begin to classify. The mixed resins are allowed to separate into two distinct layers based upon the density differences between the anion resin (lighter) and cation resin (heavier). Any additional smaller particulates from the feed or broken resin fines can be backwashed out of the bed through the top distributor at this stage, Figure 14.

Separation (complete): Once the fluidized classification of the resins is complete, the anion beads form the top layer and the cation beads form the bottom layer. At this point, the middle lateral should align with the resin interface as observed through the vessel sight glass, Figure 15.

Regeneration Caustic: The regeneration is initiated with dilute caustic (typically, 4% NaOH) pumped from the feed distributor above the anion resin bed through the anion beads and out the interface distributor/collector (middle lateral). To facilitate complete regeneration and optimized chemical utilization rates, the regeneration of the anion resin is typically started first. To help prevent unwanted caustic from leaking into the cation resin, DI water is simultaneously pumped upflow from the bottom distributor (water block), Figure 16.

Regeneration Caustic/Acid: The cation resin bed is regenerated with hydrochloric acid (7% HCl) from the bottom distributor, passing upflow through the packed cation resin. Simultaneously, dilute caustic moving downflow is applied to continue the regeneration of the anion resin. The combined regenerant chemicals and eluant byproducts of proteins, color bodies, salts, etc., are pumped out the distributor between the interface of the anion and cation resins (middle lateral), Figure 17.

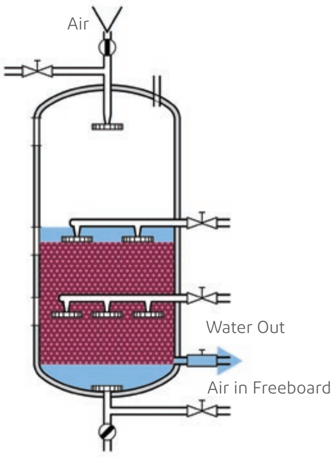


Figure 12: Blowdown (mixed resin)

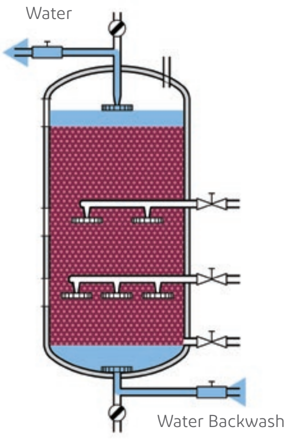


Figure 13: Backwash

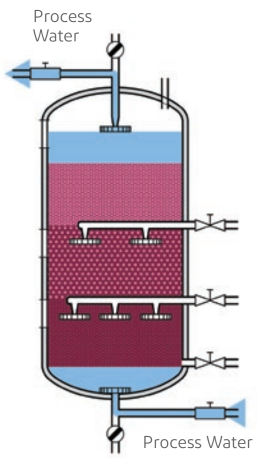


Figure 14: Separation (partial)

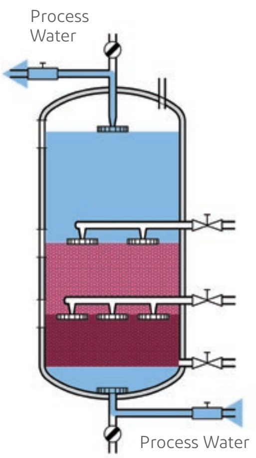


Figure 15: Separation (complete)

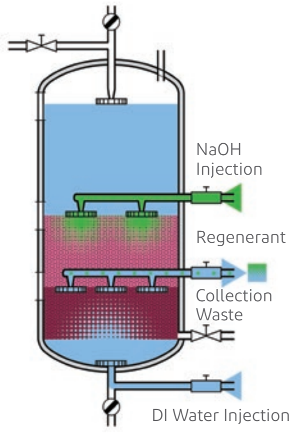


Figure 16: Regeneration Caustic

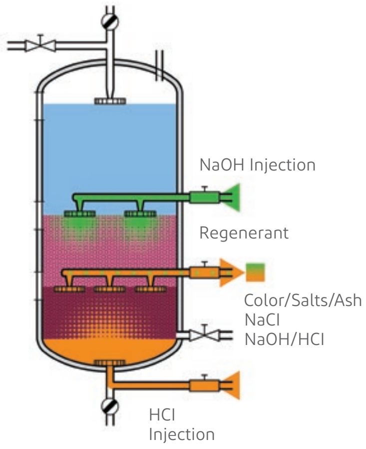


Figure 17: Regeneration Caustic/Acid

Details of a Mixed Bed Polisher Operation

Slow Rinse: DI water is fed simultaneously through the top and bottom distributors. The water passes downward through the anion resin and upward through the cation resin. This rinse water displaces the regenerant chemicals from the resins, exiting through the distributor between the resins (middle lateral), Figure 18.

Fast Rinse: DI water is fed simultaneously through the top and bottom distributors at a faster flowrate to continue the rinse of resin beds. Due to the higher volume of anion resin, fast rinse helps drive the final wash of the anion, Figure 19.

Blowdown (layered bed): Pressurized air enters the top distributor (top lateral) of the vessel and pushes the water in the freeboard space through the resin until the liquid level reaches the distributor found just above the resin bed. This lessens resin loss out the vent nozzle and top distributor during backwash fluidization and resin mixing, Figure 20.

Resin Bed Fluidization and Mixing: Air and water are co-fed through the bottom distributor, flowing up through the separated resin bed to lift, churn, and mix the resins into the freeboard space of the column. The air is vented out of the column while the water's hydraulic force fluidizes the resin bed, such that the churning air bubbles effectively mix the resin, Figure 21.

Air Mix: Once the bed is fully fluidized and mixed, the backflow water is slowed/stopped. The resin bed is kept from separating by continued air mixing as the resin bed settles back in the column, Figure 22.

Air Drain Down: To better settle the well-mixed bed, air is introduced upflow while water is drained off through either the bottom or an interface distributor (or both), allowing the mixed resin to settle into the lower portion of the vessel, Figure 23. Care must be taken to drop the water level close to the top portion of the bed.

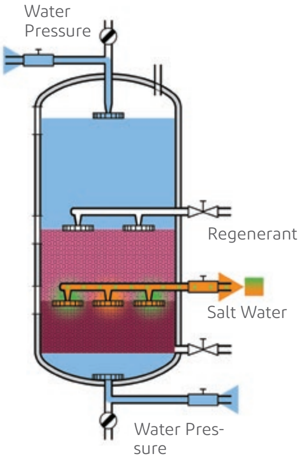


Figure 18: Slow Rinse

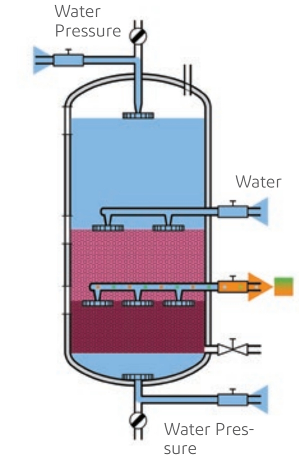


Figure 19: Fast Rinse

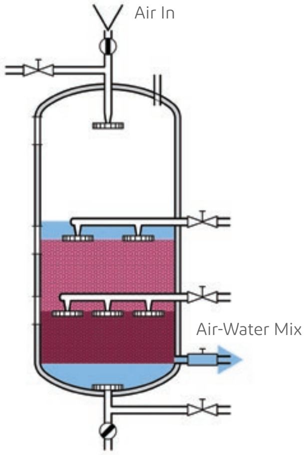


Figure 20: Blowdown (layered bed)

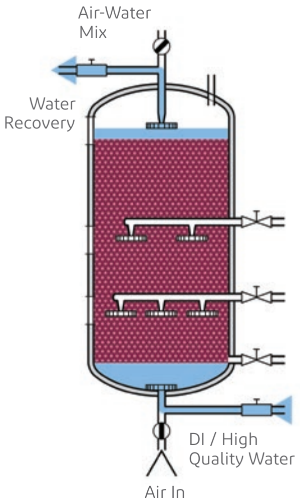


Figure 21: Resin Bed Fluidization and Mixing

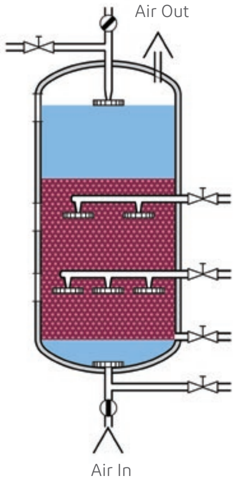


Figure 22: Air Mix

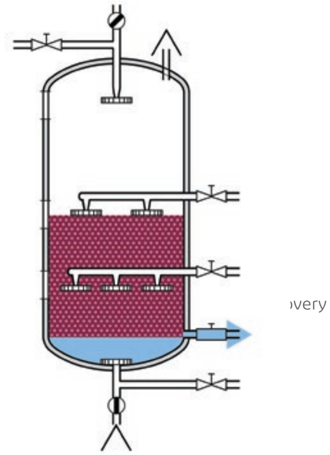


Figure 23: Air Drain Down

Details of a Mixed Bed Polisher Operation

Water Fill of Mixed Bed: DI water enters or is pumped from the top distributor to fill the resin bed. The air is vented out until the freeboard is completely filled with water, Figure 24.

Service Rinse: DI water is pushed from the top distributor and out through the bottom distributor, rinsing the resin. The rinse is continued until the conductivity is below the desired level, typically 1 μS/cm, Figure 25.

Service Rinse Recirculation: Once the targeted conductivity is achieved in the wash through service water, a recycling water wash can be used to help: 1) assure quality and 2) reduce total DI water usage, Figure 26. At the completion of this step the resin bed and vessel system is back to the Bed Ready status (refer to Figure 8 on page 9) and the process can begin again.

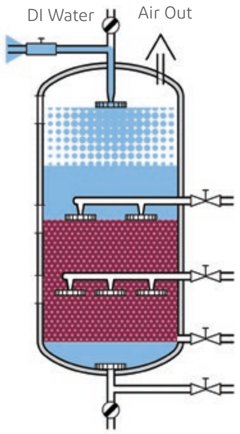


Figure 24: Water Fill of Mixed Bed

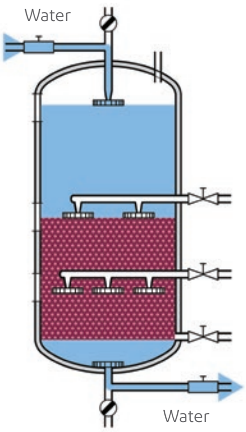


Figure 25: Service Rinse

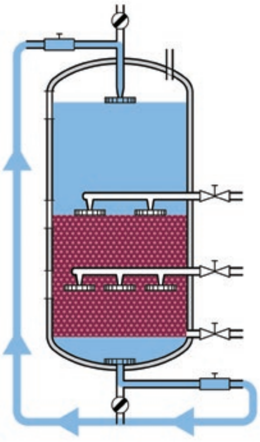


Figure 26: Service Rinse Recirculation

Details of a Mixed Bed Polisher Operation

Loading Mixed Bed Vessels

Resins for mixed beds used in sugar applications are not supplied pre-mixed but rather as individual anion and cation components. It is critical that the proper amount of cation is loaded, such that the interface layer between the anion and cation resins lines up with the interface collecting distributor between the two resins when the bed is separated.

Each plant may have specific requirements, but the following steps may be considered as a general guideline for loading resin into a mixed bed system. This procedure is intended for equipment which is internally regenerated, with an interface collector between the cation and anion layers.

1. **Before loading the resins, make a detailed inspection of the empty vessel:**
    - Remove all debris, previous resins, or any foreign material that may be present.
    - Clean out distributors and collectors, and inspect all laterals for damage or plugging.
    - Inspect the vessel rubber lining for integrity, and perform a spark test if possible.
    - Whenever possible, check the pressure loss of the empty vessel at nominal flowrate (case of *in situ* regeneration) and observe the flow patterns for uniformity.
2. **Loading of the resins:**
    - Fill vessel with sufficient water (~ 1/3 vessel height) to allow for settling and avoid resin damage.
    - Load cation resin to around 5 cm (2 in) below final desired level.
    - Backwash cation at 12 – 15 m/h (5 – 6 gpm/ft^2) for 30 minutes.
    - Settle and drain water from bed to 5 – 10 cm (2 – 4 in) above resin surface, and fill remaining cation resin up to the level of the central collector if in H^+ form, or 3 – 5 cm (1 – 2 in) below if in Na^+ form. Carry out a second backwash for 10 minutes and settle. Ensure that the resin surface is even and at the correct level.
    - With 1 m (3 ft) of water above the cation resin, load anion resin. Backwash at 5 m/h (2 gpm/ft^2) for 5 minutes.
    - If anion resin is in Cl^- form, or if the cation resin is in Na^+ form, carry out a double regeneration on both resin components.
    - Rinse resins with flow from top and bottom, with removal of rinse water through the central collector, for 30 minutes.
    - Reduce water level to around 5 cm (2 in) above the resin bed and air mix for 15 – 20 minutes.
    - Check anion resin levels and top-off with additional resin if necessary.

    An alternative loading option would be to load the set volumes of the anion and cation resins in a holding tank partially filled with water, where the resin mixture can be both pre-washed and pre-mixed to assure well rinsed, mixed resin with minimal clumping. Once the desired conductivity and/or pH is met, the pre-mixed resin can be pumped to the mixed bed vessel. Once settled, the resin is ready for the initial sweetening-on with process feed.
3. **Start-up operation:**
    - Start, run, and monitor rinse-down until the specified conductivity and/or pH is achieved.

    NOTE: If the required water quality is not reached, resin clumping and channeling may be present. To eliminate this, the mixed bed should be water rinsed for a minimum of 5 hours, followed by a 15-minute air mix, and a backwash to optimize resin mixing.
4. **Check resin levels periodically:**

    In a mixed bed system the resins are regenerated simultaneously, therefore it is critical that the correct cation resin volume is maintained in the bed. This can be accomplished by a periodic inspection of the anion/cation interface once the resin bed has been reclassified, completely separated, and settled in the bed (refer to Figure 15 on page 10). If resin add-backs of either anion or cation are required these can be done just prior to the bed fluidization and mixing step (refer to Figure 21 on page 11) so that the added resin is mixed into the resin bed.

Resin Technology

DuPont Mixed Bed Resins for Sweetener Applications

DuPont offers two options for mixed bed polishing: A traditional Gaussian mixture of AmberLite™ FPC88MB H Strong Acid Cation (SAC) Resin with AmberLite™ FPA22 OH Strong Base Anion (SBA) Resin, and a uniform particle size mixture of AmberLite™ FPC88 UPS H SAC Resin and AmberLite™ FPA22 UPS OH SBA Resin. Table 1 compares the mixed bed resin options.

Varied bead densities are the key factor for resin separation in a fluidized state. For a given mixed bed cation/anion resin pair the key "must-have" variable is the differentiated density between the heavier cation resins, which settles faster than the lighter anion resin after a bed has been completely fluidized.

While bead densities are the key factor for resin separation in a fluidized state, bead size and particle size distribution also play an important role in the terminal settling velocity of the mixed resins. This is particularly critical for the upper layer (anion resin). If there is a high population of fines in the anion layer, they can plug and/or be washed through the top distributor during the backwash operation. In addition, fines increase pressure drop concerns for the operation. If there are high populations of over-sized anion beads they have the tendency to impede the resin classification process both in the backwash fluidization step and during settling of the bed into well-separated layers around the regenerant collector distributer.

Caustic Soda (NaOH)	Hydrochloric Acid (HCl)
100% Basis	Grade: Technical
< 1200 ppm NaCl	28% (18° Bé) HCl
< 3000 ppm Na_2CO_3	< 100 ppm Fe
< 30 ppm $NaClO_3$	< 100 ppm organics as O_2 consumed
< 10 ppm Fe	< 5 ppm oxidants as Cl_2
< 2000 ppm Na_2SO_4	< 4000 ppm sulfate
< 100 ppm SiO_2	

Table 3: Recommended quality of regenerants for mixed bed resins.

General Operating Conditions

A generalized starting point of mixed bed set-up and operations for strong acid cation and strong base anion resins is summarized in Table 2. The recommended quality of regenerant chemicals for mixed bed resins is shown in

Mixed Bed Polishing Resins	Total Exchange Capacity (eq/L)	Water Retention (%)	Particle Size Range (µm)	Density Range (g/mL)	Best For
Gaussian					
AmberLite™ FPC88MB H	1.7	46 – 56	300 – 1200	1.19 – 1.26	Standard
AmberLite™ FPA22 OH	1.2 (Cl^- form)	48 – 56 (Cl^- form)	300 – 1200	1.07 – 1.10	Standard
Uniform Particle Size					
AmberLite™ FPC88 UPS H	1.7	46 – 56	500 – 600	1.19 – 1.26	Higher Throughput
AmberLite™ FPA22 UPS OH	1.1 (Cl^- form)	48 – 58 (Cl^- form)	600 – 700	1.07 – 1.10	Higher Throughput

Table 1: Mixed bed resins offered for polishing applications. (When longer shelf-life is required, Na-form cation resins and Cl-form anion resins are also available.)

Operation	Strong Acid Cation (H)	Strong Base Type II Anion (OH)
Maximum Service Temperature	Limited by the anion resin	46°C (115°F)
Minimum Bed Depth	1 m (39 in)	1 m (39 in)
Volume Fraction	40%	60%
Service Flowrate	2 – 4 BV/h	2 – 4 BV/h
Regenerant Type	7% HCl	4% NaOH
Regenerant Level (1)	6 – 7 lb/ft^3 (96 – 112 g/L)	4 – 5 lb/ft^3 (80 – 96 g/L)
Regenerant Flowrate	2 BV/h	2 BV/h
Slow Rinse Volume	3 BV or to conductivity	3 BV or to conductivity
Slow Flowrate	2 BV/h	2 BV/h

Table 2: Recommended operational starting points for mixed bed polisher resins. Note(1): Assuming a minimum 90% equipment efficiency.

Resin Technology

Table 3. Striving to complete regeneration of both the anion and the cation resins, particularly at their interface, is key for mixed bed resin systems. When working with mixed bed polishers for the regeneration of the anion side, the application of caustic soda/sodium hydroxide (NaOH) is preferred and highly recommended over soda ash (Na_2CO_3).

The Uniform Particle Size Resin Advantage

DuPont's uniform particle size technology gives polishing resins exceptional performance. This uniformity helps to:

- Provide uniform diffusion of sweetener feeds, water, and regeneration chemicals in and out of each bead at the same rate, producing a sharper wave front that reduces early breakthrough of color and salts
- Produce less sweetwater
- Utilize regeneration chemicals more efficiently, permitting a lower chemical dose
- Achieve a sharper separation between resins before regeneration that minimizes cation/anion cross-contamination
- Reduce fines in the anion resin layer, which helps decrease plugging and/or resin washout at the top distributor when the beds are fully fluidized during backwash, while reducing pressure drop concerns during syrup service

All of these advantages lead toward increased flowrates/product throughput and better utilization of existing equipment, therefore reducing mixed bed operating costs.

Pressure Drop and Backwash

Pressure drop is a key process consideration when selecting a resin. In general, pressure drop is inversely proportional to the square of the resin bead diameter. Other factors, such as bead crosslinking level and rigidity, also influence pressure drop.

Advantages in reduced pressure drop when moving from Gaussian particle size distribution AmberLite™ FPA22 OH Ion Exchange Resin to uniform particle size AmberLite™ FPA22 UPS OH Ion Exchange Resin are shown in Figure 27. Comparing the Gaussian particle size resin pair of AmberLite™ FPA22 OH and AmberLite™ FPC88MB H Ion Exchange Resins against the uniform particle size resin pair of AmberLite™ FPA22 UPS OH and AmberLite™ FPC88 UPS H Ion Exchange Resins in a typical 60/40 volume mixed bed resin blend, the AmberLite™ FP UPS resin pair shows a clear advantage in terms of pressure drop as measured in a 50% DS (dry substance) sugar feed.

Backwash expansion for fluidizing resins in a mixed bed system is important for both separating the anion and cation components prior to regeneration and during the resin mixing steps. Figure 28 compares backwash expansion plots for Gaussian AmberLite™ FPA22 OH and uniform particle size AmberLite™ FPA22 UPS OH Ion Exchange Resins as measured in water. Although particle density is the dominant factor for bed fluidization by backwash, slight improvement of expansion can be seen for the uniform particle size AmberLite™ FPA22 UPS OH resin.

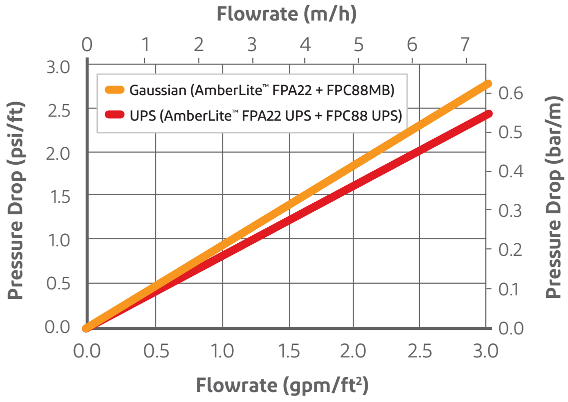


Figure 27: Comparative pressure drop for Gaussian and uniform particle size mixed beds.

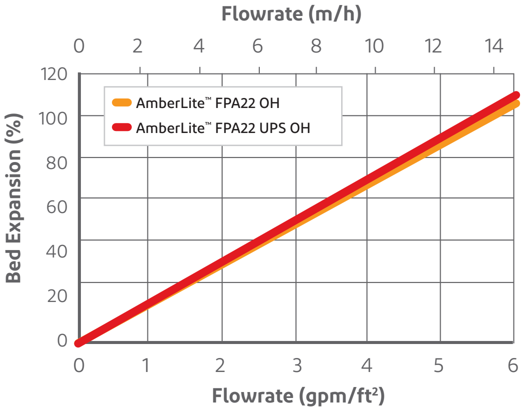
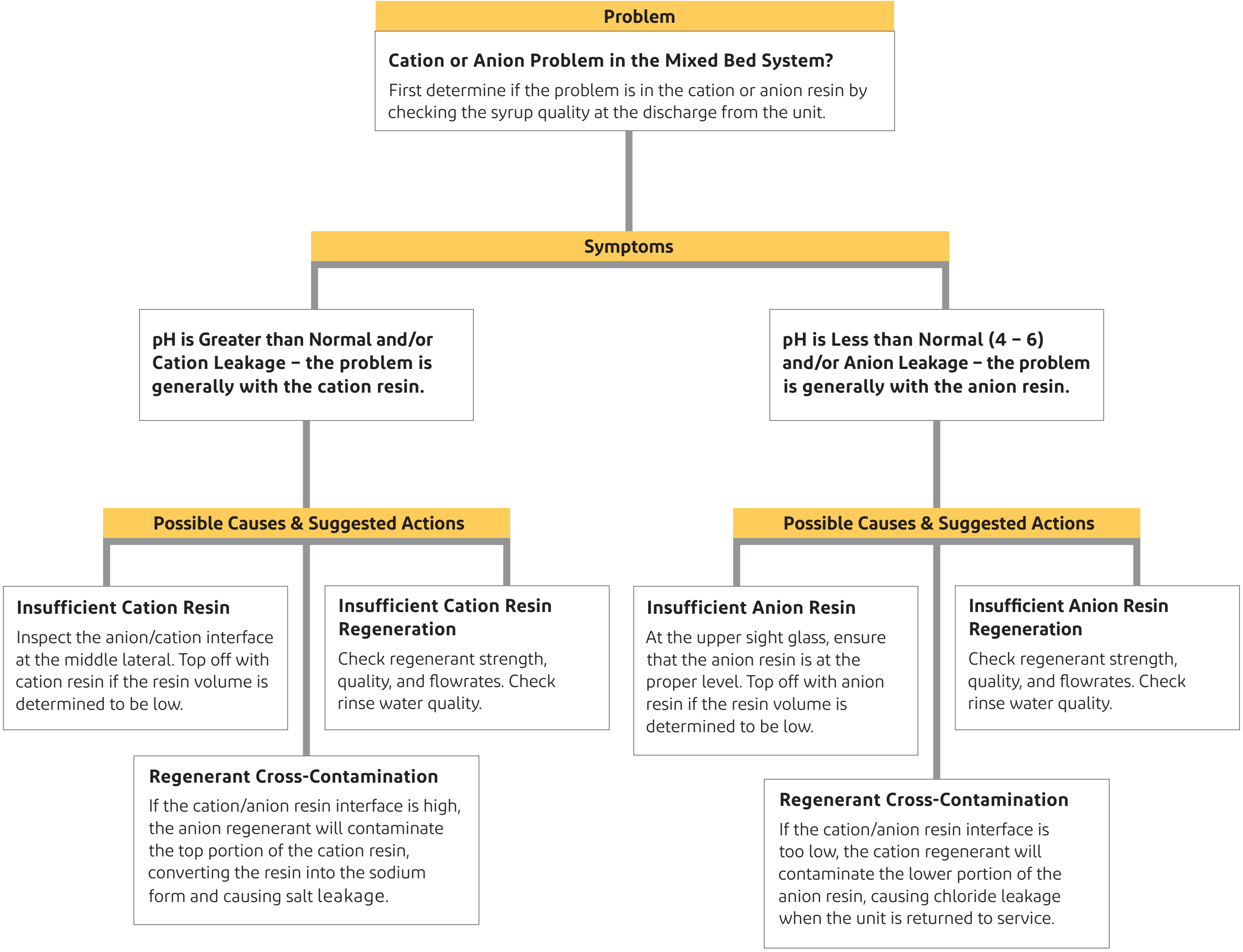


Figure 28: Overlaid backwash expansion plots for AmberLite™ FPA22 OH and AmberLite™ FPA22 UPS OH Ion Exchange Resins

Maintaining Mixed Bed Performance

Troubleshooting for Mixed Bed Polishing Systems

The following troubleshooting and corrective action flowchart can help determine the cause of problems which can arise in mixed bed polishing systems. Abrupt problems are those that occur within a few minutes, hours, days, or even weeks. These problems are distinguished from the gradual decrease in unit performance that results from normal resin aging and occurs over much longer periods of time (several months to a year). Figure 29 suggests some key troubleshooting considerations for mixed bed polisher resins. Please contact a DuPont representative for more troubleshooting assistance if needed.



Problem

Cation or Anion Problem in the Mixed Bed System?
First determine if the problem is in the cation or anion resin by checking the syrup quality at the discharge from the unit.

Symptoms

pH is Greater than Normal and/or Cation Leakage – the problem is generally with the cation resin.

Possible Causes & Suggested Actions

Insufficient Cation Resin
Inspect the anion/cation interface at the middle lateral. Top off with cation resin if the resin volume is determined to be low.

Insufficient Cation Resin Regeneration
Check regenerant strength, quality, and flowrates. Check rinse water quality.

Regenerant Cross-Contamination
If the cation/anion resin interface is high, the anion regenerant will contaminate the top portion of the cation resin, converting the resin into the sodium form and causing salt leakage.

pH is Less than Normal (4 – 6) and/or Anion Leakage – the problem is generally with the anion resin.

Possible Causes & Suggested Actions

Insufficient Anion Resin
At the upper sight glass, ensure that the anion resin is at the proper level. Top off with anion resin if the resin volume is determined to be low.

Insufficient Anion Resin Regeneration
Check regenerant strength, quality, and flowrates. Check rinse water quality.

Regenerant Cross-Contamination
If the cation/anion resin interface is too low, the cation regenerant will contaminate the lower portion of the anion resin, causing chloride leakage when the unit is returned to service.

Figure 29: Troubleshooting mixed bed polisher resins.

Maintaining Mixed Bed Performance

Controlling Microbiological Growth

In polisher systems, the upper temperature limit is dictated by the thermal stability of the Type II anion resin chemistry and the stability of the sugar being processed. Mixed bed systems are normally maintained below 46°C (115°F). While not as hot as many other operations in a typical sweetener plant, the elevated temperatures help keep viscosity and pressure drop down. The lower working temperatures of mixed beds are not as effective in keeping microbial growth in check as the 60°C (140°F) temperatures seen in deashing or chromatography steps.

Frequent chemical regeneration helps control microbial growth. The upper anion chamber and top distributor is a space that needs particular attention due to the introduction of air and available surface area for microbial growth. Whether on a routine or as-needed basis, the upper portion and top distributor should be treated with 4% caustic, either by washing through the top distributor, and/or by pumping from the anion regenerant distributor, allowing it to flow up and exit out the top distributor.

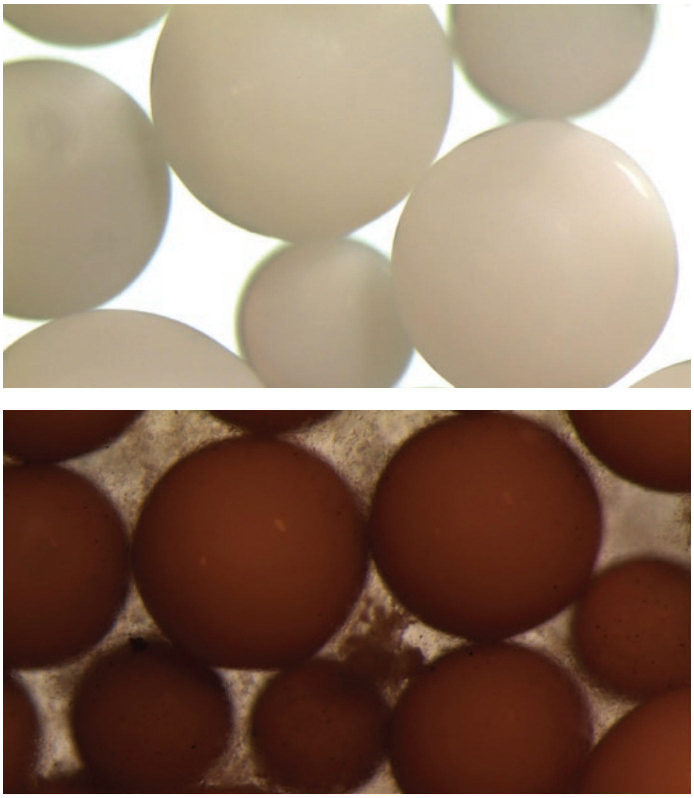


Figure 30: Macroporous, strong base anion AmberLite™ FPA22 OH Ion Exchange Resin: New (top) vs. fouled with microbial growth (bottom).

Reference and Contact Information

DuPont System Optimization Services℠ (SOS)

Working with DuPont is easy and convenient. Whenever you choose DuPont resins, you get expert support from DuPont ion exchange technical service and development teams.

For more involved issues, DuPont offers a full range of DuPont System Optimization Services℠ (SOS) to help you achieve optimal performance from your resin, system, and plant operations. SOS Services℠ place our extensive knowledge and experience at your disposal. These services can complement your R&D innovation team, lighten the burden of your system start-up and staff training, and support the ongoing operation and maintenance of your system.

Contact DuPont SOS Services℠

Sample Requests

Small orders of DuPont ion exchange resins, polymeric adsorbents, chelating resins, and copolymers can be ordered online through the Octochem website.

Request a Sample Online

Resin Properties and Product Data Sheets

The most current information on DuPont resins and related products for nutrition applications, including resin properties and product data sheets, is found on our website at: dupont.com/water

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