SOME LIKE IT HOT, SOME LIKE IT COLD

Water temperature affects both resin and system functions.

By Frank DeSilva and Bill Koebel. Published in the Water Quality Products Magazine, August 2000.

Water temperature has an effect on many parts of an ion exchange system, including the service, backwash and regeneration cycles. Integrating these effects into the operation and design of an ion exchange system helps minimize leakage and aid in troubleshooting when problems arise.

Understanding the effects of water temperature can improve system capacity, pressure drop through the bed and backwash flow rates, and reduce leakage through the resin bed.

Changes in water temperature can affect the operating capacity and effluent quality levels of ion exchange systems to some degree. Changing the temperature changes the degree of ionization. This has a much greater effect on systems that are only slightly ionized than systems that are nearly fully ionized. Therefore, temperature changes have a greater effect on weakly basic and weakly acidic ion exchange resins than on strongly basic or strongly acidic resins.

Increasing temperature tends to increase the diffusion rate of ions, which make ion exchange reactions occur more rapidly. It is reasonable to expect that increasing temperature will result in sharper exhaustion zones, more rapid exchange rates, and therefore higher capacity and better quality.

However, higher temperatures can increase solubility for ions such as silica that are left at the bottom of the bed from a previous cycle, increasing silica leakage. It also can reduce the relative affinities of ions, making it easier for monovalent ions like sodium to displace higher amounts of divalent ions like calcium in water softening applications.

How resins are impacted

The following resins are affected by temperature changes:

- **Strong-acid cation exchange resins.** Increasing operating temperatures increases the diffusion rates, which shortens the length of bed necessary to achieve the desired quality. This means a greater portion of the bed is used during the service cycle, which leads to a higher operating capacity. Increasing or decreasing the temperature a few degrees has little and sometimes no noticeable effect on operating capacity.

- **Strong-base anion exchange resins.** Operating temperature has more of an effect on strongly basic resins when they are run to a silica endpoint than it does on strongly basic resins run to a conductivity endpoint because of the effect on silica.

- **Higher temperatures increase the rate** of silica ionization, which means the silica can be removed quicker, resulting in higher utilization of the bed. However, higher operating temperatures also increase silica solubility and cause greater leakages during the operating cycle.

When strong basic resins are run in a salt cycle exchange or in an acid absorption mode where silica endpoints are not involved, the temperature effect on capacity is minimal.

- **Weak-acid cation exchange resins.** Weakly acidic resins are very slightly ionized. Consequently, the exchange zone is very long and very sensitive to flow rate. Increasing the water temperature increases the degree of disassociation, which shortens the exchange zone. This increases the operating capacity and also the effluent quality at the same time. Changes of 10 degrees Fahrenheit can make significant changes in the operating capacity of these resins when they are operated in the hydrogen cycle.

- **Weak-base anion exchange resins.** Weakly basic resins largely are not disassociated and operate primarily as acid absorbers. Increased operating temperature can result in higher leakages and reduced capacity, but kinetics is enhanced so the net result may be a slight increase in capacity. Effluent quality is not significantly affected in weakly basic resins.

- **Two-bed demineralizers.** Generally the operating capacity is increased with increasing temperature. Sodium leakage is largely unaffected and silica leakage is increased. In the case of weakly basic resins, the operating capacities are increased and the overall quality remains essentially unchanged.

- **Mixed beds. Any change in operating** conditions, such as temperature or flow rate, will result in an immediate reduction of quality, which slowly disappears as the bed re-establishes equilibrium. From the viewpoint of a sustained operation at a constant temperature, higher temperatures in mixed beds will result in high silica leakage, all other parameters remaining essentially unchanged.

Other factors can be affected
Changes in temperature can affect several functions within ion exchange systems:

- **Pressure drop.** Water temperature plays an important role in pressure loss through a resin bed. The viscosity of water changes with temperature. At higher temperatures, water flows through the resin bed easier than at cooler temperatures. This is due to less resistance between the water and resin bed.

  If the flow rate remains constant, the amount of pressure loss through the resin bed will decrease as temperature increases. As the water supply becomes cooler, an increase in pressure drop will occur. This is primarily observed in systems that have fluctuation in inlet water temperature such as a surface water source that experiences seasonal changes.

- **Backwash cycle.** The viscosity of water changes with temperature; lower-temperature water has a higher viscosity and will expand a resin bed more than warmer water. A proper backwash will expand the bed 50 to 75 percent.

If the backwash flow rate of an ion exchange unit was set using warm water (e.g., during the summer), there is a potential to exceed the recommended bed expansion and subsequently lose resin during the fall and winter months when the water is cooler. It is not unusual for resin manufacturers to receive a flurry of emergency orders at the start of the winter season to replace resin that has been backwashed out of vessels.

Backwashing with warm water also can give an incomplete backwash, if insufficient flow rate is used. One of the most common problems with softeners in the field is “dirty” resin from incomplete backwashing. When resin fines and particulate matter remain in the resin bed, they occupy the void area of the resins causing an increase in pressure drop across the bed. This eventually can lead to channeling, clumping and blinding of the resin bed. Properly compensating backwash flow rates vs. water temperature will help prevent these problems from occurring. Consult specific resin manufacturers' backwash expansion curves to find the proper flow rate at different temperatures.

- **Regeneration cycle.** Strong-base anion resins operated in the hydroxide form are best regenerated at elevated temperatures to minimize silica leakage. Warmer temperature help to solubilize silica off of the resin, and the more contact time the better.

  Ideally, strong-base anion resins are regenerated with a 4-percent heated solution of sodium hydroxide (NaOH) at a flow rate of 0.25 gallons a minute for each cubic foot to effect a contact time of 60 minutes. The temperature of the dilute caustic should be 120 F maximum for Type I anion resins and 95 F maximum for Type II or acrylic resins.

- **Rinse down.** The time it takes to rinse a resin down to a given purity level varies somewhat with the temperature of the water. As the water temperature drops, the diffusion rates decrease and it takes longer for the traces of regenerant to come out of the resin beads.

For relatively low-purity standards, this doesn't have much of an impact. However, for high-purity water systems that must be rinsed down to quality levels better than 100,000 ohms, the water temperature begins to play a significant role in determining the length of the rinse-down curve.

Cation resins are not as affected by water temperature as anion resins. New resins are not affected much by temperature changes. It is the anion resins that have been partially oxidized or have some organic matter on them that are most affected by temperature changes.

Anion resins that have been in service for a while almost always have a certain amount of weakly acidic groups attached to them. This can be in the form of organic acids due to organic fouling or oxidation of the polymer itself. During regeneration with sodium hydroxide, these weak acid groups are converted to their sodium salts.

During the rinse of an anion resin, these salts hydrolyze in water until they return to the hydrogen form. While this is going on, they are giving off sodium ions. The rate of hydrolysis is a direct function of temperature. Higher temperatures increase the rate of hydrolysis and allow the process to be completed in less time. This means that in warm weather it takes less time to rinse down the resin than it does in cold weather.

Given that the rate of hydrolysis is largely unaffected by the rate of water flowing through the bed, a higher rinse rate may only give what appears to be a better quality effluent because it is diluting the sodium ions in a larger volume of water. The sodium leakage from the bed while rinsing at the same flow rate as the service rate is a more meaningful number.

Water can be conserved by using a warmer temperature for regeneration and using slower flow rates for the rinse water rate to carry the hydrolysis product out of the bed. This can be accomplished by using warm water regeneration and a warm water displacement rinse. This could be extended to two or three times the normal time required for the displacement rinse.

One benefit is that the higher temperature allows the hydrolysis to occur faster; the slower flow rate during the extended displacement rinse and shorter fast rinse conserves water.

Taking water temperature into account when operating and designing an ion exchange system is important when consistent water quality is desired. The viscosity of water affects the backwash flow rates and pressure drop across a resin bed. Temperature also affects the solubility of silica and rates of hydrolysis.

Understanding the effects water temperature has on an ion exchange system can improve system capacity, pressure drop through the bed and backwash flow rates, and minimize the leakage through the resin bed.

Frank DeSilva is national sales manager and Bill Koebel is Northeast sales representative for ResinTech, Inc., Cherry Hill, NJ.