RO Commissioning Procedures

Test instruments, test kits and materials required

- Test instruments & Test kits.

TDS meter.	Stop watch
pH meter	Calculator
SDI test kit & Millipore filter.	Digital current meter
Iron test kit.	Digital volt meter
Chlorine test kit.	Megger tester

- Materials required.
  a. pH buffer solution, pH 7.0 & pH 4.0 (100ml each)
  b. TDS solution, 100 ppm & 1000ppm (100ml each)
  c. Glycerin oil.
  d. Spacer/ shims, for membrane permeate adapter.
     Note: *If not available, can be fabricated at site using 1½ PVC pipe.*
  e. Few pieces of spare O-rings for entry port and membrane endplate adapter.
  f. Set of mechanical tools.
  g. Marking pen
  h. Hand gloves
  i. Rubber boots

Pre commissioning check

The initial step for this task is to have a quick tour around the plant with the P&ID.
Using the P&ID as a reference, check the completeness of the installation focusing on the operational and process aspect.

Following the process flow starting from raw water tank until the product tank, note down your findings on every sequence of the process taking into account items that will hinder the plant from running/starting.
This is very essential to do, on early part of the first day of commissioning so that you can immediately send fax to our office if you find deficient/damaged accessories or materials. Thus enabling our office people to work in parallel with you at site by expediting things you currently required at site.
By this, it's just on time that you will receive the thing you required after completing other part of the commissioning task.
Hence, failure to do so will extend your day's stay at site, waiting for the required materials to arrive.

A. Check and ensure that the area is free of obstruction and safety hazards.
B. Check that all Equipment / Instruments as specified in P&ID and general arrangement drawing were installed and in good condition.
C. Check that all piping, valves and flanges were properly joined and supported. And ensure that bolts are tight and gaskets installed as required.
D. Inspect and ensure that all rotating equipment were anchored rigidly and alignments of drive and driven are acceptable.
E. Check that all valves operation (open & close) by hand, is acceptable.
F. Check that all equipment rotates freely when rotated by hand.
G. Ensure that all equipment and gear box were sufficiently lubricated with the right type of lubricant.
H. Check if filter media is loaded in sand filter. If not, ask its whereabouts.
I. Check that all level switches are set at the right level and in good condition.
J. Check that all motors are properly terminated (star/delta) with respect to the supply voltages.

K. Test and check that the main power supply voltage is as per design, and tolerance is within ± 5% of the nominal voltage rating. Phase voltages variation should be within ± 10 volts max. also, ensure that the control panel is properly earthed.

Checking and testing of Control panel

Although our control panel (CP) are tested in our factory prior to shipment, still problems sometimes exist. So, always practice extra caution and expect the unexpected during initial power on.

Be sure to follow the sequence below, especially from step '**A**' thru '**E**'.

A. Visually inspect the control panel internals. Check that all cables are connected on its termination point and no loose wires visible. Also try to figure out whether the E&I Drawings at hand are conforming to the actual CP installed. If not, call our electrical engineer immediately to clarify this.

B. **Do not switch on** the incoming isolation circuit breaker of the control panel at this stage. Turn off all other branch breakers and fuses of the control panel.

C. Megger test the control panel's main bus bar, from line to ground and line to line. The result must be more than 2 Meg Ω /500 volts. Also, megger test all motors wire from the terminal block of the CP.

D. Switch on CP's incoming isolation circuit breaker, be ready to switch it off immediately if something is not quit right such as: strange sound, spark & smell. Always have somebody around with you ready to shut off the main power switch.

E. Turn on CP's breaker/fuse for **control supply voltage only** (110/220v) and test the equipment manual on/off control (simulation only, no actual running of equipment. 3phase supply breaker of involve equipment are off).

F. Verify the required supply voltages of the installed instruments if it is conforming to the voltage provided on the CP. If so, switch on the supply breaker for the instruments to check if it's functional.

G. Set all motor's current protection to the required setting, as shown on the motor name plate.

H. Test all motors rotation one at a time (dry run), by turning on its respective circuit breaker, and position the respective selector switch to manual position for about 1 sec. to jerk the motor. The proper rotation is mark on the motor/equipment body.

Warning: 1. *Don't dry run pumps for more than 2 sec. to prevent damage of mechanical seal!*
2. *For pumps rated **15kw** and above, disengage the motor coupling first!*

I. Simulate the auto operation of the control panel as per the control philosophy. You can execute this by disabling the low feed pressure switch and isolate all motors circuit breaker, then run the RO in auto. Then manually manipulate the level switch and instruments alarm to see if the panel is working as designed.

J. Simulate the start-up and shutdown sequence and (take note of the timing) as well as RO protections and alarms such as: ORP high, pH high, REJECT FLOW low, and PERMEATE FLOW high.

Backwashing of Sand / Dual media filter

The filter loaded with new media requires extensive backwashing prior to put it on service operation. Initial backwashing duration varies from three (3) hours to three days depending on filter vessel size, so be sure that the drain water disposal facilities is ready and have enough backwash water available.

The procedure below is also applicable to dual media filter such as: Carbon filter, Birm filter, Anthracite filter and etc.

Step '*A*' thru '*C*' are very important SOP's for dual media filter that one must never by-pass to prevent media washout and blockage of filter drain line during backwashing.

After confirming the operation of filter feed pumps (FFP), start backwashing the sand/dual media filter using the procedure below. Skip step '*A*' thru '*C*' for backwashing of sand (media) filter only.

A. Position the filter to Rinse mode by opening the service inlet valve and rinse outlet valve.
B. Start one of the filter feed pump in manual to wet the filter media. Check the FFP motor current at this stage because *the flow may exceed the pump's capacity which will leads the motor to heat up due to overloading.* Throttle the FFP discharge valve if necessary to make the motor current under control.
C. Slowly throttle the rinse valve until the filter is totally filled with water, and pressurized to 40 to 60 psi for thirty (30) minutes min. to effectively wet the media. Stop the FFP pump when this step is thru. *This step is very important for media such as: Activated carbon, Birm and Anthracite, due to their nature which is buoyant when not yet absorbed by water.*
D. Position the filter to **Backwash** mode by opening the backwash inlet valve and backwash outlet valve.
E. Start both FFP pumps in manual to backwash the filter. Verify the initial backwash drain water if media carryover is acceptable! If not reduce the backwash flow. From time to time, monitor the drain water until it becomes clear, as clear like the raw water. This will take few hours.
F. When the appearance of backwash drain water become clear, position the filter to **Rinse** mode by opening the service inlet valve and rinse outlet valve. Rinse for 30 minutes. **Note :** *Always stop the running FFP pumps before changing over the valve's position!*
G. After initial rinsing is complete, test the filtered water SDI to determine the filter performance.
   Note: *If the raw feed water SDI value is above 5.5, I suggest that you flush the wells and clean the raw water tank first (it will save you from troubleshooting the filter performance).*

If the initial SDI test result yield unsatisfactory (>3 SDI), go to step '*D*' thru '*G*' again until you got the satisfying result.

Chemical dosing preparation

When preparing solution for dosing, one have to bare in mind the solution life as reference for mixing (how long the solution should last). Mix only a solution that will consume as early as 3 days (72 hrs) or 5 days max. especially when mild solution concentration is foreseen.
Factors such as air and high ambient temperature affect the solution life. this is true especially with SMBS and Sodium Hypochlorite.
A typical solution life can vary with concentration. See example below for SMBS solution:

Sodium Methabisulfite (SMBS)	
Wt. %	**Solution Life**
10	1 Week
20	1 Month
30	6 Months

For the dosing pump % speed and % stroke setting, I Prefer to set the pump **Speed higher** than the **Stroke length.** The reason behind is due to the fact that the dosing pump pumping action is intermittent pulse, while the feed water flow is continues.
In this regard, a higher dosing pulse speed will have a better mixing effect than the slower one with a high stroke length.
For safe handling of chemicals please refer to 'Material safety Data Sheet'.

1**. Pre chlorination** (Sodium hypochlorite)
With normal feed water, the usual dosage of chlorine as per site experience to achieve a free chlorine residual of 0.2 ppm after sand filter is about 1 – 1.5 ppm of chlorine (Cl_2).

Calculate the required quantity of Sodium Hypochlorite based on 1-1.5 ppm (Cl_2) dosing rate and set the dosing pump Speed / Stroke accordingly.

Always verify the actual chlorine residual after sand filter, and adjust the dosing pump speed/ stroke if necessary.

2. **De-chlorination** (SMBS)
Since chlorine oxidize membranes, de-chlorination is necessary. SMBS is the most common for removal of free chlorine.

In theory, *1.34 mg of SMBS will remove 1.0 mg of free chlorine*. In practice however, 3.0 mg of SMBS is normally used to remove 1.0 mg of free chlorine.
In our RO, I usually used to inject 2.0-2.5 mg of SMBS on the feed stream.

Calculate the required quantity of SMBS based on 2.0-2.5 ppm dosing rate and set the dosing pump Speed / Stroke accordingly.

Always verify if the actual free chlorine residual after de-chlorination dosing is successfully removed, and adjust the dosing pump speed/ stroke if necessary.

3. **Antiscalant**

The normal dosage of antiscalant we use is 3.5-5.0 ppm. In most case, once the feed water TDS is above 3500 ppm, or SDI is high near 3.0 SDI value, we have to dose 5.0 ppm of antiscalant as a practice.

For the dosing rate of antiscalant, always consult what is offered on the proposal/ contract. If not defined, use the 3.5 -5.0 ppm dosage.

Calibration of instruments

To ensure proper operation of the RO system, a number of control instruments are necessary. The accuracy of all instruments is critical.
They must be installed and calibrated according to manufacturers' instructions.

pH / ORP meter

a. Check to confirm if the sensor patch cord is correctly terminated and at the right channel of the instrument (instruments is multi channel).
b. Turn off power to the instrument and connect the pH / ORP electrode to the sensor cords.
c. Re-power the instrument after installation of sensor is complete.
d. On the sensor electrode cable you will find the sensor constant data (Cell & Temp. constant), key-in these data on the instrument for measuring accuracy (please see manufacturers' instruction).
e. Calibrate instrument as per manufacturers' instruction.
f. After calibration, check the functionality of sensor electrode by immersing the electrode to a process water with different characteristic (alkali & acidic).

   Note: The instrument reading must change with respect to the change in the value of process water.

   Note: For ORP sensor, mix a process water with light chlorine to achieve 0.1-0.2 ppm of chlorine and with swirling motion immerse the ORP electrode. The ORP reading in millivolt (mV) should increase more than 300mV.

g. Set the instrument alarm to the following:
   - High alarm pH = 7.1 pH
   - Low alarm pH = 6.4 pH
   - High alarm ORP = 300 mV

Flow meter

a) Check to ensure that the flow sensor is terminated correctly to its corresponding channel.
b) Check the size flow sensor fittings. Using the **K- Factor** table found on the instrument manual, take the K-Factor for the appropriate size of flow sensor fittings.

c) Key-in the K-factor value of the corresponding channel to the flow meter.
d) Set the alarm limits for the corresponding channel of flow meter such as:

- High permeate flow alarm = 5% more than the design permeate flow
- Low reject flow alarm = 5% less than the design reject flow

TDS / Conductivity meter

a) Check to ensure that the TDS/Conductivity sensor is terminated correctly to its corresponding channel.
b) Uninstall the sensor from the process pipe and removed the sensor protective cap (if still installed).
c) On the sensor electrode cable you will find the sensor Temperature constant value, key-in this value on the instrument for measuring accuracy (please see manufacturers' instruction).
d) Using the standard Sodium Chloride solution, calibrate the TDS meter as per manufacturers' instruction.

Note: For the permeate TDS sensor, use the 100 ppm standard sodium chloride solution.
For the feed TDS sensor, use the 1000 ppm standard sodium chloride solution.

Flushing of pipe lines

Flushing of pipeline must be carried out to flush out dust, cutting burr, and foreign object that maybe left inside the pipe during fabrication. These foreign materials will cause catastrophic damage to membrane element when mistakenly allowed to pass through the element.

Follow the procedure below for flushing the pipeline.

a) Remove the victaulic of the pressure vessel main feed headers downstream of High Pressure pump (HPP).

b) Disengage the main feed header from the discharge line of HPP.

c) Close the feed control valve fully.

d) Open the cover of micron filter housing and open also its inlet isolation valve.

e) Set the sand filter valves to service position.

f) Start the filter feed pump (FFP) to flush the line.

g) Let the water overflow from the open cover of micron filter housing to purge out any foreign materials that may be trap on the line.

h) Let the water overflow for at least 2 minutes.

i) Stop the FFP and install the micron filter elements, then close the cover of filter housing.

j) Open air vent valve of micron filter housing and start the FFP.

k) Set the feed control valve to fully open position.

l) Start the FFP again and let the water flow out from the line downstream of feed control valve for at least 2 minutes.

m) Stop the FFP and proceed to the next section for loading membranes.

Membrane loading

Loading of RO membranes is done just prior to start-up. Loading of membranes requires removal of all header manifolds, opening and closing of the pressure vessels and re-assembly. These could be very time consuming due to re-alignment of manifolds to mate the vessels port, if you fail to follow the described technique/procedure here on.

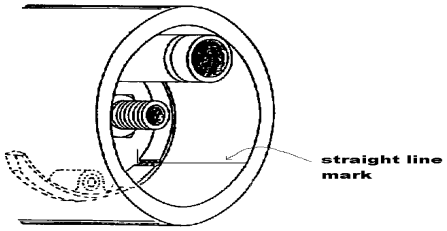
Before starting the loading of element, prepare a simple schematic diagram of the RO system for recording pressure vessel and element locations. It should show the piping of the whole rack. Record the serial number of each element in the location on schematic.
Also, check and make sure that all the items are present in the right quantities before loading starts, such as:

- RO membranes - As required per the design
- Permeate port adapter - 2 ea per vessel (required for 8" element only) (suitable/compatible with the supplied vessels).
- O-ring for vessel end cap. - 2 ea O-rings per vessels (supplied with the vessel)
- Interconnection coupler. - 1ea per membrane (supplied with the membrane)
- Brine seal. - 1ea per membrane (supplied with the membrane)
- Thrust ring. - 1 ea per vessel (supplied with pressure vessel)

Opening of Vessel:

Step 'a' to 'd', are very important steps to minimize the time spent on re-aligning the manifolds during re-assembly.

a) Ensure system is NOT pressurized before starting work.
b) Remove all the plastic wrapping (used for transport) to clear the vessels and manifolds.
c) Using a marking pen, mark with number all the vessels port (end cap port) along with its mate manifold, so that later during re-assembly you know which one is for which one (partners).
d) Also, mark with a horizontal line the end side of vessel's inner wall starting from end cap backing plate until the vessel end. This will serve as guide to set the end cap to its original position during closing of vessels. Please see figure 1, below.



e) Start removing all the victaulic couplings connecting vessel ports and put it aside on a carton box. Also verify the presence of all the gasket of victaulic coupling.
f) Using an 8mm hexagonal T or Allen key to remove the 3 cap-head screw located in recesses in the retaining rings. Please see figure 2.

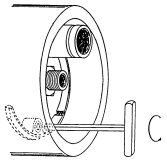


fig.2

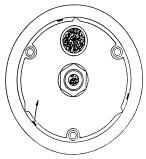


fig.3

fig.4

g) Remove the 3 segment retaining ring (see fig.4). Each segment has a slot at one end (see fig. 3) to enable it to be levered out. If removal is difficult then start at the point where the gap between two segments is greatest.
It may be of assistance to tap the backing plate with a wooden shaft of hammer to free the segment. (DO NOT strike the port). See fig. 5.

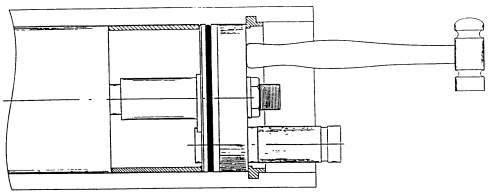


Fig.5

h) Grasp the two port and remove the end cap with a gentle rocking motion. See below.

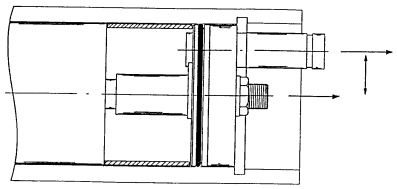
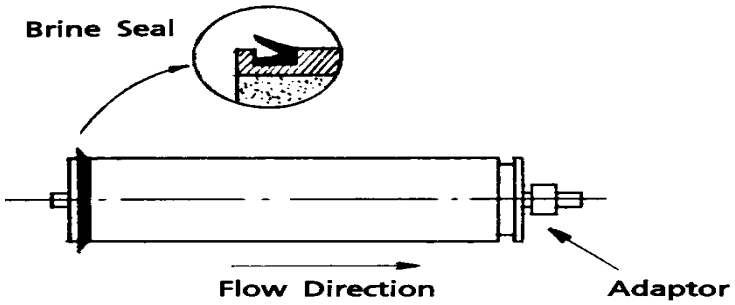


Fig.6

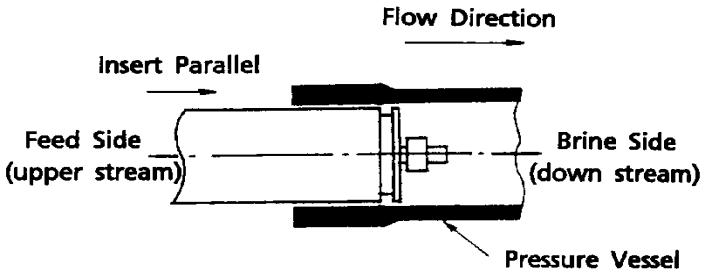
i) Follow the step 'f' to 'h' to remove the rest of the end caps.
j) Once all vessels are opened, remove all Trust Ring (1 each vessel) and put it aside.
k) Inspect all pressure vessels inside for dirt and foreign object and clean with chlorine free water the vessel internal.
l) Use pressurized water hose to spray and flush internals of all pressure vessels.

Insertion of element

a) Install the one thrust ring on the opposite feed end of all vessels.
b) Following the instruction for 'closing vessel' in the following section. Close the brine side (opposite feed side) only of all pressure vessels, in preparation for insertion of membrane elements.
c) Take the membrane element out of the carton and plastic bag. Be careful not to drop the element.
d) Lubricate the inside vessel with glycerine(about 1 foot from feed end). If this is not available then flood vessel with un-chlorinated clean water.
e) Lubricate o-ring seal of adaptor and with slight twisting motion, gently install seal end of the adaptor opposite the feed end of the first element (first element only). See fig. below



f) Apply glycerin on the outer surface of membrane brine seal.
g) With vessel in a horizontal position, slide element from the feed side (upstream) end of the vessel as shown below.



Note : Insert the element carefully and smoothly. Try to avoid touching the inner wall of vessel with the element.

h) Lubricate the interconnector slightly with glycerine and with a slight twisting motion, gently attach it to the product tube at the feed end of the first element as in fig 7.

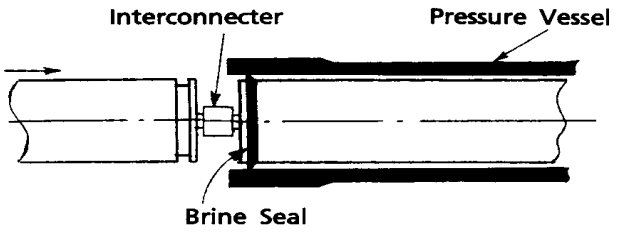


Fig.7

i) Lubricate brine seal of the second element and connect the two elements with interconnector as in fig. 7. Insert the element slowly and parallel to the vessel to avoid damage to interconnector or to the brine seal.

Warning : Maintain element alignment carefully during the process. Do not allow element's weight to be supported by interconnector. Misalignment can result in damages to permeate tube.

j) Repeat steps 'h' and 'i' until all element have been coupled and inserted. Final element will not have an interconnector inserted in feed end of permeate tube.

k) After inserting the last element, push the last element until adaptor on the first element (downstream side) enters firmly into the adaptor-receptacle (permeate port) on the brine side end plate.

l) Lubricate with glycerine O-ring of another membrane permeate adaptor and gently insert it into element permeate tube on feed end side as in fig.8.

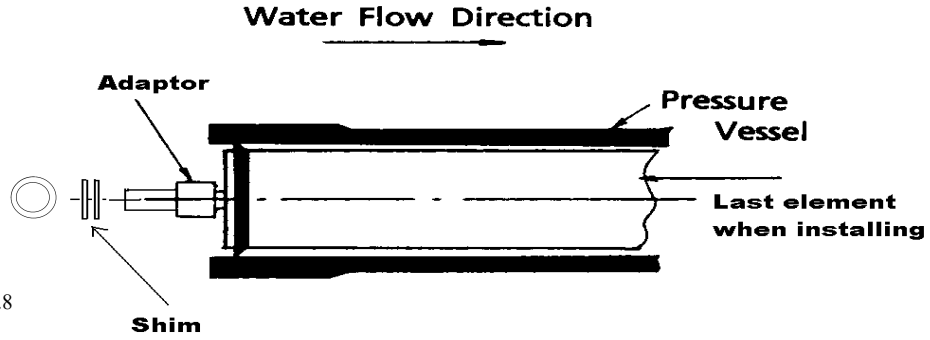


Fig.8

Note : Remaining is the feed end of vessel. Thrust ring IS NOT required on this end.

m) To determine exact number of shim required, install 5 ea of the supplied shims on the feed end of adaptor. Without a seal ring (8" O-ring) install the vessel's end cap squarely into the vessel body and push it gently by hand.
Check the gap between the end cap backing plate and the groove for retaining ring.
If the space is not sufficient to insert the retaining ring, take out the end cap and removed 1 pieces of shim then try again.

Remove one shim at a time until the retaining ring can be inserted fully.

Warning: Once the 3 segment retaining ring are fully in place, the max. gap between the end cap backing plate and retaining ring should be less than 2.5mm.
Gap more than 2.5mm will result in frequent damages of permeate adaptor o-ring.

n) Repeat steps 'c' through 'm' for the rest of vessel to load the membranes and close all vessels as per the instruction on 'closing vessel' in the next section.

Closing Vessel:

a) Locate the appropriate end cap of the respective pressure vessel as previously marked before opening.
b) Apply glycerine oil to shell chamfer and vessel inside walls about ½ inch from chamfer. Wear protective gloves to prevent cuts or penetration by glass fiber particles.
c) Lubricate the assembled end cap with glycerine, particularly the large 8" diameter O-ring seal and the permeate port.
d) Insert the end cap squarely into the vessel body sufficient to allow the segment retaining rings to be inserted fully into the groove in the end of the vessel. If the end fitting is difficult to push into the vessel then use the wooden shaft of a hammer to tap it into position.
Ensure that the previous mark on the end plate aligns with the straight line previously marked on the inner wall of vessel end.

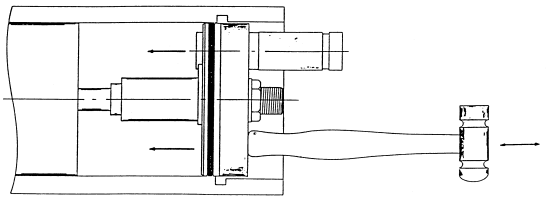
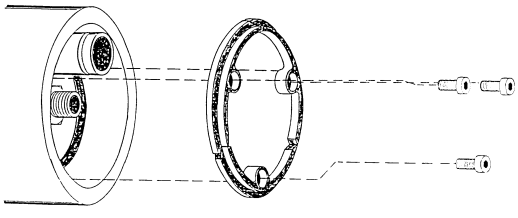
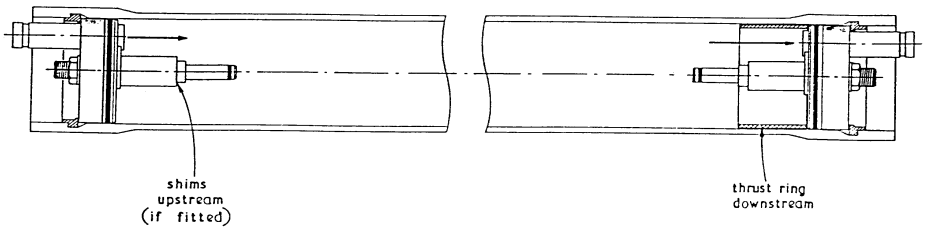


Fig.7

Warning : under no circumstances should undue force be used to insert the end cap.
A light tap is all that is required.

e) Insert back the 3 segment retaining rings and the 3 cap-head screw (do not over tight).





Initial start and setting of RO parameters

Proper start-up of Reverse Osmosis water treatment plant is essential to prepare the membranes for operating service and to prevent membrane damage due to overfeeding or hydraulic shock.
Following the proper start-up sequence also helps ensure that system operating parameters conforms to design specifications so that permeate water quality and productivity goals can be achieved.

The membranes are treated with preservative chemicals for shipment. These chemicals may be hazardous to the health if ingested and must not enter the potable water system. The complete start-up procedure must be followed before discharging product water to the storage tanks.

a) Before initiating the start-up sequence, thoroughly rinse the pretreatment section to flush out debris and other contaminants, without letting the feed water enter the R.O. elements. Furthermore, **absence** of *Chlorine*, *Iron,* and *SDI* must be determined.

b) Verify that the chemical dosing system is functional and the required chemical solutions are prepared as per Section 9.

c) Check all valves to ensure that setting are correct. The feed pressure control valve and concentrate control valve should be fully open.

d) Use low pressure water at low flow rate to flush the air and preservation chemical out of the membrane element and pressure vessels. Start FFP to flush the membrane at gauge pressure of 30-60 psi. All permeate and concentrate flows should be directed to drain during flushing.

   Warning: Do not stand in line of the end fittings of vessel while pressurization takes place.

e) During the flushing operation, check all pipe connection and tightens, repair leaks where necessary.

f) After the system has been flushed for 30-45 minutes, throttle the feed pressure control valve to almost close position (ensure that the concentrate control valve is open).

g) Start the high-pressure pump.

   Warning: Do not stand in line of the end fittings of vessel while pressurization takes place.

h) After the HPP starts, immediately monitor the system pressure and flow:

Limit the feed pressure to	: 90-110 psi only
Delta pressure between stages should not exceed	: 29 psi **Max**.
Limit the initial feed flow to at least	: 50-60% of the design flow

   Let the system stay at this condition for at least 10-15 mins. and monitor the TDS reading of all individual vessels to see if the value are equal or less than the feed TDS

   If not, continue this process until you achieved the TDS reading of equal or less than the feed TDS (individual vessels permeate TDS will go down within 10-30 mins).

i) Gradually increase feed pressure and feed flow rate to RO membranes by slowly throttle open the feed control valve.
   It is important to avoid excessive flow rate and differential pressure across the RO membranes during start-up.

Warning: Maximum pressure drop per bank (one vessel) is 2 bar (29 psi) at any time.

Warning: Feed pressure increase to membrane ***should be less than 10 psi. per second.***

Warning: Feed flow must not exceed 70% of design flow (pls. See **RO projection**)

j) Slowly close the concentrate control valve until the ratio of permeate flow to concentrate flow approaches the ratio of 40-50% (40-50% recovery).

Continue to check the system pressure and feed flow to ensure that it does not exceed 70% of the design limits as shown on the **RO projection**.

Let the system stay at this condition for another 15 mins.

k) Verify the actual flow of Reject flow and Permeate flow with respect to flow meter reading. Re-calibrate flow meter if necessary.

l) Gradually increase again feed pressure and feed flow rate to RO membranes by slowly throttle open the feed control valve.
It is important to avoid excessive flow rate and differential pressure across the RO membranes during start-up.

Warning: Maximum pressure drop per bank (one vessel) is 2 bar (29 psi) at any time.

Warning: Feed pressure increase to membrane ***should be less than 10 psi. per second.***

m) Slowly close the concentrate control valve until the ratio of permeate flow to concentrate flow approaches, but not exceed, the design ratio (recovery) as shown on **RO projection**. Continue to check the system pressure to ensure that it does not exceed the upper limit.

n) Repeat step 'l' and 'm' **slowly stepwise** until design permeate flow and brine flow are obtained.

o) Allow the system to run for one hour and take the first reading of all operating parameters.

p) Read the permeate TDS from each pressure vessel and identify any vessels that do not conform to performance expectations (e.g., vessels with leaking O-ring or other evidence of malfunction).

q) Visually inspect all vessels fittings, ports, and victaulic couplings for leaks, and mark it with marking pen for later repair.

r) Shutdown the system and repair all the marked leaks on the vessels. Also, close the permeate damp valve, to direct the permeate water to product tank for normal operation

s) Start the system again after repair and monitor the RO performance and parameters.