How water softeners work

Softening of water by the ion exchange process involves the exchange or substitution of the hardness minerals, chiefly calcium and magnesium, for sodium minerals. The exchange is made possible because the minerals are ionic in nature (often called ionised impurities), which means they have an electrical charge. The ion exchange process is based on the fact that like charges repel one another and unlike charges attract.

Calcium and magnesium ions in water are actually dissolved rock. They have been dissolved by water, the universal solvent, trickling down through strata of rock and soil dissolving the calcium and magnesium deposits as it goes. The dissolved rock eventually finds its way into an underground aquifer and when water from the aquifer is pumped to the surface, it contains the dissolved hardness minerals of calcium and magnesium and is said to be hard water.

An ion exchange softener exchanges the hardness minerals, calcium and magnesium, dissolved in water for the soft mineral, sodium, contained on the softener resin. This does far less damage to objects it comes into contact with, principally because it does not build up on surfaces as scale deposits.

All three minerals are positively charged ions called cations. The exchange takes place by passing water containing hardness minerals over a man-made ion exchange resin in a suitable pressure vessel tank. The resin, polystyrene divinyl benzene, in most modern softeners consists of millions of tiny plastic balls (beads), all of which contain many negatively charged exchange sites attracting positive cations. When the resin is in the regenerated state, these negatively charged exchange sites attracting positive cations. When the resin is in the regenerated state, these negatively charged exchange sites hold positively charged sodium cations.

As the magnesium contact the resin beads in their travel through the resin tank they displace the sodium ions from the exchange sites. During the ion exchange process relatively small amounts of other strongly charged cations such as iron and manganese are also removed along with the calcium and magnesium.

Ion exchange is possible for two reasons: 1) all cations do not have the same strength of positive charge and 2) the resin prefers the more strongly charged cations, calcium and magnesium, than it does weaker sodium cations.

The displaced sodium cations then pass downward through the resin “bed” and out the softener outlet, thus the softener delivers “soft” water.

Eventually all of the resin exchange sites are occupied by calcium and magnesium and no further softening exchange can take place. The resin is said to be exhausted and must be regenerated.

The resin of the softener is regenerated with a dilute solution of sodium chloride (common salt) and water – brine. During regeneration the flow of service water from the softener is first stopped. Brine is drawn from the brine tank mixing with a separate stream of dilution water. The diluted brine solution flows downward through the resin contacting the resin beads loaded with calcium and magnesium ions. Even though the calcium and magnesium are more strongly charged that the sodium, the concentrated brine solution contains literally billions of the more weakly charged sodium ions which have the power to displace the smaller number of calcium and magnesium ions. When the calcium and magnesium ions are displaced (exchanged), the positive sodium ions are then attracted to the negative exchange sites. Eventually, sites are taken up by sodium ions and the resin is said to be regenerated and ready for the next softening (service) cycle.