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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

IMPRO - T

Operation and Maintenance Manual

Date: November 2017

Rev: 00

Document No.: NYCS000010506

Table of Contents

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.

Tanks with deep water. 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.

Confined spaces. Follow the isolation and entry procedures before entering tank.

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 all relevant manual valves are open. Never operate against closed permeate valve.
- Two Emergency Stop push buttons are located near CIP tank and side exit door.

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.	SOO (Sequence Of Operation)
3.	Electrical drawings
4.	GA drawings

2.2 Purpose of RO system

The RO system duty is to perform reverse osmosis: separate the dissolved salts in the feed water 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 RO trailer comprises two RO units (RO1 and RO2) and a CIP tank. Each RO unit is capable of producing up to 350 gpm of permeate water at the highest recovery possible by water chemistry and pressure limitation of the system. Both RO units are fully automatic and are controlled from a single PLC and HMI located on a control panel.

RO System was designed to operate together with the PALL trailer as it's pretreatment or as a standalone system in case pretreatment is not required. When operating together with and PALL the MF PLC is connected to the RO PLC by Ethernet. In that case the MF PLC will control how many RO units are in operation by PLC messaging. Every set period of time, MF system performs CEB (chemically enhanced backwash / or Flux maintenance) during which the RO system is stopped.

The Trailer includes the following tie-in point connections: four underbed SS316 pipe manifolds with Victaulic connections on both sides for Feed (8"), Brine (4"), Permeate (4") and gravity Drainage (4"). CIP tank overflow (side wall).

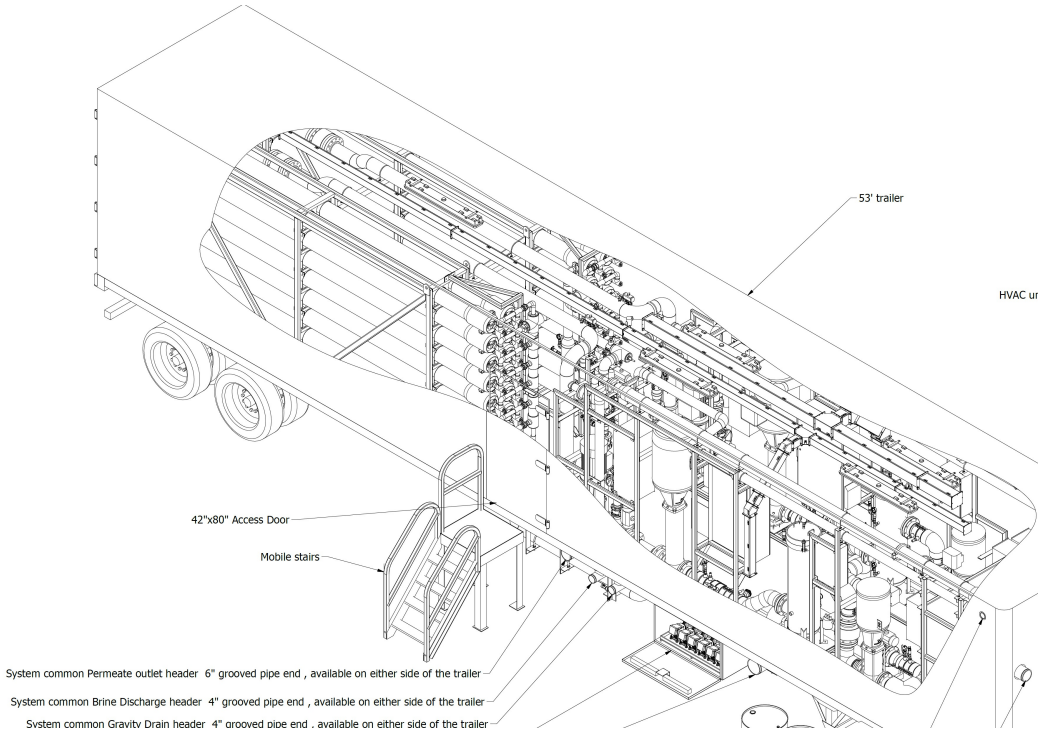


Figure 1 - RO Trailer GA drawing

The Trailer is also equipped with an HVAC unit at the front for climate control.

During this batch process each RO unit is operated in alternating cycles called CCD (closed circuit desalination) and PFD (plug flow desalination). In CCD brine is fully recirculated to the feed end of the pressure vessels by a circulation pump. In PFD the brine valve opens forcing concentrated brine to leave the system while introducing fresh volume of feed into the system for the next operating cycle. Detailed explanation about CCD and PDF operation is given in chapter 6.

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: TBD
   Antiscalant Dosage: TBD
2. Acid/Base is injected to RO feed to adjust the pH.
   Product and concentration: TBD
3. SBS is injected constantly as a chlorine scavenger to keep ORP level below 250mV.
   Product and concentration: TBD

Above chemicals may or may not be required based on water source and process targets.

MSDS files should be supplied by chemical Vendor upon selection of required chemicals.

Note: The Chemical storage tank shown on figure 1 are not part of the RO trailer and should be installed outside the trailer to the right of the chemical box containing the dosing pumps of both RO units with an appropriate secondary containment.

4 System installation

The installation of the RO trailer involves the following steps:

- Locating the trailer per site layout.
- Connecting the following tie in points:
  - Feed
  - Brine
  - Permeate
  - Drain
  - Compressed Air (80psi minimum)
- Link PALL to RO Trailer with Ethernet switch (If required).
- Connect Power supply to load panel (see electrical drawings for more info)
- Connect external Inputs/Outputs (see electrical drawings for more info)
- Locate chemical storage tanks at designated location per GA drawings and prepare the chemical solution required (Site specific).
- Connect Dosing pumps suction to storage tanks (via chemical box bulkhead).
- Connect Dosing pumps discharge to injection points location

Note: Above procedure is used only to prepare the system for startup by technician. No operation is allowed before arrival of commissioning engineer/technician.

5 CCD RO process description

CCD RO system is operated in an alternating manner: PFD (Plug flow desalination) is followed by CCD (Closed circuit desalination) and so on in a continuous repetition.

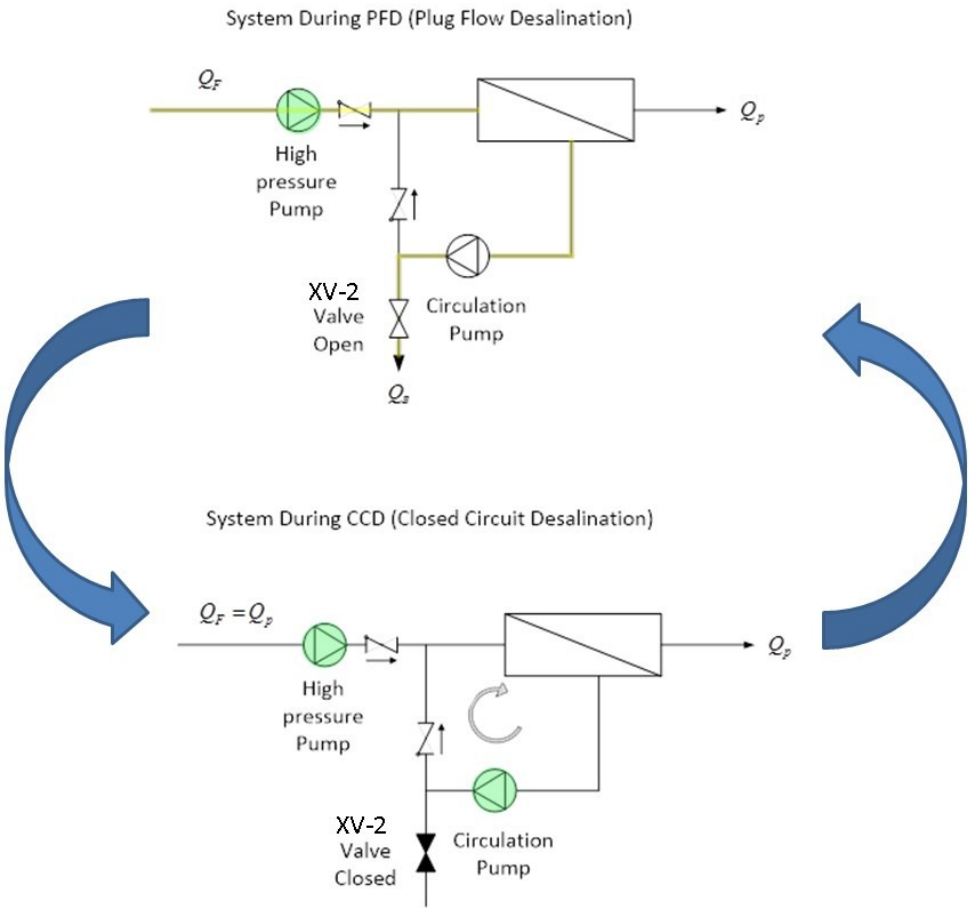


Figure 2 - CCD/PFD operation cycle

When the RO system goes to PFD the brine valve opens and the circulation pump stops.
When the Ro system goes to CCD the brine valve closes and the circulation pump starts.

During PFD water entering as Feed is force to flow through the modules due to the check valve pointing up. The RO system is operating at a certain module recovery (permeate flow rate divided by feed flow rate) set by a manual valve downstream the auto brine valve, XV-2. The close the manual valve, the high the permeate flow produced and the PFD module recovery. The volume exiting as brine stream from the time XV-2 opens is counted by a flow meter producing pulse per certain number of gallons passing through it. When the system volume set point has been reached (which also means that system volume now contains fresh feed while concentrate volume from the last CCD cycle has been evacuated from the system) the brine valve closes and system start and new CCD cycle operation.

During CCD mode, raw feed water is mixed with a circulated stream of concentrate rejected by the membranes. The concentrate flow rate depends on the circulation flow set point which defines the unit's module recovery (%MR). %MR should be in the range of 35% to 45% depends on the number of membrane elements installed the application type.

The transition from CCD back to PDF is performed by opening the brine valve (XV-2) and is triggered by the total volumetric recovery and/or module inlet pressure set points.

During CCD ions rejected by the membrane are accumulated inside the closed system volume (circulation loop). As a result the osmotic pressure of the water increase and more pressure is required to drive water flow pass the membranes to keep a constant permeate flow. VFD's are used to fulfill this task. Since the feed flow is kept constant during CCD the accumulation rate of all ions is constant and the increase in pressure between CCD start and CCD end is linear.

Permeate produced is derived from the feed water concentration inside the circulation loop. Thus during CCD permeate conductivity will increase and the average permeate quality is the average quality of all permeate produced during entire PFD and CCD cycle. At the beginning of the PFD step the permeate conductivity is normally highest as a result of the relatively low operating flux. In most cases the contribution of PFD step to overall permeate quality is negligible due to its small produced permeate volume relative to the permeate volume produced during entire CCD step.

Role of circulation pump: 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.

Recovery calculation during a cycle:

The recovery in CCD RO 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.

The recovery always increases during CCD as both nominator (permeate volume produced) and denominator (total feed consumed) increase at the same rate (reminder - permeate and feed streams are equal during CCD). Therefor the recovery achieved is merely a function of time; there longer the system operates in a CCD mode the higher the final volumetric recovery will be.

6 P&ID drawing

6.1 Important process measurements:

- Low pressure feed line:
  - FIT-1: magnetic flow meter. This flow meter measures 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 signal is used for the %volumetric recovery calculation. Both signals are critical for system operation.
  - PT-5: This analog 4-20mA pressure transmitter is located upstream the booster pump and is used to protect it from dry running or vacuum condition at pump suction.
  - 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. It is also used for PID loop control of pressure between P1 and P2.
  - 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.
  - 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 measures 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 signal is used 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.
  - PT-2: This analog 4-20mA pressure transmitter is located upstream pressure vessels. Monitor inlet pressure to membranes.
  - PT-3: This analog 4-20mA pressure transmitter is located downstream pressure vessels.
  - PT-2, PT-3 are used to calculate the pressure differential on the membranes.
- Permeate line:
  - 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.
  - PT-7: This analog 4-20mA pressure transmitter is used to monitor the permeate backpressure and warn if there is a negative differential pressure on the membranes.
- 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. These set points should not be changed since the actuators have been sized based on 80psi.

7 Individual RO Sequence Of Operation

7.1 Operation Modes

The control panel includes two selector switches with three positions: “CIP”, “0”, and “AUTO”. The selector switch sets the operation mode of its related RO unit. Below is 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 the RO system is in operation in case there is an alarm or it is not requested to produce water anymore, it 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. This mode is used for maintenance and CIP operation.

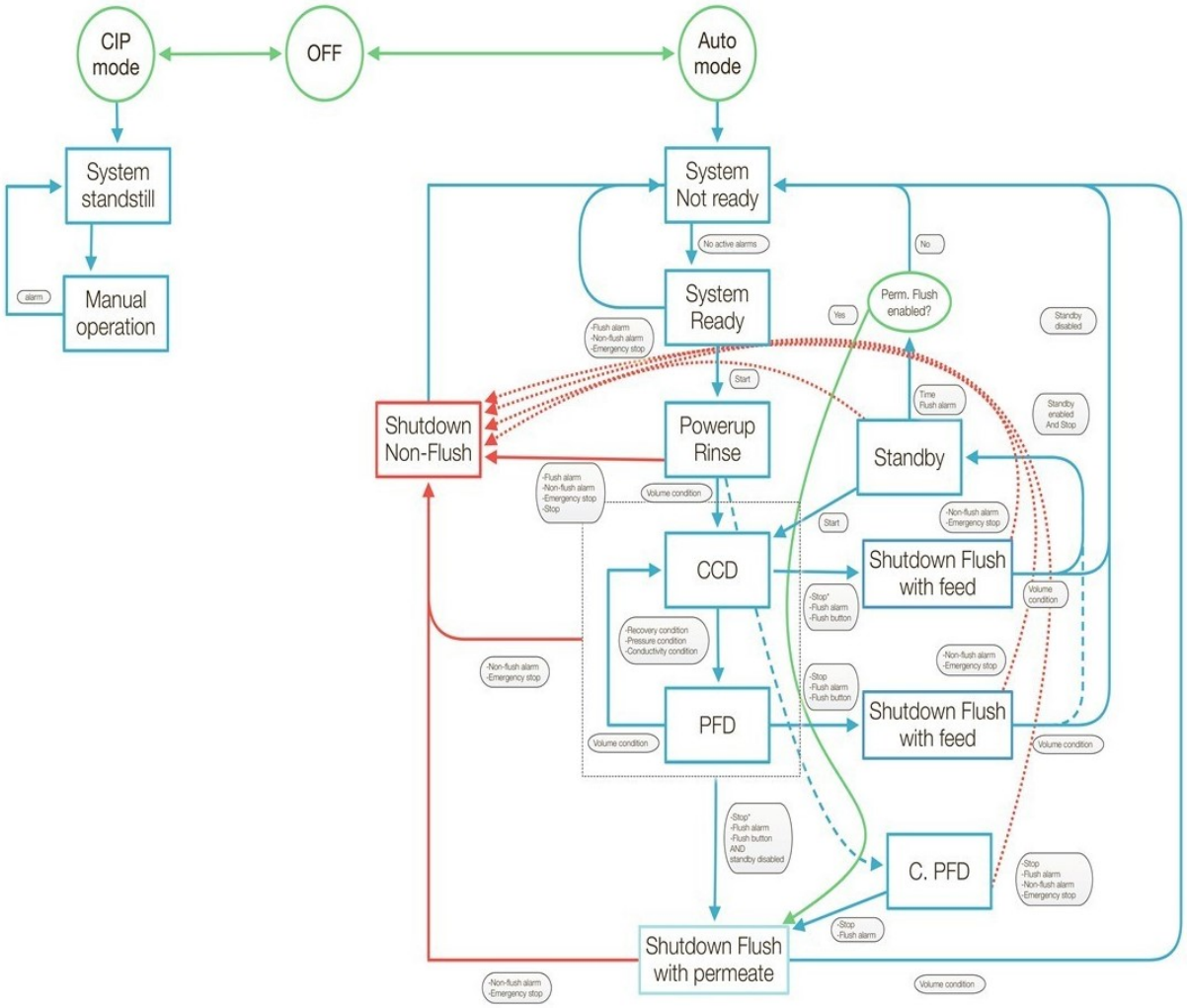
7.2 Auto mode sequences

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
- C. PDF (Constant PFD)
- Shutdown Non-Flush

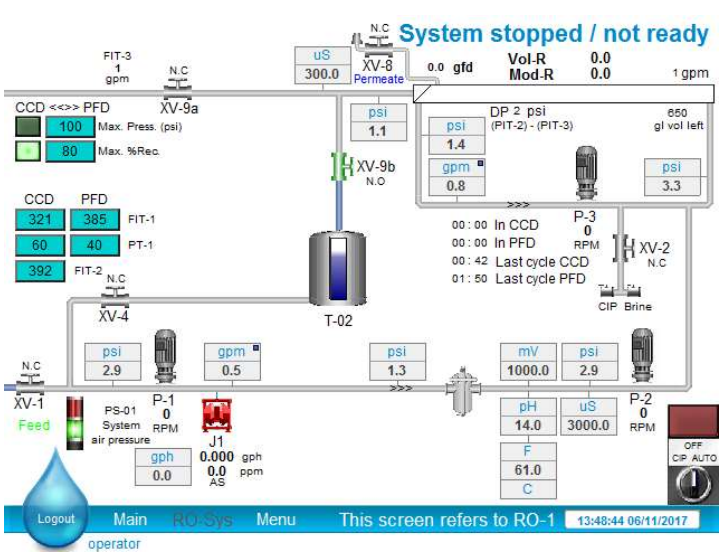
The transitions between these states are shown in the block diagram below. A detailed explanation is followed.

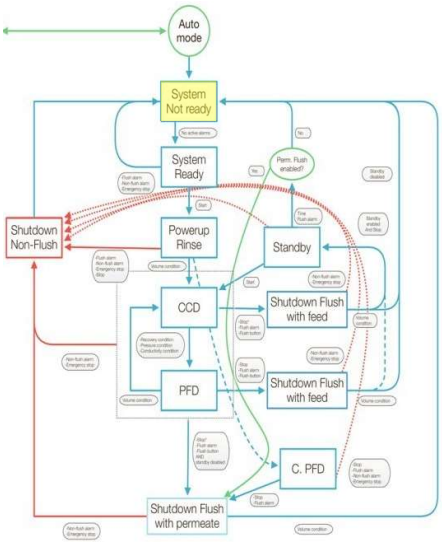
Figure 3 – RO Block diagram



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

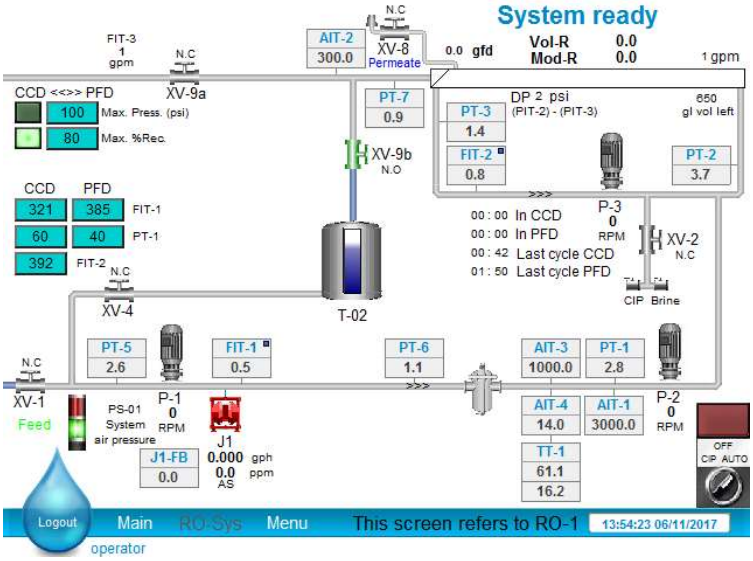
7.3.1. System stopped / not ready

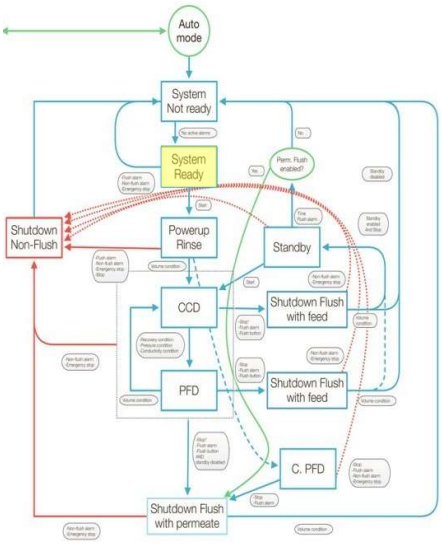




System stopped / Not ready: this is the default sequence after switching the selector switch to Auto or while the system is already in Auto after an alarm event while the alarm is still active. In this sequence the system is idle. No operation is possible even if the RO unit is a requested to produce water.

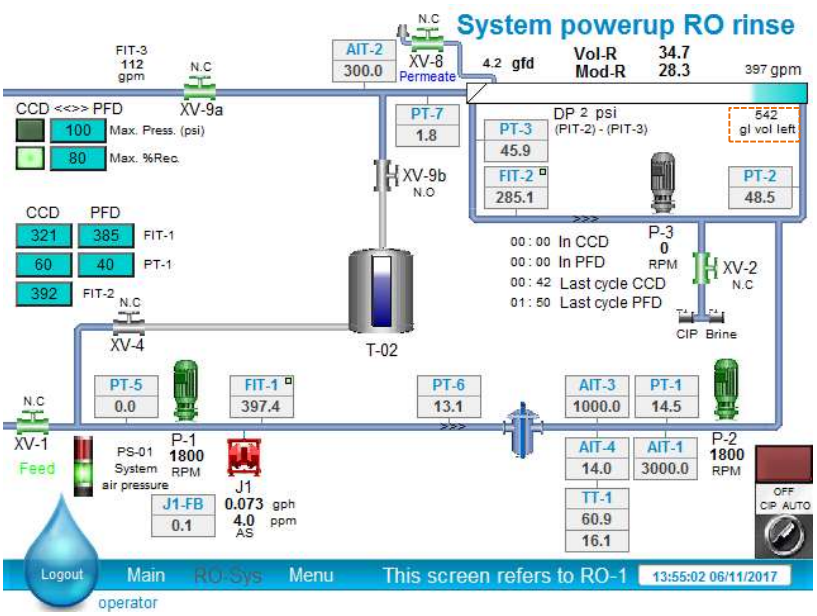
7.3.2.System ready

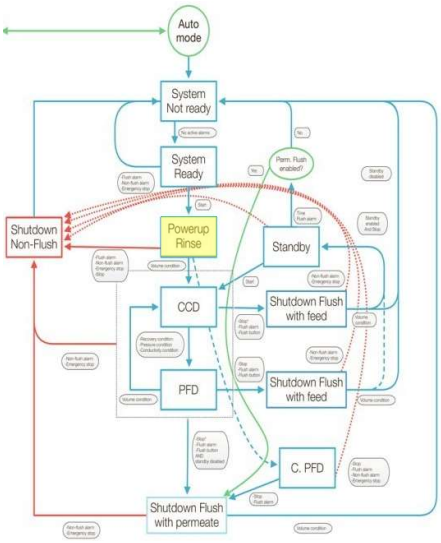


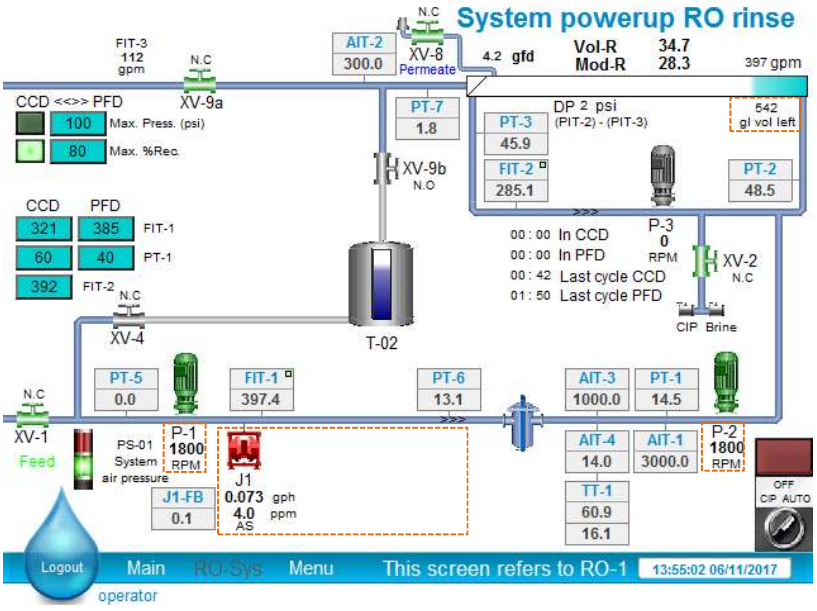


This is the next step if no alarms are active.

7.3.3. System power up rinse



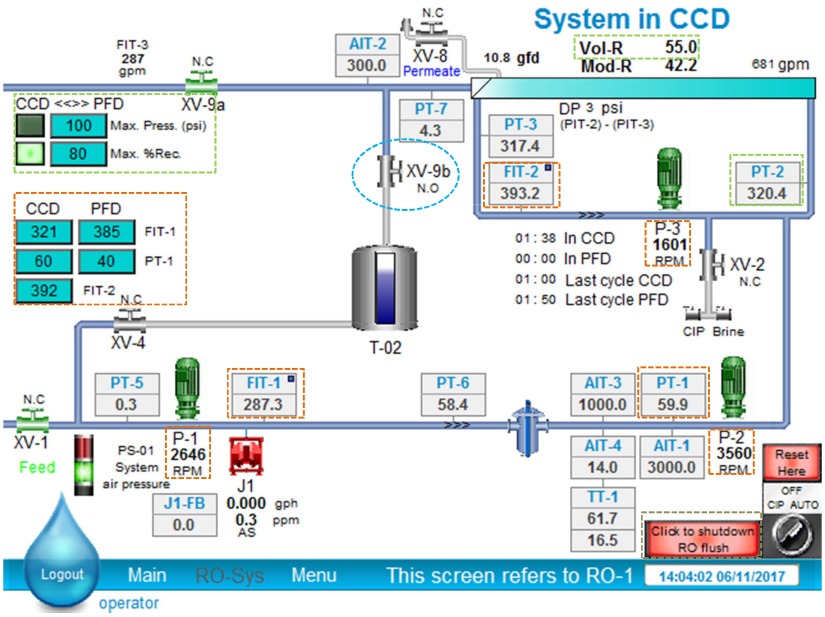


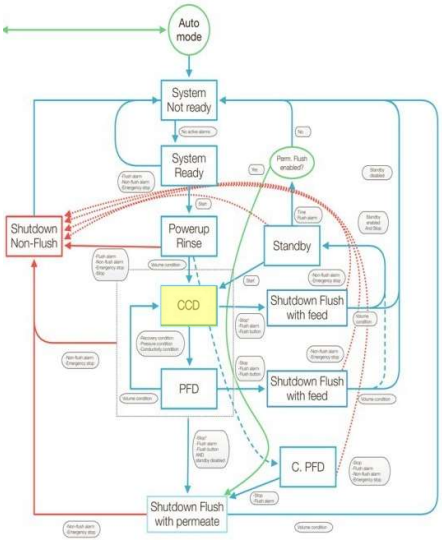


If unit is requested to produce water it will go from “ready” to “power up” sequence automatically. This step introduces fresh feed water into the system while evacuating air entrapped in the pressure vessels and piping before pressurization. First the valves shown in green opens and shortly after the feed pumps start to run at constant speed (The fixed speed of each pump is an HMI set point). Water flows from feed tank into the RO system and exit as brine to drain. Permeate is sent to customer. XV-08 (brine vent valve) is also open to allow air escape from the PV. This Sequence ends when the volume countdown below the blue bar reach zero. FIT-2 pulse signal is responsible for this volume counter.

All active dosing pumps will start to operate according to their set points (pH set point for P4 dosing pumps, ORP set point for P5 SBS dosing pump and ppm set point for P6 Antiscalant dosing pump). Chemical dosing continues in the following steps until system is shut down.

7.3.4. System in CCD





The next step after power up rinse and after each PFD is CCD. Water flows from Feed tank into the RO system and exit as permeate only (closed circuit desalination), concentrate stream is recirculated internally.

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".

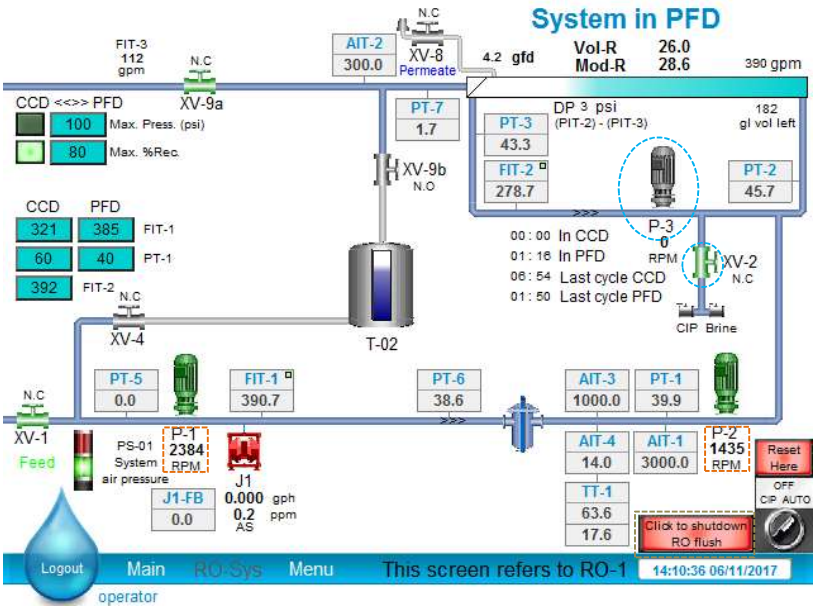
Feed/Permeate flow rate is measured by FIT-1 and controlled by one of the feed pumps speed (P-1 or P-2 according to system configuration). The set point for feed flow rate is entered at the square below “CCD” label next to "FIT-1".

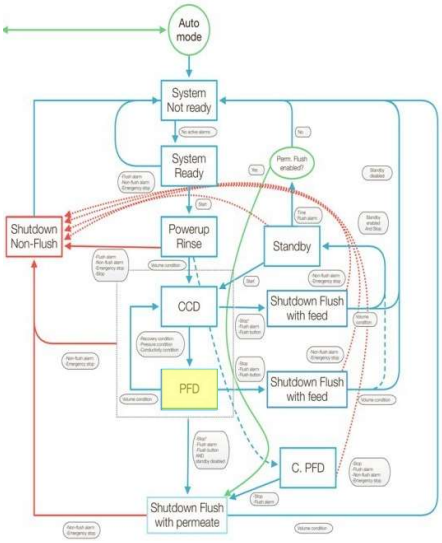
The total dynamic head required to get a certain permeate flow rate is divided between booster pump (P-1) and high pressure pump (P-2). If P1 is set to control flow then P2 will control PT1 pressure. If P2 is set to control flow then P1 will control PT1 pressure. The set point for PT1 during CCD is entered at the square below “CCD” label next to "PT-1. 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.

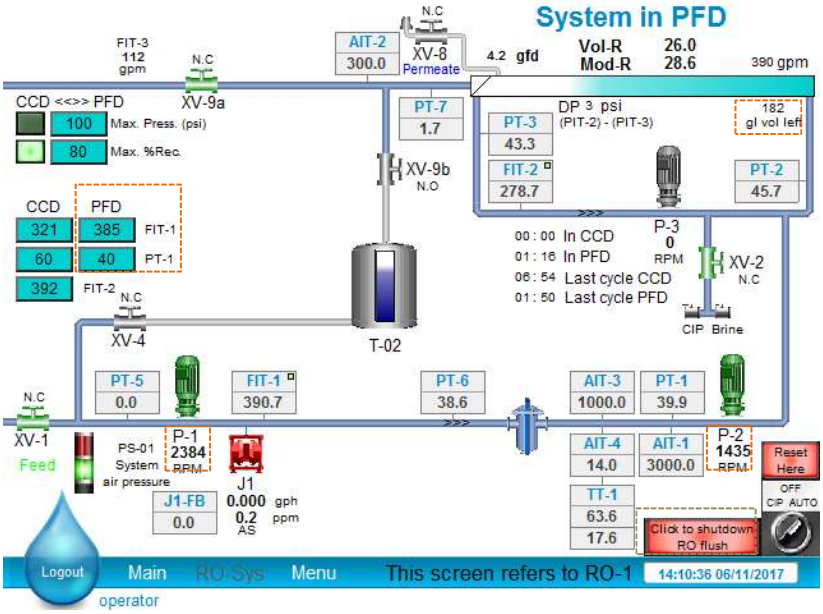
CCD step continues until the first active transition method is triggered. The set points related to the transition methods are entered below “CCD<<>>PFD” as maximum pressure or maximum %Rec and the corresponding measured/calculated values are PT-2 and Vol-R. At least one transition method should be activated by pressing the green button.
In the example above %Rec is the only active method and the set point used is 80%. When the %Vol-R gets to 80% CCD will end and the system will go to PFD.

Permeate tank filling sequence: If permeate flush option is enables (system configuration), during the first CCD and PFD cycles, permeate to CIP valve (XV-9B) will be open to divert permeate to the CIP tank. The water in the tank will be used for flushing once the system shuts down. XV-9B will remain open until the tank reaches its high level (digital switch). Once the tank is full the valve will be closed automatically.

7.3.5. System in PFD







PFD step occurs after each CCD cycle to evacuated 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 stop operation of circulation pump (P-3). During PFD, Water flows from feed water tank into the RO system and exit as brine to drain. Permeate is sent to customer. This Sequence ends when the volume countdown below the blue bar reach zero. FIT-2 pulse signal is responsible for this volume counter.

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 a PID loops are activated (Stabilization period is also an HMI set point).

Feed flow rate is measured by FIT-1 and controlled by one of the feed pumps speed (P-1 or P-2 according to system configuration). 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). If P1 is set to control flow then P2 will control PT1 pressure. If P2 is set to control flow then P1 will control PT1 pressure. The set point for PT1 during PFD is entered at the square below “PFD” label next to "PT-1. 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 PFD, PT1 pressure is expected to be lower than during CCD because XV-2 is open and there is less back pressure on the RO membranes. Normal value will be in the range 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.

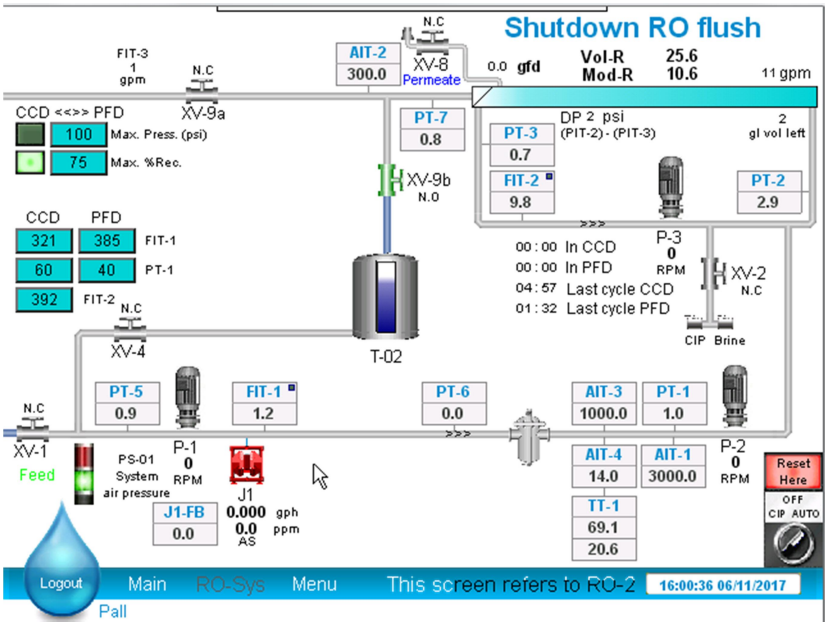
The Module Recovery during PFD is set by adjusting the position of HV-7, the manual valve downstream of XV-02. Normal module recoveries should be in the range 10% to 35%. Care should be taken to allow the minimum required cross flow (use the CCD design tool PDF file to verify your design). Once a position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

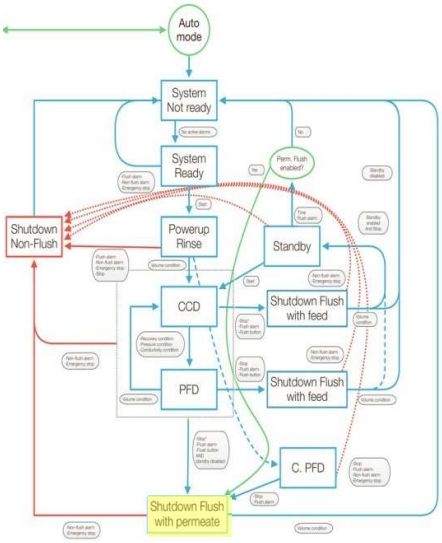
If the selector switch is turned to “0” during operation the system will immediately stop (Emergency Shutdown) and there will be no flushing sequence. In that case the water currently occupied in the system volume (which can be relatively concentrated towards the end of the CCD step) will be trapped 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.

7.3.6. Shutdown flush

- With Permeate water:





Two flushing methods are possible during shutdown: Permeate flush or Feed flush. This selection is set in system configuration menu. Flushing with permeate should be used whenever there is a scaling concern when leaving the system with feed water for prolonged times. This option however will reduce the overall system recovery especially if there are many stops per day.
Flushing with feed should be used when feed source has relatively low fouling/scaling potential. It is less effective in cleaning the membranes then permeate flush but it will not waste permeate water thus keep the average recovery closer to set point.
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).

Feed flush sequence: Shutdown flush with Feed water is same as PFD except that once volume count by FIT-2 pulse signal reach zero, system stops completely.
If Feed flush is triggered during PFD then the PFD step will continue till it’s complete and then the system will stop.
If Feed flush is triggered during CCD then several cases are possible:

- 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.

Permeate Flush Sequence: 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 flows from permeate flush water tank into the RO system evacuating the existing volume from brine valve to the drain. Permeate is recycled back to the CIP tank to keep the permeate depressurized when the system stops. The sequence ends when the volume countdown below the blue bar reach zero. FIT-2 pulse signal is responsible for this volume counter. Next, all pumps are shut down and all valves return to their normal position.
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 a PID loops are activated (Stabilization period is also an HMI set point).
PT1 Pressure control loop, FIT-1 flow control loop and Module Recovery during Permeate flush are exactly as described in PFD sequence.

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.

7.3.7. Constant PFD mode

If C.PFD mode is enabled from system configuration menu then once the RO unit complete the power up rinse step it will go directly into PFD mode and stay there. PDF mode is just like a traditional single stage RO steady state operation. This mode is sometimes useful for troubleshooting and to perform activities that require steady conditions such as SDI testing.

7.3.8. 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.

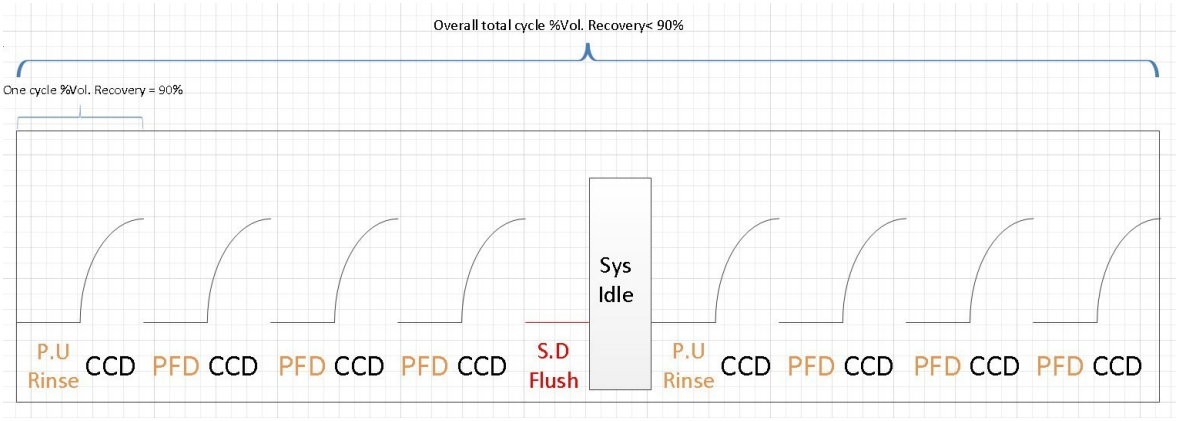


Figure 4 - St. By Mode disabled

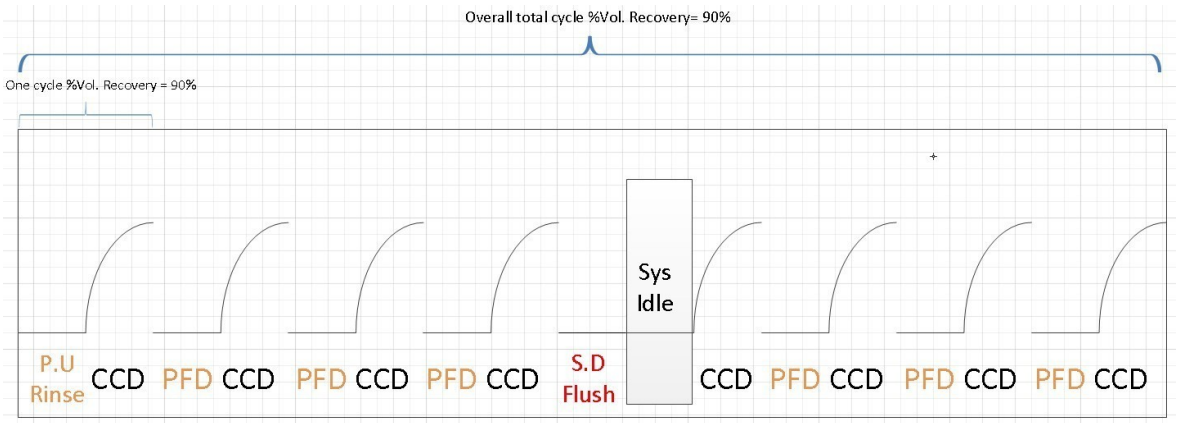


Figure 5 - St. By Mode enabled

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.

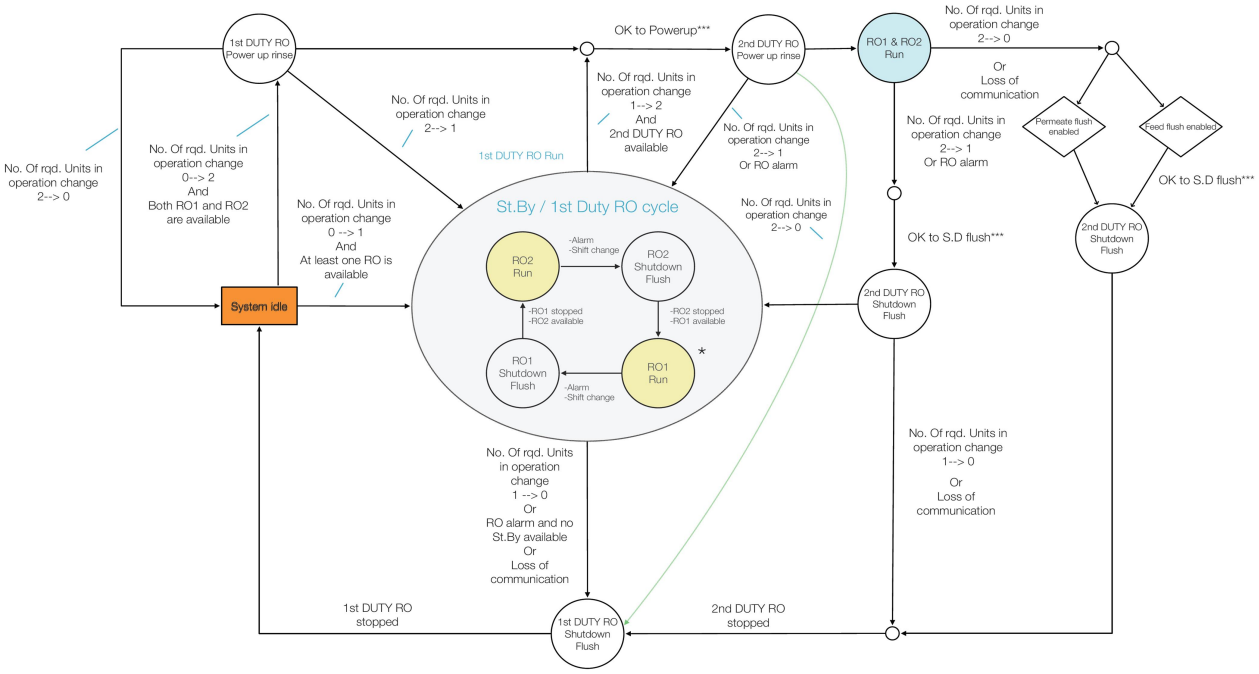
Comments:

1. Standby mode is limited in time. After certain number of hours have passed, 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.

8 Combined RO1 and RO2 operation

When RO start method is selected in configuration menu as “PLC Messaging”, the number of RO units in operation can be controlled remotely from another PLC (normally the PALL Aria PLC). The selection of start method can only be made from RO1 configuration menu and it affects both RO1 and RO2.
In order to avoid rapid depletion of the feed tank while operating with the PALL ARIA, the start and stop of each RO units when operating in parallel are carefully sequenced. The following logic is used to prevent as much as possible a scenario where both RO units are “flushing” at the same time (flushing in this sense include “Power up rinse”, “PFD” and “Feed shutdown flush”).



When only one RO unit is requested to operate the other RO unit can be used as a standby unit if “RO1/RO2 Shifts” is enabled in configuration menu and this Unit is available (Selector in Auto and no alarms exist). In this case one RO will be the “Lead” unit and the other RO will be the “St. By” unit. The roll of the RO units will switch after every set number of cycles. This number is an HMI set point called “Maximum Complete cycles per Shift”. It is advisable to use this feature if possible to keep rotating equipment like pumps run from time to time and to avoid bio-fouling growth in the membranes.

When two RO units are requested to operate, the lead RO unit is started first and after it enters the CCD step the 2nd RO unit is started.
When one RO unit is already in operation and another RO unit is requested to operated, the 2nd RO will be started at the first opportunity that allows it to complete its power up rinse step while the lead RO is still in CCD.
When two RO units are already in operation and the requested number of units change from 2 to 1 or from 2 to 0, the 2nd RO will be stopped and go through feed flush sequence at the first opportunity that allows it to complete its flush step while the lead RO is still in CCD. If the flush is done with permeate, no waiting is required.

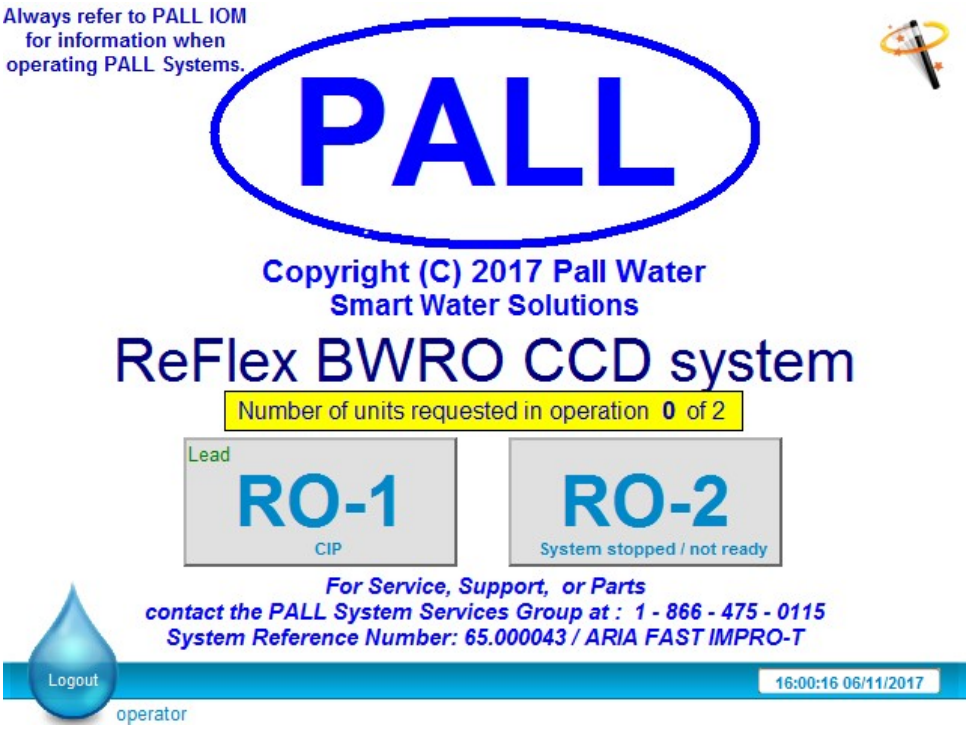
9 HMI screens overview

9.1 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 operator (view only permission), as manager (full permission) or as Admin (full permission plus system configuration permissions).

Once logged in, the screen shows links to each RO unit and gives indication of the sequence in which the RO unit is currently at.

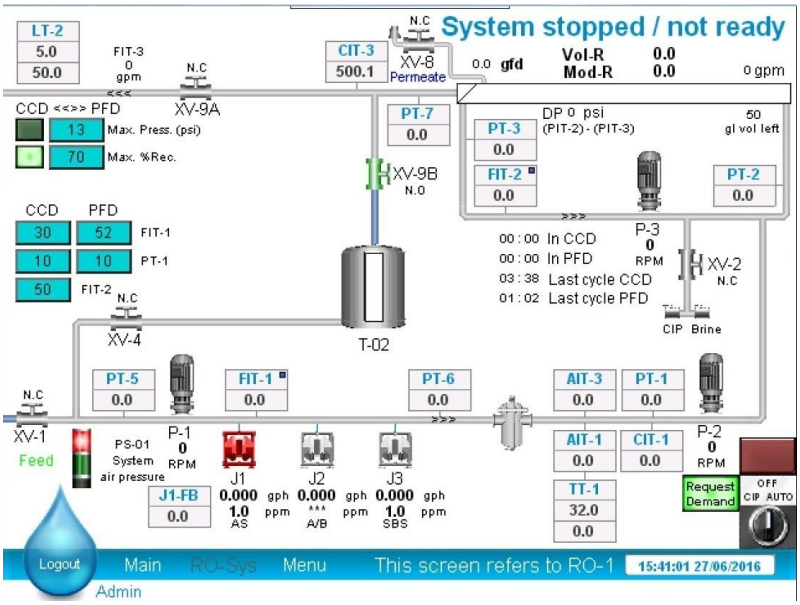
Also, the RO unit currently on duty is marked as “Lead”. The other units will be regarded as the standby unit or the 2nd RO units.



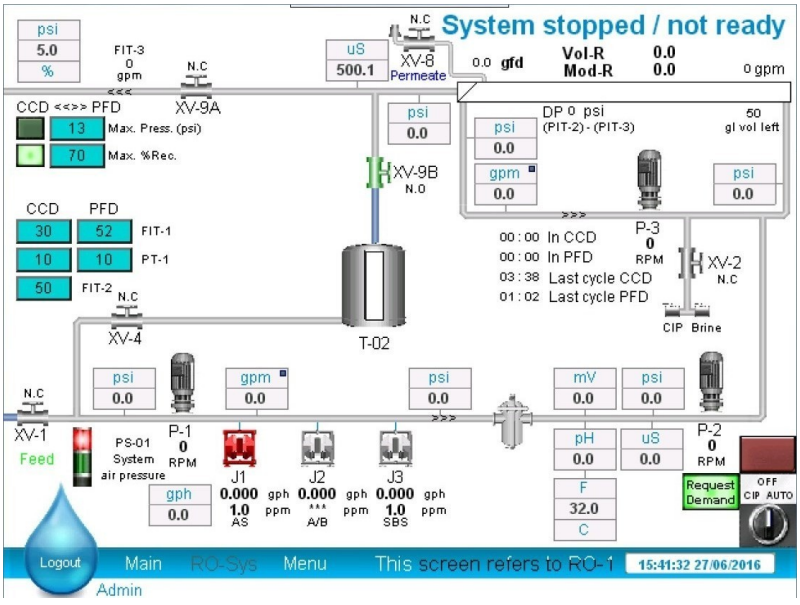
RO-sys individual screen: Once an RO unit is selected the HMI goes directly into its process screen – "RO-Sys". This process screen shows process schematics and all the data required to monitor the RO system operation. The identity of the RO unit selected appears at the bottom of the screen at all times.

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

Toggle 1:

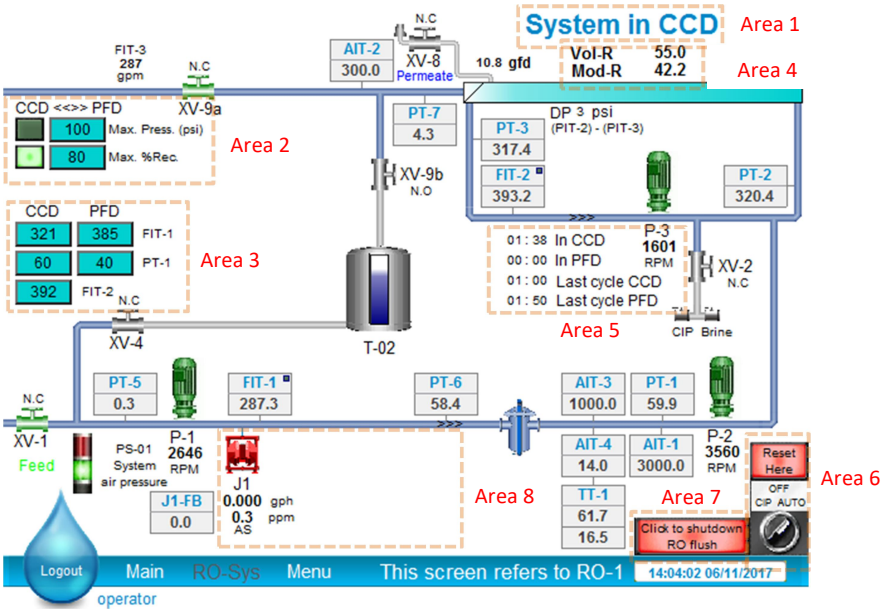


Toggle 2:



The existence of several equipment and controls on the HMI depends on the selections made in the configuration menu. For example, if feed flush is selected then XV-9B, T-02 and XV-4 will not be shown on the HMI. The SOO will change accordingly.

Process screen in details:



Color meaning: Green valve = open, Gray valve = closed, Green pump = pump is running, Gray pump = pump is idle, Red pump = Pump fault, Blue line = water flow/pressure, Gray line = no water flow.

Tag meaning: LT (level transmitter), CIT (conductivity transmitter), PIT (pressure transmitter), AIT (analytical transmitter like pH, ORP), TIT (temperature transmitter), P (process pump), J (dosing pump), XV (on/off valve).

Area 1: show the current RO sequence.

Area 2: selected transition methods from CCD to PFD. One or more method can be selected. See section 0 for details.

Area 3: CCD/PFD flow and pressure set points. Pressure set point appear only if a booster pump is selected in configuration menu. Flow set point related to FIT-2 is only for CCD as during PFD P-3 is off and brine flow is set by brine valve manual position.

Area 4: instantaneous module recovery and volume recovery.

Area 5: current and last CCD / PFD cycle time.

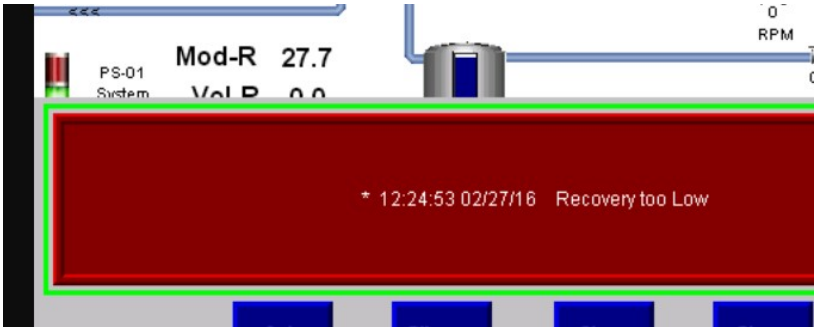
Area 6 (from top to bottom): Red rectangular – Gray color when no alarm is active, flushing red with “Reset Here” text when alarm is active.

Physical selector indication (CIP/OFF/AUTO)

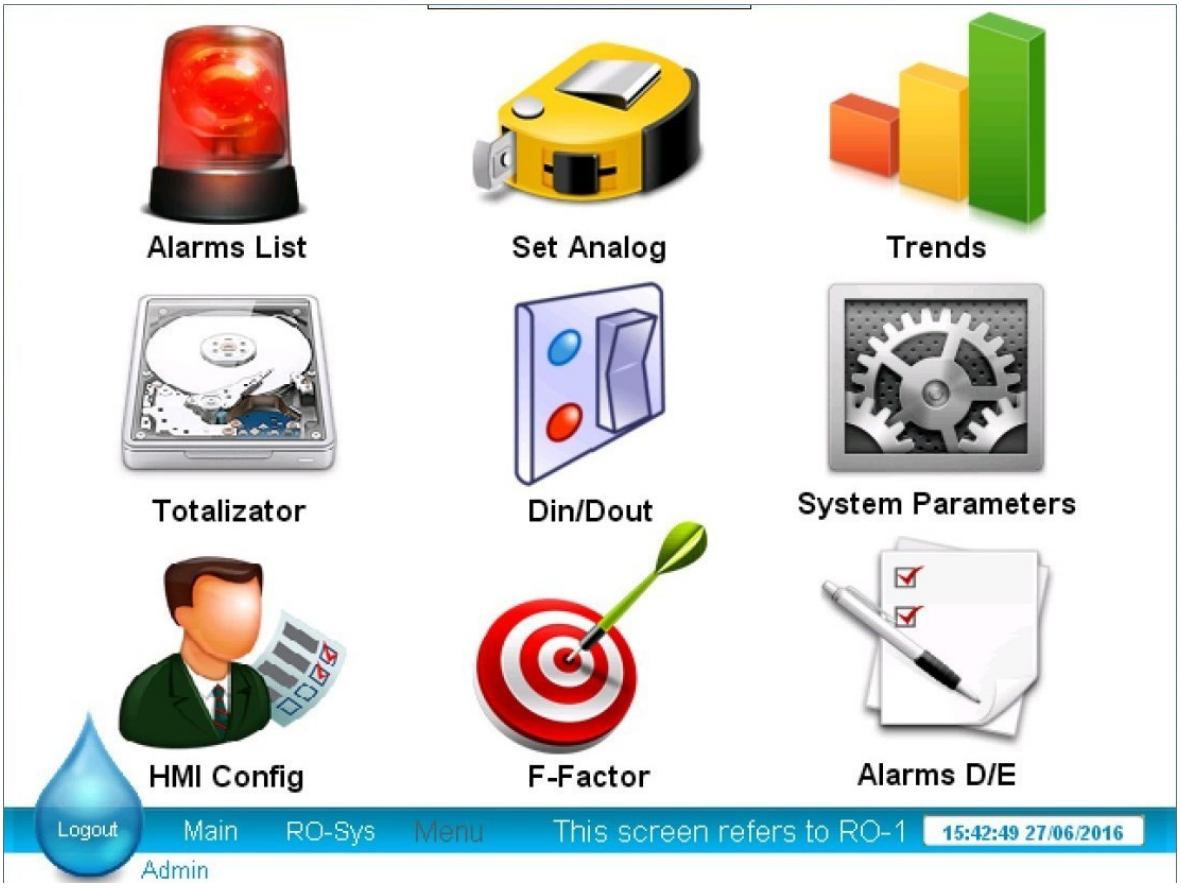
Area 7: “Click here to shutdown RO flush”, this button allows the user to initiate a flush sequence and force system to stop. This should be used before doing any maintenance activity that requires prolonged system idle time.

Area 8: Indication about dosing pump operation as actual dosing flow rate (gph) and actual dosage (ppm).

Alarm indication: When an alarm is triggered a window pops up on the screen with an alarm message:



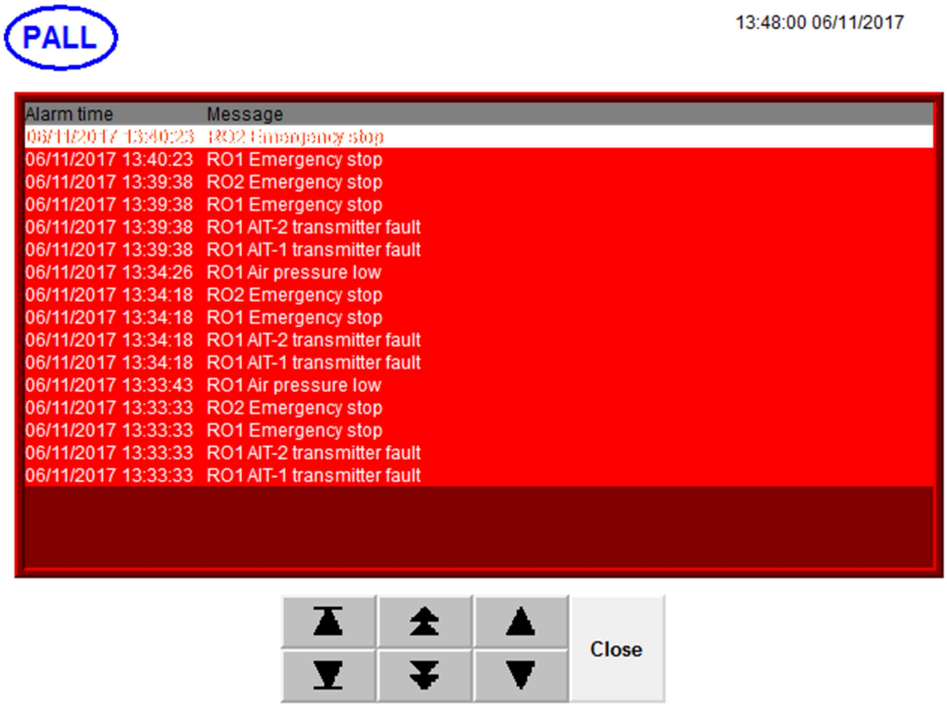
9.2 Menu screen:



This screen provides links to the following sub menus:

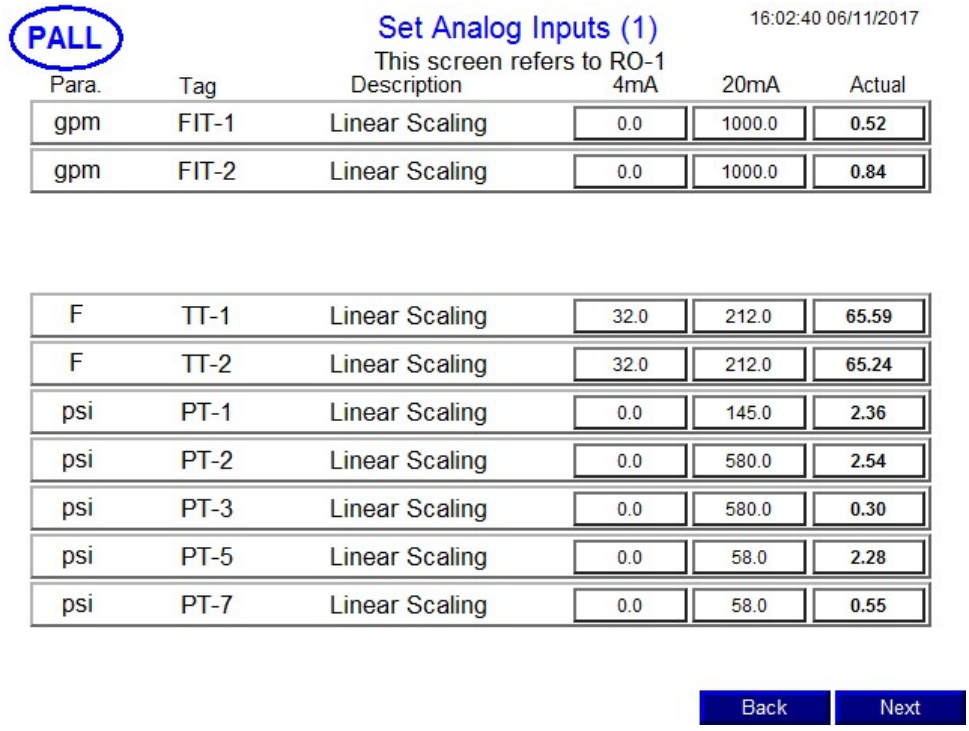
Sub Menu	Operator	Manager	Admin
Alarms list	View only	Read/Write	Full permission
Set Analog	View only	Read/Write	
Trends	View only	Read/Write	
Totalizers	View only	Read/Write	
Din/Dout	View only	Read/Write	
System Parameters	View only	Read/Write	
HMI config	Not accessible	Not accessible	
F-Factor	View only	Read/Write	
Alarms D/E	Not accessible	Not accessible	

Alarms list:



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

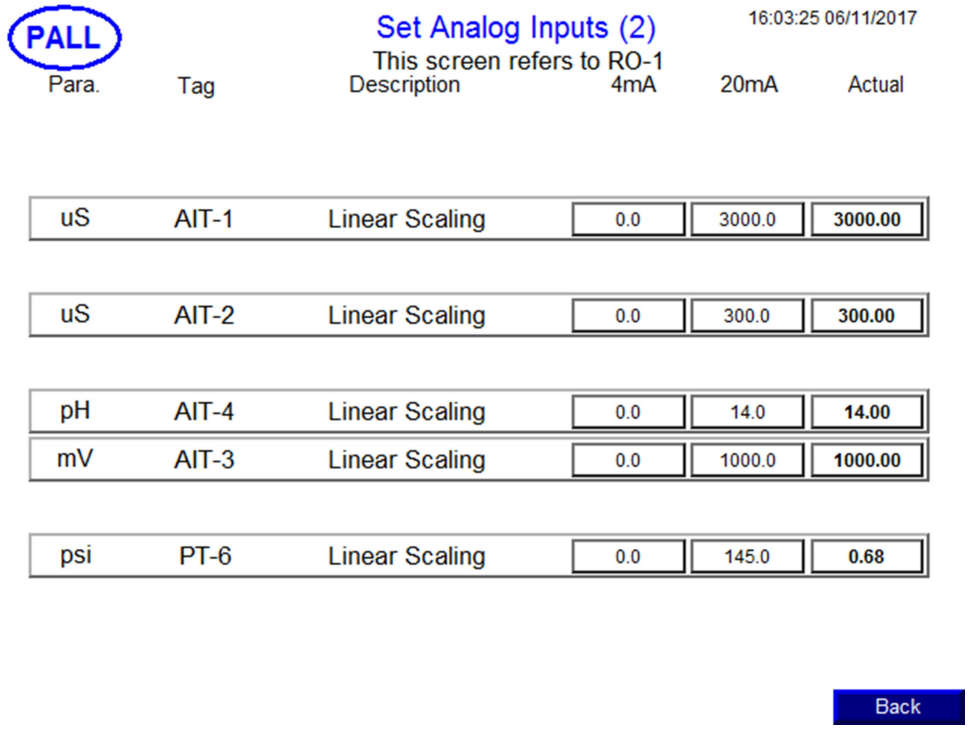
Set analog inputs:



Set Analog Inputs (1)
This screen refers to RO-1
16:02:40 06/11/2017

Para.	Tag	Description	4mA	20mA	Actual
gpm	FIT-1	Linear Scaling	0.0	1000.0	0.52
gpm	FIT-2	Linear Scaling	0.0	1000.0	0.84
F	TT-1	Linear Scaling	32.0	212.0	65.59
F	TT-2	Linear Scaling	32.0	212.0	65.24
psi	PT-1	Linear Scaling	0.0	145.0	2.36
psi	PT-2	Linear Scaling	0.0	580.0	2.54
psi	PT-3	Linear Scaling	0.0	580.0	0.30
psi	PT-5	Linear Scaling	0.0	58.0	2.28
psi	PT-7	Linear Scaling	0.0	58.0	0.55

Back Next



Set Analog Inputs (2)
This screen refers to RO-1
16:03:25 06/11/2017

Para.	Tag	Description	4mA	20mA	Actual
uS	AIT-1	Linear Scaling	0.0	3000.0	3000.00
uS	AIT-2	Linear Scaling	0.0	300.0	300.00
pH	AIT-4	Linear Scaling	0.0	14.0	14.00
mV	AIT-3	Linear Scaling	0.0	1000.0	1000.00
psi	PT-6	Linear Scaling	0.0	145.0	0.68

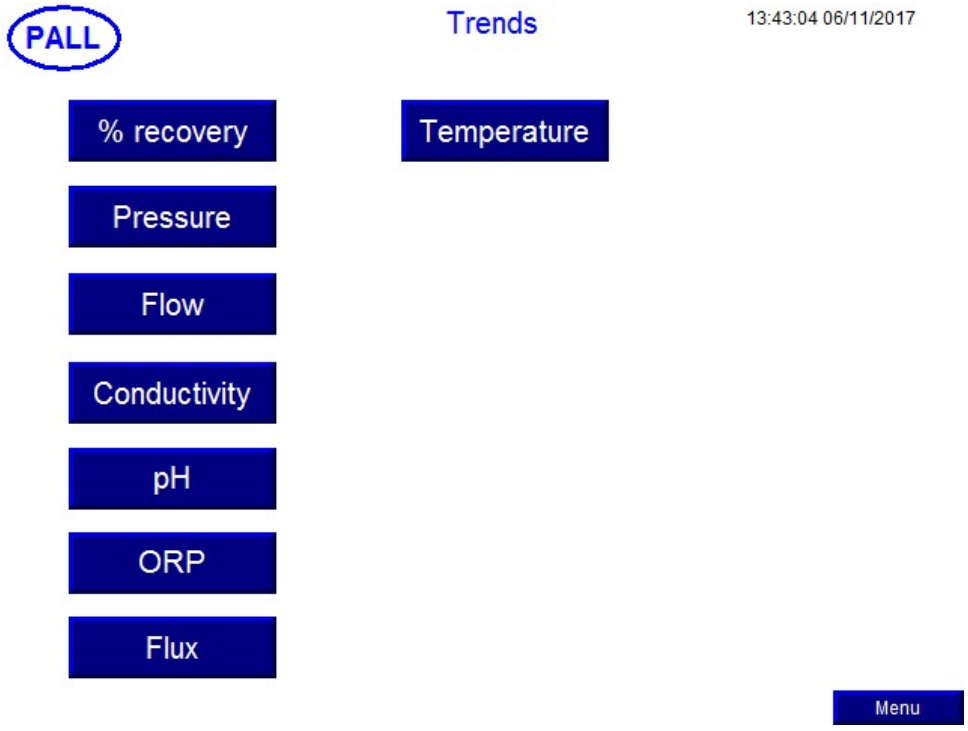
Back

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.

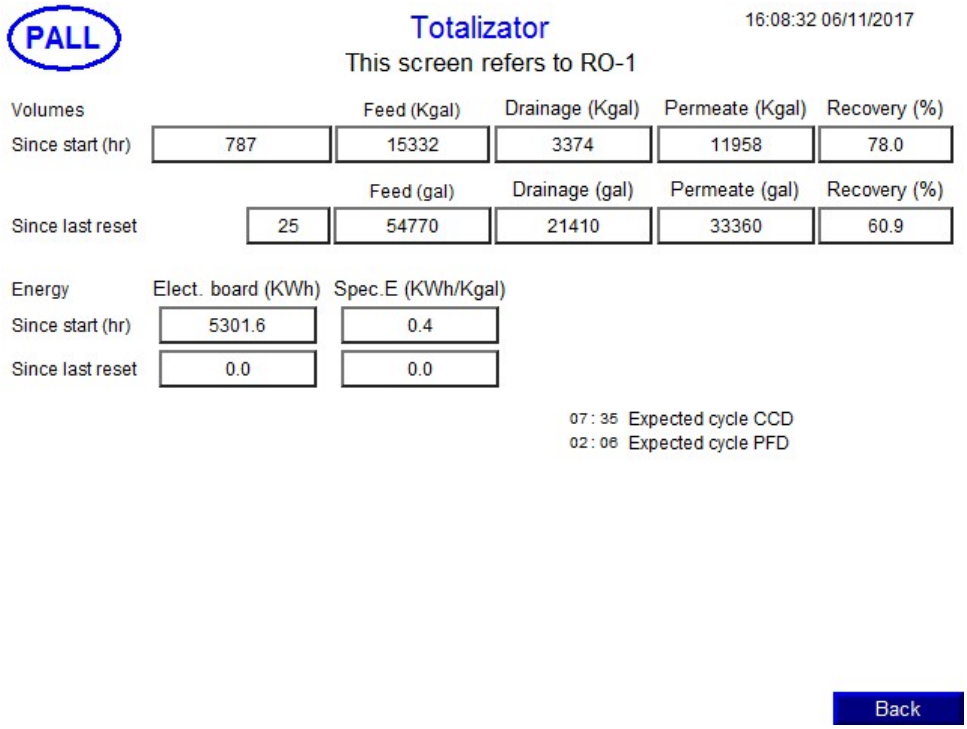
The appearance of some instruments depends on the selections made on configuration screen. This is also the reason for the few line gaps shown above.

System Trends:



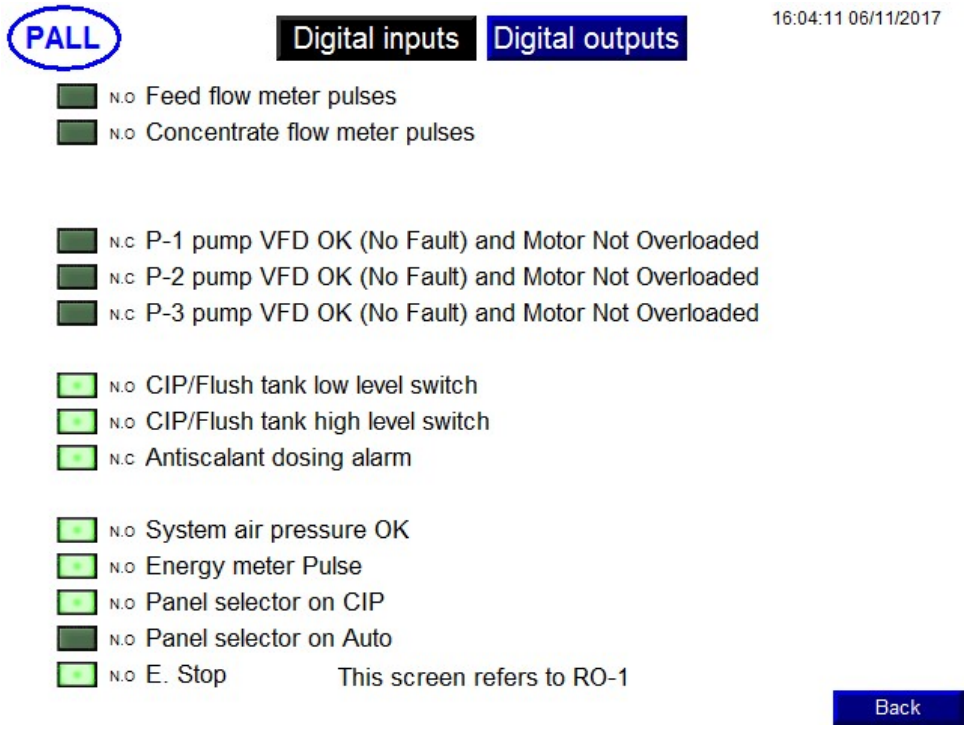
This screen includes links to trending graphs of several process parameters.

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.

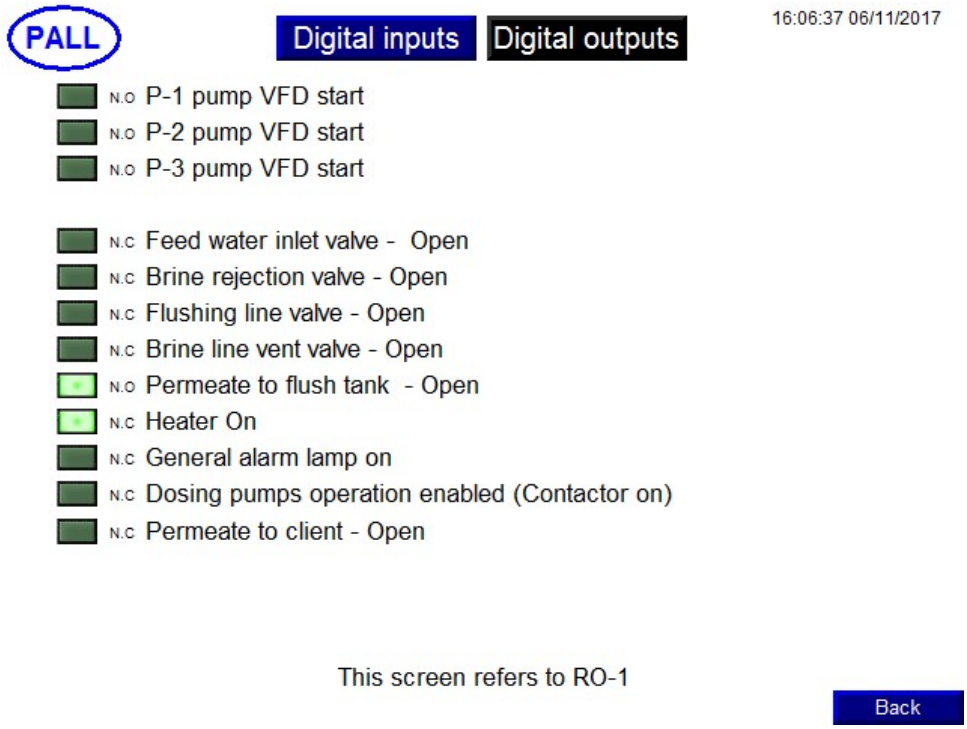
Digital Inputs:



This screen gives a summary of all digital inputs.

Inputs shown are based on selections made in configuration screen.

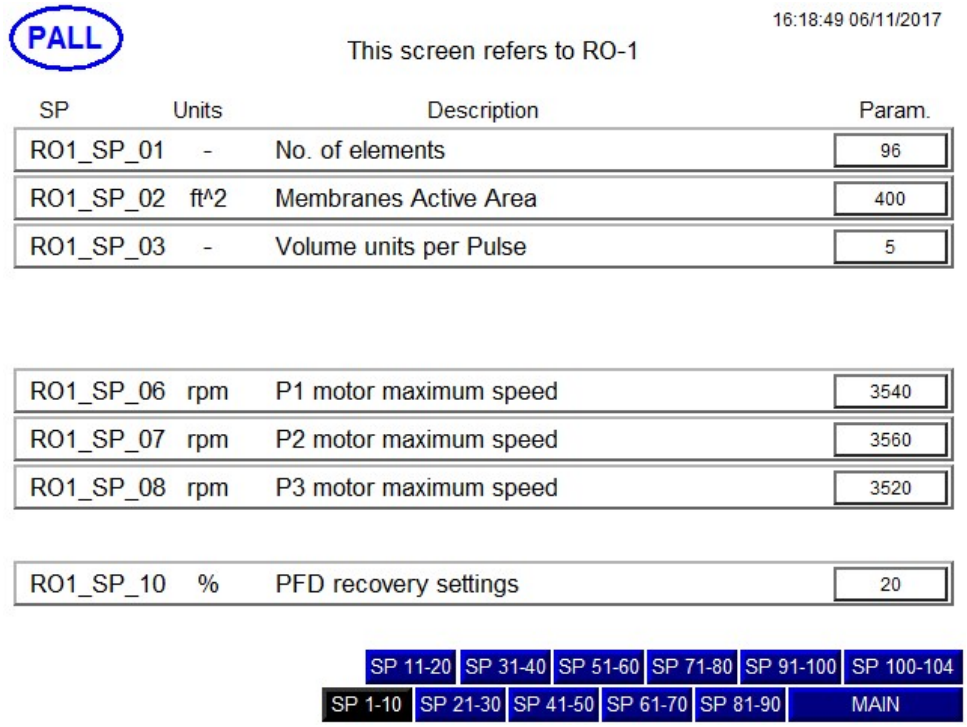
Digital Outputs:

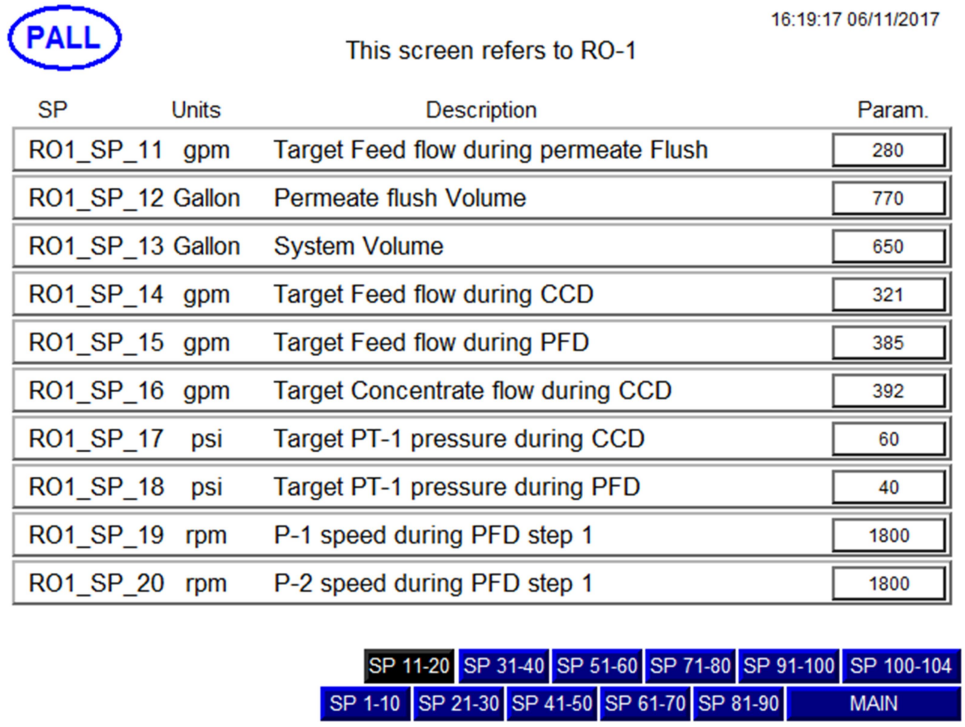


This screen gives a summary of all digital outputs. It is possible to force each output when selector is in CIP mode. A hand icon will appear next to forced signal.

Outputs shown are based on selections made in configuration screen.

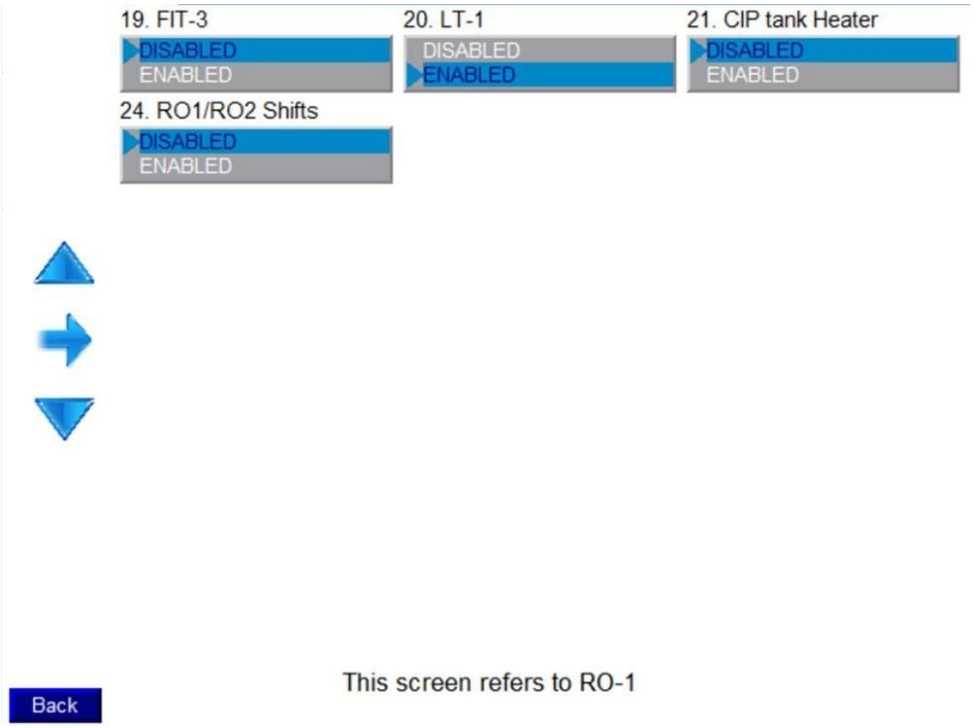
System parameters:





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

HMI Config:



Above screens are only accessibly to Admin authentication level. Changes should be made with great care as each selection has great effect on system HMI screens, alarms and control logic.

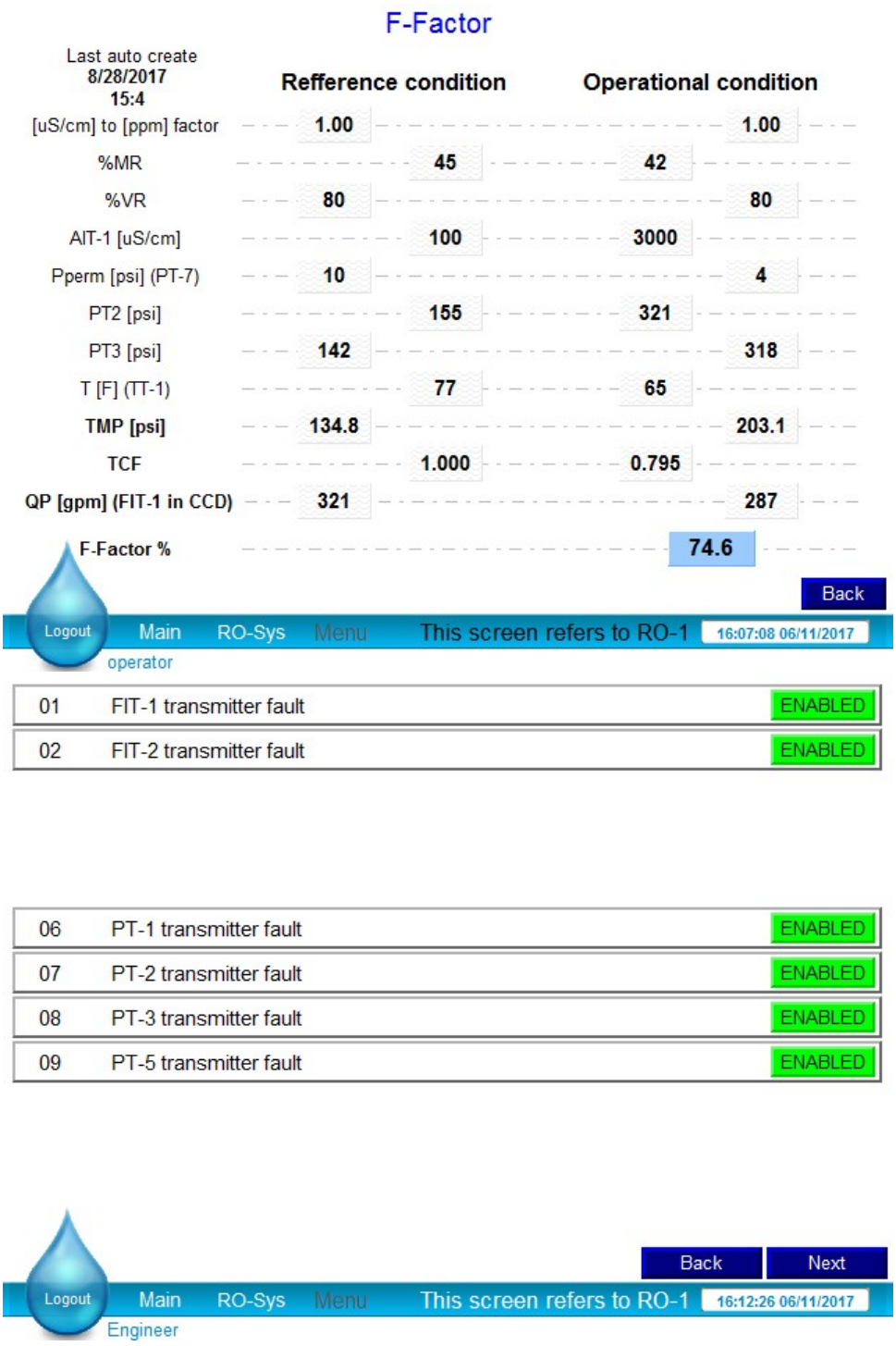
Detailed explanation of configuration parameters:

Configuration / Options	Default / Recommended for PALL RO TRAILER
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-9B will appear on the HMI. Tank filling sequence will be on.	Engineering decision – Site based selection according to feed water tendency for fouling/scaling
2. P1- Booster pump: Disabled – P1 and PT5 will not appear on the HMI. Enabled - P1 and PT5 will appear on the HMI.	Enabled
3. P4 – CIP/ Flush pump	Disabled
4. P1 – Antiscalant (Feed) Disabled – P1 will not appear on the HMI. Enabled - P1 will appear on the HMI.	Enabled
5. P4 – Acid/Base (Feed) Disabled – P4 will not appear on the HMI. Acid – P4 will appear on the HMI with Acid dosing logic. Base – P4 will appear on the HMI with Base dosing logic.	According to Antiscalant software recommendation
6. P5 – SBS (Feed) Disabled – P5 will not appear on the HMI. By ORP with ppm low limit – P5 will appear on the HMI. Dosing based on ORP reading with minimum ppm dosing defined by user (HMI set point). By ppm only – P5 will appear on the HMI. Dosing based on ppm dosing defined by user (HMI set point).	Enabled - By ORP with ppm low limit. This option should be selected if feed water has high ORP or chance to include oxidizing agent as free chlorine. By ppm only option should be selected if ORP meter becomes unreliable.
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

Configuration / Options	Default / Recommended for PALL RO TRAILER
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
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.	PT-6
12. PT-7 – Permeate pressure transmitter Disabled – P6 will not appear on the HMI. Enabled - P6 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.	P1 (If P1 is disabled P2 is selected by default)
14. Recovery saver mode (Disable/Enable). if enabled, CCD continue till end of CCD then go to Flush else CCD interrupt immediately and go to flush	Enabled unless customer permeate tank doesn't have enough buffer.
15. Standby mode (Disable/Enable). If 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.	Enabled. 6 hours is recommended as Maximum idle time in standby mode.

Configuration / Options	Default / Recommended for PALL RO TRAILER
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.	"PLC messaging" should be used when working with PALL ARIA.
17. Actuator Type (Electrical/Pneumatic) If Pneumatic is selected PS-1 will appear on the HMI and its associated alarm will be active.	Pneumatic
18. Bypass dilution (Enabled/Disabled)	Disabled
19. FIT-3 (Enabled/Disabled)	Disabled
20. LT-1 (Enabled/Disabled)	Disabled
21. CIP tank Heater (Enabled/Disabled)	Enabled

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.

After loading new membranes and allowing the system to stabilized, a baseline for RO performance should be created. This is done automatically by pressuring 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):

01	FIT-1 transmitter fault	ENABLED
02	FIT-2 transmitter fault	ENABLED

06	PT-1 transmitter fault	ENABLED
07	PT-2 transmitter fault	ENABLED
08	PT-3 transmitter fault	ENABLED
09	PT-5 transmitter fault	ENABLED

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 11.

Foe each alarm the user can define its action and whether it’s active or not.

1. S.N – F: Shutdown Non Flush. Alarm will cause shutdown with Feed or permeate flush during Auto operation.
2. S.F - Shutdown Flush. Alarm will cause immediate system stop during Auto operation.
3. S.CIP – Alarm will cause immediate system stop during Manual operation.

10 Normal Operation Parameters and CCD Design Tool

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

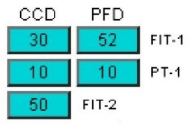
The set points highlighted will be discussed further below.

Fl	Sele	S.P Catego	S.P	For	P	Modt	Description	Lo	Hig	Un	RO1 Va	RO2 Va	Accesi thro	Comments
1		General	SP-01	INT	/1		No. of elements	1	400	-	96	96	Manager	
1		General	SP-02	INT	/1		Membranes Active Area	400	440	ft^2	400	400	Manager	
1		General	SP-03	INT	/1		Volume units per Pulse	1	10	-	5	5	Admin	
0	1	General	SP-04	INT	/1		Feed tank O.F level	0	10	psi	5	5	Manager	
1	4	General	SP-05	INT	/1		Permeate tank O.F level	0	10	psi	5	5	Manager	
1	2	General	SP-06	INT	/1		P1 motor maximum speed	0	3600	rpm	3540	3540	Manager	
1		General	SP-07	INT	/1		P2 motor maximum speed	0	3600	rpm	3560	3560	Manager	
1		General	SP-08	INT	/1		P3 motor maximum speed	0	3600	rpm	3520	3520	Manager	
0	1	General	SP-09	INT	/1		P4 motor maximum speed	0	3600	rpm	3450	3450	Manager	
1		General	SP-10	INT	/1		PFD recovery settings	0	50%	%	20%	20%	Manager	Used for cycle time calculations
1		Operation	SP-11	INT	/1		Target Feed flow during permeate Flush	SP-105	SP-106	gpm	380	380	Manager	
1	2	Operation	SP-12	INT	/1		Permeate flush Volume	1	5000	gallon	770	770	Manager	FIT-2 volume counter = Pulse counter * SP-02
1		Operation	SP-13	INT	/1		System Volume	1	5000	gallon	650	650	Manager	FIT-2 volume counter = Pulse counter * SP-03
1		Operation	SP-14	INT	/1		Target Feed flow during CCD	SP-105	SP-106	gpm	342	342	Manager	
1		Operation	SP-15	INT	/1		Target Feed flow during PFD	SP-105	SP-106	gpm	410	410	Manager	
1		Operation	SP-16	INT	/1		Target Concentrate flow during CCD	SP-107	SP-108	gpm	418	418	Manager	
1	2	Operation	SP-17	INT	/1		Target PT-1 pressure during CCD	SP-117	SP-118	psi	60	60	Manager	
1	2	Operation	SP-18	INT	/1		Target PT-1 pressure during PFD	SP-117	SP-118	psi	40	40	Manager	
1	2	Operation	SP-19	INT	/1		P-1 speed during PFD step 1	0	SP-06	rpm	1800	1800	Manager	
1		Operation	SP-20	INT	/1		P-2 speed during PFD step 1	0	SP-07	rpm	1800	1800	Manager	
0	1	Operation	SP-21	INT	/1		P-4 speed during permeate flush	0	SP-09	rpm	1800	1800	Manager	
1		Operation	SP-22	INT	/1		Target CCD to PFD Feed pressure	0	450	psi	-	-	Manager	
1		Operation	SP-23	INT	/1		Target CCD to PFD Volumetric Recovery	40%	99%	%	85%	85%	Manager	
1		Operation	SP-24	INT	/1		Target CCD to PFD Brine conductivity	0	40	mS/cm	-	-	Manager	
1	4	Operation	SP-25	INT	/1		Start signal when using LT-2	0%	SP-26	%	80%	80%	Manager	
1	4	Operation	SP-26	INT	/1		Stop signal when using LT-2	SP-25	100%	%	95%	95%	Manager	
1		Operation	SP-27	INT	/1		Longest valve open/close time	0	60	seconds	5	5	Admin	
1	2	Operation	SP-28	INT	/1		Delay between pumps in series operation	0	20	seconds	3	3	Admin	
1		Operation	SP-29	INT	/1		Time till pump stop spinning	0	30	seconds	10	10	Admin	
1		Operation	SP-30	INT	/1		Time to stabilize PFD step 1	0	60	seconds	10	10	Admin	
1		Operation	SP-31	INT	/1		Maximum idle time in standby mode	0	24	hours	6	6	Manager	
1	2	Operation	SP-32	INT	/1		Low CIP tank temperature	SP-115	SP-33	F	85	85	Manager	
1	2	Operation	SP-33	INT	/1		High CIP tank temperature	SP-32	SP-116	F	105	105	Manager	
0	1	Operation	SP-34	INT	/1		Bypass flow rate in CCD	SP-111	SP-112	gpm	-	-	Manager	
0	1	Operation	SP-35	INT	/1		Maximum Complete cycles per Shift	1	1000	-			Manager	
1			SP-36	INT	/1		Spare			-				
1			SP-37	INT	/1		Spare			-				
1		Alarms value	SP-38	INT	/1		High module inlet pressure warning value	0	450	psi	350	350	Manager	
1		Alarms value	SP-39	INT	/1		Maximum module inlet pressure alarm value	0	450	psi	450	450	Manager	
1		Alarms value	SP-40	INT	/1		Module inlet pressure Low alarm value	1	100	psi	10	10	Manager	Should be relative to lowest PT2 pressure during
1		Alarms value	SP-41	INT	/1		Feed flow Low alarm value	1	1000	gpm	100	100	Manager	
1		Alarms value	SP-42	INT	/1		Feed flow High alarm value	1	1000	gpm	700	700	Manager	
1		Alarms value	SP-43	INT	/1		Concentrate flow Low alarm value	1	1000	gpm	100	100	Manager	
1		Alarms value	SP-44	INT	/1		Concentrate flow High alarm value	1	1000	gpm	700	700	Manager	
1		Alarms value	SP-45	INT	/1		Recovery too Low alarm value	1	100	%	60	60	Manager	
1	2	Alarms value	SP-46	INT	/1		P-1 suction pressure Low alarm value	0	100	psi	5	5	Manager	Should be relative to normal inlet pressure in CCD
1	2	Alarms value	SP-47	INT	/1		P-1 discharge pressure high alarm value	1	200	psi	100	100	Manager	

1	2	Alarms value	SP-48	INT	/1		Permeate pressure high alarm value	1	150	psi	20	20	Manager	
1		Alarms value	SP-49	INT	/1		High Feed ORP level alarm value	1	500	mV	250	250	Manager	
1		Alarms value	SP-50	INT	/1		Permeate conductivity high warning value	0	1000	uS/cm	75	75	Manager	
1		Alarms value	SP-51	INT	/1		Permeate conductivity high alarm value	0	1000	uS/cm	150	150	Manager	
1		Alarms value	SP-52	INT	/1		Feed conductivity high alarm value	0	8000	uS/cm	1000	1000	Manager	Value should be set to 150% of normal CIT-01 value
1	3	Alarms value	SP-53	INT	/1		Micronic Filters Differential pressure High alar	0	30	psi	15	15	Manager	
1		Alarms value	SP-54	INT	/1		High module dP warning value	0	35	psi	20	20	Manager	Should be relative to normal pressure drop
1		Alarms value	SP-55	INT	/1		High module dP alarm value	0	35	psi	35	35	Manager	
0	1	Alarms value	SP-56	INT	/1		Blend water conductivity high alarm value	0	1000	uS/cm	500	500	Manager	
0	1	Alarms value	SP-57	INT	/1		Low feed tank level alarm value	0	100	%	20	20	Manager	
1			SP-58	INT	/1		Spare			-				
1			SP-59	INT	/1		Spare			-				
1			SP-60	INT	/1		Spare			-				
1		F-Factor	SP-61	INT	/1		FF %MR	0	100	%	60%	60%	Admin	
1		F-Factor	SP-62	INT	/1		FF %VR	0	100	%	70%	70%	Admin	
1		F-Factor	SP-63	INT	/1		FF CIT-1 [uS/cm]	SP-133	SP-134	uS/cm	300	300	Admin	
1		F-Factor	SP-64	INT	/1		FF $P_{...}$ [psi] (PT-7)	SP-125	SP-126	psi	10	10	Admin	
1		F-Factor	SP-65	INT	/1		FF PT2 [psi] at End of CCD	SP-119	SP-120	psi	141	141	Admin	
1		F-Factor	SP-66	INT	/1		FF PT3 [psi] at End of CCD	SP-121	SP-122	psi	148	148	Admin	
1		F-Factor	SP-67	INT	/1		FF T [F] (TT-1)	SP-113	SP-114	F	75	75	Admin	
1		F-Factor	SP-68	INT	/1		FF Q_P [gpm] (FIT-1 in CCD)	SP-105	SP-106	gpm	342	342	Admin	
1		F-Factor	SP-69	INT	/10		FF Conversion factor uS/cm to ppm TDS	0	1	-	0.7	0.7	Admin	
1			SP-70	INT	/1		Spare			-				
1			SP-71	INT	/1		Spare			-				
1			SP-72	INT	/1		Spare			-				
1			SP-73	INT	/1		Spare			-				
1	2	Chemicals	SP-74	INT	/1		J1-Solution Concentration (c) [%]	10%	100%	%	100%	100%	Manager	
1	2	Chemicals	SP-75	INT	/1		J1-Required Dose (C) [ppm]	0	20	ppm	3.5	3.5	Manager	
1	2	Chemicals	SP-76	INT	/10		J1-Solution Density (d) [lb/ft3]	10	100	[lb/ft3]	71.4	71.4	Manager	
1	2	Chemicals	SP-77	INT	/100		J1-D.P max flow rate [max_q] [gph]	0	5	gph	1	1	Manager	
1			SP-78	INT	/1		Spare			-				
0	1	Chemicals	SP-79	INT	/1		Target Feed pH	4	10	pH	7	7	Manager	
0	1	Chemicals	SP-80	INT	/100		J2-D.P max flow rate [max_q] [gph]	0	5	gph	0.25	0.25	Manager	
1			SP-81	INT	/1		Spare			-				
0	1	Chemicals	SP-82	INT	/1		Target Feed ORP	SP-143	SP-144	mV	250	250	Manager	
0	1	Chemicals	SP-83	INT	/1		J3-Solution Concentration (c) [%]	10	100	%	10	10	Manager	
0	1	Chemicals	SP-84	INT	/1		J3-Required Dose (C) [ppm]	0	20	ppm	1	1	Manager	
0	1	Chemicals	SP-85	INT	/10		J3-Solution Density (d) [lb/ft3]	10	100	[lb/ft3]	62.5	62.5	Manager	
0	1	Chemicals	SP-86	INT	/100		J3-D.P max flow rate [max_q] [gph]	0	5	gph	0.25	0.25	Manager	
1			SP-87	INT	/1		Spare			-				
0	1	Chemicals	SP-88	INT	/1		Target Permeate pH	4	10	pH	7	7	Manager	
0	1	Chemicals	SP-89	INT	/100		J4-D.P max flow rate [max_q] [gph]	0	5	gph	0.25	0.25	Manager	
1			SP-90	INT	/1		Spare			-				
0	1	Chemicals	SP-91	INT	/1		J5-Solution Concentration (c) [%]	10%	100%	%	100%	100%	Manager	
0	1	Chemicals	SP-92	INT	/1		J5-Required Dose (C) [ppm]	0	100	ppm	10	10	Manager	
0	1	Chemicals	SP-93	INT	/10		J5-Solution Density (d) [lb/ft3]	10	100	[lb/ft3]	62.5	62.5	Manager	
0	1	Chemicals	SP-94	INT	/100		J5-D.P max flow rate [max_q] [gph]	0	5	gph	0.25	0.25	Manager	
1			SP-95	INT	/1		Spare			-				
1			SP-96	INT	/1		Spare			-				
1			SP-97	INT	/1		Spare			-				
1			SP-98	INT	/1		Spare			-				
1			SP-99	INT	/1		Spare			-				
1			SP-100	INT	/1		Spare			-				
1			SP-101	INT	/1		Spare			-				
1			SP-102	INT	/1		Spare			-				
1			SP-103	INT	/1		Spare			-				
1			SP-104	INT	/1		Spare			-				
1		Analog limits	SP-105	INT	/1		FIT-1 - Low Eng	0	3270	gpm	0	0	Manager	
1		Analog limits	SP-106	INT	/1		FIT-1 - High Eng	0	3270	gpm	1000	1000	Manager	
1		Analog limits	SP-107	INT	/1		FIT-2 - Low Eng	0	3270	gpm	0	0	Manager	
1		Analog limits	SP-108	INT	/1		FIT-2 - High Eng	0	3270	gpm	1000	1000	Manager	
0	1	Analog limits	SP-109	INT	/1		FIT-3 - Low Eng	0	3270	gpm	0	0	Manager	
0	1	Analog limits	SP-110	INT	/1		FIT-3 - High Eng	0	3270	gpm	100	100	Manager	
0	1	Analog limits	SP-111	INT	/1		FIT-4 - Low Eng	0	3270	gpm	0	0	Manager	
0	1	Analog limits	SP-112	INT	/1		FIT-4 - High Eng	0	3270	gpm	100	100	Manager	
1		Analog limits	SP-113	INT	/1		TT-1 - Low Eng	0	3270	°F	32	32	Manager	
1		Analog limits	SP-114	INT	/1		TT-1 - High Eng	0	3270	°F	150	150	Manager	
1	2	Analog limits	SP-115	INT	/1		TT-2 - Low Eng	0	3270	°F	32	32	Manager	
1	2	Analog limits	SP-116	INT	/1		TT-2 - High Eng	0	3270	°F	150	150	Manager	
1		Analog limits	SP-117	INT	/1		PT-1 - Low Eng	0	3270	psi	0	0	Manager	
1		Analog limits	SP-118	INT	/10		PT-1 - High Eng	0	3270	psi	145.038	145.038	Manager	
1		Analog limits	SP-119	INT	/1		PT-2 - Low Eng	0	3270	psi	0	0	Manager	
1		Analog limits	SP-120	INT	/10		PT-2 - High Eng	0	3270	psi	580.152	580.152	Manager	
1		Analog limits	SP-121	INT	/1		PT-3 - Low Eng	0	3270	psi	0	0	Manager	
1		Analog limits	SP-122	INT	/10		PT-3 - High Eng	0	3270	psi	580.152	580.152	Manager	
1	2	Analog limits	SP-123	INT	/1		PT-5 - Low Eng	0	3270	psi	0	0	Manager	
1	2	Analog limits	SP-124	INT	/10		PT-5 - High Eng	0	3270	psi	58.0152	58.0152	Manager	
1	2	Analog limits	SP-125	INT	/1		PT-7 - Low Eng	0	3270	psi	0	0	Manager	
1	2	Analog limits	SP-126	INT	/10		PT-7 - High Eng	0	3270	psi	58.0152	58.0152	Manager	
1	3	Analog limits	SP-127	INT	/1		PDT-1 - Low Eng	0	3270	psi	0	0	Manager	
1	3	Analog limits	SP-128	INT	/1		PDT-1 - High Eng	0	3270	psi	15	15	Manager	
0	1	Analog limits	SP-129	INT	/10		LT-1- Low Eng	0	3270	psi	0.1	0.1	Manager	
0	1	Analog limits	SP-130	INT	/10		LT-1 - High Eng	0	3270	psi	10.0	10.0	Manager	
1	4	Analog limits	SP-131	INT	/10		LT-2- Low Eng	0	3270	psi	0.1	0.1	Manager	
1	4	Analog limits	SP-132	INT	/10		LT-2 - High Eng	0	3270	psi	10.0	10.0	Manager	
1		Analog limits	SP-133	INT	/1		CIT-1 - Low Eng	0	3270	uS/cm	0	0	Manager	
1		Analog limits	SP-134	INT	/1		CIT-1 - High Eng	0	3270	uS/cm	3000	3000	Manager	
0	1	Analog limits	SP-135	INT	/1		CIT-2 - Low Eng	0	200	mS/cm	0	0	Manager	
0	1	Analog limits	SP-136	INT	/1		CIT-2 - High Eng	0	200	mS/cm	200	200	Manager	
1		Analog limits	SP-137	INT	/1		CIT-3 - Low Eng	0	3270	uS/cm	0	0	Manager	
1		Analog limits	SP-138	INT	/1		CIT-3 - High Eng	0	3270	uS/cm	300	300	Manager	
0	1	Analog limits	SP-139	INT	/1		CIT-4 - Low Eng	0	3270	uS/cm	0	0	Manager	
0	1	Analog limits	SP-140	INT	/1		CIT-4 - High Eng	0	3270	uS/cm	1000	1000	Manager	
1		Analog limits	SP-141	INT	/1		AIT-1 - Low Eng	0	0	pH	0	0	Manager	
1		Analog limits	SP-142	INT	/1		AIT-1 - High Eng	14	14	pH	14	14	Manager	
1		Analog limits	SP-143	INT	/1		AIT-3 - Low Eng	0	0	mV	0	0	Manager	
1		Analog limits	SP-144	INT	/1		AIT-3 - High Eng	1000	1000	mV	1000	1000	Manager	
0	1	Analog limits	SP-145	INT	/1		AIT-4 - Low Eng	0	0	pH	0	0	Manager	
0	1	Analog limits	SP-146	INT	/1		AIT-4 - High Eng	14	14	pH	14	14	Manager	
1	2	Analog limits	SP-147	INT	/1		J1_FB - Low Eng	0	0	gph	0	0	Manager	
1	2	Analog limits	SP-148	INT	/1		J1_FB - High Eng	SP-77	SP-77	gph	SP-77	INT	Manager	
1	3	Analog limits	SP-149	INT	/1		PT-6 - Low Eng	0	3270	psi	0	0	Manager	

1	3	Analog limits	SP-150	INT	/1		PT-6 - High Eng	0	3270	psi	145	145	Manager
1			SP-151	INT	/1		Spare	-	-	-	-	-	-
			מקרא צבעים:										
							לעבור על כל המכשירים מחדש						
						1	Operation						
						2	Alarm value						
						3	Chemicals						
						4	General						
						5	Analog limits						
						6	F-Factor						
						7							
						8							

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 650 gallon 5 element per PV – use 574 gallon 6 element per PV – use 500 gallon	
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	These set points are 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 PFD step 1		
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	P6-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	P6-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	P6-D.P max flow rate (max_q) [gph]	This set point defines the analog output to P6 and the analog input from P6 (P6_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.	

CCD Design tool:

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: Design and Operation.

In Design 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 Operational 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 Alarms list

The list below include all alarms related to RO operation. Gray rows indicate setpoint irrelevant to PALL RO trailer. 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)
- 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 Desalitech.
- 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).

Flag	Selector	Alarm Category	No	DPLC Bit	Description [Alarm Text]	Set Alarm TAG	Trigger		units	Delay Timer	Delay Delay	Delay Units	Active during	Reset Alarm TAG	Trigger		units	Delay Timer	Delay Delay	Delay Units	Alarm Action Stop RO Stop Non-	Stop RO Stop Flush	ST OP CIP	BLINK
1		Instrument fault	1		FIT-1 transmitter fault	FIT-1	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
1		Instrument fault	2		FIT-2 transmitter fault	FIT-2	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
0	1	Instrument fault	3		FIT-4 transmitter fault	FIT-4	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
0	1	Instrument fault	4		LT-1 transmitter fault	LT-1	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
1	4	Instrument fault	5		LT-2 transmitter fault	LT-2	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
1		Instrument fault	6		PT-1 transmitter fault	PT-1	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
1		Instrument fault	7		PT-2 transmitter fault	PT-2	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
1		Instrument fault	8		PT-3 transmitter fault	PT-3	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
1	2	Instrument fault	9		PT-5 transmitter fault	PT-5	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
1	2	Instrument fault	10		PT-7 transmitter fault	PT-7	=	OUT_OF_RANGE	-		60	sec	Always	Manual										X
1	3	Instrument fault	11		PDT-1 transmitter fault	PDT-1	=	OUT_OF_RANGE	-		30	sec	Always	Manual										X
1		Instrument fault	12		TT-1 transmitter fault	TT-1	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
1	2	Instrument fault	13		TT-2 transmitter fault	TT-2	=	OUT_OF_RANGE	-		30	sec	Always	Manual									X	X
1		Instrument fault	14		CIT-1 transmitter fault	CIT-1	=	OUT_OF_RANGE	-		30	sec	Always	Manual										X
0	1	Instrument fault	15		CIT-2 transmitter fault	CIT-2	=	OUT_OF_RANGE	-		30	sec	Always	Manual										X
1		Instrument fault	16		CIT-3 transmitter fault	CIT-3	=	OUT_OF_RANGE	-		30	sec	Always	Manual										X
0	1	Instrument fault	17		CIT-4 transmitter fault	CIT-4	=	OUT_OF_RANGE	-		30	sec	Always	Manual										X
1		Instrument fault	18		AIT-1 transmitter fault	AIT-1	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
1		Instrument fault	19		AIT-3 transmitter fault	AIT-3	=	OUT_OF_RANGE	-		30	sec	Always	Manual								X		X
0	1	Instrument fault	20		AIT-4 transmitter fault	AIT-4	=	OUT_OF_RANGE	-		30	sec	Always	Manual										X
1	3	Instrument fault	21		PT-6 transmitter fault	PT-6	=	OUT_OF_RANGE	-		30	sec	Always	Manual										X
1			22		Spare																			
1			23		Spare																			
1			24		Spare																			
1			25		Spare																			
1	2	Equipment Faults	26		Booster pump VFD fault or Overload	P1_Fault	=	1	-		1	sec	Always	P1_Fault	=	0	-	-	-	-	X			X	X
1		Equipment Faults	27		High pressure pump VFD fault or Overloa	P2_Fault	=	1	-		1	sec	Always	P2_Fault	=	0	-	-	-	-		X	X	X
1		Equipment Faults	28		Circulation pump VFD fault or Overload	P3_Fault	=	1	-		1	sec	Always	P3_Fault	=	0	-	-	-	-		X	X	X
0	1	Equipment Faults	29		CIP pump VFD fault or Overload	0	=	1	-		1	sec	Always	0	=	0	-	-	-	-	X		X	X
1	2	Equipment Faults	30		A.S general alarm	JI-Alarm	=	1	-		60	sec	PowerUp,CCD, PFD, C.PFD,Standby	Manual								X		X
1			31		Spare																			
1			32		Spare																			
1			33		Spare																			
1			34		Spare																			
1	2	ocess exceeding normal operating rar	35		P-1 suction pressure Low	PT-5	<=	0.2	psi		20	sec	CIP, S.D Flush with Permeate,Standby	Manual							X		X	X
1	2	ocess exceeding normal operating rar	36		P-1 suction pressure Low (CCD)	PT-5	<=	SP-46	psi		60	sec	CCD	Manual								X		X
1	2	ocess exceeding normal operating rar	37		P-1 discharge pressure high	PT-1	>=	SP-47	psi		5	sec	Always	Manual							X		X	X
1		Process exceeding normal operating rar	38		P-2 suction pressure Low	PT-1	<=	15	psi		60	sec	owerUp,CCD, PFD, C.PFD, CIP+P1 RU	Manual							X		X	X
1		Process exceeding normal operating rar	39		High module inlet pressure warning	PT-2	>=	SP-38	psi		30	sec	PowerUp,CCD, PFD, C.PFD, CIP	Manual										X
1		Process exceeding normal operating rar	40		Maximum module inlet pressure alarm	PT-2	>=	SP-39	psi		5	sec	Always	Manual							X		X	X
1		Process exceeding normal operating rar	41		Module inlet pressure High in PFD	PT-2	>=	ast CCD pressur	psi		15	sec	PFD	Manual							X			X
1		Process exceeding normal operating rar	42		Module inlet pressure Low	PT-2	<=	SP-40	psi		120	sec	owerUp,CCD, PFD, C.PFD, CIP+P1 RU	Manual							X		X	X
1		Process exceeding normal operating rar	43		Module Differential pressure High warnin	PT2-PT3	>=	SP-54	psi		30	sec	PowerUp,CCD, PFD, C.PFD, CIP	Manual										X
1		Process exceeding normal operating rar	44		Module Differential pressure High alarm	PT2-PT3	>=	SP-55	psi		5	sec	PowerUp,CCD, PFD, C.PFD, CIP	Manual								X	X	X
1	3	ocess exceeding normal operating rar	45		Micronic Filters Differential pressure Hig	PT6-PT1	>=	SP-53	psi		30	sec	PowerUp,CCD, PFD, C.PFD, CIP	Auto										X
1	2	ocess exceeding normal operating rar	46		Permeate pressure high	PT-7	>=	SP-48	psi		5	sec	Always	Manual							X		X	X
1	2	ocess exceeding normal operating rar	47		Negetive backpressure	PT3-PT7	<=	-5	psi		2	sec	Always	Manual							X		X	X
1		Process exceeding normal operating rar	48		Low water temperature	TT-1	<=	35	F		60	sec	PowerUp,CCD, PFD, C.PFD, CIP	Manual								X	X	X
1		Process exceeding normal operating rar	49		High water temperature	TT-1	>=	113	F		60	sec	PowerUp,CCD, PFD, C.PFD, CIP	Manual								X	X	X

1		Process exceeding normal operating ran	50		Feed pH Low	AIT-1	<=	4	pH		600	sec	PowerUp,CCD, PFD, C.PFD,Standby	Manual								X			X
1		Process exceeding normal operating ran	51		Feed pH High	AIT-1	>=	10	pH		600	sec	PowerUp,CCD, PFD, C.PFD,Standby	Manual								X			X
1		Process exceeding normal operating ran	52		High Feed ORP level	AIT-3	>=	SP-49	mV		600	sec	PowerUp,CCD, PFD, C.PFD,Standby	Manual								X			X
1		Process exceeding normal operating ran	53		Feed conductivity high	CIT-1	>=	**SP-52**	uS/cm		1	hr	PowerUp,CCD, PFD, C.PFD,Standby	CIT-1	<=	SP-52	uS/cm	-	20	min					X
1		Process exceeding normal operating ran	54		Permeate high conductivity warning	CIT-3	>=	**SP-50**	uS/cm		60	sec	CCD, PFD, C.PFD	CIT-3	<=	SP-50	uS/cm	-	60	sec					X
1		Process exceeding normal operating ran	55		Permeate high conductivity alarm	CIT-3	>=	SP-51	uS/cm		60	sec	CCD, PFD, C.PFD	Manual								X			X
1		Process exceeding normal operating ran	56		Feed flow Low	FIT-1	<=	SP-41	gpm		90	sec	PowerUp,CCD, PFD, C.PFD	Manual							X				X
1		Process exceeding normal operating ran	57		Feed flow High	FIT-1	>=	SP-42	gpm		300	sec	PowerUp,CCD, PFD, C.PFD	Manual							X				X
1		Process exceeding normal operating ran	58		Concentrate flow Low	FIT-2	<=	SP-43	gpm		90	sec	PowerUp,CCD, PFD, C.PFD	Manual								X			X
1		Process exceeding normal operating ran	59		Concentrate flow High	FIT-2	>=	SP-44	gpm		300	sec	PowerUp,CCD, PFD, C.PFD	Manual											X
1	2	Process exceeding normal operating ran	60		Low Permeate flush level	LSL-1	=	0	-		5	sec	Shutdown Flush, CIP+XV4	Manual							X			X	X
1		Process exceeding normal operating ran	61		Recovery too Low	Eq-16.2	<=	SP-45	%		5	sec	CCD, PFD	Manual								X			X
1		Process exceeding normal operating ran	62		System Scaling/Fouling	F-Facotr	<	0.85	-		1	sec	CCD, PFD	Auto											X
1	2	Process exceeding normal operating ran	63		Air pressure low	PS-1	=	0	-		10	sec	Always	PS-1	=	1	-		60	sec	X			X	X
0	1	Process exceeding normal operating ran	64		Blend water conductivity high	CIT-4	>=	SP-58	uS/cm		60	sec	CCD												X
1	2	Process exceeding normal operating ran	65		High water temperature in CIP tank	TT-2	>=	120	F		60	sec	Always	Manual										X	X
0	1	Process exceeding normal operating ran	66		Low Feed tank level	LT1	<=	SP-57	%		60	sec	PowerUp,CCD, PFD, C.PFD	LT1	>	50%						X			X
1		Deviation from set points	67		Deviation from CCD feed flow setpoint	FIT-1/SP-14		>1.2 or <0.8	-		60	sec	CCD	Manual								X			X
1		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	Manual							X				X
1		Deviation from set points	69		Deviation from CCD concentrate flow setp	FIT-2/SP-16		>1.2 or <0.8	-		60	sec	CCD	Manual								X			X
0	1	Deviation from set points	70		Deviation from Bypass flow setpoint	FIT-4/SP-34		>1.2 or <0.8	-		60	sec	CCD	Manual								X			X
1	2	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	Manual								X			X
0	1	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	Manual								X			X
0	1	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	Manual								X			X
0	1	Deviation from set points	74		Low deviation from Permeate pH setpoi	AIT-4	<=	SP-88 -0.5	pH		600	sec	PowerUp,CCD, PFD, C.PFD	Manual								X			X
0	1	Deviation from set points	75		High deviation from Permeate pH setpoi	AIT-4	>=	SP-88 +0.5	pH		600	sec	PowerUp,CCD, PFD, C.PFD	Manual								X			X
1		General	76		Emergency stop	E. Stop	=	1			0	sec	Always	Manual							X			X	X
1			77		Spare																				
1			78		Spare																				
1			79		Spare																				
1		Process stuck	80		CCD Cycle time too long	CCD time	>=	1.2xEq-04	min		1	sec	CCD	Manual									X		X
1		Process stuck	81		PFD Cycle time too long	PFD time	>=	1.2xEq-05	min		1	sec	PFD, Shtudown flush	Manual							X				X
1	2	Process stuck	82		Permeate tank filling too long	LSL-1	=	0	-		600	sec	XV-9 OPEN (Not during CIP)	Manual							X				X
1		Process stuck	83		Flushing sequence too long	Wash done flag	=	0	-		240	sec	Powerup rinse	Manual							X				X
1			84		Spare																				
1			85		Spare																				
1			86		Spare																				
1			87		Spare																				
1		Event log	88		End of start signal from client	Request demand	=	0			1	sec	Always	Request deman	=	1	-	-	5	sec	er to diagram				

12 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 repeats 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.
A.S general alarm Alarms related: 30	General alarm in P6 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 problem. Loss of skid inlet pressure	Check dP on micron filters. Check skid inlet pressure.
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 problem Micron filters plugged. Empty Feed tank. Broken pipe/PV.	Check Pumps 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 P4	Check P4 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 P5 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 problem Feed line is blocked. Suction plugged or tank outlet valve closed Empty Feed tank	Check pumps 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 P4 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.

13 Routine maintenance

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-5 minus PI-6), 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 - Daily
Check HMI value and compare to value taken by portable meter. If value deviate 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

14 Cleaning and Preservation

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 results, 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.

Preparations and Logistics

During this procedure, the operator must wear required personal protective equipment. Recommend PPE: rubber gloves and safety glasses. Before cleaning the membrane elements make sure all necessary items are ready for use:

- CIP tank
- CIP pump or booster
- Cleaning bulk solution - The selection of a cleaning chemical depends upon the nature of the contaminants.
- Handheld for measuring CIP solution pH and temperature

CIP Procedure:

Cleaning involves six steps which are summarized visually at the end of this guide.

Step 1 – Making up a cleaning solution:
During normal operation wait for Level in CIP tank to be full, shut down the RO system by pressing the shutdown button on the HMI and wait until flushing is completed and system is idle. Setup Auto and manual valves position to allow brine and permeate recirculation on CIP tank. Pour required amount of concentrated cleaner chemical to CIP tank to achieve the required concentration / pH. Circulate the solution thru the system to get homogenous solution. Sample solution to verify pH and add more chemicals if required. If the system is equipped with CIP heater use the heater to achieve the required cleaning temperature (normally 30-35C).

Step 2 – Low flow pumping and brine displacing:
Enter a low pump speed to limit feed pressure and start the CIP pump. Pressure should be low enough that essentially no or little permeate is produced. A low pressure minimizes re-deposition of dirt on the membrane. CIP solution is now introduced into the RO system modules. If required, divert up to 20% of the most highly fouled cleaning solution to drain before returning the cleaning solution back to the RO Cleaning Tank. This is done by opening XV-2 and closing HV-8.

Step 3 – Slow recycling:
While brine and permeate are diverted to CIP tank, CIP solution is now circulated on the RO system in a closed loop starting from CIP tank to pressure vessels and back to CIP tank. Watch that CIP tank level is steady and no solution volume is lost. Adjust CIP pump speed to get flow rate of 3-4 m3/hr or 14-18gpm per 8” pressure vessel to eliminate any high amount of foulant from plugging the membranes feed side. Run the system for at least 10-15 minutes

Allow the temperature to stabilize and verify temperature is 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 CIP 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.

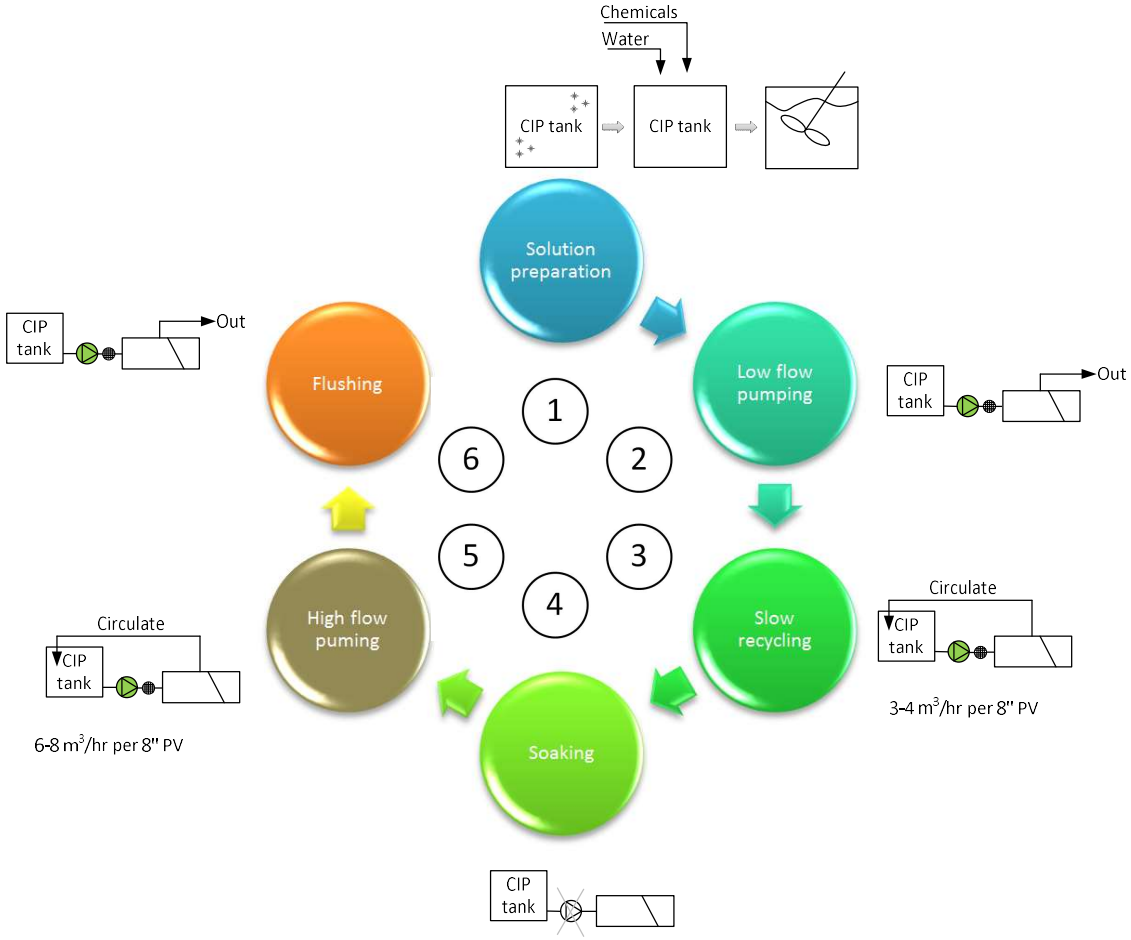
Step 5 – High flow pumping
Turn the CIP pump on and adjust the speed to get flow rate of 6-8 m3/hr or 28-36gpm per 8” pressure vessel. Operate at this rate for 30 to 60 minutes. The high flow rate flushes out the foulants removed from the membrane surface by the cleaning. It is most important not to exceed feed pressure which is usually 4 bar or 60 psi, and pressure drop limitations specified by the membranes manufacturer.
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.

Step 6 – Flushing

Divert valves to flush the system with permeate (if available) or fresh feed for at least 15 minutes while brine is diverted to drain (or neutralization tank is available) and permeate is diverted to CIP tank. Keep flushing until both permeate conductivity and permeate pH return to acceptable limits. Stop CIP pump and switch selector to 0. Return Manual valves to their normal position and startup the RO unit if necessary. Drain CIP tank and clean it with permeate for next CIP operation.

Figure 6 - The six steps of RO cleaning



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.

15 Membrane loading and unloading

Membranes should always be loaded from the feed end (side door area) and removed from the concentrate end (back of trailer).

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.

16 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: 2-11
Temperature range permitted: 33F – 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, or other Pall Water approved lubricant.

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. Use CIP tank to introduce the preservation solution.

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