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60.000405 Agnico, Meliadine, Nunavut Discharge Project

Aria Fast C60 - Operation Protocol

The following is a recommended protocol for operating the Pall Micro-filtration (MF) System deployed for the above referenced project. Please contact a Pall Service Engineer if changes in the plant performance are experienced.

System Design:

0.62 MGD Net MF Filtrate
Max feed flow at design: 901 Gal/Min
Max filtrate flow at design: 537
Flux = 24 GFD

MF SYSTEM OPERATION PROTOCOL

FLUX MAINTENANCE (FM) PROTOCOL

Flux Maintenance is a frequent cleaning process used to remove solids from the membrane surface mechanically. FM consists of an Air Scrub (AS) followed by a Feed Flush (FL). Air Scrub consists of coarse bubble agitation on the feed side of the membranes within each module while the reverse filtration pump pushes filtrate back through the membranes to the drain. Feed Flush consists of the feed pumps pushing feed through the feed side of the membrane modules to drain.

Volume Interval: 10,500 gallons per rack (350 gallons/module)
Time Interval: not to exceed 60 minutes
Air Scrub Duration: 60 seconds
Air Scrub Air Flow: 90 scfm (3 scfm/module)
Air Scrub Reverse Filtration Flow: 240 gpm (8 gpm/module)

Feed Flush Duration: 20 seconds duration
Feed Flush Flow: 540 gpm (12 gpm/module)
Feed Flush Volume: 180 gallons (6 gallons/module)

**** Note: For systems with a manual rotameter the scaling on FI2 is calibrated to either 90 psig or 0 psig. Refer to air flow meter component manual in the O&M for the corrected flow rate at 30 psig.**

EXCESS RECIRCULATION (XR)

3 gpm/module (approximately 35% of design filtrate flow) XR is recommended during most normal operation. This value may need to be higher depending on the TSS loading to the membranes. High dosages of coagulant will likely require an increase in the XR percentage required.

DIRECT INTEGRITY TEST (IT) PROTOCOL

IT is not programmed to occur automatically on this application. IT may be manually initiated when desired. Pall's Standard Pressure Hold method, which complies with USEPA MFGM guidelines, is used. The calculated system capacity allows for one IT test per rack every 7 days.

ENHANCED FLUX MAINTENANCE (EFM) PROTOCOL

Enhanced Flux Maintenance is a cleaning process that uses relatively dilute chemical solution to reduce the impact of membrane foulants that resist mechanical removal. This allows for longer Clean In Place intervals, less offline time, and reduced chemical consumption overall.

EFM – 2 Part EFM:
Volume Interval: 620,000 gallons of Filtrate produced per rack (1 days at design flow)

NOTE: Prior to circulating CIP solution through the rack, a backwash using RO permeate will be done and the system drained to minimize any residual hardness or other materials that can scale or precipitate at high pH.

Chlorine Solution EFM
1000 ppm Chlorine – 3.1 gallons of 12.5% Sodium Hypochlorite per batch
0.5% caustic – 5.1 gallons of 25% NaOH per batch
CIP Makeup Water (RO Permeate) volume: 390 gallons
Solution Temperature = 35 °C (95°F)
Circulation Time = 30 minutes
Rinses - Two rinses (one rinse with backwash water – RO Permeate & one rinse with MF Filtrate)

Citric Acid Solution EFM
0.25% HCl – 2.0 gallons of 32% HCl
0.5% Citric Acid – 3.1 gallons of 50% Citric Acid
Solution Temperature = 35 °C (95°F)
CIP Makeup Water (RO Permeate) volume: 390 gallons
Circulation Time = 30 minutes
Rinses - Three MF filtrate water rinses

Clean In Place (CIP) Protocol

Clean In Place is a longer duration cleaning process that uses chemical solutions to remove all foulants from the membrane.

Interval: Every 30 days or if the specific flux (permeability) reaches 1.5 gfd/psi; whichever comes first. Do not exceed 30 days regardless of the plant flows, TMP, specific flux, or anything less than written recommendation from the Pall Process Engineer assigned to this project.

STEP 1 - Caustic/Chlorine Wash:
Caustic/Chlorine Solution for CIP
2% Caustic – 20.4 gallons of 50% caustic
3000 ppm NaOCl – 9.4 gallons of 12.5% Sodium Hypochlorite per batch
CIP Makeup Water (RO Permeate) volume: 390 gallons
Solution Temperature = 35 °C (95°F)
Circulation Time = 120 minutes
Rinses - Two rinses (one rinse with backwash water – RO Permeate & one rinse with MF Filtrate)

STEP 2 – Acid Wash:
Citric Acid Solution for CIP
0.25% HCl – 2.0 gallons of 32% HCl
2.0% Citric Acid – 12.6 gallons of 50% Citric Acid
Solution Temperature = 35 °C (95°F)
CIP Makeup Water (RO Permeate) volume: 390 gallons
Circulation Time = 60 minutes
Rinses - Three potable water rinses

General Recipe for CIP:

1. CIP Rack Drain – 10 minutes
2. Caustic Wash on feed side for 120 minutes
3. Caustic Drain/Reclaim – 10 minutes
4. CIP Rack Rinse - Rinse volume following acid CIP step = Two 390 gallon rinses (rack is drained between each rinse)
5. CIP Rack Drain – 10 minutes
6. Acid Wash on feed side for 60 minutes
7. Acid Drain/Reclaim – 10 minutes
8. CIP Rack Rinse - Rinse volume following acid CIP step = Three 390 gallon rinses (rack is drained between each rinse)
9. CIP Rack Drain – 10 minutes
10. Recipe End

Pall Water – Agnico, Meliadine, Nunavut OP Revision History

Revision	Date	Originator	Description
0.0	3/21/18	R. Cormier	Initial Document Release

PALL Agnico

Two 450 GPM Reflex CCRO units

Operation and Maintenance Manual

Date: April 10, 2018

Rev: 1

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1 Safety

1.1 Notes

Electricity, especially high voltage

Work with hazardous chemicals. Obey all related site safety rules and requirements.

High pressure operation. Obey all related site safety rules and requirements.

Rotating equipment area. Obey all related site safety rules and requirements.

High noise environment. Always wear adequate ear protection in this area.

1.2 Instructions

- Operation and Service to the RO system should be done by a trained technician.
- Check the valves position onsite before starting the skids. Ensure that permeate valve HV-03 is open. Never operate against a closed permeate valve. Ensure that HV-07 is set at its marked position (position is marked during commissioning).

2 Introduction

2.1 References

The following table lists all the documents referenced in this manual except for equipment specifications listed under system components chapter.

Number	Description
1.	P&ID
2.	Electrical drawings
3.	GA drawings

For detailed operation, maintenance and troubleshooting instructions for equipment pertaining to the RO skid refer to the manufacturer's documentation for each individual component. This information is supplied as part of the RO system Technical folder in the following web address:
https://www.dropbox.com/sh/ubre38zfcjryo5a/AAB_-JML8wnRwpOVKKv9St5la?dl=0

2.2 Purpose of the RO system

The RO system separates water from its dissolved salts via a semi-permeable barrier (membrane), under high pressure, producing a low salinity stream (permeate) and a high salinity stream (brine).

3 System Overview

The system comprises of two independent CCRO units with independent CIP systems. Each CCRO unit is capable of producing up to 450 gpm of permeate water at the highest recovery possible by water chemistry and pressure limitation of the system. CCRO units are fully automatic and controlled by a PLC and HMI located on a control panel. The CCRO system can be controlled remotely using a VNC and includes online process monitoring using a cellular modem and a cloud-based data logging service call RealiteQ (explained in chapter 20).

Each CCRO system includes the following tie-in point connections (Figure 1A and 1B): Feed (A1 - 8"), Brine (B1 - 6"), Permeate (C1 - 4"), Pressurized Air (K - 3/8"), Permeate flush/CIP inlet (E1 - 8"), Permeate to CIP (F1 - 4"), Brine to CIP (G1 – 6"), Drain Outlets (N1, N2 - 2").

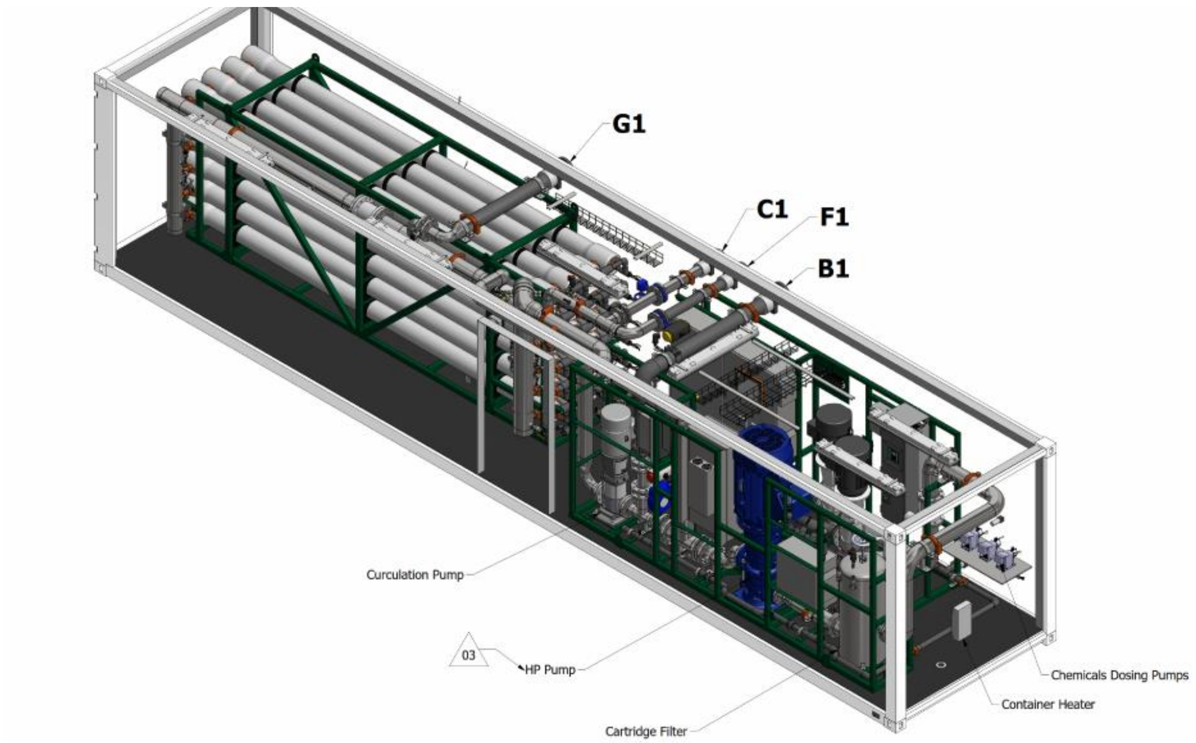


Figure 1A – Containerized CCRO system GA drawing, container entrance

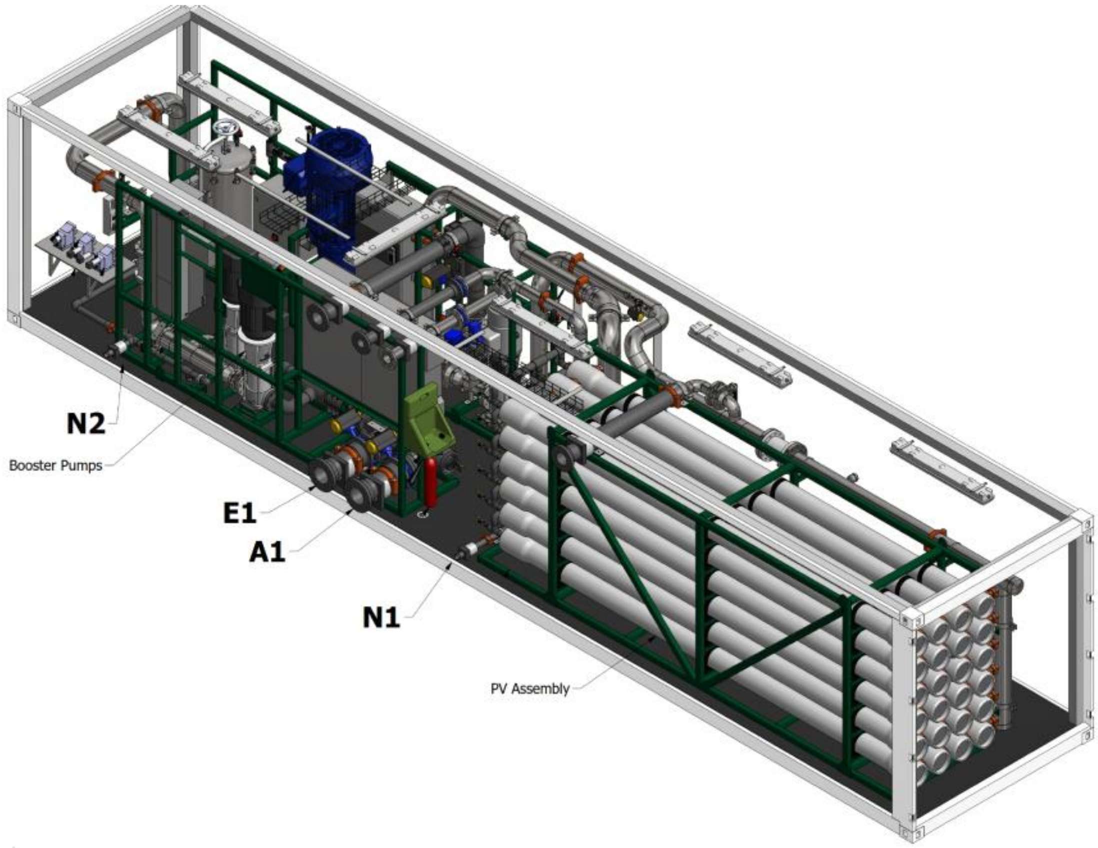


Figure 2B – Containerized CCRO system GA drawing, container back

Closed Circuit Reverse Osmosis (CCRO) technology is a batch process by which each RO unit alternates between cycles of closed circuit (CC) and plug flow (PF) operation. In CC operation brine is fully recirculated to the feed end of the pressure vessels by a circulation pump. In PF operation the brine valve opens, forcing concentrated brine to leave the system while introducing fresh feedwater into the system for the next operating cycle. Detailed explanation about CC and PF operation is given in chapter 5.

Chemicals added to the RO: the following chemicals can be injected to the RO feed:

1. Scale inhibitor is injected to prevent scaling.
   Antiscalant Product: AVISTA VITEC 4000
   Antiscalant Dosage: 3.5 ppm
2. Acid/Base is injected to RO feed to adjust the pH.
   Product and concentration: H_2SO_4 97%
3. SBS is injected constantly as a chlorine scavenger to keep ORP level below 250mV.
   Product and concentration: Sodium Bisulfite 10%

SDS files should be sourced from the chemical vendor upon selection of required chemicals.

4 System installation

The installation of the RO unit involves the following steps:

- Locating the unit per site layout.
- Connecting the following tie in points:
  - Feed
  - Brine
  - Permeate
  - Drain
  - CIP
  - Compressed Air (80psi minimum)
- Connect Power supply to load panel (see electrical drawings for more info)
- Connect external Inputs/Outputs (see P&ID and electrical drawings for more info)
- Locate chemical storage tanks at designated location per GA drawings and prepare the chemical solution required.
- Connect Dosing pumps suction to storage tanks.
- Connect Dosing pumps discharge to injection point's location.

Following the installation, the system must be commissioned by a CCRO specialist to ensure that the settings are properly tailored to the application prior to operation.

5 CCRO process description

CCRO operates by alternating between PF and CC operational modes. Figure 2 below shows the two different modes.

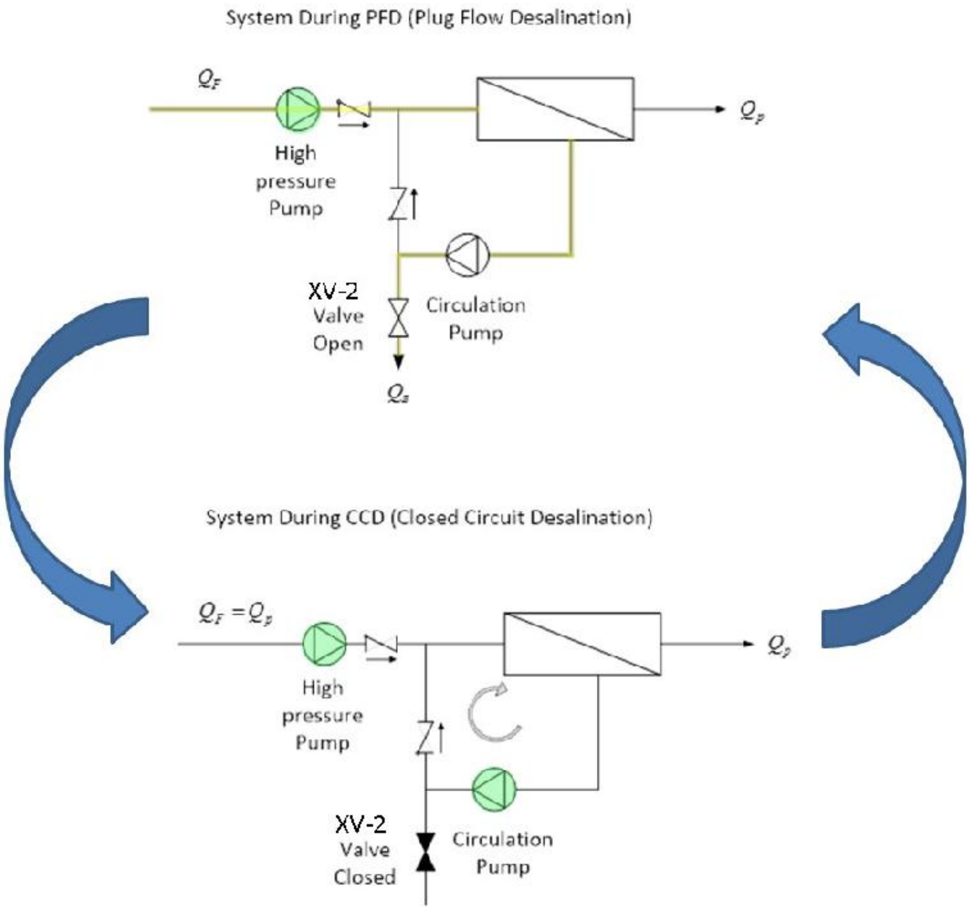


Figure 3 - CCD/PFD operation cycle

When the RO system goes to PF, the brine valve opens and concentrate leaves the system. When the RO system goes to CC, the brine valve closes and concentrate is fully recirculated.

During PF, water flows through the membranes and out the discharge valve XV-2, while a check valve prevents the flow from bypassing the membranes. A manual valve in-line with XV-2 applies some backpressure, and the more backpressure applied, the greater the PFD module recovery. All the water that leaves the membranes as brine is counted by a flowmeter, and when a volume of water equal to that of the system volume has passed, the brine valve closes and the system goes into CC cycle operation.

During CC mode, the concentrate stream leaving the membranes is fully recirculated back to the inlet to mix with the fresh feedwater before entering the membranes again. The concentrate flow rate can be changed, but typically is set to the same flowrate as the feed flowrate during CC.

The transition from CC back to PF occurs when one of the three control setpoints selected by the customer is achieved. These include after a certain pressure has been reached at the inlet to the membranes or after a total volumetric recovery has been achieved. Once either of these triggers is reached, the brine valve (XV-2) opens again and the system operates in PF as described above.

During CC operation ions rejected by the membrane are accumulated inside the closed system volume (circulation loop). As a result the osmotic pressure of the water increases and more pressure is required maintain a constant permeate flow across the membranes. The P-2 high pressure pump speed is controlled using a VFD to ensure this.

Because salt accumulates in the concentrate during CC operation, the permeate produced during CC gradually increases in conductivity until the cycle ends. Then when PF first begins, the highest permeate conductivity values will be observed, because the membranes are still full of the most concentrated water, and because the permeate flux is lower in PF than it is in CC. However, the contribution of the permeate conductivity produced during PF to the average permeate conductivity is low due to its low total volume.

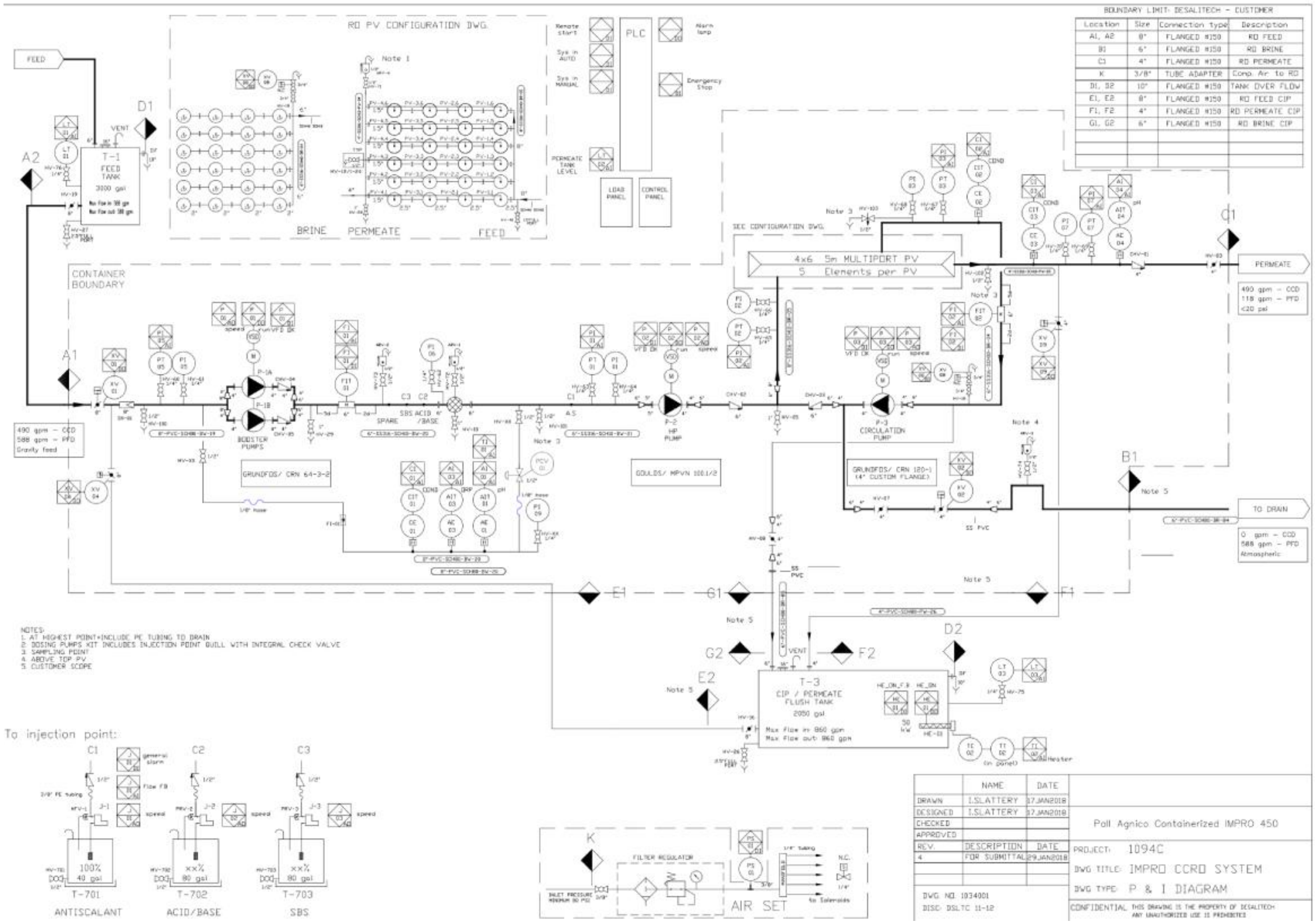
<u>Role of circulation pump</u>: This pump creates the cross flow required for the RO process. Without it there will be no cross flow and the process will be a like a dead end filtration which is impossible to sustain in RO due to the phenomenon of concentration polarization on the membrane surface.

<u>Recovery calculation during a cycle</u>:

The recovery in CCRO cannot be calculated as a simple ratio of permeate to feed flow rates because it is not a steady state process as a traditional RO process.

Instead, total Volumetric Recovery (%VR) is calculated over a complete CCD+PFD cycle and it is equal (by definition) to permeate volume produced divided by total feed consumed. The counters used for this calculation are set to zero at the start of each PFD step.

6 P&ID drawing



6.1 Important process measurements:

- Low pressure feed line:
  - FIT-1: magnetic flow meter. This flow meter measure the inlet flow rate to the skid.
    It has two signals: an analog 4-20mA signal and a digital signal. The analog signal is used for PID loop control and the digital pulse signal is used to communicate every unit of water that passes the meter for the %volumetric recovery calculation. Both signals are critical for system operation.
  - PT-1: This analog 4-20mA pressure transmitter is located upstream the high pressure pump and is used to protect it from dry running or vacuum condition at pump suction.
  - PT-6: This analog 4-20mA pressure transmitter is located upstream the Micronic filter and is used for the calculation of pressure differential over the micronic filters by calculating the value of PT-6 minus the value of PT-1.
  - TE-1 (TT-1): This analog 4-20mA temperature sensor is located downstream the Micronic filter on the pH probe.
  - CE-1 (CIT-1): This analog 4-20mA conductivity sensor is located downstream the Micronic filter.
  - AE-3 (AIT-3): This analog 4-20mA ORP sensor is located downstream the Micronic filter. It is used to monitor and control ORP level of the feed water.
  - AE-1 (AIT-1): This analog 4-20mA pH sensor is located downstream the Micronic filter. It is used to monitor and control pH level of the feed water.
- High pressure loop:
  - FIT-2: magnetic flow meter. This flow meter measure the concentrate flow rate.
    It has two signals: an analog 4-20mA signal and a digital signal. The analog signal is used for PID loop control and the digital digital pulse signal is used to communicate every unit of water that passes the meter for the %volumetric recovery calculation as well as for volume count during PFD, Power up and Shutdown Flush steps. Both signals are critical for system operation.
  - CE-2 (CIT-2): This analog 4-20mA conductivity sensor is located on the concentrate line downstream of the membranes and upstream of P-3. It is used to measure the brine conductivity.
  - PT-2: This analog 4-20mA pressure transmitter is located on the feed to the pressure vessels. Monitor inlet pressure to membranes.
  - PT-3: This analog 4-20mA pressure transmitter is located on the exit from the pressure vessels.
  - PT-2, PT-3 are used to calculate the pressure differential on the membranes.
- Permeate line:
  - FIT-3: magnetic flow meter. This flow meter measures the permeate flow rate from the skid.
    It has two signals: an analog 4-20mA signal and a digital signal. Neither signal is used to control the system.
  - CE-3 (CIT-3): This analog 4-20mA conductivity sensor is located on the permeate header downstream the permeate manifold. It is used to measure the momentary average permeate conductivity from all vessels.
- Pressurized Air line
  - PS-01: Pressure switch. Set to be on at 80psi and off at 75psi. When signal is off an alarm will be triggered. Theses set points should not be changed since the actuators have been sized based on 80psi.

7 Main system components

Soft copy of all specifications, equipment/instrumentation datasheet and manuals are available in the following link:
https://www.dropbox.com/sh/ubre38zfcjryo5a/AAB_-JML8wnRwpOVKKv9St5la?dl=0

General equipment list per CCRO Train

Tag No.	Qty.	Service	Mfg.	Part number
F-1	1	RO SKID Micronic Filter Housing	Filtrek	S6GL20-040-3-6F-150-FB
-	40	RO SKID Micronic Filter 1 micron	Filtrek	KG- 1 - 40 - E5 – BN
-	24	Pressure vessels package	Protec	PRO-8-450-SP-5
-	-	Painted CS Victaulic Connectors	SCI	-

Pumps list

Tag No.	Qty.	Service	Power [hp]	Manufacturer	Part number
P-1	2	Booster pump	50	Grundfos	CRN_64-3-2_A-G-G-V-HQQE
P-2	1	High pressure pump	150	Goulds	MPV100A-02ADRS-0150TNF26F-CCC4
P-3	1	Circulation pump	25	Grundfos	CRN120-1 I-G-G-E-HQQE

Valves list (Main valves)

Tag No.	Description	Size	Materials	Valve Type	Model
XV-1	Pneumatic valve	8”	SS316	Butterfly Valve	Sharpe / Series 17 (Double Acting)
XV-4	Pneumatic valve	8”	SS316	Butterfly Valve	Sharpe / Series 17 (Double Acting)
XV-2	Pneumatic valve	4”	SS316	Butterfly Valve	Bray / Series 43 (Double Acting)
XV-8	Pneumatic valve	3/4”	SS316	Ball Valve	Sharpe / Series 84 (Double Acting)
XV-9	Pneumatic valve	4”	SS316	Butterfly Valve	Sharpe / Series 17 (Double Acting)
HV-7	Hand valve	4”	SS316	Butterfly Valve	Bray / Series 43
HV-8	Hand valve	4”	SS316	Butterfly Valve	Bray / Series 43
HV-10	Hand valve	1”	SS316	Ball Valve	Sharpe / Series 58876
HV-5	Hand valve	1”	SS316	Ball Valve	Sharpe / Series 58876
HV-26	Hand valve	2.5”	SS316	Ball Valve	Sharpe / Series 50M76
HV-27	Hand valve	2.5”	SS316	Ball Valve	Sharpe / Series 50M76
HV-103	Hand valve	1/2”	SS316	Needle Valve	Inline 908
HV-12/1-10	Hand valve	1/2”	SS316	Ball Valve	Parker
CHV-1	Check valve	4”	SS316	Swing Check valve	Bray / Check Rite
CHV-2	Check valve	6”	SS316	Swing Check valve	Bray / Check Rite
CHV-3	Check valve	6”	SS316	Swing Check valve	Bray / Check Rite
CHV-4	Check valve	4”	SS316	Swing Check valve	Bray / Check Rite
CHV-5	Check valve	4”	SS316	Swing Check valve	Bray / Check Rite
ARV-1	Air release valve	1/2”	Nylon	V. Breaker	A.R.I / D-040 Nylon
ARV-2	Air release valve	1/2”	Nylon	V. Breaker	A.R.I / D-040 Nylon
ARV-3	Air release valve	1/2”	Nylon	V. Breaker	A.R.I / D-040 Nylon
ARV-4	Air release valve	1/2”	Nylon	V. HOLDER	A.R.I / D-40V Nylon

Instruments list

Tag No.	Size	Manufacturer	Part number
FIT-1	6”	ABB	FEP311.150.A.1.D.1.A1.B.0.A.1.A.0.A.1.B.4.C.1.B..H1....M5
FIT-2	6”	ABB	FEP321.150.A.1.D.1.A3.B.0.A.1.A.0.A.1.B.4.C.1.B..H1....M5
PT-1	1/4”	BD SENSOR	17.600G-1002-R-1-5-100- N402-000
PT-2	1/4”	BD SENSOR	17.600G-4002-R-1-5-100- N402-000
PT-3	1/4”	BD SENSOR	17.600G-4002-R-1-5-100- N402-000
PT-5	1/4”	BD SENSOR	17.600G-1002-R-1-5-100- N402-000
PT-7	1/4”	BD SENSOR	17.600G-6001-R-1-5-100- N402-000
PI-1	1/4”	Dywer	SGZ-D10622N GF
PI-2	1/4”	Dywer	SGZ-D11122N GF
PI-3	1/4”	Dywer	SGZ-D11122N GF
PI-5	1/4”	Dywer	SGZ-D10622N GF
PI-6	1/4”	Dywer	SGZ-D10622N GF
PI-7	1/4”	Dywer	SGZ-D10422N GF
PS-01	1/8"	KITA	-
CIT-1	1”	ABB	AC21-1/4-41341
CIT-2	1”	ASTI	AST41-2.0-1000-30-TL-JB
CIT-3	3/4”	ABB	AC22-1/2-31341
AIT-1	1”	ABB	AP30.1/2.1.0.0.1.12.1
AIT-3	1”	ABB	AP30.1/5.0.0.0.1.12.1
AIT-4	1”	ABB	AP30.1/2.1.0.0.1.12.1
Analyzers	-	ABB	AX411-50101/AX466-50101

Main control elements*:

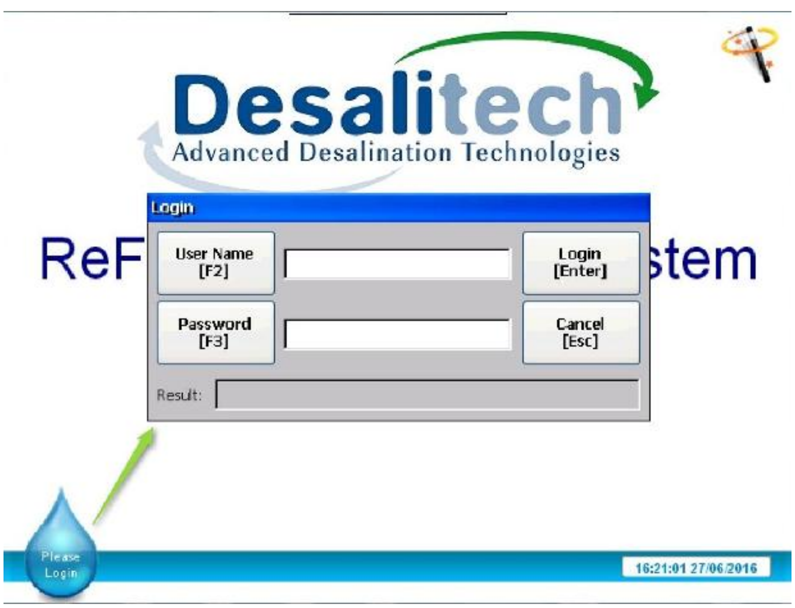
- PLC: Allen-Bradley CompactLogix 1769-L33ER
- HMI: Allen-Bradley 2711P-T10C4D8 - PanelView Plus 6 (10”)
- Digital and Analog IO cards.
- Application dedicated ladder software.
- Realiteq - iCex device and Cellular modem for GPRS communication. Used for data logging, trending and report system.
- eWon. Used for remote control of HMI. Allows remote software updates.

* For more details see electrical drawings

8 HMI screens overview

8.1 Main screen:

Main screen is the first screen that appears after turning the control panel power on. This screen allows the user to login as an operator (view only permission), as a manager (full permission) or as an admin (full permission plus system configuration permissions), depending on the password given.



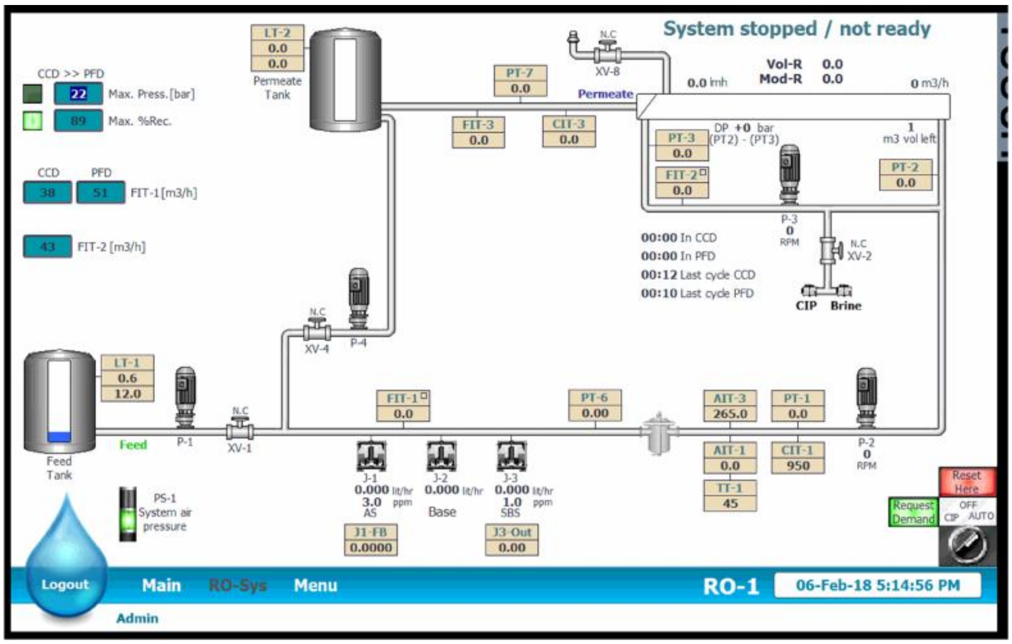
For passwords related to each authentication level please contact Desalitech.

8.2 RO-Sys Screen (Process Screen)

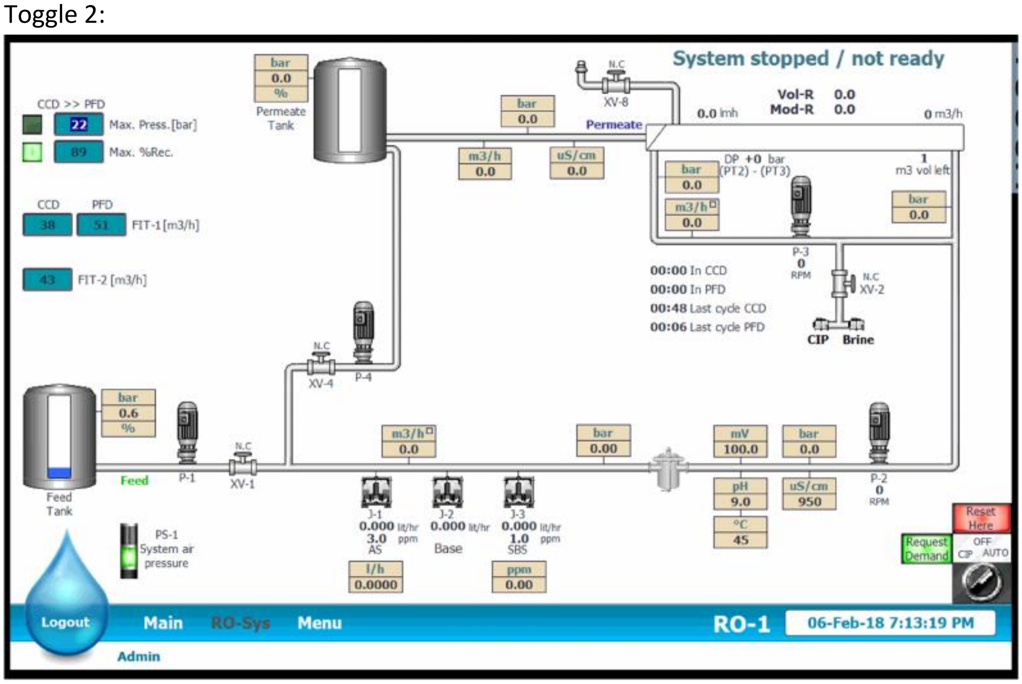
Once an RO unit is selected the HMI goes directly into its process screen – “RO-Sys”. This process screen shows process schematics and all the data required to monitor the RO system operation.

The instrument blocks shown in this screen toggle between their tag and their unit of measurement. The two figures below illustrate this.

Toggle 1:



Toggle 2:



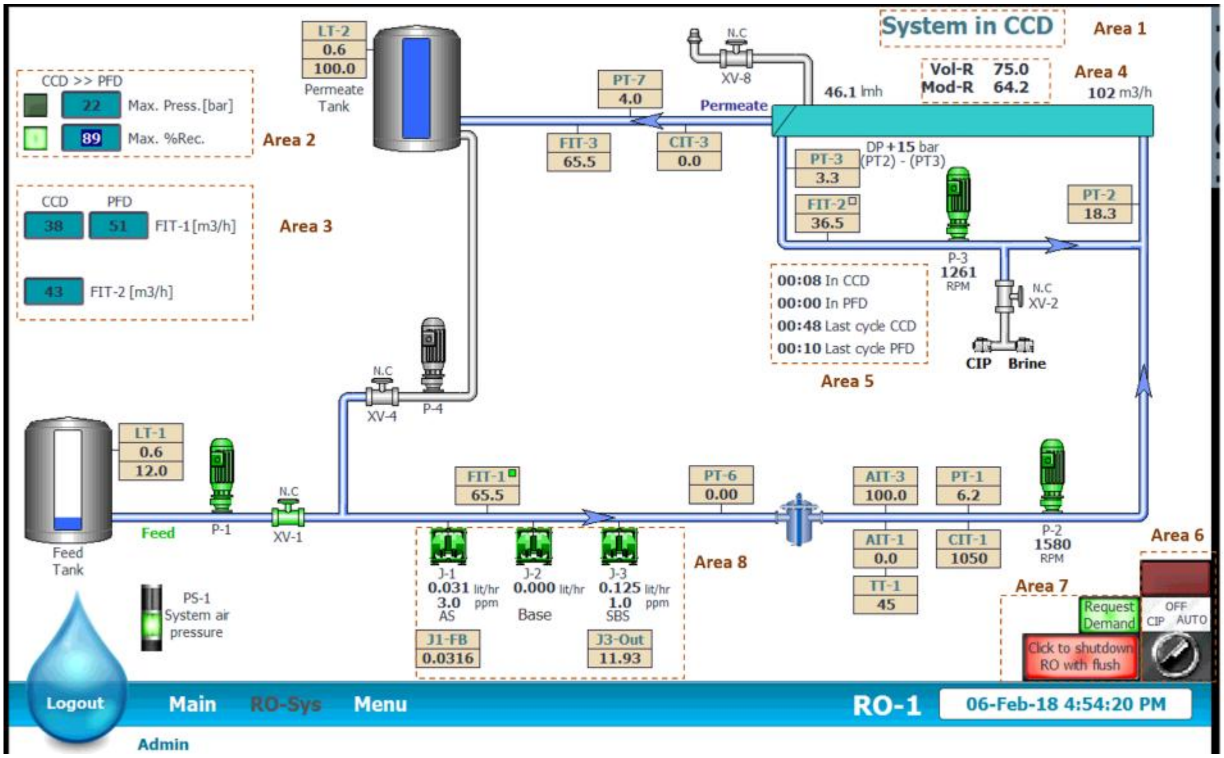
The RO system screen shows all the pumps and valves in the system, as well as the flow paths of water moving through the system. These three types of components change color on the HMI to indicate their current state, generally when they are active, inactive or faulting. The table below shows how to interpret the colors of each of the different components.

	Green	Grey	Red	Blue
Valve	Valve is Open	Valve is Closed	N/A	N/A
Pump	Pump is Running	Pump is Off	Pump Fault	N/A
Line	N/A	No water flow	N/A	Water flow/pressure

Every component in the CCRO unit that sends and receives signals from the PLC has its own tag number. Each tag number includes a letter combination followed by a number. The letter combination indicates the type of instrument, and the number combination includes its identity. The tag numbers for each instrument on each CCRO are the same to indicate the same type of service on each CCRO. The table below identifies the specific tag numbers used for the Agnico Systems.

	Tag Meaning	Specific Tag Service			
LT	Level Transmitter	LT-1	Feed Tank Level (off skid)	LT-2 LT-3	Permeate Tank Level (off skid) CIP Tank Level
CIT	Conductivity Transmitter	CIT-1 CIT -2	Feed Brine	CIT-3	Permeate
FIT	Flow Transmitter	FIT-1	Feed	FIT-2	Brine
PT	Pressure Transmitter	PT-1 PT-2 PT-3	P-2 suction Membrane Inlet Membrane Outlet	PT-5 PT-7	P-2 suction Permeate
AIT	pH/ORP Transmitter	AIT-1	Feed pH	AIT-3 AIT-4	Feed ORP Permeate PH
TT	Temperature Transmitter	TT-1	Feed Temp		
P	Process Pump	P-1 P-2	Booster Pump High Pressure Pump	P-3	Circulation Pump
J	Dosing Pump	J-1 J-2	Antiscalant Acid	J-3	Sodium Bisulfite
XV	On/off Valve	XV-1 XV-2	Feed Inlet Brine Discharge	XV-4 XV-8 XV-9	Permeate Flush Air Purge Permeate to CIP

The figure on the next page shows RO system screen for a typical CCRO system. The operator can generally interact with the RO to change values or activate system components by tapping on the value or component. Some key areas of the screen are marked on the figure and described in the following table.



HMI Section	
Area 1	Shows the current RO sequence, as described in Section 9 (Sequence of Operation).
Area 2	The selection here determines what membrane inlet pressure and what overall water recovery triggers the system to switch from CC to PF operation. Tapping on the left square lets the operator choose to activate (green) or deactivate (grey) each trigger (pressure or recovery), and tapping on the box with numbers allows the operator to change the setpoint value. One or both triggers can be active at a time.
Area 3	This section allows the operator to set the values for feed flow, P-2 suction pressure and recirculation flow during CC and PF modes.
Area 4	This area describes the instantaneous module and cumulative volumetric recovery for the current cycle. The module recovery is the ratio of the permeate produced over the feed entering the membranes. The volumetric recovery is the ratio of the total water produced during the current cycle divided by the total water feed to the RO during the current cycle.
Area 5	This area of the HMI displays how long the system spent in CC and PF for the current and last cycle. As time passes the counter for the the current counts up until the trigger set in Area 2 is achieved, at which point the value is stored as the “last cycle” parameter.
Area 6	This area shows a red box and a mirror of the three-position switch on the panel. The red box will remain inactive when no alarm is active, and will flash with the words “Reset Here” when the alarm is active. Pressing on the box will deactivate any current alarms, and will allow the system to begin to produce water. The other graphic only mirrors the position of the physical switch on the panel mentioned in section 9.1. The position cannot be changed by interacting with the HMI. It’s main purpose is to inform someone viewing the HMI remotely what state the selector is in. 
Area 7	There are two buttons here. The red one allows the user to initiate a shutdown flush and bring the system to a stop. This should be done before performing any maintenance activity to ensure the RO is sufficiently flushed.

	The green button is an HMI switch that acts as a permissive which allows the system to proceed past the system ready state. When this button is lit and the physical switch is set to auto, the system will produce water according the tank level setpoints. When unlit, the system will pause at the system ready state.
Area 8	This section shows information about the dosing rates of the chemical dosing pumps.

Alarm indication:

When an alarm is triggered a window pops up on the bottom of the screen with an alarm message, an example shown in the figure above. The user has four options when this alarm message shows up. Clicking on any of these buttons removes the alarm pop-up screen from the HMI.

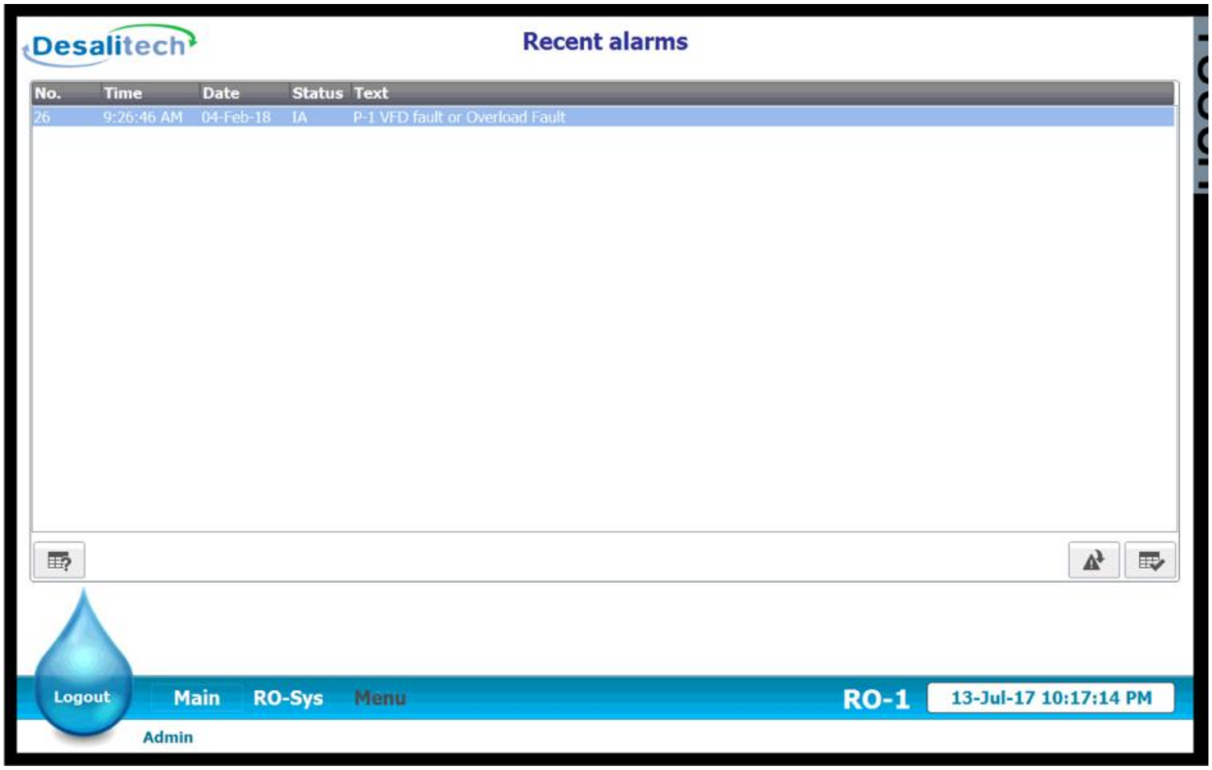
Button	Function
Ack Alarm (Acknowledge)	Allows the user to indicate in the alarm history that the alarm has been seen.
Silence Alarms	Allows the user to silence alarms, which overrides the specific alarms selected and prevents them from shutting down the system. This is visible during Admin access only.
Clear Alarm	Allows the user to clear the alarm from the alarm history screen of the HMI
Close	Closes the alarm pop-up without performing any of the other three functions.

8.3 Menu screen:

This screen provides links to the following sub menus:

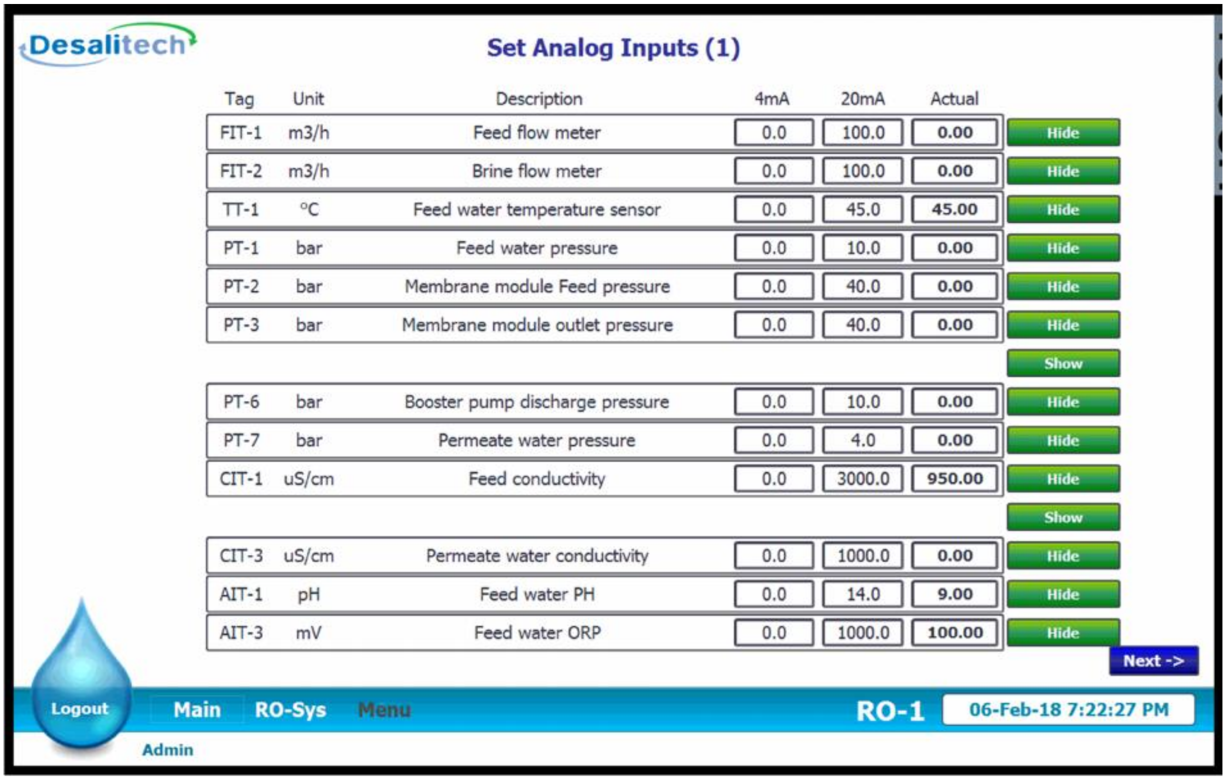
<table>
<tr><th>Sub Menu</th><th>Operator</th><th>Manager</th><th>Admin</th></tr>
<tr><td>Alarms list</td><td>View only</td><td>Read/Write</td><td rowspan="9">Full permission</td></tr>
<tr><td>Set Analog</td><td>View only</td><td>Read/Write</td></tr>
<tr><td>Trends</td><td>View only</td><td>Read/Write</td></tr>
<tr><td>Totalizers</td><td>View only</td><td>Read/Write</td></tr>
<tr><td>Din/Dout</td><td>View only</td><td>Read/Write</td></tr>
<tr><td>System Parameters</td><td>View only</td><td>Read/Write</td></tr>
<tr><td>HMI config</td><td>Not accessible</td><td>Not accessible</td></tr>
<tr><td>F-Factor</td><td>View only</td><td>Read/Write</td></tr>
<tr><td>Alarms D/E</td><td>Not accessible</td><td>Not accessible</td></tr>
<tr><td>Shutdown Runtime Application</td><td>Not accessible</td><td>Not accessible</td><td>Allows HMI software to be reset</td></tr>
</table>

Alarms list:



This screen stores the history of the recent alarms with their description, time stamp and status.

Set analog inputs:

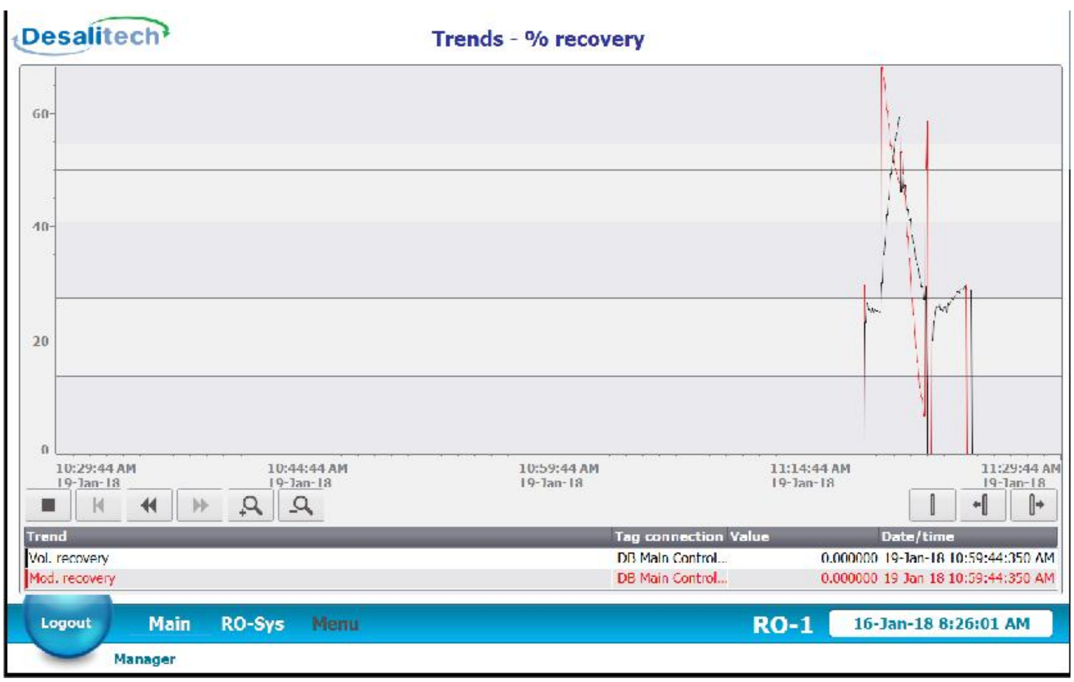


These screens define the engineering units of 4mA and 20mA for each analog instrument. The PLC range has to match range of the instrument. In case an instrument has to be replaced the new instrument has to be configured to match the PLC range. If a fixed range instrument like a pressure transmitter is replaced and has a different range than the original instrument, then the HMI range has to be modified according to instrument fixed range.

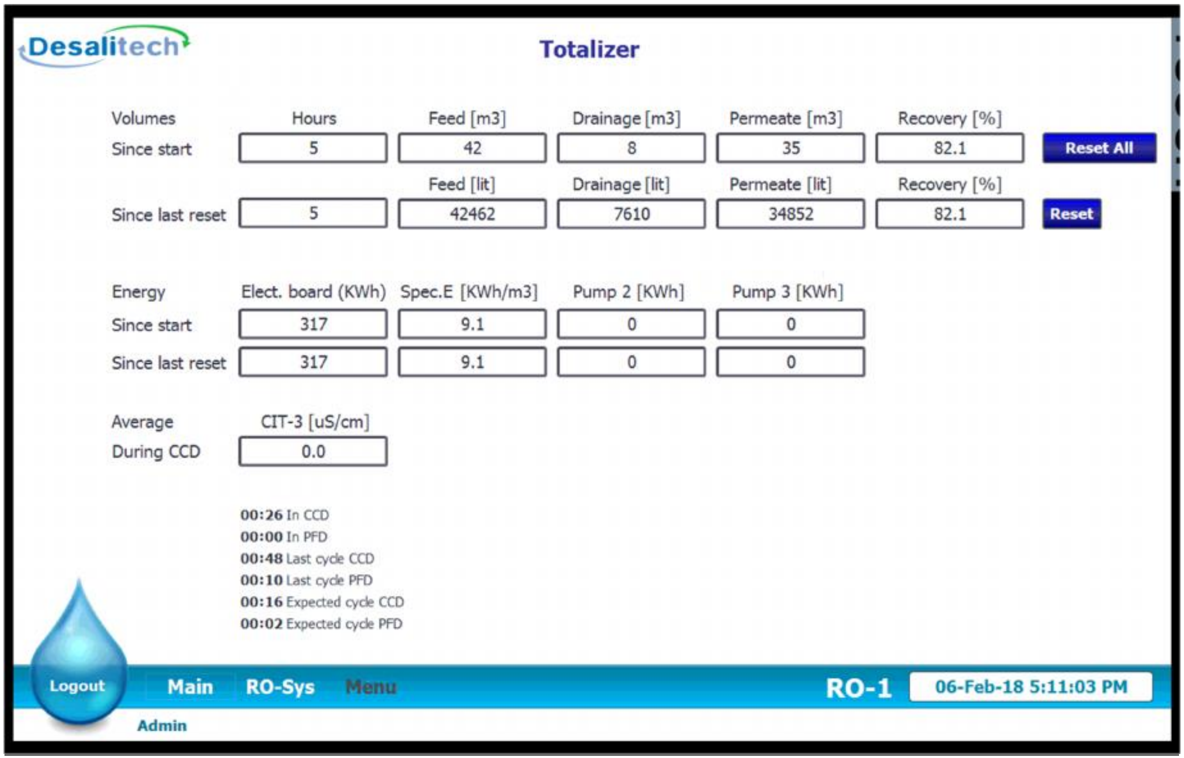
There is a standard order that instruments appear on the screen. An admin can show or hide any of these setpoints, as well as adjust the range for each instrument, according to the site requirements and specifics of the design. Any gaps in the table indicate an instrument that was not selected in the site-specific model.

System Trends:

This screen includes links to trending graphs of several process parameters. The trends appear as line graphs, which can be manipulated using the buttons at the bottom of the screen.



Totalizers:



This screen provides data about total Feed, Drainage and Permeate volumes collected since start and since last reset. Recovery is calculated accordingly. Energy and specific energy consumptions are also included.

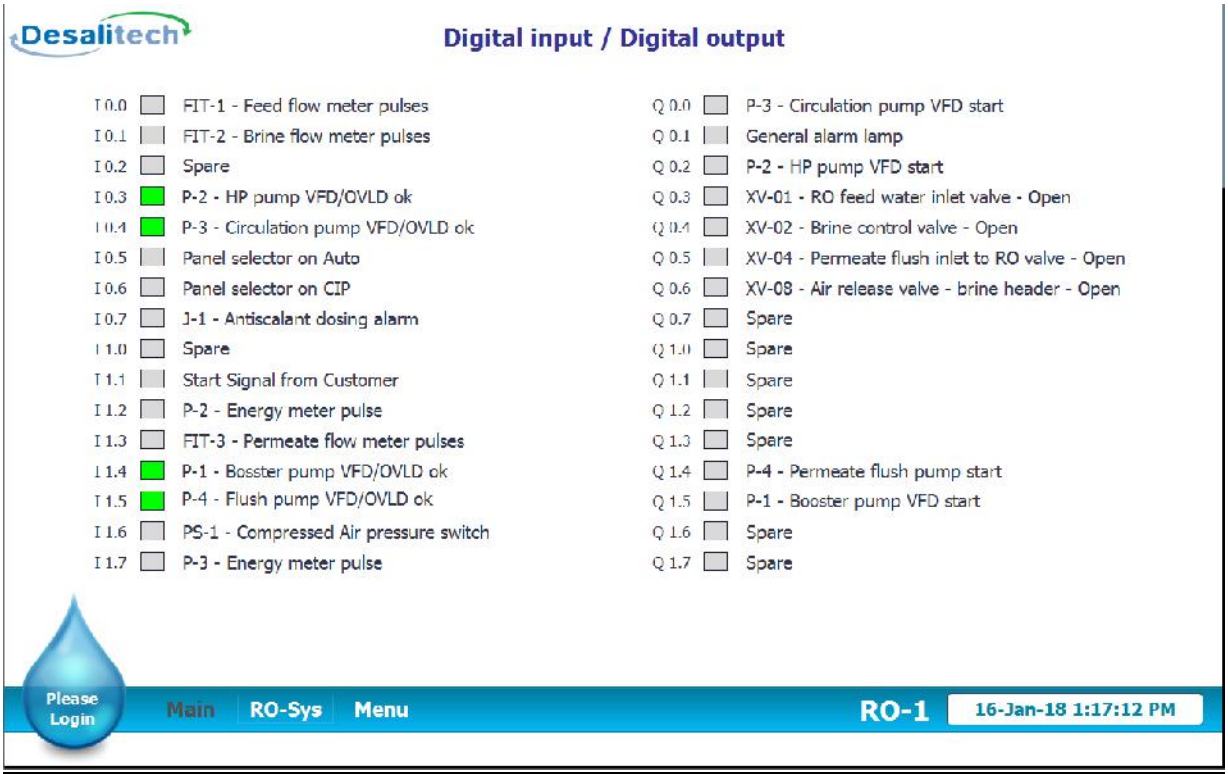
Expected CCD and PFD cycle times can be calculated with the following formulas:

$$C\quad\_ti\quad\_e\qquad [m\quad] = \frac{C\quad\_F\quad\_V\quad[li\ ]\cdot 60[\frac{m}{h}]}{1000[\frac{li}{m3}]\cdot S\ \ 14[\frac{m3}{h}]}$$

$$C\quad\_F\quad\_V\qquad [li\ ] = \frac{S\ \ 13[li\ ]\cdot\left(\frac{S\ \ 23[\%]-S\ \ 10[\%]}{100[\%]-S\ \ 10[\%]}\right)}{1-\frac{S\ \ 23[\%]}{100[\%]}}$$

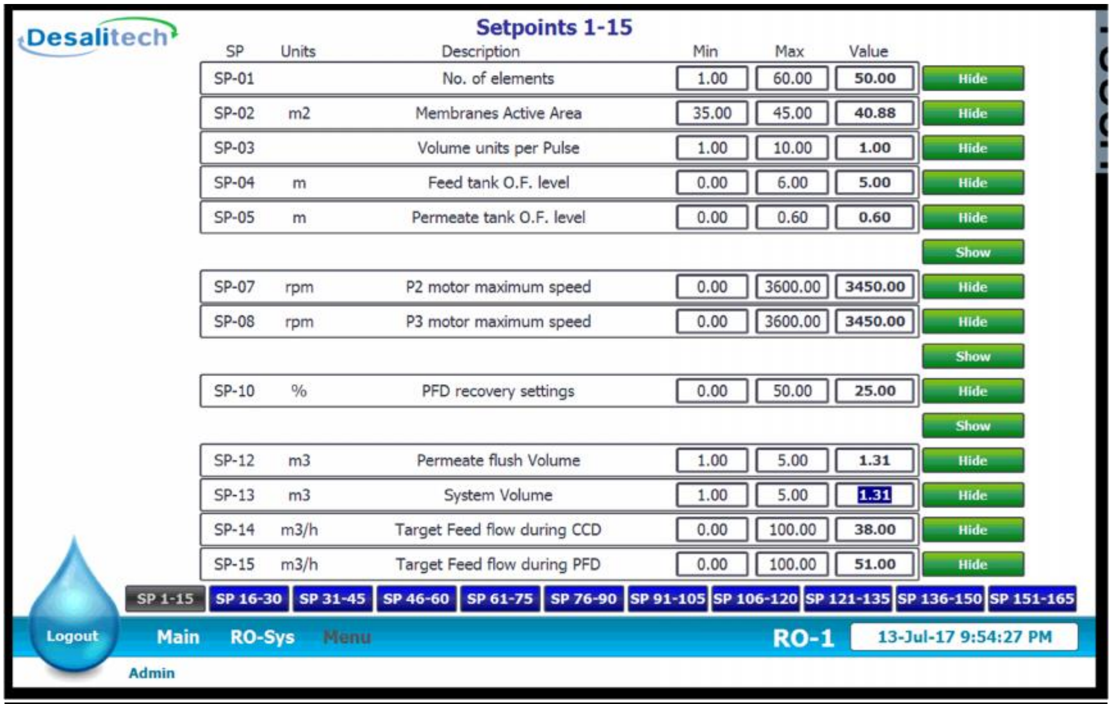
$$P\quad\_ti\quad\_e\qquad [m\quad] = \frac{S\ \ 13[li\ ]\cdot 60[\frac{m}{h}]}{1000[\frac{li}{m3}]\cdot S\ \ 15[\frac{m3}{h}]\cdot(1-\frac{S\ \ 10[\%]}{100[\%]})}$$

Digital Input / Digital Output:



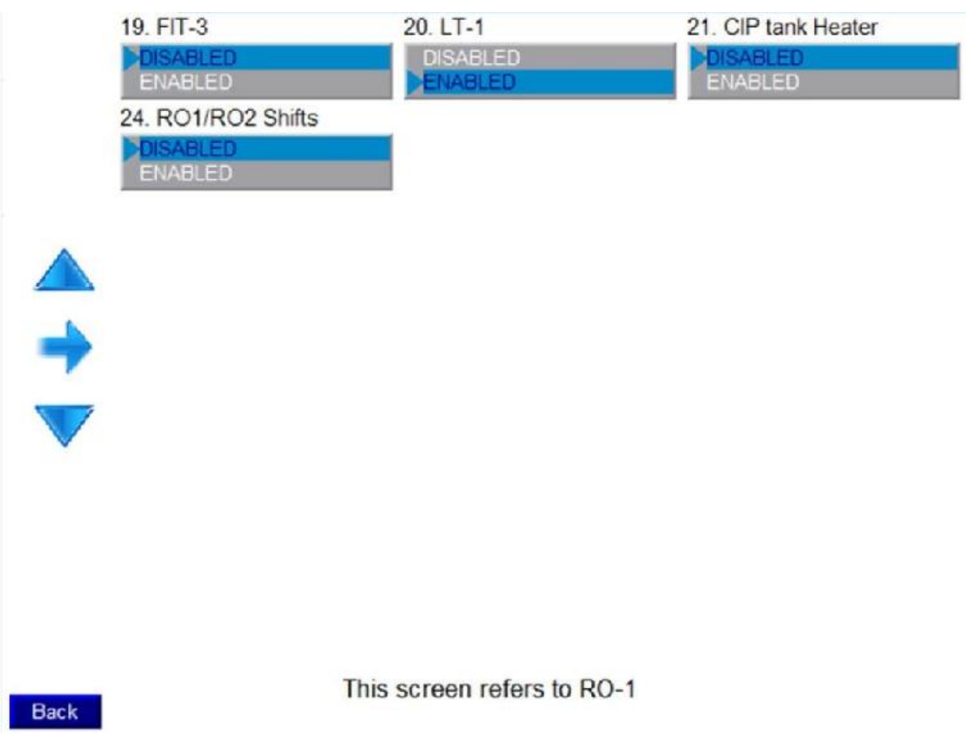
This screen gives a summary of the state of all digital inputs and outputs. Active inputs are shown in green on the left, while active outputs are shown in green on the right. Inactive digital signals are shown in grey.

System parameters:



This group of screens allows defining system setpoints. The above images is only an example of one of the setpoint screens. A full list of parameters is described in the next chapter. Parameters shown are based on selections made in configuration screen.

HMI Config:



The HMI Config screens is only accessible at the admin authentication level. Changes should be made with great care as each selection has a significant effect on system HMI screens, alarms and control logic.

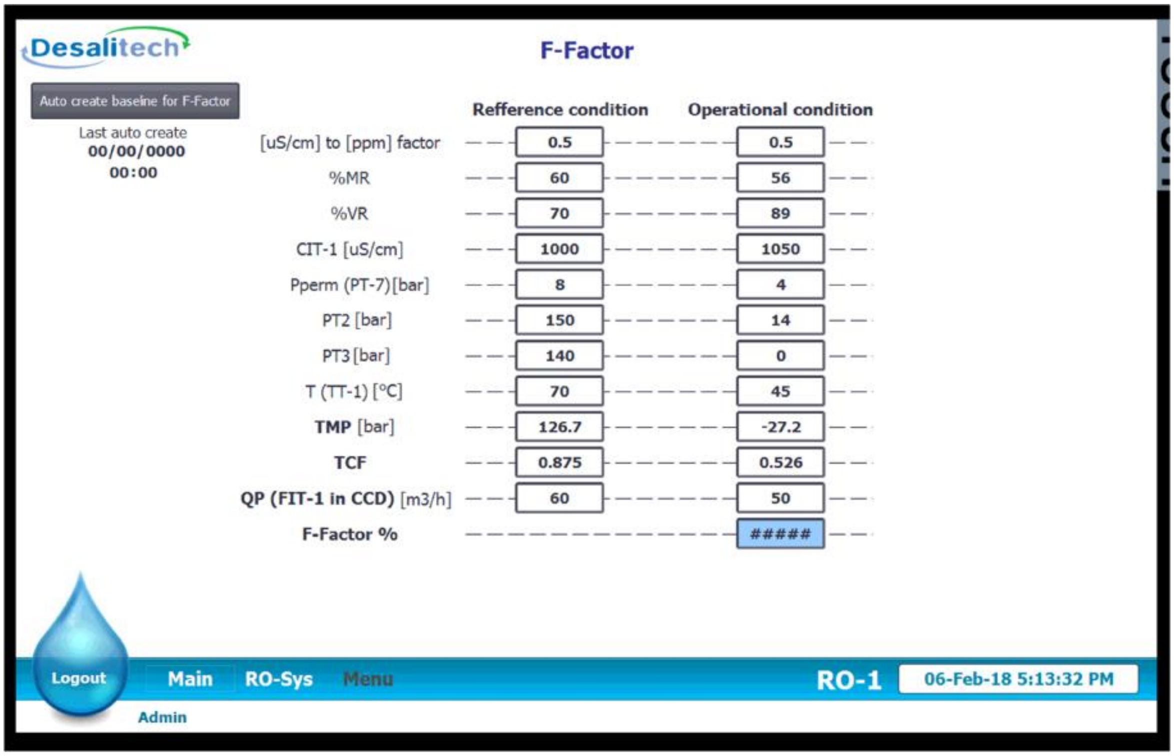
Detailed explanation of configuration parameters:

Configuration / Options	Default / Recommended for Agnico CCRO systems
1. S.D flush with: Feed- upon shut down RO will be flushed with Feed. CIP tank, XV-4, XV-9B will not appear on the HMI. Tank filling sequence will be off. Permeate - upon shut down RO will be flushed with Permeate. CIP tank, XV-4, XV-9 will appear on the HMI. Tank filling sequence will be on.	Permeate
2. P1- Booster pump: Disabled – P1 will not appear on the HMI. Enabled - P1 will appear on the HMI.	Enabled
3. P4 – CIP/ Flush pump	Disabled
4. J1 – Antiscalant (Feed) Disabled – J1 will not appear on the HMI. Enabled - J1 will appear on the HMI.	Enabled
5. J2 – Acid/Base (Feed) Disabled – J2 will not appear on the HMI. Acid – J2 will appear on the HMI with Acid dosing logic. Base – J2 will appear on the HMI with Base dosing logic.	Acid
6. J3 – SBS (Feed) Disabled – J3 will not appear on the HMI. By ORP with ppm low limit – J3 will appear on the HMI. Dosing based on ORP reading with minimum ppm dosing defined by user (HMI set point). By ppm only – J3 will appear on the HMI. Dosing based on ppm dosing defined by user (HMI set point).	Enabled - By ORP with ppm low limit.
7. J4 – Base (Permeate) Disabled – J4 will not appear on the HMI. Enabled – J4 will appear on the HMI.	Disabled
8. J5 – Biocide (Feed) Disabled – J5 will not appear on the HMI. Enabled – J5 will appear on the HMI.	Disabled
9. Constant PFD (Disable/Enable). C.PFD Can be selected during power-up rinse only. Selection will be reset to Disabled upon alarm event.	Disabled during normal operation
10. CIT-2 – Concentrate conductivity meter Disabled – CIT-02 will not appear on the HMI. Enabled – CIT-2 will appear on the HMI, CCD<<>PFD transition by CIT-02 is allowed.	Disabled

Configuration / Options	Default / Recommended for Agnico CCRO systems
11. PDT-1 Disabled – PDT-1 will not appear on the HMI. PDT-1 - PDT-1 will not appear on the HMI. Micronic filter high dP alarm will become active based on PDT-1 value. PT-6 – PT-6 will not appear on the HMI. Micronic filter high dP alarm will become active based on calculated dP value.	Disabled
12. PT-7 – Permeate pressure transmitter Disabled – J1 will not appear on the HMI. Enabled - J1 will appear on the HMI.	Enabled
13. Flow control by P1 – Booster pump is used for flow control. HP pump is used for pressure control in PT1. P2 - HP pump is used for flow control. Booster pump is used for pressure control in PT1.	P2 (If P1 is disabled P2 is selected by default)
14. Recovery saver mode. Disabled – System will immediately shut down upon the loss of start signal Enabled – A loss of start signal will cause the system to complete a full CC cycle before shutting down.	Enabled unless customer permeate tank doesn't have enough buffer.
15. Standby mode (Disable/Enable). Disabled – System will begin a power up rinse whenever it starts up from idle Enabled – Vol. Recovery calculation continues from last complete shutdown flush. This allows to avoid waste of power up rinse volume. "Maximum idle time in standby mode" set point is added to system parameters screen.	Disabled. 6 hours is recommended as Maximum idle time in standby mode.
16. Start signal Digital – operation based on digital signal. Any RO ready will start operation once signal is on. 4-20mA – operation is based on permeate tank level. LT2 will appear on the HMI. Start/stop setpoint will be included in system parameters screen. Always On – used for startup / troubleshoot. RO will run as soon as switch selector is tuned into AUTO position. PLC messaging – operation is based on communication with another PLC.	4-20mA
17. Actuators Type Electrical – Automatic valves use electrical actuators. The air-pressure switch and associated alarm is removed from the HMI Pneumatic – Automatic valves use pneumatic actuators. The air-pressure switch and associated alarm is added to the HMI	Pneumatic

Configuration / Options	Default / Recommended for Agnico CCRO systems
18. Bypass Dilution Disabled – All feed water passes through the RO. Enabled – Some feed water is allowed to pass the RO, and is mixed with the permeate. The “Bypass dilution ratio” setpoint is added to the system parameters screen.	Disabled
19. FIT-3 Disabled – No permeate flow meter Enabled – Adds measurement of permeate flow meter FIT-3 to Analog Inputs screen.	Disabled
20. LT-1 Disabled – No feed tank will be shown on the HMI and setpoints related to feed tank level will be removed. Enabled – Feed tank and level will be shown on the HMI and setpoints related to feed tank level will be enabled.	Disabled
21. CIP Tank Heater Disabled – No heater is attached to the CIP tank Enabled – A heater is attached to the CIP tank, and setpoints of CIP temperature and high temperature alarms are activated.	Enabled
22. RO1/RO2 Shifts Disabled – When multiple RO units are in communication, which RO turns on first is kept the same. Enabled – When multiple RO units are in communication, which RO turns on first is shared between all RO units based on a schedule.	Disabled

Fouling Factor screen:

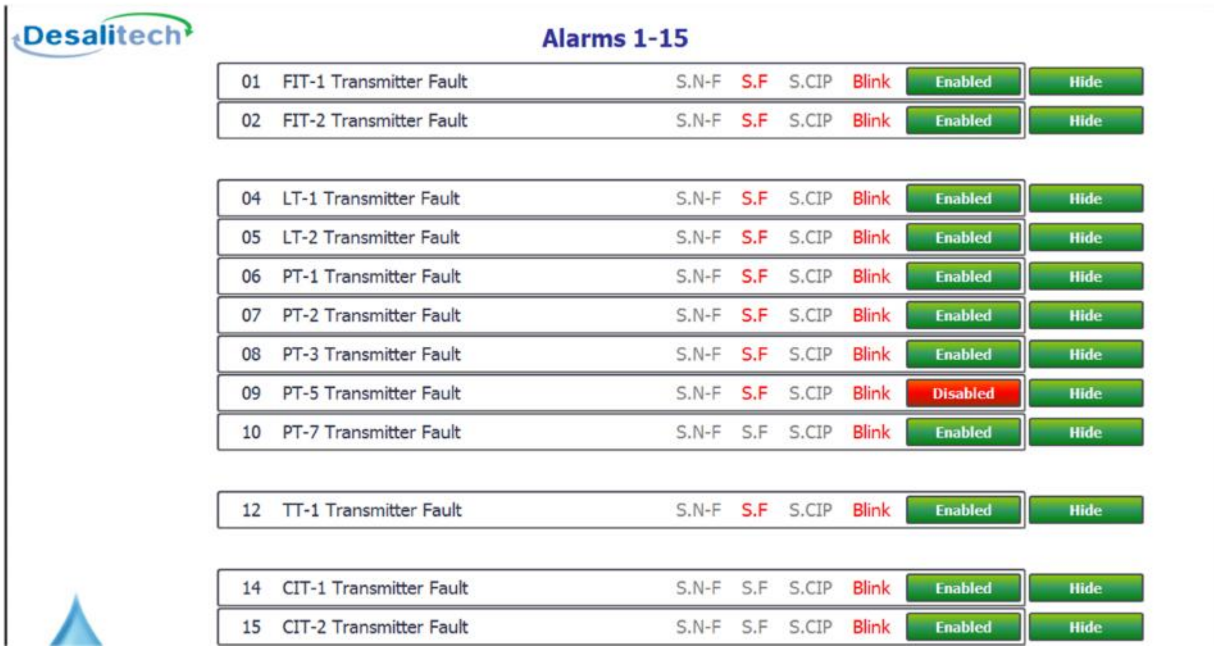


This screen allows the user to monitor system performance using a single factor called F-Factor.

The calculations related to this factor are essentially the same as those use for normalized flux calculation done in traditional RO. A description of these equations can be found in Section 21.

After loading new membranes and allowing the system to stabilized, a baseline for RO performance should be created. This is done automatically by pressing the “Auto create baseline for F-Factor” Button. During this procedure the PLC take records of 5 consecutive CCD cycles and check their variance. If the values generated deviate by less than 5% they are saved and used as the reference conditions. In case the procedure fails to generate repeatable values an error message is generated and the values used for baseline do not update.

Alarms D/E (Disable/Enable):



This screen is only accessibly to Admin authentication level. Changes should be made with great care as each selection has great effect on system HMI and control logic. The image above is one of several screens. For complete alarm list and the default settings refer to chapter 12.

For each alarm the user can define its action and whether it's active or not. Actions in red will result in the actions below. Actions in grey will not occur.

1. S.N-F Shutdown Non Flush: Alarm will cause immediate system stop during Auto operation.
2. S.F Shutdown Flush: Alarm will cause shutdown with Feed or permeate flush during Auto operation, depending on the configuration.
3. S.CIP Shutdown CIP/Manual: Alarm will cause immediate system stop during Manual operation.
4. Blink The alarm light will blink.

9 Individual RO Sequence Of Operation

9.1 Operation Modes

The control panel includes a selector switch with three positions: “CIP”, “0”, and “AUTO”. The selector switch sets the operational mode of the RO unit. Below is the explanation on each mode:

I. Shutdown mode / “0”: In this mode all valves are closed and all pumps are off. No operation is allowed.

II. Auto operation mode / “AUTO”: In this mode the system will automatically startup if no alarm is active and if it is requested to produce water. The request can be either by a digital input or by PLC messaging (only one method can trigger operation at a time).

While in this mode, if the system experiences an alarm, or if the request signal to produce water ceases, the RO will shut down automatically.

III. Manual mode / “CIP”: This mode is used to control the valves position manually and operate the pumps manually from the HMI. While in this mode, the operator can activate any and all pumps and valves at his/her discretion. This mode is used for maintenance and CIP operation.

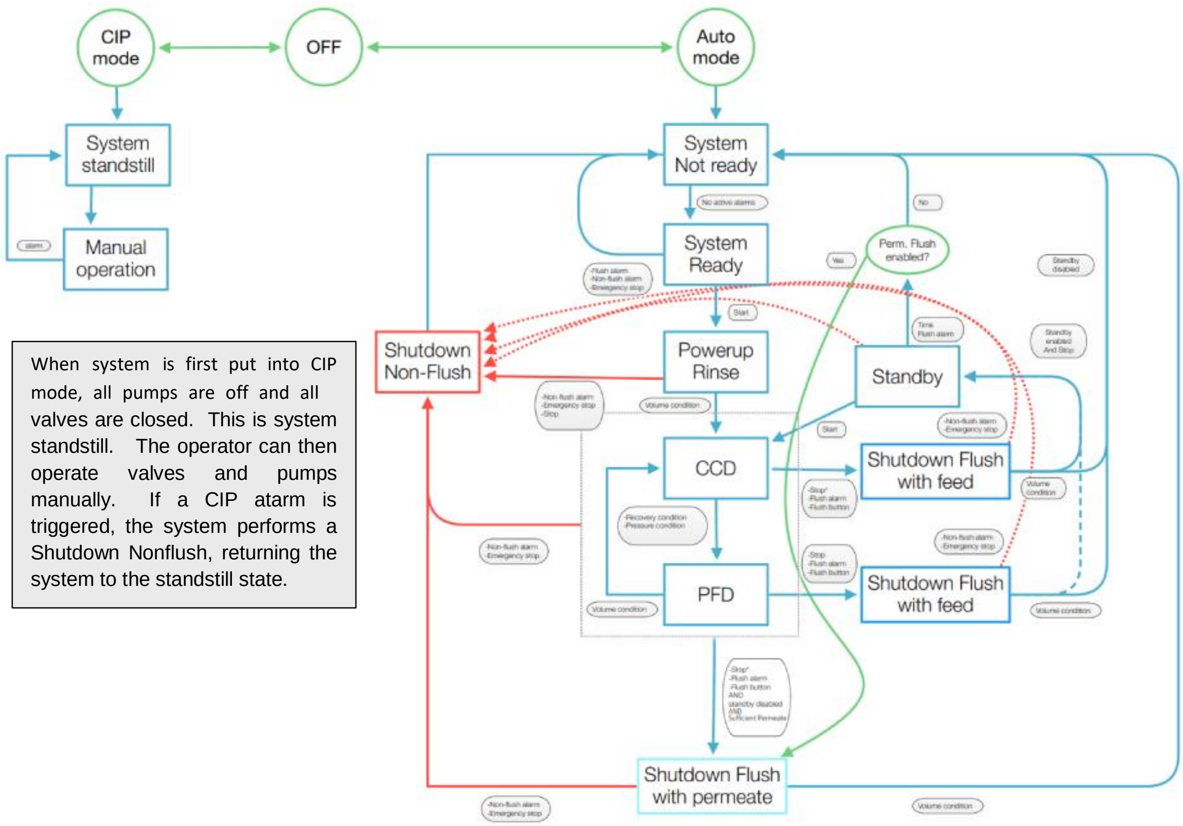
9.2 Auto mode sequences

When the RO system is in automatic mode it goes through the following sequences:

- System stopped / Not ready
- System ready
- Powerup Rinse
- CCD
- PFD
- Shutdown flush with permeate
- Shutdown flush with Feed
- Shutdown Non-Flush
- Standby

The transitions between these states are shown in the block diagram below. A detailed explanation is found in section 9.3.

Figure 4 – RO Block diagram



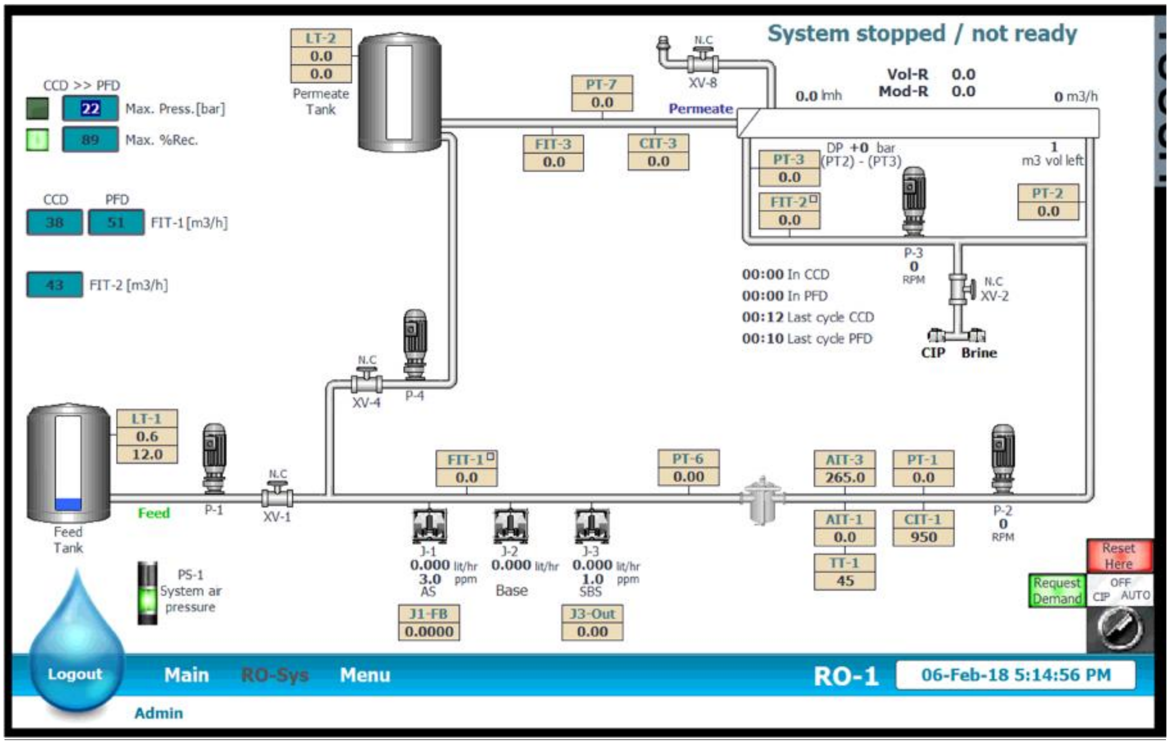
* If "Recovery saver mode" is enabled STOP allow completion of CCD Before going to FLUSH

If both permeate flush and standby options are enabled, standby priority is higher. Meaning that after "stop","feed flush" is performed first then system goto standby.

9.3 RO Sequence of operation in AUTO mode - Step by step description

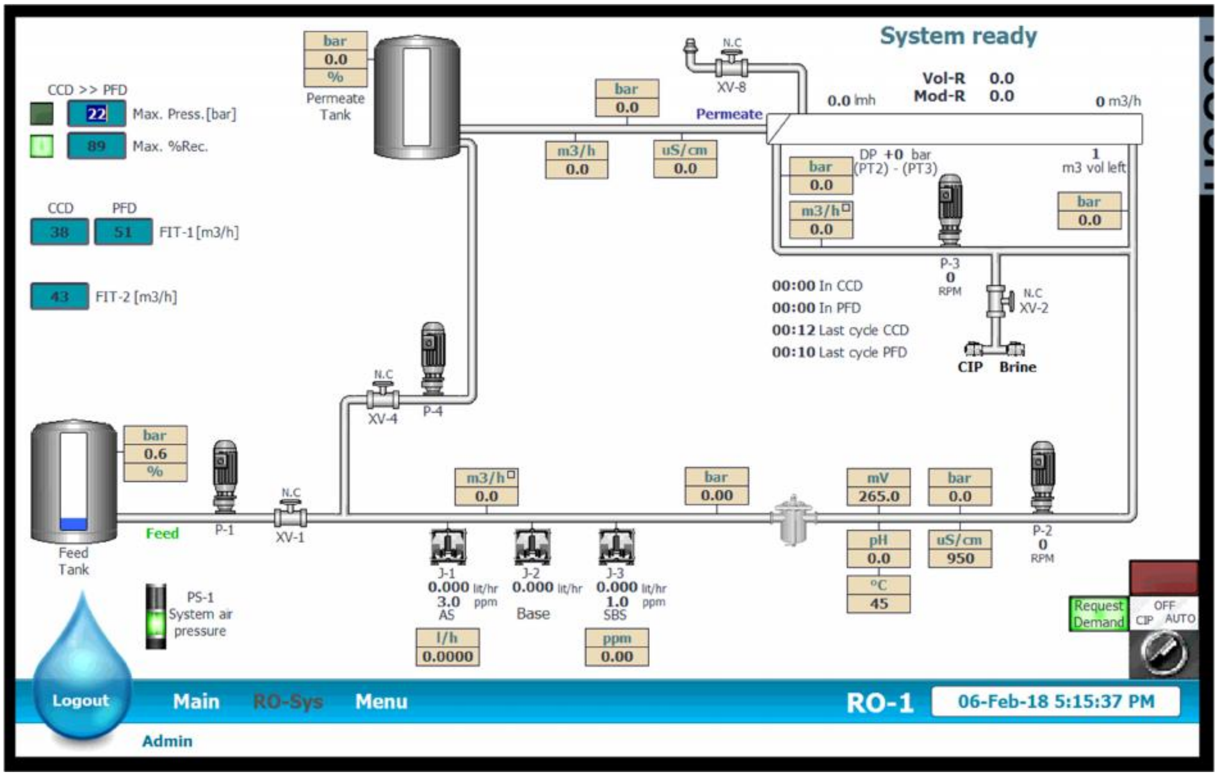
In this section, the operation of the RO unit through the various states is described. This section will include tables that indicate how the RO changes during the state. References to SP-## refer to setpoints found in section 10. Steps that are greyed out in the table do not apply to the expected configuration for the customer's RO.

System stopped / not ready



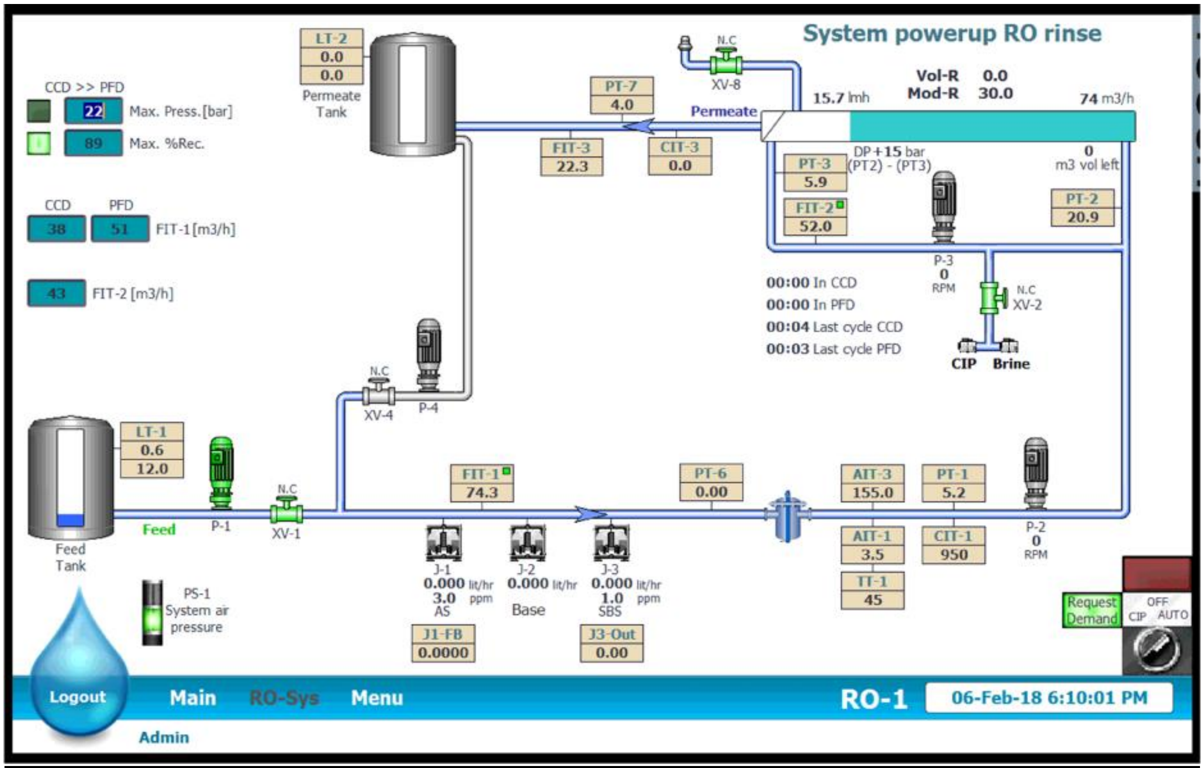
This is the first state the RO goes into when Auto is selected by the selector switch. The system goes into this state also after any shutdown that results in an active alarm. During this state all pumps are off, and all valves are closed. If a pump is experiencing an alarm, it will light up as red to indicate a fault. The system will progress to the next state, System Ready, only if no alarms are active. As soon as all alarms are inactive, the state progresses to system ready.

System ready



In the system ready state, no alarms are active, and the system waits for the start signal from the client. After the start signal from the client has been active for 10 seconds, the system proceeds to next state, System Power-up Rinse.

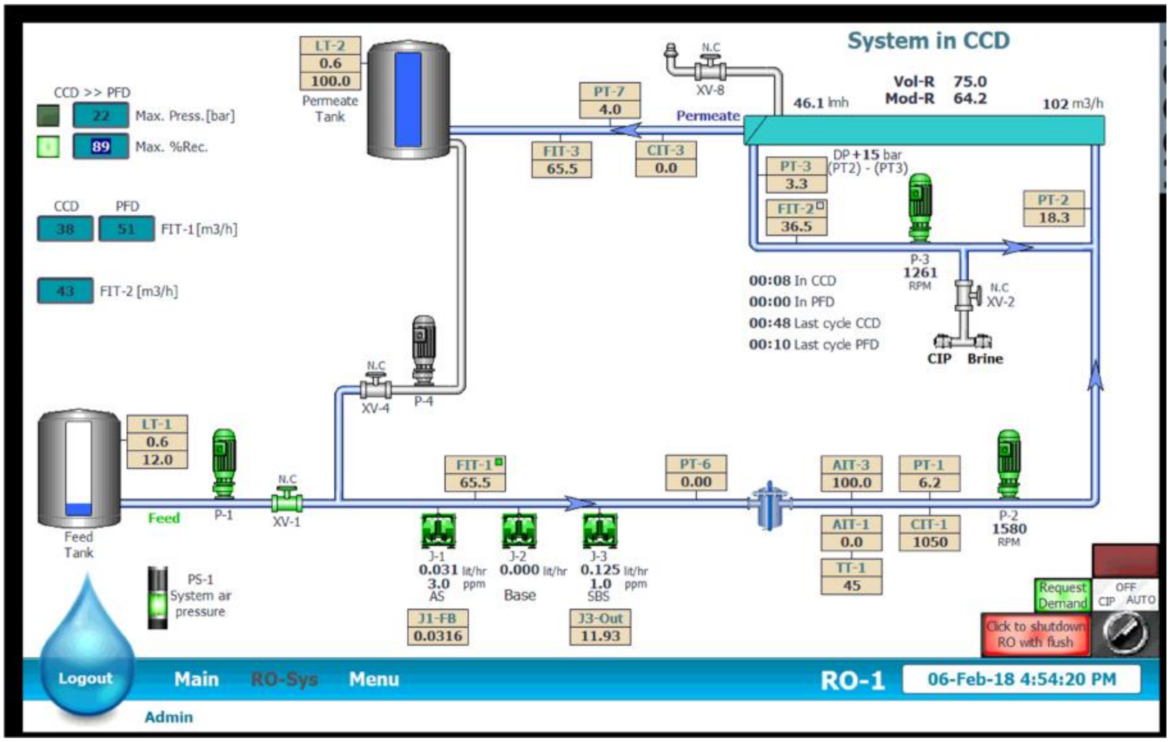
System power up rinse



During the powerup rinse the system flushes itself with feed water. This step introduces fresh feed water into the system while evacuating air entrapped in the pressure vessels and piping before pressurization. The system counts the volume leaving the pressure vessels, and compares it to the system volume. The combined volume of water entering the membranes is reported in the upper right hand corner of the screen on top of the pressure vessel graphic, and the volume left to be pumped is shown below it. The following Table describes the steps.

Step	Action	Trigger to Next Step
1	Open XV-1, XV-2, XV-8	After SP-27 (5) seconds
2	Start P-1 at SP-19	After SP-28 (3) seconds
3	Start P-2 at fixed speed SP-20 Start J-3 Start J-1, J-2 on control loops	After volume past FIT-2 = SP-13 (System Volume)

System in CCD



The next step after power up rinse and after each PFD is CCD. Water flows from the feed tank into the RO system and the concentrate is completely recycled to the front of the membranes. As a result, the only way for water to exit the system is as permeate. The combined volume of water entering the membranes is reported in the upper right hand corner of the screen on top of the pressure vessel graphic.

Step	Action	Trigger to Next Step
1	Close XV-2, XV-8 Start P-3 on control loop setting Activate P-1 and P-2 control loops	If Recovery Trigger active, Recovery >= SP-23 If Pressure Trigger active, Pressure >= SP-22

Circulation flow rate is measured by FIT-2 and controlled by the circulation pump (P-3) speed. The set point for circulation flow rate is entered at the square below “CCD” label next to "FIT-2".

Feed/Permeate flow rate is measured by FIT-1 and controlled by P-2. The set point for feed flow rate is entered at the square below “CCD” label next to "FIT-1".

The total dynamic head required for a certain permeate flow rate is divided between the booster pump (P-1) and high pressure pump (P-2). During CCD, PT1 pressure should be between 20-90 psi.

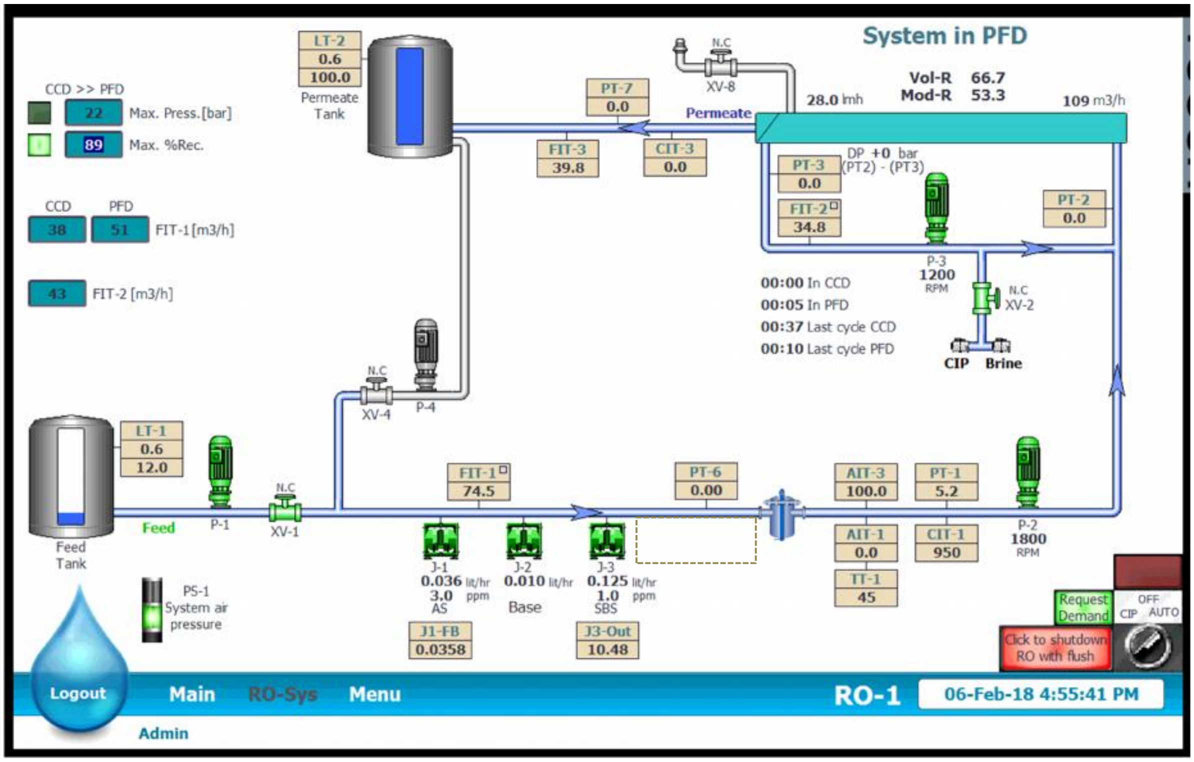
CCD step continues until the first active transition method is triggered. The set points related to the transition methods are entered below “CCD<<>>PFD” as maximum pressure or maximum %Rec and the corresponding measured/calculated values are PT-2 and Vol-R. At least one transition method must be activated by pressing the green button.

In the example above %Rec is the only active method and the set point used is 89%. When the %Vol-R gets to 89%, CCD will end and the system will go to PFD.

If the selector switch is turned to “off” during operation the system will immediately stop (Emergency Shutdown) and there will be no flushing sequence. In that case the water currently occupied in the system volume (which can be relatively concentrated towards the end of the CCD step) will be trapped until the next operation. This situation obviously must be avoided as much as possible.

“Click to shutdown RO flush” button will become visible during CCD and PFD. Pressing this button will force the RO unit to perform a shutdown flush even if it has a request to produce water. This feature should be used before maintenance. To get the system running again the “alarm reset” button should be pressed.

System in PFD



PFD step occurs after each CCD cycle to flush the brine volume inside the pressure vessels and replace it with fresh feed water. Once PFD is activated the following changes take place: Opening of brine valve (XV-2) and setting the RPM of circulation pump (P-3) to a low speed. During PFD, Water flows from feed water tank into the RO system and exit as brine to drain. Permeate is sent to customer.

The system counts the volume leaving the pressure vessels using FIT-2, and compares it to the system volume. The cumulative volume of water pumped during a given PF step is reported in the upper right hand corner of the screen on top of the pressure vessel graphic, and the volume left to be pumped is shown below it. This Sequence ends when the volume left to be pumped reaches zero.

Step	Action	Trigger to Next Step
1	Open XV-2 Set P-1 to SP-19 Set P-2 to SP-20 Set P-3 to constant RPM SP-154	After SP-30 (10) seconds
2	Set P-1, and P-2 to control loops	After volume past FIT-2 = SP-13 (System Volume)

During the first period of PFD the feed pumps (P-1 and P-2) operate at a constant speed (the same set points used for power up fixed speeds are used for PFD) and after that period the P-2 PID loop is activated (Stabilization period is also an HMI set point).

Feed flow rate is measured by FIT-1 and is controlled by P-2. The set point for feed flow rate is entered at the square below “PFD” label next to "FIT-1". The feed flow during PFD is normally higher than during CCD to compensate for the loss of circulation stream and increase the cross flow over the membranes. 20% to 50% increase is normal.

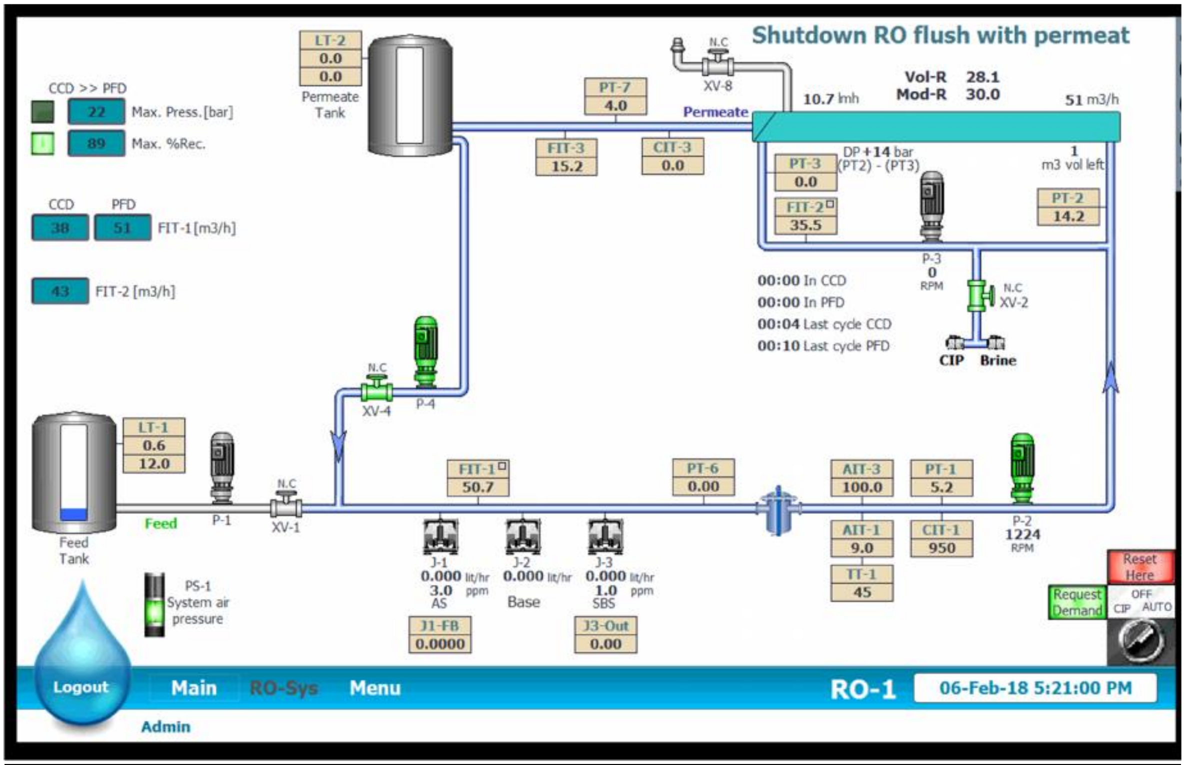
The total dynamic head required to get a certain permeate flow rate is divided between booster pump (P-1) and high pressure pump (P-2). During PFD XV-2 is open, resulting in lower pressures at the RO membranes.

The module recovery during PFD is set by adjusting the position of HV-7, the manual valve upstream of XV-02. Normal module recoveries should be in the range 10% to 35%. Care should be taken to allow the minimum required cross flow (use the CCD design tool PDF file to verify your design). Once a position has been selected, which is always done at commissioning, it is advised to remove the gear wheel to avoid undesirable changes.

If the selector switch is turned to “off” during operation the system will immediately stop (Emergency Shutdown) and there will be no flushing sequence. In that case the water currently occupied in the system volume (which can be relatively concentrated towards the end of the CCD step) will be trapped until the next operation. This situation obviously must be avoided as much as possible.

“Click to shutdown RO flush” button will become visible during CCD and PFD. Pressing this button will force the RO unit to perform a shutdown flush even if it has a request to produce water. This feature should be used before maintenance. To get the system running again the “alarm reset” button should be pressed.

Shutdown Flush



Shutdown Flush while unit is in operation will be triggered in the following events:

Event 1 - Unit is not requested to produce permeate anymore.
Event 2 - Operator has pressed “Click to shutdown RO flush” during CCD or PFD.
Event 3 - A flushing alarm has occurred (flushing alarm is an alarm that allows the system to perform flushing sequence before stopping).

The objective of this step is to replace existing system volume with low salinity water (either feed or permeate water according to system configuration) before letting the system stand still in shut down mode. This action protects the membranes from scaling. In case of Non-flush alarm (An Alarm which doesn’t allow flushing or an “Emergency stop”, the system proceeds to idle position immediately).

Shutdown With Permeate Water:

Step	Action	Trigger to Next Step
1	Stop P-2, P-3, J-1, J-2	After SP-28 (3) seconds
2	Stop P-1	After SP-29 (10) seconds
3	Close XV-1, Open XV-2	After SP-27 (5) seconds
4	Open XV-4	After SP-27 (5) seconds
6	Start P-1 at SP-19	After SP-29 (10) seconds
7	Start P-1 and P-2 at control loop	After volume past FIT-2 = SP-13 (System Volume)
8	Stop P-2	After SP-28 (3) seconds
9	Stop P-1	After SP-29 (10) seconds
11	Close all valves, Stop J-3	After SP-27 (5) seconds

First the source of water is changed by stopping the pumps, closing the inlet valve (XV-1) and opening the permeate flush inlet valve (XV-4). Now water can flow from permeate tank into the RO system, evacuating the existing volume from brine valve to the drain. Permeate is recycled back to the permeate tank to keep the permeate depressurized when the system stops.

The system counts the volume leaving the pressure vessels using FIT-2, and compares it to the system volume. The cumulative volume of water pumped during a given PF step is reported in the upper right hand corner of the screen on top of the pressure vessel graphic, and the volume left to be pumped is shown below it. This Sequence ends when the volume left to be pumped reaches zero.

During the first period of the flush, P-2 operates at a constant speed (the same set points used for power up fixed speeds are used for PFD) and after that period, a PID loop is activated to control flow. (Stabilization period is also an HMI set point).

If Permeate flush is triggered during PFD then the PFD will be interrupted and the permeate flush sequence above will proceed.

If Permeate flush is triggered during CCD there are several cases:

- If “Recovery saver mode” is enabled in system configuration, then
  “event 1” (see above) will allow CCD to continue until it ends and only then then flushing proceed. “event 2” and “event 3” will proceed immediately to flushing.
- If “Recovery saver mode” is disabled in system configuration, then
  all events will proceed immediately to flushing.

Shutdown With Feed Water:

Step	Action	Trigger to Next Step
1	Open XV-2, Stop P-3, J-1, J-2, change P-2 flowrate control loop target to SP-15	After volume past FIT-2 = SP-13 (System Volume)
2	Stop P-2	After SP-28 (3) seconds
3	Stop P-1	After SP-29 (10) seconds
4	Close all valves, Stop J-3	After SP-27 (5) seconds

The Shutdown with Feed water state is similar to the permeate flush shutdown sequence. The main difference is that the system uses feed water for the flush, and if the system shuts down during the PF state rather than the CC state, the system simply continues the PF flush sequence, continuing the same volume counter, and then shuts down with the volume setpoint is reached.

Shutdown Nonflush

In some cases an alarm condition calls for an immediate stop of all pumps. In this case and in the case that the physical selector on the panel is set to “Off”, the system goes to the shutdown nonflush state. During this state all pumps are turned off, the system depressurizes and finally closes all valves.

Step	Action	Trigger to Next Step
1	Stop P-2, P-3, J-1, J-2, J-3	After SP-28 (3) seconds
2	Stop P-1	After SP-29 (10) seconds
3	Close all valves, Open XV-2	After SP-27 (5) seconds
4	Close XV-2	After SP-27 (5) seconds

Standby Mode:

If Standby mode is enabled from system configuration menu then after shutdown flush the system will start again immediately from CCD step without first going through power up sequence. In this way vol. recovery calculation continues from last complete shutdown flush. This allows to the RO unit to operate at total average recovery closer to recovery set point by avoiding flush volume wasted during power up rinse step. The following diagram illustrates how St. By mode works.

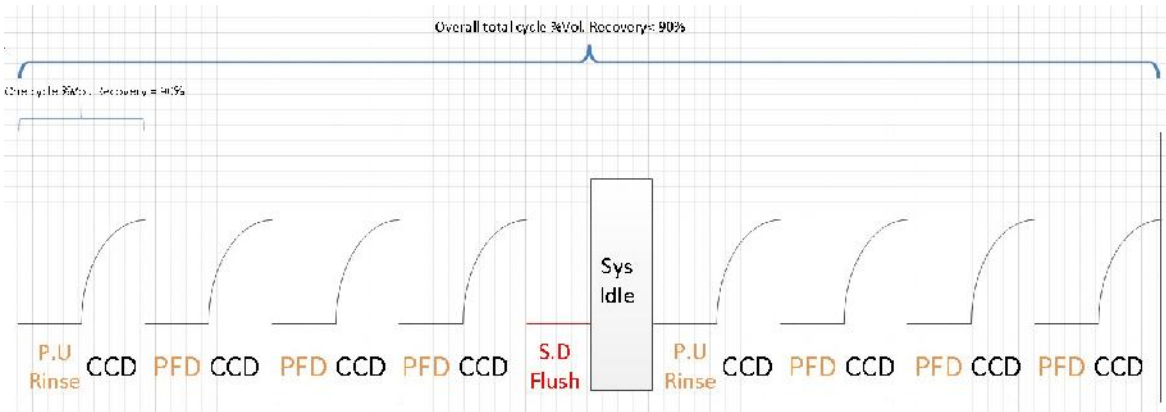


Figure 5 - St. By Mode disabled

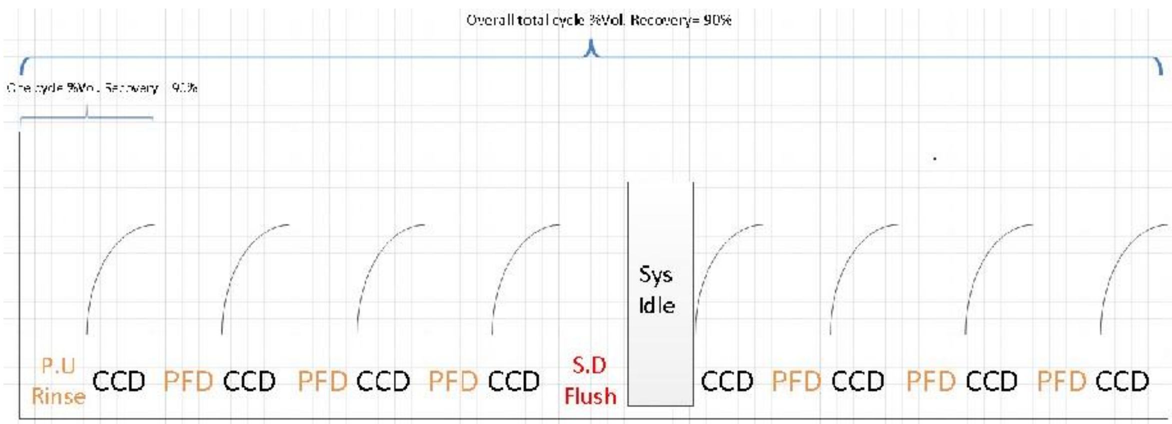


Figure 6 - St. By Mode enabled

In the upper diagram the overall total recovery is less than the complete PFD+CCD cycle recovery.
In the lower diagram the overall total recovery is the same as the complete PFD+CCD cycle recovery because there are no consecutive flushes causing water waste. Every flush has its complementary CCD step.
Comments:

1. Standby mode is limited in time. After certain number of hours have passed (SP-31), the system will move to the next step according to the block diagram. This number of hours is an HMI set point.
2. If both permeate flush and standby options are enabled at the same time, standby mode gets higher priority meaning that after the RO unit is requested to stop permeate production, it will perform a feed flush even though permeate flush was selected. The permeate flush sequence will take place only if the maximum idle time set point has been reached.

10 Normal Operation Parameters and CCRO Design Tool

The list below include all set points related to RO operation. Gray rows indicate setpoint irrelevant to the Agnico systems. These will not be shown on the HMI. Some of these set points that we expect to be somewhat commonly adjusted are discussed further in the next section.

S.P Category	S.P	Description	Low	High	Units	StartUp	Accessible	Comments
General	SP-01	No. of elements	1	500	-	120	Manager	
General	SP-02	Membranes Active Area	400.00	440.00	ft^2	400.00	Manager	
General	SP-03	Volume units per Pulse	1.0	10.0	-	1	Admin	
General	SP-04	Feed tank O.F level	0.00	10.00	psi	5.00	Manager	
General	SP-05	Permeate tank O.F level	0.00	SP-132	psi	TBD	Manager	
General	SP-06	P1 motor maximum speed	0	3600	rpm	TBD	Manager	
General	SP-07	P2 motor maximum speed	0	3600	rpm	TBD	Manager	
General	SP-08	P3 motor maximum speed	0	3600	rpm	TBD	Manager	
General	SP-09	P4 motor maximum speed	0	3600	rpm	TBD	Manager	
General	SP-10	PFD recovery settings	0.00	50.00	%	20	Manager	Used for cycle time calculations
Operation	SP-11	Target average Permeate flow	SP-105	SP-106	gpm	450.00		
Operation	SP-12	Permeate flush Volume	1.00	5000	gallon	595	Manager	FIT-2 volume counter = Pulse counter * SP-02
Operation	SP-13	System Volume	1.00	5000	gallon	595	Manager	FIT-2 volume counter = Pulse counter * SP-03
Operation	SP-14	Target Feed flow during CCD	SP-105	SP-106	gpm	489.6	Manager	
Operation	SP-15	Target Feed flow during PFD	SP-105	SP-106	gpm	587.5	Manager	
Operation	SP-16	Target Concentrate flow during CCD	SP-107	SP-108	gpm	503.6	Manager	
Operation	SP-17	Target PT-1 pressure during CCD	SP-117	SP-118	psi	TBD	Manager	
Operation	SP-18	Target PT-1 pressure during PFD	SP-117	SP-118	psi	TBD	Manager	
Operation	SP-19	P-1 speed during PFD step 1	0.00	SP-06	rpm	TBD	Manager	
Operation	SP-20	P-2 speed during PFD step 1	0.00	SP-07	rpm	TBD	Manager	
Operation	SP-21	P-4 speed during permeate flush	0.00	SP-09	rpm	TBD	Manager	
Operation	SP-22	Target CCD to PFD Feed pressure	0.00	450.00	psi	-	Manager	
Operation	SP-23	Target CCD to PFD Volumetric Recovery	60.00	99.00	%	90.00	Manager	
Operation	SP-24	Target CCD to PFD Brine conductivity	0.00	40.00	mS/cm	-	Manager	
Operation	SP-25	Start signal when using LT-2	0.00	SP-26	%	80	Manager	
Operation	SP-26	Stop signal when using LT-2	SP-25	100.00	%	95	Manager	
Operation	SP-27	Longest valve open/close time	0.00	60.00	seconds	5	Admin	
Operation	SP-28	Delay between pumps in series operation	0.00	20.00	seconds	3	Admin	
Operation	SP-29	Time till pump stop spinning	0.00	30.00	seconds	10	Admin	
Operation	SP-30	Time to stabilize PFD step 1	0.00	60.00	seconds	10	Admin	
Operation	SP-31	Maximum idle time in standby mode	0.00	24.00	hours	6.0	Manager	
Operation	SP-32	Low CIP tank temperature	SP-115	SP-33	F	95	Manager	

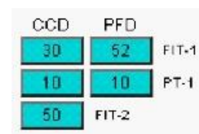
Operation	SP-33	High CIP tank temperature	SP-32	SP-116	F	105.0	Manager	
Operation	SP-34	Bypass flow rate in CCD	SP-111	SP-112	gpm	-	Manager	
Operation	SP-35	Maximum Complete cycles per Shift	1.00	1000.00	-			
Operation	SP-36	Elements per PV	3.00	5.00	-	5		
Operation	SP-37	Water type (Low fouling-0,High fouling-1)	0.00	1.00	-			
Alarms value	SP-38	High module inlet pressure warning value	0.00	450.0	psi	350.0	Manager	
Alarms value	SP-39	Maximum module inlet pressure alarm value	0.00	450.0	psi	450.0	Manager	
Alarms value	SP-40	Module inlet pressure Low alarm value	1.00	100.00	psi	10.00	Manager	Should be relative to lowest PT2 pressure during operation
Alarms value	SP-41	Feed flow Low alarm value	SP-105	SP-106	gpm	288.0	Manager	
Alarms value	SP-42	Feed flow High alarm value	SP-105	SP-106	gpm	1440.0	Manager	
Alarms value	SP-43	Concentrate flow Low alarm value	1.00	1000.00	gpm	288.0	Manager	
Alarms value	SP-44	Concentrate flow High alarm value	1.00	1000.00	gpm	1440.0	Manager	
Alarms value	SP-45	Recovery too Low alarm value	1.0	100.0	%	60.0	Manager	
Alarms value	SP-46	P-1 suction pressure Low alarm value	0.00	100.00	psi	5.00	Manager	Should be relative to normal inlet pressure in CCD
Alarms value	SP-47	P-1 discharge pressure high alarm value	1.00	200.00	psi	90.00	Manager	
Alarms value	SP-48	Permeate pressure high alarm value	1.00	150.00	psi	20.00	Manager	
Alarms value	SP-49	High Feed ORP level alarm value	1.00	500.00	mV	250	Manager	
Alarms value	SP-50	Permeate conductivity high warning value	0.00	1000	uS/cm	140	Manager	
Alarms value	SP-51	Permeate conductivity high alarm value	0.00	1000	uS/cm	211	Manager	
Alarms value	SP-52	Feed conductivity high alarm value	0.00	8000	uS/cm	3640	Manager	Value should be set to 150% of normal CIT-01 value
Alarms value	SP-53	Micronic Filters Differential pressure Highalarm value	0.00	30.00	psi	15.00	Manager	
Alarms value	SP-54	High module dP warning value	0.00	35.00	psi	20.00	Manager	Should be relative to normal pressure drop
Alarms value	SP-55	High module dP alarm value	0.00	35.00	psi	35.00	Manager	
Alarms value	SP-56	Blend water conductivity high alarm value	0.00	1000.00	uS/cm	500	Manager	
Alarms value	SP-57	Low feed tank level alarm value	0	100	%	20	Manager	
Alarms value	SP-58	Low pH boundary	0.00	SP-59	pH	4.00		
Alarms value	SP-59	High pH boundary	SP-58	14.00	pH	10.00		
	SP-60	Spare			-			
F-Factor	SP-61	FF %MR	0.00	100.00	%	60	Admin	
F-Factor	SP-62	FF %VR	0.00	100.00	%	70	Admin	
F-Factor	SP-63	FF CIT-1 [uS/cm]	SP-133	SP-134	uS/cm	1000	Admin	
F-Factor	SP-64	FF Pperm(PT-7)	SP-125	SP-126	psi	10.00	Admin	
F-Factor	SP-65	FF PT2at End of CCD	SP-119	SP-120	psi	150.00	Admin	
F-Factor	SP-66	FF PT3at End of CCD	SP-121	SP-122	psi	140.00	Admin	
F-Factor	SP-67	FF T(TT-1)	SP-113	SP-114	F	70.00	Admin	
F-Factor	SP-68	FF QP(FIT-1 in CCD)	SP-105	SP-106	gpm	60.00	Admin	
F-Factor	SP-69	FF Conversion factor uS/cm to ppm TDS	0.00	1.00	-	0.5	Admin	
SP_Factor	SP-70	SPF CIT-3 [uS/cm] at End of CCD	SP-137	SP-138	uS/cm	60		
	SP-71	Spare			-			

	SP-72	Spare			-			
	SP-73	Spare			-			
Chemicals	SP-74	J1-Solution Concentration (c) [%]	10.00	100.00	%	100	Manager	
Chemicals	SP-75	J1-Required Dose (C) [ppm]	0.00	20.00	ppm	3.12	Manager	
Chemicals	SP-76	J1-Solution Density (d)	10.00	100.00	[lb/ft3]	72.384	Manager	
Chemicals	SP-77	J1-D.P max flow rate (max_q)	0.00	5.00	gph	0.95	Manager	
	SP-78	Spare			-			
Chemicals	SP-79	Target Feed pH	4.00	10.00	pH	7	Manager	
Chemicals	SP-80	J2-D.P max flow rate (max_q)	0.00	5.00	gph	2	Manager	
Operation	SP-81	P1 motor speed during Auto Flush	0.00	3600.00	rpm	2000	Manager	
Chemicals	SP-82	Target Feed ORP	SP-143	SP-144	mV	250	Manager	
Chemicals	SP-83	J3-Solution Concentration (c) [%]	10.00	100.00	%	40	Manager	
Chemicals	SP-84	J3-Required Dose (C) [ppm]	0.00	20.00	ppm	1	Manager	
Chemicals	SP-85	J3-Solution Density (d)	10.00	100.00	[lb/ft3]	81.12	Manager	
Chemicals	SP-86	J3-D.P max flow rate (max_q)	0.00	5.00	gph	0.68	Manager	
Operation	SP-87	P2 motor speed during Auto Flush	0.00	3600.00	rpm	1500	Manager	
Chemicals	SP-88	Target Permeate pH	4.00	10.00	pH	7	Manager	
Chemicals	SP-89	J4-D.P max flow rate (max_q)	0.00	5.00	gph	0	Manager	
	SP-90	Spare			-			
Chemicals	SP-91	J5-Solution Concentration (c) [%]	10.00	100.00	%	100	Manager	
Chemicals	SP-92	J5-Required Dose (C) [ppm]	0.00	100.00	ppm	0	Manager	
Chemicals	SP-93	J5-Solution Density (d)	10.00	100.00	[lb/ft3]	81.12	Manager	
Chemicals	SP-94	J5-D.P max flow rate (max_q)	0.00	5.00	gph	0.00	Manager	
	SP-95	Spare			-			
General	SP-96	CIP tank O.F level	0.00	SP-152	psi	TBD		
Operation	SP-97	CIP Tank LL	0.00	SP-98	%	TBD		
Operation	SP-98	CIP Tank HL	SP-97	100.00	%	95		
Operation	SP-99	CIP Tank Minimum flush level	SP-97	SP-98	%	TBD		
	SP-100	Spare			-			
	SP-101	Spare			-			
	SP-102	Spare			-			
	SP-103	Spare			-			
	SP-104	Spare			-			
Analog limits	SP-105	FIT-1 - Low Eng	0.00	3270.00	gpm	0	Manager	
Analog limits	SP-106	FIT-1 - High Eng	0.00	3270.00	gpm	1008.0	Manager	
Analog limits	SP-107	FIT-2 - Low Eng	0.00	3270.00	gpm	0	Manager	
Analog limits	SP-108	FIT-2 - High Eng	0.00	3270.00	gpm	1008.0	Manager	
Analog limits	SP-109	FIT-3 - Low Eng	0.00	3270.00	gpm	0	Manager	
Analog limits	SP-110	FIT-3 - High Eng	0.00	3270.00	gpm	734.4	Manager	
Analog limits	SP-111	FIT-4 - Low Eng	0.00	3270.00	gpm	0	Manager	
Analog limits	SP-112	FIT-4 - High Eng	0.00	3270.00	gpm	100.0	Manager	
Analog limits	SP-113	TT-1 - Low Eng	0.00	3270.00	oF	32	Manager	
Analog limits	SP-114	TT-1 - High Eng	0.00	3270.00	oF	150.0	Manager	
Analog limits	SP-115	TT-2 - Low Eng	0.00	3270.00	oF	32	Manager	

Analog limits	SP-116	TT-2 - High Eng	0.00	3270.00	oF	150.0	Manager	
Analog limits	SP-117	PT-1 - Low Eng	0.00	3270.00	psi	0	Manager	
Analog limits	SP-118	PT-1 - High Eng	0.00	3270.00	psi	145.04	Manager	
Analog limits	SP-119	PT-2 - Low Eng	0.00	3270.00	psi	0	Manager	
Analog limits	SP-120	PT-2 - High Eng	0.00	3270.00	psi	580.15	Manager	
Analog limits	SP-121	PT-3 - Low Eng	0.00	3270.00	psi	0	Manager	
Analog limits	SP-122	PT-3 - High Eng	0.00	3270.00	psi	580.15	Manager	
Analog limits	SP-123	PT-5 - Low Eng	0.00	3270.00	psi	0	Manager	
Analog limits	SP-124	PT-5 - High Eng	0.00	3270.00	psi	145.0	Manager	
Analog limits	SP-125	PT-7 - Low Eng	0.00	3270.00	psi	0	Manager	
Analog limits	SP-126	PT-7 - High Eng	0.00	3270.00	psi	58.02	Manager	
Analog limits	SP-127	PDT-1 - Low Eng	0.00	3270.00	psi	0	Manager	
Analog limits	SP-128	PDT-1 - High Eng	0.00	3270.00	psi	15.00	Manager	
Analog limits	SP-129	LT-1- Low Eng	0.00	3270.00	psi	0	Manager	
Analog limits	SP-130	LT-1 - High Eng	0.00	3270.00	psi	TBD	Manager	
Analog limits	SP-131	LT-2- Low Eng	0.00	3270.00	psi	0	Manager	
Analog limits	SP-132	LT-2 - High Eng	0.00	3270.00	psi	TBD	Manager	
Analog limits	SP-133	CIT-1 - Low Eng	0.00	3270.00	uS/cm	0	Manager	
Analog limits	SP-134	CIT-1 - High Eng	0.00	10000.00	uS/cm	5000	Manager	
Analog limits	SP-135	CIT-2 - Low Eng	0.00	200.00	mS/cm	0	Manager	
Analog limits	SP-136	CIT-2 - High Eng	0.00	200.00	mS/cm	20	Manager	
Analog limits	SP-137	CIT-3 - Low Eng	0.00	3270.00	uS/cm	0	Manager	
Analog limits	SP-138	CIT-3 - High Eng	0.00	1000.00	uS/cm	1000	Manager	
Analog limits	SP-139	CIT-4 - Low Eng	0.00	3270.00	uS/cm	0	Manager	
Analog limits	SP-140	CIT-4 - High Eng	0.00	3270.00	uS/cm	1000	Manager	
Analog limits	SP-141	AIT-1 - Low Eng	0.00	0.00	pH	0	Manager	
Analog limits	SP-142	AIT-1 - High Eng	14.00	14.00	pH	14	Manager	
Analog limits	SP-143	AIT-3 - Low Eng	0.00	0.00	mV	0	Manager	
Analog limits	SP-144	AIT-3 - High Eng	1000.00	1000.00	mV	1000	Manager	
Analog limits	SP-145	AIT-4 - Low Eng	0.00	0.00	pH	0	Manager	
Analog limits	SP-146	AIT-4 - High Eng	14.00	14.00	pH	14	Manager	
Analog limits	SP-147	J1_FB - Low Eng	0.00	0.00	gph	0	Manager	
Analog limits	SP-148	J1_FB - High Eng	SP-77	SP-77	gph	SP-77	Manager	
Analog limits	SP-149	PT-6 - Low Eng	0.00	3270.00	psi	0	Manager	
Analog limits	SP-150	PT-6 - High Eng	0.00	3270.00	psi	145.04	Manager	

Analog limits	SP-151	LT-3- Low Eng	0.00	3270.00	psi	0	Manager	
Analog limits	SP-152	LT-3 - High Eng	0.00	3270.00	psi	TBD	Manager	
Operation	SP-153	Time between Auto Flush	1.00	48.00	hr	-	Manager	
Operation	SP-154	P3 rpm during PFD	0.00	2500.00	rpm	1200	Manager	

Comments on important set points

Set point	Description	Comments	
SP-10	PFD recovery settings	This set point should reflect the module recovery during PFD that has been adjusted manually with the brine hand valve.	
SP-12	Permeate flush Volume	This should be equal or greater than SP-13. Higher values will make the flush process more efficient but will consume more water and lower the total recovery.	
SP-13	System Volume	The value here is based on the number of membranes installed. 4 element per PV – use 1463 liters 5 element per PV – use 1310 liters 6 element per PV – use 1125 liters	
SP-14	Target Feed flow during CCD	These set points can also be changed from the main process screen **Use CCD design tool** to generate most suitable parameters based on average production required and other process requirements	
SP-15	Target Feed flow during PFD		
SP-16	Target Concentrate flow during CCD		
SP-17	Target PT-1 pressure during CCD	These set points can also be changed from the main process screen Increasing this set point will move more load from P2 to P1. Decreasing this set point will move more load from P1 to P2. During CCD, PT1 pressure should be between 20-90 psi. During PFD, PT1 pressure should be between 10-50 psi. Exact value should be selected based on field experience. It is important to select value high enough not to cause vacuum conditions at the suction of P2	
SP-18	Target PT-1 pressure during PFD		
SP-19	P-1 speed during PFD step 1	This set point is used to quickly tune the pumps to match the speed required to achieve both flow and pressure set points during PFD. The user can find the right speed by manually simulating PFD.	
SP-20	P-2 Speed During PF		
SP-22	Target CCD to PFD Feed pressure	These set points can also be changed from the main process screen. Normally the Max. %Rec is used based on projection of Antiscalant program with the related water chemistry. Pressure set point can be added to limit recovery in case there is a scaling event and pressure start to increase. However pressure can increase also due to lower feed temperature or an increase in feed water salinity so it this feature should be used with care.	
SP-23	Target CCD to PFD Volumetric Recovery		
SP-74	J1-Solution Concentration (c) [%]	This has to match the actual solution concentration. If a neat product is used enter 100% (otherwise an overdose will occur)	
SP-75	J1-Required Dose (C) [ppm]	The ppm required is a function recovery. If volumetric recovery set point is changed the user must run a new projection with the Antiscalant program to verify the required dosing rate.	
SP-77	J1-D.P max flow rate (max_q) [gph]	This set point defines the analog output to J1 and the analog input from J1 (J1_FB - High Eng). The range set in the DDA pump MUST match this value.	
SP-79	Target Feed pH	In case volumetric recovery set point is changed the user should verify the new required adjusted feed pH. This information can be found in the projection of Antiscalant program.	

<u>CCRO Design tool</u>:

This tool is a PDF document with Javascript calculations. To work correctly it has to be used with Adobe PDF. Other programs might generate false calculations and should be avoided.

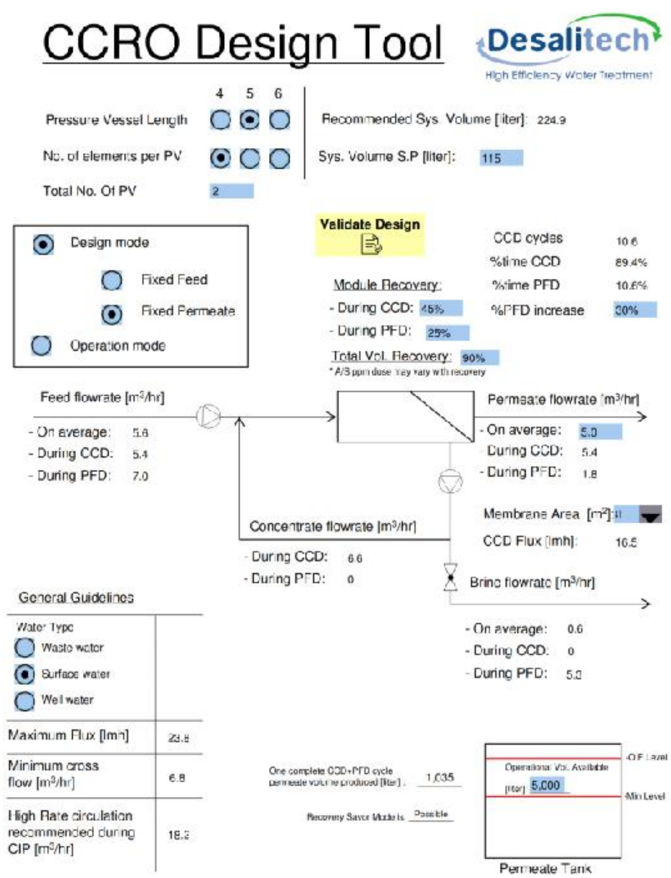
This tool has two modes: <u>Design</u> and <u>Operation</u>.

In <u>Design</u> mode the user defines the average permeate flow required as well as other system parameters like CCD MR, PFD MR and PFD increase. The output of this mode will be the HMI set points required in order to achieve the design parameters above.

In <u>Operational</u> mode the user can enter the set point as he would enter in the HMI (CCD feed flow, PFD feed flow, Circulation flow). The output of this mode will be the permeate average production which will be the result of the HMI set points used.

Additional features:

1. Validate Design button. Check design is within recommended process limits based on water type selected.
2. System volume calculation.
3. Test if Recovery savor mode is possible to use based on permeate tank data and process parameters.



11 Device configuration parameters

11.1 Analyzer configuration (ABB):

- pH meter:
  - Config Sensor A: Probe Type – pH; Diff. Input – No; Electrode – Glass; Temp. Comp. – Auto; Temp. Sensor – Pt100; Sample Comp – No; Set Min Slope: 60%
  - Congif Output 1: AO1: Assign – Sen. A; Range – 4-20mA; Span Value – 14; Zero Value – 0; Default output – Off;
- ORP meter
  - Config Sensor B: Probe Type – ORP; Temp. Sensor – None;
  - Congif Output 2: AO2: Assign – Sen. B; Range – 4-20mA; Span Value – 1000mV; Zero Value – 0mV; Default output – Off;
- Conductivity meter
  - Config Sensor A (CIT-1): Cond. Units – uS/cm; Cell Constant – 1.0K; T. Comp Range – Lo TC; Temp. Comp. – Linear; Temp. Sensor – Pt100; Temp Coeff – 2.00%; Enable Cals – No;
  - Congif Output 1: AO1: Assign – Sen. A; Range – 4-20mA; Curve – Linear; Span Value – 3000 uS/cm; Zero Value – 0; Default output – Off;
  - Config Sensor B (CIT-3): Cond. Units – uS/cm; Cell Constant – 0.1K; T. Comp Range – Lo TC; Temp. Comp. – Linear; Temp. Sensor – Pt100; Temp Coeff – 2.00%; Enable Cals – No;
  - Congif Output 2: AO2: Assign – Sen. B; Range – 4-20mA; Curve – Linear; Span Value – 1000 uS/cm; Zero Value – 0; Default output – Off;

If different spans are required – programm both HMI SP and analyzer to match.

11.2 Flow meters configuration (ABB):

ABB **Parameterization**

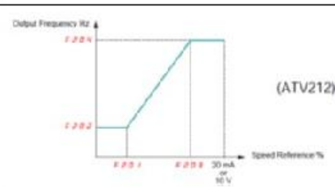
7.4 Description of parameters

7.4.1 Menu: Easy Setup

Menu / Parameter	Value range	Description
Easy Setup		**"Easy Setup" Menu**
Language	Deutsch, English, Français, Español, Italiano, Dansk, Svenska, Polski, Russki, Zhongweng, Turkce	Select the menu language.
Q (Flowrate) Unit	l/s; l/min; l/h; ml/s; ml/min; m3/s; m3/min; m3/h; m3/d; Ml/d; ft3/s; ft3/min; ft3/h; ft3/d; ugal/s; ugal/min; ugal/h; ugal/d; Mugal/d; igal/s; igal/min; igal/h; igal/d; bls/s; bls/min; bls/h; bls/d; hl/h; g/s; g/min; g/h; kg/s; kg/min; kg/h; kg/d; t/min; t/h; t/d; lb/s; lb/min; lb/h; lb/d; custom/s	Select the unit for the flow indicator. Default setting: l/min
Qmax	Min. flow range: 0 ... 0.2 m/s (0 ... 0.02 x Q_{max}DN) Max. flow range: 0 ... 20 m/s (0 ...2 x Q_{max} DN)	Select the flow range for forward and reverse flow. Default setting: 1 x Q_{max}DN. per analog set points
Totalizer/Pulse Unit	m3; l; ml; ft3; hl; g; kg; t; lb; igal; ugal; bls; Ml; Mugal; custom	Select the unit for the flowmeters. Default setting: l
Operation	Pulse Mode, Fullscale Frequency	Select the operating mode for the digital output. There are two operating modes available: • „Pulse Mode“: In pulse mode, pulses per unit are output (e.g., 1 pulse per m^3). • „Fullscale Frequency“: In frequency mode, a frequency proportional to the flowrate is output. The maximum frequency corresponding to the flow range end value is configurable (max. 5.25 kHz). Default setting: „Pulse Mode“
Pulses per Unit	- per set points	Display of the pulses per unit output by the digital output. The max. possible number of pulses is 5250 per second.
Pulse Width	0.1 ... 2000 ms 50.00 ms	Select the pulse width for the digital output. The pulse factor and pulse width are interdependent and are calculated dynamically.
Damping	0.02 ... 60 s 3 sec	Select the damping. The value set here relates to 1 T (Tau). The value refers to the response time for a step flowrate change. It affects the instantaneous value in the display and at the current output. Default setting: 1 second
Iout at Alarm	Low, High use default	Status of the current output during an error. The “low” or “high” status is set in the subsequent menu. Default setting: "High".
Low Alarm Value	3.5 ... 3.6 mA use default	Current for Low Alarm. Default setting: 3.5 mA
High Alarm Value	21 ... 23 mA use default	Current for High Alarm. Default setting: 21.8 mA
System Zero	not required	Select the "System Zero" submenu.

[Easy setup youtube guide]

11.3 VFDs configuration (schneider electric altivar 212):

No.	Parameter	Description	Value
1.	AUH>>AU4	Ref.1 channel	4 (4-20mA speed ref)
2.	AUF>>**AU1**	Auto ramp	0 (Disable)
3.	AUF>>**ACC**	Acceleration time	10 seconds
4.	AUF>>**dEC**	Deceleration time	10 seconds
5.	AUF>>**LL**	Low Limit motor frequency	0
6.	AUF>>FH	Maximum frequency	60 Hz
7.	AUF>>**UL**	Upper Limit motor frequency	60 Hz
8.	AUF>>**tHr**	Motor Thermal protection	Nominal value on nameplate (Amps) or 100%
9.	AUF>>**Pt**	Motor control mode	1 (variable torque used for pumps)
10.	AUF>>**uL**	Rated Motor frequency	60 Hz
11.	AUF>>**uLu**	Rated Motor voltage	Nominal value on nameplate
12.	AUF>>**F415**	Rated Motor current	Nominal value on nameplate
13.	AUF>>**F417**	Rated Motor speed	Nominal value on nameplate
14.	AUF>>**F601**	Motor current limit	110% of nominal value (Amps or %)
15.	F201	 (ATV212)	20%
16.	F203		100%
17.	F202		0Hz
18.	F204		60Hz

12 Alarms list

The list below include all alarms related to RO operation. Gray rows indicate setpoint irrelevant to the Agnico Systems. These will not be shown on the HMI if recommended system configurations were selected.

Notes:

- The Alarm action in below table is the default value however this action can be configured by Admin. Also an alarm can be disabled or enabled if required (e.g temporary disable alarm of a faulty instrument or nuinsance alarm). Please see page 30 for more information.
- Out of range for analog instrument will occur if signal drops below 3.8mA or increase above 21.0mA.
- Alarm delay time is hard coded. If changes are required please contact Pall.
- In general, if an alarm has no critical effect on RO system operation it will just generate a pop-up message. This should notify the user that there is a problem which should be fixed when possible. If an alarm requires the system to stop (dangerous operating condition, loss of critical resource) it will trigger a shutdown sequence. A shutdown flush will occur if the fault is not critical for the flushing procedure (loss of signal from feed pH sensor). A shutdown Non-flush will occur if the fault is critical for the flushing procedure (loss of pressurized air).

Alarm Category	No	Description [Alarm Text]	TAG		Trigger	units	Delay	Units	Active during	Stop Non-Flush	Stop Flush	STOP CIP	BLINK
Instrument fault	1	FIT-1 transmitter fault	FIT-1	=	OUT_OF_RANGE	-	30	sec	Always		X		X
Instrument fault	2	FIT-2 transmitter fault	FIT-2	=	OUT_OF_RANGE	-	30	sec	Always		X		X
Instrument fault	3	FIT-4 transmitter fault	FIT-4	=	OUT_OF_RANGE	-	30	sec	Always		X		X
Instrument fault	4	LT-1 transmitter fault	LT-1	=	OUT_OF_RANGE	-	30	sec	Always		X		X
Instrument fault	5	LT-2 transmitter fault	LT-2	=	OUT_OF_RANGE	-	30	sec	Always		X		X
Instrument fault	6	PT-1 transmitter fault	PT-1	=	OUT_OF_RANGE	-	30	sec	Always	X			X
Instrument fault	7	PT-2 transmitter fault	PT-2	=	OUT_OF_RANGE	-	30	sec	Always		X		X
Instrument fault	8	PT-3 transmitter fault	PT-3	=	OUT_OF_RANGE	-	30	sec	Always		X		X
Instrument fault	9	PT-5 transmitter fault	PT-5	=	OUT_OF_RANGE	-	30	sec	Always		X		X
Instrument fault	10	PT-7 transmitter fault	PT-7	=	OUT_OF_RANGE	-	30	sec	Always				X
Instrument fault	11	PDT-1 transmitter fault	PDT-1	=	OUT_OF_RANGE	-	30	sec	Always				X
Instrument fault	12	TT-1 transmitter fault	TT-1	=	OUT_OF_RANGE	-	30	sec	Always				X
Instrument fault	13	TT-2 transmitter fault	TT-2	=	OUT_OF_RANGE	-	30	sec	Always			X	X
Instrument fault	14	CIT-1 transmitter fault	CIT-1	=	OUT_OF_RANGE	-	30	sec	Always				X
Instrument fault	15	CIT-2 transmitter fault	CIT-2	=	OUT_OF_RANGE	-	30	sec	Always				X
Instrument fault	16	CIT-3 transmitter fault	CIT-3	=	OUT_OF_RANGE	-	30	sec	Always				X
Instrument fault	17	CIT-4 transmitter fault	CIT-4	=	OUT_OF_RANGE	-	30	sec	Always				X
Instrument fault	18	AIT-1 transmitter fault	AIT-1	=	OUT_OF_RANGE	-	30	sec	Always		X		X
Instrument fault	19	AIT-3 transmitter fault	AIT-3	=	OUT_OF_RANGE	-	30	sec	Always		X		X

Instrument fault	20	AIT-4 transmitter fault	AIT-4	=	OUT_OF_RANGE	-	30	sec	Always				X
Instrument fault	21	PT-6 transmitter fault	PT-6	=	OUT_OF_RANGE	-	30	sec	Always				X
Instrument fault	22	LT-3 transmitter fault	LT-3	=	OUT_OF_RANGE	-	30	sec	Always	X			X
Instrument fault	23	J1_FlowFB transmitter fault	J1_FlowFB	=	OUT_OF_RANGE	-	30	sec	Always				X
	24	Spare											
Equipment Faults	25	CIP Heater tripped	HE-1_run_FB	=	0	-	30	sec	Heater On				X
Equipment Faults	26	Booster pump VFD fault or Overload	VFD1_OK	=	0	-	1	sec	Always	X		X	X
Equipment Faults	27	High pressure pump VFD fault or Overload	VFD2_OK	=	0	-	1	sec	Always		X	X	X
Equipment Faults	28	Circulation pump VFD fault or Overload	VFD3_OK	=	0	-	1	sec	Always		X	X	X
Equipment Faults	29	CIP pump VFD fault or Overload	VFD4_OK	=	0	-	1	sec	Always	X		X	X
Equipment Faults	30	A.S general alarm	J1_OK	=	0	-	60	sec	PowerUp,CCD, PFD, C.PFD,Standby		X		X
	31	Spare											
	32	Spare											
	33	Spare											
	34	Spare											
Process exceeding normal operating range	35	P-1 suction pressure Low	PT-5	<=	1	psi	20	sec	CIP, S.D Flush with Permeate,Standby	X		X	X
Process exceeding normal operating range	36	P-1 suction pressure Low (CCD)	PT-5	<=	SP-46	psi	60	sec	CCD		X		X
Process exceeding normal operating range	37	P-1 discharge pressure high	PT-1	>=	SP-47	psi	5	sec	Always	X		X	X
Process exceeding normal operating range	38	P-2 suction pressure Low	PT-1	<=	1.5	psi	60	sec	PowerUp,CCD, PFD, C.PFD, CIP+P1 RUN	X		X	X
Process exceeding normal operating range	39	High module inlet pressure warning	PT-2	>=	SP-38	psi	30	sec	PowerUp,CCD, PFD, C.PFD, CIP				X
Process exceeding normal operating range	40	Maximum module inlet pressure alarm	PT-2	>=	SP-39	psi	5	sec	Always	X		X	X
Process exceeding normal operating range	41	Module inlet pressure High in PFD	PT-2	>=	Last CCD pressure	psi	15	sec	PFD	X			X

Process exceeding normal operating range	42	Module inlet pressure Low	PT-2	< =	SP-40	psi	120	sec	PowerUp,CCD, PFD, C.PFD, CIP+P1 RUN	X		X	X
Process exceeding normal operating range	43	Module Differential pressure High warning	PT2-PT3	> =	SP-54	psi	30	sec	PowerUp,CCD, PFD, C.PFD, CIP				X
Process exceeding normal operating range	44	Module Differential pressure High alarm	PT2-PT3	> =	SP-55	psi	5	sec	PowerUp,CCD, PFD, C.PFD, CIP		X	X	X
Process exceeding normal operating range	45	Micronic Filters Differential pressure High	PDT-01 or (PT6-PT1)	> =	SP-53	psi	30	sec	PowerUp,CCD, PFD, C.PFD, CIP				X
Process exceeding normal operating range	46	Permeate pressure high	PT-7	> =	SP-48	psi	5	sec	Always	X		X	X
Process exceeding normal operating range	47	Negetive backpressure	PT3-PT7	< =	-5	psi	2	sec	Always	X		X	X
Process exceeding normal operating range	48	Low water temperature	TT-1	< =	35	F	60	sec	PowerUp,CCD, PFD, C.PFD, CIP		X	X	X
Process exceeding normal operating range	49	High water temperature	TT-1	> =	113	F	60	sec	PowerUp,CCD, PFD, C.PFD, CIP		X	X	X
Process exceeding normal operating range	50	Feed pH Low	AIT-1	< =	SP-58	pH	600	sec	PowerUp,CCD, PFD, C.PFD,Standby		X		X
Process exceeding normal operating range	51	Feed pH High	AIT-1	> =	SP-59	pH	600	sec	PowerUp,CCD, PFD, C.PFD,Standby		X		X
Process exceeding normal operating range	52	High Feed ORP level	AIT-3	> =	SP-49	mV	600	sec	PowerUp,CCD, PFD, C.PFD,Standby		X		X
Process exceeding normal operating range	53	Feed conductivity high	CIT-1	> =	SP-52	uS/cm	1	hr	PowerUp,CCD, PFD, C.PFD,Standby				X
Process exceeding normal operating range	54	Permeate high conductivity warning	CIT-3	> =	SP-50	uS/cm	60	sec	CCD, PFD, C.PFD				X
Process exceeding normal operating range	55	Permeate high conductivity alarm	CIT-3	> =	SP-51	uS/cm	60	sec	CCD, PFD, C.PFD		X		X

Process exceeding normal operating range	56	Feed flow Low	FIT-1	<=	SP-41	gpm	90	sec	PowerUp,CCD, PFD, C.PFD	X			X
Process exceeding normal operating range	57	Feed flow High	FIT-1	>=	SP-42	gpm	300	sec	PowerUp,CCD, PFD, C.PFD	X			X
Process exceeding normal operating range	58	Concentrate flow Low	FIT-2	<=	SP-43	gpm	90	sec	PowerUp,CCD, PFD, C.PFD		X		X
Process exceeding normal operating range	59	Concentrate flow High	FIT-2	>=	SP-44	gpm	300	sec	PowerUp,CCD, PFD, C.PFD				X
Process exceeding normal operating range	60	Low Permeate flush level	LSL-1	=	0	-	5	sec	Shutdown Flush, CIP+XV4	X		X	X
Process exceeding normal operating range	61	Recovery too Low	Eq-16.2	<=	SP-45	%	5	sec	CCD, PFD		X		X
Process exceeding normal operating range	62	System Scaling/Fouling	F-Factor	<	0.85	-	1	sec	CCD, PFD				X
Process exceeding normal operating range	63	Air pressure low	PS-1	=	0	-	10	sec	Always	X		X	X
Process exceeding normal operating range	64	Blend water conductivity high	CIT-4	>=	SP-56	uS/cm	60	sec	CCD				X
Process exceeding normal operating range	65	High water temperature in CIP tank	TT-2	>=	120	F	60	sec	Always			X	X
Process exceeding normal operating range	66	Low feed tank level	LT1	<=	SP-57	%	60	sec	PowerUp,CCD, PFD, C.PFD		X		X
Deviation from set points	67	Deviation from CCD feed flow setpoint	FIT-1/SP-14		>1.2 or <0.8	-	60	sec	CCD		X		X
Deviation from set points	68	Deviation from PFD feed flow setpoint	FIT-1/SP-15		>1.2 or <0.8	-	60	sec	PFD, C.PFD, Shutdown Flush	X			X
Deviation from set points	69	Deviation from CCD concentrate flow setpoint	FIT-2/SP-16		>1.2 or <0.8	-	60	sec	CCD		X		X
Deviation from set points	70	Deviation from Bypass flow setpoint	FIT-4/SP-34		>1.2 or <0.8	-	60	sec	CCD		X		X
Deviation from set points	71	A.S dosing malfunction	J1_FB/Eq-06		>1.2 or <0.8	-	600	sec	PowerUp,CCD, PFD, C.PFD		X		X

Deviation from set points	72	Low deviation from Feed pH setpoint	AIT-1	<=	SP-79 -0.5	pH	600	sec	PowerUp,CCD, PFD, C.PFD		X		X
Deviation from set points	73	High deviation from Feed pH setpoint	AIT-1	>=	SP-79 +0.5	pH	600	sec	PowerUp,CCD, PFD, C.PFD		X		X
Deviation from set points	74	Low deviation from Permeate pH setpoint	AIT-4	<=	SP-88 -0.5	pH	600	sec	PowerUp,CCD, PFD, C.PFD		X		X
Deviation from set points	75	High deviation from Permeate pH setpoint	AIT-4	>=	SP-88 +0.5	pH	600	sec	PowerUp,CCD, PFD, C.PFD		X		X
Process exceeding normal operating range	76	Low Permeate flush level	LT-3	<=	SP-97	%	5	sec	Shutdown Flush, CIP+XV4	X		X	X
	77	Spare											
	78	Spare											
	79	Spare											
Process stuck	80	CCD Cycle time too long	CCD time	>=	1.2xEq-04	min	1	sec	CCD		X		X
Process stuck	81	PFD Cycle time too long	PFD time	>=	1.2xEq-05	min	1	sec	PFD, Shtudown flush	X			X
Process stuck	82	Permeate tank filling too long	LSH-1	=	0	-	600	sec	XV-9 OPEN (Not during CIP)	X			X
Process stuck	83	Flushing sequence too long	Wash done flag	=	0	-	240	sec	Powerup rinse	X			X
Process stuck	84	Spare											
Process stuck	85	Permeate tank filling too long	LT-3	<	SP-98	%	600	sec	XV-9 OPEN (Not during CIP)	X			X
	86	Spare											
	87	Spare											
Event log	88	End of start signal from client	Request demand	=	0		1	sec	Always				
Process exceeding normal operating range	89	No pulse alarm	FIT-1 Pules counter	=	0	pulse	20	sec	P1 / P2 / P4 minimum Hz + run			X	x
Process exceeding normal operating range	90	No pulse alarm	FIT-2 Pules counter	=	0	pulse	20	sec	P3 minimum Hz + run			X	x

13 Troubleshooting

HMI Trend or Alarm	Probable Cause	Recommended Action
Instrument fault (out of 4-20mA range) Alarms related: 1-21	Wiring connection issue or faulty instrument	Check for loose/broken signal wire
VFD fault Alarms related: 26-29	Overload or VFD error	Try running once again, if problem repeat check the root cause. If problem is related to pump compare pump performance to curve, check shaft for scaling. Compare VFD current to motor max Amp on nameplate. Check error code in VFD and look in VFD troubleshoot manual. Check VFD settings are per recommended values (page. 54)
A.S general alarm Alarms related: 30	General alarm in J1 Dosing pump or Alarm signal wire is broken.	If an alarm is active in Dosing pump (red screen) follow manufacturer instruction. Otherwise check wire connectivity to RO panel.
P-1 suction pressure Low (when operating from CIP tank) Alarms related: 35	CIP tank level too low or high pressure loss from tank to pump suction (flow too high or pipe blockage)	Increase tank level. Check piping, Temporary strainer.
P-1 suction pressure Low (when operating from customer Feed line) Alarms related: 36	Feed tank level too low or loss of skid inlet pressure or high pressure loss from tank to pump suction (flow too high or pipe blockage)	Check feed source level/pressure. Check piping, Temporary strainer.
P-2 suction pressure Low Alarms related: 38	Micronic filters plugged. P-1 not pumping due to mechanical/electrical problem. Loss of skid inlet pressure	Check dP on micron filters. Check skid inlet pressure. Check P1/VFD1 operation
High module inlet pressure warning Alarms related: 39	Membrane Scaling Alarm set point doesn't match process	Check PT2 and F-Factor trends for scaling evidence. Increase alarm set point. Reduce flux (lower CCD flow set point). Consider reduce recovery set point.
High module inlet pressure warning Alarms related: 40	Membrane Scaling	Check PT2 and F-Factor trends for scaling evidence. Reduce flux (lower CCD flow set point) Reduce recovery set point.
Module inlet pressure High in PFD Alarms related: 41	XV-02 not responding during transition to PFD Manual brine valve position is too closed	Check XV-2 response, Check HV-7 position.

HMI Trend or Alarm	Probable Cause	Recommended Action
Module inlet pressure Low Alarms related: 42	P-1 / P-2 not primed or has mechanical/electrical problem Micron filters plugged. Empty Feed tank. Broken pipe/PV.	Check Pumps/VFDs operation. Check dP on micron filters. Check integrity of pipes/PV.
Module Differential pressure High warning Alarms related: 43	Scaled/Fouled membranes	Check dP trend. Consider membrane cleaning. Reduce circulation rate (P3 flow set point during CCD) but do not exceed recommended module recovery rate.
Module Differential pressure High alarm Alarms related: 44	Scaled/Fouled membranes	Perform membrane cleaning.
Micronic Filters Differential pressure High Alarms related: 45	Fouled filters	Replace filters
Permeate pressure high Alarms related: 46	Blocked permeate line	Check for closed valves/orifice plate long permeate route.
High water temperature Alarms related: 49	Heater doesn't shut down.	Stop CIP heater. Allow water to cool down.
Feed pH Low/High Alarms related: 50,51	Uncontrolled operation of J2	Check J2 dosing pump operation.
High Feed ORP level Alarms related: 52	SBS Dosing pump not primed or pumping problem Low chemical tank level Plugged injection point Chemical leak Feed chlorine level is abnormal SBS solution strength has diminished	Check J3 dosing pump operation. Check chemical tank level Check chemical is injected to line Check raw feed ORP/chlorine level Check SBS solution date pH should be in the range of 3.9-4.4
Permeate high conductivity Alarms related: 54,55	Membrane interconnector O-ring failure. Membrane scaling. Membrane integrity problem. Alarm value set (SP-50, SP-51) point doesn't match process condition.	Check each PV permeate conductivity, inspect source PV problem. Check interconnectors O-ring, permeate blind/thru adaptors O-rings Check if alarm value set (SP-50, SP-51) point match process condition.
Feed flow low Alarms related: 56	P-1, P-2 not primed or has mechanical/electrical problem Feed line is blocked. Suction plugged or tank outlet valve closed Empty Feed tank	Check pumps/VFDs operation. Check XV-1 response. Check tank level.
Concentrate flow Low Alarms related: 58	XV-02 not responding during transition to PFD Manual brine valve position is too closed P-3 not primed or has mechanical problem	Check XV-2 response, Check HV-7 position. Check P-3 pump operation.
Low Permeate flush level Alarms related: 60	Level in CIP tank too low for operation with P1/P4	Increase tank level
Recovery too Low Alarms related: 61	Membrane Scaling	Check the CCD<<>>PFD settings related to pressure Consider membrane cleaning

HMI Trend or Alarm	Probable Cause	Recommended Action
System Scaling/Fouling Alarms related: 62	Membrane Scaling	Consider membrane cleaning
Air pressure low Alarms related: 63	Loss of plant air pressure, air leaks, plant pressure not adjusted to supply 80 psi.	Check air connection, plant supply pressure, and excessive air leak.
A.S dosing malfunction Alarms related: 71	Required flow rate deviate from actual flow rate	Check A.S dosing pump operation. Check dosing pump calibration
Low/High deviation from Feed pH set point Alarms related: 72,73	Acid Dosing pump not primed or pumping problem Low chemical tank level Plugged injection point Chemical leak	Check J2 dosing pump operation Check chemical tank level Check chemical is injected to line Check raw feed pH level
CCD Cycle time too long Alarms related: 80	Loss of signal from FIT-1	Check feed flow pulses
PFD/Flush Cycle time too long Alarms related: 81,83	Loss of signal from FIT-2	Check brine flow pulses
Permeate tank filling too long Alarms related: 82	XV-9B not responding LSH-1 signal not responding	Check XV-9B operation Check LS-1

Important notes:

- In any alarm it is advised first to verify that the sensor causing the alarm is in good condition and make sure it is configured correctly.
- If an analog instrument needs to be replaced it is important that its range is configured as the HMI analog range. Otherwise it will generate a false reading.
  Specifically for flow meters it is important also to verify the digital pulse input and to match the pulse per unit and volume units to the HMI set point.

14 Routine maintenance

The table below indicates a set maintenance tasks that should be completed relatively frequently. This list is not comprehensive. For in-depth maintenance information on each component of the system, please consult the maintenance manual provided by the manufacturer. These maintenance manuals are included in Appendix B.

Action	Frequency
General	
Check Level of chemical storage tanks Check dosing pump priming	Daily
Check leaks from piping	Daily
Check dP on Micronic filters (PI-6 minus PI-1), Replace if Value>15psi. Use 1-5 micron filters.	Weekly
Check pump operation: Noise, Motor temperature, Leaks from Mechanical seal, positive suction pressure	Weekly
CIP	As required (see separate guide)
Instrumentation	
Pressure gauges - Compare reading to corresponding pressure transmitters	Weekly
Calibrate conductivity sensors: Check HMI value and compare to value taken by portable meter. If value deviates considerably, calibrate sensor	Weekly
Calibrate pH and ORP sensors- For pH meter use pH 7,10 buffer solution. For ORP meter use ~250mV buffer solution.	Monthly

15 Cleaning and Preservation

15.1 Purpose and requirement of cleaning

In normal RO operation, the membrane elements can become fouled by biological matter and colloidal particles or scaled by minerals. Deposits build up on the membrane surface during operation until they cause loss in performance. Cleaning is the action used to restore the membrane element performance.

Membranes should be cleaned periodically or when there is an indication for fouling or scaling conditions as calculated by F-Factor. If one of the following conditions exists, consider cleaning the membranes:

- If the normalized permeate flow drops by 15% or more → F-Factor drops below 0.85.
- If the normalized salt passage increases by 5 - 10% or more.
- If the pressure drop increases by 10% or more (assuming circulation flow set point has not changed).

It is advised to open one or more pressure vessel to examine the membrane elements to confirm the presence of contaminants and diagnose their type.

15.2 Preparations and Logistics

During this procedure, the operator must wear required personal protective equipment. Recommend minimum PPE: rubber gloves and safety glasses. Consult the SDS of all chemicals and don any additional PPE required.

Before cleaning the membrane elements make sure all necessary items are ready for use:

- CIP tank
- CIP pump
- Cleaning bulk solution - The selection of a cleaning chemical depends upon the nature of the contaminants. Based on initial water chemistry the most probably scaling species will be Silica which is best treated with high pH caustic solution. In any case before choosing the correct treatment a valid water analysis need to be considered and a complete troubleshooting of the system should be performed.
- Handheld for measuring CIP solution pH and temperature

15.3 CIP Procedure:

Cleaning involves six steps, which are explained below.

Step 1 – Making up a cleaning solution:

During normal operation with permeate flush enabled, shut down the RO system by pressing the shutdown button on the HMI and wait until permeate flushing is completed and system is idle. Change the physical selector of RO unit from AUTO to CIP. This should close all automatic valves.

Add permeate water to the CIP tank and heat the water in the CIP tank to 30-35 C, according to recommendation of cleaning chemistry provider/expert. Do not heat the water above 45 C. Once the water is at temperature, turn off the heater.

Add the required amount of chemical to the tank according to recommendations from the cleaning chemistry provider or other expert guidance.

Step 2 – Set up a recirculation path:

Setup a path for CIP solution circulation by doing the following:

1) Close HV-03.
2) Open HV-08 and HV-16.
3) Open XV-04

Step 3 – Slow recycling:

While brine and permeate are diverted to the CIP tank, circulate the CIP solution through the RO system in a closed loop starting from CIP tank to pressure vessels and back to CIP tank using the P-1 pump. Watch that CIP tank level is steady and no solution volume is lost. Adjust system pump speed to get flow rate of 20 gpm per pressure vessel (about 480 gpm) to eliminate any high amount of foulant from plugging the membranes feed side. Feed pressure should remain below 35 psi. Run the system for at least 10-15 minutes.

The temperature will change at first when the fluid inside the pressure vessels mixes with the fluid in the tank. If necessary, continue to heat the solution to maintain temperature within recommended limits. Take measurements of circulated solution pH. If the pH increases more than 0.5 pH units during acid cleaning, more acid needs to be added. If the pH decreases more than 0.5 pH units during alkaline cleaning, more caustic needs to be added.

Step 4 – Soaking

Turn the P-1 pump off and allow the elements to soak while system stands still. Usually a soak period of about 30-60 minutes is sufficient. For difficult fouling an extended soak period of up to 12 hours is required.

Step 5 – High flow pumping

Turn the P-1 pump on to get flow rate of 35 gpm per pressure vessel (about 840 gpm). Operate at this rate for 1 to 4 hours. The high flow rate flushes out the foulants removed from the membrane surface by the cleaning. It is important not to exceed a feed pressure of 60 psi to avoid significant permeate production, and also to limit pressure drop according to the membranes' manufacturer recommendations. Keep monitoring pH and adjust if necessary by adding cleaning chemical to the CIP tank.

Note: In tough scaling conditions steps 4, 5 should be repeated multiple times for better cleaning efficiency.

Once cleaning is completed with the first bank of 5 pressure vessels, return to step 2.3, and switch which bank of pressure vessels is connected to the CIP and which is plugged. Continue with the same steps on this bank of pressure vessels as on the first.

Step 6 – Flushing the RO

Remove the cleaning solution from the RO by following the procedure below.

1) Stop all pumps and turn off the heater.
2) Close valves HV-08, HV-16, XV-04 and XV-09.
3) Open HV-26 and drain T-3.
4) Once T-3 has been drained, close HV-26
5) Refill T-3 with low salinity water
6) Open HV-16, XV-02 and XV-02
7) Use P-1 to flush the RO with the water in the tank until the water reaches the low level setting.
8) Refill T-3 and flush as stated in step 7 until permeate pH and conductivity reach acceptable limits, or until at least 2000 gallons have been pumped.
9) Return RO to "OFF".

Notes:

- For advice on cleaning solutions and cleaning methods please visit: https://navigator.orangeboatsupport.com
- The fouling or scaling of elements typically consists of a combination of foulants and scalants, for instance a mixture of organic fouling, colloidal fouling and biofouling. Therefore, it is very critical that the first cleaning step is wisely chosen. It is recommended that alkaline cleaning as the first cleaning step. Acid cleaning should only be applied as the first cleaning step if it is known that only calcium carbonate or iron oxide/hydroxide is present on the membrane elements.
- Turbid or strong colored cleaning solutions should be replaced. The cleaning is repeated with a fresh cleaning solution.
- If the system has to be shutdown for more than 24 hours, the elements should be stored in 1% w/w SBS solution preservation solution.
- Cleaning is done in Manual mode. To distinguish Manual mode from CIP, the operator is required to toggle the button below. The status of the button changes between "Manual mode" and "CIP in progress".

16 Membrane loading and unloading

Membranes should always be loaded from the feed end and removed from the concentrate end. Please refer to Desalitech movie for further details.

Caution – when placing the end caps back into the pressure vessel, never strike the permeate port. Apply pressure only on the plate itself.

Tip – use the extractor tool (two T-handles) provided with unit for remove end caps from pressure vessel.

17 CCRO Storage and Transfer

A Closed Circuit Reverse Osmosis (CCRO) system, as part of a water treatment solution is typically exposed to varying operating conditions. However, changes in operating conditions may warrant the need for long term system shut down or relocation. Such deviations in a normal operating schedule require special care and precaution to ensure proper future performance and functioning of the membrane system and its associated components. Generally, the biggest threats to a membrane system that is currently static or on a reduced operating schedule are freezing and microbiological growth. To address these threats, this document will discuss the appropriate steps of shutting down, preserving and storing your CCRO system to ensure that future functionality remains optimal.

The shut down operation of a CCRO system is the first and one of the most important steps in ensuring proper subsequent preservation and storage. Typically, CCRO systems are designed to handle continuous operation, which reduces the likelihood of significant product TDS variation, as well as providing a limited environment for microbiological growth. As soon as continuous or near-continuous operation is disrupted, microbes are given nearly free reign to reproduce and form biofilm on both the feed and concentrate plumbing of the system, including the membranes. This condition is termed biofouling. If left unchecked, biofouling may result in permeate flow loss and the need to increase feed pressure to achieve the same production. More importantly, the effects manifested by biofouling may give rise to decreased membrane system efficiency and high energy costs. To reduce this risk factor, several key steps should be performed during system shut down.

During shutdown of a CCRO system, membranes should first be flushed with permeate water. However, in cases where a large quantity of permeate water is not available, high quality feed water may be used as an appropriate substitute. Typically, what is meant by high quality feed water is softened municipal water or well water with a SDI<3. The purpose of flushing with pure or relatively pure water is to remove any water present in the system that contains a high concentration of impurities; this is especially important on systems that have multiple membranes in series, where the tail membranes may experience elevated concentrations of impurities. Most importantly, flushing with high purity water will ensure that the concentrate conductivity matches closely to the conductivity of the permeate produced by the membrane system. When flushing the membrane system during the shutdown procedure, it is also worth noting that this procedure does not have to be done at a high pressure, 40 psi will suffice in most applications. During normal or continuous operation, a high feed flush rate may offer an added beneficial effect, but it is important to keep in mind that if multi-element vessels are used, then close attention should be paid in ensuring that membrane pressure drops do not exceed the specifications stated by the membrane manufacturer. Another consideration when flushing a membrane system during shut down is that the water used for flushing should never contain pretreatment chemicals. Phosphate-based scale inhibitors are especially discouraged as they promote organic growth. In addition, all chemical injection systems should be stopped prior to membrane flushing.

In conjunction with flushing, there are several plumbing considerations of the membrane system that need to be taken to ensure the most effective flush possible. If the concentrate line ends in a drain below the level of the pressure vessels, a siphoning effect may empty even the most carefully flushed system. To combat this effect, an air break should be utilized in the concentrate line at a position higher than the highest-pressure vessel. Another plumbing consideration is that if the permeate line is pressurized during operation and the system faces unexpected shutdowns, the membranes may become exposed to a deleterious static permeate backpressure, which can delaminate the flatsheet contained within each membrane element. If this backpressure exceeds 5 psi, irreversible damage may result to the membranes; because of this, check valves or atmospheric drain valves may be used to safeguard the membranes.

One final note on membrane system shutdown is that special precautions should be taken if a system is shut down for a period greater than two days. Special care should be taken to ensure that the membrane elements do not dry out. When a membrane dries out, it will permanently lose flux and performance will suffer tremendously. There are techniques to help restore flux in dried elements, such as using an isopropyl alcohol/propylene glycol mix to help open up permeate channels in the desiccated flatsheet; however, this is mostly a stop gap measure and should not be performed unless absolutely necessary. In addition, extended shut down necessitates that the system is protected from biological growth and temperature extremes; the next section will deal with this topic exclusively.

After flushing of the CCRO system, preservation should follow within the next ten hours. Optimally, the system should be pumped full of either a 1-1.5% solution of sodium metabisulfite (SMBS), or an alternative preservative. Preservative should be introduced into the system using what is called the overflow technique, where the SMBS is circulated in such a way that all remaining air in the system is minimized after the recirculation is completed. After all the pressure vessels have been filled, preservative solution should be allowed to overflow through an opening located higher than the uppermost pressure vessel. In the case of using SMBS, the preservation solution must be isolated from outside air by closing all valves on the membrane system; any contact with oxygen will oxidize SMBS. In addition, a SMBS preservative will require periodic checking of pH on a weekly basis; when the pH drops below 3, the preservation solution must be changed to ensure resistance to biological growth. SMBS may chemically attack certain plastics such as acetal; if a large portion of the membrane system plumbing consists of this material, then an alternative should be sought. If longer term storage and chemical stability is the target, it is recommended that a third party preservative to the industry standard SMBS solution should be used.

Finally, in addition to preservation from biological growth, protection from freezing may be necessary in regions that experience sub-zero temperatures on a frequent basis. Water contained within a CCRO at freezing temperatures will start to expand as it freezes; this expansion force will damage the weakest points in the system. Some of the negative effects of a membrane system encountering temperatures are:

- Damaged fittings
- Damaged pump components
- Damaged housings
- Damaged membrane elements

In this case it may be necessary to supplement preservative solutions with a propylene glycol additive to lower the freezing point. By varying the propylene glycol concentration, resistance to freezing may be increased or decreased. For example, a 20% propylene glycol solution will lower the freezing point of the water inside a membrane system to approximately 20°F. From a technical standpoint, the glycol acts to disturb formation of an ice crystal lattice and subsequent nucleation (state change) of water molecules to ice. Adding a higher percentage of propylene glycol will allow ever further resistance to freezing.

Summarizing the previous section and some general guidelines when shutting down and preserving a CCRO system:

- Flush the system with permeate or high-quality feed water.
- Make sure plumbing configuration prohibits siphoning of water out of the pressure vessels and eliminates the chance of momentary permeate backpressure.
- Immediately after flushing, preserve the membrane system with a preservative solution; if freezing temperatures are to be encountered, supplement the preservative solution with the proper percentage of propylene glycol to help prevent freezing.
- Make sure any electrical connections are turned off and safely disconnected if the CCRO is to be moved or relocated.

As an overview, CCRO systems are designed for continuous operation. However, when a system must be shut down, proper flushing, preparation, and preservation is essential. Flushing will ensure the membrane elements are surrounded by a clean, homogeneous source of water. Preservation will help safeguard membranes and associated equipment from biological growth and freezing temperatures. **Disclaimer: This information serves only as a general guideline; when operating and storing a CCRO system.**

18 RO Precautions

Permeate valve operation:

At no time during operation of a membrane element system should the permeate valve(s) be closed.

Closing the permeate valve during any phase of operation causes a pressure differential across the tail end of the system and will likely result in irreparable damage to the glue lines of the tail element(s). This damage will cause immediate increase in salt passage of the system.

Permeate valve(s) may be closed during shutdown after the system has been flushed and/or when input of the feed water is stopped. In many cases this is necessary to prevent an aerobic environment in the pressure vessels. The permeate valve (as well as the concentrate) should be fully re-opened prior to re-introducing feed water.

Presence of free chlorine:

At no time should there be a Free Chlorine or oxidant residual in the feed water. Even very low levels of chlorine or other oxidants in the feed stream can result in irreparable oxidation damage of the membrane.
Feed water ORP should be below 350mV.

Extreme condition during CIP:
pH range permitted: 2-12
Temperature range permitted: 35F – 113F

Lubrication of O-rings and brine seals:
At no time should petroleum based lubricants be used when lubricating interconnector o-rings, end adapter o-rings or the membrane element brine seal. Acceptable lubricants include glycerin, silicon-based Molykote III, or other silicone-based lubricants which contain no hydrocarbons.

Particulate-free feedwater:
At no time should the membrane be exposed to particulate matter that can accumulate on the surface of the membrane and mechanically damage the polyamide surface.

Water Hammer: if PV drained for any reason make sure it is full before startup system in AUTO mode.
Use manual mode to fill system, first by gravity then by applying some pressure with the booster pump.
If pump line has been drained make sure pump is primed (air removed) before operating.

Manual operation:
When operating manually (like CIP) always check there is a free flow path for permeate and brine.
If MF drained for maintenance fill manually before resuming AUTO operation. Verify ARV isolation valve is open.

Prolong system shutdown:
If RO is planned to standstill for more than 1-2 days it has to be flushed with permeate water and immersed in 1% SBS solution to prevent biological activity. All valves should be isolated to prevent air contact. For longer shutdowns it is recommended to use a biocide from a qualified RO membrane chemicals supplier and follow their instructions.

19 Minimum Feed water quality requirements

Desalitech recommends following the water quality feed water requirements recommended by the membrane manufacturer. Dow has published a clear list of maxima for the most common contaminants found in water treated by ROs in their RO manual on page 69, copied below. Failure to respect these concentration limits may result in the need for more frequent cleanings. Additional information can be found in the manuals of every membrane supplier, and will not be presented here.

Component	Unit	Max level	Comments
SDI	1	5	
$MFI_{0.45}$	1	4	Target <1
Oil and grease	mg/L	0.1	
TOC	mg/L	3	Synthetic organic compounds have generally more adverse effects on membranes than natural organic materials
COD	mg/L	10	
AOC	µg/Ac-C	10	Target <5
BFR	pg/cm^2 ATP	5	Target <1
Free chlorine	mg/L	0.1	Under certain conditions, the presence of oxidizing agents like chlorine will cause premature membrane failure. It is recommended to remove these prior to exposure to membranes
Ferrous iron	mg/L	4	pH <6. oxygen <0.5 PPM
Ferric iron	mg/L	0.05	
Manganese	mg/L	0.05	
Aluminum	mg/L	0.05	

Notes:

- To minimize fouling and have trouble free RO operation SDI <3 is recommended.
- Micron filters – these filters should be regarded as safety device to protect the membranes from suspended particles. These filters are not designed to be used as a pretreatment of high TSS load water.

20 Monitoring the RO system in RealiteQ

The RealiteQ system is a web based service that allows data logging and offer graph and report views of this data. It is also possible to write data from realiteQ into the PLC set points registers.

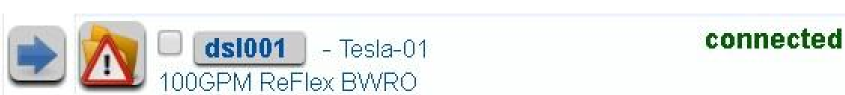
The data is sent to cloud via a cellular communication by a device call iCex located inside the control panel.

To log into the service goto:
The website is: https://desalitech.realiteq.net/ui/main
Mobile website: https://desalitech.realiteq.net/ui/mainmobile
Username and password will be provided separately.

Once logged into the site the user will see the following unit on the left frame.

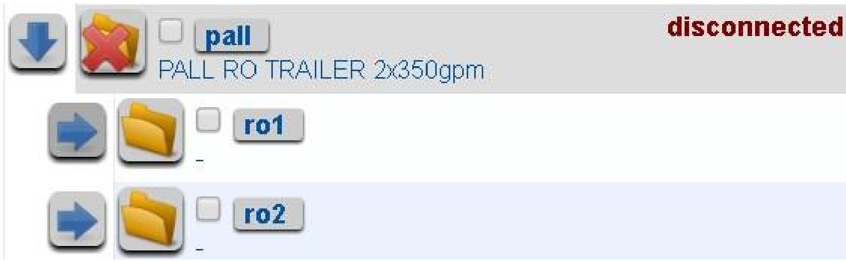
If the system is connected it will look like this:

If the system has an alarm it will look like this:

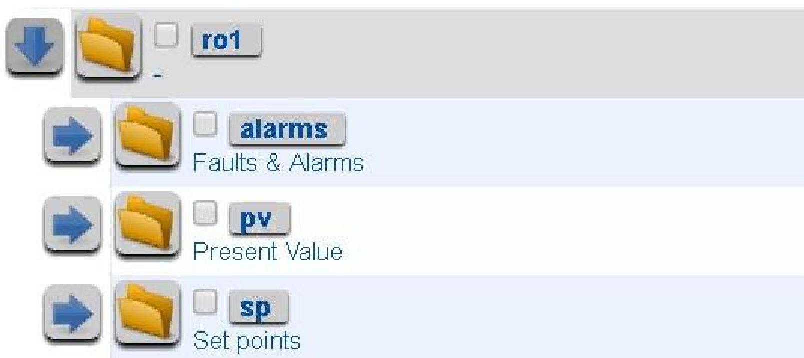


Project structure:

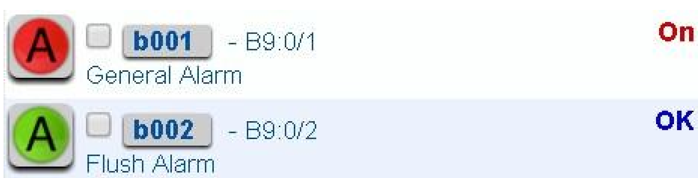
To enter the main folder, click on the arrow. The XXX RO TRAILER project TREE include two subfolder RO1 and RO2.



There are three subfolders under each unit folder:



Alarms – include a list of all alarms and their status

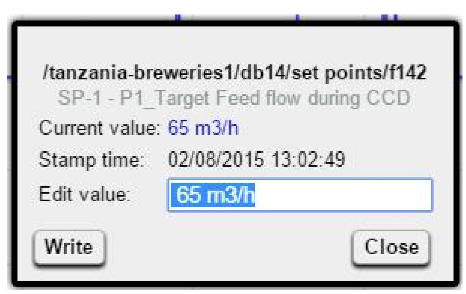


Green light and OK next to the alarm represents normal operation – no alarm triggered.

Red light and ON represents an active alarm. In case of an alarm it I possible that an e-mail will be sent to the configured e-mail addresses in Realiteq.

Present Value (PV) – this folder contains all system measurements as collected from the PLC in real time. The operator is able to view real time values for conductivity, pressures, flows etc through this folder and see the trends of each parameter on a graph.

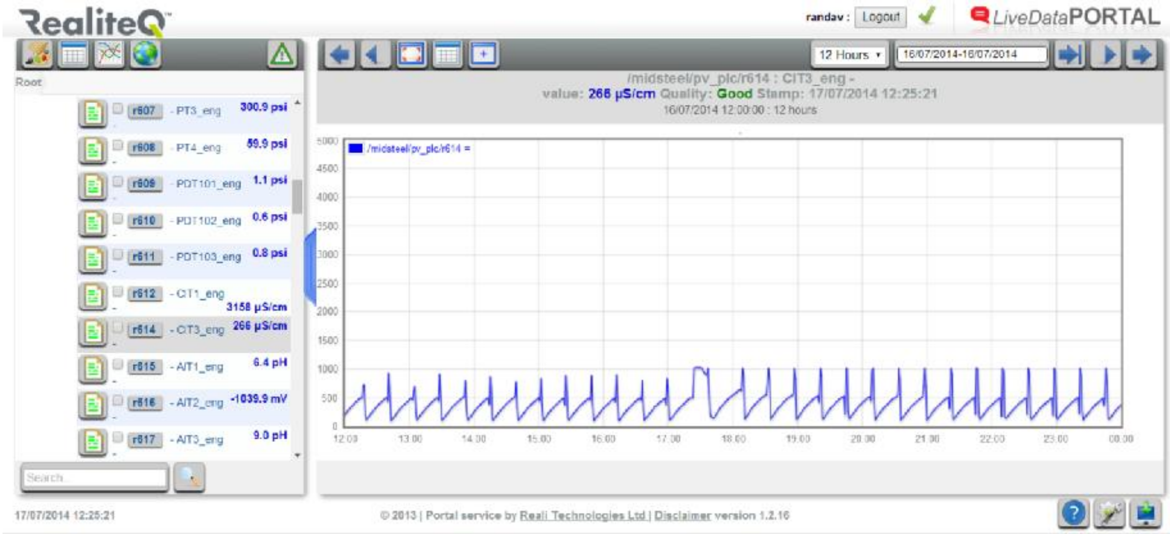
Set point (SP) – this folder contains all system parameters and set points. If the user has write permission the values of these set points can be modified remotely.



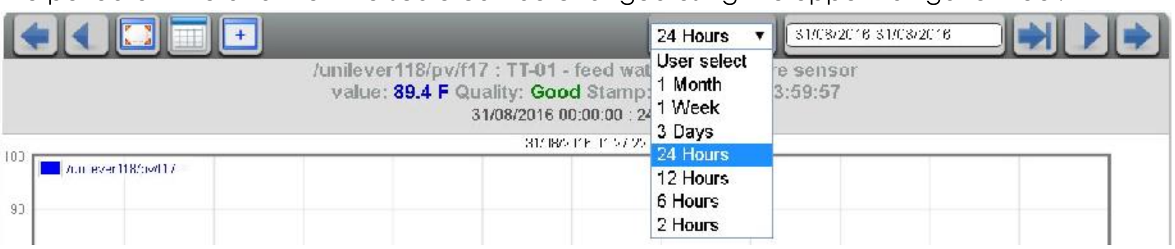
By clicking on specific set point a window will open, the value can be changed and approved by clicking "write". The SP will be updated accordingly. The change will be reflected after few seconds.

Monitoring a single process variable:

By selecting (clicking) one of the parameters listed under PV folder a graph of this parameter value vs. time will appear on the right frame.

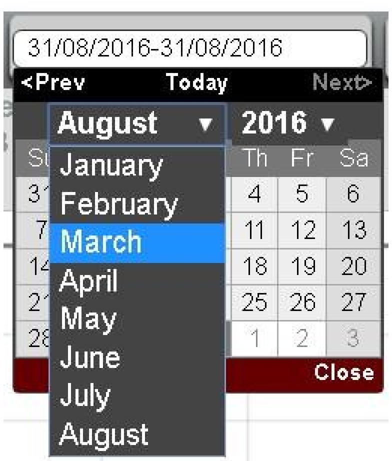


The period of time and the time scale can be changed using the upper navigation tool.

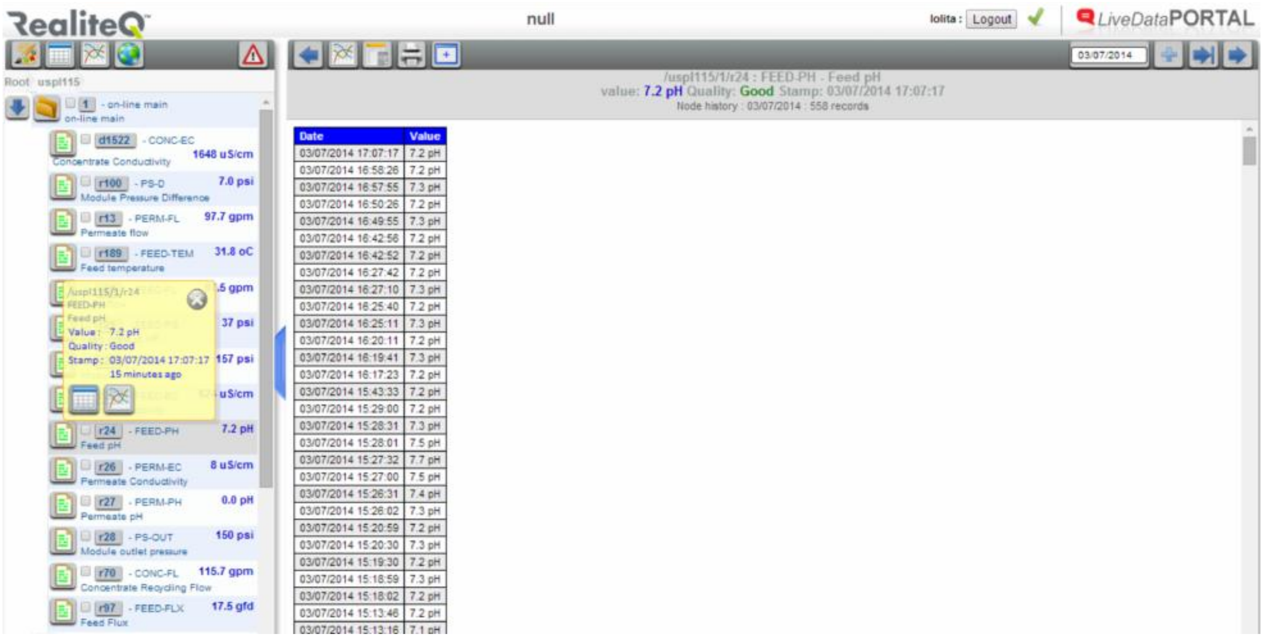


Once a time scale has been selected (2/6/12/24 hours; 3D; 1W; 1M) the left/right arrows will move the time period backwards or forwards respectively. small arrow will change half scale, large arrow will change full scale.

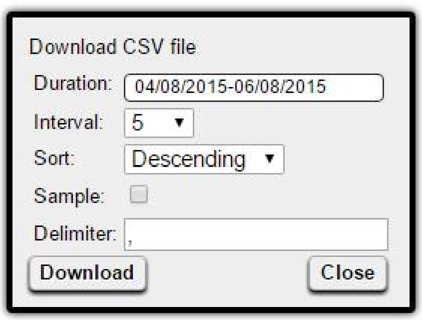
It is also possible to select an entire period of dates from here:



It is also possible to view the parameters in a table format, use the table icon on right top of the screen



The user can also download the data in that table to a CSV file. Note the data sampling interval changes with request for larger amount of dates.
To keep 1 min sampling interval user must select max of 2 days for each CSV file download.



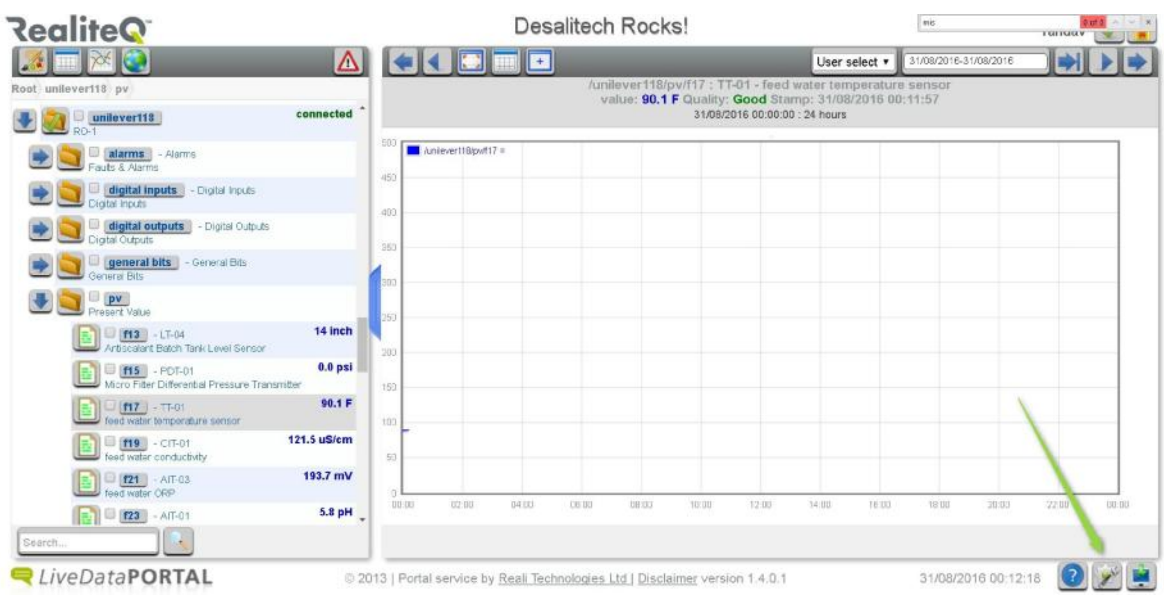
Monitoring several process variables on a common graph:

The user can also create reports when it is desired to view more than one process variable on the same graph for analysis purpose.

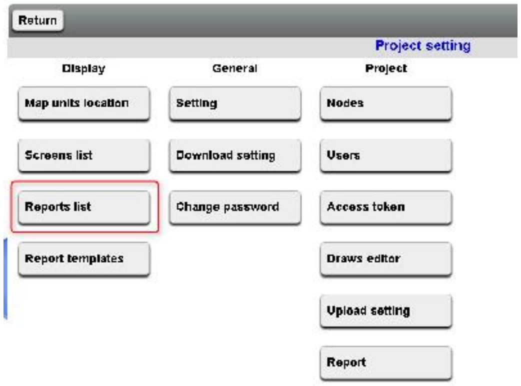
Below is an example of report showing inlet pressure, %Vol recovery, PV differential pressure and permeate quality all on the same graph.

To create a new report follow the below instructions:

1. Click on "settings" on the right bottom corner of the screen.

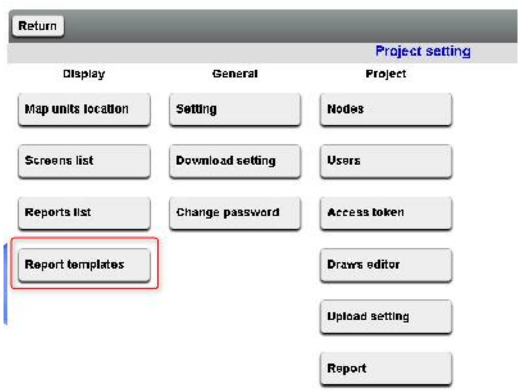


2. Continue to “report list” folder

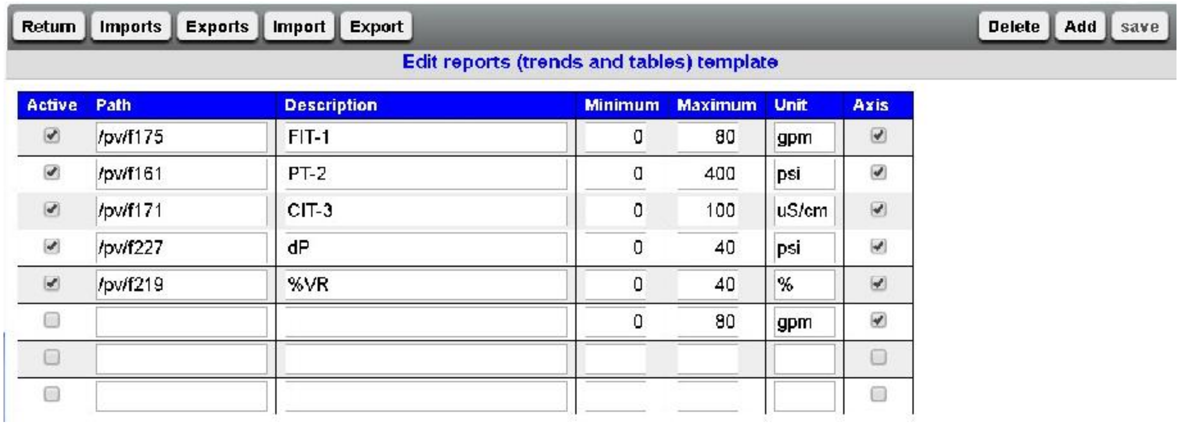


3. Click Add, enter the project path (/XXX/ro1 or /XXX/ro2), check “offset” box, enter report description and save.

4. Click return and then go to “Report Templates” for specific parameters of interest (like feed and permeate conductivity in the example)



5. Create as many templates as required – each contains up to 8 parameters.
   /pv/f56, for example, stands for "PV" folder and f56 is the register of a certain parameter,
   Make sure you check on both "active" and "axis" boxes and enter the right description of the units and the relevant range.
   Then save the data you inserted, and return to the main screen.

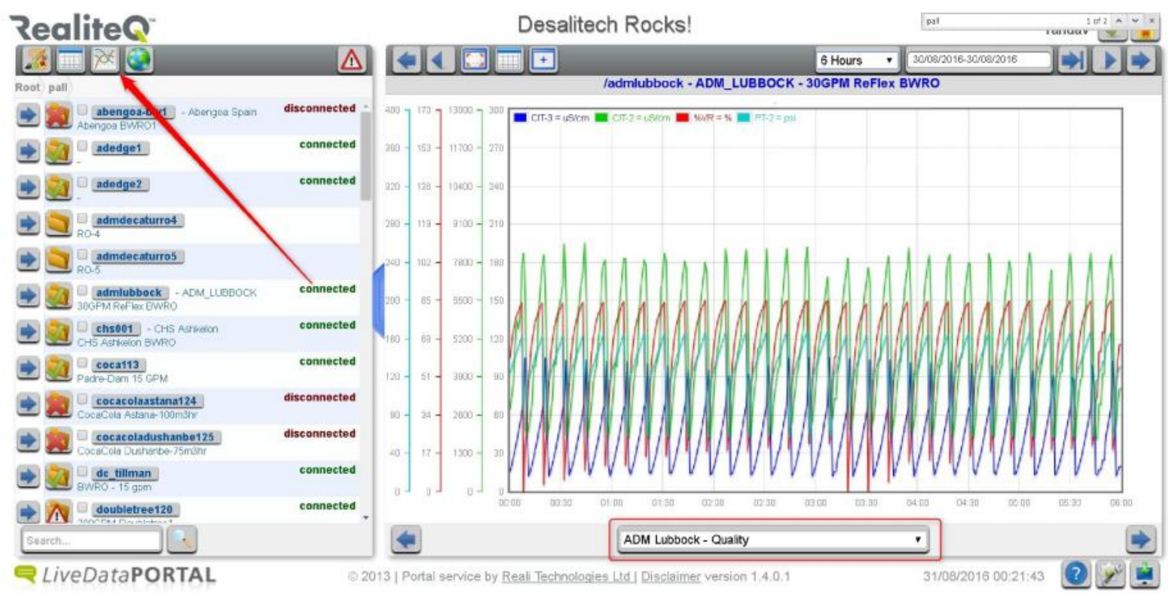


Return | Imports | Exports | Import | Export | Delete | Add | save

Edit reports (trends and tables) template

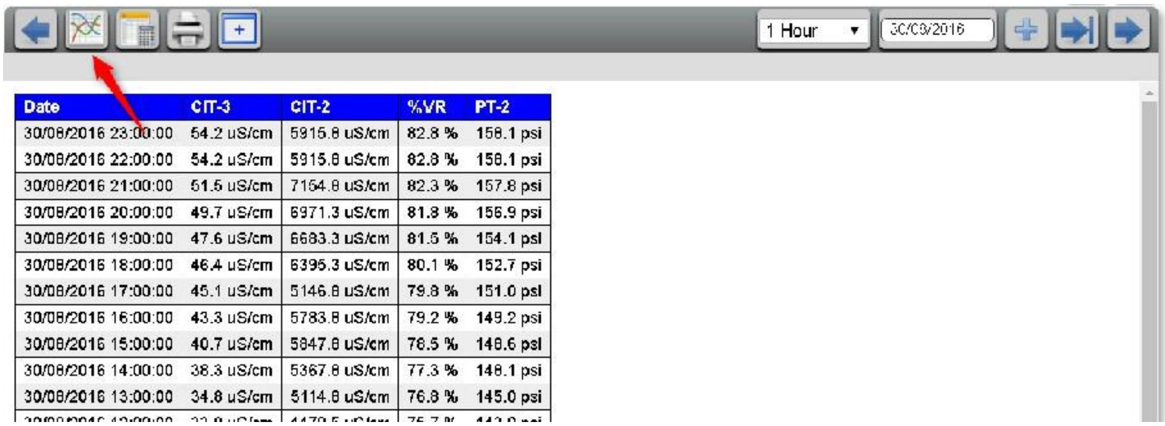
Active	Path	Description	Minimum	Maximum	Unit	Axis
☑	/pv/f175	FIT-1	0	80	gpm	☑
☑	/pv/f161	PT-2	0	400	psi	☑
☑	/pv/f171	CIT-3	0	100	uS/cm	☑
☑	/pv/f227	dP	0	40	psi	☑
☑	/pv/f219	%VR	0	40	%	☑
☐			0	80	gpm	☑
☐						☐
☐						☐

6. To see this report in action click "Return" three times until the map screen appear then Click on the marked icon:



If there are several reports, they are selected from the bottom part of the right frame (see red rectangle mark).

7. Like with a single parameter monitoring to view the data in table format Click on table icon:



Date	CIT-3	CIT-2	%VR	PT-2
30/08/2016 23:00:00	54.2 uS/cm	5915.8 uS/cm	82.8 %	158.1 psi
30/08/2016 22:00:00	54.2 uS/cm	5915.8 uS/cm	82.8 %	158.1 psi
30/08/2016 21:00:00	51.5 uS/cm	7164.8 uS/cm	82.3 %	157.8 psi
30/08/2016 20:00:00	49.7 uS/cm	6971.3 uS/cm	81.8 %	156.9 psi
30/08/2016 19:00:00	47.6 uS/cm	6683.3 uS/cm	81.5 %	154.1 psi
30/08/2016 18:00:00	46.4 uS/cm	6395.3 uS/cm	80.1 %	152.7 psi
30/08/2016 17:00:00	45.1 uS/cm	5146.8 uS/cm	79.8 %	151.0 psi
30/08/2016 16:00:00	43.3 uS/cm	5783.8 uS/cm	79.2 %	149.2 psi
30/08/2016 15:00:00	40.7 uS/cm	5847.8 uS/cm	78.5 %	148.6 psi
30/08/2016 14:00:00	38.3 uS/cm	5367.8 uS/cm	77.3 %	148.1 psi
30/08/2016 13:00:00	34.8 uS/cm	5114.8 uS/cm	76.8 %	145.0 psi

8. A CSV file with this data can be downloaded as previously explained for single parameters.

21 Appendix: A Calculation of Flow Factor (Normalized Flux)

Normalized flux for CCRO can be tracked using an index that is sometimes calls flow factor. This flow factor is a ratio of specific flux at the moment in question with a determined baseline specific flux.

$$F_f \quad = N \qquad F\ ux\ I_1 \quad = \frac{S \qquad F \quad a}{S \qquad F \quad b}$$

Specific flux is actual flux corrected by two terms, a temperature correction factor, and a pressure correction factor that is a function of the pressures experienced by the membrane, the feed conductivity, the recovery, and temperature.

$$S \qquad F \quad = \frac{F}{T \qquad C \qquad F \quad \cdot N \quad D \qquad P}$$

$$T \quad = \begin{cases} i\ T > 25, & e^{\left(2 \quad \cdot\left|\frac{1}{2} - \frac{1}{2 \quad +T}\right|\right)} \\ i\ T \leq 25, & e^{\left(30 \quad \cdot\left|\frac{1}{2} - \frac{1}{2 \quad +T}\right|\right)} \end{cases}$$

$$N \quad = \frac{P_M \qquad {}_F \quad + P_M \qquad {}_E}{2} - P_p \qquad - \pi_f$$

$$\pi_{fc} \quad \frac{C_{fc} \cdot (T + 320)}{491000}\ bar \qquad \text{for } C_{fc} < 20000 \text{ mg/l}$$

and

$$\pi_{fc} \quad \frac{0.0117 \cdot C_{fc} \quad 34}{14.23} \cdot \frac{T \quad 320}{345}\ bar \qquad \text{for } C_{fc} > 20000 \text{ mg/l}$$

with C_{fc} = concentration of the feed-concentrate

C_{fc} can be calculated from following approximation:

$$C_{fc} = C_f \cdot \frac{\ln \frac{1}{1 \quad Y}}{Y}$$

where Y = recovery ratio = $\frac{\text{product flow}}{\text{feed flow}}$

C_f = TDS feed mg/l

Because of the cycling of the Desalitech system, we calculate normalized flux at the moment of the end of CCD. The feed concentration used for this calculation is a calculated concentration based on the module recovery (Y above) and the overall recovery at the point of CCD. The following equations use the variables provided in Desalitech's data collection to make it clear how the calculation was made.

$$Y = \frac{P \quad M_F}{C \quad C_F \ + P \quad M_F}$$

$$C_f = F \quad D_E \; * 0.5 * \frac{1}{V \quad R}$$

$$C_f \; = C_f \cdot \frac{\ln \frac{1}{1-Y}}{Y}$$

These equations combined with those above should allow the osmotic pressure to be properly calculated, with temperature being taken as FEED_TEM. Note that osmotic pressure will need to be converted from bar to the pressure units being used, in this case psi. Net Driving Pressure can then be calculated as

$$N \quad = \frac{PS_{I} \; + PS_O}{2} - P_p \qquad - \pi_f$$

Where permeate pressure is whatever backpressure is expected. Because the PS_IN and PS_OUT are both gauge pressures, it is not necessary to indicate the permeate pressure is at atmospheric, and a value of about 5 psi is usually close for a system like it was plumbed at Con Ed.

With flux being proportional to permeate flowrate, it is sufficient to divide that value by the NDP and TCF calculated as mentioned above and to track those changes from a given baseline. It is important to rebaseline when new membranes are installed, or if system leaks are found and corrected, as these events could impact the calculations.

22 Appendix: B Maintenance Manuals