FILMTEC Membranes
System Operation: Record Keeping

Plant Performance Normalization

The performance of an RO/NF system is influenced by the feedwater composition, feed pressure, temperature and recovery. For example, a feed temperature drop of 4°C will cause a permeate flow decrease of about 10%. This, however, is a normal phenomenon.

In order to distinguish between such normal phenomena and performance changes due to fouling or problems, the measured permeate flow and salt passage have to be normalized. Normalization is a comparison of the actual performance to a given reference performance while the influences of operating parameters are taken into account. The reference performance may be the designed performance or the measured initial performance.

Normalization with reference to the designed (or warranted) system performance is useful to verify that the plant gives the specified (or warranted) performance. Normalization with reference to the initial system performance is useful to show up any performance changes between day one and the actual date.

Plant performance normalization is strongly recommended, because it allows an early identification of potential problems (e.g. scaling or fouling) when the normalized data are recorded daily. Corrective measures are much more effective when taken early.

A computer program called FTNORM is available for normalizing operating data and graphing normalized permeate flow and salt passage as well as pressure drop. This program is available from our web site www.filmtec.com and requires Excel® software. Alternatively, the measured plant performance at operating conditions can be transferred to standard (reference) conditions by the following calculations:

A. Normalized Permeate Flow

$$Q_S = \frac{P_{f_s} - \frac{\Delta P_s}{2} - P_{p_s} - \pi_{fc_s}}{P_{f_o} - \frac{\Delta P_o}{2} - P_{p_0} - \pi_{fc_o}} \cdot \frac{TCF_s}{TCF_o} \cdot Q_o \qquad (1)$$

with	P_f	=	feed pressure
	$\frac{\Delta P}{2}$	=	one half device pressure drop
	P_p	=	product pressure
	π_{fc}	=	osmotic pressure of the feed-concentrate mixture
	TCF	=	temperature correction factor
	Q	=	product flow
	subscript s	=	standard condition
	subscript o	=	operating condition

Plant Performance Normalization (cont.)

The temperature correction factor follows the formula:

TCF = EXP [2640 x {1 / 298 – 1 / (273 + T)}]; $T \geq 25°C$

= EXP [3020 x {1 / 298 – 1 / (273 + T)}]; $T \leq 25°C$

where T = temperature as °C.

As standard conditions, we take either the design values or the conditions at initial performance as given in the start-up report, so that a fixed reference point is available.

For the osmotic pressure, different formulas are available in the literature. A valid and practical short approximation is:

$$\pi_{fc} = \frac{C_{fc} \cdot (T + 320)}{491000} bar \qquad \text{for } C_{fc} < 20000 \text{ mg/l}$$

and

$$\pi_{fc} = \frac{0.0117 \cdot C_{f}C - 34}{14.23} \cdot \frac{T + 320}{345} \; bar \qquad \text{for } C_{fc} > 20000 \text{ mg/l}$$

with C_{fc} = concentration of the feed-concentrate

C_{fc} can be calculated from following approximation:

$$C_{fc} = C_f \cdot \frac{\ln \frac{1}{1-Y}}{Y}$$

where Y = recovery ratio = $\frac{\text{product flow}}{\text{feed flow}}$

C_f = TDS feed mg/l

B. The Normalized Permeate TDS is calculated from

$$C_{ps} = C_{po} \cdot \frac{P_{fo} - \frac{\Delta P_o}{2} - P_{po} - \pi_{fco} + \pi_{p0}}{P_{fs} - \frac{\Delta P_s}{2} - P_{ps} - \pi_{fcs} + \pi_{ps}} \cdot \frac{C_{fcs}}{C_{fco}} \qquad (2)$$

Terms not yet defined under A are:

C_p = product concentration as ion in mg/l

π_p = osmotic pressure of the permeate in bar

Plant Performance Normalization (cont.)

Example

Values of Start-Up:

Feed water analysis in mg/l:

Ca:	200	HCO_3:	152
Mg:	61	SO_4:	552
Na:	388	Cl:	633

Temp.:	59°F (15°C)	Pressure drop:	44 psi (3 bar)
Pressure:	363 psi (25 bar)	Permeate pressure:	14.5 psi (1 bar)
Flow:	660 gpm (150 m^3/h)	Permeate TDS:	83 mg/l
Recovery:	75 %		

Values after 3 months:

Feed water analysis in mg/l:

Ca:	200	HCO_3:	152
Mg:	80	SO_4:	530
Na:	480	Cl:	850

Temp.:	50°F (10°C)	Pressure drop:	58 psi (4 bar)
Pressure:	406 psi (28 bar)	Permeate pressure:	29 psi (2 bar)
Flow:	559 gpm (127 m^3/h)	Permeate TDS:	80 mg/l
Recovery:	72 %		

For the standard conditions we have:

P_{f_S} = 363 psi (25 bar)

$\frac{\Delta P_S}{2}$ = 22 psi (1.5 bar)

C_{f_S} = 1986 mg/l

$$C_{fcs} = 1986 \cdot \frac{\ln \frac{1}{1-0.75}}{0.75} = 3671 \ mg/l$$

π_{fc_S} = 36.3 psi (2.5 bar)

TCF_S = EXP [3020 x {1 / 298 – 1 / (273 + 15)}] = 0.70

Plant Performance Normalization (cont.)

For the operating conditions we have:

P_{f_o} = 406 psi (28 bar)

$\frac{\Delta P_o}{2}$ = 29 psi (2 bar)

C_{f_o} = 2292 mg/l

$$C_{fc_o} = 2292 \times \frac{\ln \frac{1}{1 - 0.72}}{0.72} = 4052 \text{ mg/l}$$

π_{fc_o} = 39.4 psi (2.72 bar)

TCF_o = EXP [3020 x {1 / 298 – 1 / (273 + 10)}] = 0.58

Substituting these values in equations (1) gives:

$$Q_s = \frac{25 - 1.5 - 1 - 2.5}{28 - 2 - 2 - 2.7} \times \frac{0.70}{0.58} \times 127$$

= 636 gpm normalized flow (144 m^3/h)

Compared to the start-up conditions, the plant has lost 4 % capacity. This is a normal value after a period of 3 months. Cleaning is not yet necessary.

The normalized permeate TDS is derived from equation (2):

$$C_{p_s} = \frac{28 - 2 - 2 - 2.72 + 0.06}{25 - 1.5 - 1 - 2.5 + 0.05} \times \frac{3671}{4052} \times 80$$

= 77 mg/l

Compared to the initial 83 mg/l, the salt rejection has slightly improved. Such behavior is typical for the initial phase.

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