Effects of Varying Operating Parameters RO & NF Systems

While membrane performance is heavily dependent on proper system design, it is also crucial to dial in the optimal operating conditions to reach the permeate flow and quality goals of the system. This bulletin provides an overview of some of the factors that have a direct effect on system performance, such as feed pressure, temperature, salt concentration, and recovery. Figure 1 shows the general trends that can be expected when varying each parameter.

FEED PRESSURE

Both permeate flux and salt rejection increase with increasing feed pressure. The net driving pressure for reverse osmosis membrane separation is defined as the feed pressure minus the osmotic pressure, permeate back pressure, and pressure drop across the vessel. When the net driving pressure is positive, water is forced through the membrane and into the permeate stream. As feed pressure increases the net driving pressure increases, and the rate of transport of water across the membrane increases. The rate of salt transport across the membrane is not dependent on net driving pressure; it is instead dependent on the salt concentration at the membrane surface.

Salt rejection increases with increasing feed pressure because water is being pushed through the membrane more quickly than salt is transported across it, thus diluting the salt. Figure 1a shows the relation between permeate flux and salt rejection with feed pressure.

TEMPERATURE

Permeate flux increases with increasing temperature, while salt rejection decreases. Permeate flux increases due to the increase in diffusion of water and decrease in water viscosity at higher temperatures.

Salt rejection decreases due to the higher rate of salt diffusion at higher temperatures. In the field, operating pressure is generally varied during the different seasons to account for these temperature changes: higher pressures in the cold winter months and lower pressures in the hot summer months. Figure 1b shows the relationship between permeate flux and salt rejection with temperature.

SALT CONCENTRATION

Both permeate flux and salt rejection decrease with increasing salt concentration. The osmotic pressure of the feed increases as the salt concentration increases. The net driving pressure is now less, and the permeate flux correspondingly decreases.

Salt rejection follows suit; a greater salt concentration means a greater osmotic pressure to overcome, and in turn a lower net driving pressure. As the net driving pressure decreases, the relative amount of water passing through the membrane compared to salt passing through the membrane decreases, resulting in a lower salt rejection. Also, there is a lower concentration of salt at the membrane surface, which decreases the rate of diffusion of salt across the membrane. Figure 1c shows the relationship between permeate flux and salt rejection with salt concentration.

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RECOVERY

Both permeate flux and salt rejection decrease with increasing recovery. As the recovery of a system is increased, a greater percentage of the water fed passes through the membrane and into the permeate stream. The residual feed is more concentrated, leading to a higher osmotic pressure. This increased osmotic pressure decreases the net driving pressure, and the permeate flux correspondingly decreases.

With higher recovery, the salt rejection also decreases. Since increased recovery causes the residual feed osmotic pressure to increase, the driving force for water decreases while the driving force for salt transport does not change. Figure 1d shows the relationship between permeate flux and salt rejection with recovery.

Apart from decreased salt rejection, the major issue that occurs when recovery is forced too high is scaling. As the recovery increases, the water at the tail end of the pressure vessel becomes more and more concentrated with salts. If the concentration of any salt increases past its solubility limit, it will precipitate out of solution, and can cause a number of problems for the membrane system.

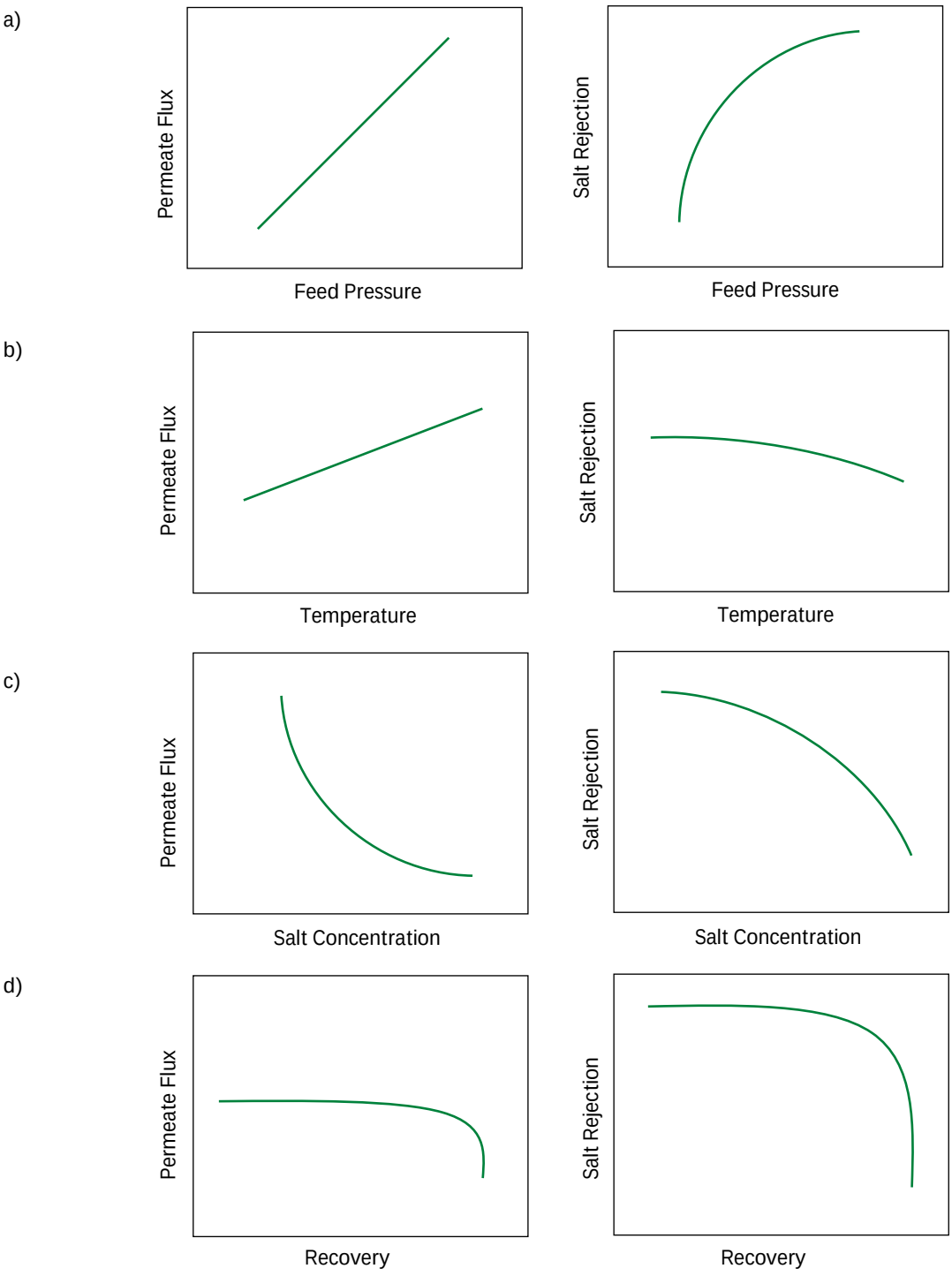

Figure 1. Effect of varying operating parameters on permeate flux and salt rejection

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