GE WATER & PROCESS TECHNOLOGIES

E-CELL STACK™

MK-2 SERIES

OWNER'S MANUAL

For additional E-Cell Stack™ information, go to the GEWPT E-Cell web page:
http://www.ecell.com

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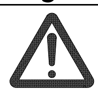
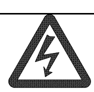
1. E-CELL STACK™ GLOSSARY

CONCENTRATE BLEED	A small portion of the Concentrate flow, which is sent to drain.
CONCENTRATE MAKE UP	The Concentrate make up is the additional water added to the Concentrate loop to make up the volume sent to drain via the Electrode outlet and the Concentrate bleed.
CONCENTRATE LOOP	The Concentrate loop is from the Concentrate Pump to the E-Cell Stack™, and back to the pump.
CONCENTRATE RECYCLE	A portion of the Concentrate flow is recycled through the Stacks in order to maintain the required conductivity in the Concentrate loop.
DILUTE FEED	Flow through the E-Cell Stacks™ that will become **Product water**.
E-CALC	An E-Calc spreadsheet (available from GEWPT) calculates all E-Cell EDI process parameters based on feed water analysis and selected operating conditions.
ELECTRODE STREAM	A small portion of recycled Concentrate flowing through the Electrode compartment of each E-Cell Stack™ of the E-Cell System™, which will be sent directly to drain after exiting the System.
GEWPT	GE Water and Process Technology.
PRODUCT	The deionized water which is produced by the E-Cell System™.
RECTIFIER	DC power supply.

2. PERSONNEL SAFETY PRECAUTIONS

The following Pictograms can be found on the E-Cell Stack™ and contained in this Manual:

Pictogram	Function	Description
	WARNING!	The E-Cell Stack™ should not be used at any time by untrained personnel. **Do not attempt to operate the E-Cell Stack™ unless you understand the contents of this manual and have received training . Serious injury may occur if the procedures in this manual are not followed.** The E-Cell Stack™ operates **under pressure** above atmospheric and/or vacuum below atmospheric. Review the safety procedures of this manual. Air scouring is not applicable to E-Cell Stacks™. Air scouring will not aid in cleaning or removing blockage of E-Cell Stacks™ Any disassembly of this E-Cell Stack™, loosening, or removal of retaining bolts or other improper handling or use of this E-Cell Stack™ may cause severe personal injury. All personnel must be trained on the hazards of working with chemical cleaning solutions. Rubber gloves, full rubber suits, full-face shields and goggles must be used when exposure to acid, caustic, oxidizers or any other chemicals is a possibility. Install flange guards on all chemical lines.
	Electrical Shock Hazard	**The E-Cell Stack™ contains dangerous high voltage when it is energized. Lockout the dc power supply before working around the E-Cell Stacks™**
⎓	Direct Current (DC)	Used with V or A to indicate DC voltage or current or with On or Off symbols.

Warning
To Prevent Stack Damage

WARRANTY MAY BE VOIDED IF THE FOLLOWING PRECAUTIONS ARE NOT FOLLOWED!

Blockage or interruption of flow will damage stacks. If stacks are powered electrically without the flow of water through any channels, they will be irreversibly damaged in 1-3 minutes.

Systems with an open system between the RO and E-Cell (ex. tank, decarbonator) must be fitted with filters immediately preceding the E-Cell, to protect the E-Cell against contamination with particulate matter! Generally, a 5um absolute or 1um nominal filter will be acceptable. For your specific system requirements, consult your E-Cell System Integrator.

Common causes of blockage:
- PVC shavings, cement, or other debris from pipe work flushed into stack inlets.
- Slime or debris from a tank not filtered before going into E-Cell.
- Improper set points on flow switches or transmitters, or malfunctioning / disabled flow meters.
- Accidental closing of manual valves.

BEFORE APPLYING ELECTRICITY OR WATER TO THE E-CELL:

- **Flush piping thoroughly with filtered water to drain** before connecting feed water piping to the E-Cell Stacks™. Failure to flush the pipes to remove debris may cause irreversible damage to the stacks.

- **Pressurize stacks slowly over 1-2 minutes** to avoid severe damage from water hammer. Do not over pressurize stacks.

- **Ensure 4 flows have been established** and all safety interlocks have been proven: Electrode Outlet flow, Dilute Product Outlet flow, Concentrate Inlet flow, and Concentrate Bleed flow.

- **Verify that no chlorine or oxidizing agent enters the E-Cell Stacks™.** Water must meet feed specifications.

- **Operation at >0.5ppm hardness (as $CaCO_3$) or >0.5ppm silica** or failure to meet any feed specifications can damage the E-Cell Stacks™ unless special precautions are being taken. Regular acid cleaning, and RO permeate softening may be required.

- **For systems with a brine pump, the quality of the salt must be carefully checked.** The salt must be of the special type listed in the E-Cell Owner's Manual, otherwise the stacks can be irreversibly damaged if run for extended period.

- **Plastic fittings and nozzles are not repairable. Handle with care.**

3. SPECIFICATIONS

3.1 FEED WATER SPECIFICATIONS

Constituent	Units	Feed
TEA	ppm as $CaCO_3$ *	* As calculated by E-Calc
pH		5 to 9
Hardness	ppm $CaCO_3$	< 0.5 **
Silica (reactive)	ppm	< 0.5 @ Minimum to Nominal product flow
Silica (reactive)	ppm	< 0.383 @ Maximum product flow
TOC	ppm	< 0.5
Total chlorine	ppm	< 0.05
Fe, Mn, H_2S	ppm	< 0.01
SDI 15min.		<1.0
Oil & Grease		None detectable
Turbidity	NTU	<1.0
Oxidizing agents		None detectable
Colour	APHA	<5

TEA - MK-2E	ppm as $CaCO_3$ *	< 25 @ 15 gpm / 3.4 m^3/h product flow (Nominal flow) < 48.8 @ 7.5 gpm / 3.4 m^3/h (Minimum flow) < 15 @ 20 gpm / 4.5 m^3/h (Maximum flow)
TEA - MK-2Pharm & PharmHT		<26 @ 15 gpm / 3.4 m^3/h (Nominal flow) <55 @ 7.5 gpm / 1.7 m^3/h (Minimum flow) <20 @ 20 gpm / 4.5 m^3/h (Maximum flow)
TEA - MK-2 Mini & MiniHT		<25 @ 5 gpm / 1.14 m^3/h (Nominal flow) <49 @ 2.5 gpm / 0.57 m^3/h (Minimum flow) <15 @ 6.7 gpm / 1.52 m^3/h (Maximum flow)

**** See section *Concentrate Bleed Stream* for information on recovery and feedwater hardness.**

Note: The feed water to the E-Cell Stack™ must be RO permeate or equivalent.

3.2 PRODUCT WATER SPECIFICATIONS

The E-Cell Stack™ will produce 16 MOhm.cm water (MK-2E, MK-2Mini, MK-2MiniHT) or 10 MOhm.cm (MK-2Pharm, MK-2PharmHT), provided the feed water meets the Feed Water Specifications and the system is operated according to the Operating Instructions.

3.3 SALT SPECIFICATIONS

Proper salt selection for brine injection is critical in avoiding long term problems with scaling and fouling. The specifications for sodium chloride are as follows:

Sodium Chloride (dry basis)	>99.80%
Ca and Mg (as Ca)	<0.05%
Copper	<0.5 ppm
Iron (as free Fe)	<5.0 ppm
Heavy Metals (as Pb)	<2.0 ppm

Note:
1. Any salt additive except yellow prussiate of soda (sodium prussiate) at up to 15 ppm in the salt may contribute to scaling and will void the warranty.
2. "Analytical" grade salt may not meet this spec and is very expensive. Several food grade salts are widely used in the food industry and are less expensive than "Analytical" grade.

3.4 E-CELL STACK™ OPERATING PARAMETERS

Parameter	Range
Product Flow	MK-2E, MK-2Pharm, MK-2PharmHT 7.5 to 20.0 gpm (1.70 to 4.54 m^3/h) MK-2Mini, MK-2MiniHT 2.5 to 6.7 gpm (0.57 to 1.52 m^3/h)
Feed Temperature	40 to 100 °F (4.4 to 38 °C)
Inlet Pressure	50 to 100 psig (3.4 to 6.9 bar) @ Minimum to Nominal flow 65 to 100 psig (4.5 to 6.9 bar) @ Maximum flow
Feed to Product ΔP	20 to 35 psid (1.4 to 2.4 bar) @ Nominal flow 10 to 15 psid (0.7 to 1.0 bar) @ Minimum flow 40 to 50 psid (2.8 to 3.4 bar) @ Maximum flow
Recovery	90 to 95% *****
Electrical Power	Up to 600 VDC (MK-2E, MK-2Pharm, MK-2PharmHT Stack) Up to 300 VDC (MK-2Mini, MK2-MiniHT) 0.5 to 4.5 amp

**** See section *Concentrate Bleed Stream* for information on recovery and feedwater hardness.**

3.5 E-CELL STACK™ TECHNICAL DATA SHEET

Design Pressure of E-Cell Stack™ .... 100 psig (6.8 Bar)
Membrane Manufacturers .... Asahi Glass Corporation (AGC)
Ion Exchange Manufacturers .... Mitsubishi Chemical
Model Designations MK-2E, MK-2Pharm, MK-2PharmHT, MK-2Mini, MK-2MiniHT
Anode Material .... IrO_x/TiO_2 on Ti
Cathode Material .... Stainless Steel
Operating Weight .... See Cutsheet

3.6 PERFORMANCE DATA

Maximum System Product Flow Rate .... See Cutsheet
Minimum System Product Flow Rate .... See Cutsheet
MK-2E, MK2-Pharm, MK-2PharmHT Stack™ Product Flow Rate ....
.... Minimum 7.5 gpm (1.70 m^3/hr)
.... Nominal 15.0 gpm (3.41 m^3/hr)
.... Maximum 20.0 gpm (4.54 m^3/hr)
MK-2Mini, MK-2MiniHT Stack™ Product Flow Rate ....
.... Minumum 2.5 gpm (0.57 m^3/hr)
.... Nominal 5.0 gpm (1.14 m^3/hr)
.... Maximum 6.7 gpm (1.52 m^3/hr)
Recovery 90-95%
MK-2E, MK-2Pharm, MK-2PharmHT Stack™ voltage input .... 100 V - 600 V
MK-2Mini, MK-2MiniHT Stack™ voltage input .... 100 V - 300 V
Stack™ current input 0.5A-4.5A

3.7 E-CELL™ CE, CSA and NRTL/C COMPLIANCE

The E-Cell Stack™ meets the principle elements of the safety objectives for the low voltage directive, EC Directive 73/23/EEC, having applied the following standard: BS EN 60204-1.

The E-Cell Stack™ meets the principal elements of the safety objectives for the electro-magnetic compatibility directive, EC Directive 89/336/EEC (as amended by 92/31/EEC and 93/68/EEC).

The following standards have also been applied:

EN 55011:1995 Group 1, Class A
EN 610001-4-2
EN 610001-4-3
EN 610001-4-4
EN 610001-4-5
EN 610001-4-6
EN 610001-4-11

In addition, the E-Cell Stack™ has CSA and NRTL/C certification.

4. BRINE INJECTION

E-Cell Stacks™ with low feed water conductivity may not be able to maintain sufficient current flow Stacks™. Without sufficient current flow, the E-Cell Stacks™ will be unable to produce high quality water. In case of low conductivity feed, the concentrate water can be supplemented with brine to attain high quality product water.

Brine injection is also required where feed water contains greater than 0.1 ppm as $CaCO_3$ of hardness.

5. ELECTRICAL

The E-Cell Stack™ uses high voltage DC power. Standard good electrical practices apply and they are as follows:

1. Regularly inspect terminations for tightness and proper connection.
2. Isolate any faulty electrical part prior to repairing or replacing it.
3. Do not disconnect the power cable to the E-Cell Stack™ with the DC power “ON”

5.1 E-CELL STACK™ MAXIMUM POWER REQUIREMENTS

INPUT VOLTAGE	INPUT CURRENT	MAX POWER
100-600V	0.5-4.5A	2.7 kW

5.2 OPERATING CURRENT

In order for the E-Cell Stack™ to produce high quality water, the current flow must be sufficient for the ionic load in the feed water. In general, more current is required as the ionic load increases. More current is also required for silica removal.

6. MECHANICAL AND HYDRAULIC

Do not adjust the bolts on the E-Cell Stack™ side and end plates as tampering may result in permanent damage to the E-Cell Stack™ and voids the warranty.

Care must be taken to protect against water hammer. Feed Water pressure should never exceed 100 psi (6.8 bar)

7. RECEIVING & INSTALLATION

7.1 RECEIVING

Inspect each E-Cell Stack™ for shipping damage and then replace the packaging material. The Stacks should remain in the packaging material until they are to be installed. Any shipping damage must be reported to the shipper and E-Cell within 5 days to validate claim.

7.2 LIFTING

There are lifting lugs at the top of the E-Cell Stack™ allowing the use of a forklift or other mechanical device to move the E-Cell Stack™. See specification for actual weight.

The E-Cell Stack™ cannot be lifted or moved or supported by the SaniTech hose connections.

7.3 E-CELL STACK™ STORAGE

The E-Cell Stack™ should be stored indoors, out of direct sunlight and at a temperature between 33°F (2°C) and 120°F (49°C).

The membranes inside the E-Cell Stack™ must be maintained wet. The Stack must remain full of water if stored for up to three days. For longer storage of up to one year, the E-Cell Stack™ must be drained of water and capped to keep the Stack™ moist. Whenever a Stack is stored it should be on its back with the nozzles pointing up.

7.4 INSTALLATION

The E-Cell Stacks™ are Installation Category II as well as Pollution Degree 2.

Remove all dust caps from the E-Cell Stack™ and connect the hoses. Hand tighten the SaniTech fittings.

The E-Cell Stack™ installation must be protected from wind, rain, direct sunlight, vibration and meet the following operating environment for the E-Cell Stack™:

Parameter	Range
Temperature range	33°F (2 °C) to 120 °F (49 °C)
Humidity	up to 95%
Seismic	Zone 1
Altitude	0 to 6,560 ft (2,000 m)

7.5 DRAINS & VENTING

Drains should be designed to carry away 20 gpm (4.54 m^3/hr) Product flow, 0.40 gpm (90 L/hr) Electrode Outlet flow, and 1.97 gpm (0.45 m^3/hr) Concentrate Bleed flow for each MK-2E, MK-2Pharm or MK-2PharmHT Stack; and 6.7 gpm (1.52 m^3/h) Product flow, 0.40 gpm (90 L/hr) Electrode Outlet flow, and 0.91 gpm (0.21 m^3/hr) Concentrate Bleed flow for each MK-2Mini or MK-2MiniHT Stack™.

The electrode stream must be vented as it contains small quantities of hydrogen, oxygen and possibly chlorine gas. (A 2:1 mixture of hydrogen and oxygen gas is produced at a maximum rate of about 11.4 ml/amp/minute (hydrogen, dry gas at 25 °C, 1.0 atm) Ensure ventilation maintains the hydrogen gas levels below 4%.

Drains should be designed so that the E-Cell Stack™ cannot drain while in Standby.

8. START UP

8.1 GENERAL OVERVIEW

The basic steps involved in the system start up are:

1. Fill the system with Reverse Osmosis quality water, or better
2. Set dilute flow
3. Start the concentrate pump and establish concentrate flow
4. Set concentrate bleed flow
5. Set the concentrate inlet pressure
6. Set the concentrate outlet pressure
7. Set the electrode flow
8. Start the rectifier

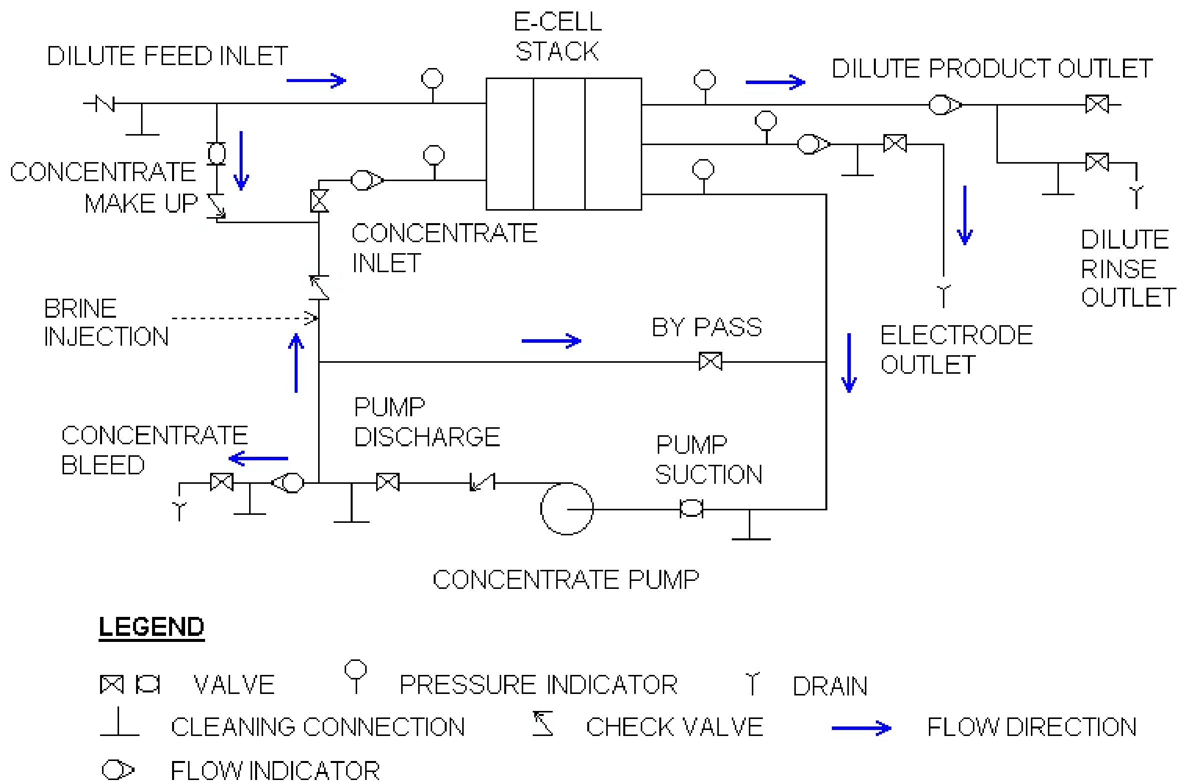
8.2 START UP

Once the E-Cell Stacks™ are ready for start up, the Concentrate Loop must be filled. The initial filling is done with R.O. permeate (or other high quality water). The feed water must always meet all the quality requirements, this will require the R.O. to be rinsed to quality before being placed into Service and sending water to the E-Cell System™. The conductivity of the Concentrate loop will initially be the same as the Feed water conductivity.

In order for the E-Cell Stacks™ to function effectively, the Concentrate Loop should have an operating conductivity of 50-600 μS/cm. In some cases, it may be necessary to inject concentrated brine into the Concentrate Loop in order to raise the conductivity once the system is operating.

E-Calc spreadsheet indicates if brine injection is necessary and calculates expected concentrate conductivity based on feed water analysis and recovery.

E-CELL SYSTEM SCHEMATIC



Before E-Cell Stacks™ **start**, check:

1. All Valves are closed
2. All pumps are in the "OFF" position
3. DC power is turned "OFF"
4. Safety equipment is installed and operational.

8.2.1 Fill the system with water and establish Dilute Flow

1. Open Concentrate Make-up Valve
2. Open Concentrate Inlet Valve
3. Open Pump Suction Valve
4. Open Pump Discharge Valve
5. Open the Concentrate Bleed Valve
6. Open the Dilute Rinse Outlet Valve
7. Slowly crack open the Dilute Feed Inlet Valve, maintain a low feed pressure (less than 40 psi) to the E-Cell Stacks™ to ensure a slow Concentrate Loop and Dilute Loop fill.
8. Adjust the Dilute Rinse Outlet Valve to establish the correct flow rate: 7.5-20.0 gpm/ 1.70-4.54 m^3/h per MK-2E, MK-2Pharm or MK-2PharmHT Stack™; 2.5-6.7 gpm/0.57-1.52 m^3/h per MK-2Mini or MK-2MiniHT Stack™.

9. Once water flows continuously through the Concentrate Bleed (no bubbles), prime the Concentrate Pump (see pump manufacturer's instructions in Vendor Data).

8.2.2 Establish Concentrate, Electrode, and Dilute Flow

1. Throttle Concentrate Inlet Valve, so that it is 10-20% open.
2. Confirm the Concentrate Pump Suction Valve is open.
3. Set the Concentrate Pump Discharge Valve 25% open.
4. Close the Concentrate Bypass Valve.
5. Confirm Concentrate Make Up Valve is open.
6. "Bump" the Concentrate Pump by quickly turning the hand-switch to "Hand" and back to "Off" (If the pump does not operate, check that the disconnect switch on the rectifier is in the "ON" position). Confirm the pump rotation, if incorrect, a qualified electrician should swap two of the leads to change the pump rotation.
7. Start the Concentrate Pump by switching it to "Hand".
8. Open the Concentrate Pump Discharge Valve 100%.
9. Open the Concentrate Bleed Valve to attain approximately 10% of Product flow.
10. Slowly adjust the Concentrate Inlet Valve until the Concentrate Inlet is at least 5 psi (0.35 bar) less than the Dilute Feed pressure.
    If the Concentrate Outlet pressure is zero open the Concentrate Bypass Valve in order to increase it above zero.
    If the Concentrate By-Pass Valve is closed and the Concentrate Outlet pressure is too high (i.e. Cout Pressure is greater than or equal to Dout Pressure) slowly close the Concentrate Make-Up Valve. The Concentrate Outlet pressure will start to decrease. Once it is at least 5 psi (0.35 bar) less than the Dilute Outlet pressure, stop and check the inlet pressures. The Concentrate Inlet pressure is probably too low. Correct this by opening the Concentrate Inlet Valve. Continue to make small adjustments to the Concentrate Make-Up and Concentrate Inlet Valves, until the Concentrate stream is at least 5 psi (0.35 bar) less than the Dilute stream. Ensure that Concentrate flow is within the correct range (see section "Operating Instructions".) If it is not, continue to make small stepwise adjustments to Concentrate Inlet and Concentrate Bypass valves until Concentrate pressures and flow are in the correct ranges.
11. Open the Electrode Outlet Valve to achieve nominal 0.35 gpm/Stack (80 l/h).
12. Re-adjust Concentrate Inlet Valve again if the pressure difference between Concentrate and Dilute Feed is not at least 5 psi (0.35 bar).
13. Set Concentrate Bleed Valve to achieve the required recovery. The recovery rate is calculated according to the recovery formula explained in the section "OPERATING INSTRUCTIONS – Concentrate Bleed Stream."

    Once Recovery is known Bleed Flow can be calculated from the definition of recovery given by the formula in that section. Also, Bleed Flow is calculated by E-Calc.

    <u>Note:</u> In conditions with very low Feed water pressures, it may be necessary to throttle the Concentrate Pump Discharge Valve in order to achieve the required flows and pressures. This is the reason for the diaphragm valve on the pump discharge.

8.2.3 Confirm all flows and pressures

1. Electrode flow is 0.35 gpm/Stack (80 l/h).
2. Dilute Flow is 7.5-20.0 gpm/ 1.70-4.54 m^3/h per MK-2E, MK-2Pharm or MK-2PharmHT Stack™; 2.5-6.7 gpm/0.57-1.52 m^3/h per MK-2Mini or MK-2MiniHT Stack™.
3. Concentrate Bleed Flow is set for the appropriate recovery.
4. Dilute Feed pressure is at least 5 psi (0.35 bar) more than Concentrate Inlet pressure.
5. Dilute Product pressure is at least 5 psi (0.35 bar) more than Concentrate Outlet pressure.

8.2.4 Initiate DC power

1. Set current to 0%,
2. Set voltage to 100%, (maximum of 600 Volts for MK-2E, MK-2Pharm or MK-2PharmHT Stacks™; maximum 300 Volts for MK-2Mini or MK-2MiniHT Stacks™.)
3. Slowly increase current to 2 amps/ E-Cell Stack™. If the concentrate conductivity is low, the maximum current will also be low. As the concentrate conductivity increases, so will the current.
   Note: The Brine Pump is set in the "Off" position because the conductivity in the Concentrate loop may be high enough to allow sufficient current flow. If the Concentrate loop conductivity remains below 50 μS/cm after half an hour of operation, start the Brine Pump by selecting AUTO (Below 50 μS/cm, current flow may be too low). The brine injection should be ramped up very slowly to prevent a sudden conductivity increase and therefore a sudden current increase through the E-Cell Stacks™, which could blow a fuse.

   E-Cell Stacks™ are shipped in regenerated form but they could be exhausted to certain degree during startup activities when water is passed through them without current. Therefore, it may take some time until the stacks are fully regenerated and produce water of required quality (typically it takes few minutes).

9. SHUT DOWN PROCEDURES

9.1 E-CELL STACK™ SHUT DOWN FROM AUTOMATIC OPERATION

If the system is to be shut down for a period of time, and the piping configuration allows the system to drain, some of the manual valves must be closed. They include the following

1. Close the Dilute Feed Inlet Valve.
2. Close the Dilute Product Outlet Valve.
3. Close the Dilute Product Rinse Valve.
4. Close the Concentrate Bleed Valve.
5. Close the Electrode Outlet Valve

9.2 E-CELL STACK™ PROLONGED SHUT DOWN

If the E-Cell Stacks™ are to be shut down for more than three days, they must be prepared for long term shutdown and storage, to hinder the development of biogrowth.

Note: Power to the E-Cell Stacks™ must be off during all steps of the preparation for long term shutdown!

Notes:

1. Power to the E-Cell Stacks™ must be off.
2. Allow E-Cell Stacks™ to drain all standing water.
3. Close or cap all E-Cell Stacks™ inlet and outlets so that they remain moist.
4. After long term shutdown, E-Cell Stacks™ may require regeneration. Regeneration will require approximately 8 to 16 hours.

10. OPERATING INSTRUCTIONS

10.1 FLOW RATES

There are four separate flow streams on the E-Cell System™ each with a distinct range and purpose.

10.1.1 Dilute Stream

Range
7.5-20.0 gpm / 1.70-4.54 m^3/h per MK-2E, MK-2Pharm or MK-2PharmHT Stack™
2.5-6.7 gpm / 0.57-1.52 m^3/h per MK-2Mini or MK-2MiniHT Stack™

The Dilute stream is the process water that is purified. It is the primary source of cooling water for the Stack. If the Stack is operated at less than minimum Product flow, localised heating will occur inside the Stack resulting in damage and external leaks.

10.1.2 Concentrate Stream

Range
1.5-5.4 gpm / 0.34-1.23 m^3/h per MK-2E, MK-2Pharm or MK-2PharmHT Stack™
0.9-2.25 gpm / 0.18-0.51 m^3/h per MK-2Mini or MK-2MiniHT Stack™

The Concentrate stream is the collecting point for all the ions removed from the Dilute stream. While this stream has a flow range, the flow rate itself is never set, only monitored. The Concentrate inlet and outlet pressures must be less than the Dilute pressures, therefore the Concentrate inlet and outlet pressures are set in order to obtain correct pressures first and flow rate second. The Concentrate flow rate is monitored to track the E-Cell Stack's performance.

If the electrical resistance of the E-Cell Stack is too high, current will not flow through the Stack. The Concentrate stream can be used to adjust the Stack's resistance in order to increase the current flow.

During operation, ions from the Dilute stream are collected in the concentrate stream. The Concentrate, is recycled through the E-Cell Stack™ to further increase the Concentrate conductivity, and thereby decrease the E-Cell Stack™'s resistance. Recycling the Concentrate through the Stack also allows the system to operate with high Concentrate flow rates. The high flows lead to high velocities through the Concentrate chambers, decreasing the opportunity for scaling.

The minimum Concentrate flow rate is 1.5 gpm (0.34 m^3/h) for MK-2E, MK-2Pharm and MK-2PharmHT Stacks™, and 0.9 gpm (0.18 m^3/h) for MK-2Mini and MK-2MiniHT Stacks™. If the Stack is operated at less than minimum concentrate flow, the stack will scale and localized heating will occur inside the Stack resulting in damage and external leaks.

In order to prevent the Concentrate stream from exceeding the solubility limits, a small amount of Concentrate is sent to drain. This water is replaced with Dilute feed water, through the Concentrate Make-up valve. The amount of Concentrate Bleed required is dependent on the Recovery required, which is itself dependent on the flow rates and the feed water hardness level. For more information on Recovery and Concentrate Bleed, see the "Concentrate Bleed" section below.

The conductivity of the Concentrate stream should be kept between 50 and 600 μS/cm. This will allow sufficient current flow through the E-Cell Stack. For applications with very low conductivity feed water, brine can be injected directly into the Concentrate loop to raise the conductivity.

Note: The Recovery must never be increased in order to increase the conductivity in the Concentrate loop. The Concentrate Bleed flow must be set to achieve the required recovery rate. If the Concentrate Bleed flow is decreased, the maximum allowable recovery will be exceeded and scaling of the Concentrate chamber will begin.

10.1.3 Concentrate Bleed Stream

Range – Dependent on required recovery ratio.

Ions removed from the Dilute stream must be expelled from the E-Cell Stack through the Concentrate Bleed stream to prevent scaling. The Concentrate Bleed flow required is dependent on the amount of hardness. Recovery ratios have been calculated to maintain an acceptable hardness level.

Feed Hardness (ppm as $CaCO_3$)	E-Cell Recovery[1]	NaCl Injection into C-loop [2] (uS/cm)
0.0 – 0.10	95%	- -
0.10 – 0.50	90%	+ 400 – 500

(1) Lowering the recovery lowers the hardness level in the concentrate loop and hence decreases the scaling potential.

(2) NaCl injection also reduces the electrical resistance of the stack, and hence the power consumption.

At feed hardness levels <0.1 ppm, a maximum recovery of 95% applies and periodic cleanings are generally not required in the absence of upsets.

At feed hardness levels >0.1 ppm, the recovery is reduced to 90% and salt is injected into the Concentrate loop as shown in the table above. Periodic cleanings are required.

Recovery ratios are provided because the amount of Concentrate Bleed required is dependent on the feed water hardness, the Dilute flow and the Electrode flow rates (as Dilute flow increases, the amount of hardness entering the E-Cell Stack also increases).

$$\text{Recovery} = \frac{\text{Dilute Product Flow}}{\text{Dilute Product} + \text{Concentrate Bleed} + \text{Electrode Outlet Flow}} \text{x} 100\%$$

Therefore,

$$\text{Concentrate Bleed Flow} = \left[\frac{\text{Dilute Product Flow}}{\text{Recovery}} \text{x} 100 \right] - \text{Electode Outlet Flow - Dilute Product Flow}$$

Example
For a system with <0.1 ppm of hardness in the feed water, 25 gpm Dilute Product flow and 0.5 gpm Electrode Outlet flow, what is the minimum Bleed flow rate?

$$\text{Concentrate Bleed Flow} = \left[\frac{25}{95} \text{x} 100 \right] - 0.5 - 25$$

Therefore the minimum Concentrate Bleed Flow = 0.8 gpm

The Concentrate Bleed is usually higher quality than the RO feed water, so it is usually recycled to the RO inlet. This improves the overall E-Cell System™ recovery to about 98%.

10.1.4 Electrode Stream

Range 0.25-0.40 gpm (60-90 l/h)

The Electrode stream flows over the electrodes. This stream cools the electrodes and removes any gases produced in the chambers. Due to the presence of H_2, O_2 and possibly Cl_2 gas in this stream, it must be sent to a vented drain.

Some of the Cl_2 gas will dissolve into the solution. The presence of oxidants, combined with the venting requirements and the small flow rate, lead to this stream flowing to drain in most installations, rather than being recovered.

The Electrode stream is supplied from the Concentrate stream.

10.2 OPERATING PRESSURES

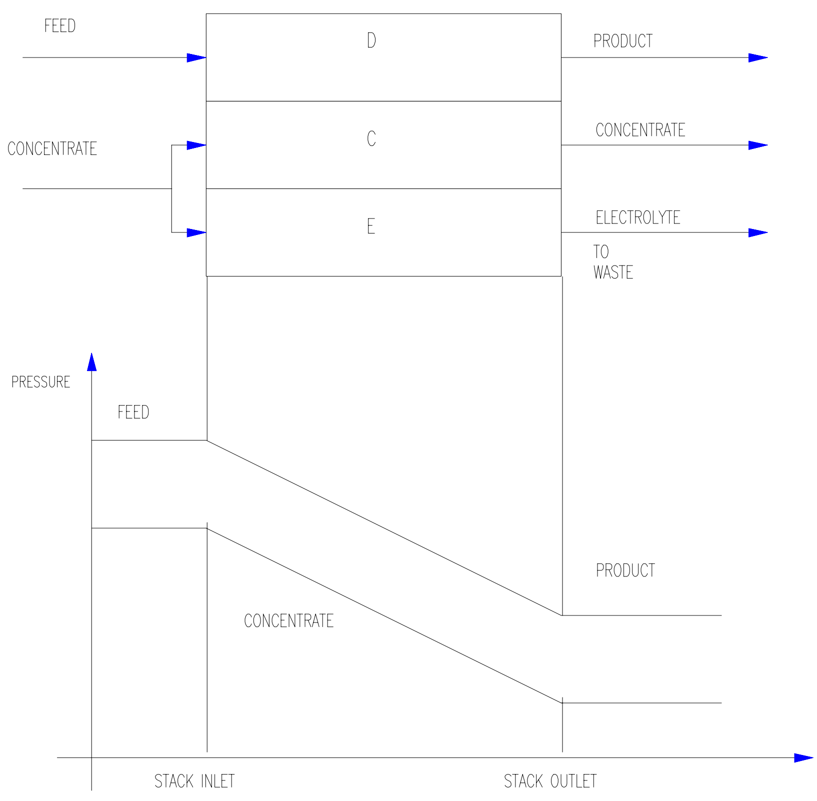
The Concentrate stream must always operate at a lower pressure than the Dilute stream to maintain high product water quality.

The Concentrate inlet must be at least 5 psi (0.3 bar) less than the Dilute inlet pressure. The Concentrate outlet must be at least 5 psi (0.3 bar) less than the Dilute outlet pressure.

The Concentrate Inlet valve controls the inlet pressure difference. Closing the valve decreases the Concentrate Inlet pressure and thereby increases the pressure difference between the Concentrate Inlet and Dilute Inlet. The Concentrate By-pass valve controls the outlet pressure difference. Closing the valve decreases the Concentrate outlet pressure and thereby increases the pressure difference between the Concentrate outlet and Dilute outlet.

The maximum E-Cell™ Dilute Feed water pressure is 100 psi (6.8 bar)

PRESSURE DIFFERENCE BETWEEN DILUTE AND CONCENTRATE



10.3 OPERATING DATA

The E-Cell System™ requires little maintenance, however it is important to keep accurate operating data. This should be used to track the performance of the system and help identify any problems as early as possible.

The following parameters should be recorded at least once a day:

- Dilute Feed Pressure (psi, bar)
- Concentrate Inlet Pressure (psi, bar)
- Dilute Outlet Pressure (psi, bar)
- Concentrate Outlet Pressure (psi, bar)
- Pump Discharge Pressure (psi, bar)
- Concentrate Bleed Flow (gpm, m^3/h))
- Concentrate Flow (gpm, m^3/h)
- Electrode Flow (gpm, m^3/h)
- Dilute Flow (gpm, m^3/h)

- Rectifier Voltage (volts)
- System Current (amps)

- Product Resistivity (Mohm.cm)
- Concentrate Conductivity (μS/cm)
- Feed Conductivity (μS/cm)

- Product Temperature (°F, °C)
- Concentrate Temperature (°F, °C)

The following parameters should be recorded on a weekly basis:

- Feed Hardness (ppm)
- Feed CO_2 (ppm)
- Feed Silica (ppm)

Sample Operating data log forms are located at http://www.ecell.com/.

The GEWPT E-Cell group developed the Field Monitoring Spreadsheet that automatically normalizes data and produces graphs similarly to RO operating data normalization programs. The spreadsheet helps to determine cleaning needs and gives early warning of potential problems and is available at http://www.ecell.com/.

11. PREVENTATIVE MAINTENANCE

11.1 GENERAL

> Maintenance personnel must exercise extreme caution as any leaking water may be electrically charged
> Check high voltage connection and grounding wires are tight every 3 months.
> Do not externally clean E-Cell Stack™ using high pressure water.

Check for proper recovery ratio once per week (minimum).

Check feed water quality on a regular basis.

11.2 E-CELL STACK™ CLEANING AND SANITIZING

11.2.1 Overview

Over time cleaning and/or sanitization of E-Cell Stacks™ may be necessary, due to:

- hardness or other metallic scaling, mainly in the Concentrate and Cathode chambers
- fouling of the ion exchange medium or membranes with inorganic material (ex. silica)
- fouling of the ion exchange medium or membranes with organic material
- biological fouling of the E-Cell Stack™ and system piping and components
- combinations of the above

In some cases, more than one type of cleaning may be needed. The chart below summarizes the scaling and fouling conditions and the cleaning/sanitizing procedures best suited to correct the condition.

The MK-2PharmHT and MK-2Mini HT Stacks™ can be sanitized at high temperature (80° C / 176°F.) For instructions, refer to the separate MK-2 Pharm-HT Mini-HT Sanitization Procedure.

Cleaning Procedure	1	2	3	4	5	6	7	8
PROBLEM								
C, E chamber metallic scaling	Yes							
D, C, E chamber metallic scaling		Yes						
Organic fouling			Yes					
Organic fouling and metallic scaling				Yes				
Biological fouling			Yes					
Biological fouling and metallic scaling				Yes				
Heavy biological fouling					Yes			
Heavy biological fouling and metallic scaling						Yes		
Severe biological fouling							Yes	
Severe biological fouling and metallic scaling								Yes

The table below summarizes the main steps that are performed for each procedure. These steps are provided in detail in subsections which follow.

Cleaning Procedure	1	2	3	4	5	6	7	8
Instruction 1	C Acid	Acid	Caustic	Acid	Brine	Acid	Brine	Acid
Instruction 2	Rinse	Rinse	Rinse	Caustic	Rinse	Brine	Rinse	Brine
Instruction 3	-	Regen	Regen	Rinse	Santize A or B	Rinse	Santize A or B	Rinse
Instruction 4	-	-	-	Regen	Brine	Santize A or B	Caustic	Santize A or B
Instruction 5	-	-	-	-	Rinse	Brine	Rinse	Caustic
Instruction 6	-	-	-	-	Regen	Rinse	Regen	Rinse
Instruction 7	-	-	-	-	-	Regen	-	Regen

<u>Notes</u>:

1) The cleaning procedures are written for an E-Cell System™ containing a single Stack. For larger systems scale up proportionally. Maintain chemical concentrations by multiplying all water and chemical amounts by the number of Stacks.
2) E-Cell System™ cleaning requires up to 8 hours per cleaning procedure.
3) After cleaning, the E-Cell Stacks™ must be regenerated (except Procedure 1). Regeneration requires up to 16 hours.

The Long Term Shutdown procedure must be followed if the E-Cell System™ is to be down for more than three days.

11.2.2 Safety

1) Avoid contact with Halane (1,3-Dichloro-5,5-dimethyl hydantoin), sodium hydroxide, peracetic acid, hydrogen peroxide and hydrochloric acid, as these are corrosive. Hydrogen peroxide is an oxidizer.
2) Depressurize all process lines to avoid high-pressure chemical spray.
3) The E-Cell System™ operates at high voltage. Before performing any maintenance, ensure rectifier power is off and the rectifier properly tagged and/or locked out.

11.2.3 Cleaning Chemical Specifications

All chemicals must be of recommended grade or better.

Sodium Chloride (NaCl) Food Grade (≥99.80%), ACS or USP grade
Halane (1,3-Dichloro-5,5-dimethyl hydantoin) USP or ACS grade
Peracetic Acid (CH_3COOOH) and Hydrogen Peroxide (H_2O_2) 30%: ACS grade, or
commercial concentrate for water system cleaning (ex. Minntec Minncare, Henkel-Ecolab Oxonia Active, Diversey Divosan, or FMC Flocide)
Hydrochloric Acid (HCl) ACS or Technical grade
Sodium Hydroxide (NaOH): Pellets, NF, ACS or Purified grade; or 50% w/w Solution

11.3 CLEANING SETUP AND INSTRUCTIONS

There are eight cleaning procedures in total, made up of combinations of four basic types of cleaning: low pH; high pH; mild oxidizing sanitization/cleaning; and sodium chloride rinse.

The first cleaning procedure is performed only on the Concentrate and Electrode chambers of the Stack. Its setup is different from the remaining seven procedures, where cleaning is done on all chambers, Dilute, Concentrate and Electrode.

The description of the four cleaning types is laid out in this section, as are the descriptions of the water rinse and final water rinse. The list of individual steps is shown for procedures 2 through 8. Procedure 1 is laid out in detail in its own section.

A cleaning tank and pump and four hoses to connect the tank and pump to the E-Cell System™ are required for procedures 2 through 8; for procedure 1, only three hoses are required.

Cleaning Setup

- Isolate the E-Cell system from upstream and downstream by closing the E-Cell System Dilute Feed Inlet, Dilute Product Outlet, and Dilute Rinse Outlet valves.
- Connect the cleaning skid discharge to the E-Cell Dilute Feed Inlet cleaning connection.
- Connect the E-Cell Dilute Product Outlet, Concentrate Bleed, and Electrode Outlet cleaning connections back to the cleaning skid.

Instruction 1: Hydrochloric Acid Solution Recirculation (Low pH Cleaning)

- Drain the cleaning skid and E-Cell skid.
- Make up 50 L per Stack of HCl 1.8% solution.
- Recirculate the HCl solution through the Dilute, Concentrate and Electrode loops for 30 minutes.
    - The E-Cell system will run with flow ranges as during normal operation, using the Concentrate pump, but with no current applied to the Stacks.

Use: To clean hardness and other metallic scale. In procedure 1, only the Concentrate and Electrode chambers of the stack are cleaned.

Instruction 2: Sodium Chloride / Sodium Hydroxide Solution Recirculation (High pH Cleaning)

- Drain the cleaning skid and E-Cell skid.
- Make up 25 L per Stack of NaCl 5% + NaOH 1% solution.
- Recirculate the NaCl+NaOH solution through the Dilute, Concentrate and Electrode loops for 30 minutes.
    - The E-Cell system will run with flow ranges as during normal operation, using the Concentrate pump, but with no current applied to the Stacks.

Use: Sodium chloride with sodium hydroxide is useful for cleaning fouling due to organics or to biological growth, and for sanitization. It can also clean light silica scaling.

Instruction 3: Halane (1,3-dichloro-5,5-dimethyl hydantoin) Solution Recirculation (Mild Oxidizing Sanitization/Cleaning)

- Drain the cleaning skid and E-Cell skid.
- Make up 25 L per Stack of halane 0.05% solution (12.5 g halane in 25 L of water.)
    - Halane is sparingly soluble. Completely dissolve the halane before proceeding to recirculate the cleaning solution.
- Recirculate the halane solution through the Dilute, Concentrate and Electrode loops for 30 minutes.
    - The E-Cell system will run with flow ranges as during normal operation, using the Concentrate pump, but with no current applied to the Stacks.

Use: Halane, a widely used source of chlorine, is useful for cleaning and sanitizing high-purity water treatment equipment. This is an oxidizing cleaning solution which is effective primarily as a biocide against biofouling and secondarily a cleaner against organic fouling. Due to its oxidizing power, this cleaning solution should be used infrequently and the directions for its use followed closely.

Instruction 4: Peracetic Acid / Hydrogen Peroxide Solution Recirculation (Mild Oxidizing Sanitization/Cleaning)

- Drain the cleaning skid and E-Cell skid.
- Make up 25 L per Stack of peracetic acid 0.04% / hydrogen peroxide 0.2% solution (0.25 L of a commercial solution such as Minntec Minncare, Henkel-Ecolab Oxonia Active, Diversey Divosan, or FMC Flocide, in 25 L of water.)
- Recirculate the peracetic acid / hydrogen peroxide solution through the Dilute, Concentrate and Electrode loops for 2 hours.
    - The E-Cell system will run with flow ranges as during normal operation, using the Concentrate pump, but with no current applied to the Stacks.

Use: Peracetic acid 0.04% / hydrogen peroxide 0.2% performs similarly to halane using a different chemical species. It should also be used only when necessary.

Instruction 5: Sodium Chloride Solution Recirculation

- Drain the cleaning skid and E-Cell skid.
- Make up 25 L per Stack of $NaCl$ 5% solution.
- Recirculate the $NaCl$ solution through the Dilute, Concentrate and Electrode loops for 10 minutes.
    - The E-Cell system will run with flow ranges as during normal operation, using the Concentrate pump, but with no current applied to the Stacks.

Use: To bring the Stack ion exchange resin into the exhausted (sodium and chloride) forms in preparation for the next cleaning step or for regeneration. It also assists in cleaning by displacing some contaminant ions from the resin.

Instruction 6: Water Rinse

- Drain the cleaning skid and E-Cell skid.
- Fill the cleaning tank with 25 L per Stack of RO (or better) quality water.
- Briefly recirculate the water and then drain the cleaning skid and E-Cell skid.
- Repeat the water rinse steps once.

Instruction 7: Final Water Rinse

- Drain the cleaning skid and E-Cell skid.
- Fill the cleaning tank with 25 L per Stack of RO (or better) quality water.
- Briefly recirculate the water and then drain the cleaning skid and E-Cell skid.
- Repeat the rinse steps until the Concentrate Outlet conductivity is < 50 uS/cm.

11.4 CLEANING PROCEDURES

Cleaning Procedure 1: Hydrochloric Acid Cleaning of Concentrate and Electrode Chambers
This procedure provides an acid cleaning of the Concentrate and Electrode (anode and cathode) chambers of the Stacks to clean hardness and other metallic scale.
Steps
Cleaning Setup – Concentrate and Electrode Acid Cleaning Procedure Only • Isolate the Concentrate and Electrode loops from the Dilute loop by closing the Concentrate Makeup valve. • Isolate the Concentrate pump by closing the Concentrate pump suction and discharge valves. • Close the Concentrate Bypass valve. • Close the Concentrate Bleed valve. • Connect the cleaning skid discharge to the E-Cell Concentrate Inlet cleaning connection. • Connect the E-Cell Concentrate Outlet and Electrode Outlet cleaning connections back to the cleaning skid.
Hydrochloric Acid Solution Recirculation – Concentrate and Electrode Acid Cleaning Procedure Only • Make up 50 L per Stack of HCl 1.8% solution. • Recirculate the HCl solution through the Concentrate and Electrode loops for 30 minutes with flow ranges as during normal operation.
Final Water Rinse

Cleaning Procedure 2: Hydrochloric Acid Cleaning of All Chambers	**Cleaning Procedure 3: Sodium Chloride / Sodium Hydroxide Cleaning/Sanitizing**
This procedure provides an acid cleaning of all chambers of the Stacks to clean hardness and other metallic scale.	Sodium chloride 5% / sodium hydroxide 1% is useful for cleaning fouling due to organics or to biological growth, and for sanitization. It can also clean light silica scaling.
Steps	**Steps**
Cleaning Setup	Cleaning Setup
Instruction 1	Instruction 2
Instruction 7	Instruction 7

Cleaning Procedure 4: Hydrochloric Acid and Sodium Chloride / Sodium Hydroxide Cleaning/Sanitizing

This procedure provides an acid cleaning of all chambers of the Stacks to remove inorganic metallic scale.

Sodium chloride 5% / sodium hydroxide 1% is useful for cleaning fouling due to organics or to biological growth, and for sanitization. It can also clean light silica scaling.

Steps
Cleaning Setup
Instruction 1
Instruction 6
Instruction 2
Instruction 7

Cleaning Procedure 5: Halane or Peracetic Acid Sanitizing

Halane, a widely used source of chlorine, is useful for cleaning and sanitizing high-purity water treatment equipment. Peracetic acid 0.04% / hydrogen peroxide 0.2% performs similarly using a different chemical species. Due to their oxidizing power, these cleaning solutions should be used infrequently.

Steps
Cleaning Setup
Instruction 5
Instruction 6
Instruction 3 **or** Instruction 4 (NOT BOTH)
Instruction 5
Instruction 7

Cleaning Procedure 6: Hydrochloric Acid and Halane or Peracetic Acid Sanitizing

Where hardness or other metallic scale is present along with heavy biological fouling an acid cleaning step is added to the beginning of the procedure.

Halane, a widely used source of chlorine, is useful for cleaning and sanitizing high-purity water treatment equipment. Peracetic acid 0.04% / hydrogen peroxide 0.2% performs similarly using a different chemical species. Due to their oxidizing power, these cleaning solutions should be used infrequently.

Steps
Cleaning Setup
Instruction 1
Instruction 6
Instruction 5
Instruction 6
Instruction 3 **or** Instruction 4 (NOT BOTH)
Instruction 5
Instruction 7

Cleaning Procedure 7: Halane or Peracetic Acid Sanitizing and High pH Sanitizing

Halane, a widely used source of chlorine, is useful for cleaning and sanitizing high-purity water treatment equipment. Peracetic acid 0.04% / hydrogen peroxide 0.2% performs similarly using a different chemical species. Due to their oxidizing power, these cleaning solutions should be used infrequently.

For severe biological fouling a high pH step is added to the procedure for improved efficiency.

Steps
Cleaning Setup
Instruction 5
Instruction 6
Instruction 3 **or** Instruction 4 (NOT BOTH)
Instruction 2
Instruction 7

Cleaning Procedure 8: Hydrochloric Acid and Halane or Peracetic Acid Sanitizing and High pH Sanitizing

Where hardness or other metallic scale is present along with heavy biological fouling an acid cleaning step is added to the beginning of the procedure.

Halane, a widely used source of chlorine, is useful for cleaning and sanitizing high-purity water treatment equipment. Peracetic acid 0.04% / hydrogen peroxide 0.2% performs similarly using a different chemical species. Due to their oxidizing power, these cleaning solutions should be used infrequently.

For severe biological fouling a high pH step is added to the procedure for improved efficiency.

Steps
Cleaning Setup
Instruction 1
Instruction 5
Instruction 6
Instruction 3 **or** Instruction 4 (NOT BOTH)
Instruction 2
Instruction 7