Ion Exchange Part 3: Tips for Loading and Unloading IX Resins

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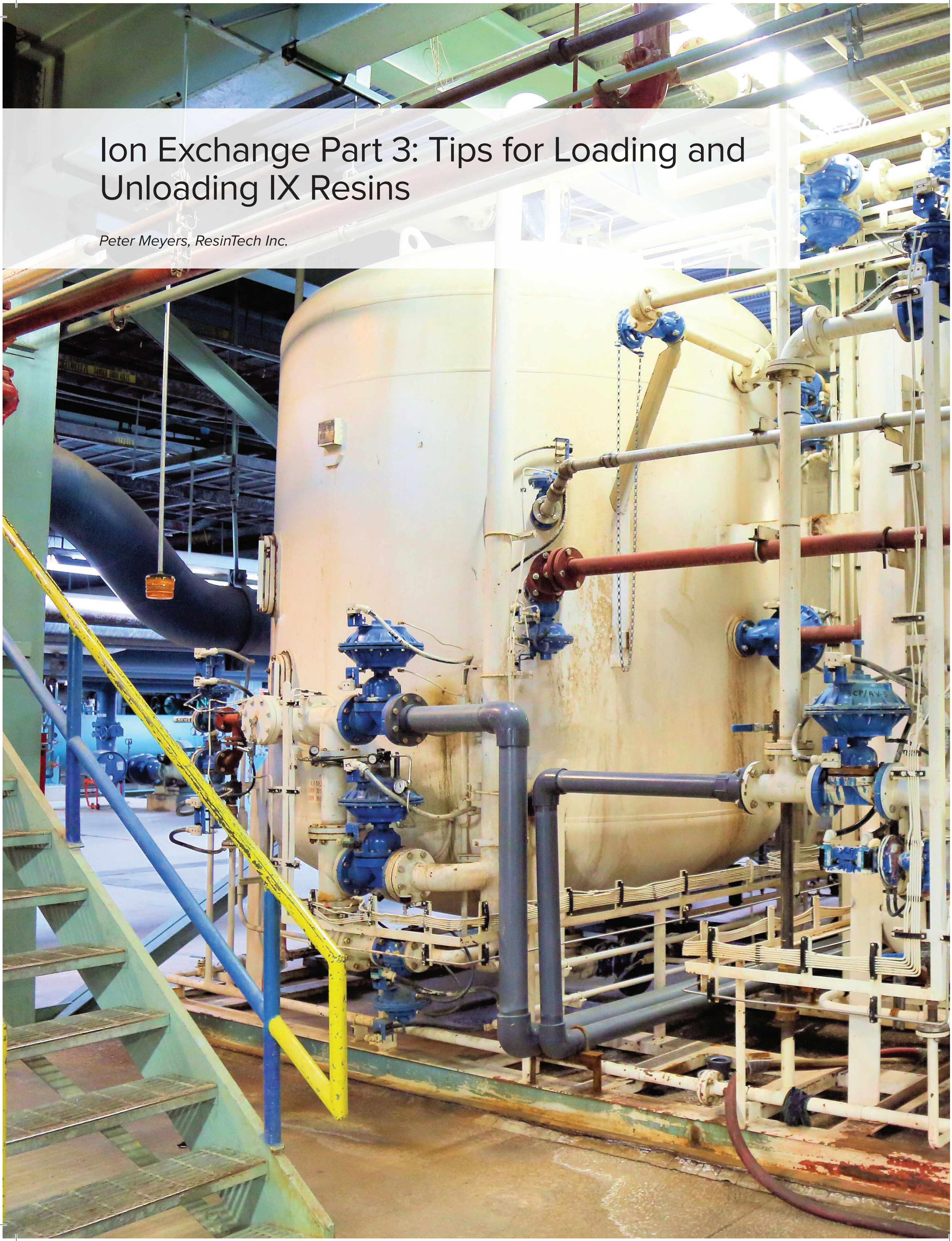


Note: This article is Part 3 of a series on various aspects of how ion exchange (IX) resins are used. Not the actual applications mind you, but the physical aspects of touching resins, feeling them, and caring for them. This part covers loading and unloading of resins, including how much to load and how to unload.

How Much Resin to Load?

IX resins shrink and swell, depending on their ionic form and the ionic strength of the solution they contact. Resins also swell or shrink in solutions other than water. In vessels that are completely full of resin, such as packed beds, the swelling must be taken into account; otherwise, it is all too likely the resin will crush itself as it tries to swell but can't.

It is beyond the scope of this discussion to list every resin and every ionic form from every resin manufacturer. However, Table 1, which shows relative volume changes for various resins, can be used as a guideline.

Table 1: Relative volume changes for different resins.

Relative size	*Gel WAC*	*Macro WAC*	*6% gel SAC*	*8% gel SAC*	*10% gel SAC*	*Macro SAC*
Sodium	1.9	1.6	1.0	1.0	1.0	1.0
Hydrogen	1.0	1.0	1.1	1.08	1.07	1.05
Calcium	1.3	1.2	.93	.94	.95	.96
Potassium	1.6	1.4	.95	.97	.98	.98

	Type 1 Gel SBA	*Type 1 Macro SBA*	*Type II SBA*	*Acrylic SBA*	*Macro WBA*	*Acrylic WBA*
Chloride	1.0	1.0	1.0	1.0	1.25	1.2
Hydroxide	1.25	1.25	1.1	1.2	1.0	1.0
Sulfate	1.03	1.02	1.01	1.02	1.30	1.25
Nitrate	.95	.96	.98	.95	1.2	1.2

Notes:
WAC = weakly acidic cation
SAC = strongly acidic cation
SBA = strongly basic anion
WBA = weakly basic anion

Please note that in Table 1, the shaded cells represent the customary reference form for various resins. Swelling is based on 100% of the stated ionic form. For resins that are partly in one form and partly in another, use the ratio of the ionic form(s) times the swelling. For other types of resins not listed here, consult a resin manufacturer's product data sheets for swelling characteristics.

Freeboard Requirements

Freeboard is defined as the empty space above the resin. Freeboard allows the water flow to spread out before it reaches the resin and helps prevent turbulence that can cause resin fluidization and consequent physical damage due to erosion. Freeboard also provides rising space to the resin can fluidize during backwash, allowing suspended solids trapped in the resin to be purged. Figures 1 through 4 show illustrations of freeboard and other spaces in various types of IX vessels. As noted in this section, the amount of allowed freeboard space will depend on the type of IX resin being loaded in the vessel.

Figure 1: Example of freeboard space in a co-flow IX vessel.

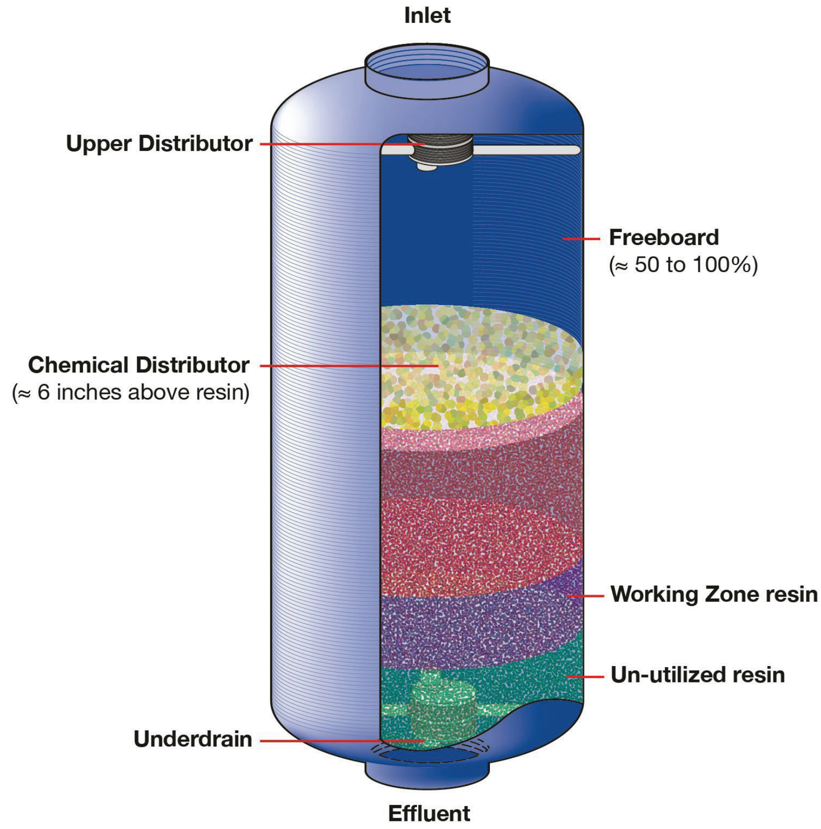


Figure 2: Example of freeboard space in a split-flow IX vessel.

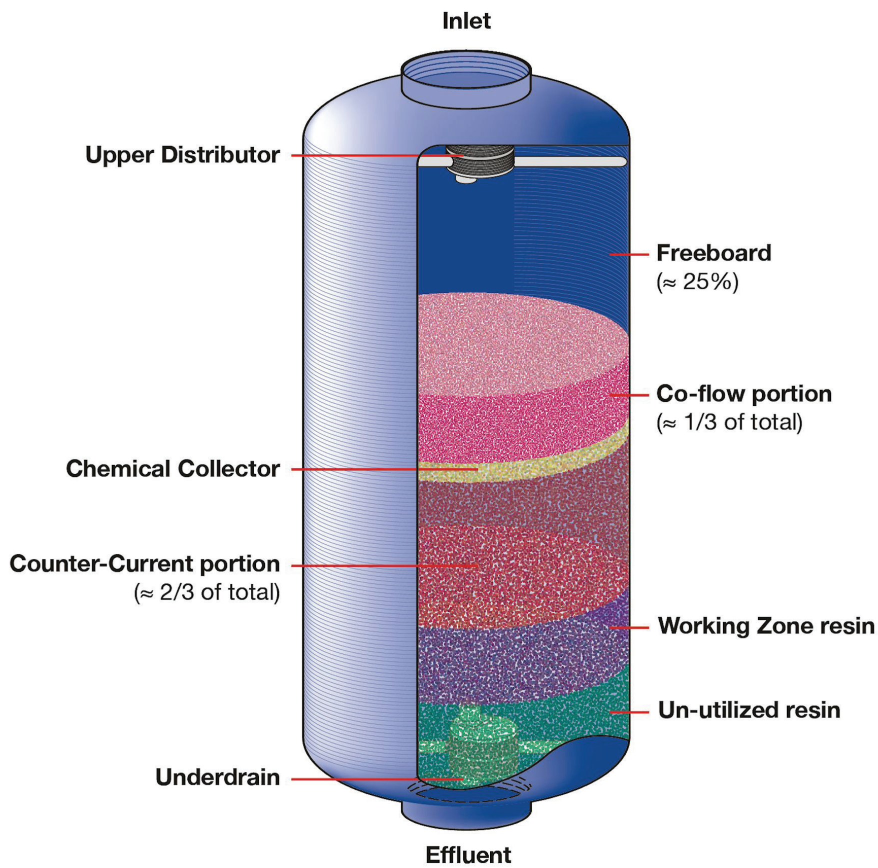


Figure 3: Example of freeboard space in a counter-current IX vessel (air block or water block).

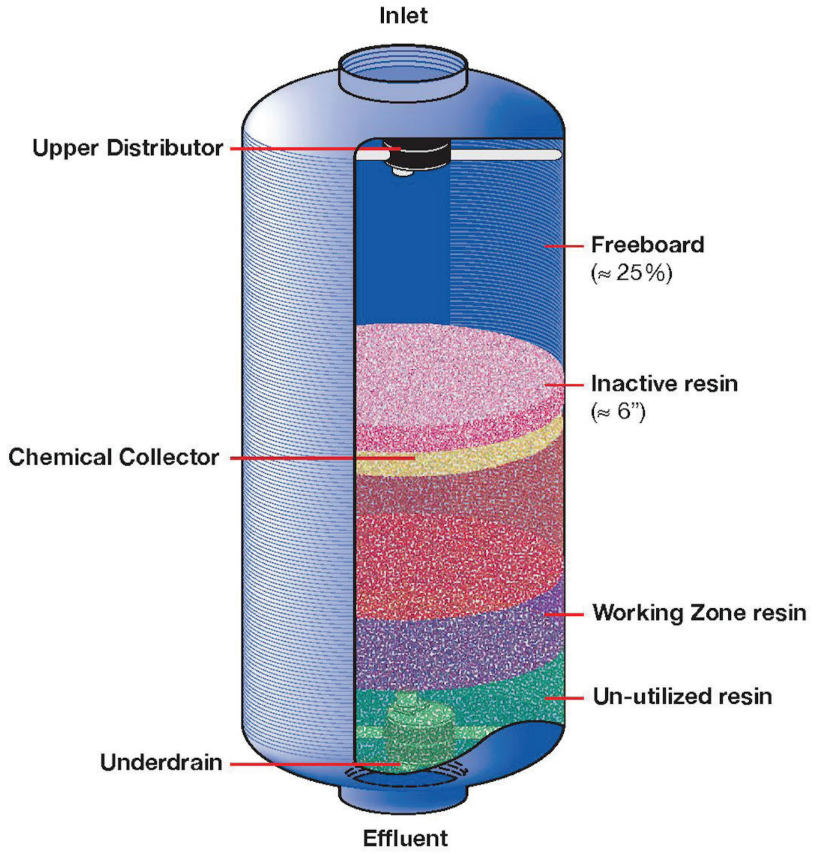
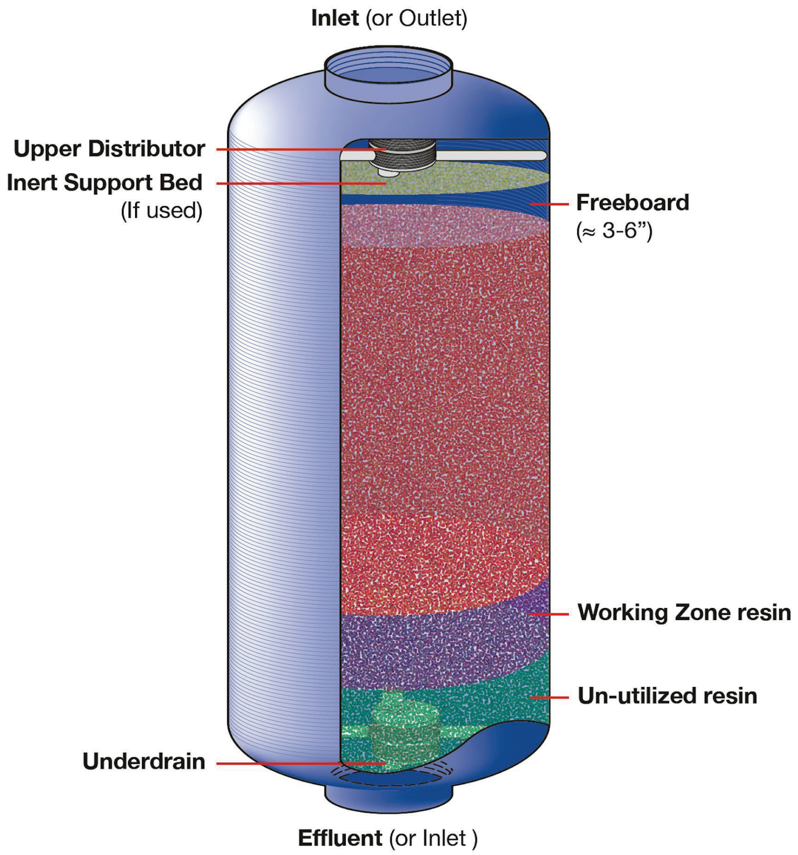


Figure 4: Example of freeboard space in a packed-bed IX vessel.



Here are some general guidelines on freeboard in IX systems:

1. For vessels where regeneration is not performed in the vessel, allow for a minimum of 3 to 6 inches freeboard, based on the most swollen form.

2. For co-flow regenerated vessels that do not have chemical distributors:
   a. Strongly acidic cation (SAC)-type cation resins— two-thirds full.
   b. Weakly acidic cation (WAC) type cation resin and all anion resins— half full.

3. For co-flow regenerated vessels that have separate chemical distributors:
   a. Cation resins 6 inches or more below the acid distributor.
   b. Anion resins 9 inches or more below the caustic distributor.

4. For countercurrent regenerated vessels with blocking flow and chemical collectors: resin 6 to 9 inches above the chemical collector.

5. For split-flow vessels with chemical collectors: follow resin manufactures advice (most splits are one-half top/bottom but some are one-third).

6. For packed beds:
   a. Cation units 1 to 3 inches freeboard in the most swollen form.
   b. Anion units 3 to 6 inches freeboard in the most swollen form.

Loading Packed Beds

Freeboard in packed beds is critical. Too much freeboard allows resin movement and results in excessive fines forming because of erosion, especially in up-flow service packed beds. Too little freeboard and the resin swells, filling the open space and crushes itself. One way to overcome this is to load the swollen form of resin (hydrogen form for SAC resins and hydroxide form for strongly basic anion [SBA] resins). In these cases, the resin can be loaded until the packed bed is essentially full.

When exhausted (shrunken) forms of resin are loaded into packed beds, it is suggested to deliberately underfill; run a regeneration (or two) then remeasure the bed height, and add or remove resin if necessary.

Loading Floating Inert Resin

The floating inert resins used in packed beds are usually granular and because their density is less than water, they are especially difficult to load. This can be further complicated if the location of the resin inlet is not at the highest possible point on the vessel. Use a high ratio of water to inert media and keep the water level low. Be patient.

Loading Layered Beds

Layered beds have two different types of resin in them that are expected to stay separate during use. In most cases, layered beds use either two types of anion resin (weak and strong) or two types of cation resin (again weak and strong). There is very little density difference and even when the bead size is carefully controlled so that the weak resin is smaller than the strong resin; it is still difficult to keep the two types from mixing.

Load the strong resin first. Backwash to remove fines and level the bed. Add 12 inches or more of water on top of the strong resin as a cushion. Add the weak resin slowly to minimize turbulence.

Loading Mixed Beds

Loading mixed beds is similar to loading layered beds, except it is not quite as important to prevent mixing and is crucially important to rinse the cation resin before adding the anion resin.

In these cases, load the cation resin first. If it is supplied in the salt form (usually sodium), the resin should be regenerated before adding the anion resin. After loading the cation resin, rinse it thoroughly until any trace of colored water is gone. This is very important because that color throw is well known to poison anion resin. The cation resin level (in the hydrogen form) should be above the interface collector. Drain the tank, open it up and remove any resin above the interface collector (by vacuum or scoop). This procedure removes any cation fines and ensures the resin interface is correctly positioned with respect to the interface collector. Mark the cation level on the outside of the tank next to the viewport.

Add the anion resin. If the anion resin is supplied in the hydroxide form it may be loaded to approximately 6 inches below the caustic distributor, or for smaller tanks where caustic is introduced from the top of the vessel, so that the mixed-bed tank is approximately half-full. For anion resin supplied in the chloride form, load proportionally less (see percent-swelling table presented earlier in this discussion). Regenerate the anion resin. It is OK to regenerate the cation resin again, but if not it is necessary to keep the acid dilution water flowing upward through the cation resin to prevent the caustic from sinking down and potentially exhausting the cation resin with sodium.

It is best not to mix the resin until after both resins have been regenerated. New mixed-bed resins tend to clump and this can make it difficult to separate them, especially when they are in their regenerated (hydrogen and hydroxide) forms.

Loading Resins for Use With Non-Water Liquids

There are several added precautions for resins used with liquids other than water. It is essential to rinse out any organic leachables, especially if the liquid is juice or wine or sugar. For these applications, the resin should be "reverse cycled" before use. Reverse cycling would be acid, followed by caustic, followed by acid for cation resins, caustic, followed by acid, followed by caustic for anion resins. The acid/base cycling purges the resin of leachables that might otherwise add unwanted color or taste to the product.

The water used for loading and regenerating should be drained out before the non-water solution is introduced. This prevents excessive dilution of the product. It should be understood that since resins are approximately 50% water by weight and shrink in most non-water solutions that some water will be squeezed out of the resin and some dilution of the initial bed volume of product is inevitable.

Unloading Resin

Unloading a tank can be as simple as opening up a resin outlet valve to as complicated as building a scaffold and temporary containment with the hazmat team overseeing every step of the process. Since circumstances dictate requirements, it is not possible to cover every eventuality. However, aside from the hoses and possibly other hardware needed to remove the resin, there are a few common things that need to be considered.

Wastewater Discharge

During the unloading process, excess water must be drained from the resin. In most cases, water can drain to the floor or building sump. If the resin was used in the hydrogen or hydroxide form and was not exhausted before removal, the interstitial water can have low or high pH (typically around pH 3 for H form cation resin and pH 11 for OH form anion resin). In cases where the resin has been used to remove some hazardous contaminant, there may be restrictions on discharge because of the presence of that contaminant in the unloading water. In these cases, containment or other means of controlling, limiting, and treating wastewater discharges should be provided.

Dewatering

Dewatering of sacks is generally fairly easy, as most sacks will drip drain. Drums, totes, and tanks require a dewatering device. A simple and reasonably simple dewatering device can be made from a shop vac and sock.* The sock is tied or taped to a pipe that is attached to the suction hose. The sock end of the pipe is pushed down to the bottom of the resin. Excess water is then sucked out. Totes and tanks can be set up with a dewatering strainer in advance to simplify the process and minimize contact with hazardous resin.

**Note: The term "sock" is meant to describe a suitable cloth cylinder, closed off at one end and securely fastened to the pipe at the other such that there are no gaps or spaces larger than 0.5 millimeter (mm). Yes, a cotton dress sock may be a convenient option. Just make sure they are reasonably new and without holes.*

Unloading Strategies

There are a variety of ways to get resin out of a tank. Smaller tanks can be physically lifted up and turned upside down. A hose can then be inserted into the tank to help flush out the resin. Companies that frequently unload small tanks generally make themselves a tank tipper or modify a drum tipper. If the tank is sufficiently elevated and there is a resin outlet connection located low on the tank, the resin can be drained by gravity. Pressure vessels with resin outlet connections can be drained under pressure. Tanks with only top entry can be vacuumed or siphoned. In addition, in extreme cases, resin can be manually unloaded by scoop and bucket methods, although this method is hard work.

Pressurized Flow

By far the easiest way to get resin out of a pressure vessel is if there is a resin outlet connection that is (hopefully) located at the low spot on the tank. Simply connect a hose to the outlet, apply water (and or air) pressure to the tank, and all (or at least most) of the resin will transfer out through the hose. The usual rules regarding resin transfer apply. It is generally easier to transfer resin with an air assist and a slow backwash flow.

Hint: *If there is a resin outlet connection but no valve (blind flange or plug), completely drain the vessel to solidify the resin. With the vessel drained, the connection can be opened without risk that the resin will pour out. Attach a modified fitting, valve, and hose connection. The tank must be completely drained though.*

Gravity Flow

Unloading by gravity flow is similar to unloading under pressure; there is only the difference in elevation between the liquid height in the tank and the height of the container used to receive the resin to work with. This means the bottom of the vessel has to be higher than the top of the container the resin is being unloaded into. A 3–4 foot elevation difference from the resin outlet to the top of the container receiving the resin is about the minimum needed to make a go of it. In general, it takes more time and water to unload a vessel by gravity flow than by pressurized flow.

Tank Tipping

Tank tipping is similar to drum tipping and is a fast, convenient way to unload smaller tanks. Simply turn the tank so the top points downward into the unloading container, open the top, and stick a hose (or pipe) in the tank to flush out the resin. Tipping tanks manually can be rather problematic. Consider that if a 9-inch diameter tank full of resin and water weighs approximately 110 pounds, considerably more weight than one person should be lifting by themselves. For occasional unloading, tanks can be laid down on their side and lifted with a forklift. For routine unloading, it is best to make a tank tipper.

Eductor Syphons

The same eductor syphon setup that can be used to load resin can also be used to unload resin. Eductors are simple to set up and use. However, they do require substantial water pressure (60+ pounds per square inch gauge [psig] is recommended) and cannot suck higher than about 10 feet nor discharge higher than about 15 feet above their suction point. They also use quite a lot of water compared to other methods. Permanent eductor setups often collect the spent motive water and reuse it (this requires repumping).

Vacuums and Vacuum Trucks

Resin can be vacuumed out of a vessel by means of a vacuum truck or permanent vacuum set up. Shop vacs are generally not strong enough for this purpose. Vacuum trucks can be a convenient and fast way to unload resin. However, this method is not recommended if the resin is going to be put back into the tank at a later date, unless the vacuum truck is carefully cleaned out prior to use.

Unloading Pumps

The same types of pumps used to load resin can also be used to unload resin. The air diaphragm type is possibly best suited, although submersible pumps with recessed impeller can be lowered down into a tank and used to remove resin.

Unloading Concerns

Damage to internal distribution systems. When unloading a tank by inserting a pump, suction pipe, or hose, it is important to be aware of and careful with the internal distribution systems. Larger tanks often have chemical distributors or collectors that partially or fully block access to the resin below. It is all too easy to damage these internals when inserting or removing pipes, hoses, or pumps from a vessel.

In some cases it is necessary to partially disassemble internal distribution systems to allow access. For older systems, especially those with plastic internals, there is significant risk of breakage, as older plastic distribution systems become increasingly brittle with age.

Getting all the resin out of a tank can be a difficult process, especially if the underdrain is up above the bottom of the tank and the resin outlet (if present) is well above the bottom of the resin bed. Vessels that have manways on the lower side shell make final cleanout reasonably easy. Open the manway and suck the last traces of resin out into a shop vac. For vessels that do not have a lower manway, a vacuum or air diaphragm pump connected to a long suction pipe can be used (with the understanding to be careful not to damage the internals). If all else fails, it may be necessary to enter the tank for final clean out. Due care regarding confined spaces should be taken before entering a tank as this can be a major safety risk.

Is it necessary to take the extra time to remove the last traces of resin? Hmmm. If the resin being removed is still in reasonably good condition, probably not. But if the resin is chemically damaged or physically fouled, leaving more than traces of the old resin behind can lead to contamination of the new resin and issues with poor performance. For ultrapure water systems, there should be no question, for best results get in there and remove every single resin bead.

Support Beds and Subfills

Subfills and support beds are usually gravel or anthracite and are more difficult to remove than resin. Eductors and pumps are generally not suitable for removing support beds. Vacuums work. Unfortunately, for large tanks, manual unloading of support beds and subfills is sometimes the only pragmatic way.

Is it necessary to replace the support bed every time the resin is replaced? If the support bed is reasonably clean and free of mud or other suspended solids it may not be necessary to remove it.

Closure

This discussion about loading and unloading IX resins is Part 3 of an article series describing the physical aspects of how resins are used. Other parts include storage, moving resins from place to place, disposal, and step-by-step procedure outlines.

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