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

By Michael C. Gottlieb. Presented at the 1997 Water Quality Association Conference.

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 [1]. Since that time the technology has been developed into a comprehensive mathematical model, which has been placed into a proprietary software program[2].

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 from **Tables 1** & **2**. **Tables 1** & **2** 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 PEDI industry (4 to 6 Lb. / cu. ft.).

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
Styrene Type 2	100	83	78	75	73

Resin replacements were usually suggested based on years in service, 4 years for Type 2's and 6 years for Type 1's or when the static capacity losses, reached 25% to 35% of the original capacity.

Almost all anion laboratory tests include both the total strong base and weak base capacities. Although 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% 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. The latter is the most rapid at the relatively low operating and regeneration temperatures experienced in the PEDI industry.

Most PEDI dealers run their DI floats with average resin ages well over the 6 year maximum recommended change out frequency. Its common to hear that despite a significant loss of strong base capacity that 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 some tanks with identical resins do better than others, from the same batch of regenerated float resin.

Weak base sites do not actually exchange ions like strong base sites. They work only by absorbing acid molecules. This means that the salts must be converted to their corresponding acids before the weak base sites will work. 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. These are strong acids and can be removed very efficiently by the weak base sites. Bicarbonate and carbonate alkalinity breaks 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 the 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. The sites at the top of the resin bed don't work at all due to there being no acids. The sites at the bottom of the bed are slow and do not work as effectively as the strong base sites. So 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. This is especially true on highly saline waters, or where alkalinity fractions are low, or in cases where carbon dioxide and silica removal are not required. In these cases the weak bas sites not only contribute to the operating capacity, they can be regenerated at near 100 % efficiency. At low regenerant dosages their effect can be significant.

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 but they 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 can be usually be ignored for most PEDI applications and is therefore ignored in this discussion.

Typically the regeneration level in the PEDI industry for strongly basic resins is 8 Lb. Of NaOH per cubic foot of resin. At this level the operating capacity of the resin doesn't increase much by increasing dosages. Any fractional loss in total capacity will therefore be virtually the same as the fractional loss of operating capacity. Some typical examples of this are shown in **Table 3**. Which shows the relative operating capacity of the remaining strong base capacity compared to a new resin of the same type.

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 6 Lb. of NaOH/ cu. ft. At lower levels like 4.0 Lb. The operating capacities are about 5 to 10 % higher than the strong base capacity ratios.

Table 3. Equivalent Of New Resin Operating Capacity From Only The Strong Base Capacity Versus Percentage Remaining Strong Base Capacity.

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

In two tank (separate beds) 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 meq/mL. 1.0 meq/mL is equal to 21.8 Kilograins 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, especially the water analyses. To accurately calculate the weak base contribution to operating capacity requires a computer. However, we can make an approximation that for waters of less than 20 % alkalinity 70 % of the weak base sites will be utilized. On waters with 100% alkalinity or in polishing mixed beds, the weak base capacity remains dormant and only the strong base capacity is used. At 50 % alkalinity we can interpolate to get a 35% utilization factor, etc. Other values can be estimated in this manner.

For example: A new Type 2 resin typically has about 1.4 meq/mL strong base capacity. This comprises 100% of the total capacity. Two years later this resin may have 0.4 meq/mL weak base capacity and 0.85 meq/mL strong base capacity. How might it perform in a two tank demineralizer, compared with being used in a polishing mixed bed? This can be estimated as follows.

The static or total weak base capacity is equal to 21.8 * .4 = 8.7 Kgrs./ cu. ft.
The strong base ratio is 0.85/1.4 = .61 (61%) of the original strong base capacity.

In the mixed bed polisher the weak base capacity remains dormant. We use the ratio method, which indicates that the resin would give about 61% as much capacity as a new resin, based on the ratio of the strong base capacity.

In the two tank system lets look at a couple of water analyses. On a water with 20% or less alkalinity, the resin would be able to use its weak base capacity to gain an additional 70% of 8.7 = 6 more Kgrs./cu. ft. New type 2 resins are typically rate at about 22 Kgrs./cu. ft. The strong base sites would contribute about .61*22 = 13.5 Kgrs./cu. ft. Adding the two together gives 19.5 Kgrs., which is almost 90% of brand new resin. On a water containing 40% alkalinity we can estimate that about 52.5% of the resin's weak base capacity will be utilized. In this case the estimated operating capacity would be about 18 Kgrs./cu. ft. about 82 % of new resin.

The above examples show how the same resin can give 61 to 90% of a new resin capacity. Even more dramatic is the 47% 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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