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## Evaluation of optimal PRO test conditions for flat sheet membranes under various DS concentrations

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Pressure retarded osmosis (PRO) holds the potential to produce renewable energy from natural and anthropogenic salinity gradients [1]. In a PRO system, water from a low salinity feed solution (FS) permeates through a semi-permeable membrane into a pressurized, high salinity draw solution (DS). Electric power is obtained by depressurizing a portion of the diluted seawater through a hydro-turbine [2]. For power generation by PRO to be commercially feasible, a semi-permeable membrane with high water flux and high mechanical strength is needed. There have been many reports on the evaluation of power generation with a PRO test cell [2-4]. In almost all of the studies for PRO, power density was measured with 0.6 M NaCl solution as DS at applied pressures from 0 to 1.0 MPa. In this study, we have evaluated PRO performance of flat-sheet cellulose triacetate membranes with high applied pressure (0 to 3.0 MPa) using NaCl solution at high concentrations (0.6M to 1.2M) as DS.

Figure 1 shows schematic diagram of a PRO evaluation system for a flat sheet membrane. PRO performance tests were conducted with the active layer of a membrane facing DS changing applied pressure from 0 to 3.0 MPa. In the experiment, two FO flat-sheet membranes (Hydration Technologies Inc. FO-1, and FO-2) were used as a sample membrane. Characteristic parameters of the membranes are listed in Table 1. Tap water, 10 mM, 40 mM and 80 mM NaCl were used as FS. NaCl solutions with various concentrations (0.6M to 1.2M) were used as DS. The custom built cell has an effective membrane area of 140 $cm^2$ on both sides of the membrane. The test was operated with counter-current cross-flow with mesh spacers in both feed and draw channels.

Table 1：Characteristic parameters of the membranes.

| Sample membrane | Water permeability coefficient, *A* [$10^{-12}$ m/sPa] | Salt permeability coefficient, *B* [$10^{-7}$ m/s] | Structural parameter, *S* [μm] |
|---|---|---|---|
| FO-1 | 2.50 | 1.37 | 1880 |
| FO-2 | 2.40 | 0.253 | 1570 |

Figure 2 shows the water flux, $J_w$, as a function of applied hydraulic pressure, $\Delta P$ with 0.6 mol/$dm^3$ NaCl. The water flux of FO-2 membrane shows 18 L/$m^2$h at zero applied pressure, and decreases with increasing applied pressure in the system.

Figure 3 shows the power density, *PD*, as a function of applied hydraulic pressure, $\Delta P$ with 0.6 mol/$dm^3$ NaCl. The power density of FO-2 membrane, which is defined as the product of the water flux and applied pressure, increases with increasing applied pressure, and shows a maximum value of 4.3 W/$m^2$ at 1.2 MPa of the applied pressure. FO-2 membrane has better performance in the water flux and power density than FO-1 membrane, because the former has lower *B* value and *S* value than the latter. The water flux through the membranes increases with

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increasing DS concentration due to the increase in effective osmotic pressure difference across the membranes. The power density with 1.2 M DS, whose data were not shown here, shows 13 $W/m^2$ at 3.0 MPa of the applied pressure.

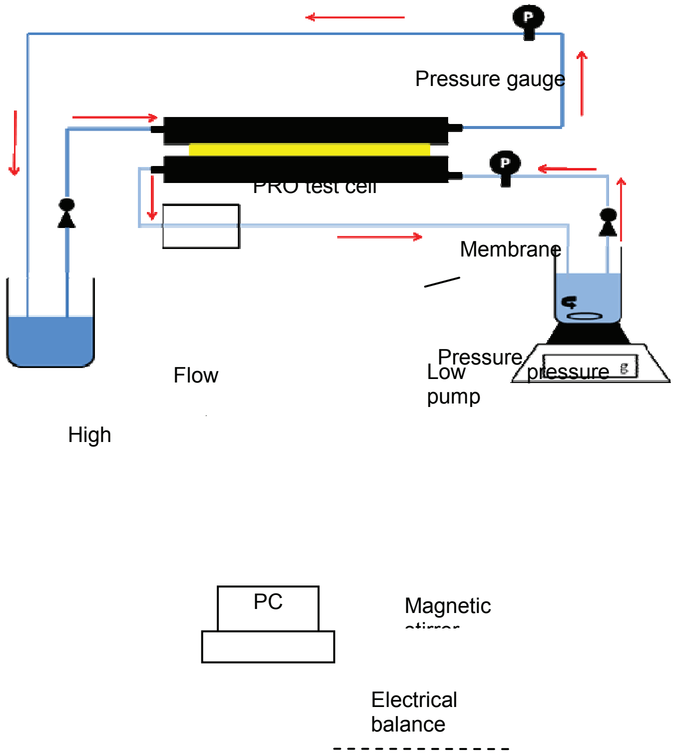


**Figure 1**. Schematic diagram of a PRO evaluation system for a flat sheet membrane.

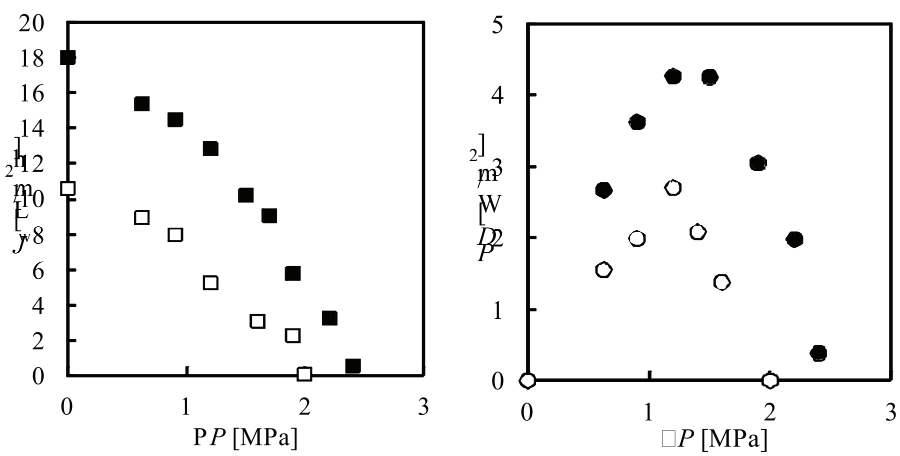

**Figure 2.** Water flux, $J_w$, as a function of applied hydraulic pressure, $\Delta P$ .$C_{DS}$: 0.6 mol/dm$^3$ NaCl. Flow rate, $Q_{FS}$: 0.5 L/min; $Q_{DS}$:1.0 L/min. Temperature: 25 $^oC$. Membrane: □: FO-1;■:FO-2.

**Figure 3.** Power density, *PD*, as a function of applied hydraulic pressure, $\Delta P$ .$C_{DS}$: 0.6 mol/dm$^3$ NaCl. Flow rate, $Q_{FS}$: 0.5 L/min; $Q_{DS}$:1.0 L/min. Temperature: 25 $^oC$. Membrane: ○: FO-1;●:FO-2.

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