DRAFT Standard Operating Procedure Ultrafiltration and Reverse Osmosis
R.Cox 8-2016

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SECTION 1 – SAFETY

- Safety Glasses Must Be Worn at All Times When Operating This Equipment
  Hoses may become dislodged and spray process fluid on operators and nearby equipment. It is advisable to wear a lab coat when operating this equipment.
- Never Leave This Equipment Operating Unattended
  This equipment may malfunction resulting in flooding or equipment damage.
- Do Not Place Any Items on the Equipment Surface
  Items placed on the surface of this equipment can vibrate into the feed chamber and become lodged in the pump causing severe pump damage.
- This Equipment Utilizes High Pressure Water and High Voltage.
  Understand the different pressures and equipment requirements associated with ultrafiltration and reverse osmosis filtration.
  Use of inappropriate fitting may result in severe injury or death.
- Trip Hazards
- Never operate the pump without liquid in the tank!
- Never make a sudden change in the pump speed, always adjust the pump speed gradually.
- Always check the hose connections before operating the pump.
- Be aware of the hoses and electrical cords located behind the equipment.
- Verify that the appropriate pressure gauges are installed for your process. Reverse osmosis requires high pressure gauges. Ultrafiltration requires low pressure gauges.
- High Pressure Equipment
  The output line from the system pump is fitted with a pressure relief valve.
  Consult with lab manager regarding pressure release settings for this valve.
  Do not adjust the pressure relief valve.
- Use only carbon filtered water from the filtration system located behind and to the right of the equipment. Do NOT use d.i water or tap water.

Carbon filter dispensing system and feed valves to dispensing system shown below.
• High Pressure Clamps

SAFETY WARNING - REVERSE OSMOSIS CLAMPS

All of the clamps from the tank outlet to the feed pump inlet can be low pressure style (as it is not high pressure until after the discharge of the pump). The 3/4" Clamps with the hinge are rated above 2000psi at 70degrF. It is only the 1.5" clamps on the pressure gauges and the 3" clamps on the 2540 Spiral housing that require the dual bolt high pressure clamp.

Note: ceramics (Tami module) are run at low pressure, this module is not used.

The high pressure bolted clamp is suitable for any Tri-clamp application. It must be used in any lines and connections in the high pressure piping circuits of the reverse osmosis system. For these lines in the high pressure circuit, do not use any other type of clamp! These clamps are properly tightened when the two halves of the clamp are butted together.

The low pressure hinged clamp is suitable for low pressure applications in any size. Do not use these types of clamps in high pressure circuits.

Pump Safety Notice

It is unsafe to operate a centrifugal pump when both the suction and discharge ports are closed.
off by valves at the same time. Such circumstances can result in the disintegration of the pump housing.

This phenomenon is fully appreciated in the engineering profession and stated in the pump literature. When a pump operates with closed valves, nearly all the motor power output is converted to heat and the temperature of the trapped liquid will continue to rise.

As it does, the liquid will expand and additional pressure will be created as the liquid expands eventually to above the liquid boiling point. The temperature will eventually stabilize were heat losses from the pump housing equal the heat generated. However at this point the internal pressure may exceed that for which the pump was designed.

*Storage and Disposal of Waste*

All waste materials must be stored in sealed Nalgene waste containers. The containers must be clearly labeled *Unwanted Material* with the contents of each chemical component in mol % or volume % concentration written clearly on the container.

The container must also be labeled with the group / experiment name and the date. The labeled and sealed container must be placed in the waste collection area located in the south-east corner of senior lab.

Any chemicals or materials that require temporary storage until the next lab period must also be labeled with the contents of each chemical component in mol % or volume % concentration written clearly on the container. Be sure to include the name of your group and the date, do not label temporary storage container as waste.

If the material to be temporarily stored is flammable it MUST be stored in the flammables cabinets located on the east wall of senior lab. If the chemicals are not flammable and not hazardous they may be stored in sealed containers next to the ultrafiltration equipment, the containers must be properly labeled as previously described. Check with the lab manager before deciding on the procedure for temporary storage of chemicals.
SECTION 2 – Equipment Description

1. Butterfly clamp
2. Ceramic Filter Module
3. Feed line
4. Heat exchanger
5. Pump Outlet
6. High pressure clamp
7. Hydraulic jack for Labstack
8. M20 Labstack Module
9. M20 Labstack Module-feed inlet
10. M20 Labstack Module-retentate outlet
11. Permeate line
12. Retentate pressure control valve
13. Clamp
14. Pressure gauge-retentate
15. Pressure gauge
16. Pump (positive displacement)
17. Pump-controller
18. Pump-power cord and outlet
19. Pump-pressure relief valve
20. Reservoir
21. Reservoir-drain valve
22. Retentate line R.O. (Spiral Membrane)
23. RO-vessel
24. Input to RO
25. Hydraulic line
26. RO-retentate outlet
27. And 28. Fitting O-ring
The base system incorporates the plate and frame Lab Module M20 with 7.8 sq. ft. (0.72 sqm) of membrane area. The Lab Module M20 accepts flat sheet polymeric membranes of all types. It has the unique feature of being able to simultaneously screen a number of flat sheet membranes. The Lab 20 module can accept as few as 4 flat sheets to as many as 40 sheets. This flexibility allows the module to run anywhere from 1 to 8 gallons per hour. A spiral membrane pressure vessel, 2.5 inch diameter by 40 inch length, is included for testing spiral elements at both low and high pressure. A ceramic membrane module for testing lab scale ceramic MF or UF elements is included as well. Feed tank volume = 4 gallons.

Figure 3: Spiral-wound type membrane (Koch Membrane Systems, 2009)

Flat sheet type membrane assembly (ultrafiltration) in plate-and-frame module shown on the right.
Spiral membrane (reverse osmosis) shown on the left.
• The top two pressure gauges are measuring the pressure on the feed/concentrate side of the membrane. The permeate pressure should be atmospheric, as the permeate hose goes directly to drain.

• The two gauges measure the pressure loss due to flow from the inlet to the outlet of the element.
SECTION 3 – R.O. Membrane Specifications

Listed below are the specifications for a reverse osmosis and ultrafiltration membrane. These are the membranes that are typically used with the GEA Model L system. Consult the lab manager for information on other membranes.

Chlorine will damage membranes – Do not use tap water or D.I water
Use the carbon filter water system located behind the filtration system.
Consult with lab manager regarding water system operation

Product Information

FILMTEC™ Membranes
FILMTEC Fiberglassed Elements for Light Industrial Systems

Features

FILMTEC™ brackish water/reverse osmosis membrane elements provide consistent, outstanding system performance in light industrial applications.

- FILMTEC LE-4040 delivers highest performance at lowest pressure resulting in less energy usage and lower costs.
- FILMTEC BW30-4040 is the industry standard for reliable operation and production of the highest quality water.
- FILMTEC BW30-2540 elements are designed for systems smaller than 1 gpm (0.4 m³/hr) offering a hard shell exterior for extra strength.

Elements with a hard shell exterior are recommended for systems with multiple-element housings containing three or more membranes, as they are designed to withstand higher pressure drops.

Product Specifications

<table>
<thead>
<tr>
<th>Product</th>
<th>Part Number</th>
<th>Active Area ft²/m²</th>
<th>Feed Spacing Thickness (mil)</th>
<th>Permeate Flow Rate gpd (m³/hr)</th>
<th>Stabilized Salt Rejection (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LE-4040</td>
<td>275713</td>
<td>78 (7.2)</td>
<td>34</td>
<td>2,400 (9.1)</td>
<td>99.5</td>
</tr>
<tr>
<td>BW30-4040</td>
<td>807031</td>
<td>78 (7.2)</td>
<td>34</td>
<td>2,400 (9.1)</td>
<td>99.5</td>
</tr>
<tr>
<td>BW30-2540</td>
<td>809106</td>
<td>28 (2.6)</td>
<td>28</td>
<td>550 (2.0)</td>
<td>99.5</td>
</tr>
</tbody>
</table>

1. Permeate flow and salt rejection based on the following test conditions: 2,000 ppm NaCl, applied pressure 150 psi (10.3 bars) for LE-4040 and 195 psi (13.5 bars) for BW30-4040 and BW30-2540; 77°F (25°C) and 15% recovery.
2. Permeate flow for individual elements may vary ±20%.
3. For the purpose of improvement, specifications may be updated periodically.
4. LE-4040 element BW30-4040.

Figure 1

Product Specifications

<table>
<thead>
<tr>
<th>Product</th>
<th>Dimensions – Inches (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>LE-4040</td>
<td>40.0 (1.016)</td>
</tr>
<tr>
<td>BW30-4040</td>
<td>40.0 (1.016)</td>
</tr>
<tr>
<td>BW30-2540</td>
<td>40.0 (1.016)</td>
</tr>
</tbody>
</table>

2. BW30-2540 elements fit nominal 2.5-inch O.D. pressure vessels. BW30-LE-4040 and BW30-4040 elements fit nominal 4-inch O.D. pressure vessels.

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Form No. 605-00150-0488

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Operating Limits

- Membrane Type: Polysulfone Thin-Film Composite
- Maximum Operating Temperature: 113°F (45°C)
- Maximum Operating Pressure: 600 psi (40 bar)
- Maximum Feed Flow Rate: 240 elements - 6 gpm (2.4 m³/h); 3040 elements - 16 gpm (6.1 m³/h)
- Maximum Pressure Drop: 15 psig (1.0 bar)
- pH Range, Continuous Operation: 2 - 11
- pH Range, Short-Term Cleaning: 1 - 13
- Maximum Feed Silt Density Index: SDI 5
- Free Chlorine Tolerance: <0.1 ppm

*Maximum temperature for continuous operation above pH 8 is 95°F (35°C).
**Under certain conditions, the presence of free chlorine and other oxidizing agents will cause premature membrane failure. Since oxidation damage is not covered under warranty, FilmTec recommends removing oxidized free chlorine by pretreatment prior to membrane exposure. Please refer to the bulletin Latex-02070 for more information.

Important Information

Proper start-up of reverse osmosis water treatment systems is essential to prepare the membranes for operating service and to prevent membrane damage due to overfeeding or hydraulic shock.

Following the proper start-up sequence also helps ensure that system operating parameters conform to design specifications so that system water quality and productivity goals can be achieved.

Before initiating system start-up procedures, membrane pre-treatment, loading of the membrane elements, instrument calibration and other system checks should be completed.

Please refer to the application information literature entitled “Start-Up Sequence” (Form No. 609-02077) for more information.

Operation Guidelines

Avoid any abrupt pressure or cross-flow variations on the spiral elements during start-up, shutdown, cleaning or other sequences to prevent possible membrane damage. During start-up, a gradual change from a standstill to operating state is recommended as follows:

- Feed pressure should be increased gradually over a 30-60 second time frame.
- Cross-flow velocity at set operating point should be achieved gradually over 15-20 seconds.
- Permeate obtained from first hour of operation should be discarded.

General Information

- Keep elements moist at all times after initial wetting.
- If operating limits and guidelines given in this bulletin are not strictly followed, the limited warranty will be null and void.
- To prevent biological growth during prolonged system shutdowns, it is recommended that membrane elements be immersed in a preservative solution.
- The customer is fully responsible for the effects of incompatible chemicals and lubricants on elements.
- Maximum pressure drop across an entire pressure vessel (housing) is 50 psi (3.4 bar).
- Avoid static permeate-side backpressure at all times.

Regulatory Note

These membranes may be subject to drinking water application restrictions in some countries; please check the application status before use and sale.

FilmTec™ Membranes
For more information about FILMTEC membranes, call the Dow Water Solutions business:
North America: 1-800-443-4389
Latin America: (+52) 55-9186-6022
Europe: (+34) 93-450-3740
Japan: (+81) 3-3808-3382
China: +86-10-2251-9000
http://www.dowfilmtec.com

Notice: The use of this product is at your own risk and does not necessarily guarantee the removal of cysts and pathogens from water. Effective cyst and pathogen reduction is dependent on the complete system design and on the operation and maintenance of the system.

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### Flat Sheet Membrane Specifications

Synder Filtration offers its complete line of membranes in a variety of flat sheet and membrane roll options. Synder can supply membrane for all scales of testing, research, and production with exceptionally fast lead times.

<table>
<thead>
<tr>
<th>Specifications</th>
<th>ST</th>
<th>ST PHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal molecular weight cut-off</td>
<td>10,000Da</td>
<td></td>
</tr>
<tr>
<td>Membrane material</td>
<td>Polyethersulfone (PES)</td>
<td></td>
</tr>
<tr>
<td>Backing material</td>
<td>Polyester</td>
<td>Polypropylene</td>
</tr>
<tr>
<td>Total thickness (Backing &amp; Membrane)</td>
<td>0.008 inches (0.20 millimeters)</td>
<td></td>
</tr>
<tr>
<td>pH range during operation</td>
<td>1-10.0</td>
<td>1-13.0</td>
</tr>
<tr>
<td>pH range during CIP</td>
<td>1-11.0</td>
<td></td>
</tr>
<tr>
<td>Maximum operating temperature</td>
<td>194°F / 90°C</td>
<td></td>
</tr>
<tr>
<td>Typical permeability on DI water @ 77°F / 25°C and 60 psi / 4.1 atm</td>
<td>146-225 GFD / 249-383 LMH</td>
<td></td>
</tr>
<tr>
<td>FDA &amp; USDA approval</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Preservative - packed wet</td>
<td>0.2% Sodium metabisulfite</td>
<td></td>
</tr>
<tr>
<td>Preservative - packed dry</td>
<td>Glycerine</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>Common applications</td>
<td>WPC/WPI, Beverage clarification, Enzyme</td>
<td></td>
</tr>
</tbody>
</table>

**Model Information:** All membranes are available in factory cut sections of 1 ft. x 1 ft. and 1 m x 1 m, and in rolls by the foot, or rolls by the meter. The standard roll width is 40”/1016 mm. Non-standard roll widths may be offered upon request. Membranes may be purchased wet or dry.

**SECTION 5 – Startup Checklist**

1. Remove all items from the top of the equipment
2. Verify that all clamps are secure.
3. **Verify that the concentrate / retentate and permeate hoses are both secure inside of the feed tank. These hoses can easily slide out of the feed tank and flood the work area.**
4. Verify that the correct membrane is installed or install a membrane as required.
5. Consult lab manager for instructions on membrane installation.
6. Verify that the feed tank drain valve is closed.
7. Connect system power – the unit does not have an on/off switch, connecting the power cord applies power to the system.
8. When the forward button is pushed on the pump control panel the pump will start at the setting it was last operated at. Be prepared to quickly stop the pump if it should start at a high speed. Verify that the pump control unit is set to zero.

Baldor motor control panel. Set the speed to zero before stopping the pump.

9. **Verify that the feed tank wire mesh is in place in the bottom of the tank.**
10. Fill Tank with carbon filtered water – NOT tap or d.i. water or your feed solution.
11. Mix feed solution as required – use carbon filtered water – NOT tap or d.i. water.
SECTION 6 – R.O. Separation
Consult with lab manager before proceeding with this section. The lab manager will install the R.O membrane before you begin your experiment.

1. Plan on operating the system with water first to verify operation.
2. Once you have established that the system is operating correctly and there are no leaks, drain the feed tank and then fill the feed tank with your process fluid.
3. Verify with the lab manager that the correct R.O filter, high pressure clamps and appropriate plumbing are installed.
4. Fill feed tank with carbon filtered water or process fluid, (sodium chloride and filtered water etc.)
5. Turn on pump by pressing “FWD” on pump controller.
6. The motor control displays motor speed in Hz (Hertz).
7. Push the increment (up arrow) button on the Baldor control module until the display reads 2 Hz. It is important to break – in a new membrane by slowly increasing the flow/pressure over a period of about 20 minutes.
8. Run the pump at a very low setting, between 2 – 8 Hz for approximately 2 minutes.
   The pump may time-out when operated between 2-6 Hz, if it does, stop the pump, set the speed to zero and then push the forward button and slowly bring the pump up to the desired speed
9. Do not make sudden changes in flow or pressure during operation, this may permanently damage the membrane.
10. Gradually increase the pump speed to (12 – 16 Hz) by pressing the up arrow on the controller.
11. When stopping the pump, gradually reduce the speed to zero and then press the stop button. Remember that the pump will start at the last speed setting used so it is important that you always reduce the speed to zero before stopping the pump.
12. Allow the system to stabilize at a low flow rate and pressure for approximately 15 minutes if you are using a new membrane. If you are using a membrane that has already been broken in you may skip this step and proceed to run the system taking care to stay within the membrane operating pressure and flow ratings.
13. Pressure across the R.O membrane is primarily controlled by pump speed. Back pressure may be increased by adjusting the back pressure control valve located at the base of the concentrate pressure gauge on the right side of the apparatus. To adjust the back pressure slowly begin to close the concentrate back pressure control valve while
carefully monitoring the pressure and flow readings.

SECTION 7 - Ultrafiltration Separation
Consult with lab manager before proceeding with this section.
Ultrafiltration typically operates at 70-120 psi. The pressure is a function of the membrane type and the material being filtered. The typical pH and temperature range for PES type ultrafiltration membrane is 2-10 pH and 55 degs C. Review the data sheet for the membrane you are using prior to operating the equipment.
The Labstack 20 is a plate and frame cross flow membrane filtering system. It is comprised of multiple spacer plates, support plates and flat sheet membrane. The frame is the two flanges in the center of the table top supported by the two metal posts. The top flange is referred to as the upper flange while the lower flange is referred to as the moving flange. The jack to the Labstack is located under the table top in the back of the cart. The method for assembly is listed below:

1. Check with the lab manager to verify that the system is clean and ready for use.
   a. Check all connections in the tubing, make sure everything is connected properly.
2. Remove and clean the old stack assembly.
   a. Release the pressure on the stack by opening the stack pressure isolation valve which is in line with the pump and stack and then open the pressure release valve on the stack compression pump. Once the bottom stack flange has lowered, remove the plate/filter assembly.
3. Remove the old filters from the stack and gently clean the support and spacer plates as instructed by the lab manager.
4. Assemble a new filtration stack.
   a. Place a damp towel, cloth or paper towels on a clean table. Moisten a support plate with carbon filtered water and place it on the towel (side facing up is arbitrary).
Wetting the support plate. Do not use tap or d.i water they contain chlorine. Use carbon filtered water only.

Support plate with permeate outlet port.
b. Now remove a single flat sheet membrane or, if you are using a roll sheet, use the membrane template to cut out flat sheet squares to fit over the support plate. Use a sharp box cutter to cut the membrane material. Try to cut as exact as possible in the inner circle of the template, extra space on the outer edge is ok.
Lock Rings shown below

1. Re-wet the support plate and then place and center the newly cut membrane on the wetted support plate SMOOTH SIDE UP and then position a lock ring in the center hole.
2. Make sure that the membrane stays wet throughout the entire process, if the membranes dry up, they are unusable.
3. Carefully turn the support plate over so that the membrane/lock ring assembly faces the table and place another cut out (repeat the previous step) membrane and lock ring on the other side of the plate. Interlock the two lock rings via the pins and holes in the lock ring. There should now be a membrane and lock ring on each side for a total of two membranes and two lock rings per support plate.
4. Then place the support plate and membrane on top of the first space plate in the stack. Then place another spacer plate with the molding nub (see photo) and ribs facing DOWN, on top of the support plate. Repeat the previous steps until the desired number of membrane/plate assemblies is reached. Always end the top of the stack with a spacer plate. Be sure to keep the membranes and plates moist while you are assembling the stack.

5. Remove the upper and lower O-rings from the two flanges, gently wipe the O-rings with a Chem-Wipe and then apply a thin layer of vacuum grease to the upper and lower O-rings before placing them back into the upper and lower grooves on the flanges.

6. Place the new stack in the plate and frame and compress the stack. The permeate tubes that connect to the support plate need to be facing the reservoir. Once everything is in
place slowly start to jack up the stack using the hydraulic jack. Just before the stack touches the upper flange make sure that all plates are still centered and the O-ring is still in place in the top flange.

a. Verify that the pressure release valve is open and the pump release valve is closed.
b. Slowly actuate the stack compression pump, this will cause the lower flange to move upward compressing the stack.
c. The stack is sufficiently compressed when the pressure reading on the hand pump reads 180 PSI. Do not exceed 200 PSI.
d. Once you have compressed the stack close the stack pressure isolation valve that is in line with the pump and stack.

7. Connect a filtrate tube to each of the stack filtrate outlet ports. Place the other end of the filtrate tube in the feed tank. Once the system is running you may take samples from each stack using these filtrate tubes.

8. Fill the tank with carbon filtered water.

9. Plug the system power cord into the outlet located behind the filtration equipment, the control panel should now turn on. When the forward button is pushed on the pump control panel the pump will start at the setting it was last operated at. Be prepared to quickly stop the pump if it should start at a high speed. Verify that the pump control unit is set to zero.

10. Always adjust the speed gradually never jump from very slow to very fast or vice versa.

11. When stopping the pump, gradually reduce the speed to zero and then press the stop button. Remember that the pump will start at the last speed setting used so it is important that you always reduce the speed to zero before stopping the pump.

12. Flush the new membrane stack with water.

13. Controlling the pump speed.

   a. Push the FWD button and then push the yellow increment/decrement arrow buttons to control the speed. Do not make sudden changes in speed! The pump may shut down when operated at low speeds in the range of 2-5, if it does, press the stop button and then restart the pump.

14. Start the pump at a low speed (setting of 2 or 3) and run at the low setting for about 3 minutes, then increase the speed to 5-8 and run for 10 minutes. Now increase the speed to 10-16 and run the system for another 10 minutes. Constantly monitor the pressure gauges during this process. Take care not to exceed the pressure rating of the
membrane.
15. Drain the water by pumping the water into a secondary container, take care not to operate the pump without liquid in the tank.
16. Prepare the feedstock and place it in the feed tank or feed vessels.
17. Review the operating parameters for your membrane and feedstock.
18. Start the pump and begin the separation process.
19. Adjusting system backpressure:
   a. As you gradually increase the pump speed you should see flow out of the filtrate tubes as well as through the retentate tube. The retentate and permeate flows may be adjusted by adjusting the system back pressure. To do this slowly close the backpressure valve while monitoring the pressure drop as displayed on the gauges.
20. Take samples as required.
21. Analyze samples as required.
22. Shutdown the equipment and store samples and feed stock as directed by lab manager.

SECTION 8 – System Shutdown

At the end of each run you must decide whether to store your sample solution or discard it. If you elect to store your solution please store it in the appropriate containers and make sure to label them correctly. Consult with the lab manager to determine the best location to store your solution. If you decide to dispose of your solution consult with the lab manager to determine the proper procedure for disposal.

Shutdown Procedure

1. Open pressure control valve [12].
2. Press the “STOP” button on the control panel to turn off the system pump.
3. Pump your solution into storage or disposal containers or drain the system solution into the appropriate container from the feed tank drain valve [21].
4. Close the reservoir drain valve.
5. Fill reservoir with carbon filtered water from the RO water supply system.
6. Turn on pump by pressing “FWD” on pump controller.
7. Slowly adjust the pump speed to the desired flow using the up and down arrows on the controller.
8. Slowly close the pressure control valve to build up system pressure. Stop increasing the pressure once fluid begins to flow through the permeate line [11].
9. Allow the water to circulate for several minutes.
10. Open the pressure control valve.
11. Press the “STOP” button on the control panel to turn off the system pump.

------CONTINUED ON NEXT PAGE ------
12. Open the reservoir drain valve to rinse the water out of the system.
13. Close the reservoir drain valve.
14. Unplug the pump power cord [18].
15. Close the main building water supply valve (ball valve) – this is the YELLOW ball valve that feeds the charcoal filtered RO water system.
16. Verify that the membrane has been cleaned and stored in the proper solution – see membrane documentation – consult with lab manager about this step.
17. Verify that your solution is stored as required. Follow chemical / waste storage procedures as outlined in lab safety procedure.