What is Reverse Osmosis?

Reverse Osmosis (RO) is a modern process technology to purify water for a wide range of applications, including semiconductors, food processing, biotechnology, pharmaceuticals, power generation, seawater desalting, and municipal drinking water. From initial experiments conducted in the 1950's which produced a few drops per hour, the reverse osmosis industry has today resulted in combined world-wide production in excess of 1.7 billion gallons per day. With demand for pure water ever-increasing, the growth of the reverse osmosis industry is poised to continue growing well into the next century.

This section will provide historical background on the development of RO, and introduce the reader to the concepts of osmosis and semi-permeable membranes. An simple illustration to show how RO works to purify water is provided.

Historical Background

Research on Reverse Osmosis began in the 1950's at the University of Florida where Reid and Breton were able to demonstrate desalination properties of cellulose acetate membrane. Loeb and Sourirajan continued the development of the RO technology with the creation of the first asymmetric cellulose acetate membrane.

Research on these promising developments spawned new and better configurations of RO elements; today the industry produces predominately spiral wound elements, or in some cases, hollow fiber elements. In the early 1980's, research in US Government Labs resulted in the first Composite PolyAmide membrane. This membrane had significantly higher permeate flow and salt rejection than cellulosic membranes. Today, with the introduction of the ESPA3 by Hydranautics, the industry has attained a 20-times increase in flow per pressure over original cellulosic membranes, with an order of magnitude decrease in salt passage.

What is Semi-permeable?

Semi-permeable refers to a membrane that selectively allows certain species to pass through it while retaining others. In actuality, many species will pass through the membrane, but at significantly different rates. In RO, the solvent (water) passes through the membrane at a much faster rate than the dissolved solids (salts). The net effect is that a solute-solvent separation occurs, with pure water being the product. (In some cases, dewatering is desired to concentrate the salts).

What is Osmosis?

Osmosis is a natural process involving the fluid flow of across a semi-permeable membrane barrier. Consider a tank of pure water with a semi-permeable membrane dividing it into two sides. Pure water in contact with both sides of an ideal semi-permeable membrane at equal pressure and temperature has no net flow across the membrane because the chemical potential is equal on both sides.

If a soluble salt is added on one side, the chemical potential of this salt solution is reduced. Osmotic flow from the pure water side across the membrane to the salt solution side will occur until the equilibrium of chemical potential is restored (Figure 1a). In scientific terms, the two sides of the tank have a difference in their "chemical potentials," and the solution equalizes, by osmosis, its chemical potential throughout the system. Equilibrium occurs when the hydrostatic pressure differential resulting from the volume changes on both sides is equal to the osmotic pressure. The osmotic pressure is a solution property proportional to the salt concentration and independent of the membrane.

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With the tank in Figure 1a, the water moves to the salty side of the membrane until equilibrium is achieved. Application of an external pressure to the salt solution side equal to the osmotic pressure will also cause equilibrium (Figure 1b). Additional pressure will raise the chemical potential of the water in the salt solution and cause a solvent flow to the pure water side, because it now has a lower chemical potential. This phenomenon is called reverse osmosis.

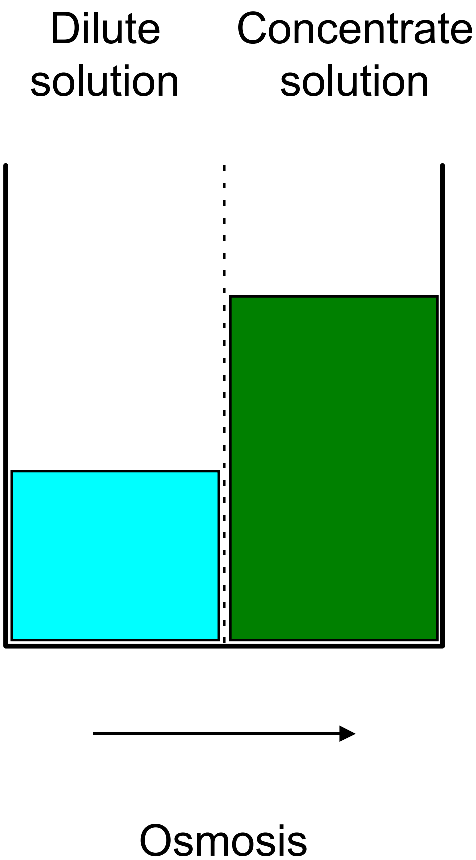

Figure 1a

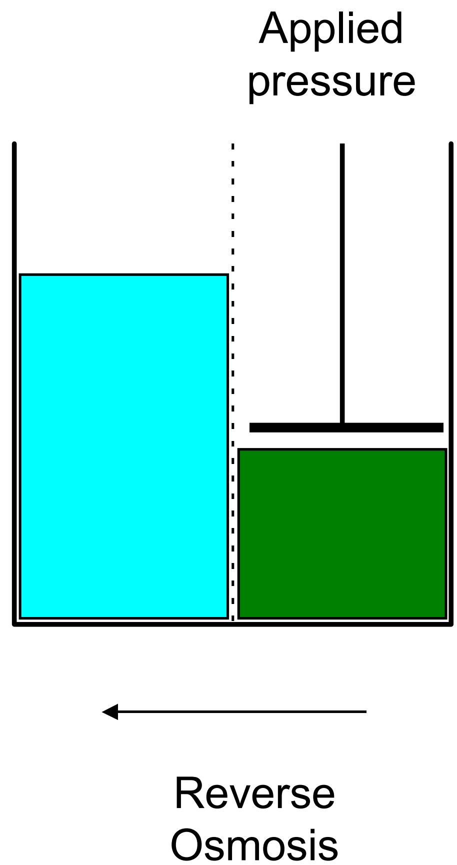

Figure 1b

The driving force of the reverse osmosis process is applied pressure. The amount of energy required for osmotic separation is directly related to the salinity of the solution. Thus, more energy is required to produce the same amount of water from solutions with higher concentrations of salt.