

**PRODUCTS & APPLICATIONS  
FOR STEAM GENERATING PLANTS  
OVERVIEW**

**Liqui-Cel<sup>®</sup>**  
MEMBRANE CONTACTORS

ENGINEERED FOR EFFICIENT DISSOLVED GAS CONTROL

# THERMAL POWER PLANTS

When generating steam, dissolved gas control is an integral part of the water treatment system.

- ▶ Steam-electric power station uses steam to drive a turbine to generate electricity.
- ▶ Gas-fired power station uses hot combustion gas to drive a turbine to generate electricity.
- ▶ Combined cycle power station is a gas fired plant equipped with a heat recovery steam generator that produces steam to drive a turbine to generate additional electricity.
- ▶ A nuclear power plant is a thermal power station in which the heat source is a nuclear reactor. As is typical in all conventional thermal power stations, the heat is used to generate steam which drives a steam turbine connected to a generator which produces electricity.

Historically vacuum towers, steam deaerators, decarbonators and chemical injection systems were common methods used to control dissolved gas in water systems in power plants. However, these methods can be much less efficient, require more maintenance and the handling of large volumes of chemicals.

Liqui-Cel® Membrane Contactors can reliably achieve very low dissolved gas concentrations and operate with less chemicals compared to alternative degassing methods. Membrane contactors contain 10x the surface area of conventional degassing tower and occupy a much smaller footprint.



## WHY DEGASIFICATION IS IMPORTANT ?

### *Minimize Corrosion Inside The Boiler*

Oxygen reacts with metals in the system and can cause pitting on the metal surfaces. Iron oxide produced during the corrosion process can promote iron deposits in the boiler. Carbon dioxide forms carbonic acid and enhances the corrosive effect of oxygen. Reducing dissolved O<sub>2</sub> will reduce corrosion in the boiler.

### *Reduce Mixed Bed Regeneration*

CO<sub>2</sub> dissociates in water and adds to the ionic loading of the ion exchange equipment. Removing carbon dioxide can extend the run time between regeneration cycles 8-10 times. This reduces the chemical costs and waste water generated associated with ion exchange regeneration.

### *Improved EDI/CDI performance*

EDI technology uses combines ion exchange with an electric current to remove ions from water. Carbon dioxide will add to the total ionic load on the equipment and will be preferentially removed over weakly charged ions reducing the performance of the EDI.

Corrosion In Boiler Piping



Pitting In Boiler Metal Surface



# POWER PLANT APPLICATIONS

## CO<sub>2</sub> Removal

As water treatment technologies have evolved from [Cation - Anion] exchange systems to [RO - mixed bed] and [RO-EDI] gas removal technologies, post RO have moved to membrane contactor degasification. Membrane contactor systems can remove carbon dioxide and reduce the ion exchange regeneration frequency in mixed beds. This substantially lowers the chemical consumption and waste water treatment of the plant. This allows the plant to operate inside its permit and at the same time reduce the chemical consumption of the plant.

## O<sub>2</sub> Removal

As steam demands increase and plants are modified to be operated at design capacity and above, conventional steam deaerators can become overloaded and may not have the capacity to meet the higher water flow demands. Liqui-Cel® Membrane Contactors can be used to supplement the steam deaerator at a significantly lower cost than installing an additional steam deaerator.

Liqui-Cel® Membrane Contactors can be used to replace the steam deaerator. In these designs, the water is degassed using membrane contactors then pre-heated prior to the boiler using a latent heat recovery system. These plants realize significant energy savings by eliminating the steam used in the deaerator.

Membrane contactors can also be used to remove dissolved oxygen from HRSG make up water during startup. This can reduce the anhydrous ammonia loss during the startup cycle when the steam deaerator (DA) vents are opened to vent the large amounts of dissolved oxygen in the cold make up water.

## AVT - All Volatile Treatment

Volatile treatment chemicals will vaporize first and will be vented in large quantities during this evolution. By supplying make up water as low as 1 ppb DO, the DA vent can be closed and the DA used as a feed water heater/storage tank. This also has the additional benefit of maintaining the volatile treatment chemicals in the system vs. venting them to the atmosphere and contributing to environmental limits, chemical usage, extra operator effort hours and operating costs.

## Reducing The Formation of Radionuclides

Dissolved gas control in a nuclear power plant water system is essential to reduce the release of radioactive materials into the environment. Controlling dissolved gases can also help reduce the formation of unwanted radionuclides, such as <sup>14</sup>C and oxides of <sup>60</sup>Co and alleviate primary water stress cracking (PWSCC). Nitrogen and oxygen in the RMWST can also lead to the formation of <sup>14</sup>C and CRUD.

Mixed Bed Resin



Steam Deaerator



Chemical Storage Tank



Nuclear Reactor



Scan to read more

# APPLICATION: O<sub>2</sub> Removal

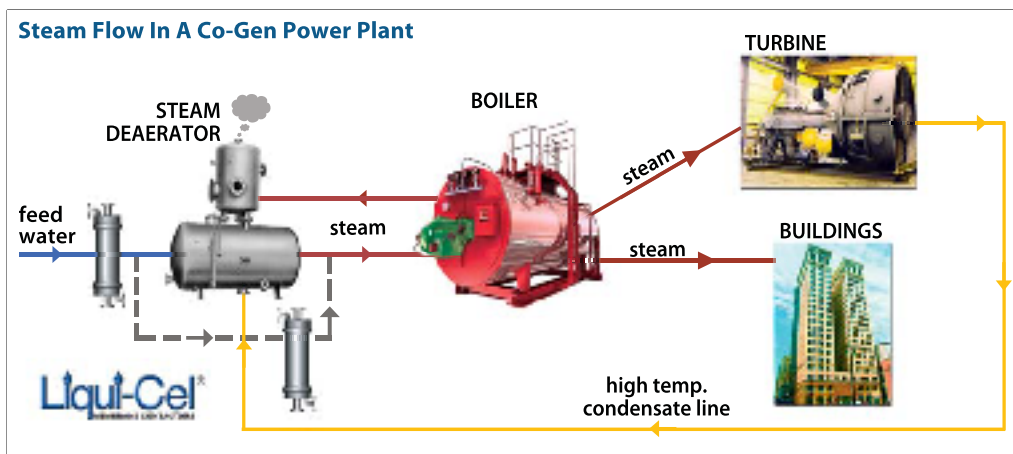
## REDUCE BLOWDOWN FREQUENCY - CONTROL CORROSION

Proper treatment of boiler feed water is an important component of a boiler system to control corrosion. As steam is produced, dissolved solids become concentrated and deposit inside the boiler. This leads to poor heat transfer and efficiency reduction of the boiler. Chemical treatment is widely used to control dissolved oxygen in a boiler. The cost of operating a chemical treatment program consists of chemical costs and blow down costs. Chemical addition to the water can increase the frequency of blow down, which increases the operating cost of the boiler. Membrane Contactors can be used to remove the dissolved oxygen from water with minimal chemical use. By removing the dissolved oxygen, the volume of chemicals added to the boiler will be lower which reduces the blowdown frequency.

## REDUCE STEAM DEAERATOR VENT RATE - SAVE ENERGY

District Heating and Cogeneration steam plants typically operate with low condensate return. These plants require additional raw water to compensate for the water loss. The raw water temperature feeding the deaerator is ambient. In winter months when steam is required for heating, the feedwater is cold. Colder water contains more oxygen. Steam deaerator vent rate is based on dissolved oxygen levels in the feedwater, lower feed water temperatures will require higher vent rates. As fuel costs increase, the cost of venting a deaerator increases accordingly.

During the cold winter months the oxygen level in the feedwater is higher and more steam is required to heat and remove dissolved oxygen. Plants can increase steam used for heating if vent rate is reduced. A boiler producing 450 mlbs/ hour of steam at 850 psig can save up to > \$650,000 per year. (based on gas price of \$5/MM Btu)



Up to  
**\$1 Million**  
Operating  
Cost Savings



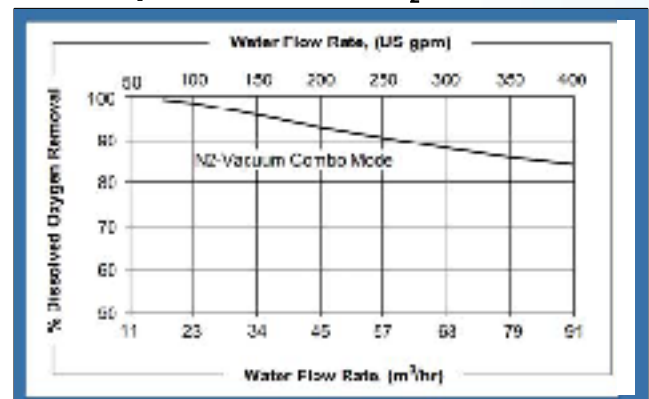
Scan here  
to read more

## REDUCE CORROSION AT START-UP

Heat Recovery Steam Generators are commonly used in Gas Fired Power Plants. HRSGs are typically used for peak loads to meet the increased demand for electricity. These plants cycle on and off frequently.

Since the gas fired power plants do not produce steam immediately after startup, steam to the Deaerator is not available for some time. These plants need a source of deoxygenated water to minimize corrosion during this start up period.

## Superior Dissolved O<sub>2</sub> Removal



Curves represent nominal values, generated using water at 20°C.  
O<sub>2</sub> Removal: 14x28 inch, X40 membrane, N2-vacuum combo mode,  
vacuum: 75 mm Hg, N2 Sweep 0.5 scfm.



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# APPLICATION: CO<sub>2</sub> Removal

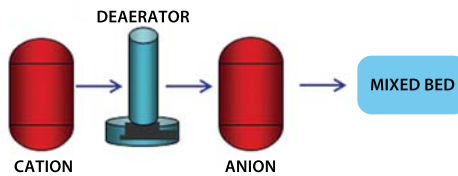
As RO membranes have become widely accepted in water treatment they have replaced the traditional cation - deaerator - anion process to produce deionized water. RO membranes offer an economical way to deionize water without the added costs of chemical regeneration. However carbon dioxide gas freely passes through RO membranes and will raise the conductivity of water and also lower the pH. Membrane contactors can remove carbon dioxide downstream of the RO membrane and greatly enhance the performance of the water system. By removing the carbon dioxide from the water the ionic load on final polishing ion exchange equipment is reduced and the life of a mixed bed is extended. This will significantly decrease the regeneration frequency of the mixed bed. Customer report a 8-10x increase in service life. This offers significant savings in chemical, feedwater, waste water and labor costs.



Mixed Bed Demineralizer for a Power Generation Facility

## REDUCING THE SIZE OF THE IX SYSTEM CAN REDUCE CHEMICAL STORAGE ON SITE

### TRADITIONAL ION EXCHANGE SYSTEM



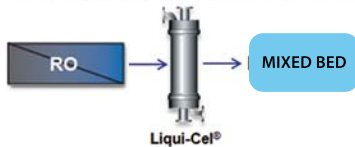
Cation and anion vessels remove ions from the water. Deaerator removes carbon dioxide. Mixed bed final polishes the water and removes any remaining ions from the water.

### RO MEMBRANE SYSTEM



RO removes ions and dissolved solids from the water. Carbon dioxide passes through the RO membrane. Mixed bed final polishes the water and removes any remaining ions from the water including ions formed from CO<sub>2</sub>.

### HYBRID MEMBRANE SYSTEM



RO removes ions and dissolved solids from the water. Carbon dioxide passes through the RO membrane. Membrane contactor removes carbon dioxide. Mixed bed final polishes the water and removes any remaining ions from the water.

## OPERATING COST SAVINGS

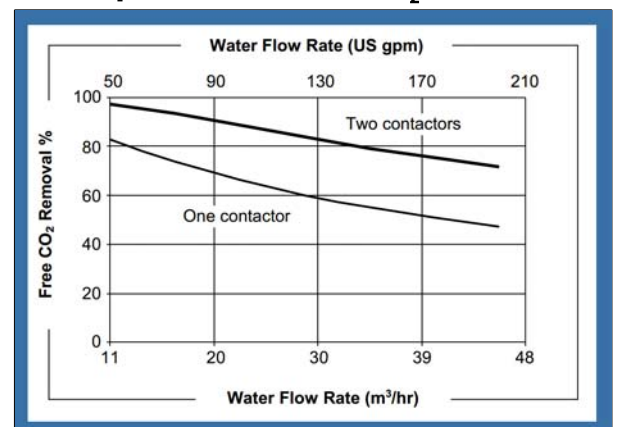
By lowering the carbon dioxide load on the mixed bed the regeneration frequency can be reduced. This can have a significant impact on the regeneration costs. Depending on the CO<sub>2</sub> level and water flow rate a typical regeneration cycle may cost the plant \$5,000-\$7,000.

A 33 MW combined cycle in the US found that they were able to extend the regenerate frequency to once a month from once a week realized a \$250,000 a year savings in regeneration costs.



Scan here to read more

## Superior Dissolved CO<sub>2</sub> Removal



Curves represent nominal values, generated using water at 20°C. CO<sub>2</sub> Removal: 14x28 inch, X50 membrane, Air vacuum combo mode, vacuum: 150mm Hg, air sweep 8 scfm.

# WHY LIQUI-CEL® ?

## Economical

Liqui-Cel® Degasification Systems:

- Do not vent steam as an integral component of their operation  
**Energy Savings**
- Do not require the reinforced floor space and support steel required by a (ASME rated) steam deaerator
- Operate with low electrical costs



14-inch Boiler Feedwater System

## Flexible

Liqui-Cel® Degasification Systems:

- Can be custom configured to fit into pre-existing available space  
**Mounting Location and System Integration Flexibility**
- Can be added on for plant expansion and to accommodate increased production needs with minimal impact
- Can be used as a temporary solution when the steam deaerator is not available

## High Performance

Liqui-Cel® Degasification Systems are engineered to outperform steam deaerators and vacuum towers for gas removal, achieving DO levels as low as 1 ppb.

- Lower DO levels require less chemical oxygen scavengers, allowing for higher cycles of concentration and less blow down. **Chemical/Energy/Water Savings**

## Reliable

Liqui-Cel® Degasification Systems:

- Typically designed with multiple trains of contactors, these systems can be fully automated and remotely monitored. With automatic switching and startup/shutdown features along with ease of upgradability, Liqui-Cel® can reduce your overall risk and add to the reliability of your system.
- Design and engineer new construction and/or expansions to take advantage of the smaller footprint, lower operating costs and without the large, steam pressurized ASME code rated Class 1 pressure vessel required for steam deaeration.



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# SUPERIOR PERFORMANCE



10-inch Oxygen Removal System

## Compact Design with 10x the Liquid-Gas Contact Area of A Conventional Degassing Tower

- ▶ Small Footprint
- ▶ Reliable, Predictable Performance
- ▶ Easily Adjustable for Water Flow Changes



8-inch Mobile Deox System

## Adapts To Your Needs

- ▶ Operate In-line
- ▶ Modular (Easily expandable after installation)
- ▶ Ideal For Mobile Systems



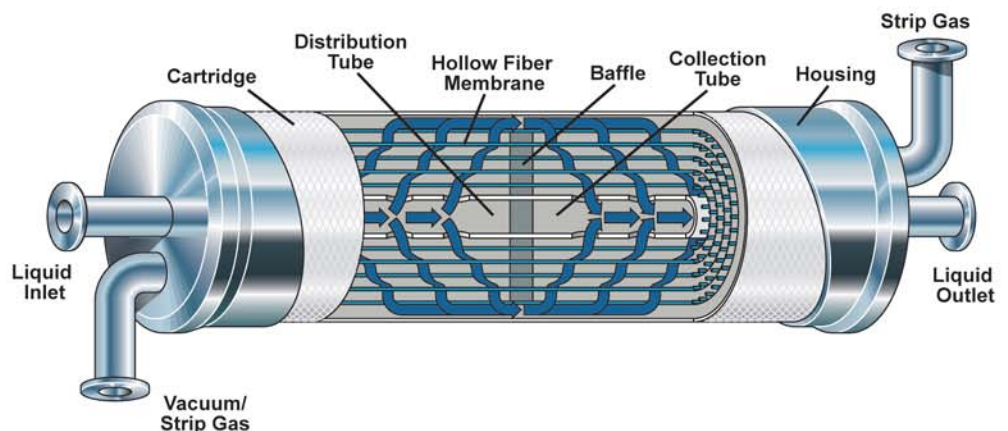
14-inch Industrial System

## Environment Friendly

- ▶ Lowers Ion Exchange Regeneration Chemicals
- ▶ Reduces Need for Oxygen Scavengers
- ▶ Lowers Disposal Costs



Scan to watch  
Product Tour video



**MODULAR**

**14-inch Deoxygenation System  
in Power Plant**

**ECONOMICAL**

**8x20-inch Industrial CO<sub>2</sub> Removal System  
Using Blower**

**MOBILE**

**8x80-inch Mobile Deoxygenation  
System in Refinery**



**Industrial Water Solutions**



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# FAQs

## **How do the contactor hold up to higher pressures and temperatures ?**

We have a new line of products that can operate at higher temperatures and pressures. For example our new product can operate at 175psig at 60°C. We can operate it in even higher temperatures if we de-rate the pressure rating.

## **As a small plant we have limited engineering resources and I'm not sure how familiar my staff is with membrane deaeration. Does Membrana offer services to help design and install systems? A small boiler feedwater system, for example ?**

Membrana manufactures and sells the membrane contactors only. We do not build systems. We do offer engineering support on how to design a system, sizing, chemical consumption and other support. We also work with system builders all the time. Many of them are quite familiar with our products and we can provide some contacts if needed.

## **How much does a Liqui-Cel® Contactor cost ?**

There are many variables that impact the answer to this question. Variables such as water flow rate, what gas is being removed (whether it's oxygen or carbon dioxide) and other operating considerations can impact the number of contactors required and price. All of these will impact the number of contactors required and price of a system. Contact a Liqui-Cel® representative to size a system for your application and to obtain cost and availability.

## **The savings on chemical costs are quite clear. Good information there. But, I am wondering if there are other costs associated with using gas transfer membranes that could offset these savings. Like energy cost ?**

Yes, there are other operating costs associated with a membrane contactor system. There would be a vacuum pump required. There would be some electrical consumption for the vacuum pump. There would also be nitrogen consumption in order to remove dissolved oxygen. So it really depends on what the customer is trying to accomplish with a membrane contactor system. We can estimate these costs and help the customer determine if this is a viable option for the particular system that they are operating.

## **Do the contactors have to be cleaned often and how is that done ?**

In our membranes only the dissolved gases pass through the membrane. In filtration, all the dissolved minerals and particles will stay on the other side of the membrane and over time these will foul the membrane and the filtration membrane will require cleaning. In the Liqui-Cel® Contactor membrane only gases pass through and the mechanism for fouling is very different. In many applications discussed today our membrane is used in addition to an RO membrane and in that case the water is very clean. In this case the contactors can be used for several years without cleaning. In some of the less clean environments where there could be contamination in the water, the membrane could be cleaned with acids and bases. So there are many different methods to clean a membrane. Polypropylene membrane is resistant to wide range of chemicals so it's relatively easy to clean our membranes.

## **I think the system in your case study for oxygen removal got down to 20ppb? Can the contactor go lower ?**

Our membranes can accurately control the dissolved oxygen in the water. We can design the system to be <10 ppb O<sub>2</sub> or even as low as < 1ppb O<sub>2</sub>. It really depends on the customer's requirements.

## **Will CO<sub>2</sub> cause damage to my vacuum pump?**

It really depends on how much carbon dioxide is being removed from the water. The carbon dioxide will dissolve into the seal of the vacuum pump and build up over time. And if the CO<sub>2</sub> levels are very high in the water, it may require special materials in construction such as stainless steel internal wetted parts to prevent corrosion in the vacuum pump. But in many applications, the standard materials of construction are satisfactory in CO<sub>2</sub> removal. We would work with the customer to select the most ideal vacuum pump for the particular application.

## **Can you provide additional references for systems that have been running for at least couple of years ?**

We manufacture the membrane contactors and supply to OEMs who build water treatment systems. So many of the OEMs have a lot of references that they would be able to share with you. We also work directly with end users that we can provide as references.



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# FAQs

## How do you know how many membrane contactors that you need ?

This is a question I hear often. In order to calculate the number of contactors needed for a system, we would need to have some information from the customer, such as water flow rate, water temperature, dissolved gas concentration and target gas. We take this information and put it into our sizing program that will provide the number of contactors needed, vacuum pump size, vacuum level, and sweep gas flow. So, as long as the customer can provide this information we can very accurately size a system.

## What is the required water pressure to operate a contactor ?

Our membrane devices operate differently than other membrane contactors. Our membrane contactors will be as efficient for removing dissolved gases at low pressures as well as up to 60 psi. What controls the membrane contactor's ability to remove gases is the pressure of the gas that comes in contact with the liquid.

## Sometimes my DI water flow fluctuates due to the needs at my plant. What happens if the DI water requirements change ?

Our membrane technology is different than conventional technologies when we are looking at other degasification devices. Our membrane contactors will operate at low flow rates as well as high flow rates. So the turndown ratio is very high. At lower flow rates the performance might be better and higher flow rates the performance might be a little bit worse. The membrane will not be damaged and no concern about breaking the membrane from flow rate changes.

## Why not use a deaerator to remove the CO<sub>2</sub> ?

A deaerator tank is essentially a tank that has packing material or trays inside. Water is pumped from the top of the tank and by gravity it falls across the trays or packing material to the bottom of the tank. Air is blown counter currently up from the bottom of the tank and out the top to strip CO<sub>2</sub> from the water. Water in the bottom of the tank is at atmospheric pressure and needs to be repressurized to move to the next unit in operation. Membrane technology degasses inline and under pressure, so water going into the contactor comes out under pressure which can eliminate a transfer pump. Also, you have a lot of surface area in the same size volume. A membrane contactor system would be one tenth the size. Also the membrane does not allow for any bacteria, yeast or mold to contact the liquid. So you can degas the water using ambient air without contaminating the water. That becomes important when you are using the membrane contactor in the downstream of an RO membrane. The RO membrane is designed to purify water, so you do not want to install a system where the water and air comes into contact after RO. So the membrane contactor technology is a cleaner, compact technology alternative.