

WATER SOFTENING— YESTERDAY, TODAY AND TOMORROW



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Yesterday

While Harm and Rümpler may be credited with the first synthetic zeolites in 1903, it was another German chemist, Robert Gans, who pioneered the applications for ion exchange and commercially introduced the regenerable softener in 1905. A series of improved sulfonated “organic” compounds followed over the next three decades with better stability and capacity as well as higher brine efficiencies. The first commercial systems were introduced in the United States in 1940.¹

The development of new synthesis and production techniques spurred by the research efforts of World War II produced the most significant advances in the history of ion exchange. G.F. D’Alelio, of General Electric, produced the first styrene/di-vinyl benzene (S/DVB) polymers in 1944, which led to the rapid development of the modern styrene-based ion exchange resins.² Less than 50 years after the introduction of the first salt-regenerated zeolite softeners, our industry entered the modern era. This composition has remained unchanged ever since. During this same time frame, man had moved from the dream of flying to the jet aircraft, from the telegraph to television, and from the Winchester rifle to the atomic bomb. It was a truly remarkable 50-year span of scientific effort and discovery.

With the batch-to-batch consistency of the new synthetic organic softener resins, scientists were able to study every aspect of the ion exchange resins structure and assess improved values while changing particle size, crosslinking and uniformity. Studies in diffusion and kinetics confirmed that smaller beads were faster than larger ones and made better use of regenerant, which improved brine efficiency. A 10-percent increase in capacity could be had merely switching to fine-mesh resin.³ Counterflow regeneration techniques popularized in Europe led to further reductions in the quantity of regenerant and increased efficiency even more.

Today

The ultimate bead configuration, however, lay in the uniformity of the resin bead rather than purely the smaller particle size. Normal bead size (16-50 mesh) is 1.2 millimeters (mm) to 0.3 mm. The ratio of the bead diameters is, therefore, 4-to-1. Regeneration efficiency is directly related to the particle size differential squared. For instance, a 0.3 mm bead (50 mesh) regenerated 16 times faster (4×4) and thus more completely than a 1.2 mm bead (16 mesh).⁴

While fine-mesh resins are more efficient, there’s still a particle size differential ratio of at least 3-to-1 that leads to inherent inefficiencies. The smaller beads

are still more highly regenerated (wasting brine) than the larger ones (producing leakage). The ultimate bead design would, therefore, be derived from a more uniform fine-mesh resin. The disadvantage would be moderate pressure drop, cost and containment (standard screens are too large for the finer mesh resins).

Uniform particle size resins are typically 30-45 mesh (0.35-0.59 mm) and have a bead diameter ratio of 1.7-to-1 and a kinetic ratio of $1.7 \times 1.7 = 2.89$ (vs. 16 for conventional resins). The rate at which these beads react and regenerate is about the same, therefore, brine efficiency increases.

The challenge of “absolute uniformity” was met with the development of shallow-shell technology, first introduced in 1980s but for which an effective, marketable product wasn’t introduced until 1997. These resins have normal size distribution and can therefore be handled by conventional screens and valves. They have shallow reactive shells that are uniform in depth and have inert, unreacted cores. This resin design combines both the short diffusion path of fine-mesh resin but with a uniform depth, similar to uniform particle size resins. Because the diffusion paths are shorter, the resin will regenerate with less brine for a given capacity, producing higher brine efficiencies and lower

leakages.⁵ Field applications readily demonstrate brine efficiencies of over 95 percent (vs. 60 percent for conventional resins). Leakages under ½ grain are achieved even at very low salt settings.⁶

While today's modern versions of D'Alelio's 1944 development can greatly reduce the sodium in the regenerant brine discharge, they don't address the chloride discharge issues that have recently become of more concern. Recent bans on residential softener installations in California were focused on the chloride discharge rather than sodium. Even at 100 percent efficiency, which would be free of sodium, the chloride discharge is still present. The growing need and trend towards water re-use will certainly lead to even more restrictions on the continued growth of water softeners everywhere despite the obvious benefits derived from softening water.

Tomorrow

Water softening for residential, commercial and industrial applications won't go away soon. There will be, however, a pronounced shift toward portable exchange softening whereby the resins

are regenerated off-site in a facility that can more properly deal with the brine discharge issues. Such facilities could utilize "zero discharge" technologies that reduce both the sodium and the chloride discharge by 90 to 95 percent.⁷ Perhaps the future will find that some budding young chemist will develop a simple and safe additive that will coagulate hardness and allow it to be simply filtered out. This could lead to hardness "recycling" by returning the calcium and magnesium to agricultural areas for soil modification. Maybe some new alternative treatment device will actually make hard water act like soft water. Perhaps some other energy source (besides salt) will drive softener regeneration in the future. Hot water? Perhaps! It ain't over yet.

References

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