Industrial filtration

Simultaneous oxygen and carbon dioxide removal from boiler feed water in waste-to-energy plant using Liqui-Cel membrane contactors and high flow filtration

Introduction

Abfallwirtschaftsgesellschaft (AWG), a waste management company located in Wuppertal, Germany, expanded their waste-fueled power station with a water heating system that is connected to the central city district heating network. This led to a significant efficiency increase for the power station. Additionally, the district heating route enabled AWG to take the coal-fired plant off the grid reducing its carbon footprint.

Central district heating systems distribute heated water from power plants to densely populated residential and industrial areas through insulated piping networks. Large tanks are typically used for heat storage, volume balance, and safety make-up water for use during peak-demand times. High water quality with low dissolved oxygen (O_2) and carbon dioxide (CO_2) gas content is required to help prevent internal corrosion and increase lifetime of piping and storage tanks.

Traditionally, a Forced Draft Degasser (FDD) would have been installed for CO_2 removal in the demineralization system in combination with the expansion of an existing downstream thermal deaerator for O_2 removal. By installing a system using Thermo Scientific™ Liqui-Cel™ Membrane Contactors, O_2 and CO_2 removal could be accomplished in a single process step. The complexity of expanding additional thermal deaerator equipment could be avoided.

Liqui-Cel membrane contactor technology

Liqui-Cel membrane contactors contain microporous hollow fiber membranes, as illustrated in Figure 1.

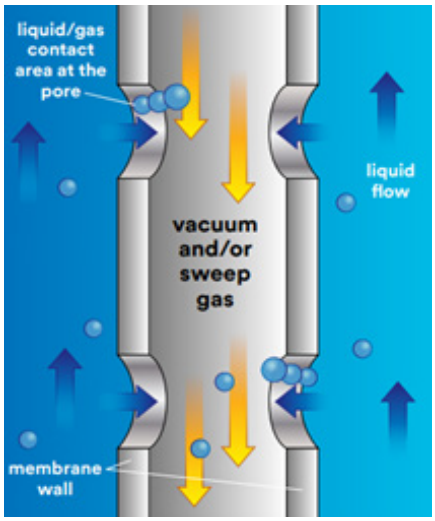


Figure 1. Principle scheme of a hollow fiber membrane in a Thermo Scientific(TM) Liqui-Cel(TM) Membrane Contactor.

Water flows through the contactor on the outside (shell side or liquid side) of the membrane. Because the membrane is microporous and hydrophobic, only gas molecules can pass through the membrane wall. Applying a vacuum or using an inert sweep gas on the inside (lumen side) of the hollow fiber membrane lowers the partial pressure of the gas that needs to be removed, carrying excess gases away into the vacuum. Liqui-Cel contactors degas water without using chemicals.

System design

Power plants requiring additional water to compensate for increased demand typically need to treat the incoming water. Depending on the feed water quality, the water treatment system can have different designs. For this project, an ion exchange demineralization system was built with membrane degassing to process the local municipal water supply for the removal of both CO_2 and O_2 content (Figure 2).

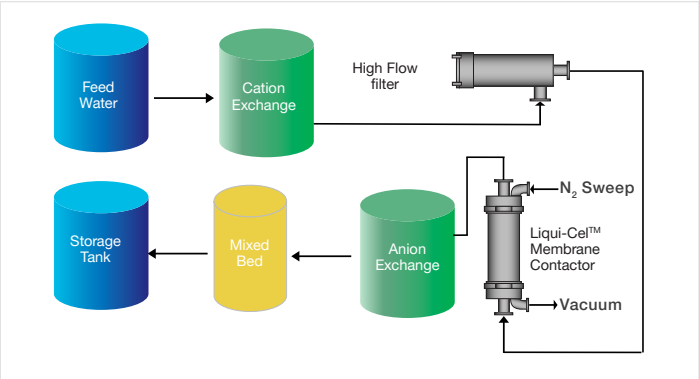


Figure 2. Flow diagram of the new water treatment system at AWG Wuppertal.

Three lines each containing three Liqui-Cel EXF-14x28 membrane contactors in series were installed between the cation exchange and anion exchange (Figure 3).



Figure 3. Three Thermo Scientific™ Liqui-Cel™ EXF 14x28 Membrane Contractors

In the original system design, no filtration was included between the cation exchange unit and the Liqui-Cel membrane contactor. During early operations, it was found that the cation exchange unit was shedding particulates, which led to an increase in differential pressure across the Liqui-Cel contactors that negatively impacted the service life and performance of the contactors.

To address this issue, a Thermo Scientific™ High Flow absolute-rated 5 µm filter was installed upstream of the Liqui-Cel membrane contactors (Figure 4). The addition of this filtration step effectively removed particulate matter, thereby reducing fouling and extending the service life of the Liqui-Cel contactors.



Figure 4. In front, a 5 µm absolute-rated Single Cartridge Thermo Scientific™ High Flow 40-inch filter.

Each line with three Liqui-Cel EXF-14x28 contactors can deliver up to 50 m^3/h water and is operating in vacuum assisted Nitrogen (N_2)-sweep gas (combo) mode to achieve low O_2 values. For simultaneous CO_2 reduction, the sweep gas rate and vacuum capacity was increased. High-purity nitrogen gas (>99.99%) supplied from the liquid nitrogen tank is introduced to the top gas port, while the vacuum is connected to the bottom gas port producing a vacuum of 70 mbar (50 torr).

Results

The goal of AWG was to remove oxygen to a requested specification of 30 ppb at maximum water capacity for a downstream nitrogen blanketed storage tank. In lower water demand situations, the O_2 level drops to lower values. The maximum performance level for deaeration with Liqui-Cel membrane contactors is 1 ppb O_2. The membrane contactor solution, along with the High Flow pre-filter, was chosen because in addition to oxygen removal the carbon dioxide could also be removed to <10 ppm. Carbon dioxide removal increases the anion exchange capacity resulting in longer lifetime and reduced regeneration maintenance. The system has been in operation since the beginning of 2019 and continues to meet specification.

Application engineering

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