FAQs

In order to help get quickly accustomed to the CapDI technology, we have prepared the below frequently asked questions guide.

Contents

1. How does CapDI work?

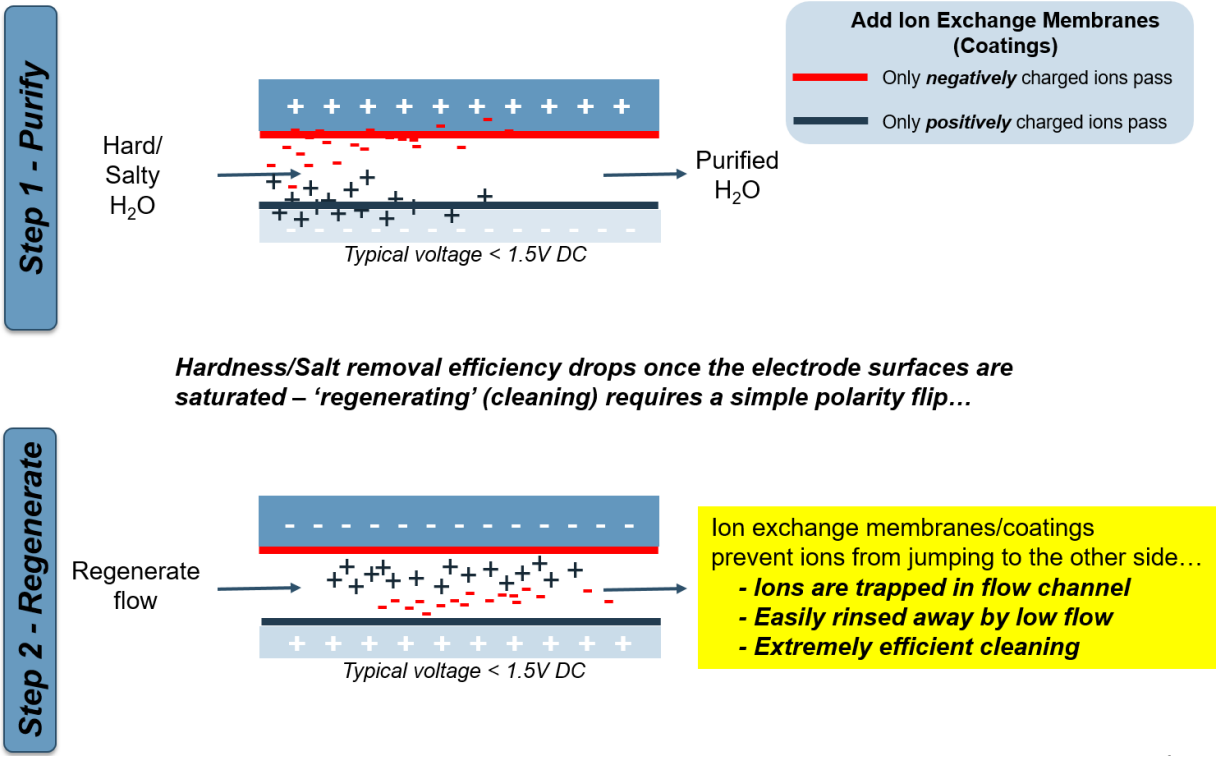
CapDI or Membrane Capacitive Deionization is a technology used to remove, or concentrate dissolved, charged species from a solution.

CapDI Cell:

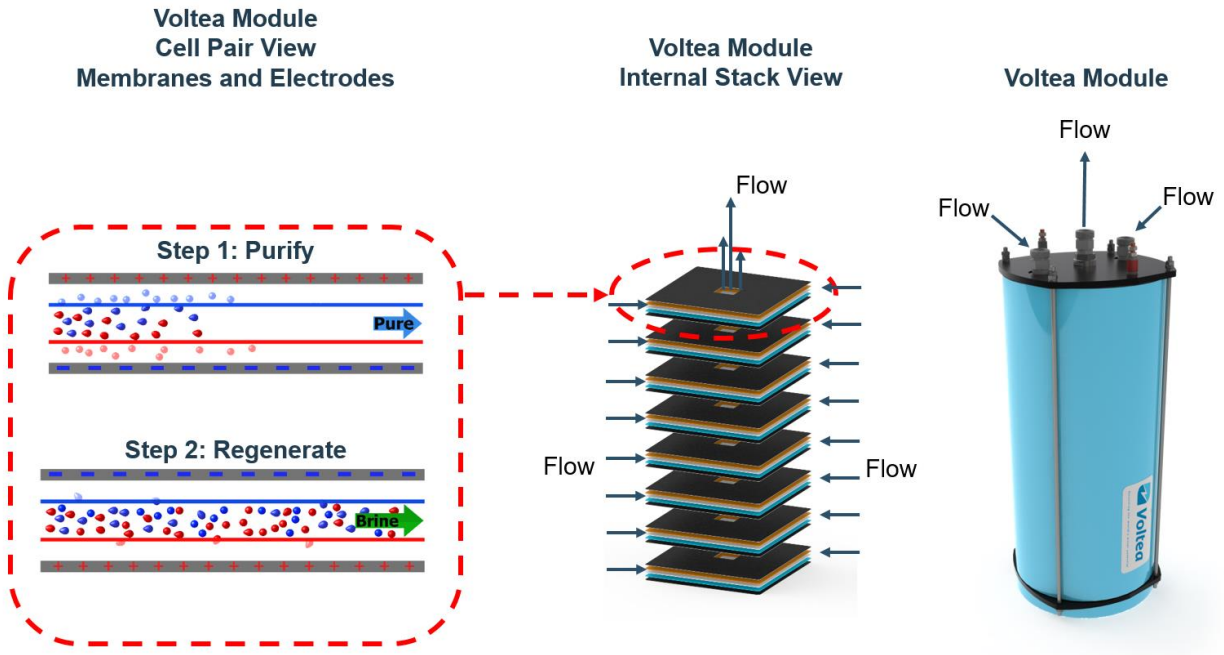
CapDI is based around the cell shown below. This cell consists of two graphite current connectors; against which a porous activated carbon layer is coated. These form the Anode and Cathode. Against these electrodes are placed Ion Exchange Membranes; an anion exchange membrane on the anode, and cation exchange membrane on the cathode. A spacer flow channel is placed between these electrode/membrane layers.

Water flows through this spacer channel parallel to the electrodes. As electricity (up to 1.5 V DC) is applied to this cell the anode is positively charged, and consequently attracts negatively charged ions such as Cl^- and SO_4^{2-}, whilst the cathode is negatively charged attractive positively charged ions such as Ca^{2+} and Na^+. These ions are stored in the porous carbon electrode. This generates a 'pure' water stream on the outlet of the cell with a reduced conductivity and TDS content compared to the inlet.

After approximately 100 - 200 s, the flow is reduced, and the applied potential reversed. This causes any stored ions to be repulsed from the electrodes, where they are flushed from the cell forming a concentrated solution and regenerating the electrodes. The addition of the ion exchange membranes in this phase prevent the reabsorption of these ions, enabling a higher water recovery, and highly efficient operation. This process takes approximately 50 - 150 s. This batch process is then continuously repeated.



These individual cells are taken and stacked on top of each other, forming stacks. In turn, these stacks are stacked on top of each other to form modules, which are then placed on a Skid to create a System as shown below. The size, and number of modules is determined by the feed water source, flow rate, and level to which the TDS should be reduced.



Tunable removal:

CapDI is a tunable technology. If 90 % reduction in TDS is required, the correct power to achieve this can be applied to the cell/module. However, if a 50 % reduction is required, the System can reduce the applied power, achieving the targeted reduction, at a lower energy consumption.

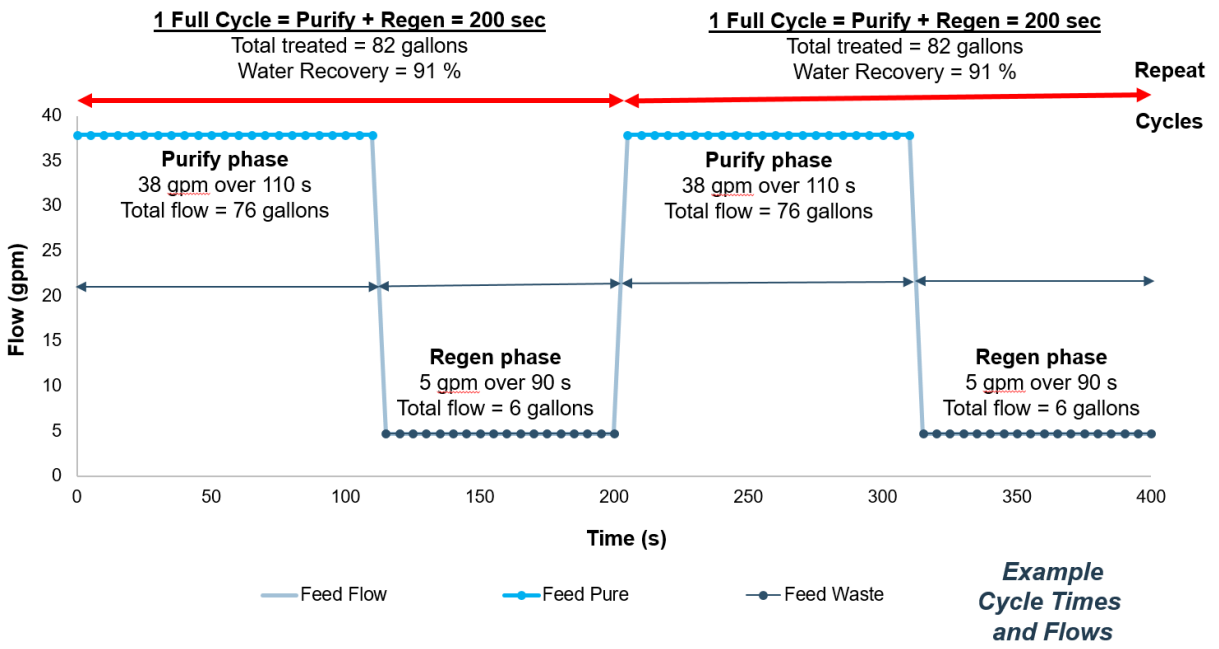
Dynamic Control:

The System can be set to give a constant % conductivity reduction, or conductivity output. This means the power applied to the modules is dynamically adjusted to compensate for a changing feed ensuring a constant quality of water is produced by the CapDI system.

This is through continuous monitoring of the feed and outlet conductivity and flow rate. This causes instant automatic adjustment of the power applied to the module to ensure the targeted water quality is achieved.

1.1. Flow Profile

The below diagram displays the flow rates during the batch process of Purify and Regeneration (waste) which form CapDI operation.



In the above flow diagram example, it is shown that the peak flow is 38 gpm and the net pure flow rate is 22.8 gpm. The net pure is lower than peak as it is averaged over the total cycle time, accounting for time when the system is in regeneration and not producing purified water.

The water supply to the CapDI should be capable of meeting the peak demand for proper CapDI operation.

2. Where is CapDI Used

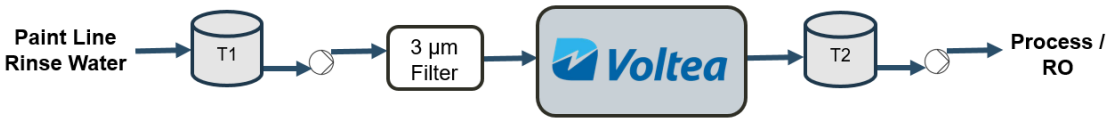
2.1. Applications

CapDI is used in a number of applications were a high quality of water with a reduced TDS is required. These range from treatment of municipal water, to recycling of waste waters. Some general applications are displayed below, comprising of the process flow diagram indicating standard requirements such as tanks and pumps. Additionally, some data is shown displaying the benefits of incorporating CapDI into these applications.

Further detail on a number of these applications can be found in the form of case studies and white papers on the Voltea website.

2.1.1. Automotive Paint line

CapDI enable paint line rinse water re-use

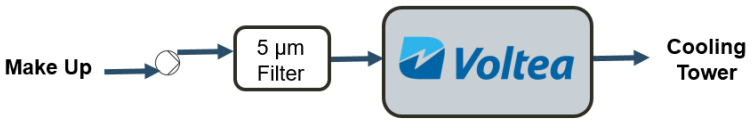


Feed (µS/cm)	Pure (µS/cm)	Recovery Actual	Salt Removal	Energy (kWh/m³)	Source
1212	169	85%	86%	0.96	Automotive Rinse Line

Sample	Feed	Purified
pH	5.5	5.8
Fluoride	75.9	40.8
Nitrite	381	43.5
Nitrate	355	39.2
Tot. Hardness (as $CaCO_3$)	2.6	0.34
Iron	0.5	0.013
Sodium	84.7	16.4
Zinc	185	16.7

2.1.2. Cooling tower make-up

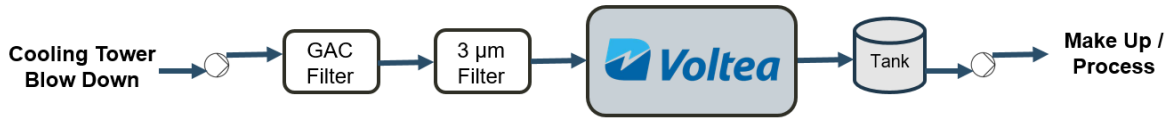
CapDI softens cooling tower feed water increasing CoC without chemicals



Feed (µS/cm)	Pure (µS/cm)	Recovery Actual	Salt Removal	Energy (kWh/m³)	Source
1722	516	90%	70%	0.56	Canal Water
1270	254	65%	80%	0.33	Canal Water

2.1.3. Cooling tower blow down reuse

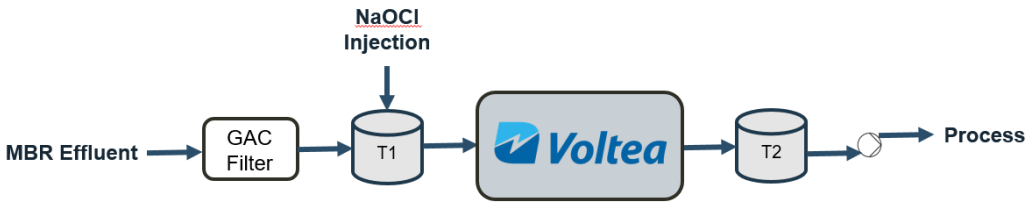
CapDI desalinates cooling tower blow down allowing water reuse



Feed (µS/cm)	Pure (µS/cm)	Salt Removal	Water Recovery	Energy (kWh/m³)	Source
6364	3881	39%	71%	0.94	Cooling Tower Blow Down
4684	2106	55%	70%	0.97	Cooling Tower Blow Down

2.1.4. MBR effluent treatment

CapDI reduces TDS from MBR effluent

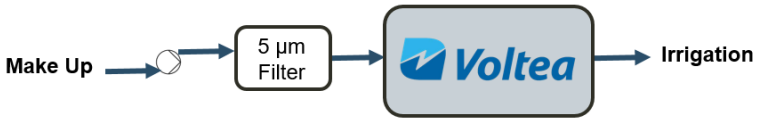


	Feed (µS/cm)	Salt Removal Target	Salt Removal Actual	Recovery Target	Recovery Actual	Energy (kWh/m³)	Source
RO	3100	65%	97%	85%	60% ✗	>1* ✗	MBR Effluent
CapDI	3000	65%	72%	75%	73% ✓	0.45 ✓	MBR Effluent

** Target energy consumption < 1kWh/m³; RO failed to achieve this target*

2.1.5. Horticulture

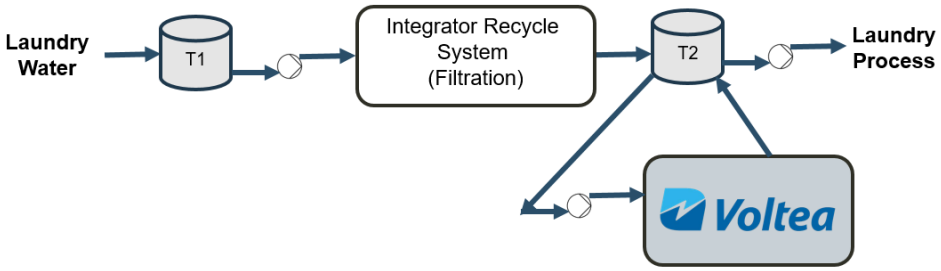
CapDI enables tunable sodium removal for optimized irrigation water



Feed (µS/cm)	Pure (µS/cm)	Feed Na^+ (ppm)	Pure Na^+ (ppm)	Water Recovery	Energy (kWh/m^3)	Source
486	196	57	29	84%	0.34	Ground Water
482	116	47	19	80%	0.53	Ground Water
487	94	54	14	80%	0.54	Ground Water
477	11	58	0	78%	0.60	Ground Water

2.1.6. Commercial Laundry

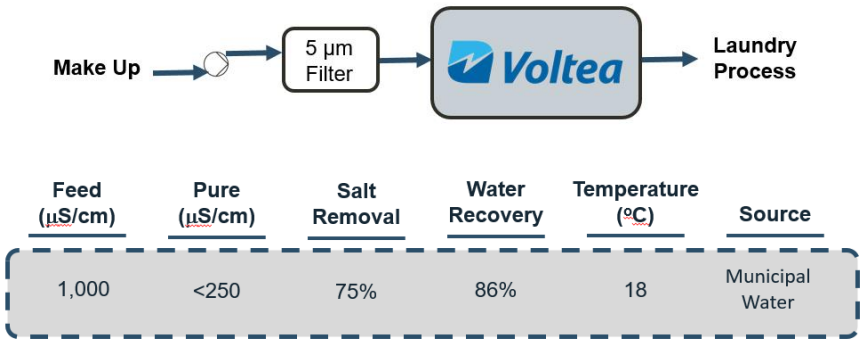
CapDI removes TDS from spent laundry water allowing re-use



Feed (µS/cm)	Pure (µS/cm)	Salt Removal	Water Recovery	Temperature (ºC)	Source
1331	679	50%	86%	50	Laundry Recycle Water

2.1.7. Commercial Laundry #2

CapDI offers salt-free, zero chemical softened feed water



3. CapDI System Design

3.1. CapDI Model

Voltea has developed a basic sizing model, a simplified version of Voltea's sizing model, which is available to approved resellers. This enables the simple and quick sizing of a CapDI System for an application utilizing basic feed water characteristics, TDS reduction and flow rate characteristics.

Please contact Voltea for support using the Model.

3.2. Water Quality

Voltea recommends that feed water meets the below quality to optimize performance and lifetime of the CapDI equipment.

Parameter	**Unit**	**Range**	**Intermittent**
Removal Limit	Δppm	0 - 2000	
Total Dissolved Solids	ppm	0 - 4000	
Total Organic Carbon	ppm	<15	
Chemical Oxygen Demand	ppm	<50	<100
Turbidity	NTU	<4	<100
Fats, Oils, Greases	ppm	<0,5	
Total Suspended Solids	ppm	<4	<20
Free Chlorine	ppm	<1	<25
pH	-	2 - 10	1 - 12
Iron Total	ppm	<0,5	
Total Hardness (as $CaCO_3$)	ppm	<1000*	
M Alkalinity (as $CaCO_3$)	ppm	<1000*	
Pre-filtration	µm	5	
Temperature	ºC	5 - 60	
	ºF	40 - 140	
Chemicals		Contact Voltea	

**Limits depend on set TDS reduction and water recovery*

3.3. Skid and Modules Sizes

Voltea manufactures a number of standard Skids, tailored to specific applications. These Skids are coupled with two module types.

Detailed information can be viewed for these Skids and Modules from the Technical Specification document.

3.3.1. Custom Systems

If Voltea's Standard Skids and Modules do not fulfill the criteria required by the customer, we are happy to offer a custom System, incorporating the design knowledge and experience of the engineering team.

3.3.2. Add on

Voltea has a comprehensive list of add on components that can be added to the Standard Systems. Please contact Voltea to discuss these add on components. These include additional sensors and pretreatment equipment.

3.4. Engineering redundancy

Engineering redundancy can be viewed in several ways. It could be additional CapDI modules, additional segments that can be switched to in the event of a segment failure or back-up components such as pumps or valves that are added in parallel and are switched to in the event of a component failure.

3.4.1. Variations in demand

Additional modules are typically included in order to compensate for any increase in the load on the system. In cases where the system was sized on an average salinity or flow, having additional modules means that when either of these increases, that CapDI is capable of coping without any further engineering.

3.4.2. Engineering safety

For applications where a safety system is required, the CapDI systems can operate in segments or multiples of Skids. These Skids can be completely independent so if a PLC failure occurs locally to the Skid, the other Skids are not affected and operation can continue. This independence also means that the Skids can be cleaned independently.

3.4.3. Expanding systems

In the event that a system needs to be expanded, there are two possible modes.

Expanding within a Skid

Where there is space within the Skid, additional electronics and modules can be added.

Expanding on number of Skids

In cases where the Skid is already being fully utilized expansion can still occur. In these instances, additional CapDI systems can be installed and linked to the original installation. This can be achieved in two ways, either a master cabinet is created and the add-on is dependent on the master control or the the expansion is fully independent. Cost differences will apply.

3.5. Questions

3.5.1. Can CapDI treat hot water?

Yes, up to 55 °C, 130 °F

Voltea has two standard modules:

- Ambient temperature: 5 - 30 °C, 40 - 86 °F
- High temperature: 5 - 55 °C, 40 - 130 °F

Module performance is favourable if it is tailored to its preferred temperature range. For example; high temperature modules can operate in the ambient temperature range, but higher performance would be achieved with ambient temperature modules.

3.5.2. Can CapDI treat water with Chemicals?

Typically, we can operate on a range of waters that contain chemicals, however, as with all membrane technologies, there is a risk of poisoning or denaturing of the membranes. If chemicals are present, please inform the technical support team.

3.5.3. Can CapDI treat silica?

No, silica is typically not ionized and as a result will not be removed by CapDI as it will not be affected by an electric field. Consequently it will generally pass straight through the CapDI modules, neither being removed or concentrated.

Colloidal silica may foul the flow channel if is it present as a large particle. The recommended 5 um prefiltration would prevent this occurring.

3.5.4. Can CapDI operate on chlorinated water?

Yes. CapDI membranes can be exposed to 2 ppm continuous and up to 20 ppm as a shock dose. This allows for chlorination to be used as a cleaning chemical in applications where organic fouling is likely.

3.5.5. Specific ion removal?

Different ions have different sizes and charge densities. These characteristics along with several others cause the ions to move at different rates and be preferentially removed from the solution.

As a basic rule, more charge dense divalent species such as Ca^{2+} and Mg^{2+} will be favourably removed compared to more weakly charged monovalent ions such as Na^{+}.

For further details please refer to the technical bulletin section of Voltea's website.

3.5.6. Can CapDI operate on high TSS (Total Suspended Solids) water?

CapDI can tolerate a degree of particulates or suspended solids. Small particles of less than 5 microns will likely pass straight though CapDI and cause no fouling risk. It is recommended that larger particles, or those that can agglomerate over time are removed with filtration prior to the CapDI. The automated cleaning systems built into the CapDI System can remove fouling if it occurs.

3.5.7. Can CapDI tolerate iron?

It is recommended that iron concentration should be below 0.5 ppm. Above this concentration, fouling is likely as soluble iron is oxidized and precipitates.

For iron based fouling, citric or glycolic acid can be used as a chelating agent, which helps the iron to re-enter solution. When combining this chemical cleaning with an 'air scour' (purging the system with a blend of compressed air and water) the iron can be removed.

3.5.8. Can CapDI tolerate organics?

Organics is a broad term that includes petrochemical waste products as well as fats, oils and greases (FOG).

CapDI operates in a number of applications where FOG are present in the water as well as applications where the biological activity has resulted in organic material dissolved in the water. For these applications, a good knowledge of the amount and type of organics is important to ensure adequate pretreatment. Pretreatment can include granular activated carbon, continuous low level chlorination as well as advanced oxidation technologies. These are typically used in combination with on board CapDI cleaning utilizing 'air scouring'.

In all cases, Technical support should be referred to.

3.5.9. What is LSI

The LSI (Langelier Saturation Index) is a calculation that determines the scaling potential of water. This is the likelihood that that hardness ions (predominately calcium and magnesium) will precipitate forming a carbonate. This scale (like that found on shower heads) can cause disturbance to the flow of water through the CapDI System. The rate of this build up affected by; the concentration of hardness and alkalinity ions, pH and water temperature, and are taken into account in the LSI calculation.

Based on the LSI calculation, Voltea can recommend the frequency of CIP cleaning which will be required to ensure optimum performance of a CapDI System. Information of this cleaning is given in the sections below.

3.5.10. What maintenance is required?

CapDI Systems require minimal site maintenance. This is a consequence of automated cleanings and continuous self-diagnostics and feedback built into the Skids.

3.5.10.1. Monitoring

Industrial Series Skids contain continuous monitoring of a number of parameters such as, ingoing and pure conductivity, flow, pressure and voltage. These parameters enable the automation of processes such as cleanings, as well as Dynamic Control ensuring the treated water always meets a certain quality.

3.5.10.2. Cleaning

Cleaning is dependent on the water quality that is to be treated. Automated cleaning includes 'air scour' (purging the system with a blend of compressed air and water) and automated chemical CIP (cleaning in place).

Both these cleanings are fully automated, and controlled either manually (initiated by the operator; remotely or via the HMI), or automatically by the CapDI system. If under automatic control, the System

will clean either after a present number of cycles have been operated, or when the pressure over the modules (ΔP) exceeds a certain preset value.

The cleaning frequency can be indicated in the sizing model, or by Voltea technical support.

3.5.10.2.1. Air Scour

This is designed for water that may have a high particulate fouling risk, particulate iron fouling risk or biofilm formation.

During an Air Scour, the Skid blows a mix of compressed air and water through the modules, from the inside to the outside to 'scour' away any particulates or fouling.

To remove a biofilm or iron fouling it may be used in combination with a CIP (acid or chlorination). The frequency of this will be indicated by technical support.

3.5.10.2.2. CIP - Clean in place

The CIP involves the recirculation of a dosed chemical around the Skid and modules. The dosing, recirculation and flush values are all preset and automatic through the System.

A number of chemicals can be used with the CIP, and are noted in the following section. Voltea Technical Support can give recommendations on the dosing time for specific chemicals, as well as further detail on recommended chemicals.

3.5.10.2.3. CIP Chemicals

3.5.10.2.3.1. Scaling

The following acids can be dosed during the CIP to remove scaling (hardness, calcium carbonate) build up:

Glycolic acid: 70 %
Citric acid: 50 %
Hydrochloric acid: 10 %

3.5.10.2.3.2. Fouling

The following chemicals can be dosed for metal, surfactant and inorganic fouling:

Glycolic acid: 70 %
Hydrochloric acid: 10 %
Sodium hydroxide
Sodium hypochlorite: 0 - 10 ppm
Simple green

3.5.10.2.3.3. Biological fouling

The following chemicals can be dosed to break down biological/biofilm fouling, or to disinfect the System:

Sodium hydroxide
Sodium hypochlorite: 0 - 10 ppm
Biocide - contact Voltea

3.5.11. What are the filtration and pretreatment requirements?

Filtration can vary significantly and is dependent on the water that is to be treated. Technical support can assist in determining what is required for the specific application.

A 5 micron nominal filter is recommended as a safety feature for most applications.

Please see also sections specific to TSS, iron, organics and chlorination.

3.5.12. Does Voltea offer Factory Acceptance Testing of equipment?

All Voltea equipment is sold with a Certificate of Assurance confirming that it has passed a rigorous quality control process.

Voltea also offers Factory Acceptance Testing that can be carried out at both the Netherlands and US locations.

3.5.13. Are Voltea's CapDI systems certified?

All systems are CE certified. If a system requires UL certification, a UL certified system can be built

4. Service

4.1. Service Models

Voltea offers a range of comprehensive Annual Service Packages giving the below advantages:

- Optimize CapDI System performance
- Reduce frequency and cost of unscheduled maintenance
- Maximize CapDI System uptime
- Discount for CapDI© spare parts and consumables
- 24/7 remote monitoring by the Voltea Field Service team
    - Generation of reports on overall System performance
    - Continuous monitoring of system diagnostics and alarms
    - Recommendation on corrective action if required on receipt of alarms
    - Reduce site staff maintenance time

Please see the below table for an overview of the benefits of each Service Level. All levels of Service incorporate our Remote Monitoring and Control Package.

Program	Bronze	Silver	Gold	Platinum	Emergency Visit
Site Visits	0 site visits	1 site visits	2 site visits	4 site visits	Service Engineer onsite within 48 hours or less
Monitoring package *	Monitoring package Twice yearly report	Monitoring package Twice yearly report	Monitoring package Twice yearly report	Monitoring package Quarterly report	N/A
Replacement modules/parts discount	N/A	10 % Discount	20 % Discount	30 % Discount	As dictated by Service Level

* Continuous monitoring of system
* Communication of alarms, issues
* Metrics monitored: Average removal, Water recovery, Flow rate, Duty cycle, Water treated, Pure/Waste volume

4.2. Spare parts

All Systems have an attached Recommended Spare parts lists associated with them, both for end users, and Reseller/Pilot Systems.

This Spare parts list can be shared on request.

4.3. RMA

The terms and conditions outline cancellation of an order. In the case of return of a product, the Return of Material Authorization can be used, at Voltea's discretion.

4.4. Terms and Conditions

Please see Terms and Conditions present on website. These include the warranty for the product.

4.5. What can be recycled?

The system is comprised of two major parts; the Modules and the Skid.

4.5.1. Modules

Module can be returned to Voltea for recycling. Shipping costs are not reimbursed, however, a discount towards future purchases will be issued. Value will dependent on the quality of the modules returned. If modules are not returned to Voltea for recycling, they can be disposed of in line with local regulations. No known hazardous components are used within the modules.

4.5.2. Skid

Please contact Voltea to discuss recycling.

The Skid can be recycled or disposed of in line with local regulations.

Change log

Changes	Changed by	Date