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I. INTRODUCTION

The separation of dissolved solids and water using RO membranes is a pressure driven temperature dependent process. The membrane material is designed to be as permeable to water as possible while maintaining the ability to reject dissolved solids.

The main system design parameters require the following:

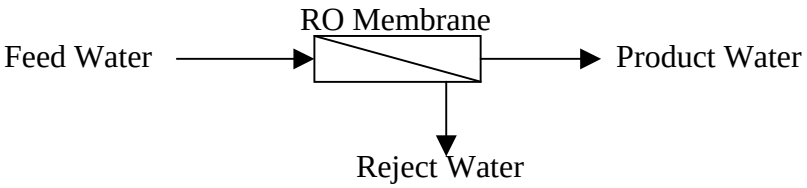
- Internal flows across the membrane surface must be high enough to prevent settling of fine suspended solids on the membrane surface.
- The concentration of each dissolved ionic species must not exceed the limits of solubility anywhere in the system.
- Pre-treatment must be sufficient to eliminate chemicals that would attack the membrane materials.

A. SPECIFICATIONS

	R14-02	R14-03	R14-04	R14-05	R14-06
Productivity (Gallons per day / Gallons per minute) Maximum production based on standard membranes and feed water of 25°C, SDI < 3, 1000 ppm TDS, and pH 8. Individual membrane productivity may vary (± 15%).	3600 / 2.5	5400 / 3.75	7200 / 5.0	9000 / 6.25	10800 / 7.5
Quality (Typical Membrane Percent Rejection) Based on membrane manufactures specifications, overall system percent rejection may be less.	98 %	98 %	98 %	98 %	98 %
Recovery without reject recycle	29 %	39 %	50 %	57 %	62 %
Recovery with reject recycle (adjustable)	50 %	50 %	75 %	75 %	75 %
Membrane Size	4 x 40	4 x 40	4 x 40	4 x 40	4 x 40
Number Of Membranes Per Vessel	1	1	1	1	1
Pressure Vessel Array	1:1	1:1:1	1:1:1:1	1:1:1:1:1	1:1:1:1:1:1
Number Of Membranes	2	3	4	5	6
Prefilter (System ships with one 5 micron cartridge)	20" BB	20" BB	20" BB	20" BB	20" BB
Feed Water Connection	1" NPT	1" NPT	1" NPT	1" NPT	1" NPT
Product Water Connection	3/4" NPT	3/4" NPT	3/4" NPT	3/4" NPT	3/4" NPT
Reject Water Connection	3/4" NPT	3/4" NPT	3/4" NPT	3/4" NPT	3/4" NPT
Feed Water Required Feed water required will be less if reject recycle is used.	9 gpm	10 gpm	10 gpm	12 gpm	13 gpm
Feed Water Pressure (Minimum)	20 psi	20 psi	20 psi	20 psi	20 psi
Drain Required	9 gpm	10 gpm	10 gpm	12 gpm	12 gpm
Electrical Requirement 230 VAC, 3-ph, 60 Hz (Other voltages available)	15 amps	15 amps	15 amps	15 amps	15 amps
Multistage Centrifugal Pump	15 stages	15 stages	15 stages	18 stages	18 stages
TEFC Motor (Horse Power)	5	5	5	5	5
Dimensions L x W x H (Inches)	60 x 18 x 56	60 x 18 x 56	60 x 18 x 56	60 x 18 x 56	60 x 18 x 56
Shipping Weight (Estimated Pounds)	400	500	600	700	800

B. RO OVERVIEW

Reverse osmosis systems utilize semipermeable membrane elements to separate the feed water into two streams. The pressurized feed water is separated into purified (product) water and concentrate (reject) water. The impurities contained in the feed water are carried to drain by the reject water.



C. PRETREATMENT

The RO feed water must be pretreated in order to prevent membrane damage and/or fouling. Proper pretreatment is essential for reliable operation of any RO system.

Pretreatment requirements vary depending on the nature of the feed water. Pretreatment equipment is sold seperatly. The most common forms of pretreatment are described below.

Media Filter - Used to remove large suspended solids (sediment) from the feed water. Backwashing the media removes the trapped particles. Backwash can be initiated by time or differential pressure.

Water Softener - Used to remove calcium and magnesium from the feed water in order to prevent hardness scaling. The potential for hardness scaling is predicted by the Langelier Saturation Index (LSI). The LSI should be zero or negative throughout the unit unless approved anti-scalents are used. Softening is the preferred method of controlling hardness scale.

Carbon Filter - Used to remove chlorine and organics from the feed water. Free chlorine will cause rapid irreversible damage to the membranes.

The residual free chlorine present in most municipal water supplies will damage the thin film composite structure of the membranes used in this unit. Carbon filtration or sodium bisulfite injection should be used to completely remove the free chlorine residual.

Chemical Injection - Typically used to feed antiscalant, coagulant, or bisulfite into the feed water or to adjust the feed water pH.

Prefilter Cartridge - Used to remove smaller suspended solids and trap any particles that may be generated by the other pretreatment. The cartridge(s) should be replaced when the pressure drop across the housing increases 5 - 10 psig over the clean cartridge pressure drop. The effect of suspended solids is measured by the silt density index (SDI) test. An SDI of five (5) or less is specified by most membrane manufacturers and three (3) or less is

recommended.

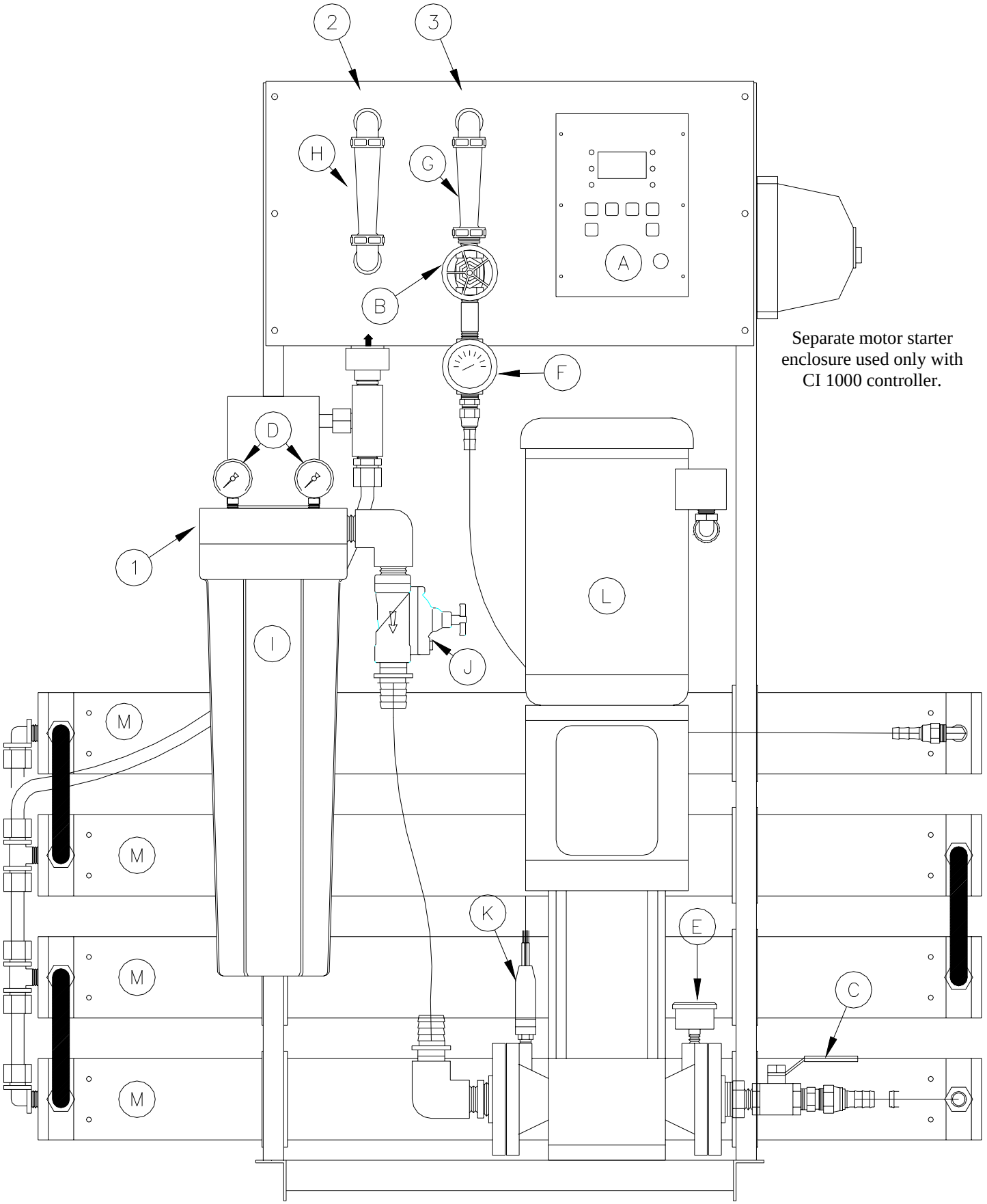
Iron & Manganese - These foulants should be removed to less than 0.1 ppm. Special media filters and/or chemical treatment is commonly used.

pH - The pH is often lowered to reduce the scaling potential.

Silica: Reported on the analysis as SiO2. Silica forms a coating on membrane surfaces when the concentration exceeds its solubility. Additionally, the solubility is highly pH and temperature dependent. Silica fouling can be prevented with chemical injection and/or reducing the recovery.

II. CONTROLS, INDICATORS, and COMPONENTS (see figure 1)

A. Controller - Controls the operation of the system and displays the product water quality. There are three controllers available. Controller # 1 has an on/off switch and an input for tank level. Controller # 2 has an on/off switch, tank level input, low pump suction pressure shutdown, and a product water TDS meter. Controller # 3 is the CI1000 (shown).
B. Reject Control Valve - Controls the amount of reject flow. *If the reject recycle option is included, two reject control valves will be present.*
C. Pump Discharge Valve - Used to throttle the pump.
D. Prefilter Pressure Gauges - Indicates the inlet and outlet pressure of the prefilter. The difference between these two gauges is the prefilter differential pressure.
E. Pump Discharge Pressure Gauge - Indicates the pump discharge pressure.
F. Reject Pressure Gauge - Indicates the reject pressure.
G. Reject Flow Meter - Indicates the reject flow rate in gallons per minute (gpm). *If the reject recycle option is included, two reject flow meters will be present.*
H. Product Flow Meter - Indicates the product flow rate in gallons per minute (gpm).
I. Prefilter Housing - Contains the RO prefilter.
J. Automatic Inlet Valve - Opens when pump is on and closes when the pump is off.
K. Low Pressure Switch - Sends a signal to the controller if the pump suction pressure is low. *Included only with controller option # 1 & 2.*
L. RO Feed Pump - Pressurizes the RO feed water.
M. RO Membrane Vessels - Contains the RO membranes.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Separate motor starter enclosure used only with CI 1000 controller.

Figure 1

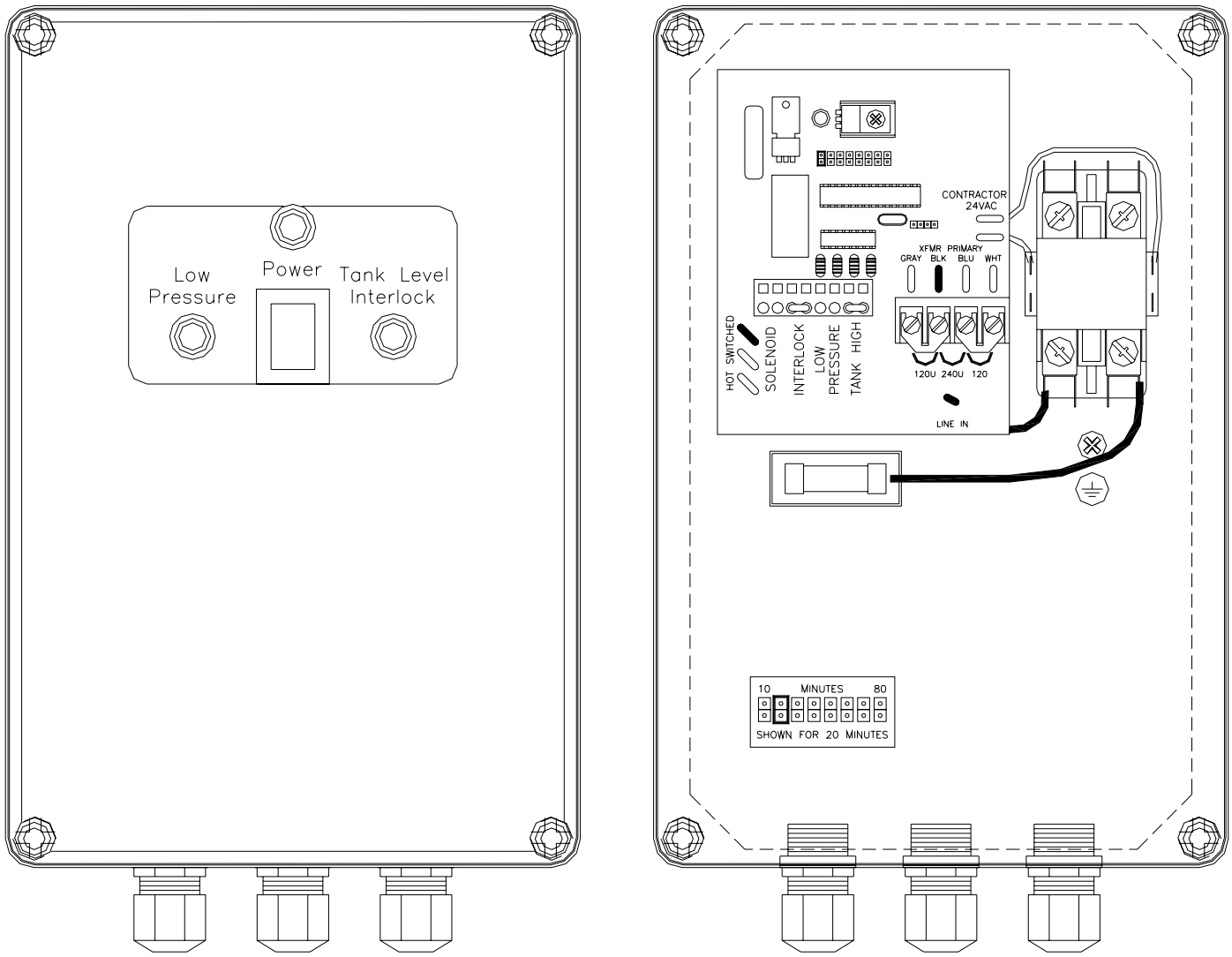
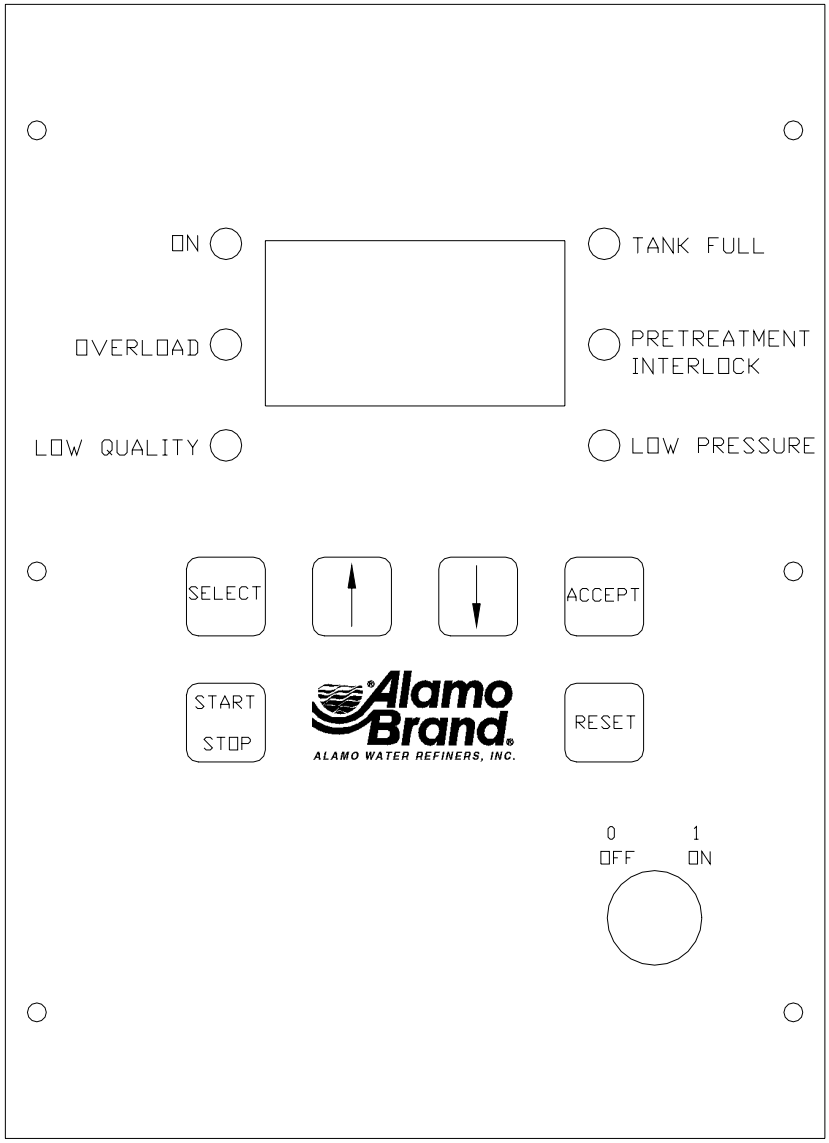


Figure 2
Controller Package One



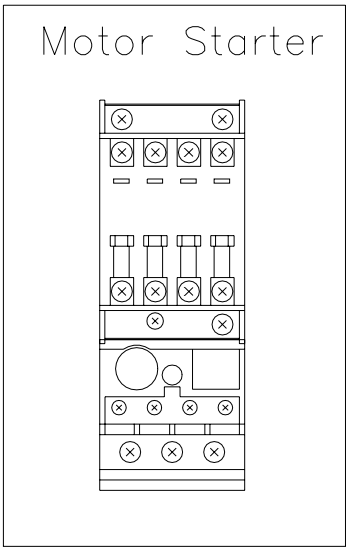


Figure 3
Controller Package Two

III. OPERATION

A. INSTALLATION

1. The water supply should be sufficient to provide a minimum of 20 psig pressure at the design feed flow.
2. Proper pretreatment must be determined and installed prior to the RO system.
3. A fused high voltage disconnect switch located within 10 feet of the unit is recommended. This disconnect is not provided with the RO system.
4. Responsibility for meeting local electrical and plumbing codes lies with the owner / operator.
5. Install indoors in an area protected from freezing. Space allowances for the removal of the membranes from the pressure vessels should be provided. *This system requires 42" minimum clear space on each side.*

B. PLUMBING CONNECTIONS

Note: It is the responsibility of the end user to ensure that the installation is done according to local codes and regulations.

1. Connect the pretreated feed water line to the inlet side of the prefilter housing. (Figure # 1 item # 1) A feed water shutoff valve should be located within 10 feet of the system.
2. Temporarily connect the outlet of the product water flow meter to drain. (Figure # 1 item # 2) The product water line should never be restricted. Membrane and/or system damage may occur if the product line is blocked.
3. Connect the outlet of the reject water flow meter to a drain. (Figure # 1 item # 3) The reject drain line should never be restricted. Membrane and/or system damage may occur if the reject drain line is blocked. An air gap must be located between the end of the drain line and the drain. The use of a standpipe or other open drain satisfies most state and local codes and allows for visual inspection and sampling.

C. ELECTRICAL

Note: It is the responsibility of the end user to ensure that the installation is done according to local codes and regulations.

1. A safety switch or fused disconnect should be installed within 10 feet of the system.
2. Verify that the disconnect switch is de-energized using a voltmeter.
3. Connect the outlet of the disconnect switch to the terminals on the motor starter (Figure # 2, or 3). Attach the power supply ground to the chassis ground. It will be necessary to drill a hole in the enclosure and install a water tight strain relief or conduit connector. The hole size and location must be determined by the installer. Check the pump motor nameplate for the amperage draw at various voltages to determine the wire size required.

4. Do not apply power to the RO unit at this time.

D. STARTUP

1. Verify that the pretreatment equipment is installed and working properly. Verify that no free chlorine is present in the feed water.
2. Verify that the on/off switch is in the off position.
3. Verify that the pump discharge valve (Figure # 1 item C) is open.
4. Install a 20" five micron filter cartridge in the prefilter housing. (Figure #1 item I)
5. Open the reject control valve completely (Figure # 1 item B) by turning it counterclockwise. Close the reject recycle control valve completely if the reject recycle option is included.
6. Open the feed water shutoff valve installed in step III-B-1 above.
7. Manually open the inlet solenoid valve (figure #1 item J) by turning the white lever located near the valve outlet.
8. Water will flow through the system and to drain through the reject flow meter (figure # 1 item G).
9. Manually close the inlet solenoid valve after the air has been purged from the system, or after 10 minutes, whichever occurs first.
10. Close the pump discharge valve half way. (Figure # 1 item C)
11. Engage the safety switch or disconnect (installed in step III-C-1 above) to apply electrical power to the RO system.
12. Move the controller on/off switch to the on position. Move the switch back to the off position after the pump starts and look at the motor fan as the pump stops to determine if the pump rotation is correct. *If the CI 1000 Controller is included (controller option # 3), put the key switch in the on position and press the start / stop button to turn the pump on and off. There is a 10 second delay before the pump starts. See the controller section for more details.* The fan should rotate in a counterclockwise direction when viewed from the top. Continue with the startup if the pump is rotating in the proper direction. If the pump is rotating backwards, change the rotation by disconnecting the power and reversing any two of the wires on the power inlet. (Figure #2 item #1) Verify proper pump rotation before continuing.
13. Turn the system on.
14. Adjust the reject control valve(s) (figure # 1 item B) and the pump discharge valve (Figure # 1 item C) until the desired flows are achieved. Closing the reject valve increases the product flow and decreases the reject flow. Opening the pump discharge valve increases both the reject flow and the product flow. See the flow rate guidelines and temperature correction table in the appendix to determine the flow rates for different operating temperatures.
15. Allow the product water to flow to drain for 30 minutes.
16. Turn off the system and connect the product line to the point of use. (Figure # 1 item # 2) The product water line should never be restricted. Membrane and/or system damage may occur if the product line is blocked.
17. Restart the system and record the initial operating data using the log sheet in the next section.

Note: See the controller section of this manual for more installation and operation information

E. Controllers

Two controller options are available.

Controller option # 1 is a basic controller with an on / off switch, low pressure, tank level, and pretreatment interlock (see figure # 2).

Automatic low pressure reset

If the unit shuts down due to low pressure, a red light on the front of the controller will illuminate. The controller will automatically restart the unit after a user selected time delay. The user selects the delay time by positioning a jumper cap inside the controller (see attached drawing).

Tank Level / Pretreatment Indicator

If the unit shuts down due to a high product tank level or pretreatment interlock, an amber lamp will illuminate. The lamp will turn off and the unit will restart when the condition clears. The same lamp is used for both tank level and pretreatment interlock.

Controller operation

1. When the power switch is turned on, the pump will run as long as the circuit between the tank level terminals and the interlock terminals are closed, and the low pressure switch contacts are open.
2. To install a tank level switch, remove the jumper wire from the terminal strip and connect the level switch to the terminals. The RO pump and inlet valve will turn on when the level switch contacts are closed (tank not full), and turn off if the level switch contacts open (tank full).
3. To install a pretreatment interlock, remove the jumper wire from the terminal strip and connect the normally closed pretreatment switch contacts to the terminals. The RO pump and inlet valve will turn on when the switch contacts are closed, and turn off if the switch contacts open.
4. If the low-pressure contacts close continuously for five (5) seconds, the RO pump and inlet valve will turn off and the low pressure light will illuminate. The controller will automatically restart the unit after the user selected time delay. Turning the controller off then back on will manually reset a low pressure shutdown.

5. Note: Use the plastic lever to push the terminal strip contacts open. Insert the bare end of the wire into the terminal and release the lever. The lever can be moved from one terminal to another as needed. One lever is included with each controller.

Controller option # 2 is the CI 1000. This is a microprocessor based controller with a product water conductivity meter. A separate manual for this controller begins on the next page.

The autoflush option is available with both controllers. On controllers # 1, the flush valve is preset to open for 2 minutes every time the pump starts and 2 minutes every hour. On controller #2, the flush times are user programmable. (See the following CI1000 information.)

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I. INTRODUCTION

The 3501 Reverse Osmosis Controller is designed to control and monitor the operating parameters of a reverse osmosis water purification system. Information is displayed on a back-lit liquid crystal display, and on individual light-emitting diodes (LEDs). Functions and controls are operated through snap-dome switches (see Figure 1).

A. Features

Temperature Compensated Conductivity Monitor

Water Temperature Monitor

Three Modes of Operation: Stand-by, Tank Feed, and Direct Feed

Pretreatment Interlock

Tank Full Shutdown

Inlet Valve Control

Pump Control

Low Feed Pressure Sensing with Automatic Reset

Autoflush with Adjustable Flush Time

Diverter Valve Output

B. Specifications

Power Requirements: The controller can operate with a power source of 115 or 230 VAC single phase. A multi-function power inlet is used to select the proper input voltage.

Fuse: 1 amp 250 volt slow blow, located inside the power inlet receptacle.

Environment: The controller can operate at a temperature from 0° to 60° C (32° to 140° F). Relative humidity must not exceed 95 percent.

Conductivity Monitor: The conductivity monitor measures the product water quality and displays this information in micro-mhos/cm. The display is temperature compensated to 25° C (770 F).

C. Outputs

Inlet Solenoid: A 24 VAC output is provided to power the inlet solenoid. This output always energizes 12 seconds before the pump turns on, and de-energizes 12 seconds after the pump turns off.

Flush Valve: A 24 VAC output is provided to power the optional reject solenoid valve. This output will energize during the flush cycle. This is an optional accessory.

Motor Starter: A 24 VAC output is included to provide controlled pump operation. This output powers the coil of the magnetic starter relay. This output is energized depending on other operating parameters.

Diverter Valve: A 24 VAC output energizes when the product water quality is below the setpoint. The valve is not included with the system. This output is intended to power a relay or some other low current device. The maximum current available is one ampere.

D. Inputs

WARNING: All the inputs described below are dry contacts. Do not apply voltage to these contacts or permanent damage to the controller will result.

Conductivity Probe: There are four inputs for the conductivity probe, two for the thermistor and two for the conductivity. Only probes with a cell constant of 1.0 and a thermistor with a nominal resistance value of 20K at 25' C will work with this controller.

Low Pressure Switch: This is a dry contact that signals the system to shut down if the pump suction pressure falls below the desired value. This is a normally open contact. When a circuit is not complete between the two terminals, the system will operate. If contact is made between the two terminals, the system will shut down. The LCD display and a LED will indicate when the system is shut down due to low pressure. The controller can be programmed to automatically restart. This is described in Section III, Operation.

Tank Level: This is a dry contact that signals the system to shut down when the storage tank is full. This contact is normally closed. When a circuit is complete between the two terminals the system will operate. If contact is broken between the two terminals, the system will shut down if it is operating in the tank feed mode. A LED will indicate when the tank is full. The system will restart itself when the contact is closed. The switch for this function in not provided with the controller.

Pretreatment Interlock: This is a dry contact that signals the system to shut down when a pretreatment device is not functioning, or regenerating. This could be used on a water softener, multi media filter, chemical feed pump, differential pressure switch, etc. This contact is normally open. When a circuit is not complete between the two terminals the system will operate. If the contact is closed the system will shut down. A LED will indicate when the system is shut down due to pretreatment interlock. The system will restart itself when the contact is opened.

E. Mode Descriptions

The stand-by mode is intended to place the system in a temporary non-operational mode. When the system is placed in this mode it will operate for the amount of time set for the flush cycle. If the flush time is set for zero the system will operate for one minute. After this cycle is complete the pump will turn off and the inlet valve will close. The system will repeat this cycle once every hour. When the system is flushing, the amount of time remaining in the flush cycle will be indicated on the last line of the display. When the system is idle, the amount of time remaining until the next flush will be indicated. When the pump is running, the reject valve and diverter valve outputs are energized.

The tank feed mode is intended to be used when the system is feeding a storage tank. When in this mode the system will shut down when the tank level switch (not provided) has an open contact. The flush cycle is also enabled in this mode. If the autoflush option has been included on the system, the controller will activate the flush cycle when the system is turned on and once every hour. When the system is flushing, the amount of time remaining in the flush cycle will be indicated on the last line of the display. When the system is not flushing the amount of time until the next flush will be indicated. The system will still flush every hour even if the tank is full. During a full tank condition the system is essentially in standby. When the system is flushing, the diverter valve output is energized. If *the flush time is set for zero the system will not flush when the tank is full.*

The direct feed mode is intended to be used when the system is feeding a distribution loop or another piece of equipment. In this mode the system will not flush and the tank level switch is disregarded. When the system is in this mode, the total number of hours the system has been operated will be indicated on the last line of the display.

F. Controls (see figure 1)

NOTE: Refer to Section III, Operation for detailed instructions on operating the controls .

Start / Stop Button: This button turns the system on and off.

Select Button: This button is used to select a function or parameter so that it can be reviewed or changed.

Up Arrow. This button increases the value of, or advances to the next option of, the function selected.

Down Arrow. This button decreases the value of, or advances to the next option of, the function selected.

Accept Button: Pressing this button causes the controller to store current values or options in memory.

Alarm Reset Button: This button is used to reset the system after a shut down due to; low pressure or overload.

Key Switch: This switch which serves as a master power switch. When the system is turned on the key may not be removed. If the system is turned off the key may be removed.

G. Indicators (see Figure 1)

Multi Function Display: This is a back-lit liquid crystal display. It provides information to the operator regarding water quality, system options, etc.

There are six individual LED's to indicate the following conditions:
(See Front View drawing)

On: Indicates when the system is on.

Overload: Indicates that the system has shut down due to an overload condition on one of the outputs.

Low Quality: Indicates that the quality of the water is below the setpoint.

Tank Full: Indicates when the system is shut down due to a full storage tank. The system will only shut down in the tank feed mode

Pretreatment Interlock: Indicates when the system is shut down due to external pretreatment equipment.

Low Pressure: Indicates that the system has shut down due to low pump feed pressure.

II. OPERATION

The key switch must be in the ON position (see Figure 1).

A. Contrast Adjustment

Press the up or down arrow when the Alamo Water logo is displayed to increase or decrease the contrast of the display.

B. Operation Screen

When the Start/Stop button is pressed the inlet valve will open. After a 12 second delay the pump will start. The system will operate according to the information stored in memory. The product water conductivity is displayed in the large numbers at the top center of the display. The temperature is displayed as degrees Celsius in the top right corner of the display. The mode of operation is displayed below the product water quality. Flush time information or pump run hours are displayed on the bottom of the display.

C. Configuration Screen

Press the SELECT button to view the configuration screen. The software revision level is displayed in the upper right corner of this screen. While the configuration screen is displayed, the SELECT button moves the highlight cursor to the next field. The up and down arrows change the value of the highlighted field. The ACCEPT button saves all of the values and brings up the timer screen. The RESET button discards all changes and brings up the timer screen. If no input is detected for a continuous 30 seconds, the controller will discard all changes and return to the operation screen. An asterisk appears next to a field whenever the value of the field equals the value stored in memory. The configuration screen contains the following field with their options:

MODE: (direct feed, tank feed, and standby)

LOW QUALITY: (2-200 micromhos) This is the set point for the diverter valve. When the product water conductivity is equal to or greater than value selected, the diverter valve output will be energized and the low quality LED will turn on.

AUTOSTART: (on/off) if "on" is selected, the system will automatically restart after a power loss. If "off" is selected, the unit will not restart after a power loss.

LOWPRESSURE RETRY: (0-10) This is the number of times the system will attempt to restart after a low pressure shutdown.

LOW PRESSURE DELAY: (15-90 seconds in 15 second increments) This is the amount of time between attempts to restart after a low pressure shutdown.

AUTOFLUSH: (0-10 minutes) This is the length of the flush cycle. The system will flush for this amount of time every hour in tank feed and standby modes.

D. Timer Screen

Pressing either the ACCEPT or the RESET button from the configuration screen brings up the timer screen. The controller has three timers (hour meters). Two are user resetable and one is not. All of these timers count up when the pump is running. The two user resetable meters are labeled PREFILTER and MEMBRANE. Pressing the reset button when either of these timers are highlighted will reset the timer to zero. The SELECT button moves the highlight cursor to the next timer. Press Accept while the membrane meter is highlighted to exit and return to the operation screen.

E. Calibration Screen

This screen is used to calibrate the conductivity and temperature. Press ACCEPT and RESET at the same time to bring up this screen. The temperature and conductivity fields on the last two lines of the display can be adjusted using the up and down arrows. Use the arrow keys to input the correct temperature and then press the ACCEPT button. The conductivity will now be highlighted. Use the arrow keys to input the correct conductivity and press the ACCEPT button. Always calibrate the temperature first. (Note: the new values are only saved when the ACCEPT button is pressed while the field is highlighted.) When the desired values are entered press the RESET button to return to the operation screen. You can only enter the calibration screen if the conductivity and temperature readings are stable.

F. Pop-Up Screens

Under certain circumstances a pop-up screen may be displayed. These look like a window that partially blocks out the screen behind it. The conditions that display pop-up screens are:

Low Inlet Pressure
Pretreatment Interlock
Overload Conditions
Trying to calibrate if the temperature and/or conductivity is not stable.

III. SERVICE AND MAINTENANCE

The 3501 Reverse Osmosis Controller is designed for ease of maintenance and minimum service. Since the highest quality of electronic semiconductor components are used in this design, it is not likely that circuit malfunctions or failures will occur. It is our recommendation that service be limited to identifying malfunctions at the board level and that component level troubleshooting be referred to the factory.

Field failures that most frequently occur are:

- Improper or broken wiring connections
- Incorrect wiring of the motor starter
- Improper grounding
- Cable run is too long
- Water in connectors
- Dirty probes
- Defective probes

A. Troubleshooting

Description of Problem	Possible Cause or Solution
System shuts down on low pressure but pressure is okay.	1. Check the pressure switch set point 2. Possible short in wiring to pressure switch 3. Defective pressure switch 4. Orifice in pressure switch may be plugged
Pressing the Start/Stop button does not turn the system on.	1. Verify that the key switch is on 2. Verify that the circular connector on the bottom of the controller is attached 3. Check the fuse in the power inlet
Conductivity monitor does not display the proper reading.	1. Calibrate the controller 2. Check the wiring to the conductivity probe 3. Clean the conductivity probe 4. Replace the conductivity probe
Erratic conductivity display	1. Conductivity probe wiring may be too close to high voltage lines. 2. Check for moisture in the connection between the probe and the lead wire.

F. Operation and Maintenance Log

DATE	PRODUCT GPM	REJECT GPM	PUMP DISCHARGE PRESSURE	REJECT PRESSURE	FEED TDS PPM	PRODUCT TDS PPM	FEED WATER TEMP	FEED WATER HARDNESS	FEED WATER CHLORINE LEVEL	PRE FILTER INLET PRESSURE	PRE FILTER OUTLET PRESSURE	REMARKS

Note: Change the prefilter when the differential pressure increases by 5 - 10 psi over the clean differential pressure.
Clean the RO membranes when the product flow drops by 15% or more. (See appendix)

F. TROUBLESHOOTING

RO TROUBLE SHOOTING GUIDE						
SYMPTOMS						
Salt Passage	**Permeate Flow**	**Pressure Drop**	**Location**	**Possible Causes**	**Verification**	**Corrective Action**
Normal to increased	Decreased	Normal to increased	Predominantly first stage	Metal oxide	Analysis of metal ions in cleaning solution.	Improved pretreatment to remove metals. Cleaning with acid cleaners.
Normal to increased	Decreased	Normal to increased	Predominantly first stage	Colloidal fouling	SDI measurement of feed/ X-ray diffraction analysis of cleaning sol. Residue.	Optimize pretreatment system for colloidal removal. Clean with high pH, anionic detergent formulation.
Increased	Decreased	Increased	Predominantly last stage	Scaling ($CaSO_4$, $CaSO_3$, $BaSO_4$, SiO_2)	Analysis of metal ions in cleaning sol. Check LSI of reject. Calculate maximum solubility for $CaSO_4$, $BaSO_4$, SiO_2 in reject analysis.	Increase acid addition and scale inhibitor for $CaSO_3$ and $CaSO_4$. Reduce recovery. Clean with an acid formulation for $CaCO_3$, $CaSO_4$ and $BaSO_4$.
Normal to moderate increase	Decreased	Normal to moderate increase	Can occur in any stage	Biological fouling	Bacteria count in permeate and reject. Slime in pipes and vessels.	Shock dosage of sodium bisulfite. Continuous feed of low conc. Of bisulfite at reduced pH. Formaldehyde sterilization. Clean with alkaline anionic surfactant. Chlorine dosage up-stream with subs. Dechlorination. Replace cartridge filters.
Decreased or moderately increased	Decreased	Normal	All stages	Organic fouling	Destructive testing, e.g. IR reflection analysis.	Optimization of pretreatment system (e.g. coagulation process.) Resin/activated carbon treatment. Clean with high pH detergent.
Increased	Increased	Decreased	Most severe in the first stage	Chlorine oxidant attack	Chlorine analysis of feed. Destructive element test.	Check chlorine feed equipment and dechlorination equipment.
Increased	Increased	Decreased	Most severe in the first stage	Abrasion of membrane by crystalline material	Microscopic solids analysis of feed. Destructive element test.	Improved pretreatment. Check all filters for media leakage.
Increased	Normal to increased	Decreased	At random	O-ring leaks, End or side seal glue leaks.	Probe test. Vacuum test. Colloidal material passage.	Replace O-rings. Repair or replace elements.
Increased	Normal to low	Decreased	All stages	Conversion too high.	Check flows and pressures against design guidelines	Reduce conversion rate. Calibrate sensors. Increase analysis and data collection.

MOTOR TROUBLE SHOOTING CHART

TROUBLE	CAUSE	WHAT TO DO
Motor fails to start	Blown fuses	Replace fuses with proper type and rating
	Overload trips	Check and rest overload in starter.
	Improper power supply	Check to see that power supplied agrees with motor nameplate and load factor.
	Open circuit in winding or control switch	Indicated by humming sound when switch is closed.
	Mechanical failure	Check to see if motor and drive turn freely. Check bearing and lubrication.
	Short circuited stator	Indicated by blown fuses. Motor must be rewound.
	Poor stator coil connection	Remove end bells, locate with test lamp.
	Rotor defective	Look for broken bars or end ring.
	Motor may be overloaded	Reduce load.
Motor Stalls	One phase connection	Check lines for open phase.
	Wrong application	Change type or size. Consult manufacturer.
	Overload motor	Reduce load.
	Low motor voltage	See that nameplate voltage is maintained. Check connection.
	Open circuit	Fuses blown, check overload relay, stator and push buttons.
Motor runs and then dies down	Power failure	Check for loose connections to line, to fuses and to control.
Motor does not come up to speed	Not applied properly	Consult supplier for proper type.
	Voltage too low at motor terminals because of line drop.	Use higher voltage on transformer terminals or reduce load. Check connections. Check conductors for proper size.
	Broken rotor bars or loose rotor.	Look for cracks near the rings. A new rotor may be required as repairs are usually temporary.
Motor takes too long to accelerate	Open primary circuit	Locate fault with testing device and repair.
	Excess loading	Reduce load.
	Poor circuit	Check for high resistance.
	Defective squirrel cage rotor	Replace with new rotor.
	Applied voltage too low	Get power company to increase power tap.
Wrong rotation	Wrong sequence of phases	reverse connections at motor or at switchboard.
Motor overheats while running under load	Overloaded	reduce load.
	Frame or bracket vents may be clogged with dirt and prevent proper ventilation of motor.	Open vent holes and check for a continuous stream of air from the motor.
	Motor may have one phase open	Check to make sure that all leads are well connected.
	Grounded could	Locate and repair.
	Unbalanced terminal voltage	Check for faulty leads, connections and transformers.
Motor vibrates after correcting have been made	motor misaligned	Realign
	Weak support	Strengthen base.
	Coupling out of balance	Balance coupling.
	Driven equipment unbalanced	Rebalance driven equipment.
	Defective ball bearing	Replace bearing.
	Bearing not in line	Line properly.
	Balancing weights shifted	Rebalance motor.
	Polyphase motor running single phase	Check for open circuit.
	Excessive end play	Adjust bearing or add washer.

MOTOR TROUBLE SHOOTING CHART (CONTINUED)

TROUBLE	CAUSE	WHAT TO DO
Unbalanced line current on polyphase motors during normal operation	Unequal terminal volts	Check leads and connections
	Single phase operation	Check for open contacts
Scraping noise	Fan rubbing air shield	Remove interference.
	Fan striking insulation	Clear fan.
	loose on bedplate	Tighten holding bolts.
Noisy operation	Airgap not uniform	Check and correct bracket fits or bearing.
	Rotor unbalance	Rebalance.
Hot bearings general	Bent or sprung shaft	Straighten or replace shaft.
	Excessive belt pull	Decrease belt tension.
	Pulleys too far away	Move pulley closer to motor bearing.
	Pulley diameter too small	Use larger pulleys.
	Misalignment	Correct by realignment of drive.
Hot bearings ball	Insufficient grease	Maintain proper quantity of grease in bearing.
	Deterioration of grease, or lubricant contaminated	Remove old grease, wash bearings thoroughly in kerosene and replace with new grease.
	Excess lubricant	Reduce quantity of grease: bearing should not be more than ½ filled.
	Overloaded bearing	Check alignment, side and end thrust.
	Broken ball or rough races	Replace bearing: first clean housing thoroughly.

These instructions do not cover all details or variations in equipment nor provide for every possible condition to be met in connection with installation, operation or maintenance. Chart courtesy of Marathon Electric.

RO SYSTEM TROUBLE SHOOTING

PROBLEM	REMEDY
General	
High Product Water TDS	
Membrane expanded.	Replace membrane.
Membrane attack by chlorine	Carbon pre-filter may be exhausted. Replace with a new cartridge.
Clogged pre-filter-creates pressure drop and low reject flow.	Replace pre-filter cartridge.
Feed pressure too low.	Feed pressure must be at least 20 psi.
Insufficiently flushed post-filter cartridge.	Flush post-filter with pure water.
Brine seal on membrane leaks.	Determine if seal or o-ring is bad. Replace as needed.
No Product Water or Not Enough Product Water	
Feed water shut off.	Turn on feed water.
Low feed pressure. Feed pressure must be at least 20 psi.	Consider booster pump.
Pre-filter cartridge clogged.	Replace pre-filter cartridge.
Membrane fouled.	Determine and correct cause; replace membrane.
Product check valve stuck.	Replace check valve fitting.
Low pump discharge pressure	Open pump discharge valve, replace pump

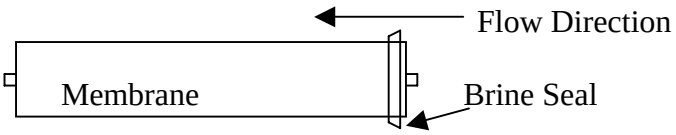
IV. REPLACEMENT PARTS LIST

A list of common replacement parts is provided below. All of these parts are not used on every system and all of the parts are not listed. Contact you dealer for replacement parts assistance.

Part Number	Description
S7563A-D/T	**Pre filter housing 20" Big Blue**
R9677-SV4040.1	**RO Membrane Pressure Vessels 4" x 40" SS**
R2451	**Pressure Gauge, 2", 0-100 psi, Dry**
R2452P	**Pressure Gauge, 2 1/2", 0-400 psi, LF**
R5177	**Flow Meter 1-10 gpm (product)**
R5380	**Flow Meter 1-10 gpm (reject)**
R23-A16301081	**Motor Starter Contactor, 16 amps, 24 volt coil**
R23-TA25DU14	**Overload Relay 8 - 14 amps**
R23-TA25DU85	**Overload Relay 6 - 8.5 amps**
R6316-V10B15S3T	**Pump & Motor, 15 stage, 5hp, 3-Phase**
R6316-V10B18ST	**Pump & Motor, 18 stage, 3-Phase**
R2316-214B	**Low Pressure Switch, 6.5 psi**
K8013-24	**Inlet Solenoid Valve, 1”, 24 volt coil**
R9622-AB	**Alamo Brand 4 x 40 RO Membranes**
R23-3501-A	**CI 1000 Controller with conductivity meter**
T10268-1	**Conductivity Probe**
R23-1060	**Standard RO Controller**
R2402-24	**Autoflush Solenoid Valve, 1/2", Brass, 24 volt coil.**

V. MEMBRANE REPLACEMENT

1. Turn off the system and close the feed water shutoff valve.
2. Disconnect the membrane feed hoses by loosing the brass fittings between the end of the hoses and the pressure vessel end caps.
3. Remove the retaining "U" pins from the pressure vessels.
4. Push the old membrane out of the vessel in the direction of the feed flow. (See flow arrows on the right side of figure #1)
5. Record the serial numbers of the new membranes.
6. Lightly lubricate the brine seals on the new membranes with clean water.
7. Install the new membranes in the direction of flow with the brine seal end going in last.
8. Lightly lubricate the end cap internal and external o-rings with glycerin.
9. Install the end caps and secure them with the "U" pins.
10. Install the membrane feed hoses.
11. Verify that all retaining "U" pins are installed.
12. Follow the start up procedure in section III-D.



VI. APPENDIX

The following tables are intended as a guide to determining the flow rates for the R14 series RO systems. All flows are in gallons per minute (GPM).

Nominal flows for systems without reject recycle and a feed water Silt Density Index less than 3.

	R14-02	R14-03	R14-04	R14-05	R14-06
Product	**2.5**	**3.75**	**5**	**6.25**	**7.5**
Reject	**6.1**	**5.9**	**5**	**4.7**	**4.6**

Nominal flows for systems with reject recycle and a feed water Silt Density Index less than 3.

	R14-02	R14-03	R14-04	R14-05	R14-06
Product	**2.5**	**3.75**	**5**	**6.25**	**7.5**
Reject	**2.5**	**3.75**	**1.7**	**2.1**	**2.5**
Reject Recycle	**3.6**	**2.2**	**3.3**	**2.6**	**2.1**

Nominal flows for systems without reject recycle and a feed water Silt Density Index of 3 to less than 5.

	R14-02	R14-03	R14-04	R14-05	R14-06
Product	**2.3**	**3.5**	**4.3**	**5.2**	**6.3**
Reject	**6.6**	**6.5**	**5.3**	**4.8**	**4.4**

Nominal flows for systems with reject recycle and a feed water Silt Density Index of 3 to less than 5.

	R14-02	R14-03	R14-04	R14-05	R14-06
Product	**2.3**	**3.5**	**4.3**	**5.2**	**6.3**
Reject	**2.3**	**3.5**	**1.4**	**1.7**	**2.1**
Reject Recycle	**4.3**	**3**	**3.9**	**3.1**	**2.3**

Temperature Correction Factors

Deg C	Deg F	Correction Factor
30	86	1.16
29	84.2	1.13
28	82.4	1.09
27	80.6	1.06
26	78.8	1.03
25	***77***	***1.00***
24	75.2	0.97
23	73.4	0.94
22	71.6	0.92
21	69.8	0.89
20	68	0.86
19	66.2	0.84
18	64.4	0.81
17	62.6	0.79
16	60.8	0.77
15	59	0.74
14	57.2	0.72
13	55.4	0.70
12	53.6	0.68
11	51.8	0.66
10	50	0.64
9	48.2	0.62
8	46.4	0.61
7	44.6	0.59
6	42.8	0.57
5	41	0.55

Multiply the nominal product flow at 25° C by the temperature correction factor to determine the flow at various other temperatures.

7. Cleaning and Disinfection

7.1 Introduction

The surface of RO membrane is subject to fouling by foreign materials which may be present in the feed water such as hydrates of metal oxides, calcium precipitates, organics and biological matter. (The term "fouling" here includes the build-up of all kinds of layers on the membrane surface, including scaling).

The pretreatment of the feedwater prior to the RO process is basically designed to reduce contamination of the membrane surfaces as much as possible. This is accomplished by installing an adequate pretreatment system and selecting optimum operating conditions such as permeate flow rate, pressure and permeate water recovery ratio.

Occasionally, fouling of the membrane surfaces is caused by

- inadequate pretreatment system
- pretreatment upset conditions
- improper materials selection (pumps, piping, etc.)
- failure of chemical dosing systems
- inadequate flushing following shutdown
- improper operation control
- slow build-up of precipitates over extended periods (barium, silica)
- change in feed water composition
- biological contamination of feed water

The fouling of membrane surfaces manifests itself in a performance decline, lower permeate flow rate and/or higher solute passage. Increased pressure drop between the feed and concentrate side can be a side effect of fouling.

Cleaning can be accomplished very effectively because of the FT30 membrane's combination of pH stability and temperature resistance.

If the time of cleaning is delayed too long however, it is difficult to remove the foulants completely from the membrane surface. The cleaning will be more effective the better it is tailored to the specific fouling problem. Sometimes, a wrong choice of cleaning chemicals can even worsen the situation. Therefore, the type of foulants on the membrane surface should be determined prior to cleaning. There are different possibilities:

- Analyze the plant performance data. Details are given in Section 10: "Troubleshooting".
- Analyze the feed water. A potential fouling problem may already be visible there.
- Check the results of previous cleanings.
- Analyze the foulants collected with a membrane filter used for SDI value determination.
- Analyze the deposits on the cartridge filter.
- Inspect the inner surface of the feed line tubing and the feed end scroll of the FILMTEC® element. If it is reddish-brown, fouling by iron materials may be considered. Biological fouling or organic material is often slimy or gelatinous.

7.2 Cleaning Requirements

Elements should be cleaned whenever:

- the normalized permeate flow drops by 10 percent,
- the normalized salt content of the product water increases by 10%,
- the differential pressure (feed pressure - concentrate pressure) Δ P increases by 15% from the reference conditions (initial performance established during the first 24 to 48 hours of operation).

It should be noted that it is important to normalize flow and salt content of the permeate according to the normalization procedure described in Section 6.7.

7.3 Safety Precautions

In using any chemicals mentioned in this section, follow accepted safety practices. Always wear eye protection as a minimum. In the case of handling corrosive chemicals (e.g. sulfuric acid) wear full face cover and protective clothing. Consult the relevant Material Safety Data Sheets as supplied by the manufacturer of the chemicals.

Check the materials of construction used in the cleaning system is adequate and compatible with the cleaning chemicals to be used. Never use aluminium as material in contact with the cleaning solution.

7.4 Cleaning Equipment

The equipment for cleaning is shown in the cleaning system flow diagram (Figure 1). The pH of cleaning solutions used with FILMTEC® elements can be in the range of 1 to 12, and therefore non-corrosive materials should be used in the cleaning system.

The mixing tank should be constructed of polypropylene or fiberglass reinforced plastic (FRP). The tank should be provided with a removable cover and a temperature gauge.

The cleaning procedure is more effective when performed at an elevated temperature. It is not recommended to use a cleaning temperature below 15°C (59°F) because of the very slow cleaning rate at low temperatures. In addition, chemicals such as sodium lauryl sulfate might precipitate at low temperatures. Cooling may also be required to avoid overheating, so heating/cooling requirements must be considered during the design.

A rough rule of thumb in sizing a cleaning tank is to use approximately the empty pressure vessel volume and then add the volume of the feed and return hoses or pipes.

For example, to clean eight 8-inch diameter pressure vessels with six elements per vessel, the following calculations would apply (for conversion of U.S. units into metric units see Section 10.7).

A. Volume in Vessels

$V_1 = \pi r^2 \times L$

$= 3.14\ (4\ in)^2 \times (6 \times 40\ in)$

$V_1 = 200$ l/vessel

$V_8 = 200 \times 8 = 1600$ l

B. Volume in Pipes, Assume 50 ft Length Total, SCH 80 Pipe

$V_p = \pi r^2 \times L$

$3.14\ (50\ mm)^2 \times (30\ m)$

$= 236$ l

$V_{ct} = V_8 + V_p = 1600\ l + 236\ l$

$= 1836$ l

Therefore, the cleaning tank should be about 450 gal.
The cleaning pump should be sized for the flows and pressures given in Table 1, making allowances for pressure drops in the piping and across the cartridge filter. The pump should be constructed of 316 SS or non-metallic composite polyesters.

Appropriate valves, flow meters, and pressure gauge should be installed to adequately control the flow. Service lines may be either hard piped or portable hoses. In either case, the flow rate should be less than 10 ft/sec.

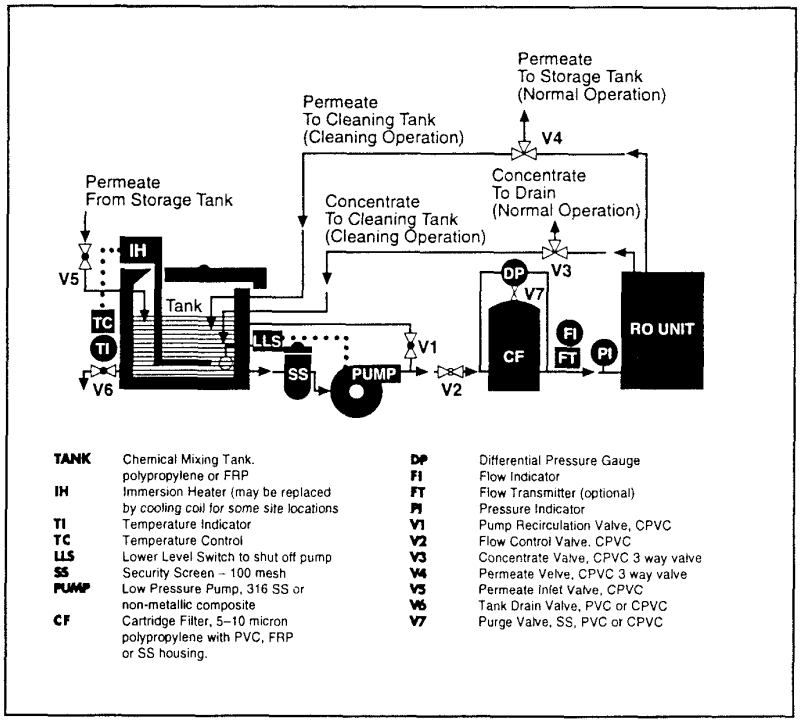


Figure 1: Cleaning System Flow Diagram

7.5 Cleaning Procedure

There are eight steps in the cleaning of reverse osmosis modules:

1. **Prepare and mix** the appropriate cleaning solution, and check pH of the solution. Ensure that all chemicals are dissolved and well-mixed before circulating the solution to the elements. Any cleaning solution must be clear.
2. **Low flow pumping.** Pump mixed, preheated cleaning solution to the vessel at conditions of low flow rate (about half of that shown in Table 1) and low pressure to displace the process water. Adjust flow rate and pressure by valves V1 and V2. Use only enough pressure to compensate for the pressure drop from feed to concentrate. The pressure should be low enough that essentially no permeate is produced. A low pressure minimizes redeposition of dirt on the membrane. Dump the concentrate, as necessary to prevent dilution of the cleaning solution.
3. **Recycle.** After the process water is displaced, cleaning solution will be present in the concentrate stream. Then recycle the concentrate to the cleaning solution tank and allow the temperature to stabilize. Observe the turbidity of alkaline or detergent solutions to judge efficiency. If the cleaning solution colors or becomes turbid, restart with a freshly prepared cleaning solution. Check the pH during acid cleaning. The acid is consumed when it dissolves inorganic precipitates. So if the pH increases more than 0.5 pH units, add more acid.
4. **Soak.** Turn the pump off and allow the elements to soak. Sometimes a soak period of about 1 hour is sufficient. For difficult fouling an extended soak period is beneficial; soak the elements overnight for 10-15 hours. To maintain a high temperature during an extended soak period, use a slow recirculation rate (about 10% of that shown in Table 1).
5. **High flow pumping.** Feed the cleaning solution at the rates shown in Table 1 for 30-60 minutes. The high flow rate flushes out the foulants removed from the membrane surface by the cleaning. If the elements are heavily fouled, which should never happen, a flow rate which is 50% higher than shown in Table 1 may aid cleaning. At higher flow rates excessive pressure drop may be a problem. The maximum recommended drops are 1.4 bar (20 PSI) per element or 4.1 bar (60 PSI) per multi-element vessel, whichever value is more limiting. For 8" elements, the direction of flow during cleaning must be the same as during normal operation to avoid telescoping of the elements.
6. **Drain** the spent cleaning solution out of the system. Recommendation: Take a sample of the spent and of the fresh cleaning solution. From the results of a chemical analysis, you can determine the amount of substances removed from the membrane elements.
7. **Flush out.** RO permeate or good quality water (filtered, SDI < 3, free of bacteria and chlorine, conductivity < 10,000 µS/cm) is used for flushing out the residual cleaning solution. To prevent precipitation, the minimum flush out temperature is 20°C. Before starting up the plant with normal operating pressures and flows, the bulk of the cleaning solution must be flushed from the elements.
8. **Rinse out.** The RO plant is started up again resuming normal operating conditions. As cleaning chemicals will be present on the permeate side after cleaning, the permeate must be discharged to drain for at least 10 minutes (or until the required permeate quality is obtained) when starting up after cleaning. When another cleaning cycle with another cleaning chemical is to follow, make sure that the permeate side of the module is rinsed out as well. Otherwise a chemical reaction with the following cleaning chemical may happen.

During the rinse out step, the operating parameters should be noted to judge the cleaning efficiency and to decide if another cleaning is required.

Table 1: Recommended Feed Flow Rate per Pressure Vessel during High Flow Rate Recirculation

Element Diameter (in)	Feed Flow Rate per PV (GPM)	(m³/h)
2.5	3 - 5	0.7 - 1.1
4	8 - 10	1.8 - 2.3
8	30 - 40	7 - 9

- If the system has to be shut down after cleaning for longer than 24 hours, the elements should be stored in a preservation solution (see Section 8: Handling and Preservation).

For multi-array (tapered) systems, cleaning should be carried out separately for each array (except rinse out), so the flow rate is not too low in the first array or too high in the last. Also, any deposits removed from the first array will not be carried all the way through the following arrays where they might clog the feed channels.

This can be accomplished either by using one cleaning pump and operating one array at a time, or using a separate cleaning pump for each array.

A multi-array system can also be cleaned successively in groups of about equal numbers of parallel vessels. For example, a 8:4 staged system can be cleaned in 3 groups each with 4 vessels in parallel. This allows an optimum selection of the cleaning pump.

7.6 Cleaning Chemicals

The FT30 membrane's chemical stability allows a wide range of cleaning chemicals to be used. However, there is no sharp borderline between cleaning chemicals not affecting the membrane performance, and cleaning chemicals affecting the membrane performance. The cleaning chemicals and cleaning conditions recommended here are such, that the specified element performance is not affected after three years of operation when the cleaning chemicals or cleaning conditions are applied for 2 hours once a week.

Harsh and frequent cleaning will shorten the membrane life (typically by increased salt passage), while mild and seldom cleaning will extend the membrane life (anticipated that no fouling occurs).

Table 2 lists suitable cleaning chemicals. Acid cleaners and alkaline cleaners are the standard cleaning chemicals. The acid cleaners are to remove inorganic precipitates including iron, while the alkaline cleaners are to remove organic fouling including biological matter. Sulfuric acid should not be used for cleaning because of the risk of calcium sulfate precipitation.

Preferably, reverse osmosis permeate should be used for the cleaning solutions but prefiltered raw water will also work in most cases. The raw water can be highly buffered, so more acid or hydroxide may be needed with raw water to reach the desired pH level, which is about 2 for acid cleaning and about 12 for alkaline cleaning.

During cleaning, the pH range and maximum temperatures as given in Table 3 must not be exceeded. **Brand name cleaning chemicals are** frequently used in the field rather than self-made formulations.

Some cleaning chemicals, however, worsen the performance of the clean membrane, e.g. by fouling and subsequent flux loss. Before brand name cleaning chemicals are used, their compatibility with FILMTEC® FT30 elements has to be secured.The procedure for compatibility testing is a long-term cleaning test on a new FILMTEC element under the harshest recommended cleaning conditions. A soak test with FT30 membrane coupons can be used as a screening test. A chemical compatability testing procedure is described in section 10.11 of this manual.

The cleaning chemicals listed in Table 4 have shown FT30 compatibility in short-term tests (cleaning efficacy has not been tested!).They can be used, provided the membrane plant performance is carefully monitored to detect any long term effects at an early stage. When cleaning, follow the cleaning chemical manufacturer's instructions and observe the pH limits of the membrane (Table 3).

Table 2: Simple Cleaning Solutions for FT30 Membrane

Foulant \ Cleaner	0.1% (W) NaOh and pH 12,30°C max. or 1.0% (W) Na_4EDTA and pH 12,30°C max	0.1% (W) NaOH and pH 12,30°C max. or 0.025%& Na-DDS and pH 12,30°C max	0.1% STP and 1.0% Na_4EDTA or 0.1% TSP and 1.0% Na_4EDTA	0.2% (W) HCl	0.5% (W) H_3PO_4	2.0% (W) Citric Acid	0.2% (W) NH_2SO_3H	1.0% (W) $Na_2S_2O_4$
Inorganic Salts (for example, Cac3, CaS_4, $BaSO_4$)				best	OK	OK	OK	
Metal Oxides (for example iron)					good		OK	good
Inorganic Colloids (silt)		good						
Silica	OK							
Biofilms	best	good	good					
Organic OK	good	good						

1. (W) denotes weight percent of active ingredient.

2. Cleaning chemical symbols, in order used: NaOH is sodium hydroxide; Na-EDTA is the sodium salt of ethylene diamine tetraacetic acid; Na-DDS is sodium salt of dodecylsulfate; STP is sodium triphosphate ($Na_5P_3O_{10}$); TSP is trisodium phosphate ($Na_3PO_4 \times 12H_2O$); HCl is hydrochloric acid; H_3PO_4 is phosphoric acid; citric acid is $C_3H_4(OH)(CO_2H_3)$; NH_2SO_3H is sulfamic acid; $Na_2S_2O_4$ is sodium hydrosulfite.

Table 3: pH Range and Temperature Limits During Cleaning

	Max Temp 50°C pH Range	Max Temp 35°C pH Range	Max Temp 30°C pH Range	Continuous Operation
SW30, SW30 HR	3-10	2-11	2-12	2-11
BW30, TW30	2-10	1-11	1-12	2-11
NF45, SR90	3-10	2-11	1-11	3-9

Table 4: Short Term Compatible Brand Name Cleaning Chemicals

ARGO-Bioclean 511, Argo Scientific	Filtrapure, Acid	Monarch 972-0-1 (5% soak test)
ARGO-Bioclean 882, Argo Scientific	Filtrapure TF	Monarch 972-0-2 (5% s.t.)
ARGO-IPA 403, Argo Scientific	Floclean 403, FMC	Monarch 972-0-3 (5% s.t.)
ARGO-IPA 411, Argo Scientific	Floclean 411, FMC	Monarch 2024-11-7 (0.5%)
ARGO-AES 510, Argo Scientific	Gambro WRO	Monarch Enzyme Cleaner 96
ARROW-TREAT 2100	Henkel P3-ultrasil 10 (1% soak test)	
	Henkel P3-ultrasil 70	MT 1000 F, BF Goodrich
ARROW-TREAT 2200	Henkel P3-ultrasil 75 (1% soak test)	MT 2000 F, BF Goodrich
ARROW-TREAT 2300	Jal/Nas 30 0.1% + 0.1NaOH	MT 2100, BF Goodrich
	KL 2000, King-Lee	MT 3000 F, BF Goodrich
Dia 707, Argo Scientific	KL 3000, King-Lee	MT 4000, BF Goodrich
Diamite-FT, King-Lee	Klenzade KX-6713B	
Diamite-FT, Antimicrobial, King Lee	Mic Chem Cleaner (4% soak test)	Scaleclean 87, Grace
Divos 115, Diversey Wyandotte		
Feedmate 151, Grace		

Test concentration was double the recommended strength unless otherwise stated.

7.7 Disinfecting RO Systems

7.7.1 Introduction

If the plant has been infected by bacteria or mold, a disinfection must be carried out after the cleaning. The procedure is the same as for cleaning, except that the high flow pumping step can be skipped.

7.7.2 Formaldehyde

Formaldehyde can be used as a disinfectant with 0.5 to 3.0% concentrations. Care should be taken in handling this chemical and in flushing the system after use.

7.7.3 Hydrogen Peroxide and Peracetic Acid

Hydrogen peroxide or **hydrogen peroxide/peracetic acid** solutions can be used at concentrations up to 0.2%. The biocidal efficacy of peracetic acid is much higher than that of hydrogen peroxide, but as most peracetic acid solutions also contain hydrogen peroxide, care must be exercised not to exceed the 0.2% concentration as a sum of both compounds. Continuous exposure at this concentration may eventually damage the membrane. Instead, periodic use is recommended.

When hydrogen peroxide is applied, **the pH of the solution must be lower than 4.** A pH of 3 is recommended. This will ensure optimal biocidal results and longer membrane lifetime. If no acid is added to the hydrogen peroxide solution, the chemical attack on the membrane will be much faster. When a mixture with peracetic acid is used, pH adjustment is usually not required.

If an alkaline cleaning has preceded disinfection, the alkalinity has to be carefully rinsed out also from the permeate side (check pH!) before peroxide/peracetic acid is applied. Otherwise the membrane might become oxidized.

Two other factors greatly influence the rate of hydrogen peroxide attack on the membrane: temperature and iron.

The disinfecting solution must not exceed 25°C. FT30 membrane samples tested with 0.5% hydrogen peroxide at 34°C showed a very high salt passage after several hours. At 24°C however, membrane samples demonstrated compatibility with 0.5% hydrogen peroxide after 96 hours.

Iron or other transition metals must not be present, because they catalyze membrane degradation in the presence of hydrogen peroxide solutions. FT30 samples were tested using a 0.15% solution of hydrogen peroxide and tapwater containing iron. After 150 hours, the salt passage of the membrane began to increase dramatically.

For RO systems using the FT30 membrane, Dow recommends the following procedure for disinfection with hydrogen peroxide solutions:

1. Any type of deposit on the membrane or other parts of the system should be removed with an alkaline cleaner before disinfecting. Removal of these deposits, which harbor microorganisms, will maximize the degree of disinfection. After alkaline cleaning, flush the system with RO permeate.
2. Clean the RO system with acid, e.g. 0.1% by volume hydrochloric acid or 0.4% by volume phosphoric acid, to remove any iron from the membrane surface. Flush the unit with RO permeate.
3. Circulate a solution of 0.2% hydrogen peroxide (preferably containing peracetic acid) diluted with RO permeate and pH adjusted to 3-4 with HCl at a temperature below 25°C for 20 minutes.
4. Allow the elements to soak in the disinfecting solution for 2 hours.
5. Flush out the disinfecting solution. Rinse the system.

7.7.4. Chlorinated Disinfectants

FILMTEC® FT30 membrane can withstand short-term exposure to free chlorine (hypochlorite); however, its resistance is limited. The membrane can be used successfully in installations where system upsets result in temporary exposure to free chlorine. Eventual degradation may occur after approximately 200-1,000 hours of exposure to one ppm concentrations of free chlorine. The rate of chlorine attack depends on various feedwater characteristics. Under alkaline pH conditions, chlorine attack is faster than at neutral or acidic pH. Chlorine attack is also faster at higher concentrations of heavy metals (e.g. iron), which catalyze membrane degradation. As in many cases there will be some iron fouling on the membrane, the intended use of chlorinated disinfectants should not be considered.

Disinfection with agents containing combined chlorine is generally not recommended. This includes such compounds as chloramine, chloramine-T, and N-chloroisocyanurate. FT30 is resistant to mild chlorinating agents such as these at low concentration (< 3 mg/l).

However, their effectiveness as disinfectants at low concentrations is limited. These compounds can also slowly damage the membrane, since they are in equilibrium with small amounts of free chlorine. When used, the pH must be <8.

7.7.5 Other Disinfectants

Iodine, quaternary germicides, and phenolic compounds cause flux losses and are not recommended for use as disinfectants.

70% ethanol can be used for disinfection. **Brand name biocides** have also been tested for effects on the membrane performance.[1] There are fully compatible and limited compatible biocides.

Those biocides which have limited compatibility can be in contact with the membrane for two hours a week for at least 3 years without any significant effect on the membrane performance. However, in continuous contact, a change in membrane performance might be detectable after a few weeks. The biocides with limited compatibility are listed in Table 1.
Biocides with full compatibility can be in contact with the membrane continuously for at least one year without significant loss of salt rejection and permeate flux (cleaning may be required, however, after long term disinfection). Those biocides can also be used for preservation (see also Section 8). Table 2 lists the fully compatible biocides:

Table 1: Brand Name Biocides with limited FT30 Compatiblity (for intermittent use)

Biocide	Max. Concentration (20-25°C)	Supplier
Rogun 881	200 ppm	Argo Scientific
Bactipal SN	1%, pH < 4	Seppic
Dow Antimicrobial 7287	200 ppm	Dow Chemical
Minncare	1%, pH < 4	Minntech
Renalin	1%, pH < 4	Minntech

Table 2: FT30 Compatible Brand Name Biocides

Biocide	Max. Concentration (20-25°C)	Supplier
Bioclean 882	0.2 %	Argo Scientific
C-68	0.09 %	Betz
Kathon GC/ICP	0.15 %	Rohm and Haas
Nalco 2593	0.15 %	Nalco
Monarch Soak 40	5 %	Monarch Chemical
Filtrapure Membrane Preservative	1 %	Monarch Chemical

[1] For the biocidal efficacy, contact the supplier.

7.8 Cleaning and Disinfection Programs

Different degrees of cleaning processes can be applied to FT30 membrane depending on the foulants. These cleaning processes range from a simple flushing with prefiltered water up to a complicated cleaning program including different harsh cleaning chemicals and disinfectants. Cleaning processes may be ranked in the following order:

1. Forward flush with pretreated raw water (high feed flow, low feed pressure).
2. Cleaning with permeate.
3a. *Cleaning with sodium hydrosulfite,* acid or alkaline at pH well within the limits.
3b. Disinfection with formaldehyde or fully approved biocide.
4a. Cleaning with acid or alkaline at pH limits.
4b. Disinfection with hydrogen peroxide.
5. Cleaning with formulations containing EDTA.
6. Cleaning program with different cleaning chemicals and/or disinfectants. A cleaning/disinfection program may include soft or harsh chemicals.

When the optimum cleaning process is to be selected, the following has to be considered:

- Minimize impact on the environment by spent cleaning solutions (e.g. EDTA, biocides).
- Optimize foulants removing efficacy.
- Minimize impact on membranes (prefer mild chemicals).
- Minimize cleaning costs.

Examples of cleaning processes tailored to specific situations are given below. The list is not meant to be complete.

◗ A. Situation: Organic Fouling, no Biofouling
Cleaning: Soft Alkaline

a. Follow instructions in Section 7.3 and 7.4. Clean each array separately.
b. *Flush with permeate or good quality water* [1] *for 5 minutes.*
c. Prepare cleaning solution:

Na-EDTA	(0.2%)
NaOH	(< 0.1%, pH 11)
Na-Laurylsulfate	(0.1-0.2%) [2]

d. Circulate about 1 hour.
e. *Soak 2-6 hours* [3].
f. Drain the cleaning solution out of the system.
g. Flush with permeate or good quality water for 5 min.

Notes:
- Measure temperature and pH before and during each of the indicated steps.
- Limit temperature to 30°C (86°F).
- Prepare cleaning solution with permeate or good quality water [1].
- Restart the RO plant within 10 hours after finishing the cleaning, or, in cases of prolonged shutdown, preserve the membranes.

◗ B. Situation: Organic Fouling, Biofouling Expected
Cleaning: Soft Alkaline and Disinfection

a. Follow instructions in Section 7.3 and 7.4. Clean each array separately.
b. Flush with permeate or good quality water [1] for 5 minutes.
c. Prepare cleaning solution:

Na-EDTA	(0.2%)
NaOH	(< 0.1%, pH 11)
Na-Laurylsulfate	(0.1-0.2%) [2]

d. Circulate about 1 hour.
e. Soak 2-6 hours [3].
f. Drain the cleaning solution out of the system.
g. Flush with permeate or good quality water for 5 min.
h. Prepare a 0.5-1% formaldehyde [4] solution.
i. Circulate about 45-60 minutes.
j. Drain formaldehyde solution out of system.
k. Flush the plant with permeate or good quality water [1] for about 10 to 15 minutes.

Notes:
- Measure temperature and pH before and during each of the indicated steps.
- Limit temperature to 30°C (86°F).
- Prepare cleaning solution with permeate or good quality water [1].
- Restart the RO plant within 10 hours after finishing the cleaning, or, in cases of prolonged shutdown, preserve the membranes.

[1] Filtered water, SDI < 3, free of bacteria and chlorine, conductivity < 10,000 µs/cm.
[2] Na-Laurylsulfate improves cleaning, but it can be omitted in case it is not available.
[3] The soaking time can be reduced to about 2 hours if the cleaning solution is recirculated every 30 minutes for about 10-30 minutes.
[4] Refer to Section 7.7.2 for cautions when using formaldehyde with FT30 membrane.

◗ C. Situation: Carbonate Scaling, Metal Oxides, Hydrolyzed SHMP *
Cleaning:

a. Follow instructions in Section 7.3 and 7.4. Clean each array separately.
b. Flush with permeate or good quality water [1] for 5 minutes.
c. Prepare cleaning solution: 0.7% Henkel P3-ultrasil 70.
d. Circulate about 20 min at 30-35°C (86-95°F) or 30 min at 20-30°C (68-86°F).
e. Drain the cleaning solution out of the system.
f. Flush with permeate or good quality water [1] for 5 min.
g. Restart the RO plant, and after stabilization of the operation (about 1 hour after steady operation) measure operating parameters to control efficiency of the cleaning.

Notes:
- Measure and record temperature and pH before and during each of the indicated steps.
- Prepare cleaning solution with permeate or good quality water [1].
- In case the pH of the freshly prepared cleaning solution increases by more than 1 pH unit during recirculation (e.g. from pH 2.5 to pH 3.8 after 5 minutes recycle), please adjust the pH to the original one by carefully adding concentrated cleaning chemical.

* Sodium hexa meta phosphate can precipitate as calcium phosphate, when hydrolyzed.
[1] Filtered water, SDI < 3, free of bacteria, conductivity < 10,000 µS/cm.

◗ D. Situation: Type of Foulants not Known
Cleaning: Soft Alkaline / Disinfection / Acid

a. Follow instructions in Section 8.3 and 8.4. Clean each array separately.
b. Flush with permeate or good quality water [1] for 5 minutes.
c. Prepare cleaning solution:

Na-EDTA	(0.2%)
NaOH	(< 0.1%, pH 11)
Na-Laurylsulfate	(0.1-0.2%) [2]

d. Circulate about 1 hour.
e. Soak 2-6 hours [3].
f. Drain the cleaning solution out of the system.
g. Flush with permeate or good quality water [1] for 5 min.
h. Prepare a 0.5-1% formaldehyde [4] solution.
i. Circulate about 45-60 minutes.
j. Drain formaldehyde solution out of system.
k. Flush the plant with permeate or good quality water [1] for about 10 to 15 minutes.
l. Prepare a 0.1% HCl solution (pH » 2).
m. Circulate about 1 hour.
n. Flush the plant with permeate or good quality water [1] for about 10 to 15 minutes.

Notes:
- Measure temperature and pH before and during each of the indicated steps.
- Limit temperature to 30°C (86°F).
- Prepare cleaning solution with permeate or good quality water [1].
- Restart the RO plant within 10 hours after finishing the cleaning, or, in cases of prolonged shutdown, preserve the membranes.

[1] Filtered water, SDI < 3, free of bacteria and chlorine, conductivity < 10,000 µs/cm.
[2] Na-Laurylsulfate improves cleaning, but it can be omitted in case it is not available.
[3] The soaking time can be reduced to about 2 hours if the cleaning solution is recirculated every 30 minutes for about 10-30 minutes.
[4] Refer to Section 7.7.2 for cautions when using formaldehyde with FT30 membrane.

7.9 Emergency Cleaning

When cleaning has not been carried out in time, e.g. the differential pressure Δ P has already doubled, or the normalized product flow has dropped by 50%, the success of previously described cleaning processes may be limited. If those standard cleaning techniques fail to remove the foulants, more harsh cleaning methods can be tried.

Please contact your Dow representative for recommendations. It has to be stressed however, that no warranty can be given on the efficiency of any cleaning, nor on the membrane performance after such cleaning attempts.