Purolite™ C100 & C100H Hydrogen Cycle Operation Hydrochloric Acid Regeneration

Purolite C100 & C100H are premium, industrial-grade gel polystyrenic strong acid cation exchange resins supplied in the hydrogen form and are ideal for water demineralization regulations while increasing profits.

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Introduction

Purolite C100 and Purolite C100H are industrial grade, premium gel, polystyrenic, strong acid cation exchange resins supplied in sodium and hydrogen form respectively. Their principal application is in water demineralization. Purolite C100, being supplied in the sodium form, needs to be converted to the hydrogen form by applying a double or triple acid regeneration. As the resin swells between the sodium and hydrogen form, this must be taken into account in any design calculations.

This document provides information and engineering data on the removal of cations as part of the demineralization process. On exhaustion, the resin can be regenerated with different acids. Those commonly employed are sulfuric acid and hydrochloric acid. This bulletin covers hydrochloric acid regeneration, and a separate bulletin is available covering the performance using sulfuric acid. For more details, please consult the Sulfuric Acid Regeneration Engineering Bulletin.

TABLE 1 Typical Physical and Chemical Characteristics

Characteristics	Description
Polymer Structure	Polystyrene crosslinked with DVB
Physical Form	Amber, clear spherical beads
Functional Groups	Sulfonic
Ionic Form (As Shipped)	Purolite C100, Purolite C100H
Total Capacity, Na^+ Form	2.0 eq/L (43.7 Kgr/ft^3) min.
Moisture Retention, Na^+ Form	44–48%
Particle Size Range	300–1200 µm (1% maximum < 300 µm)
Uniformity Coefficient	1.7 (maximum)
Reversible Swelling, $Na^+ \rightarrow H$	8% (maximum)
Specific Gravity, Na^+ Form	Approximately 1.29
Specific Gravity, H^+ Form	Approximately 1.22
Shipping Weight, Na^+ Form	800–849 g/L (50.0–52.5 lb/ft^3)

Available Grades

Purolite C100 and Purolite C100H are available in different grades. The list below indicates products supplied in the Na^+ form, but H^+ form versions are also available in most cases.

Single Bed Applications

- Purolite C100 is a standard-grade resin with a Gaussian particle size distribution range of 300–1200 µm. Its principal application is in co-flow and traditional counter-flow regenerated plants, where classification of the bed inside the operating vessel is possible.
- Purolite C100C is a modified grade with a particle size range of 400–1200 µm for use in high flow rate applications where the standard grade resin would present an unacceptably high-pressure drop across the bed.
- Purolite Purofine™ PFC100 is a uniform particle size product with a mean particle size of 570 µm and UC of 1.1–1.2, offering improved performance in softening and demineralization systems with regard to capacity, leakage, pressure drop and rinse water requirements.
- Purolite Puropack™ PPC100 is another uniform particle size product offering similar advantages, but with a mean particle size of 650 µm. This product has been specifically developed for the Puropack system and other packed bed counter-flow designs employing either up-flow or down-flow service operations. This resin has also been widely used in co-flow and other counter-flow engineering designs, including air hold down, split flow, water hold down, etc. Purofine PFC100 and Puropack PPC100 have also seen successful operations in short-cycle plants.
- Purolite C100S is a specially cleaned and trimmed food-grade resin with a particle size range of 400–1200 µm for use in food processing, such as in the sugar industry.

Dual Layer (Stratified Bed) Applications

Purolite C100DL is a specially designed, coarse-grade resin with a particle size range of 630–1200 μm. Its principal application is in layered bed cation exchange units in conjunction with a DL-grade Purolite weak acid cation resin such as Purolite C104DLPlus.

Mixed Bed Applications

Three grades of Purolite C100 are widely used in mixed beds. These are designed to separate well from anion components, whether the anion resins are gel or macroporous. These cation resins are usually delivered in H form.

- Purolite C100MBH is a modified, simple mixed bed grade resin with a Gaussian particle size distribution in the range 425–1200 μm. It is used with either gel or macroporous mixed bed grade anion resins such as Purolite A400MB, Purolite A600MB, Purolite A200MB, Purolite A500MB or Purolite A510MB.
- Purolite C100TLH is a specially graded resin with a relatively coarse particle size for use in TRILITE™ mixed bed systems, with or without intermediate inert, employing internal or external regeneration, in conjunction with a suitable TL-grade anion resin, such as Purolite A400TL or Purolite A500TL.
- Purolite Puropack™ PPC100H is a Uniform Particle Size product, typically used in mixed bed applications with a slightly finer, uniform particle size Purofine anion resin, such as Purolite Purofine™ PFA400MB or Purolite Purofine™ PFA500MB.

Typical Operating Data

Service Operation

In service operation, water is typically pumped through the resin bed, which is retained within a pressure vessel. The vessel has top and bottom distribution/ collection systems. These systems are designed to ensure the water passes evenly through the ion exchange bed in service operation. As the water passes through the resin, the cations (principally calcium, magnesium, sodium, potassium, iron and any other dissolved cations present) are exchanged with hydrogen ions. The decationized water has a higher hydrogen (H) content, a lower pH and a higher conductivity. When the resin is exhausted, it is then regenerated with an acid solution to put it back into the hydrogen form, ready for the next service operation. It is important for the internal systems within the cation unit to efficiently distribute and collect both the water in service and the regenerant acid solution, rinses, etc., especially since the regenerant and rinse flow rates are usually much lower than the service flow rate.

In service operation, optimum performance is achieved at service flow rates between 8–40 BV/h (Bed Volumes per hour) or 1–5 gpm/ft^3 (US gallons per minute per cubic foot of resin) within linear flow rates (velocities) of 10–50 m^3/m^2/h (m/h) or 4–20 gpm/ft^2 (US gallons per minute per square foot of vessel cross-section). In contrast, acid regeneration is carried out at flow rates of 4–16 BV/h or 0.5–2.0 gpm/ft^3. Within these limits, internal distribution/ collection systems can operate efficiently at higher service and lower regenerant flow rates. At very low service flow rates, channeling within the resin bed can result in poor plant performance and short capacity between regenerations. This is particularly likely when long service cycles are also employed.

The height-to-diameter ratio is important in any ion exchange unit design. While some small industrial demineralization plants operate with very shallow bed depths, bed depths below 610 mm (2 ft) should be avoided, and bed depths greater than 1,000 mm (3 ft 3 in) should be employed. Vessel height and pressure drop are typically the controlling factors on the maximum height of the bed. For Purolite C100, we recommend that pressure drop across the bed should be maintained at less than 150 kPa (22 psi), having made allowance for bed compaction and any solids loading across a classified bed. Bed depths greater than 2,500 mm (8 ft) are rarely encountered.

Although smaller freeboards are commonly encountered, we recommend a minimum of 75% freeboard (space) above the resin bed to allow at least 50% bed expansion during backwash. This usually is adequate for a co-flow regenerated vessel and assures a good hydraulic classification of the resin bed. Fully classified beds have a higher void fraction, leading to lower pressure drop. This is particularly advantageous when high specific velocities are encountered.

Service operation is usually terminated by the detection of increased conductivity at the exit of the anion column due to increased sodium leakage from the cation bed. Occasionally, on large counter-flow regenerated plants, sodium monitors are employed on the outlet of the cation unit to initiate regeneration. The subsequent regeneration can be manually or automatically initiated via the control system.

While co-flow and traditional counter-flow regenerated plant designs allow backwashing of the resin bed within the service operation unit, they will only tolerate a low level of suspended solids in the incoming water supply. The resins are not expected to work as a mechanical filter and an adequate pre-treatment should always be included in the plant layout if optimum performance is to be achieved.

Regeneration

The resin regeneration can be performed either co-flow or counter-flow. The regeneration is termed co-flow when the regenerant flows through the resin bed in the same direction, usually downwards or “top to bottom”, in which the water flows during the service operation. When the regenerant flow is opposite to service flow, the term used is counter-flow regeneration. Other terms, co-current and counter-current, are also used to describe these two principal regeneration techniques.

When counter-flow regeneration is employed, it is important to note that the bed must remain static in the up-flow stages (except backwash). Packed beds, air hold down, split flow, and water hold down are just some of the systems employed to achieve this requirement.

In some counter-flow regenerated systems, the design allows service flow upward through the bed and regeneration downwards. In such cases, the bed must remain static throughout the service operation.

Co-Flow Regeneration

The co-flow regeneration technique is usually made up of five steps and typically takes between 1–2 hours depending on the detailed design. For this type of regeneration, the influent water generally is of adequate quality for all steps, including regenerant dilution.

The first step of co-flow regeneration is backwash. The backwash water enters the unit through the bottom collection/distribution system, loosening the bed and causing the bed to expand as the water passes up through it. The flow rate should be set for the freeboard available in the unit at the minimum water temperature. The backwash is designed to decompact the resin, for better regenerant contact, and remove any suspended solids that have been filtered out of the incoming supply and accumulated within the bed. The backwash water volume required will depend on the extent of solids loading. Where the bed only requires loosening for better regenerant contact, then 1 FBV (freeboard volume) is usually sufficient. However, when filtered solids are present, the volume required can be considerably greater. After the backwash, a “bed settle” step is required.

The bed settle allows the resin to settle back and reform the static bed before regenerant injection. Depending on the size of the bed, freeboard, and backwash rate used, this step can take between 3–8 minutes.

Regenerant injection at the correct flow rate and acid concentration are critical. Good contact between the acid solution and the resin is essential for optimum performance. Hydrochloric acid is easier to use compared to sulfuric acid. This is because there is no risk of calcium sulfate precipitation as chloride salts are more soluble; hence, higher hydrochloric acid concentrations can generate less waste.

The hydrochloric acid regeneration level (amount of acid per liter or cubic foot of resin) will typically be between 60–100 g/L (3.75–6.25 lbs/ft^3). However, regeneration levels as low as 40 g/L (2.5 lbs/ft^3) and as high as 200 g/L (12.5 lbs/ft^3) are sometimes employed. Please note all regeneration levels are expressed for the pure chemical (100%) strength. To calculate the exact volume of regenerant required per regeneration, you need to know the acid concentration available on site.

Hydrochloric acid should be introduced at flow rates of 2–4 BV/h (0.25–0.5 gpm/ft^3) and concentrations from 4–6%. The contact time between the resin and the regenerant solution should be a minimum of 20 minutes.

TABLE 2 Typical Operating Conditions for Co-Flow Regeneration

Step	Design Basis	Duration
Backwash	Set for minimum water temperature to give 50% bed expansion. Refer to Figure 17 for details.	1 FBV on clean water supplies; 2–3 FBV where solids are present
Bed Settle	To allow the bed to reform fully classified	3–8 minutes
HCl Injection	60–100 g/L (3.75–6.25 lb/ft^3) applied as a 4–6% acid solution at 2–4 BV/h (0.25–0.5 gpm/ft'). Acid volume needs to be in excess of resin volume.	Typically 20–40 minutes depending on regeneration level and flow rate
Slow Rinse	1–3 BV (7.5–22.5 gal/ft^3) at approx. regenerant flow rate	Typically 20–30 minutes depending on volume of water applied and flow rate
Final Rinse	3–6 BV (22.5–45 gal/ft^3) preferably at service flow rate or alternatively > 15 BV/h (2 US gpm/ft^3)	Typically 10–20 minutes

(Key: BV = Bed Volume, BV/h = Bed Volume per hour, FBV = Free board volume above resin bed)

The slow (regenerant displacement) rinse is always carried out at flow rates similar to the acid injection step. This ensures a uniform contact time between the resin and the regenerant solution and that the rinse water follows the same route as the regenerant through the resin bed. Since slow rinses are usually more efficient in removing the spent regenerant from the resin, using a longer slow rinse can reduce the final rinse required at the end of the regeneration.

Typically 1–3 BV (7.5–22.5 gal/ft^3) of slow rinse are applied.

The final rinse is often carried out at the service flow rate. This also provides a proving condition before returning to service after regeneration. On some occasions, where flow restrictions occur, the plant final rinse is carried out at a rate lower than the service flow rate. Usually 3–6 BV (22.5–45 gal/ft^3) are required depending on the design of the distribution/collection systems and the amount of slow rinsing previously performed.

Counter-Flow Regeneration

Traditional counter-flow regeneration techniques typically have less steps than those described earlier for co-flow regeneration and usually take between 1–1½ hours, depending on the detailed design. This type of regeneration requires, for some steps, the use of cation-free water. Decationized or demineralized water must be used for the acid dilution/injection and slow rinse steps if the published leakage is to be obtained. The water is either set aside during the previous service run or, in the case of multi-stream plants, it can be supplied by one of the other online streams. Some plants use a dedicated tank when decationized water is stored for regeneration. Still, when a degassing tower is part of the process, the degassing tower sump is usually used for this duty. When demineralized water is used, the client's treated water tank or a separate tank is employed.

In a counter-flow regenerated system, the backwash step, which is always the first step of a co-flow regeneration, is not normally performed each cycle, but a means of carrying out periodic full bed backwashes, either inside the service unit or in external dedicated vessels, should always be included in the plant design. Some engineering designs allow for sub-surface backwashes to be carried out each cycle, but such partial backwashes should not be intended as a replacement of periodic full bed backwashes. After a full bed backwash the resin should always be regenerated with double the normal amount of acid to restore full counter-flow performance.

In counter-flow regeneration, bed depths below 1,000 mm (3 ft 3 in) should be avoided, and beds preferably over 1,200 mm (4 ft) employed.

The regeneration level (amount of acid applied per liter or cubic foot of resin) will be lower than for co-flow regenerated units, typically between 40–80 g/L (2.5–5 lbs/ft^3) However, regeneration levels outside of this range are sometimes employed.

Hydrochloric acid should be introduced at flow rates of 2–4 BV/h (0.25–0.5 gpm/ft^3) and concentrations from 4–6%. The contact time between the resin and the regenerant solution should be minimum of 20 minutes.

The slow (regenerant displacement) rinse is always carried out at flow rates similar to the acid injection step and in the same direction. This ensures a uniform contact time between the resin and the regenerant solution and that the rinse water follows the same route as the regenerant through the resin bed. Since a slow rinse is usually more efficient in removing the spent regenerant from the resin than a fast rinse, using more slow rinse can reduce the amount of final rinse required.

Typically 1–2 BV (7.5–15 US gal/ft^3) of slow rinse is adequate.

The final rinse is often carried out at the service flow rate. This provides a proving condition before returning to service after regeneration. Usually 2–4 BV (15–30 US gal/ft^3) are required depending on the design of the distribution/ collection system and the amount of slow rinsing previously performed.

It is increasingly common in demineralization plants to employ closed-loop recycle rinses around the cation and anion units. This offers two advantages: it reduces the amount of wastewater produced by the plant, and allows the design to include a proving pre-service rinse before placing the line back in service. Where anion resins sometimes develop long rinses due to organic fouling, a recycled rinse system can significantly reduce water consumption and avoid resins overloading.

TABLE 2 Typical Operating Conditions for Counter-Flow Regeneration

Step	Design Basis	Duration
HCl Injection	40–80 g/L (2.5–5.0 lb/ft^3) applied as a 4–6% acid solution at 2–4 BV/h (0.25–0.5 US gpm/ft^3). Acid volume needs to in excess of resin volume.	Typically 20–40 minutes depending on regeneration level and flow rate
Slow Rinse	1–2 BV (7.5–15 gal/ft’) at approx. regenerant flow rate	Typically 20–30 minutes depending on volume of water applied and flow rate
Final Rinse	2–4 BV (15–30 gal/ft^3) preferably at service flow rate or alternatively > 15 BV/h (2 gpm/ft^3)	Typically 10–20 minutes

(Key: BV = Bed Volume, BV/h = Bed Volume per hour)

Purolite C100 and Purolite C100H are perfectly suitable for traditional counter-flow regeneration systems, but when more sophisticated plant designs are used, other more specialized grades, such as Purolite PFC100 or Purolite PPC100, can enhance the performance further. Consult your local Ecolab sales office if you need any guidance.

Performance Data

The following graphs and correction factors are designed to help the design engineer to estimate the exchange capacity and hardness leakage achieved with Purolite C100 and Purolite C100H under different operating conditions. All the data shown result from years of industrial experience and are supplied in good faith. The final performance will depend on the detailed design and operation of the system, the quality of the regenerant chemicals, and the long-term maintenance of the plant. Some engineers using basic, standard plant of simple design may take a design margin (safety factor) concerning the published data to allow for less than ideal operation. Please note the data presented in this section are specific to co-flow regenerated designs with bed depths over 1,000 mm (3 ft 3 in) and counter-flow regenerated designs with bed depths over 1,200 mm (6 ft 6 in). For shallower bed depths, there may be a requirement to downrate the expected performance depending on the quality of the design.

The data supplied are divided into three groups: Figures 1 to 8 deal with capacity and leakage for co-flow regeneration, Figures 9 to 16 with capacity and leakage for counter-flow regeneration, and Figures 17 to 18 with hydraulic data (backwash expansion and pressure drop). Within each of the first two groups, there is a base capacity and a base leakage curve, followed by other curves showing correction factors. To calculate the expected capacity or leakage, multiply the base capacity or leakage by the relevant correction factors.

Ecolab's Purolite™ Resin System Modeling (PRSM™) software is available via www.puroliteresins.com at no charge for users interested in performing these engineering calculations electronically.

The data presented in this bulletin can also be used to estimate the operating performances of resins such as Purolite C100C, Purolite C100S, or Purolite C100DL. At the same time, it is recommended to refer to dedicated engineering bulletins for products like Purolite PFC100 and Purolite PPC100.

Co-Flow Regeneration Charts

FIGURE 1

Base Capacity

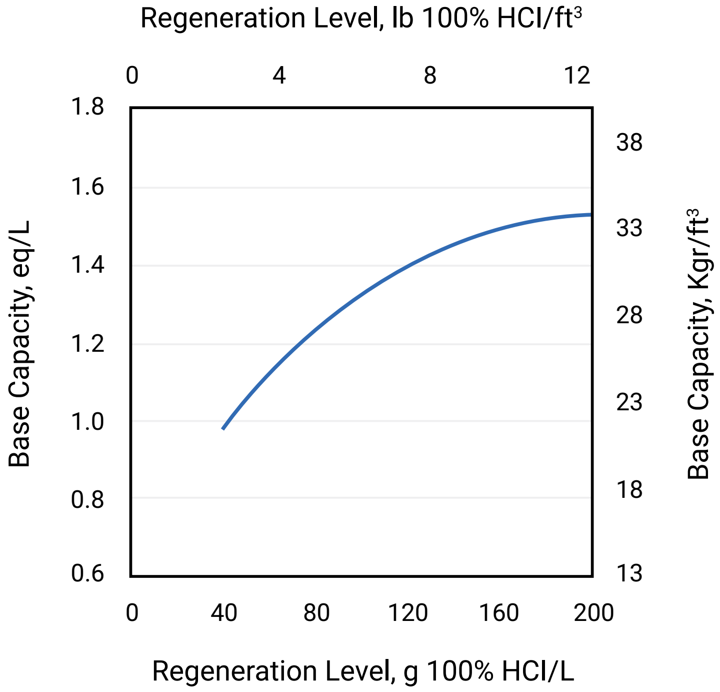


Figure 1 provides base capacity data for Purolite C100, delivered in sodium form. Capacity of Purolite C100H, delivered in hydrogen form, is expected to be 8% lower than shown in this graph.

FIGURE 2

C1: Capacity Correction Factor Total Alkalinity/ Total Anions

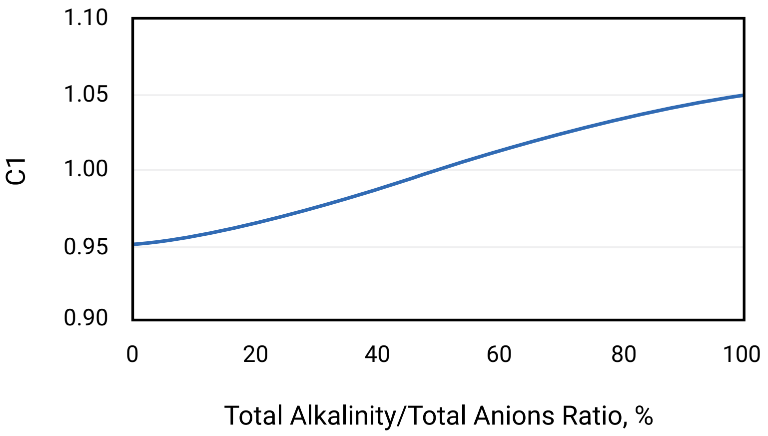


FIGURE 3

C2: Capacity Correction Factor for Temperature

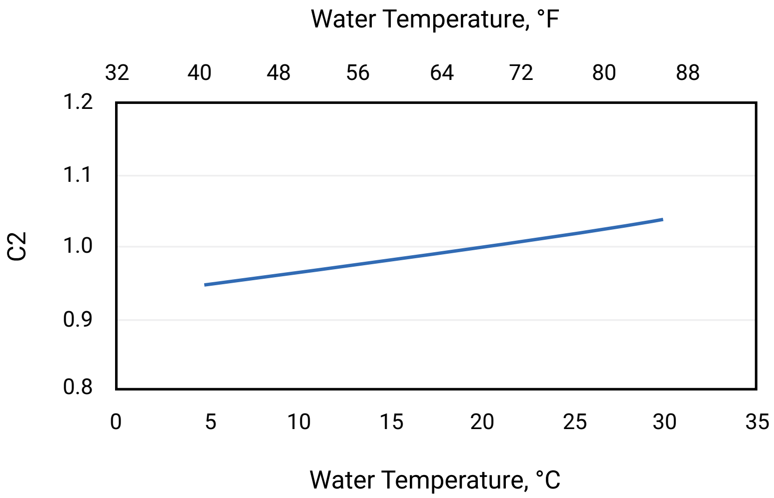


FIGURE 4

C3: Capacity Correction Factor for Na/Total Cations

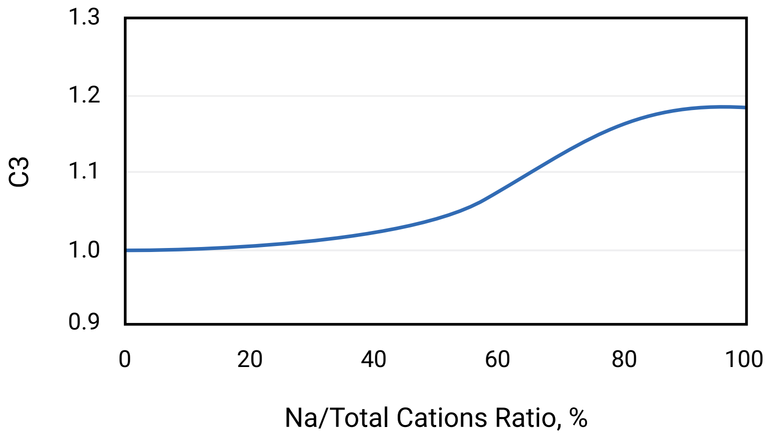


FIGURE 5

C4: Capacity Correction Factor for Kinetic Load (Specific Flow Rate — Total Cations)

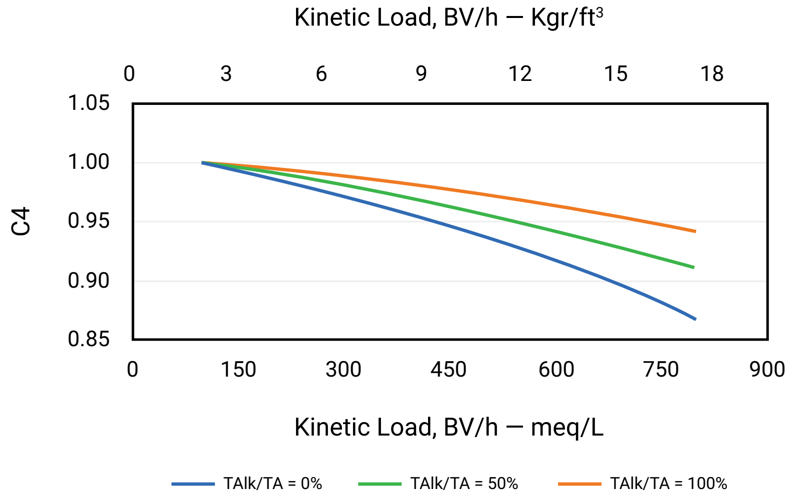


FIGURE 6

Base Sodium Leakage

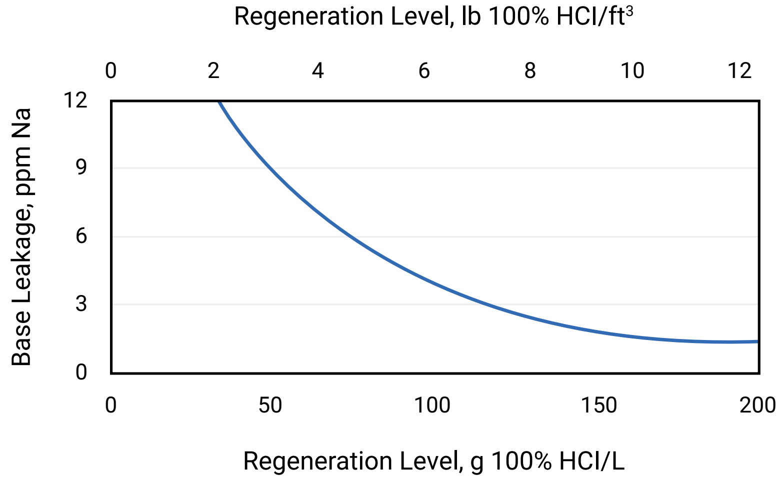


FIGURE 7

L1: Capacity Correction Factor for Equivalent Mineral Acidity

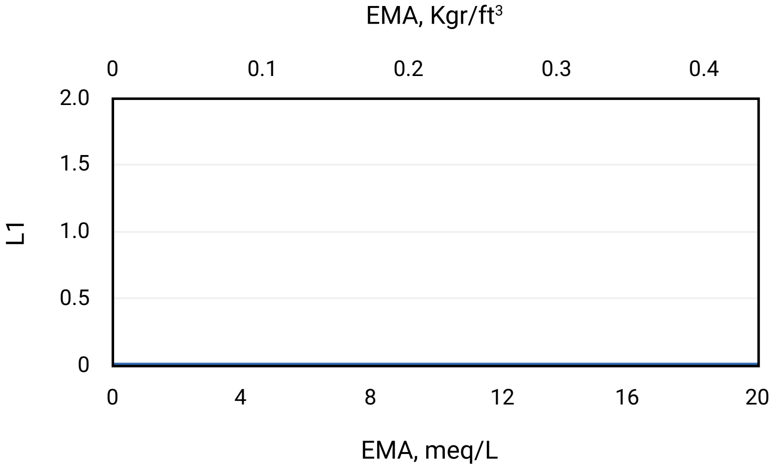
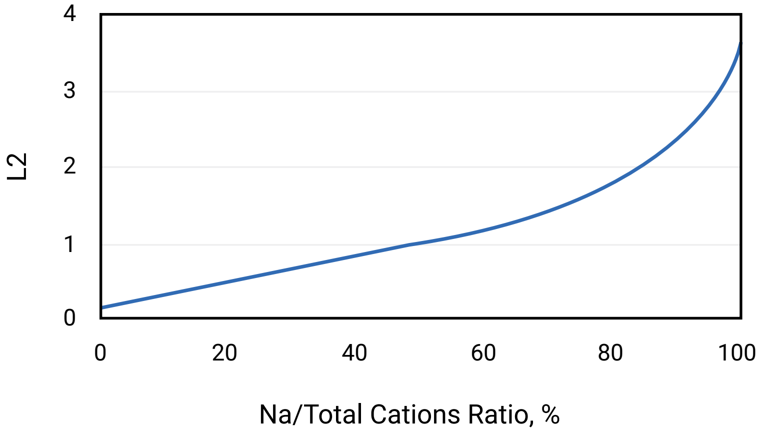


FIGURE 8

L2: Leakage Correction Factor for Na/Total Cations



Counter-Flow Regeneration Charts

FIGURE 9

Base Capacity

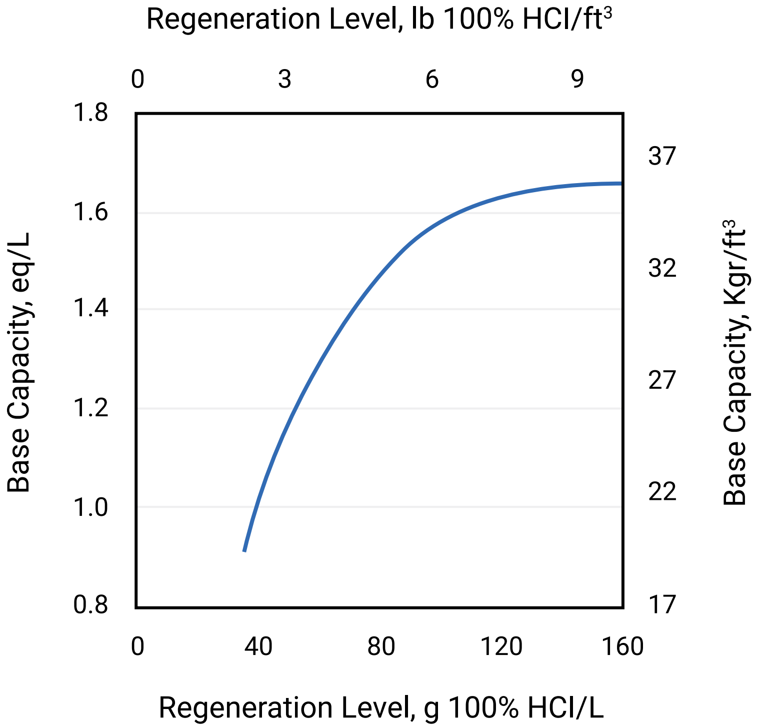


Figure 9 provides base capacity data for Purolite C100, delivered in sodium form. Capacity of Purolite C100H, delivered in hydrogen form, is expected to be 8% lower than shown in this graph.

FIGURE 10

C1: Capacity Correction Factor Na/Total Cations

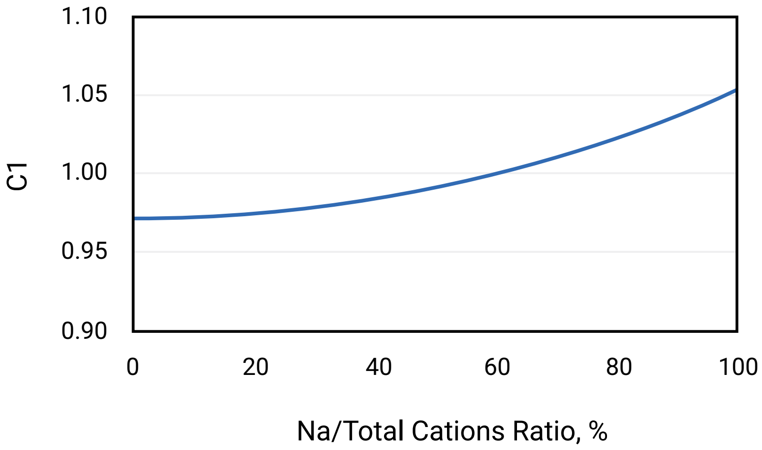


FIGURE 11

C2: Capacity Correction Factor for Total Alkalinity/ Total Anions

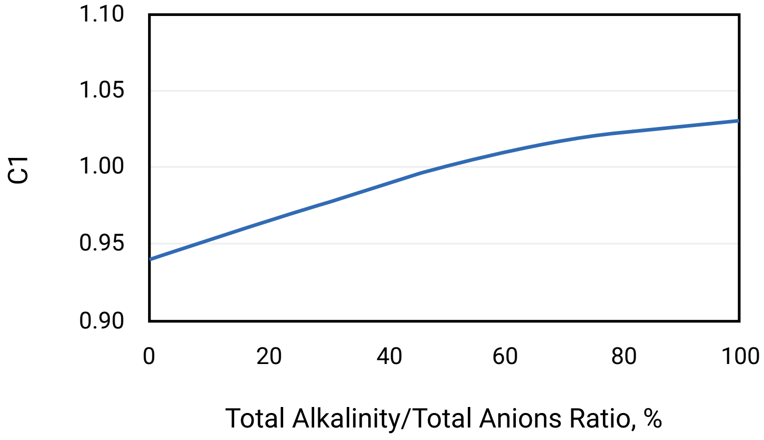


FIGURE 12

C3: Capacity Correction Factor for Temperature

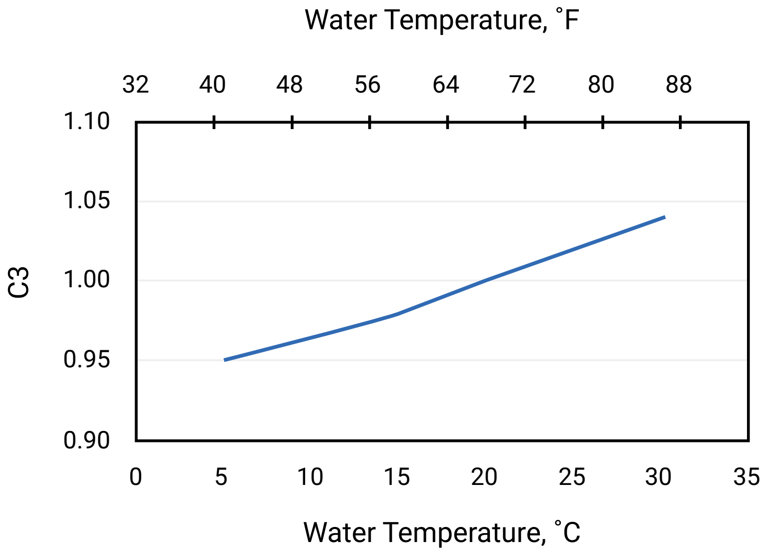


FIGURE 13

C4: Capacity Correction Factor for Bed Depth

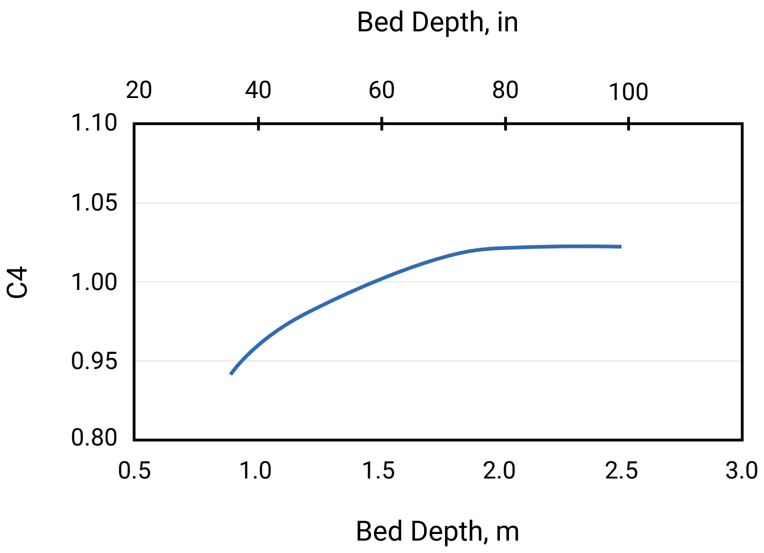


FIGURE 14

C5: Capacity Correction Factor for Specific Flow Rate

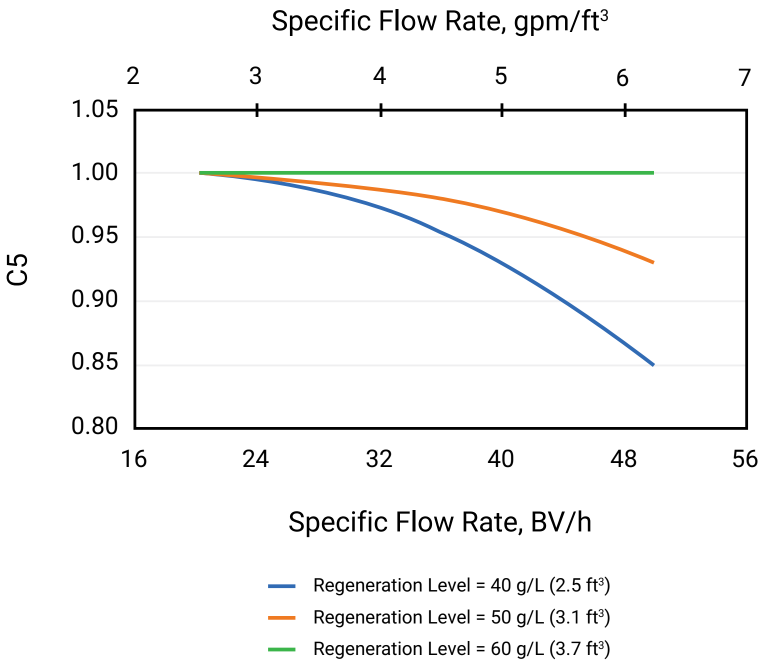


FIGURE 15

C6: Capacity Correction Factor for Kinetic Load (Specific Flow Rate — Total Cations)

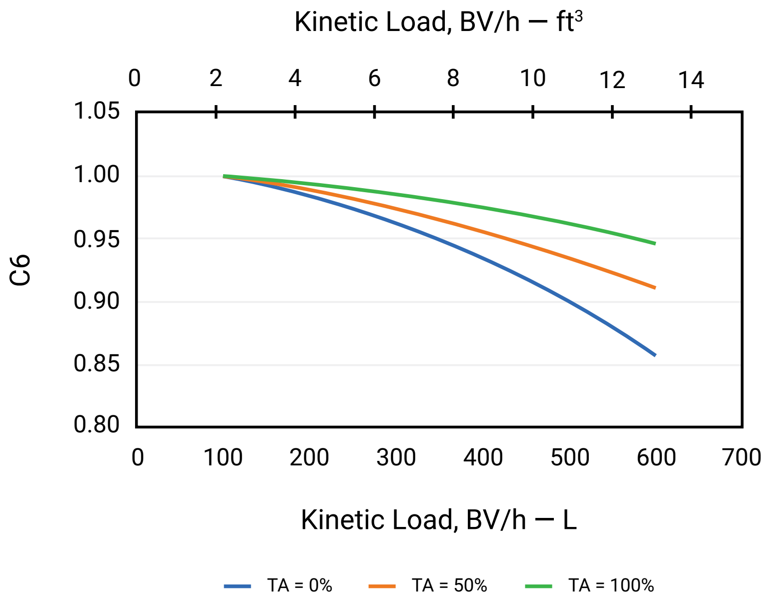
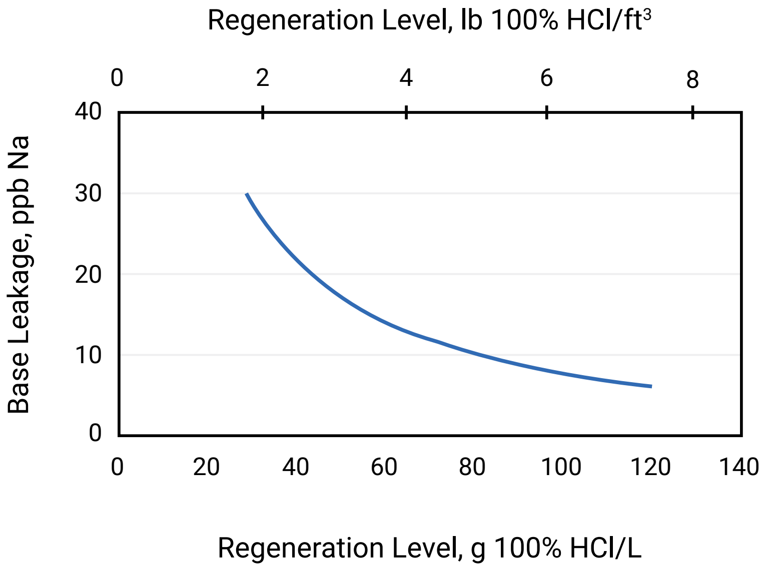


FIGURE 16

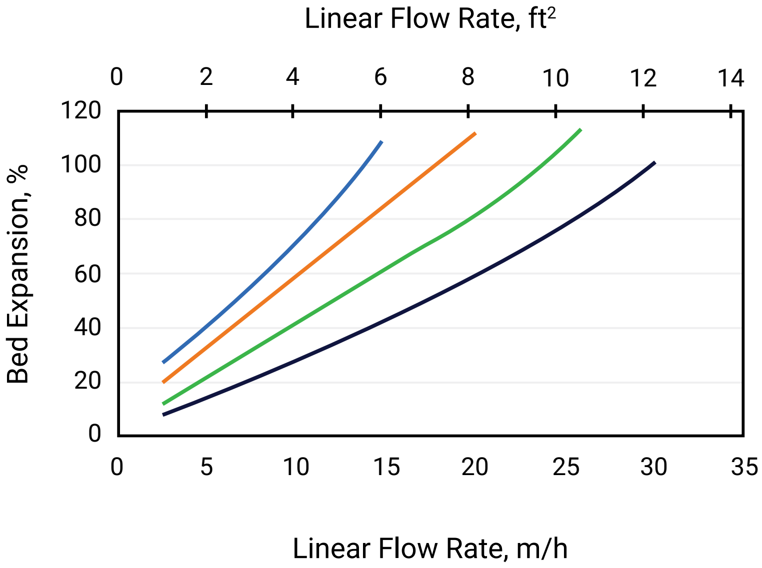
Sodium Leakage



Hydraulic Characteristics

FIGURE 17

Backwash Expansion



Additional Information & Application Notes

Safety: Strong oxidants, such as nitric acid, may cause violent reactions with ion exchange resins under certain conditions. Use of strong oxidants must be done under the care and supervision of persons knowledgeable in handling these types of materials.

MSDS/SDS: Material Safety Data Sheets/Safety Data Sheets are available on the Purolite Resin website, www.puroliteresins.com. MSDS sheets should be consulted for additional information on product safety, handling and disposal.

Storage and Transportation: Information on the proper storage and transportation can be found on the Purolite Resin website, www.puroliteresins.com.

Ecolab is a global developer, manufacturer, and supplier of Purolite™ Resins including ion exchange, catalyst adsorbent and advanced polymers that make the world cleaner and healthier.

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