Ion Exchange Softening

Ion-exchange is used extensively in small water systems and individual homes. Ion-exchange resin, (zeolite) exchanges one ion from the water being treated for another ion that is in the resin (sodium is one component of softening salt, with chlorine being the other). Zeolite resin exchanges sodium for calcium and magnesium. The following chemical reactions show the exchange process, where X represents zeolite, the exchange material.

Removal of carbonate hardness:

$$Ca(HCO_3)_2 + Na_2X \text{ ------> } CaX + 2NaHCO_3$$

$$Mg(HCO_3)_2 + Na_2X \text{ ------> } MgX + 2NaHCO_3$$

Removal of non-carbonate hardness:

$$CaSO_4 + Na_2X \text{ -----> } CaX + Na_2SO_4$$
$$CaCl_2 + Na_2X \text{ ------> } CaX + CaCl_2$$
$$MgSO_4 + Na_2X \text{ ------> } MgX + Na_2SO_4$$
$$MgCL_2 + Na_2X \text{ ------> } MgX + 2NaC1$$

These reactions represent cation exchange, the exchange of positive ions. To replenish the sodium ions used, units need to be regenerated with material containing high amounts of sodium, normally salt brine. This allows the resin to be reused many times.

Ion-exchange does not alter the water's pH or alkalinity. However, the stability of the water is altered due to the removal of calcium and magnesium and an increase in dissolved solids. For each ppm of calcium removed and replaced by sodium, total dissolved solids increase by 0.15 ppm. For each ppm of magnesium removed and replaced by sodium, total dissolved solids increase by 0.88 ppm.

Measurements used to express water hardness in ion-exchange differ from units used in lime-soda softening. Hardness is expressed as grains per gallon rather than mg/l of calcium carbonate.

1 grain/gallon 17.12 mg/l

If water contains 10 grains of hardness, would hardness be expressed 171.2 mg/l?

10 grains x 17.12 mg/l / grain
= 171.2 mg/l of hardness

ADVANTAGES OF ION-EXCHANGE SOFTENING

Compared with lime-soda ash softening, ion-exchange has certain advantages. It is compact and has a low capital cost. The chemicals used are safer for the operator to handle and operation is much easier. It can be almost totally automated. Because resins have the ability to remove all hardness from the water, treated water must be blended with water that has been by-passed around the softener (or adjustments made) to obtain a hardness level the operator needs to maintain.

Many systems have found ion-exchange to be the most cost effective way to produce quality water for their customers. If zeolite units are used to soften surface water, it must be preceded by surface water treatment.

EQUIPMENT AND OPERATION

Ion-Exchange Resins

Natural green sand called glauconite has very good exchange capabilities and was once widely used. Synthetic zeolites, known as polystyrene resins, are most commonly used now. Cost is reasonable, and it is easy to control the quality of the resin. They also have much higher ion exchange capacities than the natural material.

The ability of the resin to remove hardness from the water is related to the volume of resin in the tank. Softeners should remove about 50,000 grains of hardness per cubic foot of resin. Resins hold hardness ions until they are regenerated with a salt brine solution. The hardness ions are exchanged for sodium ions in the salt brine.

Example:

If water contains 10 grains per gallon of hardness, how many gallons of water would the resin remove? The tank holds 500 cubic feet of resin with capability of removing 45,000 grains per gallon per cubic foot.

$$\text{Gallons} = \frac{\text{cubic feet x grains per cubic foot}}{\text{grains per gallon}}$$

$$= \frac{\text{500 cubic feet x 45,000 grains/cubic foot}}{\text{10 grains per gallon}}$$

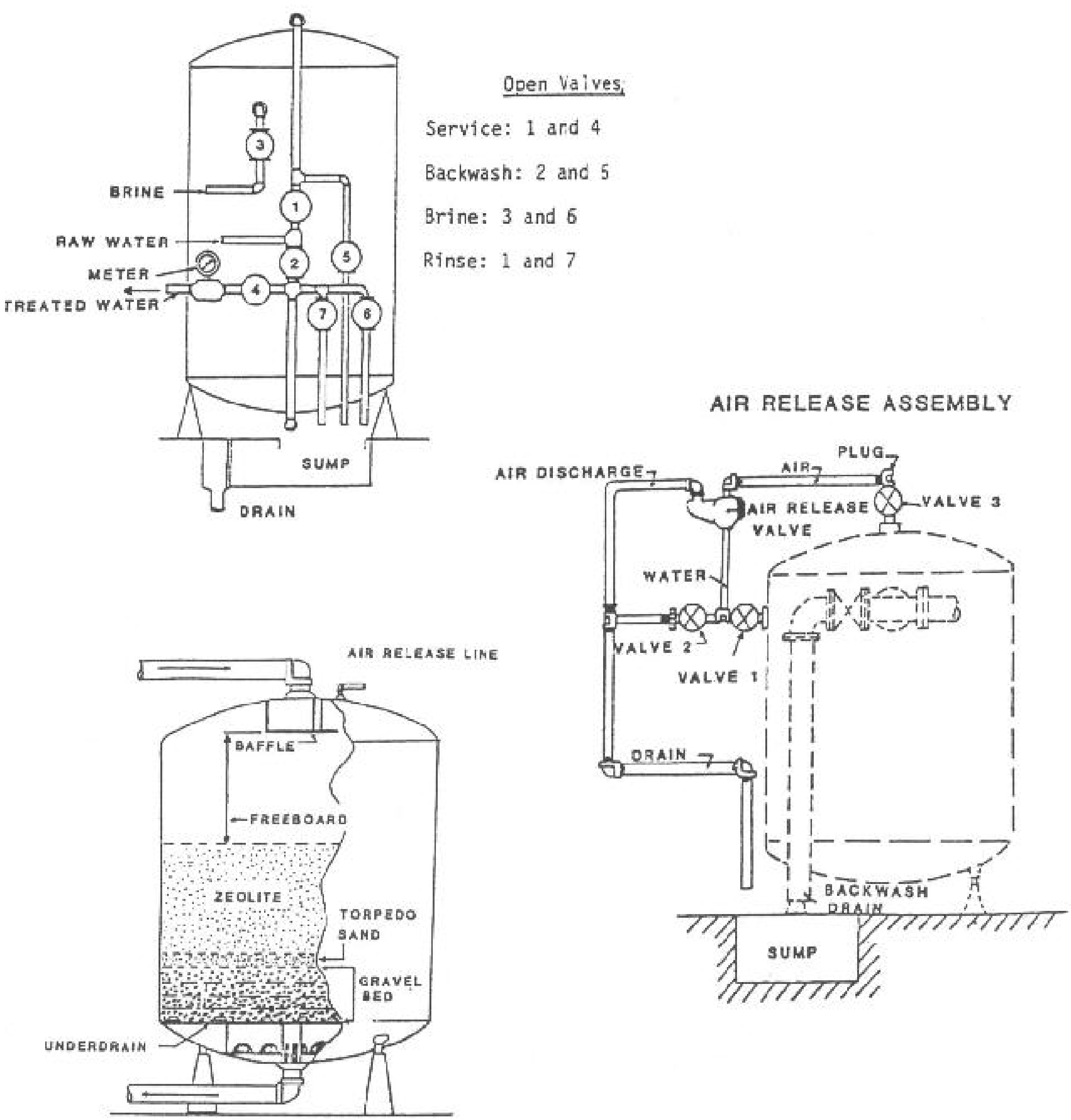
$$= \frac{\text{22,500,000 grains}}{\text{10 grains/gallon}}$$

$$= \text{2,250,000 gallons before requiring regeneration}$$

Ion-Exchange Units

These units resemble pressure filters. The interior is generally treated to protect the tank against corrosion from the salt. The units are normally of the downflow type, and the size and volume of the units are dictated by the hardness of the water and the volume of treated water needed to be produced between each regeneration cycle. Resin is supported by an underdrain system that removes the treated water and distributes brine evenly during regeneration. Minimum depth of resin should be no less than 24 inches above the underdrain.

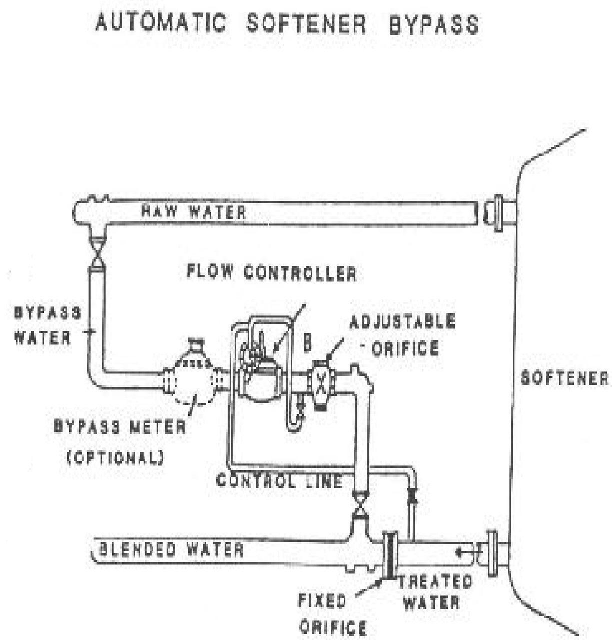
Zeolite Softening Units



Salt Storage

Salt is stored as a brine, ready to be used for regeneration of the resin. The amount of salt needed ranges from 0.25 to 0.45 pounds for every 1,000 grains of hardness removed. The tank should be coated with a salt-resistant material to prevent corrosion of the tank walls.

Salts need to meet the AWWA or NSF standards for sodium chloride. Rock or pellet salt is the best for preparing brine and road salt is not acceptable, due to the dirt that it contains.



Salt storage tanks should be covered to prevent contamination. A raised curb should be provided at each access hatch to prevent contamination by flood water or rain.

Filling a salt storage tank with water first and then adding salt is the preferred method for making brine. The brine is heavier than water and settles to the bottom of the tank. The brine is usually pumped from the tank to the ion-exchange units. When making brine, water must be added through an air gap to avoid back siphonage of the brine to the water system.

Brine Feeding Equipment

Concentrated brine contains approximately 25 percent salt. The brine should be diluted to about 10 percent before added to the softener. It is generally injected with a venturi or a metering pump. Solubility of salt decreases with a rise in temperature, which forces salt out of solution. Water that remains after the salt has separated out of the solution is subject to freezing. Therefore, brine piping should be protected from cold temperatures.

Devices for Blending

A properly operated ion-exchange unit produces water with zero hardness, but with high corrosivity. Since a total hardness of 85 to 100 mg/l is the most desirable, treated water from the ion-exchange unit is generally blended with source water to raise hardness in the finished water. Blending is normally accomplished by metering both the effluent from the softener and added raw water. Meters are installed in both lines so that the operator can adjust and monitor the blend.

Softening Cycle

The length of the softening cycle ends when 1 to 5 mg/l of hardness is detected in the effluent (loading rates for synthetic resins are in the area of 10 to 15 gpm/square foot of media surface area). Almost all softening units have an alarm on the water meter to indicate when a certain amount of water has passed through the exchange unit.

Backwash Cycle

Once hardness breaks through, the softener must be regenerated. In down-flow units, the resin must first be backwashed to loosen the resin (it becomes compacted by the weight of the water), and to remove any other material that has been filtered out of the water by the resin. The backwash rate is normally 6 to 8 gpm/square foot of zeolite bed area. The operator needs to apply enough backwash water to expand the resin bed by about 50 percent. The backwash water is usually discharged to a box containing orifice plates that measure the flow rate. Distributors at the top of the unit provide for uniform water distribution and uniform wash-water collection. Underdrains provide uniform distribution of the backwash water on the bottom of the resin.

Regeneration

Concentrated brine is pumped to the unit from the storage basin. Brine is diluted through the injector to a solution containing about 10 percent salt before it is passed through the resin. The time required for regeneration is about 20 to 35 minutes. The flow rate of brine through the resin is measured in gallons per minute per cubic foot of media. The brine needs to be in contact with the resin long enough to allow for complete exchange of hardness ions on the resin with sodium ions in the brine. It is better to allow too much time than to not allow enough. If the resin is not totally recharged, the next softening run will be short.

Rinse Cycle

The rinse cycle removes remaining brine from the tank. The total amount of rinse water needed is 20 to 35 gallons per cubic foot of resin. The rinse is started at a slow rate (-2 gpm/square foot of surface area-) and continues until the chloride concentration of the effluent (which should be monitored frequently) is quite low.

Disposal of Brine

The volume of brine used during a regeneration cycle, (together with the rinse water that follows) varies from 1.5 to 7 percent of the amount of water softened by the unit. The chloride concentration in this wastewater could be as high as 35,000 to 45,000 mg/l. Chlorides will upset a wastewater treatment plant, and disposal methods have to comply with Minnesota Pollution Control Agency requirements.

Resin Breakdown

Synthetic resins normally last 15 to 20 years, but certain conditions can cause resin to breakdown earlier. Oxidation by chlorine is probably the most common cause of resin breakdown. When chlorine is used to oxidize iron in the water, the chlorine should be removed before ion exchange.

Iron Fouling

Iron will significantly affect the ability of resins to remove hardness ions. Ferrous iron can be oxidized during softening and precipitate out as iron oxide on the resin, and no amount of brine will remove the iron fouling. If iron oxide is formed before ion exchange unit, it can be filtered out by the resin and removed during the backwashing of the unit. Normally if the iron concentration in the source water is high, iron removal is provided ahead of the exchange unit to prevent fouling of the unit.

Suspended Material

Turbidity, organic chemicals, and bacterial slimes resins resulting in the loss of some of the resin exchange capacity. The best solution is to remove of the suspended matter with coagulation, sedimentation, and filtration before the softening process.

Unstable Water

Water that has been softened by ion exchange will be corrosive and should be stabilized to prevent corrosion from taking place in the distribution system. Blending with raw water or adding phosphates or other chemicals to reduce the corrosivity of the water.

TESTING

Testing should include total hardness of raw and treated water, chloride concentration in the rinse water, and Langelier Index (pH of stability [pHs] - pH measured). If the Langelier Index is positive, a calcium scale will tend to coat the pipes in the distribution system. If the Langelier Index is negative, the water will tend to be corrosive.