In Search of Softener Efficiency

The colorful print on the consumer box indicates that the softener system being purchased will remove 32,000 grains of hardness using 1 cu ft of high capacity ion exchange resin. This may sound rather impressive, especially when you review other 1-cu-ft systems that are prominently advertised to remove 20,000 grains.

The 32,000-per-cu-ft grain capacity claim is actually a spurious concept when it comes to residential automatic self-regenerating water softeners. This kind of capacity result is generally realized with very high, inefficient salt settings or in special regeneration configurations for commercial, industrial or portable exchange operations. Let's explore how design, components and system formats contribute to regenerator efficiency.

Salt efficiency is determined based on the grains capacity attained divided by the pounds of salt used to regenerate the resin. Using 15 lb of salt to achieve 32,000 grains of capacity from 1 cu ft of resin results in an efficiency rating of 2,133 grains per lb of salt. With properly designed systems, it is not difficult to improve this efficiency rating to 3,333 or more grains removed per pound of salt. With advanced system design and salt doses of less than 4 lb per cu ft, it is possible to attain in excess of 5,000 grains capacity per lb of salt. As wastewater recycling becomes more prevalent, it is critical that the water improvement industry look for the most efficient, environmentally friendly systems available. Just lowering the salt setting to 6 lb per cu ft and going on our way is no longer sufficient.

Efficient System Design

Keys to system design that significantly impact salt efficiency include a wide range of both simple and more complex factors. Some of these elements include resin type, countercurrent/co-current brining, distribution, brine concentration, injector size, rinse cycle lengths and regeneration initiation methods. Most of these factors involve offsetting elements that must be overcome in order to design the most efficient system.

Using a resin with 8% rather than 10% cross linking offers enhanced kinetics, resulting in additional, readily available ion exchange sites. The 8% resin will have a lower tolerance to oxidation, requiring more frequent replacement. Fine mesh and other specialty resins may offer potential benefits, but must be carefully applied.

Standard co-current regeneration introduces the brine solution into the top of the mineral tank. The brine is immediately diluted as it contacts the freshwater in the freeboard zone of the tank. This dilution negatively impacts the strength and efficiency of the brine. The top of the resin bed is regenerated first, pushing the hardness down through the resin bed. As this regenerated hardness travels down through any unexhausted resin, the hardness will tend to attach back onto these unexhausted resin, the hardness will

injector size and brine concentration are critical factors when it comes to finding the most efficient design. A system can easily lose more than 25% of available capacity from a poorly designed injection system. It is important to keep the brine concentration in the 10% to 14% range and at a rate as slow as reasonably possible. This may mean using a smaller injector than recommended by the valve manufacturer to maintain the desired brine concentration for the longest period of time. Injector performance varies with incoming pressure, so take care when selecting the best size. Refrain from programming extended slow rinse or fast rinse cycles as these will diminish the available capacity.

There are many regeneration initiation methods available, each of which offers certain advantages. In general,
digital controllers with adjustable cycle times offer potentially better efficiency than traditional mechanical style configurations. Some of the various initiation options available include:

**Manual Initiation**

Manual initiation may involve automatic or even true manual, cycle-by-cycle regeneration. The need for regeneration may be determined by a regular schedule, wild guess or via a hardness test. This method is inherently inefficient as it counts on luck, tradition and low-tech operational methods. This approach could be somewhat effective provided the hardness level was accurately and consistently monitored to initiate regeneration at or just before exhaustion.

**Time Clock Initiation**

Systems with regeneration initiated by a day clock are typically very inefficient. Relying on a calculation or conjecture to determine the regeneration frequency, time clock systems should be avoided at almost all costs. The one exception is for applications that use a uniform amount of water on a daily basis with a consistent influent hardness. If the system can be sized to use nearly all available capacity as the water use for a day ends, then regeneration could be somewhat efficient. Use a metered or other type of system in lieu of a time clock.

**Meter-Delayed Regeneration**

Meter-delayed regeneration will in theory use a large portion of the available capacity before regenerating. An undersized system, however, can waste 50% or more of the system capacity, as this method of regeneration counts on a reserve capacity. Since the regeneration is delayed up to nearly a full day after the need for regeneration is sensed, it is necessary to add a reserve factor into the programming. A 1-cu-ft system with 20,000 grains of capacity operating on 25 grains per gal of hardness will have a potential capacity of 800 gal. If the family of five uses 375 gal of water per day, then the actual meter setting will be 800-375, or 425 gal. If the meter were set any higher than 425 gal, there is a chance the system will run out of soft water prior to the next regeneration. In this scenario, a softener with an 800-gal capacity will regenerate somewhere from 425 to 800 gal. Because the salt setting is calculated based on the 800-gal capability, the regeneration efficiency will be fair at best. Many newer controllers offer variable reserve functions that mitigate, but do not eliminate, this reserve capacity issue.

**Meter-Immediate Initiation**

Meter-immediate initiation may be a good solution in certain applications. Typically used with multiple valve systems, immediate initiation prompts regeneration at the point of exhaustion. With a single softener, this will result in lower service flow and hard water during the regeneration cycle. In many instances, this may be an acceptable tradeoff for the capacity and efficiency gains. For example, homes with a traditional water heater may suffer with partially hard water for a day or two. Those using tankless water heaters will have a very short period of hard water exposure.

**Twin Alternating Systems**

Twin alternating systems maintain one unit in service with the other tank in regeneration or standby mode. They are commonly used in applications that require 24/7 soft water. With the ability to regenerate multiple times in a day, they can be used in high-capacity applications with limited space availability. As an immediate regeneration system, the full capacity of each tank is used prior to regeneration. Upfront cost will be higher than a single unit, but the salt and water savings generally take a short time to pay for the increased equipment costs.

Residential applications can obtain the same benefits using a twin alternating system, though a very slight periodic service flow loss may be experienced as some of the incoming water is dedicated to the regeneration process.

Alternating systems can be expanded to include four or more tanks with enhanced capability and productivity. For example, demand-flow initiation is excellent for fluctuating service flow requirements as the number of tanks brought on line is determined by the real-time water demand.

Proportional brining is a feature incorporated into some controllers that will fill the brine tank with just enough water to dissolve the amount of salt required to regenerate the capacity that has been used. This is accomplished using a brine pre-fill that occurs about two hours prior to regeneration, typically during a period of low or no water use. If a system is scheduled to regenerate at 2,000 gal, it will trigger the cycle to begin at some point slightly or even significantly prior to the 2,000-gal set point. The amount of brine used will fluctuate with each subsequent regeneration, being proportional to the amount of exhausted capacity that needs to be regenerated. Proportional brining works best in conjunction with countercurrent regeneration as the amount of brine induced is not sufficient to regenerate the entire bed. While opinions and tests differ, using proportional brining with co-current regeneration will negate a portion of the efficiency gains. If using proportional brining with a co-current valve, plan to periodically use a full regeneration to make up for lost capacity.

In some areas, no amount of increased efficiency will stem the tide of legislation. Many areas have already banned onsite self-regenerating water softeners. We look forward to the day when true soft water can be accomplished using an innocuous regenerating, or none at all. For now, there are promising no-salt scale prevention systems that will satisfy a portion of the current softening market. From a consumer perspective, water softeners provide aesthetically pleasing results and are the best solution for a wide range of troublesome water challenges. As water improvement professionals, it is our clear mission to diminish the environmental impact of softeners by implementing the most efficient solutions possible.  

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