Technical Summary
Radial Deionization ™

Low Cost Waste Water Desalination

Atlantis Technologies
www.atlantis-water.com

Summary

Atlantis Technologies has developed a low cost produced water desalination system based on the patented Radial Deionizing super capacitor technology platform (RDI™). The RDI system evolved as a game changing technology from over $5,400,000 of funding by the US Government (DARPA & US Army TARDEC) and another $300,000 founder R&D investment. The patent protected RDI system is positioned to take significant market share from state-of-the-art technologies such as reverse osmosis and brine concentrators.

The RDI is the next generation capacitive deionization and is 10 times the speed, one quarter the price, and 15 times the range of the previous generations of the technology. The founder and CEO, Patrick Curran, was a member of the original DARPA engineering team and is a world expert in the field with multiple issued and pending patents.

The RDI™ system can deionize produced water from oil, gas, and mining operations for 40 – 70% less cost without cleaning chemicals with clean water recovery up to 95%. This lower overall cost of operation is due to lower capital cost, maintenance, operating expenses, and reduced disposal costs. In many cases, the RDI system can take the place of multiple unit operations such as reactive silica removal, hardness removal, and salt removal.

The super capacitor based system can handle low solubility species such as calcium/barium sulfate, high tds streams such as produced/fracture water and RO reject. The system is scalable to tds above 100,000 ppm, flow rates over 1,000 gpm and recoveries over 90%. The RDI is able to concentrate the brine reject stream by a factor of 10 or greater which minimizes brine waste and facilitates the isolation of desirable salts

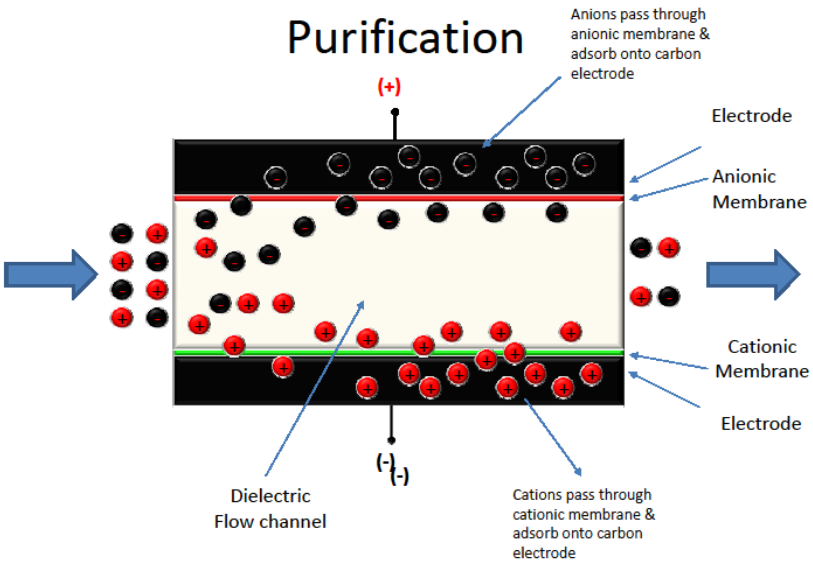
such as sodium sulfate, rare earth metals, and sulfuric acid, making the actual costs of treatment at mine sites much less.

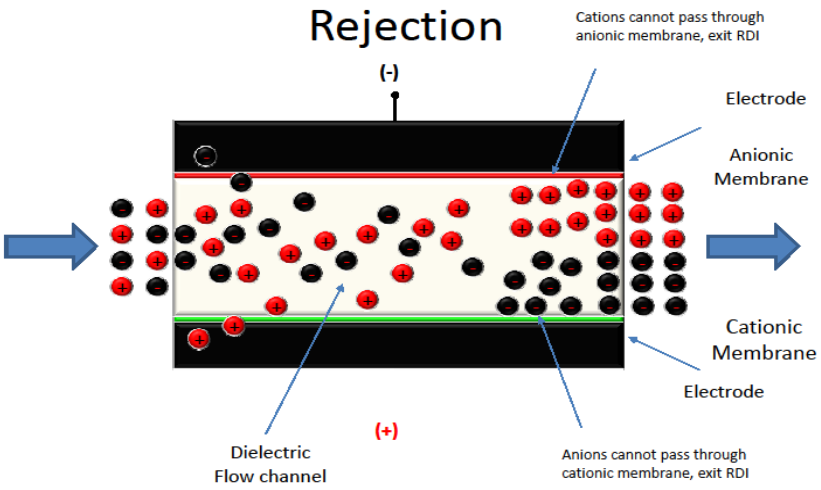
Atlantis has conducted significant laboratory and bench testing in a methodical approach to scaling the system to commercial application. The Company has built 12 and tested bench and pilot systems. We have built and shipped 2 field pilot systems for evaluation in the mining and power generation industries and have 3 pilots scheduled for deployment in Q1 in oil/gas, agriculture, and drinking water.

The system has been successfully tested on actual produced water from shale gas, heavy oil, and mining and demonstrated the bench top system at the corporate headquarters of numerous oil and water treatment companies. Our operational costs are well documented and available upon request.

Technology Platform

Radial Deionization works as illustrated in the below diagrams. An aqueous stream containing dissolved solids (salt) is passed between two oppositely charged super capacitors (electric double layer capacitors, or EDLC). As the liquid passes through the dielectric spacer separating the capacitors, ions are attracted to the oppositely charged capacitor layers. The ions leave the water within the dielectric layer, pass through a charge specific membrane coating, and are adsorbed onto the surface area of the carbon super capacitor. When the capacitors have filled with ions, the polarity is reversed and the ions are discharged back into the dielectric spacer and removed from the system. A 3-way valve is situated at the outlet of the device(s) which directs the brine away from the cleaned water. Typical cycle times range from 2 – 40 minutes.

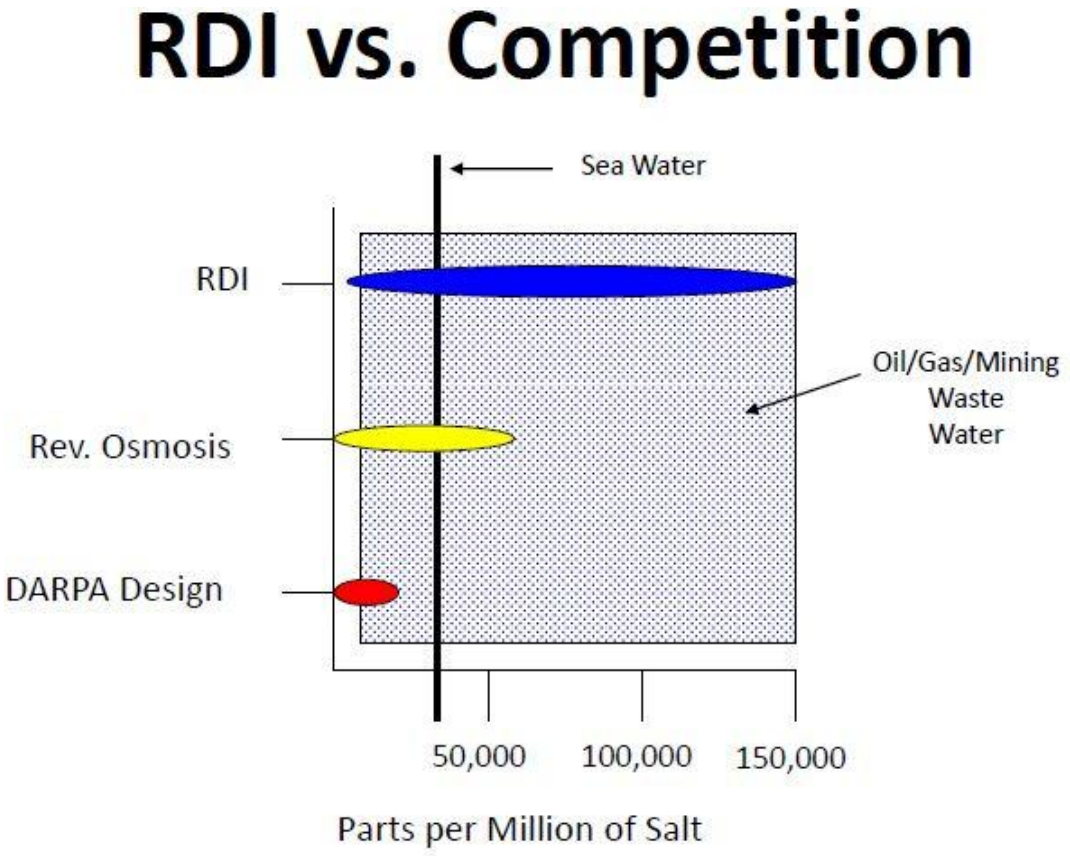




The RDI™ device is specifically designed to remove large amounts of ions and isolate the cleaned and brine streams. We have successfully deionized many types of solutions and concentrations including:

- 500 ppm hard city water
- 5,000 ppm waste sulfuric acid
- 5,400 ppm calcium sulfate from NF reject of mine waste water
- 6,400 ppm oil sands produced water
- 10,000 ppm magnesium sulfate
- 11,000 ppm produced water from heavy oil production
- 15,000 ppm sodium sulfate
- 19,000 ppm Marcellus shale gas “fracture” water
- 39,400 ppm produced water from Texas oil field.
- 100,000 ppm Eagle-Ford shale gas “produced” water

The tds capability range of the RDI spans 500 ppm to over 100,000 ppm. Existing technologies have limited ranges as shown in the below tds vs. capability graph. The RDI is able to remove any salt without fouling including carbonates, sulfates, nitrates, heavy metals, etc.



RDI™ Device

Each pair of super capacitors forms a "cell". Up to 100 cells are layered together to form the RDI™ cylinder. The stream to be processed flows through the dielectric spacers within cylinder with a minimal pressure drop. The processing capacity of a large scale cylinder is up to 5 gpm depending on salinity of water.

A single RDI cylinder is designed to remove all or most of the salt. In some cases cylinders are placed in series to optimize system cost. Because of the low pressure drop, multiple cylinders can be operated in series and at high flow rates. This enables processing of high tds streams without the need for intermediate storage. Each device will remove a portion of ions from the stream until the target dissolved solids level is reached. This design aspect of the RDI™ platform is critical to its superior performance and a key difference between RDI™ and the other versions of capacitive deionization.

Once the capacitor is full, all adsorbed ions are discharged into the flow channel and purged from the system with minimal water. Because of the device design and operation, we do not see precipitation of low solubility salts such as sulfates and hardness. These species may precipitate at a later immediately upon exiting the system, but they do cause issues within the device. This lack of fouling is a significant advantage that the RDI™ has over reverse osmosis and brine concentrators. This allows the RDI to take the place of separate operations that neither RO nor brine concentrators can do effectively. For

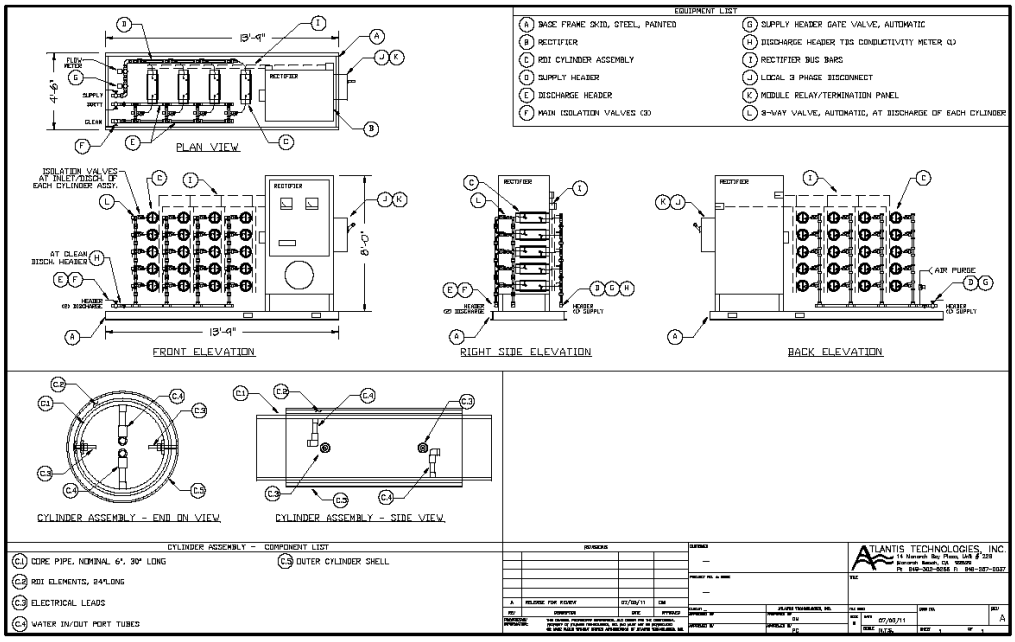
example, any application that requires the use of a boiler must treat water for hardness, and dissolved solids. In many instances, this is accomplished in 2 steps (ion exchange for hardness and RO/BC for tds). All of these steps can be combined into one RDI operation, significantly reducing opex and capex.

The cycle time of the device ranges between 2 – 20 minutes for cleaning and 2 – 20 minutes for purging. Many applications require the use of more than one cylinder which allows for constant flow to be maintained by timing the cylinders and/or modules.

In some cases, the concentrated solution is the desired product. We can adjust the operating parameters of the system to concentrate the brine to 10 – 20 times greater than the incoming stream. In applications where the customer must pay for the brine solution to be disposed, the RDI can significantly reduce this portion of their operating costs.

RDI™ Module

A module consists of one or more RDI™ cylinders, associated valving, DC power supplies, and controls. A system will typically contain one or more modules depending on purification level and flow rate required. A typical module layout is shown below. The 4 ft by 14 ft skid contains 20 cylinders and is designed to fit in a semi or flatbed. A module can process up to 100 gpm depending on the incoming salinity level.



RDI™ System Operating Costs

RDI™ modules are linked together to form a larger system depending on the desired tds reduction and volume capacity. The level of pre-treatment required for the RDI is equal to or less than state of the art technologies.

When evaluating desalination systems, it is important to calculate the total cost of operation including capital depreciation, maintenance, energy, and disposal of brine solution. Because many systems are setup as a design-build-own-operate (DBOO) arrangement all costs much be considered including the cost of financing.

Industry Cost Comparisons

Below is a chart of the major cost components of operating a produced water desalination system by technology type: Atlantis RDI, Brackish Water Reverse Osmosis, Brine Concentrator (Vacuum Compression Distillation), and Voltea CapDI (super cap competitor). One very common application is the processing a fairly dilute 1,600 ppm. In this application, approximately 72% of the operating costs are determined by the capital and maintenance costs and are therefore the most important issues to discuss when evaluating system choices. Although electrical efficiency is important, it is only 3% of the typical opex. In this salinity range, the Atlantis RDI system total operating cost is 43% less than reverse osmosis and 66% less than a brine concentrator.

Another application common in the heavy oil, oil sands, and power industry is the processing of 10,000 ppm water containing hardness, and salt. In this case, 58% of the operating costs are determined by the capital and maintenance costs and electricity rises to 11% of the opex. The Atlantis RDI system total operating cost is 50% less than reverse osmosis, 66% less than a brine concentrator and 79% less than the competitive capacitive deionization technology.

Much of the energy, capex, and other operating parameters for each technology were taken from the following publicly available reports:

1. **Colorado School of Mines, Nov. 2009**: An Integrated Framework for Treatment and Management of Produced Water, TECHNICAL ASSESSMENT OF PRODUCED WATER TREATMENT TECHNOLOGIES, 1st EDITION, RPSEA Project 07122-12

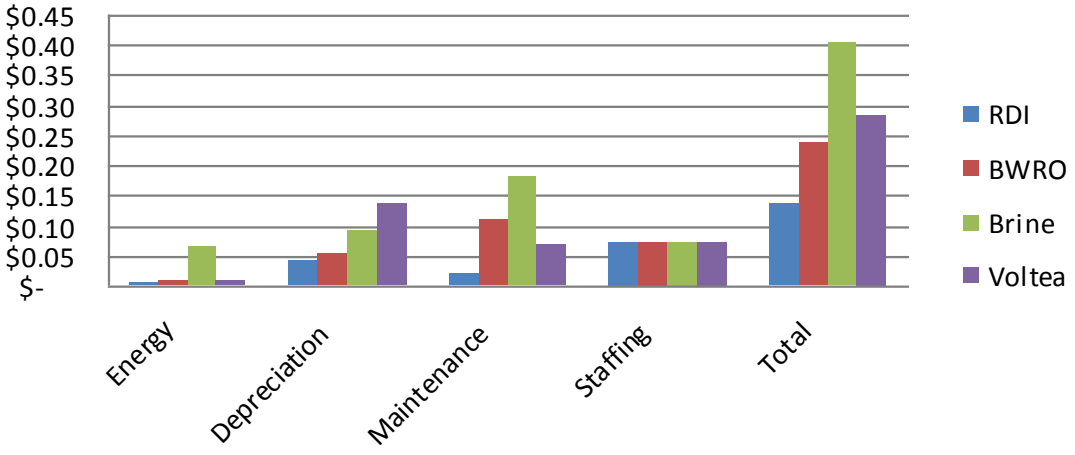
2. **Bureau of Reclamation, Sept. 2009**: Multibeneficial Use of Produced Water Through High-Pressure Membrane Treatment and Capacitive Deionization Technology.

3. **All Consulting**: Water Treatment Technology Fact Sheet

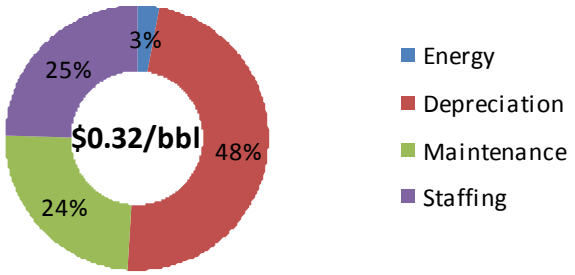
4. **University of Pretoria, Dept. of Chemical Engineering, Jan. 2005**: Multibeneficial Use of Produced Water Through High-Pressure Membrane Treatment and Capacitive Deionization Technology

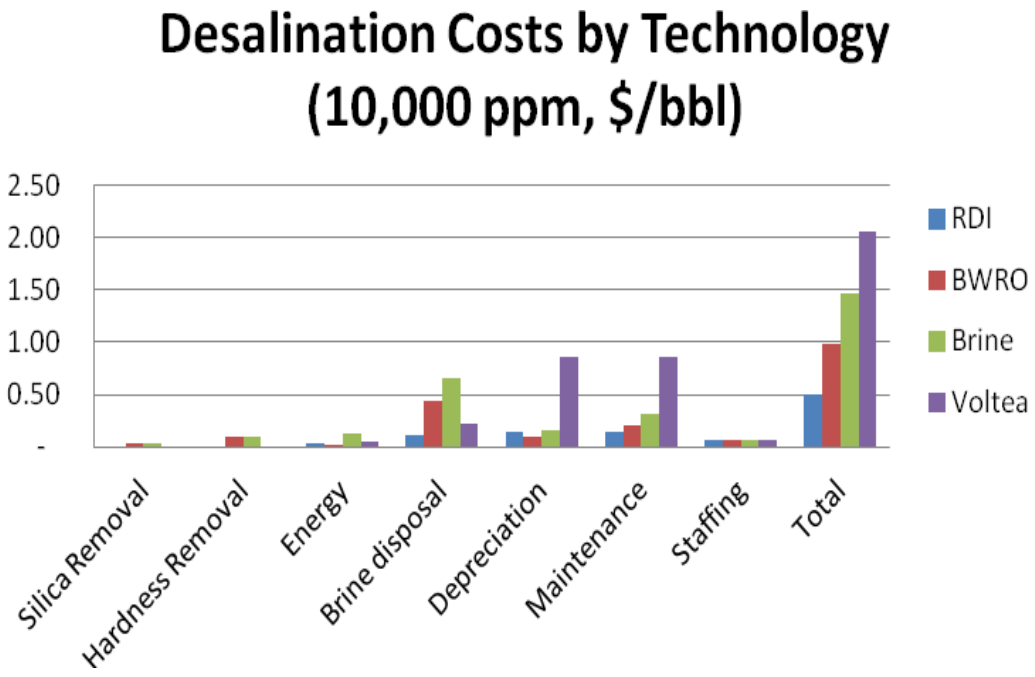
All above reports that reference capacitive deionization studies were conducted on full size production pilots.

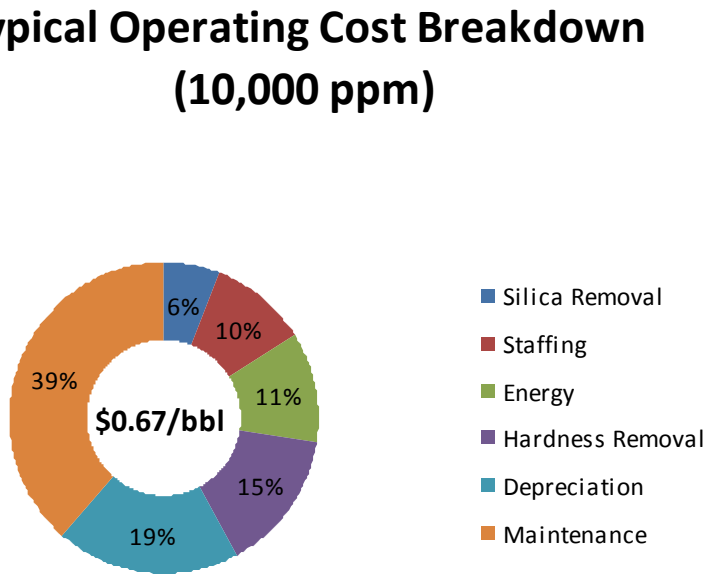
Desalination Costs by Technology (1,600 ppm)



Typical Operating Cost Breakdown (1,600 ppm)







The yield of clean water, or recovery, varies significantly by technology and salinity. The recovery of the RDI system is regularly above 80% and can reach as high as 95%. The typical range for brackish water RO is 60 – 85%, brine concentrator 40%, and the older generation capacitive deionization < 80%. Below is a chart of recoveries vs. potential brine disposal costs. These are listed separate from treatment costs because not all applications have to pay for brine disposal. But if offsite disposal is necessary, they

should be included in the total cost of operation. We assumed an offsite disposal cost of $1.10/bbl which is very conservative.

We are primarily focused on the produced water from the oil/gas, mining, and power generation. Just the oil/gas and mining segments total $1 billion per year right now and are expected to grow by 14% over the next 5 years. The most common application in this industry is the processing of water generated by heavy oil, oil sands, and standard oil production in the 10,000 ppm range. After standard pretreatment, common constituents that must be removed include hardness, and various salts including low solubility species such as Ca/Ba/Sr sulfates. Very large volumes of heated water are used in the heavy oil and oils sands segments. In order to reuse this water, it must be desalinated to be re-circulated through a boiler and heated for reuse.

Another market segment with almost identical components and a lower tds is the power generation industry. This segment also recycles large volumes of water which must be cleaned prior to entering a boiler or treated to meet permit discharge limits.

Current Applications

1. Oil/gas produced water tds removal.
2. Mine waste water deionizing.
3. Power generation.
4. RO reject purification.
5. Beverage/drinking water.

For more information contact:
Atlantis Technologies
www.atlantis-water.com
949-302-5265