REMOTE WATER TREATMENT SERVICES

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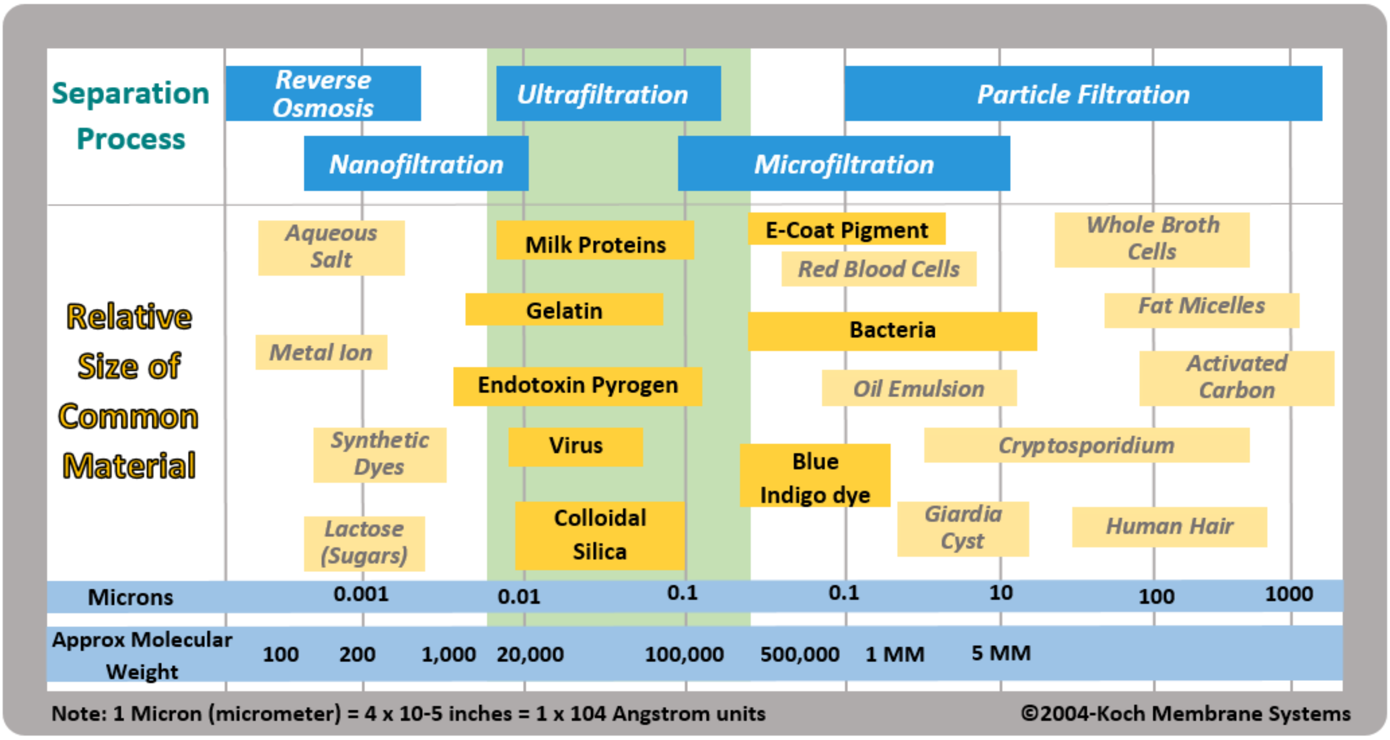
1. Introduction of Ultra-filtration separation technology

Ultra-filtration is an advanced technology to separate, purify and concentrate fluids using the principle of sieving on a molecular level.

1.1 UF is a low pressure (5~150 psig) process for separating larger size solutes from aqueous solutions by means of a semi-permeable membrane. The ultra-filtration membrane separation is in the range of 0.005 to 0.1 micron. For water treatment, the MWCO values of the UF membrane are in the range of 30,000—300,000 Dalton. UF membrane with MWCO smaller than 30,000 Dalton is usually used in separation and concentration processes.



Retains oils, particulate matter, bacteria and suspended solids large macromolecules and proteins

- Passes most surfactants, water, acid and alkaline compounds
- Pore sizes ranging from 0.005 – 0.1 micron; 1K – 500K MWCO
- Permeate is clear (non-turbid) solution void of suspended solids

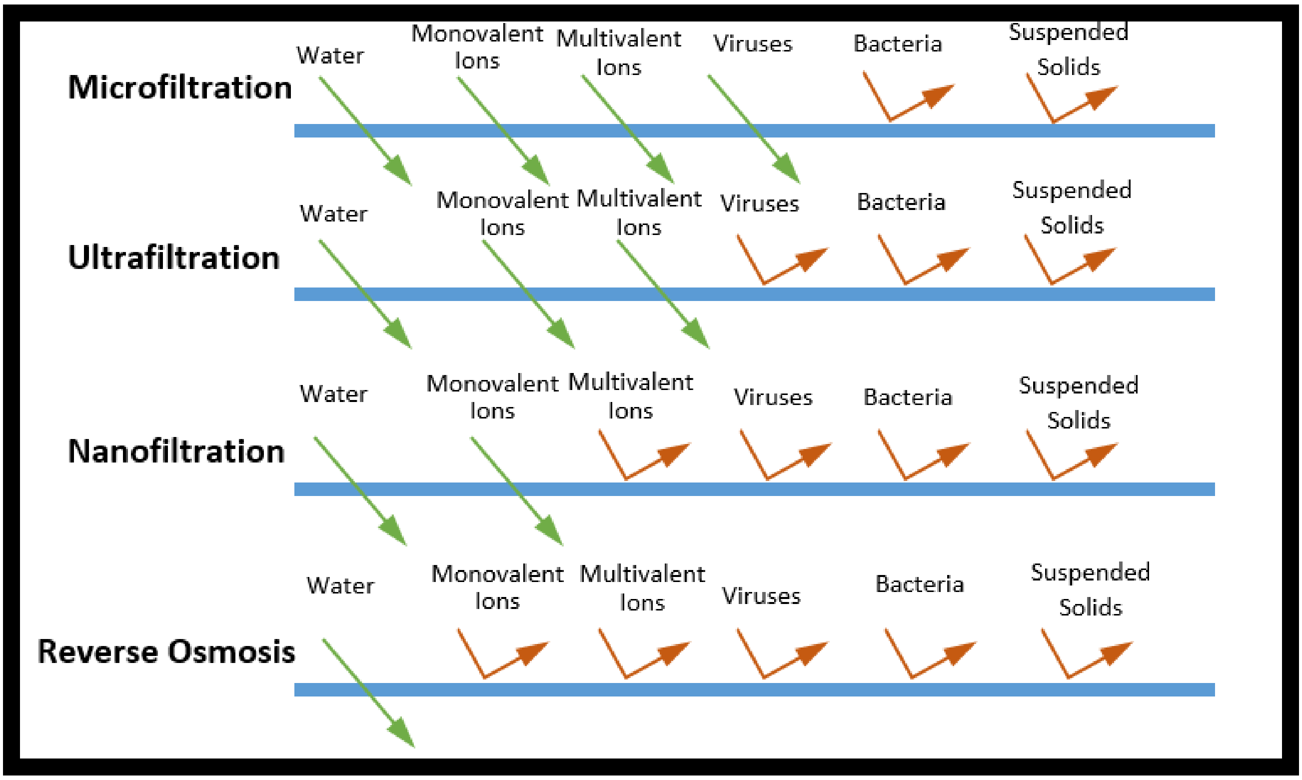
Compared with the traditional separation methods, it has the following advantages:

- High filtration capacity, back washable
- More efficiency, less energy consumption
- No pollution to the environment (Physical process)
- Overall reduced operating maintenance costs (space requirements, labor)

These advantages make ultra-filtration widely applied in industries such as petrochemicals, Bio-pharmaceuticals, medical, metallurgy, electronics, energy, light industry, textile, food and beverage, environmental protection, aerospace, marine and home applications. Currently, the worldwide market of ultra-filtration membrane, systems and engineering is about 10 billion US dollars with a remarkable annual growth rate of about 25-30%. Ultra-filtration industry promotes strongly the advancements of society, economics and technology. Specifically, its important applications and contributions in energy saving, environmental protection and water reclamation are highly noted in all nations, since the shortages of natural resources such as energy and water, and environmental pollutions are universal problems.

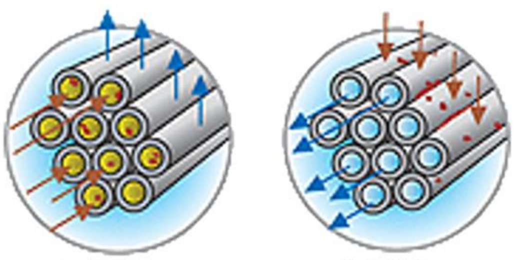
1.2 UF are in tubular, hollow fiber, spiral and flat sheet membrane configurations.

1.2.1 Hollow fiber is a tubular structure with microporous pores on the walls. When the fluid flows across the fiber wall under pressure, solutes with molecular sizes smaller than the pore sizes will flow through the fiber wall with the solvent (e.g. water) becoming permeate; while the larger ones, such as bacteria, E-coli, viruses, colloidal and suspended particles, etc., will be retained, thereby enabling separation, purification and concentration processes. To separate different materials, different molecular weight cut-offs (MWCO) UF membrane modules are be used to meet different separation goals.



1.2.2 Hollow-fiber membrane modules can be operated in two different ways.

The first is the **inside-out feed** operation. The feed is circulated through the bore of the fibers. When under pressure, the permeate passes through the fiber wall to the shell side.



The second is **outside-inside** mode, in which the permeate passes through the fiber wall from shell side to the bore side under pressure.

1.2.3 RWTS UF products for industrial applications are designed for Direct Flow or Cross flow separation, where a feed stream is introduced into the membrane modules under pressure and passed over the membrane surface in a controlled flow path. A portion of the feed passes through the membrane and is called permeate. The rejected materials are flushed away in a stream called the concentrate. Cross flow membrane filtration uses a high cross flow rate to enhance permeate passage and reduce membrane fouling.

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2. Ultra-filtration applications

Typically ultra-filtration membrane has pore sizes in the range from a few nanometers to 0.5 microns. In the purification of solutions, it can separate larger size materials such as particulates, colloids, bacteria, viruses, pyrogens, and proteins from small molecules such as solvent. Its main applications are in electronic industry, food industry, pharmaceutical industry, environmental protection and bio-industry. The following table lists some major applications of ultra-filtration:

Industry	Applications
Water treatment	1. Feed pretreatment for pure, ultra pure and RO water in electronic industry; 2. For Boiler Make-up water 3. Wastewater reclamation; potable water production; 4. Bacteria free, pyrogens-free water for injection in medical industry; 5. Bacteria free pure water for cosmetic and beverage uses.
Wastewater Treatment & reclamation	1. Integrated with bioreactor to treat all kinds of wastewater; 2. Wastewater treatment and reclamation in dextrin manufacture; 3. Treatment and reclamation of wastewater containing sugar; 4. Wastewater treatment of plating manufacture; oil-containing wastewater treatment; 5. Oil emulsion wastewater treatment and reclamation; 6. Treatment and reclamation of wastewater containing oil/fat. 7. Treatment and reclamation of wastewater containing PVA in textile industry; colored and dye-containing wastewater treatment and reclamation; 8. Wastewater treatment of photo processing industry and printing industry; 9. Wastewater treatment and recovery of electrophoretic coating 10. Wastewater treatment in paper manufacture or radioactive
Food industry	1. Recovery of whey protein and concentration of skim milk in dairy industry; 2. Clarification, bacteria removal and ripening acceleration of wine; Bacteria removal, clarification and de-coloration of soy sauce and vinegar; 3. Purification of fermentation solution, and clarification and concentration of fruit juice; 4. Concentration of gelatin; 5. Recovery of sugar from sugary water.
Medical industry	1. Purification of antibiotics and interferon (IFN); 2. Removal of pyrogens from water for injection; 3. Treatment of blood plasma, and high molecular weight biopolymer; concentration of ascites; 4. Separation, concentration and alcoholization of protein and enzymes; 5. Extraction and purification of Chinese herb medicines.
Machining Industry	1. Prolongation of residence time of electrode position paint solution; 2. Separation of emulsion oil/water solution; 3. Treatment of degreasing solution; 4. Recovery of electrocoat paint.

3. Products

Produce description: UF hollow fiber membrane modules 4-10 inches.
Membrane Chemistry: PVC, PVDF, Modified Polysulfone, PAN Housing
Shell/End Caps: UPVC/ABS
Fiber Support Netting: Polypropylene/Polyethylene
Permeate Collection Tube: PVC
Potting Material: Proprietary epoxy compound
Preservative: Glycerin

3.1 Special Features of RWTS UF membrane Modules

3.1.1 Permanently hydrophilicity (for steady flux)

The hydrophilicity of UF membrane is very important for the anti-fouling and stable flux properties. RWTS UF modified made by PVC, PVDF or modified polysulfone, are intensively chemically and thermally treated after the formation of the membrane yielding permanently hydrophilicity properties.

During filtration, material like colloids, proteins, oil, etc, would form "**spherulites** agglomeration" precipitate onto the surface of our modified membrane unlike the phenomenon of "**cake agglomeration** and precipitation" onto other compared membranes, these "spherulites agglomeration" have lower impact to filtration efficiency and allow our membrane to have a longer service time, maintaining longer time intervals between cleanings.

3.1.2 Due to the fact that there is **no electric charge** on our membranes, this feature allows feed variation and pretreatment of flocculating agent with any charges. This demonstrates an advantage when used in river water treatment or contaminated unknown quality feeds.

3.1.3 Our membrane demonstrates **strong fiber strength** with high tensile strength, high impact strength, and high dimensional stability (no post shrinkage). This feature of strong fiber strength (or lower fiber breakage) and stable dimensional stability (no post shrinkage) of our membrane allow longer service time during filtration and maintaining longer time intervals between cleanings.
Our membrane demonstrates permanent hydrophilic. With oven test at 100 ℃ for 48 hours, our membranes still maintain high filtration efficiency even though some of the fibers have been dried. This permanent hydrophilic feature allows significant reduce of pretreatment chemicals and operating flexibility. As a result, reduced cost of transportation, operating, and maintenance.

3.1.4 The pore size and pore distribution of membrane are well controlled in order to achieve high quality filtration efficiency. Compared to other membranes, it's demonstrated, for instance, that our membrane is able to run at stable filtration condition of 70-125 L/hr with water quality of SDI < 2. Higher service is also observed.

- Permanent hyrdrophilic
- Higher anti-fouling properties against organic pollutants and excellent resistance to inorganic acids & alkaline
- No electric charge which can bear flocculating agent with any charges
- High fiber strength allow for long term service and maintaining filtration efficiency even after cleanings
- Excellent hydrolytic and pH tolerant to fit majority of chemical cleanings
- Excellent chemical resistance to tolerate feeds containing various contaminants
- Control of pore size and pore distribution

3.2 Product coding system

Hollow Fiber membrane modules for water treatment. (RWTSUF-PVC Serial)

Hollow Fiber membrane modules for waste water treatment & reclamation and special applications. (RWTSUF-PVDF Serial)

Hollow Fiber membrane modules for chemicals removals. (RWTSUF-PSS Serial)

3.2.1 Pictures of different size of modules:

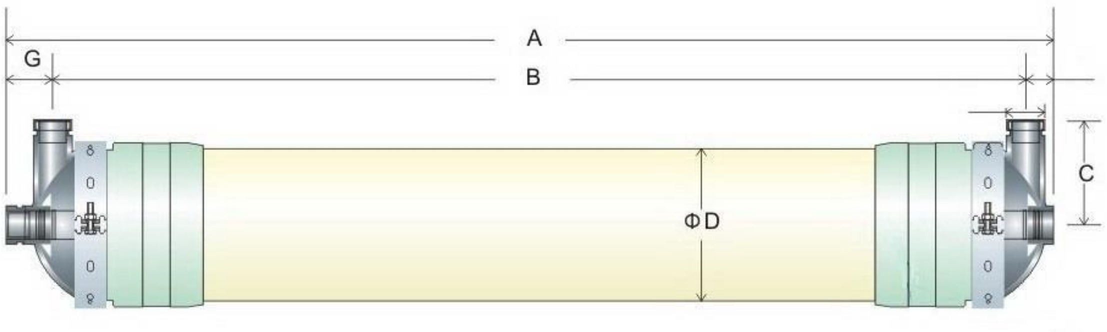
RWTSUF-90 Ultra-filtration module

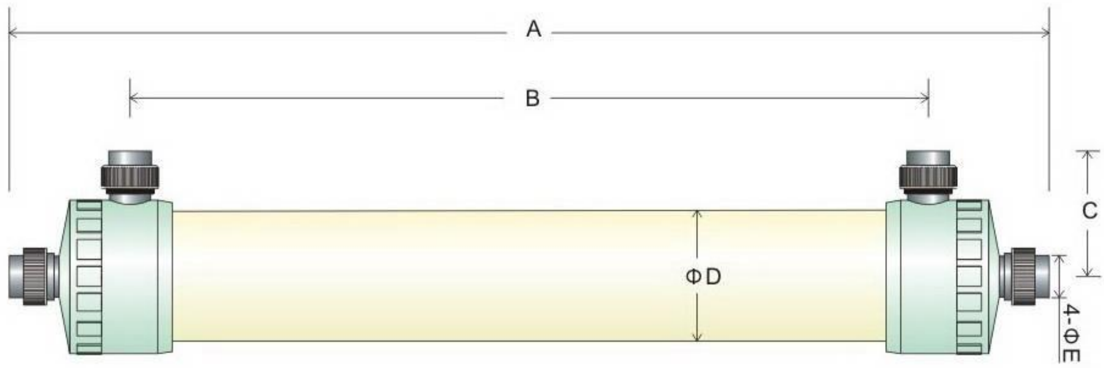
RWTSUF-160 Ultra-filtration module

RWTSUF200 Ultra-filtration module

RWTSUF250 Ultra-filtration Module

3.2.2 Drawings





PVC UF membrane modules

Product Code	Module Type	A (mm)	B (mm)	C (mm)	DØ(mm)	Inlet/outlet/Drain
RWTSUF-PVC-1060	UF250	1710	1600	173	250	DN50
RWTSUF-PVC-8060	UF200	1710	1595	160	200	DN50
RWTSUF-PVC-6060	UF160	1355	1130	160	160	Ø40
RWTSUF-PVC-4046	UF90	1190	990	112	90	Ø40

PVDF UF membrane modules

Product Code	Module Type	A (mm)	B (mm)	C (mm)	DØ(mm)	Inlet/outlet/Drain
RWTSUF-PVDF-1060	UF250	1710	1600	173	250	DN50
RWTSUF-PVDF-8060	UF200	1710	1595	160	200	DN50
RWTSUF-PVDF-6060	UF160	1810	1386	170	160	Ø50

PS Modified UF membrane modules

Product Code	Module Type	A (mm)	B (mm)	C (mm)	DØ(mm)	Inlet/outlet/Drain
RWTSUF-PSS-1060	UF250	1721	1600	171	250	DN50
RWTSUF-PSS-8060	UF200	1929	1563	186	200	Ø50
RWTSUF-PSS-6060	UF160	1355	925	136	134	Ø32
RWTSUF-PSS-4046	UF90	1170	985	107	90	Ø32

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3.3 Standard hollow-fiber UF membrane modules band specifications

3.3.1 Data Sheet of RWTS Hollow Fiber UF membrane RWTSUF-PVC

Product Code	Module Type	Module Dimension (mm)	Length (mm)	Membrane Material	Fiber ID (mm)	MWCO (Dalton)	Area (㎡)	Max. NTU	Applications
RWTSUF-PVC-1060	UF250	250	1710	PVC	1.0/1.8	100K	48	200	Water treatment, RO Pretreatment, Tap Water, Drinking Water, Underground Water,
RWTSUF-PVC-8060	UF200	200	1710	PVC	1.0/1.8	100K	34	200	
RWTSUF-PVC-8040	UF200	200	1016	PVC	1.0/1.8	100K	19	200	
RWTSUF-PVC-6060	UF160	160	1355	PVC	1.0/1.8	100K	15	200	
RWTSUF-PVC-4046	UF90	90	1190	PVC	1.0/1.8	100K	4.8	200	
RWTSUF-PVC-4040	UF95	95	1016	PVC	1.0/1.8	100K	3.8	200	

3.3.2 Data Sheet of RWTS Hollow Fiber UF membrane RWTSUF-PVDF

Product Code	Module Type	Module Dimension (mm)	Length (mm)	Membrane Material	Fiber ID (mm)	MWCO (Dalton)	Area (㎡)	Max. NTU	Applications
RWTSUF-PVDF-	UF250	250	1710	PVDF	0.8/1.3	200K	78	200	Water Treatment, RO Pretreatment, Tap Water, Drinking Water, Underground Water, Municipal, Wastewater,Sewage
RWTSUF-PVDF-	UF200	200	1710	PVDF	0.8/1.3	200K	47	200	
RWTSUF-PVDF-6060	UF160	160	1810	PVDF	0.8/1.3	200K	40	200	

Note:

The above are patent products PVC/PVDF Hollow Fiber UF membranes. Compared with common Polysulfone or other materials, it owns advantages of short time of backwash, long interval of chemical wash.

We may manufacture all kinds of Hollow Fiber Membrane Modules made of different materials such as Modified Polysulfone, PAN, PES. Different MWCO will meet your different requirements.

3.3.3 Data Sheet of RWTS Hollow Fiber UF membrane RWTSUF-PSS

Product Code	Module Type	Module Dimension (mm)	Length (mm)	Membrane Material	Fiber ID (mm)	MWCO (Dalton)	Area (㎡)	Max. NTU	Applications Water Treatment
RWTSUF-PSS-1060	UF250	250	1720	PS Modified	0.9	50K～60K	60	100	RO Pretreatment, Tap Water, Drinking Water, Underground Water, Municipal, Wastewater, Sewage
RWTSUF-PSS-8060	UF200	200	1935	PS Modified	0.9	50K～60K	35	100	
RWTSUF-PSS-8040	UF200	200	1462	PS Modified	0.9	50K～60K	25	100	
RWTSUF-PSS-4040	UF90	90	1170	PS Modified	0.9	50K～60K	5	100	

3.3.3 Hollow Fiber Membrane Modules for special applications: RWTSUF-PST

Product Code	Module Type	Module Dimension (mm)	Length (mm)	Membrane Material	Fiber IS (mm)	Area (㎡)	Applications
RWTSUF-PST-1060	UF250	250	1720	PS Modified （Dried Store）	1.6	35	Juice Clarification Citrus juice upgrading Vinegar clarification Wine filtration Dairy processing Oily
					2	30	
RWTSUF-PST-8060	UF200	200	1935	PS Modified （Dried Store）	1.6	24	
					2	20	
RWTSUF-PST-8040	UF200	200	1462	PS Modified （Dried Store）	1.6	16	
					2	13	
RWTSUF-PST-4040	UF90	90	1170	PS Modified （Dried Store）	1.6	3	
					2	2.5	

3.3.4 Resisting high temperature, strong acid or alkali, organic solvents: RWTSUF-S

Items	RWTSUF-S-	RWTSUF-S-	Applications
Membrane Materials	Special	Special	1) Wastewater treatment for plating industry and electronics industry; 2)Seawater and brackish water desalination; 3) textile industry; 4)Colored and dye-containing wastewater treatment and reclamation; 5) Photo processing industry; 6) Printing industry; 7) Chemical Industry
Module Length（mm）	1170	1935	
Module Diameter（mm）	90	200	
Inner Size（mm）	0.9~2.0	0.9~1.6	
Membrane Area（m^2）	3~5	16~32	
Max. Pressure（KPa）	500	500	
Temperature（ºC）	5~280	5~280	
pH Range	0~14	0~14	

Our patent modified Polysulfone membrane modules owns permanently hydrophilic, highly solvent resistant cellulose. These materials can be used over a wide range of applications. Environmental protection, metal processing, textiles, paper, pharma/biotech, chemical.

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3.3.4 Typical Process Conditions

UF Membrane Modules: RWTSUF-PVC

Module Type	RWTSUF-PVC-1060	RWTSUF-PVC-8060	RWTSUF-PVC-6060	RWTSUF-PVC-4046
Dimension(mm)	ϕ250×1710	ϕ200×1710	ϕ160×1355	ϕ90×1170
Interface(mm)	Coupling DN50	Coupling DN50	Union ϕ40	Union ϕ40
Membrane Area: (m^2)	48	34	15	4.8
Feed Modes	Inside-Out Side Feed		Inside-Out Top Feed	
Shell Material	UPVC			
Membrane Material	PVC			
Membrane Features and Reservation		Permanent hydrophilicity(Dried Store)		
MWCO Dalton		100K		
Hollow Fiber ID/OD (mm)		1.0/1.8		
Initial Pure Water Flux: (L/m^2.h)		150～300		
Operating Temperature (℃)		5～45		
pH Range		2～13		
Maximum Feed Turbidity: (NTU)		200NTU		
Chlorine Tolerance (ppm)		200 Cotinuous(Max 1000 Instantaneous)		
Maximum Feed Pressure: (Mpa)		0.4		
Maximum TransmembranePressure: (Mpa)		0.2		
Maximum Backwash Pressure: (MPa)		0.2		
Particles>1µm Removal :		> 6log		
Virus Removal:		> 5log		
Bacterial Removal:		> 6log		
Permeate SDI		< 2		
Permeate Turbidity: (NTU)		<0.06		
Operating Modes		Direct or Cross flow＋Backwash Timing		
Operating Pressure:(Mpa)		<0.1		
Design Permeate Flux: (L/m^2.h)(25℃,0.15MPa)		35～100		
Backwash Frequency (min)		15-60		
Backwash Duration (s)		30-60		
Backwash Pressure: (Mpa)		0.08～0.15		
Chemically Enhanced Backwash Frequency (d)		1-7		
Chemically Backwash Duration (min)		1-10		
Chemical Cleaning Frequency (d)		30-90		
Chemical Cleaning Duration (min)		30-60		
Cleaning Chemicals		NaClO or H_2O_2(200ppm),NaOH(Ph<12),Citric Acid(Ph>2)		

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UF Membrane Modules: RWTSUF-PVDF

Module Type	RWTSUF-PVDF-1060	RWTSUF-PVDF-8060	RWTSUF-PVDF-6060
Dimension(mm)	ϕ250×1710	ϕ200×1710	ϕ160×1810
Interface(mm)	Coupling DN50	Coupling DN50	Union ϕ50
Membrane Area: (㎡)	78	47	40
Feed Modes	Outside-In Side Feed		Outside-In Top Feed
Shell Material	UPVC		
Membrane Material	PVDF		
Membrane Features and Reservation	Permanent hydrophilicity(Dried Store)		
MWCO Dalton	200K		
Hollow Fiber ID/OD (mm)	0.8/1.3		
Initial Pure Water Flux: (L/㎡.h)	150～300		
Operating Temperature (℃)	5～45		
pH Range	2～13		
Maximum Feed Turbidity: (NTU)	200NTU		
Chlorine Tolerance (ppm)	200 Cotinuous(Max 1000 Instantaneous)		
Maximum Feed Pressure: (Mpa)	0.4		
Maximum TransmembranePressure: (Mpa)	0.2		
Maximum Backwash Pressure: (MPa)	0.2		
Particles>1μm Removal :	> 6log		
Virus Removal:	> 5log		
Bacterial Removal:	> 6log		
Permeate SDI	< 2		
Permeate Turbidity: (NTU)	<0.06		
Operating Modes	Direct or Cross flow＋Backwash Timing		
Operating Pressure:(Mpa)	<0.1		
Design Permeate Flux: (L/m^2.h)(25℃,0.15MPa)	40～120		
Backwash Frequency (min)	15-60		
Backwash Duration (s)	30-60		
Backwash Pressure: (Mpa)	0.08～0.15		
Chemically Enhanced Backwash Frequency (d)	1-7		
Chemically Backwash Duration (min)	1-10		
Chemical Cleaning Frequency (d)	30-90		
Chemical Cleaning Duration (min)	30-60		
Cleaning Chemicals	NaClO or H_2O_2(200ppm),NaOH(Ph<12),Citric Acid(Ph>2)		

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UF Membrane Modules: RWTSUF-PSS

Module Type	RWTSUF-PSS-1060	RWTSUF-PSS-8060	RWTSUF-PSS-8040	RWTSUF-PSS-6060	RWTSUF-PSS-4046
Dimension(mm)	ϕ250×1721	ϕ200×1929	ϕ200×1466	ϕ134×1198	ϕ90×1170
Interface(mm)	SS Coupling 2"	Union ϕ50	Union ϕ50	Union ϕ32	Union ϕ32
Membrane Area: (㎡)	45	28	20	10	4
Feed Modes	Inside-Out Side Feed			Inside-Out Top Feed	
Shell Material	ABS/UPVC				
Membrane Material	PS Modified, PAN,PES				
Membrane Features and Reservation			Permanent hydrophilicity(Dried Store)		
MWCO Dalton			50K (6K,30K,100K,200K,300K)		
Hollow Fiber ID/OD (mm)			1.2/2.0（0.9/1.5, 1.6/2.5, 2.0/3.0）		
Initial Pure Water Flux: (L/㎡.h)			150～300		
Operating Temperature (℃)			5～45		
pH Range			2～13		
Maximum Feed Turbidity: (NTU)			200NTU		
Chlorine Tolerance (ppm)			200 Cotinuous (Max 1000 Instantaneous)		
Maximum Feed Pressure: (Mpa)			0.4		
Maximum Transmembrane Pressure: (Mpa)			0.2		
Maximum Backwash Pressure: (MPa)			0.2		
Particles>1μm Removal :			> 6log		
Virus Removal:			> 5log		
Bacterial Removal:			> 6log		
Permeate SDI			< 2		
Permeate Turbidity: (NTU)			<0.06		
Operating Modes			Direct or Cross flow＋Backwash Timing		
Operating Pressure: (Mpa)			<0.1		
Design Permeate Flux: (L/m^2.h)(25℃,0.15MPa)			40～120		
Backwash Frequency (min)			15-60		
Backwash Duration (s)			30-60		
Backwash Pressure: (Mpa)			0.08～0.15		
Chemically Enhanced Backwash Frequency (d)			1-7		
Chemically Backwash Duration (min)			1-10		
Chemical Cleaning Frequency (d)			30-90		
Chemical Cleaning Duration (min)			30-60		
Cleaning Chemicals			NaClO or H_2O_2(200ppm),NaOH(Ph<12),Citric Acid(Ph>2)		

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4. The specifications range before our UF membrane system:

4.1 Our UF modules require that prefilter of 150µm, or smaller, be installed upstream of our modules to prevent the fibers from plugging.

Pre-dosing of chemicals can prolong stable performance of our UF system. Continuous injection of free chlorine (1 ppm residual chlorine) or other approved oxidants, ahead of our UF system, may be recommended for raw surface water or waters with high bioactivity.

For open intake seawater, raw surface water and tertiary waste water where significant natural organic matter is present, testing has shown that continuous dosing of ferric or aluminum salts dramatically enhances performance. When dosing coagulant, backwash effluent may contain significant amounts of iron or aluminum and disposal may be an issue.

4.2 Process Performance on RWTS UF Membrane Modules

Consistently provides high filtrate quality, independent of fluctuations in raw water feed.

Permeate SDI15	Average ＜1, granted ＜2
Permeate Turbidity	＜0.1NTU
Particle Removal(＞0.2µm)	99.9999%
Removal of E. Coli	No account in 100mL permeate
Removal of bacteria	No account in 1mL permeate

5. UF System Design

This manual only intends to describe the basic requirements for UF system design using RWTS UF modules. System designers and system integrators should design and build the system according their own expertise and experiences, and such will be fully responsible for the system. All the illustrations in this chapter, the P&I diagram and the Table of Valve Activities in Appendixes are also presented for referencing only.

In order to determine the performance of the UF modules, you should have the following instrumentation:

- Feed Pressure
- Concentrate Pressure
- Filtrate Pressure
- Filtrate Flow Rate
- Concentrate Flow Rate(Crossflow)

In addition, the following instrumentation should encompass the ultra-filtration system as well:

- Feed Turbidity
- Feed Temperature
- Total Filtrate Flow Rate
- Total Filtrate Turbidity
- Backwash Pressure
- Backwash Flow Rate
- Cleaning Flow Rate
- Cleaning pH
- Cleaning Temperature

Design parameters that will affect the fouling rate are the design flux and the mode of operation. Flux isthe volume of filtrate flow per unit area of the membrane. Flux is typically measured in GFD [gallons/(ft^2.day)] or lmh [Liters/(m^2.hour)]. Once a critical flux rate is exceeded, a more rapid flux decline will occur. TypicalMG Ultra-filtration systems will operate at a flux of 35-85GFD (59-145lmh).

5.1 The Operation Process: Filtration

There are two basic "processing" mode for MG system: direct flow, cross-flow .

For feed sources with varying turbidity or turbidity spikes, it will be necessary to automatically switch from "direct flow" to "crossflow".
Though "crossflow" will reduce flux decline, they will also have an impact on operating costs and pump size. As crossflow increases so does the energy consumption..
Each mode has its trade-offs. Direct flow is the most economical, but is limited by the feed water quality. Crossflow reduces flux decline, but increase energy and capital costs.
When feed water is not highly polluted, such as well water or municipal water, a dead flow may be used. In dead flow mode, all feed water passes through the membrane and forms the permeate stream during filtration stage, the filtered impurities are kept in the membrane modules and are flushed out by membrane flushing and back washing.
When feed water is more polluted, cross-flow modes are usually used. In crossflow mode, a part of the feed water passes through the membrane and forms the permeate stream, and the rest part of the feed water forms a concentrate stream which carries the most of impurities out of the membrane element. The concentrate flow rate may vary according to the degree of pollution of the feed water. In most of the cases, the concentrate flow is within 10-35% of the feed flow. Most of this concentrate stream is recycled back into feed water tank or into the feed stream, only a small portion (5-10% of feed) is directed to drain. In most of the cases, a recycle pump is not necessary for cross-flow operation, an increase on the feed pump capacity is usually enough to over the increase of the flow resulted from concentrate recycling. Although concentrate stream may carry out most of the impurities, some other impurities may still stick to the membrane surface, and those impurities may be washed out by membrane flushing, back washing or chemical cleaning.
In cross-flow mode, the increased feed pump capacity consumes more operation power comparing to dead flow mode, but cross flow mode reduces the backwashing frequency, and chemical cleaning frequency, such result in less backwashing power consumption, less chemical consumption and longer membrane life.
For ordinary design, feed water comes into the module through the bottom side port, and concentrate leaves the modules by the top side port. The permeate stream is produced form the top center port. This arrangement ensures the release of gas that may accumulate during operation.

5.2 Washing

During operation, the surface of UF membrane is sooner or later contaminated by colloidal maters, by organic impurities, by bacteria and/or by suspended solids. Such contamination may be observed by the increase of trans-membrane pressure (TMP).
Data from the instrumentation should be analyzed continuously by the PLC. Transmembrane Pressure (TMP) is a critical factor in the operation of our UF system. TMP is defined as average feed pressure minus filtrate pressure. An increase in TMP is indicative of solids buildup on the membrane.

This is also called fouling or flux decline. Increasing TMP is normal and each system will have a different rate of fouling, but the TMP should never exceed 20 psi (1.4bar).Though much of this fouling rate is directly dependent on feed water quality, the fouling rate can be partially controlled.
A washing process in needed to recover the membrane performance. The washing process often involves a few steps as described below.

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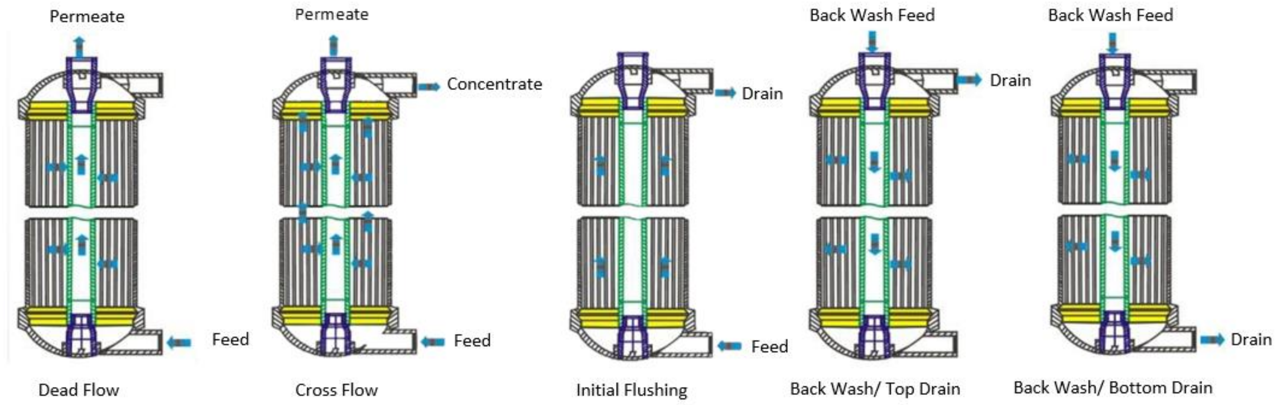

5.2.1 Initial flushing: The permeate valve is shut off, and an increased feed water stream is flushing the inner spaces of the membrane capillaries. This increased feed flow takes other contaminants that cannot be washed off just by water flush. This initial flushing usually takes 15-30 seconds.

5.2.2 Back washing/Top-drain: The feed valve is closed, permeate water is forced through the membrane wall from outside into the insides of the membrane capillaries. The water is discharged from the top of the modules. In this step, the upper part of the inner capillary surface is better washed and flushed. This back-washing step may take 15-30 seconds.

5.2.3 Bach washing/Bottom-drain: The feed valve is closed, permeated water is forced through the membrane wall from outside into the membrane capillaries. The water is discharged from the bottom of the module. In this step, the lower part of the inner capillary surface is better washed and flushed. This step may take 15-30seconds.

5.2.4 CEB(Chemical Enhanced Backwash): Chemicals may be added into the back-washing water occasionally, and when that happens, the back-washing step becomes a chemical enhanced backwash(CEB).Chemical may added to both the top-drain and bottom –drain steps or only added in the bottom drain step. A socking time (60-120 sec.) is usually used at the end of chemical added back-washing step to let the chemicals to react with contaminants on membrane surfaces. The frequency of CEB is highly determined by pollution degrees of the feed water, it may be used in every washing procedure, or once in 50-200 washing procedures or sometimes even not necessary at all.

5.2.5 Back wash/double-drain: When CEB is used, a back washing/double –drain step is necessary to flush the chemical solution out of the module in this step, the back washing water is discharged from both sides of the membrane module.

5.2.6 Final flushing: Some conditions as the initial flush. This step may be used before the module is back to service for a better washing effect.

5.3 There are three procedure for washing an inside-outside UF membrane

1. **Simplified water washing** includes a back-washing/top-drain step, and a back-washing/bottom-drain water washing.
2. **Complete water washing** includes an initial flushing step, a back-washing/top-drain step, a back-washing/bottom-drain, and a final flushing step.
3. **CEB** includes an initial flushing step, a back-washing/top drain step (with or without chemical added),a back-washing/bottom-drain step(with chemical added), a socking step, a back-washing/top and bottom-drain step and a final flushing step.

In order to decrease the off-line time of an UF system and water consumption of washing, the system operator may work out a schedule that run a full water wash after a few simplified washings and rum a CEB procedure every week or so as needed.

6. Pretreatment for UF system

Pretreatment is always the key factor that determines the UF system to be successful or not.

When feed water is municipal water or well water, a screen filter at 50-100µm is usually enough to protect the UF membrane. However when there is high iron or magnesium content, and that has to be removed by oxidation and filtration.

When feed water is surface water, a sand filter of multimedia filter is usually necessary, sometime flocculation is needed before sand or multimedia filtration. After sand or multimedia filtration, a screen at 50-100µm is required to ensure that sand leaked from sand or multimedia filter cannot reach the surface of UF membrane.

When feed water is highly polluted recycle water or waste water treatment effluent, a clarification step, such as coagulation and settlement or coagulation and flotation, a filtration step are all necessary pretreatment for an UF system.

7. System Design Procedures

A UF system has to be designed by well trained and well experienced professional, any mistake or negligence may result in the failure of the system. The following are the suggested main step for a system design.

7.1. Collection of feed water information

The information of feed water is very important for system design. The type, turbidity, suspended solids, COD, BOD are all had to be considered. The designer has also to gain enough knowledge about the variation of the feed water. Some other data, such as colloidal mater content, the types of organic pollutants and the contents of bacteria and their debris, are hard to determine but are also important. The designer should investigate the case and gain even indirect information. As mentioned above, some information are usually difficult to collect, but still are important for system design. The designer may estimate these data and design accordingly.

7.2 Selection of Operation Mode

When the feed water is well water or municipal water, and turbidity is lower than 5, COD is lower than 10, a dead end mode may be used. When the feed water is surface water, the pretreated with multimedia filter of similar means, a cross flow with only water back wash and chemical cleaning over a long period of time may be selected.

When feed water has a turbidity10, or COD 50, a cross flow with frequent CEB is suggested

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7.3 The Selection of Membrane Type

Membrane module made from larger diameter of membrane capillaries usually offers better anti-fouling properties, and it more suitable for higher polluted feed water. The basic selection rules are that the membrane modules made by larger diameter of the capillaries are designed for more polluted water, and membrane modules with shorter length are designed for more polluted water. When the feed water is well water or municipal water, and turbidity is lower than 5, COD is lower than 10, Thin inner size of 0.9 may be selected for their large membrane areas per module.

However, one may select for their higher anti-fouling abilities, so that a higher flux rate may be used and ends up a close number of membrane modules. The larger diameter capillaries are usually made stronger and last longer under the same operating conditions.

When feed water has a turbidity greater than 155, COD higher than 80, the large inner size of 2.0 is suggested.

7.4 The Selection of Flux Rate

The flux rate is determined by feed water quality and by the membrane properties. For MG membrane modules, the flux rate are all suggested to be 60-80 L/ m^2.hr in ordinary conditions when the membrane models are selected according to the feed water qualities as described above. However, one may also select the membrane modules that has high anti-fouling properties and design higher flux than 80L/ m^2.hr, so the system may run at a lower flux rate even when the feed water quality drops dramatically. Although higher than 100L/ m^2.hr flux rates are not suggested in this manual, there are examples for the MG UF modules that

are run perfectly at a flux rate of 125L/ m^2.hr for pretreated river water.

When water is highly polluted, for instance, COD is greater than 60mg/L or turbidity is higher than, the flux rate should be designed at a lower value, as much as 50-60L/ m^2.hr.

Ultra-filtration System Design Parameters

	Turbidity	**TOC**	**Flux**	**Crossflow**	**Bleed**	**BW.Freq**	**CEB Fre**	**Cleaning Freq**
Water Type	(NTU)	(mg/L)	GFD/lmh)	(gpm/ m^3hr)	(gpm/m3. .	(min)	(hr/ppm Cl2)	(days)
City	<0.5	<1	80/145	0	0	60	24/5	90
Well	0~5	<5	75/128	0	0	30	4 to 8/5	60
Surface	0~2(pretrt)		70/119	0	0	30	1-2/10	60
	0~2 raw	3	55/94	0	0	30	1/15	30
	2~5	3	50/85	0	0	30	1/15	30
	5~15	3	40/68	0	0	20	1/15	30
	15~50	<10	32/55	20-50/4.5-11.4	0	20	0.33/15~30	30
	50~100	<10	32/55	20-50/4.5-11.4	0.5~1/0.1~0.2	20	0.33/15~30	30
Sea Water	<5		60/102	0	0	20	1/5	30
Tertiary WW	2	BOD<10	42/71	0	0	15	0.25/30	30

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Continuous dosing of chlorine, or other approved oxidants, into the feed, from a raw surface water, can drastically improve the performance of the UF.
Seawater systems should include the addition of 0.5-0.1 ppm $FeCl_3$. Continuously to the feed water ahead of the UF waters (all water) with greater than 2 ppm NH_3 will require city or RO water as a backwash source to ensure free oxidant.

7.5 The Number of module

To determine the number of module a system need, one should always consider the idol time when the membrane is under back wash stages, and the amount of water needed for back washing.
For example, if a flux rate of 80L/m^2.h is selected for 1060 module for 1 100 m^3/hr system, the operating flow of one module then is :

$$80L/ m^2h*40m^2/1000L/ m^3) = 3.2\ m^3/hr$$

The backwash program is designed as water washing every 30 min as flush 15 sec., backwash/top-drain 15 sec,. Back wash/bottom-drain 15 sec. and final flush 15 sec. The total washing time is 1 minutes.
The time efficiency is

$$30/31=96.8\%.$$

The back washing flow is designed three time as the permeate flow, and used for 30 seconds (0.5 min), the water production efficiency is

$$(30min*100\ m^3/hr-0.5min*3*100\ m^3/hr)/ (30min*100\ m^3/hr)=95\%$$

The operating flow of the system is:

$$100\ m^3/hr/ (96.8\%*95\%) = 109\ m^2/hr$$

The number of membrane module is:

$$109\ m^3/hr÷3.2\ m^3/hr≈34$$

For slightly polluted feed water, the washing procedure may be only back wash/top-drain for 15 sec, and back wash/bottom-drain for 15 sec. than the time efficiency and production efficiency are 98.3% and 95%, respectively. If feed water is highly polluted, the system may designed at a lower flux rate, longer washing procedures and longer washing time, then more modules are needed for the same system flow.

7.6 Flushing System

The flushing flow rate is usually 3 times higher than permeate flow rate, and such and flush pump is needed to supply this flow. The designer should also consider the availability of the flush water, which may draw from the raw water tank or from a buffer tank. One should note that if raw water is first treated before the UF system, the flushing water should also be pretreated in the same way.
When there are units in parallel situation, the designer should always consider balance the water flows between the in-operation units and the being-flushed units.
Water hammer created by the sudden opening and closing of the valves and unbalance of water distributions often cause the breaking of the membrane capillaries, and should be avoided as much as possible.

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7.7 Backwashing System

The back wash water is supplied by a back wash pump. The capacity of this pump may be selected according the data shown in Table 2.4.When there are units in parallel situation, then a unit that is under back washing, the feed water flow should be adjusted accordingly. The designer should consider reduce the feed flow or direct the excess of the feed water to a tank that may be the raw water tank or a buffer tank.

7.8 CEB Chemicals

Chemicals may be added into the back washing water in order to enhance the back wash effects. The following formulas are often used:

1) Injection of HCl to make up the back wash water pH around 2. HCl is often used when the hardness of feed water is high or when there are coagulant-related fouling of the membrane.
2) Injection of NaOH to make up the back wash water pH around 12. NaOH addition is often effective when feed water has organic pollutants.
3) Injection of NaClO to make up the back wash water at residue chlorine at 50—200 ppm. NaClO is often used when the feed water is polluted by organics and bacteria.

8.Membrane Maintains

8.1 Integrity Test

Although MG UF membrane modules are very robust for ordinary operation, integrity tests for a UF system are still commonly used just as for other UF systems made with other brands of membrane modules. Large pores, cracks or even breaks may occur to the membrane capillaries because of long term operation or because operation upsets such as valve or pump mal-function, or human errors. To ensure the system to be in proper operating conditions, integrity tests should be run periodically to identify the problematic modules. This is important especially the UF is used in drinking water treatment.

The integrity test instrument includes oil-free pressurized air (0.1MPa), air adjusting valve and a transparent pipe installed in the permeate out-let pipe line on the top of each module. Integrity test includes the following stems:

1) Stop the operation of the UF system.
2) Connect the pressurized air tube to the feed water pipe.
3) Open the air adjust valve slowly to let the air flow into the UF system. The air pressure should be kept below 0.1MPa.
4) Adjust the air adjust valve to ensure the air pressure is 0.1MPa, and kept for 5 minutes.
5) Observe if there are air bubbles in the transparent pipe.
6) Record the observation for each module.
7) Open the back-wash/top-train valve to release the air.

Any module that has obvious air bubbles in the transparent pipe may have a few air-leaking membrane capillaries. These air-leaking capillaries may have large pores or cracks on the membrane, or may be even broken. These modules can be repaired by specially trained personals.

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8.2 CIP Chemical Cleaning

Periodical back washing the membrane removes most of the fouling materials, but sooner or later, the membrane may need chemical cleaning. At designed flow rate, when trans-membrane pressure is greater than 0.15MPa, and that cannot be reduced by CEB, then a chemical cleaning in necessary. A Clean-in Place (CIP) system should be installed with the UF system to facilitate chemical cleaning process.

The cleaning formulation may be selected according to the fouling materials and according to the operation experience. The followings may be considered:

1) a HCl or citric acid solution at pH≈2
2) A caustic solution of 0.5% NaOH and 200 ppm NaClO(pH≈12).

The Procedures are:

1) Recording the operating parameters before chemical cleaning.
2) Open the CIP feed valve and the CIP concentrate recycle valve, circulate the chemical solution for 30 minutes by turning on the circulation pump. Flow rate should be 8~12 m^3/hr for each membrane module.
3) Check the pH of the solution, if there is a significant change, add appropriate chemical to resume the chemical concentration. Circulate the solution for another 30 minutes.
4) Repeat step 2 until there is no significant pH change. Change the cleaning solution if it gets too dirty or too much chemical is added.
5) Stop the circulation pump, and let the membrane socked in the solution for 30 minutes.
6) Close the CIP concentrate recycle valve and open the CIP permeate recycle valve, circulate the chemical solution for 30 minutes by turning on the circulation pump.
7) Repeat steps 2-4.
8) Drain the solution tank.
9) Run the system by directing permeate to drain until the pH of permeate is neutral.
10) Record the operating parameters after chemical cleaning.
11) Compare the parameters before and after chemical cleaning, if the system is not resumed to its normal operation conditions, consider using another cleaning formulation, or call membrane factory for further consolations.

8.3 Membrane Reservation

New Modules Storage

New modules should be stored horizontally with the connections/ports facing up. To prevent collages of the packaged modules, stocking should be limited to four layers. All new modules are shipped in a sealed bag containing a preservation solution. Keep new modules in their original packaging. Store modules in a cool, dry location, keep out of direct sunlight. Storage time for new is limited to 1 year when kept between 2°C （35F） and 38°C（100F）. It is possible to re-sanitize modules to extend their shelf life.

Storage of Modules Installed on a Skid

Modules installed during assembly of a skid should not be allowed to dry out. Dry membrane fibers will irreversibly lose flux. When the system is turned down for less than 7 days, the membrane can be protected by just flush the system for 10-30 minutes every day. When the system is turned down for a longer period of time, run the chemical cleaning procedure first, then repeat in chemical cleaning procedures with a water solution of 20% glycerol and 1% NaHSO3, close all the valves to seal the solution in the system. The preservation solution should be changed every 6 months. The system and membrane should also be protected from direct sunshine, high temperature (>40 °C), low temperature (<0 °C), bacteria and mold growth. Any more information, please consult us: alex@remtoewts.com.au

Glossary

κ: Darcy's Law permeability coefficient

π: Osmotic pressure

ρ: Mass density (mass per volume)

ε: Porosity

τ: Tortuousity

μ": Viscosity of liquid C concentration

C: Permeate solute concentration in permeate solution

D: Water diffusivity coefficient

Ds: Salt diffusivity coefficient

Ks: Salt sorption coefficient

l: Membrane thickness

NA: Mass flux of component A

Ns: Salt flux

NAw: Water flux

P: Pressure

R: Ideal gas constant

R: Salt rejection

S: Water solubility coefficient

T: Temperature

V: Molar volume of water

V: Mass average velocity

TDS: Total dissolved solids

BOD: Biochemical oxygen demand

COD: Chemical oxygen demand

NTU: Turbidity

CA: Cellulose acetate membranes; first high performance reverse osmosis membrane in industry

CDI: Capacitive deionization; desalination technique utilising electro sorption to remove ions from solution

CTA: Cellulose triacetate; derivative of cellulose acetate used in reverse osmosis membranes

ED: Electro dialysis; desalination technique using both positive and negative-charged membranes and an applied electric potential to remove ions from feed solution

Feed Water: Solution input to a membrane

Flux: Performance characteristic of membranes, measured in either mass of material permeated per unit time per unit area of membrane or volume of material permeated per unit time per unit area of membrane

GFD: Gallons per square foot per day, English flux units.

LMH: Litres per meter squared per hour,metric flux units

MED: Multi-effect distillation, desalination technique where seawater is evaporated via direct contact with a heat transfer surface through a series of several stages and the vapor is condensed to obtain the purified product. Transmembrane Pressure (TMP): The force which drives liquid flow through a crossflow membrane. In tangential flow devices, the TMP is calculated as an average related to the pressures of the inlet, outlet and permeate ports. The TMP can be expressed as: *tmpavg=(Pin + Pout)/2 –Ppermeate*

Molecular Weight Cutoff (MWCO): Referred to as the molecular weight above which a certain percentage (e.g., 90 percent) of the solute in the feed solution is retained by the membrane, it is typically expressed in units called Daltons and used as a measure of the nominal pore size of ultrafiltration and nano filtration membranes.
MF microfiltration; membranes that reject large particles and microorganisms.

MSF multi-stage flash: Desalination technique in which seawater is vaporized in a series of flash chambers with progressively lower pressures and then condensed to obtain purified water RWTSC mechanical vapour compression; desalination technique similar to MSF but uses a mechanical compressor to condense evaporated seawater

NF: Nanofiltration; membranes with characteristics falling between those of ultrafiltration and reverse osmosis membranes

ppm parts per million: Mass fraction unit; 1 ppm is 1 gram solute per million grams of solution
**ppm is often incorrectly interchanged with mass per volume (concentration) values. This is approximately true, but not 100% accurate because solvent density is used as the solution density to calculate the volume from the mass of solution. To avoid this misuse, this paper expresses most concentrations in terms of mg/L.*
Rejection salt separation performance characteristic for reverse osmosis membranes

RO reverse osmosis membranes: Membranes that reject most particles and many low molar mass species such as salt ions

SEM Scanning Electron Microscopy: Technique used to capture magnified views of membranes TDS total dissolved solids; concentration (e.g., mass of salt / volume of solution)

TFC thin film composite: The most popular type of reverse osmosis membranes

UF ultrafiltration: Membranes that reject soluble macromolecules in addition to large particles and microorganisms

c: Solute concentration (kg/m^3)

c_m: Membrane surface concentration (kg/m^3)

c_o: Feed concentration (kg/m^3)

c_p: Permeate concentration (kg/m^3)

d_e: Equivalent diameter (m)

k: Mass transfer coefficient (m/s)

k_o: Darcy's permeability $(m\ )^2$

L: Effective membrane length (m)

L_m: Thickness of the membrane skin (m)

L_p: Membrane permeability (m /Ns)

M_w: Molecular weight of solute

R: Ideal gas constant (J/^{0} K mole)

Re: Reynolds number, $u_0\rho d_e/\mu$ (dimensionless)

R_m: Membrane resistance (m)$^{-1}$

R_g^{lam}: Gel type layer resistance in laminar flow (m^{-1})

R_g^{pro}: Gel type layer resistance in presence of promoter (m^{-1})

R_r: Real retention

R_{osm}: Osmotic pressure resistance (m)$^{-1}$

Sh: Sherwood number, kd_e/D (dimensionless)

Sc: Schmidt number, $\mu/\rho d$ (dimensionless)

T: Temperature (K)

u_0: Cross flow velocity (m/s)

v_w^{osm}: Motic pressure controlled flux (m^3/m^{2}s)

v_w^{expt}: Experimental permeate flux (m^3/m^{2}s)

Greek letters

ΔP: Applied pressure difference (Pa)

$\Delta\pi$: Osmotic pressure difference across the membrane (Pa)

π_m: osmotic pressure (Pa)

π_p: osmotic pressure at the membrane surface (Pa)

π: Osmotic pressure at the permeate stream (Pa)

M: Feed viscosity (Nm/s)

Subscripts

o: Feed

m: Membrane surface permeate

Superscripts

l: Laminar region

pro: Turbulent promoter

osm: Osmotic pressure controlled regime