Factors That Impact RO Filter Performance

By Diego Bonta

How feedwater characteristics affect RO filter performance

There are several factors that affect the performance of reverse osmosis (RO) filters. Generally, these factors can be divided into two groups: feedwater characteristics and system configuration. This article focuses on feedwater characteristics, and the next article will focus on system configuration factors. Differing feedwater can change the flow and rejection of an RO filter. The main factors to consider are the temperature, pressure and salt concentration in the feedwater.

Temperature

RO permeate flow is strongly dependent on the operating temperature. The higher the temperature of the water, the higher the permeate flow. This occurs because water with a higher temperature has a lower viscosity and higher diffusion rate, which makes it easier for the water to permeate the RO membrane. For elements from Dow Water and Process Solutions, a general rule of thumb is that for every 1° C increase in temperature, the permeate flow increases 3%. Most membrane manufacturers provide temperature correction tables that allow one to make more accurate conversions.

Temperature not only changes the amount of water that is produced, but it also impacts the amount of salt passage through the membrane. The warmer feedwater increases the temperature of the RO membrane, which allows salt to diffuse through it more quickly. The general rule of thumb is that salt passage increases 6% for every 1° C increase in feedwater temperature, so the salt passage increases about twice as much as the increase in water flux. Therefore, residential point-of-use (POU) systems that have large swings in feedwater temperature throughout the year will experience higher flows and worse rejection in the summer, and lower flow and better rejection in the winter.

Figure 1, below, shows the impact that temperature has on element flow rate for several TW30 elements produced by Dow Water and Process Solutions. As temperature increases, not only do all of the elements produce more water, but the difference between the amount of water they produce increases as well.

Pressure

In order to understand the impact of changing the feed pressure on an RO filter, one must first consider the concept of net driving pressure (NDP). The NDP is the sum of all of the forces acting on the membrane. These may include pump or feed pressure; back pressure from line restrictions and storage tank; and osmotic pressure of the feed and permeate water.

In Figure 2, below, assume the yellow pump exerts a pressure of 150 psi on water that has a total dissolved solids (TDS) measurement of 1,000 mg/L, which is on one side of an RO membrane. Assume the water on the other side of the RO membrane has a TDS of 0 mg/L. In order to determine the NDP, one must sum up all of the forces acting on the membrane.

The first step is to convert TDS to psi. A general rule of thumb is that if the TDS is measured in ppm, then divide by 100 to get the osmotic pressure of the water in psi. If you would like to get the osmotic pressure in bar, divide by 1,400. Water with a TDS of

Figure 1. Impact of Temperature on Flow Rate

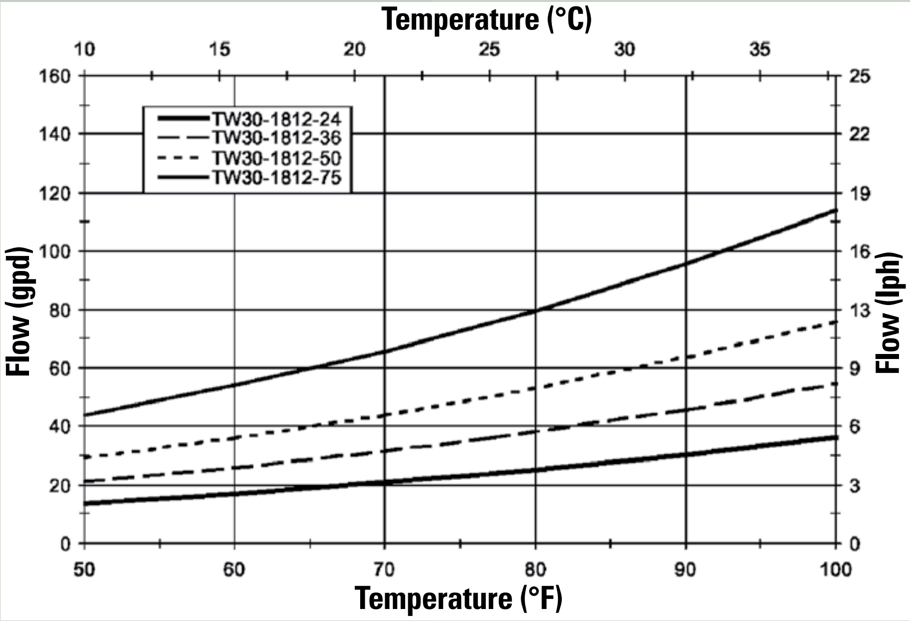


Figure 2. Determining NDP

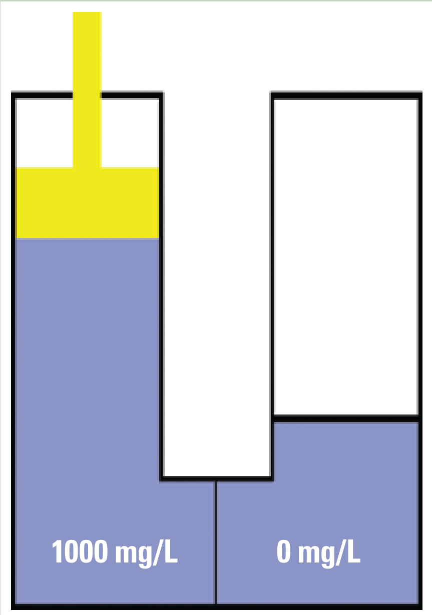
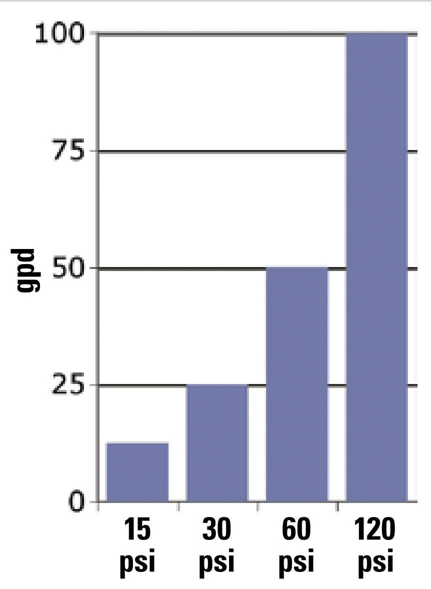


Figure 3. Effect of NDP on Permeate Flow



1,000 ppm has an osmotic pressure of about 10 psi, or 0.7 bar.

Given the example above, one can calculate the net driving pressure as:

NDP = Feed pressure – feed osmotic pressure + permeate osmotic pressure
NDP = 150 psi – 10 psi + 0 psi
NDP = 140 psi

NDP is the effective pressure the membrane feels during operation. If ones doubles the net driving pressure to an RO unit, it will double the permeate flow as shown in the hypothetical example in Figure 3 on page 16.

As the feedwater flows through the RO filter, clean water passes through the membrane. This increases the concentration of the contaminants in the feedwater, which increases the feedwater TDS. Therefore, the inlet feed TDS is always lower than the outlet concentrate TDS. By the same token, friction from the water flow traveling through the filter and vessel causes some drop in feed pressure. Therefore, the inlet pressure is always greater than the outlet pressure.

In order to calculate the average NDP over an element or a vessel, one should use the average feed osmotic pressure and average feed pressure in the calculation. Averaging the osmotic pressure is achieved by taking the average of the inlet feed osmotic pressure and the outlet concentrate osmotic pressure. The average feed pressure should be determined from averaging the inlet feed pressure with the concentrate outlet pressure.

Figure 4, below, shows the impact that different feed pressures have on element flow rate. Similar to temperature, as the feed pressure increases, not only does the element flow rate increase, but so does the difference between the amount of water produced by each type of element (see Figure 4).

Salt Concentration

The rate of salt passage across a membrane is determined by the salt concentration gradient, which is the difference between the TDS on the feed side of the membrane versus the permeate side of the membrane. The rate of salt passage is independent of pressure. However, because more permeate water is produced as the feed pressure increases, the permeate salt concentration goes down. This occurs because the same amount of salt diffuses through the membrane, but it is dissolved in more permeate water.

As we discussed earlier, higher salt concentrations (higher TDS) will decrease the permeate flow because the osmotic pressure increases, decreasing the NDP. However, higher feed salt concentration also will increase the amount of salt passage through the membrane. Therefore, the overall water quality goes down for two reasons: first, less water is produced; and second, more salt diffuses through and is dissolved in less water.

The next article in this series will focus on the impacts that different RO system components can have on the overall RO system performance. *wqp*

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Figure 4. Impact of Feed Pressure on Flow Rate