

# Deoxygenation of Boiler Feedwater with High-Pressure 3M™ Liqui-Cel™ Membrane Contactors

## Introduction

3M™ Liqui-Cel™ Membrane Contactors are regularly used for Carbon Dioxide (CO<sub>2</sub>) removal in water demineralization as well as for Oxygen (O<sub>2</sub>) removal in ultrapure water (UPW) supply. Further use is to improve flexibility of operation in district heating, steam and power generating systems where O<sub>2</sub> and CO<sub>2</sub> must be removed to very low residual levels to avoid corrosion. In some cases, membrane contactor systems can be added to or replace the thermal degasser. Thermal degassers preheat the water to approximately 105°C requiring specific considerations for the downstream boiler feed water pumps and limiting the efficiency of feed water heat exchangers.

The membrane contactor system described in the following can be operated inline at the given line pressure and at cold or moderately increased temperature level. It does not require downstream re-pressurizing and avoids vapor loss of thermal degassers.

## 3M Liqui-Cel Membrane Contactor Technology

3M Liqui-Cel Membrane Contactors contain hollow fiber membranes that allow a liquid and a gas to come into direct contact without mixing. Figure 1 shows a 3M™ Liqui-Cel™ EXF-8x80 Series Membrane Contactor with microporous hollow fiber membrane. Water flows on the outside and vacuum and/or sweep gas flows on the inside of the hollow fiber.

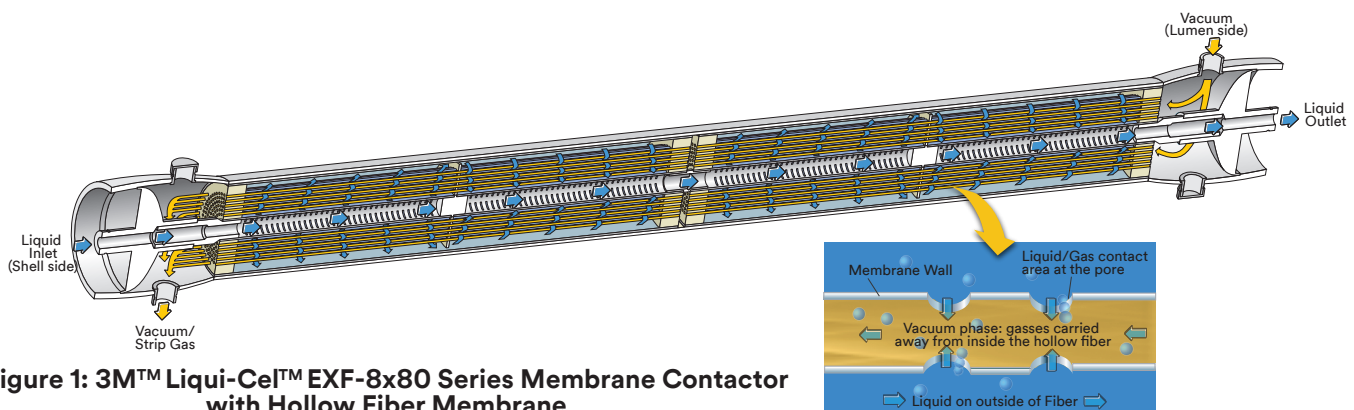
As the membrane is microporous gases can pass through the membrane wall. Applying a vacuum and/or sweep gas creates a partial pressure difference which is the driving force to remove the target gas. For O<sub>2</sub> removal from water, simultaneous use of vacuum and nitrogen sweep gas results in very low outlet values down to 1 ppb O<sub>2</sub>.

## System Description

Depending on the design of a water treatment system in a power plant, 3M Liqui-Cel Membrane Contactors can be placed in different positions. Jotem Waterbehandeling BV from the Netherlands built a membrane degassing system for a power plant where the feed water to the membrane contactors was a mixture of fresh make-up water and condensate return. Table 1 shows the inlet operating parameters as well as the desired O<sub>2</sub> outlet specification. The primary goal was the removal of O<sub>2</sub> to the required level of 10 ppb. Additionally, the system was designed to remove CO<sub>2</sub> in case it would be needed.

**Table 1: Inlet and outlet parameters of degassing system build by Jotem, NL**

Operating Parameters	Target
Flow Rate (m <sup>3</sup> /hr)	180
Temperature (°C)	35-50
Pressure (bar)	8-11
Inlet O <sub>2</sub> concentration (ppb)	6989 maximum
Outlet O <sub>2</sub> concentration (ppb)	10



**Figure 1: 3M™ Liqui-Cel™ EXF-8x80 Series Membrane Contactor with Hollow Fiber Membrane**

Due to the given pressure and temperature conditions (maximum 11 bar and 50°C) the 3M Liqui-Cel EXF-8x80 Membrane Contactor was chosen. This contactor type contains a high pressure FRP housing designed to operate up to 19 bar. To handle the flow rate of 180 m<sup>3</sup>/hr, ten parallel 8x80 contactors were installed. Two vacuum pumps connected to each of five contactors divide the degassing system into two units. Picture 1 shows the 3M Liqui-Cel EXF-8x80 Series Membrane Contactors installed in a containerized system.

The membrane contactors are operated in nitrogen-vacuum (combo) mode to achieve the low O<sub>2</sub> outlet value. Nitrogen (N<sub>2</sub>) sweep gas of ≥99,99% purity is coming from a Pressure Swing Adsorption (PSA) nitrogen generator. Upstream to the PSA generator, two air compressors and two air dryers are installed to provide air at the required quality to the PSA generator. Picture 2 shows the complete N<sub>2</sub> gas generation system. Sweep gas enters each contactor on the lumen side (inside) where the gas inlet



**Picture 1: 3M Liqui-Cel 8x80 membrane contactors in Power plant container system Courtesy of Jotem Waterbehandeling BV, NL.**

ports of the contactors are interconnected. Vacuum of 167 mbar absolute is applied to the other side of the interconnected vacuum ports. For only O<sub>2</sub> removal 0.8 Nm<sup>3</sup>/h N<sub>2</sub> sweep per contactor are needed. For simultaneous O<sub>2</sub> and CO<sub>2</sub> reduction from 6ppm to 1ppm CO<sub>2</sub> 2.5 Nm<sup>3</sup>/h per contactor are needed.

## System Advantages

3M™ Liqui-Cel™ Membrane Contactors were used instead of a thermal degasser due to two major reasons. Vapor loss associated to a thermal degasser could be avoided. Secondly, the efficiency of the feedwater pre-heater is higher when running on cold degassed water rather than running at 105°C with a thermal degasser. The mixture of fresh water and condensate return had a temperature of 35-50°C.



**Picture 2: Nitrogen generation system in Power plant container system Courtesy of Jotem Waterbehandeling BV, NL**

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LC-2115  
70-2016-0354-8  
Rev. 02/2022

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