They keep going and going and going

Predicting The Operating Capacity Of Strongly Basic Anion Resins From Static Laboratory Tests.

By Michael Gottlieb, Published in Water Conditioning & Purification Magazine, May 1997

Whether you use deionization as a water purification method in a bottling plant, a car wash or chemical formulation for electroplating, pharmaceutical or photographic operations, the recommended life of your anion resins has often been based on a "magic" number for a singular application rather than varied performance under alternative applications.

The truth is that the "standard" static capacity or years of service for the resin under one application may not hold true for another, and your resins can be utilized effectively much longer under some than others. Your resin's life, therefore, should be based more on performance and quality production cost.

About resins

To predict that, you must have an understanding of resins. There are three types of anion resins: Type 1, Type 2 and weak base. Each has different characteristics. The proper choice of resin is dictated by the water analysis, resin configuration (i.e. two bed, mixed bed, etc.) and the desired results.

Different types of resin have different methods by which they degrade in use1. Weak base are the most stable while Type 1's simply lose capacity. Type 2's tend to convert from strong base to weak base with age.

Since strong base capacity is critical to the more sophisticated operations like mixed beds, any changes in strong base/weak base ratios can cause long-term capacity problems.

Predicting resin operating capacity could mean the difference between a happy or unhappy customer. Determining the capacity will help you provide an efficient, high-performance system one that will keep your customers satisfied. But this calculation can often be difficult and confusing.

The concept of calculating the operating capacity of anion resins with both weakly and strongly basic ion exchange sites was first put forth in 1986. Since that time, the technology has been developed into a comprehensive mathematical model that has been placed into a proprietary software program.

Calculating capacity: an educated guess

Prior to 1986, there was no way to calculate the capacity. Instead, rough estimates were made by using static test ratios compared with new resins of the same type. These estimates were made on the basis of either the salt splitting test capacity (strong base capacity) or the total capacity (salt splitting plus weak base capacities). Relative operating capacity guesses were made by taking the ratio of the tests for these values compared with the values for new resins of the same types.

The estimated operating capacities could be vastly different depending on which ratios were used as can be seen in Tables 1 and 2. These tables give a general estimate of the total and strong base groups for the most common types of strongly basic resins at different ages of service. At best, these methods were occasionally correct and almost always inaccurate at the comparatively low regeneration levels used outside of the portable exchange deionization (PEDI) industry (4-to-6 pounds per cubic foot).

Table 1
Typical Remaining Strong Base Capacity in Used Strong Base Resins

Resin	New	1 Year	2 Years	3 Years	4 Years
Styrene Type 1	100	83	76	75	73
Styrene Type 2	100	57-64	41-56	39-55	37-52

Table 2
Typical Remaining Total Capacity in Used Strong Base Resins

Resin	New	1 Year	2 Years	3 Years	4 Years
Styrene Type 1	100	83	76	75	73

Replacement: recommendations and reality

Typically, resin replacements were suggested based on years in service six years for Type 1s and four years for Type 2s. Or, replacement was recommended when the static capacity losses reached 25-to-35 percent of the original capacity.

Almost all anion laboratory tests include both the total strong base and weak base capacities. However, sometimes they are listed as total capacity and salt splitting capacity, in which case the weak base capacity is the difference between the two. The salt splitting capacity, or strong base capacity, is typically near 100 percent in all new strongly basic resins. Once the resin is placed in service, its functional groups degrade as a result of thermal and oxidative reactions.

Most PEDI dealers run their DI floats with average resin ages well over the six-year maximum recommended change-out frequency. It's common to hear that, despite a significant loss of strong base capacity, the resin continues to perform well. It is also common to hear just the opposite.

The performance one can expect from a resin of a given mix of strong and weakly basic capacity depends not only on the condition of the resin, but also on the type of service and water analyses. This explains why two tanks can have identical resins from the same batch of regenerated float resin yet one will perform better than the other.

Weak base sites: a different process

Weak base sites do not exchange ions like strong base sites. They work only by absorbing acid molecules meaning that, in order to work, the salts must be converted to their corresponding acids.

Not all acids are strong enough to react with the weak base sites. Chlorides and sulfates become hydrochloric and sulfuric acids in the cation exchanger and can be removed very efficiently by the weak base site. Bicarbonate and carbonate alkalinity break down to carbon dioxide as they pass through the cation resin. This, in turn, becomes carbonic acid which, like silica, is too weak to react with the weak base sites and is not removed by them. Therefore carbonate alkalinity or carbon dioxide in raw water will appear as an equivalent concentration of carbon dioxide after the cation resin vessel. Only the strong base sites in the anion vessel can remove the carbon dioxide and silica.

The weak base capacity cannot function effectively in mixed beds. Since there are no acids, the sites at the top of the resin bed don't work and the sites at the bottom of the bed are slow and do not work as effectively as the strong base sites. This means only a relatively small portion of these sites are available for service in mixed beds, such as in working mixed beds.

In polishing applications where silica and carbon dioxide comprise the main ionic load, the weak base capacity cannot contribute to the operating capacity. On the other hand, weak base capacity is usually very effective in two-bed or separate-tank service.

Table 3
Equivalent of New Resin Operating Capacity From Only The Strong Base Capacity v. Percentage Remaining Strong Base Capacity

Resin	New Resin 100%	75% Remaining Strong Base Capacity	50% Remaining Strong Base Capacity
Styrene Type 1	100	75	53
Styrene Type 2	100	80	58

This is especially true with highly saline waters or where alkalinity fractions are low. For example, a drinking water bottling operation in the Southwest may have feed water salinity that varies from 600-700 ppm to 1,200+ ppm varied by season. The water may be so high in chlorides or sulfates at times that it actually tastes salty. This is a wonderful application for weak base resins and is routinely used for that application to produce delicious drinking water. In a separate bed ion exchange demineralizer where cation and anion resins are separate it has the additional benefit of less potential for giving off an amine odor fishy smell.

It is also true in cases where carbon dioxide and silica removal are not required. In car washes where silica is low, for example, weak base applications are commonly used for the final rinse although care has to be taken to avoid overuse situations where pH drops can create corrosion, rust spots and staining. In a lot of chemical solution preparation that require purified water and low silica, the effluent of a demineralizer using weak base resins is acceptable and, due to the greater operating efficiency, it is often the resin of choice in these applications. Specifically, these include electroplating, pharmaceutical eyewash solutions and photographic rinse water.

In all of these cases, the weak base sites not only contribute to the operating capacity, they can be regenerated at near 100 percent efficiency. At low regenerant dosages, their effect can be significant.

Losing strong base capacity

The loss of strong base capacity affects operating capacity in two ways: The reduced amount of strong base sites reduces the total capacity available for exchange. However, these sites are more fully regenerated because the effective dose level goes up in directly opposite proportion to the fraction of reduction. The amount of regenerant consumed by the weak base sites, while sometimes significant, usually can be ignored for most PEDI applications.

Industry standards

Typically, the regeneration level for strongly basic resins in the PEDI industry is eight pounds of NaOH per cubic foot of resin. At this level, the resin operating capacity doesn't increase much when dosages are increased. Any fractional loss in total capacity virtually will be the same as the fractional loss of operating capacity. Table 3 shows the relative operating capacity of the remaining strong base capacity compared to a new resin of the same type.

Table 3 -Equivalent of new resin operating capacity from only the strong base capacity vs. percentage remaining strong base capacity

In mixed bed polishing applications where the weak base capacity is dormant, the ratio method based on strong base capacity gives a good estimate of the relative operating capacities at regeneration levels above six pounds NaOH per cubic foot. At lower levels, the operating capacities are about 5-to-10 percent higher than the strong base capacity ratios.

Calculating capacity

In two-tank (separate-bed) systems, the weak base capacity usually contributes a significant portion of the total operating capacity, especially in highly saline or low alkalinity waters. In laboratory test reports, the weak base capacity is usually recorded in terms of mili-equivalents per milliliter (meq/mL). One meq/mL is equal to 21.8 kilograins (Kgrs.) per cubic foot of potential operating capacity. Most Type 2 resins lose strong base capacity by conversion to weak base. Typical values for weak base capacities often run from .2 to .7 meq/mL, which is the same as 4.4 to 15.3 Kgrs./cu. ft. How much of this will actually be available depends on the particular installation and especially the water analyses.

Accurate calculation of the weak base contribution to operating capacity requires a computer. However, we can make an approximation for waters of less than 20-percent alkalinity that 70 percent of the weak base sites will be utilized. On waters with 100-percent alkalinity or in polishing mixed beds, the weak base capacity remains dormant and only the strong base capacity is used. At 50 percent alkalinity, we can interpolate to get a 43.75 percent utilization factor for weak base capacity. Other measurements can be calculated in this manner.

For example, a new Type 2 resin typically has about 1.4 meq/mL strong base capacity. This comprises 100 percent of the total capacity. Two years later, the static laboratory test results show that this resin has 0.4 meq/mL weak base capacity and 0.85 meq/mL strong base capacity. Its performance in a two tank demineralizer, compared with use in a polishing mixed bed, can be estimated as follows:

We calculate the total weak based capacity and the relative strong based capacities. The static or total weak base capacity is equal to 21.8 X 0.4 = 8.7 Kgrs./ cu. ft. The strong base ratio is 0.85/1.4 = .61 (61 percent) of the original strong base capacity.

For the mixed bed polisher, the weak base capacity in such a case remains dormant and is not used in the calculation regardless of the water analysis of the untreated water composition. The ratio method indicates the resin would give about 61 percent as much capacity as a new resin, based on the ratio of the strong base capacities.

For the two tank system, the degree of effectiveness of the weak base sites depends on the inlet water composition. Therefore, we are looking at a couple of water analyses:

On water with 20 percent or less alkalinity, the resin would be able to use its weak base capacity to gain an additional 70 percent of 8.7 = 6.1 more Kgrs./cu. ft. New type 2 resins are typically rated at about 22 Kgrs./cu. ft. The strong base sites would contribute about .61X22 = 13.4 Kgrs./cu. ft. Adding the two together gives 19.5 Kgrs., which is almost 90 percent of brand new resin.

On a water containing 40 percent-alkalinity, we can estimate about 52.5 percent of the resin's weak base capacity will be utilized. In this case, the estimated operating capacity would be about 18 Kgrs./cu. ft., or about 82 percent of new resin.

Summary

The capacity of the demineralizer is often determined by the anion resin when the resins are new. The anion resin is the only one that degrades its normal life cycle. The performance of the demineralizer is determined by the degradation rate of the anion resin. Interpretation of static, laboratory test results is something that has not been reviewed scientifically. In the past, people typically would change out the resins when a magic number was approached when 25 percent of strong base capacity was lost, when 25 percent of the total capacity was lost or when 35 percent of either. All of these numbers have been used as guideline depending on which expert you spoke to. The real fact is we should be changing the resin when it no longer meets our needs or when its output or economic cost for producing water is no longer acceptable.

The above examples show how the same resin can give 61-to-90 percent of a new resin capacity. Even more dramatic is the 47 percent difference in operating capacity of the same resin depending on the water analyses and the application in which it is being used. By looking at the condition of the resin and performing a few simple estimates like the one above, it's easy to keep the performance levels of all the service tanks at levels that guarantee customer satisfaction.

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