AWT
ASSOCIATION OF WATER TECHNOLOGIES

Training Seminars

Membrane Training 2024 - Section 4
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Aquassuance

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SECTION 4: MEMBRANE TECH DESIGN BASICS, SOFTWARE, EXAMPLE, ANTISCALENTS, CLEANING, SERVICE, TROUBLESHOOTING:

2023 Technical Training Seminars:

- Some membrane/key component OEMs.
- Some std equipment & EPC contractors OEMs
- Some MT systems/ RO design rules of thumb
- Membrane manufacturers design software
- Worked RO software design example
- Capital costs and operating costs
- Some RO specialist chemistry & services vendors and their software, & RO element autopsies
- More in depth anti-scalent, CIP skids, cleaners
- silica and clay soak cleaners, micro bubble cleaners,
- Direct/forward shock cleaners
- biocontrol products, membrane susceptibilities
- Maintenance, and maintenance items
- RO element changeout/esting and analysis
- Silt Density Index (SDI) measurements
- In-Plant Analysis/Pretreatment System
- Evaluation of Scale inhibitor /Troubleshooting, pressure drops, and other KPI's,

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MICRO/ULTRA FILTRATION OPERATING NOTES:

- *A safety screen of 150 – 300 microns is recommended on the feed to the UF system, (e.g. use self-cleaning screens/bag, cartridge, or disc filters.)*
- *Depending on the water source or range of feed water parameters, we may need pre-treatment by oxidation, coagulation, sedimentation, media, etc.*

Parameter	Unit	Design Basis	Maximum Allowable
Turbidity	NTU	<50	300
TOC	mg/l	<10	40
Particle Size	micron	<150	300
COD_{Mn}	mg/l	<20	60
Oil /Grease	mg/l	0	< 2
pH continuous		6-9	2-11
Temperature	°C	25	40
Cl2 continuous	mg/l	0.5	200
TSS	mg/l	30	100

ACCEPTABLE FEED WATER CONDITIONS

Operating Conditions	SI	US
Feed Pressure, Maximum at Inlet at 20 °C	6.25 Bar	93.75 psi
Operating TMP (Maximum)	2.1 Bar	30 psi
Filtrate Flux @25C	40 - 120 Lm²/hr	24 - 70 gfd
Temperature (UPVC limited)	1 – 40 °C	34 - 104 °F
Operating pH Range	2 - 11	
NaOCL Cleaning Maximum	2,000 ppm	

RECOMMENDED UF OPERATING CONDITIONS

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CLEANING PROCESS FOR MF/UF MODULES

- At initial start up modules are AUTOMATICALLY forward flushed sequentially.
- Operation mode is typically from 20 to 60 minutes with 100% of feedwater converted to filtrate, before trans-membrane pressure (TMP) rises and a back-flush sequence (of typically approx. 2-3 minutes) is triggered.
- Back-flush is automatic. Typically, 20-30 second air scour is first – flushing from outside of fibers with discharge through top of module
- Next is draining by gravity. Then backwash reverses filtrate flow (from, say, inside to outside) and removed through top drain
- A second backwash passes through the bottom drain. These can be repeated. A final forward flush removes any trapped air before returning to operating mode.
- A chemical enhanced backwash (CEB) is also usually given periodically, using filtrate and either acid/base, plus oxidant. CEB chemical is fed into first stage backwash water, then a soak (5-20 mins) is added after the second backwash step. (SEE NEXT PAGE).
- CIP acid/caustic operations are usually given every 1-3 months to clean the fibers. Backwash is given 6-8 times, followed by 30-60 min recycle, then 60 min soak , further 30 min recycle, air scouring, back-flushes, and final forward flush.

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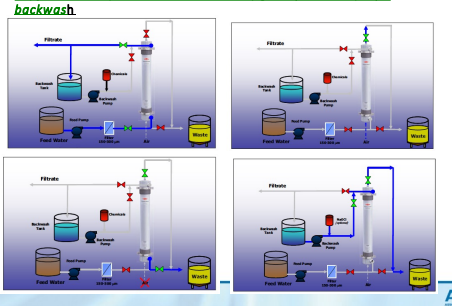
UF MODULES OPERATING CYCLES: 20-60 MINUTES:

1.) filtration, 2.) backwash/air scour, 3.) gravity drain, 4.) top backwash



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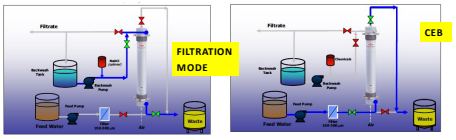
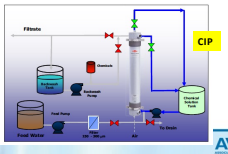
UF MODULES OPERATING CYCLES: 20-60 MINUTES:

From filtration mode, we may need a weekly CEB or a monthly CIP





when offline, a periodic, automatic CEB (Chemically Enhanced Backwash) can take place. This follows the steps of a normal backwash except a CEB chemical is dosed into the backwash water and a 5-20 min. soak step is added after the second backwash step.

Also, every 1-3 months, a CIP on inside and outside fibers@ 40ºC can take place

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CEB &CIP OF MF/UF MEMBRANE MODULES TYPICALLY ONLY INVOLVES BLEACH AND CITRIC

	Type	Chemical	Conc. (%)	Protocols
Mitsubishi	CIL	NaOCl	0.3	Backflow through membrane
		Citric acid	0.2	(2 hr) + soaking (2 hr)
Zenon	CIP	NaOCl	0.2	Backpulse and recirculate
		Citric acid	0.2-0.3	
Memcor	CIP	NaOCl	0.01	Recirculate through lumens,
		Citric acid	0.2	mixed liquors and in-tank air manifolds
Kubota	CIL	NaOCl	0.5	Backflow and soaking (2 hr)

CIL: Cleaning in line where chemical solutions are generally backflow (under gravity) inside the membrane.

CIP: Cleaning in place where membrane tank is isolated and drained; the module is rinsed before being soaked in the cleaning solution and rinsed to remove excess of chlorine.

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CEB &CIP OF MF/UF MEMBRANE MODULES CAN USE CHEMISTRIES OTHER THAN BLEACH & CITRIC

We are now seeing some specific MF/UF cleaning formulations for the first time!

For example: SOLID, Special UF cleaner, removes persistent foulants, where other cleaners fail

- 24.3% $Na_2S_2O_4$
- 24.3% Na TPP
- 3.9% Marlon ARL
- 7.8% NaCl
- 3.9% HEDP
- 3.9% Na_4EDTA
- 7.8% NaOH
- 24.3% SHMP

Note: $Na_2S_2O_4$ is sodium hydrosulfite, aka sodium dithionite

MARLON® ARL is powdered Naalkylbenzenesulphonate; NaCl < 0.5% and Na_3PO_4 < 4-6%.

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MBR CLEANING REQUIRES AIR SCOURING OF MEMBRANES AND BACK-PULSE CIP

- Conventional membrane bioreactors process immerses membranes directly into highly concentrated mixed liquor suspended solids (MLSS) - 4x normal activated sludge loadings.
- MLSS contains high levels of dispersed , small particles comprised of inert and colloidal material.
- High membrane fouling environment, which results in low membrane flux rates, which require large membrane surface area. Air scouring reduces fouling

Puron® Submerged Module

BACK-PULSE CIP

EMERGING TECHNOLOGIES NOW INCLUDE CHEMICAL-BASED INJECTION CLEANING, THAT DOES NOT REQUIRE PRIOR MLSS REMOVAL. SAVES TIME AND MONEY !

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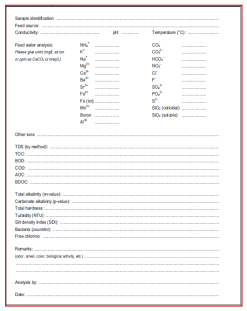

Sample identification: .....
Feed source: .....
Conductivity: ..... pH: ..... Temperature (°C): .....

Feed water analysis:
Please give units (mg/l, as ion or ppm as $CaCO_3$ or meq/L)

NH_4^+	.....	CO_3	.....
K^+	.....	CO_3^{2-}	.....
Na^+	.....	HCO_3^-	.....
Mg^{2+}	.....	NO_3^-	.....
Ca^{2+}	.....	Cl^-	.....
Ba^{2+}	.....	F^-	.....
Sr^{2+}	.....	SO_4^{2-}	.....
Fe^{2+}	.....	PO_4^{3-}	.....
Fe (tot)	.....	S^{2-}	.....
Mn^{2+}	.....	SiO_2 (colloidal)	.....
Boron	.....	SiO_2 (soluble)	.....
Al^{3+}	.....		

Other ions: .....

TDS (by method): .....
TOC: .....
BOD: .....
COD: .....
AOC: .....
BDOC: .....

Total alkalinity (m-value): .....
Carbonate alkalinity (p-value): .....
Total hardness: .....
Turbidity (NTU): .....
SDI (fouling index (SDI): .....
Bacteria (count/ml): .....
Free chlorine: .....

Remarks: .....
(color, smell, color, biological activity, etc.) .....

Analysis by: .....

Date: .....

FIRST WE NEED DATA: WE NEED LOTS OF WATER ANALYSES!

- Ba^{2+} and Sr^{2+} must be analyzed at the 1 µg/L (ppb) and 1 mg/L (ppm) level of detection, respectively.
- It is also important that the temperature be given as a range rather than an absolute value.
- Temperature variation can impact the scaling potential of an RO system, especially when silica and bicarbonate levels in the feed water are high.

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PRETREAT EQUIPMENT DESIGN REVIEW NOTES

- Aeration: may be required to remove any H_2S in deep well water feeds, or pretreat for Fe removal
- Chlorine addition: may be a prerequisite to sanitize the RO feed-water supply line and oxidize any organics, (followed by *de-chlorination* using sodium bisulfite, after the *MM filtration* stage). Provide a 20-25 minute contact period by means of a temporary storage tank, then this is followed by a repressurization pump system.
- Ion-exchange softening: is sometimes specified to remove all calcium and magnesium ions, or to at least reduce the hardness salts down to a tolerable level. RO system design engineers may limit the percentage of permeate recovery by controlling the brine reject water quality LSI to a level of perhaps +1.6 to +1.8.

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RO TESTING PARAMETER MONITORING BASICS:

- Conductivity – solids content in the water. The lower the conductivity, the lower the TDS and the purer is the water.
- Organophosphonate or PMA: – measures the level of inhibitor in the water sample.
- Low inhibitor level: can result in scale formation on the membrane.
- High inhibitor level: can result in solubilizing some minerals that could then pass through the RO membrane causing poor permeate quality.
- PSI readings: – Pressure changes in an RO indicate a problem.
- Increased pressure indicates fouling and than cleaning or membrane replacement is required
- Pressure loss indicates a blown seal or a ruptured membrane.

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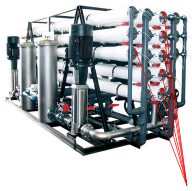
CHECK THE MEMBRANE TRAIN REGULARLY FOR FOULING: COMPARE TO LOG BOOK RESULTS

- *Check reject water conductivity to verify that conductivity is concentrating up in each train.*
- *Check permeate discharge at each train and each stage to verify conductivity changes by stage*



Each Train should be individually tested

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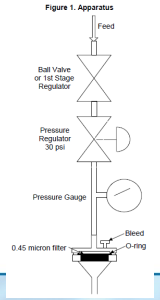
SDI (or KOLLOID-INDEX/FOULING-INDEX)



Calculations

SDI = P30 / Tt = 100 * (1 - Ti / Tf) / Tt

Where:

- **SDI = Silt Density Index**
- **P30 = % pluggage at 30 psig feed pressure**
- **Tt = Total test time in minutes (usually 15 minutes, but may be less if 75% pluggage occurs in less than 15 minutes)**
- **Ti = initial time in seconds required to obtain sample**
- **Tf = time required to obtain sample after 15 minutes (or less).**

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MEASURING SILT DENSITY INDEX (SDI)

TEST PROCEDURE

- **1. Take the temp. of feedwater , Variation + 1 °C Max from start to end**
- **2. Bleed any entrained air in the filter holder.**
- **3. Place a 500 ml graduated cylinder under the filter**
- **4. Open the ball valve fully, and measure the time required to collect 100 ml and 500 ml . Record times, leaving valve open and let flow continue.**
- **5. Repeat after 5 min., and again after 10 and 15 min of elapsed time.**
- **6. If the time reqd to obtain 100 ml sample is > 60 seconds, pluggage rate will be about 90%, and it's not necessary to continue test.**

- ***Typical membrane requirements: SDI = 5 max (NTU = 1.0)***
- ***Better requirement: SDI = 2.5 (NTU = 0.5). Ideal is: SDI = 1.0 SDI***

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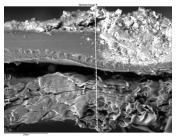
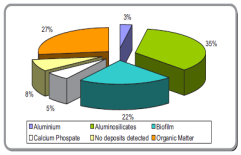
REVERSE OSMOSIS-FOULING

- *A Membrane Autopsy in a special laboratory can determine the cause of the failed membrane element*





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COMMON REVERSE OSMOSIS-FOULANTS

- Fouling Can Quickly Tear and Destroy the Membranes
  - *Particles physically embedding in membrane surface*
  - *Iron reactions with Peroxides burning holes in the membrane.*
- Silica, Barium Sulfate or Calcium Sulfate are the common inorganic foulants, and the main cause of failure in sea water and brackish water RO desalination systems. But seldom a problem when appropriate pre-treatment is designed and use of correct types of antiscalents
- Background - Clay: Autopsy labs (SEM & EDAX) analysis have found the most frequent foulant in the lead element is colloidal alumino-silicates (clay – and often with Fe oxides). Clay comes from surface waters, rivers/reservoirs but also can find its way into any RO plant feed water system. Pre treatment to remove clay is rarely a 100% efficient process.
- Issue: Clay attaches to the membrane surface rapidly and causes reduction in flux and an increase in feed pressure as the permeability of the membrane is reduced. The membrane surface becomes covered in an impenetrable mat.

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FOULANTS IN RO PLANTS USING TREATED WW AS FEED FOR WATER REUSE

- When operating ww membrane units, avoid risks of calcium phosphate deposits, as it has a low solubility that is readily exceeded - even for low concentrations of phosphates in feed water.
- Calcium phosphate forms a thin deposit layer, covering completely membrane surface. Membrane permeability dramatically decreases by nearly 50% in flux in as low as 6 hours.
- Rejection properties are not affected after foulant removal, (unlike other common scales). The best cleaning strategy to overcome calcium phosphate deposits is acid cleaning (HCl, MSA, Citric?)
- *Other WWT foulants are:*
- Colloidal matter (can be difficult to remove from feed water)
- Coagulants/flocculants - overdosed from earlier WW treatment.
- Al-based coagulants/organic flocculants have a high affinity to charged membrane surface and can dramatically affect permeability.
- Oils and fats.

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MORE NOTES ON INORGANIC FOULING:

- **Silica:**
  - 20 – 150 ppm @ 25°C <8.0 pH causes fouling *(Raise pH?)*
  - Mn, Ba, and Al catalyze silica into forming a polymerized foulant
  - Silica as SiO_2 reacts over 24 hours to form polymerized silica complexes (Colloids)
  - Pretreat silica with a low MW cationic polymer to remove colloidal silica
- **Calcium Carbonate:**
  - Calcium carbonate should be easily controlled by inhibitor. Fouling usually is a result of no flow or precipitation of salt prior to the membrane.
- **Ba, Mn, Alumino Clays:**
  - In the case of Barium, levels as low as 0.2 ppm in the make up can result in fouling
  - Sulfuric acid feed increases the fouling, so stop feed.

There are several alumino-silicas:

- Clay: $Al_2O_3SiO_2.xH_2O$
- Kaolin (china clay) 50% Al_2O_3 : 55% SiO_2
- Feldspar $KAlSiO_3$
- Mullite $3Al_2O_3.2SiO_2$
- Andalucite Al_2OSiO_4

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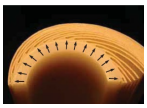
TREATMENT FOR REVERSE OSMOSIS-FOULING

Chemical Treatment is similar to that used in cooling towers, designed to keep the permeate water flowing!

Cross-section of a permeate water tube through the side glue lines of the leaves (arrows indicate even spacing of leaves)



- *Scale Inhibitors: Inject into the incoming feed water and adjunct may be required at separate trains*
- *pH Adjustment: Raising the incoming pH to 8.0 reverts CO_2 to carbonate that can be removed by the RO. It reduces corrosion*
- *Biocides: to remove biological fouling or provide for membrane storage*
- *Cleaners: Performed to renew membrane once 10 – 15% of membrane capacity is lost*

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TREATMENT FOR REVERSE OSMOSIS-FOULING

No	Typical pool of antiscalent formulatory chemistries to draw from in producing formulated products
1	**PBTC**
2	**HEDP**
3	**ATMP**
4	**Na2 DTPMP** Diethylenetriamine (Methylene PA)
5	**HDTMP** Hexamethylene diamine tetra (Methylene PA)
6	**PAPEMP** Polyaminopolyether (Methylene PA)
7	**Na PAA**
8	**Na polyaspartate & iminodisuccinate**
9	**Versaflex One (Maleic copolymer)**
10	**Versaflex Si (MA/SA)**
11	**AR 540 (AA/COPS)**
12	**Cu salts**
13	**Zn salts**

No	Typical pool of antiscalent formulatory chemistries to draw from in producing formulated products
14	**Acumer 3100**
15	**Acumer 5000**
16	**Pluronic 6100 (EO/PO block copolymer)**
17	**PMA**
18	**PCA**
19	**BHMT**
20	**EDTMP** Ethylenediaminetetra (Methylene PA)
21	**PESA**
22	**POCA/PCA**
23	**PSO** Phosphinosuccinic oligomer
24	**AA/AMPS**
25	**PAMAM dendrimer** Polyamidoamine

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TREATMENT FOR REVERSE OSMOSIS-FOULING

- RO ANTISCALENTS: RULES OF THUMB:
- Commonest antiscalents are simple formulas based on phosphonates (ATMP and/or HEDP s) or polymers, e.g. 2000 MW PAA or 800 MW PMA (with/without a dispersant such as 5000 MW PAA or AA/AMPS, to counter low MW of PMA)
- DTPMPA has better scale and corrosion inhibition effect than almost all other phosphonates at high pH and temperatures
- PAPEMP is effective in stabilizing silica, zinc, manganese, iron (II) or iron (III).
- Combos of ATMP + DTMPM are known for beneficial effect on $CaSO_4$ & $BaSO_4$
- Blends of phosphonates have stronger stabilization effect than single chemistries
- Al in the water (overfeed of alum?) needs special approach as it tends to deactivate most polymers and reacts as a coagulant to accelerate silica pptn.
- ATMP performs poorly with Al, forming an insoluble complex. HEDP/DTPMP combinations perform much better.
- HEDP has poor tolerance for calcium salts –dilue instantly using injection quill
- EDTMP shows better antiscaling control effects to $CaSO_4$/$BaSO_4$

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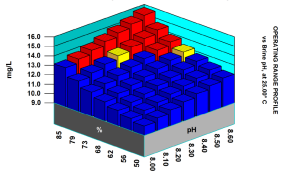
WE CAN USE FRENCH CREEK SOFTWARE FOR PREDICTIVE RO MODELING

Figure 6
PAA 30 (Residual in Brine)



NOTE: Antiscalents for drinking water: NSF most usually assigns 8 ppm as being the maximum concentration of a 50-60% phosphonate or polymer permitted in the feed water to an RO. Dilutions can have proportionally higher permitted concentrations.

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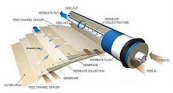
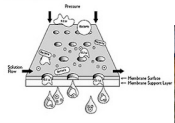
WHEN DOES AN RO SYSTEM NEED CLEANING?

Cleaning can be predicted by:





- *Loss of 10 to 15% in Normalized Permeate Flow*
- *Increase of 10-15% in Normalized Differential Pressure*
- *Decrease in 1-2% Salt Rejection*

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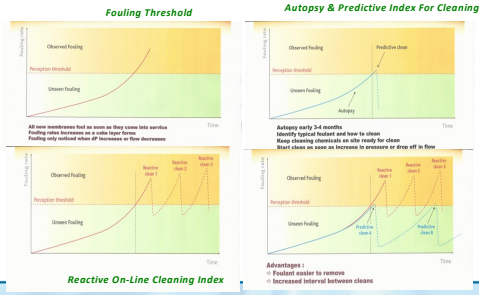
OPERATING DATA CAN BE USED FOR PREDICTIVE CLEANING & AUTOPSY



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RO SYSTEM CLEANING: CIP

Even With Proper Chemical Treatment Periodic CIP Cleanings Are Needed

- Acid Clean Membranes every 3-6 months or as needed
- Caustic Clean to remove Organics
- Biocides and Surfactants for microbio
- Chelating Agents for Special Circumstances

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RO CLEANING FORMULATIONS AND GUIDELINES

Basic Acid Cleaners:

1. *2% Citric acid: Mild cleaner @ pH3-4, for $CaCO_3$/metal oxides/hydroxides & inorganic colloids*
2. *0.5% Phosphoric acid: Mild cleaner @ pH 1-2 – same purpose as Citric*
3. *0.2-0.5% HCL: Heavier duty cleaner @ ph 1-2 - same purpose as above, but also for Ca/Ba/Sr sulfate scales*
4. *1% $Na_2S_2O_4$ (Sodium hydrosulfite): For removal of metal oxides/ hydroxides. Sodium hydrosulfite (dithionite) is a STRONG reducing agent*

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RO CLEANING FORMULATIONS AND GUIDELINES

Caustic/high pH cleaners:

1. *2% STTP & 0.11% Wiconate 1233L: Medium duty cleaner @ pH 10, for removal of bio-fouling and Natural Organic Materials (NOM) – tannins, lignins, etc. Also: we can use 2% STTP and 0.026% Wiconate 90.*
   - Wiconate 1223L is dodecylbenzene sulfonate (anionic foaming surfactant). Wiconate 90 is the flake version
2. *0.1% NaOH + 0.1% Winconate WAC LA" Heavy duty cleaner @ pH 11.5, for removal of organic colloids, bio-fouling, and NOM. Also, OK for silica.*
   - Wiconate WAC LA is a Sulfuric acid mono-dodecyl ester sodium salt, i.e. sodium lauryl sulfate
3. 0.1% 2Na2CO3.3H2O2 (Sodium percarbonate): heavy duty cleaner. Use as a booster for above formulations and to also remove organic colloids.
   - *Sodium percarbonate is a dry powder adduct of sodium carbonate and hydrogen peroxide (a perhydrate) that slowly decomposes to sodium carbonate and peroxide. It is an oxidizing agent and ingredient in eco-friendly bleach products such as OxiClean and Tide laundry detergent*

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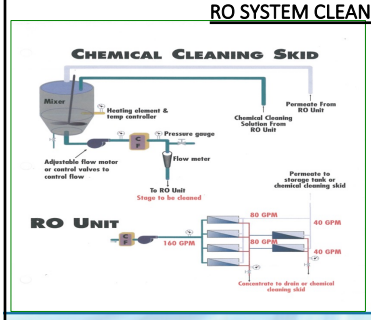
RO SYSTEM CLEANING: CIP



CLAY CLEANERS:

New, powdered high pH clay cleaners tend to provide removal through a combination of detergent and surfactant mechanisms, combined with osmosis from the permeate to the concn. boundary layer – which assists in dislodging particles.

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RO SYSTEM CLEANING: CIP

- It is not unusual to have to use a number of different cleaning chemicals in a specific sequence to achieve the optimum cleaning.
- There are times that a low pH cleaning is used first to remove foulants like mineral scale, followed by a high pH cleaning to remove organic material.
- However, there are times that a high pH cleaning is used first to remove foulants like oil followed by a low pH cleaning.
- Some cleaning solutions have detergents added to aid in the removal of heavy biological and organic debris, while others have a chelating agent like EDTA added to aid in the removal of colloidal material, organic and biological material, and sulfate scale.
- An important thing to remember is that the improper selection of a cleaning chemical or the sequence of chemical introduction can make the foulant worse.

RO Cleaning Tank: *sized to accommodate the displacement of water in the hose, piping, and PVs. Allow 100 % drainage, easy access for chemical introduction and mixing, a recirc. line from the RO Cleaning Pump, proper venting, overflow, and a return line located near the bottom to minimize foam formation when using a surfactant.*

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CIP: TYPICAL CLEANING PROCEDURE

- Clean in place by cleaning one train or stage at a time.
- Heat cleaning water to recommended temperature for the membrane (30-40°C)
- Add caustic soda to elevate the membrane pH to 10 – 11. This opens the pores of the membrane.
- Add cleaning agent and circulate for 10 – 15 minutes.
- Allow cleaning solution to soak for 2 – 8 hours on the membrane.
- Flush out cleaning solution and rinse unit.
- Add acid to remove scale and to firm pores on membrane. Acid required is based on membrane tolerance
- Flush unit and the run permeate to drain for 15 – 30 minutes.
- Sanitize with Biocide if required

• **RO Cleaning Pump:** *Sized to develop the proper crossflow velocity to scrub the membrane clean. The cleaning rate is 30 to 40 gpm for a 8-inch ID PV and 8 to 10 gpm for a 4-inch ID PV. The max. pressure is 60 psi to minimize the production of permeate during cleaning and reduce the convective redeposition of foulant back on to the membrane surface.*
•**RO Cleaning Cartridge Filter:** *Normally 5 to 10-micron and is designed to remove displaced foulants.*

AWT

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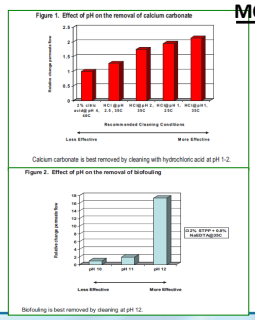
MORE CIP NOTES:



MICRO BUBBLE GENERATOR

Latest RO cleaning technique is to use high foaming, self collapsing, micro-bubbles (0.5μ) to penetrate foulants and assist in cleaning. (As developed by Mitsubishi Electric for parts cleaning).

AWT

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EVEN MORE CIP NOTES:

- ***DIRECT OSMOSIS HIGH SALINITY SOAK CLEANING (DO-HS)***
  A soak cleaning application technique that can replace CIP, by using a slug dose of high salinity cleaner added to the feed water side, to promote permeate to transfer back across the semi-permeable membrane by Forward Osmosis, to dilute the feed salinity, and in doing to so to lift foulants off the outer membrane surface.

Example of a DO-HS product: *A SOLID RO cleaner against biofouling, clay and particles, using direct osmosis cleaning.*

- 12% NaTPP
- 2% Marlon ARL (100% powdered alkylbenzene sulfonate)
- 60% NaCL
- 2% HEDP
- 12% Na_4EDTA
- 12% NaOH

The DO-HS cleaning process sends a pulse of highly concentrated sodium chloride solution into a membrane unit for a duration of typically 10-15 seconds. As the slug of salt solution sweeps across the surface of membrane it temporarily reverses the direction of permeate flow. The reverse flow of permeate lifts foulants from the membrane surface and they are carried out of the membrane system in the concentrate stream.

AWT

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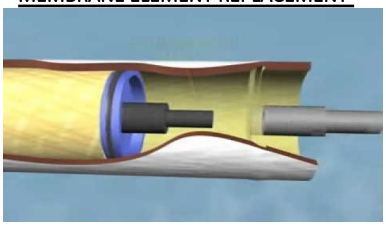
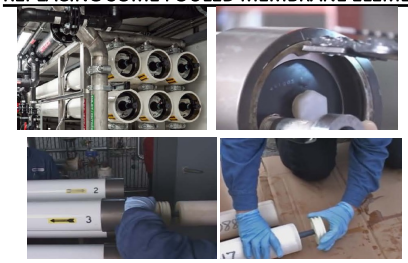
MEMBRANE ELEMENT REPLACEMENT



Sometimes it is better to have spare membrane elements and periodically replace fouled elements, then subject these to long soak time cleaning, or send them away to a specialist cleaning firm!

34

REPLACING SOME FOULED MEMBRANE ELEMENTS



Disconnect the nest of pipes and lines from both sides of an array. Remove the PV end caps. Pull out the line of connected elements (need long floor space) and disconnect the individual elements.

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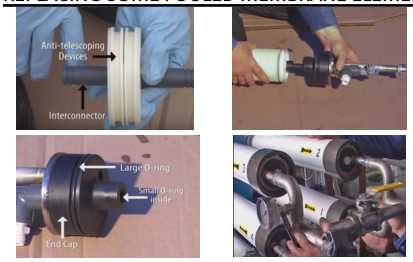
REPLACING SOME FOULED MEMBRANE ELEMENTS



Reverse the order to connect the new elements together. Next, connect the end cap and push the entire assembly into the PV. Ensure the correct "O" rings are used. Finally, replace the pipe nest and the flow lines.

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THERE ARE SPECIALIST FIRMS OUT THERE PROVIDING MEMBRANE CLEANING SERVICES

TWO RO MEMBRANE CLEANING STATIONS WITH HEATERS, CLEANING CHEMICAL ADDITION PORTS, AND SUPPLIES OF PERMEATE FLUSH WATER

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SOME OF GLOBAL VENDORS OF MEMBRANES

- AMFOR (Ande Membrane Sep. Tech,. China)
- Du Pont (USA)
- Filmtec (DOW)
- Fluid Systems (USA)
- Hollosep (Toboyo - Japan)
- Hydranautics (Nitto Denko)
- Keensen Technology (China)
- KOCH (USA)
- Membracon Process Soln. BV (Holland)
- Membralox (ceramics)
- Membrane SRL (Italy)
- Memcor (Australia, Evoqua –was Seimens/USF
- Memstar (Australia)
- Nano H2O (LG – South Korea)
- New Logic Research (V-Sep)
- Osmonics (Suez Environnment – was GE Water)
- Pall (ceramics)
- PCI Membranes (Xylem, USA - was ITT)
- Polymem (France)
- Toray (Japan)
- TriSep Corp. (USA)
- Zenon (Canada –was GE Watyer –now Suez Environnment)

APPLIED MEMBRANES INC.

Membrane Types:

- Aromatic polyamide,
- CA, CPA, CTA, -with/without vinyl acetate,
- Polysulfone, polyether/urea (thin-film composites),
- Sea Water Composite,
- Low Fouling Composite, ESNA (nano), etc.

* CA's are resistant to oxidizers. TFC is not resistant. Other types vary in tolerance to oxidizers!

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GLOBAL VENDORS OF MEMBRANE CHEMISTRIES

- AWC (was called Alkema)
- BWA (Now Italmatch)
- KEMIRA (WITH PALL)
- ARGO SCIENTIFIC (GE BETZ)
- AVISTA (Ex-owners of ARGO. Now owned by Kurita)
- KING LEE
- GENESYS (Now part of H2O Innovation)
- A&W (RHODIA)
- PROFESSIONAL WATER TECHNOLOGIES - PWT (H2O Inovation Group)
- RO CHEMICALS
- ROHM & HASS
- LUBRIZOL/NOVEON
- AKZO NOBEL/ALCO
- TRISEP - and many more, including the membrane manufacturers!

TYPICALLY: INHIBITORS ARE BASED ON AA, HEDP, PMA, PCA, AA/AMPS based polymers, or blends, such as AA/HEDP, or PMA/PCA (e.g. Belgard 2035)

BIOCIDES: BASED ON ISOTHIAZALINONES/ DBNPA/ GLUT. / SILVER

CLEANERS: BASED ON CITRIC ACID/ EDTA/ Na LAURYL SULFATE/ SODIUM BISULFITE

AND THEY MOSTLY HAVE THE SAME CRYSTAL MODIFIER-CHEMISTRIES AVAILABLE FOR SCALE INHIBITORS AND CIP!

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SOME U.S. BASED UF/RO/MBR/EDI SUPPLIERS

- Acciona Aqua (Predesa)
- Advance Equipment & Services
- Aecom
- Aerex Industries
- Agape
- Ampac
- AMPAC
- Aqua Industrial Water BV
- Aqua-Chem
- Aqua-Clear Water Tech
- AquaTech (Part owned by Nalco/Ecolab)
- Argonide
- AWTS Inc.
- Axeon
- Bechtel,
- Biwater
- Black & Veatch
- Carollo EngginersCDM
- CDM Smith
- CH2M Hill
- Consolidated Water Solutions
- Culligan International
- DAICO Water
- Desalitech
- DMP
- Doosan Hydro
- DOW Water
- Evoqua
- FCI Watermakers
- Flexeon
- Fluor
- GE Water & Process
- GEA Engineering
- Grupo ACS
- H2O Innovation
- Halient Tech. (Ed Closuit)
- Harn RO
- Hochtief
- Horizon Water
- HydroTech (Roger Biset)
- RO/ParkerHannefin
- HRE Engineering
- IDE Technologies
- Infilco (GDF Suez/Degremont)
- iWater & Power
- KOCH Membrane Systems
- Kurita
- Layne Christensen
- Lenntech
- LG NanoH2O
- Lifestream
- Marlo
- MECO
- MHW Global
- MPW Industrial Services
- New Logic Research
- Newterra/Crane Environmental/EPRO
- Ovivo (EIMCO)
- Pacific Aqua Technologies
- Pall (Danaher)
- Pentair
- Pure Aqua
- Puretc
- Puronics
- RWL Water (now merged with Fluence, Israel)
- Seven Trent
- Snowpure Water Technologies
- Suez Environnment
- Sumitomo
- Tetra-Tech
- Tonka Equipment Co.
- Toray
- URS Corp
- Veolia
- Watts Water
- Xylem (WET)
- Zincan

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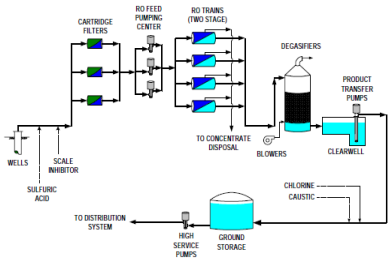
TYPICAL GROUNDWATER RO SYSTEM



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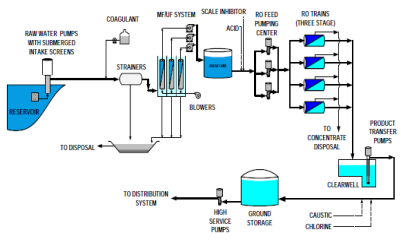
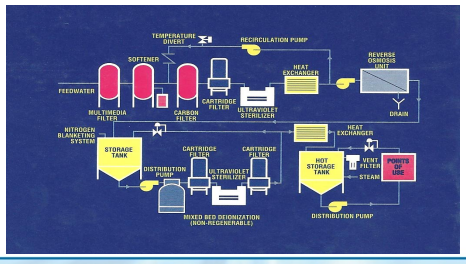
TYPICAL BRACKISH WATER RO SYSTEM



42

COMPLEX RO/MB-SDI ULTRA-PURE SCHEME

- *electronics industry, pharma, utility power, dialysis, etc.*



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EXAMPLE OF TYPICAL STANDARD PLANT RO UNIT: 1

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EXAMPLE OF TYPICAL STANDARD PLANT RO UNIT: 2

EPRO-1500

List Price: $10,493.00 Your Price: $6,995.00 (2023)
Shipping Weight: 160.00 lbs.
Manufacturer: Newterra (Crane Environmental)
Seller: www.cleanwaterstore.com

- *1,500 Gallons Per Day (5.7 m3/day) 1 gpm*
- *Heavy-Duty Commercial Reverse Osmosis System: produces high quality purified water by reverse osmosis thin film (TFC) membrane using a high pressure pump (included).*
- *Uses one 4 x 40 inch membrane.*
- *(Water production rate based on total dissolved solids of 1000 ppm and temperature of 77F 25C).*
- *Designed recovery is 20% ,but can be adjusted if water conditions allow.*
- *Voltage is 220 60hz single phase but 220v 50 hz and three-phase available.*

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EXAMPLE OF TYPICAL STANDARD PLANT RO UNIT: 3

EPRO 21500: Code: **RO000640 (2023)**
List: $71,780.00 Your Price: *$47,853*
Ship Weight: **1125 lbs.** Manufacturer:
Newterra (Crane Environmental)
21,500 GPD, (81.4 M³/day, 15 gpm)
1.5" inlet pipe
14x 4" x 40" membranes
www.CleanWaterStore.com

- **Heavy-Duty Commercial RO System: TFC membranes, using a HP pump. Removes TDS ; Cl; Na; Bo; F; minerals, and other salts.**
- ***10.0 HP heavy-duty SS multistage centrif. pump. (Long life/better performance than std rotary vane pumps.)***
- **White powder-coated steel frame; fiberglass pressure vessels (SS PVs at no extra charge); SS braided hoses; inlet solenoid valve; SS concentrate control valve; pump throttle valve; sample ports for feed/concentrate/ permeate.**
- ***Recycle valve for permeate/conc. control***
- **An excellent electronic control panel package inc UL listed control box with On/Off Switch; low-inlet water protection; function LEDs; and dry-contacts to set up float switches in a storage tank and lock out for pretreatment systems.**
- ***Control box also features contacts for locking out pretreatment filters during backwash, and makes it easy to connect anti-scalant pumps.***

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COST EXAMPLE: 100 GPM BRACKISH WATER RO UNIT:

Quantity	Item	Description	Unit Price	Extension
4.00	CDS-03	CHEMICAL DOSING SYSTEM, 35 GAL TANK, WITH MOUNTED DOSING PUMP, WITH LOW LEVEL CONTROL, INSTALLED	1,425.00	5,700.00
1.00	AFF01	AUTOMATIC FEED WATER FAST FLUSH, DESIGNED TO REMOVE THE MATERIAL DEPOSITED ON THE MEMBRANE SURFACE BY PRECIPITATION, BYPASS OF THE CONC. CONTROL VALVE BY MBV	1,355.00	1,355.00
1.00	CIP01	CLEAN IN-PLACE, TO CLEAN THE SYSTEM'S MEMBRANES WITH A CLEANING STATION INCORPORATED WITHIN THE SAME FRAME, AND HARD PIPED TO THE VESSELS.	6,985.00	6,985.00
1.00	PLC02	PLC OPTION, PROGRAMMABLE LOGIC CONTROLLER WITH SOFTWARE AND PROGRAM, INSTALLED	1,900.00	1,900.00
1.00	PALLET	PALLETIZING AND HANDLING CHARGES MOUNT UNIT ON SKIDS TO SLIDE INTO CONTAINER	550.00	550.00

Subtotal	110,035.00
Sales Tax	
Total	110,035.00

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WHAT ELSE IS SUPPLIED WITH 100 GPM BW RO?

Quantity	Item	Description	Unit Price	Extension
1.00	RO-SYSTEM	REVERSE OSMOSIS SYSTEM, UP TO 100 GPM, WITH ALL STD. COMPONENTS	88,500.00	88,500.00
1.00	PMP/MTR	PUMP/MOTOR COMBINATION, GRUNDFOS CRN32.6/1 or CRN32-6, DEPENDING ON FEED WATER PRESSURE, WITH 460V 60Hz 3Ph, 25HP MOTOR		
1.00	PFH-02	PREFILTER HOUSING, SINGLE/MULTIPLE CARTRIDGE, 316SS, INSTALLED		
2.00	PG-100S	PRESSURE GAUGE, 0-100 PSI, 316SS INTERNALS, 316SS CASE, GLYCERIN FILLED, INSTALLED PRE AND POST FILTER		
1.00	LPS03-3PH	LOW PRESSURE SWITCH, WITH MANUAL RESET, PRESET AT 5 PSI, WITH DIFFERENTIAL LEVEL CONTROL INCLUDED, INSTALLED (FOR 3 Ph MOTORS)		
1.00	HPS01	HIGH PRESSURE SWITCH, WITH MANUAL RESET, ASHCROFT, ADJUSTABLE, INSTALLED		
1.00	REC01	RECYCLE VALVE, INSTALLED (SIZE TO BE DETERMINED), BRASS OR 316SS APLICATION DEPENDANT	705.00	705.00
1.00	FM-02	FLOWMETER, 0 to 999 GPM, DIGITAL, PANEL MOUNT, INSTALLED ON RECYCLE	995.00	995.00
1.00	FM-03	DUAL FLOWMETER, 0 to 999 GPM, DIGITAL, PANEL MOUNT, INSTALLED ON PERMEATE AND CONCENTRATE		
1.00	PH-02	pH MONITOR - CONTROLLER, SIGNET, DIGITAL DISPLAY, PANEL MOUNT, INSTALLED	995.00	995.00
1.00	TDS-03	DUAL CONDUCTIVITY or TDS MONITOR - CONTROLLER, SIGNET, DIGITAL DISPLAY, PANEL MOUNT, INSTALLED ON FEED AND PERMEATE	1,395.00	1,395.00
1.00	ORP-02	ORP MONITOR - CONTROLLER, SIGNET, DIGITAL DISPLAY, PANEL MOUNT, INSTALLED	955.00	955.00

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WHAT WAS BASIS OF DESIGN FOR 100 GPM BW RO?

```
Hydranautics Membrane Solutions Design Software, v. 8.5 (c) 2003      9/2/2011
                              BASIC DESIGN
RO program licensed to: *ROGER BISET
Calculation created by: *ROGER BISET
Project name: AQUASSURANCE, 100GPM      Permeate flow:          144000.00 gpd
HP Pump flow:              153.8 gpm    Raw water flow:          221538.5 gpd
Recommended pump press.: 179.7 psi
Feed pressure:             163.5 psi    Permeate recovery ratio:     65.0 %
Feedwater Temperature:    25.0 C(77F)
Feed water pH:        7.54  (8.00)      Element age:                  3.0 years
Acid dosage, ppm (100%):   0.0 H2SO4    Flux decline % per year:      7.0
Acidified feed CO2:        3.7          Salt passage increase, %/yr: 10.0
Average flux rate:        14.4 gfd      Feed type:          Surface Water

Stage  Perm.  Flow/Vessel  Flux  Beta   Conc.&Throt.   Element     Elem. Array
       Flow   Feed   Conc                Pressures      Type        No.
        gpm   gpm    gpm    gfd          psi   psi
1-1    65.3  51.3   29.5   15.7 1.12    139.6   0.0   CPA2-400     15   3x5
1-2    34.7  44.3   26.9   12.5 1.11    116.7   0.0   CPA2-400     10   2x5

                  CALCULATION OF INVESTMENT AND WATER COST

      Plant capacity, gpd            144000.0   Plant life, years          10.0

      Investment, $                    118,500  Membrane life, years        3.0

      Interest rate, %                     4.5  Membrane cost, $/element   675

      Plant factor, %                     95.0  Number of elements          25

      Power cost, $/kWhr                 0.110  Inhibitor cost, $/lb       1.98

      Power consumption, kwhr/kgal        2.67  Inhibitor dosing, ppm       5.0

      Maintenance (as % of investment)    3.0  Acid cost, $/lb             0.43

                                               Acid dosing, ppm            0.0
```

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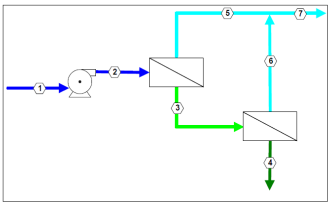
WHAT WAS BASIS OF DESIGN FOR 100 GPM BW RO?

AQUASSURANCE, 100GPM 9/2/2011

TWO STAGE SYSTEM



		1	2	3	4	5	6	7
Flow	gpm	153.8	153.8	88.8	53.8	65.3	34.7	100.0
Pressure	psi	0.0	163.5	139.6	116.7	0.0	0.0	0.0
TDS (ppm)		518.8	518.8	897.1	1466.0	5.9	14.4	8.8

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COST EXAMPLE: 100 GPM EDI UNIT:

Quantity	Item	Description	Unit Price	Extension
1.00	EDI-SYSTEM	ELECTRO DE-IONIZATION SYSTEM, UP TO 100 GPM, WITH ALL STD. COMPONENTS	89,850.00	89,850.00
4.00	FM-01	FLOWMETER, 30GPM, ACRYLIC BLOCK, PANEL MOUNT, INSTALLED WITH FEED VALVE, ONE PER STACK	375.00	1,500.00
1.00	FM-03	DUAL FLOWMETER, 0 to 999 GPM, DIGITAL, PANEL MOUNT, INSTALLED ON FEED AND PERMEATE		
2.00	FM-01	FLOWMETER, XXGPM, ACRYLIC BLOCK, PANEL MOUNT, INSTALLED ON ELECTROLYTE OUTLET AND CONCENTRATE		
1.00	RES-02	RESISTIVITY/CONDUCTIVITY MONITOR - CONTROLLER, SIGNET, DIGITAL DISPLAY, PANEL MOUNT, INSTALLED	855.00	855.00
1.00	PALLET	PALLETIZING AND HANDLING CHARGES	400.00	400.00
			Subtotal	92,605.00
			Sales Tax	
			Total	92,605.00

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EXPLORATORY RO DESIGN EXERCISE

MARLO 2X 35 GPM RO'S

MODEL2X 50 K -8H

+ COMMON CIP

PRETREATMENT:
MANGANESE GREENSAND WITH AIR SCOUR/ KMnO4 & CARBON FILTERS

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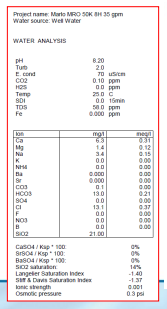
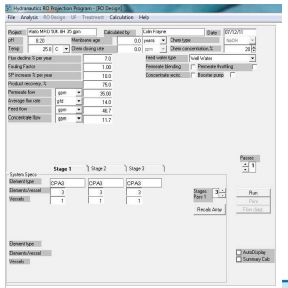
EXPLORATORY RO DESIGN EXERCISE





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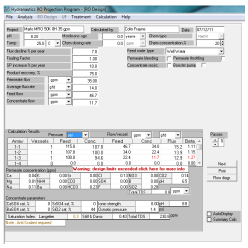
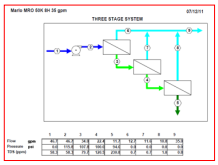
MARLO RO DESIGN EXERCISE





Note in this "What-If?" design exercise, software advises design limits exceeded!

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RO DESIGN CRITERIA AND DECISION MAKING PROCESS GOES WRONG!

HP power boiler + superheaters:
Poor quality well water source

Client's customer decides to go for lowest possible cost and purchased a 2x 35 gpm RO system + Pretreatment equipment. Cost $120K. (Culligan's price was $210K). However:

1. The pretreat plant was too small – it failed!
2. Need for MB polisher was ignored!
3. No condensate polishers installed
4. Several other compounding problems.

Result: severe carryover damage to turbine occurred within 3-4 months! Cost millions!

TAKEAWAY: DON'T DO STUPID STUFF!



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MOST RO-BASED PROJECTS ARE SMALLER AND RELATIVELY EASY DESIGNS, WITH STD. EQUIPMENT




NON-WOVEN FABRIC PLANT, WITH RO QUALITY WATER FOR DILUTION OF SUPER-ABSORBENT CHEMICAL EMPLOYED.

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EXAMPLE OF A FILTRATION/ RO COOLING WATER BLEED REUSE PROJECT (SOCOTEC UK, was OASIS)

- Waterwise Oasis Systems use a combo of macro-filtration, IX and RO to purify effluent/bleed water, enabling typically 60-75% of the water to be recycled as fresh make-up. The recycled/reuse water quality is, at least, equal to the quality of the normal water supply.
- In order for the Oasis System to operate effectively the wastewater must be free of FOG.
- The units are fully automatic in operation and operate with most chemical and non-chemical cooling water treatment methods. Available in skid mounted or free standing, the Oasis can be easily installed in either new builds or retro-fitted into an existing system.The Oasis Water Recycling/reuse system qualifies for "Green Bream" points.
- Commercial Director is Mick Pratt – *a pal of Colin!*


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SAVINGS CALCULATIONS IN THE CW BLEED REUSE PROJECT (OASIS UK)

- Typical 5 mW heat (1400 ton) rejection cooling tower operating at full load of 955 m³/hr & 5.6 ◦C (4,200 gpm & 10 ◦F) will discharge approx 3.6 m3/hr (950 gph) as bleed-off to drain (@ 3.6x COC.)

- At an average annual load of 30%, the bleed-off is 1.08 m³/hr (285 gph) or 25.9 m³/day (6,842 gpd).
- Based on Thames Water current water charges of 168.9p per m³. (i.e.: $8.42/1000 gallon) this equates to £43.77 ($57.33) per day, or £15,976.00 per year ($20,925/yr)
- By recycling 75% of bleed the Oasis System will therefore achieve a saving of £11,980.00 ($15,694) per year in water and effluent costs.
- Capital cost for a plant to recycle this volume of water is £15,000 ($19,650) to £20,000 ($26800), including installation. With an operating cost of less than £2,000 ($2,620) per annum, units will achieve payback in less than 2 years.
- The larger the system the shorter the payback time.

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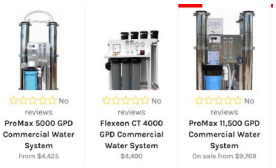
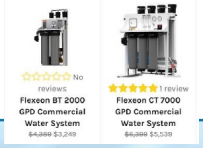
DESIGN YOUR OWN SMALL RO SYSTEM. YOU CAN ALREADY SIZE FILTERS/SOFTENERS! BUY AN RO FROM THE INTERNET, MARLO, AXEON, AGAPE, ETC.



ProMax 5000 GPD Commercial Water System — From $4,425

Flexeon CT 4000 GPD Commercial Water System — $4,400

ProMax 11,500 GPD Commercial Water System — On sale from $9,769



Flexeon BT 2000 GPD Commercial Water System — ~~$4,888~~ $3,249

Flexeon CT 7000 GPD Commercial Water System — ~~$6,888~~ $5,539

RO is one of the most effective ways to remove impurities from water, and have long been used in places like dialysis clinics, restaurants, breweries and commercial buildings. CAPEX varies based on system design. OPEX is usually below $5.00/1,000 gallon

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EXAMPLE OF BLEED/BLOWDOWN WATER RECOVERY SYSTEM, WITH SMART OPERATION SETUP

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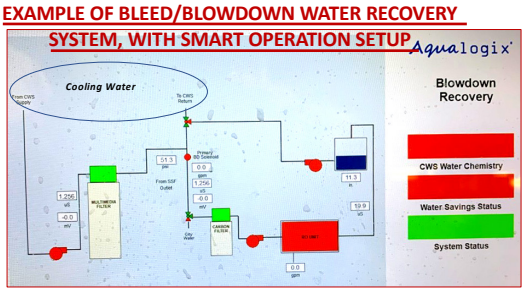
EXAMPLE OF BLEED/BLOWDOWN WATER RECOVERY SYSTEM, WITH SMART OPERATION SETUP



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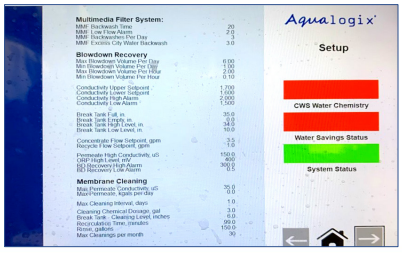
EXAMPLE OF BLEED/BLOWDOWN WATER RECOVERY SYSTEM, WITH SMART OPERATION SETUP



Aqualogix : Cost savings extracted notes	
Partial - Softening	
Gross Water Savings, $	$26,726
Offset Water, $	$1,555
Salt, $	$2,180
Net Savings, $	$22,991
Blowdown Recovery	
Gross Water Savings, $	$19,859
Offset Electric, $	$590
Antiscalant $	$371
Net Savings, $	$18,899
Sidestream Filter	
Electrical Savings, $	$10,209
Offset Water, $	$131
Offset Electric, $	$0
Net Savings, $	$10,078
TOTAL SAVINGS	$51,968

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