5-4. Data Normalization

The performance of an RO system is influenced by changes in the feed water TDS, feed pressure, temperature and recovery ratio. Data normalization is a process to convert the real performance of the RO system into a form which can be compared to a given reference performance which may be the designed performance or the measured initial performance.

A difference between the normalized data and the initial or designed performance may indicate there are some problems in the system as shown below.

- Membrane fouling and/or scaling
- Membrane chemical damage - poor salt rejection due to a chemical change in the membrane structure by excessive exposure to chlorine or extreme pH
- Mechanical failure - a broken O-ring or element glue line
- Hydraulic plugging - the presence of foulants (large size colloids) or scale stuck to the flow channel spacing between the membrane leaves of spiral - wound elements

The problems could be identified early when the normalized data are recorded daily. Three representative variables such as salt rejection, normalized differential pressure, and normalized permeate flow rate are calculated from the RO operating data. Thus, the effects of the above four problems can be directly monitored by the three variables as shown below.

- Salt rejection
- Normalized differential pressure
- Normalized permeate flow rate

5-4-1. Salt Rejection

Salt rejection is the most widely known method of monitoring the performance of an RO system, though any problem in the system could have been noticed and corrected sooner by monitoring other parameters such as normalized differential pressure and permeate flow rate, before the problem affects the salt rejection.

There are two different methods commonly used to calculate salt rejection, depending on the TDS value at the membrane surface. One method shown below utilizes the RO feed water TDS for the membrane surface TDS.

$$\text{Salt rejection (\%)} = \frac{\text{Feed TDS} - \text{Permeate TDS}}{\text{Feed TDS}} \times 100$$

This method will give a lower salt rejection than the actual individual element salt rejection. The extent of the variation will depend on the recovery of the RO system.

The other method uses a mathematical average of the feed and concentrate TDS to approximate the average TDS within the RO system, which may be closer to the real TDS at the membrane surface. This method will also normalize for changes in salt rejection due to changes in the RO permeate recovery. Thus an average feed TDS provides a more accurate way to calculate salt rejection:

$$\text{Average feed TDS} = \frac{\text{Feed TDS} + \text{Concentrate TDS}}{2}$$

$$\text{Salt rejection (\%)} = \left(\frac{\text{Average feed TDS} - \text{Permeate TDS}}{\text{Average feed TDS}} \right) \times 100$$

If the concentrate TDS has not been measured, it can be estimated using the permeate recovery of the system where recovery is a ratio of the permeate flow rate to the feed flow rate :

$$\text{Concentrate TDS} = \text{Feed TDS} \times \frac{1}{1 - \text{Recovery ratio}}$$

The rate of rejection varies for each of the particular salts in the feed water and thus a variation in the ion composition of an RO feed water will result in a change in the overall percent rejection of the TDS. Hence, it is suggested to record an individual ion rejection in order to have a basis for future performance comparison, when a system starts with a new membrane.

The data on the individual ion rejections is also helpful in diagnosing some system malfunction. For example, a rejection calculated using a divalent ion such as calcium can tell a difference between a mechanical leak in the system and membrane deterioration. Mechanical damages in membranes, glue lines and O-rings will result in a similar decrease in rejection for both monovalent and divalent ions, while, in the case of membrane deterioration, the rejection decline will be more severe for monovalent ions.

5-4-2. Differential Pressure (ΔP)

Differential pressure is the difference between the feed pressure and the concentrate or brine pressure exiting the end of the elements. It is a measure of the pressure drop as the feed water passes through the flow channels of all the elements in the system. At constant flow rate, an increase in the differential pressure indicates that large colloidal particles or physical debris such as pump shavings, inorganic scales and bio-film particulates are blocking the flow channels. The telescoping of spiral wound elements can also cause an increase in the differential pressure, which is a function of the permeate and concentrate flow rates. Since these rates may vary daily due to variation in water temperature or some other changing parameters, the actual differential pressure should be normalized according to the following equation to compare with the initial differential pressure.

$$\text{Normalized Differential Pressure} = \Delta P \times \frac{\left(2 \times Q_{c0} + Q_{p0}\right)^{1.5}}{\left(2 \times Q_c + Q_p\right)^{1.5}}$$

where Q_{c0} = initial concentrate flow

Q_{p0} = initial permeate flow

A percent change (e.g. 10%) in normalized differential pressure could suggest when to clean an RO system.

5-4-3. Normalized Permeate Flowrate

Normalized permeate flow rate is the most important monitoring parameter for an RO system. Normalizing for the effects of pressure, temperature, and solute concentration on permeate flow rate will enable the resulting flow value to reflect changes due to characteristics of the membrane, the membrane surface, and the integrity of the membrane elements or vessels. Thus the normalized permeate flow rate can be used to monitor the following problems:

① The extent of fouling and scale formation on the membrane surface, causing a decrease in the permeate flow rate

② Membrane compaction, causing a decrease in the flow rate

③ The integrity of the membrane system such as mechanical leaks in the system, causing an increase in the flow rate

④ The extent of membrane deterioration, causing an increase in the flow rate

The normalized permeate flow rate can be obtained by the following equation:

$$Q_N = Q \times \frac{P - \frac{\Delta P}{2} - P_p - \Delta\pi}{P_o - \frac{\Delta P_o}{2} - P_{po} - \Delta\pi_o} \times \frac{TCF}{TCF_o}$$

Q_N = normalized permeate flow rate.

Q = measured (actual) permeate flow rate.

P_o = initial operating pressure,

P = actual operating pressure

ΔP_o = initial differential pressure,

ΔP = actual differential pressure

P_{po} = initial permeate pressure,

P_p = actual permeate pressure

π_o = initial osmotic pressure,

π = actual osmotic pressure

TCF_o = initial temperature correction factor

TCF = actual temperature correction factor