MEMBRANE DEVELOPMENT SPECIALISTS

TECHNICAL MANUAL

PHYSICAL ADDRESS	PHONE	FAX	WEB
921 'A' SOUTH ANDREASEN DRIVE, ESCONDIDO, CA 92029, USA	(858) 345-5302	(858) 799-0867	www.MDSAmericas.com
MAILING ADDRESS	FEIN	CA BOE	EMAIL
P.O. BOX 953, SOLANA BEACH, CA 92075, USA	20-4938673	100-937-862	INFO@MDSAmericas.com

TABLE OF CONTENTS

TABLE OF CONTENTS

PHYSICAL ADDRESS	PHONE	FAX	WEB
921 'A' SOUTH ANDREASEN DRIVE, ESCONDIDO, CA 92029, USA	(858) 345-5302	(858) 799-0867	www.MDSAmericas.com
MAILING ADDRESS	FEIN	CA BOE	EMAIL
P.O. BOX 953, SOLANA BEACH, CA 92075, USA	20-4938673	100-937-862	INFO@MDSAmericas.com

NORMALIZATION OF RO SYSTEM PERFORMANCE PARAMETERS

NORMALIZATION

NORMALIZATION PROCEDURE

RO plant performance data should be collected. Permeate flow and salt passage must be normalized to a common frame of reference to accurately assess performance trends.

Reference points for normalization can include projected start-up conditions or actual start-up performance data taken after about 48-100 hours of operation. The manual calculations listed may be used to normalize performance data.

NORMALIZATION EQUATIONS

$$Q_{pn} = \frac{(NDP)_r}{(NDP)_t} \times \frac{(TCF)_r}{(TCF)_t} \times Q_{pt}$$

$$S_{pn} = \frac{(NDP)_t}{(NDP)_r} \times S_{pt}$$

$$NDP = P_f + P_r - P_p - \pi_{f/b}$$

$$\pi_{f/b} = \pi_f \times \frac{1n\ (1/1-Y)}{Y}$$

$$\pi_f = \frac{C_f}{100}$$

$$\pi_p = \frac{C_p}{100}$$

$$S_p = \frac{C_p}{C_f}$$

$$C_f = \frac{1n\ (1/1-Y)}{Y} \times C_f$$

DEFINITIONS

Q_{pn} = normalized permeate flow, gpm

S_{pn} = normalized salt passage, %

r = reference condition

t = non-reference condition

NDP = average net driving pressure, psig

TCF = temperature correction factor

P_f = feed pressure, psig

P_r = reject pressure, psig

P_p = permeate pressure, psig

Y = permeate recovery, %

C_f = feed concentration, ppm

C_f = average feed concentration, ppm

C_f = permeate concentration, ppm

$\pi_{f/b}$ = average feed-brine osmotic pressure, psig

π_p = osmotic pressure of permeate, psig

π_f = osmotic pressure of feed, psig

NATURAL WATER SYSTEMS

FOULING

Pretreatment of RO feedwater is accomplished to minimize or prevent the following types of fouling processes:

- colloidal-particulate fouling
- metal oxide fouling
- biological fouling

COLLOIDAL AND PARTICULATE FOULING

In natural water systems, fouling of membrane surfaces can be caused by microorganisms, clay, silt, colloidal silica, and other naturally occurring colloidal material. High molecular weight organic compounds and inorganic precipitates may be encountered in industrial process streams.

Colloidal fouling is usually most severe in the first stage of a multistage plant. Fouling systems include moderate to severe flux decline, increased salt passage, and differential pressure increases.

The colloid content of a feedwater may be reduced by granular media filters or ultrafilters. When granular media filters are used, multimedia filters are the preferred design. It is usually necessary to add a coagulant such as alum, ferric sulfate, or organic polyelectrolytes to achieve high levels of colloid removal by granular media filters.

Ultrafilters have the advantage of producing a superior quality feedwater without the need for coagulants.

Regardless of the efficiency of the pretreatment process, cleaning of the RO system will ultimately be required. Colloidal foulants such as clays are best removed with alkaline surfactant containing cleaners.

A common test that measures semi-quantitatively colloid concentrations in a feedwater is the silt density index (SDI) test described below. For natural water RO applications, feedwater SDI values must be 5 or less for all MDS RO elements.

PHYSICAL ADDRESS	PHONE	FAX	WEB
921 ‘A’ SOUTH ANDREASEN DRIVE, ESCONDIDO, CA 92029, USA	(858) 345-5302	(858) 799-0867	www.MDSAmericas.com
MAILING ADDRESS	FEIN	CA BOE	EMAIL
P.O. BOX 953, SOLANA BEACH, CA 92075, USA	20-4938673	100-937-862	INFO@MDSAmericas.com

Regardless of the efficiency of a pretreatment system in removing colloids and particulates, 5-10 micron cartridge filters are required ahead of RO systems as a safety precaution against feed end plugging of RO elements.

TEST PROCEDURE

1. Place a 0.45 micron Millipore filter (cellulose triacetate) in the filter holder.
2. Bleed out air by cracking the ball valve. Close valve and tighten pore filter holder bolts.
3. Open valve fully and with a stopwatch, immediately measure the time required to collect 500 ml of filtrate in a graduated cylinder.
4. Record the time required to collect a second 500 ml sample after 15 minutes of flowing.

SDI is calculated with the following equation:

$$SDI = (1-(t_o/t_f)/15) \times 100$$

where,

SDI = Silt Density Index

t_o = initial time in seconds, to collect 500 ml

t_f = final time in seconds to collect 500 ml after 15 minutes of flowing

METAL HYDROXIDE FOULING

Iron, manganese, and aluminum are frequently present in natural water supplies and are capable of fouling membrane surfaces. Fouling by metal hydroxides can be quite rapid, resulting in severe flux declines. Fouling by metal hydroxides is generally the most severe in the first stage of multistage RO systems.

For aerated or chlorinated RO feed supplies, iron concentrations should be no higher than 0.05 ppm.

For waters containing no chlorine and reduced oxygen concentrations, the following guidelines may be used.

ppm Oxygen	pH	Maximum Iron Level, ppm
<0.50	<6.00	4.00
0.50 – 5.00	6.00 – 7.00	0.50
5.00 – 10.00	<7.00	0.05

The iron content of a feedwater may be reduced by aeration and/or chlorination followed by granular media filtration. Greensand filtration is also employed frequently.

Aluminum is often present in municipal water supplies as a result of coagulation of colloids in the water by aluminum sulfate. Many municipal water treatment plants perform aluminum coagulation at a pH of 5.0 – 5.5 to optimize color removal. After filtration, the municipal plant adjusts the pH to 8.0 to 8.5 with lime.

Should water treated in this manner be reduced in pH ahead of an RO system, aluminum precipitation may occur as illustrated by the aluminum solubility curve. When pH reduction is performed ahead of an RO system, it is important that acid be added upstream of a granular media filter so that aluminum hydroxide precipitate is retained by the filter.

MICROBIOLOGICAL FOULING

Bacteria and bacterial by-products are capable of fouling both cellulose acetate and thin film RO and UF membranes. Following initial attachment of bacteria to the membrane surface, colonization may occur with the production of by-products such as polysaccharide slime. Alone or mixed with other foulants, bacteria and their metabolic by-products can create serious fouling problems.

For cellulose acetate RO systems, bacterial control can often be achieved by the injection of chlorine. For thin film membrane systems, non-oxidizing biocides such as sodium bisulfite and formaldehyde must be employed.

SCALE FORMATION

Scale formation occurs within reverse osmosis systems when the solubilities of certain sparingly soluble salts are exceeded. The most common scale formers are calcium carbonate ($CaCO_3$), calcium sulfate ($CaSO_4$), and silica (SiO_2). Less frequently, barium and strontium sulfate scales are encountered. Scaling is usually the most severe in the last stage of a multi-staged system where ion concentrations are the highest.

Scale formation may be avoided by use of one or more of the procedures listed below.

SOFTENING

Lime and sodium zeolite softening are often used to reduce the hardness content of RO feedwater. When calcium is reduced or removed (calcium is a component of hardness), the potential for calcium carbonate and sulfate precipitation is reduced. Since lime softening removes only a portion of the calcium present in water, additional scale control methods are usually required. Soluble silica concentrations are also reduced in the lime softening process.

SCALE INHIBITORS

Sodium hexametaphosphate (SHMP) and proprietary organic scale inhibitors are used to prevent the precipitation of calcium carbonate and sulfate scales. The following table lists general guidelines for the use of SHMP to inhibit sulfate precipitation. To date, there are no effective silica scale inhibitors. Manufacturers of organic scale inhibitors should be consulted regarding efficacy and dosage requirements for their products.

GUIDELINES FOR SHMP USE		
Scale	**ppm SHMP Required**	**Allowable K_{sp} Value**
$CaSO_4$	10	1×10^{-3} or $1.2 \times K_{sp}$ whichever is higher
$BaSO_4$	10	$40 \times K_{sp}$
$SrSO_4$	10	$8 \times K_{sp}$

K_{sp} is the solubility product and is defined as the mole product of sulfate and the metal ions present [e.g. $(Ca^{+2})(SO_4^{-2})$].

RECOVERY CONTROL

Precipitation of sparingly soluble salts may often be prevented by recovery control. As example, for a given feedwater, $CaSO_4$ may saturate at a recover of 80%. If the RO system is operated at a recovery less than 80%, $CaSO_4$ precipitation may be prevented.

SCALE PREVENTION CALCULATIONS

The following sample calculations illustrate procedures for determining maximum product recovery based on the saturation of scale forming components on the reject stream of RO systems.

LANGELIER OR STIFF-DAVIS SATURATION INDEX

Calcium carbonate precipitation may be prevented by maintaining a negative Langelier or Stiff-Davis Saturation Index in the reject stream. The Langelier Saturation Index of a reject stream may be calculated in the manner shown below:

1. Determine total alkalinity, calcium, total dissolved solids and CO_2 content of the feedwater.

2. From the feedwater analysis and projected recovery rate of the RO system, calculate alkalinity, calcium, total dissolved solids, and pH of the reject stream.

3. Calculate the Langelier Saturation Index with the aid of the figures provided.

Example:

The following sample calculation illustrates this procedure with a hypothetical feedwater analysis.

pH = 6.0
Total dissolved solids = 405 ppm
Total alkalinity (as $CaCO_3$) = 10 ppm
Calcium (as $CaCO_3$) = 65 ppm
CO_2 = 16 ppm
Temperature = 25°C

Based on the feedwater analysis, reject concentrations of these substances may be estimated. Assume a 75% recovery rate.

Alkalinity = 10/1-0.75 = 40 mg/l
CO_2 = 16 ppm (CO_2 is not rejected)
Calcium = 65/1-0.75 = 260 mg/l
Total Dissolved Solids = 405/1-0.75 = 1620
pH = 6.7 (calculated from the Alkalinity/CO_2 – pH curve)
From the LSI curve, pH_s is found to be 7.94.
Therefore, the LSI is 6.70 – 7.94 = -1.24

CALCIUM SULFATE SATURATION

Calcium maximum recovery based on $CaSO_4$ solubility in the brine. This value must be greater than the projected recovery rate of the plant. Maximum recovery is calculated using the following equation.

$R_{max} = [1 - 1/ \sqrt{0.8\ K_{sp}/(Ca^{+2})_f\ (SO_4^{-2})_f}] \times 100$

Where: $(Ca^{+2})_f\ (SO_4^{-2})_f$ = $CaSO_4$ mole product in feed

K_{sp} = Apparent solubility product for $CaSO_4$ of reject stream

0.8 = Safety factor

K_{sp} is obtained from the following curves. The ionic strength is used to determine K_{sp} strength should be that of the reject stream.

Ionic strength = $\frac{1}{2}(M_1Z_1^2 + M_2Z_2^2 \ldots M_nZ_n^2)$

Where: M = miles/liter of a particular ion

Z = the valance of a particular ion

Example:

Calculate R_{max} for a feedwater of the following composition:

I = 0.07
$(Ca^{+2}) = 2.5 \times 10^{-3}$
$(SO_4^{-2}) = 3.13 \times 10^{-3}$
Temperature = 25°C

from the I-K_{sp} curve, the K_{sp} value for $CaSO_4$ is found to be 2.5×10^{-4}

$R_{max} = [1 - 1/ \sqrt{0.8\ (2.5\times10^{-4})/(2.5\times10^{-3})(3.13\times10^{-3})}] \times 100 = 80.2\%$

BARIUM SULFATE SATURATION

Maximum recovery calculations for $BaSO_4$ are similar to those used to calculate calcium sulfate recovery.

$R_{max} = [1 - 1/ \sqrt{0.8\ K_{sp}/(Ba^{+2})_f\ (SO_4^{-2})_f}] \times 100$

Where,

$(Ba^{+2})_f\ (SO_4^{-2})_f$ = $BaSO_4$ mole product of feed
K_{sp} = Apparent solubility product for $BaSO_4$ of reject stream

SILICA SATURATION

Silica precipitation may be prevented by maintaining the silica concentration of the concentrate stream below the saturation point of silica. The maximum recovery achievable at a given feedwater silica concentration may be calculated with the following equations.

$R_{max}SiO_2 = [1 - SiO_{2\ feed}/SiO_{2\ max}] \times 100$

$SiO_{2\ max} = SiO_2$ correction factor x (4.39t-3.66)

Where,

$R_{max}SiO_2$ = maximum recovery possible based on silica saturation.

$SiO_{2\ max}$ = maximum silica concentration possible based upon pH and temperature of the reject stream. The SiO_2 correction is based upon the pH of the reject stream and may be chose from one of the expressions listed below.

t = reject stream temperature

Reject Stream pH	SiO2 Correction Factor
4.0 – 6.5 6.5 – 7.8 7.8 – 10.0	$3.48 \times pH_r^{(-0.667)}$ 1.00 $1.24 \times 10^{-5}\ pH_r^{(5.45)}$

Example:

Reject pH = 6.7
Temperature = 25°C
SiO_2 in feed = 10 ppm
SiO_{2max} = 106 ppm
$R_{max}SiO_2 = [1 - 10/106] \times 100 = 90.6\%$

DECHLORINATION

Dechlorination may be performed with activated carbon, sodium bisulfite, sodium sulfite, or sodium metabisulfite. The concentration of chemical required to neutralize 1 ppm of chlorine are listed below.

Compound	ppm Chemical/ppm Chlorine
Sodium bisulfite Sodium sulfite Sodium metabisulfite	1.46 1.77 0.70

These chemicals should be added far enough ahead of an RO or UF system to provide 20 seconds of reaction time. Chlorine residuals should be measured after chemical addition and just before the RO or UF system to insure that enough chemical has been added to completely neutralize the chlorine. All of these chemicals react with oxygen as well as chlorine. For this reason, solutions exposed to air should be changed on a regular basis. The following table estimates maximum solution life based on chemical concentration.

Solution Wt. %	**Maximum Solution Life**
2	1 week
10	3 weeks
20	1 month
30	6 months

NF OR RO ELEMENTS	
Foulant	**Cleaners/Sanitizers**
Mineral Scale Calcium Carbonate Calcium Sulfate Barium Sulfate Strontrium Sulfate	• HCl or citric acid, pH 2 • Pfizer IPA 403 • 12% NaCl + EDTA 0.05%
Iron or Manganese	• Same as mineral scale cleaners
Organics, Silt, Bacterial Slime	• Sodium hydroxide, 0.5% Sodium dodecyl sulfate, 0.1% Adjust to pH 11.5 with HCl if necessary • Trisodium phosphate, 1% Sodium tripolyphosphate, 1% Sodium dodecyl sulfate, 0.1% Tetrasodium EDTA, 1% Adjust to pH 11.5 with HCl if necessary • Pfizer IPA 411
Bacteria (Sanitizers)	• Sodium bisulfite, 0.1% • Formaldehyde, 0.1% • Chlorine dioxide, 30 ppm • Preservation sodium bisulfite, 0.05%, change every 2 months

PHYSICAL ADDRESS	PHONE	FAX	WEB
921 ‘A’ SOUTH ANDREASEN DRIVE, ESCONDIDO, CA 92029, USA	(858) 345-5302	(858) 799-0867	www.MDSAmericas.com
MAILING ADDRESS	FEIN	CA BOE	EMAIL
P.O. BOX 953, SOLANA BEACH, CA 92075, USA	20-4938673	100-937-862	INFO@MDSAmericas.com

PLANT SHUTDOWN INSTRUCTIONS

1. At shutdown, flush the system with RO permeate. If sodium hexametaphosphate (SHMP) is used for pretreatment, the system must be flushed with water that is free of SHMP.

2. After the system is secured, check that all additive systems are also secured.

3. When the system is secured, insure that water does not drain from the elements. Also insure that there is not back pressure on the elements from the permeate side.*

4. For extended shutdowns (greater than one week), a preservative solution should be added to the system (see attached table for details).

5. If the plant is to be secured for less than one week, it is usually sufficient to merely displace the water in the system with fresh, pretreated feed once per day to minimize biological growth.

*If there is greater than atmospheric pressure on the permeate line during operation, check and dump valves should be included in the permeate line to prevent even momentary back pressure on the membrane elements during a shutdown.

NF OR RO ELEMENTS	
Foulant	**Cleaners/Sanitizers**
Mineral Scale Calcium Carbonate Calcium Sulfate Barium Sulfate Strontrium Sulfate	• HCl or citric acid, pH 2 • Pfizer IPA 403 • 12% NaCl + EDTA 0.05%
Iron or Manganese	• Same as mineral scale cleaners
Organics, Silt, Bacterial Slime	• Sodium hydroxide, 0.5% Sodium dodecyl sulfate, 0.1% Adjust to pH 11.5 with HCl if necessary • Trisodium phosphate, 1% Sodium tripolyphosphate, 1% Sodium dodecyl sulfate, 0.1% Tetrasodium EDTA, 1% Adjust to pH 11.5 with HCl if necessary • Pfizer IPA 411
Bacteria (Sanitizers)	• Sodium bisulfite, 0.1% • Formaldehyde, 0.1% • Chlorine dioxide, 30 ppm • Preservation sodium bisulfite, 0.05%, change every 2 months

PHYSICAL ADDRESS | PHONE | FAX | WEB
921 'A' SOUTH ANDREASEN DRIVE, ESCONDIDO, CA 92029, USA | (858) 345-5302 | (858) 799-0867 | www.MDSAmericas.com
MAILING ADDRESS | FEIN | CA BOE | EMAIL
P.O. BOX 953, SOLANA BEACH, CA 92075, USA | 20-4938673 | 100-937-862 | INFO@MDSAmericas.com

TECHNICAL INFORMATION

TABLE OF CONTENTS

PHYSICAL ADDRESS	PHONE	FAX	WEB
921 'A' SOUTH ANDREASEN DRIVE, ESCONDIDO, CA 92029, USA	(858) 345-5302	(858) 799-0867	www.MDSAmericas.com
MAILING ADDRESS	FEIN	CA BOE	EMAIL
P.O. BOX 953, SOLANA BEACH, CA 92075, USA	20-4938673	100-937-862	INFO@MDSAmericas.com

TECHNICAL INFORMATION

MATERIALS OF CONSTRUCTION

Standard Materials of Construction	
Permeate Carrier:	Polyester
Feed Spacer:	Polypropylene
Central Tube:	ABS for 2.5” & 4.0” diameter elements Noryl for 8.0” diameter elements
Glue:	Urethane
Brine Seal:	Buna N
O-rings:	Buna N
External Wrap:	Polypropylene tape, FRP, or Durasan™
Anti-telescoping Device:	ABS

TECHNICAL INFORMATION

PLANT START-UP/SHUTDOWN INSTRUCTIONS

Plant Start-Up

The following procedures should be followed step-by-step for the start-up of MDS spiral wound element systems.

1. Flush system without elements to remove any residual debris from system fabrication.

2. Recheck and test all in-line sensors, set points of interlocks, time delay relays, and alarms.

3. Feedwater quality should be checked prior to plant start-up. Pretreatment systems must be fully operational.

4. Purge all air out of the system at low feed pressure and flow.

5. Check systems for leaks.

6. Slowly increase feed pressure and flow to obtain design performance by adjusting feed and brine throttle control valves.

7. For reverse osmosis plants, sample the reject stream to check that the Langelier Saturation Index is negative and $CaSO_4$ and silica concentrations are within acceptable limits.

8. After the system has reached design conditions and has stabilized (about 1 to 2 hours), record operating conditions and performance parameters.

9. Let the system run to waste for about 2 hours to flush out residual chemicals from the elements.

Plant Shutdown

1. At shutdown, flush the system with permeate or pretreated Dl water, if available. The flush water must be free of any chemical additives.

2. Relieve system pressure and shut down feed pumps.

3. When the system is secured, insure that water does not drain from the elements. Also insure that there is no back pressure on the elements from the permeate side.*

4. For extended shutdowns (greater than one week), a preservative solution should be added to the system to eliminate biological growth.

5. If the plant is to be secured for less than one week, it is usually sufficient to merely flush the system with fresh, pretreated feed once per day to minimize biological growth.

**If there* is *greater than atmospheric pressure on the permeate line during operation, check valves should be included in the permeate line to prevent even momentary back pressure on the membrane elements during a shutdown.*

TECHNICAL INFORMATION

MDS SLEEVE OUTERWRAP

MDS Sleeve Outerwrap

MDS has developed and patented the MDS sleeve, an innovative element outerwrap. The design features of this outerwrap have been proven in dairy, food, pharmaceutical, dialysis, and other applications for over five years.

The MDS sleeve consists of a rigid, tubular plastic cage that contains and protects the spiral-wound element. It is designed to form a close fit within pressure vessel walls, without the use of brine seals, while maintaining a controlled bypass around the outside of the element.

Eliminates dead space The controlled flow around the element eliminates the voids and dead spaces conducive to bacterial growth and adhesion.

Improves sanitizing effectiveness The MDS sleeve allows for complete cleaning and sanitizing and is ideal for CIP sanitary systems.

Faster rinse-out Controlled bypass allows for faster rinse-out of cleaning and sanitizing residuals.

Minimizes leaching The elimination of fiberglass and tape adhesives minimizes organic leaching.

Easier element loading Due to tight manufacturing tolerances, MDS elements are more easily loaded into pressure vessels.

TECHNICAL INFORMATION

SPECIAL FEED SPACERS

Feed Spacers

MDS spiral-wound elements incorporate net-type plastic feed spacers between the membrane leaves. These spacers serve two important functions: they form a feed flow path between the leaves and they generate turbulence resulting in increased shear at the membrane surface. This shear force reduces concentration polarization and minimizes the effect of colloidal and particulate foulants at the membrane/feed interface.

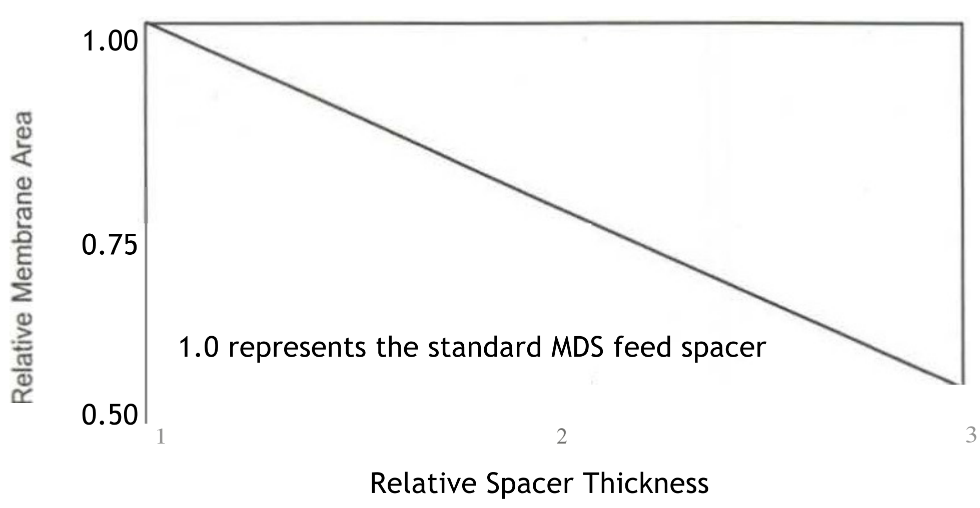
In addition to standard spacers for traditional water applications, MDS has developed and patented special feed spacers for wider, more open feed channels. These special spacers allow MDS spirals to be used in feed streams with high viscosities, high levels of suspended solids, or high fouling potential. The need for special spacers can best be determined through pilot studies.

Design factors for special feed spacers include:

1. Effective membrane area decreases with increasing spacer thickness. The figure below plots relative membrane area as a function of feed spacer thickness (for 4" x 40" elements).

2. Higher feed velocities are sometimes required to achieve a given shear value at the membrane surface.

Feed Spacer Thickness vs. Membrane Area



TECHNICAL INFORMATION

TEMPERATURE CORRECTION FACTORS

Temperature Correction Factors

Temperature correction factors are listed for all MDS reverse osmosis, nanofiltration, ultrafiltration, and microfiltration elements. The reference temperature is 77˚F (25˚C).

Temperature F˚(C˚)	*Cellulose Acetate*	*MDS-3, 5 and 11*	*UF Elements*
40 (4)	.55	.48	.54
50 (10)	.66	.60	.64
60 (16)	.77	.73	.76
70 (21)	.90	.88	.90
77 (25)	1.00	1.00	1.00
80 (27)	1.04	1.06	1.05
90 (32)	1.20	1.26	1.22

TECHNICAL INFORMATION

ELEMENT LOADING INSTRUCTIONS

Element Loading Instructions

1. Load an element into the upstream or feed end of the pressure vessel. The brine seal should face the upstream end of the vessel to prevent feed bypass when the unit is in operation. Leave 6" of the element exposed beyond the end of the pressure vessel to facilitate loading succeeding elements.

2. Record the serial number and location of the element.

3. Apply glycerine to the O-rings of an interconnector. With a twisting motion, insert the interconnector into the central tube on the upstream end of the previously loaded element. Rotate the interconnector to insure that the 0-rings have been seated.

4. Line up a second element with the interconnector of the first element. With a gentle pushing and twisting motion, insert the interconnector into the downstream end of the second element.

5. Push both elements forward until about 6" of the second element extends beyond the feed end of the pressure vessel.

6. Record the serial number and location of the second element.

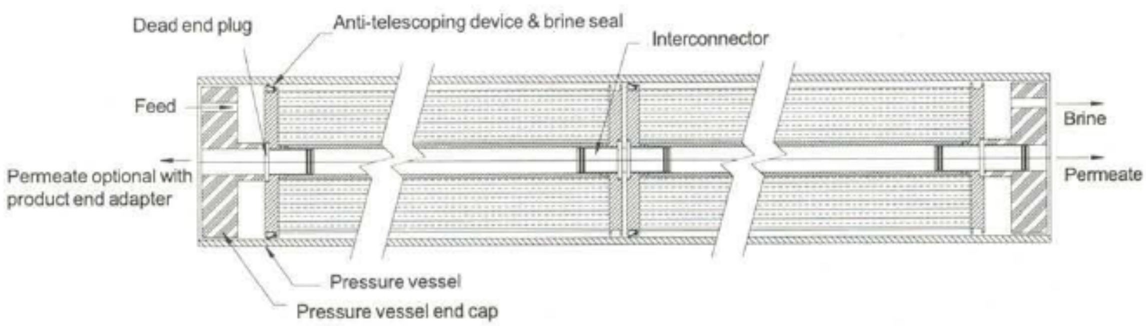
7. Repeat the loading process for the remaining elements.

8. When all elements have been loaded into a pressure vessel, insert glycerine lubricated product end adaptors into the first and last elements in the vessel.

9. Connect the downstream pressure vessel end cap to the product end adapter and secure the end cap.

10. The following figure illustrates the correct placement of interconnectors and elements within a pressure vessel.

Typical Installation



TECHNICAL INFORMATION

MEMBRANE CHEMICAL COMPATIBILITIES

General Compatibility Data

Coagulants Metal coagulants, such as chlorides or aluminum and iron sulfates, are often used as pretreatment ahead of reverse osmosis systems. The end products and metal hydroxides, are potential foulants. Acid cleaning is usually effective in removing such deposits if cleaning is initiated before excessive quantities of material have accumulated.

Antiscalants The following antiscalants have been used successfully with MDS cellulose acetate and thin-film membranes.

Sodium hexametaphosphate (generic)
Cyanamer P-35 (American Cyanamid)
Dequest 2052 and 205 (Monsanto)
Flacon 100 (Pfizer)

Organic antiscalants must be used with care as they may not be compatible with other water treatment chemicals. For example, antiscalants may form gummy precipitates when mixed with cationic organic polymers.

Lubricants The lubricants listed below may be used on 0-rings and brine seals. Never use petroleum based products such as Vaseline or mineral oil.

Glycerine
Sodium alginate
Dove or Ivory liquid detergent

MDS-CA

Organic Polymers Cationic polyelectrolytes and non-ionic filter aids have no detrimental effects on cellulose acetate membranes. However, mixtures of polymer, suspended solids, and other water treatment chemicals may severely foul cellulose acetate membranes.

Oxidizing Agents Cellulose acetate membranes are subject to attack by strong oxidizing agents. Feedwater to cellulose acetate elements should be free of hydrogen peroxide, ozone, potassium permanganate, and peracetic acid. Chlorine should be limited to 1 ppm or less on a continuous basis with 30 ppm for 30 minutes during periodic chlorine sanitization.

pH Feed pH should be maintained between 5.0-6.5 with a pH range of 3-8 for periodic cleaning.

MDS-3, MDS-11

Organic Polymers Nalco 8103 and Magniflox 573C have been tested on MDS-3 and MDS-11 membranes. Floc composed of polymer and suspended solids may foul these thin-film membranes.

Oxidizing Agents MDS-11 has a chlorine tolerance of 1,000 ppm hours. MDS-3 has a chlorine tolerance of 500 ppm hours. Dechlorination with sodium bisulfite or activated carbon is recommended.

Feedwater must also be kept free of hydrogen peroxide, potassium permanganate, ozone, and peracetic acid.

pH (MDS-3) Optimum rejection 5.5-7.0. Recommended operating range 2.0-11. Cleaning range pH 1.0-11.5.

pH (MDS-11) Optimum rejection 6.5-7.0. Recommended operating range 4.0-11. Cleaning range 2.0-11.5.

MDS-5

Organic Polymers Nalco 8103 and Magniflox 573C have been shown to be compatible with MDS-5 membranes. Floc composed of polymer and suspended solids may foul this thin-film membrane.

Oxidizing Agents MDS-5 has a chlorine tolerance of 1,000 ppm hours. Dechlorination with sodium bisulfite or activated carbon is recommended.

pH Recommended operating range 2.0-11 (pH of <1 with special construction). Cleaning range 1.0-11.5.

G-Series

Organic Polymers Nalco 8103 and Magniflox 573C have been shown to be compatible with G-Series membranes. Floc composed of polymer and suspended solids may foul these thin-film membranes.

Oxidizing Agents Chlorine tolerance varies according to the specific G-Series membrane as noted below.

G-Series Membrane	*Chlorine Tolerance (ppm-days)*
G-80	1,000
G-50	1,000
G-20	500
G-10	20-50
G-5	None

The G-50 membrane will tolerate approximately 100,000 ppm-days of one of several different oxidants including hydrogen peroxide, sodium chlorite, povidine iodine, and chloramine T.

pH Recommended operating range 2.0-11. Cleaning range 1.0-11.5.

UF Elements

Oxidizing Agents These membranes have a chlorine tolerance in excess of 5,000+ ppm-days and may be cleaned and sanitized with a 5-10% hydrogen peroxide solution.

pH Recommended operating range 2-11. Cleaning range 1.0-11.5.

TECHNICAL INFORMATION

CLEANERS AND SANITIZERS

Cleaners and Sanitizers

The following cleaners and sanitizers have been evaluated by Membrane Development Specialists (MDS), and found to be compatible with the MDS element types listed below. In addition to the generic cleaners listed below, there are many chemical companies that market membrane cleaners. Please consult the chemical manufacturer about their specific products.

MDS-CA	
Foulant	***Cleaner / Sanitizer***
Mineral Scale and metal precipitates	• HCl, pH3 • Citric acid, 2% Adjust to pH3 with NH_4OH
Organics, silt, bacterial slime	• Trisodium phosphate, 1% Sodium tripolyphosphate, 1% Sodium dodecyl sulfate, 0.1% Tetrasodium EDTA, 1% Adjust to pH 8.0 with HCl (*see note)
Bacteria (Sanitizers)	• Sodium bisulfite, 0.1% • Chlorine, 30 ppm for 30 minutes

***Caution:** frequent cleaning will cause premature hydrolyzing of the membrane.

MDS-3, 5, 11, and G-Series	
Foulant	***Cleaner / Sanitizer***
Mineral Scale and metal precipitates	• HCl, or citric acid, pH2
Organics, silt, bacterial slime	• Sodium hydroxide, 0.5% Sodium dodecyl sulfate, 0.1% Adjust to pH 11.5 with HCl if necessary • Trisodium phosphate, 1% Sodium tripolyphosphate, 1% Sodium Dodecyl sulfate, 0.1% Tetrasodium EDTA, 1% Adjust to pH 11.5 with HCl if necessary
Bacteria (Sanitizers)	• Sodium bisulfite, 0.1% • Chlorine dioxide, 30 ppm

UF Elements	
Foulant	***Cleaner / Sanitizer***
Mineral Scale and metal precipitates	• Hydrochloric acid, pH2
Organics, silt, bacterial slime	• Trisodium phosphate, 1% Sodium tripolyphosphate, 1% Sodium Dodecyl sulfate, 0.1% Tetrasodium EDTA, 1% Adjust to pH 11.5 with HCl if necessary
Bacteria (Sanitizers)	• Hydrogen peroxide, 5-10% • Sodium bisulfite, 0.1% • Chlorine, 5-10 ppm

SALES INFORMATION

TABLE OF CONTENTS

SALES INFORMATION

TERMS & CONDITIONS OF SALE

ACCEPTANCE OF ORDERS – Modifications of orders, shipping schedules, and shipping schedule changes are subject to acceptance by the corporate office of Membrane Development Specialists.

PAYMENT – Net 30 days on approved credit. Others, cash with order. 1.5% per month charge after 30 days.

SHIPMENT – Prices are F.O.B. Escondido, California, USA.

QUANTITY PRICES – Quantity prices apply on firm orders with delivery scheduled during a period not in excess of six (6) months from the date of order. Modifications of delivery schedules after the date of the order will result in adjustment to reflect the quantity price for the new quantity.

DELIVERY – Membrane Development Specialists will normally ship standard products within sixty (60) days of the acceptance of an order. Delivery times for non-standard products will be quoted when requested. Membrane Development Specialists shall have no liability for delay in shipping any of its products unless a specific time is agreed to by Membrane Development Specialists, and even in such case, Membrane Development Specialists will have no liability for any delay in shipment of any cause outside the control of Membrane Development Specialists. In every case, the obligation of Membrane Development Specialists to ship products by a specified date shall be satisfied when Membrane Development Specialists has delivered such goods or equipment to a common carrier for shipment to the buyer.

TITLE TRANSFER – Title of goods or equipment shipped will be transferred to the buyer upon delivery to a common carrier for shipment to the buyer.

TRAFFIC CLAIMS – If goods are damaged or lost in transit, it is the purchaser's responsibility to provide a properly receipted delivery bill and hold open for inspection all packaged delivered by the carrier. F.O.B. point of shipment requires buyer to file all claims with the carrier for lost or damaged goods.

RETURN POLICY – Please see Returned Goods Authorization (RGA) Procedures section.

TAXES – Applicable federal, state, or local sales or use taxes will be paid by the buyer.

WARRANTY – One (1) year material and workmanship warranty from date of delivery.

GENERAL – The respective rights of the buyer and Membrane Development Specialists will be governed by the laws of the State of California. Prices, terms, and conditions may be changed without notice by Membrane Development Specialists and clerical errors are subject to correction. If any of these terms and conditions shall be held to be invalid, then they shall be deemed to be severable and the remaining terms and conditions shall continue to be in full force and effect.

All shipments made by Membrane Development Specialists will be deemed to be made under the above terms and conditions, supplements by the nonconflicting provisions of any purchase order accepted by Membrane Development Specialists unless otherwise indicated to Membrane Development Specialists in writing. Acceptance and/or use by the purchase of any materials or equipment shipped by Membrane Development Specialists will constitute acceptance of the terms and conditions herein.

SALES INFORMATION

RETURNED GOODS PROCEDURE

The following points apply to the return of elements to MDS for warranty evaluation or a return to stock:

1. Contact the Customer Service Department to obtain a return authorization number. Products returned without written authorization will be returned to the customer unopened, freight collect.

2. The following information is required prior to release of a returned goods authorization (RGA) number:
   A. Element type
   B. Element serial number
   C. Reason for return
   D. Time on line
   E. Performance data,% rejection, and flow rates
   F. Feed stream data, pH, temperature, pressure, and total dissolved solids
   G. Product application
   H. System description (total elements, array)

3. Elements returned in the following condition will immediately void warranty consideration:
   A. Unauthorized altering of the elements
   B. Visible operational damage
   C. Improper storage and handling

4. There will be a $25.00 per element service charge plus return freight charges for elements that test within specified performance ranges.

5. There will be a 10% restocking charge to return an order to stock.

6. Customers will receive a summary report explaining test results and warranty decisions. The following procedures should be followed step-by-step for the start-up of MDS spiral wound element systems.