Engineering Bulletin

PUROLITE® C100
Sodium Cycle Operation

Purolite C100 is a premium industrial grade, gel polystyrenic strong acid cation exchange resin, supplied in the sodium form. Its principal application in the sodium form is in industrial water softening. Due to its robust nature **Purolite C100** is also used as a cation exchanger in demineralization plants, where it is operated in the hydrogen form following full acid regeneration.

This document refers specifically to the resin use in water softening, for the removal of total hardness, with sodium chloride (salt) regeneration. For its use as cation exchange resin in demineralization processes, please refer to the **Purolite C100** Hydrogen Cycle Engineering Bulletins.

Purolite C100 has a standard particle size distribution and it is primarily used in co-flow and traditional counter-flow regenerated softening units. It operates successfully over a wide range of operating conditions and it offers a higher resistance to the attack by oxidizing agents, such as chlorine, compared to some other less robust softening resins, resulting in a longer resin life.

TYPICAL PHYSICAL AND CHEMICAL CHARACTERISTICS	
Polymer structure	Polystyrene crosslinked with DVB
Physical form	Amber, clear spherical beads
Functional groups	Sulfonic
Ionic form, as shipped	Na^+
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% max. <300 µm
Uniformity coefficient	1.7 max.
Reversible swelling, $Ca^{2+} \rightarrow Na^+$	8% max.
Specific gravity, Na^+ form	Approx. 1.29
Shipping weight	800 - 840 g/l (50.0 - 52.5 lb/ft^3)
Maximum temperature limit	120°C (250°F)

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PUROLITE®
ION EXCHANGE RESINS

Available Grades

Purolite C100 is available in different grades, all supplied in the Na^+ form.

- **Purolite C100** is a standard grade resin with a Gaussian particle size distribution in the range 300-1200 µm. Its principal application is in co-flow and traditional counter-flow regenerated softening and demineralization plants, where classification of the bed inside the operating vessel is possible.
- **Purolite C100C** is a modified grade with a particle size in the range 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.
- **Purofine® PFC100** is a Uniform Particle Size product with a mean particle size of 570 µm and a UC of 1.1-1.2, offering improved performance in softening and demineralisation systems, with regard to capacity, leakage, pressure drop and rinse water requirements.
- **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 operation. Both **Purofine® PFC100** and **Puropack® PPC100** have also seen successful operation in short cycle plants.
- **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**.
- **Purolite C100S** is a specially cleaned and trimmed food grade resin with a particle size in the range 400-1200 µm, for use in food processing, such as in the sugar industry.

Typical Operating Data (Guide to Service Operation and Regeneration)

Service Operation

In service operation hard water is normally 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 raw water passes evenly through the ion exchange bed in service operation. As the water passes through the resin, the hardness (principally calcium and magnesium) is exchanged with sodium ions. Hence the treated softened water has a higher sodium content and a somewhat higher conductivity. When the resin is exhausted it is then regenerated with a NaCl solution to put the resin back into the sodium form, ready for the next service operation. Therefore the internal systems also have to efficiently distribute and collect the regenerant brine solution, rinses, etc.

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In service operation optimum performance is achieved at service flow rates between 8 and 40 BV/h (Bed Volumes per hour) or 1 to 5 gpm/ft^3 (US gallons per minute per cubic foot of resin) within linear flow rates (velocities) of 10 to 50 $m^3/m^2/h$ (m/h) or 4 to 20 gpm/ft^2 (US gallons per minute per square foot of vessel cross section), whereas brine regeneration is carried out at flow rates of 2 to 4 BV/h or 0.25 to 0.5 gpm/ft^3. Within these limits internal distribution / collection systems can operate efficiently both at the higher service and lower regenerant flow rates. At very low service flow rates channelling can occur within the resin bed resulting in poor plant performance and short capacity between regenerations. This is particularly likely when long service cycles are also employed at these low flow rates.

While some small industrial and domestic softeners operate with very shallow bed depths, bed depths below 610 mm (2 ft) should be avoided and preferably bed depths greater than 1000 mm (3 ft 3 in) employed. Vessel height and pressure drop are normally the controlling factor 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 2000 mm (6 ft 6 in) are rarely encountered. The ratio of height to diameter is important in any ion exchange unit design.

Although smaller freeboards are sometimes encountered, we recommend a minimum 75% freeboard (space) above the resin bed to allow at least 50% bed expansion during backwash. This is normally adequate for a co-flow regenerated vessel, and assures a good hydraulic classification of the resin bed.

Service operation is usually terminated by detection of hardness leakage, or volumetric throughput (water meter control), or on a time basis (time clock control). Regeneration can be manually or automatically initiated via the control system.

While co-flow regenerated resin beds with backwashing will tolerate a low level of suspended solids present in the incoming water supply, the resin bed should not be expected to work as a mechanical filter. Adequate pre-treatment should always be included if optimum resin performance is required.

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

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It should be remembered when counter-flow regeneration is employed, it is important that in the up flow stage(s) the bed must remain static and hence packed beds, air hold down, split flow and water hold down are just some of the systems employed to achieve this requirement.

Co-flow regeneration

The co-flow regeneration technique is normally made up of 5 steps and typically takes between 1 and 2 hours depending on the detailed design. For this type of regeneration, the influent water is usually 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 both decompact the resin, for better regenerant contact, as well as for removing 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 (free board volume) is normally 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 prior to regenerant injection. Depending on the size of the bed, free board, and backwash rate used, this step can take between 3 and 8 minutes.

Regenerant injection at the correct flow rate and brine concentration are critical. Good contact between the NaCl solution (brine) and the resin is essential for optimum performance. Purolite recommend the brine is introduced at 10% concentration. Experience shows that at concentrations above and below this strength a small loss in performance can be expected. The brine should be introduced at 2 to 4 BV/h (0.25 to 0.5 gpm/ft^3) and the regeneration level (amount of NaCl per litre of resin) employed will typically be between 80 and 160 g/l (5 – 10 lb/ft^3), though regeneration levels as low as 50 g/l (3 lb/ft^3) and as high as 250 g/l (16 lb/ft^3) have been employed.

The slow (regenerant displacement) rinse is always carried out at flow rates similar to the brine injection step. This is to ensure, first, a uniform contact time between the resin and the regenerant solution and, second, that the rinse water follows the same route of the regenerant through the resin bed. As slow rinses are usually more efficient in removing the spent regenerant from the resin, the more slow rinsing employed can be beneficial in reducing the amount of final rinse required at the end of the regeneration. Normally 1 to 3 BV (7.5 to 22.5 gal/ft^3) of slow rinse are applied.

The final rinse is often carried out at the service flow rate and this also acts as a proving condition prior to returning to service after regeneration. On some occasions, where flow

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restrictions occur, the plant final rinse is carried out at a lower than the service flow rate. Normally 3 to 6 BV (22.5 to 45 gal/ft^3) are required depending on the design of the distribution / collection system and the amount of slow rinsing previously performed.

Typical Operating Conditions for Co-flow Regeneration

Step	Design Basis	Duration
Backwash	Set for minimum water temperature to give 50% bed expansion	1 FBV on clean water supplies and 2-3 FBV where solids are present
Bed settle	To allow the bed to reform fully classified	3 to 8 minutes
NaCl injection	50-250 g/l (3-15 lb/ft^3) applied as a 10% brine solution at 2-4 BV/h (0.25 to 0.5 gpm/ft^3)	Typically 20-45 minutes depending on regeneration level and flow rate
Slow rinse	1-3 BV (7.5 to 22.5 gal/ft^3) at approx. regenerant flow rate	Typically 20-45 minutes depending on volume of water applied and flow rate
Final rinse	3-6 BV (22.5 to 45 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, FBV = Free board volume above resin bed)

Counter-flow regeneration

While counter-flow regeneration can also be applied to **Purolite C100**, this technique is often used with other more specialised grades of Purolite cation resin to enhance the performance further. Consult your local Purolite sales office for guidance.

In counter-flow regeneration bed depths below 1000 mm (3 ft 3 in) should be avoided and preferably beds in excess of 1200 mm (4 ft) employed.

The traditional counter-flow regeneration technique is normally made up of 3 steps, as opposed to the 5 steps described earlier for co-flow regeneration, and typically takes between 1 and 2 hours depending on the detailed design. This type of regeneration requires the use of a water free from hardness for the brine make up, injection and the slow rinse steps if the published leakage is to be obtained. The softened water produced by the same plant is usually adequate,

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and the required quantity is either set aside during the previous service run or, in case of two-line units, supplied by the other on-line unit.
In a counter-flow regenerated system, the backwash, that always represents the first step of co-flow regeneration, is not normally performed each cycle. Some engineering designs allow for subsurface backwash or periodic full bed backwash, either inside the service unit or in separate external dedicated towers. In the vast majority of designs backwash is not part of the standard regeneration, although it should be included in the design of the unit. After a full bed backwash the resin should be regenerated with double the normal amount of brine to restore full performance.

The regenerant brine should be introduced at 2 to 4 BV/h (0.25 to 0.5 gpm/ft^3) and the regeneration level (amount of NaCl per litre of resin) employed will typically be lower than for co-current regenerated units, typically between 50 and 150 g/l (3 – 9 lb/ft^3).

The slow (regenerant displacement) rinse is always carried out at flow rates similar to the brine injection step and in the same direction. This is to ensure, first, a uniform contact time between the resin and the regenerant solution and, second, that the rinse water follows the same route of the regenerant through the resin bed. As slow rinses are usually more efficient in removing the spent regenerant from the resin, the more slow rinsing employed can reduce the amount of final rinse required. Normally 1 to 2 BV (7.5 to 15 US gal/ft^3) of slow rinse are adequate.

The final rinse is often carried out at the service flow rate and this also acts as a proving condition prior to returning to service after regeneration. Normally 2 to 4 BV (15 to 30 gal/ft^3) are required depending on the design of the distribution / collection system and the amount of slow rinsing previously performed.

Typical Operating Conditions for Counter-flow Regeneration

Step	Design Basis	Duration
NaCl injection	50-150 g/l (3-10 lb/ft^3) applied as a 10% brine solution at 2-4 BV/h (0.25 to 0.5 gpm/ft^3)	Typically 20-45 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 20-45 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

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

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Performance Data

The following data are designed to help the design engineer to estimate the exchange capacity and hardness leakage achieved with **Purolite C100** under different operating conditions. All the data shown are the result of years of industrial experience and are supplied in total good faith, but the final performance will equally depend on the detailed design and operation of the system, the quality of the regenerant chemicals as well as the long term maintenance of the plant. Some engineers who are using basic, standard plant of simple design may wish to take a design margin (safety factor) with regard to 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 1000 mm (3 ft 3 in) and counter-flow regenerated designs with bed depths over 1200 mm (6 ft 6 in). For shallower bed depths there may be a requirement to down rate the expected performance depending on the quality of the design.

The data supplied are divided in three groups: figures 1 to 9 deal with capacity and leakage for co-flow regeneration, figures 10 to 18 with capacity and leakage for counter-flow regeneration and figures 19 to 20 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, both 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.

For users interested in performing these engineering calculations electronically, Purolite's PureDesign™ software is available for download via www.purolite.com at no charge.

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**, while it is recommended to refer to dedicated engineering bulletins for products like **Purofine® PFC100** and **Puropack® PPC100**.

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Figure 1
Base capacity (co-flow regeneration)

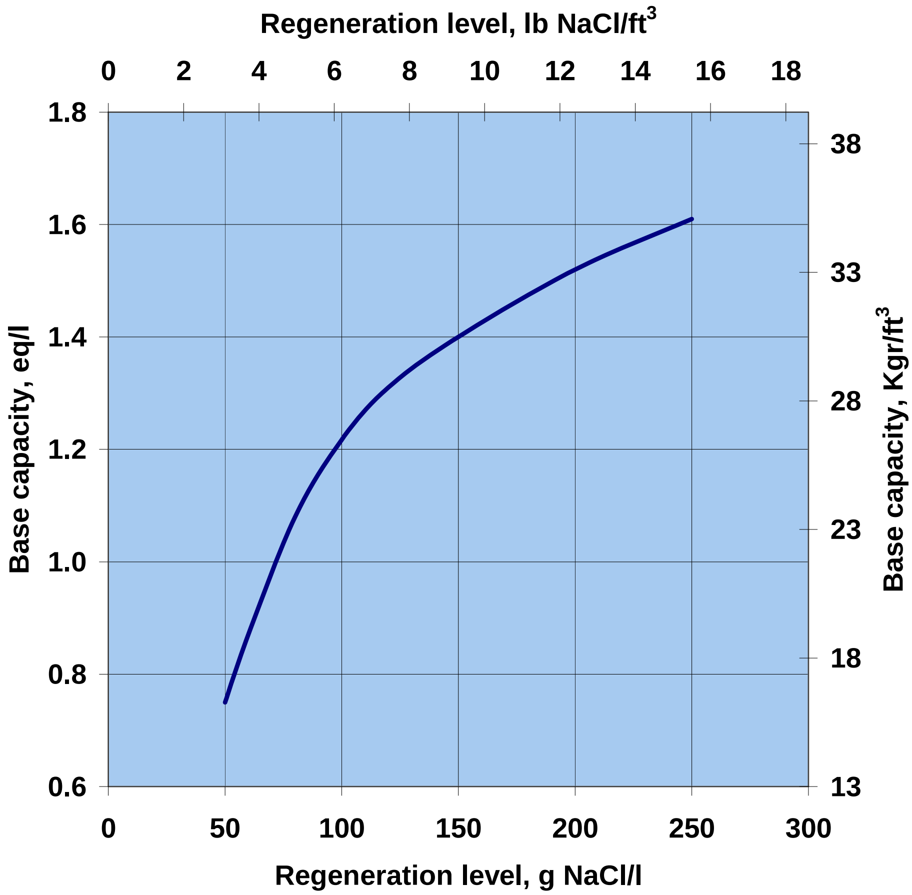

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Figure 2
C1 - Capacity correction factor for influent TH

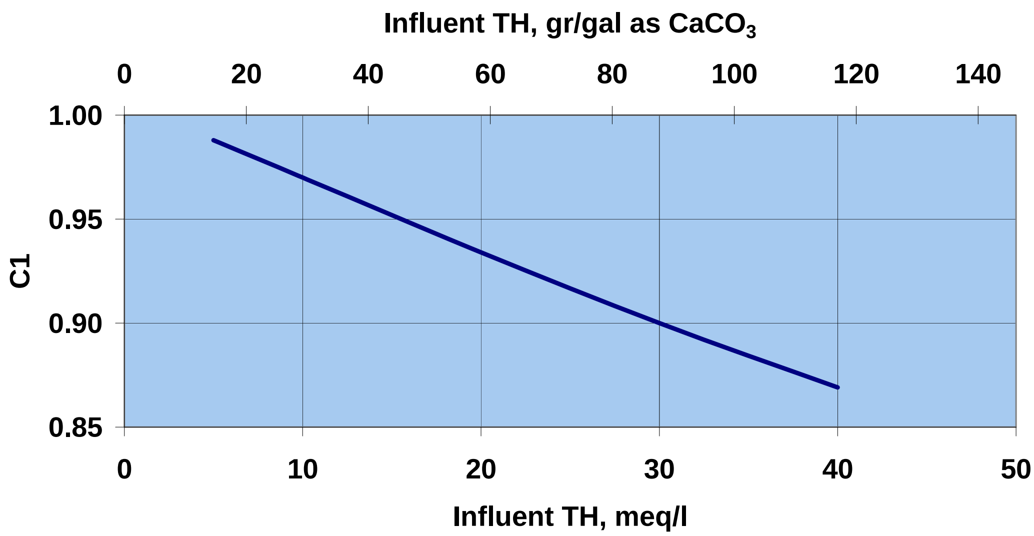

Figure 3
C2 - Capacity correction factor for service flow rate

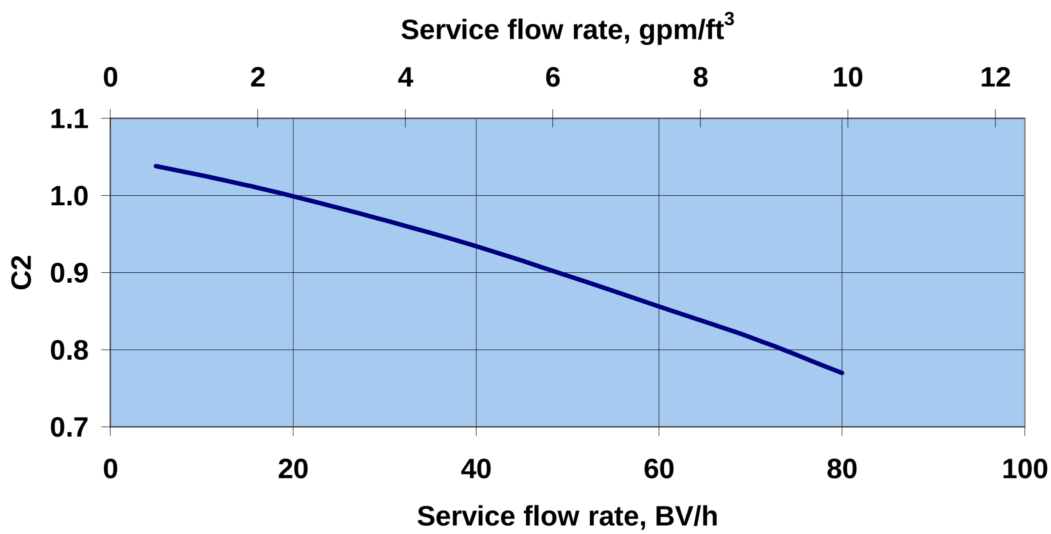

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Figure 4
C3 - Capacity correction factor for influent Na

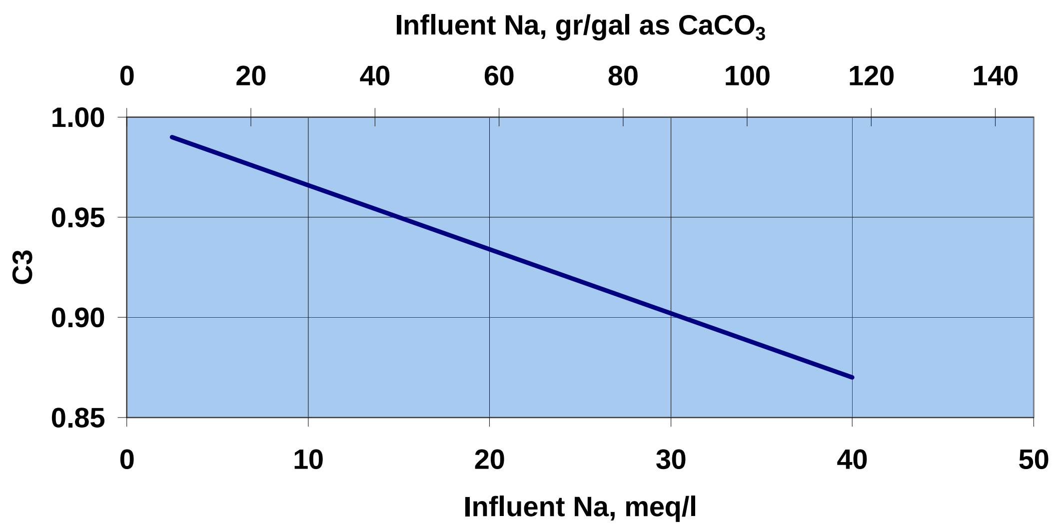

Figure 5
C4 - Capacity correction factor for brine concentration

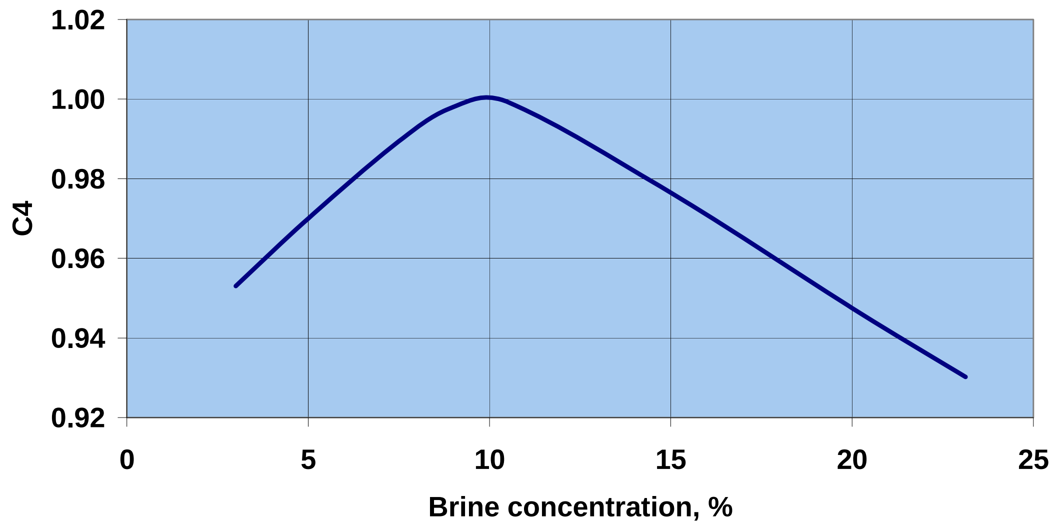

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Figure 6
Base hardness leakage

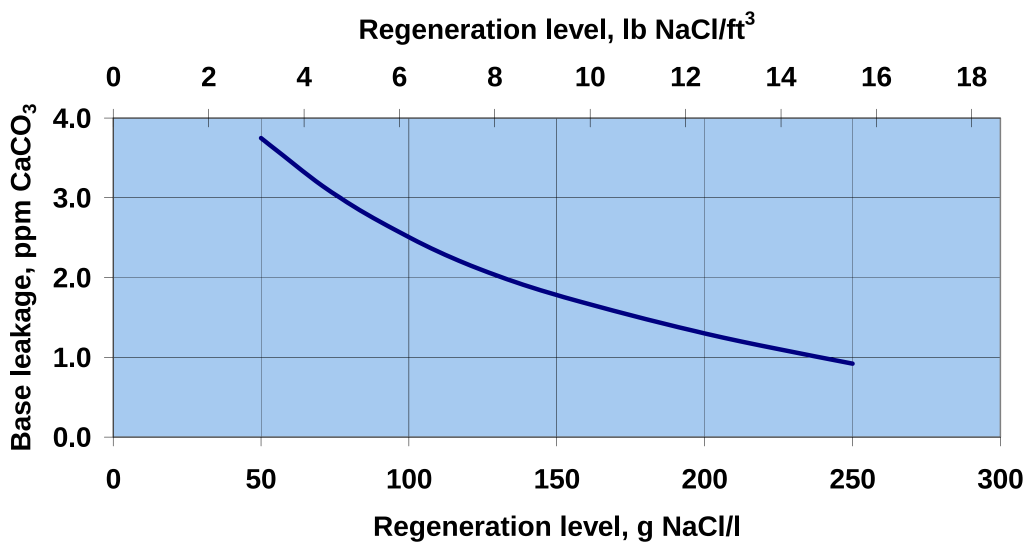

Figure 7
L1 - Leakage correction factor for Na / Total Cations

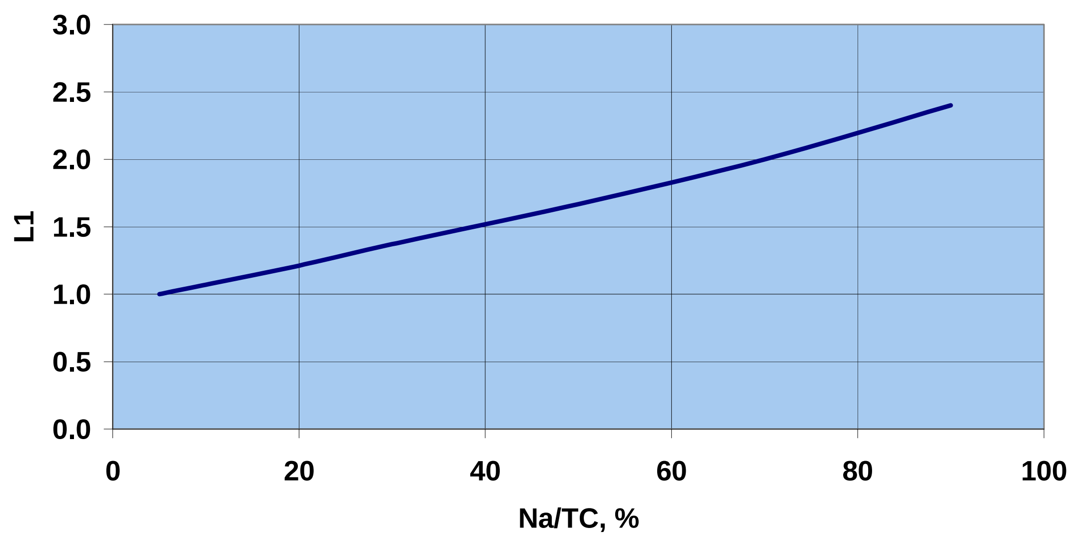

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Figure 8
L2 - Leakage correction factor for Total Hardness

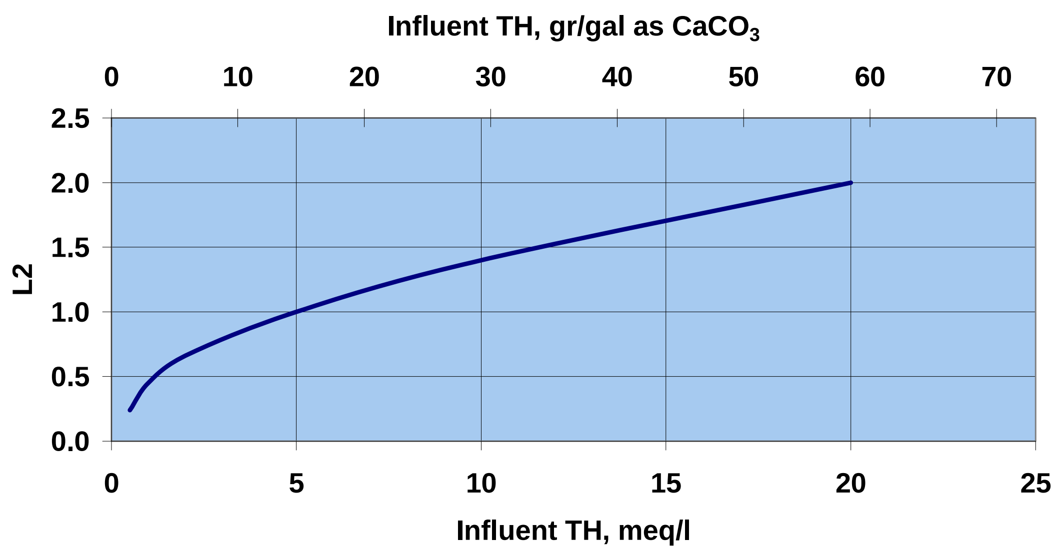

Figure 9
L3 - Leakage correction factor for Total Dissolved Solids

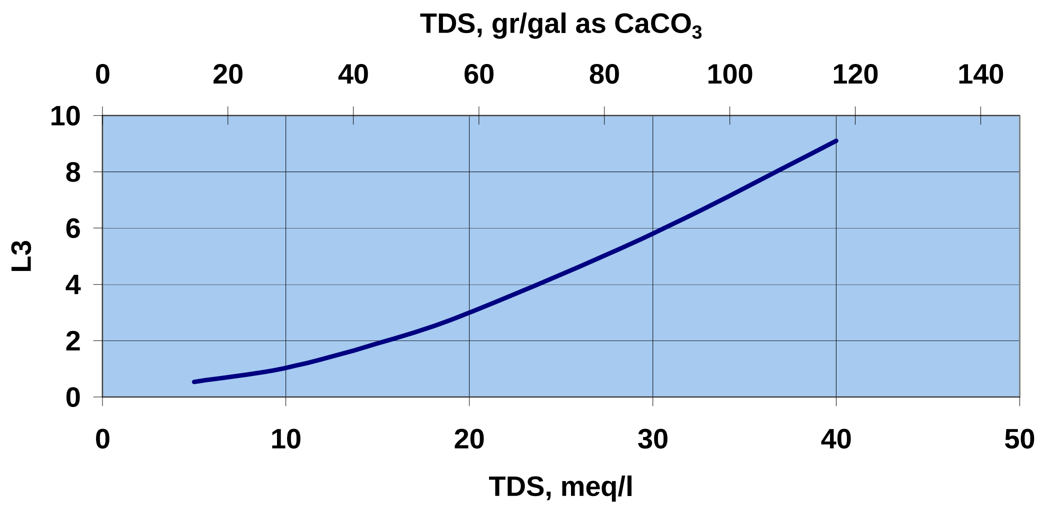

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Figure 10
Base capacity (counter-flow regeneration)

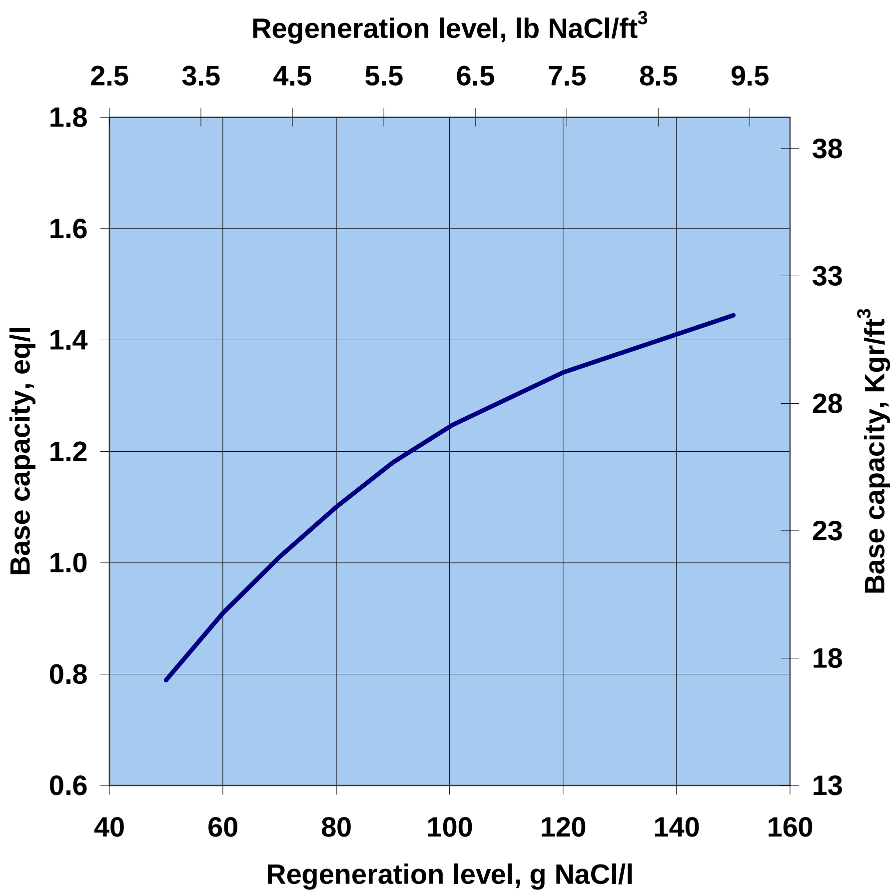

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Figure 11
C1 - Capacity correction factor for Total Hardness

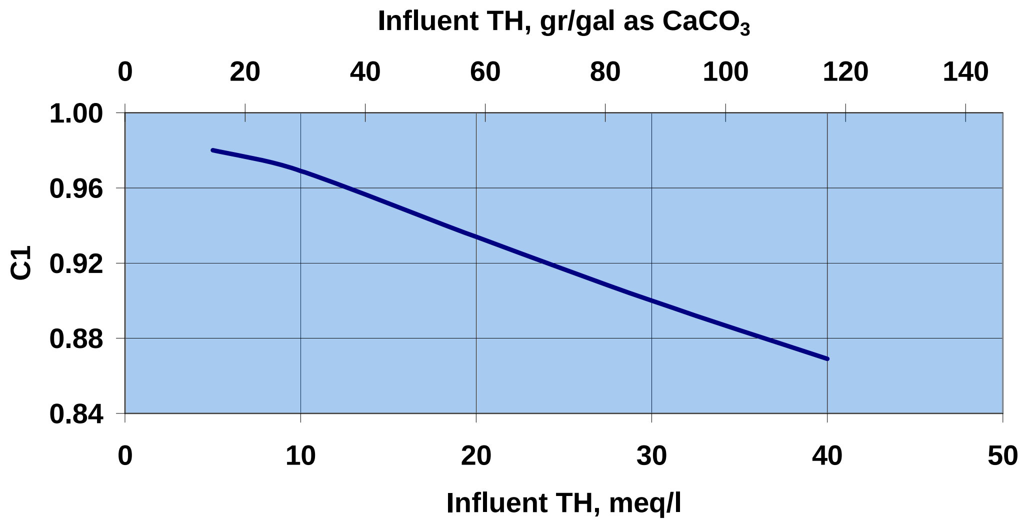

Figure 12
C2 - Capacity correction factor for service flow rate

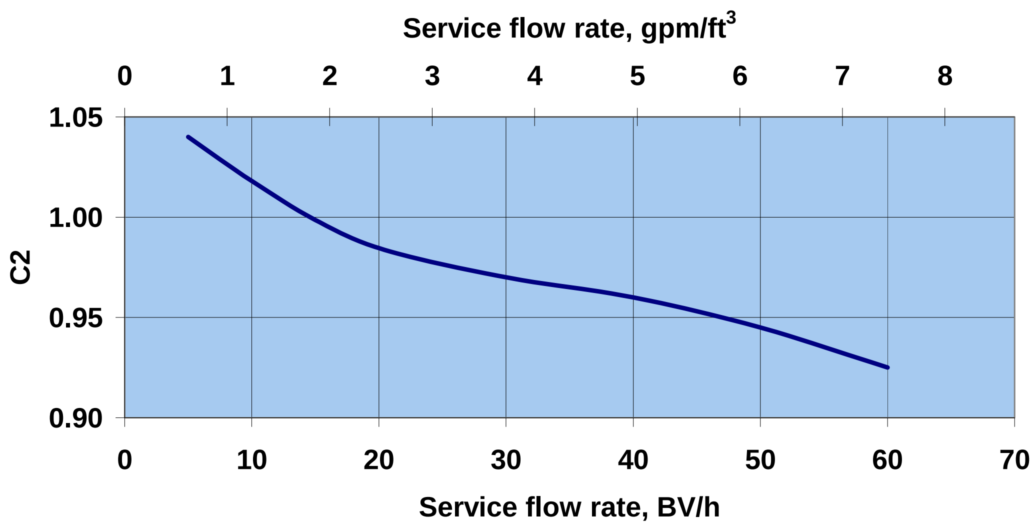

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Figure 13
C3 - Capacity correction factor for resin bed depth

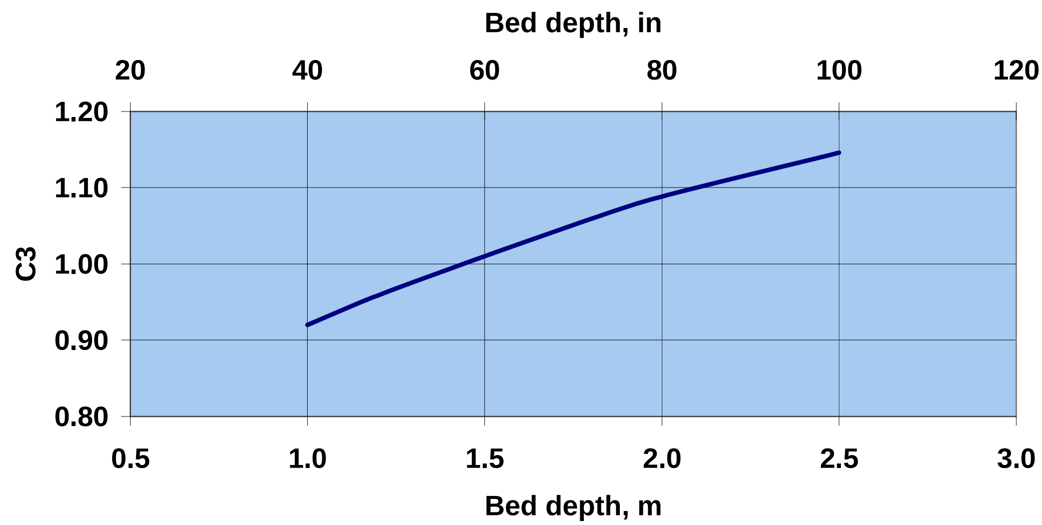

Figure 14
C4 - Capacity correction factor for brine concentration

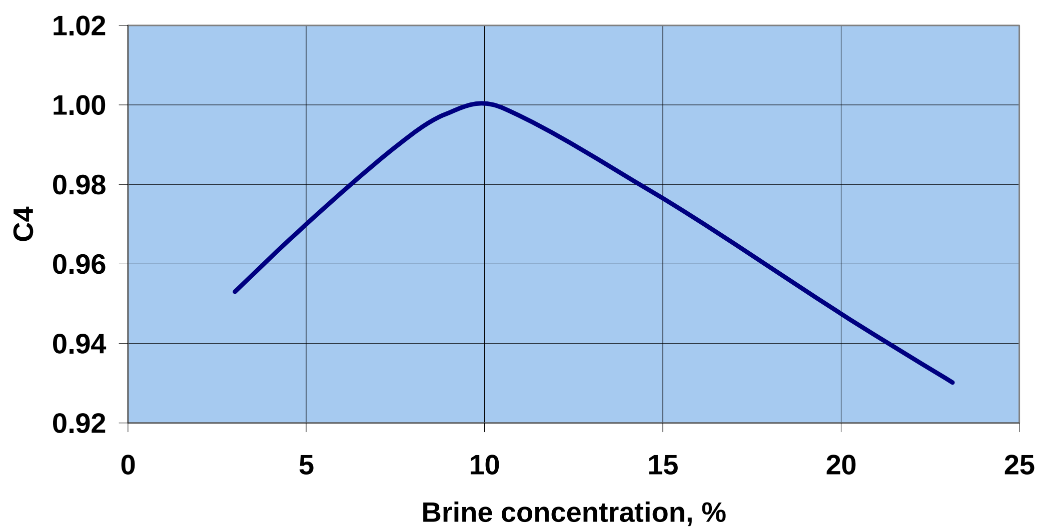

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Figure 15
Base hardness leakage

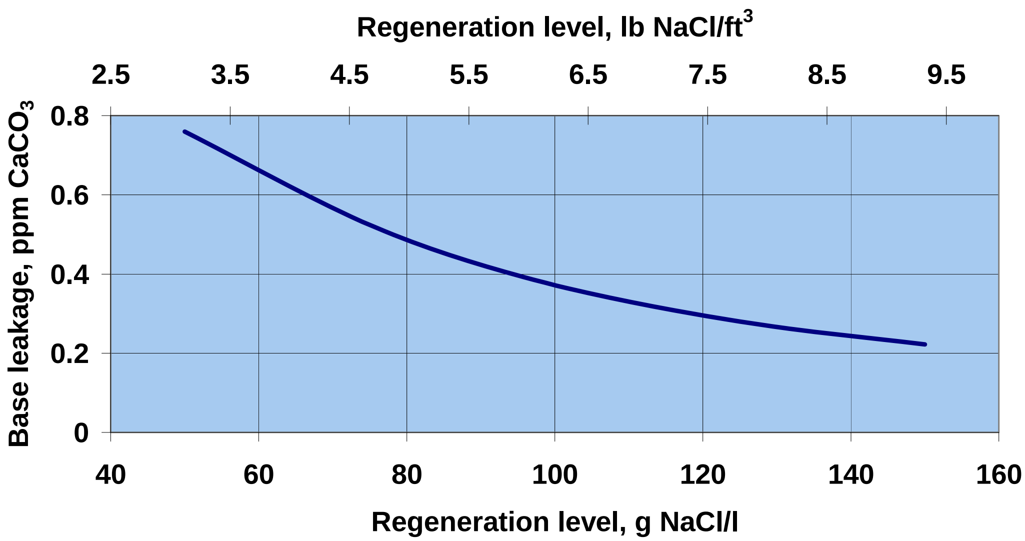

Figure 16
L1 - Leakage correction factor for Na / Total Cations

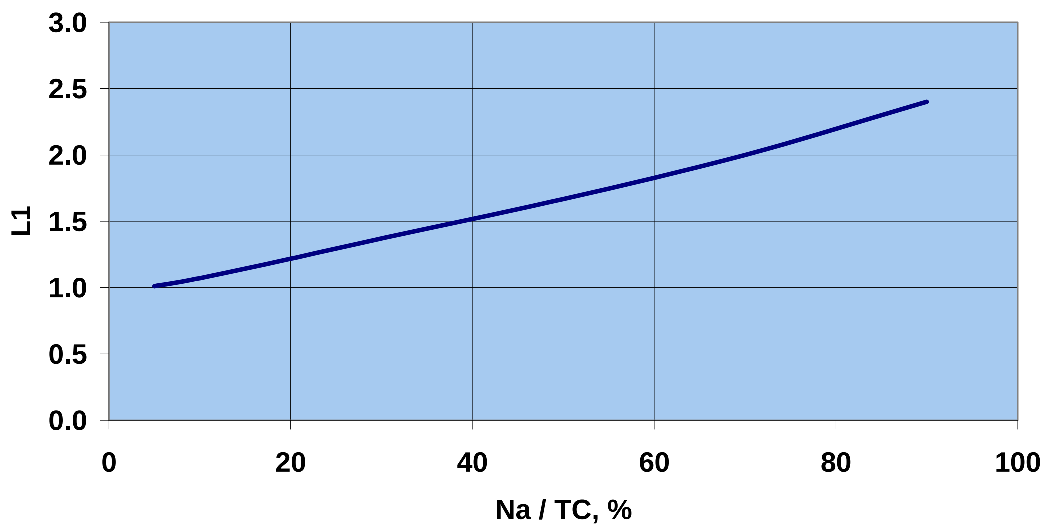

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Figure 17
L2 - Leakage correction factor for Total Hardness

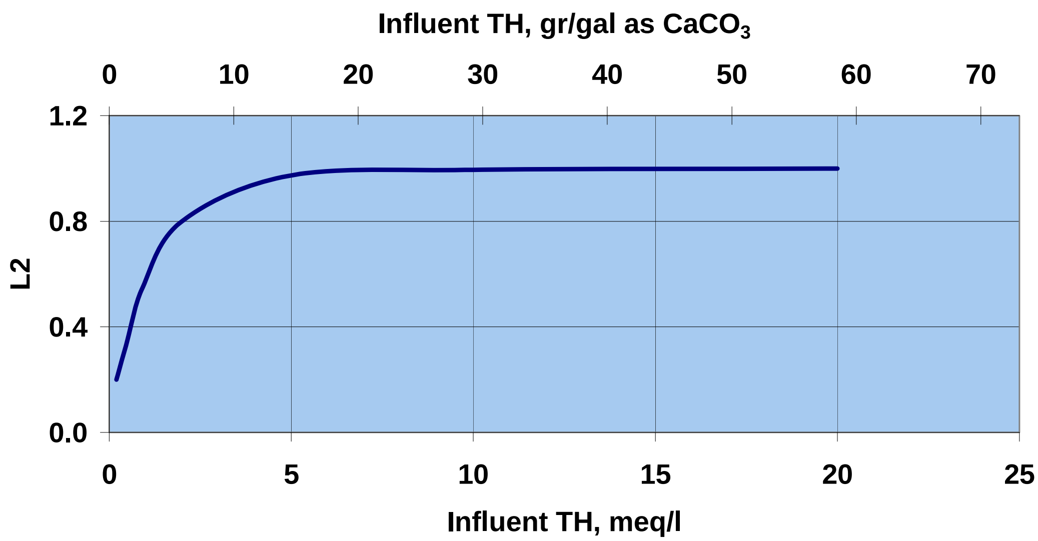

Figure 18
L3 - Leakage correction factor for Total Dissolved Solids

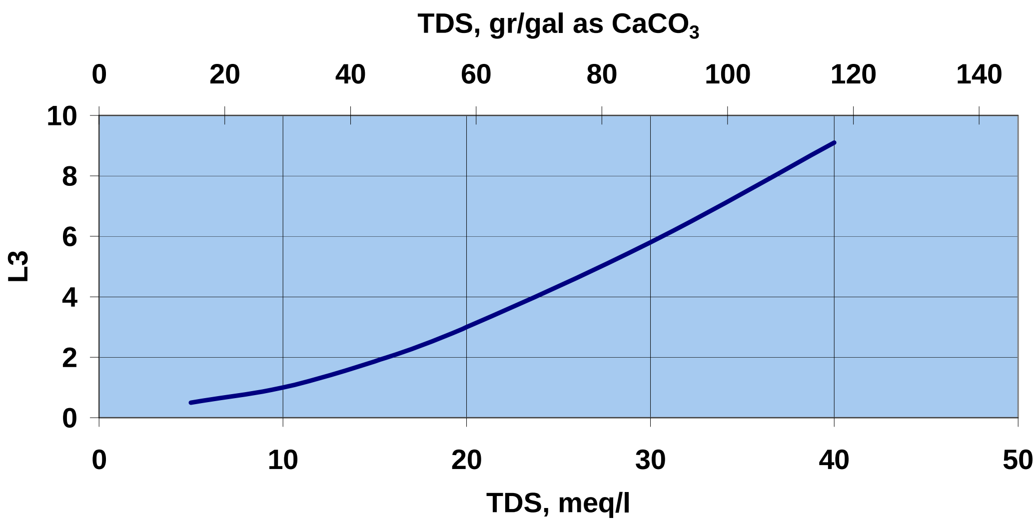

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Figure 19
Backwash expansion

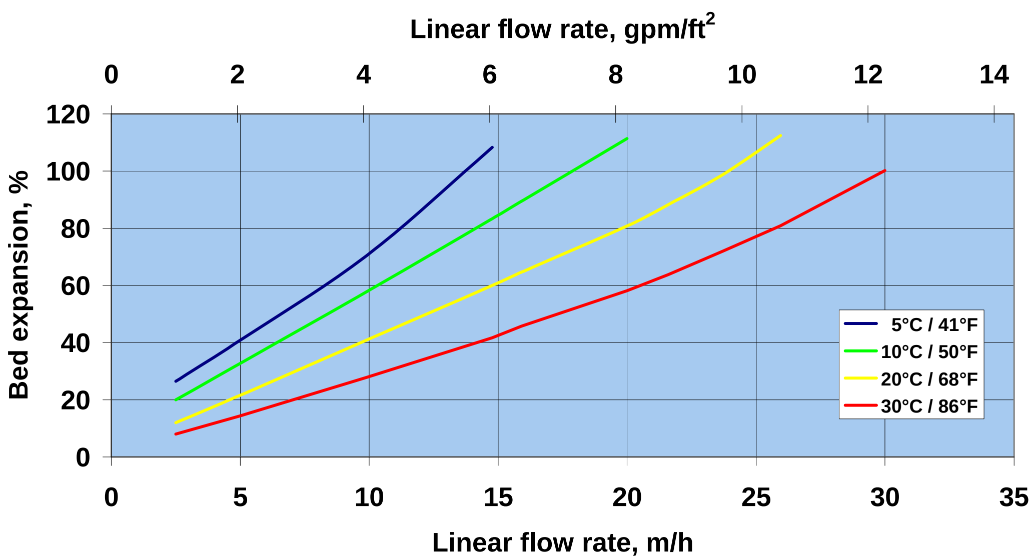
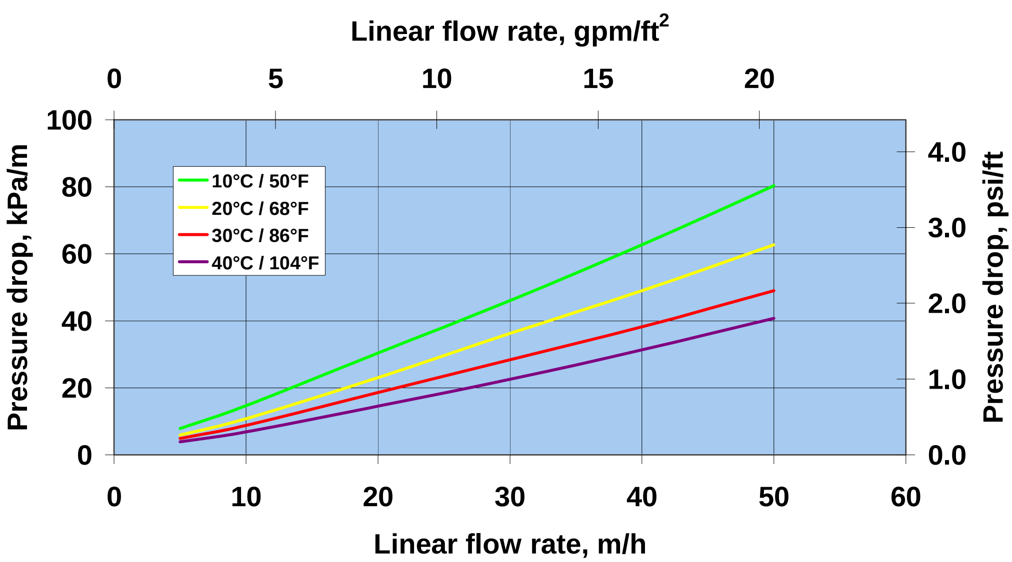


Figure 20
Pressure drop



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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 Purolite's website, www.purolite.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 Purolite's website, www.purolite.com.

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