PSI Membrane®

TFN RO & NF Membrane Elements
Product and Technical Manual

Water Treatment Solutions & Technologies

Professional Share Innovate



ABOUT US



Corporate Headquarter



Proshare Membrane Technology Industrial Park

Proshare Technology was founded by a national high-level talent, specializing in the research and industrial application of next-generation Nanocomposite Thin-Film (TFN) technology for high-end reverse osmosis, nanofiltration, and material separation membranes.

In 2017, Proshare was established in Suzhou Nano City, the world's largest nanotechnology industrial application community. In 2024, Proshare's production and R&D base, the Proshare Membrane Technology Industrial Park, was established in Yancheng, spanning an area of over 30,000 square meters.

Proshare's team, through the integration of layer-by-layer self-assembly technology with nano-enhanced materials, has pioneered a new generation of Nano-composite Thin-Film (TFN) membranes for reverse osmosis and nanofiltration. This innovation marks a significant advancement over the traditional TFC technology pathway, as detailed in the company's own documentation. The company successfully established the country's first TFN nano-composite thin-film coating line, with the capacity to produce millions of square meters per annum, solidifying its position as one of the select few specialized membrane suppliers globally.

Proshare TFN membrane products have the advantages of high flux, anti-fouling , oxidation resistance and high customization, with a comprehensive range of product types, all independently developed and produced. We provide industry-leading membrane products and technical services and have served hundreds of industrial projects and have been widely recognized.
Proshare is committed to delivering globally advanced professional products and services, aiming to enhance energy efficiency, promote resource recycling, and achieve sustainable development goals.



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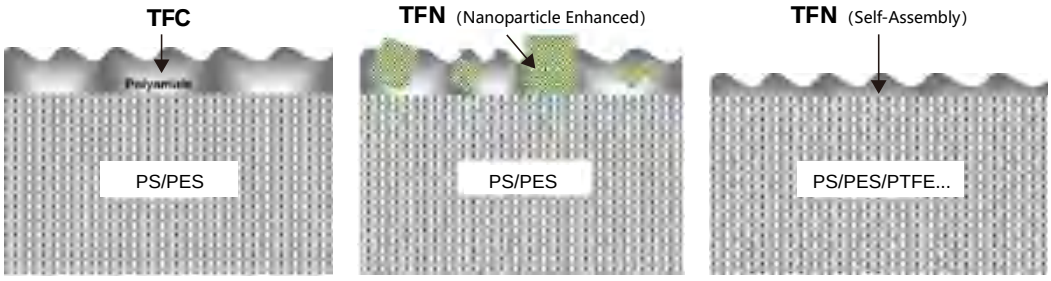
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Chapter 1. Technical Features and Advantages

1-1 About PSI TFN

Since its establishment, Proshare Innovation Suzhou Co.,Ltd. has been committed to the R&D and industrial production of a new generation of reverse osmosis membranes that can break foreign monopolies at one stroke. The company's main founders consist of multiple doctors and engineers with years of R&D experience in the field of nanomaterials and filtration materials. By fully leveraging the accumulated experience in the field of polymer interface nano-self-assembly technology and cooperating with top scientific research institutions at home and abroad, Proshare is dedicated to the R&D and manufacturing of the third-generation nano-composite thin-film high-end reverse osmosis and nanofiltration membranes (TFN) with low cost, high flux, and strong chemical weather resistance.

1-2 Technical Features

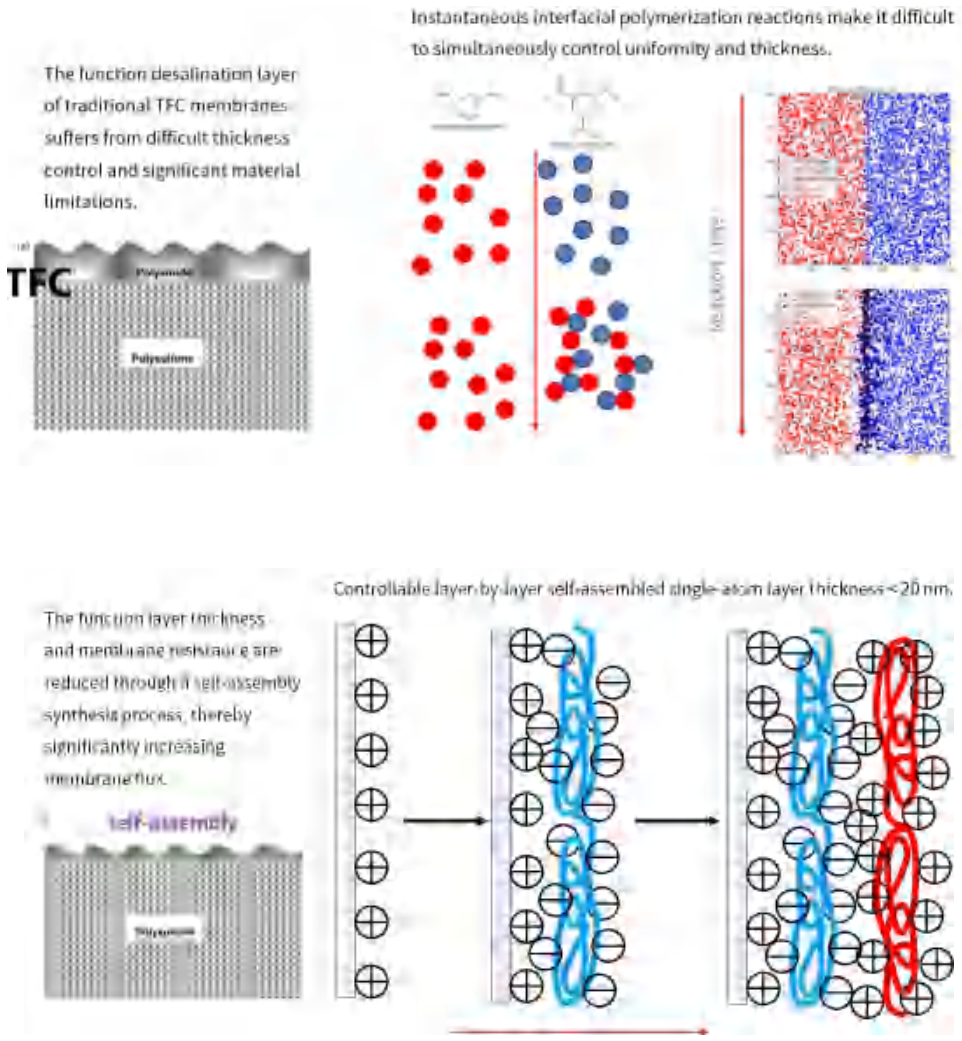


Breaking away from the limited thinking of traditional reverse osmosis membrane development, Proshare team started from the source of membrane-forming polymer types and mechanisms. By adopting nanoparticles combined with polymer interface nano-self-assembly thin-film technology, they have creatively developed a new generation of reverse osmosis membranes based on polymer interface nano-self-assembly technology. Its two most important innovations are:

- Using polymer interface nanotechnology, it can successfully break through the 100nm thickness limit of the polyamide thin film of traditional reverse osmosis membranes, reducing the thickness of the separation layer by at least 3 times, thereby doubling the water flux of the membrane;

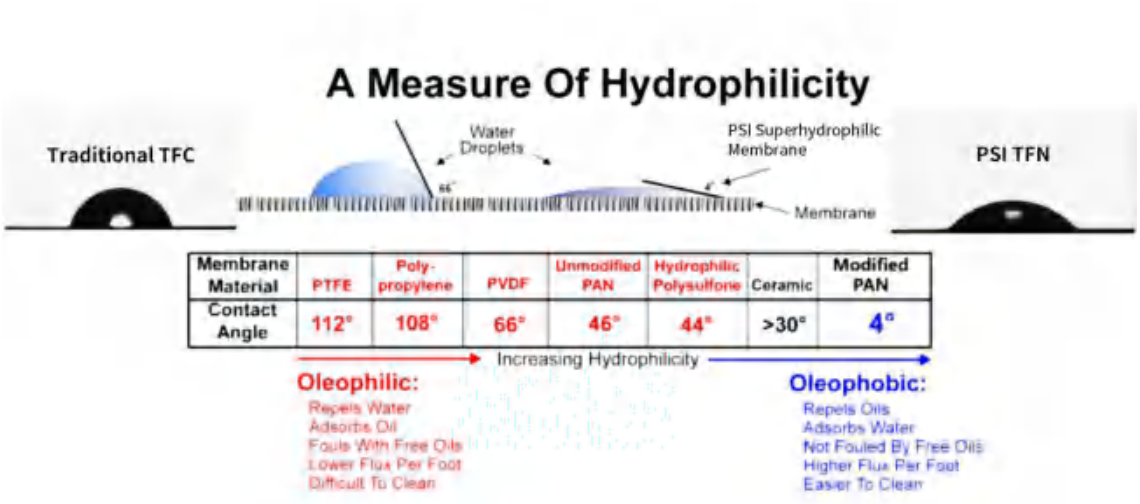
- By introducing nanoparticles and special hydrophilic polymers, the new generation of reverse osmosis membranes has achieved significant breakthroughs in hydrophilic anti-pollution performance, durability, and oxidation resistance.

1-3 Advantages



Compared with traditional polyamide reverse osmosis membranes:

- Nano-scale precise control combined with nano-doping modified self-assembled thin films.
- Obtain higher water flux and reduce energy consumption by controlling the thickness of the functional layer through layer-by-layer self-assembly process.
- New polymer thin-film materials not limited to traditional polyamide endow more excellent chemical properties.
- Super hydrophilic surface reduces membrane fouling tendency and decreases the cycle and cost of chemical cleaning.



Innovation	Disadvantages of Traditional TFC	Advantages of Proshare TFN
Material Innovation	High cost (due to monopoly supply of raw materials, equipment and technology by international Companies)	Cost efficiency (Master core source technology, domestic raw materials, independent equipment design
Structural Innovation	Low flux, high energy consumption,Separation layer thickness > 100nm	High flux, low energy consumption,Separation layer thickness can be as low as 20nm
	Limitations of polyamide、Non-customizable (Poor hydrophilicity、poor oxidation resistance <1000 ppmh)	✓ Takes the lead among domestic manufacturers in the development and customization of large pore size Nanofiltration saparation membrane. ✓ Super-hydrophilicity (Modification of hydrophilic nanomaterials) ✓ Antioxidant (intrinsic nano-coating >500,000 ppmh) ✓ Acid & alkali resistant (20% H_2SO_4 , 20% NaOH)
	Organic solvent pollution	Environmentally friendly and clean production

Chapter 2. Product Information

2-1 Product Model Naming Rules

Household and Commercial Membrane Element: Pro-ULP-1812-50

Pro-ULP	18	12	50
Product Type	Product Diameter	Product Length	Product Flow Rate (Unit: GPD, Gallons Per Day)

Industrial Membrane Elements: Pro-FR-8040F34-Wet

Pro-FR	80	40	F	34	-	Wet
Product Type	Product Diameter	Product Length	Housing Type	Feed Spacer Thickness	Product Configuration	Additional Information
Position 1	Position 2	Position 3	Position 4	Position 5	Position 6	Position 7

Position 1: Indicates the product type, and different product types are suitable for different applications and operating conditions.

Product	Product Name	Model Description
Pro-ULP	Ultra-Low Pressure Low Energy Membrane Element	ULP: Ultra-Low Pressure
Pro-LP	Low Pressure Low Energy Membrane Element	LP: Low Pressure
Pro-LPHR	Low Pressure Low Energy High Rejection Membrane Element	LPHR: Low Pressure, High Rejection
Pro-LPFR	Low Pressure Low Energy Fouling Resistant Membrane Element	LPFR: Low Pressure, Fouling Resistant
Pro-FR	Fouling Resistant Brackish Water Membrane Element	FR: Fouling Resistant
Pro-XFR	Extra Fouling Resistant Brackish Water Membrane Element	XFR: Extra-Fouling Resistant
Pro-XFRHR	High Rejection Extra Fouling Resistant Brackish Water Membrane Element	HR: High Rejection
Pro-BW	Standard Low Pressure Brackish Water Membrane Element	BW: Brackish Water
Pro-SWHR	Standard High Rejection Seawater Desalination Membrane Element	SWHR: Sea Water, High Rejection
Pro-SW	Standard High Flux Seawater Desalination Membrane Element	SW: Sea Water
PX170	High-Salinity Brine Concentration Membrane Element	Alternative to DuPont XC70
PX180	High-Salinity Brine Concentration Membrane Element	Alternative to DuPont XC80
PX120	Ultra-High Pressure Membrane Element	Pressure Resistance: 120bar
UNF	Tight Ultrafiltration / Loose Nanofiltration Membrane Element	UNF: Ultra-Nano Filtration
NF98-HF	High Flux Nanofiltration Membrane Element	NF: NanoFiltration, HF: High Flux
NF98-SP	Salt-Separation Nanofiltration Membrane Element	NF: NanoFiltration, SP: Salt-separation
NF90	High Rejection Nanofiltration Membrane Element	NF: NanoFiltration
NF98-SPEC	Customized Nanofiltration Membrane Element	SPEC: SPECIAL

Pro-Acid	Special Alkali-Resistant Membrane Element	Acid
PSI-Acid	Acid-Resistant Specialty Membrane Element	Acid
Pro-Base	Strong Alkali-Resistant Specialty Membrane Element	Base
PSI-Base	Alkali-Resistant Specialty Membrane Element	Base
Pro-Therm	High Temperature Resistant Specialty Membrane Element	Thermal
Pro-CR	Chlorine-Resistant Specialty Membrane Element	CR: Chlorine-resistant
Pro-POS	Polar Solvent Resistant Specialty Membrane Element	POS: Polar Solvent
Pro-NPOS	Non-Polar Solvent Resistant Specialty Membrane Element	NPOS: Nonpolar Solvent
PSI-AS	Ammonium Sulfate Acid-Resistant Membrane Element	AS: Ammonium Sulfate

Position 2: Indicates the product diameter in inches; the example here is 8.0 inches.

Position 3: Indicates the product length in inches; the example here is 40 inches.

Position 4 (Optional): Indicates the product housing type.

T (Tape)	F (Glass Fiber)	N (Sanitary Net)	O (Other types)
Tape-Type	Glass Fiber-Type	Net-Type	Other Types

Position 5 (Optional): Indicates the concentrate flow channel width or concentrate flow channel type.

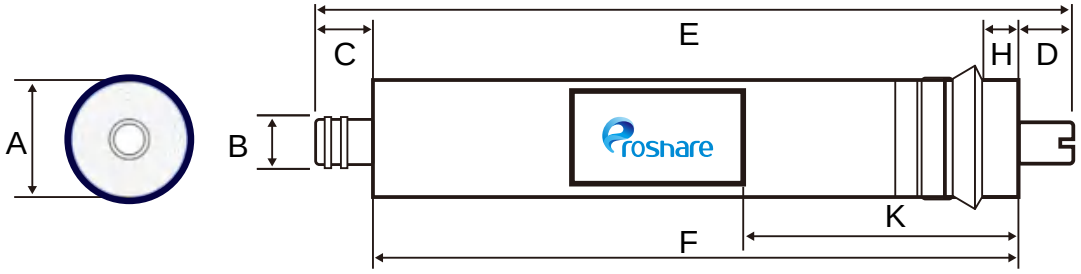
Position 6 (Optional): Indicates the membrane element structure type; M for male connector, blank for flat connector.

Position 7 (Optional): Indicates additional product information, such as wet membrane, dry membrane, sample membrane, certification information, etc.

2-2 Performance Parameters of Household and Commercial Membrane Element

Ultra-Low Pressure Low Energy Membrane Element performance parameters

Product	A	B	C	D	E	Average Permeate Flow Rate GPD(m^3/d)	Average Salt Rejection (%)
	Inch (mm)	Inch (mm)	Inch (mm)	Inch (mm)	Inch (mm)		
Pro-ULP-1812-50	1.75 (44.5)	0.72 (18.2)	0.87 (22.0)	0.87 (22.0)	12.00 (298.0)	50 (0.19)	97
Pro-ULP-1812-75	1.75 (44.5)	0.72 (18.2)	0.87 (22.0)	0.87 (22.0)	12.00 (298.0)	75 (0.29)	97
Pro-ULP-2012-100	1.81 (46.0)	0.72 (18.2)	0.87 (22.0)	0.87 (22.0)	12.00 (298.0)	100 (0.38)	97
Pro-ULP-2812-300	2.68 (68.0)	0.72 (18.2)	0.87 (22.0)	0.87 (22.0)	12.00 (298.0)	300 (1.14)	97
Pro-ULP-3012-400	2.68 (68.0)	0.72 (18.2)	0.87 (22.0)	0.87 (22.0)	12.00 (298.0)	400 (1.52)	97
Pro-ULP-3012-600	2.91 (74.0)	0.72 (18.2)	0.87 (22.0)	0.87 (22.0)	12.00 (298.0)	600 (2.28)	97
Pro-ULP-3013-400	2.68 (68.0)	0.72 (18.2)	0.78 (20.0)	0.78 (20.0)	13.00 (333.0)	400 (1.52)	97
Pro-ULP-3013-500	2.68 (68.0)	0.72 (18.2)	0.78 (20.0)	0.78 (20.0)	13.00 (333.0)	500 (1.90)	97
Pro-ULP-3013-600	2.68 (68.0)	0.72 (18.2)	0.78 (20.0)	0.78 (20.0)	13.00 (333.0)	600 (2.28)	97
Pro-ULP-3113-800	3.11 (78.0)	0.72 (18.2)	0.78 (20.0)	0.78 (20.0)	13.00 (333.0)	800 (3.04)	97
Pro-ULP-3213-1000	3.20 (83.0)	0.72 (18.2)	0.78 (20.0)	0.78 (20.0)	13.00 (333.0)	1000 (3.80)	97



Note: Except for the specified dimensions A, B, C, D, and E, other dimensions can be customized according to customer requirements.

Data Description: 1. Product flow rate and salt rejection are based on the following test conditions: 250ppm NaCl, 77ºF (25ºC), 15% recovery rate, test pressure of 60psi for < 400GPD, and 90psi for ≥ 400GPD; 2. The water production of a single element may vary within ±15%.

2-3 Performance Parameters of Summary Industrial Membrane Element

RO Membrane Element performance parameters

Type	Product	Stabilized Salt Rejection (%)	Average Permeate Flow Rate GPD(m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)	Test Condition			
						Pressure psi (MPa)	Solution Concentration of NaCl (ppm)	Recovery (%)	Temperature ℉(℃)
Pro-LP Low Pressure Low Energy Membrane Element	Pro-LP-4040	99.40	2800 (10.6)	85 (7.9)	34	150 (1.03)	1500	15	77 (25)
	Pro-LP-8040	99.40	12000 (45.9)	400 (37.2)	34	150 (1.03)	1500	15	77 (25)
Pro-LPHR Low Pressure Low Energy High Rejection Membrane Element	Pro-LPHR-4040	99.55	2500 (9.5)	85 (7.9)	34	150 (1.03)	1500	15	77 (25)
	Pro-LPHR-8040	99.55	10500 (39.7)	400 (37.2)	34	150 (1.03)	1500	15	77 (25)
	Pro-LPHR-8040	99.65	12500 (47.3)	440 (40.9)	28	150 (1.03)	1500	15	77 (25)
Pro-LPFR Low Pressure Low Energy Fouling Resistant Membrane Element	Pro-LPFR-4040	99.55	2500 (9.5)	85 (7.9)	34	150 (1.03)	1500	15	77 (25)
	Pro-LPFR-8040	99.55	10500 (39.7)	400 (37.2)	34	150 (1.03)	1500	15	77 (25)
Pro-FR Fouling Resistant Brackish Water Membrane Element	Pro-FR-4040	99.60	2400 (9.1)	85 (7.9)	34	225 (1.55)	2000	15	77 (25)
	Pro-FR-8040	99.60	11000 (41.6)	400 (37.2)	34	225 (1.55)	2000	15	77 (25)
	Pro-FR-8040	99.60	12500 (47.3)	440 (40.9)	32	225 (1.55)	2000	15	77 (25)
Pro-XFR Extra Fouling Resistant Brackish Water Membrane Element	Pro-XFR-4040	99.70	2500 (9.5)	85 (7.9)	34	225 (1.55)	2000	15	77 (25)
	Pro-XFR-8040	99.70	12000 (45.9)	400 (37.2)	34	225 (1.55)	2000	15	77 (25)
Pro-XFRHR High Rejection Extra Fouling Resistant Brackish Water Membrane Element	Pro-XFRHR-4040	99.80	2500 (9.5)	85 (7.9)	31	225 (1.55)	2000	15	77 (25)
	Pro-XFRHR-8040	99.80	11000 (41.6)	400 (37.2)	31	225 (1.55)	2000	15	77 (25)
Pro-BW Standard Low Pressure Brackish Water	Pro-BW-4040	99.50	2600 (9.8)	85 (7.9)	34	225 (1.55)	2000	15	77 (25)
	Pro-BW-8040	99.50	10500 (39.7)	400 (37.2)	34	225 (1.55)	2000	15	77 (25)
	Pro-BW-8040	99.50	12500 (47.3)	440 (40.9)	28	225 (1.55)	2000	15	77 (25)
Pro-SWHR	Pro-SWHR-2521	99.85	300 (1.1)	13 (1.2)	34	800 (5.52)	32000	8	77 (25)

Standard High Rejection Seawater Desalination Membrane Element	Pro-SWHR-2540	99.85	700 (2.7)	28 (2.6)	34	800 (5.52)	32000	8	77 (25)
	Pro-SWHR-4021	99.85	800 (3.0)	33 (3.1)	34	800 (5.52)	32000	8	77 (25)
	Pro-SWHR-4040	99.85	2300 (8.7)	90 (8.4)	34	800 (5.52)	32000	8	77 (25)
	Pro-SWHR-8040	99.85	7500 (28.3)	400 (37.2)	28	800 (5.52)	32000	8	77 (25)
	Pro-SWHR-8040	99.85	9000 (34.1)	440 (40.9)	28	800 (5.52)	32000	8	77 (25)
Pro-SW Standard High Flux Seawater Desalination Membrane Element	Pro-SW-8040	99.80	11000 (41.5)	440 (40.9)	28	800 (5.52)	32000	8	77 (25)
PX High-Salinity Brine Concentration Membrane	PX170-8040	99.75	8800 (33.3)	400 (37.2)	34	800 (5.52)	32000	8	77 (25)
	PX180-8040	99.50	9000 (34.1)	440 (40.9)	34	600 (4.13)	32000	8	77 (25)
PX Ultra-High Pressure Membrane Element	PX120-8040	99.70	7400 (28.0)	330 (30.6)	34	800 (5.52)	32000	8	77 (25)

Loose NF / Compact UNF Membrane Element performance parameters

Product	Stabilized Salt Rejection (%)	Average Permeate Flow Rate GPD(m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)	Test Condition			
					Pressure psi (MPa)	Solution Type PEG (Da)	Recovery (%)	Temperature ℉(℃)
UNF500-8040	95	7400 (28.0)	400 (37.2)	34	70 (0.48)	500	15	77 (25)
UNF1000-8040	95	7400 (28.0)	400 (37.2)	34	70 (0.48)	1000	15	77 (25)
UNF2000-8040	95	7400 (28.0)	400 (37.2)	34	70 (0.48)	2000	15	77 (25)
UNF3000-8040	95	8000 (30.3)	400 (37.2)	34	70 (0.48)	3000	15	77 (25)
UNF5000-8040	95	16000 (60.6)	400 (37.2)	34	70 (0.48)	5000	15	77 (25)

NF Membrane Element performance parameters

Type	Model	Rejection rate of Bivalent Salt ion (%)	Rejectionrate of Monovalent salt ion (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)	Test Condition			
							Pressure psi (MPa)	Solution Concentration of $MgSO_4$/NaCl (ppm)	Recovery (%)	Temperature ℉(℃)
High Flux Nanofiltration Membrane	NF98-HF-4040	96	30-50	2800 (10.6)	85 (7.9)	34	70 (0.48)	2000	15	77 (25)
	NF98-HF-8040	96	30-50	13800 (52.2)	400 (37.2)	34	70 (0.48)	2000	15	77 (25)
Salt Fractionation Nanofiltration Membrane	NF98-SP-4040	99	30-50	2500 (9.5)	85 (7.9)	34	70 (0.48)	2000	15	77 (25)
	NF98-SP-8040	99	30-50	12500 (47.3)	400 (37.2)	34	70 (0.48)	2000	15	77 (25)
High Rejection Nanofiltration Membrane	NF90-4040	99	85-90	1850 (7.0)	85 (7.9)	34	70 (0.48)	2000	15	77 (25)
	NF90-8040	99	85-90	9100 (34.4)	400 (37.2)	34	70 (0.48)	2000	15	77 (25)
Customized Nanofiltration Membrane	NF98-SPEC-4040	custom made	custom made	-	85 (7.9)	34	-	-	-	-
	NF98-SPEC-8040	custom made	custom made	-	400 (37.2)	34	-	-	-	-

Pro-Acid Specialty Acid Resistant Membrane Element performance parameters

Product	Stabilized Salt Rejection (%)	Average Permeate Flow Rate GPD(m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)	Test Condition			
					Pressure psi (MPa)	Solution Concentration (ppm)	Recovery (%)	Temperature ℉(℃)
Pro-Acid-NF98-8040	98	12000 (45.4)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)
Pro-Acid-NF96-8040	96	18000 (68.1)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)
Pro-Acid-NF92-8040	92	22000 (83.2)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)
Pro-Acid-NF80-8040	80	24000 (90.8)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)
Pro-Acid-NF35-8040	35	36000 (139.5)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)
Pro-Acid-RO1-8040	99.5	9000 (34.1)	400 (37.2)	34	290 (2.0)	NaCl 2000	15	77 (25)
PSI-Acid-NF98-8040	98	9000 (34.1)	400 (37.2)	34	290 (2.0)	$MgSO_4$ 2000	15	77 (25)
PSI-Acid-RO1-8040	99.5	9000 (34.1)	400 (37.2)	34	290 (2.0)	NaCl 2000	15	77 (25)
PSI-AS-8040	99.5	9000 (34.1)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)

Pro-Base Specialty Alkali Resistant Membrane Element performance parameters

Product	Stabilized Salt Rejection (%)	Average Permeate Flow Rate GPD(m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)	Test Condition			
					Pressure psi (MPa)	Solution Concentration (ppm)	Recovery (%)	Temperature ℉(℃)
Pro-Base-NF98-8040	98	13000 (49.2)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)
Pro-Base-NF96-8040	96	19500 (73.8)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)
Pro-Base-NF92-8040	92	24000 (91.0)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)
Pro-Base-NF80-8040	80	26000 (98.4)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)
Pro-Base-NF35-8040	35	39000 (147.6)	400 (37.2)	34	580 (4.0)	$MgSO_4$ 2000	15	77 (25)
Pro-Base-RO1-8040	90	9000 (34.1)	400 (37.2)	34	290 (2.0)	NaCl 2000	15	77 (25)
PSI-Base-NF98-8040	98	13000 (49.2)	400 (37.2)	34	290 (2.0)	$MgSO_4$ 2000	15	77 (25)
PSI-Base-RO1-8040	99.5	9000 (34.1)	400 (37.2)	34	290 (2.0)	NaCl 2000	15	77 (25)

Pro-Therm Specialty High Temperature Resistant Membrane Element performance parameters

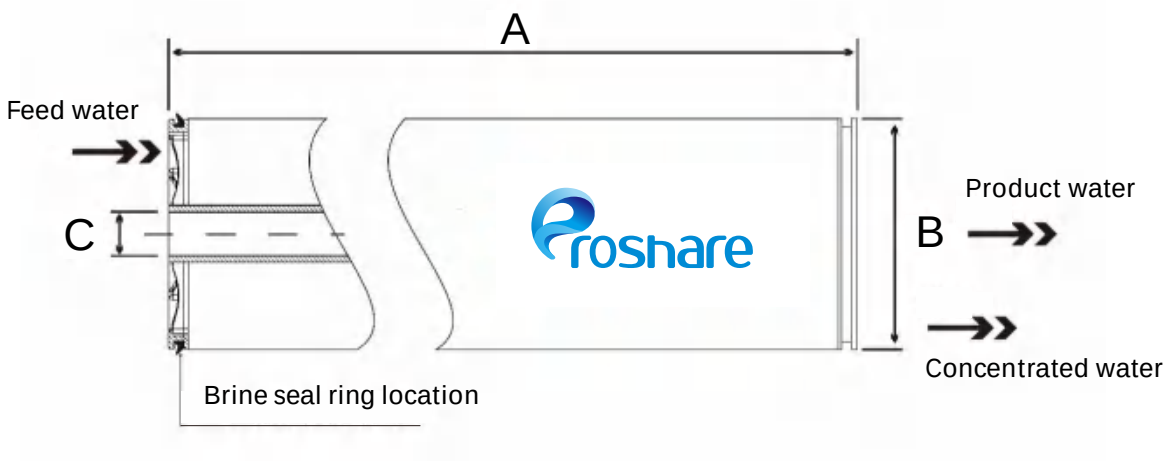
Product	Stabilized Salt Rejection (%)	Average Permeate Flow Rate GPD(m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)	Test Condition			
					Pressure psi (MPa)	Solution Concentration (ppm)	Recovery (%)	Temperature ℉(℃)
Pro-Therm-RO1-8040	98	9000 (34.1)	400 (37.2)	34	225 (1.55)	NaCl 2000	15	77 (25)
Pro-Therm-NF98-8040	98	6000 (22.7)	400 (37.2)	34	70 (0.48)	$MgSO_4$ 2000	15	77 (25)
Pro-Therm-NF96-8040	96	9000 (34.1)	400 (37.2)	34	70 (0.48)	$MgSO_4$ 2000	15	77 (25)
Pro-Therm-NF92-8040	92	11000 (41.6)	400 (37.2)	34	70 (0.48)	$MgSO_4$ 2000	15	77 (25)
Pro-Therm-NF80-8040	80	12000 (45.4)	400 (37.2)	34	70 (0.48)	$MgSO_4$ 2000	15	77 (25)
Pro-Therm-NF35-8040	35	18000 (69.8)	400 (37.2)	34	70 (0.48)	$MgSO_4$ 2000	15	77 (25)

Pro-CR Specialty Oxidation Resistant Membrane Element performance parameters

Product	Stabilized Salt Rejection(%)	Antioxidant Capacity (ppmh)	Permeate Flow Rate (m^3/d)	Active Area ft^2(㎡)	Feed Spacer Thickness(mil)	Test Condition			
						Pressure psi (MPa)	Solution Concentration (ppm)	Recovery (%)	Temperature ℉(℃)
Pro-CR-RO1-8040	98	> 500000	12500 (47.3)	400 (37.2)	34	225 (1.55)	NaCl 2000	15	77 (25)
Pro-CR-NF1-8040	98	> 500000	7800 (29.5)	400 (37.2)	34	70 (0.48)	$MgSO_4$ 2000	15	77 (25)
Pro-CR-NF2-8040	96	> 500000	9200 (34.8)	400 (37.2)	34	70 (0.48)	$MgSO_4$ 2000	15	77 (25)
Pro-CR-NF3-8040	92	> 500000	12800 (48.4)	400 (37.2)	34	70 (0.48)	$MgSO_4$ 2000	15	77 (25)
Pro-CR-NF4-8040	80	> 500000	15000 (56.8)	400 (37.2)	34	70 (0.48)	$MgSO_4$ 2000	15	77 (25)

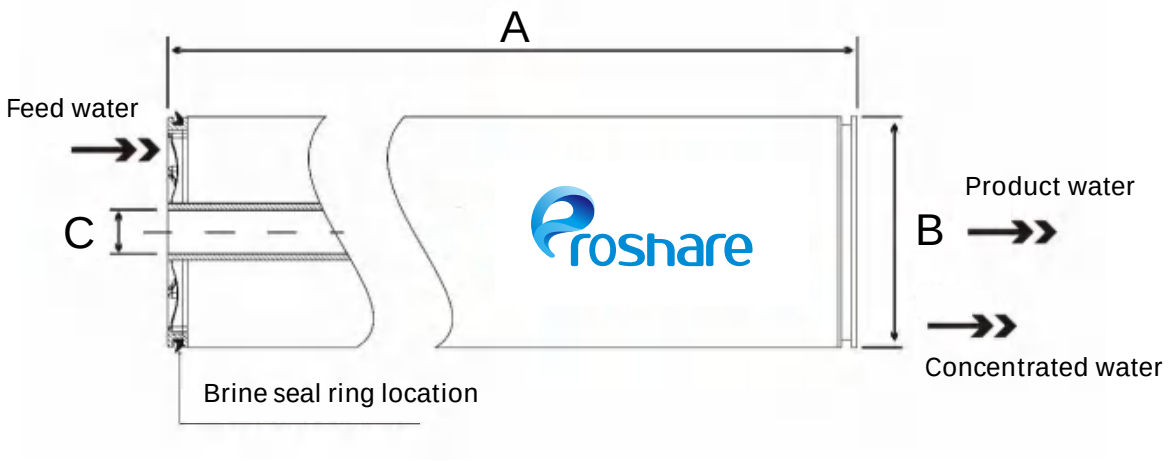
2-4 Product Dimensions Above 20 Inches (1.0 inch = 25.4mm)

Membrane element 8040:



Specification	A/mm (inch)	B/mm (inch)	C/mm (inch)
8040	1016 (40)	200 (7.9)	28.6 (1.125)

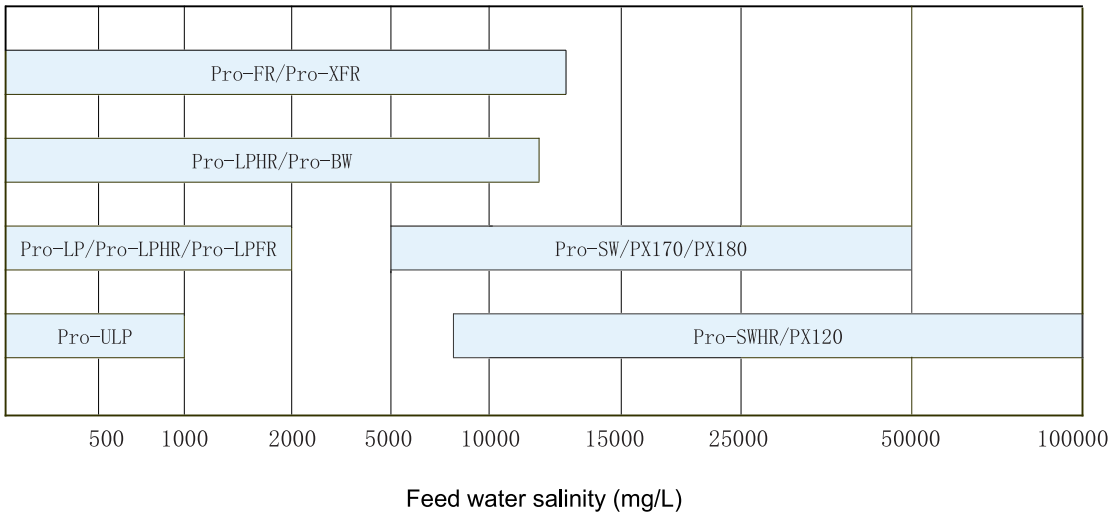
Membrane elements 2521, 2540, 4021, 4040:



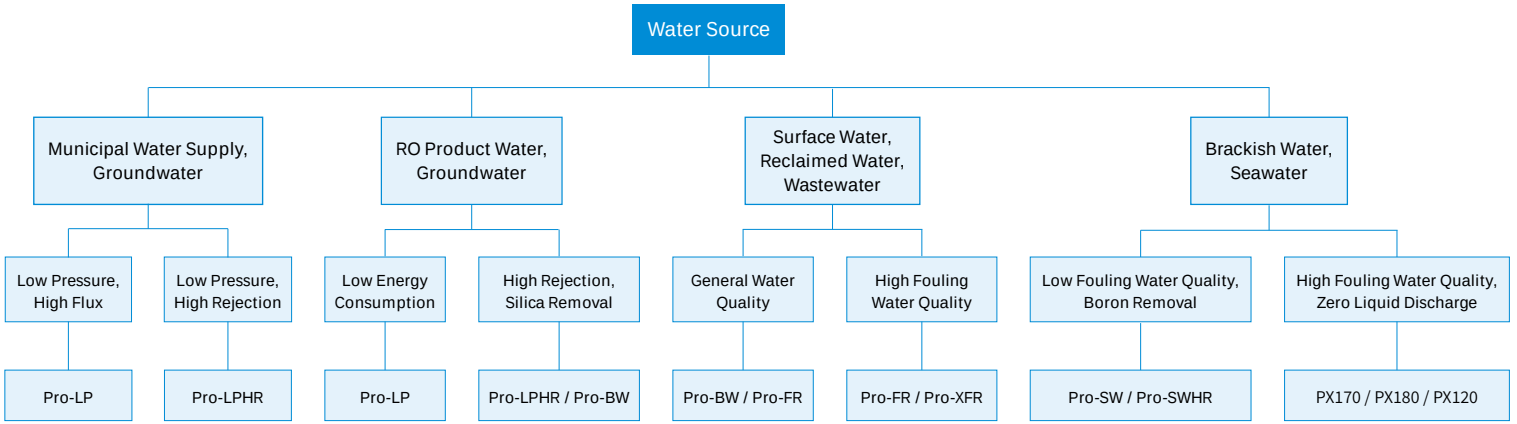
Specifications	A/mm (inch)	B/mm (inch)	C/mm (inch)	D/mm (inch)
2521	533.4 (21)	61 (2.4)	19.1 (0.75)	30.2 (1.19)
2540	1016 (40)	61 (2.4)	19.1 (0.75)	30.2 (1.19)
4021	533.4 (21)	99.7 (3.9)	19.1 (0.75)	26.7 (1.05)
4040	1016 (40)	100.3 (3.95)	19.1 (0.752)	26.7 (1.05)

2-5 Product Selection Guide

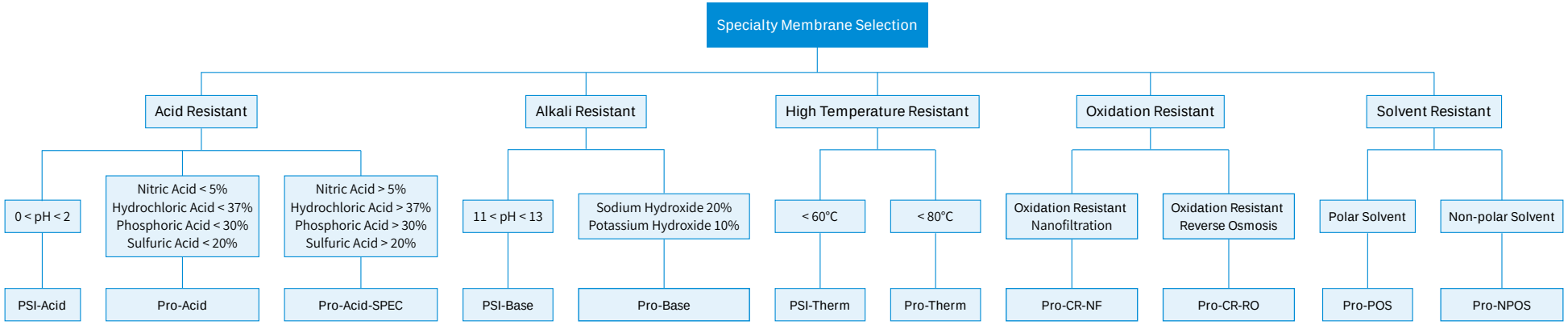
1. Select membrane element based on feed water salinity



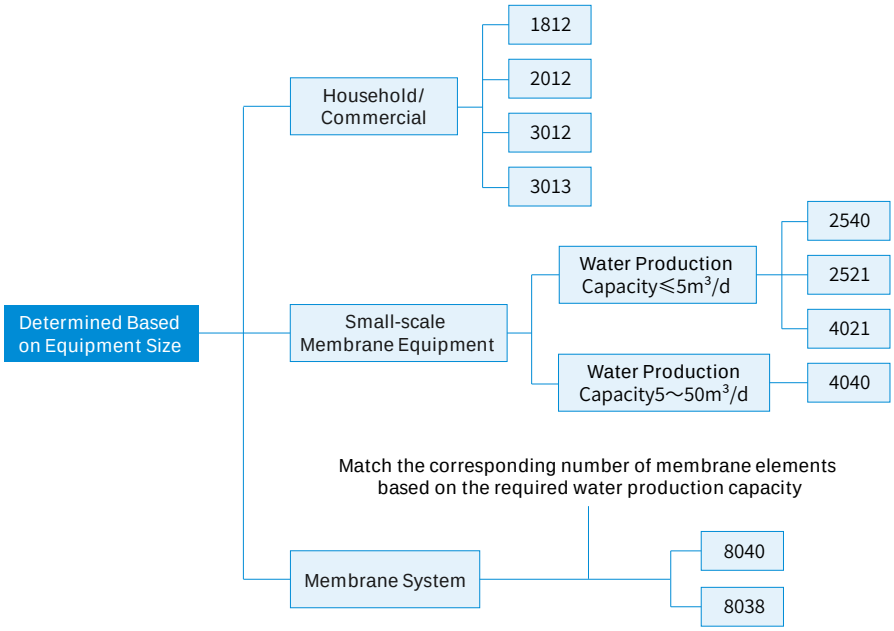
2. Select RO membrane element based on raw water quality



3. Special membrane element selection guide



4. Membrane element size selection



5. What should be considered when selecting reverse osmosis and nanofiltration equipment?

(1) Abstract

When the actual performance of reverse osmosis (RO) and nanofiltration (NF) systems fails to meet design goals, it usually leads to increased operating costs, user dissatisfaction, and complaints to suppliers. This discrepancy is partly due to insufficient awareness or attention by some users to the importance of properly managing system operating conditions, thereby affecting system performance. In addition, inadequate understanding of RO and NF technologies and their equipment is a major contributing factor, which may lead to inappropriate decisions during the project preparation and planning phases.

This article aims to introduce key parameters in RO and NF system design to users, helping them make more informed choices when purchasing equipment based on the characteristics of RO and NF and their specific needs. With this information, users can expect their RO and NF systems to achieve optimal operating results and meet expectations.

(2) Preface

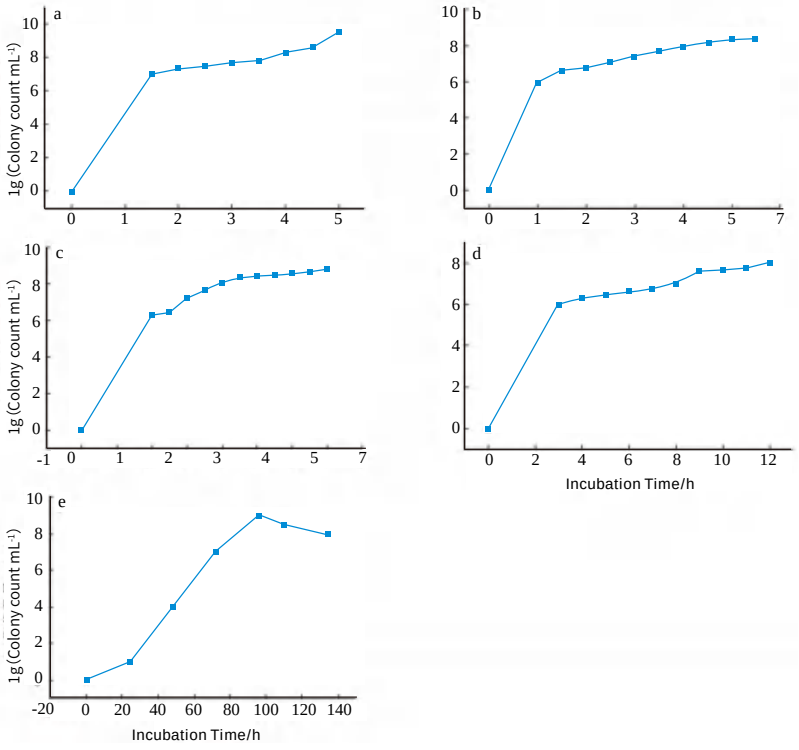
With the continuous advancement of RO and NF technologies, the emergence of new high-performance membrane materials has provided users with more choices, enabling system designs to more accurately meet specific needs while reducing operating costs. Nevertheless, cases of subpar system operation still occur, which can usually be avoided through users' understanding of key technical details. Users need to make reasonable plans to ensure that equipment, control, and operational training meet requirements.

When expanding or constructing new systems, each capital investment should be based on a comprehensive economic and technical analysis to ensure the reliability and rationality of decisions. Referring to nearby similar successful cases and consulting suppliers helps optimize choices and reduce risks and costs.
Most industrial-scale RO and NF systems use spiral-wound membrane elements. This article focuses on considerations for users when purchasing these equipment rather than discussing membrane element structures in detail.

(3) RO and NF Basics

To improve system performance and efficiency, users need to understand some key concepts when designing and operating RO (Reverse Osmosis) and NF (Nanofiltration) systems. RO and NF technologies adopt the principle of cross-flow filtration, which can effectively remove impurities from water, and their purification capacity is sufficient to remove dissolved ions. These technologies can obviously also remove macromolecular substances from water. However, common pollution problems in systems mainly stem from colloids, scale, and microorganisms (including bacteria, viruses, and algae). To avoid additional costs caused by these pollution problems, comprehensive preventive measures should be taken during the design phase.

Understanding the reproduction mechanism of bacteria over time is crucial for preventing biological pollution. Biological pollution is a particularly important issue in RO and NF systems, especially when the water source contains high concentrations of microorganisms, such as surface water, wastewater, and seawater. These water sources are highly prone to causing membrane system pollution. For example, the growth curves of 5 types of bacteria shown in the following figure indicate that microbial growth can cause serious pollution problems to the membrane system in a relatively short period of time. Therefore, sufficient attention must be paid to microbial pollution when designing and operating RO and NF systems, and corresponding preventive measures should be taken.



Note: Growth Curves of Escherichia coli (a), Staphylococcus aureus (b), Pseudomonas aeruginosa (c), Candida albicans (d), and Aspergillus niger (e)

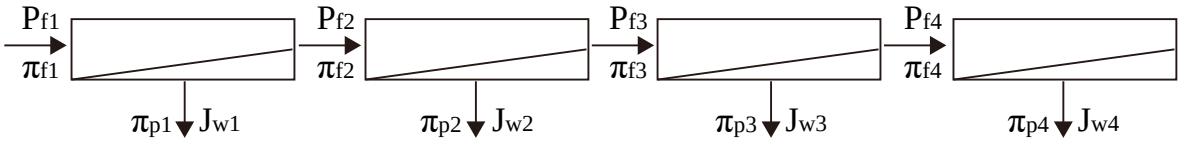
Source: Journal of Zhejiang Agricultural Sciences, Volume 61, Issue 1, 2020

In standard industrial reverse osmosis (RO) and nanofiltration (NF) systems, membrane elements are arranged in series in pressure vessels, which can be connected in parallel to form a single-stage, two-stage, or multi-stage system. This configuration allows the second-stage system to treat the concentrate from the first stage, thereby improving the overall feed water recovery rate.

When water flows through these series-connected membrane elements, product water and concentrate are produced, and their flow rates change. Water is pumped into the membrane element by a high-pressure pump, and product water is produced after filtration, while the water that does not pass through the membrane becomes the concentrate of the element. This part of the concentrate then enters the next membrane element as its feed water. As the water flows, the water volume gradually decreases, the flow rate decreases, and the concentration of pollutants in the water gradually increases. This change continues along the flow direction within each pressure vessel until the flow rate decreases to just maintain the eddy current state on the membrane surface.

When using computers for design calculations, it is necessary to ensure that the flow rate and pollutant concentration in the last stage of the system, i.e., the last membrane element, are maintained within the minimum limits. This is to avoid weakening the self-cleaning ability of the membrane element due to excessively low flow rates, thereby causing pollutants to deposit on the membrane surface. Therefore, RO and NF systems must operate within the designed parameter range. Any changes in parameters, such as feed water temperature, chemical properties, flow rate changes, uneven or unbalanced water distribution, may cause the system to operate beyond the set range, leading to membrane fouling.

Concentration and Flow Rate Changes on the Feed and Product Sides of Membrane Elements



Feed Water $P_{f1}>P_{f2}>P_{f3}>P_{f4}$, $\pi_{f1}<\pi_{f2}<\pi_{f3}<\pi_{f4}$

Product Water $\pi_{p1}<\pi_{p2}<\pi_{p3}<\pi_{p4}$, $J_{w1}>J_{w2}>J_{w3}>J_{w4}$

(4) Feed Water

When planning a water treatment system, we must carefully consider multiple aspects of the feed water, including the expected water volume, water quality, and potential problems with the water source. Although the current raw water supply may seem sufficient, when predicting future water demand, we need to take potential growth into account, as well as fluctuations in current water consumption.

The quality standards of product water should be determined based on the end use. As the purity of product water increases, the production cost also increases accordingly. If the end use does not require the high standard water quality achieved by reverse osmosis (RO) technology, we should consider other more economical treatment methods and incorporate this into the design phase.

We need an in-depth understanding of the chemical composition and characteristics of the water source. When designing any water treatment system, it is necessary to consider its ability to operate under optimal and worst-case conditions. For example, the water temperature and chemical composition of well water are usually relatively constant, and the suspended solids content is low, but each well should be regarded as an independent water source. In contrast, surface water varies greatly; although the dissolved solids content is low, the content of suspended solids, organic matter, and microorganisms may be high. Municipal tap water usually comes from surface water, and its supply status often changes, so the water quality will also fluctuate accordingly.

Retaining the original data of water source quality is crucial because only data obtained through correct sampling and analysis methods is reliable. Sampling containers should be acid-washed, bottle caps should be equipped with plastic gaskets, and sampling points should be set in areas with smooth water flow rather than dead zones. Obtaining samples from a single sampling point is not sufficient; we need to collect a series of samples to cover different seasons and conditions, such as after rain or during droughts. Detailed water quality analysis must be conducted for any potential future water sources.

(5) Pretreatment

After fully understanding the characteristics of the water source, implementing appropriate raw water pretreatment is crucial to ensuring the normal operation of the system. Pretreatment steps usually include clarification or lime softening, as well as the use of multi-stage filters, such as multimedia filters, softeners, activated carbon filters, security filters, and microfiltration filters, which may be followed by ultraviolet (UV) sterilizers to control bacterial growth. Accurate analysis and careful pilot testing help prevent problems caused by improper pretreatment. All pretreatment equipment, including filters and softeners, should be rubber-lined or made of corrosion-resistant materials to reduce the iron ion content in RO and NF feed water.

Experience has shown that a more conservative design approach can usually improve the stability of system operation and enhance adaptability to changes in water quality. Although this design may increase initial investment, it can reduce overall operating costs in the long run. Therefore, considering both investment and operating costs, the higher initial investment brought by conservative design is reasonable. The following table provides reasonable design parameters for common equipment in RO and NF pretreatment processes.

Pretreatment equipment design parameters

Equipment Type	Main Process Parameters (Flow Rate)	Remarks
Clarifier	1.83-2.07m/h	Removes turbidity, suspended solids, and colloids
Multi-medium filter	Surface water 5-8 m/h Groundwater 7-10 m/h	Refined quartz sand and anthracite; reasonable gradation and filling height; required filtration accuracy better than 10μm
Softener	15-25m/h	Requires high-quality regenerant to remove hardness
Activated Carbon Filter	10-15m/h	Refined granular fruit shell activated carbon to remove organic matter and free chlorine

A reasonable pretreatment design should fully consider the membrane cleaning frequency. The standards in the following table will guide you in evaluating the effectiveness of RO and NF pretreatment.

Pretreatment Evaluation Criteria

Cleaning Interval	Pre-treatment Status
More than 3 months	Pre-treatment design and operation management are appropriate
1-3 months	Pre-treatment design may be insufficient or operation management needs improvement
Less than 1 month	Pre-treatment design or operation management must be enhanced

The addition of chemicals has a significant impact on pretreatment. It is necessary to accurately control the dosage of cationic coagulants and flocculants to avoid excess, which may cause these chemicals to remain on the membrane surface and cause pollution. At the same time, the encounter between cationic coagulants and anionic scale inhibitors may produce precipitates, further polluting the membrane elements. If $NaHSO_3$ is used for dechlorination, it should be added in the later stage of the pretreatment process, usually before the security filter, and the pH value during pretreatment must be strictly controlled, as it affects flocculation and sterilization effects.

(6) RO and NF Equipment

In designing RO and NF systems, the selection of membrane type is a crucial step, as the design will vary depending on the selected membrane. There are multiple membrane element suppliers in the market, making it a challenge to select the appropriate membrane. Currently, the selection of membrane materials mainly includes composite membranes and cellulose acetate membranes (CA or CA-CTA). Our mainstream products are TFN nano-composite thin films, which are more commonly used in industrial applications due to their diverse models (such as high flux, high rejection rate, etc.). These membranes have different chemical compositions and materials; under reasonable design, different membrane elements can be used in the same system to meet specific treatment needs. When selecting membrane elements, consultation with manufacturers and engineering companies is recommended to ensure the most suitable membrane element is selected according to the application requirements, as each membrane element has its specific optimal application method and scope.

When designing RO and NF systems, three core operating parameters of membrane elements must be carefully considered:

- Water production of the first membrane element
- Concentrate discharge of the last membrane element
- Recovery efficiency of each membrane element

Water production, i.e., the amount of water permeating per unit area within a certain time, is usually measured in gallons per square foot per day (GPD) or liters per square meter per hour (l/m^2 h).

In the early design stage, computer-aided design software can be used to simulate the system design and predict the system's performance under different operating conditions. Users can save printed copies of the design results. These design tools are very useful for evaluating the performance comparison of different membrane elements under specific conditions.

During design, attention should also be paid to water flow distribution and pressure balance, especially when using high-flux membrane elements. In addition, factors such as the size of the installation space, the convenience of membrane element replacement and cleaning, the elimination of dead zones, the automatic flushing function of the system, the prevention of water loss in standby mode, and soft start protection during startup are all considerations when selecting RO and NF equipment. For high-pressure pipelines, it is recommended to use stainless steel or other corrosion-resistant materials to ensure system durability.

(7) Waste Disposal

When planning RO and NF systems, the treatment of concentrate is an important consideration, especially for large-scale systems with a treatment capacity exceeding 500 cubic meters per hour. Although theoretically, the concentrate produced by RO and NF is only a concentration of raw water, which may seem insignificant, in practice, the concentrate discharge usually accounts for 25% of the total raw water, which is a considerable amount. Therefore, a comprehensive design plan should explore various possible methods for concentrate treatment and reuse to minimize waste and improve water resource utilization efficiency.

(8) Cleaning

As the system operates over time, membrane cleaning becomes a necessary task, and the process should be as simple as possible for operators. Usually, membrane water treatment systems are equipped with a local cleaning system connected to RO and NF equipment through hard pipes or quick connectors, which can serve multiple RO and NF equipment. When selecting a cleaning pump, it is necessary to ensure that its flow rate can meet the needs of each pressure vessel in the first stage, and the higher the turbulence of the cleaning solution, the better the cleaning effect usually is. To improve cleaning efficiency, it is recommended to perform segmented cleaning for multi-stage reverse osmosis systems to address different pollution conditions.

For large-scale water treatment systems, it is recommended to establish an independent single-element cleaning effect evaluation test platform. The reason for this is that when only the membrane elements in the front section of the system are contaminated, unified cleaning of the entire system may cause pollutants eluted from the front section to enter the less contaminated membrane elements in the rear section, thereby reducing overall cleaning efficiency. A single-element cleaning test platform can effectively avoid this situation and can also be used to evaluate the operating performance of each membrane element.

(9) Conclusion

Comprehensive consideration and planning are required before implementing RO (Reverse Osmosis) and NF (Nanofiltration) systems in factories. It is recommended to form a project team, invest sufficient time to fully understand the entire treatment process, and evaluate all technologies that can meet water volume and quality requirements. If it is decided to adopt RO and NF technologies, it is recommended to establish contact with our pre-sales engineers as early as possible to discuss together, ensuring that the RO and NF equipment can operate safely, economically, stably, and reliably for a long time.

Brief Table of Product Application Cases

Industry	Region	User	Feed Water Type	Main Process Flow	Membrane Model
Semiconductor	Jiangsu, China	Well-known Semiconductor Enterprise	RO Concentrate	Pro-BW (Complete Equipment)	Pro-BW8040
	Japan	Listed Japanese Semiconductor Enterprise	Tap Water	UF + Two-Stage Pro-BW + EDI + Two-Stage Degassing + UV-TOC + Two-Stage Polishing + One-Stage Boron Removal (Complete Equipment)	Pro-BW8040
Petrochemical/Coal Chemical	Jiangsu, China	Large-Scale Petrochemical Enterprise	Secondary Circulation Slurry of Ammonia Desulfurization System	Secondary Circulation Slurry of Ammonia Desulfurization System	PSI-AS Series-4040
	Inner Mongolia, China	Large-Scale Coal Coking Enterprise	Ammonia Desulfurization and Coordinated Decarbonization Wastewater	Ammonia Desulfurization and Coordinated Decarbonization Wastewater	NF98-ZK-8040
	Jiangsu, China	A Large National Enterprise Group	Tertiary Circulating Water + Secondary Condensed Water of Ammonia Desulfurization System	Tertiary Circulating Water + Secondary Condensed Water of Ammonia Desulfurization System	NF98-ZK-8040
					PSI-AS Series-4040
					PSI-AS Series-2540
New Energy	Sichuan, China	Leading New Energy Enterprise	Acidic Water	Pretreatment + ProAcid Acid-Resistant Membrane	PSI-AS-8040F34
			Tap water + Reuse	MMF+ACF+Pro-FR	Pro-FR8040
Copper Foil	Guangdong, China	Leading Copper Foil Enterprise	waste water	Copper Water - ACF - One-Stage RO - Two-Stage RO - NF - DC	PSI-NF-8040
	Jiangsu, China	Leading Copper Foil Enterprise	Copper recovery	Pretreatment + Pro-XFR	Pro-XFR8040
Municipal	Jiangsu, China	Large-Scale Full-Industry Chain Water Service Operator	Sewage Treatment Plant Effluent	MMF + ACF + Pro-XFR	Pro-XFR8040
Desalination Plant	Guangdong, China	ZhaoShang Yidun	seawater	Preprocess + Pro-SW	Pro-SW8040
Living Things	Guangdong, China	China Merchants Edinburg	Seawater	Pretreatment + Pro-SW	NF98-ZK-8040
					NF98-ZK-4040
Forging	Shandong, China	Leading Biotechnology Enterprise	Humic Acid	MMF + TFN Membrane + Evaporator (Complete Equipment)	Pro-UNF1000(8040)

Chapter 3. Product Features and Performance Specifications

3-1 RO Membrane Element

Pro-LP Ultra-Low Pressure RO Membrane Element

PSI MEMBRANE® Pro-LP Ultra-Low Pressure Membrane is a third-generation Thin Film Nanocomposite (TFN) RO membrane element. It achieves high flux at ultra-low operating pressure and led to system investment and operating costs.

- Ultra-low operating pressure combined with high salt rejection rate;
- Stable chemical resistance to cleaning ensures long-term operational reliability;
- Excellent anti-fouling performance of TFN surface for long service life;
- TFN membrane flux is generally 30% higher than traditional TFC, with lower energy consumption.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
Pro-LP-4040	99.40	2800 (10.6)	85 (7.9)	34
Pro-LP-8040	99.40	12000 (45.9)	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 150 psi (1.03 MPa), 1500 ppm NaCl, 77 ℉(25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	45℃
Maximum Operating Pressure	600 psi (41 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

Pro-LPHR Ultra-Low Pressure High Salt Rejection RO Membrane Element

PSI MEMBRANE® Pro-LPHR Ultra-Low Pressure High Salt Rejection Membrane is a third-generation Thin Film Nanocomposite (TFN) RO membrane element. It enhances salt rejection performance while maintaining ultra-low operating pressure, thereby reducing system investment and operating costs.

- Ultra-low operating pressure combined with high salt rejection rate;
- Stable chemical resistance to cleaning ensures long-term operational reliability;

- Excellent anti-fouling performance of TFN surface for long service life;
- TFN membrane flux is generally 30% higher than traditional TFC, with lower energy consumption.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
Pro-LPHR-4040	99.55	2500 (9.5)	85 (7.9)	34
Pro-LPHR-8040	99.55	10500 (39.7)	400 (37.2)	34
Pro-LPHR-8040	99.65	12500 (47.3)	440 (40.9)	28

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 150 psi (1.03 MPa), 1500 ppm NaCl, 77 ℉(25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	45℃
Maximum Operating Pressure	600 psi (41 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

Pro-LPFR Ultra-Low Pressure Low-Energy Anti-Fouling RO Membrane Element

PSI MEMBRANE® Pro-LPFR Ultra-Low Pressure Low-Energy Anti-Fouling Membrane is a third-generation Thin Film Nanocomposite (TFN) RO membrane element. It enhances salt rejection performance while maintaining ultra-low operating pressure, thereby reducing system investment and operating costs.

- Ultra-low operating pressure combined with high salt rejection rate;
- Stable chemical resistance to cleaning ensures long-term operational reliability;
- Excellent anti-fouling performance of TFN surface for long service life;
- TFN membrane flux is generally 30% higher than traditional TFC, with lower energy consumption.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
Pro-LPFR-4040	99.55	2500 (9.5)	85 (7.9)	34
Pro-LPFR-8040	99.55	10500 (39.7)	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 150 psi (1.03 MPa), 1500 ppm NaCl, 77 ℉(25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	45℃
Maximum Operating Pressure	600 psi (41 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

Pro-FR Anti-Fouling Brackish Water RO Membrane Element

PSI MEMBRANE® Pro-FR Anti-Fouling Brackish Water RO Membrane adopts a proprietary composite membrane. The unique anti-fouling membrane technology endows it with excellent anti-fouling ability and cleanability, ensuring good salt rejection performance while reducing energy consumption and extending cleaning cycles.

- Reduces chemical cleaning frequency and chemical dosage while extending membrane service life;
- Lowers energy consumption, with energy savings of up to 30% at the same permeate flow;
- Widest pH tolerance range, significantly limiting the growth space of microorganisms.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
Pro-FR-4040	99.60	2400 (9.1)	85 (7.9)	34
Pro-FR-8040	99.60	11000 (41.6)	400 (37.2)	34
Pro-FR-8040	99.60	12500 (47.3)	440 (40.9)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 225 psi (1.55 MPa), 2000 ppm NaCl, 77 ℉(25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	45℃
Maximum Operating Pressure	600 psi (41 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

Pro-XFR Extreme Anti-Fouling Brackish Water RO Membrane Element

PSI MEMBRANE® Pro-XFR Extreme Anti-Fouling Brackish Water Membrane is a third-generation Thin Film Nanocomposite (TFN) RO membrane element. Enhanced anti-fouling technology endows it with excellent anti-fouling ability and cleanability, ensuring high salt rejection performance while reducing energy consumption and extending cleaning cycles. It can perfectly replace anti-fouling brackish water membranes such as DuPont BW30XFR and Suez AG8040F.

- Wide flow channel reduces membrane fouling probability and improves cleaning efficiency;
- Industry's widest pH cleaning range (1-13) and good chemical resistance, providing the most effective cleaning performance, stability, and durability;
- Excellent anti-fouling performance of TFN surface for long service life;
- TFN membrane flux is generally 30% higher than traditional TFC, with lower energy consumption.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
Pro-XFR-4040	99.70	2500 (9.5)	85 (7.9)	34
Pro-XFR-8040	99.70	12000 (45.9)	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 225 psi (1.55 MPa), 2000 ppm NaCl, 77 ℉(25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	45℃
Maximum Operating Pressure	600 psi (41 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

Pro-XFRHR High Salt Rejection Extreme Anti-fouling Brackish Water RO Membrane Element

PSI MEMBRANE® Pro-XFRHR High Salt Rejection Extreme Anti-Fouling Brackish Water Membrane is a third-generation Thin-Film Nanocomposite (TFN) RO membrane element. Unique anti-fouling membrane technology endows it with excellent anti-fouling ability and cleanability, ensuring high salt rejection performance while reducing energy consumption and extending cleaning cycles. It can perfectly replace high salt rejection anti-fouling brackish water membranes such as Toray TML.

- Wide flow channel reduces membrane fouling probability and improves cleaning efficiency;

- Industry's widest pH cleaning range (1-13) and good chemical resistance, providing the most effective cleaning performance, stability, and durability;
- Excellent anti-fouling performance of TFN surface for long service life;
- TFN membrane flux is generally 30% higher than traditional TFC, with lower energy consumption.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
Pro-XFRHR-4040	99.80	2500 (9.5)	85 (7.9)	31
Pro-XFRHR-8040	99.80	11000 (41.6)	400 (37.2)	31

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 225 psi (1.55 MPa), 2000 ppm NaCl, 77 ℉(25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	50℃
Maximum Operating Pressure	600 psi (41 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

Pro-BW Brackish Water RO Membrane Element

PSI MEMBRANE® Pro-BW Brackish Water Membrane is a third-generation Thin-Film Nanocomposite (TFN) RO membrane element. Unique anti-fouling membrane technology endows it with excellent anti-fouling ability and cleanability, ensuring high salt rejection performance while reducing energy consumption and extending cleaning cycles.

- Stable chemical resistance to cleaning ensures long-term operational reliability;
- Excellent anti-fouling performance of TFN surface for long service life;
- TFN membrane flux is generally 30% higher than traditional TFC, with lower energy consumption.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
Pro-BW-4040	99.50	2600 (9.8)	85 (7.9)	34
Pro-BW-8040	99.50	10500 (39.7)	400 (37.2)	34
Pro-BW-8040	99.50	12500 (47.3)	440 (40.9)	28

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 225 psi (1.55 MPa), 2000 ppm NaCl, 77 ℉(25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	45℃
Maximum Operating Pressure	600 psi (41 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

Pro-SWHR High Rejection Seawater Desalination RO Membrane Element

PSI MEMBRANE® Pro-SWHR High Rejection Seawater Desalination Membrane is a third-generation Thin-Film Nanocomposite (TFN) RO membrane element. Unique anti-fouling membrane technology endows it with excellent anti-fouling ability and cleanability, ensuring high salt rejection performance while reducing energy consumption and extending cleaning cycles.

- Wide flow channel reduces membrane fouling probability and improves cleaning efficiency;
- Stable chemical resistance to cleaning ensures long-term operational reliability;
- Excellent anti-fouling performance of TFN surface for long service life;
- TFN membrane flux is generally 30% higher than traditional TFC, with lower energy consumption.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
Pro-SWHR-2521	99.85	300 (1.1)	13 (1.2)	34
Pro-SWHR-2540	99.85	700 (2.7)	28 (2.6)	34
Pro-SWHR-4021	99.85	800 (3.0)	33 (3.1)	34
Pro-SWHR-4040	99.85	2300 (8.7)	90 (8.4)	34
Pro-SWHR-8040	99.85	7500 (28.3)	400 (37.2)	28
Pro-SWHR-8040	99.85	9000 (34.1)	440 (40.9)	28

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 800 psi (5.52 MPa), 32000 ppm NaCl, 77 ℉(25 ℃), 8% recovery.
2. Permeate flow rate varies by +/-20%.

Maximum Operating Temperature	45℃
Maximum Operating Pressure	1200 psi (83 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

1. Maximum operating temperature is related to operating pressure and pH value;
2. Maximum operating pressure is related to feed water temperature and pH. If the feed water temperature exceeds 35℃ or the feed water pressure exceeds 69 bar, please consult the service personnel;
3. Continuous operating pH limit is related to feed water temperature and operating pressure.

Pro-SW High Flux Seawater Desalination RO Membrane Element

PSI MEMBRANE® Pro-SW High Flux Seawater Desalination Membrane is a third-generation Thin-Film Nanocomposite (TFN) high-pressure high salt rejection RO membrane element. Unique anti-fouling membrane technology endows it with excellent anti-fouling ability and cleanability, ensuring high salt rejection performance while reducing energy consumption and extending cleaning cycles.

- Wide flow channel reduces membrane fouling probability and improves cleaning efficiency;
- Stable chemical resistance to cleaning ensures long-term operational reliability;
- Excellent anti-fouling performance of TFN surface for long service life;
- TFN membrane flux is generally 30% higher than traditional TFC, with lower energy consumption.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
Pro-SW-8040	99.80	11000 (41.5)	440 (40.9)	28

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 800 psi (5.52 MPa), 32000 ppm NaCl, 77 ℉(25 ℃), 8% recovery.
2. Permeate flow rate varies by +/-20%.

Maximum Operating Temperature	45℃
Maximum Operating Pressure	1200 psi (83 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

1. Maximum operating temperature is related to operating pressure and pH;
2. Maximum operating pressure is related to feed water temperature and pH. If the feed water temperature exceeds 35℃ and/or the feed water pressure exceeds 69 bar, please consult the service personnel;
3. Continuous operating pH limit is related to feed water temperature and operating pressure.

PX High-Salinity Brine Concentration Membrane Element

PSI MEMBRANE® PX High-Salinity Brine Concentration Membrane is a third-generation Thin-Film Nanocomposite (TFN) high-pressure RO membrane element. It provides reliable and efficient technical solutions for industrial users, helping to solve difficult water treatment problems, assist in wastewater reuse and zero-discharge projects to reduce the amount of concentrated water, reduce the amount of salt water in subsequent thermal processes such as evaporation, and optimize the operating cost of zero-discharge systems. They can perfectly replace high-multiple concentration reverse osmosis membranes such as XC70 and XC80.

- Upgraded chemical-resistant membrane formula ensures long-term reliability and improves cleaning efficiency;
- Professional and efficient national-level expert team provides first-class technical support for customers;
- Super hydrophilic anti-fouling technology ensures long-term operational reliability;
- Within the normal operating ultra-high pressure boundary conditions of organic membranes, PX170 can concentrate the concentrated water TDS to >170000 ppm; PX180 can concentrate the concentrated water TDS to >180000 ppm.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
PX170-8040	99.75	8800 (33.3)	400 (37.2)	34
PX180-8040	99.50	9000 (34.1)	440 (40.9)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 800 psi (5.52 MPa), 32000 ppm NaCl, 77 ℉(25 ℃), 5% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	45℃
Maximum Operating Pressure	1200 psi (83 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

1. Maximum operating temperature is related to operating pressure and feed water pH. If the feed water pH is higher than 10, please consult the service personnel;
2. Maximum operating pressure is related to feed water temperature. If the feed water temperature exceeds 30℃, please consult the service personnel.

PX Ultra-High Pressure Membrane Element

PSI MEMBRANE® PX Ultra-High Pressure Membrane is a third-generation Thin-Film Nanocomposite (TFN) high-pressure RO membrane element.It provides reliable and efficient technical solutions for industrial users, helping to solve difficult water treatment problems, assist in wastewater reuse and zero-discharge projects to reduce the amount of concentrated water, reduce the amount of salt water in subsequent thermal processes such as evaporation, and optimize the operating cost of zero-discharge systems.

- Upgraded membrane chemical formula ensures long-term pressure resistance reliability;
- Professional and efficient national-level expert team provides first-class technical support for customers;
- Super hydrophilic anti-fouling technology ensures long-term operational reliability;
- Special membrane sheet and membrane element design can withstand ultra-high feed water pressure of 120 bar.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
PX120-8040	99.70	7400 (28.0)	330 (30.6)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 800 psi (5.52 MPa), 32000 ppm NaCl, 77 ℉(25 ℃), 5% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	45℃
Maximum Operating Pressure	1740 psi (120 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	2-11
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

1. Maximum operating temperature is related to operating pressure;
2. Maximum operating pressure is related to feed water temperature. If the feed water temperature exceeds 30℃, please consult the service personnel.

3-2 Loose NF / Compact UNF Membrane Element

PSI MEMBRANE® UNF series of Loose NF or Compact UNF Membrane element incorporating innovative Thin Film Nanocomposite (TFN) technology, the UNF series features nano-level, ultra-thin hydrophilic coating technology that offers excellent anti-fouling performance. These membranes deliver flux rates four times higher than traditional TFC membranes while operating at least 50% lower pressure. They are the perfect replacement for conventional TFC membranes.

- Offers multiple precise cutting molecules, tailored to meet specific customer requirements;
- Maximum flux up to four times that of imported competitors, significantly reducing energy consumption and engineering budget;
- Superior Selective Separation:Boasts ultra-high selectivity, effectively removing most colloidal iron, colloidal silicon, humic acid, and other dissolved organic matter (DOM) while allowing the passage of inorganic single and bivalent ions;
- Widely used in dye removal or concentration, heavy metal removal, acid purification, sodium chloride diafiltration, sugar concentration and fractionation, whey protein concentration and desalination, peptide concentration and desalination, etc.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2 (m^2)	Feed Spacer Thickness (mil)
UNF500-8040	95	7400 (28.0)	400 (37.2)	34
UNF1000-8040	95	7400 (28.0)	400 (37.2)	34
UNF2000-8040	95	7400 (28.0)	400 (37.2)	34
UNF3000-8040	95	8000 (30.3)	400 (37.2)	34
UNF5000-8040	95	16000 (60.6)	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: pure water with a conductivity of less than 10 μS/cm, a 200 ppm solution of polyethylene glycol (PEG) with the corresponding molecular weight cut-off (e.g., UNF2000 corresponds to a PEG molecular weight cut-off of 2000Da), 70 psi (0.48MPa), 77 ℉(25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

3-3 NF Membrane Element

NF98 series NF Membrane Elements adopt PSI® proprietary multi-layer composite membrane. Nano-level and ultra-thin hydrophilic coating technology endows excellent anti-fouling ability.These membranes deliver twice the flux of traditional TFC membranes and operate at least 50% lower pressure, making them a superior replacement for NF270, XC-N, DL, DK, and other traditional TFC membranes.

- NF98 membrane surface is super hydrophilic, with excellent anti-fouling performance and long service life;
- NF98 membrane flux is generally 30% higher than traditional TFC, and some models even have up to 2 times the flux, resulting in significant energy reduction;
- High rejection rate of divalent salts >98% (sulfate, iron, heavy metals, etc.), and allows monovalent salts to pass through;
- High Removal of Organic Compounds such as pesticides, herbicides, antibiotics, and THM precursors, etc.

Product	Model	Rejection rate of Bivalent Salt ion (%)	Rejectionrate of Monovalent salt ion (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)
High Flux Nanofiltration Membrane	NF98-HF-4040	96	30-50	2800 (10.6)	85 (7.9)	34
	NF98-HF-8040	96	30-50	13800 (52.2)	400 (37.2)	34
Salt Fractionation Nanofiltration Membrane	NF98-SP-4040	99	30-50	2500 (9.5)	85 (7.9)	34
	NF98-SP-8040	99	30-50	12500 (47.3)	400 (37.2)	34
High Rejection Nanofiltration Membrane	NF90-4040	99	85-90	1850 (7.0)	85 (7.9)	34
	NF90-8040	99	85-90	9100 (34.4)	400 (37.2)	34
Customized Nanofiltration Membrane	NF98-SPEC-4040	Customized	Customized	-	85 (7.9)	34
	NF98-SPEC-8040	Customized	Customized	-	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 70 psi (0.48 MPa), 2000 ppm $MgSO_4$, 77 ℉(25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

3-4 Specialty Membrane Element

Pro-Acid Specialty Acid Resistant Membrane Element

PSI MEMBRANE® Pro-Acid Specialty Acid Resistant Membrane incorporating innovative Thin-Film Nanocomposite (TFN) acid-resistant membrane sheets and unique acid-resistant materials. They have anti-fouling, high flux, high pressure resistance, and extreme acid resistance properties. They can achieve metal concentration in acidic solutions such as sulfuric acid below 20% and phosphoric acid below 30%, and can also be used for acid purification and recovery. They are suitable for removing large molecular impurities in acid solutions and can maintain high flux and stable operation for more than 12 months in strong acid environments.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)
Pro-Acid-NF98-8040	98	12000 (45.4)	400 (37.2)	34
Pro-Acid-NF96-8040	96	18000 (68.1)	400 (37.2)	34
Pro-Acid-NF92-8040	92	22000 (83.2)	400 (37.2)	34
Pro-Acid-NF80-8040	80	24000 (90.8)	400 (37.2)	34
Pro-Acid-NF35-8040	35	36000 (139.5)	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 580 psi (4.01 MPa), 2000 ppm $MgSO_4$, 77 ℉ (25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	50℃
Maximum Operating Pressure	1200 psi (83 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	0-12
Cleaning pH Range	0-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

PSI-Acid Specialty Acid Resistant Membrane Element

PSI MEMBRANE® PSI-Acid Specialty Acid Resistant Membrane incorporating innovative Thin-Film Nanocomposite (TFN) acid-resistant membrane sheets and unique acid-resistant materials. They have anti-fouling, high flux, high pressure resistance, and good acid resistance properties. They can achieve metal concentration in acidic solutions as low as pH1, and can also be used for acid purification and recovery. They are suitable for removing large molecular impurities in acid solutions and can operate stably in acidic environments for more than 12 months.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)
PSI-Acid-NF98-8040	98	9000 (34.1)	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 580 psi (4.01 MPa), 2000 ppm $MgSO_4$, 77 ℉ (25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	50℃
Maximum Operating Pressure	1200 psi (83 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	1-10
Cleaning pH Range	0-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

PSI-AS Ammonium Sulfate Acid-Resistant Membrane Elements

The Ammonium Sulfate Acid-Resistant Membrane Elements are proprietary membrane elements specially developed by the PSI Team for projects involving ammonium sulfate wastewater (such as ammonium phosphate iron production, desulfurization wastewater, ammonia removal wastewater, etc.). They feature fouling resistance, high flux, high pressure resistance, and excellent acid resistance. These elements enable high-concentration concentration of acidic ammonium sulfate solutions, providing a reliable and efficient technical solution for treating this type of wastewater. They help address challenging water treatment problems, facilitate wastewater reuse and zero-liquid discharge (ZLD) projects by reducing the volume of concentrated water, decreasing the brine volume for downstream thermal processes such as evaporation, and optimizing the operating costs of ZLD systems.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft2(m^2)	Feed Spacer Thickness (mil)
PSI-AS-8040	99.5	9000 (34.1)	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 580 psi (4.01 MPa), 2000 ppm $MgSO_4$, 77 ℉ (25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	50℃
Maximum Operating Pressure	1200psi (83bar) / 1740psi (120bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	1-10
Cleaning pH Range	1-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

Pro-Base Specialty Alkali Resistant Membrane Element

PSI MEMBRANE® Pro-Base Specialty Alkali Resistant Membrane incorporating innovative Thin-Film Nanocomposite (TFN) alkali-resistant membrane sheets and unique alkali-resistant materials. They have anti-fouling, high flux, high pressure resistance, and extreme alkali resistance properties. They can achieve concentration of cellulose, hemicellulose, papermaking fibers, and other compounds in alkaline solutions such as sodium hydroxide below 20% and potassium hydroxide below 10%, and can also be used for alkali purification and recovery. They can maintain high flux and stable operation for more than 12 months in strong alkali environments.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft2(㎡)	Feed Spacer Thickness (mil)
Pro-Base-NF98-8040	98	13000 (49.2)	400 (37.2)	34
Pro-Base-NF96-8040	96	19500 (73.8)	400 (37.2)	34
Pro-Base-NF92-8040	92	24000 (91.0)	400 (37.2)	34
Pro-Base-NF80-8040	80	26000 (98.4)	400 (37.2)	34
Pro-Base-NF35-8040	35	39000 (147.6)	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 580 psi (4.01 MPa), 2000 ppm $MgSO_4$, 77 ℉ (25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	60℃
Maximum Operating Pressure	1200 psi (83 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	3-14
Cleaning pH Range	2-14
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

PSI-Base Specialty Alkali Resistant Membrane Element

PSI MEMBRANE® PSI-Base Specialty Alkali Resistant Membrane incorporating innovative Thin-Film Nanocomposite (TFN) alkali-resistant membrane sheets and unique alkali-resistant materials. They have anti-fouling, high flux, high pressure resistance, and good alkali resistance properties. They can achieve concentration of cellulose, hemicellulose, papermaking fibers, and other compounds in alkaline solutions of pH 12, and can also be used for alkali purification and recovery. They can maintain high flux and stable operation for more than 12 months in alkaline environments.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)
PSI-Base-NF98-8040	98	13000 (49.2)	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: operating pressure of 580 psi (4.01 MPa), 2000 ppm $MgSO_4$, 77 ℉ (25 ℃), 15% recovery.
2. Permeate flow rate varies by +/-15%.

Maximum Operating Temperature	60℃
Maximum Operating Pressure	1200 psi (83 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	3-12
Cleaning pH Range	2-13
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

Pro-Therm Specialty High Temperature Resistant Membrane Element

PSI MEMBRANE® Pro-Therm Specialty High Temperature Resistant Membrane incorporating innovative Thin-Film Nanocomposite (TFN) high-temperature resistant membrane sheets and unique high-temperature resistant materials. These elements are ideal for hot water disinfection systems, replacing chemical disinfection to enhance product quality and meet regulatory standards. They are suitable for water purification or process fluid systems with low cross-flow environments, no suspended solids, and a maximum temperature of 70℃ (158℉), and can be used for concentrating high-temperature process fluids. Typical applications include concentration, purification, and separation of high dissolved solids fluids that are difficult to use membrane processes due to high viscosity at lower temperatures.

Product	Stabilized Salt Rejection (%)	Permeate Flow Rate (m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)
Pro-Therm-RO1-8040	98	9000 (34.1)	400 (37.2)	34
Pro-Therm-NF98-8040	98	6000 (22.7)	400 (37.2)	34
Pro-Therm-NF96-8040	96	9000 (34.1)	400 (37.2)	34
Pro-Therm-NF92-8040	92	11000 (41.6)	400 (37.2)	34
Pro-Therm-NF80-8040	80	12000 (45.4)	400 (37.2)	34
Pro-Therm-NF35-8040	35	18000 (69.8)	400 (37.2)	34

1. Permeate flow rate and stabilized salt rejection were based on the following standard test conditions (before any hot water disinfection):

For RO membrane——operating pressure of 225 psi (1.55 MPa), 2000 ppm NaCl, 77 ℉ (25 ℃), 15% recovery.

For NF membrane——operating pressure of 70 psi (0.48 MPa), 2000 ppm $MgSO_4$, 77 ℉ (25 ℃), 15% recovery;

2. Permeate flow rate varies by +/-15%, and the final water yield may fluctuate more due to the heat treatment process.

Maximum Operating Temperature (Disinfection temperature)	70℃ (90℃)
Maximum Operating Pressure	1200 psi (83 bar)
Maximum Pressure Drop	1 bar
Continuous Operating pH Range	3-10
Cleaning pH Range	1-12
The largest water SDI_{15}	5
Maximum influent turbidity	1 NTU
Maximum residual chlorine concentration of influent	＜0.1 ppm

Pro-CR Specialty Oxidation Resistant Membrane Element

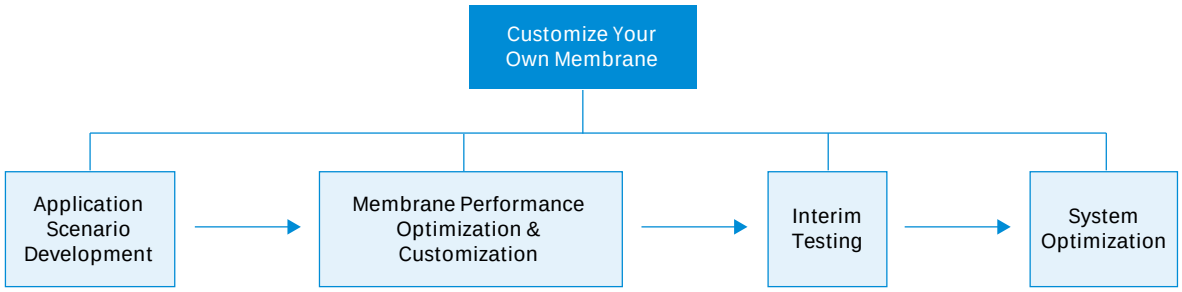
PSI MEMBRANE® Pro-CR Specialty Oxidation Resistant Membrane incorporating innovative Thin-Film Nanocomposite (TFN) oxidation resistant membrane sheets and unique oxidation resistant materials, is specifically designed for water containing oxidizing agents. This design eliminates the need for reducing agents in the system, enhancing efficiency and reducing chemical usage. They are suitable for water purification or process fluid systems that require efficient oxidants for chemical cleaning and can be used for concentrating process fluids. Typical applications include municipal nanofiltration water treatment plants, rural decentralized water supply, industrial wastewater resource recycling, etc.

Product	Stabilized Salt Rejection (%)	Antioxidant Capacity (ppmh)	Permeate Flow Rate (m^3/d)	Active Area ft^2(m^2)	Feed Spacer Thickness (mil)
Pro-CR-RO1-8040	98	＞500000	12500 (47.3)	400 (37.2)	34
Pro-CR-NF1-8040	98	＞500000	7800 (29.5)	400 (37.2)	34
Pro-CR-NF2-8040	96	＞500000	9200 (34.8)	400 (37.2)	34
Pro-CR-NF3-8040	92	＞500000	12800 (48.4)	400 (37.2)	34
Pro-CR-NF4-8040	80	＞500000	15000 (56.8)	400 (37.2)	34

1.Permeate flow rate and stabilized salt rejection were based on the following standard test conditions: NF membrane (2000ppm MgSO4, 0.48 MPa, 25℃,15% recovery), RO membrane (2000ppm NaCl solution, 1.55 MPa, 25℃,15% recovery) before any hot water disinfection.

2. The variation range of permeate flow rate is +/-15%, and the final water yield may fluctuate more due to the heat treatment process.

3-5 SPEC Customized Membrane



As a high-tech enterprise dedicated to the development of a new generation of special high-end nano composite film membranes, our company continuously researches and develops new generation TFN membranes with various special properties to meet the application needs of different industries.

Compared with the traditional TFC membrane, in addition to the advantages of high throughput, low operating pressure, anti-pollution and chemical cleaning resistance, the biggest advantage of Proshare TFN membrane is that it can provide a full range of customized development services and professional solutions from diaphragm to membrane element to membrane system, compared with both international brand membrane manufacturers and domestic membrane manufacturer.

Chapter 4. Fundamentals of Reverse Osmosis and Nanofiltration

4-1 History of Reverse Osmosis and Nanofiltration Technology

Since the late 1950s and early 1960s, when reverse osmosis (RO) and nanofiltration (NF) technology products were commercialized and launched on the market, initially, reverse osmosis was mainly used for desalination of seawater and brackish water. Due to the increasing demand in the industrial field for protecting water sources, reducing energy consumption, controlling pollution, and recovering valuable substances from wastewater, new applications of reverse osmosis and nanofiltration have become more economically valuable. In addition, with the development of membrane separation technology, it has promoted technological progress in the biotechnology and pharmaceutical industries. Compared with traditional distillation methods, membrane separation and concentration technology saves more energy consumption and does not cause thermal decomposition and deterioration of products.

Since then, existing products have been continuously improved, and new products have been continuously launched, which have improved the quality of water produced by membrane elements and reduced the total cost of water treatment.

Nowadays, reverse osmosis membranes can achieve higher salt rejection rates and water production under the condition of significantly reducing operating pressure, and nanofiltration membranes can also provide higher separation selectivity for certain salts or compounds under relatively low operating pressure.

At present, conventional filtration processes can be classified according to the size of the particles to be removed. Traditional filtration of suspended solids is achieved by water flowing vertically through the filter medium, and all the water volume completely passes through the filter medium and becomes effluent flowing out of the system. Similar filtration processes include: cartridge filtration, bag filtration, sand filtration and multi-media filtration. This form of large-particle filtration is only effective for insoluble solid particles with a particle size greater than 1μm.

In order to remove smaller particles and soluble salts, cross-flow membrane filtration must be used. Cross-flow membrane filtration applies pressure to the fluid to be treated that is parallel to the membrane surface, and part of the fluid passes through the membrane surface. Particles in the fluid are excluded in the concentrated water. Since the fluid continuously flows through the membrane surface, the excluded particles will not accumulate on the membrane surface, but are carried away from the membrane surface by the concentrated water. Therefore, one stream of fluid is turned into two streams of fluid, namely permeate and concentrate.

4-2 Classification of Filtration Processes

Conventional filtration can be divided into cartridge filtration, bag filtration, sand filtration and multi-media filtration according to the size of the particles to be removed, which are effective for particles larger than 1μm. Microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) belong to membrane-based liquid separation technologies, and their filtration accuracy increases in sequence.

- **Microfiltration (MF)**: Retains particles of 0.1～1μm, allows macromolecular organics and soluble solids to pass through, blocks suspended solids, bacteria, etc., with a general operating pressure difference of 0.7bar;

- **Ultrafiltration (UF)**: Retains particles of 0.002～0.1μm, allows small molecular substances and soluble solids to pass through, blocks colloids, proteins, etc., with an operating pressure difference of 1～7bar;

- **Nanofiltration (NF)**: Retains substances of about 1nm, with an operating range between ultrafiltration and reverse osmosis. It retains organics with a molecular weight of about 200～400, and has a 20～98% ability to retain soluble salts. The operating pressure is 3.5～16bar, which is used to remove organics and chroma from surface water;

- **Reverse Osmosis (RO)**: The most precise membrane-based liquid separation technology, which can block all soluble salts and organics with a molecular weight greater than 100, and has a high salt rejection rate. It is widely used in desalination of seawater and brackish water, etc. The operating pressure varies according to the type of feed water.

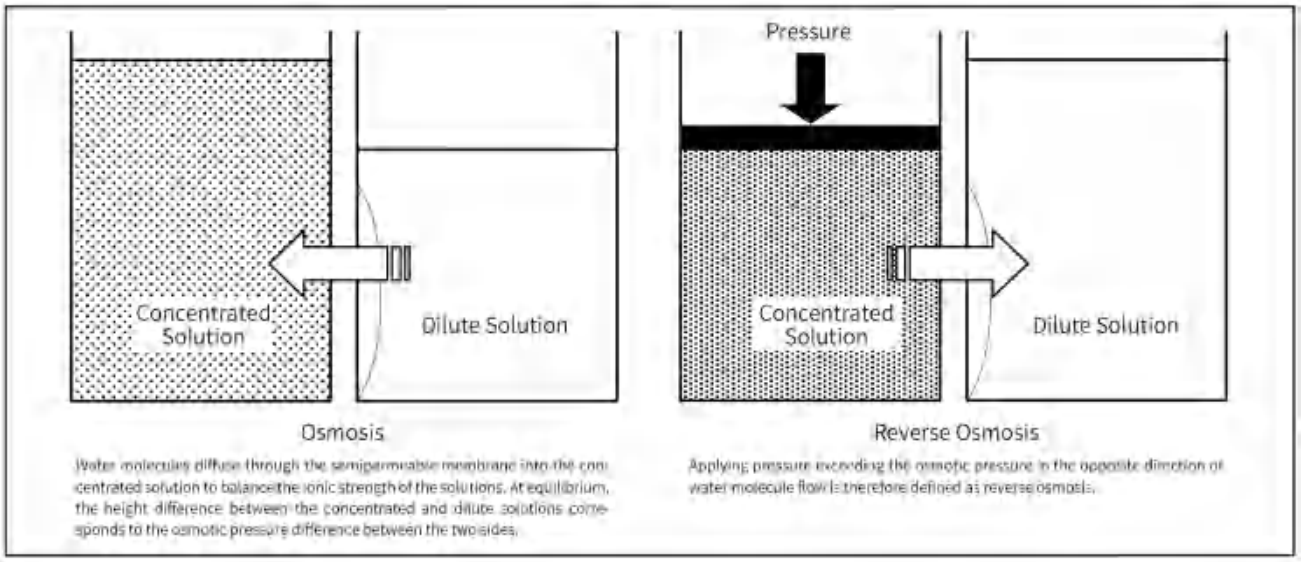
4-3 Principles of Reverse Osmosis and Nanofiltration

- **Osmosis and Osmotic Pressure**: Osmosis is a phenomenon where the solvent (water molecules) in a dilute solution spontaneously passes through a semipermeable membrane and flows into a concentrated solution. Osmotic pressure is the liquid column pressure formed when the liquid level on the concentrated solution side rises to a certain extent, which counteracts the migration of solvent molecules and balances the osmosis process.

- **Reverse Osmosis Principle**: An operating pressure higher than the natural osmotic pressure is applied on the feed water (concentrated solution) side to reverse the natural osmosis direction of water molecules, and part of the water molecules in the feed water pass through the membrane to become purified product water on the dilute solution side.

- **Nanofiltration Principle**: Nanofiltration membranes do not perfectly block soluble salts or solutes. The permeability of solutes through nanofiltration membranes depends on the type of salts or solutes and nanofiltration membranes. The lower the permeability, the higher the osmotic pressure on both sides of

the nanofiltration membrane, and the closer it is to the reverse osmosis process; the higher the permeability, the lower the osmotic pressure, and the smaller the impact on the nanofiltration process.



4-4 Factors Affecting the Performance of RO and NF Membrane

Water flux and rejection rate are key parameters in the reverse osmosis and nanofiltration processes, which are mainly affected by pressure, temperature, recovery rate, feed water salt content and pH value.

1. Definitions:

- **Recovery Rate**: The percentage of feed water converted into product water in the membrane system, which is affected by the preset feed water quality. The concentrated water valve can adjust the recovery rate, but it is necessary to avoid supersaturation and precipitation of salts.

- **Salt Rejection Rate and Salt Permeation Rate**: The salt rejection rate is the percentage of the total concentration of soluble impurities removed, and the salt permeation rate is the opposite value, that is, the percentage of soluble impurities passing through the membrane.

- **Flow Rate and Flux**: The feed water flow rate and concentrated water flow rate refer to the flow rate entering the membrane element and the flow rate not passing through the membrane, respectively. Flux refers to the flow rate of permeate per unit membrane area.

- **Dilute Solution and Concentrated Solution**: The dilute solution is the purified product water, and the concentrated solution is the concentrated water that does not pass through the membrane.

2. Influencing Factors:

- **Pressure**: The feed water pressure affects the water flux and salt rejection rate. Increasing the pressure can increase the water flux and salt rejection rate, but the salt rejection rate no longer increases after reaching a certain level.

- **Temperature**: As the water temperature rises, the water flux increases almost linearly, but the salt rejection rate decreases or the salt permeation rate increases.
- **Salt Concentration**: With the increase of salt concentration, the osmotic pressure increases, which counteracts the feed water driving force, resulting in a decrease in water flux and an increase in salt permeation.
- **Recovery Rate**: With the increase of recovery rate, the salt content in the raw water becomes higher, the osmotic pressure increases, which counteracts the feed water pressure, and the flux decreases.
- **pH Value**: Different membrane elements have different applicable pH ranges, please refer to Proshare's technical documents.

Chapter 5. Water Chemistry and Pretreatment

5-1 Introduction

To improve the efficiency of reverse osmosis (RO) and nanofiltration (NF) membrane systems, effective pretreatment of raw water is required. Based on design parameters such as raw water quality and system recovery rate, selecting an appropriate pretreatment process can reduce fouling, scaling, and membrane degradation, optimize system performance, and achieve the optimization of water production, desalination rate, recovery rate, and operating costs.

- **Fouling**: Refers to the deposition of organic matter and colloids on the membrane surface.
- **Scaling**: Refers to the precipitation of certain salts on the membrane surface when their concentrations exceed their solubility products, such as calcium carbonate, barium sulfate, calcium sulfate, etc.
- **Membrane Degradation**: Refers to the attenuation of membrane element performance.

Pretreatment must consider the continuous and reliable operation of the system. For example, unreasonable design or operation of coagulation and clarification tanks will increase the load on sand filters or multimedia filters, leading to frequent membrane cleaning, increased costs and downtime, and reduced system performance.

The pretreatment scheme depends on the water source, raw water composition, and application conditions, especially the water source. Well water has stable quality and low pollution risk, requiring only simple pretreatment such as acid addition, scale inhibitor addition, and a 5μm security filter. Surface water is affected by seasons and is susceptible to microbial and colloidal pollution, requiring complex pretreatment including chlorination disinfection, flocculation/coagulation aid, clarification, multimedia filtration, dechlorination, acid addition, or scale inhibitor addition. Industrial and municipal wastewater has complex components, and certain organic substances can affect RO/NF membranes, requiring more comprehensive pretreatment.

After determining the influent water source, a comprehensive and accurate full analysis of raw water must be conducted to develop an appropriate pretreatment scheme and RO/NF system design. Different industries have different requirements for the type and complexity of RO/NF pretreatment; for example, the pretreatment in the electronics industry is more complex and stringent than that in the municipal water treatment industry.

5-2 Raw Water Types and Water Quality

Raw water entering RO/NF pretreatment systems is classified by total dissolved solids (TDS) and total organic carbon (TOC) content as follows:

- **Low-salinity high-purity water**: From the polishing stage of primary RO product water or ultrapure water systems, with TDS not exceeding 50mg/L.
- **Low-salinity tap water**: TDS less than 500mg/L.
- **Medium-low salinity groundwater**: Low natural organic matter content, TDS less than 5000mg/L.
- **Medium salinity brackish water**: TDS less than 5000mg/L.
- **Medium salinity tertiary wastewater**: High TOC and BOD content, TDS less than 5000mg/L.
- **High salinity brackish water**: TDS between 5000-15000mg/L.
- **Seawater**: TDS approximately 35000mg/L.

1. Seawater

The salt content of standard seawater is usually 35000mg/L, and the salt content and ion composition ratio of most seawater worldwide are similar. However, the total TDS of actual seawater varies widely, from 7000mg/L in the Baltic Sea to 45000mg/L in the Red Sea and Persian Gulf. In addition, the salt content and composition of coastal well water are significantly affected by soil and inland water infiltration.

Table 1. Ionic Composition of Standard Seawater

Ion	Concentration (mg/L)	Ion	Concentration (mg/L)
Calcium (Ca)	410	Sulfate (SO_4^{2-})	2740
Magnesium (Mg)	1310	Fluoride (F^-)	1.4
Sodium (Na)	10900	Bromide (Br^-)	65
Potassium (K)	390	Nitrate (NO_3^-)	< 0.7
Barium (Ba)	0.05	Bicarbonate(HCO_3^-)	152
Strontium (Sr)	13	Boron (B)	4 ~ 5
Iron (Fe)	< 0.02	Other Items	
Manganese (Mn)	< 0.01	TDS	35000mg/L
Silicon (SiO_2)	0.04 ~ 8	pH	8.1
Chloride (Cl^-)	19700		

Note: Some physical and chemical properties of seawater with different salt contents are shown in Tables 2 and 3.

Table 2. Inorganic Ion Composition of Seawater with Different Salt Contents

Seawater	K (ppm)	Na (ppm)	Mg (ppm)	Ca (ppm)	HCO_3 (ppm)	Cl (ppm)	SO_4 (ppm)	SiO_2 (ppm)
Standard Seawater-32,000ppm	354	9854	1182	385	130	17742	2477	0.9
Standard Seawater-35,000ppm	387	10778	1293	421	142	19406	2710	1.0
Standard Seawater-36,000ppm	398	11086	1330	433	146	19960	2787	1.0
Standard Seawater-38,000ppm	419	11663	1399	456	154	20999	2932	1.0
Standard Seawater-40,000ppm	441	12278	1473	480	162	22105	3086	1.1
Standard Seawate-45,000ppm	496	13812	1657	539	182	24868	3472	1.2
Standard Seawate-50,000ppm	551	15347	1841	599	202	27633	3858	1.4

Table 3. Relationship Between Seawater Salt Content and Conductivity

Location	Salt Content TDS (ppm)	Conductivity K (μS/cm)	Ratio K/TDS (μS/cm.ppm)
South Pacific	< 36000	< 51660	1.43-1.44
Gran Canaria (Atlantic Ocean)	37600	53280	1.42
Sardinia (Middle East)	40800	57240	1.40
Bahrain	42500	59350	1.40
Egypt (Red Sea)	44000	62990	1.38

When designing and operating seawater desalination pretreatment and reverse osmosis systems, the characteristics of seawater must be considered. The high salinity of seawater leads to high osmotic pressure. To avoid membrane element overpressure, reduce energy consumption, and decrease salt and boron content in the product water, the recovery rate of seawater desalination systems is usually controlled between 40% and 50%. In addition, if a seawater desalination system taking surface water has no anti-biological pollution measures, biological pollution is likely to occur on the membrane surface.

2. Brackish Water

Brackish water resources are widely distributed in China (including rivers, lakes, and groundwater). According to the results of "China River and Lake Encyclopedia", "Third National Water Resources Survey and Evaluation" and other studies involving brackish water, China's existing brackish water resources are mainly distributed in 6 major regions: Northwest, North China, East China, Central China, Southwest, and Northeast China, involving 19 provinces (cities, districts) and more than 500 county-level administrative regions (counties, districts, cities, banners, forest areas); the main distribution area of brackish water is $57.73\times10^4 km^2$, accounting for 7.9% of the total area of provinces (cities, districts) with brackish water; it affects about 52 million water users, accounting for 7% of the total population of provinces (cities, districts) with brackish water.

According to "Technical Specifications for Surface Water Resources Quality Evaluation" (SL395-2007), water bodies are called brackish water when their mineralization degree, chloride, or sulfate concentration exceeds the standard limits (2,000mg/L, 450mg/L, 400mg/L).

Brackish water has complex and variable components. To formulate a scientific and reasonable process plan, a comprehensive water quality analysis is required.

The main challenge faced by brackish water treatment systems is chemical scaling, such as calcium carbonate and calcium sulfate. As the influent is concentrated, once it exceeds its solubility product, it will precipitate on the membrane surface. In addition, potential microbial pollution is also an important influencing factor, especially when treating industrial or municipal wastewater. The organic matter, inorganic matter, microorganisms, and algae in it make the system not only limited by physical and chemical factors but also need to pay attention to microbial indicators, such as organic carbon with affinity for membranes, biodegradable dissolved organic carbon, and potential phosphate scaling.

Due to the large fluctuation range of brackish water influent quality, the first step must be to understand the water quality characteristics. Before conducting RO or NF system design calculations, a complete and accurate water quality analysis report must be obtained. A complete raw water quality analysis report as listed in the following table is required, and the anions and cations must be balanced. If the anions and cations are unbalanced, it is recommended to add Na^+or Cl^- for balance.

The following table is used for the preliminary system and raw water analysis report of the RO/NF design system.

System Design Data Summary Report

Reference No.: Record Date: Contact Person:
Tel: E-mail: Fax:

Project Location: Engineering Company:
End User: Address:

Design Permeate Flow (m^3/h)::
Expected Recovery Rate or Maximum Feed Water Supply (m^3/h):
Peak Water Consumption (m^3/h): Peak Duration(h):
Feed Water Source:
□ Groundwater □ Deep Well Water □ Surface Water □ Seawater
□ Softened Water □ MF/UF Permeate □ RO Permeate
□ Self-Supplied Water □ Municipal Wastewater □ Industrial Wastewater
Feed Water Temperature:
Minimum _____℃, Maximum _____℃, Average _____℃, Design _____℃

Pre-treatment Overview:

Chemical Dosing: □ Flocculant □ Coagulation Aid □ Bactericide
□ Reducing Agent □ Acidifier □ Scale Inhibitor
Existing Pre-treatment: □ None □ Yes □ SDI_{15} Value(if have pre-treatment)
Existing Pretreatment Equipment:

On-site Conditions:

System Application:
□ Power Industry □ Petrochemical Industry □ Metallurgical Industry □ Electronics Industry
□ Food Industry (Purified Water) □ Pharmaceutical Industry
□ Boiler Feed Water (High/Medium/Low Pressure) □ Municipal Domestic Drinking Water
□ Wastewater Reuse Treatment
Post-treatment Equipment & Process:

System Operation Mode:
□ 24-hour Continuous □ 8-hour Continuous □ 24-hour Intermittent □ 8-hour Intermittent

Other Requirements and Instructions:

Raw Water Quality Analysis Report

Raw Water Analysis Institution: Analyst:
Water Source Description: Date:
Conductivity: pH : Water Sample Temperature:

Composition Analysis
Please indicate the unit of measurement, e.g., mg/L, ppm, meq/L, as $CaCO_3$, etc.)

Ammonium Ion (NH_4^+):
Potassium Ion (K^+):
Sodium Ion (Na^+):
Magnesium Ion (Mg^{2+}):
Calcium Ion (Ca^{2+}):
Barium Ion (Ba^{2+}):
Strontium Ion (Sr^{2+}):
Ferrous Ion (Fe^{2+}):
Total Iron (Fe^{2+}/Fe^{3+}):
Manganese (Mn^{2+}):
Copper Ion (Cu^{2+}):
Zinc (Zn^{2+}):
Aluminum Al^{3+}):

Carbon Dioxide (CO_2):
Carbonate (CO_3^{2-}):
Bicarbonate (HCO_3^-):
Nitrite (NO_2^-):
Nitrate (NO_3^-):
Chloride (Cl^-):
Fluoride (F^-):
Sulfate (SO_4^{2-}):
Phosphate (PO_4^{3-}):
Hydrogen Sulfide (H_2S):
Reactive Silica (SiO_2):
Colloidal Silica (SiO_2):
Free Chlorine (Cl_2):

Other Ions (such as Boron Ion):
Total Organic Carbon (TOC):
Chemical Oxygen Demand (COD):
Carbonate Alkalinity (Phenolphthalein Alkalinity):
Turbidity (NTU):
Bacteria (count/mL):
Remarks (Odor, Color, Biological Activity, etc.):

Total Dissolved Solids (TDS):
Biochemical Oxygen Demand (BOD):
Total Alkalinity (Methyl Orange Alkalinity):
Total Hardness:
Silt Density Index (SDI_{15}):

Note: If there is a significant imbalance between anions and cations, the analysis should be re-performed. If the imbalance is minor, manual balancing may be achieved by adding sodium or chloride ions. Barium (Ba^{2+}) and strontium (Sr^{2+}) must be detected down to the order of 1 μg/L (ppb) and 1 mg/L (ppm) respectively. Additionally, the possibility of temperature fluctuations within a certain range should be considered, as temperature changes can also create a risk of scaling in the system, particularly when the raw water contains high levels of silica and bicarbonate.

Once the system is put into operation, the raw water should also be analyzed regularly to keep track of the fluctuation of raw water quality at any time, and adjust the operating parameters of the pretreatment process and the operating conditions of the entire water treatment plant in a timely manner.

5-3 Scale Control

1. Introduction

In RO/NF systems, when sparingly soluble salts are concentrated beyond their solubility limits, they will scale on the membrane surface. For example, when an RO system operates at a 50% recovery rate, the salt concentration in the concentrate will be twice that of the influent; the higher the recovery rate, the greater the scaling risk. Currently, to address water shortages and reduce environmental impacts, reverse osmosis concentrate recovery systems are usually installed to improve the recovery rate. In this case, carefully designed scale control measures must be taken to prevent micro-soluble salts from precipitating and scaling due to exceeding their solubility. Common sparingly soluble salts in RO/NF systems include calcium sulfate ($CaSO_4$), calcium carbonate ($CaCO_3$), and silicon dioxide (SiO_2). Other compounds that may scale include calcium fluoride (CaF_2), barium sulfate ($BaSO_4$), strontium sulfate ($SrSO_4$), and calcium phosphate ($Ca_3(PO_4)_2$).

2. Acid Addition

Calcium carbonate ($CaCO_3$) in most surface water and groundwater is almost saturated. As shown in the following formula, the solubility of $CaCO_3$ depends on the pH value:

$$Ca^{2+}+HCO^{-} \leftrightarrow H^{+}+CaCO_3$$

Therefore, by adding H+ from acids, the chemical equilibrium can shift to the left, maintaining calcium carbonate in a dissolved state. The quality of the acid used must be food-grade. In most regions, sulfuric acid is easier to use than hydrochloric acid; however, the increase in sulfate content in the influent will exacerbate the problem of sulfate scaling.

It is worth noting that $CaCO_3$ tends to dissolve rather than precipitate in the concentrate. For brackish water, the Langelier Saturation Index (LSI) can be used, and for seawater, the Stiff and Davis Saturation Index (S&DSI) can be used to indicate this tendency to dissolve. Under the saturated pH (pHs), $CaCO_3$ in water is in equilibrium between dissolution and precipitation.

The definitions of LSI and S&DSI are:

$$LSI=pH-pHs \quad (TDS \leqslant 10000mg/L)$$

$$S\&DSI=pH-pHs \quad (TDS > 10000mg/L)$$

When only acid addition is used to control calcium carbonate scaling, the LSI or S&DSI index in the concentrate must be negative. Acid addition is only effective for controlling carbonate scaling.

3. Scale Inhibitor Addition

Scale inhibitors can effectively control the formation of scales such as carbonates, sulfates, and calcium fluoride. Common scale inhibitors on the market are mainly divided into three categories: sodium hexametaphosphate (SHMP), organophosphates, and polyacrylates.

Compared with polymeric organic scale inhibitors, sodium hexametaphosphate is cheaper but less stable. It can be slightly adsorbed on the surface of microcrystals, thereby preventing the further growth and precipitation of scale crystals. However, food-grade sodium hexametaphosphate must be used, and its hydrolysis in the dosing tank must be prevented. Once hydrolyzed, it will not only reduce the scale inhibition effect but also may cause calcium phosphate precipitation, so SHMP is rarely used now.

Organophosphate scale inhibitors have better effects and strong stability, and are particularly suitable for preventing scaling of insoluble aluminum and iron. High-molecular-weight polyacrylates effectively reduce the formation of silicon dioxide (SiO_2) scaling through dispersion.

However, polymeric organic scale inhibitors may undergo precipitation reactions when encountering cationic polyelectrolytes or multivalent cations (such as aluminum or iron), generating colloidal substances that are difficult to remove from the membrane surface. Therefore, when adding scale inhibitors, the dosage must be accurately controlled, and the specific dosage should be consulted with the scale inhibitor supplier. At the same time, excessive addition should be avoided, because excessive scale inhibitors themselves can become membrane contaminants.

In seawater reverse osmosis systems with a salt content of 35000mg/L, scaling is not as serious as in brackish water systems. Due to the limitation of concentrate osmotic pressure, the system recovery rate of seawater is usually between 30% and 45%. However, to ensure system safety, it is recommended to use scale inhibitors when the operating recovery rate exceeds 35%.

In addition, cationic polyelectrolytes may undergo synergistic precipitation reactions with negatively charged scale inhibitors, thereby contaminating the membrane surface. Therefore, when adding anionic scale inhibitors, it must be ensured that there are no obvious cationic polymers in the water.

4. Strong Acid Cation Resin Softening

The sodium ion (Na^+) exchange method can be used to replace and remove scaling cations in water, such as calcium ions (Ca^{2+}), barium ions (Ba^{2+}), and strontium ions (Sr^{2+}). When the ion exchange resin reaches exchange saturation, it can be regenerated with sodium chloride (NaCl), a process called raw water softening. During this process, the pH value of the influent can be kept stable, so no degassing operation is required. However, carbon dioxide (CO_2) in the raw water can pass through the membrane to the product water side, leading to an increase in conductivity. To solve this problem, operators can add an appropriate amount of sodium hydroxide (NaOH) to the softened water until the pH value reaches 8.2, which can convert the

remaining carbon dioxide in the water into bicarbonate, and bicarbonate can be removed by the membrane, thereby reducing the conductivity of the reverse osmosis product water.

Selecting ion exchange resins produced by regular manufacturers, their removal efficiency for calcium ions (Ca^{2+}), barium ions (Ba^{2+}), and strontium ions (Sr^{2+}) can exceed 99.5%, which can effectively eliminate the risk of carbonate and sulfate scaling. If the resin is regenerated in a timely manner, softening with strong acid cation exchange resin is an efficient and reliable method. However, this method is mainly used for small and medium-sized brackish water treatment systems and is not suitable for seawater desalination. The main reason is that this process consumes a large amount of sodium chloride, which not only brings environmental problems but also leads to high treatment costs and is not economical.

5. Weak Acid Cation Resin Softening

Weak acid cation exchange resins are mainly used for dealkalization treatment in large-scale brackish water treatment systems, reducing the use of regenerants through partial softening. During this process, only Ca^{2+}, Ba^{2+}, and Sr^{2+} combined with bicarbonate are removed, reducing the pH value of the raw water to 4～5. Since the carboxyl groups of the resin stop dissociating at pH 4.2, ion exchange stops accordingly, so only partial softening can be achieved. This process is suitable for water sources with high bicarbonate content and can convert it into CO_2.

$$HCO_3^- + H^+ \quad H_2O + CO_2$$

In reverse osmosis systems, it is usually not desirable to have carbon dioxide (CO_2) in the product water, so degassing treatment is required. Degassing can be carried out at the raw water or product water stage, but when there is a risk of biological pollution such as high total organic carbon (TOC) and high total bacterial count in surface water or water, degassing the product water is more appropriate.

In the membrane system, high concentration of CO_2 can inhibit bacterial growth. If the system needs to operate at a high desalination rate, it is more appropriate to degas the raw water. In addition, the removal of CO_2 will lead to an increase in the pH value of the water. When the influent pH value＞6, the desalination rate of the membrane system is higher than when the influent pH value＜5.

The advantages of using weak acid dealkalization technology are as follows:

- Economy and environmental protection: The amount of acid required for regeneration does not exceed 105% of the theoretical acid consumption, which can reduce operating costs and environmental impacts.
- Optimization of product water TDS: By removing bicarbonate, the total dissolved solids (TDS) in the water is reduced, thereby reducing the product water TDS.

However, this technology also has some disadvantages:

- Residual hardness problem: If complete softening is required, a sodium exchange process with strong acid cation resin can be added, or even placed in the same exchange column as the weak acid resin. Although this makes the regenerant consumption lower than using strong acid resin alone, the initial

investment is higher, and it is more meaningful only when the system capacity is large. Another solution is to add scale inhibitors to the dealkalized water. Although scaling problems are rare when using weak acid cation resin for dealkalization alone, it is still recommended to calculate the solubility of residual sparingly soluble salts and take corresponding measures.

- pH value change: The change in resin saturation during operation causes the effluent pH value to fluctuate between 3.5 and 6.5, bringing difficulties to the control of the plant's desalination rate. When the pH value is lower than 4.2, inorganic acids may pass through the membrane, which may increase the product water TDS. To address this issue, it is recommended to add parallel weak acid softeners, stagger the regeneration time to stabilize the effluent pH value; or adjust the pH value by removing CO_2 and adding NaOH to prevent effluent with extremely low pH value.

6. Lime Softening

Carbonate hardness can be removed by adding calcium hydroxide to the water.

$$Ca(HCO_3)_2+Ca(OH)_2 \quad 2CaCO_3+2H_2O$$

$$Mg(HCO_3)_2+2Ca(OH)_2 \quad Mg(OH)_2+2CaCO_3+2H_2O$$

Non-carbonate hardness can be further reduced by adding sodium carbonate (soda ash).

$$CaCl_2 + Na_2CO_3 \rightarrow 2NaCl + CaCO_3\downarrow$$

Lime-soda ash treatment helps reduce silica concentration. When sodium aluminate and ferric chloride are added, complexes of $CaCO_3$, silicic acid, alumina, and iron are formed. By adding a mixture of lime and porous magnesium oxide, the silica concentration can be reduced to below 1mg/L using a hot lime-silica removal process at 60～70℃.

Lime softening can effectively reduce the content of barium, strontium, and organic matter, but it requires the use of a reactor to form high-concentration precipitable particles as crystal nuclei, usually using an upflow solid contact clarifier. The effluent must be filtered through a multimedia filter, and the pH value must be adjusted before entering RO/NF. The use of iron-containing flocculants, whether or not polymer coagulation aids (anionic or non-ionic) are used, can improve the solid-liquid separation effect of lime softening. Lime softening pretreatment is only considered for brackish water systems with a water production rate exceeding 200m^3/hr.

7. Preventive Cleaning

In some cases, scale control is achieved by regularly performing preventive cleaning of membrane elements, in which case the system does not require softening treatment or the addition of scale-inhibiting chemicals. Such systems usually operate at a low recovery rate (about 25%), and membrane elements are replaced every 1～2 years. Most of these systems use tap water or seawater as the water source and are small-scale systems for producing drinking water. The simplest cleaning method is to open the concentrate valve for low-pressure flushing. Setting shorter cleaning intervals is more effective than longer intervals; for example, performing a 30-second low-pressure flush every 30 minutes of operation. A batch operation mode similar to

that in wastewater treatment can also be adopted, i.e., cleaning the membrane elements after each batch operation. The cleaning steps, chemicals, and frequency need to be optimized according to specific conditions to prevent scaling from worsening over time.

8. Adjusting Operating Parameters

When other scale control measures are ineffective, the system operating parameters must be adjusted to prevent scaling. Ensuring that the concentration of sparingly soluble salts in the concentrate is below the solubility product can avoid precipitation, usually by reducing the recovery rate. Solubility is affected by temperature and pH value; when silicon is present in the water, increasing temperature and pH can increase its solubility. Silicon dioxide is often the only reason for adjusting operating parameters to prevent scaling, because adjustment has high energy consumption or other scaling risks (such as $CaCO_3$ precipitation at high pH). For small-scale systems, selecting a low recovery rate combined with preventive cleaning is one of the simplest scale control methods.

5-4 Scale Prevention

1. Prevention of Calcium Carbonate Scaling

Brackish water source:

For brackish water with a concentrate salt content TDS ≤ 10000mg/L, the Langelier Saturation Index (LSIC) is used as an indicator of the possibility of $CaCO_3$ scaling:

$$LSIC=pHC-pHS$$

Where pHC is the concentrate pH value, and pHS is the pH value when $CaCO_3$ is saturated. When LSIC⩾0, $CaCO_3$ scaling will occur.

Most natural water has a positive LSIC without treatment. To prevent $CaCO_3$ scaling, unless scale inhibitors are added or preventive cleaning measures are taken, it is necessary to ensure that LSIC is negative:

- LSIC＜0: No need to add scale inhibitors;
- LSIC⩽1.8～2.0: Add scale inhibitors alone or perform complete chemical softening;
- LSIC＞1.8～2.0 :Add acid to reduce LSIC to 1.8～2.0, then add scale inhibitors, or perform complete chemical softening.

Seawater source:

For high-salinity brackish water or seawater with a concentrate salt content TDS＞10,000mg/L, the Stiff and Davis Saturation Index (S&DSIC) is used as an indicator of the possibility of $CaCO_3$ scaling:

$$S\&DSIC=pHC-pHS$$

Where pHC is the concentrate pH value, and pHS is the pH value when $CaCO_3$ is saturated. When S&DSIC ⩾0≥ 0, $CaCO_3$ scaling will occur.

Most natural high-salinity water sources have a positive S&DSIC without treatment. To prevent $CaCO_3$ scaling, acid must be added to make S&DSIC negative. If scale inhibitors are used, S&DSIC can be positive, but the

technical data of the scale inhibitor manufacturer should be referred to. If the conditions are not met, the following measures must be taken:

- Reduce the recovery rate to make the S&DSIC value meet the requirements;
- Adopt lime or lime-soda ash softening to remove calcium hardness and alkalinity from the influent;
- Add acid (such as HCl, CO_2, H_2SO_4, etc.) to the influent to make the S&DSIC value meet the requirements. For seawater desalination systems, sulfuric acid is usually added at a dosage of 10mg/L to achieve pH 7, ensuring that the concentrate S&DSIC is negative.

2. Prevention of Calcium Sulfate Scaling

To achieve a higher reverse osmosis recovery rate, one of the following measures can be taken:

- Strong acid cation resin softening or weak acid cation resin dealkalization to remove calcium ions;
- Lime or lime-soda ash softening to reduce the Ca^{2+} concentration in the water;
- Add scale inhibitors according to the scale inhibitor supplier's regulations;
- Reduce the system recovery rate.

3. Prevention of Barium Sulfate Scaling

Barium sulfate is one of the least soluble alkaline earth metal salts. The presence of barium sulfate in the influent will promote its precipitation. The preventive measures are the same as those for calcium sulfate. In most natural water, the barium content will cause barium sulfate precipitation in the concentrate. The limit concentration of barium in seawater is less than 15 μg/L, and the limit concentration of barium in brackish water is less than 5 μg/L; if sulfuric acid is added, it should be less than 2 μg/L.

4. Prevention of Strontium Sulfate Scaling

The preventive measures are the same as those for calcium sulfate.

5. Prevention of Calcium Fluoride Scaling

When the calcium concentration is high and the fluoride ion content in the water reaches 0.1 μg/L, calcium fluoride precipitation may occur. The preventive measures are the same as those for calcium sulfate.

6. Prevention of Silica Scaling

The content of soluble silicon dioxide (SiO_2) in most water sources is between 1～100mg/L. Supersaturated SiO_2 will form insoluble colloidal silica, contaminating the membrane. The maximum allowable SiO_2 concentration in the concentrate depends on its solubility. The calculation of silica scaling must be determined according to the raw water quality and reverse osmosis operating parameters (recovery rate). If metals such as Al^{3+} are present in the water, metal silicates may be formed, changing the solubility of SiO_2. Preventive measures include:

Add magnesium oxide or sodium aluminate during lime-soda ash softening pretreatment to reduce the SiO_2 concentration in the influent;

- Adjust the pH value; a pH value below 7 or above 7.8 can increase silica solubility, but $CaCO_3$ precipitation must be prevented;
- Use a heat exchanger to increase the influent temperature and improve water recovery rate, but the maximum allowable temperature of the membrane system is 45℃;
- Use high-molecular-weight polyacrylate scale inhibitors to increase SiO_2 solubility.

7. Prevention of Calcium Phosphate Scaling

Calcium phosphate scaling is more common in municipal wastewater treatment. Phosphorus exists in various compounds, including particulate phosphate, orthophosphate, polyphosphate, and organic phosphorus. Low-solubility phosphorus-containing compounds include brushite, calcium phosphate, calcium acid phosphate, basic apatite, fluorapatite, magnesium ammonium phosphate, aluminum phosphate, and iron phosphate. Preventive measures include reducing the concentrations of orthophosphate, calcium, fluoride, and aluminum, and selecting appropriate scale inhibitors. In a municipal wastewater treatment plant in North America, citric acid is used to clean phosphate scales on the membrane surface at pH 2.4 ～ 2.8. It is recommended to lower the influent pH to 6 to prevent phosphate scaling.

5-5 Prevention of Colloidal and Particulate Fouling

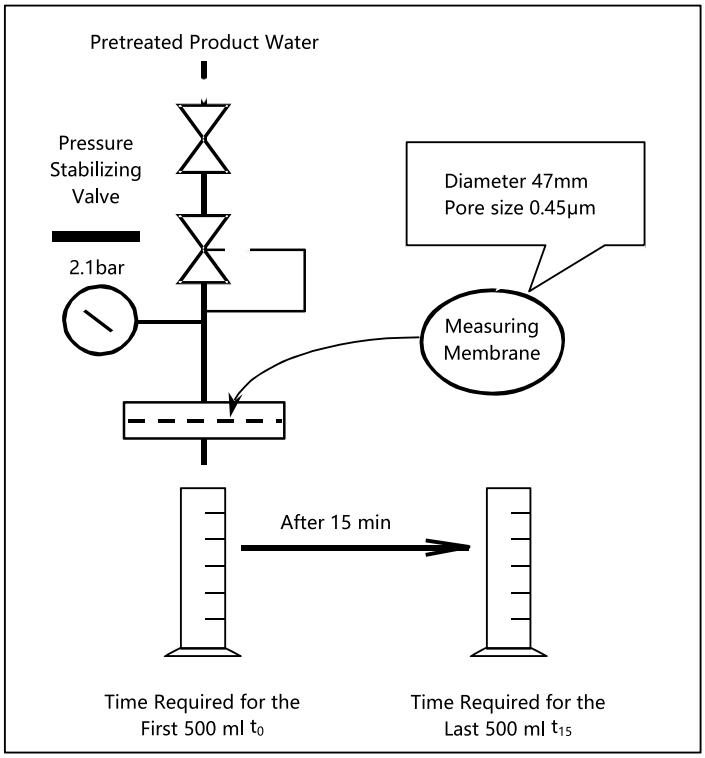
1. Introduction

Colloidal and particulate fouling can seriously affect the performance of reverse osmosis and nanofiltration elements, leading to reduced water production and even reduced system desalination rate. The initial manifestation is an increase in system pressure difference.

Colloids and particles in reverse osmosis and nanofiltration influents come from various sources, including bacteria, clay, colloidal silica, and iron corrosion products. Flocculants used in pretreatment (such as polyaluminum chloride, ferric chloride, cationic polyelectrolytes) can combine with tiny colloids and particles to form large flocs, which are easily trapped by media or filter elements. However, excessive flocculants may be trapped in the membrane elements and contaminate the membrane surface. Positively charged polymers may also undergo precipitation reactions with negatively charged scale inhibitors, contaminating the membrane elements.

The best method to determine the degree of colloidal and particulate pollution in reverse osmosis and nanofiltration influents is to measure the Silt Density Index (SDI) of the influent. The SDI value is an important indicator before designing the RO/NF pretreatment system and must be tested regularly during daily operations (three times a day is recommended for surface water). The SDI measurement method follows the ASTM D4189-82 standard.

Silt Density Index Tester



Test Steps:

① Prepare the test device: Assemble the test device as required, ensuring that all components are tightly connected without leakage. A 0.45 μ m pore size microporous filter membrane with a diameter of 47mm is usually used.

② Install the filter membrane: Use clean tweezers to install the filter membrane into the test chamber, ensuring that the filter membrane is flat without wrinkles or damage. At the same time, check whether the O-ring is clean, intact, and correctly installed.

③ Connect the test device: Connect the test device to the sampling point of the RO system's inlet pipeline and ensure the connection is firm.

④ Adjust the pressure: Open the inlet valve, adjust the inlet pressure to 30psi (2.1bar or 207kPa), and keep the pressure stable.

⑤ Measure the initial time: After the pressure stabilizes, immediately measure the time T0 (seconds) required to collect 500ml of water sample.

⑥ Continuous filtration: Maintain a constant pressure and allow water to continuously filter through the membrane for a certain period of time (usually 15 minutes).

⑦ Measure the subsequent time: After 15 minutes of filtration, measure the time T1 (seconds) required to collect 500ml of water sample again.

⑧ Calculate the SDI value: Based on the measured T0 and T1, calculate the SDI value using the following formula:

$$SDI = \frac{100 \times (1 - \frac{T0}{T1})}{15}$$

Where 15 represents the 15-minute test time.

Notes:

- During the entire test process, the pressure and water temperature should be kept stable, with a pressure fluctuation not exceeding ±5% and a water temperature fluctuation not exceeding ±1℃.
- If during the test, the time required to collect 500ml of water sample exceeds 4 times the initial time, or the filter membrane is severely clogged, the test time can be appropriately shortened (e.g., to 10 minutes or 5 minutes), and the denominator in the calculation formula should be adjusted accordingly.
- After the test, it is best to save the used filter membrane for future reference.

Standard Requirements:

- The influent of reverse osmosis systems usually requires an SDI value of less than 5; when the SDI value is less than 3, the pollution risk of the reverse osmosis membrane system is low.
- Different membrane modules have different requirements for the influent SDI value; for example, hollow fiber membrane modules generally require an SDI value of around 3, and spiral-wound modules generally require an SDI value of around 5.
- By measuring SDI in accordance with the above standards and steps, the influent water quality of the reverse osmosis system can be effectively evaluated, providing an important basis for the stable operation of the system.

2. Media Filtration

Media filters trap particles, suspended solids, and colloids through filter media. The filtration effect depends on impurity characteristics, media particle size, surface charge and shape, raw water composition, and operating conditions. A reasonably designed and operated media filter can achieve SDI15≤5≤5.

Common filter media are quartz sand and anthracite. In dual-media filters, the effective diameter of quartz sand is 0.35～0.5mm, and the effective diameter of anthracite is 0.7～0.8mm. The minimum design total bed depth of the filter media is 0.8m; in dual-media filters, the height of the quartz sand layer is 0.5m, and the height of the anthracite layer is 0.4m.

Filters are divided into gravity filters and pressure filters. Pressure filter cylinders are pressure-resistant and can use higher filter beds, finer media particle sizes, and higher filtration flow rates. The design filtration flow rate is usually less than 10～20m/h, and the backwash flow rate is 40～50m/h. For raw water with a high pollution tendency (such as surface water, contaminated well water, or wastewater), the filtration flow rate should be less than 10m/h (generally 5m/h) or a two-stage media filter should be used.

During operation, raw water enters the top of the filter, and after filtration, enters the bottom water collection system. When the pressure difference between the inlet and outlet of the pressure filter increases by 0.3～0.6 bar, and the pressure difference of the gravity filter increases by 1.4mH_2O, the filter needs to be backwashed

and rinsed to remove sediments. Backwashing usually takes more than 10 minutes, and large-diameter filters also require auxiliary air scrubbing. Frequent start-up and shutdown should be avoided to prevent sediment release caused by flow rate changes.

3. Oxidation-Filtration

Certain well water contains divalent iron and manganese in a reduced state and may contain hydrogen sulfide and ammonia. When chlorination is performed or the oxygen content in the water exceeds 5mg/L, Fe^{2+} will be oxidized to Fe^{3+}, forming insoluble colloidal hydroxide particles. The oxidation reactions of iron and manganese are as follows:

$$4Fe(HCO_3)_2+O_2+2H_2O \rightarrow 4Fe(OH)_3+8CO_2$$

$$4Mn(HCO_3)_2+O_2+2H_2O \rightarrow 4Mn(OH)_3+8CO_2$$

Iron oxidation also occurs at low pH values, and iron pollution is more common than manganese pollution. Even if the SDI is less than 5 and the iron content in the RO influent is less than 0.1mg/L, iron pollution may still occur. Raw water with low alkalinity has a high iron ion content because the solubility of $FeCO_3$ limits the Fe^{2+} concentration.

Treatment methods include preventing contact with air and oxidants (such as chlorine). Higher Fe^{2+} concentrations are allowed at low pH values (＜6) and low oxygen content (＜0.5mg/L). Air, Cl_2, or $KMnO_4$ can also be used to oxidize iron and manganese, and the oxides can be removed by media filters. However, it should be noted that colloidal sulfur formed by hydrogen sulfide oxidation may be difficult to remove by filters. Adding oxidants in the media filter to oxidize Fe^{2+} through electron transfer can complete oxidation and filtration simultaneously.

Glauconite is a granular filter medium that can be regenerated by $KMnO_4$ oxidation, but residual $KMnO_4$ must be rinsed to prevent membrane oxidation. This method can be used when the Fe^{2+} content in the raw water is less than 2mg/L; when the Fe^{2+} content is high, $KMnO_4$ must be continuously added, and measures must be taken to prevent it from contacting the membrane.

Birm filter media can also effectively remove Fe^{2+} from RO/NF influents. It is an aluminum silicate matrix coated with manganese dioxide, which catalyzes the reaction between dissolved oxygen and divalent iron to form precipitates that are removed by backwashing. This process may affect the pH value, so $CaCO_3$ precipitation must be prevented.

4. In-line Filtration

In-line filtration improves the efficiency of media filters in reducing SDI by adding flocculants or coagulation aids to the raw water, and is suitable for water sources with an SDI slightly higher than 5. Flocculants form tiny flocs with colloids, which are trapped by media filters. Common flocculants are ferric sulfate and ferric chloride. Aluminum-containing flocculants are not recommended due to residual aluminum ion pollution, unless high-molecular-weight polyaluminum is used. The dispersion and mixing of flocculants must be rapid; it is

recommended to use a static mixer or inject at the suction section of the booster pump. The optimal dosage is usually 10～30mg/L, but it must be determined according to specific projects.

Coagulation aids are soluble high-molecular-weight organic compounds, such as polyacrylamide, which can improve the floc strength and filtration performance of flocculants or promote bridging of colloidal particles. The reaction products of coagulation aids and flocculants may precipitate and cover the membrane surface, indirectly interfering with the RO membrane. The reaction gel layer between cationic polyelectrolytes and scale inhibitors has also severely contaminated RO membranes. To eliminate direct and indirect interference, anionic and non-ionic coagulation aids are recommended, and excessive addition should be avoided.

5. Flocculation-Coagulation Aid

When the raw water has high suspended solids and high SDI, the traditional coagulation-coagulation aid treatment process is adopted. The generated hydroxide flocs grow and precipitate in the reaction space, discharged as sludge, and the supernatant enters the multimedia filter for further treatment. A solid contact clarifier or a compact coagulation-coagulation aid reactor can be used in the coagulation-coagulation aid process.

6. Microfiltration (MF) or Ultrafiltration (UF)

Microfiltration (MF) or ultrafiltration (UF) membranes can remove suspended solids from water, and ultrafiltration can also remove some organic matter. Using MF/UF as RO/NF pretreatment, the product water turbidity can be less than 1, and the SDI can be less than 3. MF/UF intercepts particles, colloids, bacteria, viruses, algae, and organic matter in the raw water, reducing RO/NF pollution and operating load. Compared with traditional multimedia filters, MF/UF can improve the stable operating flux of RO/NF and reduce equipment investment, but increases the MF/UF investment. MF/UF needs to be cleaned regularly to restore performance, which can be physical cleaning and chemical cleaning. When the influent water quality is poor, higher requirements are placed on the physical strength and chemical resistance of the membrane filaments. The industry-recognized best MF/UF membrane filament material is polyvinylidene fluoride (PVDF).

7. Cartridge Filtration

Each reverse osmosis and nanofiltration system should be equipped with a cartridge-type security filter with a minimum pore size requirement of less than 10 μm, and it is recommended to use≤5 μm. The better the pretreatment, the fewer the number of RO/NF membrane cleanings. When the silica concentration in the concentrate exceeds the theoretical solubility, it is recommended to select a filter cartridge with a pore size of 1 μm. The cartridge filter should select the filtration flow rate according to the manufacturer's recommendations and replace the filter cartridge in a timely manner, avoiding not replacing it for more than three months. Cleanable cartridge filters are not recommended because of their low efficiency and biological pollution risk. The filter cartridge material should be a non-degradable synthetic material, such as nylon or polypropylene, and the filter should be equipped with a pressure gauge to indicate the pressure drop. Regular inspection of used filter cartridges can help obtain pollution hazard alarms and cleaning information.

8. Other Methods

In addition to the above methods, there are lime softening and strong acid cation exchange resin softening methods. Lime softening can remove silica, iron, and colloids. Strong acid cation exchange resin softening can not only remove hardness but also reduce iron and aluminum concentrations, reducing the pollution tendency. A cleanable precision filter can be installed upstream of the cartridge filter, but it cannot replace the replaceable cartridge filter.

9. Design and Operation Considerations

Preventing colloidal and particulate pollution requires a combination of reasonable pretreatment technology, system design, and operation. For example, a surface water using flocculation-coagulation aid or ultrafiltration pretreatment, the RO/NF system can operate at a high flux with almost no cleaning required. When only cartridge filtration is used, the system requires more membrane area, and the membrane needs to be cleaned and maintained more frequently. Poor pretreatment can only be compensated by replacing membrane elements, adjusting operating parameters, or more frequent cleaning, but improving pretreatment can save membrane costs and operating costs.

To reduce the pretreatment burden and improve influent quality, priority should be given to selecting water sources with good water quality. The selection of water intake points for surface water and seawater treatment systems is extremely important. Raw water contaminated by wastewater will cause serious operational problems in RO/NF systems. It is recommended to take water from deep wells near the coast and rivers; if surface open water intake is used, it should be far away from the embankment, and the water intake should be several meters below the water surface. Newly built wells will release suspended solids initially and need to be cleaned first. Attention should also be paid to iron oxide pollution, and non-corrosive materials should be selected for the system.

5-6 Prevention of Membrane Biological Fouling

1. Introduction

All raw water contains microorganisms, such as bacteria, algae, fungi, and viruses. Microorganisms can be regarded as colloidal substances and can be removed by pretreatment methods to prevent colloidal pollution. Unlike inanimate particles, microorganisms have reproductive capabilities and can form biofilms under suitable conditions. After microorganisms enter the reverse osmosis system, they use soluble organic nutrients in the water to accumulate on the membrane surface and form biofilms. Biological pollution can seriously affect the performance of the reverse osmosis system, leading to a rapid increase in pressure difference, damage to membrane elements, reduced water production, and even contamination of the product water. Once a biofilm is formed, cleaning is very difficult, so microbial control is a key task of pretreatment.

2. Biological Pollution Assessment Methods

(1) Culture Method

The bacterial concentration in water is directly related to the possibility of biological pollution. The Total Bacterial Count (TBC) is a quantitative indicator of the total amount of microorganisms in a water sample. Filter the water sample using a specified membrane filtration method, place the retained biological tissues in nutrients for culture, form colonies, and count them. This method does not require expensive equipment, but the results can only be obtained after 7 days, and it can only reflect 1%～10% of the actual total number of viable microorganisms. Nevertheless, the culture method is still an effective method to evaluate the degree and trend of microbial pollution.

(2) Direct Bacterial Count

Direct counting technology counts the retained microorganisms under a microscope after filtering the water sample. To facilitate observation, the microorganisms need to be stained with safranin and then counted under a light-transmitting fluorescence microscope. This method can immediately obtain the exact number of microorganisms and distinguish between different types of microorganisms, but it cannot distinguish between live and dead cells. Since the direct bacterial counting method is faster and more accurate, it should be preferred.

(3) Biofilm Detection

The microbial content in raw water, membrane device influent, and concentrate is an important indicator for evaluating potential biological pollution. Biofilm formation is affected by nutrient composition, operating parameters, and other factors. An early method to confirm biofilm is to observe the "Robin test sample" in the influent, which involves placing a small sample in the water sample and removing it regularly to check for bacterial adhesion. In actual operation, regularly inspect the security filter cartridge and the inner surface of the influent and concentrate pipes; the presence of slime and odor indicates microbial pollution.

(4) Other Methods

The Werner method can be used to estimate the possibility of bacterial occurrence in the water source through sample transplantation. Filter and sterilize the water sample, add inorganic salt nutrient solution, filter again with a sterile filter, rinse the bacterial suspension for transplantation and culture. Determine the bacterial production rate based on the increase in concentration using the light scattering method. Other methods include measuring the content of Adsorbable Organic Carbon (AOC) or Biodegradable Organic Carbon (BDOC).

3. Chlorine Disinfection

Chlorine is widely used as a disinfectant in municipal, industrial water supply, and wastewater treatment, and can quickly inactivate pathogenic microorganisms. Its efficiency depends on chlorine concentration, contact time, and water pH value. In drinking water disinfection, the residual chlorine concentration is usually 0.5ppm; in industrial water treatment, maintaining a residual chlorine of 0.5～1.0ppm can prevent microbial pollution. The chlorine dosage depends on the organic matter content in the influent.

For surface water, chlorine disinfection is usually required in the reverse osmosis pretreatment section. The method is to add chlorine at the water intake and maintain a reaction time of 20～30 minutes to keep a residual chlorine concentration of 0.5～1.0ppm in the entire pretreatment pipeline. However, thorough dechlorination must be performed before entering the membrane element to prevent membrane oxidation damage by chlorine.

(1) Chlorination Reaction

Common chlorine-containing disinfectants are chlorine gas, sodium hypochlorite, or calcium hypochlorite, which quickly hydrolyze into hypochlorous acid in water. Hypochlorous acid decomposes into hydrogen ions and hypochlorite ions in water. The sum of chlorine is called Free Available Chlorine (FAC) or Free Residual Chlorine (FRC), calculated as mg/L Cl_2. Chlorine reacts with ammonia compounds in water to form chloramines, called Combined Available Chlorine (CAC) or Combined Residual Chlorine (CRC). The sum of residual chlorine and combined chlorine is called Total Residual Chlorine (TRC).

The bactericidal efficiency of residual chlorine is proportional to the concentration of undissociated HClO. Hypochlorous acid is 100 times more bactericidal than hypochlorite. The proportion of undissociated hypochlorous acid increases with decreasing pH value.

(2) Chlorine Dosage

Part of the added chlorine reacts with ammonia nitrogen in the water to form combined chlorine, and the other part consumes chlorine due to oxidation reactions. The entire process needs to determine the optimal chlorine dosage, dosing point, pH value, and contact time.

(3) Seawater Chlorination Treatment

Seawater contains about 65mg/L bromine. During chlorination, bromine reacts rapidly with hypochlorous acid to form hypobromous acid. When chlorinating seawater, the main bactericidal agent is HBrO rather than HClO.

4. Dechlorination

Our company's membrane sheets themselves have a certain chlorine resistance, but dechlorination treatment is still required to prevent membrane degradation. The rate of chlorine attack on the membrane depends on the influent characteristics; the attack rate is faster under alkaline conditions. In the chlorination disinfection process, acidic pH conditions are more suitable.

Residual chlorine can be reduced to harmless chloride ions through activated carbon or chemical reducing agents.

$$C+2Cl_2+2H_2O \rightarrow 4HCl+CO_2$$

Sodium Metabisulfite (SMBS) is the most commonly used chemical for removing residual chlorine.

When dissolved in water, SMBS forms sodium bisulfite (SBS):

$$Na_2S_2O_5+H_2O \rightarrow 2NaHSO_3$$

SBS then reduces hypochlorous acid:

$$NaHSO_3+HClO \rightarrow HCl+NaHSO_4$$

Theoretical calculations show that 1.34mg of SMBS can remove 1.0mg of residual chlorine, but in engineering practice, 3.0mg of SMBS is required to remove 1.0mg of residual chlorine.

Solid SMBS has a shelf life of 4～6 months under dry and cool conditions. In aqueous solution, it undergoes redox reactions with oxygen in the air. The shelf life of the solution varies with concentration, as shown in the following table.

Solution Concentration (wt%)	2	10	20	30
Maximum Shelf Life	3 days	1 week	1 month	6 months

SMBS must be food-grade and free of impurities. Dechlorination should be completely mixed with the water to be treated; it is recommended to install a static mixer at the dosing point. To ensure that the security filter cartridge is still under the sterilization protection of residual chlorine, the injection point can be set at the outlet of the security filter, in which case the added SMBS solution must be filtered. The dechlorinated water should not be stored in the water tank for too long.

5. Shock Disinfection Treatment

Shock treatment is to add a bactericide to the reverse osmosis or nanofiltration influent within a limited time period. Sodium bisulfite is often used for this purpose. Usually, 500～1000ppm of $NaHSO_3$ is added for about 30 minutes. Shock treatment can be performed periodically at fixed time intervals or when biological growth is suspected. During shock treatment, the produced water will contain 1%～4% of the added sodium bisulfite concentration, and whether to recover or discharge it depends on the purpose of the produced water.

6. Periodic Disinfection

Regularly disinfect the system to control biological pollution, which is suitable for systems with medium biological pollution hazards, but in highly polluted systems, disinfection is only an auxiliary method. Preventive disinfection is more effective than corrective disinfection because isolated bacteria are easier to kill and remove than thick biofilms. The disinfection interval is generally once a month, but systems with strict hygiene requirements and high-pollution raw water systems may require once a day. Membrane life is affected by the type and concentration of chemicals used; strong disinfection may shorten membrane life.

7. Other Methods

(1) Microfiltration or Ultrafiltration

They can effectively remove microorganisms, especially algae, and MF/UF must be made of chlorine-resistant materials to withstand regular disinfection.

(2) Copper Sulfate

It can be used to control biological growth. The concentration of continuously added $CuSO_4$ is 0.1～0.5mg/L, but it is not recommended for widespread use due to possible impurities, precipitation, environmental hazards, effectiveness against limited microorganisms, and environmental regulations.

(3) Ozone

It has stronger oxidizing properties than chlorine but decomposes rapidly. A certain amount must be maintained to kill microorganisms, and the ozone resistance of the equipment must be considered. To protect the membrane elements, ozone must be carefully removed, which can be achieved by ultraviolet irradiation.

(4) Ultraviolet Irradiation

Ultraviolet light at 254nm has a bactericidal effect, suitable for small water plants, no need to add chemicals, and low equipment maintenance requirements, but only suitable for relatively clean water sources.

(5) Sodium Bisulfite

When it reaches 50mg/L in the influent of seawater desalination systems, it can effectively control biological pollution and reduce colloidal pollution. Its acidic reaction generates hydrogen ions, and no acid addition is needed to control calcium carbonate.

$$HSO^{3-} \rightarrow H^{+}+SO_4^{2-}$$

(6) Granular Activated Carbon (GAC)

As a pretreatment, there is a risk of bacterial re-shedding, which may lead to biological pollution of the membrane. The large internal pore surface area of activated carbon will adsorb organic nutrients and promote biological growth. Only when the flow rate is low enough and the bed height is high enough, biological activities will be concentrated in the upper part of the filter layer, and the produced water will contain almost no bacteria and nutrients. Ozonation of the influent before entering the activated carbon filter will promote microbial activity.

8. Pretreatment Design and Operation

To prevent the membrane from biological pollution, the entire system from water intake to the membrane device must be kept clean and hygienic.

9. Selecting anti-pollution membrane elements can significantly reduce or delay biological pollution.

5-7 Prevention of Organic Pollution

The adsorption of organic matter on the membrane surface will cause flux loss. High-molecular-weight, hydrophobic, or positively charged organic matter is more likely to be adsorbed. A high pH value helps prevent organic pollution, but emulsified organic matter will form a pollution layer on the membrane surface.

The organic matter in natural water is mainly humic acid substances; when TOC exceeds 3mg/L, special consideration should be given to removal. Humic acid substances can be removed by flocculation, ultrafiltration, or activated carbon adsorption. When the oil and grease content in the influent exceeds 0.1mg/L, flocculation or activated carbon filtration should be adopted. These organic substances will be adsorbed on the membrane surface, but if the resulting flux decline does not exceed 15%, alkaline cleaning agents can be used for cleaning. In wastewater treatment, even if the organic matter content is very high, it can be treated, and on-site tests should be conducted for specific objects.

5-8 Prevention of Membrane Degradation

In addition to the pollution of the membrane by certain substances in the influent, the chemical stability of the membrane material to these substances must also be considered. Oxidants are harmful to polyamide composite membranes, and dechlorination methods must be used to remove them. Other chemicals, as long as they are in a dissolved state and do not aggregate into an organic phase, the membrane elements are stable to most chemicals within the pH range of 2～11.

5-9 Prevention of Iron and Manganese Fouling

Certain well water with a salt content in the brackish water range is in a reduced state and contains divalent iron ions and manganese ions. Iron, aluminum, and sludge are the main causes of membrane fouling. When such water sources are chlorinated or the oxygen content in the water reaches more than 5ppm, divalent iron will be converted into trivalent iron and form insoluble colloidal hydroxide particles. Iron oxidation occurs at a lower pH value, and iron fouling occurs more frequently than manganese fouling. Even if the SDI_{15} is less than 5 and the ferrous content in the reverse osmosis and nanofiltration influent is less than 0.1mg/L, fouling problems may still occur. Water sources with low alkalinity have a high iron concentration. The situations that cause the deposition of soluble iron and related pollutants on the membrane surface include the entry of oxygen into the influent containing divalent iron, the formation of $FeCO_3$ in water sources with high alkalinity, the reaction of iron with silicon to form insoluble iron silicate, the oxidation of iron-reducing bacteria, the transformation of iron-containing flocculants, the precipitation of steel pipe corrosion products, and the mixing of water sources containing divalent iron with water sources containing H_2S to form FeS. Treatment methods for such water sources include preventing the system from contacting air or oxidants; a low pH value is conducive to inhibiting the oxidation of Fe^{2+}. When pH＜6 and oxygen＜0.5mg/L, the maximum allowable Fe^{2+} concentration is 4mg/L. The following table lists some methods to remove ferrous or iron ions and prevent iron fouling.

Method	Description
Ion Exchange Softening	Cation exchange resin softening can remove soluble iron from water, with removal efficiency depending on the type of iron. Fe^{2+} and Fe^{3+} can be effectively adsorbed by strong acid cation resins. However, if their concentration exceeds 0.05ppm, they can foul the resin and lead to its degradation. Colloidal or organic-iron complexes are typically not adsorbed; their removal depends on particle size, operating flow rate, and bed depth. When treating water sources with high ferrous iron content, iron fouling is a primary concern. The addition of sodium metabisulfite can help prevent resin fouling caused by iron.
Flocculation	In-line flocculation can remove ferrous iron.
Scale Inhibitor	Some scale inhibitors can effectively prevent iron pollution, but different brands of scale inhibitors have different maximum allowable iron contents.
Oxidation Followed by Media Filtration 【Aeration】 【Chlorination】 【Ozonation】	Iron and manganese can be removed through oxidation and filtration. However, at higher pH levels, the oxidation reaction for removing divalent manganese by aeration alone is slow; therefore, potassium permanganate or chlorine dioxide is often used to improve removal efficiency. 【Aeration】can convert dissolved iron into insoluble iron, but if the carbon dioxide concentration in the water is too high, tiny colloidal iron will be formed, which is difficult to filter. 【Chlorination】uses sodium hypochlorite or bleaching powder to oxidize Fe^{2+} to Fe^{3+}, which is then removed by filtration through a multi-media filter. 【Ozonation】utilizes the strong oxidizing properties of ozone itself and the hydroxyl radicals (·OH) it readily produces upon decomposition in water to first oxidize Fe^{2+}.
Simultaneous Oxidation and Filtration ❖ Manganese Greensand Sand ❖ Pyrolusite (MnO_2) ❖ Specialized Products	This process uses filter media capable of oxidizing Fe^{2+}, such as manganese greensand, pyrolusite (MnO_2), or specialized products, to achieve simultaneous oxidation and filtration. In its dry state, manganese greensand has a spongy texture. When its oxidizing capacity is exhausted, it can be regenerated with $KMnO_4$. After regeneration, thorough rinsing is required to prevent oxidative damage to the membrane. This process is suitable when the Fe^{2+} concentration in the water is less than 2mg/L. For high Fe^{2+} concentrations, continuous dosing of $KMnO_4$ is necessary, and measures must be taken to prevent it from contacting the membrane. Some specialized filtration products effectively remove Fe^{2+} from RO feed water but may increase the pH, leading to a change in the LSI (Langelier Saturation Index); therefore, precautions must be taken to prevent $CaCO_3$ precipitation.
Oxidation—MF/UF Filtration	This is a newer technology where oxidation forms iron and manganese particles, which are then removed by microfiltration (MF) or ultrafiltration (UF).

Aluminum silicate fouling is prone to occur in the first and last stages of reverse osmosis or nanofiltration systems. Even a low concentration of aluminum (such as 50ppb) can lead to a decrease in system performance, the reasons include:

- Aluminum can react with silicon; even if the silicon concentration is as low as 10ppm, it will cause aluminum silicate fouling. Therefore, the use of aluminum-containing compounds in pretreatment will increase the fouling risk; it is recommended to prefer iron-containing products over aluminum-containing products.

- A low pH value (＜7) will affect the solubility of aluminum. According to the raw water composition, it is recommended to maintain the system operating pH value between 7～9 without forming carbonate scale.

- Polymer scale inhibitors (such as acrylic acid) are sensitive to heavy metals such as iron and manganese; improper selection will lead to scale inhibitor failure, causing scaling or scale inhibitor fouling, and the fouling products may become nutrients for microorganisms, leading to biological pollution.

- Fine sludge/sand particles; the treatment section should be equipped with a multimedia filter, ultrafiltration, or microfiltration for removal, and sometimes flocculants need to be added to increase particles to improve the removal efficiency.

When no flocculants or scale inhibitors are added to the raw water, the iron, manganese, and aluminum contents in the influent usually need to meet certain indicators.

Component	Maximum Content(ppm)	Conditions
Ferrous Iron	4	pH＜6, Oxygen＜0.5ppm
Iron and Manganese	0.05	-
Aluminum	0.05	-

Note: Since flocculants and material corrosion can also cause iron and aluminum fouling, the content of these ions must be analyzed in the influent or effluent of the security filter.

5-10 Treatment of Water Sources Containing H_2S

Certain well water sources have high salt content, are in a reduced state, and may contain hydrogen sulfide (H_2S). In an oxygen-free environment, H_2S exists as a soluble gas. Colloidal sulfur pollution caused by H_2S is difficult to clean and will lead to a significant decline in membrane element performance, such as reduced water production and desalination rate. An early signal of colloidal sulfur pollution is usually an increase in system pressure difference. When divalent iron is present in the water, it will also react with H_2S to form iron sulfide pollution. Phosphoric acid cleaning can effectively solve such pollution.

To avoid colloidal sulfur or sulfide fouling, the following measures are recommended:

- Maintain an oxygen-free state of the system: Keep the system oxygen-free by adding reducing agents such as sodium bisulfite.
- Influent degassing: Install a degassing device upstream or downstream of the membrane system to remove H_2S. If the RO/NF system cannot ensure that H_2S exists in a dissolved gas state, it is recommended to install the degassing device upstream (influent side); if the product water transportation system cannot ensure that H_2S exists in a dissolved gas state, it is recommended to install the degassing device downstream (product water side).
- Oxidize H_2S: Oxidize H_2S into insoluble sulfur using air, chlorine, or potassium permanganate. Insoluble sulfur can be removed by a multimedia filter or a combined process of flocculation and UF/MF. The chemical reaction is as follows:

$$2H_2S + O_2 \rightarrow 2H_2O + 2S\downarrow$$

Summary of Pretreatment Methods:

Summary Table of Scale and Fouling Prevention Measures for Membrane Systems

Pretreatment	$CaCO_3$	$CaSO_4$	$BaSO_4$	$SrSO_4$	CaF_2	SiO_2	SDI	Fe	Al	Bacteria	Oxidizing Agent	Organic Matter
Acid Addition	●							○				
Scale Inhibitor Dosing	○	●	●	●	●	○						
Ion Exchange Resin Softening	●	●	●	●	●							
Ion Exchange Dealkalization	○	○	○	○	○							
Lime Softening	○	○	○	○	○	○	○	○				○
Preventive Cleaning	○					○	○	○	○	○		○
Adjustment of Operating Parameters		○	○	○	○	●						
Multimedia Filtration						○	○	○	○			
Oxidation-Filtration							○	●				
In-line Flocculation							○	○	○			○
Flocculation-Coagulation Aid						○	●	○	○			●
Microfiltration (MF)/Ultrafiltration (UF)						●	●	○	○	○		●
Cartridge Filtration						○	○	○	○	○		
Chlorination Oxidation									●			
Dechlorination											●	
Shock Treatment									○			
Preventive Disinfection									○			
Granular Activated Carbon (GAC) Filtration									○		●	●

Note: ○ Possibly effective ● Highly effective

Reference Methods for Determination of Various Chemical Measurement Indicators of Water Quality

Chemical Measurement Index	Test Methods
Total Hardness	GB/T6909
Total Alkalinity	GB/T1576-2008 Appendix H
Chloride Ion	GB/T15453
Residual Chlorine	GB/T14424
pH Value	GB/T6904
Turbidity	GB/T12151
Acidity	DL/T502.5
Conductivity	GB/T6908
Carbon Dioxide	DL/T502.8
Silicon Dioxide	GB/T12148；GB/T12149
Sodium Ion	GB/T14640
Total Iron Ion	DL/T502.25; For pure water:GB/T14427
Total Copper Ion	GB/T13689；DL/T502.14
Chemical Oxygen Demand (COD)	GB/T14420；DL/T502.22
Oil	GB/T12152

Chapter 6. System Design

6-1 Preface

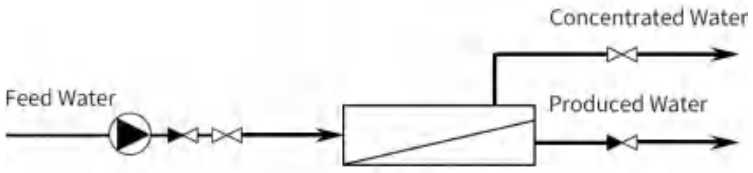
Reverse Osmosis (RO) and Nanofiltration (NF) systems generally consist of pre-treatment equipment, RO/NF equipment, and post-treatment equipment. The pre-treatment equipment adjusts the raw water quality to meet the requirements of the RO/NF system, while the post-treatment equipment ensures the produced water meets the application standards and the concentrated water meets the discharge standards. During the design process, it is crucial to accurately grasp the raw water quality and produced water requirements; optimizing the design of each unit is the key to ensuring the normal operation of the system. Collecting basic design data (such as the Summary Report of System Design Data and the Raw Water Quality Analysis Report) is essential for optimized design—the more complete the data, the better the design can meet the user's needs.

6-2 System Configuration

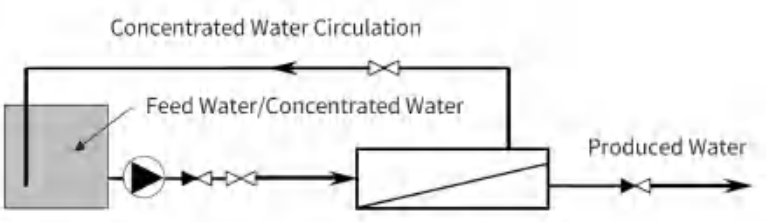
When designing RO/NF systems, the selection of membrane element model, determination of water flux, and setting of recovery rate are critical. Although high recovery rates can reduce post-treatment costs, they increase scaling risks, reduce produced water quality, raise operating pressure, and increase equipment costs. Therefore, during design, a balance must be struck between recovery rate and system cost, while adhering to safety standards and maintaining design flexibility.

System operation modes are divided into continuous operation and batch operation. Batch operation is suitable for small-scale concentration and situations with insufficient water supply, while continuous operation separates produced water and concentrated water continuously at a certain operating pressure by setting the recovery rate and water production capacity, which is often used in large-scale RO/NF units.

Continuous Treatment Operation Mode

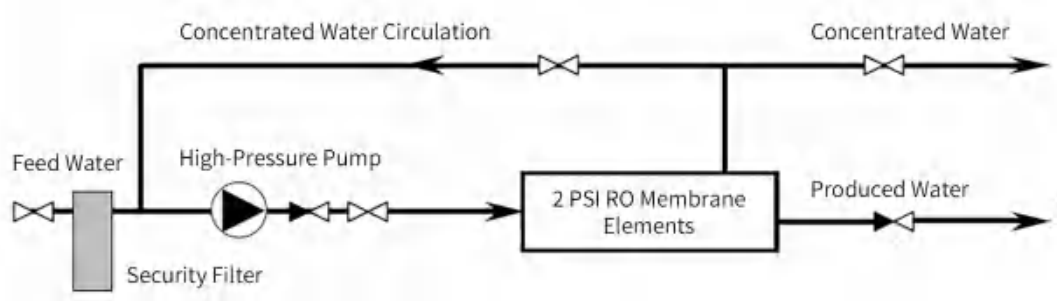


Batch Treatment Operation Mode



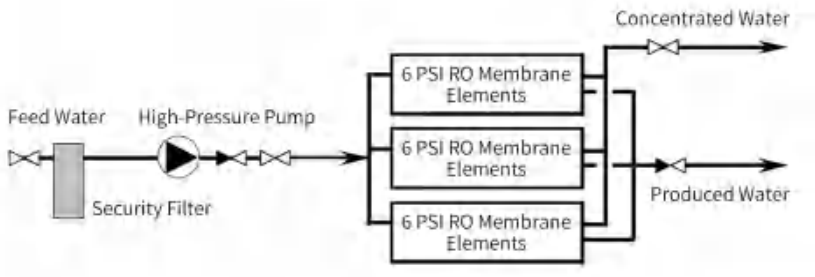
1. Single-Element System

The single-element system is the most basic RO or NF system. Although it contains only one membrane element, it is equipped with complete supporting equipment. Understanding its structure and design is helpful for understanding the design of large-scale systems. Controlling an appropriate feed water range (maximum feed water flow and minimum concentrated water flow) is critical to preventing water flux reduction and membrane fouling caused by concentration polarization. Since the system uses only one membrane element, and the design requires that the ratio of concentrated water discharge to produced water volume for a single 40-inch membrane element is at least 5:1 (approximately 18% recovery rate), it is difficult for a single membrane element system to achieve a high system recovery rate. To improve the recovery rate, part of the concentrated water discharged from the system can be returned to the feed water, thereby increasing the system recovery rate to over 50%. However, since part of the concentrated water is returned to the feed water, the produced water quality will decrease, and energy consumption will also increase.



2. Single-Stage System Arrangement

A single-stage system is composed of multiple membrane elements in parallel, and its arrangement is similar to that of a single-element system, with a recovery rate usually between 15% and 50%. The recovery rate can be increased by connecting more membrane elements in series within the pressure vessel. The following table shows the relationship between the number of series-connected membrane elements and the recovery rate:

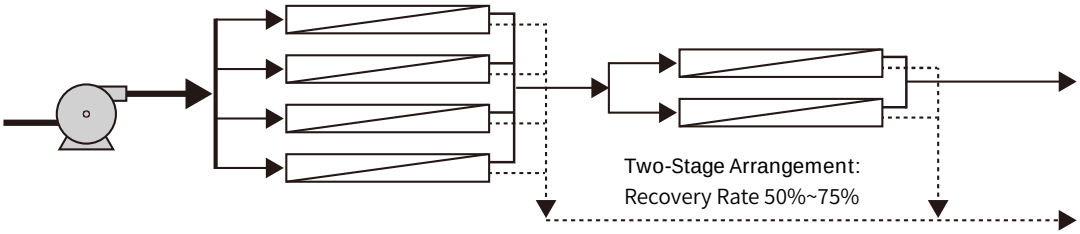


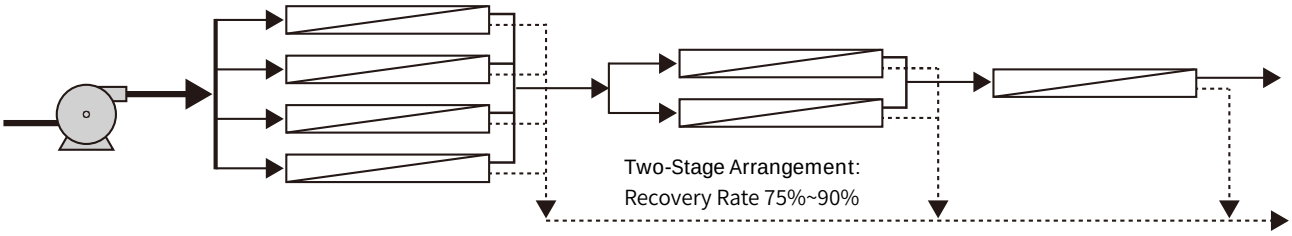
Number of Series-Connected Membrane Elements	1	2	3	4	5	6
Recovery Rate (%)	16	29	38	46	53	59

3. Multi-Stage System Arrangement

When the system recovery rate needs to be higher than 50%, a multi-stage system can be adopted. In a multi-stage system, the concentrated water from the previous stage serves as the feed water for the next stage. The feed water flow rate decreases gradually, and the salt content increases gradually from one stage to the next. Therefore, the number of membrane elements in the latter stages must be less than that in the previous stages to ensure an appropriate feed water flow rate. Common arrangement ratios are 2:1 or 4:2:1. The recovery rate of a two-stage system can reach 50% to 75%, and that of a three-stage system can reach 75% to 90%.

In a multi-stage system, the osmotic pressure on the concentrated water side will increase continuously, which may lead to insufficient Net Driving Pressure (NDP) and cause unbalanced produced water between the front and rear stages.





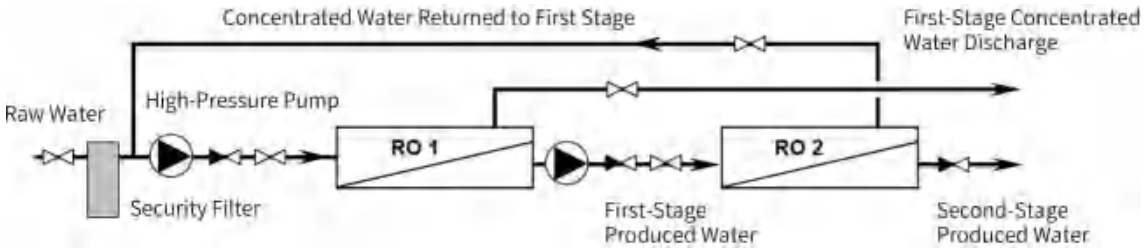
To solve this problem, there are the following three methods:

- Install a booster pump between each stage: Increase the driving pressure of the latter stages to ensure balanced water production among all stages.
- Install throttling valves on the produced water side of the first and second stages: Reduce the water production of the front stages by increasing the produced water backpressure to maintain the balance of the overall effective pressure (NDP). However, it should be noted that backpressure (produced water side pressure > feed water side pressure) may occur when the system stops operating, so careful handling is necessary during design and operation.
- Use membrane elements with different filtration resistances in the front and rear stages: Use membrane elements with high resistance (such as XFR, FRHR, or even SW series seawater desalination membrane elements) in the front stages, and membrane elements with low resistance (such as LP series) in the rear stages to ensure water production.

4. Multi-Stage System

In some applications, the produced water quality of single-stage RO cannot meet the water use requirements. To reduce the salt content of the produced water as much as possible, a multi-stage RO system can be adopted, where the produced water from the previous RO stage serves as the feed water for the next RO stage. When designing a multi-stage RO system, depending on the required produced water quality, it can be considered that all or part of the produced water from the first stage enters the second-stage RO system. That is, the feed water of the second-stage RO is the produced water of the first-stage RO. The produced water after the second-stage treatment is mixed with the low-concentration produced water of the first stage, while the concentrated water of the second-stage RO is recycled back to the feed water of the first-stage RO. Since the salt content of the second-stage concentrated water is usually lower than that of the first-stage feed water, recirculation can reduce the salt content of the first-stage feed water, thereby improving the overall recovery rate. This design is called the split-flow partial two-stage design.

Two-Stage RO System

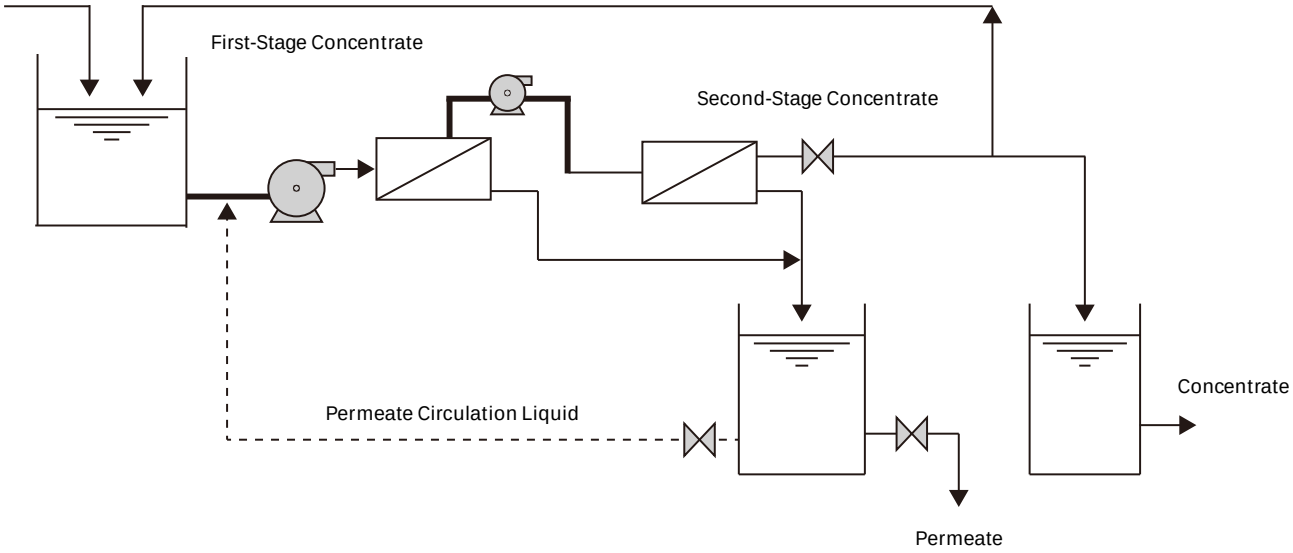


In the design of the second-stage RO system, in addition to the basic system configuration and operating parameters, the following points require special attention:

- Select ultra-low pressure RO membrane elements with high flux: For example, the LP series. These membrane elements can achieve high water production flux at lower pressure, thereby reducing energy consumption and improving system economy.
- A higher water flux can be selected in the design of the second-stage RO system. Generally, an 8-inch membrane element can be designed to produce 1.5 to 2.0 m^3/h of water, i.e., 40 to 54 LMH.
- In the second-stage RO, the Concentration Polarization Index (β) can be as high as 1.70.
- The arrangement of the second-stage RO system should preferably be close to 3:1.
- It is preferable to select pressure vessels with 4 to 5 elements.
- The recovery rate should be greater than or equal to 85%, and preferably reach 90%.

5. Batch Operation Concentration Circulation System

In the design of RO and NF systems, especially for industrial applications requiring concentration such as tea, fruit juice, and pharmaceuticals, a batch operation concentration circulation system is usually adopted. The design of such a system needs to comprehensively consider the treatment capacity and treatment time.



The batch treatment system increases the raw liquid concentration by returning the concentrated water to the raw liquid tank. However, as the concentration ratio increases, the osmotic pressure rises significantly, which requires precise control of pressure adjustment and membrane fouling. The design should also consider raw liquid temperature control, anti-corrosion measures, and cleaning and disinfection methods.

Compared with continuous treatment, batch treatment is more complex but can better handle problems arising during the concentration process.

6. Possibilities of Special Arrangements

According to special requirements, the following special designs are available for selection:

(1) Improving Product Quality

- For brackish water sources, select seawater elements in part or in full.
- Select seawater elements in a certain stage of the multi-stage treatment system or use seawater elements in all stages.
- Return the produced water of the last stage to the feed water.

(2) Improving System Recovery Rate

- After special pre-treatment, use the concentrated water as the feed water for the second system, i.e., add a concentrated water recovery system.
- Achieve high system recovery rate and balanced membrane element water production for raw water with medium salt content.
- Install inter-stage booster pumps between stages to offset the increase in osmotic pressure in the latter stages.
- Apply backpressure to the produced water of each stage in a decreasing manner from the first stage to the last stage.
- Use SW or SWHR membrane elements in the first stage.

(3) Producing Produced Water of Different Qualities

- Collect the produced water of different stages separately. The produced water of the first stage has the best quality, especially when seawater desalination membrane elements are selected for the first stage.
- Reduce the system water production to obtain the required produced water quality exactly.
- Mix the produced water with part of the raw water.

(4) Providing Opportunities for Future System Expansion

- Use blank elements (i.e., replace elements with produced water pipes) in pressure vessels.
- Adopt a modular design for the membrane module support to facilitate the installation of additional pressure vessels in the future.

6-3 Membrane System Design Steps

Step 1: Consider the feed water source, water quality, feed water and produced water flow rates, and the required produced water quality

The design of the membrane system depends on the characteristics of the raw water and the purpose of the treated produced water. Therefore, it is necessary to first collect the system design data and raw water analysis report in detail in accordance with relevant standards and requirements.

Step 2: Select the system arrangement and number of stages

The conventional arrangement of water treatment systems is the single-pass feed water type, while the concentrated water circulation arrangement is often used in smaller systems. For example, most commercial water treatment systems adopt the concentrated water circulation arrangement; when a system of a certain scale with a small number of required elements cannot achieve a sufficient system recovery rate by using the single-pass feed water type, the concentrated water circulation arrangement is also adopted; in special application fields such as process material concentration and wastewater treatment, the concentrated water circulation system is usually adopted.

RO/NF systems usually adopt continuous operation mode, where the operating conditions of each membrane element in the system do not change with time. However, in some application scenarios, such as wastewater treatment, process material concentration, or when the water supply is small and discontinuous, a batch treatment system is selected. At this time, the feed water is collected in the raw water tank and then treated in a circulating manner. Some batch treatment operations are improved versions of batch treatment, where raw water is continuously injected into the raw water tank during operation.

A multi-stage (two-stage) treatment system is a combined process of two traditional RO/NF systems, where the produced water of the first stage serves as the feed water of the second stage. Each stage can be a single-stage or multi-stage type, and can adopt either the single-pass raw water type or the concentrated water recirculation type. The production of pharmaceutical and medical water often uses the multi-stage

produced water treatment process. If it is desired to replace the second-stage membrane system, the ion exchange process can be considered.

Step 3: Selection of Membrane Elements

Select membrane elements based on the feed water salt content, potential feed water pollution, required system desalination rate, water production capacity, and energy consumption requirements. When the system water production is greater than 10 gpm (2.3 m^3/h), select 8-inch diameter and 40-inch length membrane elements; when the system is small, select small-sized elements. For the characteristics of Proshare membrane elements and their selection in specific fields, please refer to the relevant chapters of this manual or contact Proshare representatives. When extremely high produced water quality is required, ion exchange resins are usually used for advanced treatment of RO/NF produced water.

Step 4: Determination of Average Membrane Flux

The selection of the average flux design value f (GFD or L/m^2h) can be based on on-site test data, previous experience, or the typical design flux values recommended in the design guidelines.

Step 5: Calculate the Required Number of Elements

When the design produced water flux and water production capacity are determined, the required theoretical number of membrane elements can be calculated using the following formula:

$$N_e = \frac{Q_p}{J \times S}$$

Where:

Qp = Water production capacity, unit: m^3/h

J = Water production flux per unit area, unit: LMH

S = Membrane element area, unit: m^2

Ne = Theoretical number of membrane elements, unit: piece

Step 6: Calculate the Required Number of Pressure Vessels

After determining the number of membrane elements that can be loaded in each pressure vessel, the required number of pressure vessels can be calculated using the following formula:

$$N_v = \frac{N_e}{V_e}$$

Where:

Nv = Number of pressure vessels

Ne = Number of membrane elements

Ve = Number of membrane elements that can be loaded in a single pressure vessel

Step 7: Determination of the Number of Stages

The number of stages is determined by the number of series-connected pressure vessels. Each stage consists of a certain number of pressure vessels in parallel. The number of stages is a function of the system design recovery rate, the number of elements contained in each pressure vessel, and the feed water quality. The higher the system recovery rate and the worse the feed water quality, the longer the system should be, i.e., the more elements should be connected in series.

Number of Stages for Brackish Water Desalination Membrane Systems

System Recovery Rate (%)	Number of Series-Connected Elements	Number of Stages for Pressure Vessels with 6 Elements
40-60	6	1
70-80	12	2
85-90	18	3

Note: If the concentrated water circulation method is adopted, a single-stage system can also be designed to achieve a higher recovery rate.

When designing a seawater desalination system, its recovery rate should be lower than that of a brackish water system. The number of stages of the membrane system depends on the system recovery rate, as shown in the following table:

Number of Stages of Pressure Vessels

System Recovery Rate (%)	Number of Series-Connected Elements	6-Elements/ Housing	7-Elements/ Housing	8-Elements/ Housing
35-40	6	1	1	1
45	7-12	2	1	1
50	8-12	2	2	1
55-60	12-14	2	2	2

Step 8: Membrane Element Arrangement Ratio

The ratio of the number of pressure vessels in adjacent stages is called the arrangement ratio. When using conventional 6-element housings, the arrangement ratio between adjacent two stages is usually close to 2:1. Another important factor in determining the pressure vessel arrangement is the feed water flow rate of the first stage and the concentrated water flow rate of each pressure vessel in the last stage.

Step 9: Analyze and Optimize the Membrane System

The established membrane system structure can be analyzed and adjusted using the Proshare® RO System Analysis Software. This program can automatically provide the recommended membrane arrangement combination and calculate the feed water pressure, system produced water quality, and operating parameters of each element. Experienced membrane system design engineers can also easily further optimize the system design by manually changing the number, type, and arrangement of membrane elements.

The steps are as follows:

① Open the Proshare® membrane system design software;

② Enter membrane system-related information such as system water volume and recovery rate in the "System Data" of Step;

③ Enter the ion composition of the raw water in the "Water Quality Information" of Step ②, and automatically perform ion balance calculation;

④ Select the type of membrane element in the "Design and Selection" of Step ③, enter the produced water pressure and the increased pressure between stages, then click "Recommended Design", and the system will automatically provide the recommended membrane arrangement and quantity (experienced membrane system design engineers can adjust it by themselves), then click "Start Calculation", and the system will start the simulation calculation, which will be completed after a few seconds;

⑤ The system data and ion data obtained after calculation can be viewed in the subsequent Step ④, ⑤, ⑥, and ⑦ windows.

Step 10: Design Equations and Parameters

The performance of a specific RO/NF system includes the system water production and desalination rate under a given feed water pressure. In simple terms, the water production Q of the RO/NF system is proportional to the effective membrane area S and the net osmotic driving pressure ($\Delta P - \Delta \pi$). The proportional constant is called the hydraulic permeability coefficient A of the membrane. The hydraulic permeability equation is as follows:

$$Q=A \times S \times (\Delta P - \Delta \pi)$$

Salt passes through the membrane surface through diffusion. The salt flux NA is proportional to the salt concentration difference between the two sides of the membrane. The proportional constant is called the salt diffusion coefficient B:

$$NA=B \times (Cfc - Cp)$$

Where:

Cfc = Average concentration between feed water and concentrated water

Cp = Produced water concentration

Step 11: Testing

For desalination systems with clear source and composition of general water sources, their performance can be predicted through calculation. However, in the following cases, it is recommended to use testing to assist in system design:

- Unclear feed water quality;
- Unclear fluctuation of feed water quality;
- Special or new application fields, such as new processes or wastewater treatment;
- Special produced water quality requirements;
- Extremely high system recovery rate (>80%);
- Large-scale systems, >500 m^3/h (3.2 mgd).

Tests are usually carried out in the following levels in sequence:

(1) Screening Test

Purpose: Select suitable membrane sheets and initially understand their water flux (L/m^{2}h or GFD) and rejection rate performance.

Method 1: Install a small flat membrane in a small evaluation cell and operate the test solution system in a cross-flow manner. This method is fast, low-cost, and requires only a small amount of test solution, but cannot provide engineering data required for scaling up and long-term impact data of the membrane.

(2) Application Test

Purpose: Provide data required for scale-up design, such as the change trend of produced water flux and produced water quality with feed water pressure and system recovery rate.

Method: Use 2540 or 4040 membrane elements. The test solution requires 50 to 200 liters (15 to 30 gallons). Install the membrane elements on the application test evaluation device and adjust the feed water flow rate, pressure, and temperature.

Determine the operating pressure—

Adjust the feed water pressure to achieve the required produced water quality and flux (generally 10 to 34 L/m^{2}h, 6 to 20 GFD), and determine the optimal operating pressure. When the membrane flux increases, maintain sufficient water inflow to ensure a low recovery rate (<5%). The feed water pressure in the first stage is used to determine the recovery rate in the second stage.

Determine the concentration ratio and recovery rate—

Carry out the second-stage test through the batch treatment mode, monitor the produced water flow rate and quality until the produced water volume drops to an uneconomically low level or the water quality is unqualified. Determine the Concentration Factor (CF) by calculating the ratio of the initial raw water volume to the residual solution volume. Determine the recovery rate by calculating the ratio of (raw water volume minus residual solution volume) to the original raw water volume. Repeated tests can obtain data on membrane stability and fouling.

(3) Simulation Test

Purpose: Verify the system design, fine-tune operating parameters, and reduce unforeseen risks in large-scale systems.

Method: Take representative raw water from the site for continuous operation. At least one 40-inch long membrane element is required. It is recommended to use the same element arrangement as the large-scale system. The water production of the simulation device should be at least 1% of that of the large-scale system, and the operation should last for more than 30 days.

Step 12: Main Components of the System

(1) High-Pressure Pump

The outlet pressure of the high-pressure pump must be controlled to maintain the designed water production while not exceeding the maximum allowable feed water pressure of the membrane element. The maximum pressure limits are as follows:

LP, BW, and NF elements: 41 bar;

SW elements: 83 bar;

PX120 special elements: 120 bar.

Positive Displacement Pump (Plunger Pump)—

The outlet flow rate and pressure of a positive displacement pump (such as a plunger pump) cannot be controlled by a throttle valve, but can only be adjusted by setting a backpressure valve on the bypass between the pump inlet and outlet. In addition, a buffer device must be installed on the pump outlet pipeline to reduce pressure pulsation, and a safety relief valve must be installed to ensure that the outlet pressure does not exceed the maximum allowable value of the membrane element.

Centrifugal Pump—

The outlet flow rate and pressure of a centrifugal pump can be controlled by a throttle valve installed on the outlet pipeline. Most membrane systems use centrifugal pumps driven by constant-speed motors. However, centrifugal pumps driven by variable-speed motors, although having a higher initial investment, have lower operating energy consumption, especially suitable for situations where the feed water temperature difference exceeds 5℃.

In seawater desalination systems, about 55% to 60% of the high-pressure concentrated water leaves the system at a pressure of about 60 bar. This part of energy can be recovered in the following ways to reduce the unit energy consumption of the system:

- Impulse water wheel type
- Reverse turbine
- Piston-type work exchanger
- Pressure exchange type
- Energy recovery devices can convert the energy of high-pressure concentrated water into mechanical energy to assist in driving the high-pressure pump, with an energy-saving effect of up to about 40%.

(2) Pressure Vessel

Pressure vessels have various diameters, lengths, and pressure ratings. When selecting a pressure vessel, the selected pressure rating must be higher than the maximum pressure when the operating pressure needs to be increased due to membrane fouling (usually required to be 10% higher than the system operating pressure design value after 3 years). When dynamic pressure occurs on the produced water side during operation, the strength of the produced water outlet of some pressure vessels may become a limiting factor,

especially for some pressure vessels made of polyvinyl chloride (PVC) material. In this case, the pressure vessel manufacturer should be consulted.

(3) Emergency Switch

Under abnormal operating conditions, the system must be shut down immediately to protect the membrane elements. The following are some abnormal operating conditions and their handling methods:

Abnormal Condition	Method
Excessively high feed water pressure	Install a high-pressure protection switch on the high-pressure pump outlet pipeline
Insufficient water supply pressure	Install a low-pressure protection switch on the high-pressure pump suction pipeline
Excessively high feed water temperature	Install a high-temperature protection switch on the feed water pipeline
Produced water pressure exceeds feed water pressure by 0.3 bar	Install a pressure relief safety device on the produced water pipeline
Excessively high concentration of particles and colloids in feed water	Install turbidity and SDI automatic control devices on the feed water pipeline
Excessively high concentration of insoluble salts in feed water	The chemical dosing pumps for acid and scale inhibitor addition must be electrically interlocked with the high-pressure pump motor, and a high pH protection switch must be installed
Presence of oxidants in feed water	Install an ORP controller or chlorine automatic monitoring device in the feed water, which can automatically shut down the system
Presence of oil in feed water	Install oil monitoring equipment in the feed water

(4) Valves

Common valve types and their functions in RO/NF systems are as follows:

- System feed water valve: Used to cut off water flow during maintenance or system preservation.
- Regulating valve: Installed at the outlet of the centrifugal pump or the bypass of the positive displacement pump to control the operating pressure and system pressure rise rate.
- Check valve: Installed at the pump outlet and on the produced water pipeline to prevent water backflow.
- Pressure relief valve: Installed on the produced water pipeline to prevent the produced water pressure from exceeding the feed water pressure.
- Concentrated water flow control valve: Installed on the concentrated water pipeline to control the recovery rate (Note: Backpressure valves cannot be used).
- Drain valve: Installed on the produced water pipeline for draining unqualified produced water during cleaning or startup.
- Cleaning circuit valve: Installed on the feed water and concentrated water pipelines to connect the cleaning circuit (each stage can be cleaned separately).

(5) Control Instruments

To ensure the normal operation of the RO/NF system, the following instruments must be installed and installed and calibrated in accordance with the manufacturer's regulations:

- Pressure gauge: Measures the pressure drop of the security filter, pump inlet and outlet pressure, membrane element inlet pressure, pressure drop between system stages, and produced water pressure. For liquid-filled pressure gauges, a liquid compatible with the membrane should be used, such as water or glycerin.
- Flowmeter: Measures the total flow of concentrated water and produced water, as well as the produced water flow of each stage. Feed water = concentrated water + produced water.
- Thermometer: Installed at the inlet of the feed water pressure vessel.
- Water meter: Records the cumulative produced water volume and system water consumption.
- Timer: Records the cumulative operating time.
- pH meter: Installed on the feed water pipeline after acid addition to monitor whether carbonate scaling occurs.
- Conductivity meter: Installed on the feed water, concentrated water, and produced water pipelines to detect the produced water quality and system desalination rate.
- Feed water ORP meter (Oxidation-Reduction Potential meter).
- Sampling port: Set on the feed water, concentrated water, and produced water pipelines to facilitate the evaluation of system performance. It is recommended to set a sampling port at the produced water outlet of each pressure vessel for troubleshooting.

(6) Water Tanks

The water level of the water tank should be maintained above the minimum water level. The inlet and outlet pipelines must be installed correctly to avoid dead ends, and dust-proof and anti-microbial contamination measures must be taken. In situations with strict requirements, the water tank should be closed-type and equipped with a special breather filter.

Raw Water Tank

- Chlorine-treated raw water: A reaction time of 20 to 30 minutes is required, and the free space in the media filter can also meet this requirement.
- Buffering function: Enable the RO/NF system to operate continuously during the filter backwashing period.
- Operation mode: A raw water tank must be equipped for batch or semi-batch operation modes.

Produced Water Tank

- Produced water storage: A produced water tank is required when the produced water is the final product.
- System control: System startup and shutdown are interlocked with the liquid level of the produced water tank.
- Design consideration: The treatment capacity of the RO/NF system should match the size of the produced water tank to ensure that the system can operate continuously for several hours, reduce the shutdown frequency, and improve performance.

Drawback Tank

- Function: Prevent produced water from returning to the membrane elements due to natural osmosis when the system is shut down, causing pollution and other problems.
- Necessity of setting: Common in seawater desalination systems, but not in brackish water systems.
- Problem prevention:
  - Prevent bacterial and fungal contamination from the air on the produced water side of the membrane.
  - Avoid air impact damaging instruments and affecting set values.
  - Prevent the membrane sheets in the membrane elements from drying out due to water loss, resulting in water flux loss.
  - Avoid reductive substances in the feed water coming into contact with air, causing membrane oxidation and colloidal precipitation pollution.

- Design requirements:
  - Small volume.
  - Chlorine-treated produced water must not be drawn back into the membrane elements.
  - The water level is higher than the highest point of the pressure vessel but does not exceed the lowest pressure vessel of the system by 3 meters.
  - Produced water enters from the bottom and flows out from the top, and the water tank should be covered.
  - The chlorine addition point should be after the drawback tank.

- Volume calculation: $VDBT = (25TE) - VPP$
  - VDBT = Drawback tank volume (liters)
  - TE = Number of elements used in the system
  - VPP = Volume of the produced water pipeline between the pressure vessel and the drawback tank (liters)

Chemical Dosing Tank

- Purpose: Used for dosing treatment of feed water.
- Volume: Generally, it is the daily chemical consumption.

Cleaning Tank

- Purpose: As part of the cleaning system equipment, it is used to store cleaning solution.
- Details: See the introduction in the Cleaning and Disinfection section.

(7) Pipeline Requirements

Material and Strength

Pipelines should be made of materials with strong corrosion resistance and capable of withstanding the system pressure when the valve is closed. The design pressure should be greater than the pressure when the valve is closed, and the pressure when the valve is closed should be greater than the operating pressure. Generally, low-pressure RO systems use SUS304 or higher-grade stainless steel. Produced water pipelines usually use PVC materials.

Pipe Diameter

The diameter of the pipeline should ensure that excessive pressure loss does not occur within the system flow range. The diameter of the produced water pipeline is particularly important, because an excessively small produced water pipeline can easily lead to backpressure, thereby damaging the membrane elements. The following table lists the relationship between flow rate, maximum flow velocity, and pipeline inner diameter:

Flow Range (GPM)	Pipe Inner Diameter (Inch)	Maximum Linear Velocity (m/s)
0-4	1/2	1.98
4-10	3/4	2.19
10-20	1	2.50
20-50	1-1/2	2.77
50-100	2	3.11
100-175	2-1/2	3.47
175-300	3	4.15

6-4 Design Recommendations for Facilitating Future System Troubleshooting

When designing or purchasing a large-scale membrane system, to facilitate future troubleshooting, it is recommended to consider the following equipment designs and accessories. Although these are not necessary for the basic operation of the system, they can make daily operations and troubleshooting easier, faster, and more effective.

1. Space for Loading/Unloading and Troubleshooting

Even if the membrane system is designed to be very compact, the layout of equipment, pipelines, and supports should not be too crowded, so as not to restrict the access of operators and maintenance personnel to the membrane system. A good design should ensure that operators and maintenance personnel can access the feed water and concentrated water ends of all pressure vessels without obstacles for element loading/unloading and troubleshooting. When loading elements, the space between the feed water end of the pressure vessel and the nearest equipment or support should be at least the length of one element. When removing elements, more space is usually required to push elements toward the concentrated water end of the pressure vessel using wooden boards or other tools.

2. Sampling Interfaces for Detecting Single Elements and Single Pressure Vessels

During troubleshooting, it is first necessary to determine the specific location of the problem, which may be a certain stage, a certain pressure vessel, or even a single element. Setting sampling ports at the produced

water outlets of all pressure vessels allows the single-element detection tube to pass through, which helps to quickly locate the problem. In addition, special sampling points for feed water, concentrated water, and inter-stage should be set to lock the problem in a certain stage, facilitate system mass balance, and verify the accuracy of the flow measurement instrument and set the maximum system recovery rate.

3. Inter-Stage Performance Monitoring Instruments

In addition to simple sampling ports, to facilitate data collection and system performance standardization, it is recommended to install appropriate instruments between system stages to measure the conductivity or TDS, pressure, temperature, and flow rate of inter-stage feed water, concentrated water, and produced water. With these data, the performance of each stage can be monitored, thereby diagnosing faults at an early stage. Although some instruments can be reduced through system mass balance calculations, equipping all instruments and then performing mass balance can not only verify data consistency but also monitor instrument reliability.

4. Online Standardization

To realize continuous tracking and performance monitoring of the system, the highest-level approach is to use online instruments to continuously transmit the collected on-site data to the standardization program for continuous standardization. For extra-large systems or systems with constantly changing feed water conditions, setting up online control is particularly important.

5. Capability for Individual Stage Cleaning

Many large and medium-sized systems are equipped with a Clean-in-Place (CIP) system. To enhance cleaning efficiency, it is recommended to configure sufficient piping and valves to allow for chemical cleaning of each individual stage of the system separately. If multiple stages are cleaned simultaneously, contaminants such as dirt, biological foulants, and inorganic scale from the first stage must pass through the subsequent stages before being removed from the system, which reduces cleaning efficiency. The CIP system should also provide an appropriate flow rate and include components for heating the cleaning solution.

6. Capability for Permeate Flush

To reduce the frequency of cleaning, it is advisable to equip the system with a periodic permeate flush function. By circulating reverse osmosis permeate for flushing, or allowing product water to flow through the system at a high flow rate, foulant layers can be loosened and flushed out from the membrane elements before they firmly adhere to the membrane surface. Designing an automatic permeate flush function is particularly important when treating wastewater.

7. SDI Measurement Device and Sampling Points

The SDI (Silt Density Index) measurement device is an important tool for diagnosing the pretreatment system. By installing sampling connections and configuring an SDI instrument in the pretreatment section, the location of a pretreatment system malfunction can be quickly identified.

8. On-Site Test Bench

Setting up a simple on-site laboratory for water quality tracking analysis is particularly beneficial for the dosing and efficacy evaluation of pretreatment chemicals.

9. Single-Element Test Device

Conducting single-element tests at the water treatment site allows for the rapid testing and performance assessment of membrane elements suspected of having issues. Furthermore, before cleaning an entire plant, cleaning strategies can be tested and validated by experimenting on a single fouled element. For systems using standard 8-inch membrane elements with a total number exceeding 500 elements—especially those treating complex source water, wastewater, or in concentration/separation applications—it is recommended to install a single-element device capable of simultaneously cleaning and evaluating one membrane element within a pressure vessel. This assists operators in exploring optimal cleaning conditions or, for severely fouled trains, continuously removing elements from each pressure vessel to clean them individually and in parallel, thereby maximizing the restoration of membrane element performance.

Chapter 7. Transportation, Installation and Operation of Membrane Element

7-1 Transportation, Storage and Installation of Membrane Element

1. Transportation and Storage of Membrane Element

New Proshare membrane elements are delivered either dry or wet. Prior to initial use, all membrane elements must be stored in their original packaging under the specified storage conditions (including but not limited to vacuum sealing and intact packaging bags). During storage before installation and transportation to the site, membrane elements should be kept in a dry and ventilated environment with a recommended temperature range of 5～45℃. Direct sunlight exposure and contact with oxidizing gases must be avoided.

Precautions for Transportation and Storage of Membrane Element

No.	Precautions	Reasons	Impact on Performance
1	Wet elements should be kept above 5℃ as much as possible; freezing of membrane elements is strictly prohibited.	Freezing will cause volume expansion of the protective solution inside the membrane elements, which may reduce the performance of the membrane elements when reused. In such cases, our company does not provide performance guarantee for the products. We apologize for any inconvenience caused.	Very High
2	Dry elements should be stored in a dark indoor environment at -4～45℃.	Storing outside the temperature range of -4～45℃ will lead to performance degradation of the membrane elements when reused. In such cases, our company does not provide performance guarantee for the products. We apologize for any inconvenience caused.	Very High
3	Avoid rough handling, throwing or dropping the packaging during transportation.	The protective solution for wet elements is 1% sodium bisulfite. If the plastic bag inside the packaging box is damaged, the protective solution will leak, losing its protective effect on the membrane elements and wetting the outer packaging box, resulting in reduced strength of the packaging box. Therefore, brutal operation should be avoided during transportation, and the fixed large packaging should not be disassembled. Do not use equipment that may cause packaging damage.	High
4	Do not immerse the packaging box in water.		
5	Do not place vertically.		
6	Even if the membrane element is sealed with protective solution, please use the membrane product as soon as possible. Wet membrane elements should be used within 6 months of purchase, and dry membrane elements should be used within 12 months of purchase.	If stored for a long time before use, the protective solution may decompose and cause performance changes. If the protective solution inside the membrane element has completely volatilized, a new protective solution should be prepared and added to the packaging of the membrane element. Our company will not provide corresponding performance guarantee for inventory backup products that do not undergo this operation. We apologize for any inconvenience caused.	High

Disposal of Spent Elements

- Spent membrane elements can be disposed of as general municipal waste provided that the following conditions are met:
- The element does not contain protective solution or other toxic liquids;
- No toxic substances are present on the membrane surface (if the element is used for wastewater treatment).

2. Installation of Membrane Elements

The following precautions must be followed when installing membrane elements. Failure to strictly comply with these precautions may cause varying degrees of damage to the membrane elements and lead to performance degradation. Therefore, please confirm the following precautions before installing membrane elements and strictly prohibit prohibited items.

Precautions for Installation of Membrane Elements

No.	Precautions	Reasons	Impact on Membrane Element Performance
1	Be careful not to scratch the surface of the membrane element when taking it out of the packaging bag with tools.	When cutting open the packaging bag with tools such as scissors or knives, excessive force may damage the membrane surface.	Very High
2	The packaging bag of wet elements is filled with 1% sodium bisulfite as the protective solution. Please wear protective glasses and gloves.	Since 1% sodium bisulfite is used as the protective solution, please open the packaging in a well-ventilated place. At the same time, be sure to wear glasses and protective gloves when opening the packaging. If the chemical accidentally splashes into the eyes, on the body or clothes, rinse immediately with clean water and seek medical treatment in a timely manner.	No impact on membrane performance, but certain danger to human body.
3	Moisten and lubricate the sealing rings at the connection parts with clean water. Do not use any lubricants (petroleum-based, grease, petrolatum, detergents), gasoline or thinners.	The material of the collecting pipe is plastic. Applying petroleum, grease, petrolatum, detergents (such as Baimao brand), gasoline or thinners on it will cause the collecting pipe to crack in a short time. These substances should not be applied to the sealing rings either, otherwise it may lead to serious degradation of membrane performance. When installing membrane elements into the membrane shell, use clean water or water-soluble glycerin to lubricate the connection parts and sealing rings for easy installation.	Very High
4	Handle membrane elements with care. Do not throw or drop membrane elements.	Damage to membrane elements caused by throwing or dropping will affect their performance.	Very High
5	Prohibit brutal installation behaviors such as hitting with a hammer.	This will cause the shell of the membrane element to break, so it is strictly prohibited to directly hit the membrane element with a hammer or perform brutal installation. In such cases, it is difficult to guarantee the performance of the membrane element. Please pay close attention.	Very High

Note: After the system is started, when producing water for beverages, food and pharmaceuticals, please ensure that the produced water meets the usage standards before use.

Installation Sequence of Membrane Elements

① Before the operation of the membrane system, it should be fully flushed with pure water (qualified pretreated produced water or reverse osmosis produced water).

② As shown in Figure 1, the water inlet side of the membrane element is equipped with a concentrate sealing ring. Note that the installation direction of the sealing ring is that the opening faces the water inlet side. The function of the concentrate sealing ring is to seal the gap between the membrane element and the membrane shell, ensuring that all incoming water flows through the channels inside the membrane element. The pressure on the water inlet side will press the opening of the concentrate sealing ring tightly against the inner wall of the membrane shell for sealing. If the installation direction of the sealing ring is reversed, the sealing ring cannot be sealed tightly, causing part of the incoming water to flow outside the membrane element, resulting in reduced flow rate on the membrane surface, failure to inhibit the concentration polarization on the membrane surface, and thus shortening the service life of the membrane.

③ The outer surface annular grooves of the connectors and adapters for 8-inch membrane elements are respectively equipped with rubber O-rings; the inner surface annular grooves of the connectors and adapters for 4-inch membrane elements are respectively equipped with rubber O-rings. First, confirm that the O-rings are installed at the designated positions of the adapters and connectors. During installation, ensure that there are no scratches or attachments on the surfaces of the O-rings and connectors, and avoid distorted installation of the O-rings. If the connector leaks, the incoming water will mix into the produced water, leading to a decrease in the quality of the produced water. When installing on the collecting pipe, lubricate the surfaces of the O-rings and the collecting pipe with pure water, distilled water or hydrophilic glycerin for easy installation.

④ Remove the end plates on both sides of the membrane shell to install the membrane elements. Install the adapter on the collecting pipe of the concentrate side of the first membrane element. Then slowly push the membrane element into the membrane shell from the water inlet side to the concentrate side of the membrane shell.

⑤ As shown in Figure 2, when installing multiple membrane elements in series, prepare to connect the next membrane element with the connector before the previous membrane element is fully inserted into the membrane shell. At the same time, be careful not to let the membrane element contact the edge of the membrane shell to prevent scratches, and push it in as parallel as possible.

⑥ Finally, install the product adapter on the collecting pipe of the last installed membrane element. Finally, confirm that the membrane element is completely tightly connected to the adapter, and between membrane

elements and connectors, then connect the concentrate side end plate to the membrane shell. For the connection method of the end plate, refer to the instruction manual of the membrane shell manufacturer.

⑦ After completing the installation of the concentrate side end plate, push the membrane element again from the water inlet side to the concentrate side to ensure complete tight connection, and then install the water inlet side end plate. When installing the water inlet side end plate, pay attention to measuring the gap between the end plate and the adapter, and eliminate the existing gap by adding hard plastic gaskets (see Figure 3). For the connection method of the end plate, refer to the instruction manual of the membrane shell manufacturer.

Figure 1. Installation of a Single Membrane Element

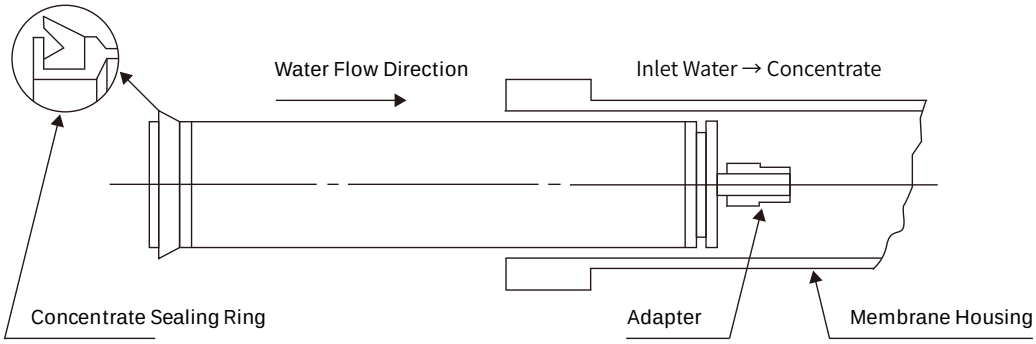
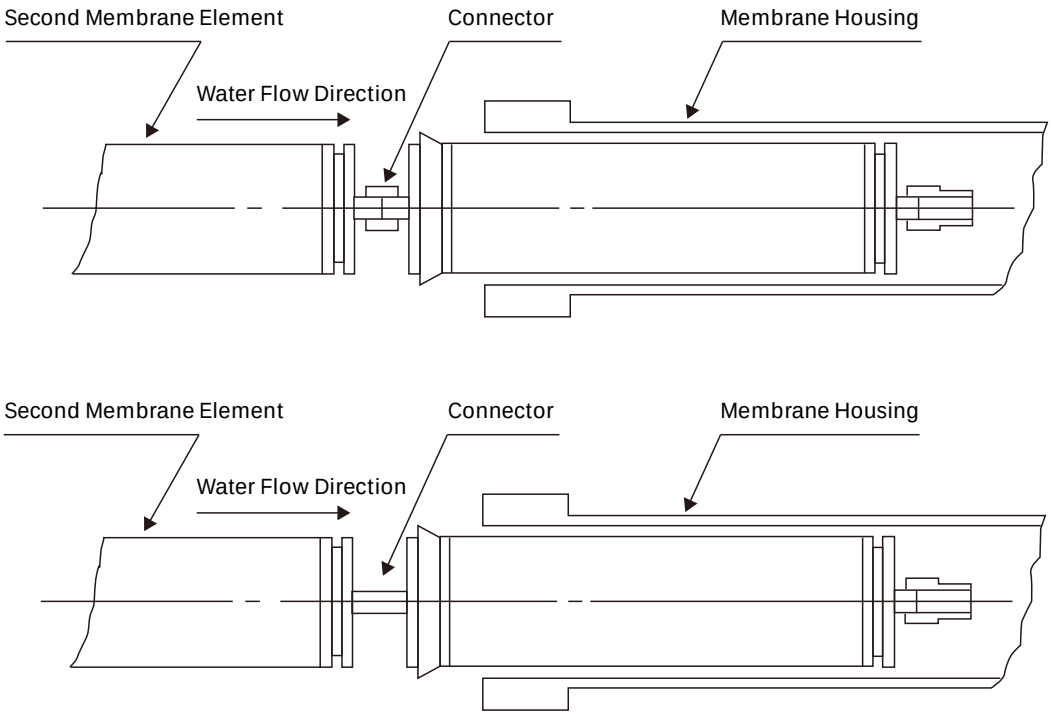
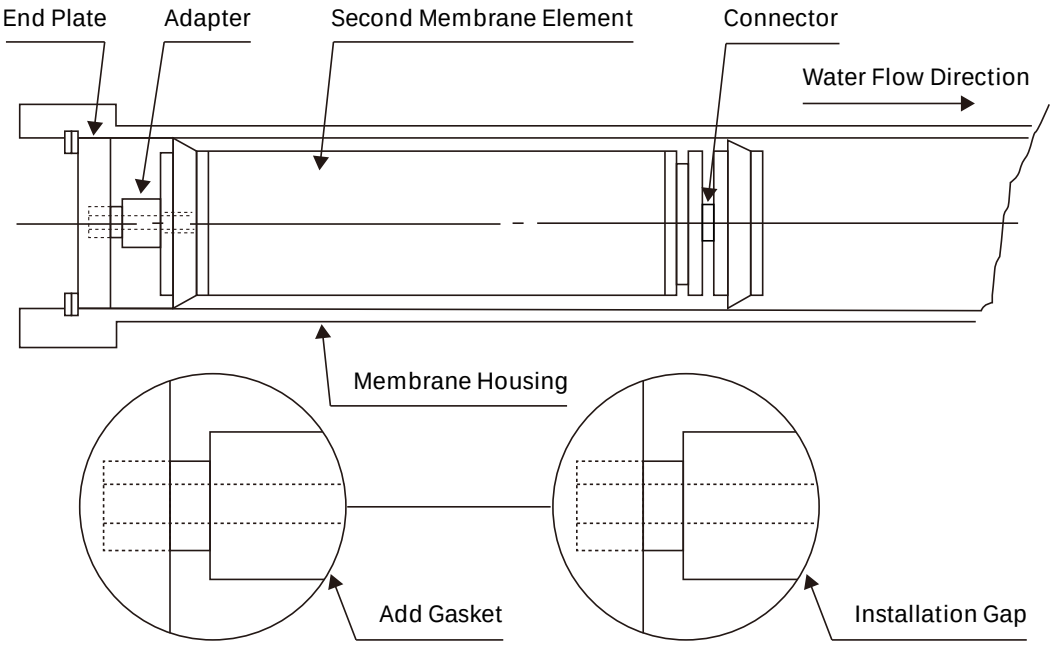


Figure 2. Schematic Diagram of Serial Installation of Multiple Membrane Elements



Note: The connectors for 4-inch (above) and 8-inch (below) have different external shapes.

Figure 3. Installation of Gap Adjustment Gaskets



7-2 System Start-up and Shutdown

1. Confirmation Items Before Initial Operation

■ **Security Filter**

To prevent metal chips, foreign objects, sand particles and fibers from entering the membrane module, install a security filter (below 5 μm) in front of the high-pressure pump before operation, and confirm that the filter element in the security filter is correctly installed.

■ **Pipeline Flushing Before System Operation**

To prevent residual foreign objects (metal chips, welding chips, mechanical oil, adhesives, etc.) in the device from entering the membrane elements during system operation, fully clean the pipelines and devices before installing the membrane elements. Through flushing, remove residual metal chips and welding chips in the pipelines, remove rust in the pipelines through acid cleaning, and remove mechanical oil through alkali cleaning. After all impurities are removed, finally flush the device with clean water until the effluent is neutral. It is recommended to filter the flushed effluent with an SDI filter membrane, and grasp the flushing effect by confirming the surface condition of the filtered membrane.

■ **SDI Value of Inlet Water**

Qualified pretreated water needs to remove colloids, organic matter, iron, bacteria and other substances to prevent contamination of the membrane surface. The pretreated produced water usually requires an SDI value ≤ 5. Regularly detect the SDI value, and re-adjust the operation of the pretreatment if it exceeds the normal value.

- **Residual Chlorine in Inlet Water**

  Generally, the residual chlorine content in the inlet water during operation is required to be 0.1mg/L. If the residual chlorine concentration in the inlet water exceeds this requirement, it will cause oxidation of the membrane elements and lead to a decrease in desalination rate. If there is residual chlorine in the inlet water, use SBS (sodium bisulfite) for neutralization. If the residual chlorine is 1mg/L, 1.8～3mg/L of SBS is required.

  Residual chlorine is monitored online by an ORP meter or measured by a colorimetric method.

  Note: Transition metals such as iron and manganese will aggravate the oxidation of membrane elements by residual chlorine. Therefore, when transition metals are present in the inlet water, ensure that there is no residual chlorine in the inlet water.

- **pH of Inlet Water**

  If the pH of the inlet water is outside the following range, it may lead to performance degradation of the membrane elements.

Normal Operating pH Range of Membrane Elements

Water Supply Condition	pH Range
Normal operating inlet water pH	2-11

- **Inlet Water Temperature**

  The inlet water temperature during operation should be below 45℃. If the inlet water temperature exceeds this range, it may cause performance degradation of the membrane elements.

- **Low Solubility Salts**

  To prevent scaling of insoluble salts on the membrane surface, methods such as adjusting pH value, softening treatment or adding scale inhibitors can be used. In addition, the Langelier index can be calculated to prevent calcium carbonate scaling.

- **Silicic Acid and Silicon Dioxide**

  To prevent silicon dioxide scaling on the membrane surface, methods such as removing silicon dioxide through pretreatment, adjusting pH value, adjusting temperature or adding silicon dispersants can be used to prevent silicon dioxide scaling on the concentrate side.

- After confirming the precautions 1-7 and ensuring that the membrane is correctly installed, the system can be started.

2. Daily Start-up of the System

- Fully open the concentrate and produced water valves.
- Flushing of RO Device

  When flushing the RO device, discharge the air remaining in the membrane elements and membrane shell at low pressure and low flow rate. After starting the feed pump, slowly open the inlet valve of the RO device to adjust the flow rate. Gradually increase the flow rate until no air bubbles emerge from the concentrate pipe outlet or flow meter, and flush for about 30 minutes. During the flushing process, check for leaks in valves and pipelines. The concentrate and produced water are all discharged. No scale inhibitors or other chemicals need to be added during the flushing process. If there is residual chlorine in the inlet water, fully add SBS.

Low-Pressure Flushing Operating Conditions of RO Device

Specification	Pressure	Inlet Water Flow Rate
8-inch membrane shell	≤0.3bar	7.2-17.0m³/h
4-inch membrane shell	≤0.3bar	1.8-2.5m³/h

When the size of the feed pump cannot meet the above operating requirements, try to adopt the method of low pressure and high flow rate for flushing. The valves on the concentrate side and produced water side cannot be fully closed during cleaning. Closing the valve on the produced water side will cause the membrane element to rupture.

- Before starting the high-pressure pump, adjust the opening degree of the valve at the outlet of the high-pressure pump to prevent instantaneous high flow rate and high pressure from damaging the membrane elements.

- After starting the high-pressure pump, open the inlet valve of the RO device as uniformly as possible, and gradually increase the inlet pressure of the RO device to make the concentrate flow rate reach the design value. However, the pressure rise rate must not exceed 0.07MPa/second at any time. Too fast a pressure rise rate may cause mechanical damage to the membrane elements, including telescope phenomenon of the membrane elements due to excessive axial pressure, or FRP cracks or even serious damage.

- While adjusting the RO device inlet valve at the outlet of the high-pressure pump, slowly close the RO device concentrate valve. While maintaining the concentrate flow rate, pay attention to the rise of the produced water flow rate, and gradually adjust to make the recovery rate reach the design value. The metering pump for adding scale inhibitors and other chemicals should be turned on when closing the concentrate valve. Confirm the dosage of the added chemicals and measure the inlet water pH value.

- After the RO device operates continuously and stably for one hour, measure the produced water conductivity and conduct water quality analysis. Introduce the qualified RO device produced water into the produced water tank, and record the initial operating data of the RO device.
  Note: Within 24 hours of the operation of the RO device, contact between formaldehyde and membrane elements is prohibited.

3. Shutdown Operation

- **Turn off the high-pressure pump**
  Gradually close the inlet valve of the RO device until it is fully closed, then stop the high-pressure pump. If the high-pressure pump is controlled by frequency conversion, the frequency converter can be used to control the high-pressure pump to gradually decelerate to stop.

- **Flushing**
  Confirm that the concentrate valve and produced water valve are fully open. Start the flushing feed pump, gradually open the inlet valve until the flow rate reaches the set value. Flush for five minutes to replace the concentrate in the RO device with flushing water. When shutting down the seawater desalination system, it is recommended to flush the system with RO produced water to replace the high-concentration seawater in the system. It is not allowed to stop the system without flushing, leaving high-concentration seawater in the RO device.

- Stop operation. Gradually close the inlet valve, and stop the operation of the high-pressure pump after it is fully closed.

  During system design, the flushing circuit can be set according to actual conditions. For systems with general water sources, the system's inlet water can be used as the flushing water source; for systems with special water sources, it is recommended to use the system's produced water for shutdown flushing. Especially for reverse osmosis involving seawater desalination membranes with concentrated salt water, during shutdown, RO produced water must be used for flushing to completely replace the high-concentration salt water in the system.

4. Precautions

- **Start-up and Shutdown**
  During start-up and shutdown, the flow rate and pressure will change to a certain extent. Severe flow rate and pressure shocks may cause the membrane element to rupture. Therefore, during start-up and shutdown operations, the inlet valve of the RO device needs to be opened and closed slowly. The pressure rise and fall rate must not exceed 0.07MPa/second at any time.

- **Residual Chlorine in Inlet Water**

Residual chlorine in the inlet water will oxidize the polyamide layer of the membrane element. Therefore, SBS needs to be used to neutralize the residual chlorine in the inlet water. The equipment can only operate when the residual chlorine is 0mg/L. When transition metals are present in the inlet water (such as Fe, Mn, etc.), the oxidation of the membrane by residual chlorine will be intensified. Therefore, when transition metals are present in the inlet water, ensure that there is no residual chlorine in the inlet water.

- **Produced Water Side Pressure (Back Pressure)**

  When the pressure on the produced water side is higher than the pressure on the inlet water side by more than 5psi, the membrane sheet bonding area will be physically damaged. Back pressure occurs at the moment of reverse osmosis and equipment valve opening and closing. For example, when the system is shut down, closing the produced water valve before turning off the feed pump usually causes back pressure. Fully confirm the opening and closing of valves and pressure changes to ensure that no back pressure occurs on the produced water side during operation. If the produced water pipeline is more than 5m higher than the upper part of the membrane shell, the water head difference (0.5bar) on the produced water side during system shutdown will exert force from the produced water side to the inlet water side, i.e., back pressure on the produced water side occurs, leading to tearing of the membrane sheet bonding area. Therefore, attention should be paid to the vertical elevation difference between the inlet pipe and the produced water pipe during pipeline installation, as well as the elevation difference between the produced water pipe and the membrane shell.

7-3 System Operation Management

1. Management of Reverse Osmosis and Pretreatment Systems

The main purpose of reverse osmosis and pretreatment is to remove pollutants harmful to reverse osmosis. When reverse osmosis and pretreatment are not sufficiently improved, the normal operation of the reverse osmosis system will be affected. In daily operation management, it is also very important to find problems in a timely manner through data recording, calculation, analysis and comparison. The indicators for monitoring the operation of the pretreatment system are the turbidity, SDI, pH value and conductivity of the RO inlet water. If the monitored indicators are much higher than the daily measured values, it indicates that the pretreatment or water source is abnormal. The pretreatment system needs to be re-adjusted to restore it to the normal value.

Pretreatment System Management

Item	Monitoring Data	Faults and Countermeasures
Residual Chlorine	＞0.1mg/L	Causes oxidation of membrane elements; add SBS (sodium bisulfite)
SDI	＞5	Causes rapid fouling of membrane elements; adjust pretreatment effect
pH	Outside the allowable range	Desalination rate decreases, and the possibility of scaling is high; adjust the dosing pump
Recovery Rate	Abnormal recovery rate and produced water volume	High possibility of scaling and membrane fouling; need to adjust flow balance
Pressure Difference of Security Filter	Sharp rise in pressure difference	Causes rapid fouling of membrane elements; adjust pretreatment effect
Conductivity	Rapid rise	Identify the cause of conductivity change

2. Management of Operating Data of Reverse Osmosis and Pretreatment Systems

To maximize the performance of the membrane and maintain long-term stable operation, the key is to maintain appropriate operating conditions and record daily operating data in a timely manner. Timely confirmation and adherence to correct operation management can extend the service life of membrane elements.

(1) Importance of Reverse Osmosis Membrane Operating Data Management

Reverse osmosis water production devices are greatly affected by external factors. The following points should be noted during operation management:

- Do not exceed the specified recovery rate and operating pressure;
- Fully ensure the concentrate flow rate;
- Prevent the inflow of foreign objects, pollutants and oxidants;
- Regular physical flushing and chemical cleaning.

(2) Determination of Operating Data

Produced water volume, desalination rate and pressure difference are important indicators for reverse osmosis membrane performance management. Recording operating data every day can timely detect abnormalities in these performance management indicators. In addition, as supplementary items to identify the causes of abnormalities, it is also necessary to record the recovery rate, operating pressure, pH value, concentrate flow rate and temperature.

Daily Monitoring Items for Reverse Osmosis Device Operation Management

No.	Measurement Item	Symbol	Unit
1	Produced Water Flow Rate	Qp	m^3/h
2	Concentrate Flow Rate	Qc	
3	First Stage Pressure	P1	MPa
4	Second Stage Pressure	P2	
5	Concentrate Side Pressure	P3	
6	Produced Water Pressure	P4	
7	Inlet Water Conductivity	ECf	μS/cm
8	Concentrate Conductivity	ECb	
9	Produced Water Conductivity	ECp	
10	Inlet Water Temperature	Tf	℃
11	Inlet Water pH	pHf	-
12	Inlet Water ORP	ORP	mV
13	Security Filter Inlet Pressure	PF1	bar
14	Security Filter Outlet Pressure	PF2	bar

(3) Collation of Operating Data

It is very important to collate the recorded data and analyze them.

① Normalized produced water volume. The produced water volume of reverse osmosis membranes will change according to operating pressure, temperature, etc. Therefore, comparing daily operating data records can correct the effect to achieve normalization. Usually, the produced water at 20～25℃ and pressure of 0.1～1MPa is taken as the standard to confirm the change;

② Average inlet water concentration. Since the salt content (conductivity) of the feed water of the reverse osmosis system changes with the flow of water, the reverse osmosis membrane elements at different positions are in contact with different feed water conductivities. Therefore, when calculating the desalination rate or using the conductivity rejection rate instead of the desalination rate, the concentration of the feed water is very important, and the inlet water conductivity cannot be simply used as a substitute. There are usually two methods to calculate the relatively accurate feed water conductivity:

Arithmetic average conductivity = (ECf + ECb)/2

Where: ECf——Inlet water conductivity, μS/cm;

ECb——Concentrate conductivity, μS/cm;

Logarithmic average conductivity = ECf×[-ln(1 - Rec.)/Rec.]

Where: Rec.——System recovery rate.

In general, the arithmetic average feed water conductivity should be used to calculate the actual desalination rate of the system. However, when the system recovery rate is greater than 85%, the logarithmic average inlet water conductivity should be used to calculate the desalination rate to obtain a more accurate system desalination rate.

Calculation Items for Two-Stage RO Device Operation Management

No.	Calculation Item	Code	Unit	Calculation Formula
1	First Stage Pressure Difference	△P1	bar、MPa	P1 - P2
2	Second Stage Pressure Difference	△P2		P2 - P3
3	Security Filter Pressure Difference	△Ppr		PF1 - PF2
4	Overall Average Pressure	Pav		(P1 + P2 + P3)/3
5	Overall Effective Pressure	Pn		Pav - P4
6	Recovery Rate	Rec	%	Qp/(Qp + Qb) × 100%
7	Conductivity Rejection Rate	Rej	%	(1 - ECp/Average Inlet Water Conductivity) × 100%
8	Temperature Correction Factor	TCF	N/A	exp{2700×〔1/(273+T) - 1/298〕}
9	Normalized Produced Water Volume	J	$m^3/h·MPa$	Qp/Pn × TCF

3. Shutdown Protection of Reverse Osmosis System

(1) Short-term Storage

The short-term storage method is applicable to reverse osmosis systems that are out of operation for 5～30 days. At this time, the membrane elements are still installed in the pressure vessels of the RO system. The specific steps of the storage operation are as follows:

① Flush the reverse osmosis system with feed water, and pay attention to completely removing air from the system;

② Fill the pressure vessel and related pipelines with water, then close the relevant valves to prevent air from entering the system;

③ Flush once every 5 days according to the above method.

(2) Long-term Shutdown Storage

The long-term shutdown storage method is applicable to reverse osmosis systems that are out of use for more than 30 days, and the membrane elements are still installed in the pressure vessels. The specific steps of the protection operation are as follows:

① Before shutting down the RO device, it should first be chemically cleaned to maximize the removal of various pollutants accumulated in the RO membrane elements during operation, because the pollutants accumulated during operation may be more difficult to remove after long-term shutdown;

② Prepare 1% SBS (sodium bisulfite) bactericide with reverse osmosis produced water, and circulate and flush the reverse osmosis device with the bactericide;

③ When the bactericide fills the reverse osmosis system, turn off the high-pressure pump, and quickly close all valves of the device to retain the bactericide in the system. At this time, confirm that the system is completely filled;

④ If the system temperature is below 27℃, repeat steps ② and ③ with new bactericide every 30 days; if the system temperature is above 27℃, replace the bactericide every 15 days;

⑤ Before putting the reverse osmosis system back into use, flush the system with low-pressure feed water for 1 hour, then flush with high-pressure feed water for 5～10 minutes. During both low-pressure and high-pressure flushing, the produced water discharge valve of the system should be fully open. Before restoring the system to normal operation, check and confirm that the product water does not contain any bactericides.

Chapter 8. Troubleshooting

Failures of membrane elements usually manifest as performance degradation, physical damage, chemical deterioration, etc. The main manifestations include a decrease in the desalination rate of membrane elements (increase in produced water conductivity), changes in produced water volume (increase or decrease in operating pressure), and an increase in pressure loss (pressure difference).

System failure symptoms often also appear on membrane elements. Therefore, when investigating the cause, attention is usually focused on the analysis of membrane performance. When a membrane system failure is detected, reviewing operating records and analyzing raw water quality are indispensable for making correct judgments.

Troubleshooting can be carried out in the following order:

- Review operating records. On the premise that daily operating data records are saved, confirm the system operation status and conditions, and investigate whether there are abnormal operating conditions;
- Supplement necessary data. Determine whether the system performance has degraded overall or partially. If the system performance has degraded partially, the problematic membrane element can be disassembled to check its appearance and the sealing rings of the connectors;
- Investigation and analysis of raw water characteristics;
- Perform performance testing on the membrane elements removed from the device, and conduct disassembly inspection of the membrane elements (membrane analysis, cleaning test).

8-1 Fault Diagnosis

1. System Diagnosis

Overall system failures manifest in different phenomena due to different causes. When signs of performance degradation appear, it is particularly critical to take timely countermeasures to avoid the expansion of the failure. Therefore, in daily operation, recording data and standardizing parameters in the form of charts will achieve twice the result with half the effort. For relevant standardization methods, you can consult customer service personnel.

2. Diagnosis of Each Pressure Vessel

Observing the performance data of each pressure vessel is very important for identifying the cause of system failures. Failures such as poor sealing of connectors and sealing rings or damage to membrane elements will cause performance degradation per pressure vessel. Whether the membrane elements in the first and second stages of the system have similar performance degradation also indicates different failure causes. Failures caused by membrane degradation or contamination are also possible. If it is impossible to obtain performance data in sections, test each pressure vessel. Usually, the produced water conductivity in each

pressure vessel is tested. When sampling, pay attention to investigating the piping installation method and whether the produced water of the pressure vessel being measured is affected by the produced water of other pressure vessels. Generally, it is very difficult to measure the produced water volume of each pressure vessel.

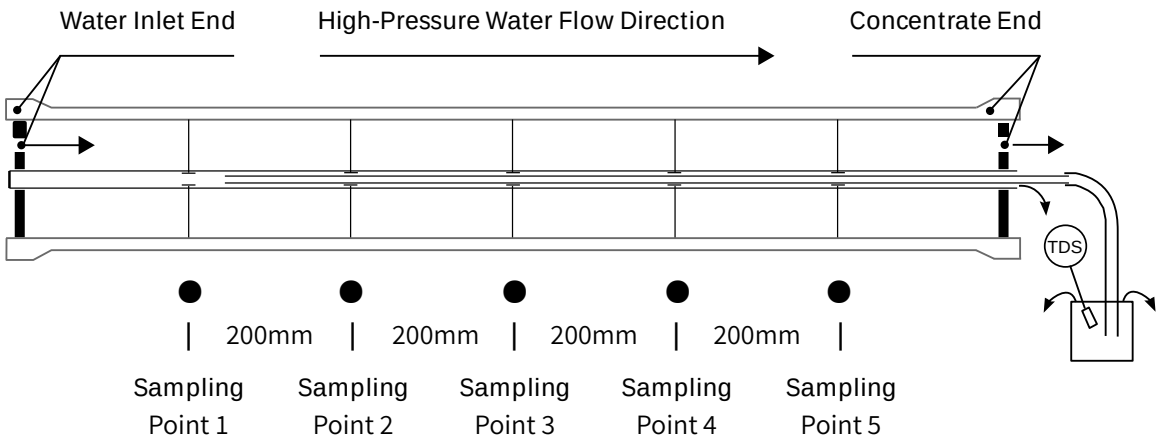
3. Diagnosis of Each Membrane Element in the Pressure Vessel

To check which part of the membrane elements installed in each pressure vessel has a decrease in desalination rate, the probe method (online detection) or extraction detection method (offline detection) can be used. Here, the use of the probe method will be focused on.

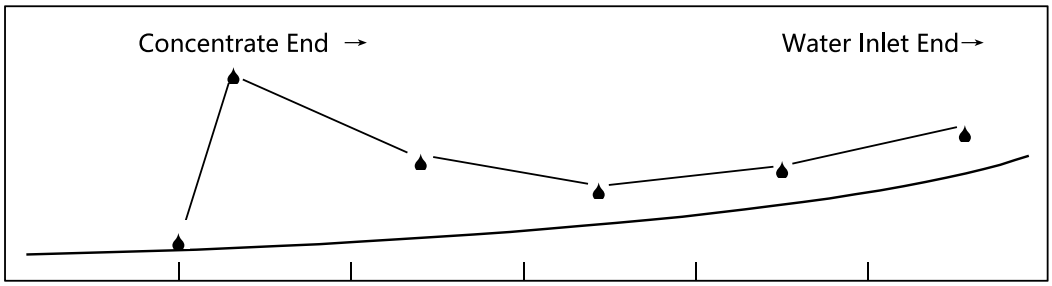
The probe method uses a plastic hose inserted into the central collecting pipe and running through the entire length to test the produced water conductivity of membrane elements at different positions. The sampled produced water comes from the produced water upstream of the front end of the hose, indicating the water quality at the front end of the hose.

Explanation of the detection point positions for the performance of a single membrane element:

- Sampling Point 1: The hose should be pulled out about 150mm from the deepest position (varies by membrane shell brand) to measure the produced water conductivity at the adapter (commonly known as a grenade) between the pressure vessel end plate and the membrane element.
- Sampling Points 2, 3, 4: Each separated by 200mm. These three points reflect the current performance of the membrane element (of course, Sampling Point 3 can also be directly tested, which is 400mm away from Sampling Point 1).
- Sampling Point 5: 200mm apart from Sampling Point 4 (400mm apart from Sampling Point 3), used to detect the sealing condition of the connector between two elements.



Explanation of the produced water conductivity distribution of the entire pressure vessel:



From the water inlet end to the concentrate end of the pressure vessel, the conductivity distribution of normal produced water shows a balanced increasing trend. If there is an abnormal deviation from this distribution law, the location of the fault can be determined. An "O" ring failure generally reflects a sudden change in the conductivity curve corresponding to the connector or adapter. A significant increase in conductivity at other positions indicates a fault in the corresponding membrane element.

Operating Procedure:

① Prepare materials: Take a plastic hose with a diameter of 6mm or 8mm and a conductivity meter (handheld or desktop), and cut the end of the hose inserted into the membrane element into a bevel with a knife;

② Start the reverse osmosis system, insert the beveled end of the hose into the deepest part of the central collecting pipe of the membrane element. It is recommended to estimate the total length of the hose according to the total number of cores or total length of the pressure vessel before testing to confirm that the inserted end of the hose is indeed the deepest part as the starting position;

③ The water sample initially diverted from the central produced water pipe of the pressure vessel is not representative. Wait for a few minutes to flush the hose;

④ Pull the hose out to Sampling Point 1. After about 500ML of produced water is discharged from the hose, the system reaches equilibrium, and record the data;

⑤ Continue to pull out the hose and proceed to sample at the next position. Repeat Step 4. It should be noted that each time a sampling point is reached, it is necessary to wait for a certain amount of produced water to be discharged from the hose before recording the data; it is recommended to mark intervals on the hose in advance for higher accuracy;

⑥ Complete interval sampling for other membrane elements in the pressure vessel. The length of a single membrane element is 1016mm;

⑦ Summarize and confirm the fault point by referring to the produced water conductivity distribution diagram of the pressure vessel.

8-2 Fault Phenomena, Causes and Solutions

Check the operating conditions and data. If it is found that the system operation is beyond the operable range, put forward improvement requirements to the user. However, due to unclear causes, it is often common to analyze the membrane elements.

Phenomenon	Cause	Solution
Salt Rejection ↓, Water Flux ↗, Differential Pressure →	Oxidation: Residual Chlorine, Ozone	Replace Membrane, Improve Pre-treatment
Salt Rejection ↓, Water Flux ↗, Differential Pressure →	Back Pressure, Water Hammer	Replace Membrane
Salt Rejection ↓, Water Flux ↗, Differential Pressuree →	Loose Connector Seal	Replace "O" Ring
Salt Rejection ↘, Water Flux ↓, Differential Pressure ↗	Colloidal Fouling	Improve Pre-treatment, Clean
Salt Rejection ↘, Water Flux ↓, Differential Pressure ↗	Inorganic Scaling	Adjust pH, Recovery Rate, Clean
Salt Rejection →, Water Flux ↓, Differential Pressure ↗	Biological (Microbial) Fouling	Regular Disinfection, Clean
Salt Rejection →, Water Flux ↓, Differential Pressure ↑	Adsorption of Surfactants, Oil	Improve Pre-treatment
Salt Rejection →↘, Water Flux ↗↘, Differential Pressure →	High Temperature	Adjust Within Allowable Range
Salt Rejection →↘, Water Flux ↗↘, Differential Pressure →	High Pressure	Adjust Within Allowable Range

8-3 Membrane Element Analysis

After confirming the system's operating conditions and operating records, to make the analysis more clear, it is necessary to analyze the membrane elements. Grasp the phenomenon of performance degradation, determine what kind of pollutants they are, identify the causes of performance degradation to find countermeasures, and establish cleaning methods. For the confirmation method of membrane modules including analysis, refer to the following table. The analysis methods in the test items listed in the table can yield more comprehensive judgment results through combined analysis. A relatively accurate judgment can be made through the combination of membrane element performance inspection, appearance of attachments, and SEM-XMA/FT-IR.

When analysis is required, it is necessary to clarify the installation position of the membrane element, including its exact position in the pressure vessel, and feedback it on the sample. It is best for the user to record it on the sample when removing the membrane element.

Of course, the composition of raw water is more important. You can communicate with us in advance before making a decision.

Confirmation Method	Degradation	Cake Layer	Scale Layer	Adsorption Layer	Pore Blocking	Channel Blocking
Appearance, Weight	x	o	o	x	o	o
Dye Test	o	x	x	x	x	x
Flat Membrane Observation	o	o	o	Δ	o	o
Feed Water Analysis	o	o	o	o	o	x
Membrane Element Performance	o	Δ	Δ	Δ	o	o
Quantitative Analysis of Foulants	x	o	o	o	x	o
SEM	o	o	o	x	o	o
XMA	x	o	o	x	x	o
X-Ray	x	x	o	x	o	o
FT-IR	o	o	o	o	o	x
Chemical Cleaning	x	o	o	o	x	x

1. Appearance and Weight

Through visual observation, it can be confirmed whether the membrane element has physical damage or organic matter attachment. If the membrane element exhibits a telescope phenomenon or damage to the outer winding layer such as fiberglass, this usually indicates hydraulic impact exceeding the design limit, which may be caused by extremely high pressure drop or incorrect element installation. If mechanical damage to the produced water pipe is found, it may lead to a high salt leakage rate. In addition, check whether the brine sealing ring is intact and confirm that its installation orientation is correct.

The weight of the membrane element is an important indicator to judge the degree of fouling. In some cases, the weight of a severely fouled element may more than double, which provides a quantitative basis for evaluating the degree of fouling.

2. Membrane Element Performance Inspection

Re-inspection of membrane element performance can only be carried out before the membrane element is disassembled. Even when contaminant components have been confirmed, the performance of the membrane element should be tested first, and then the membrane element should be disassembled to analyze the composition of the pollutants. First, vacuum retention or water tightness testing can be used to determine the damage or damage location of the membrane sheet. Then, retest the membrane element under standard test conditions. By comparing changes in desalination rate, produced water volume, and pressure difference, it

can be judged whether there is membrane damage, membrane performance degradation, contamination, flow channel blockage, or poor contact of connectors.

3. Dye Test

To determine whether the performance of the membrane has degraded or to find the location of damage to the membrane element, a dye test can be performed. Usually, the dye Rhodamine B (molecular weight about 479.01g/mol) or Methyl Violet (molecular weight about 389.6g/mol) is used to pressurize the membrane element under standard test conditions for about 10 minutes. After dyeing, disassembling the membrane element can determine the location of defects such as membrane damage and sealing leakage of the membrane element.

4. Disassembly of Membrane Elements

Generally, proceed according to the following steps:

① Take photos of the appearance of the membrane element (overall and close-ups of both end faces);

② Remove the end plates at both ends and clearly mark the direction of raw water flow;

③ Remove the outer fiberglass;

④ Open the membrane element, inspect each membrane leaf, and take photos of the entire membrane leaf or necessary parts. To make it clear where the raw water side and concentrate side are on the membrane leaf when viewing the photos, mark or label them in advance;

⑤ Carefully inspect the membrane surface comprehensively, cut membrane samples or collect fouling substances for chemical analysis or flat membrane performance testing.

5. Membrane Surface Analysis

- **Sediment Morphology Analysis**

  The morphology of sediments can be determined by stereomicroscopy, standard optical microscopy, or scanning electron microscopy (SEM).

- **Chemical Element Analysis**

  Chemical elements in the membrane surface of the element or in the fouling and scale layers can be determined by energy-dispersive X-ray fluorescence spectroscopy (EDXRF). By analyzing untreated membrane samples, cleaned and rinsed membrane samples, and collected dry fouling substances, semi-quantitative results of chemical elements in the membrane and fouling can be obtained. This method can serve as evidence of membrane damage by halogenated compounds. Typical elements that may be detected include:

  Ca, Ba, Sr, S in scale deposits

  Fe, Si, Pb, Zn in colloidal contaminants

  Cl, Br, I in oxidative damage

However, this method cannot determine failures caused entirely by organic and microbial contamination.

- **Analysis of Oxidative Damage Sources**

  Electron Spectroscopy for Chemical Analysis (ESCA) can identify impurities organically bound to the membrane surface, mainly used to determine the source of oxidative damage.

- **Flat Membrane Evaluation**

  This evaluation test is performed after element dissection. Cut membrane samples, clean or treat them with various chemicals, and evaluate the cleaning effect by comparing the performance changes of the membrane samples after different treatment methods.

6. Common Contamination Images

Microorganisms on the membrane surface



Organic matter and colloids on the screen



Chapter 9. System Cleaning

9-1 Brief Introduction

Raw water in reverse osmosis (RO) systems contains particles, colloids, scale-forming ions, organics, microorganisms, and other substances. Although the pretreatment process minimizes the content of these pollutants, it cannot completely remove them, which will inevitably cause membrane fouling. Appropriate operating conditions can delay membrane surface fouling and reduce cleaning frequency. When the membrane surface is contaminated, it usually manifests as decreased water production, reduced desalination rate, and increased pressure difference between the feed water and concentrate. Corresponding cleaning methods should be adopted for different types of contamination to achieve the best cleaning effect.

9-2 Physical Cleaning

After the system has been in operation for a period of time, pollutants will adhere to the membrane surface. Since these pollutants have been formed recently and have weak adhesion, a low-pressure, high-flow flushing method can be used for rapid cleaning. The recommended flushing duration is several hours, which can effectively remove newly formed pollutants on the membrane surface. This method is only a protective flushing measure and is best used in combination with chemical cleaning.

9-3 Chemical Cleaning

1. Chemical Cleaning Standards

Since the pretreatment process cannot completely remove colloidal particles, scale-forming ions, organics, microorganisms, and other pollutants from the feed water, residual pollutants will contaminate the membrane elements, leading to a decrease in normalized water production and desalination rate, and an increase in the pressure difference between feed water and concentrate. However, the performance of RO systems is affected by factors such as feed water pH, temperature, and feed water TDS. Therefore, normalization should be performed when determining the cleaning timing. Membrane elements must be cleaned when the following conditions occur:

Normalized water production decreases by 15%;

Normalized pressure difference between feed water and concentrate increases by 15%.

2. Chemical Cleaning Frequency and Precautions

(1) Cleaning Cycle

The cleaning cycle for contaminated RO membranes should be determined based on actual conditions, as the water quality after pretreatment varies with different raw water sources, resulting in different fouling rates and types on the membrane. The normal cleaning cycle is once every 1 to 12 months. If the conditions specified in Section 4.3.1 occur within a short period (within 1 month), adjustments to the RO and pretreatment systems or optimization of operating parameters are required.

(2) Precautions

- Before starting the pump, ensure that the pipeline connections are correct and the valves are in the proper positions;
- The cleaning solution must be fully dissolved and uniformly mixed before it enters the membrane elements for circulation;
- Follow the cleaning procedures. After cleaning, it is recommended to rinse the system with RO product water. Before restoring to normal operating pressure and flow, the system must be rinsed at low flow and low pressure to remove the cleaning solution until the RO system is thoroughly rinsed;
- During the circulation of the cleaning solution, if the pH range of the cleaning solution is 2－12, the water temperature should not exceed 30° C;
- For elements with a diameter greater than 6 inches, the flow direction of the cleaning solution must be the same as the normal operation direction, as the thrust ring inside the pressure vessel is only installed at the concentrate end of the pressure vessel.

(3) Selection of Cleaning Agents

Targeted cleaning agents should be selected for different types of membrane fouling. The type of membrane fouling can be determined based on the following points:

- Identify substances that are prone to causing membrane fouling based on detailed raw water reports;
- Identify potential contamination based on operating records;
- Determine the type of fouling by analyzing previous cleaning results;
- Analyze substances on the SDI test membrane and security filter element;
- Measure the water quality of the concentrate outlet;
- Compare the appearance differences between upstream and downstream membrane elements.

Select appropriate cleaning agents based on the identified type of membrane fouling. Ensure that the selected cleaning agent is certified by our company as suitable for cleaning the membrane or is listed in our technical manual. Comprehensive factors such as cleaning solution temperature, pH value, and flow rate should be considered during the cleaning process. Strictly controlling the contact time between the cleaning solution and the membrane elements and the pH range of the cleaning solution is conducive to extending the service life of the membrane elements. The following table lists the general cleaning solutions for our company's membrane elements.

General Cleaning Solutions for Membrane Elements

Cleaning Agent / Fouling Type	0.2% (W) HCl	0.5% (W) H_3PO_4	2.0% (W) $C_6H_8O_7$	0.1% (W) NaOH	0.1% (W) NaOH + 0.025% (W) SDS	0.1% (W) NaOH + 0.025% (W) SDBS	0.1% (W) NaOH + 1.0% (W) Na_4EDTA
Inorganic scale ($CaCO_3$)	Optimal	Good	Optimal	-	-	-	-
Sulfate scale ($CaSO_4$, $BaSO_4$)	-	-	-	-	Good	Good	Optimal
Metal oxides (Fe, Mn)	-	Good	Optimal	-	-	-	-
Inorganic colloids	-	-	-	-	Optimal	-	-
Silicon-based fouling	-	-	-	Good	Optimal	Good	-
Microbial fouling	-	-	-	-	Optimal	-	Good
Organic fouling	Optimal for second-step cleaning	-	-	-	Optimal for first-step cleaning	Good for first-step cleaning	Good for first-step cleaning

Note: "Optimal" indicates the recommended cleaning agent; (W) indicates weight percentage; SDS stands for sodium dodecyl sulfate; SDBS stands for sodium dodecyl benzene sulfonate; Na_4 EDTA stands for tetrasodium ethylenediaminetetraacetate; the pH of acid cleaning should be≥2, and the pH of alkali cleaning should be≤12; the temperature of the cleaning solution should be less than 30° C.

9-4 Types of Contaminants and Their Impacts

1. Scaling Fouling and Its Impacts

When insoluble salts are continuously concentrated in the membrane module and exceed their solubility limit, they will precipitate on the RO membrane surface. Carbonate scale is particularly prone to formation. Insoluble salt scaling often occurs at the end section of the system and gradually spreads upstream. The type of scaling can be determined by methods such as microscopy and X-ray analysis. Generally, scaling can be effectively controlled by adjusting the feed water pH in the treatment unit and optimizing the system recovery rate. When scaling occurs, the system pressure drop increases rapidly, water production decreases gradually, and the desalination rate declines.

2. Colloidal and Particulate Fouling and Its Impacts

Colloids and particles in natural water bodies mainly consist of sand, clay, colloidal silica, iron corrosion products, microorganisms, etc. The SDI value is often used to characterize the content of colloidal and particulate pollutants in the feed water. The feed water SDI of the system is required to be < 5, and SDI < 3 is optimal. This type of fouling often occurs in the first stage of membrane elements. If the pretreatment process malfunctions (e.g., the media filter or ultrafiltration device fails to operate normally), colloidal and particulate fouling will occur quickly. When this type of fouling occurs, both water production and desalination rate will decrease.

3. Metal Oxide Fouling and Its Impacts

Water bodies contain a certain amount of metal ions (such as iron and manganese) that are prone to forming oxides. To prevent iron and manganese fouling, divalent iron and manganese in the raw water must be oxidized to trivalent to form precipitates for removal. Common oxidation methods include aeration, chlorine, or potassium permanganate oxidation. In actual operation, iron fouling occurs more frequently than manganese fouling, and most cases occur in the first stage. When metal oxide fouling occurs, water production, pressure difference, and desalination rate all decrease rapidly.

4. Microbial Fouling and Its Impacts

Microbial fouling is the most distinctive type of RO membrane fouling and causes the most severe difficulties for system operation. Raw water after pretreatment still contains a certain amount of microorganisms, which will reproduce under suitable conditions and form a biofilm on the membrane surface. This biofilm has strong adhesion and is difficult to remove. When microbial fouling occurs, the feed water flow decreases gradually, the feed water pressure increases gradually, and both water production and desalination rate decline.

5. Organic Fouling and Its Impacts

Organic substances in natural water bodies are mainly humic acid substances, with a TOC content usually ranging from 0.5 to 20 mg/L. Organic substances may deposit on the membrane surface, forming an additional barrier that prevents salt permeation. This leads to increased feed water pressure, decreased water production, and increased desalination rate.

9-5 Introduction to Conventional Cleaning Processes

When fouling occurs, it is recommended to clean the RO system according to the following steps:

① Low-pressure, high-flow flushing

Operate the system with product water at low pressure and high flow to flush out the feed water in the system and remove weakly adherent substances. The flushing pressure must be lower than the operating pressure, and the standard is to produce little or no product water.

② Preparation of cleaning solution

Select the cleaning solution according to the type of fouling, with reference to the "General Cleaning Solutions for Membrane Elements" table in Section 9-3. Ensure the cleaning solution is uniformly mixed.

③ Low-flow feeding and circulation of cleaning solution

Feed the uniformly mixed cleaning solution into the system at low pressure and low flow. The pressure should be set to avoid significant product water production. Discharge the initial concentrate to prevent dilution of the cleaning solution. When the cleaning solution appears at the concentrate end, it can be recycled back to the cleaning solution tank. If the pH decreases significantly or the cleaning solution changes color during the cleaning process, the cleaning solution must be reconfigured for cleaning.

④ Soaking

Stop the pump circulation. To prevent the cleaning solution from flowing out of the membrane shell, close the cleaning solution inlet valve, product water valve, and concentrate valve. Determine the soaking time based on the contamination level of the membrane elements, generally about 1 hour. For severe fouling, overnight soaking is acceptable. During soaking, the circulation pump can be turned on intermittently to maintain a very low flow rate for circulation.

⑤ High-flow circulation

After soaking, open the valves and increase the flow rate to 1.5 times the normal flow rate for cleaning. Under this condition, control the pressure to produce little or no product water. Ensure that the pressure difference of the membrane elements and pressure vessels does not exceed the limit value. Circulate for 30 – 60 minutes.

⑥ Rinsing

Rinse the system with RO product water or water that meets the system feed water requirements. The rinsing duration is usually 20 – 60 minutes, until no cleaning solution remains in the effluent. This can be confirmed by indicators such as conductivity.

9-6 On-Line Chemical Cleaning

On-line chemical cleaning refers to cleaning directly with cleaning solutions without removing the membrane elements from the system. Most systems adopt this cleaning method. The characteristics of this method are as follows:

- No need to disassemble the membrane elements, saving time and effort;
- All membrane elements or multiple elements can be cleaned at one time, resulting in high cleaning efficiency;
- Before cleaning the system, the tank containing the cleaning solution must be cleaned;
- On-line cleaning is prone to cross-contamination, causing pollutants from the front end to be washed to the back end.

9-7 Off-Line Cleaning (Contact Technical Engineers for Details)

Off-line cleaning refers to removing the membrane elements from the system and cleaning them with separate cleaning equipment. The characteristics of this method are as follows:

- Can prevent cross-contamination;
- Targeted cleaning solutions and methods can be adopted based on the type and location of fouling:
  - Cleaning individual membrane elements can enhance the cleaning effect;
  - This method is recommended when the system is severely contaminated;
  - Removing membrane elements is time-consuming and labor-intensive;
  - Cleaning individual membrane elements is inefficient and time-consuming.

9-8 System Disinfection

System disinfection is generally performed after system cleaning. However, if the feed water contains a large number of active microorganisms, disinfection should be carried out as needed. In summer, when the RO system operates with feed water with high microbial activity, the regular cleaning frequency is 3～5 days; in winter, it is generally once every 7 days. Common system disinfectants include hydrogen peroxide, formaldehyde, peracetic acid, and non-oxidizing bactericides.

When using hydrogen peroxide as a disinfectant, the system must first undergo alkali cleaning to remove sediment that may contain bacteria, then acid cleaning. After thorough rinsing with system product water, use a 0.2% hydrogen peroxide solution, adjust the pH of the solution to 3～4 with HCl to maximize the disinfection effect, circulate for 20 minutes, and then soak. Soaking for 2 hours can kill 90% of bacteria, while soaking for 12 hours can kill 99% of bacteria. Finally, rinse the entire system with the system's product water.

When using formaldehyde as a disinfectant, protective measures should be taken, as formaldehyde is a carcinogen. In addition, formaldehyde can only be used after the membrane elements have been in continuous operation for at least 6 hours; otherwise, water production attenuation may occur. The effective concentration of formaldehyde is 0.5%～3%.

When using peracetic acid as a disinfectant, the maximum concentration should not exceed 0.2%; otherwise, the membrane will be damaged. In addition, there should be no heavy metals in the system, as they will act as catalysts and damage the membrane elements. Continuous use of 0.2% peracetic acid will eventually damage the membrane, so intermittent use is recommended.

Chapter 10. Quality Assurance and Services

One-Year Quality Guarantee for RO / NF Membrane Elements

When Proshare reverse osmosis/nanofiltration membrane elements (hereinafter referred to as "membrane elements") are used in accordance with the membrane element technical manual and relevant technical documents of Proshare Innovation Suzhou Co., Ltd. (hereinafter referred to as "Proshare"), Proshare shall provide the following limited quality guarantee for the membrane elements produced and sold. This guarantee is granted to the customer by the legal entity of Proshare (supplier) that sells the membrane elements to the customer, and the customer's sole remedy under this guarantee shall be obtained from the supplier. Acceptance of this guarantee indicates that the customer agrees to the terms specified in this guarantee.

1. Guarantee for Manufacturing Process and Materials

Proshare guarantees that the membrane elements produced and sold are free from defects in terms of manufacturing process and materials. The warranty period for manufacturing process shall be valid for 12 months from the date when the membrane element is delivered to the carrier at any shipping point (place of production). This manufacturing process warranty shall be deemed invalid if the customer fails to install, operate and maintain the product in accordance with the terms of this warranty or the user instructions issued by Proshare, or fails to notify the supplier of the defect within 30 days of discovering or reasonably being supposed to discover the defect. The customer's sole remedy and the supplier's obligation under this limited manufacturing process warranty are explicitly limited to, after review by the supplier (if applicable), repairing the defective element or replacing the defective element.

2. Limited Initial Performance Warranty (Initial Performance Warranty)

The supplier guarantees that after the performance of the membrane element stabilizes, the membrane element will meet the initial minimum water production and salt rejection rate under the standard test conditions specified in the membrane element product parameters, until the first occurrence of the following situations: the 30th day after the first installation and use of any membrane element; or 6 months after the delivery of any such membrane element to the carrier from the shipping point (place of production).

If the customer fails to notify the supplier in writing of the membrane element failure within 30 days of the first commissioning, this initial performance warranty shall be deemed invalid. The customer's sole remedy and the supplier's sole obligation under the initial performance warranty are explicitly limited to repairing, or at the supplier's discretion, replacing any membrane element that fails to meet the initial performance warranty upon inspection. If the customer fails or refuses to provide the supplier with the usage and operation parameters of the membrane element in case of membrane element performance failure, the initial performance warranty shall be declared invalid.

3. Limited Proportional Performance Warranty (One-Year Warranty)

- The one-year starting time for the supplier's guarantee on the performance of membrane elements shall be whichever of the following occurs first:

For wet membrane elements

- The date of first commissioning;
- 3 months after the delivery of any such membrane element to the carrier from the shipping point (place of production).

For dry membrane elements

- The date of first commissioning;
- 12 months after the delivery of any such membrane element to the carrier from the shipping point (place of production).

- The supplier guarantees that the membrane elements:
  - Under the premise of normal operating pH, when the operating temperature is below 40℃, the minimum water production shall not be less than 70% of the initial average water production specified in the membrane element product parameters; when the operating temperature is above 40℃, the minimum water production shall not be less than 60% of the initial average water production specified in the membrane element product parameters;
  - The maximum salt permeability shall not exceed 1.35 times the maximum salt permeability specified in the membrane element product parameters.

Please note that the salt permeability provided by Proshare is based on the stable salt rejection rate, not the minimum salt rejection rate or maximum salt permeability.

If the supplier deems the claim valid, under this warranty, the customer's sole remedy and the supplier's sole obligation and liability are explicitly limited to, after review by the supplier, refunding 1/12 of the original purchase cost of the membrane element per month for the unused months within the warranty period, which shall be used to offset the current cost of purchasing the membrane element for replacement.

4. Invalidity Conditions for Initial Performance Warranty and One-Year Limited Proportional Performance Warranty

The aforementioned one-year limited performance warranty and initial performance warranty shall be invalid if any of the following conditions are not met:

- The customer fails to record and retain the operation data in accordance with the appendix as required by the supplier;
- The customer fails to provide the operation data to the supplier as required;
- The customer fails to install, operate and maintain the membrane elements in accordance with the requirements of this warranty and the documents issued by Proshare, or in accordance with good engineering practices;
- The customer fails to meet any of the following conditions related to any membrane element and the system using the membrane element:

- The turbidity of the feed water to the membrane element shall be ≤ 1.0 NTU, and SDI_{15} ≤ 5 (15 minutes, pressure 30 psi);
- The design parameters (arrangement, recovery rate, etc.), instruments and other components in the system using the membrane element must comply with correct engineering experience and specifications. The supplier reserves the right to review the system design and operation;
- The feed water temperature must be below 45 ℃, unless otherwise specified in the membrane element product parameters or this warranty document;
- The feed water shall not contain any colloidal sulfur;
- The feed water shall not contain any oxidants, including but not limited to chlorine, ozone or permanganate, etc.;
- The feed water to the membrane element shall not contain oxidizing substances such as chlorine gas, potassium permanganate and hypochlorite;
- The pH range of the membrane element during normal operation shall be 2～11; during cleaning, the pH range of the feed water to the membrane element shall be 1～13;
- Before installation or use, the membrane elements shall be stored in plastic packaging bags. The storage temperature of dry membrane elements shall be≤45℃, and the storage temperature of wet membrane elements shall be 5～45℃;
- Under any circumstances, the back pressure (product water static pressure greater than feed water or concentrated water static pressure) generated on the membrane element shall not exceed 5 psi. At the same time, water hammer impact on the membrane element and severe pressure fluctuations in the system shall be avoided during system operation;
- When the system performance decreases by 10% under standard conditions, or membrane fouling or scaling occurs, cleaning shall be carried out in a timely manner in accordance with the specified procedures. The membrane must not be contaminated by particulate matter, colloids or sediments, or biological growth;
- The membrane module arrangement, instrument configuration, recovery rate and other system composition and design parameters shall be consistent with reasonable engineering design;
- Sufficient preventive measures must be formulated during the system design, operation and maintenance process to prevent the membrane elements from being contaminated by particulate matter, colloidal precipitated solids or microbial growth;
- Scaling caused by the failure of the chemical dosing system or ineffective anti-scaling measures (e.g., Ca, Ba or Sr scaling);
- The soluble silica content on the concentrated water side shall be less than 150 mg/L at 25℃;
- Damage caused by chemical compounds (such as surfactants, solvents, soluble oils, free oils, lipids and high molecular weight natural polymers) is not allowed;
- The membrane elements can only be cleaned with compatible chemicals. Non-ionic or cationic surfactants or any other chemicals incompatible with the membrane elements shall not be used for cleaning;

- The customer is responsible for providing the user with a correct system operation and maintenance manual, and providing training to the operators to ensure that the user is capable of completing the cleaning, performance recovery and fault diagnosis procedures;
- The customer shall ensure that the standardized performance data of the system and subsystems are regularly and fully recorded and reviewed in a systematic manner. Once the customer files a claim with the supplier in accordance with this performance guarantee, the claim shall be submitted to the supplier on a reasonable basis with this information;
- The membrane elements must be stored in accordance with the documents and specifications published by Proshare;
- All permeate (product water) and concentrate (concentrated water) during the first hour of operation must be discharged;
- After the initial wetting, the customer must keep the membrane elements wet at all times;
- The supplier shall make the final decision on whether it is necessary to repair or replace the membrane elements to maintain the product water quality and water production;
- If the customer fails or refuses to disclose to the supplier the usage and operation parameters of the membrane element in the event of a system failure, the performance warranty shall be invalid;
- If the customer fails to notify the supplier in writing of the membrane element failure within 30 days after the first occurrence of non-compliance with the performance standards described in this warranty document.

5. Invalidity Conditions for All Warranties

If any of the following conditions are not met, all other warranties except the aforementioned warranty clauses (i.e., limited quality guarantee for materials and manufacturing, initial performance warranty and three-year limited proportional performance warranty) shall be invalid:

- If the customer fails to make full payment to the supplier, the warranty shall be deemed invalid;
- Damage caused by accidents or external forces, or damage caused by improper use, is not covered by this warranty. The aforementioned damages are caused by, but not limited to, operations and exposure to conditions outside the product specifications, user instructions and this warranty document of Proshare. In case of any dispute, the customer shall provide evidence to the supplier;
- Consumables and parts (such as O-rings, sealing rings) are not within the scope of the warranty;
- Damages or malfunctions caused by repairs, replacements or substitutions without the special authorization of the supplier are not covered by this warranty;
- Defects or malfunctions caused or resulted from any incorrect or incomplete operation process information, operation parameters, or work done by the customer or its authorized representatives are excluded from the scope of the warranty;
- If the user fails to have sufficient and competent operation, supervision and maintenance personnel, as well as necessary laboratory equipment, testing equipment and personnel, the warranty shall be deemed invalid;

- The membrane elements will be used in larger-scale water or wastewater treatment processes. The supplier must be given the opportunity to review the engineering documents under reasonable conditions and participate in all tests and commissioning related to the water or wastewater treatment processes that may affect the membrane life and performance; otherwise, this warranty shall be invalid. Failure to review the engineering documents, failure to participate in the commissioning operation, or reduction of participation opportunities will have an impact and liability on any part of the system;
- When the customer and the end user are different entities, the customer has the sole and separate responsibility to make the user aware of its obligations under the terms of this warranty. The customer's failure to perform its respective obligations specified in this limited warranty may render these warranties invalid.

6. Warranty Liability

- Within 30 days of receipt of the goods, if the membrane element fails to work normally without improper use, after being returned to the factory, the company will provide free repair or replacement, excluding transportation costs and local labor costs;

- If the membrane element has not been put into use by the end of the allowed storage period, the first use of the membrane element shall be deemed to be outside the allowed storage period;

- All membrane elements returned for reasons other than warranty must be unused products and kept in the original factory packaging. Returned membrane elements that do not meet the above standards will be rejected or subject to additional charges.

7. Warranty Statement

- This limited warranty is the only warranty provided by the supplier for the elements (including but not limited to the quality and performance of the membrane elements). All other warranties (whether express, statutory or implied, including but not limited to any implied warranties for fitness for a particular purpose or merchantability) are invalid. Any liability or obligation of the supplier arising from the aforementioned warranty shall not be expanded, reduced or affected by the technical advice or services provided by the supplier or its affiliates in relation to the membrane element products.

- If the product fails to comply with any of the above warranty clauses, the supplier's liability shall be limited to the remedies explicitly specified in this contract. Whether it is the replacement or repair of the membrane element, the supplier shall not be liable for any indirect, consequential losses, costs or expenses related to the warranty, including labor, installation or other expenses incurred by the customer, especially the expenses related to the disassembly or replacement of the system or any other membrane element. The customer shall bear all risks and liabilities arising from the use of the membrane elements and shall not transfer them to the supplier. This warranty excludes any joint, special, punitive or

exemplary damages of the supplier, as well as losses of production, profits and gains incurred by the customer, or losses caused by the customer's use of the membrane elements or violation of the terms of this warranty.

- Membrane elements used in food or dairy processing, special applications and sulfate removal are not within the scope of this warranty.

- The salt permeability of nanofiltration membrane elements is determined using magnesium sulfate.

- Proshare shall not bear any warranty liability for accidents, economic losses, etc., caused by justified, accidental, intentional or malicious damage, or membrane performance damage caused by incompatibility of third parties.

8. Repair, Return and Replacement Procedures

If the customer really needs to implement the repair, return and replacement procedures for membrane elements, please follow the following procedures of Proshare:

- The approval of the after-sales service department of Proshare must be obtained before repair, return and replacement;
- When returning the membrane elements, the user needs to assist in complying with the following terms:
  - Provide a detailed description of the product failure;
  - Provide all data reflecting the returned membrane elements (such as salt rejection rate, temperature, pressure, feed water salt concentration, product water flow rate, etc.);
  - Ensure that the membrane elements are placed in sealed bags and then put into cartons to avoid mechanical damage, and at the same time take moisture-proof and sun-proof protection measures;
  - After obtaining the repair notice from Proshare, the customer shall send the membrane elements as soon as possible to avoid changes in the performance of the membrane elements due to prolonged storage;
  - If the quality inspection department of Proshare finds that the returned goods are damaged (including damage caused by improper use, storage, transportation and unauthorized modification of the membrane elements), the company will not be responsible for replacement and return the goods to the user, and the transportation costs shall be borne by the user;
  - All unused products returned to Proshare must be in the original factory packaging.

- Repair, return and replacement inspection procedures:
  - After inspection, if the problem is indeed caused by the membrane material and production process of Proshare within the warranty period, Proshare shall bear all inspection costs, and the customer can obtain membrane elements that meet the technical standards as compensation from the company, and the transportation costs shall be borne by Proshare;

- After inspection, if the problem is not caused by the membrane material and production process of Proshare within the warranty period, the customer shall bear all inspection and membrane element replacement costs, and the transportation costs shall be borne by the customer;
- For membrane elements beyond the warranty period, the customer shall bear all inspection, membrane element replacement costs and transportation costs.

- The quality guarantee shall be invalid if any of the following situations occurs:
  - There is no Proshare Environmental Protection product serial number on the membrane element;
  - Obvious water pollution on the membrane element during use is visible;
  - Visible mechanical damage to the membrane element caused during use, or damage to the membrane element resulting from improper storage and transportation;
  - The membrane element is modified without the permission of Proshare Environmental Protection

9. Important Reminders

- Formalin is not recommended as a protective solution, and its application in drinking water is not supported. Before using formalin as a bactericide, the membrane element must be operated continuously for more than 24 hours. If the membrane element is exposed to formalin before this period, the water production will decrease significantly.
- The use of membrane elements themselves does not guarantee the removal of cysts and pathogens in water. The effective removal of cysts and pathogens depends on the design of the entire system and the operation and maintenance of the system.

10. Appendix

Mandatory Measurement and Recording of Operating Parameters.

Both parties have read, understood and agreed.

Supplier:	**User:**
Company Name:	Company Name:
Contact Person:	Contact Person:
Contact Information:	Contact Information:
Date:	Date:

Annex. Mandatory Measurement and Recording of Operational Parameters

PSI™ Membrane Element

From the effective date of the initial performance warranty and the one-year performance warranty, the following terms shall be accurately recorded by continuous online recording equipment and manually measured and recorded at least once during each operator shift, each system shall be recorded:

1. Continuous Online recording

1.1 pH of both raw water and adjusted with acid addition

1.2 Inlet water conductivity and produced water conductivity

1.3 Residual chlorine concentration in influent water

1.4 Inlet pressure

1.5 Total produced water flow and conductivity

1.6 Acid dosage (in case)

1.7 Dosage of scale inhibitor

1.8 Water inlet temperature

1.9 Water production pressure

1.10 Difference in inlet and concentration water pressure (DP)

If the system consists of multiple segments or levels, in addition to the parameters listed above, each segment of each level needs to record the following parameters:

1.11 Intake pressure, water production pressure, and differential pressure

1.12 Intake and water production conductivity

1.13 Influent and water production flow

2. Manual measurements/laboratory tests, recorded at least once (1) per day

2.1 Record all of the items listed above continuously

2.2 Water inlet SDI (15 minutes, 30psi)

2.3 Recovery rate

2.4 Flow balance per unit (total intake, concentrated and produced water)

2.5 Material balance for each unit (total intake, concentrated water and produced water)

2.6 Chloride ion balance for each unit (total intake, concentrated and produced water)

3. Laboratory measurements and records should be taken at least once a month

3.1 Influent, concentrated, and water-producing total dissolved solids

3.2 Total water quality analysis report

4. Calibration of all continuously recorded sensors should be performed at least once a month

The user shall record and maintain the data in a systematic and standardized file format and provide the data to the supplier upon request..

Chapter 11. Application Cases

11-1 Application of PSI TFN Anti-pollution Membrane in Semiconductor Wastewater Recycling

PSI MEMBRANE® Pro-XFR anti-fouling membrane elements are used in the comprehensive wastewater treatment of semiconductor plants, with the product water reused for production line.

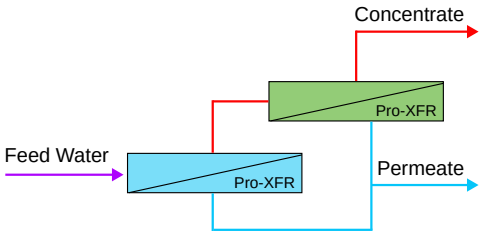


Project Overview

- Location: Wuxi City, Jiangsu Province
- Water Source: A Semiconductor Plant Group
- Capacity: RO Permeate Flow Rate 16,416m^3/d
- User: Semiconductor Industrial Park

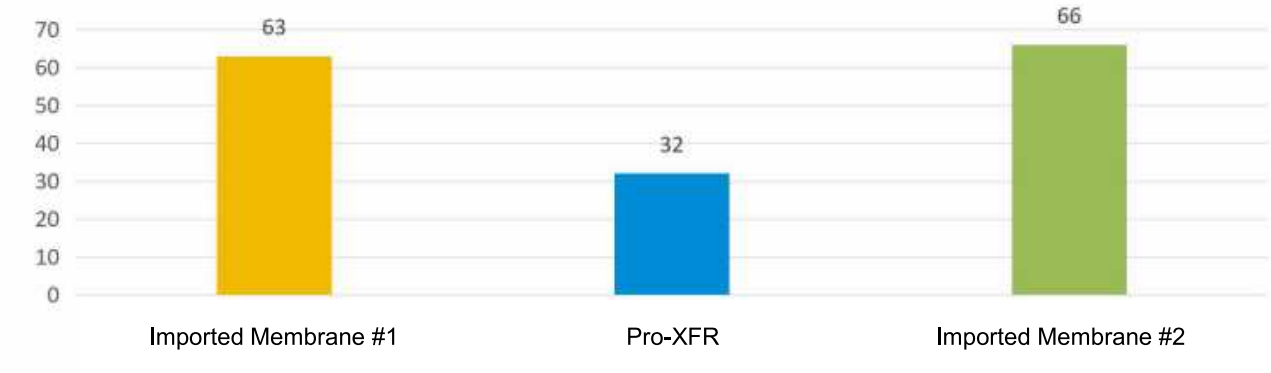
Reverse Osmosis System Design Information

- Average Design Flux: 19.05 LMH
- RO System Single Unit Design Recovery Rate: 70%
- Quantity of Membrane Systems: 6 units
- Adoption of Membrane Elements: PSI MEMBRANE® Pro-XFR
- Advance pilot testing and compare the performance of other imported membrane elements with significant advantages in anti-pollution PSI MEMBRANE® Pro-XFR.



Parameter	Pressure Vessel Quantity	Per Pressure Vessel Membrane Quantity	Membrane Model	Total Membrane Quantity
1st	17	6	Pro-XFR-8040	102
2nd	9	6	Pro-XFR-8040	54
TDS	mg/L	Around 1600	-	-
Turbidity	NTU	< 5	-	-
F-	mg/L	2.5-3.5	-	-

Statistics on Chemical Cleaning Frequency of Membrane Elements from Different Brands Under Identical Pilot Conditions



11-2 Application of PSI TFN Reverse Osmosis Membranes in Purified and Ultrapurified Water Production



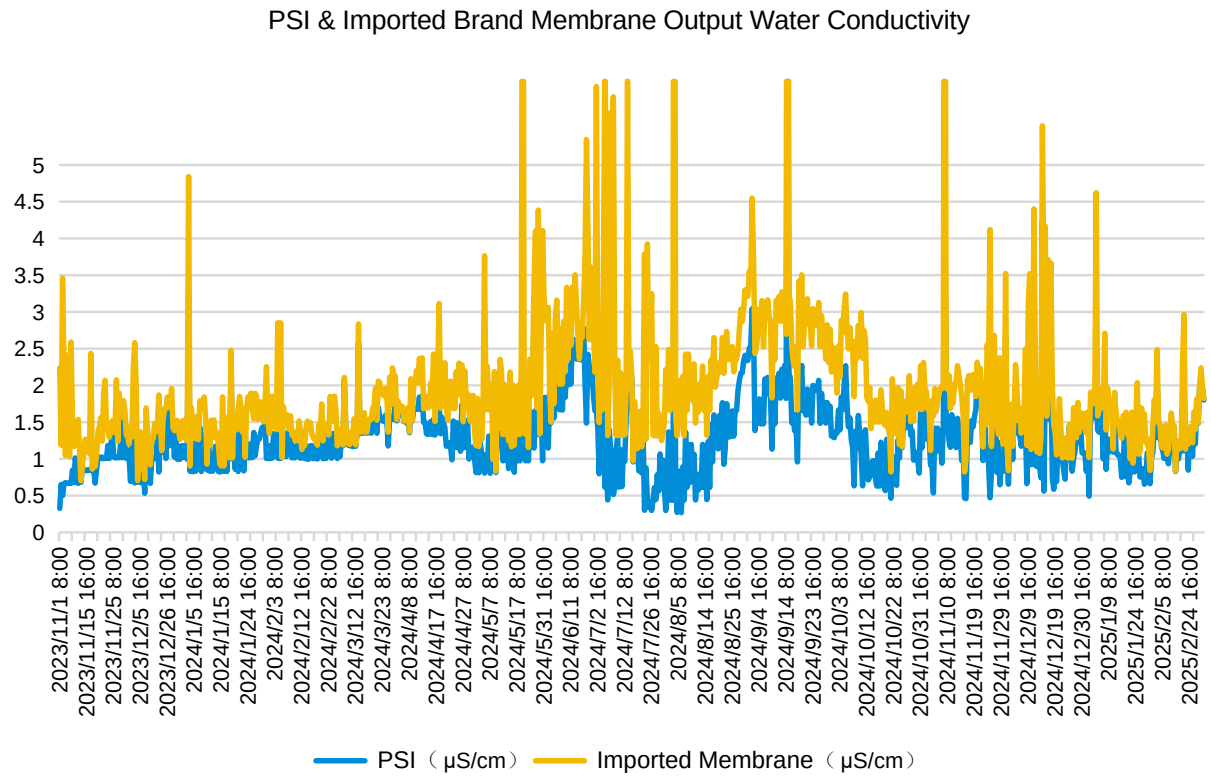
Japan Kuramoto 2*3 m^3/h Ultrapure Water Project

- Process: MMF + ACF + 2-Stage RO + EDI + MB+UV+SF
- Application: Production of Ultrapure Water for the Semiconductor Industry
- Location: Hanaizumi, Japan
- Feed Water: Japanese Municipal Tap Water
- Feed Water Conductivity: 290 μS/cm & 310 μS/cm
- System Recovery Rate: 60%
- Maximum Water Consumption: 10 m^3/h
- Product Water Quality: Resistivity >18 MΩ • cm



Suzhou Suna Optoelectronics 2*11 m^3/h Electronic-Grade Ultrapure Water Project

The product water complies with ASTM D5127-07 Type E1.1 standards, featuring extremely low impurity levels. It is specifically designed for high-cleanliness processes in semiconductor chip manufacturing, representing the highest grade of water purity.



11-3 Application of PSI TFN Specialty Acid-Resistant Membranes in New Energy Battery Cathode Materials

PSI MEMBRANE® Pro-Acid specialty acid-resistant membrane elements are used for material concentration in new energy cathode material plants. The concentrated brine is discharged to an evaporator, and the product water is reused as pure water for production line processes.



Project Overview

- Location: Fuquan City, Guizhou Province
- Water Source: New Energy Battery Chemical Workshop
- Capacity: 6000m³ /d in the First Phase
- User: New Energy Battery Cathode Materials Top Enterprise
- Purpose: Material Concentration, Water Reuse
- Commissioning Date: August 2023

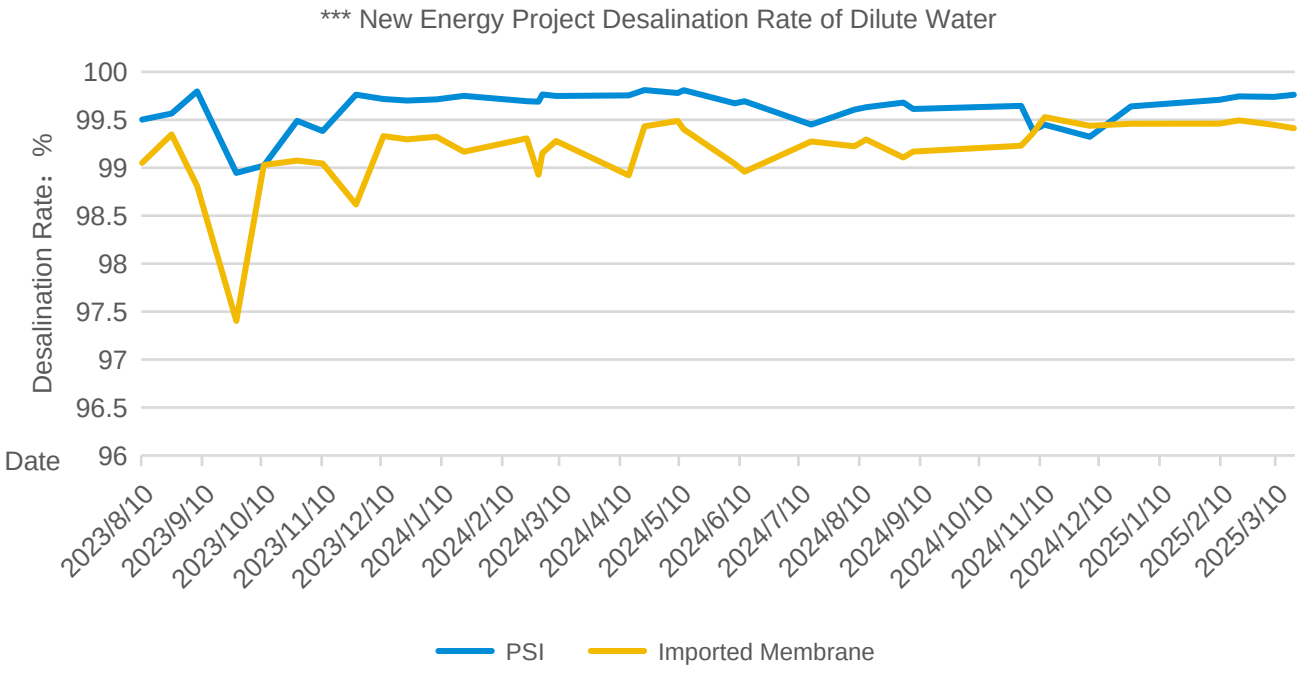
Reverse Osmosis System Design Information

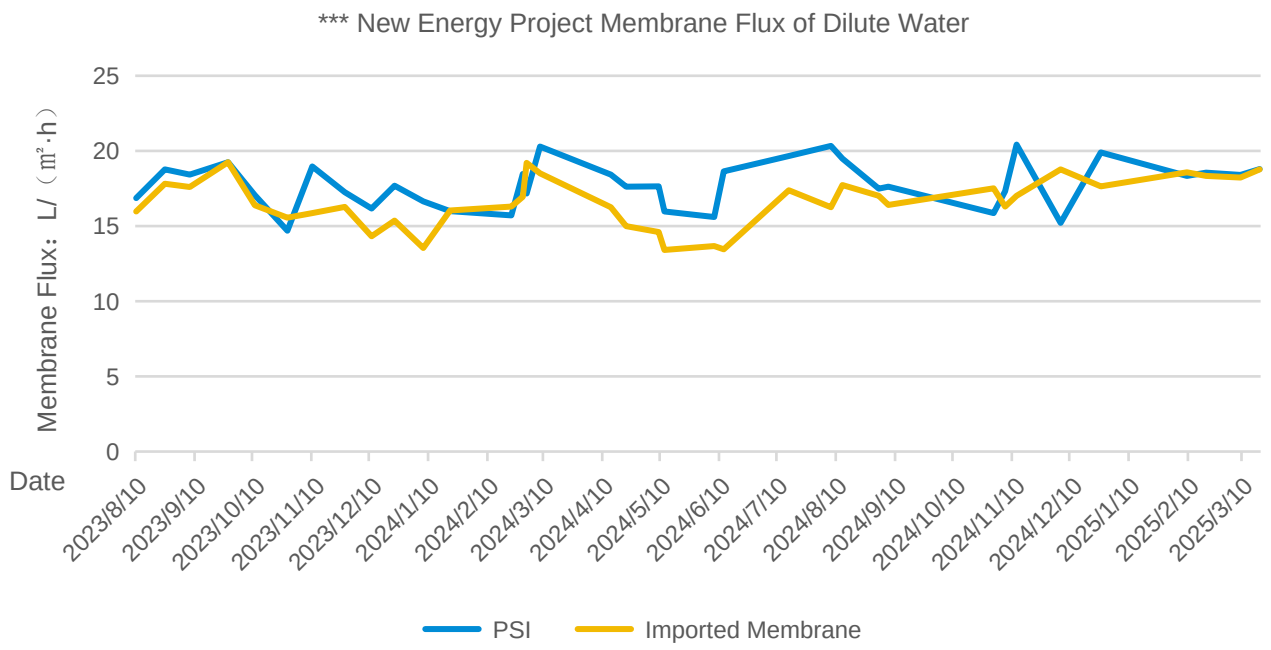
Position	Quantity of Membrane System	Average Design Flux	Recovery Rate	Quantity of Membrane per Unit
Dilute Water 1st	6	18LMH	65%	144
Dilute Water 2nd	4	15LMH	50%	144
Dilute Water 3rd	3	11LMH	45%	144
Concentrate Water 1st	7	15LMH	55%	144
Concentrate Water 2nd	6	8.5LMH	40%	144

- Influent pH: 2
- Quantity of Membrane System: 26 Units in the Acid-resistant Membrane Workshop
- Adoption of Membrane Elements: PSI MEMBRANE® Pro-Acid
- PSI Membranes were installed and operated simultaneously with imported membranes, demonstrating significant advantages in salt rejection, flux stability, and cleaning resistance compared to other imported acid-resistant membrane elements.

Taking the Dilute Water First Stage as an Example

Comparison of Salt Rejection and Permeate Flux with a Well-Known Imported Brand Membrane
— Installed in the Same Period, Using the Same Water Source, and Operating Over the Same Duration





11-4 Application of PSI Ultra-High Pressure Reverse Osmosis in Zero Liquid Discharge (ZLD) Projects for Coal Chemical Wastewater

PSI MEMBRANE® PX120 Ultra-High Pressure Reverse Osmosis Membrane Elements are used for high-concentration brine enrichment in zero liquid discharge (ZLD) projects for coal chemical wastewater. The concentrated brine is discharged to an evaporator for further treatment.



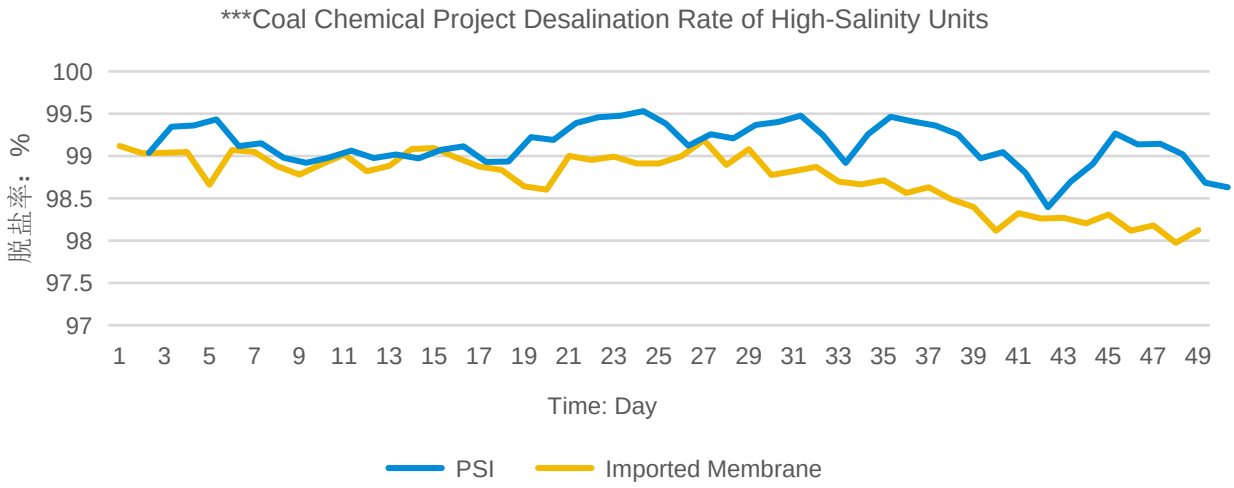
Project Overview

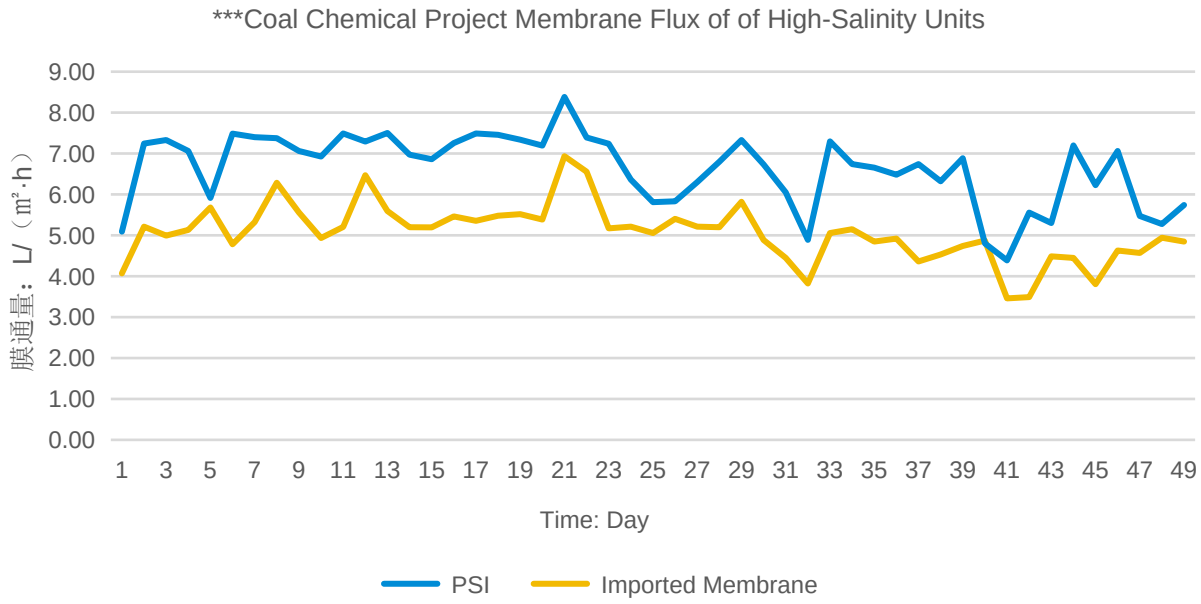
- Location: Ordos, Inner Mongolia
- Water Source: High-Salinity Wastewater from Coal Chemical Industry
- Capacity: Phase I 2,000m³ /d
- User: Large-Scale Modern Coal Deep Processing Enterprise
- Purpose: Water Resource Reuse
- Commissioning Date: March 2025

Position	Quantity of Membrane System	Design Water Intake Flux per Unit	Recovery Rate	Quantity of Membrane per Unit	Operating Pressure
High salt ultrahigh pressure system	2	40m³/h	≥35%	90	11.5Mpa

- **Reverse Osmosis System Design Information**
- Influent TDS: 60,030-149,130mg/L (Average 77,558mg/L)
- Quantity of Membrane System: 2 Sets for High-salinity Wastewater Treatment
- Adoption of Membrane Elements: PSI MEMBRANE® PX120
- PSI membranes were compared with imported membranes during the same period, demonstrating significant advantages in salt rejection, flux stability, and cleaning resistance compared to imported ultra-high-pressure membrane.

Comparison of membrane desalination rate and flux with Between
PSI Membranes and Imported Membrane Brand During the Same Operational Period





11-3 Application of PSI TFN Membranes in Landfill Leachate Treatment

Project Background

With the acceleration of urbanization, the volume of waste generated continues to increase. Waste-to-energy incineration has become one of the primary methods for waste disposal. However, during the storage and transportation of waste, landfill leachate is generated, posing a serious threat to the environment.

Landfill leachate exhibits a complex composition, containing high concentrations of organic pollutants, ammonia nitrogen, heavy metals, and other contaminants. If discharged without effective treatment, it can cause significant pollution to soil, surface water, and groundwater. Therefore, the development of efficient and reliable landfill leachate treatment technologies is crucial.

Project Details

1. Project Name: Landfill Leachate Treatment Project at Shenzhen Energy Environmental Protection East Co., Ltd. Wastewater Station

2. Project Location: No. 1 Huanbao Road, Pingdi Street, Longgang District, Shenzhen

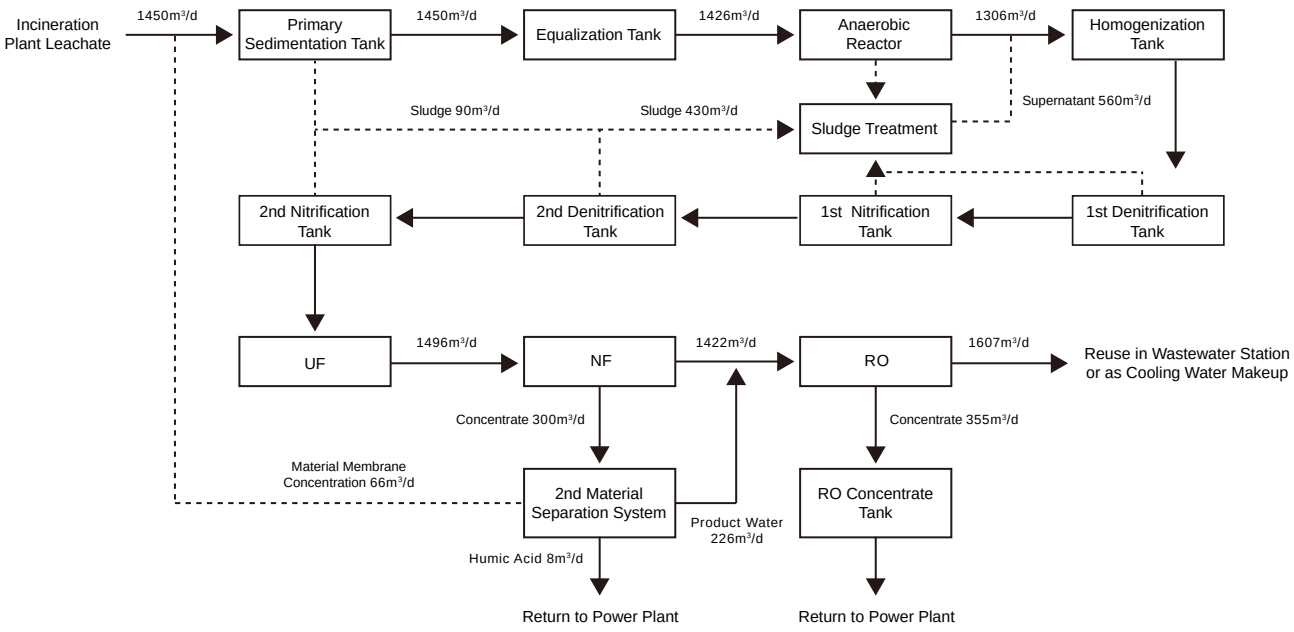
3. Project Description:

Shenzhen Energy Environmental Protection East Co., Ltd. is located in Shangkengtang, Sifangpu Community, Pingdi Street, Longgang District, Shenzhen. The facility is equipped with a leachate treatment system designed for a daily capacity of 1,450 m^3 /d.The core process of the leachate treatment system includes: Pretreatment + Anaerobic Treatment + External MBR + Nanofiltration (NF) + Reverse Osmosis (RO). The system is configured with dual parallel lines operating independently starting from the anaerobic tanks.The membrane advanced treatment system comprises:4 sets of ultrafiltration (UF) membrane integrated units (8 groups total),1 set of nanofiltration (NF) membrane integrated units (2 groups total),1 set of reverse osmosis (RO) membrane integrated units (2 groups total),1 set of nanofiltration concentrate reduction membrane integrated units (2 groups total).By-products such as RO concentrate and primary membrane concentrate generated from NF concentrate reduction are returned to the power plant for further treatment.The treated leachate meets the water quality standards for make-up water in open recirculating cooling water systems specified in GB/T 19923-2005 (Reuse of Urban Recycling Water — Water Quality Standards for Industrial Uses).

4. Leachate Source and Characteristics:

The leachate treated in this project primarily originates from fresh leachate generated during waste transfer and storage collected by the incineration plant. Landfill leachate exhibits characteristics such as diverse pollutant types, complex composition, and

significant fluctuations in water quality and quantity. It contains high concentrations of pollutants including chemical oxygen demand (COD), ammonia nitrogen, and total nitrogen, along with various heavy metals and microorganisms, posing severe environmental hazards if discharged untreated.



Treatment Process

1. Overall Process Flow:

This project adopts a two-stage AO + built-in MBR + NF + SWRO treatment process. The nanofiltration concentrate is treated by a large-aperture ultrafiltration/nanofiltration humic acid recovery process, and the nanofiltration product water is desalinated by seawater reverse osmosis (SWRO) for reuse in the power plant. This process combines biochemical treatment and advanced treatment, effectively removing organic pollutants, ammonia nitrogen, suspended solids, dissolved substances, colloids, and other impurities from the leachate.

2. Detailed Process Description:

Regulation and Homogenization: Fresh and aged leachate enter the existing reinforced concrete regulation tank within the landfill according to the designed ratio. After being lifted, they first flow into the equalization tank, where they are mixed and homogenized with other returned wastewater. This step effectively mitigates fluctuations in leachate quality and quantity, providing stable influent conditions for subsequent treatment units.

- Two-stage AO biochemical treatment: A two-stage AO process with pre-denitrification and post-nitrification is adopted. In the denitrification tank, carbon sources in the influent are utilized to reduce nitrate nitrogen and nitrite

nitrogen. The secondary nitrification-denitrification further ensures complete nitrogen removal and compliance with total nitrogen standards in the effluent. This process fully utilizes carbon sources in the influent, reduces the oxygen demand for degrading organic pollutants in the nitrification tank, and improves treatment efficiency.

- Built-in MBR System: After wastewater enters the membrane reactor, the majority of pollutants are degraded. The built-in MBR membranes utilize the upward shear force generated by gas-liquid interaction during aeration to achieve a cross-flow effect on the membrane surface, thereby reducing membrane fouling. Compared to external ultrafiltration membranes, the built-in ultrafiltration membranes operate with lower energy consumption, reducing operational costs. Ultrafiltration effectively removes suspended solids, colloids, macromolecular organic matter, and other impurities from the wastewater, ensuring stable operation of subsequent nanofiltration systems.

- Nanofiltration Deep Treatment: The nanofiltration treatment process is adopted, with the nanofiltration system achieving a clear water yield of 85%. The concentrate enters the concentrate treatment system, and the treated effluent is returned to the regulation tank, while the clear water proceeds to the RO system for further removal of residual pollutants. Nanofiltration effectively removes small-molecule organic matter, divalent and multivalent ions, and other impurities from the leachate, further enhancing the effluent quality.

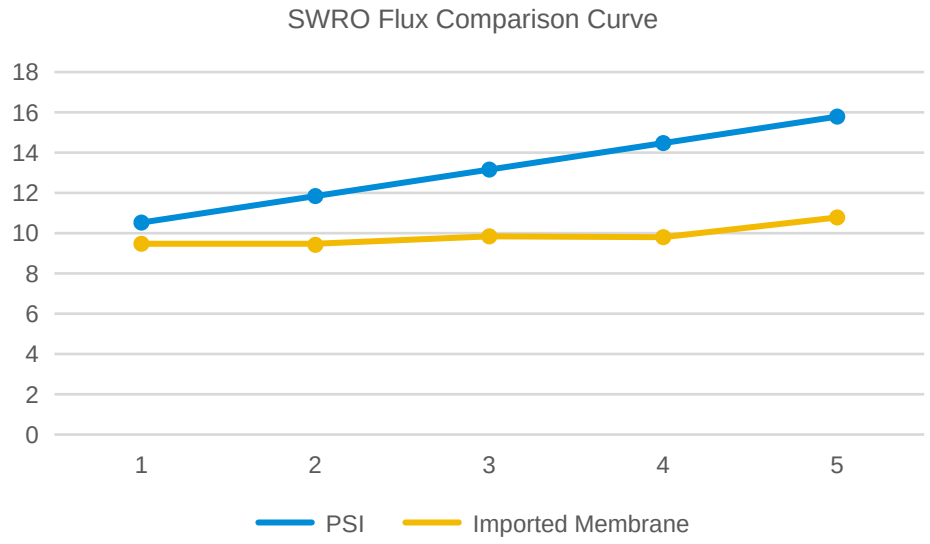
- Nanofiltration Concentrate Treatment: The nanofiltration concentrate in this project is treated using a two-stage material separation membrane process. After treatment with the two-stage material separation membranes, the COD and color of the concentrate are significantly reduced, while the BOD5/COD ratio increases, enhancing the biodegradability of the concentrate. The effluent, after further filtration through the RO system, can essentially meet the reuse water standards for the power plant.

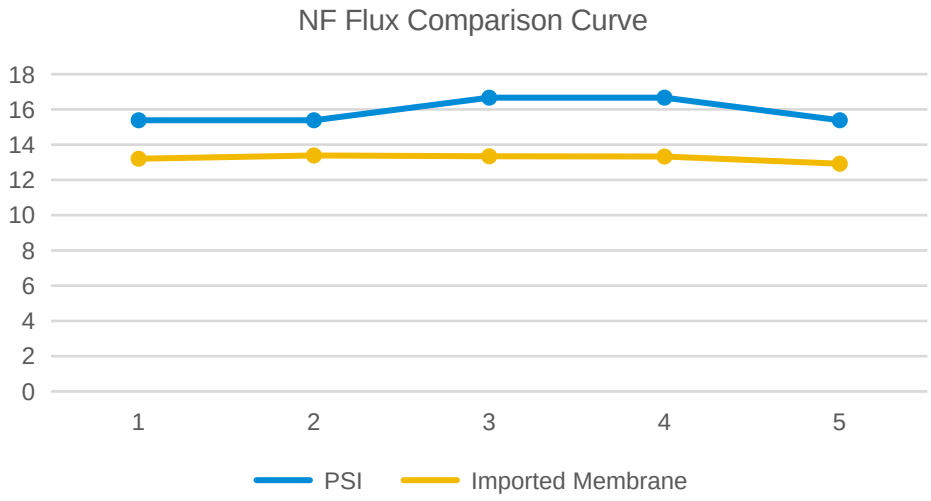
- Reverse Osmosis Deep Treatment: The RO treatment process is adopted, with the RO system achieving a clear water yield of 75%. The concentrate enters the concentrate collection tank and is returned to the power plant for further treatment, while the clear water flows into the reuse water tank to serve as make-up water for the power plant's circulating cooling system.

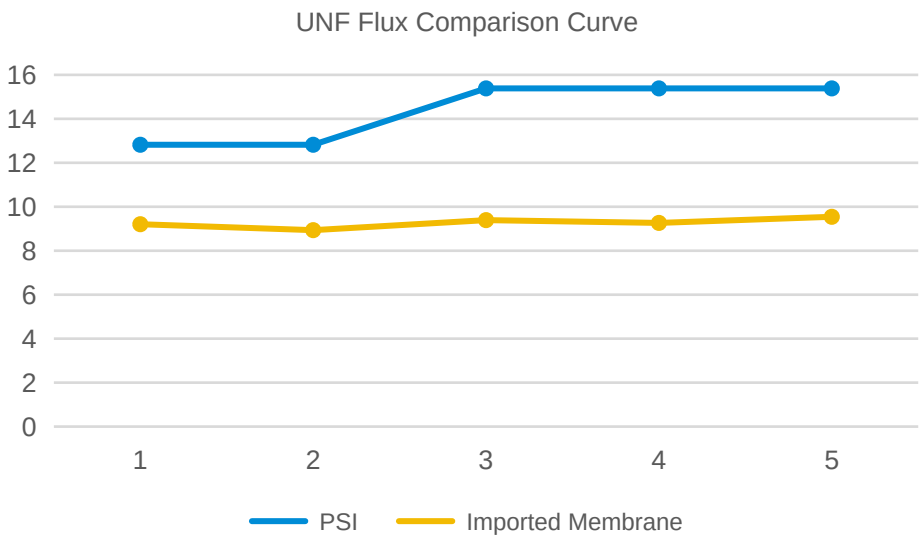
Flux Comparison Analysis Between PSI Membranes and Imported Membranes

SWRO Flux Performance Comparative Chart: Based on extensive data collected from practical applications and pilot tests, the following comparative chart of membrane flux is presented.

Series	Model	Membrane Flux	Test Condition
SWRO	Pro-SW	11-15	Operating Pressure: 31bar Recovery Rate: 75% Inlet Water pH: 7.5 Inlet TDS: 10200mg/L
	Imported Membrane SW30HRLE	9-11	
NF	Pro-NF2	15-17	Operating Pressure: 6bar Recovery Rate: 85% Inlet Water pH: 7.0 Inlet TDS: 11300mg/L
	Imported Membrane NF270	13	
UNF Membrane	Pro-UF	13-15	Operating Pressure: 11bar Recovery Rate: 75% Inlet Water pH: 7.2 Inlet TDS: 16280mg/L
	Imported Membrane 8040F30	9-10	







As clearly demonstrated in the chart, under identical operating conditions, the flux of PSI's SW, NF and UNF Membrane exceeds imported series.

11-5 Application of PSI TFN Reverse Osmosis Membranes in Seawater Desalination Projects

1. Domestic Membrane Replacement for Desalination System on ZHAO SHANG YI DUN

PSI MEMBRANE® Pro-SW Seawater Desalination Membrane Becomes the First Domestically Produced Membrane Applied in International Cruise Ship Desalination Systems.





Project Overview

- Location: ZHAO SHANG YI DUN
- Capacity: 1,200m³/d
- Purpose: Seawater Desalination
- Water Source: International Waters
- User: China Merchants Group
- Commissioning Date: July 2023

Reverse Osmosis System Design Information

- Design Flux: 13LMH
- Recovery Rate: 40%
- Quantity of Membrane System: 1unit
- Quantity of Membrane: 60pcs

2. Domestic Membrane Replacement for the Seawater Desalination System at Xinquan Seawater Desalination Plant

PSI MEMBRANE® Pro-SW Seawater Desalination Membrane Serves National Water Security Strategy as the First Domestic Membrane Supplier for Landmark Complex Water Source Desalination Plant in China.

Project Overview

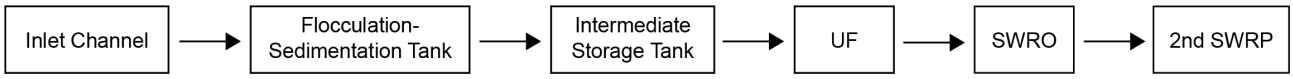
- Location: Tianjin City, China
- Capacity: 13,200TPD per unit
- Purpose: Seawater Desalination
- Water Source: Bohai Bay Seawater
- User: LiRun Technology
- Commissioning Date: January 2024



Reverse Osmosis System Design Information

- Design Flux: 12-16LMH
- Recovery Rate: 45%
- Water Production per SWRO Unit: ⩾550m^3/h
- Conducted one-year parallel comparative testing with multiple domestic and international brands, demonstrating performance comparable to internationally advanced levels in flux, salt rejection, and antifouling propertie.
- Quantity of Membrane: Seawater Desalination System, 1, 176 pcs per unit; 2nd RO System, 588 Elements per unit
- Quantity of Membrane Systems: Seawater Desalination Systems, 8units; 2nd RO Systems, 6 units

Process Flow



11-6 Application of PSI TFN Membranes in Petrochemical Desulfurization Wastewater Treatment

1. Addition of White Smoke Elimination Membrane Separation Facilities to the Flue Gas System of Shenghong Refining & Chemical's Sulfur Recovery Unit



Project Overview

- Location: Lianyungang City, Jiangsu Province
- Capacity: 31m³/h
- Purpose: Zero Liquid Discharge (ZLD)
- Commissioning Date: December 2022
- Water Source: Ammonium Sulfate Evaporation Condensate + Tertiary Circulating Water
- User: Refining Division, Shenghong Refining & Chemical

Project Information

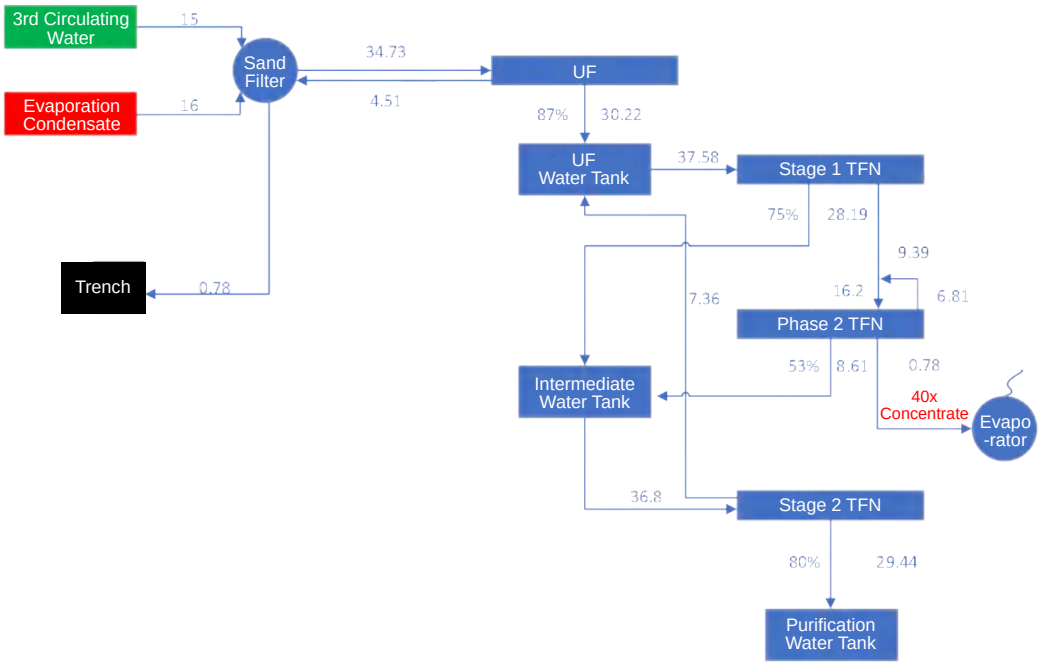
1. Tertiary Circulating Water
   - Flow Rate: 15m³/h
   - Temperature: 50℃
   - pH=3～8
   - Ammonium Sulfate and Ammonium Bisulfate Concentration: 0.02-z0.8% (wt)

2. Evaporation and Crystallization of Secondary Condensate
   - Flow Rate: 16m³/h
   - Temperature: 50℃
   - pH=3-8
   - Ammonium Sulfate Content: 0.005-0.2% (wt), Containing Trace Amounts of Ammonia (NH_3), SO_2, Sulfite, Bisulfite, Chloride Ions, etc.

Technical Proposal

1. Within the water processing capacity of 60-150%, the maximum concentration of ammonium sulfate and ammonium bisulfate remains below 0.5% (wt). The TFN main unit achieves a 40-fold concentration, while combined with wastewater discharge, the total concentrated water entering the evaporator reaches a 20-fold concentration. With maximum influent concentrations of ammonium sulfate and ammonium bisulfite not exceeding 2%, normal operation is guaranteed.
2. The maximum concentration of ammonium sulfate in the concentrated water shall not be less than 20% to ensure the normal operation of the equipment.
3. The equipment meets the requirements of 1 year maintenance every 3 years and the service life of the equipment is more than 20 years.

Technical Proposal Treatment Process Flow

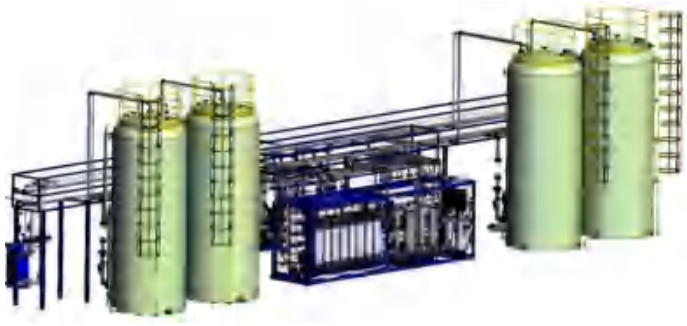


Core Technology & Advantages

The core of the project is the PSI TFN membrane separation system, which features the following characteristics:

1. Optimized multi-layer membrane structure specifically designed for challenging ammonium ion removal in ammonium sulfate solutions, ensuring optimal sulfate retention efficiency;
2. High flux performance, achieving higher water production without increasing operating pressure;
3. Chemical cleaning resistance, with a broad pH cleaning range (pH 1 – 13), effectively removing inorganic scaling, organic foulants, and microbial contaminants;
4. Fully automated and precision manufacturing technology, incorporating an advanced design with shortened membrane leaf length and increased leaf count, reducing overall fouling potential and maximizing membrane efficiency.

2. Installation of Skid-Mounted Membrane Separation Unit for Evaporation Condensate Treatment in the Ammonium Sulfate Plant of Zhongke Refining & Chemical



The custom-developed NF98-SPEC-8040 specialty nanofiltration membrane has successfully replaced imported membrane, achieving efficient separation of ammonium sulfate wastewater in the petrochemical industry. It enables purified water reuse and high-concentration enrichment of ammonium sulfate brine.

Project Overview

- Location: Zhanjiang City, Guangdong Province
- Water Source: Ammonium Sulfate Evaporation Condensate
- Capacity: 20m³ /h
- User: Refining Department III, Zhongke Refining & Chemical
- Purpose: Reuse of Evaporation Condensate Water
- Commissioning Date: July 2022

Medium		Evaporation Condensat
Treatment Capacity	m^3/h	25
Inlet Temperature	℃	< 80
Operating Pressure	MPa	< 2.5
pH	-	2 ~ 5
Ammonia Nitrogen	mg/L	< 2000
Suspended Solids	mg/L	< 50
Conductivity	μS/cm	< 12000
Permeate Ratio	-	80%
Concentrate Ratio	-	20%
Piping & Flange Standards		SH/T 3405, SH/T 3406

NO.	Item	Value
1	pH	6.5 ~ 9.0
2	COD, mg/L	< 60
3	BOD, mg/L	< 10
4	Ammonia Nitrogen, mg/L	< 10
5	Suspended Solids (SS), mg/L	< 30
6	Turbidity, NTU	< 10
7	Sulfide Ion, mg/L	< 0.1
8	Petroleum Substances, mg/L	< 2.0
9	Volatile Phenols, mg/L	< 0.5
10	Calcium Hardness (as $CaCO_3$), mg/L	50-300
11	Total Alkalinity (as $CaCO_3$), mg/L	50-300
12	Chloride Ion, mg/L	< 30
13	Sulfate Ion, mg/L	< 50
14	Iron, mg/L	< 0.5
15	Conductivity, μS/cm	< 100

Project Information

The raw feed liquid to be treated in this project is ammonium sulfate evaporation condensate from ammonia-based desulfurization units. It exhibits high ammonia nitrogen content, strong acidity, and elevated temperature. The key design parameters for feeding into the skid-mounted system are listed in the right table.

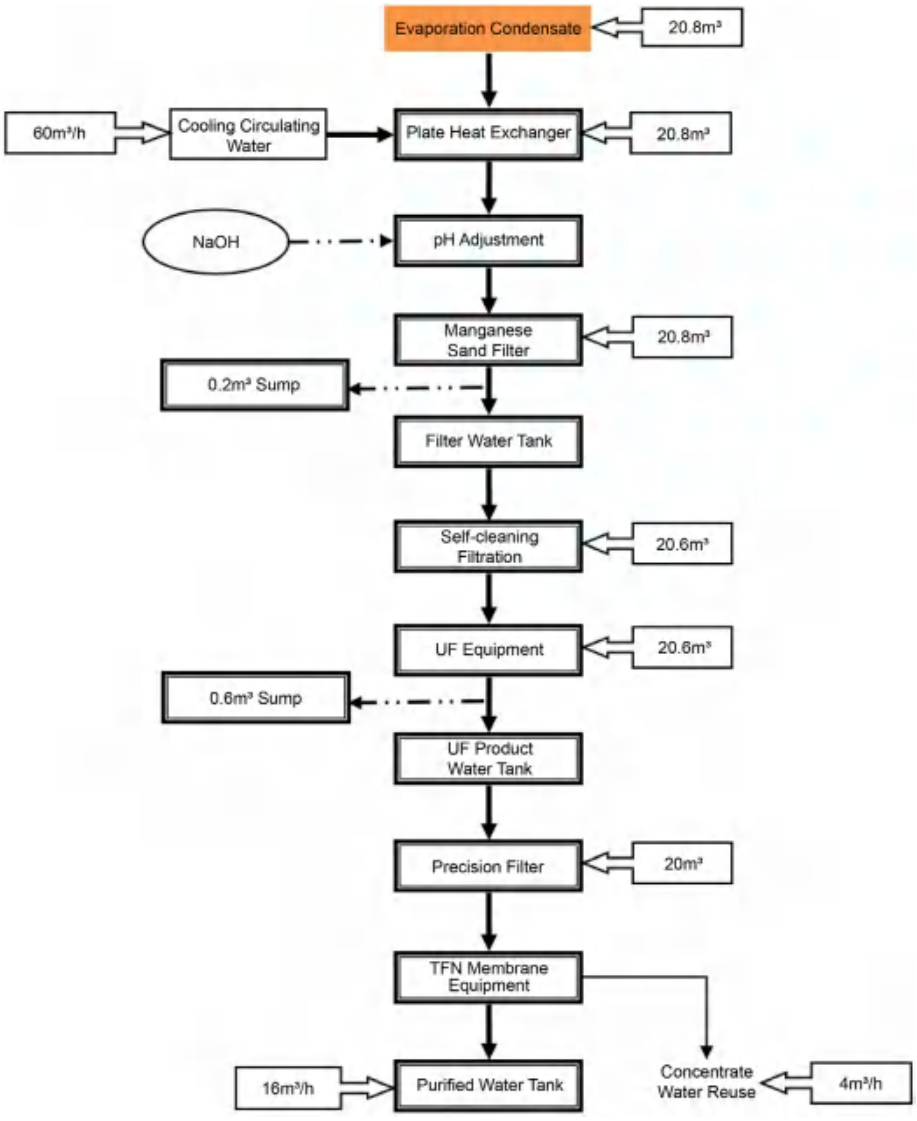
Technical Results

Under the condition that the raw water meets the designed inlet requirements, the purified water shall comply with the China Petrochemical Corporation Enterprise Standard Q/SH 0628.2-2014 for make-up water quality. Additionally, the outlet pressure shall be no less than 0.6 MPa(g), and the temperature shall be below 40° C. Specific indicators are listed in the above table.

Within 60-110% of the designed operational range, the purified water quality shall meet the Sinopec Q/SH 0628.2-2014 make-up water standard, with a recovery rate of no less than 80%.

- The equipment shall require maintenance only once every 4 years, with a service life exceeding 15 years.
- The system must support continuous operation for 4 years. For membrane treatment facilities incapable of continuous operation, a configuration of one in operation and one on standby shall be adopted to ensure continuous operational capability. (Routine consumable replacement, maintenance, and cleaning within 12 hours shall not be considered as affecting continuous operation.)

Technical Proposal



Core Technology & Advantages

The core of the project is the PSI TFN membrane separation system, which features the following characteristics:

- Optimized multi-layer membrane structure specifically designed for challenging ammonium ion removal in ammonium sulfate solutions, ensuring optimal sulfate retention efficiency;
- High flux performance, achieving higher water production without increasing operating pressure;
- Chemical cleaning resistance, with a broad pH cleaning range (pH 1 – 13), effectively removing inorganic scaling, organic foulants, and microbial contaminants;
- Fully automated and precision manufacturing technology, incorporating an advanced design with shortened membrane leaf length and increased leaf count, reducing overall fouling potential and maximizing membrane efficiency

11-8 Application of PSI TFN Specialty Acid-Resistant Membranes in Strong Acidic Wastewater Treatment

1. Purification and Recovery of 25% Sulfuric Acid in Aluminum Electrolysis Plants



Project Overview

- Location: Huzhou City, Zhejiang Province
- Water Source: Sulfuric Acid Wastewater from Aluminum Electrolysis Plant
- Capacity: 20m³/h
- User: Operations & Maintenance Company
- Purpose: Sulfuric Acid Purification and Reuse
- Commissioning Date: February 2019

Project Information

The raw feed liquid to be treated in this project is waste acid solution with approximately 25% sulfuric acid concentration from the anodizing and pickling process of aluminum alloy profiles. By adopting a specialty acid-resistant nanofiltration membrane method, the process is simplified and enables recovery of 60-90% of the waste liquid.

Technical Results

Flux exceeds twice that of a leading imported acid-resistant membrane; Service life > 12 months.

2. Titanium Dioxide Plant 5%-12% Sulfuric Acid Purification and Recovery





Project Overview

- Water Quantity: 30m^3/h
- Location: Qianjiang City, Hubei Province
- User: Engineering Company
- Water Source: Titanium Dioxide Plant Sulfuric Acid Wastewater
- Commissioning Date: December 2024
- Purpose: Sulfuric Acid Purification and Reuse

Project Information

The sulfuric acid method is one of the primary global processes for titanium dioxide production. However, this process generates a significant amount of waste acid liquor, which has a complex composition primarily including sulfuric acid, ferrous sulfate, and other metal sulfates. If not treated effectively, this waste acid liquor can cause severe environmental pollution, and the valuable components within it cannot be recycled, leading to substantial resource waste. Therefore, the effective treatment of waste acid liquor is of great significance, as it concerns both environmental protection and resource recovery.

A titanium dioxide production enterprise utilizes PSI Specialty Acid-Resistant Nanofiltration Membranes to enable the resource recovery and regeneration of ferrous sulfate and sulfuric acid from acidic wastewater in titanium dioxide production.

3. Application of PSI TFN Specialty Acid-Resistant Membrane Equipment in Nitric Acid Recovery



Project Overview

- Location: Wuzhou City, Guangxi Province
- Water Source: Cleaning Wastewater
- Capacity: 5m³ /h
- User: Electronic Aluminum Foil Enterprise
- Purpose: Purification and Recovery of Nitric Acid Solution
- Commissioning Date: June 2025

Project Information

During the production process, wastewater is generated from the chemical cleaning of corroded aluminum foil surfaces using nitric acid solution. This wastewater contains small amounts of sulfate and chloride ions, with the primary salt content being aluminum compounds. Through nanofiltration equipment, aluminum salts and sulfates are effectively retained, enabling the purification and recovery of nitric acid solution.

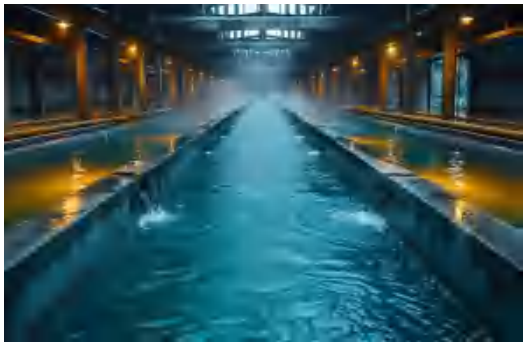
Main Parameters of Membrane Equipment

Design Water Temperature	≤35℃	Working Pressure	< 5MPa
Treatment Capacity	5m³/h	Water Yield	3m³/h
Recovery Rate	60%	Salt Rejection Rate	99%
High-Pressure Pump	Flow Rate 5m³/h, head 500m	Concentrate Recirculation Pump	Flow Rate 5m³/h, Head 80m,Inlet Pressure 50bar
Membrane Model	Pro-Acid-NF98-8040F34 (Rolling Type)		

11-9 Application of PSI TFN Alkali-Resistant Membranes for Alkali Solution and Hemicellulose Recovery from Waste Alkali in the Chemical Fiber Industry

Project Overview

- Location: Tangshan City, Hebei Province
- Water Source: Waste Alkali
- Capacity: 5m³ /h
- User: Chemical Fiber Industry
- Purpose: Recovery of Alkali Solution and Hemicellulose
- Commissioning Date: June 2025



Project Information

In the production of viscose fiber, an alkali solution is used to dissolve hemicellulose from pulp. If the concentration of hemicellulose in the alkali solution becomes too high, it can adversely affect the quality of the viscose fiber products. To maintain the hemicellulose content in the impregnation alkali solution, the common practice is to discharge a portion of the impregnation alkali solution and supplement it with fresh alkali. The discharged impregnation alkali solution is referred to as waste alkali. The main components of waste alkali are sodium hydroxide and hemicellulose. PSI alkali-resistant membranes are employed to purify and recycle the alkali solution and recover hemicellulose.

Main Parameters of Membrane

Material Temperature	45 ~ 55℃ (highest <70℃)	Working Pressure	1.5 ~ 3.5MPa
Alkali Concentration	220 ~ 225g/L	Hemicellulose Content	35g/L
Net Alkali Quantity	5m³/h	Net Alkali Recovery Rate	> 55%
Hemicellulose Content in Net Alkali	5.0g/L (within two years)	Black Liquor Hemicellulose Content	80g/L
Membrane Model	Pro-Base series		

11-10 Application of PSI TFN Solvent-Resistant Membranes for DMSO Concentration in the Carbon Fiber Industry

Project Overview

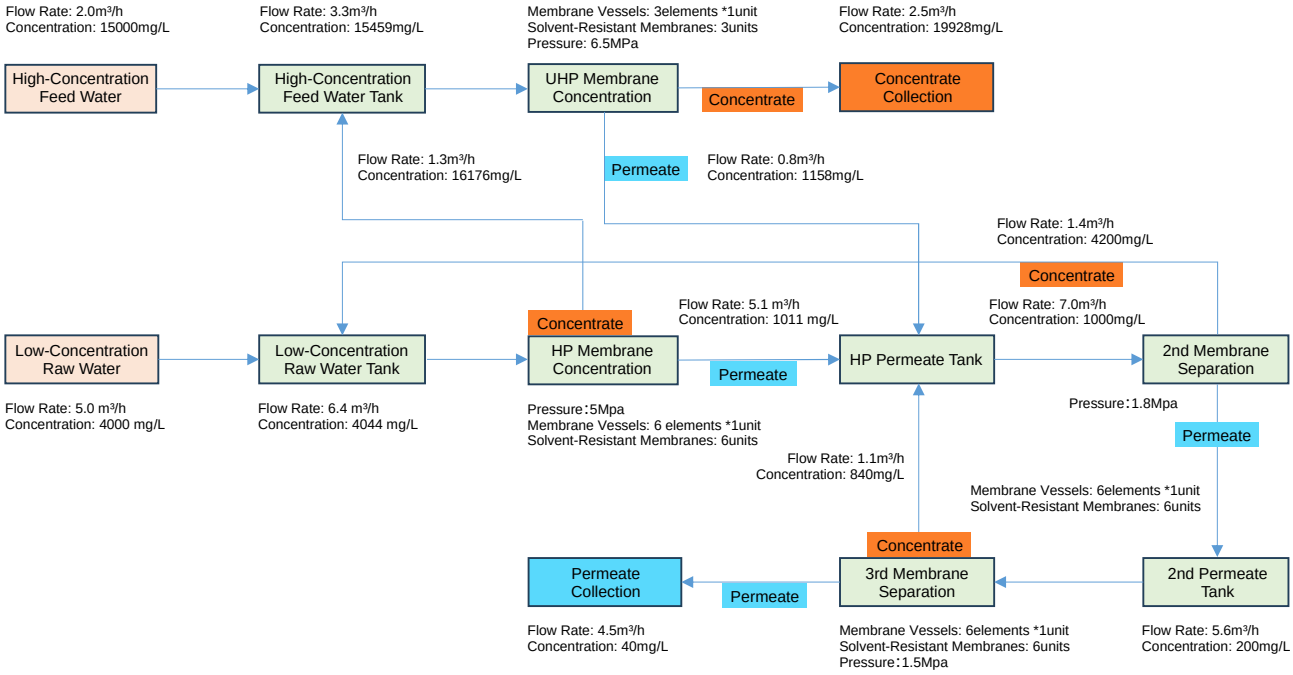
- Location: Zhenjiang City, Jiangsu Province
- Water Source: Solvent Wastewater
- Capacity: 7m³ /h
- User: Carbon Fiber Industry
- Purpose: Resource Recovery
- Commissioning Date: July 2024



Project Description

Polyacrylonitrile is the primary raw material for carbon fiber precursor production. The solvent dimethyl sulfoxide (DMSO) used in its manufacturing process is present in high concentrations in the resulting wastewater. DMSO is an organic compound that is difficult to biodegrade. Its presence not only increases the COD value of the wastewater but also makes wastewater treatment more challenging. By using solvent-resistant membranes to concentrate and recover DMSO from the wastewater, resource recovery is achieved, turning waste into valuable material.

Balance Diagram for DMSO Membrane Concentration and Purification System



11-11 Application of PSI TFN Nanofiltration Membranes in Lithium Extraction from Salt Lakes

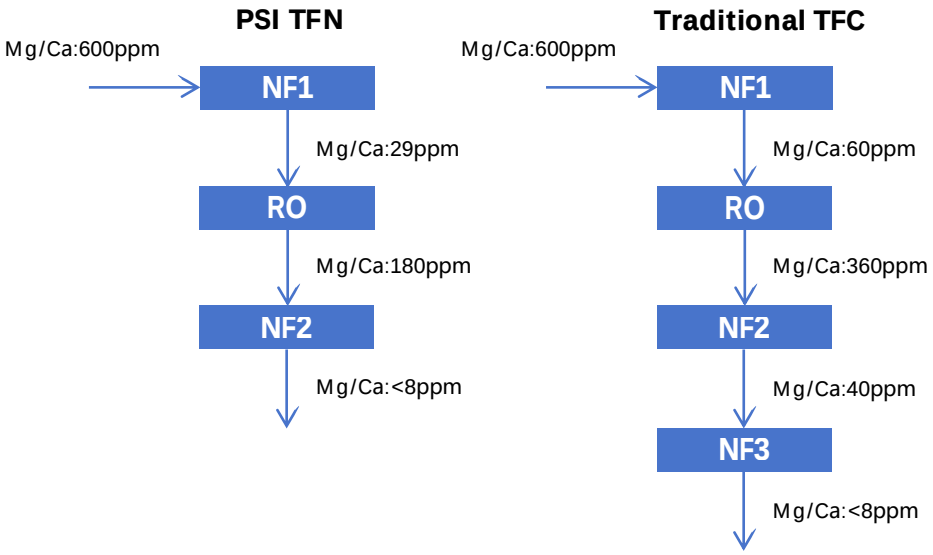
Project Overview

- Location: Tibet Autonomous Region
- Water Source: Salt Lake Brine
- Capacity: 120m³ /h
- User: Zijin Mining
- Purpose: Lithium Extraction from Salt Lake Brine
- Commissioning Date: August 2023



Project Information

PSI's latest generation of customized TFN fractional salt nanofiltration membranes boasts exceptional anti-fouling and anti-scaling properties. Leveraging the highly customizable nature of TFN technology, it enables optimal membrane performance design tailored to different salt lakes and various lithium extraction processes through membrane methods. This provides core technical support for reducing costs, improving efficiency, and optimizing processes in lithium extraction from salt lakes. The right figure shows PSI's TFN fractional salt nanofiltration membranes at the lithium extraction project site in Ali Salt Lake, Tibet.

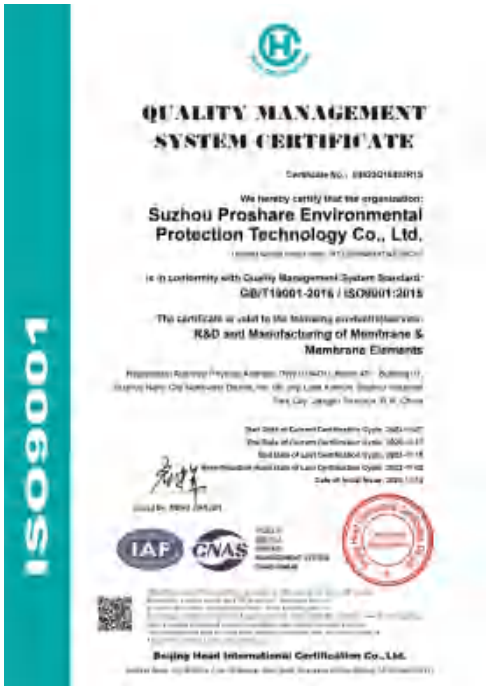


Technical Results

The qualified stripping solution was treated with only two stages of PSI NF, producing water with magnesium at 2.9 mg/L and calcium at 2.25 mg/L. The rejection rates were >99% for magnesium and >98% for calcium, while the lithium transmission rate reached 96.6%. Under an operating pressure of 1 MPa, the flux reached nearly 20 LMH. The performance significantly outperforms traditional mainstream imported fractional salt nanofiltration membranes. The optimization of the membrane treatment process for the qualified stripping solution has been completed. By replacing the conventional three-to-four-stage nanofiltration purification with a two-stage PSI TFN system, the requirements for hardness removal and lithium transmission have been successfully met.

Appendix. Qualifications and Certifications
United Nations Sustainable Development Goals

Qualifications and Certifications



Quality Management System Certification



CE Certification



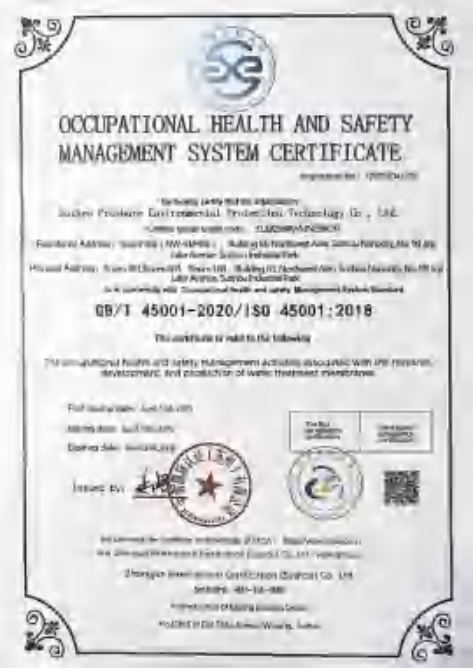
Health, Safety, and Environment (HSE) Management System Certification



After-Sales Service Certification



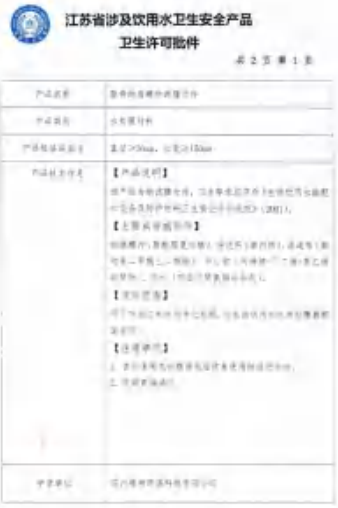
Environmental Management System Certification



Occupational Health and Safety Management System Certification



PSI Nadun Reverse Osmosis Membrane Element Water-Related Approval



PSI Nadun Nanofiltration Membrane Element Water-Related Approval



PSI Nadun Ultrafiltration Membrane Element Water-Related Approval

Contribution to the United Nations Sustainable Development Goals (SDGs) by Proshare

The United Nations Sustainable Development Goals (SDGs) set out a common global agenda for 2030. In addition to our general responsibilities, we also focus on sustainable development goals where our business activities can have the greatest impact. We are working with our customers, supply chain partners, and other stakeholders to develop greener, safer and more efficient solutions. Launched in 2015, the SDGs provide a clear direction for the 2030 World Agenda for Sustainable Development. Here you can learn about some of our main activities and our contribution to achieving the SDGs.

Ongoing Activities - United Nations Sustainable Development Goals 2030 Agenda



GOOD HEALTH AND WELL-BEING

We provide employees with a comfortable and healthy working environment, offer the Five Social Insurances and One Housing Fund for all staff, and arrange regular health check-ups. Holiday benefits are distributed to employees during each traditional Chinese festival. Employees are also entitled to paid annual leave.



QUALITY EDUCATION

We oppose any form of discrimination, such as discrimination based on race, color, language, gender, religion or sexual orientation. Through different working hours models, we cater to the individual needs of our employees and provide equal opportunities for men and women in the company. In management and operation department, over 40% of our employees are women.



CLEAN WATER AND SANITATION

The founder of Proshare, Dr Lin, was involved in an association donation program called Operation Lotus, which donated water purification equipment to primary schools in remote areas of China.



AFFORDABLE AND CLEAN ENERGY

Proshare's main products, including reverse osmosis membrane, nanofiltration membrane, and material separation membrane, are all recyclable. Our membrane products are widely used in water reuse and wastewater treatment in various industries, such as traditional petrochemical industry, municipal sewage treatment, production and processing of lithium battery materials, seawater desalination, etc. We are committed to helping to achieve global water renewable. At our new plant site, we plan to install photovoltaic panels on top of the plant to recover clean energy and use it.



DECENT WORK AND ECONOMY GROWTH

Safety and health at work depend on our own operations. Our work in health and safety is built on the belief that accidents, near-misses and work-related illnesses can be prevented. We have developed a comprehensive safety and environmental emergency plan to cope with possible emergencies. The plan includes accident reporting, emergency response, accident handling, etc., to ensure that when an accident occurs, it can be handled quickly and effectively.



INDUSTRY, INNOVATION AND INFRASTRUCTION

Our industry is driven by innovation and infrastructure development. Proshare's annual R&D investment is as high as 30%. Besides, our production lines are now semi-automated, and we have self-developed and customized intelligent platforms and databases.



REDUCE INEQUALITIES

We extend from internal management (internal equality) to the industrial chain (fair trade and procurement) and the social impact level (inclusive design, community and public participation), actively fulfilling corporate social responsibilities and obligations through compliance, innovation, and collaboration.



SUSTAINABLE CITIES AND COMMUNITITIES

The service life of our products is longer than that of many international brands. In addition, many of our products are recyclable or already contain recyclable ingredients.Our new generation of products has a great breakthrough in the process than the traditional membrane, more environmentally friendly and lower cost. It overcomes the serious secondary waste pollution caused by the traditional reverse osmosis membrane after being used.We will continue to work with our customers and partners to develop this potential in the long term.



CLIMATE ACTION

Through continuous innovation and development, Proshare actively fulfills its social responsibilities and supports the "Dual Carbon" strategy. From the design stage of our membrane products, we consider recyclability, durability, and low-carbon attributes. During the production process, we reduce our carbon footprint by improving techniques, adopting clean energy, and enhancing energy efficiency. Through our membrane products and services, we have enabled energy conservation, resource recovery, and greenhouse gas emission reduction across various sectors, including industrial, municipal, household, and commercial applications.

PROSHARE
INNOVATION

Lead TFN Membrane Tech,
Become A Global Leader in High-End
Separation Membrane Industry.

Proshare Innovation Suzhou Co.,Ltd.

Corporate Headquarter

Building 01, Northwest District, Nanopolis Suzhou, No.99 Jinji Lake Avenue, Suzhou Industry Park 215123, Jiangsu, China

Proshare Membrane Technology Industrial Park

No.7 Huijin Road, Environmental Protection Technology City, Tinghu District, Yancheng City, Jiangsu Province, China

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