## 4-8. Number of Elements and Pressure Vessels for System Design

As mentioned in the introduction, RO systems are usually designed for a specified amount of water production per day (total permeate flow $Q_T$). Then a number of membrane elements ($N_E$) required to produce $Q_T$ is estimated from dividing $Q_T$ by average permeate flow per element ($Q_A$)

$$N_E = \frac{Q_T}{Q_A} \tag{1}$$

In most standard applications, the average permeate flow per element ($Q_A$) is about 75 % of the maximum permeate flow per element ($Q_M$) which is shown in Table 1 in the section of system design guide lines.

$$Q_A = 0.75 \times Q_M \tag{2}$$

Thus equation (1) can be converted to equation (3).

$$N_E = \frac{Q_T}{0.75 Q_M} \tag{3}$$

And also the number of pressure vessels, $N_V$ is obtained from dividing $N_E$ by $P_E$ which is the number of elements per pressure vessel.

$$N_V = \frac{N_E}{P_E} \tag{4}$$

Standard vessels contain six elements. $N_v$ is rounded to the next highest whole number.

To calculate the number of elements more accurately, average permeate flow should be calculated by multiplying effective surface membrane area (S) and average permeate flux (f) which is provided on table 3.

$$Q_A = S \times f \tag{5}$$

Thus equation (1) can be converted to equation (6)

$$N_E = \frac{Q_T}{S \times f} \tag{6}$$

With $Q_T$, $N_E$, $N_V$ and the analysis of the feed water source, a system can be selected. The selected system must then be verified using Woongjin Chemical CSMPRO v3.0 computer simulation program. This program calculates the feed pressure and the permeate quality of the system including the operating data of all individual elements. Furthermore, the system design can easily be optimized by changing the number and type of elements and their arrangement (e.g. single array or multi array). However the optimization should fall within the physical limit of the elements and the empirical limit of the recovery rate according to the guidelines of the fouling potential of the feed waters.

For examples, Two-array systems with 6-element vessels effectively employ twelve spiral wound elements in series and are generally capable of operating at an overall recovery rate of 60 to 75 %. For such systems the average individual recovery rate per element will vary from 7 to 12 %. To operate a two-array system at an overall recovery much higher than 75 % will cause an individual element to exceed the maximum recovery limits (e.g. 15 % for a feed water with SDI in the range of 3 to 5). Then, a third array will have to be employed to place eighteen elements in series for a recovery rate lower than 15% per element.

If two-array systems are operated at too low a recovery (e.g. < 60 %), the feed flow rates to the first-array vessels can be too high causing excessive feed/concentrate-side pressure drops and potentially damaging the elements. As a result, systems with lower than 60 % recovery will typically utilize single array configurations.

**Table 3. Recommended average permeate flux vs various water source**

| Water Source | Recommended permeate flux |
|---|---|
| Waste water (SDI < 5) | 8 ~ 12 gfd |
| Waste water pretreated by UF (SD < 3) | 10 ~ 14 gfd |
| Seawater, open intake (SDI < 5) | 7 ~ 10 gfd |
| High salinity well water (SDI < 3) | 8 ~ 12 gfd |
| Surface water (SDI < 5) | 12 ~ 16 gfd |
| Surface water (SDI < 3) | 13 ~ 17 gfd |
| Well water (SDI < 3) | 13 ~ 17 gfd |
| RO/UF permeate (SDI < 1) | 21 ~ 30 gfd |