Prevention of precipitation fouling in RO by reverse flow operation

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Precipitation of sparingly soluble salts is one of the main factors limiting the recovery in reverse osmosis of brackish water sources. Recoveries can be increased and antiscalant usage reduced or curtailed by applying flow reversal to RO trains. Flow reversal works by changing the place of the entrance and exit of the feed before the induction time of the supersaturated solution along the membrane wall runs out and precipitation occurs. Reversing the flow before the induction time of the system is reached replaces the supersaturated brine at the exit with the unsaturated feed flow and thus "zeroes the induction clock".

Reversing the flow in a series of RO elements was simulated in laboratory experiments by running a flat sheet test cell with two solutions, one supersaturated and one undersaturated, that were periodically switched. The supersaturated solution simulated the concentrate stream at the exit of an RO pressure vessel. The undersaturated solution simulated the feed stream into an RO pressure vessel. In the lab experiments, the flat sheet test cell was run for 30-90 minutes on the supersaturated solution and then 10 minutes on the undersaturated solution. The feasibility of flow reversal was thus successfully demonstrated supersaturated calcium sulfate solution (2.0 saturation index) formed from calcium chloride and sodium sulfate and 300 mg/L SiO_2 in the presence of 300 mg/L $CaCl_2$ and 125 mg/L $MgCl_2$. Membranes which scaled in 170-180 minutes without switching were run for three times that time without scaling when the above switching technique was employed.

In order to carry out actual pilot testing of the flow reversal technique, an automatic flow switching manifold was constructed. The mechanical stability of spiral wound elements in this system were evaluated by frequent repeated flow reversals. It was run continuously for 10 days with switching every 10 minutes – equivalent of 3 months operation with flow reversal every two hours. The test solution was 1500 ppm NaCl and rejection was maintained at >99.5% for the entire test time. This demonstrates that the method of flow reversal was not deleterious to the element seals or performance.

Testing of a 6 element RO train was tested on solutions of 7.5 mM and 10 mM calcium sulfate in the feed at recoveries ranging from 67 – 82% leading to supersaturation indices as high as 3.5-5.4 at the membrane wall at the concentrate end. The induction times ranged from 18 hours (at 65-72% recovery and concentrate saturation index of 1.27) to 0-1.5 hours (at 80-82% recovery and a concentrate saturation index of 2.07) (see Figure 1). On applying reverse flow every half hour the membrane was kept free of fouling for over 18 hours and the unit was successfully run at 80% recovery and at flow rates significantly below the recommended flow rate of the manufacturer (see Figure 2).

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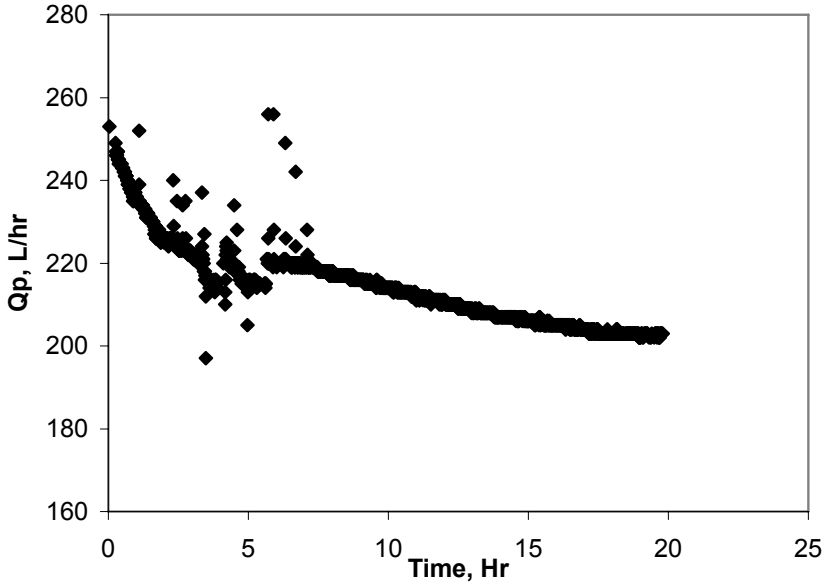

Figure 1: Permeate flow rate from last pressure vessel in series, pilot experiment at 82% recovery with 10 mM $CaSO_4$, 20 mM NaCl feed.

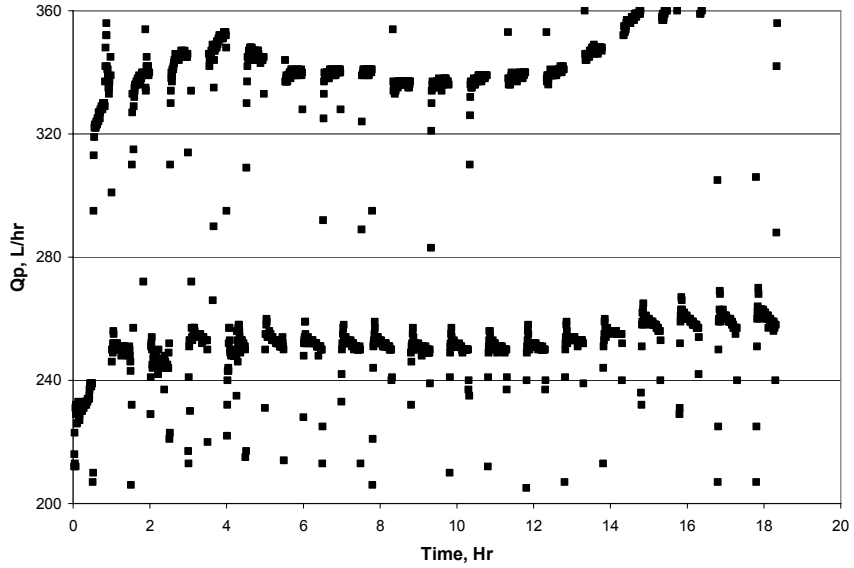

Figure 2: Reversed flow experiment at 82% recovery, 10 mM $CaSO_4$ and 20 mM NaCl feed. Applied Pressure 21.5 bar, Feed flow rate- 1100 L/h. Upper trace is permeate flow in third pressure vessel when is first in train, and lower trace is permeate flow when third pressure vessel is last in train.