After SB1006:

Factors Affecting the Brine Efficiency of Softeners

Part 1 of 2

By C.F. "Chubb" Michaud, CWS-VI

Summary: *With the June passage in California of Senate Bill 1006, water conditioning manufacturers and dealers are going to be searching more than ever for ways to make their equipment operate with greater brine efficiency. One of the requirements will be installation of only softeners with demand initiated regeneration valves after Jan. 1, 2000. But more will be required than that. Here we offer the first part of a two-part series to discuss the subject, concentrating on the salt setting and the water analysis.*

Brine efficiency for a water softener is defined as the number of grains (gr) of hardness removed per pound of salt used for regeneration.[1] This, of course, also assumes a fixed breakthrough end-point—usually 1 grain (17.1 parts per million, or ppm, of total hardness, or TH, as calcium carbonate, or $CaCO_3$). The theoretical maximum efficiency is 6,000 grains per pound (gr/lb). This would mean that every ion of sodium (Na) or potassium (K) in the regenerant brine finds its way onto a reactive site on the resin matrix and the regenerant waste is pure hardness with no sodium or potassium ions. Many hybrid modern softeners are very highly efficient, but none are 100 percent. Typical softeners operate with recoveries of 22,000-to-25,000 grains per cubic foot (gr/ft^3) on 8 lbs of salt, or a brine efficiency of 3,000 gr/lb—about 50 percent efficient.

To calculate efficiency, one simply has to multiply the grains per gallon (gpg) in the feed by the total gallons processed between runs and divide by the number of pounds of salt per cubic foot used to regenerate. A 2-cubic-foot softener that processes 3,100 gallons of 15.5-grain water removes 48,050 grains of hardness. If that system regenerates with 14 lbs of salt (7 lbs/ft^3), we have an efficiency of 48,050/2 x 7 = 3,432 gr/lb, or 57.2 percent efficient.

If that same softener was used for boiler feed with a maximum hardness breakthrough tolerance of 2 ppm (TH as $CaCO_3$), it may only process 2,800 gallons and require 24 lbs. of salt for regeneration. Our efficiency, therefore, becomes 2,800 x 15.5/12 x 2 = 1,808 gr/lb, or 30.1 percent efficient. This also means that 69.9 percent—100 - 30.1—of the salt used or about 16.8 lbs goes down the drain as salt discharge. This excess salt is very soluble and passes through sewage treatment unchanged. The processed sewage is eventually discharged into a waterway, reinjected into the ground or sold as reclaimed water for non-agricultural irrigation. It will have a higher total dissolved solids (TDS) count than the original feed source because of the added salt.

The brine discharge issue

Sooner or later, excess salt discharge becomes a concern. Often, it's the chloride content that draws attention—and even a 100 percent efficient softener discharges all of its chlorides. In sodium chloride (NaCl), the chloride represents 66 percent of the total weight of the salt. Potassium chloride (KCl) is still 48 percent chlorides.

At least two states, California and Wisconsin, have enacted legislation to set the minimum brine efficiency at 3,350 gr/lb (now set to take effect in California on Jan. 1, 2000) and require meter or demand initiated regeneration (DIR). No time clocks will be used on new systems. The Water Quality Association (WQA) has also adopted the 3,350/DIR standards.[2] California also has passed legislation that will raise the bar to 4,000 gr/lb effective Jan. 1, 2002. No doubt, others will follow. The driving force for higher efficiency is to reduce TDS creep (which may limit the ability of municipalities to resell reclaimed water from sewage for other uses) and other environmental issues.

Understanding the variables

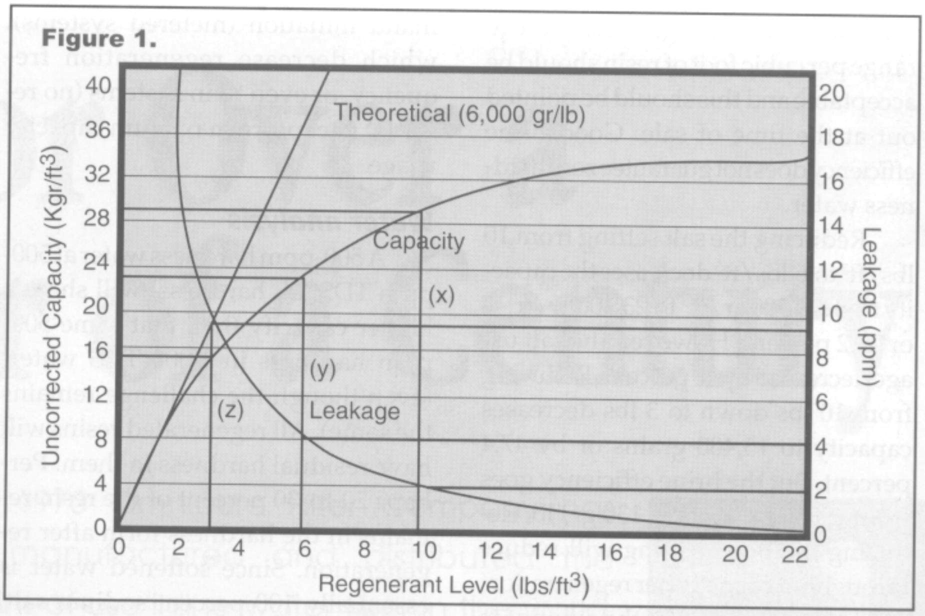
Those of you who install and service softeners may have experienced a

Table 1.
Factors to consider in brine efficiency

1. Salt setting—capacity and leakage
2. Water analysis—fixed total hardness and total dissolved solids, iron compensation
3. Valve controls—timer, up- or downflow
4. Injector selection—brine concentration and flow rate
5. Tank configuration—bed depth, head space, underbedding
6. Resin selection—size and function
7. Service flow—gpm/ft^3 of resin

situation where two identical softeners installed on feed water with the same hardness result in more frequent complaints of running out of soft water on one of the units. Increasing the reserve capacity, regenerant level or increasing the regeneration frequency may solve the problem—but it decreases the brine efficiency on the fixed or "modified" unit. That's because there are numerous other variables that factor into the true operation of any softener. Each case can be different. This article will discuss those variables and offer insight as to why that is and how we can properly "engineer" good design into a softener to help achieve and maintain good efficiency. Table 1 lists a number of factors that affect brine efficiency.

Figure 1.



Salt level and capacity

Figure 1 shows a typical capacity response curve for a given brine setting. This data, usually generated in a 1-inch laboratory column, represents uncorrected data.[3] That is, it's collected under ideal conditions of water analysis, flow rate, brine concentration and regenerant flow without consideration for real world conditions you'll actually encounter in the field and inside your softener during operation. I refer to this data as "two dimensional." To achieve a proper picture of true operation, we must open both eyes and apply corrections (all of which decrease capacity) to view it in "three" dimensions.

The single variable responsible for the largest impact on brine efficiency is the salt level setting. While commercial softeners may demand very low leakages (1 ppm or less), the residential user can easily tolerate 5-to-10 ppm of average hardness bleed. This indicates that brine settings in the 4-to-6 lb range per cubic foot of resin should be acceptable and this should be pointed out at the time of sale. Good brine efficiency does not guarantee zero hardness water.

Reducing the salt setting from 10 lbs/ft^3 to 6 lbs/ft^3 decreases the capacity from 29,300 gr/ft^3 to 23,100 gr/ft^3—or 21.2 percent. However, the salt usage decreased by 40 percent. Reducing from 10 lbs down to 3 lbs decreases capacity to 15,400 grains or by 47.4 percent. But the brine efficiency goes from 2,930 gr/lb to 5,130 gr/lb. Reducing the brine setting will reduce throughput capacity per regeneration. Throughput volume is the amount in gallons or liters of water passed through an ion exchange resin bed or water treatment system before exhaustion of the exchanger or system is reached. This means more frequent regeneration. It also means the reserve capacity will be a larger percentage of the total throughput. In the future, this means larger systems, as well as demand initiation (metered systems), which decrease regeneration frequency, or even twin systems (no reserve) to capture maximum capacity usage.

Water analysis

A 500-ppm hardness water at 500-ppm TDS (all hardness) will show a higher capacity than that same 500-ppm hardness in 1,000 TDS water[4] (even though the challenge remains the same). All regenerated resins will have residual hardness in them. Perhaps 20-to-30 percent of the resin remains in the hardness form after regeneration. Since softened water is essentially 100 percent sodium salt, this acts as a mild regenerant for the residual hardness and it slowly pushes the hardness off the bed as background leakage. This adds to the breakthrough leakage and shortens the run length. The higher the TDS, the higher the leakage and, therefore, the shorter the run. Extremely high TDS (over 5,000 ppm) will be impossible to soften in a conventional manner because the background leakage will already exceed the maximum for the intended softened water.

Likewise, if the TDS is some fixed level but seasonal variation in the feed hardness reduces the hardness levels, the actual capacity will drop. In those instances, you would have to reset the control valve to regain good efficiency. Feed water variables can have a 10 percent negative impact on true brine efficiency. Without constant monitoring, this factor cannot be compensated for in the installation set-up.

Another feed water variable that can decrease brine efficiency is the presence of iron and how you calculate the compensation. Each ppm of iron is only 1 ppm as far as the resin is concerned. However, if this is included as 3 gr or 4 gr of hardness in your hardness calculations, brine efficiency suffers accordingly. More frequent regeneration will reduce the need to overcompensate for iron. Systems that regenerate every two days do not have to compensate for iron at all. Selecting a salt that helps remove oxidized iron from the resin bed (these usually contain a small amount of citric acid) will also eliminate the compensation and help maintain good brine efficiency. Granular citric acid is readily available from most chemical supply houses at about $1.25 per pound and can be added with salt to the brine tank at a level of ¼-to-½ lbs/50-lb bag of salt.

Conclusion

Thus, iron compensation, TDS and TH as well as the effect of the salt setting on capacity and leakage are significant issues that need to be considered by the dealer in designing and maintaining an efficient, properly running system. In the next part of this two-part series, we'll discuss other factors affecting brine efficiency—valve controls, injector selection, tank configuration, resin selection and service flow.❑

References

1. ANSI/NSF Standard 61, NSF *International*, Ann Arbor, Mich.
2. WQA Gold Seal Standard S-100, Water Quality Association, Lisle, Ill.
3. The Purolite Company Engineering Manual, Purolite Company, Bala Cynwyd, Pa.
4. R&H Engineering Manual, Rohm and Haas Company, Philadelphia, Pa.

About the author

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WATER FACTOID

United Nations estimates only five percent of wastewater generated by cities worldwide is chemically treated before being dumped into rivers or into the ground.