TechBrief

Technology Qualification of Liqui-Cel® Membrane Contactors for Deoxygenation of Low Salinity Water for Polymer Flooding

Introduction

Polymer flooding using low salinity water has been shown to improve oil reservoir recovery rates by altering the reservoir characteristic from an oil-wet state to a water-wet state. It has also been shown to be cost competitive with other Enhanced Oil Recovery (EOR) processes. The combined cost savings and increased recovery rate have prompted a lot of attention in the polymer flooding process with low salinity water in recent years.

However, as with any offshore water flooding process, dissolved oxygen in the injection water may cause unwanted effects to the reservoir, such as souring and bacteria growth. Therefore, it is common practice to remove oxygen from water before injection. In cases where polymers are added, oxygen removal is critical to prevent a reduction in the polymer's effectiveness.

Weight can also be a critical factor for offshore installations, especially on existing platforms. If no vacuum tower or similar equipment is already in place on the platform, a deaeration process must be installed. For these reasons, RO Solutions was asked to evaluate the feasibility of using Liqui-Cel® Membrane Contactors in an offshore polymer flooding plant before the design was finalized.

Membrane Contactor Technology

Liqui-Cel® Membrane Contactors are compact, modular devices that utilize microporous hollow fiber membrane to remove dissolved O_2 from injection water. Their size enables the design and construction of low weight deoxygenation systems that can be quickly adapted to meet changes in capacity requirements after installation. System weight can be reduced by up to 50% compared to conventional vacuum towers.

A vacuum and/or inert gas is introduced to the inside of the membrane hollow fiber while liquid flows on the outside. Because the membrane is hydrophobic it acts as an inert support that allows direct contact between a gas and a liquid phase without dispersion. Applying a vacuum and/or inert sweep gas lowers the partial pressure of the target gas. This creates the driving force for dissolved oxygen in the liquid to transfer through the hollow fiber membrane pores. The transferred oxygen is then carried away by the vacuum pump or sweep gas.

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RO SOLUTIONS

RO Solutions designs and manufactures desalination plants for the oil and gas sector with a focus on application areas, such as low salinity water flooding, polymer flooding, membrane systems for sulphate removal from sea-water, crude wash, water makers for potable water production and compact deaeration membrane solutions.

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8x80-inch Liqui-Cel® Membrane Contactor at the RO Solutions Test & Pilot Facility in Norway

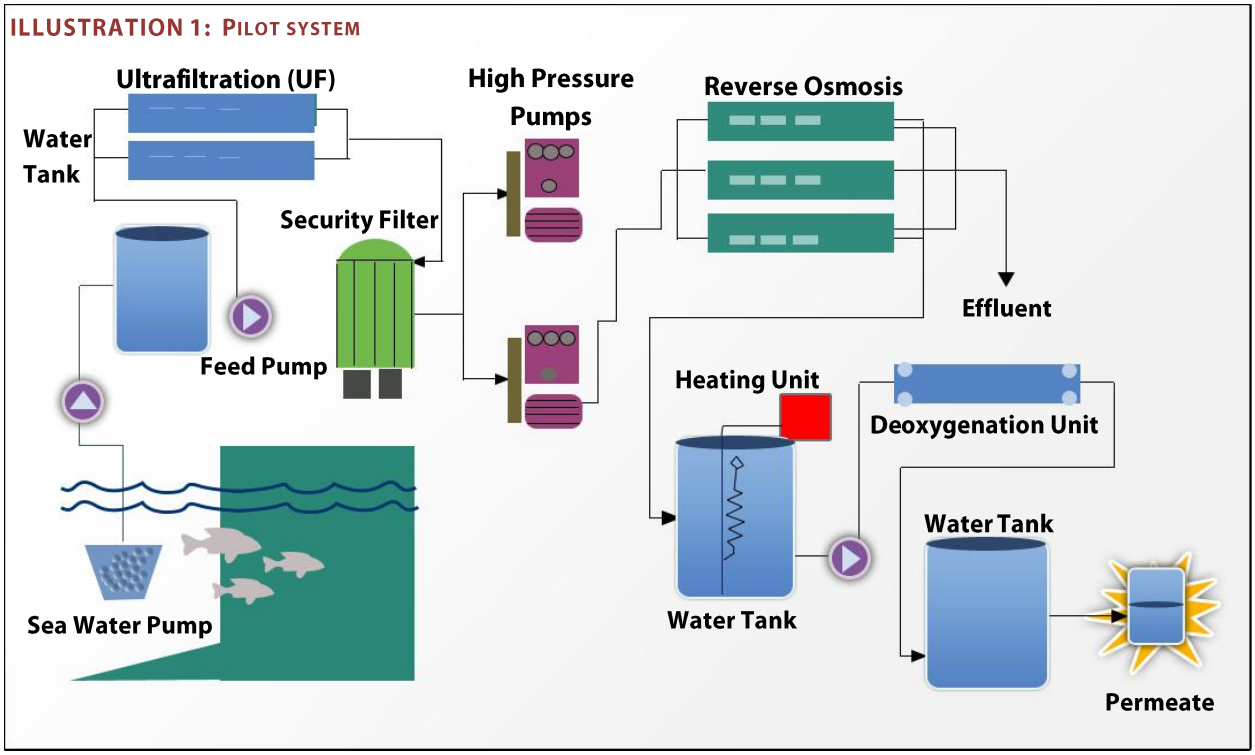
Test Procedure and Purpose

In 2011 and 2012 RO Solutions performed several studies and tests for Statoil to develop an optimized design of a compact offshore desalination plant for a polymer flooding project. Tests were conducted in the RO Solutions full-scale testing facilities in Norway.

The purpose of the test described here was to verify the feasibility of using Liqui-Cel® 8x80 High Pressure Membrane Contactors for dexoygenation and to evaluate flow and rejection efficiency. The test conditions were selected using recommended guidelines for operating Liqui-Cel® Membrane Contactors.

The compact plant design included an Ultrafiltration (UF) pre-treatment unit followed by Nanofiltration (NF) and deoxygenation. The basic design of the pilot unit is shown in Illustration 1.

ILLUSTRATION 1: PILOT SYSTEM



Seawater for the pilot plant was extracted from the ocean at a depth of 20 meters outside the test facility in Malm. Water here is representative of normal Atlantic seawater composition. The seawater was pre-treated in cartridge filters and desalted in NF membranes to a salinity of approximate 3000 ppm. The nitrogen sweep gas source was a battery of gas bottles of 4.0 quality (99.99% purity). One additional test used 4.8 quality nitrogen.

Test Results

Several test runs were conducted and each test cycle operated continuously for at least one hour. The results are shown in table 1. The results clearly indicated that the Liqui-Cel® Membrane Contactors met expectations and a recommended design flow of 10 m^3/h was approved. The impact of temperature on performance was not conclusive due to test operating limitations although there were clear indications that higher temperatures improved oxygen removal performance.

Table 1

Run	8 m³/hr	10 m³/hr	12 m³/hr
Result in treated water, ppb O_2	6.5	7.2	10.7
Charging of N_2, Nm³/h	2.1	2.3	2.7
Vacuum, hPa	52	60	68
Specific feed of N_2, Nm³ N_2/m³ water	0.25	0.23	0.23
Water temperature C	8	8	8

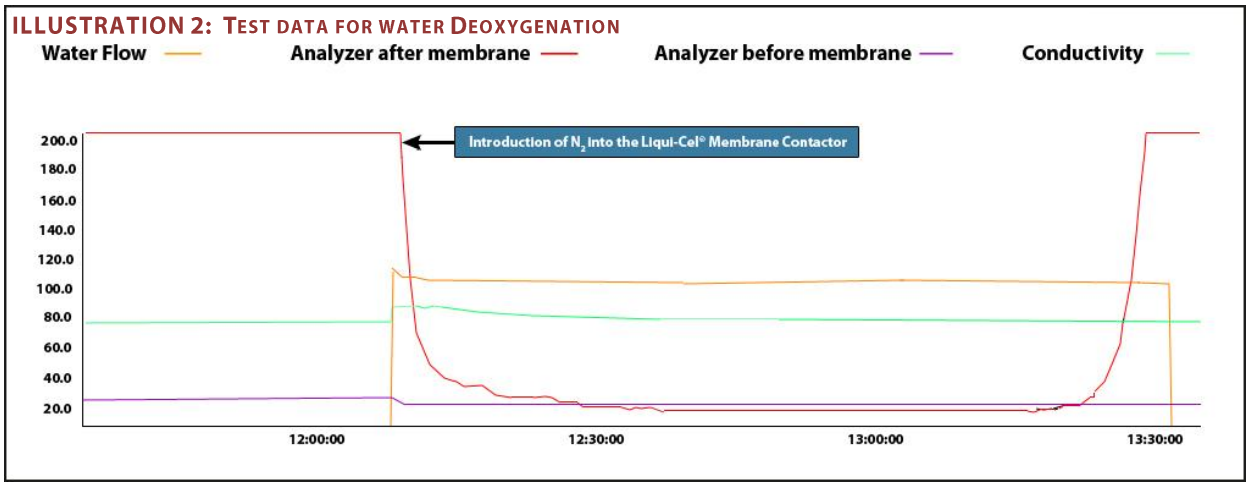
Operating Liqui-Cel® Membrane Contactors was simple and reproducibility was also demonstrated. Performance was directly observed with an O_2 sensor; however, 5-10 minutes of operating time was needed to reach the lowest O_2 ppb levels due to the sensor's response time.

It was understood at the start of the test that the grade of nitrogen used for the sweep gas would impact the concentration of dissolved oxygen at the liquid outlet and to achieve very low oxygen levels high purity nitrogen was needed. However, the measured differences between quality 4.8 and 4.0 were not significant during the test

Table 2

Nitrogen Quality	Quality 4.0	Quality 4.8
Measured O_2 in ppb	7	7
Volume of N_2 in Nm³/h	2.2	2.1

Illustration 2 shows data from one of the test runs. The drop in free oxygen with the introduction of nitrogen into the Liqui-Cel® Contactor can be clearly seen.



Conclusions

- Due to the successful test at RO Solutions, Liqui-Cel® Membrane Contactors were acknowledged by Statoil as an approved deoxygenation technology that can be used in pre-projects and for field testing/piloting
- The system is reliable and will not significantly increase complexity in a complete seawater membrane treatment process
- To achieve the lowest values of residual oxygen in a total process solution that utilizes Liqui-Cel® Contactors, nitrogen sweep gas quality and vacuum level must be optimized

For more information about Liqui-Cel® Membrane Contactors or a detailed system sizing, please contact your Membrana representative or visit us online at www.Liqui-Cel.com. For more information about the pilot system, please visit www.rosolutions.no.

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