ION EXCHANGE (IX)
The ion exchange process is an ancient technique that remains very relevant today. By records, the exchange of cations as a phenomenon was first discovered more than a hundred years ago. Two English chemists, Thompson and Way, observed that certain soils had a greater ability than others to absorb ammonia from fertilisers - with complex silicates in the soil that performed an ion exchange function. They began to prepare such materials in the laboratory from solutions of sodium aluminate and sodium silicate. In 1906, Rober Gans used such materials for softening water and for treating sugar solutions. Since then, ion exchange technologies have evolved to become an essential part of various industrial applications worldwide.
Whenever an ion is removed out of an aqueous solution and is replaced by another ionic species, it is generally referred to as “ion exchange.” It involves a specific chemical process in which unwanted dissolved ions are exchanged for other ions with a similar charge. Ions are atoms or molecules containing a total number of electrons that are not equal to the total number of protons. There are two different groups of ions, cations, which are positively charged, and anions, which are negatively charged.

This attraction is used to remove dissolved ionic contaminants from water. The exchange process occurs between a solid (resin or a zeolite) and a liquid (water). In the process, the less desired compounds are swapped for those that are considered more desirable. These desirable ions are loaded onto the resin material. Choosing and using ion exchange resins is often a complex process.

Don’t take chances on IX applications.

Engage a water specialist with in-depth expertise & experiences.

With several types of resins available for water applications, more often than not, there is more than one technically effective solution that will meet all the system’s design specifications. Hence, in-depth experience and knowledge, both in the selection of the types of resins as well as process and system designs, are needed to meet the requirements of a project. While ion exchange technologies and processes are proven and mature for industrial applications, the requirements of high-level expertise and established experiences can prove to be a complex and challenging process for some water companies and their clients.
Resins.

Major categories and structures.

There are four major classes of resins used in industrial water treatment: strong acid cation, weak acid cation, strong base anion and weak base anion. Each of these major resin classes has several physical or chemical variations within the class. The variations impart different operating properties to the resin.

Different categories of ion exchange resins.

A good ion exchange system designer not only will design the system to meet all design specifications but also will utilise resins that will allow the system to operate at peak efficiency and maximum cost effectiveness.
Removing hardness in water. And beyond.

The ion exchange (IX) technology generally removes hardness of any feed water by reducing the total dissolved solids (TDS). But by varying the process designs and using different types of resins, the technology can be used to remove specific types of undesired ionic contaminants for different applications:

- Softening (removal of hardness).
- Demineralisation (removal of all ions).
- Mixed bed polishing.
- De-alkalisation (removal of bicarbonate).
- Decationisation (removal of all cations).
- Nitrate removal.
- Selective removal of various contaminants.

As the chemical processes of these are rather complex, we mainly address the process designs or flows and do away with the details of chemical reactions that will place in our content.

Different configurations. Different applications.
IX process - service & regeneration.

Over a period of service cycles in any IX system, resins will get exhausted, a stage whereby the resins can no longer effectively facilitate any desired ion exchange reaction. This happens when contaminant ions have bound to nearly all available active sites on the resin matrix. All resins, when exhausted, must go through the regeneration process where anionic or cationic functional groups are restored to the spent resin matrix. The regeneration cycle may be through either a Co-flow Regeneration (CFR) or a Reverse-flow Regeneration (RFR) configuration.

In a CFR process, the regenerant solution is injected as the feed water is to be treated, which is usually from the top to the bottom of an IX column. CFR is not typically used for large IX capacities or when high output water qualities are desired, since excessive quantities of regenerant solution would be required to uniformly regenerate the resins. In RFR configuration (or counter-flow regeneration), on the other hand, the injection of the regenerant solution is in the opposite direction of the service flow. In this case, the regenerant solution contacts the less exhausted resin layers first, making the regeneration process more efficient. But this process is effective only if the resin layers stay in place throughout regeneration. Hence, RFR should be used with packed bed IX columns, or if some retention device is used to prevent the resins from moving within the column. In whichever case, a full operating cycle of any IX process typically involves service, backwash (for CFR only), regeneration and rinse.

1. service
During the service cycle, the ionic contaminants are absorbed by the resins, producing the soft water’s qualities desired. This cycle continues until the resins in the column are exhausted, and regeneration process is required to restore the resins’ effectiveness.

2. backwash
Backwash process is performed in CFR only, and involves rinsing the resin to remove suspended solids and redistribute compacted resin beads. The agitation of the beads helps remove any fine particles and deposits from the resin surface.

3. regeneration
During the regeneration process, the regenerant solution is injected into the IX column at a low flow rate to allow adequate contact time with the resins. In the case of CFR configuration, the regenerant is injected in the same direction of the service flow.

4. slow rinse
The regenerant is flushed out gradually by the slow flow of feed water, typically at the same flow rate as the regenerant solution. The flow rate of this “slow rinse” stage must be carefully managed to avoid damage to the resin beads.

5. fast rinse
In the final step, the resins are rinsed with water at the same flow rate as the service process. The rinse cycle should continue until a target water quality level is reached before the service cycle commences again.
**Water softening.**

**Removing Ca\(^{2+}\) & Mg\(^{2+}\).**

Water softening process is the most basic of the IX technology. It removes calcium and magnesium ions most frequently found in natural water. These cations are hardness ions, together with the less common and less soluble strontium and barium cations. When water evaporates, this cations precipitate and form scale in pipes, boilers and even kitchen appliances. SAC resins are used in the sodium form to remove these hardness cations from the water. When exhausted, they can be regenerated with sodium chloride (NaCl). However, softening the water does not reduce its salinity, it merely removes the hardness ions they don’t form scale or deposits. For more stringent industrial use, simple water softening process may not be adequate.

These days, zeolite water softening process is most widely used in domestic and commercial water softening applications. There are natural and synthetic/artificial. The natural zeolite that is used for water softening is gluconites or greensand. Permutit is the synthetic zeolite that is most used in commercial water softening applications. This is used as ion exchanger and odor removal in water softener. Permutit are more porous, glassy, and have higher softening capacity than greensand.

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**Demineralisation.** **Removing all ions.**

Many industrial applications require all ions in the water to be removed, and this can be attained through a demineralisation (also called deionisation) process. As there are cations and anions in the water, both cation exchanger and an anion exchanger must be applied to produce the pure water desired. The cation resin is used in the hydrogen form (H\(^+\)) and the anion resin in the hydroxyl form (OH\(^–\)), and the cation resin can be regenerated with an acid while the anion resin with an alkali. The cation exchanger is usually configured before the anion exchanger, and subject to various factors and consideration, a demineralisation process can be configured in a few ways, from a simple 2-bed demineralising process to a 4-bed combination in sequence. A degasifier may be added in a train of demineralisation systems to remove the carbon dioxide created after cation exchange, if the water contains a significant concentration of bicarbonate.

Demineralised water is generally free of ions, except some residual traces of sodium and silica because the SAC and SBA resins have their lowest selectivity for these. In a simple demineralisation line's regenerated in reverse flow, the treated water should have conductivity of only about 1.0 µS/cm, with some silica residual (of between 0.005 and 0.05 ppm).
**Mixed bed polishing.**

**Removing salinity & silica.**

Where last traces of salinity and silica are to be removed from water, a mixed bed polishing process, where highly regenerated strong acid cation and strong base anion resins are mixed, can be used to produce excellent results. However, these beds are complicated to be regenerated as the resins must first be separated by backwashing before the regeneration cycles. They also require large amounts of chemicals for regeneration. Mixed beds are usually used to treat pre-demineralised water when the service cycles are long. Mixed bed polishing produces water with less than 0.1 µS/cm conductivity (or of pure water standard of 0.055 µS/cm with more sophisticated designs), and silica residual value lower than 0.01 ppm.

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**Dealklisation.** **Removing hardness & alkalinity.**

Dealklisation process uses WAC resins where relatively large concentration of hardness and alkalinity are present in the feed water. After this process, the treated water contains carbon dioxide and this can be removed with a degasifier. Dealkalisation process can produce water with zero temporary hardness. SAC exchanger may be added as the final polishing step to remove the remaining cations in the water for the desired qualities needed for a certain applications.

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**Decationisation.** **Removing all cations.**

The removal of all cations is not often used except as the first stage of the demineralisation process, or it is sometimes used for condensate polishing where the decationiser is followed with a mixed bed process. A SAC exchanger is used in the H+ form for decationisation process.

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**Nitrate removal.** **Using SAC exchanger.**

Nitrate can be removed selectively from water using SBA exchangers in the regeneration cycle with NaCl brine.

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**Selective removals.** **Of other contaminants.**

Selective removal of metals and other contaminants (e.g. boron, Cd, Cr, Fe, Ni, Pb, Zn etc) is also possible with special resins.
Standard & modular IX systems.  
Undaunted by the technology’s complexity.

Over the years, we have created a wide range of pre-engineered, plug-and-play, ready-to-use standard IX systems for various industrial applications. Be it a straightforward single (simplex)- or double-bed (duplex) water softening system, or a more complex multi-bed demineralisation or mixed polishing system, or super-deionised (SDI) or continuous electro-deionisation (CEDI) system, we have all these pre-designed in the most compact and ideal configurations on skids - easy for selection in views of different applications, short lead time for production, cost-effective for container shipping, hassle-free installation at project sites, trouble-free (post factory-acceptance tests) testing and commissioning at sites before actual operations.

Water softening systems.  
Simple. Yet versatile.

Our standard water softening systems are fully mounted on skids, plumbed, wired and ready to use. Using a fully automatic and programmable multi-port control valve, they offer a simple and convenient solution for most of the water–softening requirements. The use of multi-port control valves allow our water softeners being versatile in handling varying feed water’s qualities, while producing consistent soft water’s qualities desired by a certain applications.
Complete 2-bed (or multi-bed) demineralisation systems.

Our standard and modular complete demineralisation systems typically incorporate the newer but proven reverse-flow (or counter current) configuration in packed resin beds. In operation, feed water enters the packed bed upward and downwards in the regeneration cycles. In the upward service cycle, the resin bed is lifted up in a compacted state. As the water progressively comes into contact with the more regenerated resin, high quality water production is ensured with lower ionic leakage. The columns are packed with narrow bead size resins which provides excellent fluid hydraulics and minimises channeling during regeneration. The resultant improved resin kinetics also means less mechanical and hydraulic damage to the resin beads during service and regeneration. The effluent from our systems are largely neutral due to the equivalence of cations to anions. As acid and caustic are both introduced into the packed beds at the same time during regeneration, the effluent generated is mostly neutral and relatively environmental friendly.

<table>
<thead>
<tr>
<th>Typical Flow Rates gpm, (m³/hr)</th>
<th>Pipe Size (in.)</th>
<th>Resin Volume (Litre)</th>
<th>Chemical Per REGEN (Litre)</th>
<th>Effluent Vol/REGEN (m³)</th>
<th>Throughput Per REGEN (m³)</th>
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</thead>
<tbody>
<tr>
<td>10 (2.3)</td>
<td>1.5</td>
<td>150</td>
<td>200</td>
<td>35</td>
<td>2</td>
</tr>
<tr>
<td>15 (3.4)</td>
<td>1.5</td>
<td>200</td>
<td>300</td>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td>20 (4.5)</td>
<td>1.5</td>
<td>300</td>
<td>400</td>
<td>60</td>
<td>5.2</td>
</tr>
<tr>
<td>25 (5.7)</td>
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<td>375</td>
<td>600</td>
<td>80</td>
<td>7.6</td>
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<tr>
<td>35 (7.9)</td>
<td>2</td>
<td>550</td>
<td>800</td>
<td>120</td>
<td>10</td>
</tr>
<tr>
<td>45 (10.2)</td>
<td>2</td>
<td>750</td>
<td>1100</td>
<td>140</td>
<td>15</td>
</tr>
<tr>
<td>60 (13.6)</td>
<td>2.5</td>
<td>1250</td>
<td>1400</td>
<td>175</td>
<td>20</td>
</tr>
</tbody>
</table>

Note: for general reference only.
Super Deionised (SDI) systems.

Our SDI systems are with added features to our 2-bed demineralisers for more demanding applications. With a Hydrogen-cycle cation exchanger as the final polisher, our SDI systems produce high purity water with low sodium leakage in a continuous reverse-flow configuration. As in our 2-bed demineralisation systems, the service and regeneration process and cycles of our SDI systems are similar. Our SDI systems also feature layered-bed in each resin tank as an option. Layered-beds are efficient and economical alternatives to employing separate vessels for strong and weak resins within the same tank. Layered-beds have higher chemical efficiency and total capacity. In anion layered-beds, optimal silica removal can be achieved. Layered-bed options have top-down feed flow.

![Super Deionised (SDI) systems](image)

### General specifications for standard SDI systems

<table>
<thead>
<tr>
<th>Typical Flow Rates (gpm, m³/hr)</th>
<th>Pipe Size (in)</th>
<th>Resin Volume (Litres)</th>
<th>Chemical Per REGEN (Litres)</th>
<th>Effluent Vol/REGEN (m³)</th>
<th>Throughput Per REGEN (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-20 (4)</td>
<td>1.0</td>
<td>250</td>
<td>300</td>
<td>40</td>
<td>28</td>
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<tr>
<td>25-30 (6)</td>
<td>1.5</td>
<td>400</td>
<td>550</td>
<td>80</td>
<td>65</td>
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<tr>
<td>35-40 (8)</td>
<td>2.0</td>
<td>550</td>
<td>750</td>
<td>120</td>
<td>80</td>
</tr>
<tr>
<td>45-50 (11)</td>
<td>2.0</td>
<td>800</td>
<td>1000</td>
<td>145</td>
<td>110</td>
</tr>
<tr>
<td>60-70 (16)</td>
<td>2.5</td>
<td>1100</td>
<td>1400</td>
<td>170</td>
<td>150</td>
</tr>
</tbody>
</table>

Note: for general reference only.
Example of a standard super-deionised (SDI) system.
Simple features but do wonders.

< 1.0 µS/cm
conductivity
(based on 150 ppm feed water's TDS)

5.5 - 7.5
pH

IP65 powder coated carbon steel control panel (c/w 415V AC/3-phase, VSDs, PLC, conductivity meter, alarm etc.).

Sch 80 uPVC Piping.

Pressure gauges.

Pneumatic actuated valve.

Pneumatic actuated valve.

Flow meter.

Pressure gauges.

Epoxy coated corrosion resistant carbon steel frame.

Y-strainer.

Stainless steel multi-stage pumps for service/ regeneration.

Flow meter.

FRP pressure vessels containing resins.
Chemical-free Continuous electro-deionisation (CEDI) systems.

This is a non-chemical electric regenerated ion-exchanger that allows a continuous operation without stopping for regeneration. It is normally used in conjunction with RO systems, degassifiers and UV components to produce bacteria free and low TOC ultra-pure (up to 18m Ω cm) water for the pharmaceutical or semiconductor industries. CEDI process overcomes the limitation of ion exchange resin beds, particularly the release of ions as the beds exhaust and the need to change or regenerate the resins.

Containerising a standard IX system is challenging in view of the column tanks (of different diameters and heights) required by the process designs. Often than not, high-cube 40' containers may have to be applied to provide not only the height clearance required by the tanks, but also for the clearance required for maintenance and the change-out process of resins (or the unloading and unloading of the resin will have to be carried out externally, having the tanks disassembled out of the containers). However, containerised IX systems certainly offer many advantages as well depending on the end-users’ requirements and their sites’ constraints, apart from the usual ease of mobility of the systems in term of shipments and transportation.

Containing the exchange process in “exchange” for containerisation advantages.
Modularised skids or configured for larger plants.

Some industrial applications requiring IX technology may require high capacity systems. Such industrial sectors may include power plant operation, refinery processing and the like. Our teams are experienced in providing modular skids for ease of shipment and installation at the project sites, or specifically configured systems to suit a certain site layout constraints. Where large tanks are required for such purposes, or when carbon or stainless steel tanks are required for a certain applications, we provide ASME-certified (or other international standard-compliant) tanks for such projects.

The usefulness of the century-old ion exchange technology.

Wide range of applications to industries ranging from as simple as softening water for household consumption to laboratory, brewery, semi-conductor, pharmaceutical production, power plant, oil refinery etc.
Applications. Wide spectrum.

Aviation processing.

Ultra-pure water for processing.

The project involved supply of a 5 m$^3$/hr SDI system to produce ultra pure water for Singapore Aerospace Engineer Services Pte Ltd's (SAEPL) processing of aviation parts and components. In this project, we supplied physio-chemical wastewater treatment plant to treat the plant's effluent to meet the discharge standards of Singapore's national environmental agency. The project was executed on an EPC basis.

Municipal water.

Removal of traces of uranium.

With selective type of resin, we designed and supplied a 7.7 m$^3$/hr containerised system for the purpose of removing traces of uranium present in the well water for Pilbara community in Western Australia. Located at a rather remote rural area, the containerised system was designed to be fully automatic and to be monitored remotely by the local government agency. The signal connectivity was through a satellite disc mounted on top of our container.

Oil & gas refinery.

Ultra pure water for refinery.

We supplied a standard and modular 250 m$^3$/day SDI system to Oil & Gas Development Co. (Pakistan) Ltd for its oil and gas refinery's operations. As a well established company, our teams went through very stringent tendering and clarification process to secure this project, which was well delivered and on schedule for the end-user's project implementation.

Nitrates processing.

DI water for ammonium processing.

We supplied a standard and modular 20 m$^3$/hr SDI system to Queensland Nitrates Pty Ltd for its day-to-day operations in Queensland. Our systems meet the stringent AS3000 (Australian Standards 3000) usually required by Australian end-user. The installation at the site was relatively hassle-free and our engineers were at the site for the final testing and commissioning before official hand-over.
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