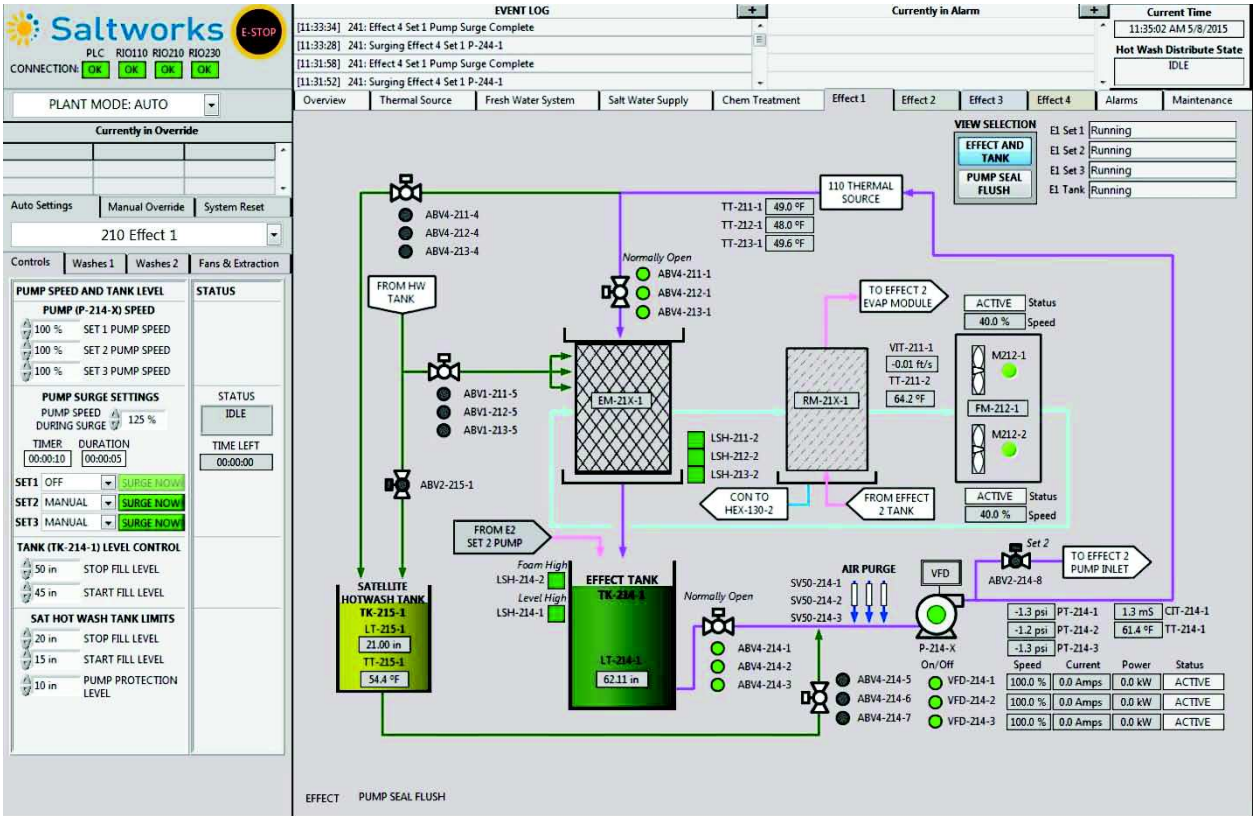

Figure 6: **Effect 1 HMI**

(Numbers on this screenshot are not representative of process setpoints)

5.2 Effect 1-4 Auto Settings

Descriptions of the settings found under Effect 1 “Controls” tab are listed below in Table 6 :

Table 5 : **SaltMaker Effect Controls**

Setting	Component	Control Function
Pump Settings	Set 1 Pump Speed *Reference (100 %)*	Controls Set 1 Pump speed during normal operation. The pump speed setting should not exceed 60 Hz.
	Set 2 Pump Speed *Reference (100 %)*	Controls Set 2 Pump speed during normal operation. The pump speed setting should not exceed 60 Hz.
	Set 3 Pump Speed	Controls Set 3 Pump speed during normal operation. The pump speed setting should not

	Reference (100 %)	exceed 60 Hz.
Pump Surge Settings	Pump Speed During Surge *Reference (125 %)*	This is the pump speed setting during a surge event. A surge periodically increases flow during operation to break any salt build-up.
	Timer *Reference (00:00:10)*	The time interval between surge events.
	Duration *Reference (00:00:05)*	The length of time of surge events.
	Surge (Off/Manual/Timer)	**OFF** – Pump surging is not triggered in the selected set. **MANUAL** – The operator can manually start a pump surge in the selected set with the "Surge Now" button. **TIMER** – Pump surge in the selected set is automatically triggered by timers or manually by operator pressing the "Surge Now" button.
	Surge Now	Triggers a pump surge in the selected set immediately if the Surge Mode setting is set to MANUAL or TIMER.
Tank Level Setting	Stop Fill Level *Reference (50 in)*	The level at which the brine tank stops filling.
	Start Fill Level *Reference (45 in)*	The level at which the brine tank starts filling. This setting must be above the tank outlet**.**
Sat Hot Wash Tank Limits	Stop Fill Level *Reference (20 in)*	The level at which the hot wash tank stops filling.
	Start Fill Level *Reference (15 in)*	The level at which the hot wash tank starts filling.
	Pump Protection Level *Reference (10 in)*	This is level in which the wash pump will stop running to prevent the pump from emptying the tank and running dry.

5.3 Effect 1-4: Washes 1 Menu

The "Washes 1" menu contains the settings for performing the following washes:

- Pipework Wash ("Hot Wash")
- Shutdown Wash

Pipework Wash ("Hot Wash")

The pipework wash, or "hot wash," is for flushing the piping, heat exchanger and pump with hot fresh water. This hot wash can be initiated manually by the operator, or automatically by timer or pump load, set by the operator.

Once the pipework wash is initiated (either manually or automatically), the main hot wash tank fills the satellite hot wash tank for the effect. When the tank is filled to the operator setpoint, the hot wash tank fill pump turns off and the saltwater inlet valves close. The pipework air purge valve opens to allow compressed air to enter the piping to push the saltwater back into the cone tank. The pipework is then allowed to drain for a short duration, before the hot wash inlet valve opens. The hot water runs in a closed loop through the piping, pump, heat exchanger, and back to the satellite hot wash tank. Once the hot wash is finished in the first set, the same procedure is performed in the remaining sets. For the final set, instead of returning the hot wash water back to the satellite tank, the hot wash water is recycled back into the main Effect tank. The duration of the air purging, draining and pipework washing are set by the operator.

For both the manual and auto hot wash, the wash cleans all the sets within the effect regardless of which set triggered the hot wash cycle. Additionally, the hot wash cycle begins cleaning a different set each time (i.e. if the order of the sets cleaned was Set 1, Set 2, Set 3 in the first hot wash cycle, the next hot wash cycle will clean the sets in the following order: Set 2, Set 3, Set 1, etc.).

Shutdown Wash

A Shutdown Wash is a full pipework wash automatically performed on each set when a plant shutdown has been triggered. To prevent salt build-up in the pipelines, a shutdown wash should always be performed during a plant shutdown.

The following table describes each control in the "Washes 1" menu in detail.

Table 6 : **SaltMaker Effect 1 Washes 1**

Setting	Component	Control Function
Wash Settings	Effect Wash Delay *Reference (00:01:30)*	This timer controls how long a set can run before the next hot wash cycle starts. Set Wash Control needs to be set to "Timer" for this to take effect.
Hot Wash Settings	Pump Speed During Wash (100 %)	Controls pump speed during wash cycle
	Pump Load (2 KW)	This is the limit to the load on the pump before a hot wash is triggered to clean the pipework in order to reduce the pump load.
	# of Washes before Drain *Reference (50)*	Number of cycles before recycled wash water is discharged and refreshed.
	Timer *Reference (12:00:00)*	The time interval between two hot wash cycles in the sets.
	Air Purge Duration	The time interval where compressed air is

	Reference (00:00:30)	sent through the pipework system to push any fluid back to respective tank, and helps to remove any salt build-up from the pipework system
	Drain Duration *Reference (00:05:00)*	The length of time for allowing fluid in the pipework to drain before the hot wash pump turns on.
	Hot Wash Duration *Reference (00:07:00)*	Time interval for hot wash water to circulate through pipework system.
	Evaporator Wash Duration *Reference (00:00:00)*	Time interval for hot wash water to wash the evaporator before the hot wash is complete.
	Set Wash Control (Off/Manual/Timer)	**OFF** – hot wash is not triggered in the selected set. **MANUAL** – The operator can manually start a hot wash in the selected set with the "Surge Now" button. **TIMER** – hot wash in the selected set is automatically triggered by timers or manually by operator pressing the "Wash Now" button.
	Wash Now	This immediately triggers the hot wash in the respective set, if "Set Wash Control" is set to MANUAL or TIMER.
Shutdown Wash Settings	Enabled	Enables the shutdown wash for the selected effect. The shutdown wash should always be enabled to minimize salt build-up.
	Air Purge Duration *Reference (00:00:30)*	Time interval where compressed air is sent through the pipework system to push any fluid back to respective tank, and helps to remove any salt build-up from the pipework system. This setting is applied during shutdown.
	Drain Duration *Reference (00:05:00)*	The length of time for allowing fluid in the pipework to drain before the hot wash pump turns on. This setting is applied during shutdown.
	Hot Wash Duration *Reference (00:07:00)*	Time interval for hot wash water to circulate through pipework system. This setting is applied during shutdown.
	Evap Module Wash Duration *Reference (00:00:05)*	Time interval for hot wash water to wash the evaporator before the hot wash is complete. This setting is applied during shutdown.

5.4 Effect 1-4: Washes 2 Menu

The "Washes 2" menu contains settings for performing the following washes:

- Evaporator Spray
- Evaporator Wash
- Air Purge
- Pump Seal Flush

Evaporator Spray

The evaporator spray cleans the evaporator fill. Nozzles are mounted inside the evaporator to increase the effectiveness of the spray. When an evaporator spray is triggered, the effect pumps stop before the valves for the evaporator spray wash open. The hot water for the evaporator spray wash is supplied by the main hot wash system instead of the satellite hot wash tanks in each effect.

Evaporator Wash

The evaporator wash is a short wash that cleans the salt water pump, piping, heat exchanger and evaporator. It is designed to reduce salt build-up with minimum downtime. When an evaporator wash is triggered, the Effect satellite hot wash tanks fill up before the salt water inlet valves close and hot wash inlet valves open. Hot water is sent through the pump and into the piping, flowing through the heat exchanger and into the evaporator modules. Normal SaltMaker operation resumes immediately after this burst of hot water is sent through the system.

Air Purge

While a full hot wash cleans the pipelines, pumps and heat exchanger thoroughly, the hot wash water recycled back into the main tank dilutes the salt water. If cleaning is required while the diluting of the salt water is undesired, a separate air purge can be performed, triggered manually or automatically based on timer setting. The air purging process is identical to the air purge part of a full hot wash.

Pump Seal Flush

The pump seal flush is a short hot wash that directs water to the pump seal to prevent salt build-up.

Table 7: **SaltMaker Effect 1 Washes 2 Controls**

Setting	Component	Control Function
Evaporator Module Spray Settings	Timer *Reference (04:00:00))*	This timer controls how long an evaporator can be in service before the next nozzle spray cycle. This setting is only active if at least one of the sets is set to "timer"
	Duration *Reference (00:00:05)*	This is the time interval for the evaporator nozzle sprays to clean the evaporator.

	Set (Off/Manual/Timer)	**OFF** – Evaporator spraying is not triggered in the selected set. **MANUAL** – The operator can manually start an evaporator spray in the selected set with the "Spray Now" button. **TIMER** – Evaporator spraying in the selected set is automatically triggered by timers or manually by operator pressing the "Spray Now" button.
	Spray Now	Triggers an evaporator spray in the selected set immediately if the Evaporator Spray Mode setting is set to MANUAL or TIMER.
Evaporator Module Wash Settings	Timer *Reference (04:00:00)*	This timer controls how long the set can be in service before the next evaporator wash cycle. This setting is only active if at least one of the sets is set to "timer". The wash cycle diverts wash water to the main pump and through the evaporator.
	Duration *Reference (00:00:05)*	This is the time interval for water to transfer through the main pump and piping to the evaporator for washing.
	Set (Off/Manual/Timer)	**OFF** – Evaporator washing is not triggered in the selected set. **MANUAL** – The operator can manually start an evaporator wash in the selected set with the "Wash Now" button. **TIMER** – Evaporator washing in the selected set is automatically triggered by timers or manually by operator pressing the "Wash Now" button.
	Wash Now	Triggers an evaporator wash in the selected set immediately if the Evaporator Wash Mode setting is set to MANUAL or TIMER.
Air Purge Setting	Timer *Reference (04:00:00)*	This timer controls how long the set can be in service before the next air purge.
	Air Purge *Reference (00:00:30)*	This timer controls how long the air purge lasts after it has been triggered.
	Drain *Reference (00:03:00)*	This timer controls the length of the draining time after the air purge.
	Set (Off/Manual/Timer)	**OFF** – Air purge is not triggered in the selected set. **MANUAL** – The operator can manually start an

		air purge in the selected set with the "Surge Now" button. **TIMER** – Air purge in the selected set is automatically triggered by timers or manually by operator pressing the "Purge Now" button.
	Purge Now	Triggers an air purge in the selected set immediately if the Air Purge Mode setting is set to MANUAL or TIMER.
Pump Seal Flush Settings	Timer *Reference (00:04:00)*	This timer controls how long the set can be in service for before a pump seal wash action happens.
	Duration *Reference (00:00:05)*	This is the time interval how long the pump seal wash will go for when the action is triggered.
	Set (Off/Manual/Timer)	**OFF** – Pump seal flushing is not triggered in the selected set. **MANUAL** – The operator can manually start a pump seal flush in the selected set with the "Flush Now" button. **TIMER** – Pump seal flush in the selected set is automatically triggered by timers or manually by operator pressing the "Flush Now" button.
	Flush Now	Triggers a pump seal flush in the selected set immediately if the Pump Seal Flush Mode setting is set to MANUAL or TIMER.

5.5 Effect 1-4: Fans & Extraction

VFD-driven fan modules are installed to introduce air flow into the sets to move the moistened air from the evaporators to condensers. The fan speed can be controlled to ensure maximum capacity and efficiency.

Table 8: **SaltMaker Effect 1 Fans & Extraction Controls**

Setting	Component	Control Function
Fan/Slurry/Auger Control	Fan Speed Control *Reference (100 %)*	Controls fan speed in specific Effect Set.

6 Effect 2 – 3 Specific Controls

As Effects 2 and 3 are designed to operate at higher concentration with salt extraction system, the HMI for these two Effects have extra controls for components which do not exist in Effects 1 and 4. Due to the higher concentration, salt build-ups are more likely to occur in the Effects 2 and 3 cone tanks. To prevent salt build-up, vibrators, powered by compressed air, are installed in these cone tanks to agitate the tank contents periodically.

Salt extraction is also performed in Effects 2 and 3 cone tanks. Two methods of salt extraction are available – extraction by slurry pump and extraction by auger. Concentrated brine near saturation can be extracted by slurry pumps. Augers are used for extracting solid waste at the bottom of the cone tank if the application requires ZLD (zero liquid discharge).

6.1 Effect 2 & 3: Fans & Extraction Controls

Table 9: **SaltMaker Effect 2 Fans & Extraction Controls**

Setting	Component	Control Function
Fan/Slurry/Auger Control	Fan Speed Control	Controls fan speed in specific Effect Set.
Cone Tank Vibration Trigger	Mode	**OFF** – Cone tank vibrators are not triggered. **MANUAL** – The operator can manually trigger the cone tank vibrators with the "Vibrate" button. **TIMER** – Cone tank vibrators are automatically triggered by timers or manually by operator pressing the "Vibrate" button.
	Manual	The user can trigger a vibrate sequence immediately if mode is set to Manual or Timer mode.
	Timer *Reference (00:10:00)*	This is the length of time between each time the vibrator goes on in timer mode.
	Duration *Reference (00:00:20)*	This is the length of time for how long the vibrator stays on when the action is triggered.
Slurry Circulate / Discharge	Mode (Off/Manual/Timer/ Conductivity)	**OFF** – Slurry extraction is not triggered. **MANUAL** – The operator can manually trigger the slurry extraction sequence with the "Discharge" button. **TIMER** – Slurry extraction is automatically triggered by timers or manually by operator pressing the "Discharge" button. **CONDUCTIVITY** – Slurry extraction and

		circulation are triggered based on conductivity in the cone tank.
	Manual	The user can trigger an extraction sequence immediately. This button is only active if slurry extraction mode is set to MANUAL or TIMER.
	Timer *Reference (00:10:00)*	The length of the down time between the extraction sequences. Triggering of slurry extraction by this timer is only active if slurry extraction mode is set to TIMER.
	Duration *Reference (00:00:10)*	The length of time for how long the extraction sequence will go for when the action is triggered. Triggering of slurry extraction by this timer is only active if slurry extraction mode is set to TIMER.
Slurry Discharge	Conductivity High Start Discharge *Reference (200 mS)*	The conductivity level in the effect tank at which the slurry pump switches to discharge from circulation.
	Discharge Trigger Delay *Reference (00:00:10)*	The length of delay that the system waits before switching to slurry discharge.
Slurry Circulation	Conductivity Low Start Circulation *Reference (100 mS)*	The conductivity level in the effect tank at which the slurry pump switches to circulation from discharge.
	Circulation Trigger Delay *Reference (00:00:10)*	The length of delay that the system waits before switching to slurry circulation.

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SaltMaker: Appendix E Spare Parts List		
Part description	**Saltworks #**	**Quantity**
Electrical components		
PLC relay, 24VDC	1000743	4
Meltric connector set	1002133	2
Wieland RST AC connectors for electrical infrastructure: RST20i3	1001462	1
Wieland RST AC connectors for electrical infrastructure: RST20i3	1001463	1
Spare Cables		
Single pair instrumentation cable, quantity in m	1001286	300
Instrumentation cable 2 pair, quantity in m	1001287	200
Tray cable, 4C (3+G), 12awg, 600V rated	1001277	50
Tray cable, 3C (2+G), 12awg, 600V rated	1001276	50
Ethernet Cable, 1000FT ROLL	1001323	1
Instrumentation components		
Air Pressure transducer	1000776	1
Temperature transducer	1000768	1
Level Switch Ultrasonic	1001582	2
pH sensor probe, Foxboro	1000789	1
Level Switch, Cable float, finetek	1000770	2
Level Switch, Cable float, weight	1000771	2
Conductivity probe: toroidal conductivity, Foxboro	1000778	1
Fuses		
250A Fuse	1001713	3
0.25A glass fuse: 5 per box	1001721	4 boxes of 5
1A glass fuse: 5 per box	1001722	2 boxes of 5
2A glass fuse: 5 per box	1001723	2 boxes of 5
4A glass fuse: 5 per box	1001724	2 boxes of 5
5A glass fuse: 5 per box	1001725	2 boxes of 5
1A class CC fuse, 10 per box	1001981	3
2A class CC fuse, 10 per box	1001718	5
5A class CC fuse, 10 per box	1001720	5
8A class CC fuse, 10 per box	1001719	2
10A class CC fuse, 10 per box	1001714	1 box of 10
15A class CC fuse, 10 per box	1001715	1 box of 10
20A class CC fuse, 10 per box	1001716	1 box of 10
25A class CC fuse, Time delay, , 10 per box	1001717	6
Pumps and motors		
MDM Genesys pump (prebuilt with fittings)		1
MDM Genesys pump head (pump head, adapter bracket, shaft adapter, impeller and seal)		3
MDM Genesys pump seals		10
Plumbing fittings		
4" CPVC pipes, 5.8 m long	1001332	3
1" bulkhead fittings, PP, EPDM	1000984	7
1" clear PVC pipe, 3 meters long	1001584	3
1" NPT 45 deg fitting	1001002	7
1" PVC close nipple	1000924	12
1" PVC couples	1001380	7
1" PVC elbows (ANSI)	1001019	8
1" PVC male adapters	1000962	7
1" PVC pipes, 5.8 m long	1001325	7
1" PVC plug	1001088	7
1" PVC true union ball valves	1001234	7
1" PVC unions (ANSI)	1001142	8
1" PVC unions (NPT)	1001151	8
2" builkhead fittings	1000640	6
2" CPVC couples	1000835	5
2" CPVC elbows (ANSI)	1001022	5
2" CPVC unions (ANSI)	1001143	6
2" CPVC unions (NPT)	1001156	6
2" PVC close nipple	1000793	6
2" PVC couples	1000694	5
2" PVC elbow	1001025	6
2" PVC male adapter	1000691	6
2" PVC pipes, 5.8 m	1001328	6
2" PVC true union ball valve (ANSI)	1001242	6
2" PVC true union ball valve (NPT)	1001243	6
2" pvc unions (ANSI)	1001154	6
2" pvc unions (NPT)	1001141	6
3" PVC van stone flange	1001043	2
4" builkhead fittings	1000987	3
4" CPVC couples	1000836	3
4" CPVC elbows	1001033	4
4" CPVC unions (ANSI)	1001165	3
4" PVC couples	1000695	3
4" PVC elbows	1001034	4
4" PVC male adapter	1001566	3
4" PVC true union ball valve (ANSI)	1001252	3
4" PVC unions	1001166	3
4"PVC pipes, SCH80 5.8m long	1001332	4
4" x 2" PVC bushing (ANSI x ANSI)	1000705	2
4" x 2" CPVC bushing (ANSI x ANSI)	1000842	2
2" x 1" PVC bushing (NPT x NPT)	1000717	6

2" x 1" CPVC bushing (NPT x NPT)	1000854	6
2" x 1" PVC bushing (ANSI x ANSI)	1000700	3
2" x 1" CPVC bushing (ANSI x ANSI)	1000840	3
1" x 1/2" PVC bushing (NPT x NPT)	1001404	6
1" x 1/2" CPVC bushing (NPT x NPT)	1002213	6
1/2" x 1/4" PVC bushing (NPT x NPT)	1000865	6
1/2" x 1/4" CPVC bushing (NPT)	1001414	6
1/2" PVC pipe, SCH 80	1001322	2
1/2" CPVC pipe, 5.8m long	1001321	2
1/2" PVC unions (ANSI)	1001138	6
1/2" CPVC unions (ANSI)	1001132	6
1/2" PVC unions (NPT)	1001139	6
1/2" CPVC unions (NPT)	1001134	6
1/2" PVC elbows (ANSI)	1001012	6
1/2" CPVC elbows (ANSI)	1001008	6
1/2" x 3" PVC nipples	1000666	10
1/2" x 3 " CPVC nipples	1000813	10
4" PVC Van stone flange	1001045	4
4" CPVC van stone flange	1001044	4
2" PVC check valve	1001203	1
1" PVC check valve	1001198	1
1/2" PVC check valve	1001187	1
1" CPVC bulkhead fittings	1000993	2
1" PP bulkhead fitting	1000984	4
1/2" PP bulkhead fitting	1000982	2
2" CPVC Pipe	1001321	4
1" CPVC Pipe	1001324	3
4" O-ring	1001077	40
2" O-ring	1001068	40
1" O-Ring	1001063	20
1/2" O-Ring	1001059	20
4" CPVC MBV	1001271	2
4" CPVC Check Valve	1001253	2
4" CPVC ABV	1001181	1
2" CPVC MBV	1001199	4
2" CPVC Check Valve	1001178	2
2" CPVC ABV	1001242	1
1" CPVC MBV	1001232	6
1" CPVC Check Valve	1001191	4
1" CPVC ABV	1001175	2
1/2" CPVC MBV	1001223	6
1/2" CPVC Check Valve	1001185	2
1/2" CPVC ABV	1002025	1
4" PVC Check Valve	1001271	2
4" PVC ABV	1001183	1
2" PVC ABV	1001178	1
1" PVC ABV	1001176	1
1/2" PVC MBV	1001228	4
1/2" PVC ABV	1002218	1
6" Flange Gasket	1001057	4
4" Flange Gasket	1001056	20
3" Flange Gasket	1001054	10
2" Flange Gasket	1001051	4
4" CPVC blind flange	1001038	2
Hardware and SS fittings		
3/8" x 1.25" long fiberglass bolts (used inside effect modules)	1000480	24
3/8" x 6ft S redirod (spare pipe hangers rods)	1000231	2
1/2" x 6ft S redirod (spare pipe hangers rods)	1000230	2
FRP unistrut x 10ft long	1000167	6
FRP angle, 50mm, 10ft long	1000651	4
Unistrut fitting - 1 x 1 SS L fitting	1000251	10
Unistrut fitting - 2 x 2 SS L Fitting	1000252	6
Unistrut fitting - 1 Hole SS Square washer	1000246	20
Unistrut fitting - 2 hole SS plate	1000247	10
3/8" Spring Nut	1000242	10
1/2" Spring Nut	1000244	20
M- Clip	1000153	26
1/2" UNISTRUT CLAMPS S.S	1000257	6
1" UNISTRUT CLAMP S.S	1000258	6
2" UNISTRUT CLAMPS S.S	1000259	6
4" UNISTRUT CLAMPS S.S	1000260	6
1/2" CLEVIS	1000262	6
1" CLEVIS	1000263	6
2" CLEVIS	1000264	6
4" CLEVIS	1000265	6
3/8" X 1" LONG SS HEX BOLT	1000223	50
3/8" X 1.5" LONG SS HEX BOLT	1000224	50
3/8" X 3" LONG SS HEX BOLT	1000054	20
3/8" X 5.5 LONG SS HEX BOLT	1001741	10
1/4" X 1" LONG SS HEX BOLT	1000053	50
1/4" X 2" LONG SS HEX BOLT	1000229	20
1/4" X 2.5" LONG SS HEX BOLT	1001708	20
1/4" X 5/8" LONG SS SOCKET HEAD, C SUNK BOLT	1001739	50
TECH SCREW, #10, 1" LONG, SS	1000240	50
4" SS riser clamp	1000269	4

2" SS riser clamp	1000268	4
1" SS riser clamp	1000267	4
1/2" SS riser clamp	1000266	4
3/8" Nut	1000058	50
3/8" Flat washer	1000364	100
3/8" Lock Washer	1000062	50
1/2" Nut	1000363	50
1/2" Flat washer	1000214	100
1/2" Lock Washer	1000365	50
5/8" Nut	1000219	50
5/8" Flat washer	1000213	100
5/8" Lock Washer	1002169	50
5/8" x 3.5" hex bolt	1000222	50
3/4" nut	1000137	20
3/4" washer	1001906	40
Misc.		
inflatable seals	1000040	6
pack teflon tape (pink)		3
pack Teflon tape (yellow)		3
Ethernet RJ45 Coupler, water proof plug	1001239	2
computer mouse		1
computer keyboard		1
splash fill nozzles	1002013	12
hotwash spray manifold nozzles	1000272	24
Ti Rad bio film spray nozzles	1002237	6
High Temperature Cartridge Filter Elements for Boiler Skid		3
1/2" union o rings, epdm	1001059	10
1" union o rings, epdm	1001064	20
2" union o rings, epdm	1001068	20
3" union o rings, epdm	1001074	10
4" union o rings, epdm	1001077	20
2" flange gasket, paper	1001051	4
3" flange gasket, paper	1001054	4
4" flange gasket, paper	1001056	12
6" flange gasket, paper	1001057	4
CABLE TIE, HIGH TEMP,14" LONG, 30LBS, PP, UV BLACK	1002238	1000
Air fittings		
Spare 1/2" SS solenoid air valve	1000206	2
Spare 1/4" - push to connect x NPT	1000305	30
Spare 1/2" - push to connect x NPT	1000313	10
Spool Spare 1/4" Air tubing	1000318	1
Spool Spare 1/2" Air tubing	1000319	1
Spare 1/2" tube coupler	1000314	10
Spare 1/4" tube coupler	1000306	20
Spare 1/4" male tube adapter	1000308	10
Spare 1/2" male tube adapter	1000317	10
Spare 1/2" tube bulkhead fittings	1000316	5
Spare 1/4" tube bulkhead fittings	1000309	5
1/2" SS Ball Valve	1001944	2
1/2" SS Elbow	1001345	4
1/2" SS Tee	1001352	4
1/2" SS Nipple x 3"	1001349	6
1/4" push to connect plug	1000307	10
1/2" push to connect plug	1000315	10
3/16" x 1/4" hose barb adapter to male push to connect	1000647	10

Saltworks Technologies Inc.

Appendix F: SaltMaker Critical Tools List		
Part Name	**Quantities**	**Notes:**
Saltworks Provided Tools		
Module removal dolly	1	
Module removal dolly drive socket, 1 1/4" with 1/2" square drive	1	
Ratcheting wrench, 9/16" closed end	2	
Tubing cutter, for 1/4" - 1/2" air tube	1	
air seal installation tool	2	
Saltworks Provided Chemicals		
Boiler Corrosion Inhibitor	5 gallons	
SBS Sodium (meta) bisulfate	5 lbs	Oxygen Scavenger for boiler water
Sodium Hypochlorite 12%	5 gallons	Chlorine for radiator biofouling control
Antifoam	5 gallons	
Site Tools		
9/16" ratchet and wrench	1 per person	most common bolt size
7/16" ratchet and wrench	1 per person	second most common bolt size
1/2" drive heavy duty electric impact drill	1 per dolly	e.g. http://www.canadiantire.ca/en/pdp/tools-hardware/power-tools-accessories/impact-drivers/mastercraft-3ko-corded-impact-wrench-0541216p.html#.UpOWkcQ3t8E High torque is required to drive the modules in and out.
misc. screw drivers (flat, square, #1 Philips, #2 Phillips , etc….)	1 per person	for electrical connections, duct hose clamps, etc.
Misc. sockets and wrenches	1 per person	for pipe hangers, ground clamps, etc.
5.5" channel lock pliers	2	used to tighten unions
2" channel lock pliers	2	used to tighten unions
large, heavy duty chain wrench	1	used to tighten unions, e.g.: rigid C-36
vise-grip style chain wrench with extension chain	2	used to tighten unions, e.g.: Mcarr, 5376A11 and 5376A16
geese gun, 12" whip	1	used to grease fan and motor bearings
6ft heavy duty pry bar	1	used to adjust modules
6ft step ladder	2	used to install under work platform plumbing
exacto knives	2	
adjustable wrench, 8" long	2	
Site Materials and Chemicals		
PVC cement	4L	needed to assemble overflow and feed system
PVC primer	3L	needed to assemble overflow and feed system
CPVC cement	4L	needed to assemble overflow and feed system
Never-seize paste, white	1L	needed to assemble all Stainless steel to Stainless steel bolted connections
Teflon tape (for plastic pipes)	~100 rolls	needed to assemble plastic threaded pipe connections
Teflon Tape (for steel pipes)	~10 rolls	needed to assemble steel threaded pipe connections
Glycerol	<50ml	needed to install replacement pump seals
Thermalmastic	1 tube	needed to install replacement thermal sensors
dow corning molycoat 110, 150gram tube	6	needed to lube union o-rings and union threads
POLYREX EM grease, standard tube	1	used to grease fan motor bearings
lithium based grease, standard tube	1	used to grease fan shaft bearings
electrical joint compound	1 bottle	needed to make ground connections
Installation Equipment and Tools		
A laser level may be helpful to level and align the containers	1	
A forklift will be required to assemble and install the flexible duct support frames (see assembly instructions)		
A crane will be required to unload the trucks and to place the containers and work platforms onto the concrete pad. Max container weight approx. 22,500Lbs		
crane should be equipped with slings long enough and capable of lifting shipping container, effect cages and work platforms		
15 ft extension ladder	1	used to unhook slings when installing containers work platforms and frames
pallet jack	1	used to unload container
3/4" x 2" long eye bolt with a shoulder, load rated	4	used to lift work p[platforms, also as tie off points for fall arrest
fall arrest harness with 10ft leash	2	used to allow workers access to top of container, (depends upon customer site safety requirements)

Saltworks Technologies Inc.

SaltMaker Commissioning Manual

Appendix G

Revision A

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1 Preparation

1.1 Tools Required

- Adjustable Wrench
- Screwdriver Set
- Insulated Screwdriver Set for electrical work
- Multimeter

1.2 Documents Required

- P&ID for the systems being commissioned
- Electrical Schematics and drawings.
- SaltMaker Commissioning Checklist (Appendix H)
- SaltMaker Alarms List for alarm testing (Appendix M)

1.3 Safety Precautions

Only qualified electrical personnel should perform the electrical commissioning activities such as commissioning the main AC panel. Proper lockout procedures should be followed and panels should be electrically isolated before gaining access.

Warning: 480V voltage present when power is turned ON. Take proper pre-cautions and double check isolations before powering up systems and components.

1.3.1 Personal Protective Equipment (PPE)

PPEs Required:

- Hard hat
- High-visibility vest
- Steel-toed boots
- Safety glasses
- Protective gloves

Figure 1: PPE required

2 Physical Inspection of Plant

Physically inspect the entire plant. Mark on P&ID and add tape to identify incomplete work or visible damages, including but not limited to:

- Incomplete installation etc.
- Damaged equipment or cabling
- Problems with electrical and air system:
    - Loose cables
    - Mismatched connections

Warning: before proceeding to commission each individual electrical panel, all wire to terminal block interfaces must be checked for tightness. Wires may get loose from transportation and vibration. Failure to do so may result loose connections leading to burnt blocks and potential fire hazard.

3 Commission the Main AC Control Panel

Make sure power to the plant is locked out.

- Confirm that main ground is securely installed in the panel.
- Check for and secure loose wiring and cabling inside main panel
- Ensure components are securely installed.
- Keep circuit breakers and fuse blocks open.

Visually confirm that it is safe to turn on power to main panel. Turn on power when ready.

Warning: 480V voltage present when power is turned ON.

- Check and confirm that voltages in L1, L2 and L3 matches nameplate.
- Turn on power to one electrical subsystem at a time. Confirm that the sub-system powers up and behaves normally.
- Turn on power to the UPS. Confirm that UPS output is 120V.

4 Commission AC Distribution Service panel

Make sure that power to all circuits is in the “Off” position. Confirm that power to AC service sub-panel is “Off”.

- Inspect electrical cables from AC service sub-panel to lights, receptacles and ventilation. Make sure there are no signs of obvious damage.

Turn on power to main AC service sub-panel. 120/240V is now available to the circuit breakers.

- Turn on each circuit at a time.
- Confirm that branch has power and is functioning properly (e.g. lights turn on, ventilation fan runs, receptacles have power).

5 Commission Main DC Panel

Visually inspect the main DC panel.

- Check and secure loose wiring and cabling inside main DC panel.
- Open up all fuse blocks and/or circuit breakers in the panel.
- Power up DC instrumentation and control power supplies in the Main AC panel. Confirm that their output is 24VDC.

Power up one system at a time.

- IT (e.g. main router, network switches)
- Main PLC and HMI

Commission the E-stop System.

- Hit e-stop to see indicator lights on safety relay turn off.
- Release the e-stop.
- Press e-stop reset on the HMI and check if the indicators lights on the safety relay come back on.
- Hit e-stop reset to engage safety relay.

6 Commission Satellite AC and DC panels

For each panel:

- Check for loose wiring and cabling inside the panel.
- Open all fuse blocks or breakers in the panel.
- Confirm visually that each component is safe to power up. Turn “ON” components one at a time.
- Mark down any discrepancies and problems related to commissioning in the electrical schematics.

7 Commission Air compressor

- Check oil level in air compressor.
- Make sure air lines to each subsystem is isolated.
- Bump the motor and check rotation (switch any 2 phases on the AC feed if rotation is backwards)
- Run air compressor and make sure the pressure indicator on the air tank is increasing and going up to the specified pressure. Confirm that the pressure limit switches cycle the air compressor correctly. (e.g. Air compressor shuts off at high pressure, and turns back on at low pressure). Bleed out some air as needed.

8 Commission Air Panels and Actuated Ball Valves

- Open the air valve to each individual air sub-system, one at a time.
- Confirm there is available air pressure of 90-100 psi at each effect air box.
- Listen and check for air leaks.

ABV Commissioning:

Review the Appendix H Commissioning Checklist for the full list of valves.

- Check if valve indicator indicates correct positioning
- Check NC/NO position as per P&ID and HMI
- Manually override ABVs, confirm that valve actuates.
- ensure state display on HMI matches actual state of ABV
- Check that the position in manual mode matches NO/NC positions as noted on the P&IDs.
- If incorrect, ensure DO is "ON" for the NC valves and "OFF" for the NO valves when valve should be open. One way to check this is to identify the DO module and the channel from the schematics, and look for the output indicator. The indicator will go "green" when the DO for that channel is "ON". If DO is correct, pneumatic air-lines may need to be swapped.
- Record the valve results on Appendix H.
- Commission solenoid valves. Check for HMI lights and actuation.

Note 1: All manual valves are normally open, except for drain, wash, and sample valves.

Note 2: Ensure there is a fuse schedule inside control panels.

9 Commission equipment (e.g. Motors, VFDs)

Review the Appendix H Commissioning Checklist for the full list of motors.

- Ensure utility water supply is available for commissioning.
- Make sure pumps are primed.
- Put in equipment fuses in the corresponding AC panel. For motor protectors, confirm over current protection setting and turn the motor protector ON. If unsure, the full load amperage (FLA) on motor nameplate and set protection to 110%-125% of FLA.
- Put the motor or pump in manual override on the HMI.
  - Bump the pumps to check on/off.
  - Check for direction of rotation.
- Bump the fans to check on/off, rotation and speed control.

For E2 and E3:

If auger is present: check on/off, speed control, forward and reverse operation.
If slurry pump is present: check on/off, rotation.

Commissioning heater control panel for the hot wash system:

- Manually enable the heater on the HMI. Confirm that there is power to the panel.
- Confirm that the pressure switch protects the heater.
- Ensure heater turns on/off.
- Test temperature and pressure controls.

10 Commission Instruments

Review the Appendix H Commissioning Checklist for the full list of instruments.

- Put in instrument fuses and check 4-20mA input reading for transmitters. Confirm feedback signal for switches. Calibrate as required.

Type of Instrument	Check Calibration after
Level Transmitter (LT)	Check when filling tanks with freshwater during plant leak test procedure.
Temperature Transmitter (TT)	Confirm with temperature indicator (TI)
Conductivity Transmitter (CT)	Confirm inline readings match handheld reading in process sample. This should be done with salt water or waste feed.
pH Transmitter (AIT)	Confirm inline readings match handheld reading in process sample. This should be done with salt water or waste feed.
Pressure Transmitter (PT)	Calibration can be checked after process finishes start up and is operating in steady state. Confirm that PT reading corresponds to pressure gauge (PI) reading.

11 Plant Leak Test

Ensure pumps are primed! Do not run pumps dry!

- Fill Plant with Freshwater (turn on HMI, Manual mode)
- Feed System to fill E1, E2, E3, and E4 with water.
- Also test transfer from E1 to E2, and E4 to E3
    - Check for leaks
    - Calibrate Level sensors (LT) as the Effect tanks fill up with water.
    - Ensure tanks do not overfill
    - Manually fill up condensate tank. Test transfer from Condensate tanks to the main Hot wash tank, and then distribute to E1, E2, E3, and E4 satellite tanks
- Start-up E1 pumps (for S1, S2, and S3) on the HMI in manual mode.
    - Check VFD speed control. Ensure VFD responds to changes in operator input.
    - Check for leaks
    - Check PTs are registering pressure, ensure air is vented out of lines
    - Recommended pressure range = 15-30 psi
- Repeat for all 4 effects
- Run hot wash system, biofilm and antifoam system (test all pipework for leaks).
- Allow plant to circulate for a couple hours and note any leaks.
- Ensure the plant is sufficiently leak- free before advancing to the next step.

12 Commission Controls for Individual Modules

Once plant is leak-free, and all valves, equipment and instruments are confirmed functional, commission controls for each equipment module (subsystem) separately.

Ensure that each equipment module:

- displays the correct configuration on the HMI
- displays the proper reading on the HMI. (i.e. the correct valves are open/closed, the correct equipment is on/off etc.)

Equipment Module	**States**
Effect Sets (3x modules/Effect, 4 Effects; **Total = 12 equipment modules**)	• Stop • Running • Hot Wash (pipework) • Air Purge • Evaporator (slug) wash • Pump Surge • Transfer Brine • Drain • Trip
E1: Set 1, Set 2, Set 3	
E2: Set 1, Set 2, Set 3	
E3: Set 1, Set 2, Set 3	
E4: Set 1, Set 2, Set 3	
Effect Tanks (1x modules/Effect, 2 Effects; **Total = 2 equipment modules**)	• Cone Tank vibration • Slurry or Brine Extraction • Off • Cool Down • Trip
E2: Tank	
E3: Tank	

Once the individual modules of each Effect is commissioned, commission the entire Effect.

Effect	States
Effect 1	• Stop • Running • Shutdown • Trip • Air Purge • Flush Pump Seal • Hot wash set (pipework hot wash) • Evaporator Wash Set • Spray Set Packing • Surge Set Pump • Trip Set • Slurry Extraction • Cone Tank Vibration **Note:** when running through the different states, ensure that the washes on the set occur one set at a time.
Effect 2	
Effect 3	
Effect 4	

Once the individual effects are commissioned, commission the Balance of Plant systems.

BoP System	States
Saltwater Supply System	• Stop • Fill E1, E2, E3, E4 • Hot wash (Pipework and HEX) • Air Purge • Trip
Hot Wash System	• Stop • Heating Cycle • Distribute E1, E2, E3, E4 • Distribute Other ○ Pump seal flush

	○ Packing wash ○ Saltwater Supply System • Trip
Condensate System	• Stop • Transfer • Discharge • Trip
Antifoam/Acid Dosing Systems	• Stop • Distribute E1, E2, E3, E4 • **Antifoam Only:** Cycle • Trip
Biofilm	• Stop • Distribute E1, E2, E3, E4 • Trip

Note: Refer to SaltMaker Control Philosophy document (available from electrical & controls team) for details regarding sequences and equipment states associated with equipment module states.

13 Commission Plant Control

Start Plant in Auto (Normal mode).
Check that Level Control is functioning properly.
Initiate all washes.

- Hotwash (Pipework)
- Spray Set Packing
- Evaporator Wash (Slug)
- Air purge
- Pump seal flush
- Pump surge

Swap Concentration. Operate in SWUNG mode

- Initiate washes again

Check Alarms/Trips. Use the SaltMaker Alarm List (Appendix M).

- Ensure that the alarm trip shows on HMI
- Ensure that the plant takes appropriate action when tripped.

Check shutdown wash sequence.

13.1 Thermal Commissioning

Thermal commissioning can be completed with salt water or utility water.

The thermo-source supply to the SaltMaker can be customer's own waste heat source or Saltworks' Thermal package. Commissioning this system is not within the scope of document. Please refer to manufacturers' commissioning manual and follow their procedures.

Once the thermo-source supply system has been commissioned, run plant with heat supply on. Ensure the condensed water drain is recycled back to plant feed.

- Set temperature setpoint to 90ºC.
- Run plant for a few hours. Check and record leaks. And ensure temperature controls are working.

Warning: when running water at high temperatures during commissioning, keep away from hot pipes and plumbing. Weakness in pipe units and connection plants may lead to sudden release of hot fluid that could cause serious burns. Wear protective coveralls for extra protection.

SaltMaker: Instrument Commissioning List

P&ID Tag	Description	Installed	Reading 4-20mA	Raw Range	Scaled Range	Calibrated (Y/N)	Displayed on HMI	Notes
PT_120_1	Hot Wash Pump Pressure							
LT_120_2	Hot Wash Tank Level							
TT_120_1	Hot Wash Tank Temperature							
TT_120_2	Hot Water Heater Outlet Temperature							
PT_142_1	Balance of Plant 2 Container Compressed Air Pressure							
PT_234_1	E3-S1 Pump Outlet Pressure							
PT_234_2	E3-S2 Pump Outlet Pressure							
PT_234_3	E3-S3 Pump Outlet Pressure							
CIT_234_1	E3-S2 Pump Outlet Conductivity							
TT_234_1	E3-S2 Pump Outlet Temperature							
LT_234_1	E3 Tank Cone Tank Level							
AIT_234_1	E3-S2 Pump Outlet pH							
PT_244_1	E4-S1 Pump Outlet Pressure							
PT_244_2	E4-S2 Pump Outlet Pressure							
PT_244_3	E4-S3 Pump Outlet Pressure							
CIT_244_1	E4-S2 Pump Outlet Conductivity							
TT_244_1	E4-S2 Pump Outlet Temperature							
LT_244_1	E4 Tank Cone Tank Level							
AIT_244_1	E4-S2 Pump Outlet pH							
PT_140_1	Plant Installed Air Pressure							
PT_140_2	Air Purge Valves Installed Air Pressure							
ACCESSORY_AI_1	Accessory AI 1							
ACCESSORY_AI_2	Accessory AI 2							
TT_110_1	H.E. S1 HEATED SALT WATER TEMPERATURE							
TT_110_2	H.E. S2 HEATED SALT WATER TEMPERATURE							
TT_110_3	H.E. S3 HEATED SALT WATER TEMPERATURE							
CIT_120_1	CONDENSATE TANK CONDUCTIVITY							
LT_120_1	CONDENSATE TANK LEVEL							
AIT_130_1	SALT WATER SUPPLY PH							
CIT_130_1	SALT WATER SUPPLY CONDUCTIVITY							
FIT_130_1	SALT WATER SUPPLY FLOW							
LT_130_1	PLANT INLET AND OVERFLOW TANK LEVEL							
TT_130_1	SALT WATER SUPPLY BEFORE EXCHANGE TEMPERATURE							
TT_130_2	SALT WATER SUPPLY AFTER EXCHANGE TEMPERATURE							
PT_141_1	Balance of Plant 2 Container Compressed Air Pressure							
PT_214_1	E1-S1 SALT WATER PRESSURE							
PT_214_2	E1-S2 SALT WATER PRESSURE							
PT_214_3	E1-S3 SALT WATER PRESSURE							
CIT_214_1	E1-S2 SALT WATER CONDUCTIVITY							
TT_214_1	E1-S2 SALT WATER TEMPERATURE							
LT_214_1	E1 TANK LEVEL							
AIT_214_1	E1-S2 SALT WATER PH							
PT_224_1	E2-S1 SALT WATER PRESSURE							
PT_224_2	E2-S2 SALT WATER PRESSURE							
PT_224_3	E2-S3 SALT WATER PRESSURE							
CIT_224_1	E2-S2 SALT WATER CONDUCTIVITY							
TT_224_1	E2-S2 SALT WATER TEMPERATURE							
LT_224_1	E2 TANK LEVEL							
AIT_224_1	E2-S2 SALT WATER PH							
PT_216_1	E1 AIR SYSTEM PRESSURE							
TT_211_1	E1-S1 SALT WATER IN TEMPERATURE							
TT_212_1	E1-S2 SALT WATER IN TEMPERATURE							

TT_213_1	E1-S3 SALT WATER IN TEMPERATURE							
FIT_211_1	E1-S1 EVAPORATE AIR FLOW							
TT_211_2	E1-S1 EVAPORATE AIR TEMPERATURE							
TT_221_1	E2-S1 SALT WATER IN TEMPERATURE							
TT_222_1	E2-S2 SALT WATER IN TEMPERATURE							
TT_223_1	E2-S3 SALT WATER IN TEMPERATURE							
FIT_221_1	E2-S1 EVAPORATE AIR FLOW							
TT_221_2	E2-S1 EVAPORATE AIR TEMPERATURE							
LT_215_1	E1 SATELLITE HOTWASH LEVEL							
TT_215_1	E1 SATELLITE HOTWASH TEMPERATURE							
LT_225_1	E2 SATELLITE HOTWASH LEVEL							
TT_225_1	E2 SATELLITE HOTWASH TEMPERATURE							
PT_236_1	E3 AIR SYSTEM PRESSURE							
TT_231_1	E3-S1 SALT WATER IN TEMPERATURE							
TT_232_1	E3-S2 SALT WATER IN TEMPERATURE							
TT_233_1	E3-S3 SALT WATER IN TEMPERATURE							
FIT_231_1	E3-S1 EVAPORATE AIR SPEED							
TT_231_2	E3-S1 EVAPORATE AIR TEMPERATURE							
TT_241_1	E4-S1 SALT WATER IN TEMPERATURE							
TT_242_1	E4-S2 SALT WATER IN TEMPERATURE							
TT_243_1	E4-S3 SALT WATER IN TEMPERATURE							
TT_243_2	E4-S1 EVAPORATE AIR TEMPERATURE							
TT_241_2	E4-S1 EVAPORATE AIR TEMPERATURE							
LT_235_1	E3 SATELLITE HOTWASH LEVEL							
TT_235_1	E3 SATELLITE HOTWASH TEMPERATURE							
LT_245_1	E4 SATELLITE HOTWASH LEVEL							
TT_245_1	E4 SATELLITE HOTWASH TEMPERATURE							
YSH_160_1	BOP 2 SMOKE DETECTOR							
YSH_160_2	BOP 2 SMOKE DETECTOR							
LSH_234_1	E3 TANK LEVEL SWITCH							
LSH_244_1	E4 TANK LEVEL SWITCH							
LSH_234_2	E3 ANTIFOAM LEVEL SWITCH							
LSH_244_2	E4 ANTIFOAM LEVEL SWITCH							
ACCESSORY_DI_1	ACCESSORY DI 1							
ACCESSORY_DI_2	ACCESSORY DI 2							
LSH_214_1	E1 TANK LEVEL SWITCH							
LSH_224_1	E2 TANK LEVEL SWITCH							
YSH_160_6	BOP 1 SMOKE DETECTOR							
YSH_160_7	BOP 1 SMOKE DETECTOR							
LSH_214_2	E1 ANTIFOAM LEVEL SWITCH							
LSH_224_2	E2 ANTIFOAM LEVEL SWITCH							
LSH_211_2	E1-S1 HUMIDIFIER LEVEL HIGH							
LSH_212_2	E1-S2 HUMIDIFIER LEVEL HIGH							
LSH_213_2	E1-S3 HUMIDIFIER LEVEL HIGH							
LSH_221_2	E2-S1 HUMIDIFIER LEVEL HIGH							
LSH_222_2	E2-S2 HUMIDIFIER LEVEL HIGH							
LSH_223_2	E2-S3 HUMIDIFIER LEVEL HIGH							
LSH_231_2	E3-S1 HUMIDIFIER LEVEL HIGH							
LSH_232_2	E3-S2 HUMIDIFIER LEVEL HIGH							
LSH_233_2	E3-S3 HUMIDIFIER LEVEL HIGH							
LSH_241_2	E4-S1 HUMIDIFIER LEVEL HIGH							
LSH_242_2	E4-S2 HUMIDIFIER LEVEL HIGH							
LSH_243_2	E4-S3 HUMIDIFIER LEVEL HIGH							
LT_130_2	LEVEL SENSOR ON FEED TANK							

PS_130_1	PRESSURE SWITCH FOR FEED TANK FILL PUMP PROTECTION							

Saltworks Technologies Inc.

Acid & Base Dosing System O&M Instructions

Appendix I

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1 Safety

1.1 Personal Protective Equipment (PPE)

Figure 1: PPE required

2 Build-In pH Control System

Acid and Base Dosing systems are options for the SaltMaker water treatment solutions. The system consists of

- sensors for accurate detection of pH levels
- Acid and base dosing pumps, fluid storage
- control logic hardware and software that interfaces sensors and dosing pumps (hardware is shared with SaltMaker components)

3 pH Electrode Operating and Maintenance Instructions

The SaltMaker uses 2 different types of electrodes for pH measurement.

Glass electrode: this method of measurement integrates pH and reference electrodes built into the tip of the sensor. This tip is submersed in the solution. The pH electrode is sensitive to hydrogen ions and develops an electrical potential. The reference electrode consists of Silver/Silver Chloride connected to the process via a potassium chloride salt bridge through a ceramic junction. This provides a stable reference potential against the pH electrode. The two electrodes form a galvanic cell having a mV output proportional to the pH of the solution being measured.

Ion-selective field effect transistor (ISFET): This transistor is similar to the transistors used in the semi-conductor industry, except that the gate isolator layer comes in contact with the solution. A charge potential is proportional to the pH of the solution.

3.1 Probe Care and Storage Instructions

The instructions below are general instructions for pH probes. For specific instructions, check the part number of your pH transmitter and probe and refer to the manufacturer's operating instructions. This is also available in your MDR.

3.1.1 Electrode Calibration and Handling of a pH probe

- When obtaining pH readings of multiple samples, the electrode must be rinsed between each sample with distilled or deionized water.
- Ensure that the electrode is kept moist at all times. This applies to both glass electrode probes and ISFET probes. When electrode is not in use, place a small amount of potassium chloride solution or a pH 4 or pH 7 buffer solution in the protective cap, and place cap on the electrode.

3.1.2 Storing a pH probe

- Use a protection cap if the sensor is removed from the process for more than a few hours. The tip cannot be dried up. Place a small amount of potassium chloride solution or a PH 4 or pH 7 buffer solution in the protective cap, and place cap on the electrode.
- do not store the pH electrode in deionized water for more than one day as the water will cause the leaching of ions out of the ion exchange membrane on the glass bulb.
- Shake excess deionized water from the electrode or blot the electrode with lint-free paper. **Never wipe the electrode dry as this changes the charge on the electrode, resulting in erroneous in pH readings**.

3.1.3 Electrode Calibration of pH sensor:

To ensure accurate and repeatable measurements, pH electrodes are required to be periodically calibrated to their reference half-cells by a two-point calibration.

- Remove protective cap and rinse the sensor and bottom of the electrode with deionized water.
- Place the rinsed electrode in a pH 7.00 buffer solution. The pH reading on the pH meter will stabilize. Once stable, “confirm” will appear on the screen; this indicates the electrode is calibrated to pH 7.00.
- Remove the electrode from the buffer solution and rinse with deionized water.
- Place the rinsed electrode in a pH 10.00 buffer solution. The pH meter will stabilize around pH 10.00. Note: The pH meter may need to be adjusted to read the pH of the buffer solution.
- Remove the electrode from the buffer solution and rinse with deionized water.
- To ensure the electrode is properly calibrated, place the electrode in a pH 7.00 buffer solution. The reading will return to 7.00. If the pH meter does not read 7.00, the calibration procedure must be repeated.

4 pH Control System Troubleshooting Matrix

Use this troubleshooting guide to identify and troubleshoot problems with the pH Doser system.

Table H1: pH Doser Troubleshooting Matrix

Symptom	Possible Cause	Solution
System does not turn on	No power	• Check that the system is plugged in. • For an electrical dosing pump, check that the 120VAC line is powered. • For an air dosing pump, confirm that air solenoid is actuating and there is available air to the dosing pump
System is on but dosing does not trigger	pH level is not in trigger range	• Check the pH level setting on the pH transmitter
	pH level setting is incorrect	• TX3000 ONLY: (*1) • Check that the correct relay is selected: Relay 1 for acid dosing (lowering pH), relay 2 for base dosing (raising pH). • Check that the relay in use (see above) is set to Auto mode. • Check that the wires connecting to the timer relay are connected the correct terminals: 7/8 for acid dosing, 5/6 for base dosing. • Endress+Hauser CM442 ONLY: (*2) • Check that the correct relay is selected in the limit switch settings. • Check that the correct monitoring mode is selected: “Above limit check” for acid dosing, “Below limit check” for base dosing.
	Timer relay is not correctly connected	• Check the Crouzet MLR1 timer relay’s connections.

pH measurement is incorrect	Sensor probe is dirty	• Clean the sensor probe with water to remove residues.
	Sensor needs calibration	• Follow the pH transmitter manuals to recalibrate the sensor probe.
Dosing timing is incorrect	Timer relay setting is incorrect	• Check the settings on the timer relay – refer to pH Doser operation manual for how to set the ON and OFF time.
Dosing is occurring but no acid/base enters the tank	Acid/base tank is empty	• Check the acid/base tank for liquid level
	Ball valve is not open	• Check and open the ball valve on the acid/base tank.
	Solenoid pinch valve is not opening	• Check that the solenoid pinch valve is opening during the “ON” time of the timer relay. • Check that the hose does not remain pinched or twisted when the solenoid pinch valve is open.
Acid/base leaking into the tank	Solenoid pinch valve is not closing	• Check that the solenoid pinch valve is closing during the “OFF” time of the timer relay. • Check that the hose is properly pinched close by the pinch valve.

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Antifoam Dosing System O&M Instructions

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1 Safety

Please review the Material Safety Data Sheet for Antifoam solution and follow the safety precautions when handling antifoam.

Warning – Ensure that PPE is worn during installation, operation and troubleshooting of the antifoam dosing system (eye protection, appropriate gloves, long sleeves, and respiratory protection).

Figure 1: PPE required

Hazards working with the antifoam dosing system include the antifoam chemical mixture, as well as the foaming fluid in the tanks. Avoid exposure to skin.

2 Process Description

The Antifoam Dosing control is timer based. Each Effect Tank will receive a dose of antifoam based on a duration setpoint after a duration of the given timer setpoint. In addition to the timer based dosing, the Effect Tank will also receive a dose of antifoam everytime it is being filled with new leachate water for a user settable duration setpoint. Under excess foaming circumstances for Effect 2 and Effect 3 only, the antifoam dosing for those Effects will occur more frequently by a user settable factor setpoint. These excess foaming circumstance settings can be adjusted under the 120 Fresh Water System Condensate tab. There is only 1 antifoam dispensing pump feeding all 4 effect tanks. There is an air actuated valve to divert the flow to each of the effect tanks. The shared pump means that only 1 effect can dose at a time.

3 Calibration of Foam Sensor

The sensitivity of the anti-foam sensor should be tested and periodically to ensure the proper operation of the antifoam doser. And overly sensitive sensor will cause repeated cycles of antifoam dosing and increase the waste of antifoam, while an under-sensitive sensor would not be able to sense the foam in the tank, leading to foam overflow.

Please confirm the type of foam sensor you have. The instructions below are sensor specific.

3.1 Testing the GEM capacitive CAP-200 Sensor:

- Remove the CAP-200 sensor from the tank.
- Clean and dry the sensor head.
- Mix a glass of soap water with a thick layer (approximately 1.5 inches) of foam.
- Slowly immerse the sensor head into the foam layer while monitoring the signal to the HMI.
- When the sensor is triggered, the signal will go from “ON” to “OFF”.

3.2 Calibrating the CAP-200 Foam Sensor Switch

We recommend that sensor should be installed in the tank for calibration if possible. Foam in the process tank under the same process and mounting conditions provide the best scenario for calibration.

To decrease sensor sensitivity:

1. Locate the small hole on top of the sensor.

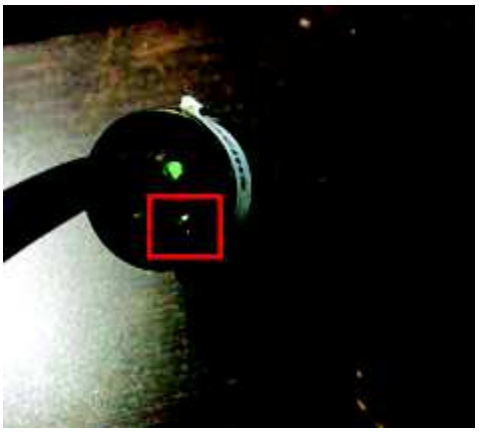

Figure 2: changing the sensitivity of the capacitive sensor

2. Hold the sensor at the desired triggering level in the foam layer.

3. Using a small Philips screwdriver, turn the potentiometer inside the small hole **counter-clockwise** until HMI

4. To set a safety distance, turn the potentiometer **clockwise** by ¼ of a full turn.
5. Wash and dry the sensor and test again. Repeat the process if necessary.

To increase sensor sensitivity (if sensor is not detecting foam):

1. Locate the small hole on top of the sensor.
2. Hold the sensor at the desired triggering level in the foam layer.
3. Using a small Philips screwdriver, turn the potentiometer inside the small hole **clockwise** until the sensor triggers. (X2 input on CLICK PLC goes LOW.)
4. To set a safety distance, turn the potentiometer **further clockwise** by ¼ of a full turn.

4 Antifoam Operating Settings

Effect has antifoaming settings are found in the Chemical Treatment Anti Foaming tab control. The Operator can disable or enable the timer based dosing and/or the tank fill based dosing. The Antifoam system will dose the Effect tank with antifoam for the “DURATION” time setpoint when the “TIMER” setpoint duration has elapsed. On a tank fill antifoam dose the antifoam system will also dose the given Effect tank for the “DURATION” setpoint.

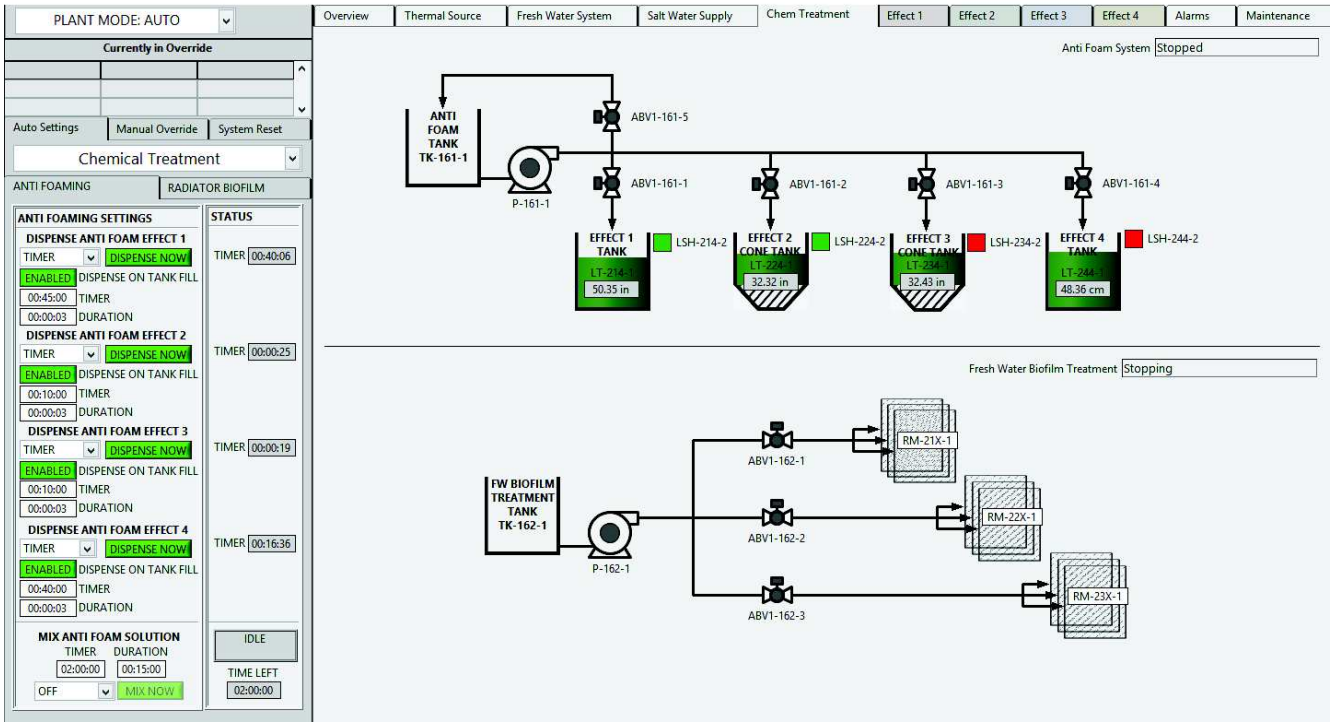

Figure 3: Antifoam Settings and HMI

5 Antifoam Dosing Troubleshooting Matrix

Use this troubleshooting guide to identify and troubleshoot problems with the Antifoam Doser system.

Table J1: Antifoam Dosing Troubleshooting Matrix

Symptom	Possible Causes	Possible Solutions
System is on but dosing does not trigger	Switch sensitivity is too low	• Test the triggering of the CAP-200 sensor. Recalibrate the sensor to **increase** the sensitivity of the sensor. See section 3.
Dosing triggered when liquid/foam is not touching the sensor	Sensor is dirty	• Clean the sensor head with water to remove residues. • Check that the washing water is thoroughly rinsing the sensor during rinsing phase.
	Switch sensitivity is too high	• Recalibrate the sensor to **decrease** the sensitivity of the sensor, following steps listed in "CAP-200 Foam Sensor Testing and Calibrating Procedure" document.
	Sensor resistor is burnt out	• Test sensor resistor.
HMI panel shows dosing cycle, but no antifoam/water comes out	Antifoam liquid ran out	• Check antifoam tank for liquid level – refill as necessary.
	Manual ball valves not open	• Check that the manual ball valves are in ON position.
	Problem with antifoam pump or air actuated valve actuation.	• Check that PLC is triggering the air actuated valves. • Check that actuated valves are triggering when signal is sent from PLC. • Check actuated valves for blockage.

		• Check air supply and pressure to valve. • Check air supply and pressure to antifoam pump
	Hoses are plugged	• Check the hoses connecting the solenoid valve outputs to the tank for blockage.

Saltworks Technologies Inc.

Salt Crust Prevention Instructions

Appendix K

Revision A

CONFIDENTIAL INFORMATION

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1 Sources of Salt Crust Buildup

The SaltMaker is designed to concentrate brine up to crystallization. To achieve this, the SaltMaker separates water from brine at relatively low temperatures using waste heat or a low temperature thermo source. Concentrated brine may crystallize or "scale" in all parts of the process at different rates. The goal is to control the build-up and remove enough solids from the system that it can maintain reliable operation.

1.1 Conditions that Exaggerate the Rate of Salt Crust Buildup

To understand why scaling occur in some areas and not others, it is necessary to identify different process conditions that impact the solubility of a solution. The list below outlines many of these conditions that may exist in the SaltMaker which increases the rate of salt crust buildup.

1.1.1 Low Flow Sections

Moving flow prevents the accumulation of salt crust due to constant agitation of moving fluids. If a section of a pipe sees low or stagnant flow, salt crust is much more likely to stick to surfaces. This salt attracts other crystals to stick to it and the crust increases in size.

Mitigation methods include increasing flow and agitation through these sections. Washes with lower concentration solution helps re-dissolve some of this salt crust. Higher flow will also help "loosen" the crust from the surface and move these crystals back to the tank where they can be managed.

1.1.2 Changes in Temperature

Solubility of most solutions increases with an increase in temperature. For example, a solid liquid mixture at 60ºC may become totally dissolved at 80ºC. However, some solutions behave in the opposite manner meaning that crystals tend to form at higher temperatures. The important takeaway of all this is that a change in temperature will impact the rate that salt crust forms in different sections of the plant.

The SaltMaker relies on effective heat exchangers to transfer heat from effect 1 -> 2 -> 3 -> 4. If the temperature of the effects starts drifting away from normal operating conditions, the operator should investigate the cause and apply the washes that target problem.

1.1.3 Process Interruptions

A process interruption would mean a stop in agitation or flow. This can cause salt crust formation very quickly in the system. SaltMaker has a built in wash sequence that helps keep pipes clean and crust from forming when stopping the system.

An emergency stop or power lost would interrupt this wash sequence. This means that if that salt crust will form in many areas if the SaltMaker is operating at high concentrations before the interruption. If there is a power interruption or if it is unsafe to clear the e-stop for a period of more than a few hours, it is necessary for the operator wash the system manually assuming that a pressurized fresh water supply is available. Doing manual washes will prevent many problems with SaltMaker startup once power comes back on-line.

1.1.4 Exposure to ambient air

Ambient air is cooler and drier than the air inside the effects. When a highly concentrated solution is exposed to this air, evaporation and the reduction in temperature will cause salt crust to form in the solution. It is therefore important to keep the effects and modules well insulated. Insulation will also help increase thermal efficiency of the system. Basins of modules need periodic washes to prevent this type of buildup.

2 Methods to prevent Salt Crusting

2.1 Washes:

Automated washes at specific intervals provide the best protection against permanent crusting. Periodic washes loosen salt crust build up on heat exchanger surfaces, pump internals and evaporation module fill.

2.1.1 Evaporator Basin Wash (Timer Based and User Triggered)

This wash is a short hot wash is used to clean saltwater pump, piping, the heat exchanger in the heat recovery module, and the evaporator. Once the evaporator wash is initiated (automatically or manually), hot water is sent through the pump and into piping. This water then flows through the heat exchanger and into the evaporation module. This wash reduces salt build up with minimal downtime and brine dilution. Normal operation of the SaltMaker resumes immediately after this burst of hot water is sent through the system.

Use this when: operator suspects a salt build-up problem (e.g. pump loads increase), it is recommended that the operator try this wash first. This wash will be enough to help clean pumps and dislodge salt buildup in many cases.

2.1.2 Pipe work Wash (Timer Based and User Triggered)

The pipework hot wash is a thorough wash to clean the saltwater pump, piping, and the heat exchanger in the heat recovery module. Once the pipework wash is initiated (either manually or automatically), compressed air will enter the piping and push the saltwater back into its respective main tank for a user defined duration. Hot water flows closed loop through the piping, pump, heat exchanger, and back to the satellite hot wash tank. The duration of this cycle will be set by the operator. Once the hot wash is finished with the first set, it will then clean the remaining sets in the effect using the same order of operations described above. For the final set, instead of returning hot wash water back to the satellite tank, the hot wash water will be cycled back into the main tank.

Use this when: operator sees reduced effectiveness of heat exchanger surfaces or lower than normal flow on the effect, and evaporator basin wash is ineffective. This wash can run on timers or triggered by clicking the “wash” button on the HMI.

2.1.3 Evaporator Spray Wash (Timer Based and User Triggered)

The evaporator spray hot wash cleans the evaporator fill. Nozzles are mounted inside the evaporator to increase the effectiveness of the spray. Once the evaporator spray wash is initiated, the pump will stop, and

the valve for the evaporator spray wash will open. The hot water from the evaporator spray wash will come from the main hot wash system. Duration of the evaporator spray wash can be set by the operator.

Use this when: air velocity through the effect modules is reduced or when there is an abnormal temperature difference between this and previous effect. This wash can run on timers or triggered by clicking the "wash" button on the HMI.

2.1.4 Pump Seal Flush & Pump Shaft Wash (Timer Based and User Triggered)

The pump shaft wash is a short hot wash that sprays water directly onto the pump shaft to prevent salt buildup. Once the pump shaft hot wash is initiated hot water from the main hot wash system is sprayed onto the pump shaft. Duration is set by the operator.

Use this when: there is visible salt build up around the shaft between the pump and the motor. Also may help with abnormal sounds and vibrations coming from the pump. This wash can run on timers or triggered by clicking the "wash" button on the HMI.

2.1.5 Shutdown and Start-up Wash (Triggered during Shutdown / Start-up)

Shutdown washes should be performed before plant shut down to remove concentrated brine from the SaltMaker pipe work system to prevent potential salt crystallization and clogging in valves, pumps, or pipe work. The shutdown wash sequence is automated. Before shutting down the SaltMaker, confirm the "Shutdown Wash" control is enabled for each effect, and the system will perform the proper washes before shutting down.

Before commencing SaltMaker operation after an emergency stop or alarm trip with no shutdown wash, the operator should perform a start-up flush. This wash cycle will aid in removing any crystallized salts resulting from concentrated brine remaining in the system. It is important to remove any crystallized salts from the system to protect equipment (e.g. pumps, valves, pipe work) and ensure SaltMaker reliability, The start-up wash is manually initiated by selecting "FLUSH NOW" under the "Overview" auto settings 1 tab on the HMI.

Use this when: the plant is shutting down or starting up. If this wash is interrupted, the user can trigger the sequence manually. If there is a power outage, Saltworks highly recommends that operators perform a manual wash using pressurized tap-water. When this wash is "enabled" on the HMI, it will run during the shutdown or startup process.

2.1.6 Chemically Enhanced Hot Wash (Manual)

A chemically enhanced hot wash is used in the event that the SaltMaker heat exchanger surface or pipe work system becomes crusted with salts. This hot wash involves cycling a chemical solution through the pipe work system where the crust has formed; the type of chemical solution used in the hot wash cycle is dependent on the type of crust formation. Manual inspections of heat exchanger surface and evaporator will inform the operator the need of a chemically enhanced hot wash.

Use this when: pipework washes and other washes are not effective. Operator suspects heavy salt crusting in pipework / heat exchangers.

2.2 Effect Swap Cycles (Timer Based and User Triggered)

To prevent salt crust forming on the evaporation modules of the SaltMaker, effect 1 and 4 operate at a concentration where solid salt does not form. Effect 2 and effect 3 operate at higher concentrations, thus have the potential to build up salt crust which can severely limit the operability of the plant. To reduce salt crust formation, effects 2 and 3 operate at alternating high and low concentrations by swapping water sources based on a timer. Cycling lower concentration water to a high concentration effect will dissolve and remove any crust build up that has formed. The concentration swap mode is fully automated. The operator can adjust the time interval between swaps, or manually trigger a concentration swaps between effects 2 and 3.

Use this when: effect 2 or effect 3 is near saturation, and effect 2 is showing rapid signs of crusting.

2.3 Removal Rate of Brine or Crystallized Salt

Different solutions behave differently at high concentrations. The SaltMaker uses conductivity sensors to infer the concentration of solution. However, at high concentrations, the relationship between concentration and conductivity is not linear. In some cases, the conductivity of the solution may decrease with increasing concentrations. To illustrate this, see figure below:

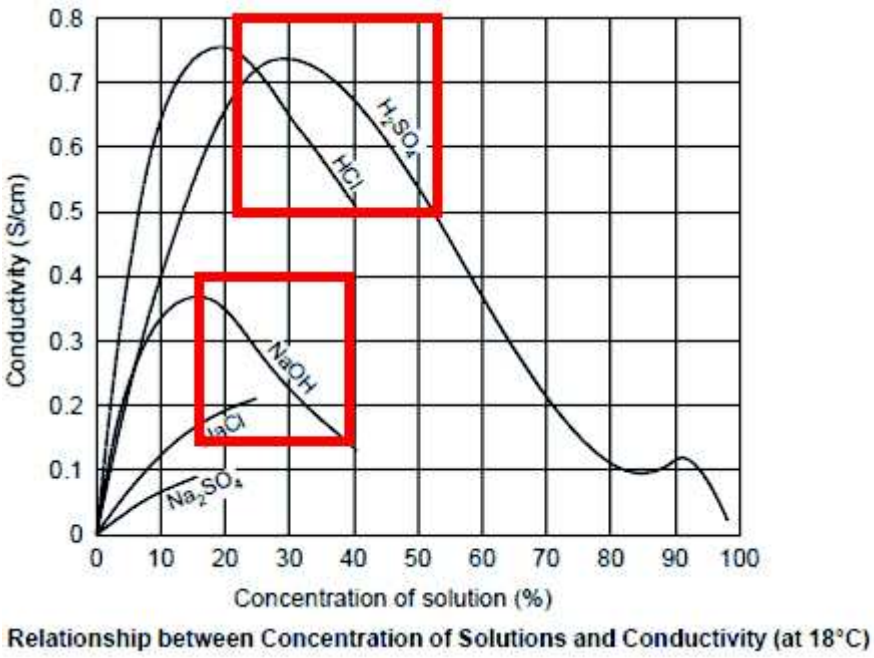

Figure 1: Different Solutions have different relationships between Concentration and Conductivity (source: Yokogawa)

If the SaltMaker is concentrating brine or producing salt at a faster rate than it is being removed, salt crusting will cause problems with operations. In the cases where conductivity of solution decreases with increasing concentration, the operator may not recognize that the SaltMaker is taking the feed water above the target concentration.

In this case, the operator can review the volume of feed in vs. volume of salt or brine discharged. If the SaltMaker is processing to much feed water and not discharging enough brine or solids, adjustment should be made to increase discharge rates.

Saltworks can assist in reviewing this data and making adjustments to the SaltMaker to achieve reliable steady operation.

Saltworks Technologies Inc.

Biofilm O&M Instructions

Appendix L

Revision A

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Table of Contents

1 Safety

Please review the Material Safety Data Sheet for the biofilm treatment solution and follow the safety precautions.

Warning – Ensure that PPE is worn during installation, operation and troubleshooting of the biofilm treatment system (eye protection, appropriate gloves, long sleeves, and respiratory protection).

Figure 1: PPE required

Hazards working with the biofilm treatment system include harmful exposure to the biofilm treatment solution. Avoid contact with skin and eyes.

2 Process Description

The system consists of a Biofilm Treatment Tank which contains a chemical mixture that hinders biological growth when sprayed on heat exchangers in the radiator modules and radiator basins in Effects 1, 2, and 3. The system is timer based. When controls are set to “timer” mode, the system is on hold until the timer duration ends, which then initiates dispensing of the biofilm solution to the targeted effect heat exchanger for the duration specified. Then the cycle repeats itself.

The biofilm treatment system consist of a solution holding tank, a biofilm solution dispensing pump, air actuated valves, manual valves, piping and nozzles to each of the effects that require biofilm control. The nozzles are installed inside the heat exchangers in the radiator modules.

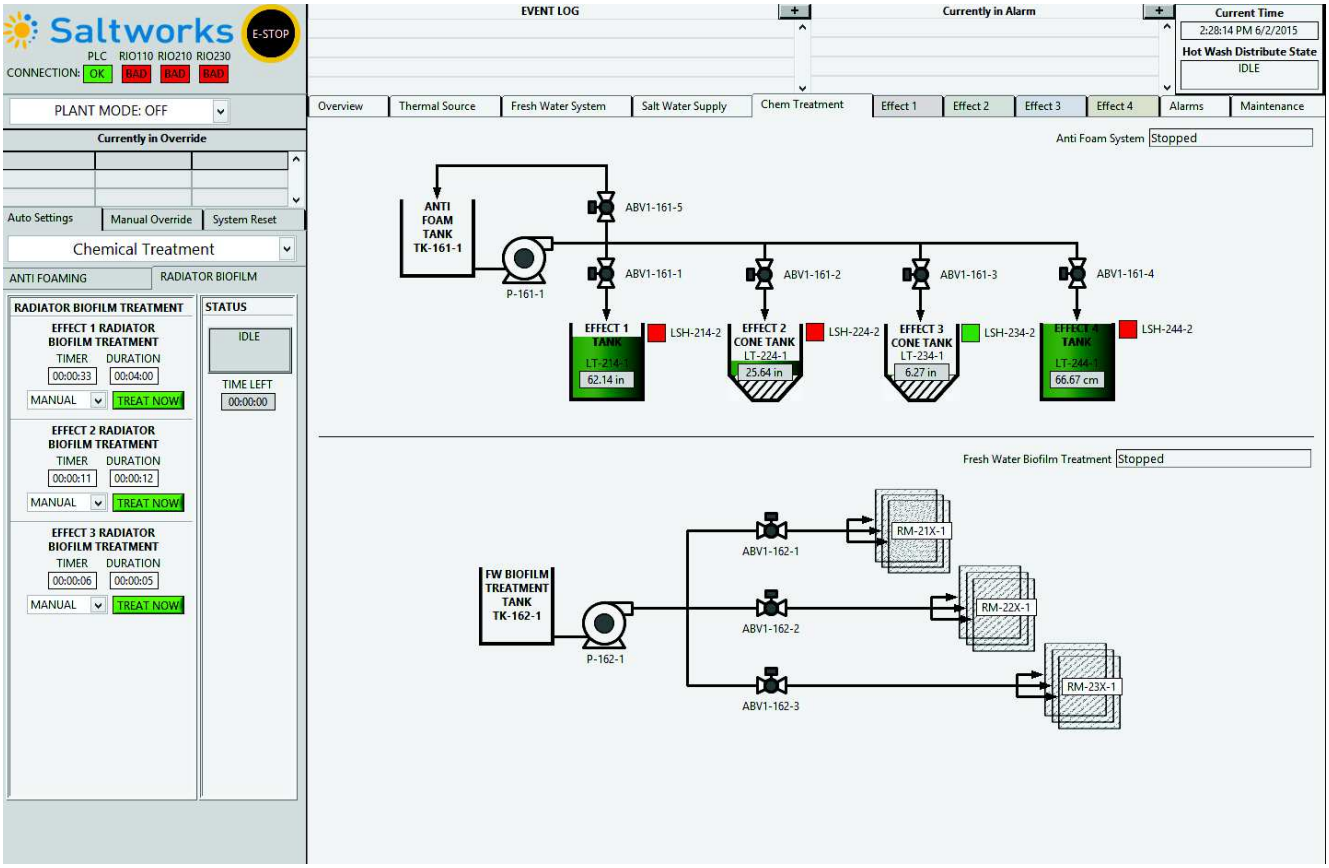


Figure 2: Biofilm Settings and HMI

3 Biofilm Treatment Solution

No preparation required for biofilm solution.

4 Biofilm System Maintenance

Item	Service	Remarks
Daily		
Confirm sufficient fluid	Operator	Check biofilm feed tank
Controls setting	Operator	Check HMI timer duration settings, adjust as needed

Weekly		
Heat Exchanger Inspection	Operator	Open port holes to inspect heat exchanger surface for fouling

5 Biofilm System Troubleshooting Matrix

Symptom	Possible Causes	Possible Solutions
HMI panel shows dosing cycle, but no antifoam/water comes out	Antifoam liquid ran out	• Check antifoam tank for liquid level – refill as necessary.
	Manual ball valves not open	• Check that the manual ball valves are in ON position.
	Problem with antifoam pump or air actuated valve actuation.	• Check that PLC is triggering the air actuated valves. • Check that actuated valves are triggering when signal is sent from PLC. • Check actuated valves for blockage. • Check air supply and pressure to valve. • Check air supply and pressure to antifoam pump
	Hoses are plugged	• Check the hoses connecting the solenoid valve outputs to the tank for blockage.

Appendix M: SaltMaker Alarm List

Index	Input	HH Action	LL Action	HH	H	L	LL	Delay (s)	H Unhibited	L Uninhibit
0	IT_101	Trip: Entire Plant	None	150	140	-10	-10	60	Always	Always
1	IT_102	Trip: Entire Plant	None	150	140	-10	-10	60	Always	Always
2	IT_103	Trip: Entire Plant	None	150	140	-5	-10	60	Always	Always
3	PT_120_1	Trip: Hotwater	Trip: Hotwater	40	35	4	2	10	Always	Pump On
4	LT_120_2	None	Trip: Hotwater	35	32	7	4	10	Always	Always
5	TT_120_1	Trip: Hotwater	None	155	145	32	30	5	Always	Always
6	TT_120_2	Trip: Hotwater	None	155	145	32	30	5	Always	Always
7	PT_142_1	Trip: Entire Plant	Trip: Entire Plant	125	120	85	80	20	Always	Always
8	PT_234_1	Trip: Effect 3 Set 1	Trip: Effect 3 Set 1	35	30	8	5	10	Always	Set Pump On
9	PT_234_2	Trip: Effect 3 Set 2	Trip: Effect 3 Set 2	35	30	8	5	10	Always	Set Pump On
10	PT_234_3	Trip: Effect 3 Set 3	Trip: Effect 3 Set 3	35	30	8	5	10	Always	Set Pump On
11	CIT_234_1	None	None	350	300	-10	-10	60	Always	Always
12	TT_234_1	Trip: Effect 3	Trip: Effect 3	203	194	32	30	30	Always	Always
13	LT_234_1	None	Trip: Effect 3	40	37	19	17	10	Always	Effect On
14	SPARE	*None*	*None*	-	-	-	-	-	-	-
15	SPARE	*None*	*None*	-	-	-	-	-	-	-
16	AIT_234_1	*None*	*None*	-	-	-	-	-	-	-
17	PT_244_1	Trip: Effect 4 Set 1	Trip: Effect 4 Set 1	35	30	8	5	10	Always	Set Pump On
18	PT_244_2	Trip: Effect 4 Set 2	Trip: Effect 4 Set 2	35	30	8	5	10	Always	Set Pump On
19	PT_244_3	Trip: Effect 4 Set 3	Trip: Effect 4 Set 3	35	30	8	5	10	Always	Set Pump On
20	CIT_244_1	None	None	350	300	-10	-10	60	Always	Always
21	TT_244_1	Trip: Effect 4	Trip: Effect 4	203	194	32	30	30	Always	Always
22	LT_244_1	None	Trip: Effect 4	65	60	30	25	10	Always	Effect On
23	PT_140_1	Trip: Entire Plant	Trip: Entire Plant	125	120	85	80	20	Always	Always
24	PT_140_2	Trip: Entire Plant	Trip: Entire Plant	125	120	85	80	20	Always	Always
25	LT-234-2	*None*	*None*	-	-	-	-	-	-	-
26	LT-244-2	*None*	*None*	-	-	-	-	-	-	-
27	SPARE	*None*	*None*	-	-	-	-	-	-	-
28	SPARE	*None*	*None*	-	-	-	-	-	-	-
29	SPARE	*None*	*None*	-	-	-	-	-	-	-
30	ACCESSORY_AI_1	None	None	-	-	-	-	-	-	-
31	ACCESSORY_AI_2	None	None	-	-	-	-	-	-	-
32	TT_110_1	Trip: Thermal Source	None	203	200	35	32	5	Always	Always
33	TT_110_2	Trip: Thermal Source	None	203	200	35	32	5	Always	Always
34	TT_110_3	Trip: Thermal Source	None	203	200	35	32	5	Always	Always
35	CIT_120_1	Trip: Condensate	None	25	20	-2	-2	30	Always	Always
36	LT_120_1	None	Trip: Condensate	80	75	15	10	10	Always	Always
37	AIT_130_1	Trip: Saltwater Supply	Trip: Saltwater Supply	10	9	4	3	5	Always	Always
38	CIT_130_1	Trip: Saltwater Supply	None	325	300	-10	-10	10	Always	Always
39	FIT_130_1	None	Hibernate Plant	180	160	1	0	10	Always	Pump On
40	LT_130_1	None	Hibernate Plant	70	65	15	10	20	Always	Always
41	TT_130_1	Trip: Saltwater Supply	None	95	90	5	1	5	Always	Always
42	TT_130_2	Trip: Saltwater Supply	None	95	90	5	1	5	Always	Always
43	PT_141_1	Trip: Entire Plant	Trip: Entire Plant	125	120	85	80	20	Always	Always
44	PT_214_1	Trip: Effect 1 Set 1	Trip: Effect 1 Set 1	35	30	8	5	10	Always	Set Pump On
45	PT_214_2	Trip: Effect 1 Set 2	Trip: Effect 1 Set 2	35	30	8	5	10	Always	Set Pump On
46	PT_214_3	Trip: Effect 1 Set 3	Trip: Effect 1 Set 3	35	30	8	5	10	Always	Set Pump On
47	CIT_214_1	None	None	350	300	-10	-10	60	Always	Always
48	TT_214_1	Trip: Effect 1	Trip: Effect 1	203	194	32	30	30	Always	Always
49	LT_214_1	None	Trip: Effect 1	75	65	35	30	10	Always	Effect On
50	AIT_214_1	*None*	*None*	-	-	-	-	-	-	-
51	PT_224_1	Trip: Effect 2 Set 1	Trip: Effect 2 Set 1	35	30	8	5	10	Always	Set Pump On
52	PT_224_2	Trip: Effect 2 Set 2	Trip: Effect 2 Set 2	35	30	8	5	10	Always	Set Pump On
53	PT_224_3	Trip: Effect 2 Set 3	Trip: Effect 2 Set 3	35	30	8	5	10	Always	Set Pump On
54	CIT_224_1	None	None	350	300	-10	-10	60	Always	Always
55	TT_224_1	Trip: Effect 2	Trip: Effect 2	203	194	32	30	30	Always	Always
56	LT_224_1	None	Trip: Effect 2	40	37	19	17	10	Always	Effect On
57	LT_224_2	*None*	*None*	-	-	-	-	-	-	-
58	LT_224_3	*None*	*None*	-	-	-	-	-	-	-
59	AIT_224_1	*None*	*None*	-	-	-	-	-	-	-
60	LT_130_2	None	Hibernate Plant	-	-	-	-	-	-	-
61	LT-224-2	*None*	*None*	-	-	-	-	-	-	-
62	LT-214-2	*None*	*None*	-	-	-	-	-	-	-
63	SPARE	*None*	*None*	-	-	-	-	-	-	-
64	PT_216_1	Trip: Entire Plant	Trip: Entire Plant	125	120	85	80	20	Always	Always
65	TT_211_1	Trip: Effect 1 Set 1	Trip: Effect 1 Set 1	203	194	32	30	15	Always	Always
66	TT_212_1	Trip: Effect 1 Set 2	Trip: Effect 1 Set 2	203	194	32	30	15	Always	Always
67	TT_213_1	Trip: Effect 1 Set 3	Trip: Effect 1 Set 3	203	194	32	30	15	Always	Always
68	TT_211_2	None	None	203	194	32	30	15	Always	Always
69	TT_221_1	Trip: Effect 2 Set 1	Trip: Effect 2 Set 1	203	194	32	30	15	Always	Always
70	TT_222_1	Trip: Effect 2 Set 2	Trip: Effect 2 Set 2	203	194	32	30	15	Always	Always
71	TT_223_1	Trip: Effect 2 Set 3	Trip: Effect 2 Set 3	203	194	32	30	15	Always	Always
72	TT_221_2	None	None	203	194	32	30	15	Always	Always
73	LT_215_1	None	None	30	28	3	1	10	Always	Always
74	TT_215_1	None	None	203	194	32	30	10	Always	Always
75	LT_225_1	None	None	30	28	3	1	10	Always	Always
76	TT_225_1	None	None	203	194	32	30	10	Always	Always
77	VIT_211_1	*None*	*None*	-	-	-	-	-	-	-
78	VIT_221_1	*None*	*None*	-	-	-	-	-	-	-
79	AIT_215_1	*None*	*None*	-	-	-	-	-	-	-
80	PT_236_1	Trip: Entire Plant	Trip: Entire Plant	125	120	85	80	20	Always	Always
81	TT_231_1	Trip: Effect 3 Set 1	Trip: Effect 3 Set 1	203	194	32	30	15	Always	Always
82	TT_232_1	Trip: Effect 3 Set 2	Trip: Effect 3 Set 2	203	194	32	30	15	Always	Always
83	TT_233_1	Trip: Effect 3 Set 3	Trip: Effect 3 Set 3	203	194	32	30	15	Always	Always
84	TT_231_2	None	None	203	194	32	30	15	Always	Always
85	TT_241_1	Trip: Effect 4 Set 1	Trip: Effect 4 Set 1	203	194	32	30	15	Always	Always
86	TT_242_1	Trip: Effect 4 Set 2	Trip: Effect 4 Set 2	203	194	32	30	15	Always	Always
87	TT_243_1	Trip: Effect 4 Set 3	Trip: Effect 4 Set 3	203	194	32	30	15	Always	Always

88	TT_241_2	None	None	203	194	32	30	15	Always	Always
89	LT_235_1	None	None	30	28	3	1	10	Always	Always
90	TT_235_1	None	None	203	194	32	30	10	Always	Always
91	LT_245_1	None	None	30	28	3	1	10	Always	Always
92	TT_245_1	None	None	203	194	32	30	10	Always	Always
93	VIT_231_1	None	None	-	-	-	-	-	-	-
94	TT_243_2	None	None	-	-	-	-	-	-	-
95	SPARE	None	None	-	-	-	-	-	-	-
96	TT-001	None	None	207	204	40	35	5	Always	Always
97	LEL-001	None	None	-	-	-	-	-	-	-
98	PT-001	None	None	-	-	-	-	-	-	-
99	PCV-001	None	None	-	-	-	-	-	-	-
100	SPARE	None	None	-	-	-	-	-	-	-
101	SPARE	None	None	-	-	-	-	-	-	-
102	SPARE	None	None	-	-	-	-	-	-	-
103	SPARE	None	None	-	-	-	-	-	-	-
104	SPARE	None	None	-	-	-	-	-	-	-
105	SPARE	None	None	-	-	-	-	-	-	-
106	SPARE	None	None	-	-	-	-	-	-	-
107	SPARE	None	None	-	-	-	-	-	-	-
108	SPARE	None	None	-	-	-	-	-	-	-
109	SPARE	None	None	-	-	-	-	-	-	-
110	SPARE	None	None	-	-	-	-	-	-	-
111	SPARE	None	None	-	-	-	-	-	-	-
112	SPARE	None	None	-	-	-	-	-	-	-
113	SPARE	None	None	-	-	-	-	-	-	-
114	FIT-001	None	None	-	-	-	-	-	-	-
115	ModulationSignal	None	None	-	-	-	-	-	-	-
116	LFG_Totalizer	None	None	-	-	-	-	-	-	-
117	SPARE	None	None	-	-	-	-	-	-	-
118	SPARE	None	None	-	-	-	-	-	-	-
119	SPARE	None	None	-	-	-	-	-	-	-
120	SPARE	None	None	-	-	-	-	-	-	-
121	SPARE	None	None	-	-	-	-	-	-	-
122	SPARE	None	None	-	-	-	-	-	-	-
123	SPARE	None	None	-	-	-	-	-	-	-
124	SPARE	None	None	-	-	-	-	-	-	-
125	SPARE	None	None	-	-	-	-	-	-	-
126	SPARE	None	None	-	-	-	-	-	-	-
127	SPARE	None	None	-	-	-	-	-	-	-
128	SPARE	None	None	-	-	-	-	-	-	-
129	SPARE	None	None	-	-	-	-	-	-	-
130	SPARE	None	None	-	-	-	-	-	-	-
131	SPARE	None	None	-	-	-	-	-	-	-
132	SPARE	None	None	-	-	-	-	-	-	-
133	SPARE	None	None	-	-	-	-	-	-	-
134	SPARE	None	None	-	-	-	-	-	-	-
135	SPARE	None	None	-	-	-	-	-	-	-
136	SPARE	None	None	-	-	-	-	-	-	-
137	AIT-320-1	None	None	-	-	-	-	-	-	-
138	TIT-320-1	None	None	-	-	-	-	-	-	-
139	LT-320-2	None	None	-	-	-	-	-	-	-
140	LT-320-1	None	Hibernate Plant	-	-	-	-	-	-	-
0	ESTOP_SOFT	None	None	-	-	-	-	-	-	-
1	ESTOP_100_2	None	None	-	-	-	-	-	-	-
2	ESTOP_110_2	None	None	-	-	-	-	-	-	-
3	ESTOP_210_2	None	None	-	-	-	-	-	-	-
4	ESTOP_210_4	None	None	-	-	-	-	-	-	-
5	ESTOP_220_4	None	None	-	-	-	-	-	-	-
6	ESTOP_230_4	None	None	-	-	-	-	-	-	-
7	ESTOP_OK	None	None	-	-	-	-	-	-	-
8	RCM_100	None	Trip: Entire Plant	-	-	-	-	5		
9	RCM_210	None	Trip: Entire Plant	-	-	-	-	5		
10	RCM_230	None	None	-	-	-	-	-	-	-
11	YSH_160_1	None	Trip: Entire Plant	-	-	-	-	10		
12	YSH_160_2	None	Trip: Entire Plant	-	-	-	-	10		
13	SPARE 1513	None	None	-	-	-	-	-	-	-
14	SPARE 1514	None	None	-	-	-	-	-	-	-
15	SPARE 1515	None	None	-	-	-	-	-	-	-
16	LSH_234_1	None	Disallow Effect 3 Fill	-	-	-	-	15	-	Always
17	LSH_244_1	None	Disallow Effect 4 Fill	-	-	-	-	15	-	Always
18	LSH_234_2	None	None	-	-	-	-	-	-	-
19	LSH_244_2	None	None	-	-	-	-	-	-	-
20	SPARE 1520	None	None	-	-	-	-	-	-	-
21	SPARE 1521	None	None	-	-	-	-	-	-	-
22	SPARE 1522	None	None	-	-	-	-	-	-	-
23	SPARE 1523	None	None	-	-	-	-	-	-	-
24	SPARE 1524	None	None	-	-	-	-	-	-	-
25	SPARE 1525	None	None	-	-	-	-	-	-	-
26	SPARE 1526	None	None	-	-	-	-	-	-	-
27	SPARE 1527	None	None	-	-	-	-	-	-	-
28	SPARE 1528	None	None	-	-	-	-	-	-	-
29	SPARE 1529	None	None	-	-	-	-	-	-	-
30	ACCESSORY_DI_1	None	None	-	-	-	-	-	-	-
31	ACCESSORY_DI_2	None	None	-	-	-	-	-	-	-
32	LSH_214_1	None	Disallow Effect 1 Fill	-	-	-	-	10	-	Always
33	LSH_224_1	None	Disallow Effect 2 Fill	-	-	-	-	10	-	Always
34	SPARE 1534	None	None	-	-	-	-	-	-	-

35	YSH_160_6	None	Trip: Entire Plant	-	-	-	-	15	-	Always
36	YSH_160_7	None	Trip: Entire Plant	-	-	-	-	15	-	Always
37	LSH_214_2	None	None	-	-	-	-	-	-	-
38	LSH_224_2	None	None	-	-	-	-	-	-	-
39	SPARE 1539	None	None	-	-	-	-	-	-	-
40	SPARE 1540	None	None	-	-	-	-	-	-	-
41	SPARE 1541	None	None	-	-	-	-	-	-	-
42	SPARE 1542	None	None	-	-	-	-	-	-	-
43	SPARE 1543	None	None	-	-	-	-	-	-	-
44	SPARE 1544	None	None	-	-	-	-	-	-	-
45	SPARE 1545	None	None	-	-	-	-	-	-	-
46	SPARE 1546	None	None	-	-	-	-	-	-	-
47	SPARE 1547	None	None	-	-	-	-	-	-	-
48	SPARE 1548	None	None	-	-	-	-	-	-	-
49	LSH_211_2	None	Trip: Effect 1 Set 1	-	-	-	-	10	-	Always
50	SPARE 1550	None	None	-	-	-	-	-	-	-
51	LSH_212_2	None	Trip: Effect 1 Set 2	-	-	-	-	10	-	Always
52	SPARE 1552	None	None	-	-	-	-	-	-	-
53	LSH_213_2	None	Trip: Effect 1 Set 3	-	-	-	-	10	-	Always
54	SPARE 1554	None	None	-	-	-	-	-	-	-
55	LSH_221_2	None	Trip: Effect 2 Set 1	-	-	-	-	10	-	Always
56	SPARE 1556	None	None	-	-	-	-	-	-	-
57	LSH_222_2	None	Trip: Effect 2 Set 2	-	-	-	-	10	-	Always
58	SPARE 1558	None	None	-	-	-	-	-	-	-
59	LSH_223_2	None	Trip: Effect 2 Set 3	-	-	-	-	10	-	Always
60	SPARE 1560	None	None	-	-	-	-	-	-	-
61	SPARE 1561	None	None	-	-	-	-	-	-	-
62	SPARE 1562	None	None	-	-	-	-	-	-	-
63	SPARE 1563	None	None	-	-	-	-	-	-	-
64	SPARE 1564	None	None	-	-	-	-	-	-	-
65	LSH_231_2	None	Trip: Effect 3 Set 1	-	-	-	-	10	-	Always
66	SPARE 1566	None	None	-	-	-	-	-	-	-
67	LSH_232_2	None	Trip: Effect 3 Set 2	-	-	-	-	10	-	Always
68	SPARE 1568	None	None	-	-	-	-	-	-	-
69	LSH_233_2	None	Trip: Effect 3 Set 3	-	-	-	-	10	-	Always
70	SPARE 1570	None	None	-	-	-	-	-	-	-
71	LSH_241_2	None	Trip: Effect 4 Set 1	-	-	-	-	10	-	Always
72	SPARE 1572	None	None	-	-	-	-	-	-	-
73	LSH_242_2	None	Trip: Effect 4 Set 2	-	-	-	-	10	-	Always
74	SPARE 1574	None	None	-	-	-	-	-	-	-
75	LSH_243_2	None	Trip: Effect 4 Set 3	-	-	-	-	10	-	Always
76	SPARE 1576	None	None	-	-	-	-	-	-	-
77	SPARE 1577	None	None	-	-	-	-	-	-	-
78	SPARE 1578	None	None	-	-	-	-	-	-	-
79	SPARE 1579	None	None	-	-	-	-	-	-	-
80	SPARE 1580	None	None	-	-	-	-	-	-	-
81	SPARE 1581	None	None	-	-	-	-	-	-	-
82	SPARE 1582	None	None	-	-	-	-	-	-	-
83	LSH_CUSTOMER_TANK	None	None	-	-	-	-	-	-	-
84	PS-130-1	None	None	-	-	-	-	-	-	-
85	SPARE 1585	None	None	-	-	-	-	-	-	-
86	SPARE 1586	None	None	-	-	-	-	-	-	-
87	SPARE 1587	None	None	-	-	-	-	-	-	-
88	SPARE 1588	None	None	-	-	-	-	-	-	-
89	SPARE 1589	None	None	-	-	-	-	-	-	-
90	AirInterlockSwitch	None	Hibernate Plant	-	-	-	-	-	-	-
91	LFGPressureHi	None	Hibernate Plant	-	-	-	-	-	-	-
92	LFGPressureLow	None	Hibernate Plant	-	-	-	-	-	-	-
93	LWCOFF	None	Hibernate Plant	-	-	-	-	-	-	-
94	HiTempSwitch	None	Hibernate Plant	-	-	-	-	-	-	-
95	MainFuelLight	None	None	-	-	-	-	-	-	-
96	PSL-320-1	None	None	-	-	-	-	-	-	-
97	BoilerTripped	None	Hibernate Plant	-	-	-	-	-	-	-
98	RO_PreconditionerTankFull	None	Hibernate Plant	-	-	-	-	-	-	-
99	FeedTankEmpty	None	Hibernate Plant	-	-	-	-	-	-	-

Saltworks

Operator Handover Form

Rev A
August 2016

The purpose of this document is to improve communication between operators during shift changes. Site operators should complete this sheet and forward to next operator & project manager. Communicate these items to the next operator in person whenever possible, and answer any questions the next operator might have.

Project Name	
Project Manager	
Operator in Current Shift	
Operator in Next Shift	
Date & Time of Handover	

1. Safety *(Please describe any safety related concerns for the next operator, any actions taken, and any futher actions required, for the next operator.)*

Area/System	Description

2. Operation/Maintenance *(Please describe any upcoming operation/maintenance issues pending.)*

Area/System	Description

3. Observations & Changes *(Please describe any other details, changes that the next operator needs to be aware of.)*

Area/System	Description

Saltworks Technologies Inc.

Post Treatment Reverse Osmosis Operating Manual

Revision A

CONFIDENTIAL INFORMATION

www.saltworkstech.com

Table of Contents

1 Safety

Please review **General Safety**, **Hazards and Awareness** sections of the SaltMaker Operating Manual. These are safety steps that apply to the post-treatment Reverse Osmosis (RO) as well as the SaltMaker. This section will cover safety specific to the post-treatment RO system.

1.1 Operating Ranges and Constraints

For the safety of the operator and protection of equipment, always operate the system within the operating ranges as specified below.

- Max Operating pressure of RO: refer to your local P&ID and unit
- Operating temperature range: 35 – 95 ^{o}F (2 - 35ºC)
- Operating pH Range: 4.5 to 6 for optimal ammonia removal
- Electrical: 480V, 3P, 60Hz. Inlet Specifications
- Post-treatment RO is designed to treat SaltMaker condensed water.

RO elements are housed in RO pressure vessels and will see high operating pressures. Proper care and maintenance is required to keep these pressure vessels in safe operating condition. Please use due care and refer to the manufacturer's manual for safe handling and proper maintenance instructions.

All personnel must be familiar with this manual and the Manufacturers Data Registry (MDR) before operating or maintaining the Post-Treatment RO. The MDR contains piping and instrumentation diagrams (P&ID), electrical schematics, operating and maintenance manuals, datasheets and other useful documentation. Original manufacturer's documentation is included in the MDR.

Operators must be familiar and skilled with water pumps and piping systems. Inappropriate Post-Treatment RO operation or maintenance will void Saltworks' warranty.

1.2 Emergency Stop

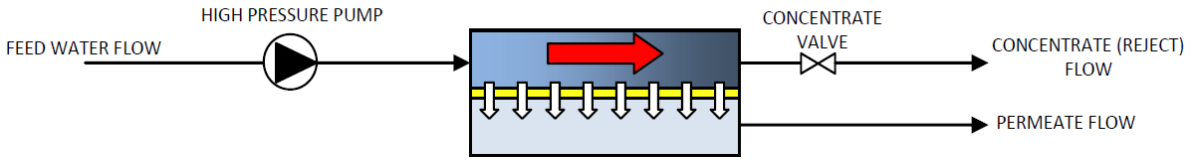
The RO Post Treatment Emergency Stop only shuts down the Post Treatment RO system. The SaltMaker and other ancillary systems will continue to run. To shut down all systems one of the six SaltMaker Emergency Stops must be engaged.

2 Process Description

This section outlines a high level process overview of the post-treatment RO, followed by operating procedures.

2.1 Post Treatment RO Process Overview

The Post Treatment RO is designed to remove ammonia in the produced SaltMaker condensed water. Reverse Osmosis is a separation process where water is forced through the membrane and leaves dissolved ions in the concentrate stream. A simplified diagram of the process is shown below.



The RO system operates at variable recovery based on conductivity (salt and ammonia content) of the permeate. If the permeate conductivity is too high, the RO will lower recovery by opening the concentrate valve allowing more water to go to the concentrate stream and less water to go to the product stream.

2.2 Acid Dosing Process

Acid is dosed to the RO Pre-conditioner holding tank (if RO pre-conditioner is necessary). Otherwise dosing will happen within the Post Treatment RO system. The pH set point should nominally be 5.5. If process water pH is above the post treatment RO set point, acid dosing to the tank will be activated for a set duration timer. Ample mixing time is provided after each dose. The cycle will repeat of pH is still high after mixing time has expired.

2.3 CIP System

The CIP system is designed to clean fouled RO membranes by circulating a warm caustic solution though the RO system. The CIP system consists of a caustic pump, a CIP tank, a CIP tank mixer, and a CIP tank heater. The caustic pump will run for a predetermined time to ensure that adequate caustic has been added to the tank.

The CIP sequence is as follows:

- The tank will fill with permeate or chlorine free service water
- The heater and circulation pump will start.
- Caustic is added to the tank by the caustic pump
- The heater will run until the temperature set point is achieved
- The CIP solution will displace residual water in the RO system.
- The CIP solution will circulate though the RO for 30 minutes.

Both the concentrate and permeate will return to the CIP tank during circulation. Once the wash timer expires, the CIP solution will be discharged. The RO will then be rinsed with chlorine free service water or SaltMaker fresh water.

Caustic Dosing

Caustic is dosed to the RO permeate in order to meet the pH discharge permit requirements. The set point is 6.5. The caustic is continuously dosed into an injection quill. There is a static mixer between the quill and the pH probe to ensure mixing.

2.4 RO Pre-Conditioner (Optional)

The RO Pre-conditioner is an optional cooling and pH adjustment system designed to lower the temperature and acidify SaltMaker condensed water. SaltMaker condensed water circulates through cooling modules where the temperature is decreased to near ambient temperature. The RO Pre-conditioner tank is equipped with an acid dosing system and tank recirculation pump. The acid dosing system includes an acid dosing pump, dosing hardware, and automated controls. Solution pH is continuously monitored and mixed by the tank recirculation pump to protect downstream RO system.

3 RO Post-Treatment System Construction

This section describes the major physical components of the Post-Treatment RO system.

3.1 RO Feed Pump

The RO Feed Pump draws water from the RO feed tank and provides adequate pressure to drive it through a bag filter and a cartridge filter to feed the RO High Pressure Pump System.

The flow circuit includes bag filter and cartridge filter housings between the RO Feed Pump and the RO High Pressure Pumps. These filters are in place to ensure particulate matter does not enter the RO Membrane Pressure Vessel.

3.2 RO High Pressure Pump and Recirculation System

The RO High Pressure Pumps are vertical in line pumps designed to generate adequate pressure and flow to drive water though the membranes.

The Recirculation system moves brine back to the RO pressure vessel inlet so that adequate membrane cross flow velocity is maintained.

3.3 RO Pressure Vessel and Membranes

The RO Pressure Vessel is designed to hold six 8” diameter by 40” long membrane elements and is rated to 600 psi.

The membranes are thin film polyamide composite membranes designed for high rejection of dissolved ions.

3.4 CIP Cleaning System

The CIP system consists of a caustic pump, a CIP tank, a CIP tank mixer, and a CIP tank heater. CIP solution pH is continuously monitored to ensure pH target is maintained. If solution pH drops below set point the caustic

pump dispenses caustic solution for a predetermined time and the solution is mixed by the CIP tank mixer. The pH is measured again to ensure fluid is within pH operating range.

3.5 Electrical and Control System

The electrical and control system consists of a main control panel with multiple AC drives, switch gear, terminal blocks as well as the control PLC and modules. AC Drives allow variable speed on the feed pump, high pressure pumps, and RO recirculation pump. The drives allow control system to make flow and pressure adjustments to maximize RO recovery and efficiency. The panel houses the HMI, conductivity and pH transmitters for operators. All instrumentation and automation functions are carried out by the PLC based on signals from sensors.

3.6 RO Pre-Conditioner

The RO Pre-Conditioner consists of these main components:

- A fan and radiator module designed to bring SaltMaker condensate to near ambient temperature.
- Condensate holding tank.
- Circulation pump.
- Acid Tote and pump.

The RO Pre-Conditioner contains its own electrical control box with its own remote IO (RIO) modules, for temperature sensing, pH control, and switching of cooling pump and fans.

3.7 Instrumentation and Automation

The Post-Treatment RO system uses a variety of sensors and automation hardware to achieve reliable plant operation. Sensors include temperature, pressure, flow, level, conductivity, and pH. Saltworks has standardized on 4-20 mA analogue sensor outputs to minimize signal loss issues. 4-20mA signals are read by input/output (I/O) modules on the PLC in the main control panel. Besides sensors, Saltworks have also installed pressure and temperature gauges at different process locations to help operators monitor the condition of the system.

The Post-Treatment RO uses the following types of instruments:

Pressure:

These sensors are used to measure pump inlet/discharge pressures. Trends in pressure readings can help the operator identify filter clogging or membrane fouling issues. It can also be used to identify pump problems.

Level:

These sensors are used to measure the level on Post-Treatment RO tanks.

Level sensor feedback allows for automated level control by filling and transfer of water in process tanks. The system is vital to continuous operations of the Post-Treatment RO. Automated level warnings help operators locate issues before they become serious enough to interrupt operations.

Conductivity:

These sensors are used to measure conductivity of water, which is proportional to the ionic or salt concentration of the water. The Post-Treatment RO deploys different contacting conductivity sensors:

> ***Contacting conductivity sensors:*** These sensors employ a potentiometric method. Two or four electrodes are submersed in the sample fluid. The sample fluid completes the electrical circuit. An alternating current is applied on the electrodes and the voltage potential is measured. This voltage potential is proportional to the conductivity of the fluid. Saltworks uses this type of sensor to measure conductivity range from 0-5mS.

Conductivity sensor signals help operators monitor concentration of the concentrate and permeate process streams. By tracking conductivity changes over time, these sensors ensure that the Post-Treatment RO is functioning normally.

pH:

These sensors contain a potentiometric cell made of pH-sensitive electrodes. Voltage is measured across the electrodes and the signal is amplified and processed into a 4-20mA signal. PH sensors help monitor condition of treated and untreated water. They are also used in optional acid and base dosing systems to monitor and control pH to adjust solubility of the process water to different salts.

Temperature:

These sensors measure the temperature of the process streams in the Post-Treatment RO. The Post-Treatment RO uses resistive RTDs (resistance temperature detectors) which are sensors that change in resistance due to a change in temperature. This signal is amplified and processed into a 4-20mA signal with a transmitter.

4 Operating the HMI

The Post Treatment RO is controlled by a programmable logic controller (PLC). This PLC communicates with an industrial PC through the plant's network. The industrial PC acts as the human-machine interface (HMI), and allows operators to monitor operating conditions in real time, adjust set-points, and investigate alarms. The HMI is primarily divided into two sections: controls and indicators. The left side of the HMI houses two levels of controls: plant level ("Main Mode"; upper left). Below screenshot shows the HMI and the sections.

All operators should first familiarize themselves with the HMI for their plant and the associate process and instrumentation diagrams (P&ID). Without controlling the plant, navigate the control screens and locate all key process devices such as pumps, valves, and instrumentation both on the HMI and physically in the plant.

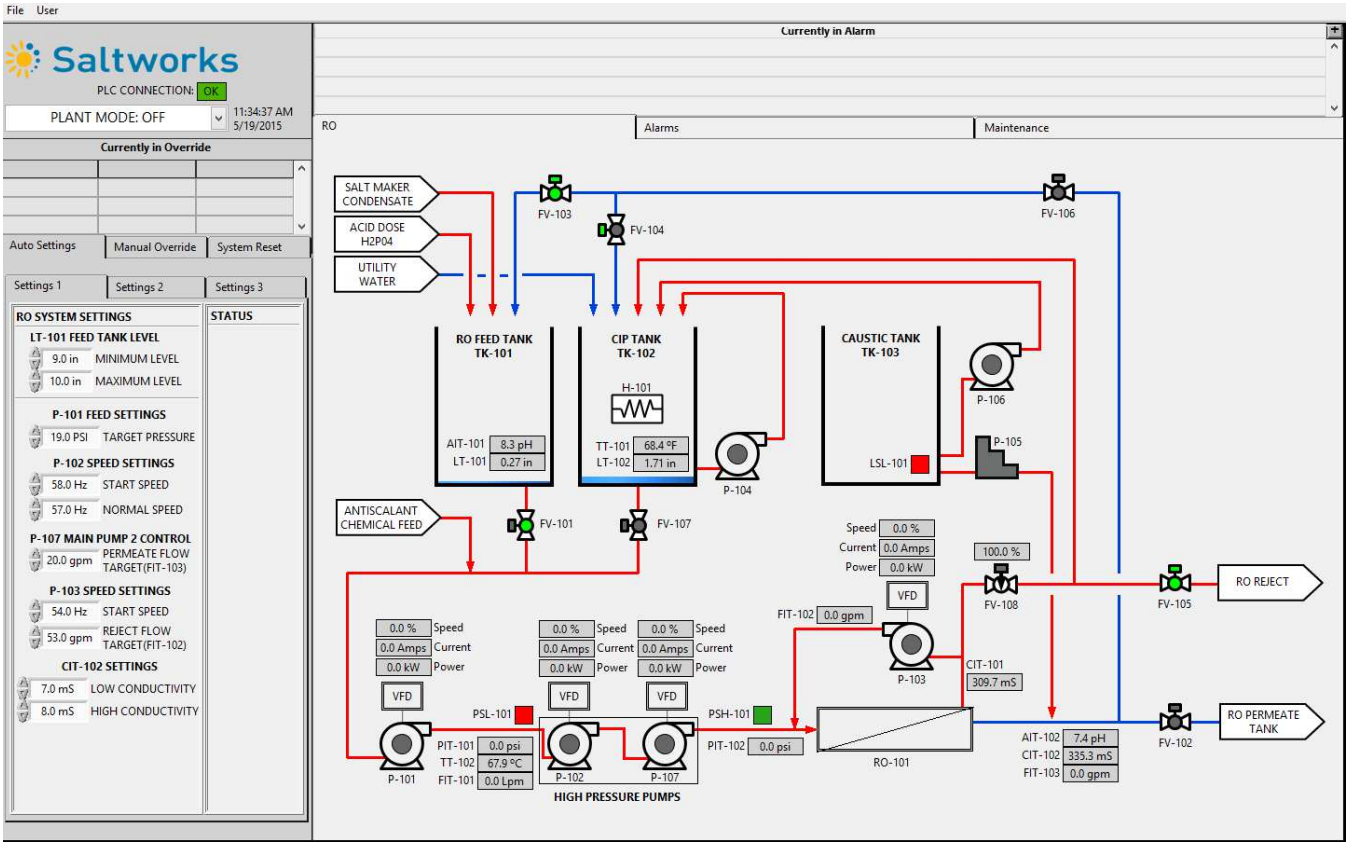


Figure 1: HMI Interface

4.1 HMI: Pre-Start up

4.1.1 Post-Treatment RO Operating Parameters

Post-treatment RO operating settings can be loaded from and/or saved to a file with a .sil extension. To save or load the Post-Treatment RO settings go to "File" and select "Plant settings" to bring up the Plant Settings Datafile Path dialog box (see figure below). Select the proper parameter settings file (e.g. default.sil) using the folder button on the lower left, and click "Load" to load parameters from file, or click "Save" to save the current operating settings to the selected file.

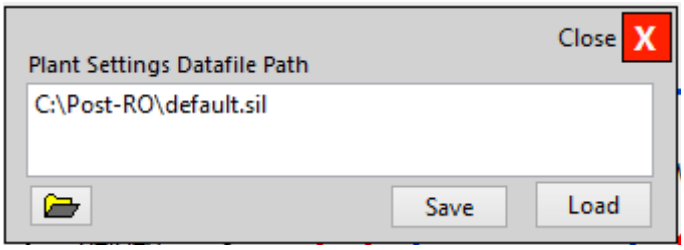


Figure 2: Save or Load Plant Settings

4.1.2 Datalogging

All data related to the Post-Treatment RO is logged in a local file on the industrial PC, and then copied to cloud storage for backup and access. Datalog settings are located under the Datalog tab, and allow the user to set the path to store the datalog files. See figure below.

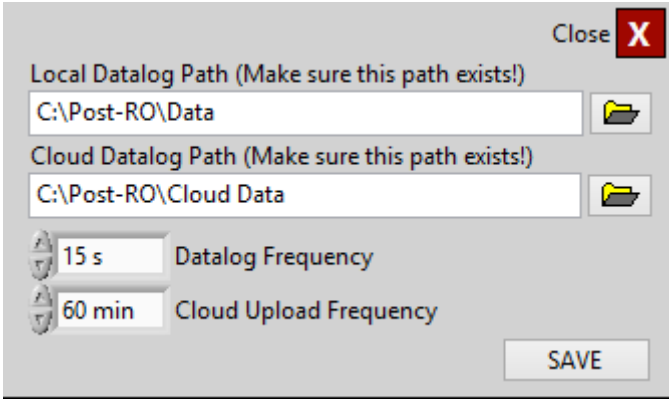


Figure 3: Data Log Settings

4.1.3 User Settings

The HMI uses accounts and user profiles to assign different access levels for different users. Three accounts and three user profiles are built into the HMI. More accounts and user profiles can be added as necessary.

The following list explains the three built-in users and their associated user profiles in the HMI:

Saltworks:

This is the account used by Saltworks engineers for taking full control of the HMI. It is assigned to the user profile “saltworks”, which grants access to all functions available in the HMI, including plant controls, alarm controls and user controls. This account should only be used by Saltworks personnel.

Admin:

This is the account assigned to administrators of the plant. This account is associated to the user profile “admin”. It also grants full access to all functions available in the HMI.

Default:

This is the account that the HMI runs on by default when launched. This account is associated to the “default” user profile, which grants access to plant settings and alarm settings, but has no access to user settings of the HMI.

Each account must be associated to an existing user profile. A new user profile can be created if a new set of access rights is required for an account.

4.2 HMI Operation

If all mechanical checks are completed and operating settings are correct, the user can change the “Main mode” from “PLANT MODE: OFF” to “PLANT MODE: ON”. The Post-Treatment RO system will start automatically based on operating settings.

Enabling Override mode allows the operator to have granular control of automated valves, pumps and all other devices that are controlled by the PLC. This is useful in identifying, isolating and fixing the problem whether the plant is running or off.

To override a particular device, go to the manual override tab and make sure that main “override mode” is enabled. Then press the override button for the particular device, and then select “Close” or “Open”.

4.3 Alarms on the HMI

The Post-Treatment RO has alarms for each digital and analog input. A *warning* status indicates a warning that an instrument reading is outside of a predefined low (L) or high (H) threshold. This warning status does not

affect the operation of the plant. An *alarm* status indicates that an instrument reading is outside a predefined alarm low (LL) or alarm high (HH).

4.3.1 Currently in Alarm Display

The "Currently in Alarm" display shows the digital and/or analog inputs that are currently in alarm. When the alarm is triggered, this display blinks in red and automatically updates tripped alarm status in real time.

4.3.2 Alarm Settings

Alarm Settings allow the user to select a specific digital or analog alarm to change its settings. Use the drop down filter to select the type of alarm to be adjusted. Select a specific alarm and change the set points in the control panel. To apply these changes, click Save. To discard changes to, click Cancel. On the far right of the Alarm Settings are the alarm indicators that display the current status of the alarm, as well as the current value of the analog input if it is an analog alarm.

4.3.3 Alarm Email Forwarding

When an alarm is triggered, the HMI automatically sends an email with the alarm information to all recipients specified in the "To:" column.

4.3.4 Alarm Email Settings

The Alarm Email Settings are the email server settings that allow the program to send emails to the recipients. These settings are to be modified by authorized personnel only.

4.3.5 System Reset

The System Reset button on the HMI resets all system faults.

5 Operating Procedures

5.1 Start-up Procedures

Make sure you are familiar with the previous section on HMI operation. For details on HMI parameters and settings, see the last section on this document.

Checks before Start-up:

Water:

- Verify that there is water in the RO Feed Tank
- Verify that there is room in permeate and concentrate tanks.

Valves:

- Verify that all manual valves leading from the RO feed tank to the RO Feed Pump are open.
- Verify that manual permeate valve is open.
- Verify that manual concentrate valve is open.

Air:

- Verify that air has been purged out of pre-filter pressure vessels and the RO membrane pressure vessel.
- This is done by opening manual vent valves while the RO Feed Pump is performing the pre-start up flush.

Temperature and pH

- Verify that feed temperature is below 95 ^{o}F (35ºC) and pH is between 4.5 and 6. If the RO-Pre-conditioner used, make sure the unit is operating and keeping process water to the RO system within the above parameters.

Start-up:

- When ready, change the main control from “PLANT MODE: OFF” to “PLANT MODE: AUTO”.
- “PLANT MODE: AUTO” will enable the RO system to start based on tank levels.
- RO Feed pump will start drawing water from RO Feed tank.
- The bag filters between the RO Feed Pump and the RO High Pressure Pumps should be vented of air at start-up. The pressure loss across either filter housing should be no more than 15 psi when operating. If the pressure loss is 15 psi or greater, go back to “PLANT MODE: OFF” and replace the filter bag or the cartridge filters.
- Check pressure gauge on the high pressure pump inlet to confirm there is sufficient pressure. If pressure is low, stop and investigate. Likely causes included clogged filters.

5.2 Operating the Post-Treatment RO

The post-treatment RO is fully automated and can be left with minimal supervision after initial start-up. Intelligent controls will notify the user through warnings and alarms if the plant needs operator attention. Daily checks are recommended to ensure increased uptime and early detection of problems.

5.2.1 Daily Checks

- Do not tolerate leaks. If a leak is found, correct it immediately. Big problems can be avoided if preventative maintenance is taken.

- Process and Controls: check pressures, flows and analytical data based on the daily Reverse Osmosis Operator Log. See below.

U.S. WATER ENGINEERING & EQUIPMENT

Reverse Osmosis Operator Logs

U.S. WATER ENGINEERING & EQUIPMENT

	Operator Initials:														
	Date:														
	Time:														
	RO Machine:														
Pressures (Manual Gauges)															
A	Pre-Filter Pressure (psig)														
B	Post-Filter Pressure (psig)														
C	Cartridge Filter Pressure Drop = A-B (psi)														
D	Pump Discharge Pressure (psig)														
E	Membrane Feed Pressure (psig)														
F	Reject Pressure (psig)														
Flows															
G	Permeate Flow (gpm)														
H	Reject Flow (gpm)														
I	Feed Flow = G + H (gpm)														
J	Recovery Rate % = G/I*100 (%)														
K	Normalized Permeate Flow														
Analytical Data															
L	Inlet Temperature (°F)														
M	Inlet pH														
N	Feed Conductivity (µmhos)														
O	Permeate Conductivity (µmhos)														
P	Reject Conductivity (µmhos)														
Q	% Rejection = (1 - O/N)*100 (%)														
R	Feed Free Chlorine (ppm as Cl_2)														
S	Feed Total Chlorine (ppm as Cl_2)														
T	Feed Bisulfite (as SO_3)														
U	Inlet Hardness (as $CaCO_3$)														
V	Antiscalant Concentration														
W	Cartridge Filters Changed (Y/N)														
X	CIP Conducted (Y/N)														

Figure 4: RO Operator Log

Pumps:

- Check for leaks and unusual noises.

5.2.2 Recommended Checks after Shutdown

Check for leaks and corrosion. Leaks should be recorded and fixed in the earliest available instance. Pipes that show signs of corrosion should be replaced immediately with corrosion resistant piping. Corrosion will cause membrane fouling, leading to increased replacement cost and downtime.

5.3 Post-Treatment RO Wash Cycles

The Post Treatment RO should be cleaned when the normalized flux decreases by more than 10% of the baseline flux. –The normalized flux is calculated from data accumulated from the HMI and displayed.

See membrane manufacture's literature for details (Nano H20 Technical Bulletin 111 and 113).

Startup Flush: This flush happens every time on startup. The valve from CIP opens. After a delay, the feed pump turns ON. The high pressure pumps turn ON next, and the brine recirculation pump turns ON to increase cross flow. The RO reject valve will be open to discharge flush water. The flush is complete after a user-set time has expired. The RO Feed Tank Valve opens and the CIP Tank closes and the plant starts up.

Shutdown Flush: This flush happens every time on shutdown. The valve from CIP opens. After a delay, the feed pump turns ON. The high pressure pumps turn ON next, and the brine recirculation pump turns ON to increase cross flow. The RO reject valve will be open to discharge flush water. The flush is complete after a user-set time has expired.

In-activity Flush: When this flush setting is enabled, the RO system will flush after a certain period of in-activity of the RO system, based on the set-point. This flush is necessary to preserve the RO membranes. This flush sequence is similar to Shutdown flush.

CIP Flush: this flush is a thorough cleaning process which involves the use of caustic stored in the caustic tank. The flush is meant to be done once every 6 months to 1 year. Before triggering this flush, please make sure that there is enough caustic in the tank for a proper wash.

When this flush is triggered, the caustic pump will transfer fluid to the CIP tank. The CIP circulation pump runs to keep the caustic evenly mixed. When this is complete, the CIP inlet valve to fed pump will open, and the feed pumps, high pressure pumps, and the brine re-circulation pump will run in succession. The RO Reject valve will be closed, and the CIP fluid will circulate back into the CIP tank. The wash will keep going until the user-settable timer has expired.

5.4 Shutdown

Normal Shut Down

The RO system will automatically shut down if the RO Feed Tank reaches a low level. A shutdown flush will commence to make sure that the membranes will not scale after the system turns off.

Emergency Shutdown or Power Lost

5.5 Manual Flush Procedure:

In the event of a power loss, a wash can be done using a pressurized freshwater supply. Connect the pressurized water hose downstream of the high pressure pumps before the RO unit. Open the concentrate RO discharge line to drain. Open the water hose and run fresh water across the RO membranes for X minutes. Perform permeate flush once power becomes available again.

5.6 Process Disruptions and Alarm Management

High Pressure protection: online pressure sensors are implemented to ensure optimal operating pressures are maintained and to prevent over pressure. For each system trip, identify the cause and take corrective actions before resetting the alarms.

- Pressure Low alarm: Confirm bag filter and microfilters are not clogged, changes as needed.
- Pressure High alarm:

PH protection: online pH sensors are implemented to ensure solution pH is maintained within pH 4.5 - 6.

- High pH: Confirm dosing control setpoints. Confirm valve and pump function
- Low pH: Ensure sufficient volumes of acid/base solution in tanks, check dosing lines for clogging, confirm pump function

Conductivity protection: Conductivity sensors with alarms notify the operator when conductivity of the concentrate and permeate process streams are out of specified range.

- High Concentrate Conductivity: confirm operating pressures, confirm discharge valve function and controls functions working correctly
- High Permeate Conductivity: confirm operating pressures. Perform membrane probing to confirm membrane function.

5.7 Post-Treatment RO Maintenance

Item	Service	Remarks
DAILY		
Inspection Checklist	Operator	Confirm calibration of all instrumentation as per daily checklist Confirm filters not clogged
Leaks	Operator	Check for water leakage (1) Pumps (2) RO pressure cell (3) System flow lines
WEEKLY		
Sensor function	Operator	Perform instrument calibration as

		needed. Conductivity and pH sensors need to be calibrated weekly. If readings drift, calibrate more frequently.
Clean pressure vessel heads	Operator	Rinse with fresh water Remove any deposits using a small wire brush or a medium grade ScotchBrite scrubbing pad.
MONTHLY		
Instrument Calibration (Excludes conductivity and pH)	Operator	Confirm instrument readings are stable (See instrument manuals for details)

6 References

14046 USHR RO Manual

Saltworks

Saltworks Technologies Inc.

Reverse Osmosis Filter Replacement Procedure

Appendix P

Revision A

CONFIDENTIAL INFORMATION

www.saltworkstech.com

Table of Contents

1 Reverse Osmosis Filter Replacement

1.1 Personal Protective Equipment (PPE)

Figure 1: PPE required

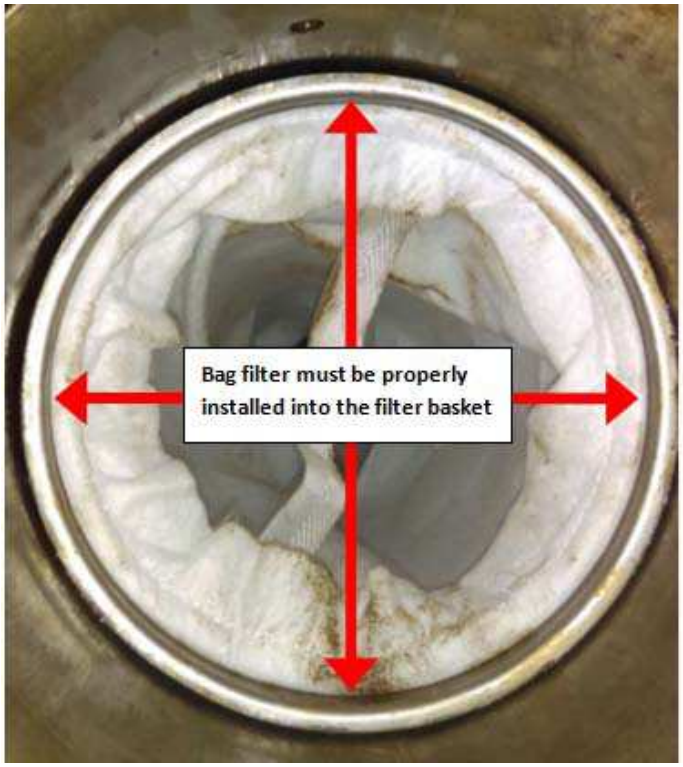
2 Filter Replacement Procedure:

The following procedures must be followed to ensure safe and proper replacement of the filters.

1. Turn the RO system OFF: change the "PLANT Main Mode" from "PLANT MODE: AUTO" to "PLANT MODE: OFF"
2. RO system will perform a shutdown flush. When shutdown flush is completed
3. Push E-stop
4. Close Bag filter inlet valves

RO bag Filter Replacement Procedure:

- Relieve filter housing pressure by opening the purge valve at the top of the filter housing. Drain water from the filter housing by opening the bottom drain valve.
- Open filter housing by unscrewing the filter housing collar clamp
- Remove the dirty RO filter and bag filter basket from the filter housing.
- Clean the inside and outside of the bag filter basket using utility water hose
- Clean the inside of the bag filter housing, using the utility water hose, until clean water is flowing from the drain valve. Close drain valve.
- Place bag filter basket back into the filter housing. Place the new bag filter in the filter basket. **Ensure the bag filter is placed all the way into the housing and is properly fitted into the filter basket, with the filter bag edge secured inside the basket edge (see picture below).**
- Secure filter housing lid by tightening the housing collar clamp.

Incorrect Placement	Correct Replacement
	

RO Cartridge Filter Replacement Procedure:

- Relieve filter housing pressure by opening the purge valve at the top of the filter housing. Drain water from the filter housing by opening the bottom drain valve.
- Open filter housing by unscrewing the filter housing collar clamp
- Remove dirty RO cartridge filters
- Clean the inside of the filter housing using the utility water hose. Clean the filter housing until clean water is draining from the filter housing drain valve. Close drain valve.
- Place new filter cartridge into the filter housing. When placing the filters, press down on the cartridge to ensure the filters are secured in place. Place the filter top cover on and tightly secure using wing nut. Proper tightening of the top cover will ensure all four filter elements are secured in place.
- Secure filter housing lid by tightening the housing collar clamp.

5. Open bag filter inlet valves.
6. Release the E-Stop
7. Turn RO system ON

Saltworks Technologies Inc.

RO Membrane Replacement

Appendix X

Revision A

CONFIDENTIAL INFORMATION

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Table of Contents

1 Safety

1.1 Personal Protective Equipment (PPE)

Figure 1: PPE required

1.2 General Safety

- Know and correctly use PPE for Plant operation.
- Know how and where to isolate sources of energy, such as electrical, thermal, compressed air etc.
- Understand potential physical and chemical hazards associated with plant operation.
- Ensure tools and equipment are in good working condition before use.
- Prior to getting to task, stop and think about your safety and your co-workers

2 Procedure

Please follow the procedure below to ensure safe and proper replacement of RO membrane elements.

2.1 Pre-Loading Instructions:

1. Please ensure you are familiarize with the following:

Brine seal	
RO element interconnections	

End cap adapters	
End caps	
Retaining rings	

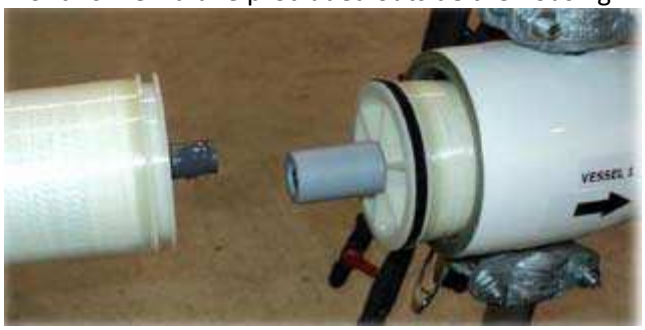
2. Before opening the vacuumed sealed membrane package visually inspect the packaging for any damage or signs of leaking. Once package is opened, inspect each membrane element to identify direction of flow (arrow indicating flow direction)

3. When loading the elements, record the installed location (housing number or name) of each element.
   NOTE - Do not unpack an element unless it will be installed immediately. Do not set an exposed element on any surface. Any dirt or particulate matter can contaminate the element. The elements must not become contaminated and must not be allowed to dry out.
   CAUTION - RO elements are typically shipped in a preservative/disinfectant solution that may cause eye and skin irritation. Wear rubber gloves, eye protection, and protective clothing when handling the elements.
4. Verify that all of the flush procedures have been completed to properly drain and depressurize the RO system.
5. Open the permeate sample valves at the RO modules to relieve internal pressure.
6. Remove the retaining rings holding the end caps.
   NOTE - Be careful not to lose any o-rings or gaskets for the piping connectors.

7. Mark the pressure vessels' end caps and related components to indicate their proper location. Because of minor variations in the piping dimensions, components must be returned to their original locations to avoid stress on the inlet and outlet piping.
8. Water will flow from the pressure vessels onto the floor when the end caps are removed. Make provisions for this flow of water as necessary.
9. Select the vessel to be loaded first and open the housing using the manufacturer instructions.
10. Inspect the vessel and components for cleanliness and damage. Wash components with filtered/softened water if additional cleaning is warranted. **NOTE**: Wash water must be free of chlorine. Any chlorinated water must be flushed from the system before loading the new membranes.
11. Load the required RO elements into the vessel using the loading instructions that are shown below.
12. As soon as all of the pressure vessels have been loaded with elements, perform the startup procedures for the RO system. The pressure vessels must be filled with water to prevent drying of the elements.

2.2 RO Membrane Loading:

1. Remove all end caps (feed side and reject side) from all housings; identify the feed end of the RO vessel.
2. Remove RO elements from the box. Each RO membrane is supplied with new interconnectors.
3. Apply glycerin on the brine seal. **NOTE**: Check membrane manufacture for recommended lubricant (ie: Dow membranes use Molykote 111).
4. Partially insert the first elements to the feed side of the membrane housing, typically the brine seal goes in last in the direction of feed (see note above and verify brine seal location in regards to flow direction). Leave a portion of this membrane protruded outside the housing.



5. Install interconnector on the first element after applying glycerin on the O-rings. **NOTE**: Check membrane manufacture for recommended lubricant (ie: Dow/LG membranes use Molykote 111).
6. Attach the second element to the interconnector of the first element. Make sure that an assistant restrains the first element while attaching the second element to the interconnector before partially inserting the second element into the vessel.
7. Repeat the above procedures until all elements are loaded, making sure that there is sufficient room on the downstream end to insert the end cap.
8. Install the downstream end cap. Install an end adaptor on the feed-end element followed by the end cap. Supply sufficient force to the end cap to move the elements until they sit firm against the

downstream end cap. Complete the installation of the feed-end cap as well install the retaining rings. ***See Section 2.3 for Membrane Element Shimming before closing the end cap.***

9. Repeat the above steps for all remaining membrane housing on the RO skid.

2.3 Membrane Element Shimming

Shimming the membrane elements once loaded into the pressure vessel will minimize element shifting during start-up and shutdown and minimize wear on the internal seals and ensure the adapters are properly sealed.

The process of shimming is performed once the membrane elements have been loaded. The element stack should be pushed all the way into the vessel such that the downstream element is against the thrust rind at the brine end of the vessel. Once this is completed shimming can be completed by the following procedure.

1) Remove adapter o-ring and head seal from the feed end of these vessel components.
2) Remove the end plate and slide spacers over the head end of the adapter that fits into the permeate port. Add enough spacers so it is not possible to install the retaining rings after seating the head.
3) Remove one spacer at time until you can just install the retaining rings.
4) Remove the head and reinstall the adapter o-ring and head seal.
5) Close the vessel according to manufacturer's instructions.

2.4 Removal of RO Elements

1. Before removing the elements, perform a normal cleaning sequence for the RO skid and make sure that all cleaning chemicals are rinsed from the pressure vessels.
2. Close all isolating hand valves on the skid.
3. Open the sample valves on the RO pressure vessels to relieve all pressure in the housings.
4. Remove the housing retaining rings that hold the end cap.
5. Mark the element housing end caps and related components to indicate their proper location. Because of minor variations in the piping dimensions, components must be returned to their original locations to avoid stress on the inlet and outlet piping.

   NOTE - Be careful not to lose any o-rings or gaskets for the piping connectors.
6. Water will flow from the element housings onto the floor when the end caps are removed. Make provisions for this flow of water as necessary.

7. Select the housing to be unloaded first, and open it up using the manufacturer instructions.
8. Remove the RO elements from the vessel.
9. If the elements will be reinstalled later, store them as directed in the element manufacturer's literature.
10. When elements are reinstalled in the housing, use the loading procedures.

Saltworks

Saltworks Technologies Inc.

SaltMaker Reverse Osmosis System
RO CIP Procedure

Revision C

CONFIDENTIAL INFORMATION

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1 Safety

1.1 Personal Protective Equipment (PPE)

- Wear proper required PPE per operation site requirement. This may include but not limited to: Steel toe boots, Safety glasses, gloves and hard hat

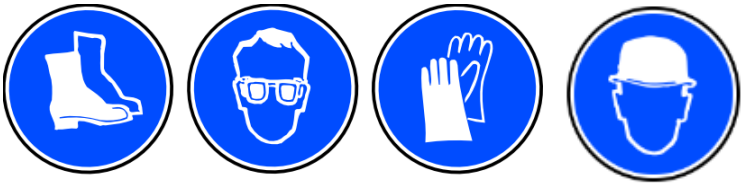

Figure 1: PPE required

1.2 General Safety

- Know and correctly use PPE for Plant operation and maintenance.
- Know how and where to isolate sources of energy, such as electrical, thermal, compressed air etc.
- Understand potential physical and chemical hazards associated with plant maintenance.

2 CIP Preparation

2.1 Chemical Preparation

- Base CIP: AVISTA ROCLEAN L211 in liquid form: 2 % wt/wt solution @ target pH 12
  - At CIP Tank level 5 inch on HMI LT-102, Approx. 18 L (4.76 gal) of L211 to be dosed in to CIP Tank.
  - Every 1 inch of tank level change = 0.6 L (0.16 Gal) of chemical dosing amount change
  - If pH is under 12 please set CIP pH set point to 12 and Caustic CIP Dosing Setting in Auto as shown below.

- Acid CIP: AVISTA ROCLEAN P303 in powder form: 1.5 % wt/wt solution @ target pH 2
  - At CIP Tank level 5 inch on HMI LT-102, Approx. 13.5 kg (30 lbs) of P303 to be dosed in to CIP Tank. As P303 is power chemical it needs to be manually dosed into CIP tank gradually while CIP tank mixing pump (P-104) is running to mix chemical well.
  - Every 1 inch of tank level change = 0.45 kg (1 lb) of chemical dosing amount change
  - During Acid CIP, caustic dosing and SLS dosing setting should OFF as shown below.

  - Acid CIP should be done after Base CIP.

2.2 Check Point Before Starting CIP Preparation

- Make sure Utility water network has pressure to perform RO CIP. Also make sure utility water line is not city water, as chlorine in city water can damage RO membrane.
- Do not proceed CIP while utility water is not available.
- Check RO Preconditioning Tank level is to have enough room to perform RO CIP (~ 2 hours). It is recommended to start the RO CIP when the RO PC Tank level is approximately @ 40 in.
- Check pressure gauge PI-105 and PI-106 and log it.

2.3 Chemical dosing

- Base CIP
    - Stop RO with shutdown flush.
    - Change RO CIP Tank (TK-102) level setting to START FILL: 1 in / STOP FILL 2 in.
    - Set SLS Dosing setting timer 2 hours in auto.
    - Turn off Shutdown flush. After flush recommended CIP tank level is 5 in.
    - Restart RO and run for 2 hours.
    - If RO PC tank let and RO stops, then override on P-107 to dose ROClean L211 ~ 15 L. (Pump capacity: 7.5L per hour)
    - Once ROClean L211 is dosed into CIP Tank for desired amount, stop RO without flush.
- Acid CIP
    - Acid CIP will always be after base CIP.
    - After Base CIP, the tank and system is to be flushed with utility water.
    - ROClean P303 to be dosed into CIP tank manually and gradually while P-104 in manual override.
    - Target pH is 2 so if pH is above 2 after all P303 dosed, add Sulfuric acid slowly while monitoring pH to achieve pH 2. Add Sulfuric acid very slowly not to overshoot pH.

3 CIP Procedure

- Base CIP
    - As chemical dosing is completed. RO must be shutdown @ OFF STOPPED without shutdown flush.
    - RO needs to be flushed to pushout the brine in the system for effective CIP.
    - Override open FV-103 & FV-104 and open utility water inlet valve (3”) HV-108 to flush out brine in the system to drain. Flush until drain water is clean or CIT-101 goes down < 0.5 mS.
    - Once flush is done, close manual HV-108 and release all override including FV-103/104.
    - Make sure RO is OFF Stopped.
    - Make sure RO CIP timer is set for 1 hour.
    - Make sure CIP ph setting is set for 12.
    - Make sure Caustic CIP dosing setting is Auto.
    - Make sure SLS dosing setting is in Auto.
    - Click and hold START RO CIP for 2 sec.
        - Observe that the PSL-101 changes form red to green after you hold start. If the pressure switch does not change from red to green, the main pump, P-102 will not turn on and

the RO CIP timer will not begin to countdown and you will have a less effective CIP. If after CIP start, the PSL-101 is red and P-102 is off, please change the bag filters.

- Let RO CIP run 1 hour.
- Let SLS pump dose RO Clean Chemical during CIP.
- Once RO CIP is completed RO will be turned off automatically.
- Drain RO CIP Tank completely and leave drain valve open (HV-122)
- Override open FV-103 and FV-112.
- Open utility water inlet manual valve HV-108 until drain water from CIP tank drain or CIT-101 goes down < 0.5 mS.
- Once flush is done, fill up RO CIP Tank ~ 5 in with utility water.
- Make sure HV-108 and 122 are closed and release all override on valve FV-103 and 112.
- Make sure return normal setting on:
  - Shutdown Flush enabled for 1 min
  - CIP Tank level setting Start fill 12 in and Stop fill 34 in
  - CIP pH setting is 10.
  - SLS Dosing is off
- Set RO Inlet target pressure @ 400 psi and control RO pressure until RO is stabilized.
- FV-107 opening min: 15 % and operate above 15%
- FIT-103 operating around 25 ~28 gpm to catch up SaltMaker production
- Check pressure gauge PI-105 and PI-106 and compare to before CIP during normal operation.
- PIT-102 to be adjusted until above to variables are stabilized. (usually takes an hour so needs monitoring.)

- Acid CIP
  - After Base CIP and CIP tank refreshed, chemical to be added as 2.3 Chemical dosing for Acid CIP above.
  - Make sure RO is OFF Stopped.
  - Make sure RO CIP timer is set for 1 hour.
  - Make sure Caustic CIP dosing setting is **OFF**.
  - Make sure SLS dosing setting is in **OFF**.
  - Click and hold START RO CIP for 2 sec.
    - Observe that the PSL-101 changes form red to green after you hold start. If the pressure switch does not change from red to green, the main pump, P-102 will not turn on and the RO CIP timer will not begin to countdown and you will have a less effective CIP. If after CIP start, the PSL-101 is red and P-102 is off, please change the bag filters.
  - Let RO CIP run 1 hour.
  - During the CIP, monitor the pH of CIP tank and if necessary dose acid (30% Sulfuric acid) manually into the CIP Tank.
  - Once RO CIP is completed, the RO will be turned off automatically.
  - Drain RO CIP Tank completely and leave drain valve open (HV-122)
  - Override open FV-103 and FV-112.
  - Open utility water inlet manual valve HV-108 until drain water from CIP tank drain or CIT-101 goes down < 0.5 mS.
  - Once flush is done, fill up RO CIP Tank ~ 5 in with utility water.

- Make sure HV-108 and 122 are closed and release all override on valve FV-103 and 112.
- Make sure to return normal settings on:
  - Shutdown Flush enabled for 1 min
  - CIP Tank level setting Start fill 12 in and Stop fill 34 in
  - CIP pH setting is 10.
  - SLS Dosing is off
- Set RO Inlet target pressure @ 400 psi and control RO pressure until RO is stabilized.
- FV-107 opening min: 15 % and operate above 15%
- FIT-103 operating around 25 ~28 gpm to catch up SaltMaker production
- Check pressure gauge PI-105 and PI-106 and compare to before CIP during normal operation.
- PIT-102 to be adjusted until above to variables are stabilized. (usually takes an hour so needs monitoring.)

4 When do we need CIP?

Typically fouling is progressive and if not controlled early, will impair the RO membrane element performance and can cause physical damage to the membrane and /or the element. Cleaning should occur when the RO shows evidence of fouling including decrease in permeate flow by 10%, decrease in permeate quality by 10%, and normalized pressure drop increase by 15%. Cleaning should be carried out before these values are exceeded to maintain the elements in ideal condition.
In this regard, at the similar brine concentration (CIT-101) and the similar RO inlet pressure (PIT-102) if RO permeate flow (FIT-103) is lowered by 10 % please consider RO CIP.

U.S. WATER®
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OPERATION AND MAINTENANCE MANUAL

FLUX™ REVERSE OSMOSIS – USHR SERIES SALTWORKS

US Water Services
12270 43rd St. NE
St. Michael, MN 55376
Phone (866) 663-7632

Revision 9-2-2016

CAUTIONS AND WARNINGS

Prior to operating or servicing this device, this manual must be read and understood. If something is not clear, call for assistance before proceeding. Keep this and other associated manuals for future reference and for new operators or qualified service personnel. All electrical work should be performed by a qualified electrician in accordance with the latest edition of the National Electrical Code, as well as local codes and regulations.

DISCLAIMER STATEMENT

This operation and maintenance manual is intended to be used with the component manufacturer literature provided in the Appendix. These manuals should provide complete and accurate information to meet your operating and/or service requirements based on the information available at the time of publication. However, U.S. Water Services assumes no responsibility for the technical content of the manufacturer literature.

This manual should be read fully and understood before installation, operation or maintenance of the system is attempted. The information in this manual may not cover all operating details or variations or provide for all conditions in connection with installation, operation and maintenance. Should questions arise which are not answered specifically in this manual, contact U.S. Water Services at the phone number provided on the cover of this manual.

U.S. Water Services reserves the right to make engineering refinements that may not be reflected in this manual. The material in these manuals is for informational purposes and is subject to change without notice and should not be construed as a commitment by U.S. Water Services. U.S. Water Services assumes no responsibility for any errors that may appear in this document. This manual is believed to be complete and accurate at the time of publication. In no event shall U.S. Water Services be liable for incidental or consequential damages in connection with or arising from the use of this manual.

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SECTION 1.0: DESIGN SPECIFICATIONS

U.S. Water Services FLUX™ HR Series design parameters are as follows:

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Feed Water Flow (GPM)	
Permeate Flow (GPM)	
Reject Flow (GPM)	
Array Elements	
Flux Rate (GFD)	
High Pressure Pump	
Prefilter Housings	
Inlet Pipe Size	
CIP Inlet Pipe Size	
Permeate Pipe Size	
Reject Pipe Size	

Table 1.1, Design Specifications

USWS FLUX™ HR Series require the following utilities:

- High Voltage: 460VAC, 3 Phase, 60Hz
- Control Voltage: 120VAC, 1 Phase, 60Hz, Control Transformer Included
- Instrument Air: 5 SCFM @ 80 psig

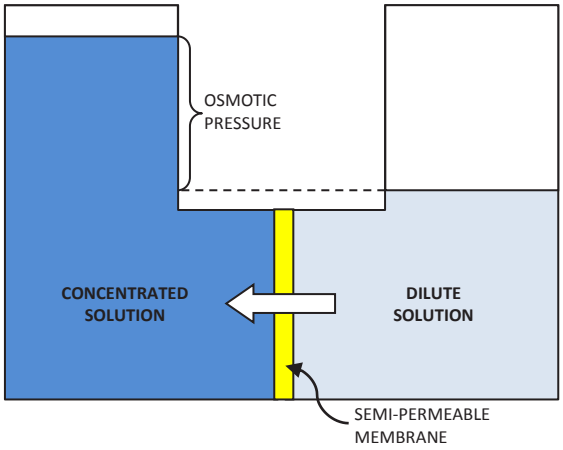
SECTION 2.0: GENERAL RO PRINCIPLES

HOW RO SYSTEMS WORK

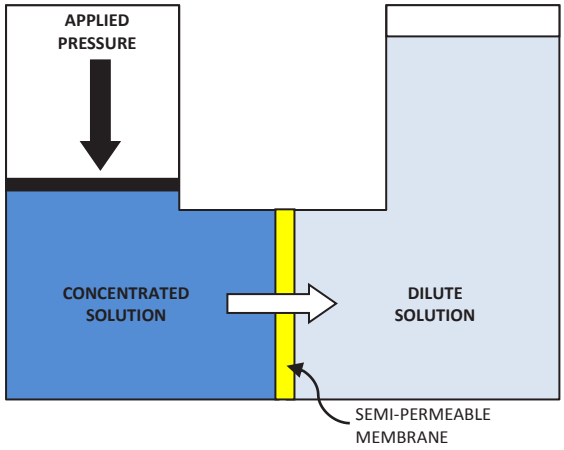
The phenomenon of osmosis occurs when pure water flows from a dilute saline solution through a membrane into a higher concentrated saline solution.

The phenomenon of osmosis is illustrated in Figure 1.4. A semi-permeable membrane is placed between two compartments. "Semi-permeable" means that the membrane is permeable to some species, and not permeable to others. Assume that this membrane is permeable to water, but not to salt. Then, place a salt solution in one compartment and pure water in the other compartment. The membrane will allow water to permeate through it to either side. But salt cannot pass through the membrane.

OSMOSIS



REVERSE OSMOSIS



Osmosis

Water diffuses through a semi-permeable membrane from the dilute solution to the concentrated solution to equalize solution strength. Ultimate height difference between columns is the "osmotic" pressure.

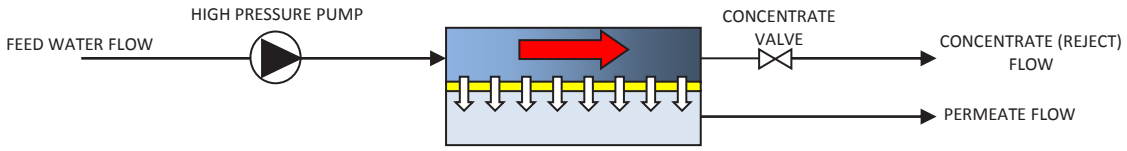
Reverse Osmosis

Applied pressure in excess of osmotic pressure reverses water flow direction. Hence the term "reverse osmosis".

As a fundamental rule of nature, this system will try to reach equilibrium. That is, it will try to reach the same concentration on both sides of the semi-permeable membrane. The only possible way to reach equilibrium is for water to pass from the dilute solution compartment to the concentrated compartment, to dilute the concentrate solution. The figures above also show that osmosis can cause a rise in the height of the salt solution. This height will increase until the pressure of the column of water (concentrated solution) is so high that the force of this water column stops the water flow. The equilibrium point of this water column height in terms of water pressure against the membrane is called osmotic pressure.

If a force is applied to this column of water, the direction of water flow through the membrane can be reversed. This is the basis of the term reverse osmosis. Note that this reversed flow produces pure water from the concentrated solution, since the membrane is not permeable to salt.

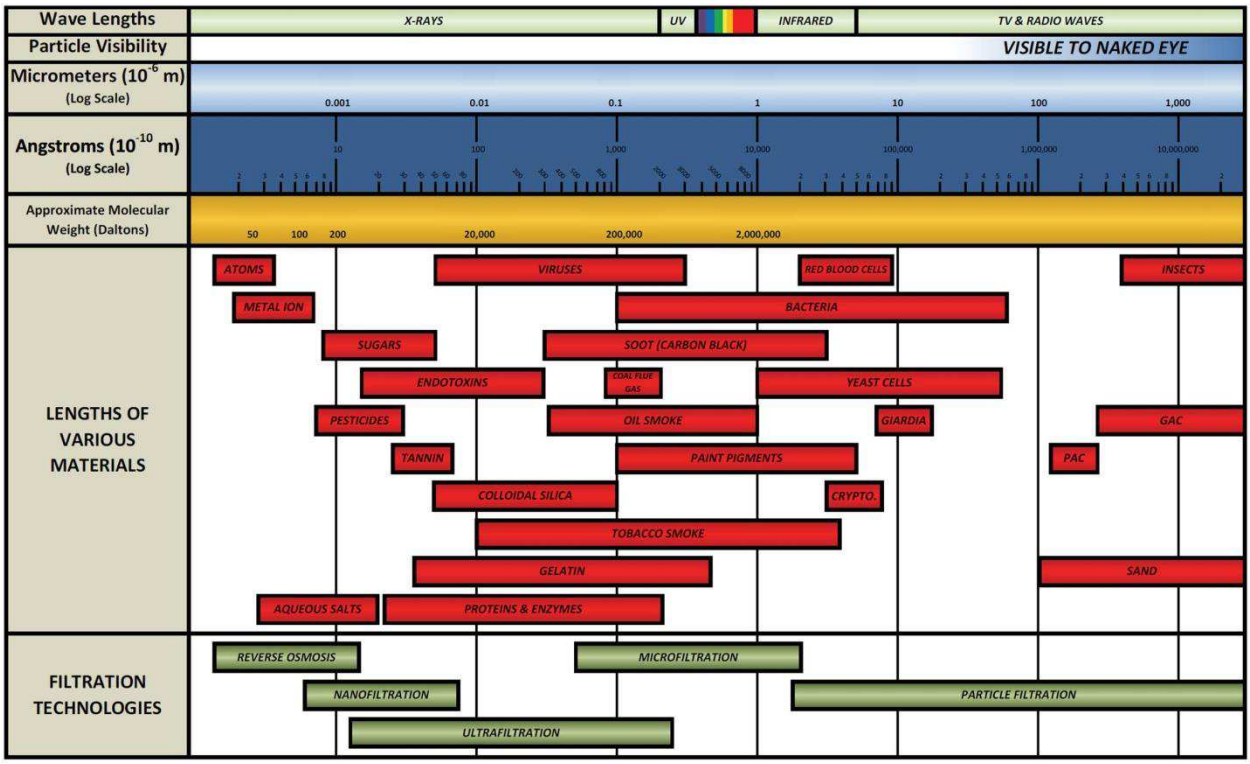
In practice, reverse osmosis systems are applied as a crossflow filtration process. The simplified process is shown the figure below:



With a high pressure pump, feed water is continuously pumped at higher pressure to the membrane system. Within the membrane system, the feed water will be split into a dilute stream called permeate, and a concentrated brine stream called concentrate or reject. A flow regulating valve, called a concentrate valve, controls the percentage of feed water that is going to the reject stream and the permeate stream.

FILTRATION SPECTRUM

The application of filtration processes is used in a wide variety of applications. The target constituent that is being removed dictates the type of filtration process that needs to be employed. The figure below outlines the filtration spectrum and the pertinent ranges of different processes that can be employed.



TERMINOLOGY

Reverse osmosis systems have a language of themselves. The table below outlines some of the common terms and acronyms encountered.

TERM	DEFINITION
Antiscalant	A chemical that is fed to the feed water to inhibit the precipitations of salts that may cause scale.
Anti-Telescoping Device (ATD)	Typically a plastic device attached to the end of a membrane to prevent the spiral wound filaments from moving in the direction of flow.
Array	The arrangement of membrane housings for a system. If the unit has two stages and the first stage has 4 housing and the second stage has 2, the array would be a 2:1 array.
Brackish Water	Water that has an approximate concentration of dissolved solids ranging from 1,000 mg/l to 10,000 mg/l.
Break Tank	A tank either prior to a system or after a system to provide hydraulic isolation from the rest of the system and the better manage pressures.
Brine Seal	The rubber seal around one end of an RO membrane that prevents feed water from bypassing the membrane by flowing between the membrane and housing.
BWRO	Brackish Water Reverse Osmosis
CIP	Clean-In-Place, a process of cleaning reverse osmosis membranes.
Compaction	The compressing of a membrane due to temperature and pressure, which may result in a decline in flux.
Concentrate	The stream leaving an RO system that contains elevated concentrations of impurities relative to the feed water. This is the portion of the water that doesn't pass through the membrane and become permeate. Also referred to as Reject.
Concentration Factor (CF)	The ratio of reject concentration (C_R) versus feed water concentration (C_F) $$CF = \frac{C_R}{C_F}$$
Concentrate Recycle	A technique where concentrate (or reject) is recycled back to the feed water line to either improve recovery or help maintain minimum cross-flow velocities in the RO.
Conductivity	A general indication of water quality. The inverse of resistivity. Measured by a conductivity meter, and described in microsiemens/cm, µmhos/com, micromhos/cm or µS/cm.
Feed Channel Spacer	A plastic netting between membrane leaves which provides the flow channel for the fluid passing over the surface of the membrane and increases the turbulence of the feed-brine stream. Typical values for feed channel spacers are 28 mils, 31 mils and 34 mils. The larger the feed channel spacer the lower the risk of fouling.
Feed Water	The water entering the RO system.
Flux	The membrane throughput, usually expressed in volume of permeate per unit area per unit time, such as gallons per day per ft^2 or GFD. The lower the flux rate the lower the risk of fouling.

TERM	DEFINITION
Fouling	The reduction of permeate flow (or flux) due to a build-up of solids on the surface or within the pores of the membrane, resulting in changed element performance.
High Brackish Water	Water that has an approximate concentration of dissolved solids ranging from 10,000 mg/l to 30,000 mg/l.
High-Purity Water (HPW)	Highly treated water with attention to microbiological, particle, organics and mineral reduction or elimination. Typically used in electronics or medical industries.
Interconnector	The device used to connect adjacent membranes in series and to seal the permeate collection tube from the feed brine channel.
Ion Exchange	A reversible process by which ions are interchanged between a resin and a liquid with no substantial structural changes in the resin; ions removed from a liquid by chemical bonding to the resin.
Langelier Saturation Index (LSI)	An index calculated from total dissolved solids, calcium concentration, total alkalinity, pH, and solution temperature that shows the tendency of a water solution to precipitate or dissolve calcium carbonate.
Membrane	Thin semi-permeable film which serves as a barrier permitting the passage of materials only up to a certain size, shape, or electro-chemical character. Reverse osmosis membranes are typically manufactured of polyamide and some are manufactured of cellulose acetate.
Membrane Feed Pressure	The pressure feeding the first stage of an RO system. If there is a high pressure pump throttling valve the membrane feed pressure is downstream of this.
Normalization	Converting actual performance data to a set of reference conditions in order to "standardize" operation to a common base. This helps distinguish between actual performance loss and the performance loss due to temperature.
ORP	Oxidation-Reduction Potential. This parameter is used to monitor the presence of oxidizing agents that can degrade thin film composite RO membranes.
Osmosis	The spontaneous flow of water from a less concentrated solution to a more concentrated solution through a semi-permeable membrane until chemical potential equilibrium is achieved.
Pass	Typical RO systems are one pass, meaning the water only permeates an RO membrane one time. Some high-purity applications require further processing by a second pass where the permeate from the first pass is sent to another set of membranes.
Permeate	The stream leaving an RO system that contains reduced concentrations of impurities relative to the feed water. This is the portion of water that has passed through the membrane.
Recovery Rate	Recovery Rate is typically expressed as a percentage where % Recovery is the ratio of permeate flow (F_P) versus feed water flow (F_P) $$\% \, Recovery = \frac{F_P}{F_F} \times 100\%$$

TERM	DEFINITION
Reject	The stream leaving an RO system that contains elevated concentrations of impurities relative to the feed water. This is the portion of the water that doesn't pass through the membrane and become permeate. Also referred to as Concentrate.
Rejection	Rejection is typically expressed as a percentage where % Rejection is defined by the following formula where C_P is the conductivity of the permeate and C_F is the conductivity of the feed water: $$\% \, Rejection = 1 - \frac{C_P}{C_F} \times 100\%$$
Scaling	The phenomenon that occurs when concentrations of salts exceed their solubility and precipitate out of solution on the membranes.
Silt Density Index (SDI)	An index calculated from the rate of plugging of 0.45 µm membrane filter. It is an indication of the amount of particulate matter in water, sometimes called fouling index. Typical SDI values are expressed as SDI_{15} where the final measurement is obtained after filtering for 15 minutes. Typical membranes manufacturers require an SDI_{15} value < 3.
Seawater	Water that has an approximate concentration of dissolved solids ranging from 30,000 mg/l to 60,000 mg/l.
Stage	A grouping of RO housings where the feed water flows in parallel. For example, if the RO has a 4:2 array, the first stage has 4 housings and the second stage has 2 housings.
Stiff & Davis Stability Index (S&DSI)	An index calculated from total dissolved solids, calcium concentration, total alkalinity, pH, and solution temperature that shows the tendency of a water solution to precipitate or dissolve calcium carbonate. S&DSI is typically used in seawater applications.
SWRO	Seawater Water Reverse Osmosis
Total Dissolved Solids (TDS)	Total Dissolved Solids, usually expressed as mg/l or ppm (parts per million), are the total amount of dissolved impurities in a water sample.
Telescoping	The movement of the outer layers of a spiral wound cartridge in the direction of the feed flow caused by excessive pressure drop through the feed channel spacer.
Temperature Correction Factor (TCF)	Defines the effect of temperature on permeate flow relative to a base temperature (77°F), is mainly a function of fluid characteristics but also membrane polymer.
Thrust Collar	A plastic cylinder placed between the last spiral wound cartridge and vessel end plate to support the last cartridge in a pressure vessel against telescoping.
Turbidity	A suspension of fine particles that scatters or absorbs light rays. Values are typically reported in the units of NTU where most membrane manufacturers recommend feed water NTU values of < 1.

TEMPERATURE CORRECTION FACTOR

Reverse osmosis system production capabilities are impacted by the temperature of the feed water. Colder feed water has a higher viscosity and the membranes will not allow as much water to permeate the membrane. The USWS FLUX™ HR Series reverse osmosis units are designed assuming 60°F inlet water. The table below shows the temperature correction factor at various temperatures below.

EXAMPLE:

- Design conditions are 50 gpm permeate at 60°F
- The actual inlet water temperature is 55°F
- The corrected permeate flow rate at the reduced inlet temperature (assuming same membrane feed pressure) is calculated as follows:

$$Corrected\ Permeate\ Flow = \frac{1.3935}{1.541} \times 50\ gpm = 45.2\ gpm$$

Temperature (°F)	Temperature Correction Factor	Temperature (°F)	Temperature Correction Factor	Temperature (°F)	Temperature Correction Factor	Temperature (°F)	Temperature Correction Factor	Temperature (°F)	Temperature Correction Factor
50.0	1.711	57.2	1.475	64.4	1.276	71.6	1.109	78.8	0.971
50.2	1.705	57.4	1.469	64.6	1.272	71.8	1.105	79.0	0.968
50.4	1.698	57.6	1.464	64.8	1.267	72.0	1.101	79.2	0.965
50.5	1.692	57.7	1.459	64.9	1.262	72.1	1.097	79.3	0.962
50.7	1.686	57.9	1.453	65.1	1.258	72.3	1.093	79.5	0.959
50.9	1.679	58.1	1.448	65.3	1.254	72.5	1.090	79.7	0.957
51.1	1.673	58.3	1.443	65.5	1.249	72.7	1.086	79.9	0.954
51.3	1.667	58.5	1.437	65.7	1.245	72.9	1.082	80.1	0.951
51.4	1.660	58.6	1.432	65.8	1.240	73.0	1.078	80.2	0.948
51.6	1.654	58.8	1.427	66.0	1.236	73.2	1.075	80.4	0.945
51.8	1.648	59.0	1.422	66.2	1.232	73.4	1.071	80.6	0.943
52.0	1.642	59.2	1.417	66.4	1.227	73.6	1.067	80.8	0.940
52.2	1.636	59.4	1.411	66.6	1.223	73.8	1.064	81.0	0.937
52.3	1.630	59.5	1.406	66.7	1.219	73.9	1.060	81.1	0.934
52.5	1.624	59.7	1.401	66.9	1.214	74.1	1.056	81.3	0.932
52.7	1.618	59.9	1.396	67.1	1.210	74.3	1.053	81.5	0.929
52.9	1.611	60.1	1.391	67.3	1.206	74.5	1.049	81.7	0.926
53.1	1.605	60.3	1.386	67.5	1.201	74.7	1.045	81.9	0.924
53.2	1.600	60.4	1.381	67.6	1.197	74.8	1.042	82.0	0.921
53.4	1.594	60.6	1.376	67.8	1.193	75.0	1.038	82.2	0.918
53.6	1.588	60.8	1.371	68.0	1.189	75.2	1.035	82.4	0.915
53.8	1.582	61.0	1.366	68.2	1.185	75.4	1.031	82.6	0.913
54.0	1.576	61.2	1.361	68.4	1.180	75.6	1.028	82.8	0.910
54.1	1.570	61.3	1.356	68.5	1.176	75.7	1.024	82.9	0.908
54.3	1.564	61.5	1.351	68.7	1.172	75.9	1.021	83.1	0.905
54.5	1.558	61.7	1.347	68.9	1.168	76.1	1.017	83.3	0.902
54.7	1.553	61.9	1.342	69.1	1.164	76.3	1.014	83.5	0.900
54.9	1.547	62.1	1.337	69.3	1.160	76.5	1.010	83.7	0.897
55.0	1.541	62.2	1.332	69.4	1.156	76.6	1.007	83.8	0.894
55.2	1.536	62.4	1.327	69.6	1.152	76.8	1.003	84.0	0.892
55.4	1.530	62.6	1.323	69.8	1.148	77.0	1.000	84.2	0.889
55.6	1.524	62.8	1.318	70.0	1.144	77.2	0.997	84.4	0.887
55.8	1.519	63.0	1.313	70.2	1.140	77.4	0.994	84.6	0.884
55.9	1.513	63.1	1.308	70.3	1.136	77.5	0.991	84.7	0.882
56.1	1.508	63.3	1.304	70.5	1.132	77.7	0.988	84.9	0.879
56.3	1.502	63.5	1.299	70.7	1.128	77.9	0.985	85.1	0.877
56.5	1.496	63.7	1.294	70.9	1.124	78.1	0.982	85.3	0.874
56.7	1.491	63.9	1.290	71.1	1.120	78.3	0.979	85.5	0.871
56.8	1.486	64.0	1.285	71.2	1.116	78.4	0.977	85.6	0.869
57.0	1.480	64.2	1.281	71.4	1.112	78.6	0.974	85.8	0.866

SECTION 3.0: MATERIAL HANDLING, RECEIVING AND STORAGE

The purpose of this section is to provide general information on receipt and handling of new equipment. Specific information on the installation of equipment and components is found in the equipment and drawing sections of this manual. All equipment must be installed as shown on the drawings for this job.

EQUIPMENT HANDLING

Unloading and handling of the major components for this job must be performed by experienced workers using approved lifting and moving procedures. The following subsections provide general guidelines for lifting and moving heavy equipment.

MAJOR COMPONENT HANDLING GUIDELINES

All lifting and moving procedures must be performed by experienced construction workers using standard rigging methods.

Before beginning any equipment handling procedure, refer to the following sections in the Occupational Health and Safety Administration (OSHA) Manual #2206: "General Industry Standards."

OSHA MANUAL #2206

- Subpart N: "Materials Handling and Storage"
- Section 1910.176: "Handling Materials - General
- Section 1910.178: "Powered Industrial Trucks"
- Section 1910.179: "Overhead and Gantry Cranes”
- Section 1919.180: "Locomotive and Truck Cranes"
- Section 1919.181: "Slings"

Also, refer to any other applicable literature and information for cranes, lift trucks, and other equipment used for lifting and moving.

Make sure that all equipment used for lifting and moving is properly maintained and is in good repair. Always inspect slings, cables, clevises, and other equipment prior to every lifting and moving event.

CAUTION -
Damaged lifting devices can cause severe personal injury or equipment damage.

When using cables or woven straps as slings or chokers, place heavy carpeting, sections of tires, or other material between the sling and the object being lifted. This will help protect the sling device and the object being lifted.

If lifting lugs or eyelets are installed on a component, use these devices for lifting whenever possible.

Do not lift a vessel or equipment skid by attaching lifting devices to piping or other components.

Be sure that components being lifted are balanced and will not tip or slip out of a sling. When lifting a large component, raise the object until it just clears the surface it was resting on and then stop. Observe the object to verify that it is balanced and is firmly held by the lifting devices. If there is any doubt about the safety of the lifting method, set the object down and reposition the lifting devices or else use another method.

Use extra caution when lifting equipment skids using lift points on the skid (base). Equipment skids are often top-heavy and may tip when lifted more than a few inches off the ground.

When moving a component with a crane or a lift truck, keep the load as low as possible at all times. This can minimize component damage if the load tips over, slips, or falls.

Keep hands and feet from under raised components. If operators must reach under a raised component, place some type of heavy blocking under the component to support it if the lifting device fails.

Once a component is connected to lifting devices and is ready to lift, a foreman or lead person should verify that all workers are clear of the lifting devices, the object, and the immediate lift area before proceeding. When a large component is to be lifted and moved, all workers in the general area should be warned of the lifting event and should be instructed to stand clear of the component and the lift area. When a component is lifted with a crane or fork lift, all workers must remain in the operator's view during the lifting operation.

If two or more lift points on a component are connected to a single crane or crane trolley, use cable spreader bars to prevent excessive side loads on legs, lifting lugs, eyelets, and other lift points.

If a large component must be lifted more than a few inches off the ground, attach tag lines to the component. Workers can use these tag lines to stabilize and control the component while it is suspended.

LIFTING CONTAINER, EQUIPMENT SKIDS AND PANELS

Always lift container and/or equipment skids evenly; avoid flexing the equipment. Also, keep the equipment level and close to the ground as it is being moved.

CAUTION -
Many equipment skids or containers are top heavy and can be unstable when lifted from their bases. These skids can tip during lifting and can cause equipment damage and worker injury. Always use a separate cable for each lift point to prevent cable slip at the crane hoods. Keep the skid as close to the ground as possible during the lifting and moving procedures.

As with vessel lifting, use spreader bars to eliminate excessive side-loading on lifting lugs and eyelets and to keep cables from pinching the equipment on the skids. See the drawing on the next page. Finally, attach tag lines to the skid, container or other component if it must be lifted more than a few inches off the ground. An experienced operator is necessary to move the container.

CAUTION -
Use extra care when moving control panels. These panels contain delicate instruments that can be damaged by rough handling.

HANDLING OTHER EQUIPMENT

The following outline gives handling guidelines for smaller components.

Many of the smaller components that are shipped loose for this job can be moved using forklifts or small cranes and woven straps. Workers must be sure that any equipment used for moving loose components is properly maintained and is in good repair. Refer to OSHA Manual #2206 for more information on material handling and handling equipment.

When moving components with a forklift, be careful not to damage the components. Avoid "ramming" the lifting forks under pieces; use a crane or pry bar to lift the piece up enough to drive the forks under. Be careful not to damage tubing, indicators, and other delicate devices or parts attached to larger components.

Make sure that any load on the forks is secure and balanced. When carrying pipe or pipe spools on the forks, keep the forks tilted all the way back and avoid sudden stops.

Be aware of the weight capacity of the forklift being used; do not overload the forklift. When carrying long or wide pieces, watch carefully when making turns.

When lifting and moving individual pumps, lift by the pump base or at any indicated lift points.

CAUTION -
Do NOT lift pumps using eyelets found in the pump body or in the drive motor. These eyelets are generally used by the pump manufacturer during the assembly of the pump and are not intended for lifting the entire unit.

When moving lengths of pipe or long spools with woven straps, use two straps equally spaced from the balance point of the piece; this will prevent tipping and loss of control of the piece when it is lifted.

Use special precautions when moving large control valves. When lifting valves, use a woven strap as a choker around the valve body or around the stem between the actuator and the valve body.

Do not lift valves by their hand wheels or actuators. Also, be careful not to damage tubing, indicators, and other delicate devices or parts attached to the valves.

Use extreme caution when moving instruments or components with instruments attached. Instruments are delicate and can be damaged by dropping or bumping them. Be especially careful not to damage gauges or sensors attached to the instrument.

HANDLING CHEMICALS

CAUTION -
Refer to Chemical Suppliers' MSDS plus Plant Safety Procedures for proper handling and storage of chemical products associated with this RO unit.

INITIAL EQUIPMENT RECEIPT, INSPECTION AND STORAGE

INSPECTION AT RECEIPT

When the job shipment is received from USWS, it must be inspected **immediately** for completeness and for shipping damage.

Refer to the Packing List/Shipping List to verify that the items listed are in the shipment.

CAUTION -
Use care when moving equipment and components and when opening crates.

Record the "item" and crate numbers of all received pieces. Some crates will contain several different tagged items; these crates should be opened temporarily to check the different items. Compare the item and crate numbers recorded to those shown on the shipping list, and check off each item (on the shipping list) that has been located. If items appear to be missing, contact the carrier and USWS immediately.

NOTE -
Some small components that were removed from major components during preparation for shipping may not have item numbers. These untagged components can be identified referring to the piping drawings and the parts lists for this job. These components may include pressure gauges, sample valves or membrane housing internal parts.

Perform a thorough inspection of the major component equipment skids, and of piping and other components already installed on these components. Damage to these components is easy to miss during a quick inspection. Make sure that gauges, sample piping, and tubes have not been broken off. Also look for broken or bent piping. Pay particular attention to any fiberglass or plastic vessels; these vessels are easily damaged by rough handling.

NOTE -
Any equipment damage that is found must be reported to the carrier immediately to file for a claim with the transportation company. Avoid releasing equipment for assembly until all damage claims and/or shortage problems have been resolved.

If the equipment will be stored before being assembled, reseal any crates that were opened for inspection.

Perform a close inspection of all shipping crates and boxes and of other loose components. Verify that no damage has occurred to these pieces. Check for visible damage to crates, piping, and piping ends. If a crate or box appears damaged, open the crate or box and investigate further.

STORAGE OF COMPONENTS

Use the following instructions if the job shipment will be stored before it is actually assembled:

1. Place a copy of the marked-up shipping list and the written list of received item numbers together and store them in a safe place. If necessary, make copies of these lists and distribute them to the individuals who will be involved in the assembly of the equipment.

2. If any crates were opened for the inspection procedures, reseal these crates securely.

3. Select a storage location where all of the equipment will fit and can be stored.

4. Avoid separating the USWS equipment components. On large jobsites, it is easy for small components to become misplaced or lost. Always try to group the equipment in one place. If the equipment must be separated, note the exact locations of all pieces on the shipping list or the written list of received pieces.

CAUTION -
Use extreme caution when moving the equipment. Be careful not to drop fragile items or to damage parts when lifting with forklifts.

5. Store all equipment indoors where it will be protected from sunlight and adverse weather conditions.

NOTE -
RO membranes should be stored indoors and should be protected from freezing or overheating.

6. Set the vessels, skids, and other components on wooden blocks to keep them out of any standing water and to protect their painted surfaces. If the equipment will be stored for a great length of time, cover it with plastic or canvas tarps to protect it from water, dust, paint overspray, etc.

If the equipment must be stored outside, special precautions must be taken. The following procedures should be followed:

NOTE -
USWS does not recommend storing any equipment outdoors.

7. Items that can be damaged by water must be securely wrapped with plastic and covered with tarps. Store the equipment in a shaded area or cover it with light-colored tarps. If the outdoor temperature is very warm, remove all vessel manhole covers to allow air circulation.

8. Some equipment may be factory tested using water. While USWS works to make sure the equipment is fully drained prior to shipping, some water may collect in the areas of treatment systems. When the outdoor temperature is below 32°F (0°C), it is important to verify that the vessels, piping, pumps, and other parts are drained of liquids. Expanding ice can damage vessels and other components. Open all hand valves partially on the equipment to allow trapped water and moisture to escape. USWS cannot be responsible for freezing damage occurring onsite.

NOTE -
Always drain all liquids from components that must be stored in freezing temperatures. Expanding ice can damage vessels and other components.

9. Plastic pipe must not be exposed to direct sunlight. High temperatures can distort and damage plastic piping.

10. When equipment has been stored in extremely hot or cold temperatures and then is moved to an assembly area, always allow the equipment temperature to stabilize before beginning assembly. This is especially important if the equipment is very cold.

11. When equipment is brought out of storage, the original shipping list and the written list of received pieces should be retrieved and used to double-check the existing equipment. Any pieces noted as missing at this time must be located as quickly as possible to avoid delays in assembly and startup of the equipment.

12. Prior to assembly of the equipment, perform a quick recheck for possible equipment damage. Use the applicable procedures in this manual.

SECTION 4.0: EQUIPMENT INSTALLATION

GENERAL GUIDELINES

All equipment and mechanical components listed on the part list must be installed according to the US Water Service's drawings for this job. Only qualified electricians, installers, operators, maintenance personnel, and/or construction personnel should be allowed to perform any work relating to the system in order to avoid serious injuries or equipment damage. All work should be performed in accordance with accepted plumbing, wiring, and construction procedures.

NOTE -
While equipment is shipped from US Water Service's facility complete and factory tested, it is possible that mechanical or electrical components may become loose as a result of shipping. Also, some fittings may be loosened to aid in proper draining or to prevent damage during shipping. Once the equipment is positioned into place, it is important to verify that all bolts and fasteners are properly tightened. Also, all electrical terminations should be verified so that no wiring is loose at either the control enclosure or instrumentation point.

MECHANICAL INSTALLATION

1. Prior to pipe installation, all skid and tanks should be correctly located and properly anchored and aligned. *Refer to any supplied layout drawings for this information.* Workers must pay particular attention to elevations and to center-to-center dimensions.

2. RO systems shall never be installed in an area exposed to direct sunlight. USWS recommends RO units to be installed in a shaded area if the system is installed outdoors.

3. All equipment must be level and resting solidly on the plant floor before further construction is allowed. USWS recommends full concrete pads, grouting and anchoring of this RO skid. All other components of the skid (i.e. pumps, probes, motors, etc.) are securely fastened to the skid and require no additional anchoring.

CAUTION -
Empty units may tip suddenly and without warning, causing equipment damage or injury to workers. Always brace equipment securely until they are loaded or are bolted to the plant floor.

4. If pumps are shipped loose (not skid-mounted), they must be positioned and then mounted and grouted using approved construction procedures. As with the equipment skids, loose pumps must be securely anchored to the plant floor to prevent movement caused by vibration.

CAUTION -
Many pump manufacturers ship their pumps without lubricants installed; these lubricants are often shipped in separate containers. As soon as these pumps are mounted and aligned, the proper types and quantities of lubricants should be located and installed in the pumps.

NOTE -
Once pumps and pump skids have been installed, the alignment of the pump-drive couplings must be checked and corrected as necessary. Refer to the pump manufacturer's instructions for information on coupling alignment.

NOTE -
Vibration-induced movement of pumps or equipment skids can result in misalignment and damage to piping components. Always anchor equipment skids to the plant floor.

5. Feed Line: The inlet feed stream must be piped properly as per drawings. Customer-supplied feed piping should be of material non-susceptible to corrosion. Feed piping made material susceptible to corrosion may cause serious membrane fouling. The pipe size of the customer-supplied feed line to the USWS supplied equipment must be at least the same, or larger size of the inlet of such equipment.

6. Reject Line: The reject stream must be piped properly as per drawings. Customer-supplied reject piping should be of non-corrosive material. The pipe size of the customer-supplied reject line from each of the USWS supplied equipment must be at least the same, or larger size of such equipment. If reject piping is routed to drain, the drain must be able to handle the design reject flow rates identified in Section 1.0.

7. Permeate Line: The permeate stream must be piped properly as per drawings. RO Permeate can be corrosive and should be constructed of material that is unsusceptible to corrosion. Stainless steel and non-metallic piping systems are preferred while carbon steel and copper lines should not be used. The pipe size of the customer-supplied permeate line from each of the USWS supplied equipment must be at least the same, or larger size of such equipment. The maximum backpressure on the permeate line should not exceed 10 psig.

NOTE -
The reject and permeate piping run should be as straight and as short as possible. Pipe elbows, tees, and other fittings combined with long pipe runs can increase back pressure to the point that proper flows cannot be achieved.

NOTE -
Attention should be paid to preventing or eliminating vacuum conditions on the RO permeate or reject lines. Failure to prevent vacuum conditions will lead to equipment damage and void product warranty.

NOTE -
All piping connected to the skid must be supported. The connection points on the skids are not designed to support external forces.

CHEMICAL SYSTEM INSTALLATION (IF PROVIDED/APPLICABLE/SHIPPED LOOSE)

Because of the hazardous chemicals used with cleanup systems, special attention must be paid to the installation of any chemical-handling components.

CAUTION –
Chemicals used in RO treatment may be highly corrosive. Bodily contact with these chemicals can cause severe burns or blindness. Failure to install, pretest, and operate the chemical system properly can result in serious injury to workers due to leaks and mechanical malfunctions.

1. Always use acid and caustic resistant materials for the chemical system components.

2. All supplied caution and warning labels must be installed and maintained at chemical storage tanks and other components. If labels are lost or damaged, new labels should be requested from the chemical supplier.

3. Be sure that check valves are properly installed.

4. When installation is complete, USWS recommends that the entire chemical system be pressure tested top operating conditions before chemicals are introduced.

SYSTEM FLUSHING AND PIPE HYDROTESTING

System Flush Procedures

The piping and other components must be flushed thoroughly prior to the installation of RO elements. The flushing procedures are critical to the proper startup and operation of the equipment.

Customer Supplied Inlet Piping Flushes

1. All system inlet piping must be flushed thoroughly before it is connected to the USWS system.

NOTE -
Newly installed piping usually contains welding slag, dirt and other debris that will plug filters and can damage pumps.

2. If the inlet piping runs have already been connected to the skid, the piping must be disconnected at this time.

3. Each inlet piping run must be flushed with clean, clear water at the maximum possible velocity.

4. Each piping run must be flushed for as long as required to obtain a clean effluent.

5. If possible, the effluent flow from the process feed piping should be checked for its silt density index during the flush procedures.

NOTE -
The feed piping should be flushed until the SDI is the same as that of the normal feed supply.

6. When a piping run has been flushed thoroughly, it can be connected to the USWS system.

Storage Tank Flush

Inspect the interiors of all liquid storage tanks. If dirt or other material is present, use clean water to rinse out the tanks.

Immediately replace the tank covers to keep dirt out. Keep the tank covers in place except when mixing the chemicals.

PRESSURE TESTING

When all equipment and components have been installed, the system must be pressure tested with water. Note: All skid piping was pressure tested in a USWS factory prior to shipping. However, after pressure testing and before shipping, some parts may be loosened to aid in proper draining and to avoid damage during transport.

Once site interconnecting piping is completed, it is necessary to retest the piping prior to operation. Any leaks must be repaired and the leak test repeated before the system is placed in operation. Study the following guidelines before performing the pressure test.

CAUTION -
Mechanical failure during pressure testing can result in serious injury to workers. Do not exceed the pressure rating of components when performing pressure tests. Wear eye and face protection when performing pressure tests.

GENERAL PRESSURE TEST GUIDELINES

1. Be sure that the piping and vessels to be tested are filled with water. This minimizes the possibility of injuries should a mechanical failure occur during the pressure testing.

CAUTION -
Do not pressure test the system with compressed air. If a mechanical failure occurs while the system is pressurized with air, the released air can propel fragments of metal or plastic, resulting in injury to personnel.

2. Do not pressurize vessels and piping over the maximum design pressures. USWS does not warranty systems that have been subjected to pressures higher than applicable vessel rating.

3. During the pressure testing, stand away from vessel windows, inline sight glasses, glass-tube flow meters, and plastic piping. These components are most likely to fail during pressure testing.

4. Relieve all pressure from the system before attempting to repair any leaks.

5. Any leaking valves must be adjusted, repaired, or replaced and then retested before the system is operated.

SECTION 5.0: TESTING AND PRE-START-UP CHECKS/PREPARATION

This section describes the following:

1. Electrical Testing
2. Pneumatic Line Testing
3. Instrument Checks/Testing/Calibration
4. Chemical Pumps Test/Calibration
5. Pumps Check-up/Motor Unbalanced Tests
6. Valves Pre-start checks/tests
7. Pre-start-up checks and preparation

ELECTRICAL TESTING

The following general guidelines for checking the electrical materials and termination points shall be conducted prior to introduction of power in the system. Check for physical damage, fitting and alignment, bolt tightness, cleanliness of bushings, and free operation of starters and circuit breakers during connection.

3 PHASE FEEDER BREAKERS

The breaker and incoming feeder connected cable shall be subjected to a 1000 VDC megger test for 1 minute. (Care should be taken to ensure test voltages are not induced into electronic equipment when testing the outgoing supply cables).

3 PHASE POWER CABLES

The power cables shall be given an insulation resistance test using a megger meter at 1000 VDC for a period of one minute for phase-to-phase and phase-to-ground readings. (Use meter discharge facility or short cables to ground before touching tested cables.)

SINGLE PHASE POWER CABLES

The power cables shall be given an insulation resistance test using a megger meter at 1000 VDC for a period of one minute between conductors (including neutrals) and conductors to ground prior to connecting the cables to the control panel.

Data shall be recorded on an appropriate data sheet provided by others.

SECONDARY GROUND GRID

The secondary ground grid shall be given a “Drop of Potential” ground test prior to being connected to the Primary Ground Grid.

Equipment grounding to motors and transformers, etc. shall be routed in the same conduit as the feeder cables to that equipment. Equipment skids which are fabricated from conductive materials shall be grounded to the main ground ring.

All paint shall be removed from the area where the ground lug is attached or bolted to the skid. A light coating of petroleum jelly should be applied on the ground lug faces prior to attaching it to the skid or frame.

Ensure that grounding terminals are secure and tight during the check-out inspection.

ELECTRICAL CONDUITS

Inspect conduits for damage which may have occurred during the construction phase of the project. Check all pull boxes and tee's to ensure that no covers are missing. Cable fill space shall not exceed 40% of the conduit area.

Metallic equipment/pipes must be grounded at each end at the connecting panel by means of a grounding lug connection on the conduit securing nut which shall be connected to the panel ground bus by means of a ground wire.

CABLE TRAYS

Ground bonding jumpers shall be bolted to straddle each of the tray joints and fish plates. The cable tray shall be effectively grounded by means of attaching it to the system ground at each end of the tray run. Cable fill space shall not exceed 40% of the tray area.

CONTROL WIRING

Control wiring shall be subject to a continuity test only. Testing of these wires from each point of termination shall suffice prior to the discrete signal check-out. This procedure will apply to the control wires for the level switches installed in site to the Main RO Panel.

INSTRUMENTATION WIRING

Instrumentation wiring shall be tested for continuity as part of the loop check-out procedure.

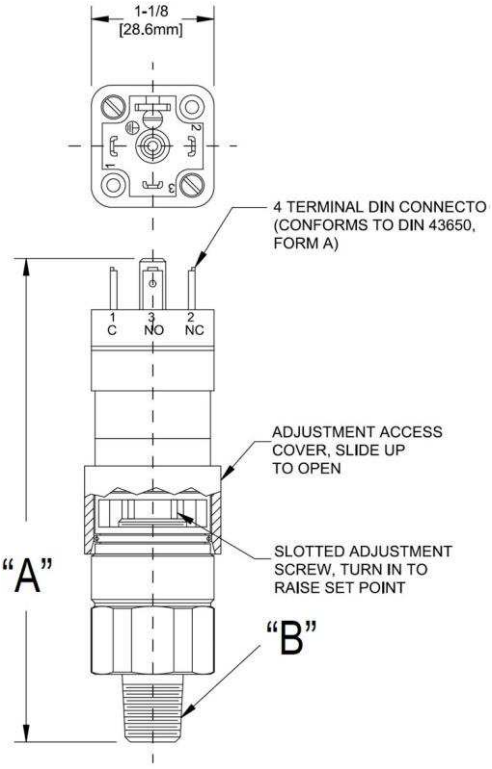
PANEL TESTING

Once all electrical checks are completed, panels can be powered. During this time, power supply indicating lights and instrument display shall be noticed and checked.

INSTRUMENT CHECKS/TESTING/CALIBRATION

All instruments in the equipment are wired and tested in USWS's shop. Most of the instruments are factory calibrated; however, some instruments need to be re-calibrated on site and set-points verified and updated, if required.

PRESSURE SWITCHES



This will be adjusted and tested to activate or close/open the contact at the rated pressure. Pressure setting can be adjusted either up or down at Owner's risk.

Connect control to an adjustable pressure source.

1. With power disconnected, slide cover toward electrical terminations while twisting it to overcome friction.
2. Connect power to terminals or leads.
3. When adjusting the high pressure setting, slowly close the valve after the pressure switch. Observe the rising pressure and adjust your pressure setting as required.
4. Insert screwdriver into adjustment slot and turn clockwise (left) to increase setting or counter clockwise (right) to decrease setting.
5. After completing adjustments, slide cover closed over adjustment compartment.
6. Recheck set point.

<u>Bench Test (if applicable)</u>

1. Remove the pressure switch in the line.
2. Using Handheld Pneumatic Pressure Tester, connect the pressure line of the tester to the pressure switch.
3. Using electric meter, connect the line and neutral wires.
4. Operate the pneumatic tester and raise the pressure.
5. Adjust the pressure setting so that it will activate or close/open the contact when pressure is reached.

PRESSURE GAUGES

These instruments are factory calibrated and cannot be field calibrated.

CONDUCTIVITY SENSOR AND TEMPERATURE PROBE CALIBRATION

Because the conductivity measurement is affected by the physical environment in which it operates, it is best to calibrate while installed in the system and operating under normal conditions. This requires an external conductivity measurement device that is known to be accurate to serve as a reference.

1. Operate the RO long enough for the membranes, operating temperature and permeate conductivity reading to stabilize.

2. Take a sample of the permeate stream and measure it with the reference meter.

3. Isolate the probe in the system and remove it from the system line. Follow the directions on the next page.

4. After calibration is complete, insert the probe back into the system line.

5. The same procedure applies to the Inlet Conductivity Probe calibration (if applicable)

6. See manufacturer's documentation for troubleshooting recommendations.

PUMPS CHECK-UP/MOTOR UNBALANCED TESTS (IF APPLICABLE)

NOTE -
Do not run coupled motors with dry pumps. Operating pumps without liquid can damage the pump and void warranty.

NO LOAD/FULL LOAD TESTING

Pumps can be checked with the motors coupled as full load condition AND/OR motors can be tested separately under NO load conditions.

1. If No load test is to be conducted, motors have to be uncoupled from the pump and reinstalled after test is complete. Follow the uncoupling and re-installation of the motors as per the pump manual instructions.

2. Record the Full Load or No Load current in the motor nameplate and run the motor with pump or motor only.

3. Compare the actual current with the nameplate current. If the difference between nameplate and actual current exceeds 10%, notify USWS immediately.

VIBRATION TESTING

Vibration tests can be checked using instruments suited for the purpose. This is normally checked if vibration or is in doubt. In most cases, this is not necessary. Follow the testing procedures in the instrument manual.

MOTOR ROTATION TEST

Pumps need to be checked for proper rotation. Pumps rotating backwards can be damaged and will not produce the head pressure desired. Ensure the direction of rotation is consistent with the markings on the pump base frame.

VALVES PRESTART-UP/TESTS

There are several types of valves supplied in this project. Each and every valve has to be checked to determine if it is opening and closing properly.

Manual Butterfly or Ball Valves – test the valve by manually opening and closing action. Make sure that it can be opened and closed 100%. Sometimes the valves are very hard to open and close; correct this by removing the valve and check if it hits pipe fitting, etc. In the case of ball valves, check that the ball is undamaged and seals are free of damage. Replace if defective.

Check or Non return valves – these valves are checked before installation. However, check during operation if the flow is acceptable.

Automatic Inlet Valve – this valve was tested in USWS's facility. However, as soon as power is available, the valve should be checked using the system "On/Off" switch; its operation should be observed. When power is applied, the inlet valve should move to the open position. When power is removed, after a factory set time delay, the valve should close. A local indicator is supplied on the top of the valve actuator to indicate valve position.

PRE-START-UP PREPARATION

1. Backwashing of media filters (if applicable) – This will clean the filter media and remove dust/fine particles. If not removed, the SDI (Silt Density Index) will be high. After backwashing and rinsing the filters, SDI_{15} should be tested. If SDI_{15} is more than 3.0, USWS should be consulted to help resolve this problem before operating the RO system.

2. Install the appropriate sized cartridge filters in the cartridge filter housing(s).

3. Ensure the chemical feed system(s) are ready and primed to the injection point.

4. Run the system in manual to determine that the equipment and instrument are working properly.

5. Perform instrument calibrations.

For systems shipped without membranes loaded, the following steps should be added:

1. Sanitizing the RO pressure vessels: This process kills bacteria in the lines. It is required before membrane loading.

2. De-sanitization to remove traces of chlorine; chlorine is detrimental to the membranes.

3. Membrane Loading

CARTRIDGE FILTER LOADING AND STARTUP

1. Close the inlet valve on the feed water located before the cartridge filter, the high-pressure pump throttle valve and the recirculation valve (if applicable).
2. Open the air relief valve on the top of the filter housing (if applicable) to relieve water pressure stored in the filter housing.
3. Open the cartridge filter housing(s), inspecting the interior of the housing(s) and removing any foreign material. Filter housings are opened by removing the band clamp near the top (or middle) of the filter housing.
4. Check filter manufacturer's instructions for the loading of the cartridges into the housing(s).
5. Close the cartridge filter housing(s).
6. Open the inlet valve to allow feed water to fill the cartridge filter(s).
7. Open the air relief valve on the top of the filter housing until water flows freely and all air has been removed.
8. Open the high-pressure throttle valve and recirculation valve (if applicable) to their previous positions.

MEMBRANE LOADING

Before you start loading the membranes and starting up the RO, familiarize yourself with the following:

BRINE SEAL

The brine seal is a flared gasket located at one end of the RO membrane. This gasket prevents the RO feed water from bypassing the active membrane area by flowing around the element. Before you load the membranes, identify feed end of the housing, identify the location of the brine seal on the RO element, and insert the RO element—brine seal last in the direction of the feed (see note below).

The brine seal gasket is actually inserted inside the U-cup of the membrane. The membranes are equipped with feed spacers only at the feed-end. Lubrication (glycerin) must be applied to the gasket before inserting the membrane.

INTERCONNECTORS

Interconnectors are used to connect membrane to membrane. Inside the interconnectors there are O-rings. These O-rings require lubrication. Apply glycerin on all O-rings before inserting the interconnectors or adapters.

END CAP ADAPTERS

End cap adapters are used to connect the membrane to the housing end cap - which only applies to the first and the last membranes. Inside the end cap adapters, there are O-rings. These O-rings require lubrication. Apply glycerin on all O-rings before inserting the end cap

END CAPS

End caps go on each end of the housings. They have end cap adapters installed in them to provide a connection to the permeate tube. Typically one end cap will have a plug in it whereas the other end will collect permeate. End caps have an O-ring that needs to be installed and lubricated with glycerin prior to installing.

RETAINING RINGS

Retaining rings are used to hold in the end caps. These are installed by starting with one inserted into the groove on the membrane housing and working it around until fully inserted. They may be removed by pulling on the finger pull portion and removing in a circular order. The retaining rings are often damaged by improper removal techniques (pliers, locking pliers, etc.).

Figure 5 1: RO Membrane Element

Note: Prior to loading membranes, inspect each membrane to identify the direction of flow as different membrane manufacturers may require different feed directions. Each membrane should have an arrow pointing in the direction of flow. Install membranes accordingly.

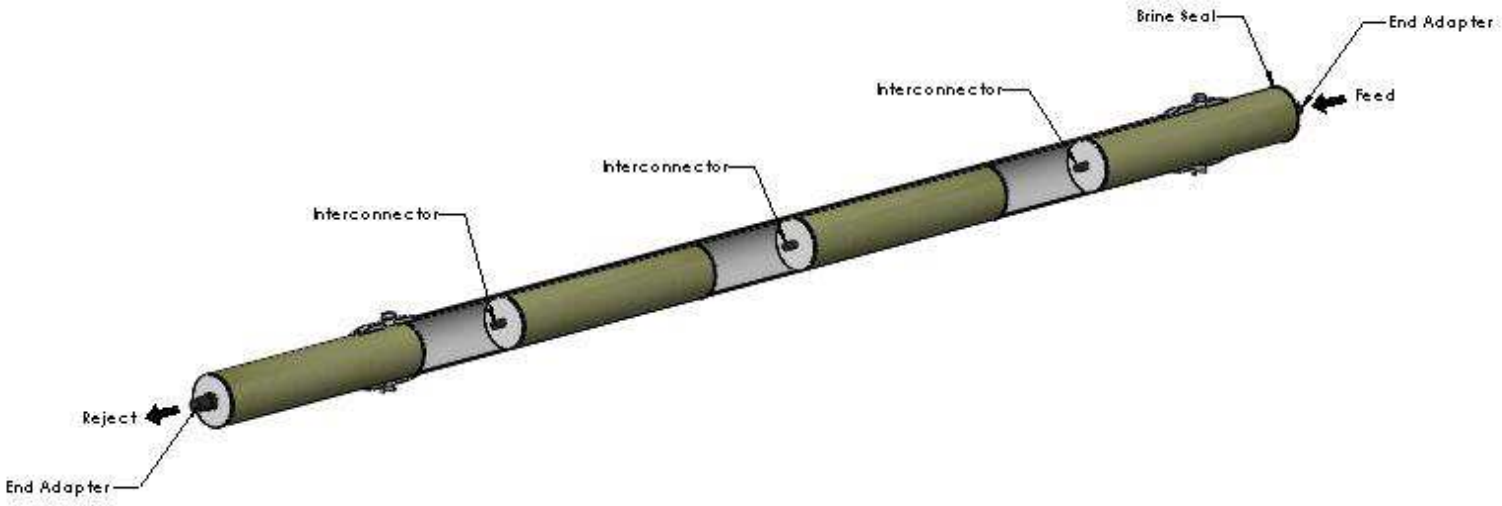


Figure 5.2: RO Membranes Interconnectors and Adapters

REQUIREMENT FOR MEMBRANE LOADING:

1. RO membrane elements
2. Interconnectors – one per each membrane
3. End Cap Adapters per housing – 2 per pressure vessel
4. End Caps & Retaining Rings – 2 per pressure vessel
5. Minimum two people to do the job
6. Glycerin as needed
7. Gloves, clean cloth, heavy duty pliers, etc.
8. Removal of end caps from RO pressure vessels (check the manual of the pressure vessels)

PRE-LOADING INSTRUCTIONS

1. Prior to loading membrane elements, record the serial number of each element.

2. When loading the elements, record the installed location (housing number or name) of each element.

NOTE -
Do not unpack an element unless it will be installed immediately. Do not set an exposed element on any surface. Any dirt or particulate matter can contaminate the element. The elements must not become contaminated and must not be allowed to dry out.

CAUTION -
RO elements are typically shipped in a preservative/disinfectant solution that may cause eye and skin irritation. Wear rubber gloves, eye protection, and protective clothing when handling the elements.

3. Verify that all of the flush procedures have been completed to properly drain and depressurize the RO system.

4. Open the permeate sample valves at the RO modules to relieve internal pressure.

5. Remove the retaining rings holding the end caps.

NOTE -
Be careful not to lose any o-rings or gaskets for the piping connectors.

6. Mark the pressure vessels' end caps and related components to indicate their proper location. Because of minor variations in the piping dimensions, components must be returned to their original locations to avoid stress on the inlet and outlet piping.

7. Water will flow from the pressure vessels onto the floor when the end caps are removed. Make provisions for this flow of water as necessary.

8. Select the vessel to be loaded first and open the housing using the manufacturer instructions.

9. Inspect the vessel and components for cleanliness and damage. Wash components with filtered/softened water if additional cleaning is warranted.

10. Load the required RO elements into the vessel using the loading instructions that are shown below.

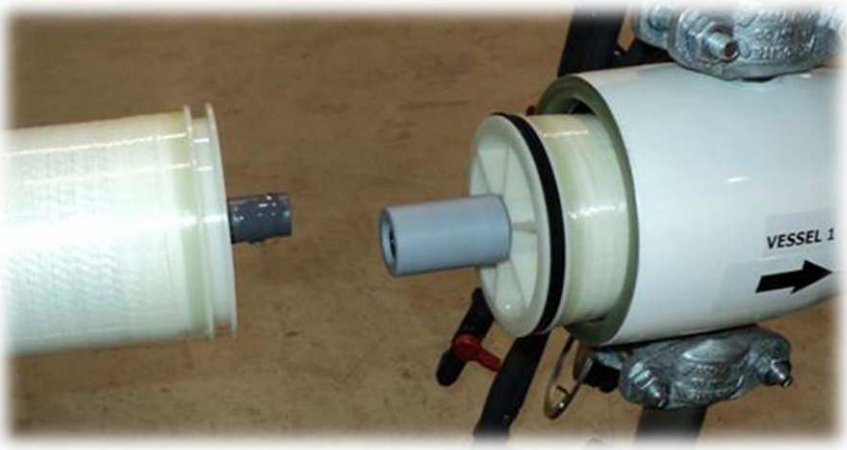
11. As soon as all of the pressure vessels have been loaded with elements, perform the startup procedures for the RO system. The pressure vessels must be filled with water to prevent drying of the elements.

NOTE -
Following installation of new RO elements, the system must be flushed to drain for a minimum of three hours to remove all traces of the shipping chemicals.

LOADING INSTRUCTIONS

The most important thing before loading membrane elements in a specific RO membrane housing is to identify the feed end. The opposite end is always the reject. Once the feed end is identified, the membrane elements may be loaded.

1. Remove all end caps (feed side and reject side) from all housings, identify the feed end of the RO vessel.
2. Remove RO elements from the box. Each RO membrane is supplied with new interconnectors.
3. Apply glycerin on the brine seal.
4. Partially insert the first elements to the feed side of the membrane housing, typically the brine seal goes in last in the direction of feed (see note above and verify brine seal location in regards to flow direction). Leave a portion of this membrane protruded outside the housing.



5. Install interconnector on the first element after applying glycerin on the O-rings.
6. Attach the second element to the interconnector of the first element. Make sure that an assistant restrains the first element while attaching the second element to the interconnector before partially inserting the second element into the vessel.
7. Repeat the above procedures until all elements are loaded, making sure that there is sufficient room on the downstream end to insert the end cap.

8. Install the downstream end cap. Install an end adaptor on the feed-end element followed by the end cap. Supply sufficient force to the end cap to move the elements until they sit firm against the downstream end cap. Complete the installation of the feed-end cap as well install the retaining rings.

9. Repeat the above steps for all remaining membrane housing on the RO skid.

REMOVAL OF RO ELEMENTS

It may be necessary to remove one membrane during this procedure. When removing the elements, adhere to the following guidelines.

1. Before removing the elements, perform a normal cleaning sequence for the RO skid and make sure that all cleaning chemicals are rinsed from the pressure vessels.
2. Close all isolating hand valves on the skid.
3. Open the sample valves on the RO pressure vessels to relieve all pressure in the housings.
4. Remove the housing retaining rings that hold the end cap.
5. Mark the element housing end caps and related components to indicate their proper location. Because of minor variations in the piping dimensions, components must be returned to their original locations to avoid stress on the inlet and outlet piping.

NOTE -
Be careful not to lose any o-rings or gaskets for the piping connectors.

6. Water will flow from the element housings onto the floor when the end caps are removed. Make provisions for this flow of water as necessary.
7. Select the housing to be unloaded first, and open it up using the manufacturer instructions.
8. Remove the RO elements from the vessel.
9. If the elements will be reinstalled later, store them as directed in the element manufacturer's literature.
10. When elements are reinstalled in the housing, use the loading procedures.

SECTION 6.0: SYSTEM SAFETY PRECAUTIONS

This section contains general safety guidelines that workers must follow when installing, operating, and maintaining RO Water Treatment Plant Systems. This section must be read and understood prior to system startup. The guidelines listed here must be followed at all times to prevent worker injury and equipment damage.

CHEMICAL SAFETY

CAUTION -
Refer to Chemical Suppliers' MSDS plus Plant Safety Procedures for proper handling and storage of chemical products associated with this RO unit.

OPERATIONS SAFETY

Description: High-voltage electricity (≥ 115 VAC)

Health Hazard: Can potentially cause severe burns, cardiovascular failure, and death.

Description: High pressures (≥15 psig) - pneumatic or liquid

Health Hazard: Possibility of various physical injuries from accidental release of high pressure.

Description: High-speed rotational mechanical components (i.e., pumps and motors).

Health hazard: Possibility of injury from accidental contact with rotating parts.

Further Information: Reference the applicable equipment manufacturers' literature.

OPERATOR TRAINING

Equipment operators must be trained in the operation of the equipment and in the proper handling of hazardous chemicals. Only experienced operators who have studied this entire manual should be allowed to operate the equipment.

CAUTION -
Highly corrosive chemicals are used to clean the membranes and in the process. Contact with these chemicals can cause severe burns or blindness. Equipment operators must be trained in the safe use and handling of hazardous chemicals.

FIRST-AID EQUIPMENT

First-aid equipment, eyewashes, and emergency showers must be available in areas where chemicals are stored or used. Facilities such as eyewashes and showers must conform to national and local safety codes and laws.

PERSONAL PROTECTIVE EQUIPMENT

Workers must wear safety glasses, face shields, respirators, protective clothing, or other appropriate safety gear when working with hazardous materials, such as corrosive cleanup chemicals. All measures must be taken to avoid contact between hazardous chemicals and exposed skin. Refer to the Material Safety Data Sheets (MSDS's) supplied by the chemical manufacturer for information on recommended safety gear for specific chemicals.

EQUIPMENT ACCESS

Workers must use caution when accessing equipment. All measures must be taken to prevent falls and other accidents when equipment is being installed or serviced. Use extreme caution when working around the system components. Valve handles, sample pipes, and other protruding components can cause severe injury to body parts that strike them. Workers should wear hard hats and safety glasses and should move cautiously when working under piping and around the equipment. If equipment to be installed or serviced is above an operator's normal reach, use safe, approved ladders or lifting devices to reach the required area.

ELECTRICITY

Operators and workers must use caution when working with motors, control panels, and other electrical components. These components must be properly wired and grounded, and should not be allowed to come in contact with process fluids or other liquids.

CAUTION -
Electricity can shock, injure, or cause death. Always disconnect and lock out electrical power for panels or components before performing repairs or service. Electrical control panels and instruments must be properly grounded.

PUMPS

Any pumps that are supplied loose (un-mounted) must be properly mounted to avoid movement and excessive vibration. Motor drive safety shields must be properly installed, and all supplied WARNING and CAUTION signs and labels must be maintained at the device.

CAUTION -
Contact with rotating drive mechanisms can cause severe personal injury. Never operate pumps without safety shields around the motor drive mechanisms.

AUTOMATIC SYSTEM TESTING

An automatically controlled system, including the cleanup system, must be test-run without process liquids prior to the initial operation of the equipment. Operators must be sure that the entire system operates properly before using chemicals or process liquids.

CAUTION -
Improper flows of corrosive chemicals or other liquids during a system test run can cause worker injury or equipment damage. During a test run of a system, all hand valves must remain closed to prevent the accidental entry of process fluids.

PRESSURES

Extreme caution must be used when working with high air or liquid pressure. Pressure monitoring devices must always be installed and working properly. The system must be operated within the proper pressure limits.

CAUTION -
The sudden release of pressure from pressurized components can cause serious injury to workers. Relieve all pressure from piping and components before performing service.

SERVICING SYSTEM COMPONENTS AND EQUIPMENT

Before performing maintenance on system components and equipment, and especially when disassembling individual components, workers must be certain that the components are isolated from pressure, fluids, and electricity. Spring-loaded devices, such as valves, must be in their "relaxed" state—that is, with no compression on the loading spring—to avoid the sudden and accidental motion of individual parts.

Refer to the individual vendor component literature in Section 18 for specific maintenance guidelines.

SERVICING AUTOMATICALLY CONTROLLED COMPONENTS

Workers must use extreme caution when servicing automatically controlled components. Sudden and unexpected operation of components being serviced can cause severe injury to the workers involved. Before working on automatically controlled components, make sure that the automatic controller is disabled to the point that it cannot be used to operate remote components. Close, lock, and tag valves, and lock out and tag electrical motor starters and other electrical devices. Finally, inform other operators and control room workers of repairs or servicing in progress.

CAUTION -
Accidental and unexpected operation of remote components can cause personal injury or death. If controller programming or program modification is performed while system components are being serviced, disconnect the controller output devices or individual component tubing or wiring to avoid accidental operation.

SECTION 7.0: SYSTEM START-UP AND OPERATION

Reverse Osmosis Systems provided by USWS have been engineered and fabricated to run in a safe and trouble-free manner when they are operated and maintained as specified in this manual. The operators and service personnel should be alert to the following points:

MEMBRANE PRESERVATIVE

All USWS packaged RO systems are shipped fully assembled and factory tested. In most cases membranes are shipped loose to be installed by the customer in the field.

If the system has been pre-loaded with membranes, membranes are filled with a preservative solution to prevent biological fouling during shipping. This preservative solution is typically a solution of food-grade sodium metabisulfite. Such preservatives must be completely flushed out of the membranes before using the permeate water. USWS recommends diverting the permeate line to the drain and flushing the machine for 3 hours at low pressure of 30 - 50 psig, and then operating at normal operating pressure for another 30 minutes, before diverting the permeate line back to the point of use (permeate tank).

MECHANICAL COMPONENTS

FEED & DISCHARGE PIPING

USWS RO systems are manufactured with corrosion-resistance piping. Customer-supplied feed and discharge piping should be of similar material and under NO CIRCUMSTANCES should the diameter of the customer-supplied feed and discharge pipe to the point-of-use be less than the associated size on the skid. Feed piping made of metal that is susceptible to corrosion will cause membrane fouling.

PERMEATE WATER PIPING

A single line is provided for delivery of permeate water from the system. Under NO CIRCUMSTANCES should the diameter of the customer-supplied permeate pipe to the point-of-use be less than the permeate outlet from the system, as this could create permeate back pressure and decrease the efficiency of the machine. Permeate piping should be free of any corrosive material.

PERMEATE WATER STORAGE (CUSTOMER SUPPLIED)

The maximum productivity of the system can be reached when the permeate water flows free of any back pressure to an atmospheric tank. Permeate back pressure will negatively affect the permeate flow rate. If the water is to be used for human consumption, it is strongly recommended that permeate water be disinfected in the permeate storage tank to guarantee continuous protection against bacteriological contamination.

FEED WATER CONDITIONS

Any variation in feed water conditions from design conditions may substantially affect performance of the machine. If the system is not performing as expected, please contact USWS immediately. Unless specifically accounted for in the design of your system, any change in feed water conditions from what is listed below may reduce the performance of the system, damage the machine components, and void the warranty of the membranes.

TURBIDITY AND SDI (SILT DENSITY INDEX)

The turbidity of the feed water to the membranes should be less than 1.0 NTU and the Silt Density Index at 15 minutes (SDI_{15}) should be less than 3.0; otherwise, additional pretreatment will be required.

TEMPERATURE

Lower temperatures will reduce the flow rate substantially, while improving the quality of the permeate (lower permeate conductivity). Higher temperatures will increase the permeate flow rate and lower the quality of the permeate water (higher permeate TDS). To avoid causing damage to the membranes, the feed water temperature should always be above 40°F (4.4°C) and NEVER exceed 100°F (37.8°C).

PH

The membranes should not be exposed during cleaning, or in shutdown period, to water of pH less than one (1) nor greater than eleven (11) unless otherwise directed by a membrane manufacturer. During continuous operation, the pH should not be less than four (4) nor greater than nine (9) unless otherwise directed by a membrane manufacturer.

FEED PRESSURE

Feed pressure to the system should be controlled to provide a steady, non-turbulent flow to the inlet connection of the unit. Feed pressure of about 20-30 psig after the cartridge pre-filter is optimal. The system is equipped with a pre-set low inlet pressure switch that will shut down the system if the feed pressure is less than 12-15 psig to protect the high pressure pump.

TOTAL DISSOLVED SOLIDS (TDS)

Permeate flow rate and quality will directly depend on the quality of the feed water. If the feed water TDS exceeds the design value (check the system performance data sheet), the permeate flow rate will decrease and its conductivity will increase at the same operating pressure. If the feed conductivity decreased from the design value, the productivity of the system could increase. Nevertheless, operators should never increase the productivity of the system without consulting USWS as it may cause serious membrane fouling. If feed water conditions changed more than 10% from the design assumptions, new membrane computer projections would be needed to simulate the actual feed water conditions.

SCALING AND FOULING AGENTS

The elements should be maintained in a clean condition, free of particulate matter, precipitates, or/and biological growth. If scaling or fouling occurs, or normalized element flow declines ten percent (10%), cleaning procedures should be initiated.

NOTE -
Cleaning process should be applied immediately if the normalized system flow rate, normalized feed-to-reject, pressure drop, or permeate quality changes by 10%. Any delay may result in an irreversible membrane fouling and permanent loss of membrane active surface area.

NOTE -
Feed water to the membranes should not contain **ANY** chlorine, ozone, permanganate, or other oxidizing agents. Such oxidizing agents will cause the membrane material to deteriorate.

Iron, calcium, magnesium, and any heavy metals in the feed water should be removed prior to the RO system. Antiscalant and/or anti-foulant injections are recommended as a pre-treatment for these inorganic foulants. RO permeate should be used when diluting such chemicals. Calcium present in untreated water may form a precipitate with the antiscalant at high antiscalant concentrations. Precautions must also be taken so there is no microbiological growth in the antiscalant dilution tank. The antiscalant must not be diluted more than what it is recommended by the chemical supplier. Antiscalant in powder form should not be stored in liquid form after dissolving for more than one week to keep its original efficiency. Antiscalant should be injected into the feed stream before the pre-filter. In few cases, it might be necessary to use acid injection in addition to the antiscalant, which will depend on the feed water analysis.

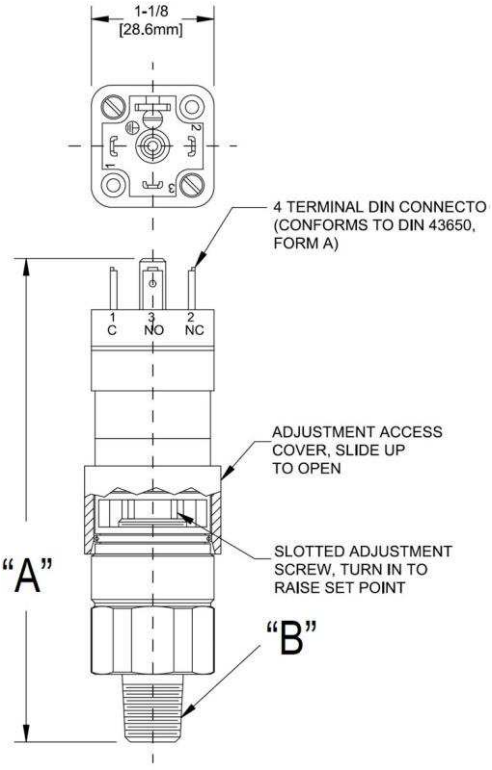
INSTRUMENTATION

USWS RO systems are equipped with many control features with which the operator should be familiar to ensure safe and smooth operation. The most important controls and instruments of the RO system are listed as follows

PRESSURE GAUGES

RO systems are equipped with liquid-filled pressure gauges connected at various portions of the system. The pressure gauges monitor the pressure at these locations to monitor the system performance over time to assist in troubleshooting and to determine when a CIP procedure needs to be conducted.

PRESSURE SWITCHES



The pressure switches will be adjusted and tested to activate or close/open the contact at the rated pressure. Pressure setting can be adjusted either up or down at Owner's risk.

Connect control to an adjustable pressure source.

1. With power disconnected, slide cover toward electrical terminations while twisting it to overcome friction.
2. Connect power to terminals or leads.
3. When adjusting the high pressure setting, slowly close the valve after the pressure switch. Observe the rising pressure and adjust your pressure setting as required.
4. Insert screwdriver into adjustment slot and turn clockwise (left) to increase setting or counter clockwise (right) to decrease setting.
5. After completing adjustments, slide cover closed over adjustment compartment.
6. Recheck set point.

<u>Bench Test (if applicable)</u>

1. Remove the pressure switch in the line.

2. Using Handheld Pneumatic Pressure Tester, connect the pressure line of the tester to the pressure switch.

3. Using electric meter, connect the line and neutral wires.

4. Operate the pneumatic tester and raise the pressure.

5. Adjust the pressure setting so that it will activate or close/open the contact when pressure is reached.

FLOW TRANSMITTERS

Flow transmitters are provided on the permeate and reject streams. The permeate flow transmitter is to be used to regulate the feed pressure (by adjusting the pump discharge throttling valve) to obtain the appropriate amount of permeate desired, but never exceeding the maximum design. The reject flow transmitter is to be used to regulate the recovery rate by adjusting the needle valve.

CONDUCTIVITY SENSORS

Conductivity sensors are provided to monitor the water quality of the inlet and permeate streams. In addition to monitoring the conductivity in either µmhos/com or ppm, it also monitors the temperature so that the temperature can be recorded for normalizing the data obtained.

SECTION 8.0: PERFORMANCE MONITORING

PERFORMANCE MONITORING

Every two to four hours of operation, the operator should measure and record data. Note that a recommended operator log sheet, for plant use, is provided in Appendix A of this manual. Performance monitoring and completion of a log sheet should be a part of the daily maintenance and operation of the RO system. This information is critical to the factory warranty and troubleshooting process.

NOTE -
This form (or similar form with the same data) must be completed on a daily basis for warranty claims.

One of the most important aspects of running an RO plant is effective monitoring of plant performance. RO plants use a very vulnerable type of water purification process. Allowing the membrane to operate on incorrectly treated feed water or under conditions beyond the membrane's safe operating envelope may result in extensive damage to the membranes in a relatively short time. It is, therefore, essential that early detection of any deviation from normality of plant operation is made. Detection of malfunction is not an easy matter since membrane performance is affected by:

- A natural deterioration with time (a phenomenon known as "membrane compaction") that is characterized by the need to increase feed pressure in order to maintain system performance.
- Feed water composition (which can vary both seasonally and absolutely)
- Feed pressure
- Recovery Rate
- Temperature

Normalizing the data relative to temperature will help aide in diagnosing real versus perceived membrane performance. For example, a feed temperature drop of 7°F (4°C) will cause a permeate flow drop of about 10%. This, however, is a normal phenomenon.
Normalized Permeate Flow (NPF) can be calculated per the following equation:

$$Q = \frac{180 \times TCF}{P} \times Flow$$

Where:

- Q = Normalized Flow (in gpm)
- P = Effective Pressure (Average of Primary and Final Pressures, in psig)
- TCF = -0.000003144*T^3 + 0.0007724*T^2 - 0.04064*T + 0.9842 (See Table in Section 1)
    - Where T is the temperature (in °F)
- Flow = Current measured Permeate Flow (in gpm)

Monitoring the performance of the system will provide the data needed to determine when a CIP needs to be conducted. The following guidelines are provided to determine when these should be conducted.

1. When the normalized permeate flow decreases by 10-15%
2. When the pressure drop across the unit increases by 10-15%
3. When the normalized salt passage increases by 10-15%

PERFORMANCE TROUBLESHOOTING GUIDE

REVERSE OSMOSIS TROUBLESHOOTING						
SYMPTOMS			LOCATION	POSSIBLE CAUSES	VERIFICATION	CORRECTIVE ACTION
Salt Passage	Permeate Flow	Pressure Drop				
NORMAL to INCREASED	DECREASED	NORMAL to INCREASED	PREDOMINATELY FIRST STAGE	METAL OXIDE FOULING	ANALYSIS OF METAL IONS IN CLEANING SOLUTION	IMPROVE PRETREATMENT TO REMOVE METALS. CLEAN WITH ACID CLEANERS.
NORMAL to INCREASED	DECREASED	INCREASED	PREDOMINATELY FIRST STAGE	COLLOIDAL FOULING	SDI MEASUREMENT OF FEED WATER	OPTIMIZE PRETREATMENT FOR COLLOID REMOVAL. CLEAN WITH HIGH pH, ANIONIC CLEANER.
INCREASED	DECREASED	INCREASED	PREDOMINATELY FIRST STAGE	SCALING (CaSO4, CaS03, BaSO4, SiO2)	ANALYSIS OF METAL IONS IN CLEANING SOLUTION. CHECK LSI OF REJECT. CALCULATE MAX. SOLUBILITY OF CaSO4, BaSO4, SiO2 IN REJECT.	INCREASE ACID ADDITION AND ANTISCALANT DOSEAGE FOR CaCO3 AND CaSO4. REDUCE RECOVERY. CLEAN WITH ACID CLEANERS.
NORMAL to MODERATE INCREASE	DECREASED	NORMAL to MODERATE INCREASE	ANY STAGE	BIOLOGICAL FOULING	BACTERIA COUNT IN PERMEATE AND REJECT. SLIME IN PIPES AND PRESSURE VESSELS.	SHOCK DOSEAGE OF SODIUM BISULFITE. CONTINUOUS FEED OF SODIUM BISULFITE AT REDUCED pH. FORMALDEHYDE DISINFECTION. CHLORINATION AND DECHLORINATION. REPLACE CARTRIDGE FILTERS.
DECREASED or SLIGHTLY INCREASED	DECREASED	NORMAL	ANY STAGES	ORGANIC FOULING	DESTRUCTIVE TESTING	ACTIVATED CARBON OR OTHER PRETREATMENT. CLEAN WITH HIGH pH CLEANER.
INCREASED	INCREASED	DECREASED	MOST SEVERE IN THE FIRST STAGE	CHLORINE OXIDATION	CHLORINE ANALYSIS OF FEED WATER. DESTRUCTIVE	CHECK CHLORINE FEED EQUIPMENT AND DECHLORINATION SYSTEM.
INCREASED	INCREASED	DECREASED	MOST SEVERE IN THE FIRST STAGE	ABRASION OF MEMBRANE BY CRYSTALLINE MATERIAL	MICROSCOPIC SOLIDS ANALYSIS OF FEED. DESTRUCTIVE ELEMENT TEST.	IMPROVE PRETREATMENT. CHECK ALL FILTERS FOR MEDIA LEAKAGE.
INCREASED	NORMAL to INCREASED	DECREASED	AT RANDOM	O-RING LEAKS, END or SIDE SEAL LEAKS	PROBE TEST. VACUUM TEST. COLLODIAL MATERIAL	REPLACE O-RINGS. REPAIR OR REPLACE ELEMENTS.
INCREASED	NORMAL to LOW	DECREASED	AT RANDOM	RECOVERY TOO HIGH	CHECK FLOWS AND PRESSURES AGAINST DESIGN GUIDELINES.	REDUCE RECOVERY RATE. CALIBRATE AND/OR ADD SENSORS

SECTION 9.0: EQUIPMENT WARRANTY

U.S. Water Services warrants all water treatment products manufactured and/or distributed by it to be free from defects in materials and workmanship for a period of one (1) year from the date of shipment. If within that period any products shall be proven to USWS's satisfaction to be defective, those products will be replaced, or the price refunded at USWS's option.

USWS's obligations or nonperformance, defective, or any damage caused by its products or their use, and buyer's exclusive remedy therefore, shall be limited to product replacement or refund and shall be conditioned upon USWS's receiving written notice together with a demand for such replacement or refund.

The foregoing warranty is exclusive and in lieu of all other expressed implied warranty (except of title) including but not limited to implied warranty of merchantability and fitness for particular purpose.

USWS will not be subject to and disclaims the following:

- Any other obligations or liabilities arising out of breach of contract or out of warranty.
- Any obligations whatsoever arising from tort claims (including negligence and strict liability) or arising under other theories of law with respect to products sold or services rendered by USWS or any undertakings, acts, or omissions relating thereto.
- All consequential, incidental, and contingent damages.
- Labor charges, change backs or handling charges are excluded from USWS's warranty provisions. Any mechanical equipment proving defective in workmanship or material within one year after installation or (18) months after shipment, whichever comes first, shall be replaced FOB factory.

U.S. WATER® ENGINEERING & EQUIPMENT
Supporting You Every Step of the Way.

Reverse Osmosis Operator Logs

U.S. WATER® ENGINEERING & EQUIPMENT
Supporting You Every Step of the Way.

	Operator Initials:														
	Date:														
	Time:														
	RO Machine:														
Pressures (Manual Gauges)															
A	Pre-Filter Pressure (psig)														
B	Post-Filter Pressure (psig)														
C	Cartridge Filter Pressure Drop = A-B (psi)														
D	Pump Discharge Pressure (psig)														
E	Membrane Feed Pressure (psig)														
F	Reject Pressure (psig)														
Flows															
G	Permeate Flow (gpm)														
H	Reject Flow (gpm)														
I	Feed Flow = G + H (gpm)														
J	Recovery Rate % = G/I*100 (%)														
K	Normalized Permeate Flow														
Analytical Data															
L	Inlet Temperature (^{o}F)														
M	Inlet pH														
N	Feed Conductivity (μmhos)														
O	Permeate Conductivity (μmhos)														
P	Reject Conductivity (μmhos)														
Q	% Rejection = (1 - O/N)*100 (%)														
R	Feed Free Chlorine (ppm as Cl_2)														
S	Feed Total Chlorine (ppm as Cl_2)														
T	Feed Bisulfite (as SO_3)														
U	Inlet Hardness (as $CaCO_3$)														
V	Antiscalant Concentration														
W	Cartridge Filters Changed (Y/N)														
X	CIP Conducted (Y/N)														

UNILUX ADVANCED MANUFACTURING

OPERATING AND MAINTENANCE MANUAL

VERSON 03-03-15

This is engineered equipment. Only trained qualified service technicians should attempt to start and / or operate this equipment. Read and understand all manuals, product specification sheets, applicable codes and safety guidelines before performing any start up and / or service procedures. This manual is to be used as a guide for professional, trained technicians only. This guide, if followed should result in a successful start up / service program. It is good practice to know as much as possible about a piece of equipment before trying to install or operate it. Always refer to the OEM data sheets, drawings, specifications and operating instructions.

Information contained herein is to be used as a guide ONLY and not as the final authority. This manual does not relive the customer from obtaining qualified site engineering, installation, and start-up support. Plant operating personnel should familiarize themselves with the content of this manual and the physical installation and equipment provided before attempting to start and operate equipment. It is not possible to cover in written form all possible operating scenarios and conditions. Any deviation from the operating discipline outlined in this document should be based on extensive operating experience, sound engineering judgment, and consultation with your Unilux contact. **Unilux strongly recommends that an authorized Unilux field service representative be retained for initial system commissioning and plant personnel training.** Unilux Advanced Manufacturing and it's employees assume no responsibility for any liability or damages caused by an inoperable, inadequate or unsafe boiler condition which is the result, either directly or indirectly, of any improper or inadequate condition.

INSTALLATION, OPERATION AND SERVICE MANUAL
To be used for reference with separate burner manual

Important Instructions For Receiving Unit In Case Of Loss Or Damage

1. Examine the shipment carefully before signing freight bill. If any DAMAGE is noted or if the number of pieces received DOES NOT agree with the BILL OF LADING, DO NOT ACCEPT SHIPMENT without shortage or damage noted on the freight bill by the carrier's agent. Failure to do so may jeopardize your recovery and at your own risk.

2. If any concealed DAMAGE OR SHORTAGE is discovered with unpacking, LEAVE MATERIAL AND PACKING AS IS and NOTIFY Agent or carrier to inspect and make reference thereto on the freight bill.

3. All packaged material should be unpacked and inspected within 24 hours after receipt of same. If damage could not be detected until goods were unpacked, contact the transportation company and request IMMEDIATE inspection. Require him to give you a “concealed” bid order report, stating the condition of the goods when examined. It is his duty to do this, and this service should be insisted upon. This, with other documents, will properly support your claim.

4. When the above instructions are complied with, we will assist you in establishing claims against the transportation companies for loss or damage in transit. We cannot, however, be responsible for entry or collection of claims or replacement of lost or damaged material.

5. Claims for loss or damage on transportation charges resulting there from must not be deducted from our invoice. Non-payment of invoices withheld awaiting adjustment of claims is not acceptable. It is the function of the carrier to guarantee safe delivery of the equipment.

6. **DO NOT RETURN GOODS WITHOUT WRITTEN AUTHORIZATION**. Returned goods will not be accepted from the transportation company unless written authorization has been issued by an official of our Company. Credit for goods returned by authorization will depend on the market value, less a fair charge to cover expense of shipping, rehandling, inspection, refinishing, etc., providing material is received in good condition.

Important Instructions for Owners, Operators or Maintenance Personnel

- No attempt to install or operate the boiler should be attempted until this manual is read and understood.

- This operating manual presents information that will help to properly operate and care for the equipment. Study its contents carefully. The unit will provide good service and continued operation if proper operating and maintenance instructions are followed. No attempt should be made to operate the unit until the principles of operation and all of the components are thoroughly understood.

- Only trained and authorized personnel should be allowed to operate, adjust or repair this equipment.

- Unilux products are designed and engineered to provide long life and excellent service on the job. The devices supplied as part of the unit were chosen because of their known ability to perform. Although these components afford a high degree of protection and safety, operation of equipment is not to be considered free from all dangers and hazards inherent in operating this equipment.

- It is solely the operator's responsibility to properly operate and maintain the equipment. No amount of written instructions can replace intelligent thinking and reasoning. This manual is not intended to relieve the operating personnel of the responsibility for proper operation.

- The operation of this equipment by the Owner and his operating personnel must comply with all requirements or regulations of his insurance company and/or any other authority having jurisdiction. These legal requirements take precedence over anything contained herein.

- Unilux Service Representatives present for start-up or service are present only in an advisory capacity. The operation of the equipment is under the scope of work to be performed by the Owner's operating personnel at the Owner's risk, and under the Owner's insurance protection. Recommendation for proper adjustments required to make the equipment perform can be made by these Service Representatives.

INSTALLATION INFORMATION

Setting the Boiler

- The boiler should be located on a level concrete floor. A concrete foundation is preferable. The dimensions should be slightly larger than the outside dimensions of the boiler.

- If boiler is installed directly on a concrete floor where it is important that the floor be kept cool, such as an upper floor or mezzanine, set the boiler up on insulating tile or steel framework, so air can circulate underneath. There is little standby heat loss through the Unilux Boiler, but this precaution is considered good practice.

- The boiler may be mounted on vibration isolation pads in order to provide smooth and trouble free operation. Check local codes for seismic frequencies. Add keyed slots in the base rail to allow for expansion.

- Care should be taken in locating the boiler, so that all four sides are easily accessible for service. Check local codes. From 24” to 30” should be maintained around all four sides between any wall or obstruction, leaving room to clean and service the boiler.

- On boilers equipped with removable or swing type hinged burners for fireside inspection through the boiler front, the burner piping arrangement must be planned accordingly.

- Typically, boilers are rigged from the front and rear exposed upper drum ends. When using a sling for lifting ensure that spacers are used to avoid damaging jacket panels.

Boiler Clearances

- Tube removal is on each side. Refer to the specification data sheet to determine required clearances for your boiler. Avoid running pipes along side of boiler as they will interfere with removing boiler panels. Gas trains should have strategically placed unions to allow for easy removal. Refer to “minimum recommended clearances” on boiler rating tag.

Heating Boilers

- These boilers have a flange at the upper drum front for connection to the heating system main. A non return stop valve should be provided between each boiler and the main, located as near the boiler as is practical, to provide for draining the boiler without draining the system.

- All piping should be designed and installed to relieve any possibility of stress or strain on boiler connections or the piping. All piping from the boiler to the first non return stop valve should be installed as per the appropriate ASME boiler code.

- The system return connection is located at the back of the bottom drum on water boilers. On Steam boilers the feed water supply connections are on the rear downcomer. A non return stop valve should be installed in the return line as near the boiler as is practical, to provide for draining the boiler without draining the system.

- NOTE: Non-return stop valves are not supplied as standard with the Unilux package.

- Each boiler has a drain connection located at the bottom drum. Boilers up to and including size 400 have one drain connection at the rear of the bottom drum. All boilers from size 500 and larger have two drain connections, located at the front and back of the bottom drum. A drain valve and piping to drain should be installed to provide for draining the boiler.

- Each hot water boiler is supplied with an open pipe connection at the highest point off the boiler pressure vessel for venting of air which may have entered the boiler from the system. This point is tagged on all hot water boilers with “To Vent” for proper connection by the installing contractor.

- Tappings for the one or more boiler safety relief valves are at the boiler top rear. The discharge from the relief valves should be piped to a safe location. The discharge should be as short and direct as possible. It should be supported to prevent any strain on the valve. The ASME boiler code should be followed.

- The chimney must be of sufficient size and height to provide proper draft and venting. Contact boiler stack manufacturers for venting system recommendations and design. Follow local utility and municipal codes for breeching and chimney requirements.

TRIM & CONTROLS

There are three distinct control systems on any boiler: the **Firing Rate Controller**, the **Flame Safeguard**, and the **Operating Controller**. Other controllers and devices may be subsets of these systems.

Firing Rate Control

Refer to detailed burner manual for actual control and operating sequences before operating burner. *

Start up should be performed by a qualified start up technician only. Contact Unilux or your Unilux representative for start-up technician support.

Boiler controls should never be bypassed.

Never dry-fire a boiler !

The Firing Rate Controls regulate the firing rate of the burner to track load change. Regulating the firing rate is defined as maintaining a specific fuel-air ratio for a required rate of fire at a given demand point. Load change is defined as the demand of the system for the output of the boiler, either hot water or steam as is interpreted in the following way:

- Hot Water Boiler – If the temperature of the supply water falls below the preset temperature then the firing rate control interprets this as a system demand therefore increasing firing rate. Likewise if the supply temperature begins to exceed the preset temperature then this is interpreted as a reduction in system demand therefore reducing the fuel input to the boiler.

- Steam Boiler – if the pressure inside of the steam drum begins to fall then this is interpreted by the firing rate control as an increase in system demand and the firing rate is increased. Likewise when the pressure inside of the steam drum increases above the preset point then this is interpreted as a reduction in demand and the firing rate is reduced.

Firing rate control is measured as turndown. The turndown of the boiler is the ability of the burner to control firing rate between the Manufacturers Continuous Rating (MCR) and some minimum value. There are two types of firing rate control: **Step Firing** and **Modulating Firing Rate**.

- Stepped firing rates operate the burner at a few specific preset firing rate positions, examples would be On-Off combustion where the burner is either On or Off. Another example of stepped firing is Low-High-Low-Off, a method commonly used on Unilux boilers

- A modulating burner has the ability to vary the firing rate to any point between maximum fire and a minimum firing rate. A fully modulating burner utilizes an actuator to modulate the fuel flow control valve and fan air damper position. Modulating firing rate controls are also called Proportional Controllers.

Turndown is measured as a ratio of MCR to the minimum firing rate. An On-Off burner has a turndown ratio of 1:1 meaning it can only fire at its maximum input or shut off. The turndown of a fully modulating burner will vary with the firing rate control scheme as well as the fuels fired. On natural gas most burners will vary between 10:1 and 4:1 meaning the burner can fully modulate between 100% firing rate to 10% firing rate for a 10:1 burner or 100% to 25% of firing rate for a 4:1 turndown boiler.

#2 fuel oil firing turndown is typically not as low as gas firing because of the difficulty of maintaining proper firing at the lower end. #2 oil burners typical at best can achieve 8:1 turndown but commonly are less than 6:1 to as low as 3:1

Almost all Unilux boilers will utilize one of the following two firing rate control schemes: single point positioning or parallel point positioning that is also commonly called linkageless positioning. Proper combustion requires the firing rate controller to maintain a precise fuel-air ratio. The forced draft fan provides combustion air and the fuel delivery system provides natural gas or fuel oil. It is the responsibility of the firing rate controller to control the amounts of both that are fed to the burner at the requiring firing rate at any given time. An improper fuel-air ratio can lead to poor efficiency at best and an explosive situation at worst.

A description of the two firing rate control schemes is as follows:

- Single Point Positioning: This is the most common firing rate control utilized on Unilux boilers. The firing rate controller interprets a required firing rate based on system demand. A control signal is sent to the actuator on the burner. The actuator has a linkage that physically connects the fan damper and fuel flow control valve to the damper allowing the actuator to move the damper and fuel valve in unison. The fuel valve is supplied with a cam assembly that creates a curve which allows for the start-up technician to fine tune the fuel-air ratio for the full range of the turndown.

- Parallel Point / Linkageless Systems: this type of system replaces the linkage between the actuator, fuel valve, and air damper with individual actuators on both the fuel valve and the air damper. This system allows the firing rate controller to actuate each independently. Feedback potentiometers in the actuators provide a signal back to the firing rate controller to insure the actuators are moving in the manner that the firing rate controller requires. This is called Cross Limiting and is a very important safety feature on these types of systems.

Unilux Boilers normally feature **Low-High-Low** operation for models 100 – 400 as standard and **Full Modulation** for models 500 and up.

Full Modulation is available as an option for all boilers. The standard burner package meets all of the requirements of UL and CGA.

For the standard Unilux steam boiler package the burner master function is accomplished with the Honeywell 404 for step firing burners and the Honeywell L91 for modulating burners. Hot water boilers utilize the Honeywell 4008. The Controls & Trim list provided on following pages define the types of control, model, and manufacturer supplied as a standard by Unilux.

If required, your burner may be equipped to meet the requirements of Factory Mutual, Industrial Risk Insurers, National Fire Protection Association, Improved Risk Insurers.

Typical Hot Water Boiler Burner Firing Sequence – On a call for heat, the burner will light up in the sequence below. Steam systems will operate in similar fashion except it will be based on steam drum pressure, not water temperature.

TIME[1]	Event	WATER TEMPERATURE (F)
0	Burner Off	140
1	Call for Heat	138
	Call for Heat	
	Call for Heat - Pre-purge	
	Call for Heat	138
60	Pilot lights and establishes	138
70	Lo fire lights and establishes	139
80	Hi fire	140
“		
“		
“	No call for heat	180
	Burner switches off	

[1] Time in Seconds

Flame Safeguard (BMS)

The flame safeguard, also known as a Burner Management System (BMS), has three functions:

I. To control the sequence of events that lead to the burner firing. (starting and stopping the burner)

II. To ensure that all operating and safety limits (controls, switches) are in the correct position to ensure safe operation throughout the burner firing cycle.

III. To instantly shut off the fuel supply in the event of a flame failure during normal operation or to stop the start-up procedure if an adequate pilot or low fire is not detected within a code dictated time period.

The flame safeguard should not be confused with the firing rate controller. Most insurance agencies do not permit a single controller to handle both flame safeguard and firing rate control functions for reasons of redundancy for safety. The flame safeguard, also commonly referred to as the Burner Management Systems (BMS), is a microprocessor-controlled devise that monitors the burner for safe operation. The most common BMS systems are the Fireye E110 or the Honeywell 7800 series controllers. Supply of the BMS is by the burner vendor.

The flame safeguard is responsible for the safe starting of the burner as well as monitoring the burner during operation. The flame safeguard will monitor parameters such as windbox pressure, fuel supply pressures, flame strength, and other safety-related parameters. Should the safeguard detect an improper signal it will shut the burner off. Any safety trip will require a manual reset requiring the operator to acknowledge and understand the reason for the shut-down. This is a key safety requirement.

NOTE: A flame safeguard that is in the safety position requiring a manual user to re-establish burner operation should not be reset until the boiler and burner are checked to ensure that a safe start can be made.

Flame Safeguard (cont)

Component	Explanation
AIR SWITCH	The air switch checks that the burner fan is running and supplying sufficient air for combustion.
GAS TRAIN	The gas train is a series of valves, switches and regulators connected by pipe to supply gas at the correct pressure and at the appropriate time.
OIL TRAIN	The oil train is a similar device to a gas train in that it supplies oil to the burner at the correct pressure and at the appropriate rate. An oil train will usually include an oil pump.
COMBUSTION AIR FAN	The combustion air fan supplies air to the burner for purging and for combustion.
PILOT	The pilot supplies a small amount of gas to the burner to ignite the main flame

Multiple Boiler Installation Controllers

Multiple boiler installations introduce unique operating requirements. A device that is commonly utilized is called a Lead-lag Sequencer. A lead-lag system has the ability to control multiple boilers and circulating pumps for hot water systems. A lead-lag sequencer will coordinate the operation of multiple boilers to act as a single system. A lead-lag sequencer will control the firing rates of the multiple boilers based off of a single system demand signal. The sequencer will override the firing rate signal generated on each individual boiler. For example a plant with three boilers could operate their units in the following method: The load can be evenly distributed between the three units with each boiler supplying 33% of the total load; two boilers can each meet 50% of the total load with the third serving as a standby, or one boiler can be firing to full load and if demand is not met then the next boiler is started and modulated until load is satisfied.

- Hot Water Boilers: A lead-lag sequencer will have a temperature controller in the common supply line to the plant, not on each individual boiler. The sequencer can then operate the multiple boilers in a preset method to meet system demand.

- Steam Boilers: A lead-lag sequencer will have a pressure transmitter in the common steam header to the plant, not on each individual steam drum. The sequencer can then operate the multiple boilers in a preset method to meet system demand.

Lead-lag sequencers are not required, however they provide for a much more efficient and orderly operation of multiple boilers. It is easy to understand the control issues that can result from allowing the individual firing rate controllers to compete with each other to meet the system demand.

Sequencers can also be used to set the control point of the burner firing rate controller with respect to outside air temperature. For example, on a cold day the boiler water temperature may be 180°F whereas on a warmer day the temperature may be set to a lower value.

Water Flow Control

All Unilux boilers are typically equipped with water flow control devices. Hot water boilers are of a forced circulation-type requiring a positive and constant water flow through the boiler. A circulation pump accomplishes flow through a hot water boiler. Steam boilers utilize a natural circulation pattern inside of the boiler but require a feedwater source to maintain proper water level inside of the drum.

- Hot Water Boilers: These systems are relatively straightforward. A pump circulates water through a system. The cold water entering the boiler is defined as the **Return Water**, the heated water discharged from the boiler is known as the **Supply Water**. A detailed typical scope of supply is on a following page. Check this list for the type of pump controller that would be installed on your boiler.

- Steam Boilers: Maintaining a proper water level inside of the steam drum is critical to proper operation of a steam boiler. There are two distinct methods of water level control inside of the steam drum: On-Off or Modulating. Similar in operation to the Firing rate Controller boilers can be supplied with water in an intermittent manner, On-Off, or a Modulating controller can be supplied for a more precise level control. Modulating feedwater control systems are further defined based on the number of parameters that are measured. The three different types of modulating feedwater control are as follows:

    - Single Element: the most common type of control is a single element feedwater level control. This uses a water level device to transmit an analog signal to a modulating feedwater valve.

- Two-Element: A two-element feedwater control system combines a steam flow meter located in the steam header leaving the boiler with the water level transmitter to add a second signal to the feedwater level controller. The level controller will interpret both the steam flow signal as well as the drum level signal to determine the optimum position of the feedwater regulating valve. A two-element system will level out the peaks and troughs associated with drum swell and shrinkage to provide a more accurate level control signal.

- Three-Element: A three element system incorporates a boiler feedwater flow meter into the two-element system to provide for the most precise level control possible. Three-element systems are rarely utilized.

Two and three element feedwater control systems will require a Proportional, Integral, Derivative (PID) loop controller capable of interpolating the correct feedwater valve output based on the given inputs from the steam drum level and steam and feedwater flow meters. Unilux does not typically supply these controllers.

Recycling

Recycling is the boiler's ability to automatically restart when the burner is tripped due to low demand. A boiler that is tripped because of a safety-related event can never automatically restart and must be manually reset by the operator. Some customers do not wish to ever have a boiler automatically start without an operator nearby therefore may not want or require a recycling feature. Check the detailed scope of supply for your specific burner to see if the unit is capable of recycling.

Unilux boilers supplied with modulating firing rate controls will utilize the Honeywell 404 series controls for high and low pressure settings for recycling.

The following pages will detail the types of controls and trim typically supplied on Unilux steam and hot water boilers.

Standard Controls & Trim Supplied on Unilux Hot Water Boilers.

Operation	Component	Function
To CONTROL the burner operation to provide the desired water TEMPERATURE	Aquastat L4006 or T991	Control
To SHUT-OFF burner in the event of excessive water TEMPERATURE	. Aquastat L4006	Safety
To INDICATE the pressure and temperature of the hot water	Thermometer and Pressure Gauge	Indicator
To SHUT-OFF the burner in the event of a falling water level	Low Water Cut-off Probe Type	Safety
To VENT excess pressure out of the boiler	Safety Relief Valve per ASME Code	Safety

Other components which are not supplied as standard but which may be required for proper operation.

Component	Explanation
Expansion Tank	Provides a cushion for water expansion.
Stack Thermometer	A thermometer indicating the temperature of the combustion gases leaving the boiler
Drain Valve	A valve piped into the bottom of the boiler to drain the boiler
Stop Valve	Installed as close as possible to boiler inlet and outlet to drain boiler without draining the system.

Key Controls Overview and Picture Identification

Not all of these components may be installed on your boiler. Check your submittal package for components included as well as the specific model numbers.

Hot Water Boilers

Component Overview	Picture
T991 Series Controller For modulating control of water temperature in boilers.	
L4006 Series Controller Aquastat® Controllers are immersion type devices for limiting or regulating the temperature of liquids in boilers.	
PS-851-M-120 McDonnell Miller Low water Cut Out is a safety devise to insure burner shut down in the event of a low water condition inside of the boiler.	

Standard Boiler Trim List – Hot Water Boilers

On-Off Firing Rate Control

Description	Quantity	Model	Manufacturer
Operating Aquastat	One	L4008A1015	Honeywell
Low-High Aquastat W/ Manual Reset	One	L4008E1040	Honeywell
Aquastat Well	Two	121371A	Honeywell
Pressure Gauge (xxx psig)	One	Q32-xxx	Winters
B-Metal Thermometer	One	30060B8	Winters
Probe Type LWCO[2] w/ Manual Reset	One	PS-851-M-120	McDonnell Miller
Safety Relief Valve	One	174A or 740 10-61-xxx	Watts or Conbraco

Low-High-Low Firing Rate Control

Description	Quantity	Model	Manufacturer
Proportional Aquastat	One	T991AN61	Honeywell
Operating Aquastat	One	L4008A1015	Honeywell
High Limit Aquastat W/ Manual Reset	One	L4008E1040	Honeywell
Aquastat Well	Three	121371A	Honeywell
Pressure Gauge (xxx psig)	One	Q32-xxx	Winters
B-Metal Thermometer	One	30060B8	Winters
Probe Type LWCO w/ Manual Reset	One	PS-851-M-120	McDonnell Miller
Safety Relief Valve	One	174A or 740 10-61-xxx	Watts or Conbraco

Modulating Firing Rate Control

Description	Quantity	Model	Manufacturer
Proportional Aquastat	One	L4008A1015	Honeywell
Operating Aquastat	One	L4008A1015	Honeywell
High Limit Aquastat W/ Manual Reset	One	L4008E1040	Honeywell
Aquastat Well	Three	121371A	Honeywell
Pressure Gauge (xxx psig)	One	Q32-xxx	Winters
B-Metal Thermometer	One	30060B8	Winters
Probe Type LWCO w/ Manual Reset	One	PS-851-M-120	McDonnell Miller
Safety Relief Valve	One	174A or 740 10-61-xxx	Watts or Conbraco

[2] Low Water Cut Off

Picture of Typical Unilux Hot Water Boiler

Standard Controls & Trim Supplied on Unilux Steam Boilers.

Operation	Component	Function
To CONTROL – the burner operation to provide the desired steam PRESSURE	Pressuretrol – L404 or L91/P78	Control
To SHUT-OFF the burner event of excessive steam PRESSURE	Pressuretrol – L404/P78	Safety
To INDICATE the PRESSURE of the steam	Pressure Gauge	Indicator
To CONTROL the operation of feedwater pump to provide the correct water level inside the boiler	Pump Control As required	Control
To INDICATE the water level in the boiler	Gauge Glass	Indicator
To INDICATE the water level in the boiler	Trycocks	Control
To SHUT-OFF the burner if the boiler water level falls to a dangerous level (primary)	Low-water-cut-off – Float type	Safety
To SHUT-OFF the burner if the boiler water level falls to a dangerous level (secondary)	Auxiliary Low-water-cut-off – Probe type	Safety
To VENT excess pressure out of the boiler safety valve	Per ASME Code	Safety

Other components which are not supplied as standard but which may be required for proper operation.

Component	Explanation
Blowdown Valves	Slow and quick opening valves connected to the bottom of the boiler to allow sediment to be removed
Modulating Feedwater Controls	Feedwater pump controls which will incrementally increase or decrease the feedwater flow rate to maintain a precise control
Regulating Valve	For controlling feedwater flow from the feedwater system into the boiler
Surface Blowdown Valve	Slow opening valve connected to the water level to filter suspended solids out of the boiler

Not all of these components may be installed on your boiler. Check your submittal package for components included as well as the specific model numbers.

Steam Boilers

L404 Series Controller Provide operating control, automatic or manual reset limit protection for pressure systems up to 300 psi (2068 kPa).	
L91 Series Controller Modulating pressure operating control for regulation of liquid or air and other non-corrosive gases.	
P78 Series Controller Line voltage pressure controller that provides automatic operating control, automatic limit protection, manual reset limit protection, and 4-20ma modulating firing rate control for pressure systems up to 300 psi.	

Steam Boiler (cont)

MM 157 Mechanical Low Water Cutoff / Pump Controller for Steam Boilers For residential, commercial, or industrial low or high pressure boiler applications.	
Conbraco Gauge Glass Set Use for steam drum liquid level verification. Aluminum hand wheels; EPDM gauge glass gaskets standard.	
Conbraco Tricock Set Allows for water level verification in event of gauge glass failure.	

Standard Boiler Trim List – Low Pressure Steam Boilers

Low-High-Low Firing Rate Control

Description	Quantity	Model	Manufacturer
Low-High Pressuretrol	One	L404A1588	Honeywell
Operating Pressuretrol	One	L404A1588	Honeywell
High Limit Pressuretrol W/ Manual Reset	One	L404C1147	Honeywell
Pressure Gauge (0-30 psig)	One	Q321	Winters
Probe Type LWCO w/ Manual Reset	One	PCH-G-M-1K	McDonnell Miller
LWCO Sensor	One	RS-1-BR-1	McDonnell Miller
LWCO Probe	One	P-2-SS	McDonnell Miller
Feedwater Control / Auxiliary LWCO – auto reset	One	157	McDonnell Miller
½" Gauge Glass Set	One	20 104 00	Conbraco
½" Tricock Set	Three	26 305 28	Conbraco
Safety Relief Valve	One	TBA	Watts

Fully Modulating Firing Rate Control

Description	Quantity	Model	Manufacturer
Proportional Pressuretrol	One	L91B1035	Honeywell
Operating Pressuretrol	One	L404A1588	Honeywell
High Limit Pressuretrol W/ Manual Reset	One	L404C1147	Honeywell
Pressure Gauge (0-30 psig)	One	Q321	Winters
Probe Type LWCO w/ Manual Reset	One	PCH-G-M-1K	McDonnell Miller
LWCO Sensor	One	RS-1-BR-1	McDonnell Miller
LWCO Probe	One	P-2-SS	McDonnell Miller
Feedwater Control / Auxiliary LWCO – auto reset	One	157	McDonnell Miller
½" Gauge Glass Set	One	20 104 00	Conbraco
½" Tricock Set	Three	26 305 28	Conbraco
Safety Relief Valve	One	TBA	Watts

Standard Boiler Trim List – High Pressure Steam Boilers

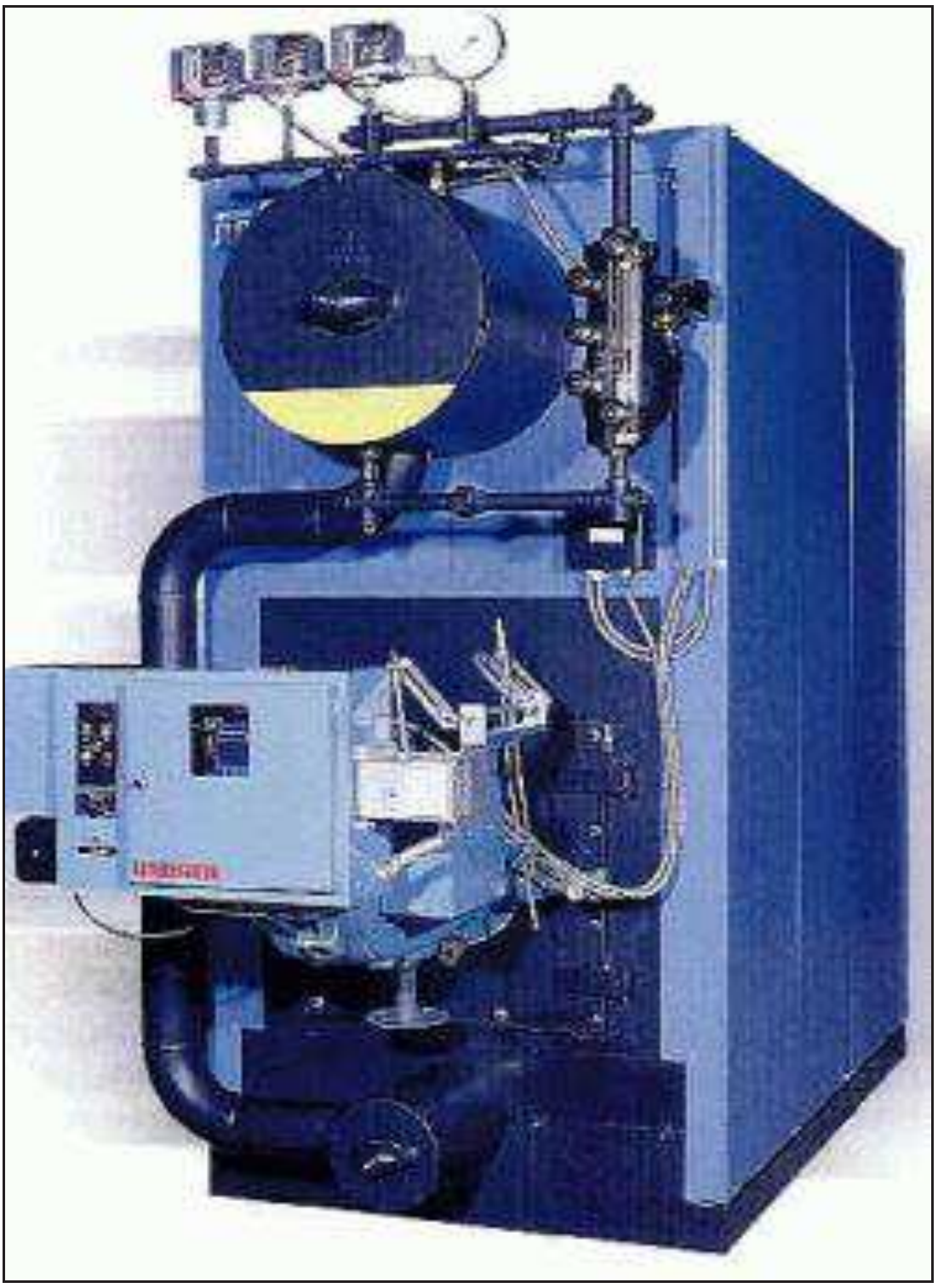
Low-High-Low Firing Rate Control

Description	Quantity	Model	Manufacturer
Low-High Pressuretrol	One	L404A1602	Honeywell
Operating Pressuretrol	One	L404A1602	Honeywell
High Limit Pressuretrol W/ Manual Reset	One	L404C1162	Honeywell
Pressure Gauge (0-300 psig)	One	Q326	Winters
Probe Type LWCO w/ Manual Reset	One	PCH-G-M-1K	McDonnell Miller
LWCO Sensor	One	RS-1-BR-1	McDonnell Miller
LWCO Probe	One	P-2-SS	McDonnell Miller
Feedwater Control / Auxiliary LWCO – auto reset	One	157	McDonnell Miller
½" Gauge Glass Set	One	20 250 00	Conbraco
½" Tricock Set	Three	26 705 01	Conbraco
Safety Relief Valve	One	TBA	Watts

Fully Modulating Firing Rate Control

Description	Quantity	Model	Manufacturer
Proportional Pressuretrol	One	L91B1050	Honeywell
Operating Pressuretrol	One	L404A1602	Honeywell
High Limit Pressuretrol W/ Manual Reset	One	L404C1162	Honeywell
Pressure Gauge (0-300 psig)	One	Q326	Winters
Probe Type LWCO w/ Manual Reset	One	PCH-G-M-1K	McDonnell Miller
LWCO Sensor	One	RS-1-BR-1	McDonnell Miller
LWCO Probe	One	P-2-SS	McDonnell Miller
Feedwater Control / Auxiliary LWCO – auto reset	One	157	McDonnell Miller
½" Gauge Glass Set	One	20 250 00	Conbraco
½" Tricock Set	Three	26 705 01	Conbraco
Safety Relief Valve	One	TBA	Watts

Picture of Typical Unilux Steam Boiler



INSTALLATION

Combustion Air Supply

IMPORTANT: Positive means for supplying an ample amount of outside air to permit combustion of the fuel must be provided. Automatic or manually adjustable control devices for outside air intake can be interlocked with the burner. Air openings must never be obstructed. To determine minimum size (free area) of ventilation openings, the following guidelines may be applied:

OPENING TO INTERIOR SPACE – In confined boiler rooms, two openings should be provided, one near the top and one near the bottom of the boiler room. Each opening should have 1 sq. in. of free opening for each 1,000 BTU of boiler input rating.

OPENINGS TO OUTDOORS – Openings to outdoors are required if boiler room is confined or if building is of tight construction. Two openings, one near the top and one near the floor of the boiler room, each opening having 1 sq. in. per 2,000 BTU per hour of input rating must be provided if attached to horizontal ducts, and 1 sq. in. per 4,000 BTU if attached to vertical ducts. Rectangular ducts shall not have dimensions of less than 3 inches. The requirements of the local utility take precedence over these guidelines.

Gas Supply Connection

- Consult the local gas utility company for authorization and inspection of all gas supply piping and flue connections.
- Installation must conform to the requirements of the authority having jurisdiction or, absence of such requirements, refer to the National Fuel Gas Code, ANSIZ223.1-1974 and addenda, Z223.1a-1978.
- Regulator vent line must be vented to atmosphere (outside building) on all boilers equipped with electric pilot ignition.
- Drip leg must be installed on gas supply piping.

The following is only a general recommendation. It is the responsibility of the installing contractor or customer appointed engineer to insure compliance with all required codes and procedures.

The installation must conform to the requirements of the authority having jurisdiction or, in the absence of such requirements, refer to the National Fuel Gas Code, ANSI Z223.1-1974 and addenda, Z223.1a-1978. Consult the local gas utility company to authorize and inspect all gas connections and flue connections. A drip leg must be connected to a supply main at least as large as the gas fittings supplied with the boiler. Use local gas company charts for sizing gas piping from the gas meter to the boiler. This connection should be made with a union so that the boiler gas train components and burner may be easily removed if necessary for service. Upon completion of the gas piping hookup, the installation should be checked for gas leaks, using soap and water solution. Disconnect the boiler and gas train from the gas supply piping during any pressure testing of the gas supply system.

Venting – Gas pressure regulator – On boilers equipped with electrically ignited pilot(s), the regulator vent must be vented to the outside air, using minimum ¼" tubing or pipe. The vent line should terminate in a downward direction to be free of restriction.

Electrical Connection

IMPORTANT: Electrical work should be performed by a trained electrical Tech. All electrical connections must conform to the National Electrical Codes and all applicable State and Local Codes. This manual is to be used as a guide only.

Equipment Grounding – The boiler must be grounded in accordance with the American National Standard National Electrical Code, ANSI/NFPA #70-1978.

Hydrostatic Test of System Piping

After completing the boiler and burner installations, the boiler connections, fittings, attachments and adjacent piping should be checked for leaks by filling with water. The pressure should be increased to a level just below the boiler safety relief valve setting. Although the boiler is hydrostatically tested at the factory, minor leaks in fittings can develop from shipping vibration or from installation procedures. It may be necessary to retighten such fittings after installation and after the boiler has been operated for some time.

UNILUX BOIL-OUT OF A NEW UNIT

The internal surfaces of a newly installed boiler may have oil, grease or other protective coatings used in manufacturing. Such coatings must be removed since they lower the heat transfer rate and could cause over heating of the tube. Before boiling out procedures begin, the burner should be ready for firing. The operator must be familiar with the procedure outlined under burner operation and in accordance with the detailed burner manufacturer's start up procedure.

Suggested procedure for boiling out new units prior to initial firing as follows:

I. Consult a local water treatment professional. They will know the characteristics of the water being introduced to the boiler.

II. When dissolving chemicals, the following procedure is suggested. Warm water should be put into a suitable container. Slowly introduce the dry chemical into the water stirring at all times until the chemical is completely dissolved. Add the chemical slowly and in small amounts to prevent excessive heat and turbulence.

CAUTION

Use suitable facemask, goggles, rubber gloves and protective garments are strongly recommended when handling or mixing caustic chemicals. Do not permit the dry material or the concentrated solution to come in contact with skin or clothing.

III. An overflow pipe should be attached to one of the top boiler openings and routed to a safe point of discharge. A relief or safety valve tapping is usually used.

IV. Water relief valves and steam safety valves must be removed before adding the boil-out solution so that neither it nor the grease which it may carry will contaminate these valves. Use care in removing and reinstalling valves.

V. All valves in the piping leading to or from the system must be closed to prevent cleaning solution from getting into the system.

VI. Fill pressure vessel with clean water until top of tubes are covered. Add the cleaning solution and then fill up to the top. The temperature of the water used in this initial fill should be at ambient temperature.

VII. The boiler should then be fired intermittently at a low rate sufficient to hold solution just at the boiling point. Boil the water for at least five hours. Do not produce steam pressure.

VIII. Allow a small amount of fresh water to enter boiler to create slight overflow that will carry off surface impurities.

IX. Continue boil and overflow until water clears. Shut burner down.

X. Let boiler cool to 120°F or less, and then drain using caution that the water is discharged safely and in accordance with local codes.

XI. Remove hand hole plates and wash the waterside surfaces thoroughly.

XII. Inspect surfaces and if not clean, repeat the boil out.

XIII. After closing openings and reinstalling safety or relief valves, fill boiler and fire until water is heated to at least 180°F to drive off any dissolved gases which might otherwise corrode metal. On a steam system, the condensate should not be returned until tests show the elimination of undesirable impurities. During the period that condensate is not returned, attention must be given to the treatment of the raw water used as makeup so that an accumulation of unwanted materials or corrosion does not occur. Follow the advice of your local water treatment company.

On hot water systems, chemical cleaning is generally necessary and the entire system should be drained after treatment. Consult water treatment companies for recommendations, cleaning compounds and application procedure. Do not flush the system through the boiler.

WASHING OUT

Unilux Steam Boiler

No later than 3 months after initially placing the boiler into operation and starting service, and thereafter as conditions warrant, the pressure vessel should be drained after being properly cooled to near ambient temperature, handhole covers removed and internal waterside surfaces inspected for corrosion, pitting or formation of deposits.

Unilux Hot Water Boiler

In theory, a hot water system and boiler that has initially been cleaned, filled with raw water (and that water treated) and with no make-up water added will require no further cleaning or treatment. However, since the system (new or old) may allow entrance of air and unnoticed or undetected leakage of water, introductions of raw water make-up or air may lead to pitting, corrosion and formation of sludge, sediment, scale, etc., on the pressure vessel waterside.

If the operator is absolutely certain that the system is tight, then, an annual waterside inspection may be sufficient. If there is any doubt, then the pressure vessel waterside should be inspected no later than 3 months after initially placing the boiler into operation and periodically thereafter as indicated by conditions observed during inspections.

Starting Procedure

- Be sure that the installation is complete and that all electrical, fuel, water and vent stack connections have been made.
- The operator should be familiar with the burner, all operating and safety controls and other components prior to attempting start up operation.
- Make sure that manhole and handhole covers have been replaced and that the pressure section of the boiler is ready for operation.
- Verify supply of fuel and proper voltage.
- Check for blown fuses; open circuit breakers, chopped out overloads, etc.
- Check resets of all starters and controls having manual reset features.
- Check the flame safeguard lockout or safety switch and be sure the programmer is in the start position.
-

Never dry-fire the boiler. Always insure the correct water level is inside of the boiler prior to firing

Caution: Do not bypass the pre-purge cycle, as four (4) complete air changes are required through the furnace prior to ignition.

- Before any start, be sure there is no trace of fuel oil, gas or fumes.

Caution: Carefully check the fireside prior to attempting "light off".

- Check the main stop valve. Be sure it is closed.
- Check the safety valve for correct setting.
- Make sure that discharge piping from safety valves is piped to a SAFE point of discharge.

Caution: The emission of hot water or steam can cause serious injury to personnel or damage to property. Make sure the system is "SAFE".

- Steam Boilers should be filled with water to proper operating level (refer to point marked on steam drum) using water or ambient temperature. Make sure that treated feedwater is available and used. Open the test valve to vent air displaced during filling. Leave test valve open until escape of steam is noted after burner is operating.
- Watch the water level as the boiler is being warmed.
- When the steam gage records a pressure on the boiler, blow down the gage glass, water column and LWCO.
- When the boiler is a few pounds below the header pressure slowly crack the main boiler stop valve and allow the pressure to equalize, then open the main boiler stop valve slowly until it is wide open. The steam boiler is now on-line.

24 HOUR FIRING SCHEDULE

This is the recommended firing schedule for refractory curing and only for initial boiler commissioning. This does not need to be repeated at every start up

1St. Hour – 15 minute intervals, (ie; fire 1 minute) at low fire

HOLD 8 hours at 200-700 F
Raise at 75 degrees Fahrenheit per hour to 50% firing rate (1200 F)
HOLD 8 hours at 1200 F
Raise at 100 degrees Fahrenheit per hour to 75% firing rate (2000 F)
HOLD 8 hours at 2000 F
Raise at 150 degrees Fahrenheit per hour to operating firing rate

The schedule is designed to maximize the service life of refractories. Where time does not permit adherence to these procedures, greater stress will be generated and may reduce the service life through increases in crack formation. Unilux utilizes a multi-layer refractory wall system that should stop any cracks from affecting steel but in no case does this design compensate for improper curing.

- Hot Water heating applications require the entire system to be filled and vented. A hot water boiler that has been cleaned and filled with raw water (and that water treated) and with no make-up water added will require no further cleaning or treatment. If the system allows the entrance of air or unnoticed or undetected leakage of water, introduction of raw water make-up or air may lead to pitting, corrosion and formation of sludge, sediment, scale etc., on the pressure vessel waterside.
- If the system is tight, an annual waterside inspection is adequate. If there are any doubts, then the pressure vessel waterside should be inspected within 3 months after placing the boiler in service.
- A hot water system not properly vented could cause air pockets to fool the low water cut-off causing a manual reset. Check for proper venting.
- Check all linkage for full and free movement of the damper, metering valves and cams.
- Check for rotation of all motors by momentarily closing the motor starter or relay.
- Be sure that boiler feed pump or oil supply pump valves are properly positioned.
- Inspect operating limit control for proper setting.

(a) The pressure control on a steam boiler should be set slightly above the highest desired steam pressure, but at least 10% lower than the setting of the safety valves.

(b) The temperature control on a hot water boiler should be set slightly above the highest desired water temperature and within the limits of the pressure vessel.

- Inspect the high limit control for proper setting.

(a) On a high pressure steam boiler this should be set approximately 10 lbs. above the operating limit pressure control setting, if feasible, or midway between operating limit pressure and safety valve setting. The setting on a low pressure steam boiler may be 2 or 3 lbs. above the operating limit setting but must not exceed valve setting.

(b) On a hot water boiler the temperature control should be 5 to 10° above the operation limit temperature control setting.

- Inspect the modulating control for proper setting.

  This control must be set and adjusted so that the modulating motor returns to low fire position before the operating limit control opens.

NOTE: The settings of all the above controls may require some re-adjustment after boiler is started and running for a short period. The scale settings on the controls are relatively accurate, but are principally for use as guides. Final adjustment should be based on and agree with the reading of the steam pressure gauge or the water temperature thermometer.

- Inspect the low water cut-off and pump control as well as the auxiliary low water cut-off (if your boiler is equipped with this optional device). Normally no adjustment is required since these controls are pre-set by the original manufacturer. Check for freedom of movement. Float movement can be verified by observing the level of water in the gauge glass when the water supply has been cut-off either by the stopping of the feed pump or by the closing of a valve, and the restarting of the pump or opening of the valve when water is drained from the pressure vessel. The importance of proper functioning of low water controls cannot be over-emphasized. Make sure that the control and the piping is plumb.

- The settings of controls relating to fuel, either oil or gas, are covered in subsequent sections.
- In the event the boiler is equipped with optional control devices not listed here, be certain to ascertain that their settings are correct. If additional information is required, see your local Unilux representative or contact Unilux.
- On initial start-up or whenever the boiler is placed into operation from a “cold” start, the manual–automatic selector switch should be set at “manual” and the manual control set at “minimum”. After boiler is in operation and thoroughly warmed the selector switch should be turned to “automatic”, so that the burner firing rate may be controlled by the modulating control in accordance with load demands.
- Close all power entrance switches (supplied by others).

Gas Pilots

- The gas pilot should be checked for satisfactory performance prior to initial firing. Follow the pilot flame adjustment instructions in the burner manual.
- On initial starting attempts, several efforts might be required to accomplish bleeding time of time pilot line. While checking pilot adjustment observe whether pilot flame is extinguished promptly when burner switch is open. Lingering flame is indicative of a leaking gas pilot valve and a condition requiring correction before proceeding.

Atomizing Air

- The supply and pressure of the atomizing air on an oil fired burner should be checked. Before starting, inspect the oil pump lube oil level. Add oil if necessary.

Startup, Operating and Shutdown – All Fuels

- Set the manual-automatic switch to "manual" and turn manual flame control to "minimum".
- Turn burner switch to "on". Load demand light should glow. Low water level light should remain out indicating safe water level in boiler.
- The programmer is now sequencing.

NOTE: On an initial starting attempt, several efforts might be required to accomplish "bleeding" of fuel lines, main or pilot. If ignition does not then occur, do not repeat unsuccessful attempts without rechecking burner and pilot adjustment.

- On ignition failure the flame light will glow and the blower will purge the boiler of unburned fuel vapors before stopping. After ignition failure wait a few moments before re-setting the lockout switch.

Caution: Do not re-light the pilot or attempt to start the main burner, either oil or gas, if combustion chamber is hot and/or gas or oil vapor combustion gases are present in the furnace or flue passages. The burner and control system is designed to provide a "pre-purge" period of fan operation prior to establishing ignition spark and pilot flame. Do not attempt to alter the system or take any action that might circumvent this feature.

- After main flame ignition the burner should be left on manual control at its low fire setting (that is, with manual flame control at "close") for about 30 minutes or until boiler is properly warmed, unless it reaches its normal operating pressure or temperature sooner.
- In the case of a steam boiler, CLOSE THE TEST VALVE when steam begins to appear.
- A hot water boiler must have a continuous flow of system water through the vessel during warm-up period. The entire water content of the system and boiler must be warmed prior to increasing fuel input.
- If flame at low fire setting is insufficient to reach normal operation pressure or temperature after 30 minutes, gradually increase the firing rate by turning the manual flame control in one point increments to no higher than the midpoint between close and open. Operate at this increased fuel input rate for a period of time until an increase is noted in pressure or temperature. Sustained operation of the boiler should never be maintained when the manual control is set beyond midpoint.
- After unit is thoroughly warmed, turn the manual flame control to high fire. At this point a combustion analysis should be made, with instruments, and fuel flow regulated as required. After making the high-fire adjustment manually position the burner over the range from high to low fire stopping at intermediate points, analyzing combustion gases and adjusting as required.
- To properly perform this testing and adjusting, it is necessary that the burner be allowed to fire at maximum rate sufficiently long enough to achieve desired results.

Operating

- Normal operation should be with the manual-automatic switch set at “auto” and under the control of the modulating or temperature control.

Caution: If the firing rate controller is operated in the manual position at other than low fire, the pressure vessel steel and refractory are subjected to undesirable conditions. If the manually selected firing rate generates more steam than the system is demanding the boiler will be subject to overheating or over-pressurization potentially damaging the boiler and lifting safety relief valves.

- With the switch set at “auto”, burner will operate on a modulating basis according to the load demand.
- The burner will continue to operate with modulated firing until operating limit pressure or temperature is reached, unless:
  a) Burner is manually turned “off”.
  b) Low water condition is detected by low water level control.
  c) Current or fuel supply is interrupted.
  d) Pressure of combustion (or atomizing) air drops below minimum level.
  e) There can be many other reasons for a burner shutdown such as but not limited to motor overheat, flame outages, tripped circuit breakers, blown fuses, or through other interlock devices in the circuitry.
- When the burner is shut down normally, by either the operating limit control or by manually switching burner off, the load demand light no longer glows.
- Shutdown through conditions causing safety or interlock controls to open will actuate the flame failure light (and alarm if so equipped) and the load demand light will remain lit. The cause of this type of shutdown will have to be located, investigated and corrected before operation can be resumed. Refer to the “trouble-shooting” section of your burner manual.

CAUTION: If the safety relief valve has discharged there is a significant problem. Immediately remove the boiler from service and consult a trained service technician.

Shutdown

When the operating limit control setting is reached to open the circuit or if the burner switch is turned “off”, the following sequence occurs:

1. The fuel valve(s) is de-energized and flame extinguished.
2. The blower motor continues running to force air through the furnace in the post-purged period.
3. The air or oil pump motor of an oil-fired burner is de-energized
4. At the end of the programmed post-purge period the blower motor is de-energized.
5. The fuel linkages are returned to low fire position
6. The unit is ready to re-start

CAUTION: It is advisable to check for tight shutoff of fuel valves. Despite precautions and strainers, foreign material in either new or renovated fuel lines may lodge under a valve seat preventing tight closure. This is especially true in new installation. Promptly correct any conditions causing leakage.

Control Operational Test and Checks

Proper operation of the various controls should be verified and tested when the boiler is initially placed into service or whenever a control is replaced. Periodic checks should be made thereafter in accordance with a planned maintenance program as performed by a qualified technician.

- Operating Limit Test: The operating limit control may be checked by allowing steam pressure or water temperature to increase until the burner shuts down.
    - Hot Water Boiler: On a hot water boiler that may be operating at less than full load supply water temperature may be raised by manually increasing the firing rate until the burner shuts down through the action of the operating limit control. Observe the thermometer to verify the desired settings at the point of cutout and again when burner restarts. Return the manual automatic switch to “automatic” and check the modulating control for the desired temperature range

- Steam Boiler: Depending upon the load, it may be necessary to manually increase the firing rate to raise steam pressure to the burner shut off point. If load is heavy, the header valve can be closed or throttled until the pressure increases. Observe the steam gauge to check the cutoff pressure as the pressure or vent steam and check the cut-in setting as the burner restarts. Check the modulating control for desired operating pressure range.

- Observe the ignition and programming control operations to make sure that they are correct. Check the proper operation and setting of the low water cut-off (and pump control, if used).

- Proper operation of the flame failure device should be checked at time of starting and at least once a week thereafter.

- Check for tight shut-off of all fuel valves. Despite precautions and strainers, foreign material may lodge under a valve seat preventing tight closure. Promptly correct any conditions causing leakage.

Care and Maintenance

Boiler Water Treatment - Heating Boilers: Water treatment is required for satisfactory operation of a boiler to prevent depositing of scale and to prevent corrosion from acids, oxygen and other harmful elements that may be in the water supply. A qualified water treatment specialist should be consulted and the water treated.

The basic aims and objectives of boiler water conditioning are:

I. Prevent the accumulation of scale and deposits in the boiler.
II. Remove dissolved gases from the water.
III. Protect the boiler against corrosion.
IV. Eliminate carryover and/or priming (steam only).
V. Maintain the highest possible boiler efficiency.
VI. Decrease the amount of boiler down time for cleaning.

Water treatment should be checked and maintained on a regular basis. The end user should be sure that the boiler is not operated for long periods for approval tests or any other operation of firing without water treatment. It should also be noted that water boilers may well need chemical treatment for the first filling of water and additional periodic chemical treatment, depending on the system losses and the make-up requirements. Water treatment may vary from season to season or over a period of time; therefore, there should be a requirement that a water treatment procedure is checked no less than four times a year and possibly more frequently as the local water conditions may require. When the system is drained and then refilled, chemical treatment is required, in as much as raw water has been put into the boiler and system.

Weekly Maintenance

- Although the Unilux boiler is fully automatic, it must not be put into operation and forgotten.
- At least once a week, all controls and burner operation should be checked for proper, automatic operation.
- The fire must be observed, noting whether it is clean and normal.
- As carbon (soot) is an insulator, as well as corrosive, the heating surfaces of the boiler must be kept free from any soot accumulations to keep the boiler operating at its highest efficiency, note the stack temperature regularly.
- If the yearly inspection of the boiler tube surfaces reveals a build-up of soot (carbon) or rust (due to condensation), the tube surfaces should be thoroughly brushed. The flue gas venting system should also be thoroughly inspected internally and cleaned as necessary.
- IMPORTANT: If either soot or condensation are apparent, a reputable service agency should be consulted. The presence of soot indicates poor combustion, and a combustion test and readjustment should be undertaken at once. Rust on the tubes indicates operating temperatures are too low.
- A minimum boiler water temperature must be maintained to prevent corrosion or scaling of the fireside heating surface.

- The product of combustion from the burning of all types of fuels contain water vapor (H2O) resulting from the chemical union of hydrogen in the fuel with oxygen in the air. Therefore, there is a boiler tube temperature at which the water vapor will condense on the tube surfaces. Since such condensation will result in rusting, scaling and early failure of boiler metals, a minimum boiler temperature must be maintained which is above that temperature at which condensation will take place.

- The average dew point temperature for natural gas combustion products is 127°F. Most boiler manufacturers recommend a minimum boiler water temperature of 150°F, but due to the modern design of the Unilux boiler we generally recommend that the minimum water temperature for our boiler be maintained between 140°F - 145°F.

- Normally, fuel gas condensation problems occur under any one or a combination of:

  I. An outside reset temperature control is used to vary boiler water temperature according to outside temperature.
  II. The system design involves a combination hot and chilled water system in which a portion of the chilled water is returned to the boiler.
  III. The boiler is greatly oversized for the actual load, resulting in intermittent operation at low firing rates.
  IV. The boiler installation is located near a body of water where the atmosphere is highly humid.
  V. The low fire setting is set to low. A boiler naturally extracts all of the possible heat it can from the flue gases. Even if the boiler water temperature is maintained at a reasonable level to prevent condensation within the boiler, it is still possible (by setting the low fire too low) to incur condensation, and subsequent deterioration in metal breechings and stacks.

Replacement Boiler Installations

Protection Against Corrosion & Sediment

The number of boilers being sold for replacement (retrofit) applications is on the rise. This is due, in part, to energy costs of old, inefficient boilers; to conversion from municipal or central steam to on-site boilers; and to replacement of damaged or worn out boilers. Unilux is very active in this market. And the Unilux boiler line lends itself well because of the small package size and the capability of being shipped as field erect *"FE"* construction.

We want to alert you to some of the precautions, which must be exercised when installing a new boiler on any old system. It is imperative that the owner and the installer be made fully aware of the hazards of simply pulling out an old boiler and putting in a new one.

The following guidelines must be stressed to the owner and the installer to assure that the new boiler will perform well, last a useful life, and provide energy efficiency.

- Clean, or Replace, All System Piping and Heating Units
- Arrange for chemical and mechanical cleaning of the entire system.
- A chemical treatment company should be consulted for the proper means of chemical cleaning.
- Replace any piping considered to be deteriorated beyond safe or cleanable condition.
- Flush the system clean, independent of the boiler. DO NOT FLUSH THE SYSTEM THROUGH THE BOILER.

When filling the system, provide chemical treatment as previously outlined. For some older systems, there is a reluctance to chemically clean the piping because of the likelihood of leaks occurring in badly corroded lines. Should the customer decline cleaning; it is good practice and may be necessary to install filtration equipment. Install either a fibrous filter or a centrifugal filter in the boiler return piping. This will collect and remove sediment from the system. A booster pump may be necessary to overcome the additional pressure drop introduced in the line by the filter. Supply of this pump by others.

CAUTION: FAILURE TO PROPERLY CLEAN THE SYSTEM OR INSTALL MECHANICAL SEDIMENT REMOVAL EQUIPEMENT CAN RESULT IN TUBE STOPPAGE AND CORROSION PLUS DAMAGE TO PUMPS, AIR REMOVAL DEVICES AND CONTROLS. THESE CONDITIONS WILL AFFECT BOILER WARRANTY.

- Inspect the system for proper location and design of air elimination devices.
- Inspect and test all air elimination devices in the system and replace any suspect devices.
- Install gauge glasses on airhead expansion tanks and install a tank fitting in the system connection to the tank.

EXTENDED BOILER LAYUP

If the boiler is to be placed into an extended lay-up the following items need to be accomplished.

- Use the burner controls to safely shut the burner off
- The electric power to the control panel should be disconnected to insure no accidental restart of the boiler
- Once shut-off isolate the boiler from the system and allow the boiler to cool slowly.
    - Water-side: close isolation valves
    - Gas-side: close manual gas cocks
- The flue gas isolation damper (if installed) should be closed to minimize air flow through the boiler
- Once cool, slowly open the vents to allow pressure to be safely bled off
- If the lay-up is to be of a short-term then the unit may be kept in a wet lay-up
    - Insure that the boiler is not exposed to a freezing condition
    - Once pressure is equalized close all vents to insure no additional fresh air is allowed to enter the system
- If the boiler is to be kept off-line for an extended period of time the unit can be placed into a dry lay-up
    - The boiler should be drained and a desiccant placed into the boiler
    - After installation of the desicant all pressure side openings should be closed to keep fresh air and oxygen out of the boiler
    - It is recommended that blind flanges be installed in the gas and/or fuel oil lines for additional insurance that no fuel is able to leak into the furnace.
    - Upon restarting of the boiler, a complete waterside and fireside inspection should be accomplished
- For either lay-up insure that the safety relief valve is free of standing water and is dry to avoid corrosion of the assembly

PRESSURE VESSEL REPAIR

The ability to quickly and easily replace individual tube elements is a key design feature of the Unilux boiler. This feature requires the utilization of both easily removable outer casing as well as tube elements that do not require code welders. No ASME Code welding is required to execute the repair of a Unilux boiler. All Unilux boilers feature a mechanical tapered fitting connection and a bolted base plate to secure the tubes in position. All outer casing panels are connected to the boiler with easily removable and reusable screws. The panels also allow for the quick and easy identification of the location of a potential tube problem. Anyone that has had to repair a membrane boiler will appreciate the ease of repair of the Unilux design.

If you suspect that a tube may be leaking the procedure for identification and repair is as follows:

1. Secure the boiler for the system and insure that the burner cannot be lit. This can be accomplished by closing and tagging the gas cocks or even physically removing a segment of gas line. Insure that the stop and non return valves are closed to isolate the boiler from a common steam header if applicable

2. Once the boiler has cooled down you may remove the outer casing from the area where you suspect the problem to be. Do not drain the boiler yet as the water pressure will help point to he problem area.

3. Once the problem has been identified the boiler may be drained.

4. Unbolt the nut that holds the plate over the tube ferrules from the upper and lower drums

5. Remove the damaged tube by utilizing Unilux tube removal tools.

6. Once removed the tube holes on the drums should be inspected to insure proper surface conditions.

7. Install the replacement tube as supplied by Unilux.

Note! Unilux tube end ferrules are machined to extreme tolerances. Unilux does not recommend the use of aftermarket parts not manufactured directly by Unilux

8. With the new tube in position a 10 to 12 pound sledge hammer should be used in conjunction with Unilux drive tool to insure the striking force is directed onto the landing on the ferrule and no other place on the tube. The ferrule may require two to three strong strikes with the sledge to insure proper sealing. Measure insertion depth to recommended setting.

9. Once the tube ferrules have been hammered into both drums the retaining plates can be reinstalled with their bolt.

10. The unit should be refilled with water insuring proper sealing of the repaired area.

11. Once the connection is confirmed as sealed the outer panels can placed replaced and the boiler returned to service using the start-up instructions as provided in this manual.

TROUBLESHOOTING

If you are not a professional trained boiler service technician qualified to work on this equipment then do not attempt any repair on the equipment and contact Unilux or your local agent for support.

Prior to conducting any service insure that all safety precautions are taken including isolating the boiler, electric, and fuel from the boiler system as applicable.

Not all scenarios can be identified in a manual. The suggestions below are the most common. All corrective actions ultimately are the responsibility of the service technician.

Problem: Boiler Will Not Fire

1. Is the boiler on ?

   - Check to insure that the boiler has correct utilities supplied including electricity and fuel.
   - Check fuses, breakers, and disconnects to the control panel.
   - Check the position of shut-off lines from fuel sources. Pressure gages on the fuel lines should verify proper fuel supply.

2. Is there a demand for heat?

   - Is the firing rate control receiving a demand for heat signal, either steam or hot water?
   - If the BMS is receiving a demand for heat signal from either it's local firing rate control or a remote lead-lag system then the BMS should identify the demand signal and begin the start-up process.
   - If no demand signal is received by the BMS then the issue probably lies with the local operating control pressuretrols for steam and aquastats for hot water boilers or the lead-lag sequencer for a multiple boiler installation. Refer to the specific manufacturer's manuals for those components to diagnose the fault further.

3. A demand for heat is established but the boiler is still not firing

   - If the demand signal to the BMS exist and the boiler is not firing check the BMS for a start-up or operational permissive fault. Refer to the manufacturers instructions for the specific BMS or supplied with the burner for fault identification. Examples of BMS limits are as follows but not limited to:
     - High or low fuel supply pressure
     - Failure of automatic fuel supply valves
     - High or low water level inside of the boiler
     - High pressure or high water temperature inside of boiler
     - Insufficient combustion air pressure
     - Failure to light or sustain the flame

   - The BMS has a specific start-up sequence. Refer to the manufacturer's manual for the specific BMS supplied with the burner
     - When the BMS receives a demand for heat signal it will follow a defined sequence of events to start the burner including but not limited :
       - Insure automatic fuel valves are in close position
       - Check low water/high pressure/high temperature cut offs
       - Return the burner to a low fire position
       - Start the FD fan and execute the required purge
       - Light off pilot and prove flame
       - Light off main burner and prove flame at low fire
     - Once flame has been proven at low fire the BMS hands the firing rate control off to the local firing rate controller or lead-lag sequencer.
     - By taking information from the BMS as well as observing the start-up sequence it should be able to diagnose the specific reason for the fault.

4. Boiler starts but immediately shuts off

   - If the boiler shuts off immediately after a successful start-up it is most probable that the boiler is "Short Cycling".
   - This is most probably a problem with the boiler operating controls being configured as not to allow for a normal operating span.
     - Check the manufacturers manual as to proper set points for the pressuretrols or aquastats
   - This may also be a case of a boiler oversized for the demand not allowing the burner to operate at very low turndown range forcing the boiler to shut off.
   - Short cycling can lead to damage to the boiler and steam system and is extremely inefficient

5. The boiler shuts off during normal operation when there is a demand for heat.

   - Check the BMS for the reason for the shutdown. There are many reason that a boiler would shut off during normal operation including the following but not limited to:
     - Aggressive load swings or improper water level control can lead to low water trip
     - Aggressive load swings could lead to a system over pressurization leading to a shutdown due to apparent system load satisfied
     - Water in the fuel could lead sputtering combustion and a flame scanner safety shutdown
     - Fuel pressure fluctuations could lead to the BMS safety shutdown
     - If firing oil check for a clogged tip and proper atomizing media
     - Electric utility issues could lead to a safety trip
     - Any electrical component in the system could be faulty

6. The boiler makes excessive noise when firing

   - There are many different sources of noise inside of a boiler in service. The source of the noise must first be identified:
     - Combustion Rumbling:
       - A burner that is not properly tuned can rumble. Varied atmospheric conditions, high operating hours without tuning, and changes to the boiler system in general could lead to burner rumbling. This could be a dangerous situation and a qualified combustion technician should immediately be consulted. If there is any question about the safety of the unit the boiler should immediately be shut off.
         - **Danger: Improper fuel-air ratios can lead to an explosive situation**.
         - The vibration can lead to damage of the boiler and trim
     - Leaks
       - A boiler suffering leaks can emit a water or steam spray as well as making a noise.
       - **Danger: Be careful not to allow the spray to come in contact with unprotected body parts**
     - Failing Components
       - Failing fan bearings or failing automatic valves can emit a distinctive noise

- Once the reason for the noise has been identified the suspect device should be repaired or replaced as applicable.
- Use the sight opening in either the burner or located in rear of the boiler (if installed) to observe the flame pattern. Viewing the flame pattern is an effective way to diagnose combustion issues.

7. The safety relief valves are lifting

- The safety relief valves should never lift. If they do it is indicative of a major problem within the system. There are many reasons the valves may be lifting. The include but are not limited to:
  - Failure of high-fire limit: if the firing rate control is broken or improperly adjusted the burner may be at a fifing rate that exceeds system demand causing an excessive build-up of pressure within the boiler. This would be excessive pressure for a steam boiler and high temperature for a hot water boiler.
  - Aggressive load change: If the system places aggressive load swings on the boiler it is possible that the boiler controls may not be able to track these load swings. An instantaneous stopping of demand on a boiler already at a high firing rate could allow the pressure to build faster than the burner can ramp down.
  - Damaged safety valves: Safety relief valves can suffer scarring across the seat leading to weeping and improper lifting.
  - Damaged burner: the firing rate control mechanism on the burner may be damaged not allowing the burner to accurately track load

8. The boiler trips because of water level

- Low and high water level trips are an important safety interlocks. The action of the level inside of the steam drum can be observed on the gauge glass. Catastrophic damage can occur if a boiler is dry fired. Damage to the plant can occur from excessive water levels either through poor quality steam or flooding of the steam header. Some common reasons for low water trips is as follows:
  - Excessive demand: if the system is demanding more steam than the boiler can produce the drum pressure will begin to fall ultimately sucking the water out of the boiler leading to a low level trip
  - Insufficient feedwater pump capacity: If the boiler is demanding more water than the feedwater pump is capable of pumping the boiler can trip on low water.

- Aggressive load swings: Aggressive load swings can lead to excessive water level fluctuations leading to low or high level trips
- Poor water chemistry or contaminated water: poor water chemistry can lead to excessive solids in the steam drum. This will lead to foaming that can provide false signals to the level controls. Bubbles formed in poor water can mask low water level conditions with float-type water level devices. Improper chemistry can also lead to nuisance trips of probe-type devices.
- Improper control system: The type of drum level control system may not be sufficient to the actual operation of the boiler. Some problems may be as follows:
  - Slow operating feedwater regulating valve: Boilers equipped with a modulating feedwater system may not have a fast enough response time to react to load change
  - Level control scheme: Boilers equipped with only a single element feedwater control system may need to be upgraded to a two element control if the boiler is subjected to aggressive load swings.
  - Adequate feedwater flow rate: The flow rate of a feedwater pump must be suitable to not only meet the demand of the boiler at a given firing rate but provide additional water flow capacity to fill a steam drum that could be rapidly depleted by a high instantaneous demand. Boilers equipped with on-off feedwater system are susceptible to low water trip if the pumps are undersized .

9. The boiler may be leaking

- There are many ways to identify a leak inside of the boiler, Should a leak be detected it is important to have your service technician examine the situation.
  - Water leaking from boiler drains
  - Water leak observed through boiler sight glass
  - Excessive plume exiting stack
  - Excessive condensation in ductwork drains
  - Excessive make-up water usage
  - Reduced stack temperatures
- Boilers can remain in service until a time convenient to shut down the boiler and execute a repair
- If a leak is identified contact Unilux for the supply of replacement parts

UNILUX ADVANCED MANUFACTURING

INSTALLATION, OPERATION AND SERVICE MANUAL

THE INFORMATION CONTAINED IN THIS MANUAL IS PROVIDED AS A GUIDE ONLY. IF FOLLOWED, A SUCCESSFUL START UP AND OPERATIONAL HISTORY SHOULD RESULT.

Unilux – We Know Performance