BACK TO BASICS

MONITORING A REVERSE OSMOSIS UNIT

Effectively monitoring a reverse osmosis (RO) unit does not take very much time. It takes only a few minutes per day per RO unit and can save a plant money. This article discusses the three most important monitoring tools.

Background

As one travels and visits different water plants, it is sometimes amazing what can be learned from the data that an operator records and to learn what this data means to the operator. It is no wonder that a good operator is at a premium at any facility.

Many times, as we look at operating logs and data sheets, we see that the information taken is not well understood by the people taking the readings. On the daily performance data sheets, pressures, conductivities, flowrates, temperature, and other data may be taken. However, the operator is frequently unaware of the reasons for taking this data.

At many plants, even if appropriate data points are recorded on performance data sheets, the readings are not entered into software programs that can provide easy-to-interpret trending graphs. There is no good reason not to trend the data since most membrane manufacturers provide monitoring software free of charge. In some cases, you can download free monitoring software directly from the Internet.

Results engineers, first-line supervisors, and upper management must make decisions based on performance data. Unfortunately, improper decisions concerning RO unit operations are made everyday in the water treatment industry because of inadequate or inaccurate performance data.

There are three main tools used in monitoring and trending an RO unit. Each is as important as the others in the monitoring of an RO unit. They are: Normalized Permeate Flow (NPF), Differential Pressure (DP), and Salt Rejection (SR).

Normalized Permeate Flow

The two things that determine how much actual permeate will be produced are:

- Net driving pressure (NDP)
- Temperature

An RO unit's performance is generally not uniform over time. Pressures, feed chemistry and feed temperature may change over time due to several conditions, including seasonal changes and fouling and/or scaling.

In order to allow for these operational changes, we must perform an NPF calculation. NPF is the amount of water that would be produced by an RO unit adjusted for the variables such as temperature and NDP.

The NPF then is calculated from the readings that the operators are already taking. It is very important that accuracy and neatness are stressed to the operators taking these readings.

The NPF calculation is as follows in Equation 1.

$$NPF = \text{Flow of the permeate} \times \frac{NDP_{\text{start-up}}}{NDP_{\text{today}}} \times TCF \qquad \text{Eq. 1}$$

Where:
Q_p = Actual permeate flow
NDP_{su} = Net Driving Pressure at startup
NDP_{today} = Net Driving Pressure today
TCF = Temperature Correction Factor

The NDP is found by taking the pressure of the feed minus the osmotic pressure of the feed minus the permeate pressure (Equation 2).

$$NDP = P_f - P_o - P_p \qquad \text{Eq. 2}$$

Where:
P_f = Feed Pressure
P_o = Osmotic pressure (of the feed)
P_p = Permeate pressure

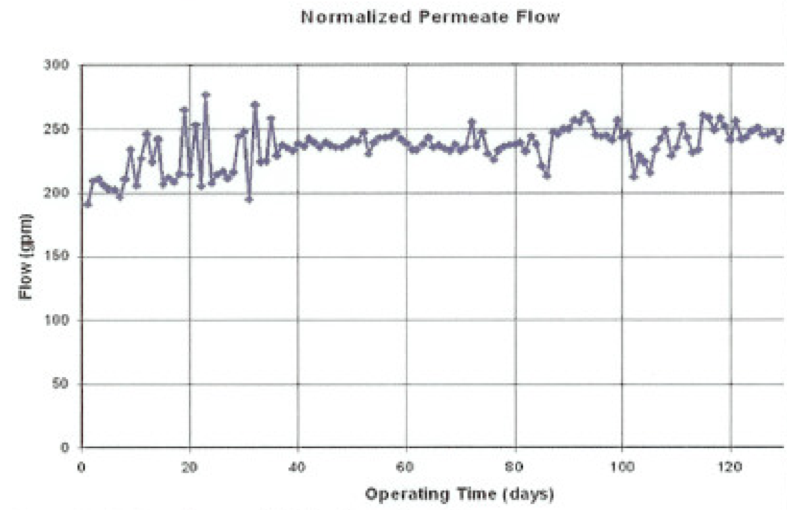

Figure 1. NPF trending graph of a chemical attack.

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Figure 2. A DP trend for the first stage of an RO unit that indicates some form of foulant.

Figure 3. A salt rejection graph that would indicate either scaling or membrane damage.

Readers should recall that osmotic pressure is a function of the type and amounts of dissolved materials in a solution. A "rough rule of thumb" is that for every 100 milligrams per liter (mg/L) of dissolved material, there is about 1 pound per square inch gauge (psig) of osmotic pressure. Therefore, dividing the dissolved material concentration by 100 (moving the decimal place to the left 2 places) gives us an approximate osmotic pressure determination.

Of course to determine the average NDP, the same calculations has to be performed both at the feed and the concentrate of the unit, and then divided by two.

The TCF calculates what the RO unit membranes would produce if the water temperature was 77°F (25°C). If you use the membrane manufacturers free monitoring programs, the TCF is already in the program. If you are designing your own spreadsheet-monitoring program, TCF can be obtained from the manufacturer of the membranes that are installed in the unit.

NPF should never increase. The first day of operation will be the most an RO unit should ever produce. If NPF increases suddenly, or over time, then this indicates some type of membrane damage usually from chemical attack. Chemical attack is usually the result of oxidation of the membrane by oxidizing agents such as chlorine compounds. An increase in NPF could also be an indication of tears or holes in the membrane.

Figure 1 shows a real world NPF trending graph of chemical attack. A decrease in NPF indicates that we may have fouling or scaling occurring. Consequently, the operators may have to initiate a chemical cleaning of the unit.

Differential Pressure

DP is the drop in pressure from one point to another. This also can be called "delta P (ΔP)" or "pressure drop (PD)". The pressure will drop every inch or centimeter of the way through an RO unit. The DP is found by measuring the pressure of the feed into a unit (or stage) minus the pressure of the concentrate out (Equation 3).

$$DP = P_f - P_c \qquad \text{Eq. 3}$$

Where:
DP = Differential Pressure (Pressure Drop)
P_f = Feed Pressure
P_c = Concentrate Pressure

The reason why we are interested in monitoring DP is because it will tell us when our system is becoming fouled and/or scaled. Any foulant, or scalant that decreases the volume of a pipe or an RO element causes increased resistance to flow. The greater the resistance to flow, the greater the DP.

Therefore, we want to measure the DP when the system is new, and compare it to the readings that are taken each day. If DP rises (at the same feed/concentrate flowrates), then this tells us that the system is not new and something has gotten into the system causing a greater resistance to flow.

Most operators are already taking pressures and may even be calculating DP. However, many do not know what the readings are telling them.

Care should be taken to ensure the pressure at each RO stage is read and recorded accurately. If the first stage DP increases, we would suspect fouling. One should open the feed end of a pressure vessel in this stage and inspect the first element.

Figure 2 shows a real world DP trend for the first stage of an RO unit. This would indicate some form of foulant.

If the last stage DP increases, we would suspect scaling in the unit. In this case, one should open the concentrate end of a pressure vessel in the last stage, and inspect the last element.

Salt Rejection/Salt Passage

Many operators in the field measure the conductivities of the feed, concentrate and permeate. Operators can go one step further and figure the salt rejection at the same time.

Every membrane has the ability to restrict or reject a certain percentage of the dissolved materials found in the feedwater. Even though it is not chemically correct, in water treatment, we commonly call all dissolved materials salts. A salt is actually made up of a positive ion, that is not H^+, and a negative ion, which is not OH^-. Acids, bases, silica, and various organic compounds are dissolved in water but are not truly salts. However, it is the standard to refer to the overall dissolved substances rejection as salt rejection.

The membrane manufacturer's specification gives us an accurate salt rejection performance. The amount of feedwater-dissolved substances that are rejected depends on ionic charge, the size of the substances, and combinations of the different ions. Because of the different ionic combinations, it is very difficult to predict exactly what percentages a membrane will reject prior to putting it into service. It is extremely important to take good start-up data after a couple of days of operation.

We want to monitor the percent salt rejection (%SR) from the initial startup, then continue to measure %SR, to see if the membrane performance is what we expect it to be. If it remains constant, the membrane is undamaged.

If the %SR drops, this means that chemical attack, mechanical damage, scaling defects, or a combination of problems has damaged the membrane's ability to reject dissolved materials.

In cellulose acetate systems, decreased %SR can be caused by pH excursions, or bacterial attack. In polyamide thin-film systems, oxidizing agents like chlorine, bromine, hydrogen peroxide, or any other oxidizing agent can cause decreased salt rejection.

Decreased %SR can also be caused by scaling and fouling. %SR will also decrease due to tears in the membrane, holes in the membrane, O-ring leaks, or any situation that allows water, along with salts, to bypass the membrane.

A simplified way to figure %SR is shown in Equation 4.

$$\frac{C_f - C_p}{C_f} \times 100 \qquad \text{Eq. 4}$$

Where:
C_f = Feed conductivity
C_p = Permeate conductivity

There are more accurate methods for determining salt rejection, but we are mainly interested in trending the information. Once again, most membrane manufacturers supply software, free of charge, which you can use to enter and graph the performance data.

Figure 3 shows a real world salt rejection graph. This would indicate either scaling or membrane damage.

Salt rejection refers to how much contaminants have been rejected by the RO membrane and then exit out the concentrate end of the RO unit. Some plants instead use salt passage to determine how well the membranes are operating. Salt passage is the inverse of salt rejection, and tells how much contaminants have passed through the membrane into the permeate. Either will tell us how well the membranes are removing the contaminants from the feedwater.

Trending

Entering the data points from the RO unit only takes 30 seconds, more or less, into the software and then trending the information to see if there are problems with the unit or train. All three will need to be studied to determine what, if any, problems are occurring in an RO unit, and how the unit should be cleaned.

If NPF drops 10% to 15%, or if DP increases 15% to 25%, whichever comes first, a chemical cleaning needs to be initiated. Waiting too long may result in not achieving the desired effect of the cleaning. In other words, we may not be able to bring the membranes back to their original performance.

If the DP increases 15% to 25% in only the first stage, then this indicates fouling, and the first stage should be cleaned with a high-pH cleaner. If only the second stage DP increases, then this indicates scaling, and it should be cleaned with a low-pH cleaner.

The %SR, or %SP changes are dependant on a plant-to-plant basis, and therefore there are no set parameters stating when an RO unit should be cleaned. Enduse quality of the plant will determine what is acceptable for whichever is used.

With this information in hand, the operator will be able to make good, sound decisions with respect to the daily operation of the unit, thus saving the company time and money. He or she will be able to initiate chemical cleaning in a more timely fashion, and use fewer resources to perform the chemical cleaning.

This information will also be able to help the company save electrical power, and perhaps find better and cheaper chemicals for controlling scaling. The fouling potential will also be recognized, and appropriate actions can be taken sooner.

Summary

An RO unit's operational data that is already being taken should be inputted into a trending program on a daily basis, and the trends analyzed on a weekly basis to catch problems at an early stage as possible before irreversible fouling/scaling can occur.

The three trends to be graphed are NPF, DP, and %SR, or %SP. If NPF decreases by 10% to 15%, or if DP increases by 15% to 25%, whichever comes first, the RO unit must be chemically cleaned. When trending is implemented at a plant, it generally results in smoother operation, less down time, and cost reduction of the overall operation of the water plant, which can save the company money.❑

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