Purolite™ A400 Industrial-Grade, Polystyrenic Gel Type I Strong Base Anion Resin

This Engineering Bulletin provides engineering data for using Purolite A400 supplied in the chloride (salt-exhausted) form for water demineralization. Capacity and leakage data is presented for co-flow and counter-flow systems.

ECOLAB®

Purolite A400 Industrial-Grade, Polystyrenic Gel Type I Strong Base Anion Resin

Contents

Introduction

Purolite A400 is an industrial grade, polystyrenic gel, Type I strong base anion exchange resin that is typically supplied in the chloride (exhausted) form. It is also available in the hydroxide (regenerated) form as Purolite A400OH. The data in this engineering bulletin is specific to Purolite A400 supplied in the chloride form with information and engineering data on the removal of anions as part of the demineralization process. The principal application of Purolite A400 is in water demineralization.

The anion resin encounters higher water temperatures when operated in the hydroxide form where very good silica removal with low silica leakage is required, primarily in co-flow regenerated plants. This anion has excellent regeneration efficiency and is used where frequent regenerations are required, such as makeup demineralizers.

Purolite A400 is ideal in systems servicing hot climates or situations where warm water is encountered e.g., raw water or regenerant solution is preheated. Purolite A400 is widely used worldwide as the anion component in separate bed demineralization trains and in both working and polishing mixed beds.

TABLE 1 Purolite A400 Typical Physical and Chemical Characteristics

Characteristic	Description/Value
Polymer Structure	Gel polystyrene crosslinked with divinylbenzene
Appearance	Spherical Beads
Functional Group	Type I Quaternary Ammonium
Ionic Form	Cl^-
Total Capacity (min.)	1.3 eq/L (28.4 Kgr/ft^3) (Cl^- form)
Moisture Retention	48–54% (Cl^- form)
Particle Size Range	300–1200 µm
< 300 um (max.)	1%
Uniformity Coefficient (max.)	1.7
Specific Gravity	1.08
Shipping Weight (approx.)	680–715 g/L (42.5–44.7 lb/ft^3)
Temperature Limit	100 °C (212.0 °F) (Cl^- form)
Temperature Limit	60 °C (140.0 °F) (OH^- form)

Available Grades

Purolite A400 is available in different bead size grades and supplied in the Cl^- form, unless otherwise stated. Most grades are available in other ionic forms with product data sheets available on our website, www.puroliteresins.com.

Single Bed Applications

- Purolite A400 is a standard grade resin with a Gaussian particle size distribution in the range of 300–1200 µm. Its main application is in co-flow and traditional hold down counter-flow regenerated plants, where classification of the bed inside the operating vessel is possible.
- Purofine® PFA400 is a uniform particle size product with a mean particle size of 570±50 µm and a UC of 1.1–1.2, offering improved performance with operating capacity, leakage, pressure drop and rinse water volumes in co-flow and counter-flow systems.
- Puropack® PPA400 is another uniform grade product, offering similar advantages, but with a mean particle size of 650±50 µm. This product has been specifically developed for Puropack systems and other packed bed designs that use either up-flow or down-flow service operation. This resin is also used in co-flow and other counter-flow engineering designs such as split flow, air and water hold down, etc.
- Purolite A400E is specially cleaned resin for use in food processing and food-grade applications.

Dual Layer (Stratified Bed) Applications

Purolite A400DL is a specially designed, coarse grade version of Purolite A400. Its main application is in layered bed anion exchange units in conjunction with a DL Plus grade Ecolab weak base anion resin such as Purolite A100DLPlus.

Mixed Bed Applications

Three grades of Purolite A400 are for use in mixed beds and are specifically designed to separate efficiently from the cation components. All three grades are anti-static treated to reduce clumping when first installed.

- Purolite A400MB is a modified, simple mixed bed grade resin designed to give better separation than the standard grade product. It is usually used with gel mixed bed grade cation resins and is most often encountered in combination with Purolite C100MB, Purolite C100MBH, or Purolite C100x10MBH.
- Purofine PFA400MB is a uniform particle size product typically used in mixed bed applications and usually used in conjunction with Puropack PPC100H.

Typical Operating Data

Service Operation

In the demineralization process, the anion column is always located downstream of the cation column, sometimes with a weak base anion unit and/or a degasser tower between the cation and strong base anion, depending on the raw water quality and plant design. This resin is best downstream of the cation because calcium and magnesium ions must be removed prior to the anion bed. If not, these ions will precipitate when in contact with the anions hydroxide functional group resulting in a precipitant that fouls and contributes to loss of performance.

When raw water contains a significant amount of alkalinity (bicarbonate), degassing towers can be located after the cation column, prior to the strong base anion bed. The cation components in the raw water influent will exchange with hydrogen (H^+) ions on the cation resin, which reacts with alkalinity converting bicarbonate to carbonic acid. In turn, carbonic acid dissociates into carbon dioxide and water in the cation bed's low pH conditions. Degassers significantly reduce this bicarbonate ionic load onto the anion resin, decreasing the volume of anion resin and regenerant required and significantly cutting operating costs if alkalinity loading is high.

A degassing tower consists of a column filled with ceramic or plastic pall rings that get sprayed with decationized water. Water flows down through the packing, while a flow of low-pressure air is blown into the bottom of the tower. The high contact surface between water and air created by the pall rings speeds up the migration of carbon dioxide dissolved in the water to the air, thus reducing the concentration of carbon dioxide in degassed water to or close to the solubility level. The degassed water is then collected in a sump for pumping through the next stage using dedicated pumps.

In service operation, decationized water — or decationized and degassed water — is normally pumped through the anion resin bed, retained within a pressure vessel. The vessel has top and bottom distribution/collection systems which are designed to ensure water passes evenly through the ion exchange bed during service operation. As the water passes through the resin, the anions (principally sulfate, nitrate, chloride, carbon dioxide, silica, and any other dissolved anionic species) are exchanged with hydroxide ions. The pH of the anion-treated water increases across the resin bed, from the acid to the slightly alkaline range, and at the same time, the conductivity falls significantly. When the plant is working correctly, the conductivity at the exit of the anion column is dictated by the sodium leakage from the cation bed. When the anion resin is exhausted, it is regenerated with sodium hydroxide solution to put the resin back into the regenerated hydroxide form, making it ready for the next service operation. It is important that the internal systems within the unit efficiently distribute and collect both the water during service operation and the regenerant solution, rinses, etc., during regeneration, especially since the regenerant and the slow rinse run at much lower flow rates 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), with 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), whereas caustic regeneration is carried out at flow rates of between 2–6 BV/h or 0.25–0.75 gpm/ft^3. Internal distribution/collection systems can operate efficiently at higher service and lower regenerant flow rates within these limits. Channeling can occur within the resin bed at very low service flow rates and result in poor plant performance and short runs between regenerations.

The resin vessel 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. Bed depths greater than 1,000 mm (3 ft 3 in) are recommended. Vessel height and pressure drop are normally the controlling factors on the maximum height of the bed. We recommend that pressure drop across the bed should be maintained at less than 150 kPa (22 psi) for Purolite A400 as this allows for bed compaction and any solids loading across a classified bed. Bed depths greater than 2,500 mm (8 ft) are rarely encountered.

Freeboard, which is the space between the top of the resin and the backwash effluent laterals in co-flow and counter-flow hold down, is recommended at a minimum of 75% of the resin bed height to allow at least 50% bed expansion during backwash. This is usually adequate to decompact the bed and assures good hydraulics for proper regeneration, allowing water movement during warm up, dilute caustic feed and slow rinse. This freeboard is also advantageous when high backwash flow is encountered. Water that has passed through a cation stage should be free of solids; therefore, a backwash strainer can be used. If a higher backwash rate is mistakenly employed, this will ensure no loss of resin. A lower water temperature will also increase bed expansion during backwashing and is another reason why a backwash strainer can prevent resin loss if the water temperature falls significantly between the summer and winter seasons.

Anion service operation is usually terminated based on several different factors:

- Detection of increased conductivity at the exit of the anion column often due to increased sodium leakage from the cation bed. This can only be reliably used if the capacity of the anion resin bed is greater than that of the cation.
- Detection of increased silica leakage at the exit of the anion column.
- Volumetric throughput, based on the volume of water treated, terminating the service cycle before either the cation or anion columns exhaust.
- A time schedule is also occasionally used, but this is the least precise control method as it relies on consistent influent water quality and service flow.

Regeneration can be manually or automatically initiated via the control system, but plant regeneration steps are now fully automatic. Depending on the engineering design, either regeneration can start with the cation bed followed by the anion regeneration, or in more sophisticated designs, the two regenerations will be performed almost simultaneously to reduce the time the plant is offline.

Variation in Performance

This document includes capacity and leakage curves. The operating capacity of Purolite A400 is related to the proportion of sulfate and carbon dioxide in the water and to the silica endpoint terminating the service cycle. This data also shows a higher regenerant temperature improves silica leakage and capacity. Therefore, plants need to elevate the anion resin bed temperature and the sodium hydroxide regenerant before and during the caustic feed.

Regeneration

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 as water during the service operation, usually downwards or “top to bottom.” When the regenerant flow is in the opposite direction to service, the term used is counter-flow regeneration. Other words such as co-current and counter-current are also used to describe these two principal regeneration techniques.

Counter-flow units have two options, either up-flow service and downflow regeneration or downflow service and up-flow regeneration. It is important to note that in the up-flow stages (except backwash) the bed must remain packed. Packed beds with up-flow service will have a small freeboard, and the bed remains packed by service flow. Systems with downflow service will then have up-flow regeneration. Here the packed bed will be maintained by air hold down, split flow or water hold down.

Co-flow Regeneration

Co-flow regeneration typically consists of five steps and takes between 1 1/2–2 hours to complete, depending on the detailed design. Decationized water is adequate quality for all steps, including regenerant dilution.

The first step of co-flow regeneration is backwash. Backwash water enters the unit through the bottom collection system, loosens the bed and causes the bed to expand as the water passes up through it. Flow rate should be set based on freeboard available and the coolest water temperature. Backwash is designed to decompact the resin for better regenerant contact and remove suspended solids that should be minimal in the anion bed. The volume of backwash water will depend on the extent of solids loading. Decationized water should be free of solids, and a relatively small amount of backwash water is usually required to loosen the bed. After the backwash, a “bed settle” step is required.

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 5–10 minutes. Anion resins are lighter than cation resin, so the bed settle time is usually longer.

When low-level silica leakage is required, it is essential to preheat the anion bed and the dilute caustic solution to 120 °F (50 °C) to ensure sufficient elution of silica from the resin. Failure to preheat the caustic and bed will result in silica fouling on the anion and silica leakage above acceptable levels.

TABLE 2 Typical Sodium Hydroxide Regeneration Conditions for Co-Flow Regenerated Columns

Step	Design Basis	Duration
Backwash	Set for the minimum water temperature to give 50% bed expansion. Refer to Figure 24 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	5–10 minutes
Anion Bed Preheat	Flow rate comparable to caustic dilution water	Approximately 1 BV or 7.5 gallons/ft^3
NaOH Injection (Preheated to 120 °F or 50 °C)	60–100 g/L (3.75–6.25 lb/ft^3) applied as a 3–6% caustic solution at 2–4 BV/h (0.25 to 0.5 gpm/ft^3)	Typically 45–60 minutes, depending on regeneration level and flow rate
Slow Rinse	2–3 BV (15–22.5 gal/ft^3) at approx. regenerant flow rate	Typically 30–40 minutes, depending on the 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 gpm/ft^3)	Typically 10–20 minutes. The less slow rinse employed, the more final rinse required.

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

Regenerant injection at the correct flow rate and caustic concentration are critical. Good contact between the caustic solution and the resin is essential for optimum elution of unwanted ions. The sodium hydroxide regeneration level (amount of caustic per liter or cubic foot of resin) will typically be between 60–100 g/L (3.75–6.25 lb/ft^3), although regeneration levels as low as 48 g/L (3.0 lb/ft^3) and as high as 200 g/L (12.5 lb/ft^3) are sometimes used. Note that all regeneration levels are expressed as 100% sodium hydroxide. To calculate the exact volume of regenerant required per regeneration, the concentration of sodium hydroxide available on site must be known.

Sodium hydroxide should be introduced at flow rates of 2–4 BV/h (0.25–0.5 gpm/ft^3) and concentrations from 3–6%. The contact time between the resin and the regenerant solution should be a minimum of 60 minutes.

The slow (regenerant displacement) rinse is always carried out at flow rates similar to the caustic injection step. This ensures 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 at removing spent regenerant from the resin, a longer slow rinse can reduce the amount of final rinse required at the end of the regeneration. Typically, 2–3 BV (15–22.5 gal/ft^3) of slow rinse are applied.

The final rinse is often carried out at the service flow rate. This also acts as 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 fewer steps than those described for co-flow regeneration and usually take between 1–1½ hours, depending on the detailed design. This type of regeneration requires the use of anion-free water to achieve optimal performance, so demineralized water is used for sodium hydroxide dilution and slow rinse steps. Only then can the published silica leakage be obtained. The required amount of demineralized water is either produced and set aside during the previous service cycle or, in the case of multi-stream plants, it can be supplied by one of the other online streams.

The backwash step, which is always the first step of a co-flow regeneration, is not usually performed each cycle in a counter-flow regenerated system. However, 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 sub-surface backwashes to be carried out each cycle, but such partial backwashes should not be intended to replace periodic full bed backwashes. The resin should always be regenerated with double the usual amount of sodium hydroxide to restore full counter-flow performance after a full bed backwash. These full bed backwashes can be as infrequent as every 30 cycles and are normally determined by the increased pressure drop across the bed.

In counter-flow regeneration, bed depths below 1,000 mm (3 ft 3 in) should be avoided. It is preferential for beds to be in excess of 1,200 mm (4 ft).

The regeneration level (amount of sodium hydroxide 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 lb/ft^3). However, regeneration levels outside of this range are sometimes used. Systems with critical silica limits the regenerant caustic and anion resin bed must be preheated to a minimum of 120 °F (50 °C) as in the co-flow system. The regenerant should be introduced at flow rates of 2–4 BV/h (0.25–0.5 gpm/ft^3) with concentrations from 3–6%. The contact time between the resin and the regenerant solution should be a minimum of 40 minutes.

The slow (regenerant displacement) rinse is always carried out at flow rates similar to the regenerant injection step and in the same direction. This ensures 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. Normally 1.5–2 BV (11–15 US gal/ft^3) of slow rinse are adequate. The final rinse is often carried out at the service flow rate. This also acts as a proving condition before returning to service after regeneration. Normally 2–4 BV (15–30 US gal/ft^3) are required, depending on the design of the distribution system, age of the anion and the amount of slow rinsing previously performed.

TABLE 3 Typical Sodium Hydroxide Regeneration Conditions for Counter-flow Regenerated Columns

Step	Design Basis	Duration
Anion Bed Preheat	Flow rate comparable to caustic dilution water	Approximately 1 BV or 7.5 gallons/ft^3
NaOH Injection (Preheated to 120 °F or 50 °C)	40–80 g/L (2.5–5.0 lb/ft^3) applied as a 3–6% caustic solution at 2–4 BV/h (0.25–0.5 gpm/ft^3)	Typically 40 minutes, depending on regeneration level and flow rate
Slow Rinse	1–2 BV (7.5 to 15 gal/ft^3) at approx. regenerant flow rate	Typically 20–30 minutes, depending on volume of water applied and flow rate
Final Rinse	2–4 BV (15 to 30 gal/ft^3) preferably at service flow rate or alternatively > 15 BV/h (2 gpm/ft^3)	Typically 10–20 minutes; closed-loop recycle rinse can be introduced during final rinse

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

It is common to employ closed-loop recycle rinses around the cation and anion units in counter-flow regenerated demineralization plants. This offers two advantages: reducing the amount of wastewater produced by the plant and allowing the design to include a proving pre-service rinse prior to placing the unit back into service. Anion resins sometimes develop long rinses due to organic fouling, and a recycle rinse system can significantly reduce water consumption and avoid preloading of resins. With efficient distribution and collections systems, the recycle rinse on well-designed counter-flow plants can sometimes begin after 50% of the final rinse if influent water quality allows.

Purolite A400 and other grades are perfectly suitable for traditional hold down counter-flow regeneration systems. When more sophisticated packed bed plant designs are used, specialized grades, such as Purofine PFA400 or Puropack PPA400, will be used to enhance performance. Consult your local Ecolab sales office for guidance.

Performance Data

The following figures are intended to help design engineers estimate exchange capacity and silica leakage achieved with Purolite A400 under operating conditions. All the data shown resulted from years of industrial experience and are supplied in good faith. The ultimate 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. Engineers using a standard plant of simple design may wish to take a design margin (safety factor) regarding the published data to allow for less-than-ideal operation.

The data presented in this section are specific to 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 (4 ft 0 in). For more shallow 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 1–11 deal with capacity and leakage for co-flow regeneration
- Figures 12–23 with capacity and leakage for counter-flow regeneration
- Figures 24–25 with hydraulic data (backwash expansion and pressure drop)

Within each of the first two groups, there are base capacity and leakage curves, followed by curves showing correction factors. To calculate the expected capacity or leakage, multiply the base capacity or leakage by the relevant correction factors.

Ecolab's PRSM™ resin system modeling software is available on 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 A400E or Purolite A400DL. Engineering data for Purofine PFA400 and Puropack PPA400, which offer enhanced performance under some operating conditions which can be found in the PRSM software which is available on Ecolab's website www.puroliteresins.com.

Co-Flow Regeneration Charts

FIGURE 1

Base Capacity

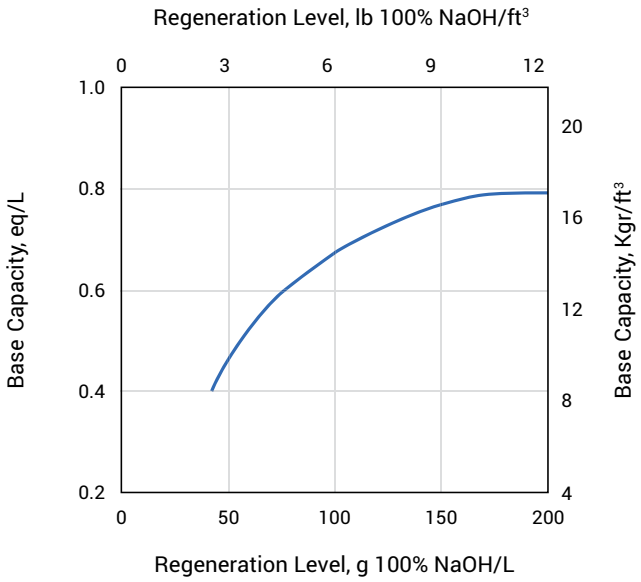


FIGURE 2

C1: Capacity Correction Factor Sulfates/Total Anions

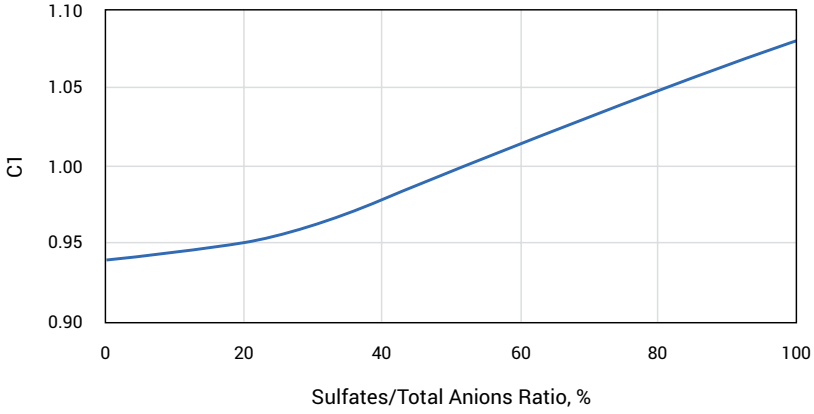


FIGURE 3

C2: Capacity Correction Factor CO_2/Total Anions

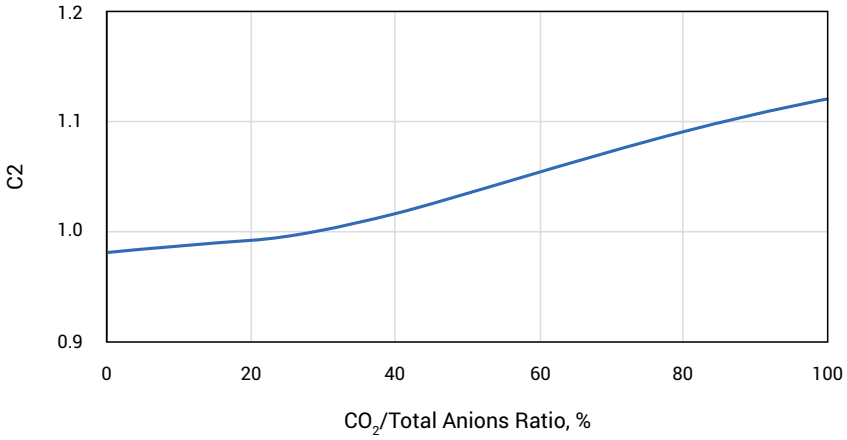


FIGURE 4

C3: Capacity Correction Factor Silica Endpoint

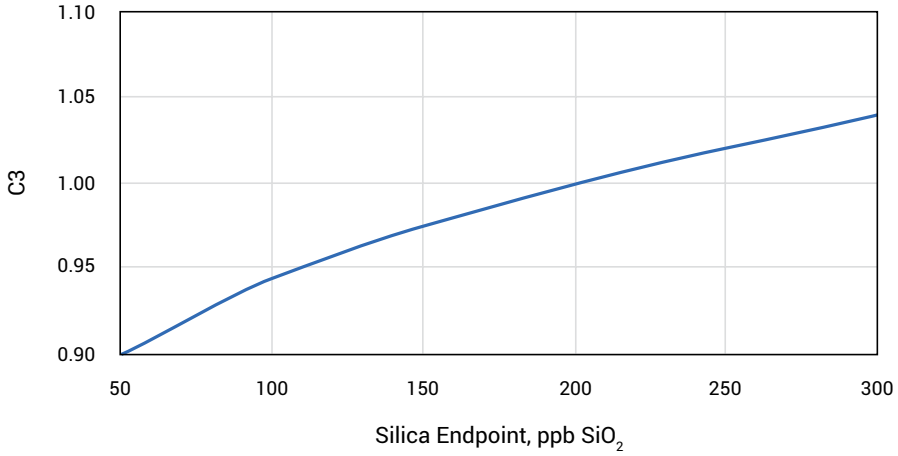


FIGURE 5

C4: Capacity Correction Factor for Bed Depth

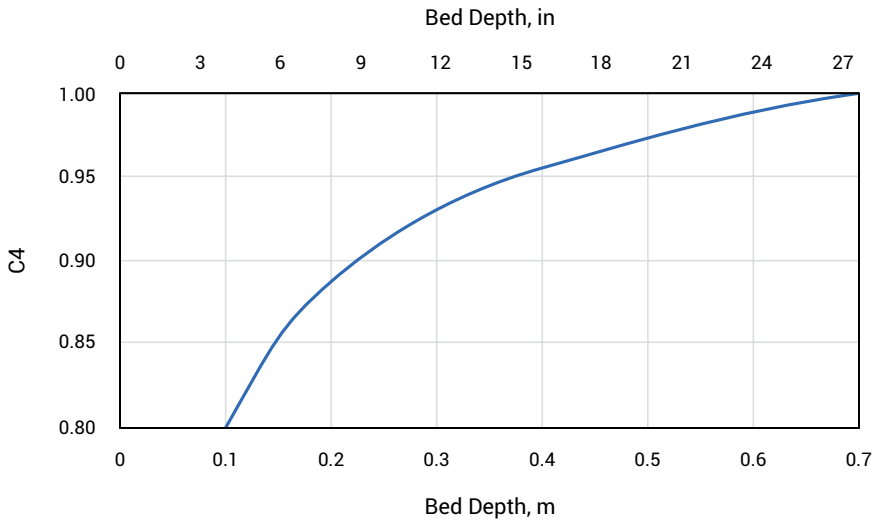


FIGURE 6

C5: Capacity Correction Factor for Silica and Regeneration Temperature

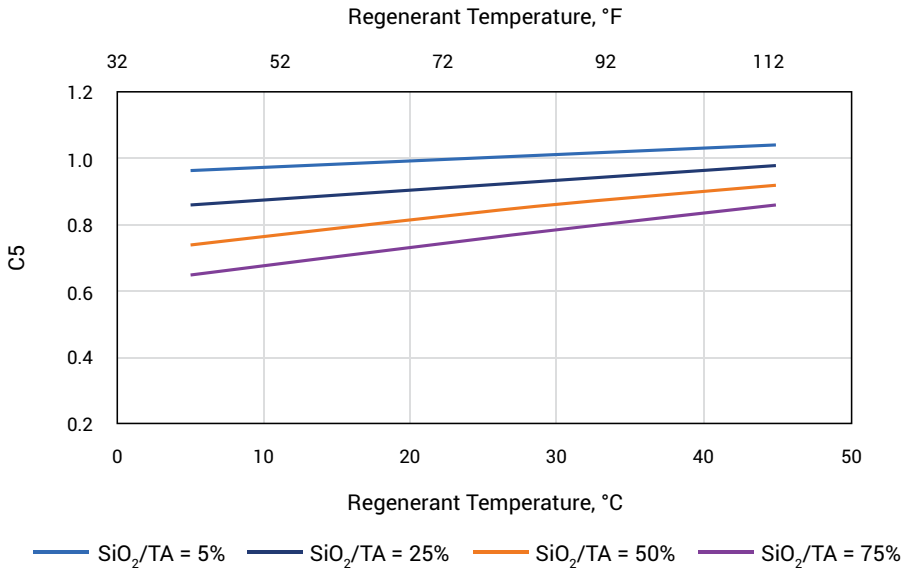


FIGURE 7

Basic Silica Leakage

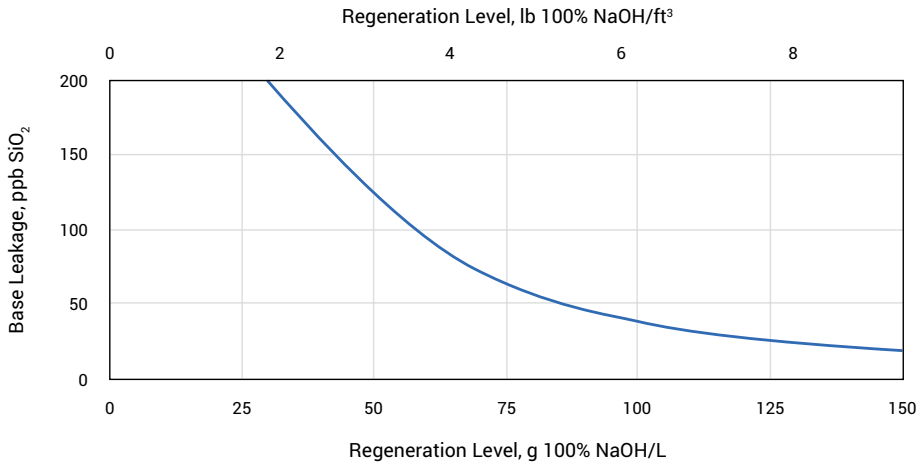


FIGURE 8

L1: Leakage Correction Factor $Si0_2$/Total Anions

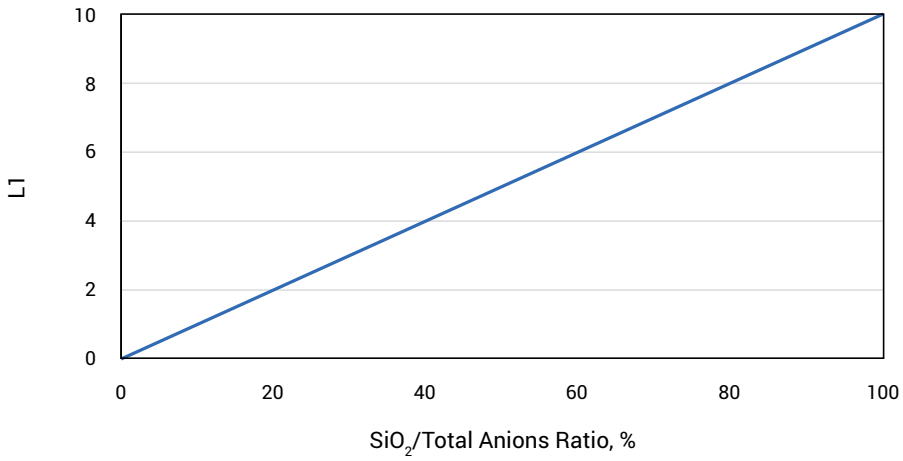


FIGURE 9

L2: Leakage Correction Factor for Feed Water Temperature

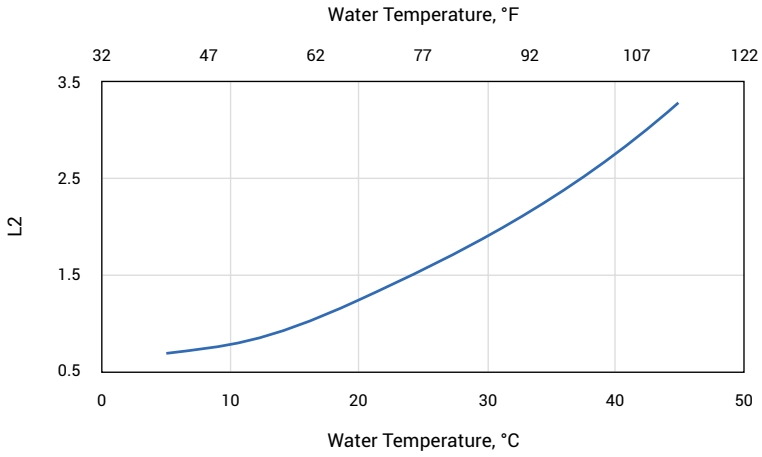


FIGURE 10

L3: Leakage Correction Factor for Regeneration Temperature

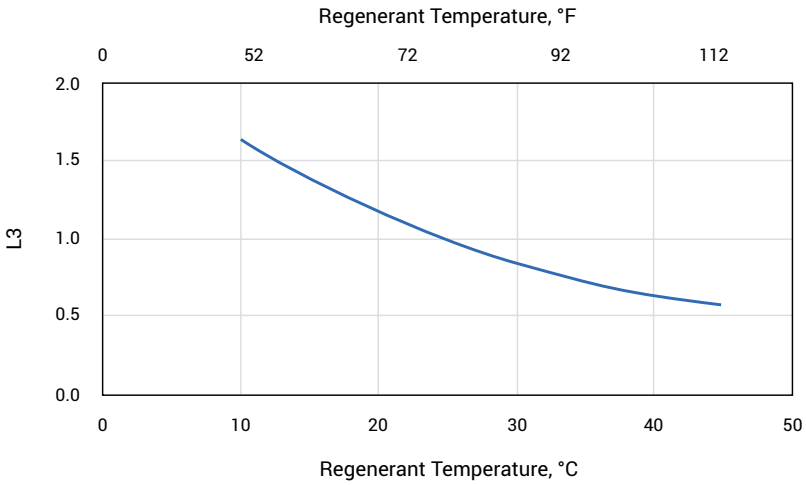
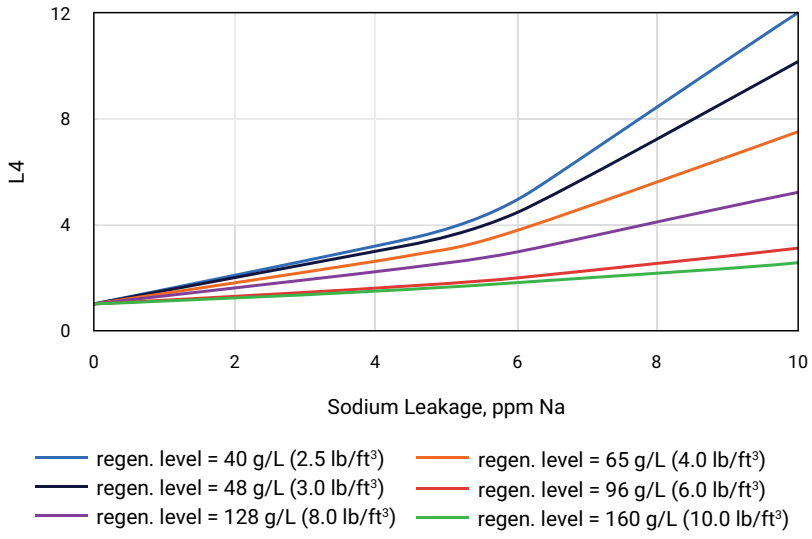


FIGURE 11

L4: Leakage Correction Factor for Sodium Leakage/ Regeneration Level



Counter-Flow Regeneration Charts

FIGURE 12

Base Capacity (Counter-Flow Regeneration)

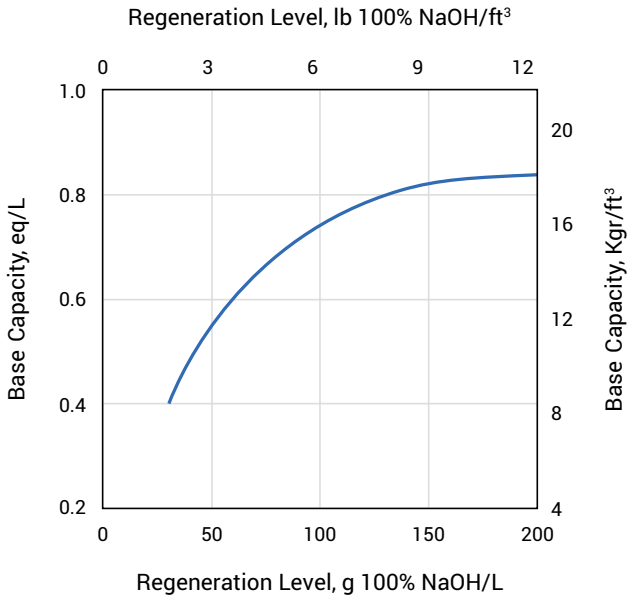


FIGURE 13

C1: Capacity Correction Factor Sulfates/Total Anions

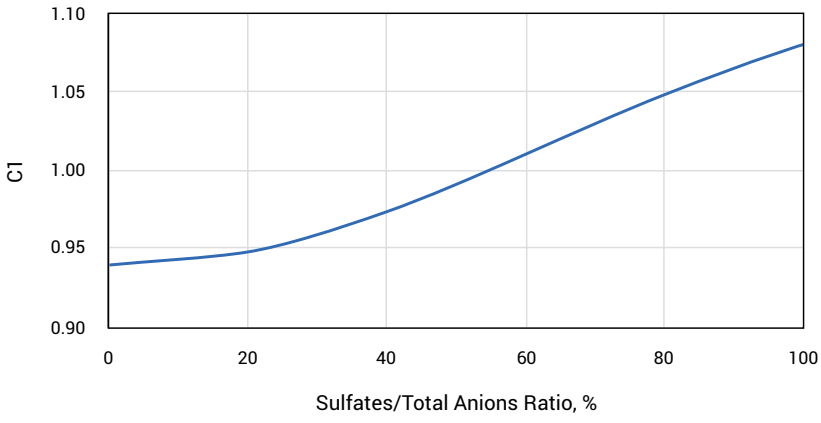


FIGURE 14

C2: Capacity Correction Factor CO_2/Total Anions

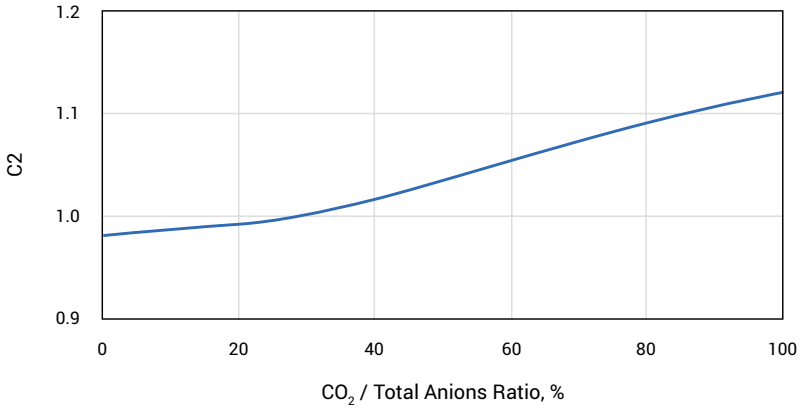


FIGURE 15

C3: Capacity Correction Factor Silica Endpoint

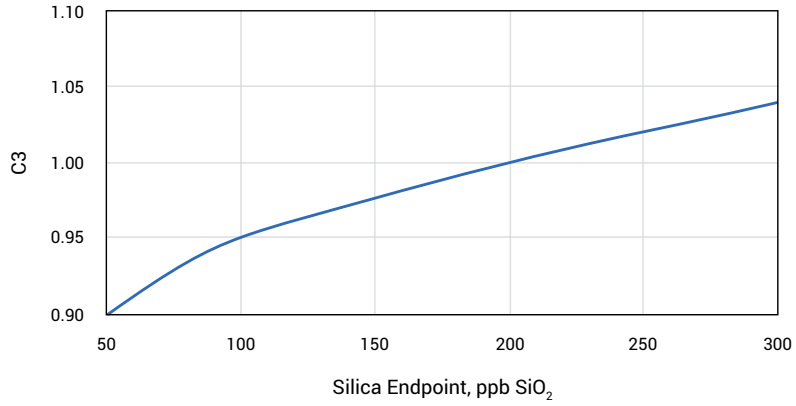


FIGURE 16

C4: Capacity Correction Factor for Resin Bed Depth

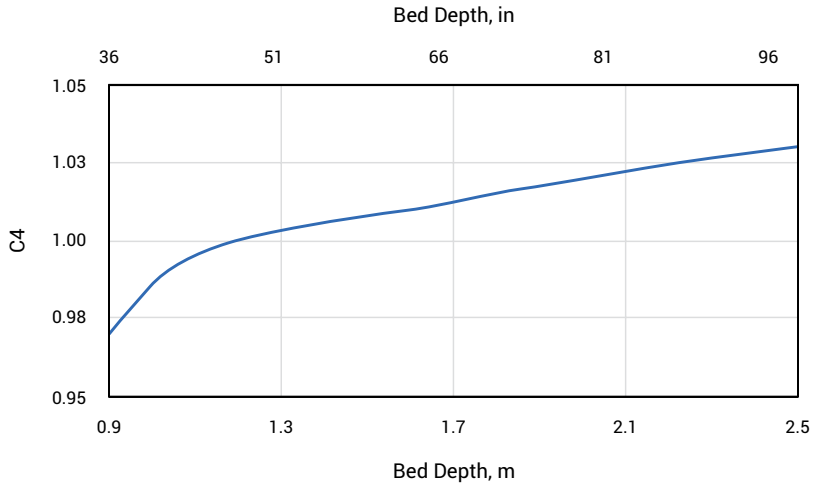


FIGURE 17

C5: Capacity Correction Factor for Silica Regeneration Temperature

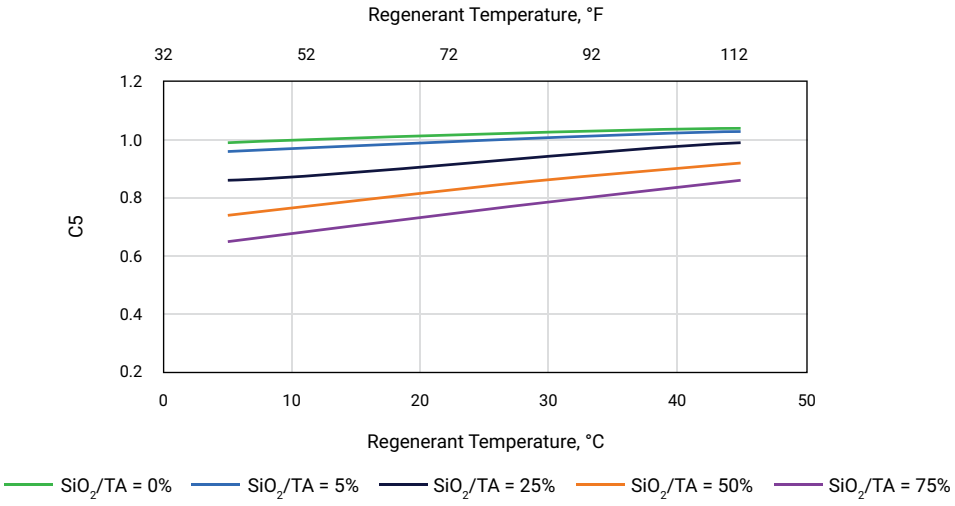


FIGURE 18

Base Silica Leakage

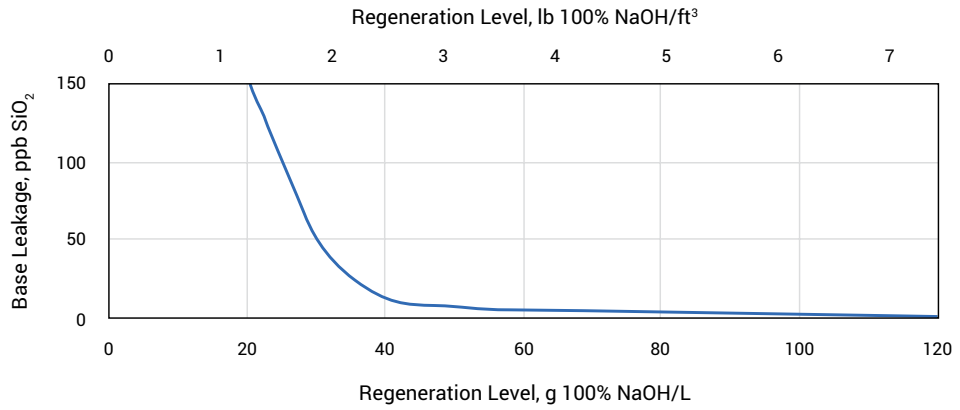


FIGURE 19

L1: Leakage Correction Factor SiO_2/Total Anions

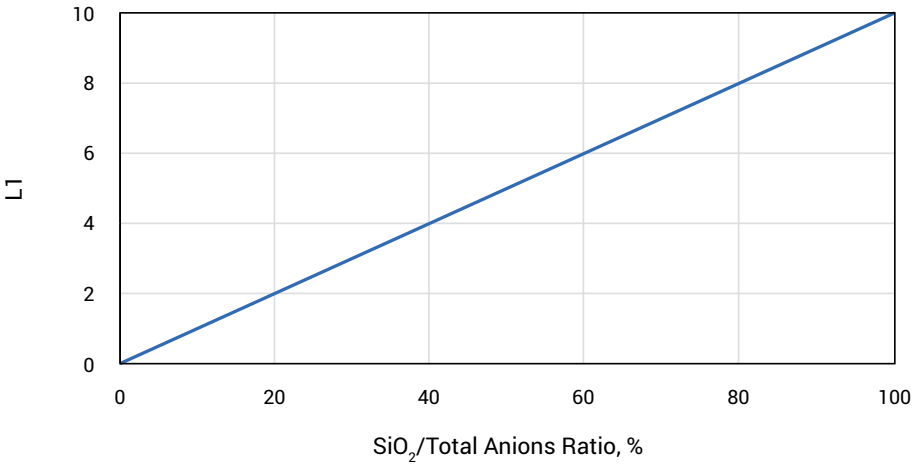


FIGURE 20

L2: Silica Leakage for Feed Water Temperature

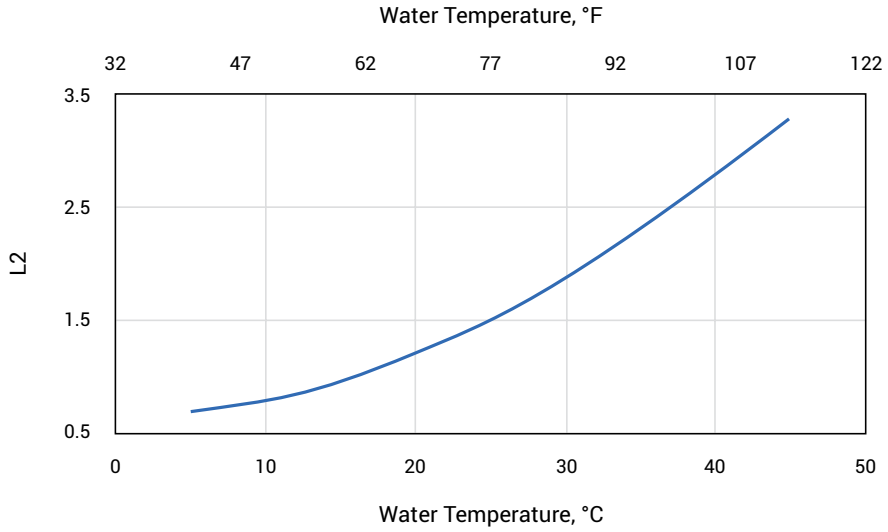


FIGURE 21

L3: Silica Leakage for Regeneration Temperature

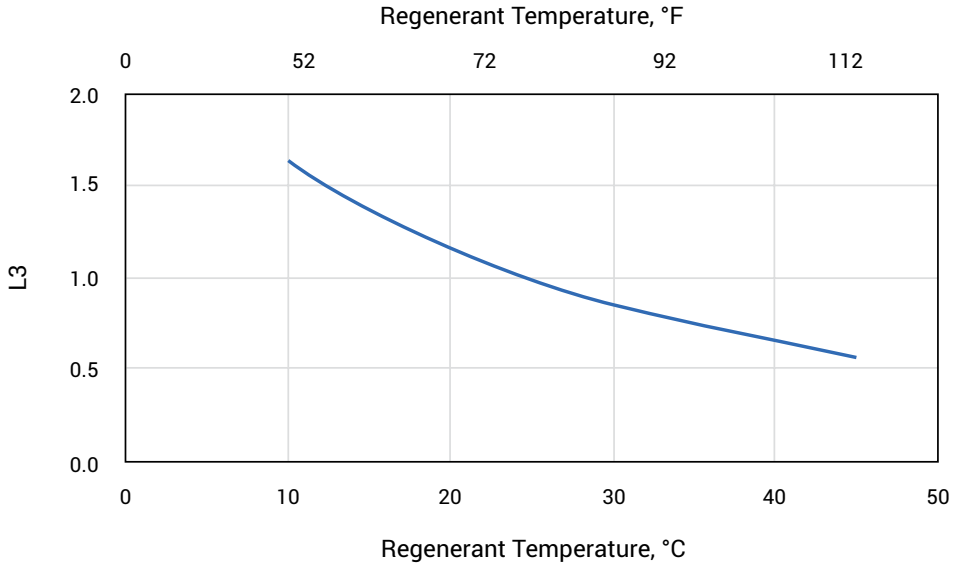


FIGURE 22

L4: Leakage Correction Factor for Sodium Leakage/ Regeneration Level

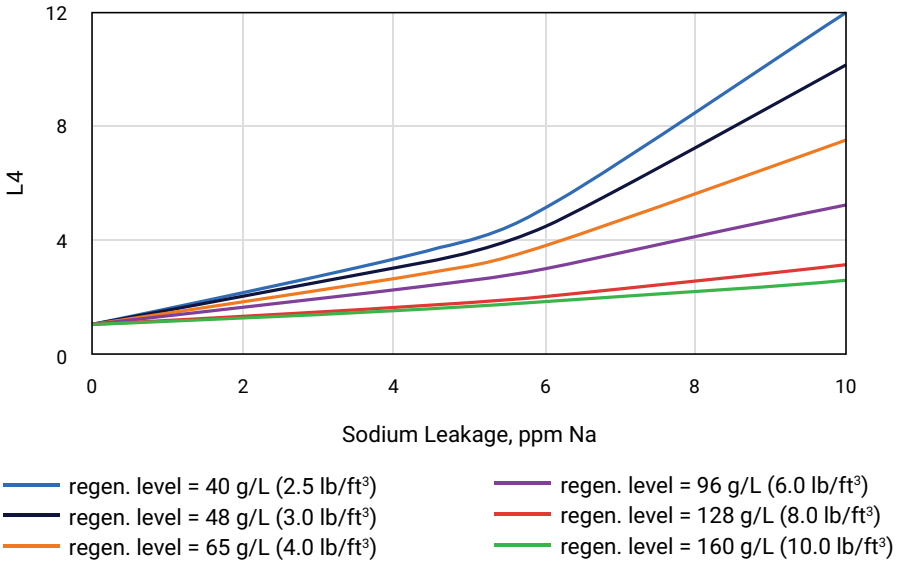
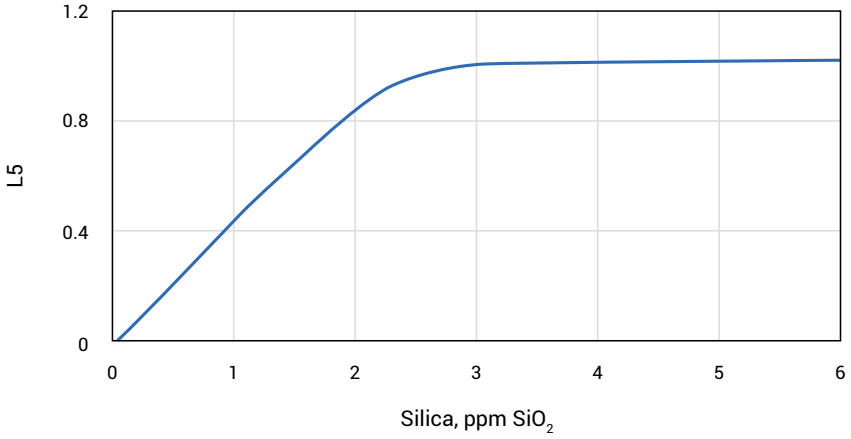


FIGURE 23

L5: Leakage Correction Factor Silica in Feed



Hydraulic Characteristics

FIGURE 24

Backwash Expansion

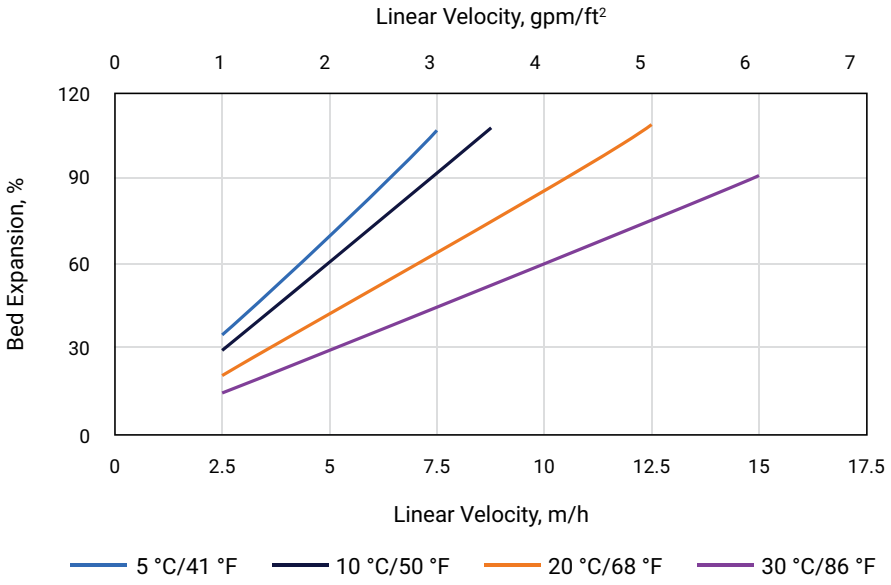
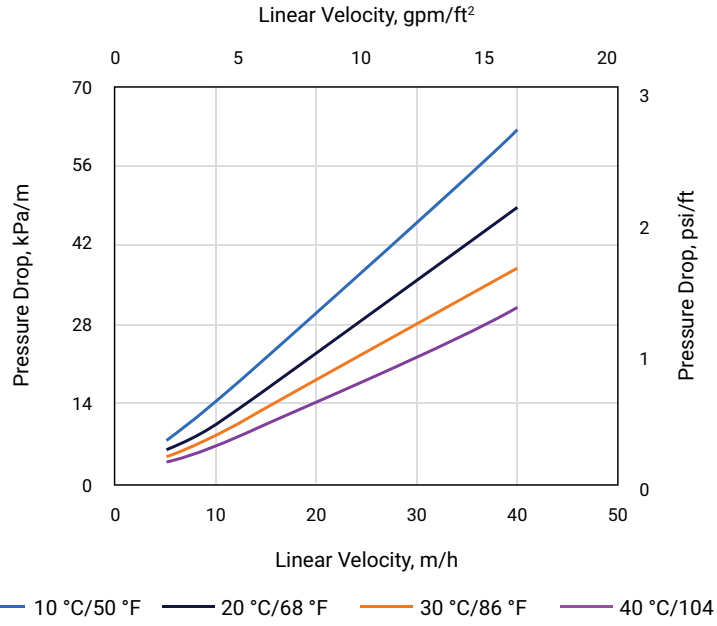


FIGURE 25

Pressure Drop



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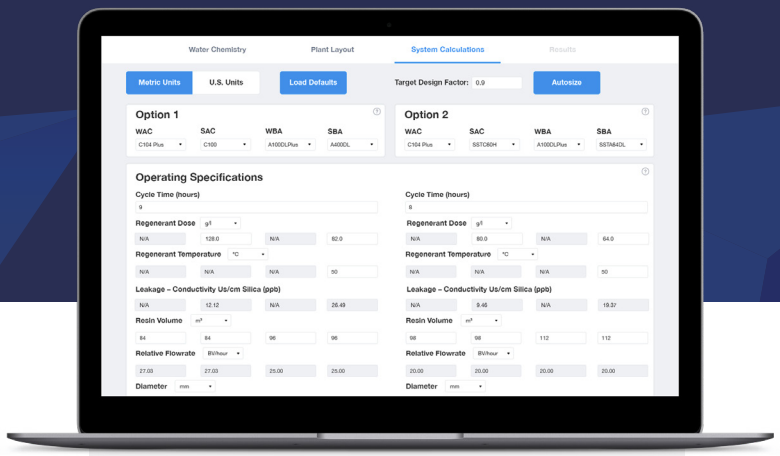

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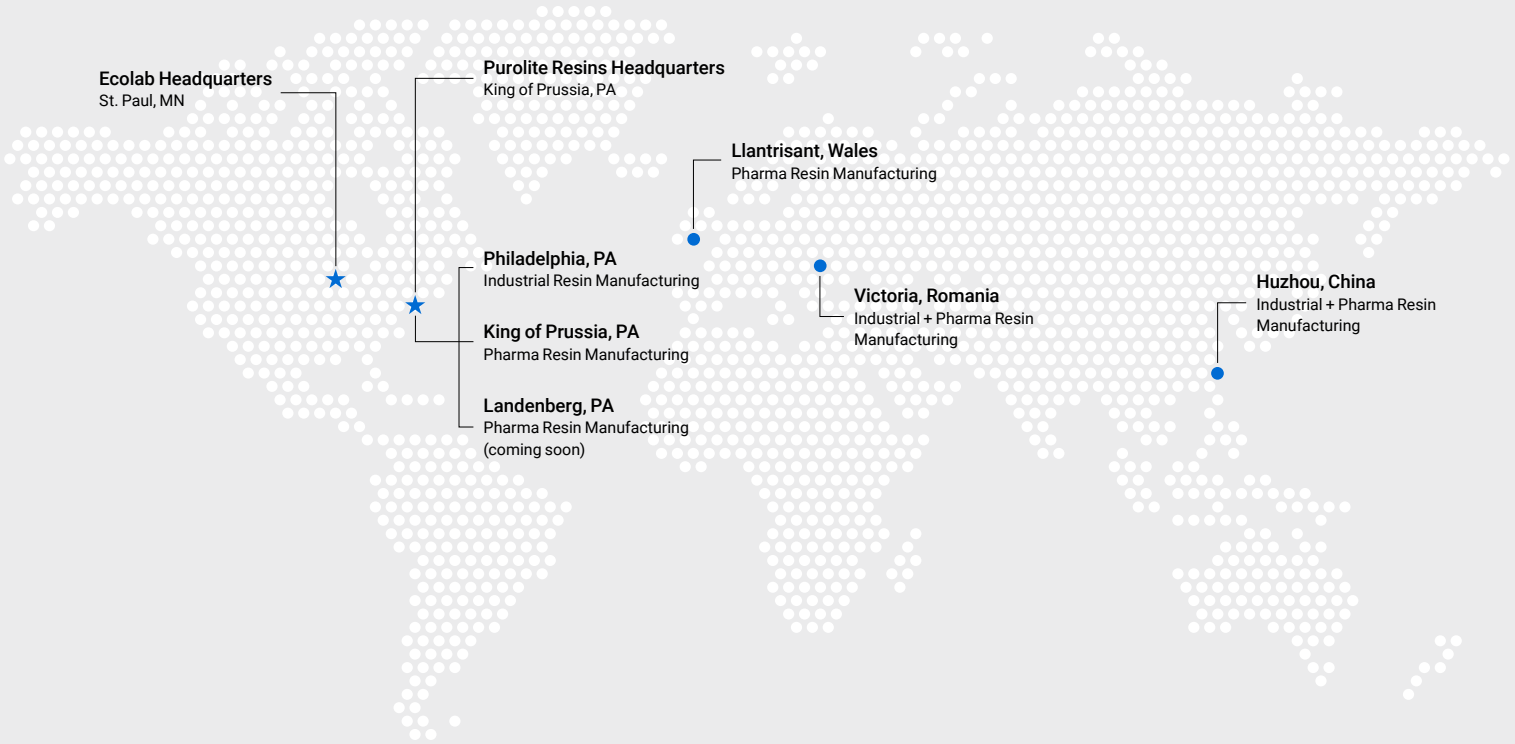

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