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Closed circuit desalination series no-3: high recovery low energy desalination of brackish water by a new two-mode consecutive sequential method

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ABSTRACT

A new method for continuous Brackish Water desalinated by a two-mode consecutive sequential process which incorporates closed circuit and plug flow desalination (PFD) techniques is exemplified with a commercial apparatus (named REIM-II) comprising 10 modules (8″), each of four elements (ESPA2+), with their inlets and outlets connected in parallel, and with recycled concentrate mixed with fresh pressurized feed admitted at inlet to modules. When the salinity of the recycled concentrate inside the closed circuit manifests the desired system recovery level, the apparatus switches from closed circuit to PFD by valve means until the entire brine in the closed circuit replaced by fresh feed, and thereafter, closed circuit desalination (CCD) resumed. CCD in said apparatus experienced most of the time with the same fixed flow rate of feed and permeate under variable pressure conditions; whereas, PFD takes place briefly only after the system attains its desired recovery level at a predefined pressure in order to enable replacement of brine by fresh feed without stopping desalination. Replacement of brine by fresh feed takes place with enhanced feed flow under reduced pressure with a lower momentary recovery in order to expedite the process and minimize brine energy losses. The new method is exemplified by the commercial operation of the REIM-II unit with feed of 6800 μS cm^{-1} according to conditions as followed: *CCD Mode*: 35 m^3 h^{-1} flow rate of feed and permeate (≈19 lmh); 36 m^3 h^{-1} flow rate of recycled concentrate; 1.1 bar of module pressure difference (Δp); and 17–25 bar of an effective variable pressure range. *Plug Flow Desalination Mode*: 45 m^3 h^{-1} flow rate of feed; 16 m^3 h^{-1} flow rate of permeate (≈10 lmh); 29 m^3 h^{-1} flow rate of rejected brine; 0.5 bar of module pressure difference (Δp); and 9 bar average pressure. *Overall Performance*: 30.7 m^3 h^{-1} average flow rate of permeate; 37.04 m^3 h^{-1} average flow rate of feed; 82.9% recovery; 28.83 kW power consumption; 0.94 kWh m^{-3} specific energy with 61.5% efficiency of the high pressure pump; 20 min total sequence duration with 65% of the time experienced with CCD, 20% experienced with PFD, and 15% experienced during transitions between cited modes. The commercial REIM-II unit has been operated continuously over the past 20 mo and produced some 400,000 m^3 permeates with 88–80% recovery in the respective feed salinity range 5800–8900 μS cm^{-1}.

Keywords: High salinity brackish water; Closed circuit desalination; High recovery; High flux; Low energy; Reduced fouling; Commercial unit performance

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