

Engineering Procedure

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Chemical Cleaning, Disinfection, Post Treatment and Storage of Reverse Osmosis Membranes

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1 Purpose

For efficient reverse osmosis (RO) operation it is necessary to clean, disinfect, post-treat, and store RO membranes as per this procedure. This can be accomplished by one or more of the following steps:

- 1) Acid chemical cleaning, e.g., citric acid
- 2) Alkaline chemical cleaning, e.g., detergent cleaning
- 3) Enhanced sodium hypochlorite cleaning
- 4) PT-A (polyvinyl methyl ether) post-treatment
- 5) PT-B (tannic acid) post-treatment
- 6) Disinfection
- 7) Storage (short term and long term)

The cleaning frequency of RO membranes will be dictated by the efficiency of RO pretreatment, antiscalant application, operating recovery, operating pH, bacterial contamination, etc. This procedure does not override the membrane manufacturers' cleaning recommendations especially where warranty rights are involved. Differences shall be questioned and resolved by the proponent and ME&CCD/CSD.

2 Scope

This procedure covers the following:

- 2.1 Defines when the RO membranes should be cleaned in order to restore their productivity and salt rejection. It also defines how to choose the most appropriate cleaning procedure for removing foulants and scalants from the membranes.

- 2.2 Outlines the chemical cleaning equipment that should be used to carry out the chemical cleaning, disinfection and post-treatment of the RO membranes.
- 2.3 Describes the low and high pH cleanings for spiral wound (SW) polyamide membranes. It also outlines all steps that need to be taken for their disinfection and storage.
- 2.4 Describes the chemical cleaning of hollow fine fiber (HFF) polyamide membranes using citric acid, detergent cleaning and the enhanced pH hypochlorite cleaning procedure for removing biofouling.
- 2.5 Describes the post-treatments (PT-A and PT-B) that need to be applied to HFF polyamide membranes after chemical cleaning to enhance their salt rejection. It also outlines all steps that need to be taken for their disinfection and storage.
- 2.6 Describes the chemical cleaning of HFF cellulose triacetate membranes and their storage.
- 2.7 Supplements the membrane manufacturers' cleaning procedures. If warranty rights are involved, the selected cleaning procedures are to be discussed with the membrane manufacturer and differences to be resolved.
- 2.8 Appendix A-1 shows a detailed flow diagram of the RO cleaning, disinfecting post-treatment and flushing equipment. Appendix A-2 provides general guidelines for choosing the optimum cleaning chemical. Appendix A-3 provides a table for the recommended operating parameters and measurements log sheet. Appendix A-4 provides a typical clean in place (CIP) log sheet, Appendix A-5 describes the cleaning solutions for the SW polyamide membranes, Appendix A-6 lists the approved RO cleaners and Appendix A-7 outlines the quality testing procedure for tannic acid to determine its suitability for membrane post-treatment application.

3 Conflicts and Deviations

- 3.1 Any conflicts between this Procedure and other applicable Saudi Aramco Engineering Procedures (SAEPs), Saudi Aramco Engineering Standards (SAESs), Saudi Aramco Materials System Specifications (SAMSSs), Saudi Aramco Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.
 - 3.2 Direct all requests to deviate from this Procedure in writing to the Company or Buyer Representative, who shall follow internal company procedure [SAEP-302](#) and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.
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4 References

The requirements contained in the following documents apply to the extent specified in this procedure.

4.1 Saudi Aramco Documents

Saudi Aramco Engineering Procedures

[SAEP-302](#)

*Instructions for Obtaining a Waiver of a
Mandatory Saudi Aramco Engineering
Requirement*

[SAEP-327](#)

*Disposal of Wastewater from Cleaning, Flushing,
and Dewatering Pipelines and vessels*

4.2 Manufacturer Documents

Permasep Products Engineering Manual, DuPont De Nemours

Technical Service Bulletins, Hydranautics Nitto Denko Company

5 Responsibilities

The facility operating department takes over the responsibilities for cleaning RO membranes after the membranes are commissioned, and handed over to Operations.

5.1 Facility Operating Department

Has the overall responsibility for the operational chemical cleaning.

5.1.1 Maintenance

- a) Provide maintenance support during the chemical cleaning operation.
- b) Coordinate chemical cleaning.

5.1.2 Operations Engineering

- a) Advise and assist the foreman of the RO plant during all chemical cleaning, disinfection, post-treatment and storage activities involving the RO membranes and all associated equipment.
 - b) During the chemical cleaning, disinfection, post-treatment and storage of the reverse osmosis membranes, act as a technical representative to facility operator.
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- c) Ensure adequate safety procedures and precautions are taken.
- d) Coordinate and obtain the approval of chemical cleaning procedures and formulations from the Materials Engineering and Corrosion Control Division/Consulting Services Department (ME&CCD/CSD), waste disposal plans per [SAEP-327](#) from Environmental Engineering Division/ Environment Protection Department (EED/EPD) and the Research and Development Center (R&DC). Maintain history of membranes chemical cleaning, post-treatment and storage. Incorporate relevant reports and data into permanent plant records.

5.2 Regional Laboratories

- a) Perform chemical analysis, monitor and log chemical cleaning analyses and foulant/scalant removal rates on-site during actual cleaning operations.
- b) Verify the purity of solvents and chemicals used for chemical cleaning.

5.3 Consulting Services Department/ME&CCD

- a) Review and approve the membrane cleaning, sanitization, post-treatment and storage procedures
- b) Provide specialist/consultant advice on request, during membrane cleaning, disinfection, post-treatment and storage.

6 Safety

- 6.1 Wear all the necessary personal protective equipment and take all necessary precautions when handling hazardous cleaning chemicals. These should include: Eye and face protection from splashes (goggles and face shields), hearing protection (ear plugs), head protection (hard hat), body protection, (rubber gloves, rubber boots, proper personal clothing), and respiratory protective equipment.
 - 6.2 Have all the Material Safety Data Sheets (MSDS) available on site for all the cleaning chemicals used.
 - 6.3 Add acids and caustic to water, not vice versa (apply continuous stirring to dissipate the heat produced).
 - 6.4 Have an eye wash and a safety shower in the vicinity of the chemical cleaning area.
 - 6.5 Mark dangerous chemicals and store them in designated areas.
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- 6.6 Use cover on the chemical mixing tank to avoid splashes and a fan extractor for produced fumes as indicated in figure 1 of appendix A-1. If a procedure produces fumes wear respiratory equipment such as Scott Air Pack or Self Contained Breathing Apparatus (SCBA).
- 6.7 Beware of chemical leaks during chemical cleaning (wear protective equipment for eyes, face, hands and feet).
- 6.8 Follow work permit procedures when installing blinds
- 6.9 Pressure test to 1.5 x the operating pressure any temporary connections to avoid chemical leaks during chemical solution circulation.
- 6.10 To report emergencies ring 110 utilizing the following steps
 - a) Provide location of the emergency
 - b) Nature of the emergency
 - c) Name and badge number of caller
 - d) Repeat the above three steps
 - e) Wait for further instructions before hanging up

7 Cleaning Equipment

The equipment for cleaning, disinfection, post-treatment and flushing of RO membranes is shown in Figure 1 in Appendix A-1. The materials of construction of the cleaning equipment must be chemically compatible with all chemicals used and corrosion resistant.

- 7.1 The mixing tank shall be made of non-corrosive materials such as reinforced plastic and should be sized for a minimum of three-minute retention time, considering the number of membrane elements to be cleaned at one time and the volume of the liquid in the cleaning pump and piping. It should be provided with a cover, exhaust fan to outside of building, mixer, cooling coil, temperature indicator and temperature alarm. A valve at the bottom of the mixing tank is needed to assure that the tank can be completely drained and flushed of waste chemical solutions.
- 7.2 The chemical cleaning skid can be placed on fixed foundation or it could be mobile by being placed on railings so that it can easily be moved from one RO unit to the next. Similarly, the piping can be hard piping or flexible hosing. For a mobile CIP skid a flexible vent hose to fan will be required.
- 7.3 Temperature indicator and temperature alarm are required to ensure that the temperature of the cleaning solution will not exceed the temperature limit set in

the procedures of this specification. Heat added by pumping and dilution of chemicals will cause a rise in cleaning solution temperature.

- 7.4 The circulation pump should be 316 stainless steel (SS) or non metallic compatible with the chemicals mentioned in Appendices A-5 and A-6 and sized for the flow and pressures that are required by the various procedures in this standard. A centrifugal pump is most suitable for flexibility and safety.
- 7.5 If flexible hoses are to be used for supply and return lines, these should be of adequate pressure ratings as required in the cleaning procedures of this procedure. The use of quick lock connections makes flexible hose handling easy and reliable.
- 7.6 Provisions should be made to send both the concentrate and permeate to drain or back to the mixing tank during cleaning. During the initial recirculation of the cleaning solution, it is sometimes desirable to allow the cleaning solution to run to drain if it is highly discolored with foulant or scalant which is removed from the membranes. The cleaning solution return should not be throttled. The permeate and concentrate should be returned below the liquid surface in the mixing tank to minimize foaming. A flow bypass line around the cleaning pump should be installed. This bypass is needed to control the fluid velocity through the membranes so that it does not exceed the membrane bundle pressure drop guideline during cleaning.
- 7.7 A strainer and a 5-10 micron cartridge filter should be installed to avoid circulating sediment which may dislodge from the system during the cleaning operation. The cartridge filtration should be located on the pump discharge and not the return to the tank.
- 7.8 Flow meters are needed to establish proper flow rates through the membranes. The flow requirements for effective membrane cleaning, disinfection, post-treatment and flushing vary. These flow requirements are stated in the various procedures of this specification. Sampling ports are needed for monitoring the progress of the cleaning operation.

8 Membranes Cleaning Frequency

Membrane chemical cleaning is generally required when any of the following conditions occur:

- A 10-15% decrease in normalized permeate flow
 - A 10-15% increase in salt passage
 - A 10-15% increase in feed pressure to maintain normalized permeate flow.
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- A 10-15% increase in differential pressure across all or part of a reverse osmosis system. (This is what is recommended by membrane manufactures. However, a maximum DP of 60 psi can be tolerated).

Knowing the nature of the membrane foulant will help in deciding the optimum cleaning chemical or combination of chemicals (see Appendix A-2).

Adopt the following general precautions in selecting and using a cleaning chemical

- 1) Whether proprietary or generic chemicals are used, make sure that the chemical has been qualified for use by the membrane manufacturer.
- 2) Use the least harsh cleaning regime to optimize the useful life of the membranes. This includes the cleaning parameters of pH, temperature, and contact time.
- 3) Clean at the recommended temperature.

Membrane foulants are typically mixtures of two or more of the following:

- Scale (e.g., CaCO_3 , CaSO_4 , and BaSO_4)
- Bacteria and bacterial slime
- Organic debris (e.g., algae)
- Colloids (clays, silicates)
- Metal hydroxides
- Chemical precipitates

Clean RO systems sequentially, usually acidic cleaning followed by alkaline cleaning. Foulant deposits are complex mixtures and do not always get removed by a single cleaning. When the sequential technique is applied it is generally most effective to begin with acid cleaning. An exception to this practice is when the foulant is organic. For organic fouling alkaline cleaning should precede acid cleaning. The cleaning procedure should be selected after determining if scaling, particulate fouling, or biofouling are suspected (see Appendix A-2).

To determine the cause of fouling, operating records (see Appendix A-3) should be reviewed and instruments checked. It is often very helpful to conduct complete water analyses and microbiological assays on samples taken throughout the system. In the event where an element has failed, it is very beneficial to have it opened and examined (perform autopsy).

Scaling is suspected when there is decreased salt rejection, increased pressure drop in the final stage, and decreased normalized permeate flow. Scaling first occurs in the final stage, where the brine is more concentrated and the solubility of the scale forming ions is exceeded. When scaling occurs in one element, it will always occur in the

following elements since the brine becomes more concentrated as it passes from one element to the next.

Fouling by particulates or bacteria is suspected when there is increased pressure drop and decreased normalized permeate flow.

The pH exposure time, flow rate, and temperature of the cleaning solution need to be considered when planning the cleaning. Compatibility of the cleaner with the membrane is also critical. Every membrane has limited pH and temperature ranges and chemical reactivities vary for different membranes.

Acid or low pH cleaning is often the first step, especially when scaling is suspected.

Typical low pH cleaner is the 2% wt. ammoniated citric acid.

The citric acid cleaning is effective for removing calcium carbonate and iron oxide scales that must be removed before attempting to use a high pH cleaner since calcium carbonate and iron are highly insoluble at high pH. A chelant such as EDTA can also be used to remove metal salts. Iron and calcium carbonate can be successfully removed, however, some inorganic compounds are very difficult to remove when they have deposited on membrane surfaces. These include the following:

- Calcium sulfate
- Barium sulfate
- Strontium sulfate
- Silica
- Elemental sulfur

The most common high pH cleaners are:

- 1% Sodium tripolyphosphate
- 1% Trisodium phosphate
- 1% Sodium hydroxide
- Laundry detergents

These cleaners are effective in removing clay and silt particles, biofilms, and certain organics. High cleaner flow rates are preferred when using these cleaners since the mechanical action of the cleaner passing over the deposits helps to remove them.

When high and low pH cleaners have failed to restore performance and biofouling is suspected, it may be necessary to disinfect the RO unit. Disinfection may be accomplished by using a biocide such as sodium hypochlorite. Disinfection chemicals are very reactive with membranes. Their application should be carried out only by experienced personnel who will consider all the necessary parameters that need to be taken care of, such as temperature, pH and contact time.

9 Cleaning Polyamide SW Membranes

9.1 Preparation for Membranes Cleaning:

- 9.1.1 Ensure that all required chemicals are available and in sufficient quantities.
- 9.1.2 Ensure that all instruments, e.g. conductivity, meters, pH meter, flow meters, temperature meters are properly calibrated and working reliably.
- 9.1.3 Apply all the safety procedures as per the safety section 6, paragraphs 6.6 to 6.10.
- 9.1.4 Conduct conductivity and DP profile and note the RO unit operation data (feed pressure, product flow, recovery, unit DP, salt passage, temperature, and product pressure).
- 9.1.5 Stop RO module to be cleaned and flush per the normal procedure using chlorine free product (CFP) water. Normal procedure flush is a once through flush with CFP water (brine and product to drain). Do not exceed maximum allowed DP (0.7 bar per SW element in housing). Use a flushing pressure of 100 psig.
- 9.1.6 Install a blind flange or isolation ball valve between the stages to be cleaned and conduct the cleaning on each stage separately.
- 9.1.7 Record in the log book all the chemical cleaning parameters (e.g., flow, pressure, pH, conductivity, chemical concentration, circulation time, temperature etc) during all steps [see clean in place (CIP) log sheet in Appendix A-4].

9.2 Estimating the Cleaner Quantity for SW Membranes

The cleaner quantity in the tank should take into consideration the following:

- The water volume contained in the hoses or piping
- The water volume contained in the pressure vessels.

9.2.1 The water contained in the hoses or piping can be determined by following two ways:

- a) Fill the cleaning tank to the desired level with water, e.g., 200 gallons. Then fill the hoses or piping with the cleaning pump. Loss in tank volume equals the hose or piping volume.

- b) Hose volume may also be estimated mathematically from hose diameter and length (see Table 1).

- 9.2.2 The volume of water contained within the elements in the pressure vessels may be estimated from Table 2. The total volume of water may be estimated by multiplying with the number of elements to be cleaned.

Table 1 - Calculation of Hose Volumes

Hose Diameter Inches	Hose Volume Gallons/Foot
2	0.16
3	0.37
4	0.65

Table 2 - Estimation of Element Volumes in Pressure Vessels

Element Diameter Inches	Element Length Inches	Gallons Per SW Element
4	40	2
6	40	3.5
8	40	6

9.3 Ammoniated Citric Acid (pH 4.0) Cleaning for SW Membranes

- 9.3.1 Flush the membranes in the pressure tubes for 5 minutes (once through flush reject and product to waste) by pumping chlorine free product (CFP) water from the cleaning tank. Apply 60 psi (4 bars) flushing pressure and flow rate of 6 gpm x number of 8-inch elements to be cleaned. This flow rate is expected to be 24 to 40 gpm per pressure tube.
- 9.3.2 Fill cleaning tank to required level with CFP water (work out the total volume including piping and housing vessels as per 8.2.1 and 8.2.2). Ensure that there is sufficient water in the mix tank to permit circulation through the piping and membranes without causing vortex formation in the tank. Vortex formation can result in air being drawn into the pump causing a loss of prime.
- 9.3.3 Start stirrer and gradually add citric acid ($C_6H_8O_7$) to prepare a 2 wt percent solution (Solution 1, see Appendix A-5). Add 7.6 Kg of citric acid (as 100% powder) per 100 gallons of water. Adjust the temperature of the solution in the tank to about 104°F (40°C). Citric acid may be pre-dissolved in a separate container before adding it to the mix tank.

- 9.3.4 Allow mixing for 10 minutes and measure the solution pH from top and bottom of the cleaning tank. Adjust pH of citric acid solution to 3.9-4.1 using small quantities of ammonium hydroxide (if required). Wear protective equipment including a respirator to prevent inhalation of ammonia fumes.
- 9.3.5 Check out piping, valve positions, pump selection etc. Open chemical tank valves (pump suction, brine return and product return valves). Allow few minutes priming by venting out air from all piping high points.
- 9.3.6 With chemical pump discharge valve partially closed, start chemical pump. Adjust flow 6 gpm x number of 8-inch elements and pressure of 60 psig. Send to drain the first 20% of solution. Monitor DP and ensure it stays below 60 psi (4.0 bars) at all times.
- 9.3.7 Ensure that the temperature of the solution is about 104°F (40°C) and that the solution pH is 3.9-4.1
- 9.3.8 Continue treatment for the next 5-6 hours. Monitor iron levels, calcium levels, pH and DP drop. Check visual appearance of solution.

Commentary Note:

As iron is removed from the membrane surfaces, it turns green and if excessive quantities are removed, solution turns brownish.

- 9.3.9 If the color is brownish and iron concentration in the solution is > 10 ppm, dump the solution and prepare another batch.
- 9.3.10 When iron levels in three consecutive samples taken 15 minutes apart are the same (within 10% difference) stop cleaning. Divert brine return and product return to drain. Drain chemical tank.
- 9.3.11 Flush the membranes as per 9.3.1. If further rinsing is required fill the cleaning tank and flush the membranes again.

Commentary Note:

Step 9.3.8 can be replaced with an optional soak and recirculation sequence if required. This involves stopping after 30 minutes of circulation and allow soaking for 15 minutes. Continue with circulation/soaking whilst checking pH, iron, calcium and DP drop.

9.4 Detergent Cleaning (pH 10) for Polyamide SW Membranes

- 9.4.1 Fill cleaning tank as per 9.3.2.

- 9.4.2 Start the stirrer and add sodium hydroxide to reach pH of 9.0. Circulate in the membranes for 10-15 minutes to neutralize any acidity in the membranes. Stop membrane circulation and continue circulating within the tank.
- 9.4.3 Add more sodium hydroxide to reach pH of 10.0. Make up 2 wt percent solution of sodium tripolyphosphate ($\text{Na}_5\text{P}_3\text{O}_{10}$) and 0.8 wt percent of Na-EDTA (sodium salt of ethylenediaminetetraacetic acid). This is known as Solution 2 (see Appendix A-5). The pH adopted during the detergent cleaning will depend on the type of the detergent used.
- 9.4.4 Circulate the cleaning solution through the permeators. Take the first 20% of the solution to drain via the brine return valve, and then recycle the cleaning solution through the mix tank for 2 hours. Alternatively, a flush/soak method in 15 minutes cycles may be used. Use flow rate of 6 gpm x number of 8-inch elements to be cleaned and pressure of 60 psig. Adjust the flow so as not to exceed 60 psi bundle pressure drop.
- 9.4.5 When cleaning is complete, stop circulation. Drain mix tank solution to waste. Flush the mix tank and refill it with CFP water.
- 9.4.6 Add sodium hydroxide until the pH reaches 9.0 to 10.0. Flush the membranes and piping with both brine and product going to drain. At all time do not allow DP across the membrane bundle to exceed 60 psi. If DP across the membrane bundle reaches 60 psi then decrease the feed water pressure.
- 9.4.7 Flush system again as per 9.3.1. If further rinsing is required fill the cleaning tank and flush the membranes again. Feed water can also be used for flushing. Flushing flow rate can increase to 9 gpm x the number of elements to be flushed. Collect a sample of the brine in a jar and shake it to test for any remaining detergent. If foaming occurs, continue the flushing until all the foaming stops. If no foaming occurs then the detergent cleaning is complete.
- 9.4.8 Restart RO and place into service rinse. Divert the RO product to drain until it meets the quality requirements (e.g., conductivity, pH, etc.). It is not unusual for the system to take few hours to few days for the RO permeate quality to stabilize, especially after high pH cleaning.

10 Disinfecting Polyamide SW Membranes

Solutions that may be used for disinfection and long term storage are:

- a) Glutaraldehyde: A solution of 0.1 to 1.0% concentration may be used for disinfection and long term storage. The membrane elements should be operated for at least 24 hours before being exposed to glutaraldehyde.
- b) Isothiazoline: It is distributed under the trade name "Kathon". The commercial solution contains 1.5% of active ingredient. The recommended concentration of Kathon for disinfection and storage is 15 to 25 ppm.
- c) Sodium bisulfite: It can be used as inhibitor for biological growth. To control biological growth apply at a dosing rate of 500 ppm for 30 to 60 minutes daily. It can also be used as a preservative during long term storage at 1% concentration.

Commentary Note:

Formaldehyde solution of 0.1 to 1.0% concentration may also be used for disinfection and long term storage. However, it is not recommended because it is carcinogenic.

Hydrogen peroxide or solution of hydrogen peroxide with paracetic acid can be used for disinfection. Special care must be taken that transition metals (Fe, Mn) are not present in the feed water, since in the presence of transition metals, oxidation of the membrane surface may occur resulting in membrane degradation. The concentration of hydrogen peroxide for disinfection should not exceed 0.2% and the temperature should not exceed 77°F (25°C). Hydrogen peroxide should not be used as a preservative for long term storage of membrane elements.

11 Storing Polyamide SW Membranes

11.1 Short-Term Storage of SW Membranes

- 11.1.1 Flush the RO unit with feed water while simultaneously venting any gas from the system.
- 11.1.2 When the pressure tubes are filled, close the appropriate valves to prevent air from entering the system.
- 11.1.3 Reflush as described above at 5-day intervals.

11.2 Long-Term Storage of SW Membranes

Long-term storage is for periods where the RO plant is out of service for more than thirty days with the RO elements in place.

- 11.2.1 Clean the RO membranes in place
- 11.2.2 Flush the RO unit with an approved disinfecting solution (see Section 9) prepared with CFP water.

- 11.2.3 When the RO section is **completely** filled with this solution, close the valves to retain the solution in the RO section.
- 11.2.3 Repeat steps 2 and 3 with fresh solution every thirty days if the temperature is below 80.6°F (27°C), or every fifteen days if the temperature is above 80°F (27°C).
- 11.2.4 When the RO system is ready to be returned to service, flush the system for one hour using low pressure feed water with brine and product going to waste. Flush for 5-10 minutes at high pressure with brine and product going to waste. Before returning the RO system to service, make sure that there is no residual disinfecting solution in the product.

11.3 Storage of SW Membranes Prior to Installation

When RO elements are stored prior to installation, they should be protected from direct sun light. Store the RO elements in cool and dry place with an ambient temperature range of 68°F to 95°F (20°C to 35°C).

12 Cleaning Polyamide HFF Membranes

12.1 Preparation for Membranes Cleaning:

- 12.1.1 Ensure that all required chemicals are available and in sufficient quantities.
- 12.1.2 Ensure that all instruments, e.g. conductivity, meters, pH meter, flow meters, temperature meters are properly calibrated and working reliably.
- 12.1.3 Apply all the safety procedures as per the safety section 6, paragraphs 6.6 to 6.10.
- 12.1.4 Conduct conductivity and DP profile and note the RO rack operation data (feed pressure, product flow, recovery, unit DP, salt passage, temperature, and product pressure).
- 12.1.5 Stop RO module to be cleaned and flush per normal procedure using chlorine free product (CFP) water. Normal procedure flush is a once through flush with CFP water (brine and product to drain) of 30 gallons per 8-inch permeator. Do not exceed maximum allowed DP (60psi). Use flushing pressure of 100 psig. The brine pH must be 6.0 or above.

- 12.1.6 Install a blind between the RO stages to be cleaned and conduct the cleaning on each stage separately.
- 12.1.7 Record in the log book all the chemical cleaning parameters (e.g. flow, pressure, pH, conductivity, chemical concentration, temperature etc) during all steps.
- 12.2 Estimating the Cleaner Quantity for HFF Membranes
 - 12.2.1 The water contained in the hoses or piping can be determined in the same way as per 9.2.1 (a) and (b) shown in Table 1.
 - 12.2.2 The volume of water in the HFF permeators may be estimated from Table 3. The total volume of water may be estimated by multiplying with the number of permeators to be cleaned.

Table 3 - Estimation of HFF Permeators Volumes

Element Diameter Inches	Gallons Per Single HFF Element
4	2.5
8	7.5

- 12.3 Ammoniated Citric Acid (pH 4.0) Cleaning for Polyamide HFF Membranes
 - 12.3.1 Fill cleaning tank as per 9.3.2.
 - 12.3.2 Start the stirrer and gradually add citric acid to prepare a 2 wt percent solution. Add 7.6 Kg of citric acid (as 100% powder) per 100 gallons of water.
 - 12.3.3 Allow mixing for 10 minutes and measure the solution pH from top and bottom of the cleaning tank. Adjust the pH of citric acid solution to 3.9-4.1 using small quantities of ammonium hydroxide (if required).
 - 12.3.4 Measure the total iron in the citric acid solution. Ensure that the temperature of the solution is < 95°F (35°C).
 - 12.3.5 Check out piping, valve positions, pump selection etc. Open chemical tank valves (pump suction, brine return and product return valves). Allow few minutes priming by venting out air from all piping high points.
 - 12.3.6 With chemical pump discharge valve partially closed, start chemical pump. Adjust flow 7.5 gpm x number of 8-inch single element/permeator (minimum brine flow 6 gallons per 8 inch membrane) and pressure to 90-125 psig. Send to drain the first 20%

solution. Monitor DP and ensure it stays within 60 psi (4.0 bars) at all times.

12.3.7 After 15 minutes, measure iron and calcium in brine return. Monitor DP across the RO module/permeator. Check citric acid solution pH to ensure it is 3.9-4.1.

12.3.8 Continue treatment for the next 5-6 hours. Monitor iron levels, calcium levels, pH and DP drop. Check visual appearance of solution.

Commentary Note:

As iron is removed from the membrane surfaces, it turns green and if excessive quantities are removed, solution turns brownish.

12.3.9 If the color is brownish and iron concentration in the solution is > 10 ppm, dump the solution and prepare another batch.

12.3.10 When iron levels in three consecutive samples taken 15 minutes apart are the same (within 10% difference) stop cleaning. Divert brine return and product return to drain. Drain chemical tank.

12.3.11 Flush per normal procedure using CFP water.

12.4 Detergent Cleaning for Polyamide HFF Membranes

12.4.1 Fill cleaning tank as per 9.3.2.

12.4.2 Start the stirrer and add sodium hydroxide to reach pH of 9.0. Circulate in the membranes for 10-15 minutes to neutralize any acidity in the membranes. Stop membrane circulation and continue circulating within the tank.

12.4.3 Add more sodium hydroxide to reach pH of 11.0. Add required detergent amount to give the appropriate wt percentage which will depend on the detergent chosen e.g. if the PermaClean 67 is used, add 1 gallon for each 100 gallons of water.

12.4.4 Circulate the cleaning solution through the permeators. Take the first 20% of the solution to drain via the brine return valve, and then recycle the cleaning solution through the mixing tank for 2 hours. Alternatively, a flush/soak method in 15 minutes cycles may be used. Use brine flow of 9 gpm per 8-inch permeator and pressure of 50-150 psig. Adjust the flow so as not to exceed 60 psi bundle pressure drop.

12.4.5 When cleaning is complete, stop circulation. Drain the mixing tank solution to waste. Flush the mixing tank and refill it with CFP water.

- 12.4.6 Add sodium hydroxide until the pH reaches 9.0 to 10.0. Flush the membranes and piping with both brine and product going to drain. At all time do not allow DP across the membrane bundle to exceed 60 psi. If DP across the membrane bundle reaches 60 psi then decrease the feed water pressure.
- 12.4.7 Flush the system again as per normal procedure using CFP water until foaming stops. Collect a sample of the brine in a jar and shake it to test for any remaining detergent. If foaming occurs, continue the flushing until all the foaming stops. If no foaming occurs then the detergent cleaning is complete.

12.5 Enhanced pH Hypochlorite Cleaning for Polyamide HFF Membranes

Important Note:

This cleaning procedure is very effective for removing membrane biofouling. However, this procedure can harm the membranes irreversibly if it is not carried out correctly. This procedure can only be carried out by experienced personnel; otherwise assistance from a CSD specialist should be sought.

- 12.5.1 Fill cleaning tank as per 9.3.2.
- 12.5.2 Start chiller to reduce cleaning tank temperature to < 86°F (30°C).
- 12.5.3 Start the stirrer and add sodium hydroxide gradually to adjust pH to 11.8-12.0 range.
- 12.5.4 Allow mixing for 5 minutes and measure the solution pH. Ensure that the temperature is < 86°F (30°C).
- 12.5.5 Recheck piping, valve positions, pump selection etc. Open chemical tank valves (pump suction, brine return and product return valves). Allow few minutes priming by venting out air from all piping high points.
- 12.5.6 With the chemical pump discharge valve partially closed, start the chemical pump. Adjust the flow to achieve a minimum brine flow of 6 gpm per permeators and pressure of 100-150 psig. Monitor DP and ensure it stays within 60 psi (4.0 bars) at all times.
- 12.5.7 After 10 minutes, measure the pH in brine and product return. Ensure it is 11.8-12.0. Monitor DP across the RO module/permeator.

-
- 12.5.8 Continue the treatment for the next 30 minutes. Monitor pH and DP drop. Check the visual appearance of the solution (Note: As organic and biofoulants are released removed from the membrane surfaces, the solution turns brownish).
 - 12.5.9 At the end of the high pH treatment, drain the cleaning chemical tank.
 - 12.5.10 **DO NOT FLUSH.** It is very important to allow the high pH solution to remain in the RO module and to avoid damage to the permeators.
 - 12.5.11 Fill the cleaning tank to the required level with CFP water.
 - 12.5.12 Start the stirrer and add sodium hydroxide to adjust pH to 11.8-12.0.
 - 12.5.13 After about 5 minutes of mixing, add about 2 liters sodium hypochlorite.
 - 12.5.14 Allow mixing for 5 minutes and measure the solution chlorine and pH. Adjust chlorine to 150 mg/L (as Cl₂) using small quantities of sodium hypochlorite.
 - 12.5.15 Check pH and adjust it in the range of 11.8-12.0 using sodium hydroxide (if required). Ensure that the temperature is < 86°F (30°C).
 - 12.5.16 Check out piping, valve positions, pump selection etc. Open chemical tank valves (pump suction, brine return and product return valves). Allow few minutes priming by venting out air from all piping high points.
 - 12.5.17 With the chemical pump discharge valve partially closed, start the chemical pump. Adjust the flow to 7.5 gpm x number of permeators to be cleaned and pressure to 100-150 psig. Monitor DP and ensure it stays < 60 psi (4.0 bars) at all times.
 - 12.5.18 Monitor the chlorine level and DP across the RO module/permeator. Check brine and product pH to ensure it is 11.8-12.0. (If pH decreases to < 11.7, stop circulation, readjust pH and restart).
 - 12.5.19 Continue the treatment for the next 30 minutes. Monitor chlorine, pH, and DP change. If chlorine is consumed and its concentration has been reduced to about 50 mg/l, add additional sodium hypochlorite to bring the chlorine to 150 mg/l. Check visual appearance of solution (Note: As organic and biofoulants are removed, the clear solution turns tan-brown color).
 - 12.5.20 At the end of hypochlorite treatment, check Cl₂ content of solution and record. If the consumption of chlorine has stopped this means that the
-

treatment is complete. Stop the circulation and dump the cleaning tank solution to drain.

- 12.5.21 Fill the cleaning tank to the required level with CFP water.
- 12.5.22 After about 5 min. of mixing, add 0.5 Kg of sodium bisulphite (SBS) per 100 gallons of CFP water.
- 12.5.23 Start stirrer and add sodium hydroxide to adjust pH to 11.8-12.0
- 12.5.24 Allow mixing for 5 minutes and measure the solution SBS content and pH. SBS should be about 1,200-1,300 mg/l. If required, adjust SBS to this level using small quantities of SBS.
- 12.5.25 Recheck the pH of the SBS solution to ensure that it is 11.8 to 12.0. Add NaOH if needed to adjust the pH.
- 12.5.26 Recheck the piping, valve positions, pump selection etc. Open the chemical tank. Allow few minutes priming by venting out air from all piping high points.
- 12.5.27 With the chemical pump discharge valve partially closed, start the chemical pump. Adjust the flow to 7.5 x number of permeators to be cleaned and pressure to 100-150 psig.
- 12.5.28 After 10 minutes, measure the pH in brine and product return. Monitor the chlorine of returning brine. The chlorine content must be zero. Monitor the SBS level and DP across the RO module/permeator. Check pH to ensure it is 11.8-12.0.
- 12.5.29 Continue the treatment for the next 30 minutes.
- 12.5.30 Check the chlorine residue to confirm it is zero. At the end of high pH SBS circulation treatment, add SBS gradually as required to reduce SBS solution pH to 7.5-8.5. Circulate for 10 minutes and divert the brine and product return to the drain. Drain the cleaning chemical tank.

13 Disinfecting Polyamide HFF Membranes

- 13.1 Fill cleaning tank as per 9.3.2.
- 13.2 Add the required quantity of disinfection chemical to the mixing tank and start the stirrer. If PermaClean 55 is to be used, prepare a solution of 0.3% in the mixing tank by adding 0.3 gallons of PermaClean 55 for each 100 gallons of CFP water.

- 13.3 Circulate the disinfection solution in the membranes module to be sterilized and direct the first 20% of the solution to drain via the brine drain valve. Then, recycle the brine through the mixing tank. Use a circulation pressure of 50-150 psig and a circulating flow rate of 7.5 gpm x number of permeators to be sanitized. At all times do not allow DP across the membrane bundle to exceed 60 psi. If DP across the membrane bundle reaches 60 psi then decrease the feed water pressure.
- 13.4 After 6 hours of circulation, stop circulation, direct brine to waste and drain the mix tank.
- 13.5 Flush the system as per normal procedure using CFP water until foaming stops. Collect a sample of the brine in a jar and shake it to test for any remaining detergent. If foaming occurs, continue the flushing until all foaming stops. If no foaming occurs then the disinfection is complete.

14 Post-Treating Polyamide HFF Membranes

HFF polyamide membranes [Permasep B-9 (brackish membrane) and Permasep B-10 (seawater membrane)] need to be post treated with PT-A (polyvinyl methyl ether) and PT-B (tannic acid). PT-A increases the salt rejection by reducing the salt flow through the membrane or fiber imperfections. PT-B works differently than PT-A. It absorbs on the membrane surface and enhances the salt rejection. Chlorine and iron will react with PT-B and destroy its effect on salt rejection. Thus, all the water used to prepare the solution must be free from chlorine and iron. PT-B and PT-A also react between them and form precipitate. When both treatments are used, the membranes must be thoroughly flushed between treatments. Polyvinyl methyl ether (PVME) may purchase from BASF directly and is sold under the trade name "Lutanol 40" as a 50 wt percent aqueous solution. The tannic acid used for PT-B must be of good grade (see Appendix A-7). Before using PT-A or PT-B post treatments, membranes should be thoroughly cleaned.

14.1 PT-A Post-Treatment for Polyamide HFF Membranes (Off Line)

- 14.1.1 Flush the permeators with CFP water prior to post-treatment using a once-through flush (brine and product to drain) of 30 gallons per 8-inch permeator.
- 14.1.2 In the mixing tank, prepare a well mixed solution containing 80 mg/l BASF Polyvinyl Methyl Ether (PT-A) active ingredient plus 530 mg/l iodine free sodium chloride (NaCl) taking into account the volume of water in the piping, hoses and permeators. Assume 7.5 gallons of water per 8-inch permeator to be post treated. Use CFP water. Allow mixing for 5 minutes and measure the solution pH.

-
- 14.1.3 Ensure that the temperature is <95°F (35°C) during treatment. Start chiller to reduce cleaning tank temperature if necessary (Cloud point of PT-A equals 98.6°F (37°C). **Note:** At higher concentrations, the cloud point is lower; at 3 wt percent and above it is 86°F (30°C). Therefore, these solutions should be stored at temperatures lower than 86°F (30°C).
 - 14.1.4 Check out piping, valve positions, pump selection etc. Open the chemical tank valves (pump suction, brine return and product return valves). Allow few minutes priming by venting out air from all piping high points.
 - 14.1.5 With the chemical pump discharge valve partially closed, start the chemical pump. Adjust the flow to achieve a minimum brine flow of 6 gpm per permeator and pressure to 100-150 psig. Monitor DP at all times and ensure it stays within 60 psi (4.0 bars).
 - 14.1.6 Monitor the product conductivity every 15 minutes. Terminate the PT-A post-treatment when the product conductivity is constant for 30 minutes.
 - 14.1.7 At the end of PT-A treatment, divert the brine return and product return to the drain. Drain the chemical tank and clean with fresh water.
 - 14.1.8 Flush (once through flush, both brine and product going to waste) the residual PT-A solution from the permeators with CFP water by operating at brine rate of 13.5 gpm for 5 minutes.
 - 14.1.9 Repeat the flushing as per the normal procedure for 15 minutes. Feed water may be used for this flushing.
- 14.2 PT-B Post-Treatment for Polyamide HFF Membranes (Off Line)
- 14.2.1 Flush the permeators with CFP water prior to post treatment using a once-through flush (brine and product to drain) of 30 gallons per 8-inch permeator. Good flushing is very important to avoid PT-A reaction with PT-B that results in precipitate formation.
 - 14.2.2 In the mixing tank prepare a solution containing 1 wt percent citric acid plus 80 mg/l of PT-B (tannic acid) taking into account the volume of water in piping, hoses and permeators (assume 7.5 gallons per permeator to be post treated. Use CFP water. Since the PT-B is a solid which does not dissolve immediately, the PT-B may be added as a dilute aqueous stock solution containing 3 wt. percent of PT-B. The
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PT-B should be of good quality. Its suitability for membrane post-treatment can be determined as per Appendix A-7.

- 14.2.3 Ensure that the temperature is 77°F to 86°F (25°C to 30°C). Never should the temperature be over 90°F (32°C) during treatment. Start chiller if necessary.
- 14.2.4 Allow 5 minutes of mixing and check pH to ensure that it is 4.0. If pH is higher than 4.0, add more citric acid to obtain pH 4.0. Ensure that the pH is the same by checking the top and bottom solution of the tank.
- 14.2.5 Check out the piping, valve positions, pump selection etc. Open the chemical tank valves (pump suction, brine return and product return valves). Allow few minutes priming by venting out air from all piping high points.
- 14.2.6 With the chemical pump discharge valve partially closed, start the chemical pump. Adjust the flow to achieve a brine flow of 6 gpm per permeator and pressure to 100-150 psig. Monitor DP at all times and ensure it stays within 60 psi (4.0 bars).
- 14.2.7 After 15 minutes, start monitoring the product conductivity. Continue the treatment for the next 1 hour.
- 14.2.8 At the end of PT-B treatment, divert the brine return and product return to the drain. Drain the chemical tank and clean with fresh water.
- 14.2.9 Flush (once through flush, both brine and product going to waste) the residual PT-B solution from the permeators with CFP water by operating at brine rate of 13.5 gpm for 5 minutes.
- 14.2.10 Repeat the flushing as per the normal procedure for 15 minutes. Feed water may be used for this flushing.
- 14.2.11 Start up the RO unit and monitor data for normalization and evaluation of cleaning effectiveness.

15 Storing Polyamide HFF Membranes

15.1 Storing new HFF permeators

As shipped, HFF permeators contain a standard aqueous solution of approximately 18 wt percent glycerine and 0.5 wt percent sodium metabisulfite plus 200 to 350 mg/l as Mg^{++} $MgCl_2$ to provide protection against freeze damage and to maintain biostatic conditions. To avoid flux loss membranes should be stored at temperatures not exceeding 95°F (35°C) and not to be stored

under direct sunlight. Permeators stored as per 11.1 will retain their salt passage performance for a period of at least two years. If storage for more than 2 years is required then the pH of the solution should be checked periodically to ensure that it has not dropped to a level below 4.0. If the pH of the preservative solutions approaches 4.0 then the preservative solutions should be replaced.

15.2 Storing used HFF permeators (preparing and adding storage solution)

- 15.2.1 Prepare 0.5 wt. percent sodium metabisulfite and 18 wt percent glycerine in the mixing tank using CFP water. Use a hydrometer to check the glycerine content. The specific gravity should be 1.045 to 1.050 for the temperature range of 15°C to 25°C. Adjust the specific gravity by adding glycerine or water.
- 15.2.2 Thoroughly mix the solution. Recirculate the solution in the feed direction through the permeators at a pressure of 100 to 200 psig and brine flow of 6 gpm for 8-inch single bundle permeators and 12 gpm for 8-inch twin bundle permeators. Product and brine should be recycled back to the mix tank. There will be very low permeate flow due to high osmotic pressure.
- 15.2.3 Continue the circulation for 1.5 hours. After the first half hour check the specific gravity of glycerine and add more glycerine if required. At the end of 1.5 hours, stop the circulation, reduce the pressure to zero, and disconnect the permeators.
- 15.2.4 Drain the permeators from excess solution. Seal all ports promptly to prevent additional loss of solution. The permeators are now ready for storage.

16 Cleaning Toyobo HFF Cellulose Triacetate Membranes

Commentary Note:

Toyobo HFF Cellulose Triacetate Membranes are used at Tanajib Seawater Desalination Plant. The Toyobo types of membranes used are HB9155 for seawater and HB9130 for brackish. Only acid cleaning can be applied to both these membranes, since under alkaline conditions they hydrolyze. The membrane cleaning guideline at Tanajib RO plant is when one of the following two criteria is reached:

- a) When the differential pressure of the RO module reaches 54 psi*
- b) When the operating time of the RO module without cleaning reaches 4400 hours.*

16.1 Preparation for Membranes Cleaning

As per section 12, paragraphs 12.1.1 to 12.1.7.

16.2 Ammoniated Citric Acid (pH 4.0) Cleaning for Toyobo Cellulose Triacetate Membranes.

- 16.2.1 Flush the membranes (once through flush, permeate and reject going to waste) with CFP water for one hour.
- 16.2.2 Fill the cleaning tank as per 9.3.2.
- 16.2.3 Start the stirrer and gradually add citric acid to prepare a 2 wt percent solution. Add 7.6 Kg of citric acid per 100 gallons of water.
- 16.2.4 Allow mixing for 10 minutes and measure the solution pH from top and bottom of the cleaning tank. Adjust the pH of citric acid solution to 3.9-4.1, using small quantities of ammonium hydroxide (NH₄OH) if required.
- 16.2.5 Measure the total iron in the citric acid solution. Ensure that the temperature of the solution is <104°F (40°C).
- 16.2.6 Check out the piping, valve positions, pump selection etc. Open the chemical tank valves (pump suction, brine return and product return valves). Allow few minutes priming by venting out air from all piping high points.
- 16.2.7 With the chemical pump discharge valve partially closed, start the chemical pump. Adjust the flow to 7.5-10.0 gpm x number of 8-inch single element/permeator (minimum brine flow 6 gallons per 8 inch membrane) and pressure of 90-125 psig. Send the first 20% solution to the drain. Monitor DP and ensure it stays below 60 psi (4.0 bars) at all times.
- 16.2.8 After 15 minutes, measure the iron and calcium in the brine return. Monitor DP across the RO module/permeator. Check the citric acid solution pH to ensure it is 3.9-4.1.
- 16.2.9 Continue the treatment for the next 2-3 hours. Monitor iron levels, calcium levels, pH and DP drop. Check the visual appearance of the solution.

Commentary Note:

As iron is removed from the membrane surfaces, it turns green and if excessive quantities are removed, solution turns brownish.

- 16.2.10 If the color is brownish and iron concentration in the solution is > 10 ppm, dump the solution and remake another batch.

16.2.11 When iron levels in three consecutive samples taken 15 minutes apart are the same (within 10% difference) stop cleaning. Divert the brine return and product return to drain. Drain the chemical tank.

16.2.12 Flush per the normal procedure using CFP water.

17 Storing Toyobo HFF Cellulose Triacetate Membranes

17.1 Storing new HFF Cellulose Triacetate Membranes

Shipped RO elements are filled with preservative solutions. Store these elements prior to their installation satisfying the following conditions:

- a) Store in well ventilated area.
- b) Store away from direct sunlight.
- c) Store at a temperature of less than 104°F (40°C). This temperature specification should be adhered to for inland transportation, before installation, at start up, standby and storage.
- d) Avoid impact or severe vibration.
- e) Do not store for more than 2 years.
- f) Store RO elements horizontally.
- g) Do not stack more than 4 stories for the elements in the packing style delivered.
- h) After element unpacking the element should be immediately installed and put into service.

17.2 Storing used HFF Cellulose Triacetate Membranes

The preservative method for standby of the RO modules should be observed according to the period of shutdown of the RO system as indicated in Table 4.

Table 4 - Guidelines for Preservation of Used HFF Cellulose Triacetate Membranes

Shut-down Period	Preservative Procedure
Less than 3 days	1) Operate with chlorinated feed water for more than 0.5 hour 2) Flush with permeate or feed water 3) Seal the RO system
Less than 1 month	1) Operate with chlorinated feed water for more than 0.5 hour 2) Flush with permeate or feed water 3) Fill with preservative solution (*) 4) Seal the RO system
More than 1 month	1) Operate with chlorinated feed water for more than 0.5 hour 2) Flush with permeate or feed water 3) Perform chemical cleaning 4) Flush with permeate or feed water 5) Fill with preservative solution (*) 6) Seal the RO system

(*) Preservative solution is 0.25% sodium bisulfite. Formaldehyde of 0.5% can also be used but it is not recommended because it is carcinogenic.

Revision Summary

31 July, 2004

New Saudi Aramco Engineering Procedure.

Appendix

A-1: Cleaning Equipment

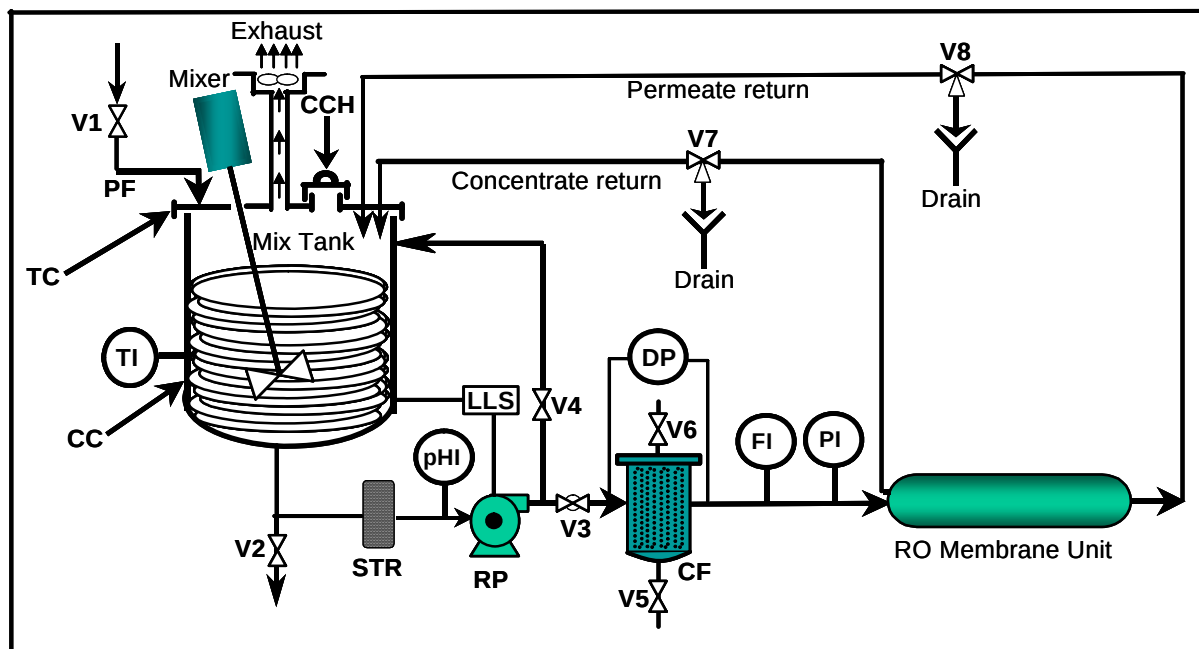


Figure 1 - RO Cleaning, Disinfecting, Post-Treatment and Flushing Flow Diagram

LEGEND

Mixing tank:	Chemical tank, polypropylene or fiber reinforced plastic (FRP)
CCH	Chemical charging hatch
TC	Tank cover
PF	Permeate fill
TI	Temperature indicator
CC	Cooling coil
STR	Strainer
pHI	pH indicator
RP	Recirculation pump, 316 stainless steel (SS) or non-metallic composite
LLS	Low level switch to shut off pump
DP	Differential pressure gauge
CF	Cartridge filter, 5-10 micron polypropylene with PVC, FRP or SS housing
FI	Flow indicator
PI	Pressure indicator
V1	Permeate inlet valve, CPVC
V2	Tank drain valve, PVC or CPVC
V3	Flow control valve

V4	Pump circulation valve
V5	Cartridge filter drain valve, PVC or CPVC
V6	Purge valve, SS, PVC or CPVC
V7	Concentrate return valve, CPVC 3 way valve
V8	Permeate valve, CPVC 3 way valve

A-2: General Guidelines for Choosing Optimum Cleaning Chemical

Foulant	General Symptoms	Response
Calcium precipitates (carbonates/phosphates found at the tail end of the system)	A marked decrease in salt rejection, moderate increase in DP, slight decrease in permeate flow.	Chemically clean the RO system with Solution 1.(+)
Hydrated Oxides (iron, nickel, copper etc.)	A rapid decrease in salt rejection and a rapid increase in DP. Also a rapid decrease in permeate flow.	Chemically clean the RO system with Solution 1.(+)
Organic Deposits	Possible decrease in salt rejection and gradual increase in DP. Also, a gradual decrease in permeate flow.	Chemically clean the RO system with Solution 2.(+)
Bacterial Fouling	Possible decrease in salt rejection and marked increase in DP. Also, a marked decrease in permeate flow.	Chemically clean the RO system with Solution 2.(+)

(+) For solution descriptions see Appendix A.5

A-3: Operating Parameters and Measurements Log Sheet

Operating Time	pH	Temp.	Feed Pressure	Feed Flow	Permeate Flow	Feed Conductivity	Permeate Conductivity

A-4: Clean In Place (CIP) Log Sheet

RO module:.....

RO stage:.....

Date:.....

Operator:.....

Item #	Process Data	Commissioning Data	Pre-CIP	Post-CIP
1	Feed temperature			
2	Feed pressure (psi)			
3	Reject pressure (psi)			
4	DP pressure (psi)			
5	Permeate pressure (psi)			
6	Pressure—intermediate (psi)			
7	Flow-permeate (gpm)			
8	Flow concentrate (gpm)			
9	Conductivity-Feed (µs/cm)			
10	Conductivity-permeate (µs/cm)			
11	Conductivity Conc. (µs/cm)			

Key:

- 1) Pressure gauge directly downstream of Feed Control valve
- 2) Pressure gauge directly upstream of Concentrate Control Valve
- 3) Pressure gauge difference between 1 and 2
- 4) Pressure gauge in permeate piping
- 5) Pressure gauge between stage 1 and stage 2
- 6) Flow meter reading in permeate piping
- 7) Flow meter reading in concentrate piping
- 8) Measurement with hand held conductivity meter from feed sample valve
- 9) Measurement from on line or hand held conductivity meter from permeate
- 10) Measurement with hand held conductivity meter from concentrate sample valve

Item #	Chemical Data	Units
1	Cleaner name	N/A
2	Amount of cleaner used (neat)	Kg
3	Tank dilution volume	liters/gallons
4	pH of solution	pH units
5	Recirculation begins	time
6	Recirculation flow	gpm
7	Recirculation ends	time
8	Appearance	N/A
9	Flush begins	time
10	Flush flow rate	gpm
11	Flush ends	time
12	Recirculation pressure	psi

A-5: Description of Cleaning Solutions for SW Polyamide Membranes

Solution 1: This is a low pH cleaning solution (target pH 4.0) of 2.0% wt citric acid ($C_6H_8O_7$). It is useful in removing inorganic scales, e.g., calcium carbonate, and metal oxides/hydroxides (e.g., iron, manganese, nickel, copper, zinc), and inorganic-based colloidal materials.

Commentary Note:

*Citric acid has chelating properties that function better when the upward pH adjustment is done **using** ammonium hydroxide and **not** sodium hydroxide.*

Solution 2: This is a high pH cleaning solution (target pH of 10.0) of 2.0% wt of STPP (sodium tripolyphosphate) ($Na_5P_3O_{10}$) and 0.8% wt of Na-EDTA (sodium salt of ethylenediaminetetraacetic acid). STPP functions as an inorganic-based chelating agent and detergent, and it is effective in removing calcium sulfate scale and light to moderate levels of organic foulants. Na-EDTA is an organic based chelating agent that aids in the removal of divalent and trivalent metal ions.

Solution 3: This is a high pH cleaning solution (target pH of 10.0) of 2.0% wt of STPP (sodium tripolyphosphate) ($Na_5P_3O_{10}$) and 0.255 wt Na-DDBS ($C_6H_5(CH_2)_{12}-SO_3Na$) (sodium salt of dodecylbenzene sulfonate). It is recommended for the removal of heavier levels of organic foulants. STPP functions as an inorganic-based chelating agent and detergent. Na-DDBS functions as an anionic detergent.

Solution 4: This is a low pH cleaning solution (target pH of 2.5) of 0.5% wt of HCl (hydrochloric acid). It removes scales, metal oxides and foulants as per solution 1. However, this cleaning solution is considered to be harsher than solution 1. It is recommended to be used only in extreme cases of scaled and fouled membranes.

Solution 5: This is a high pH cleaning solution (target pH of 11.5) of 1.0% wt of $Na_2S_2O_4$ (sodium hydrosulfite). It removes metal oxides and hydroxides, and to a lesser extent calcium sulfate, barium sulfate and strontium sulfate.

Solution 6: This is a high pH cleaning solution (target pH of 11.5) of 0.1% wt of NaOH (sodium hydroxide) and 0.03% wt of SDS (sodium dodecylsulfate). It removes organic foulants, organic and inorganic colloidal foulants and biological material (fungi, mold, slimes and biofilm). SDS is an anionic surfactant and will cause foaming. This

cleaning is considered a harsh cleaning regiment for the membranes and it should only be used in extreme cases.

Solution 7: This is a high pH cleaning solution (target pH of 11.5) of 0.1% wt of NaOH (sodium hydroxide). It removes polymerized silica. This cleaning is considered a harsh cleaning regiment for the membranes and it should only be used in extreme cases.

A-6: Approved RO Chemical Cleaners

Cleaner	Supplier	Membrane Manufacturer	Type of Membrane	SA Stock # or Direct Charge
Solutions 1, 2, 3, 4, 5, 6, and 7.	Multisource	Hydranautics Osmonics	Spiral Wound	Direct Charge
Bioclean 103	GE Betz	Osmonics	SW Desal	Direct Charge
Bioclean 511	GE Betz	Osmonics	SW Desal	Direct Charge
PermaClean 67 PermaClean 55 PermaClean 11 Permaclean 77	Nalco	DuPont, Hydranautics	HFF DuPont & SW Hydranautics	Direct Charge
Alconox	Alconox Inc. USA	DuPont	HFF Dupont	Direct Charge
Alcojet	Alconox Inc. USA	DuPont	HFF Dupont	Direct Charge
Drewperse 738	Drew Chemical, USA	DuPont	HFF Dupont	Direct Charge
Dobanol 91/6	United Kingdom	DuPont	HFF Dupont	Direct Charge
Tergitol 15/5/7	Union Carbide Co, USA	DuPont	HFF Dupont	Direct Charge
Biox	Unibound, USA	DuPont	HFF Dupont	Direct Charge
Microdetergent	International Product Group, USA	DuPont	HFF Dupont	Direct Charge
DMCA-14A	Al-Kawther, Saudi Arabia	DuPont	HFF Dupont	Direct Charge
P3 Utrasil 53	Henkel Germany	DuPont	HFF Dupont	Direct Charge
P3 Utrasil 30 (pH11)	Henkel Germany	DuPont	HFF Dupont	Direct Charge
MT 1000 MT 2000 MT 3000 MT 5000	B.F. Goodrich, USA	DuPont	HFF Dupont	Direct Charge
Floclean 103 Floclean 107 Floaclean 403 Floaclean 411	FMC, USA	DuPont	HFF Dupont	Direct Charge
Elgalite RF 11	Elga Corp. UK	DuPont	HFF Dupont	Direct Charge
Kemazur 2166	Degremond, France	DuPont	HFF Dupont	Direct Charge
Kemazur 2160	Degremond, France	DuPont	HFF Dupont	Direct Charge
Kemazur Cleaner	Degremond, France	DuPont	HFF Dupont	Direct Charge
Citric acid	Saudi Aramco Stores	DuPont, Osmonics, Hydranautics	HFF DuPont SW Desal & Hydranautics	1000177936
PT-A	Saudi Aramco Stores	DuPont	HFF Dupont	1000185320
PT-B	Saudi Aramco Stores	DuPont	HFF Dupont	1000187061
Ammonium Hydroxide	Saudi Aramco Stores	DuPont, Osmonics, Hydranautics	HFF DuPont SW Desal & Hydranautics	1000178427
Sodium Hypochlorite	Saudi Aramco Stores	DuPont	HFF Dupont	1000179158

A-7: Tannic Acid (PT-B) Quality Testing

a) Specification for Tannic Acid

The suitability of tannic acid for membrane post-treatment can be determined by titration with caustic (NaOH). If the % of the first acid (end point at a pH of approximately 5) is ≤ 6.0 of the total acid titrated, the tannic acid is of acceptable quality and can be used to PT-B the Permasep membranes.

Example: First acid = 0.11 m Eq/g of tannic acid

Total acid = 5.25 m Eq/g of tannic acid

$0.11/5.25 \times 100 = 2.1\%$ Therefore, Quality is acceptable

b) Procedure for Titration of Tannic Acid

1. Weigh 1 g (to nearest 0.0001 g) sample of tannic acid into a 250 ml beaker
2. Add 100 ml water and a magnetic stirring bar
3. Stir the solution
4. Titrate with 1.0 n sodium hydroxide using a combination glass electrode (Metrohm EA-120) and an automatic titrator (such as Metrom E-436).
5. Calculation:

Neutral Equivalent (m Eq/g) = Volume x Normality/Sample wt

Commentary Note:

When two end points are observed, they occur at pH 5 and 10, when only one end point is observed, it occurs at pH 10.