

Trouble Shooting

Presenter : Matthew Jeon

CSM®

Woongjin Chemical Co. Ltd Filter Division

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CSM®

I. Field Inspection

Introduction

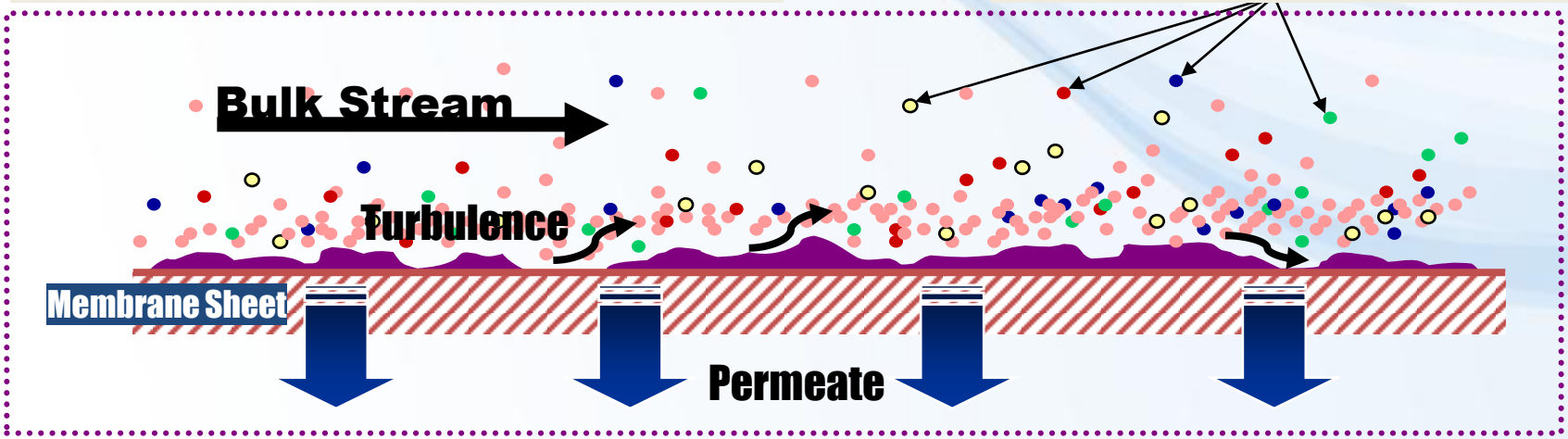
Loss of salt rejection, loss of permeate flow and pressure drop increase **are the most common problems encountered in reverse osmosis.**

Common Problems

- Loss in Flowrate
- Loss in Salt Rejection
- Increase in differential pressure

Causes

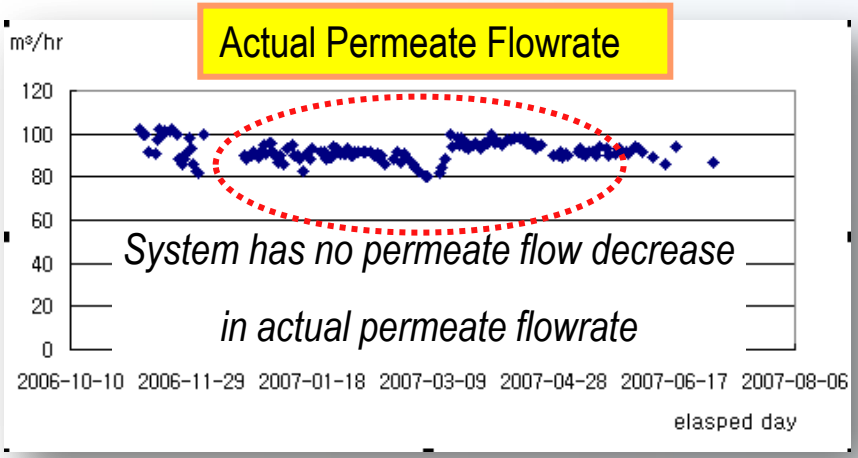
- Charged (+, -) and/or Non Charged Foulants
- Organic / Colloidal Matters
- Oxidizer / Debris
- Hydraulic Shock

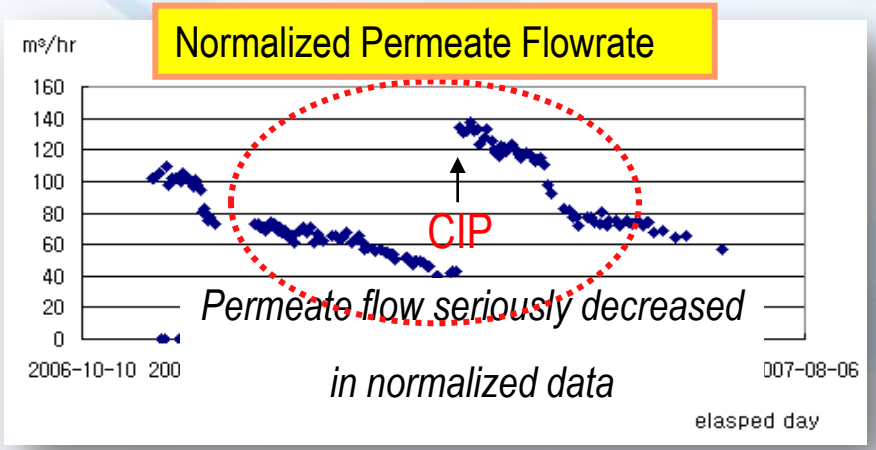


Evaluation of System

- **Data Normalization**
  - Comparing real operating data to reference data (initial data) to predict membrane fouling and chemical damages, mechanical failure

- **Normalization parameter**
  - Salt rejection ; Can be affected by pressure, temperature, recovery, etc.
  - Flow rate ; Can be affected by pressure, temperature, pH, etc
  - Differential pressure ; Can be affected by pressure and flow rate





This graphs are permeate flowrate trend before and after normalization

Evaluation of System

If the normalized performance show severe deterioration, the following should be checked.

- Calibration of all meters, sensors and pressure gauges
- Stabilization of system at least for 24 to 72 hours in continuous operation
- Consideration of permeate pressure
- Significant pressure loss from the feed to the concentrate
- Check of the start-up and shut-down procedure for hydraulic shocks, permeate backpressure and back-flow of permeate
- Check of CIP procedure and chemical
- Check of CIP frequency
- Water Analysis : Carbon dioxide can increase the permeate conductivity
- Check of the potential oxidation problem by chlorine and oxidizing chemicals
- Check of replacement rate of prefilters
- Check of the SDI
- Check of the scaling calculations and dosage rates of chemicals.

Field Inspection

Check of Biogrowth and mold in tanks and pipes

Check of the vessels leakage which suck air during shut down and lead to hydraulic shock

Field Inspection

Inspection of feed side by opening pressure vessel
: any fouling, smell, properly shimmed

Inspection of concentrate side by opening pressure vessel
: scaling

Field Inspection

Check of couplers for torn, damaged or misplaced O-rings by removal the element from the pressure vessel

Inspection of element for fouling, scaling and mechanical damage

Localization of High Solute Passage

Profiling

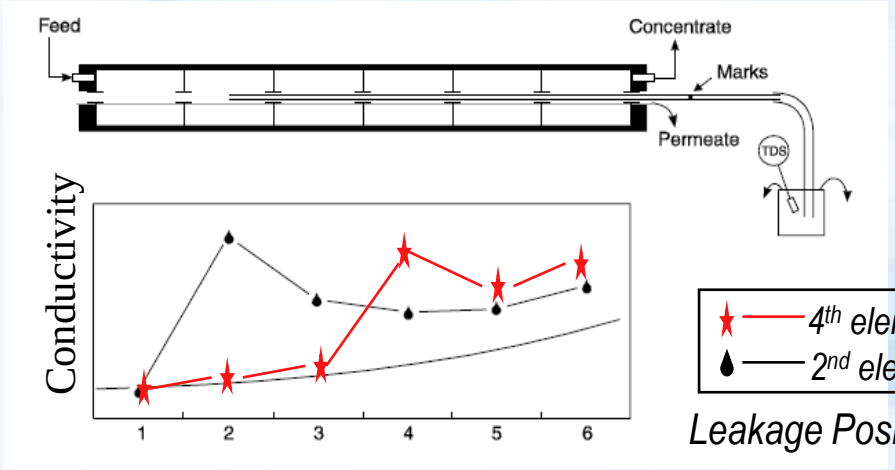
If a system exhibits high solute passage, all individual vessel's TDS or conductivity or other relevant quality values must be checked.

Probing

If one pressure vessel shows a significantly higher permeate concentration than the other vessels of the same stage, conductivity of every elements need to be checked

Profiling

Probing



II. Membrane Analysis

Visual Inspection

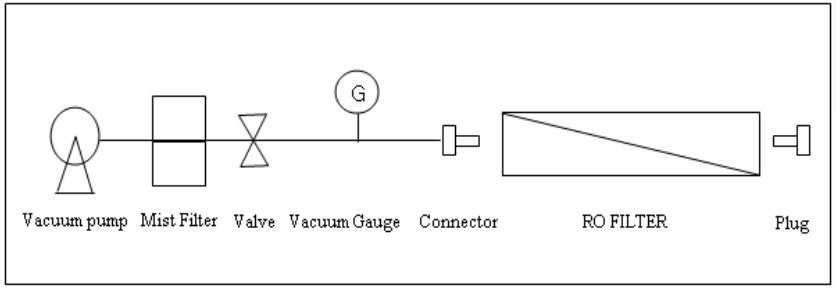
Visual inspection provides some information on problems like fouling and scale.

Check Point

- Potential fouling or scaling problem
- Discolorations of the outer wrapping and the fiberglass
- Any deposits or foreign matter
- Telescoping, channeling and fiberglass damage
- Mechanical damage of permeate water tube

Vacuum Test

Vacuum Test is performed to detect any mechanical leaks by checking the vacuum decay rate. (Based on San Diego Protocol or ASTM)



Vacuum test equipment

Check Point

- Leaks by puncture or scratches
- Delamination and physical damage by permeate back pressure or water hammer
- Membrane integrity

※ Test acceptance criteria
- vacuum decay rate < 100 mbar/min.

Performance Test

Standard element performance test is used to confirm the performance comparison with initial value under standard test conditions

Table 1. Performance Data on Returned Membrane

Bar code	Catalogue Value		Re-tested value			VDR (mbar/min)	Weight (kg)	Remarks
	Flowrate (GPD)	Rejection (%)	Flowrate (GPD)	Rejection (%)	DP (kgf/cm²)			
BJFAA0110032	11,000	99.5	16,700	98.3	0.5	20	15.8	1st stage A42-1

Initial differential pressure is 0.3kgf/cm²

※ Test conditions

Feed Concentration : 2,000 ppm NaCl
Feed Pressure : 225 psi
Temperature : 25℃
Recovery : 15%
pH : 6.5

Check Point

- Comparison of salt rejection, permeate flowrate and differential pressure increase with initial data
- Performance comparison before and after any cleaning test

Flat Sheet Test

Flat sheet test is performed to check the performance by parts

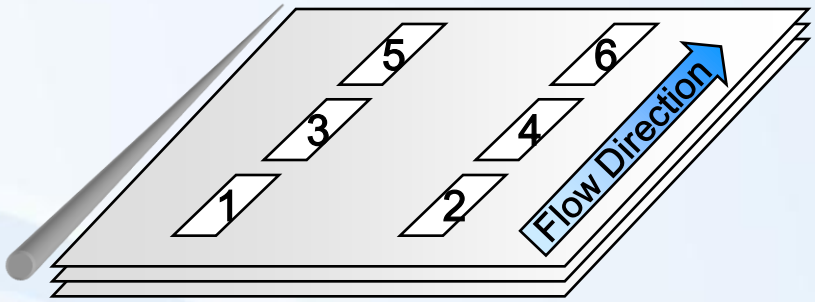


Figure. Membrane Sampling Points & Examples

Check Point

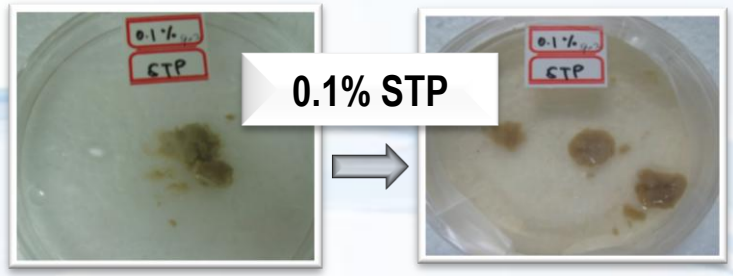
- Comparison of salt rejection and permeate by location
- Performance comparison before and after any cleaning test

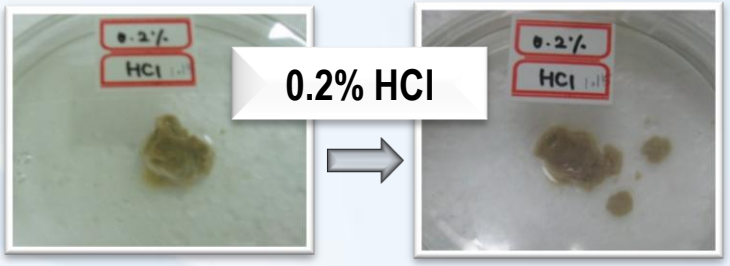
Table 2. Flat Sheet Performance Test

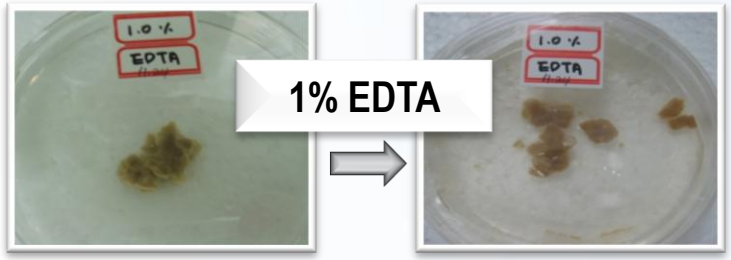
Sample	Flux (GFD)	Rejection (%)	Remarks
1	50.2	93.21	Feed part
2	46.2	94.92	
3	test error		Middle Part
4	48.5	95.68	
5	47.2	97.33	Concentrate Part
6	46.6	97.83	
average	47.7	95.79	

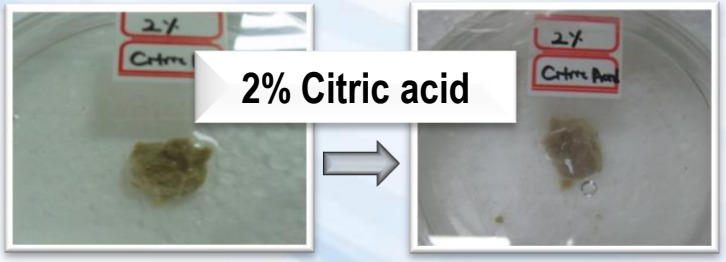
Cleaning Test

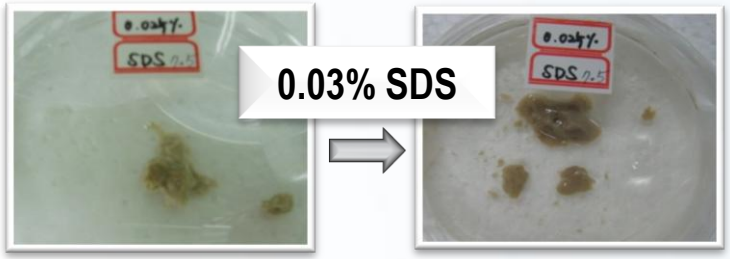
To confirm whether bio-fouling or scaling is the cause of decline in membrane performance, either acid or caustic solution soaking methods are used.

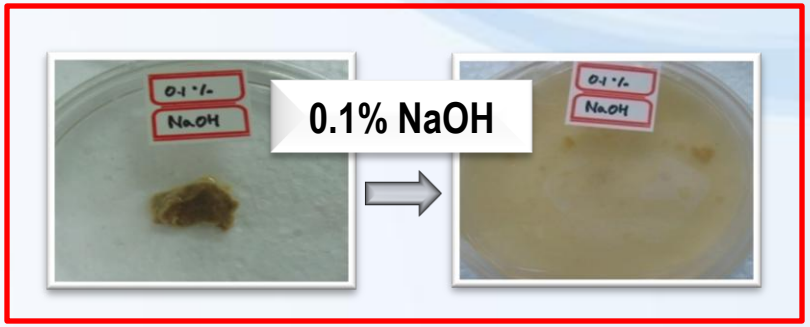










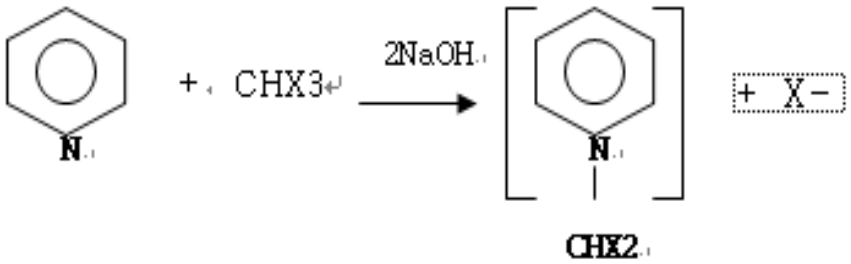


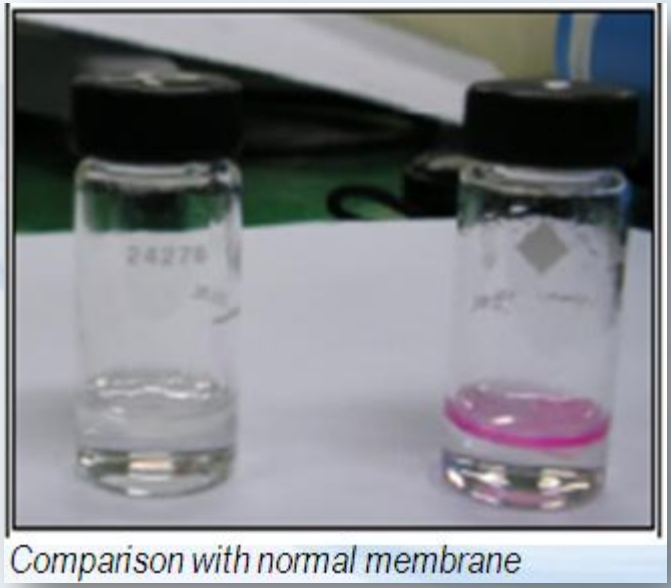
Fujiwara Test

Fujiwara test method is to confirm qualitatively whether the PA polymer structure was attacked by oxidative halogen chemicals like chlorine, bromine and iodine or not

Only oxidized RO membrane turns pink by this test.

① 1cm² membrane is placed in the bottom of tube
② Several milliliters of 5N NaOH are added
③ Followed by 0.5mL of Pyridine
④ Test tube is placed in a beaker of boiling water





Comparison with normal membrane

Dye Test

***To determine the causes and the location of a salt passage*, the element is operated with a pressurized dye solution prior to an autopsy. A pink permeate would indicate membrane damage.**

Check Point

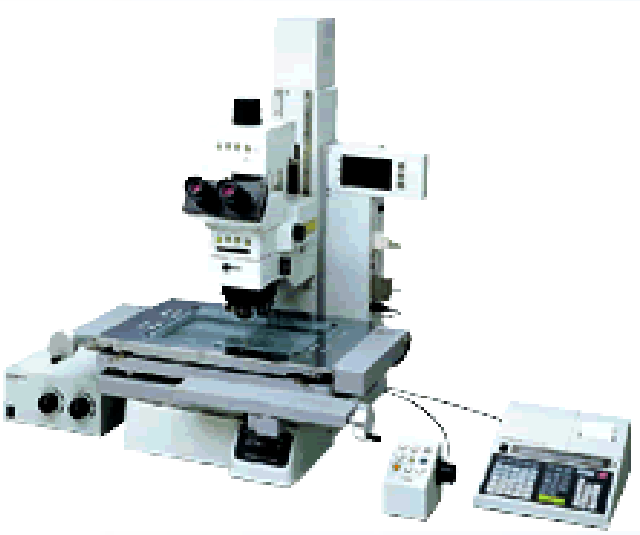
- Oxidation and damage of membrane
- Permeate Back-Pressure

Rhodamine B is used for dye test.
-> Rhodamine B's M.W. is 400 ~500 and can not pass Non-Damaged Membrane.

Dye solution passed through the damaged part of concentrate side.

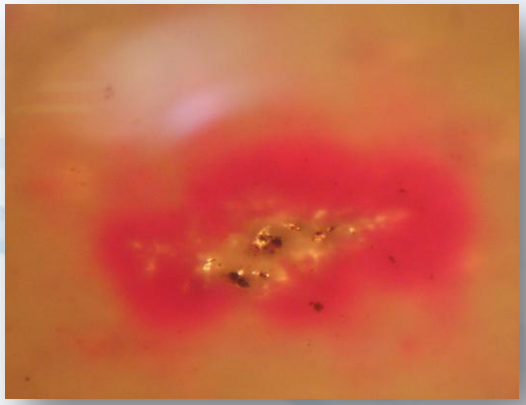
Optical Microscope

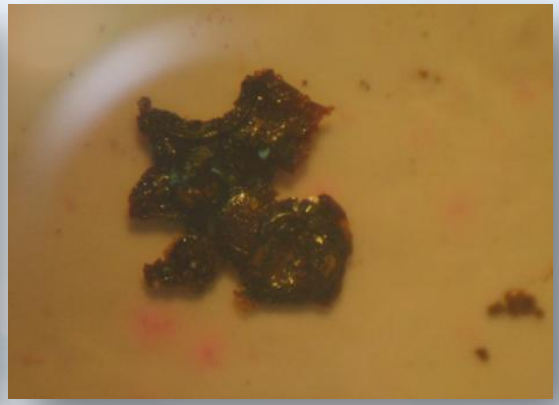
To verify the causes and location of decline in performance, microscope inspection is performed.

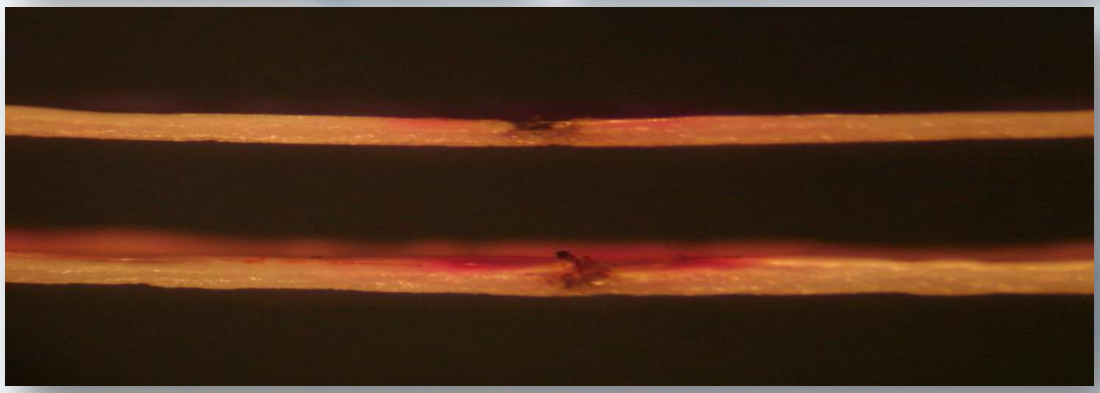


Check Point

- Fouling Particles
- Membrane Damage Part





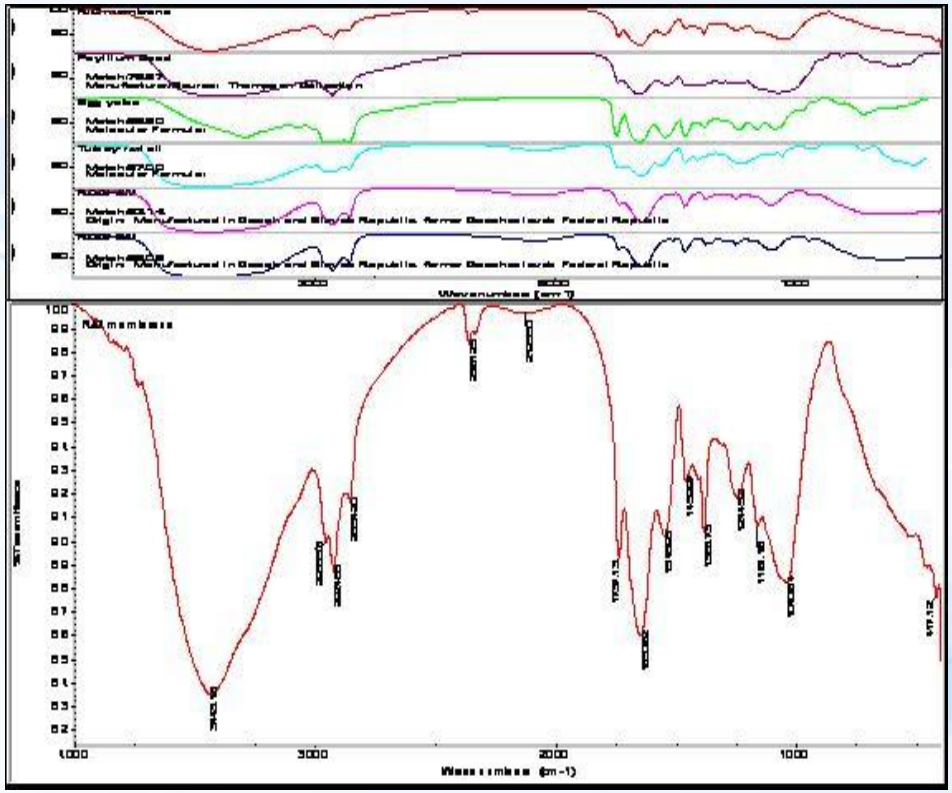


Above pictures show damaged membrane by some welding particles

***Specific organic / inorganic matters are confirmed* by FT-IR (Fourier Transform Infrared Spectroscopy)**

Check Point

- Infrared radiation wave indicate property of organic matter functional group
- Through the comparison of spectrum of matter, possible to confirm pollutants



TGA (Thermo gravimetric Analysis)

***The content rate of organic/inorganic matter* is verified.**

Residual rate indicates inorganic ratio of foulants.

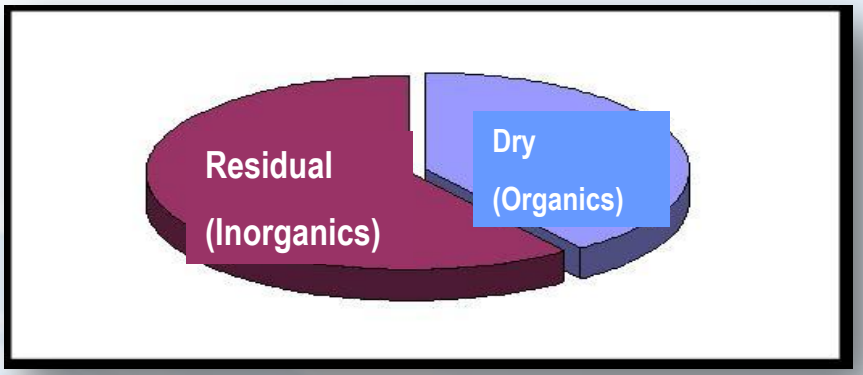
① Weight calibration of crucible

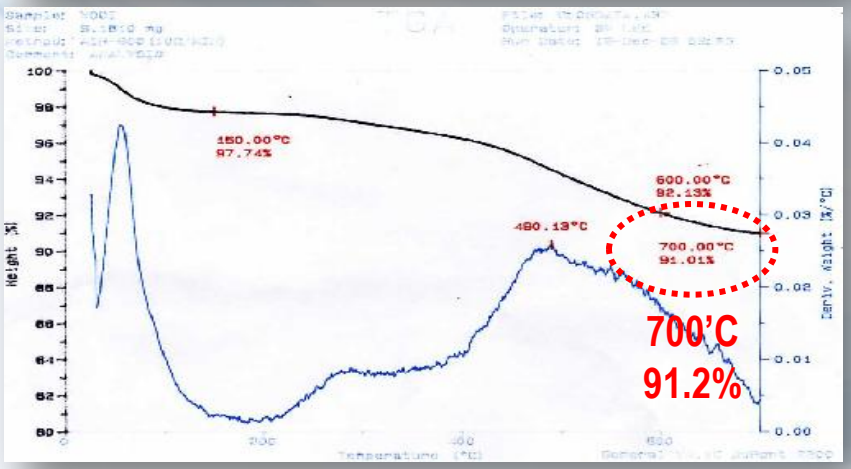
② Weight calibration of crucible and sample

③ Heating of crucible and sample

④ Weight calibration of crucible and ash

⑤ Calculation of organic matter : [②- ④]





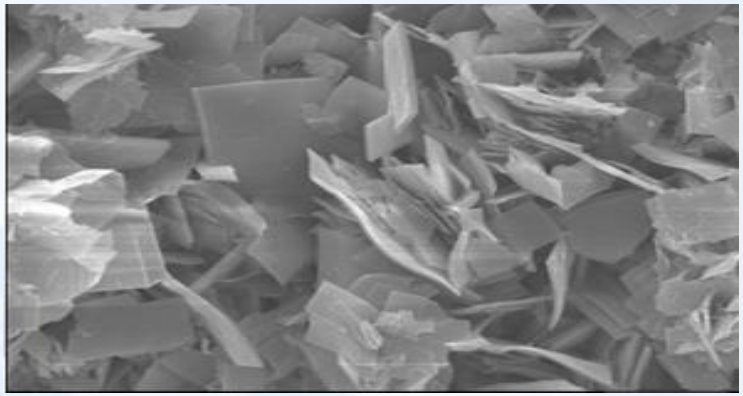
This figure shows 90% of most foulants are resided and these are inorganic matters.

SEM (Scanning Electron Microscope)

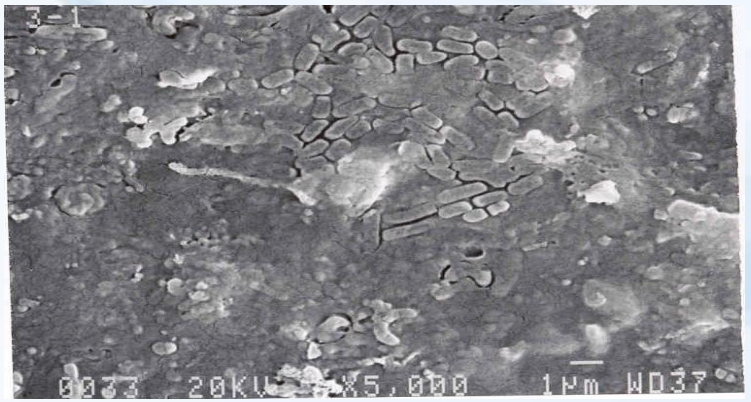
The sample is examined under a microscope at various magnifications to verify some foulants.

Check Point

- The structure
- Crystalization
- Size and kind of the membrane foulants



SEM image of CaCO3 Scale



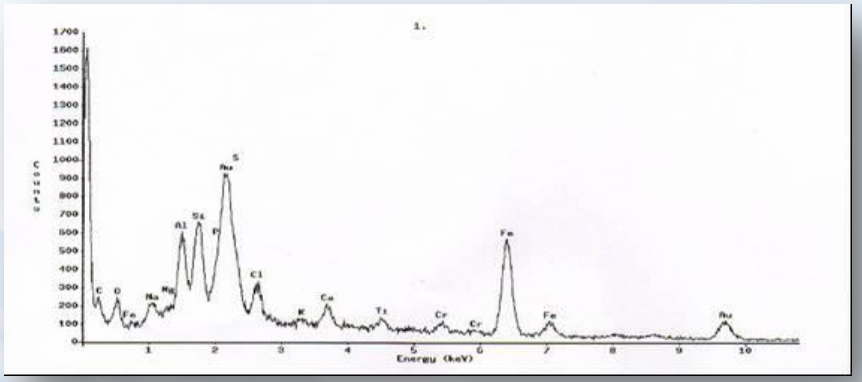
SEM image of micro-organism

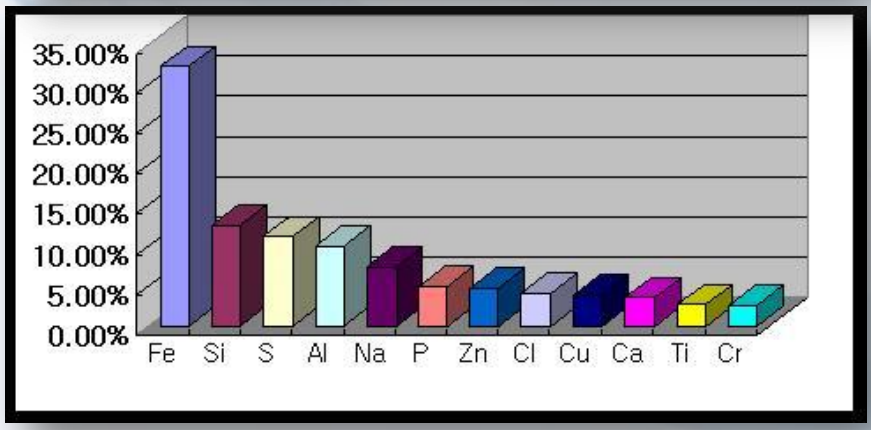
EDS (Energy Dispersive Spectrometer)

EDS gives a semi-quantitative composition of chemical elements of the membrane and the foulants.

Check Point

- Proportion between energy intensity and content of matters (Semi-quantitative)
- Useful to choose CIP method





Fe is main fouling component, this value indicate semi-quantitative of fouling matters.

III. Trouble Shooting Guide

Metal Oxide Fouling

Symptoms

- ✓ Normalized DP Increases Especially in 1st Stage
- ✓ Normalized Permeate Flow Decreases
- ✓ Normalized Salt Rejection Decreases

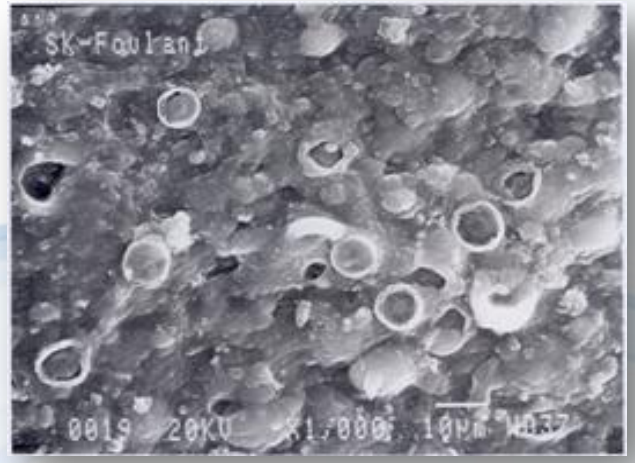
Corrective Methods

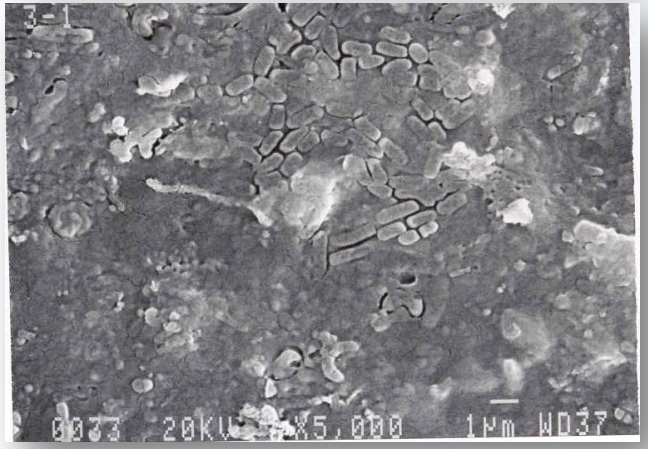
- ✓ Clean the membrane elements
- ✓ Adjust, correct and /or modify the pretreatment
- ✓ Retrofit piping or system components with appropriate materials.

Verification Method

- ✓ Analyze feedwater for iron and aluminium
- ✓ Check system components for evidence of corrosion

Biological Fouling





Symptoms

- ✓ Normalized DP Increases at Any Stage
- ✓ Normalized Permeate Flow, Salt Rejection decrease

Corrective Methods

- ✓ Clean and sanitize the entire system
- ✓ Soak and rinse in High pH
- ✓ Installation of fouling resistance elements

Verification Method

- ✓ Bacteria Count : TBC, DBC
- ✓ SEM Analysis

Colloidal Fouling

Symptoms

- ✓ Normalized DP Increases Especially in 1st Stage.
- ✓ Normalized Permeate Flow, Salt Rejection decreases

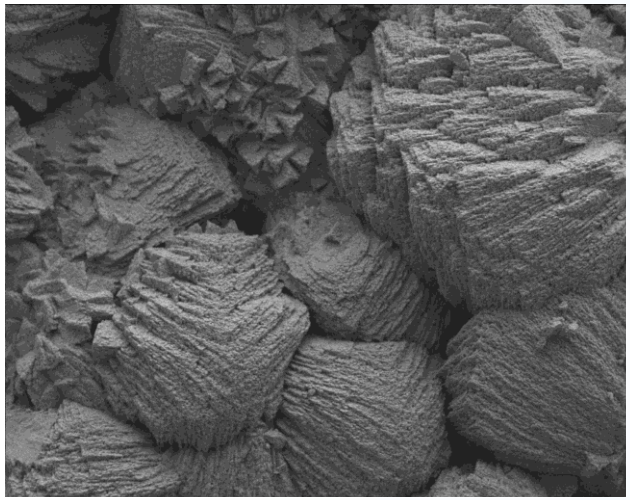
Corrective Methods

- ✓ Clean the elements depending on foulants
- ✓ Adjust, correct and /or modify the pretreatment

Verification Method

- ✓ Check the feed water SDI
- ✓ Analyze accumulations on prefilter cartridges
- ✓ Inspect and analyze deposits on elements

Scale



Symptoms

- ✓ Normalized DP Increases Especially in last Stage.
- ✓ Normalized Permeate Flow, Salt Rejection decreases

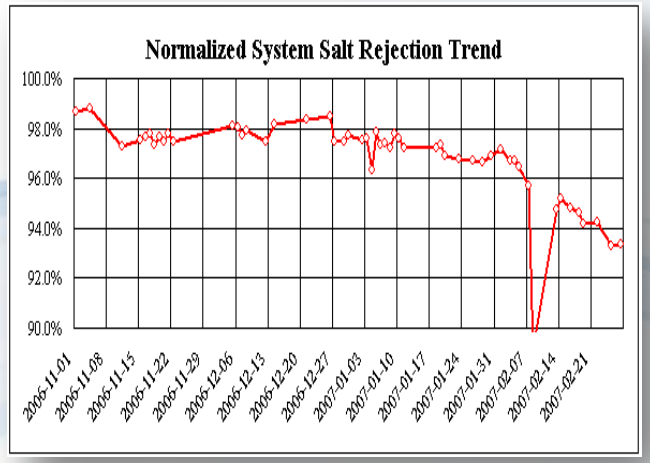
Corrective Methods

- ✓ Pretreatment : Softening, Lime softening, Acid injection
- ✓ Optimize cleaning depending on present scaling salts
- ✓ Anti-scalant Injection : SHMP, Organo phosphate etc

Verification Method

- ✓ Check feedwater analysis for the scaling potential at system recovery
- ✓ Inspect concentrate side of system : weigh and touch the tail-element

Oxidation



Symptoms

- ✓ Normalized Salt Rejection Decrease
- ✓ Normalized Permeate Flow Increase
- ✓ Normalized DP is Stable

Corrective Methods

- ✓ Monitoring Free chlorine, ORP value
- ✓ Injecting SBS
- ✓ Chloramine disinfection instead of chlorine

Verification Method

- ✓ Dye Test
- ✓ Fujiwara Test
- ✓ ESCA Analysis

RO Installation Mistakes

Conductivity increase of several vessel by O-ring leak.

RO2231 1st Stage Skid1

			A4 15.5	A5 15.0	A6 16.2	A7 15.2
B1 15.7	B2 15.4	B3 15.1	B4 15.4	B5 15.8	B6 15.7	B7 16.0
C1 15.3	C2 15.8	C3 15.3	C4 15.5	C5 15.5	C6 15.6	C7 14.8
D1 15.5	D2 15.1	D3 14.1	D4 15.3	D5 15.5	D6 15.1	D7 14.0
E1 13.5	E2 15.1	E3 14.1	E4 15.3	E5 15.5	E6 15.1	E7 14.0
F1 15.7	F2 14.4	F3 14.5	F4 16.3	F5 **688.0**	F6 15.3	F7 13.0

1st feed water conductivity ; ㎲/㎝

1st Stage Permeate Conductivity ; 53.8㎲/㎝

RO2231 1st Stage Skid2

A8 15.5	A9 15.4	A10 15.5	A11 13.7			
B8 16.1	B9 15.3	B10 15.3	B11 **20.4**	B12 **18.3**	B13 14.6	B14 15.4
C8 14.6	C9 16.0	C10 17.0	C11 16.1	C12 13.9	C13 13.8	C14 15.3
D8 15.6	D9 14.8	D10 14.0	D11 15.3	D12 15.3	D13 15.3	D14 14.6
E8 14.1	E9 14.9	E10 15.2	E11 14.9	E12 14.4	E13 15.0	E14 14.3
F8 13.4	F9 15.2	F10 16.0	F11 14.3	F12 15.0	F13 **30.5**	F14 15.0

1st concentrate water conductivity ; 886㎲/㎝

Common Permeate Conductivity ; 49.18㎲/㎝

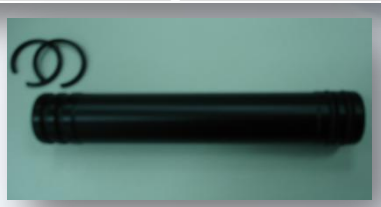
RO2231 2nd Stage

A15 **30.8**	A16 **44.9**	A17 28.3	A18 26.7	A19 29.1		
B15 **33.2**	B16 27.3	B17 28.1	B18 25.8	B19 28.2	B20 **33.3**	B21 28.5
C15 27.3	C16 **34.2**	C17 28.8	C18 27.2	C19 27.0	C20 27.4	C21 27.2
D15 **29.9**	D16 27.5	D17 28.6	D18 **41.9**	D19 **37.3**	D20 **43.0**	D21 **32.0**
E15 28.7	E16 **38.4**	E17 **30.9**	E18 **32.3**	E19 **33.0**	E20 **31.7**	E21 **34.5**
F15 **29.9**	F16 28.4	F17 26.8	F18 28.7	F19 28.0	F20 26.7	F21 27.3

2nd concentrate water conductivity ; 31.2㎲/㎝

2nd Stage Permeate Conductivity ; 31.2㎲/㎝

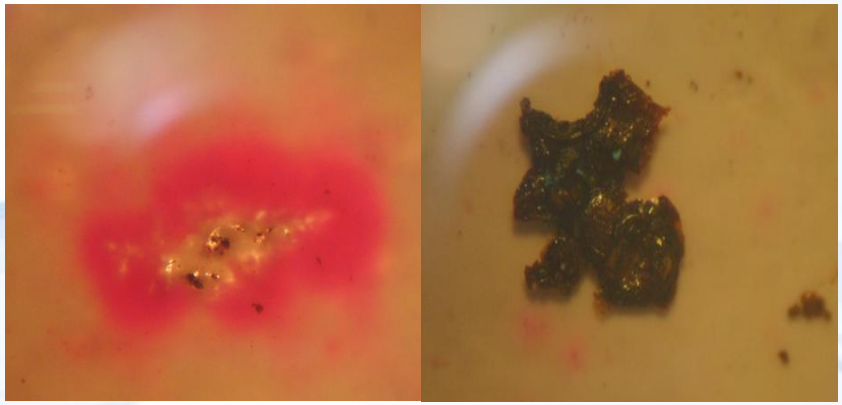
Figure. Profiling for each vessel



Cause broken o-ring

Others

Mechanical Damage by Welding Debris

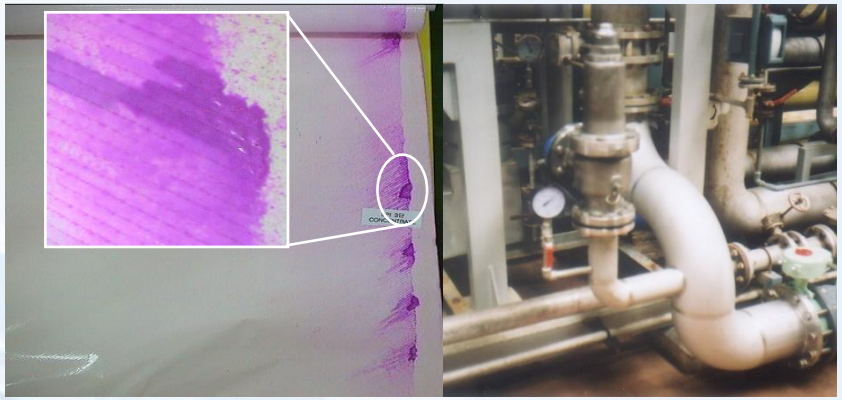


Symptoms
- ✓ Normalized Salt Rejection Decrease

Corrective Methods
- ✓ Enough system flushing before installation

Verification Method
- ✓ Optical Microscope

Permeate Back Pressure



Symptoms
- ✓ Normalized Salt Rejection Decrease

Corrective Methods
- ✓ Check valve in the permeate pipe inspection
- ✓ Installation Pressure Release Valve In Permeate Line

Verification Method
- ✓ Dye Test / Probing

Trouble Shooting Matrix

Symptoms		Causes
Low Permeate Flow	First Stage	Deposition of organic/colloidal matter Initial biofouling / Metal Oxide Fouling
	Last stage	Scaling
	Others	Aged Preservation Solution While Stocked Compaction and Intrusion Incomplete Wetting
High Salt passage	overall	Membrane Oxidation Membrane Surface Abrasion
	specified	O-rings leakage / Telescoping Permeate Backpressure
High differential Pressure		By pass in Cartridge Filter Pretreatment Media Filter Breakthrough Pump Impeller Deterioration /Precipitated Antiscalants Brine Seal Issues Biological Fouling / Scaling

IV. CIP (Clean In Place)

CIP (Clean In Place)

CIP is, spelled 'Clean In Place', cleaning membranes in the RO vessels with equipped , not change an arrangement.

Elements should be cleaned immediately when one of the following symptoms is detected.

- ✓ Normalized water flow has decreased by 10-15% from start-up conditions.
- ✓ Delta P, or pressure drop over a stage or the system, has increased by 10-15%.
- ✓ Salt rejection has decreased (ie permeate TDS has increased) significantly over time.

Even if the above symptoms don't show, it is good to do CIP every 1-2 times per year for preventing some problems.

Inorganic scale

The main cause of inorganic scale is the concentration increase due to high recovery on RO operation.

Scale	Scale with Ca & Mg	CaSO4	SiO_2	Fe & Al	Remark
Cause	The concentration increase due to high recovery			Corrosion of pipe	
Location	Tail vessel & elements			Overall	
Cleaning chemical	Strong Acid	Chelate	None	Weak Acid	
pH	2.0~	10.5~12.0	-	3.5	
Temp.	30 ~35 ℃	30 ~35 ℃	-	25 ℃	

✓ In case of SiO_2, there are not effective chemicals particularly. Decreasing recovery & pre-treatment for SiO_2 are important.

✓ In case of Fe, it is necessary to remove Fe in pretreatment because oxidizing would be stronger if the oxidizer meet Fe.

Organic fouling

The main cause of organic fouling is the concentration increase of fouling on membrane surface on RO operation.

Fouling	Organic compound	Bio-Film	Silt & colloid	Remark
Cause	The concentration increase of fouling on membrane surface			
Location	Lead vessel & elements			
Cleaning chemical	Surfactant	Alkali+Surfactant	Chelate	
pH	10.5~12.0	10.5~12.0	10.5~12.0	
Temp.	30 ~45 °C	30 ~45 °C	30 ~45 °C	

✓ Bio-film occurs due to microbial synecology. This can be suppressed by injecting a biocide prior to RO system. However, oxidizing biocide for PA should be prohibited or neutralized before RO feed stream.

CIP Procedure

CIP procedure is determined by feedwater component, trouble symptom and field condition. The engineer's experience is the most important factor.

The following is a common procedure of CIP

Prepare the cleaning solution per the instructions
- Temp. : up to 35℃ (upper 35 ℃, change in PA properties is concerned)
- pH : Acid 1.5~2.5, Alkali 11~12

Circulation overall system - 10~60 min.

Circulation 1st, 2nd, 3rd bank : each 10~60 min.

Soaking : 4~15 hours (max. 3 days)

Re-circulation 1st, 2nd, 3rd bank : each 10~60 min.

Low pressure flushing : each 10~60 min.

High pressure flushing : until obtain a target permeate quality

✓ Circulation - Feed pressure : 1.4~4.1 bar, Feed flow each vessel(8") : 30-40gpm

✓ The size of CIP Tank = all pipes volume(feed+return) + all vessels volume

Thank You!

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