LG QuantumPure™ IX Resins

Technical Service Bulletin 906

Exchange Process for Silica Removal

1. What is the Silica?

In a state of nature, Si ion exists as silicates with metal ions, in the form of crystals, or sand as silica (SiO_2). When surface water flows over the ground and comes into contact with silicate minerals, a small amount of silica dissolves, and the concentration varies depending on the region. In natural water, silicate ions exist in various forms, most typical form is SiO_3^{2-}, with some resembling phosphate ions, and when they aggregate, they can be classified as colloid particles. In this state, they are no longer ions and exist in a suspended solid state in the solution. These characteristics can lead to difficulties in operation or analysis.

In water, silica can be classified into three major types.

1) Ionic Silica: Also known as reactive silica or monomeric silica, is readily removed by ion exchange resins. Although silica has a very low solubility in water, its solubility increases when the pH is high.
   Ionic Silica
   $SiO_2 + H_2O \rightarrow H_2SiO_3$
   Silica removed by anion exchange resin
   $R\text{-}N\cdot OH + H_2SiO_3 \leftrightarrow R\text{-}N\cdot HSiO_3 + H_2O$
2) Colloidal Silica: It is impossible to remove it by ion exchange resin, and when dried, it is deprived of moisture and precipitates as SiO_2. If it is deposited on anion exchange resins, it can cause a decrease in the performance of the resin.
3) Non-ionic Silica: Silica component that does not have an ion charge and does not form a polymer with other ions or substances. It exists in trace amounts and cannot be removed by ion exchange resins.

2. Silica Leakage

When dissolved silica leaks, it does not affect the conductivity (in fact there is slight dip in conductivity initially), but it can cause critical problems in equipment such as Steam Turbines & high-pressure boilers. The leakage of silica is related to the amount of residual silica in the ion exchange resin after the regeneration process. When silica is adsorbed onto an anion exchange resin, it can be adsorbed as a simple ion such as H_2SiO_3 or as a relatively small molecular weight soluble polymer. Larger molecular weight polymers are classified as colloidal silica and cannot be removed by ion exchange resin. The formation of silica polymers can occur during the process of surface water treatment, but it can also be accelerated when it comes into contact with acid at the cation exchange resin column. Acidic media catalyze the formation of silica polymers, while alkaline media catalyze their decomposition. If silica is not completely removed during the regeneration process, the small amount of Na leaked from the cation exchange column can generate an alkaline medium, which catalyzes the decomposition of adsorbed silica. Therefore, to reduce silica leakage, the following should be noted

1) Silica can be removed by strong base anion exchange resin. During multiple usage cycle of the strong base exchange resin, the exchange capacity tends to deteriorate and become weakly base exchange functional group. Therefore, it is necessary to replace the portion of exchange resin with new resin.

2) It is recommended to use excess amount of anion exchange resin than calculated at the design stage and manage the silica through total conductivity measurement.

For the 2B3T+MBP system, it is recommended to manage the regeneration process of MBP to prevent regeneration failure and maintain the appropriate temperature during the regeneration process. At the high temperature, it is easier to remove silica deposited on the anion exchange resin. Therefore, the temperature should be controlled within the limit of the heat resistance limits of the ion exchange resin.

3. Cause of Silica Leakage

3.1 Alkalization and Performance Degradation of Strong Base Anion Exchange Resin

The exchange group of strong base anion exchange resin is tertiary or quaternary amines, which can be easily oxidized by dissolved oxygen in water. After oxidization, the exchange capacity decreases because the exchange group is transformed from strong base to weak base. The oxidation of strong acid cation exchange resin only affects the resin support structure, but the oxidation of strong base anion exchange resin affects both the resin support structure and the exchange functional group. This means the exchange group of anion exchange resin is chemically unstable. When strong base anion exchange resin is changed to weak base, the efficiency of silica removal decreases, which can cause leakage.

3.2 An Increase in Silica Concentration in Raw Water

When the TDS or silica concentration in the influent water increases rapidly, silica leakage may occur in the treated water. If the silica concentration in the influent water is high, increasing the regeneration level during operation can reduce silica leakage.

3.3 Accumulation of Silica in Ion Exchange Resin

When silica adsorbed on the strong base cation resin is not completely removed during regeneration, silica will accumulate in the ion exchange resin. This can cause continuous leakage during operation, leading to a decrease in water production. Silica adsorbed on strong base anion exchange resin can be removed more efficiently during regeneration at higher temperatures of the regenerant. Therefore, regenerating at the highest temperature allowed by the strong base anion exchange resin can reduce silica leakage in the next cycle.

3.4 Feed Water Temperature Increase

Silica is more easily removed from ion exchange resin at higher temperatures. Conversely, if the temperature of the influent water is high, the ion exchange resin will have a stronger tendency to remove silica rather than retain it. Therefore, during the summer when the amount of silica in the feed water increases and the temperature of the raw water is high, it is desirable to increase the regeneration level during operation.

3.5 Alkalization and Performance Degradation of Strong Base Anion Exchange Resin

During the ion exchange process, strong base anion exchange resins undergo not only ion exchange reactions with inorganic ions but also adsorption and exchange reactions with organic matter. Organic matter adsorbed during the ion exchange process is removed from the resin during regeneration using NaOH, but the process is slow and generally less efficient than the ion exchange process. As a result, organic matter accumulates inside the resin. The characteristics of organic contamination include prolonged rinse time, decreased exchange capacity, and especially in the case of strong base anion exchange resin, silica leakage.

The cleaning of ion exchange resin is typically performed with brine cleaning, and the procedure is as follows:

1) The removal of organic contamination from ion exchange resin is carried out at the end of the service cycle.
2) Prepare a 10% w/v brine solution including 2% w/v NaOH at a volume as three times of BV (Bed Volumes) of resin.
3) First, pass through 1 BV of the brine solution through the fouled ion exchange resin at a flow rate of less than or equal to SV (Spatial Velocity, BV/h). Drain the first BV.
4) After step 3), introduce 1 BV of the brine solution and let the resin soak for at least 2 hours in the resin tank. Stirring the solution will enhance the effect. Drain the solution (second BV) to drain.
5) Pass though the last 1 BV of the brine solution through the ion exchange resin at a flow rate of SV.
6) Rinse the resin bed with pure water and perform double regeneration before returning to service.

Note

To maximize the effectiveness of organic fouling removal, brine solution temperature is recommended to be between 35℃ (95°F) and 60℃ (140°F).