MPR1000 Technology for TOC and Silt Density Index Reduction

Purolite® MPR1000, a proprietary blend of ion exchange resins and adsorbents, is specifically designed to reduce membrane fouling by removal of colloidal and organic matter from the feedwater.

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About Purolite

Purolite is a leading manufacturer of ion exchange, catalyst, adsorbent and specialty resins. With global headquarters in the United States of America, Purolite is the only company that focuses 100% of its resources on the development and production of resin technology.

Responding to our customers' needs, Purolite has the widest variety of products and the industry's largest technical sales force. Globally, we have strategically located research and development centers and application laboratories. Our ISO 9001 certified manufacturing facilities in the USA, United Kingdom, Romania and China combined with more than 40 sales offices in 30 countries ensure complete worldwide coverage.

Purolite has been part of Ecolab since 2021. A trusted partner at nearly three million commercial customer locations, Ecolab (ECL) is the global leader in water, hygiene and infection prevention solutions and services. Ecolab delivers comprehensive solutions, data-driven insights and personalized service to advance food safety, maintain clean and safe environments, optimize water and energy use, and improve operational efficiencies and sustainability for customers in the food, healthcare, hospitality and industrial markets in more than 170 countries around the world.

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The quality and consistency of our products is fundamental to our performance. Throughout all Purolite plants, production is carefully controlled to ensure that our products meet the most stringent criteria, regardless of where they are produced.

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We are technical experts and problem solvers. Reliable and well trained, we understand the urgency required to keep businesses operating smoothly. Purolite employs the largest technical sales team in the industry.

INNOVATIVE SOLUTIONS

Our continued investment in research and development means we are always perfecting and discovering innovative uses for ion exchange resins and adsorbents. We strive to make the impossible possible.

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Technical Data and Product Description

Membrane fouling is a major part of the operating cost for reverse osmosis and nanofiltration systems. Many new membrane plants are designed to operate at high flux rates and hence maintaining good quality feed conditions is essential if plant performance is to be maintained. Purolite MPR1000, a proprietary blend of ion exchange resins and adsorbents, is specifically designed to reduce membrane fouling by removal of colloidal and organic matter from the feedwater.

Purolite MPR1000 has been demonstrated to simultaneously reduce feedwater silt density index (SDI) and total organic matter (TOC) by over 40% and 85% respectively. SDI values as low as 1.5 have been demonstrated.

Reduced membrane fouling means lower operating costs with fewer chemical cleanings, lower power consumption, higher overall permeate recovery and longer membrane life. With lower SDIs, higher membrane flux rates can be tolerated, allowing for retrofit of existing plants to achieve higher production rates or design of new plants with smaller sizes and lower capital costs.

TABLE 1 Typical Physical and Chemical Characteristics

Polymer Matrix Structure	Macroporous polystyrene and polyacrylic, crosslinked with divinylbenzene
Physical Form and Appearance	Spherical beads
Functional Groups	Quaternary ammonium
Ionic Form, as Shipped	Cl-
Shipping Weight	630–670 g/l
Particle Size Range	0.400–1.200 mm
Uniformity Coefficient	1.7 max
Moisture Retention, Cl- Form	68–74%
Max. Operating Temperature	60 °C
Chemical Stability	Insoluble in all common solvents
pH Range, Stability	0–14

Current pre-treatment equipment (clarifiers, multimedia filters, etc.) can readily control suspended solids, but sub-micron colloidal particles, comprised of colloidal silica, silt, organic matter, iron and aluminum, and ranging in diameters from 80 to 10,000 Angstroms, are not efficiently removed. RO and NF membranes, acting as discrete filters for particles generally larger than 1 and 5 Angstroms respectively, can easily trap these colloids.

Purolite MPR1000 uses a blend of colloidal particle scavenger and TOC removal resins to efficiently and simultaneously remove colloidal particles and dissolved organic matter from the feedwater. The resins are efficiently regenerated with either a simple brine solution or mixture of brine and caustic. Recycle and reuse of the regenerant at least five times before disposal is optional.

Purolite MPR1000 is part of Purolite's patent-pending membrane protection technology MPR™ program utilizing proprietary blends of regenerable resins for simultaneous reduction of multiple contaminants from membrane feedwater.

Application of Purolite MPR Technology

Figures 1 and 2 below show other traditional pre-treatment approaches using conventional clarification/filtration technology and more recent UF technology for protecting RO membranes. Figure 3 shows our new approach using Purolite MPR1000 technology for reduction of SDI and colloidal and organic matter fouling.

FIGURE 1

Typical Conventional Surface Water Pre-Treatment to RO Systems

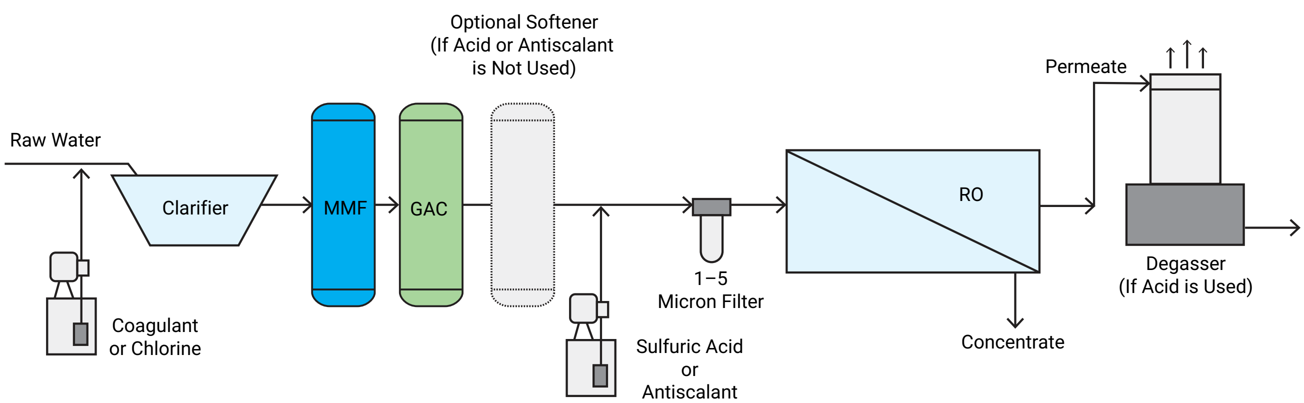


FIGURE 2

Newer Ultrafiltration Membrane Pre-Treatment to RO Systems

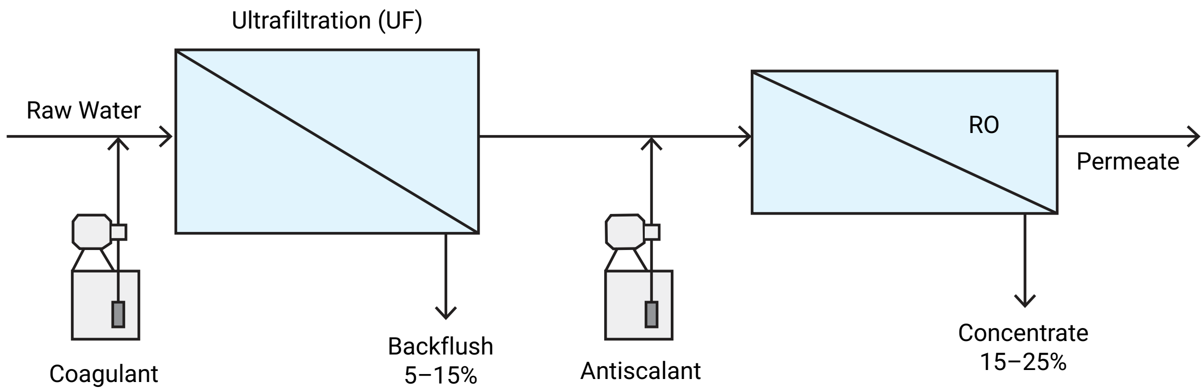
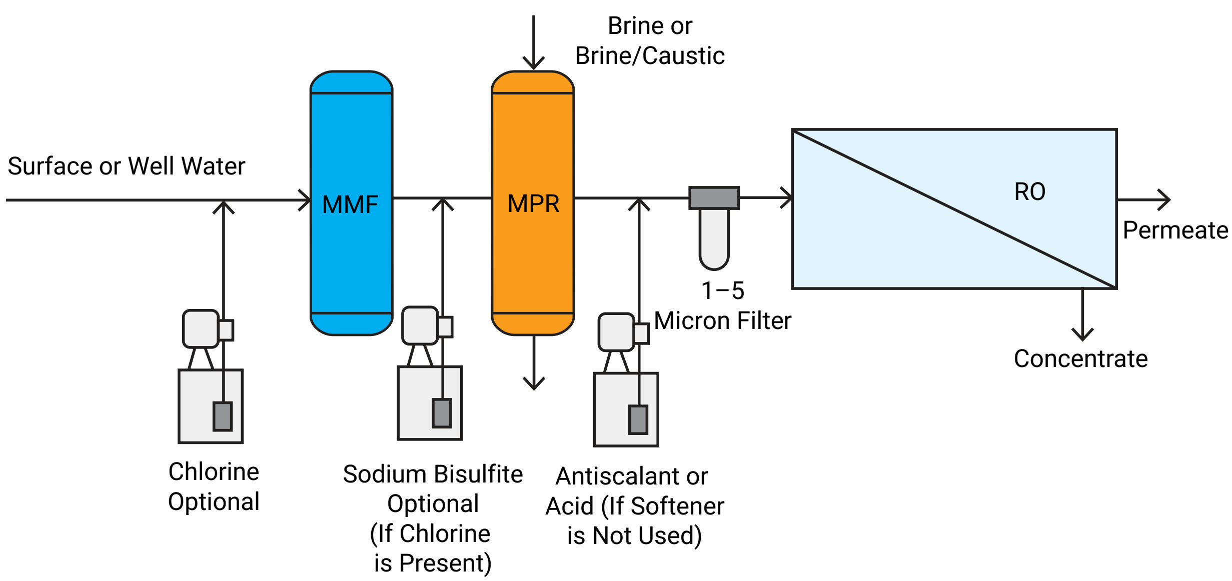


FIGURE 3

Typical Pre-Treatment with Purolite MPR1000 Technology (Reduction of Colloids, Silt Density Index and Organic Matter)



The conventional system shown in Figure 1 occupies a large footprint, is labour intensive and difficult to control if the raw water supply quality varies often and is more subject to operator error. The UF pre-treatment unit in Figure 2 is capital intensive and wastes about 5% to 15% of the feedwater that is needed for frequent backflushing of the UF membranes to keep them clean. The UF also requires periodic chemical cleaning for fouling from especially low molecular weight organic compounds. Purolite MPR Technology utilizes a compact small footprint vessel containing a combination of ion exchange resins and adsorbents for simultaneous reduction of colloidal particles, the Silt Density Index (SDI) value of the water and dissolved organic matter. On exhaustion, a simple brine or brine/caustic solution is used to regenerate all resins simultaneously. Our new technology also offers an option whereby the system can be designed to recover part of the spent regenerant for reuse on multiple occasions before final disposal, thus reducing waste and operating cost. The influent water quality and efficiency of the design will determine the amount of regenerant recoverable and the amount of top up regenerant that is needed. The level of sulfate in the feedwater affects the performance but practical experience shows that the regenerant can be reused at least five times before final disposal is needed based on typical feedwater quality.

Important Design and Operating Parameters

Critical factors for good performance include contact time (flow velocity), bed depth, cycle time and compliance with the recommended regeneration protocols. Details are given below.

Contact Time

Purolite MPR1000 requires contact times ranging from 5 to 3.75 minutes corresponding to specific flow rates ranging from 12 to 16 BV/h. This is particularly critical in obtaining adequate removal of the colloidal particles. Best results are usually achieved at 12 BV/h or even lower flow rates.

Minimum Regeneration Frequency

Ideally, the MPR system should be operated to a defined breakthrough point for either SDI value or TOC content of the effluent. Based on actual field studies, over 40% SDI reduction can be expected while organic matter reduction will range from 50% to 85% (typical >70%) depending on sulfate concentration and water composition. Typically, breakthrough occurs within three days, but can vary depending on the specific inlet water composition.

At 12 to 16 BV/h a three-day run to breakthrough corresponds to 860 to 1150 BV.

For new or existing membrane systems, it is advisable to run a simple pilot with a 1-liter cartridge of the MPR resin to get a better estimate of operating capacity. Normally three complete cycles will be required to reach equilibrium in the trial and we would recommend operating to a maximum 72 hour run length. Please consult with Purolite if considering exceeding these guidelines.

Minimum Bed Depth

For minimum leakage, a minimum bed depth of 900 mm is recommended for co-flow regenerated systems and a minimum of 1200 mm for counter-flow regenerated systems. Deeper beds usually provide better retention of colloidal particles.

Regeneration Protocol

It is very important to follow the established protocol for regeneration so that optimum and reliable performance is obtained from the unit.

Two regeneration options are available:

1. A single use of the regenerant in a once-through fashion, and
2. A procedure for recirculation and retention of the regenerant, for reuse in subsequent cycles for at least 5 cycles before final disposal.

Once-Through Regeneration Procedure

See details in Tables 2 and 3 for co-current (co-flow) and counter-current (counter-flow) respectively for standard operating conditions.

TABLE 2 Co-Flow Regeneration – Once Through Procedure

Operation	Rate	Solution	Minutes	Amount
Service	8–16 BV/h 1.0–2.0 gpm/ft³	Influent Water	Per Design	Per Design
Backwash	Dependent on freeboard and temperature *See Note 1 Below*	Influent Water (10–20 °C) (50–68 °F)	*See Note 2 Below*	*See Note 2 Below*
Regeneration	2–3 BV/h 0.25–0.375 gpm/ft³ *See Note 3 Below*	10% NaCl (10–50 °C) (50–120 °F) *See Note 4 Below*	30–45 (45 Preferred)	160 g/l 10 lb/ft³
Rinse (Slow)	2–3 BV/h 0.25–0.375 gpm/ft³	Influent Water	30–60 Approx.	1–2 BV 15–30 gal/ft³
Rinse (Fast)	8–16 BV/h 1.0–2.0 gpm/ft³	Influent Water	15–30 Approx. *See Note 5 Below*	2–4 BV 15–30 gal/ft³

1. Backwash Expansion: Minimum of 50% and up to 75% depending on freeboard space available (usual design rising space should be 100% of bed depth. Backwash flow rate is dependent on water temperature. Refer to Figure 5 showing bed expansion versus flowrate for different water temperatures.
2. Backwash Time: Use 5 minutes minimum for clean waters. Use a minimum of 2 FBV (freeboard bed volumes) for waters in which solids are expected. After backwash, a bed settling time of 5 minutes should be allowed before commencing regenerant injection.
3. Flow rate shown above is for the dilution water. The saturated brine flow rate is additional.
4. For high TOC levels or when significant levels of colloidal silica are present, use 2% NaOH and 10% NaCl for regeneration. Heating the solution is beneficial to a maximum of 50 °C. When using NaOH, the regenerant injection and slow rinse water source should be either RO permeate or softened.
5. Fast rinse should be continued until the difference between the effluent and influent conductivity values are acceptable (typically < 50 microsiemens/cm).

Minimum bed depth recommended — 91 cm (36 inches).

"Gallons" refer to U.S. Gallon = 3.785 liters.

TABLE 3 Counter-Flow Regeneration — Once Through Procedure

Operation	Rate	Solution	Minutes	Amount
Service (Upflow)	8–16 BV/h 1.0–2.0 gpm/ft³	Influent Water	Per Design	Per Design
Backwash *See Note 1 Below*	*See Note 2 Below*	Influent Water (10–20 °C) (50–68 °F)	*See Note 3 Below*	*See Note 3 Below*
Regeneration (Downflow)	2–3 BV/h 0.25–0.375 gpm/ft³ *See Notes 4 & 5 Below*	10% NaCl (10–50 °C) (50–120 °F) *See Note 6 Below*	30–45 (45 Preferred)	160 g/l 10 lb/ft³
Rinse (Slow) (Downflow)	2–3 BV/h 0.25 gpm/ft³	Influent Water	30–60 Approx.	1.5–2.5 BV 10–20 gal/ft³
Rinse (Fast)	8–16 BV/h 1.0–2.0 gpm/ft³ *See Note 7 Below*	Influent Water	10–30 Approx. *See Note 7 Below*	2–4 BV 15–30 gal/ft³

1. Only carried out on counter current systems employing air hold down or split flow regeneration or on packed bed systems employing external backwash towers. With external backwash, you can sometimes transfer 50% of the bed and the balance can be backwashed in the service unit.
2. Backwash Expansion: Minimum of 50% and up to 75% depending on freeboard space available (usual design rising space should be 100% of bed depth). Refer to Figure 5 showing bed expansion versus flowrate for different water temperatures.
3. Backwash Time: Use 5 minutes minimum for clean waters. Use a minimum of 2 FBV (freeboard bed volumes) for waters in which solids are expected. After backwash, a bed settling time of 5 minutes should be allowed before commencing regenerant injection.
4. On packed bed systems operating with up flow regenerant injection the brine flow rate needs to be higher to ensure the bed remains packed at all times — consult system supplier or Purolite.
5. Flow rate shown above is for the dilution water. The saturated brine flow rate is additional.
6. For high TOC levels or when significant colloidal silica levels are present, use 2% NaOH and 10% NaCl for regeneration. Heating the solution is beneficial to a maximum of 50 °C. When using NaOH, the regenerant injection and slow rinse water source should be either RO permeate or softened.
7. Check flow rate if employing up flow service mode to ensure there is sufficient velocity to maintain bed packed against top distributor. Fast rinse should be continued until the difference between the effluent and influent conductivity values are acceptable (typically < 50 microsiemens/cm). Fast rinse can also be recycled to save on water

Minimum bed depth recommended — 91 cm (36 inches).

"Gallons" refer to U.S. Gallon = 3.785 liters.

Recirculate Regenerant & Retain for Reuse Procedure

TABLE 4 Recirculation and Retention of Regenerant for Next Regeneration

Operation	Rate	Solution	Minutes	Amount
Service	8–16 BV/h 1.0–2.0 gpm/ft³	Influent Water	Per Design	Per Design
Backwash	Dependent on Freeboard and Temperature *See Note 1 Below*	Influent Water (10–20 °C) (50–68 °F)	*See Note 2 Below*	*See Note 2 Below*
Drain Resin Bed	By gravity or with assistance from compressed air port located at top of vessel. Send backwash water to waste water system.			
Recirculation and Retention *See Note 3 Below*	4–8 BV/h 0.5–1 gpm/ft³	16% NaCl +3.2% NaOH (10–50 °C) (50–120 °F). Use soft water or RO permeate for makeup to avoid hardness precipitation. *See Note 4 Below*	60 minutes at 8 BV/H or 120 minutes at 4 BV/H	160 g/l NaCl + 32 g/l NaOH (10 lb/ft³ NaCl + 2 lb/ft³ NaOH) Total of 1.8 BVs *See Note 5 Below*
Drain Resin Bed	By gravity or with assistance from compressed air port located at top of vessel. Send all regenerant water drained from the vessel and piping back to a spent regenerant tank for storage and reuse in the next regeneration.			
Rinse (Fast)	8–16 BV/h 1.0–2.0 gpm/ft³	Influent Water	15–30 approx. *See Note 6 Below*	2–4 BV 15–30 gal/ft³

1. Backwash Expansion: Minimum of 50% and up to 75% depending on freeboard space available (usual design rising space should be 100% of bed depth). Refer to Figure 5 showing bed expansion versus flowrate for various water temperatures.
2. Backwash Time: Use 5 minutes minimum for clean waters. Use a minimum of 2 FBV (freeboard bed volumes) for waters in which solids are expected. After backwash, a bed settling time of 5 minutes should be allowed before commencing regenerant injection. Minimum bed depth recommended — 48 inches (1.2m) for counterflow; 36 inches (0.91m) for coflow.
3. Regeneration with recirculation and retention of the solution for use in the next regeneration. Recirculate effluent from the bottom of vessel to the spent regeneration tank then back to top of vessel with a pump.
4. Heating the solution is beneficial to a maximum of 50 °C. When using NaOH, the regenerant injection and slow rinse water source should be either RO permeate or softened.
5. All of the regenerant should be collected and retained in a suitable tank for later use in the next regeneration.
6. Fast rinse should be continued until the difference between the effluent and influent conductivity values are acceptable (typically < 50 microsiemens/cm).

"Gallons" refer to U.S. Gallon = 3.785 liters.

Notes on Multiple Reuse of Regenerant

For automated regeneration it is necessary to have a good PLC design for controlling the various regeneration phases, including the backwash, air-assist draindown of the backwash water, pumped recirculation of the regenerant, air-assist draindown of the spent regenerant, routing to a spent recovery tank for subsequent reuse after top-up with water, followed by the final rinse.

The spent regenerant collected in the recirculation tank can be reused at least 5 times before disposing of same after neutralization. It is estimated that no more than 0.33 bed volumes of the spent regenerant will be lost as part of the slow rinse. The recovered spent regenerant must be topped up with an equal volume of water to keep the total regenerant volume close to the original of 1.8 bed volumes. After 5 reuses, the concentration of NaCl is expected to decline to approximately 7% while the concentration of sulfate and TOC will have increased. The actual reuse times will depend on how well the system is designed and/or operated and it is recommended to initially optimize the top up routine and determine the acceptable number of uses before disposal. This will save on chemicals and operating costs as well as minimize waste and any neutralization needed.

Controlling Regenerant Concentration

The chloride concentration of the spent regenerant will be lower than the fresh regenerant due to losses from pick up by the resins. The equivalent concentration of sulfate will increase in the spent regenerant as a result of this. However, the selectivity of the resins for sulfate under regenerant conditions is very low, so the resin will be predominantly in the chloride form after regeneration with spent regenerant. The loss in hydroxide concentration of the regenerant will generally be small, again because of the very low selectivity of the resin for the hydroxide ion. Starting with a higher than normal salt dosage of 320 g NaCl/l and caustic dosage of 64 g NaOH/l at 16% and 3.2% respectively, allows for ease of operation in that an operator is not needed after each regeneration to top up with more chemicals. At the same time, there is a natural decline in the concentration of the salt and caustic.

The Number of MPR Vessels Needed

While a single vessel can be used, consideration should be given to using at least two vessels operating in parallel. Cycle time will depend on the specific water chemistry but will typically be about 72 hours while budget time for completion of the regeneration procedure is about 4 hours. If two vessels are designed to operate in parallel handling 50% of the full flow, then during the regeneration period the other vessel can be used to provide the full flow needed. At recommended design flowrate of 12 to 16 BV/h for each vessel, this would result in a temporary reduction in contact time from 5 minutes to 2.5 minutes. For such a relatively short period, this may be acceptable; otherwise a third vessel can be installed. Using two vessels in parallel allows each vessel to process only half the flow (except when one is regenerating), and so the size and cost of the system can be reduced.

Retrofit of Existing Softener System for Purolite MPR1000

Please consult Purolite if considering retrofitting an existing water softener as it is absolutely essential for the MPR resins for colloidal organic and silica removal to get enough contact time. Without adequate contact time, the percentage reduction of these contaminants will be much lower than expected. Design should allow for a preferred contact time 5 to 3.75 minutes minimum or 12 to 16 BV/h for Purolite MPR1000; longer contact times are more efficient.

Many softener designs make use of much shorter contact times of 2.5 to 1.5 minutes or 24 to 40 BV/h and these would not provide optimum contact for the Purolite MPR1000 resin.

If there are other considerations that require a softener to be used (instead of say dosing a scale inhibitor, or feeding of acid to reduce the scaling potential), then it should be recognized that the softening cycle time will usually be shorter than for Purolite MPR1000. Also, the regenerant can only be used once with softening. Please consult Purolite for further guidance.

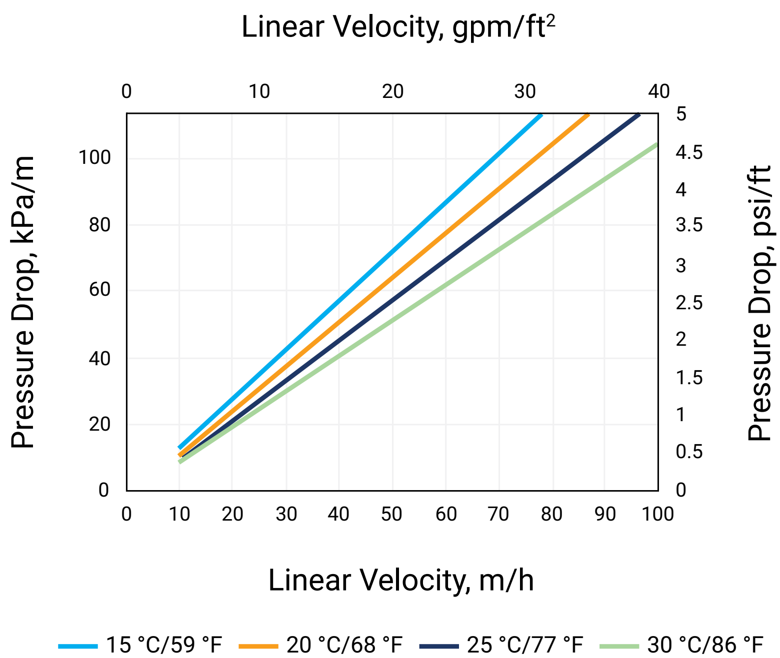
Hydraulic Characteristics

The pressure drop or head loss across a properly classified bed of ion exchange resin depends on the particle distribution, bed depth and voids volume of the exchange material, as well as on the viscosity (and hence on the temperature) of the influent solution. Factors affecting any of these parameters, for example the presence of particulate matter filtered out by the bed, abnormal compaction of the resin bed, or the incomplete classification of the resin spheres will have an adverse effect and result in increased head loss.

Depending on the quality of the influent water, the application and the design of the plant, service flow rates may vary from 8–32 BV/h. The typical pressure drop data is given in Figure 4.

FIGURE 4

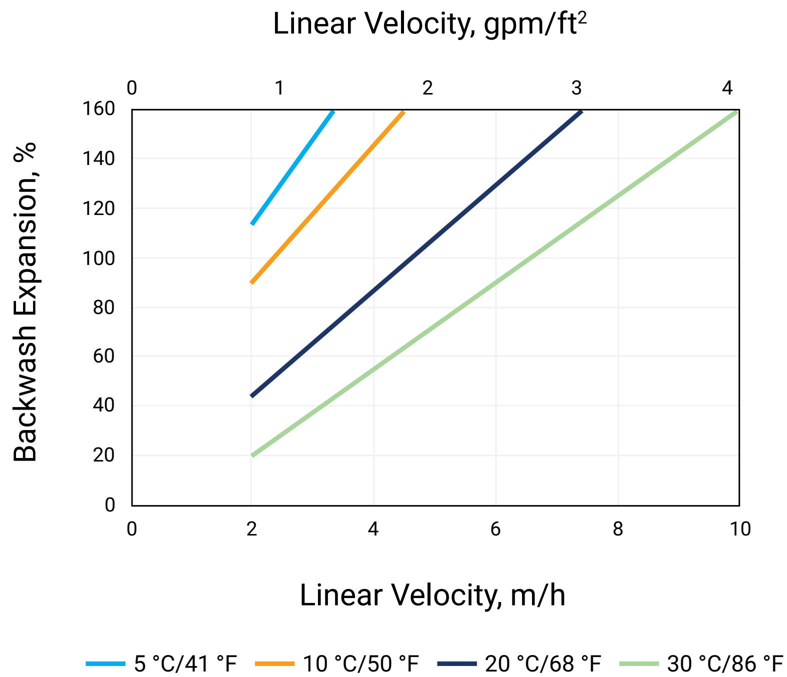
Pressure Drop Across the Resin Bed vs. Linear Velocity



During upflow backwash, the resin bed should be expanded in volume by between 50% and 75%. This operation will free it from any particulate matter, clear the bed of bubbles and voids, and reclassify the resin particles ensuring minimum resistance to flow. Bed expansion increases with flow rate and decreases with temperature, as shown in Fig.5. Care should be taken to avoid over expansion of the bed. Backwash is done for every regeneration for co-flow systems and eventually (when pressure drop across the bed reaches 2 kg/cm²) for counter-flow systems.

FIGURE 5

Backwash Expansion of the Resin Bed vs. Linear Velocity



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Purolite, the leading manufacturer of quality ion exchange, catalyst, adsorbent and specialty high-performance resins, is the only company that focuses 100% of its resources on the development and production of resin technology.

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