



DEPARTMENT OF RADIOLOGY AND IMAGING SCIENCES

Skin Cooling System

USER MANUAL

Revision E

September 2020

UCAIR

UTAH CENTER FOR ADVANCED IMAGING RESEARCH

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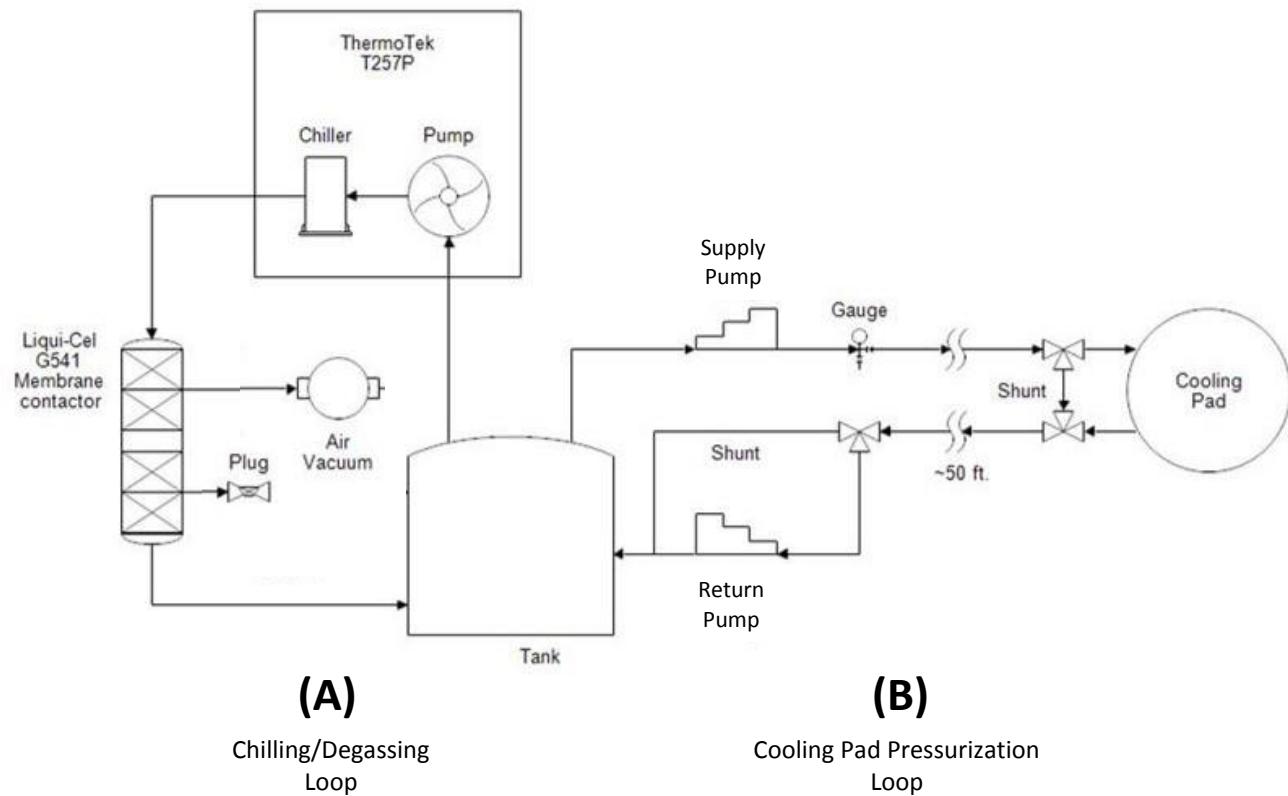
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Section 1 - System Overview

1.1 General Operation

The Skin Cooling System consists of two plumbing circuits shown in the Simplified Plumbing Diagram below. In Loop (A), the ThermoTek Chiller both chills the water and pumps it through the Liqui-Cel degassing membrane. A Vacuum unit removes dissolved oxygen from the water through this membrane, which improves Ultrasound transmission through the water in the Cooling Pad. Loop (B), the Cooling Pad loop, has two different operating modes:

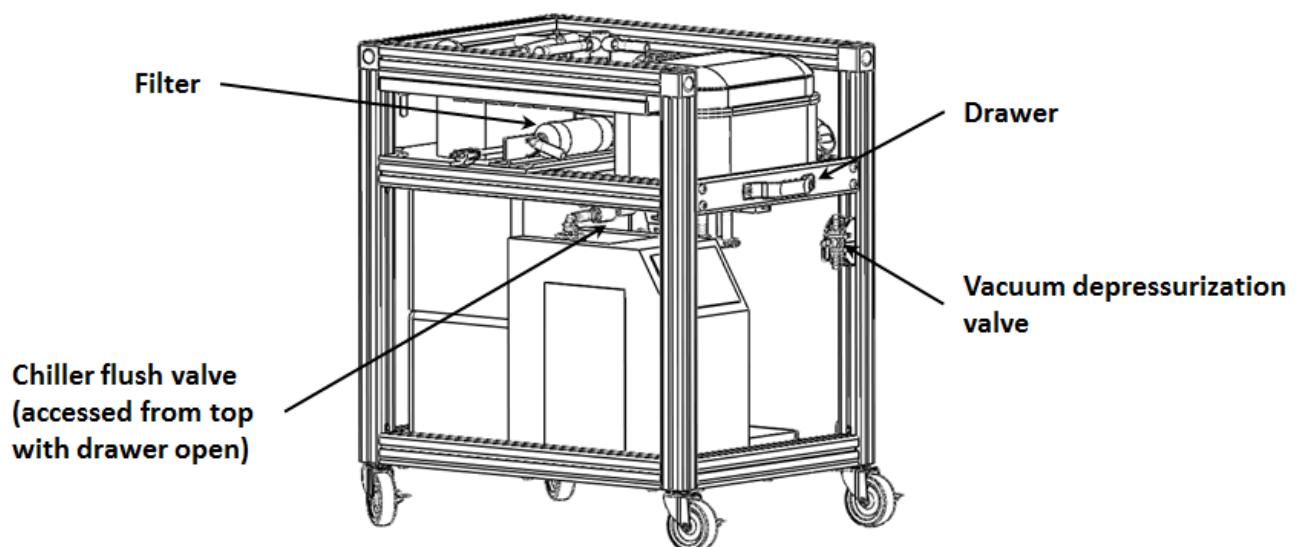
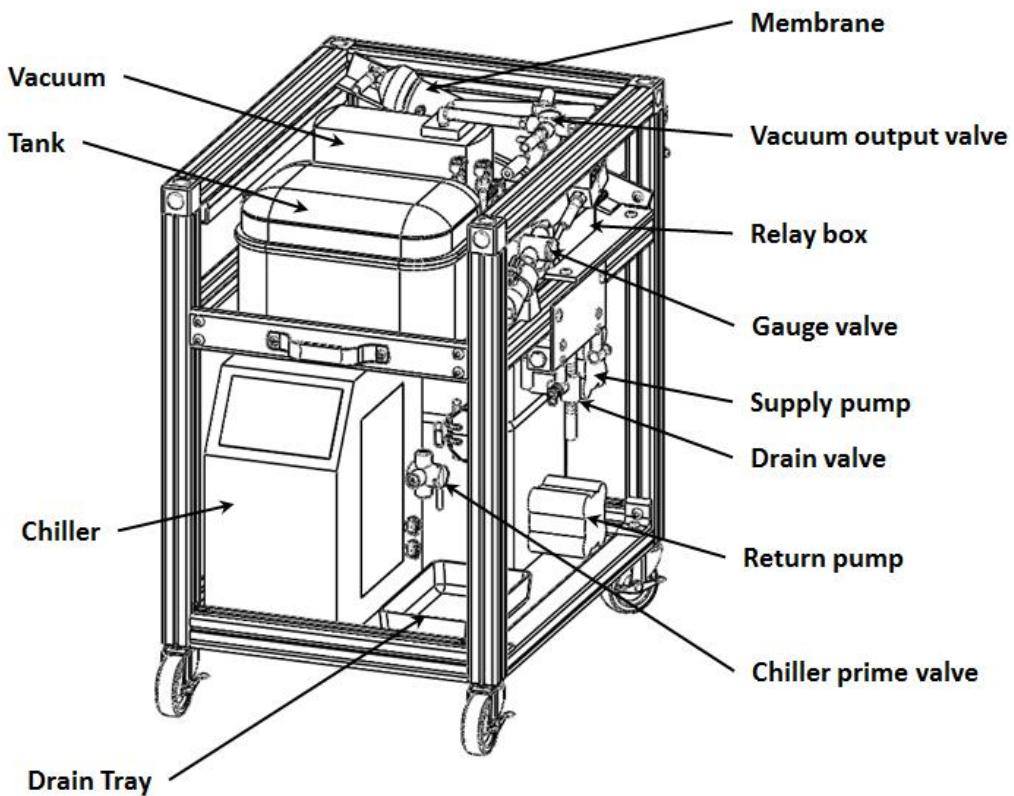
- (1) System start-up: Both 'Shunt' lines (near the pad and across the Return pump) are activated to circulate chilled water through the system while preventing bubbles from entering the Cooling Pad. Only the Supply pump is active during this mode.
- (2) Normal operation: Both pumps actively maintain the Cooling Pad at a constant pressure. The Supply pump delivers chilled water from the Tank to the Cooling Pad at a constant flow rate. The Return pump draws water from the Cooling Pad back to the Tank at a rate controlled by continual feedback from the Pressure Gauge.



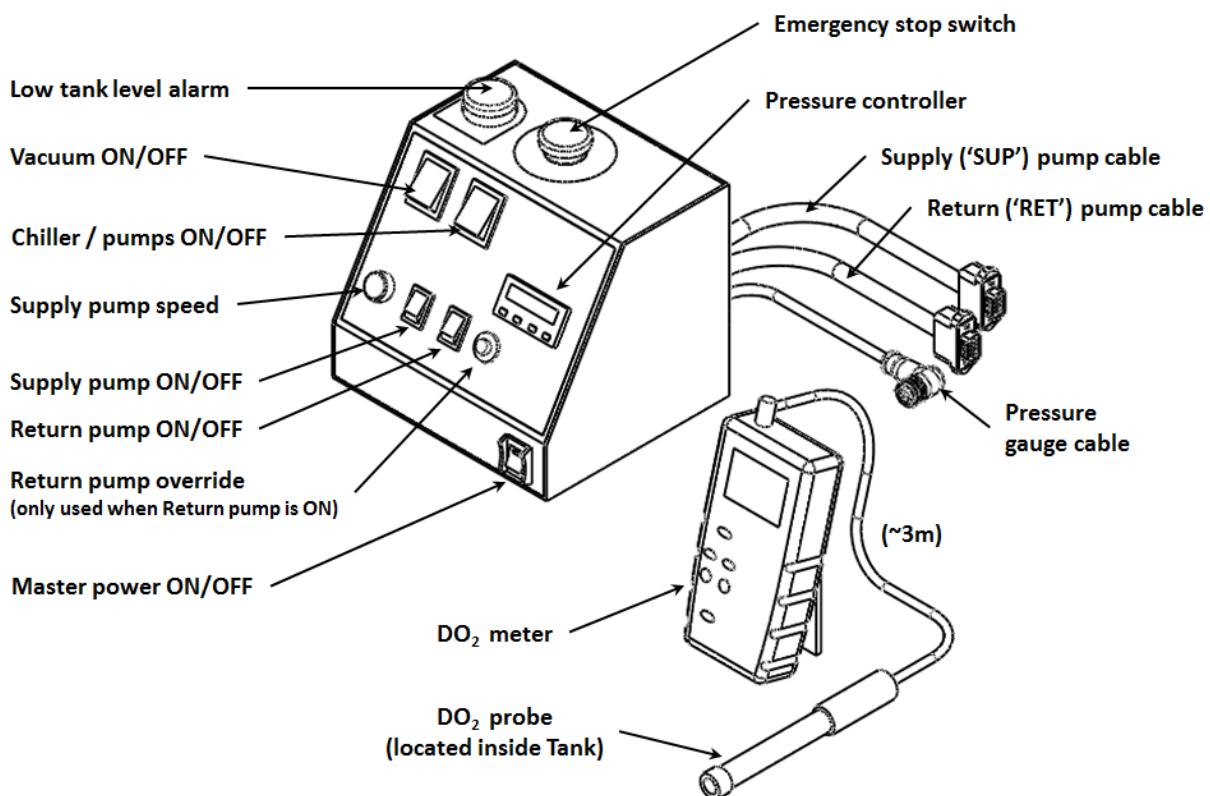
Simplified Plumbing Diagram

(See Appendix C for Actual Plumbing Diagram)

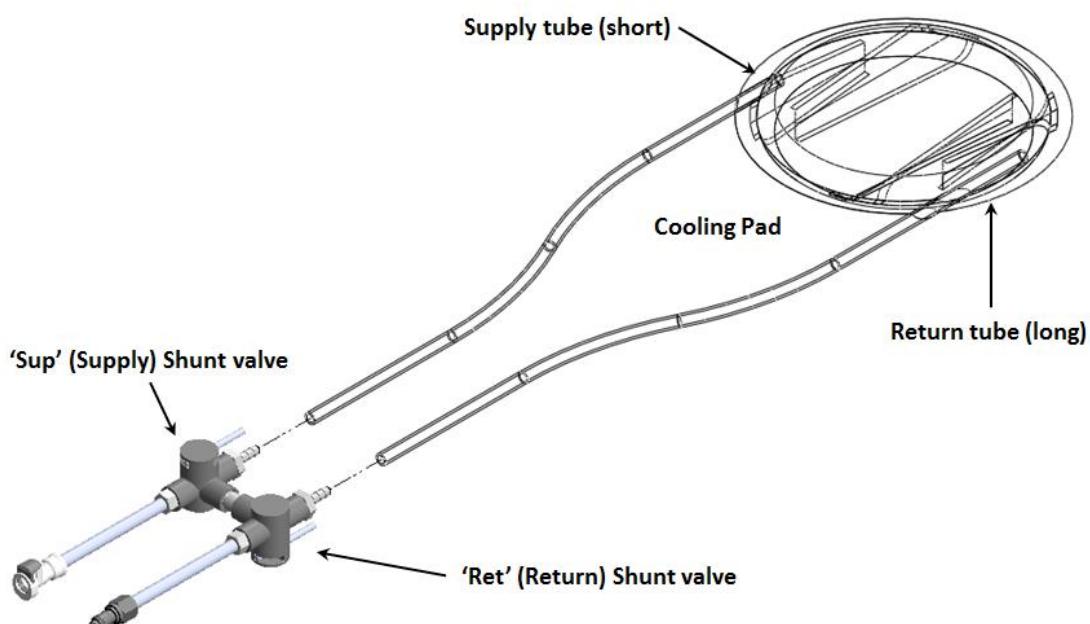
1.2 Cart Components



1.3 Control Box



1.4 Cooling Pad Assembly



Section 2 - System Components

2.1 Control Box

SOLO SL4824-LR Temperature Controller
www.automationdirect.com (supplier)



2.2 Chiller

ThermoTek T257P Recirculating Chiller
www.thermotekusa.com (manufacturer)
www.megadepot.com (supplier)



2.3 Degasser Contactor Membrane

3M Liqui-Cel EXF 1.7x8.75 Series Membrane Contactor
G541
www.3m.com (manufacturer)
www.pwrfs.com (supplier)



2.4 Pressure Gauge

ProSense Digital Pressure Sensor
EPS25-14-1001
-0.72 to 14.5 psig range
www.automationdirect.com (supplier)



2.5 Vacuum Pump

Thomas 1/3 HP Vacuum Pump
MFG Model #688CE44
www.grainger.com (supplier)



2.6 Supply / Return Pumps

Masterflex L/S Variable-Speed Digital Drive
Remote I/O, 6 to 600 rpm
Item # HV-07528-10
www.coleparmer.com (supplier)



2.7 Flow Pump Head

Masterflex L/S Standard Pump Head
Tubing Size: L/S 17
Item # HV-07017-21
www.coleparmer.com (supplier)



2.8 Flow Pump Tubing – Return Pump

Masterflex L/S Precision Pump Tubing
Tubing Size: L/S 17
Item # HV-96410-17
www.coleparmer.com (supplier)



2.9 Flow Pump Tubing – Supply Pump

Masterflex L/S Precision Pump Tubing
Tubing Size: L/S 25
Item # HV-96410-25
www.coleparmer.com (supplier)



2.10 Cooling Pad Assembly

Welded pad with baffles – University of Utah
Tygon ¼" tubing: McMaster-Carr item#: 6516T21
Tight-seal fittings(2): McMaster-Carr item#: 5463K445
Barbed fittings(2): McMaster-Carr item#: 5218K686
Directional valves(2): McMaster-Carr item#: 45695K221
Quick Coupler Socket(1): McMaster-Carr item#: 5923K43
Quick Coupler Plug(1): McMaster-Carr item#: 5923K73



2.11 Tank

KitchenFlower brand (Korea)
Size: 8.5L
Seller: **hyunjun20110117**
Item search term:
"camping outdoor cooler ice box hard plastic"
www.ebay.com (supplier)



2.12 DO₂ Meter & Probe

Oakton D0 6+ Dissolved Oxygen Meter, EW-35643-10
Replacement Probe, 10 ft. cable, EW-35642-52
www.coleparmer.com (supplier)



2.13 empty

Section 3 - Unit Controls and Default Settings

3.1 Chiller Unit Temperature

- a. Press 'Start' on Chiller touchscreen



- b. Press 'Set Temp'



- c. Press Up/Down arrows to set desired operating temperature lower limit

(chiller unit may not achieve lower limit temperature during operation)



Default Temperature: 5 degrees C

- d. Press 'Accept'

- e. Press 'Stop'



3.2 Chiller Unit Fluid Flow Rate

- a. Press 'Start' on Chiller touchscreen



- b. Press 'Next'



- c. Press 'Set Pump Drive'



- d. Press Up/Down arrows to set desired operating fluid pump speed

Default Pump Rate: 10%



- e. Press 'Accept'

- f. Press 'Back'

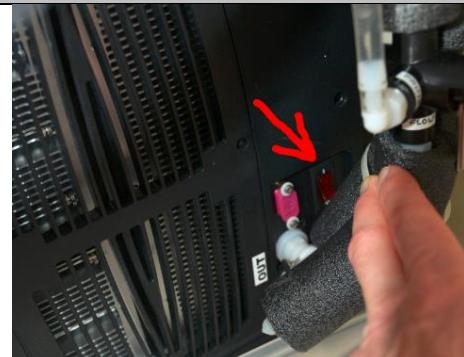
- g. Press 'Stop'

3.3 Chiller Unit Power Switch

Power switch is located on right side of unit, near the input/output ports

(gently push insulated tubing aside to access switch, as shown in photo)

Default Switch Position: ON ('I' position)



3.4 Vacuum Unit Power Switch

Power switch is located on the front of the unit

Default Switch Position: ON

3.5 SOLO Pressure Controller

- a. Press up/down arrows to select desired 'Set Value' ('SV') operating pressure (*green numbers*)
- b. Press 'Set' to confirm

Default Operating Pressure on Scanner Table (Utah): 145 mBar

Default Unit Settings: (These settings are provided in case controller must be reset. See SOLO Quick Start Guide pamphlet for reset procedure)

Proportional: 50

Integral: 2

Derivative: 0

AL1H: 15 (Alarm offset, mBar)

Input: _10 (0-10V)

tP-H: 1000

tP-L: 0

S-HC: Cool

ALA1: 2



3.6 Supply Pump Remote Control Rate

- a. Unlock the Supply Pump Rate dial by pushing the locking lever counter-clockwise.
- b. Adjust the dial to the default pump rate
- c. Push the locking lever clockwise to lock

Default Pump Rate Dial Reading: 5.75 (for 0.5 L/min.)



3.7 MasterFlex Flow Pump - Supply

Use membrane keys on front panel to set parameters

*Default Flow Direction: Clockwise
Default Control: External*



3.8 MasterFlex Flow Pump - Return

Use membrane keys on front panel to set parameters



Default Flow Direction: **Clockwise**
Default Control: **External**

3.9 Gauge Valve

Default Position: “**Gauge**”



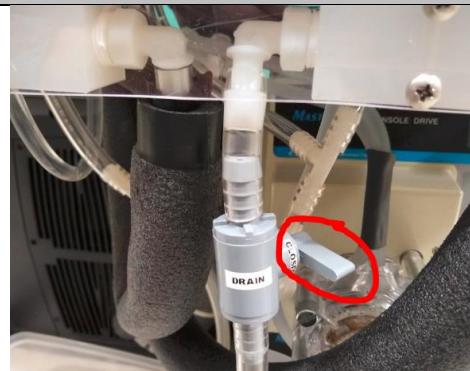
3.10 Vacuum Depressurize Valve

Default Position: **Closed** (perpendicular to valve body)



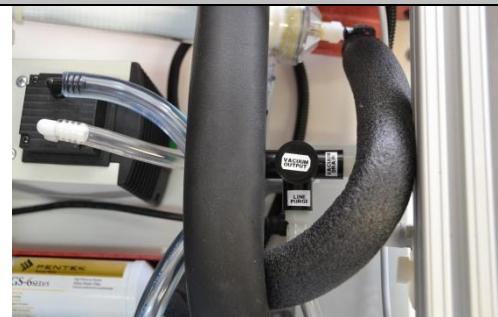
3.11 Drain Valve

Default Position: **Closed** (perpendicular to valve body)



3.12 Vacuum Output Valve

Valve lever is beneath valve body



Default Position: "Vacuum Drain"

3.13 Chiller Flush Valve

Default Position: Closed (perpendicular to valve body)



3.14 Chiller Prime Valve

Default Position: "Flow"



3.15 Tank Connections

Supply and Return hoses should be attached to the Supply and Return fittings, respectively, on rear of Tank

*Default Positions: Supply – Supply
Return – Return*



3.16 Cooling Pad Assembly

Shunt valve arms should point toward each other
(‘Shunt’ position)



Default Position: Shunt

3.17 DO₂ Meter & Probe

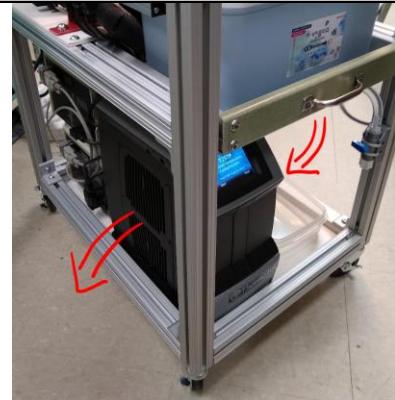
Meter mode should be set to ‘mg/l’ using the ‘Mode’ button
(‘mg/l’ is the same as ‘ppm’ or ‘part per million’)



Section 4 – Warnings

4.1 Cart placement

- ∅ Do not place the cooling cart directly against a wall, or near obstructions, on the **left** side of the cart (when looking at the front screen of the chiller). This would block the ventilation output of the Chiller unit fans.



4.2 Cooling fluid

Distilled water must be used as the coolant in this system.

- ∅ Deionized water would cause de-plating issues in the Chiller unit and valves
- ∅ Tap water would cause mineral deposits within the system



4.3 Over-pressurization

- ∅ DO NOT turn on the Supply Pump unless one of the following conditions is met:
 - a Cooling pad is attached to the system
 - the Gauge Flush valve is turned perpendicular to the pressure gauge (for Weekly Maintenance)

Failure to do so may cause the plumbing system to burst



4.4 Residual vacuum

- ∅ DO NOT turn on the Vacuum without first depressurizing the vacuum line to eliminate any residual vacuum. Failure to do so will cause the Vacuum Pump to malfunction and burn out
- When opening the Vacuum Depressurize Valve, do so slowly to prevent damage to system components



4.5 Emergency / Stopping flow

To stop flow to the cooling pad, press the **Emergency Stop** button or turn off **Supply Pump** switch (both operations perform the same function)

- ∅ DO NOT turn off Return Pump. Doing so will cause the Cooling Pad to drain.



4.6 DO₂ Probe

Be very careful when cleaning the tip of the DO₂ Probe. The sensitive membrane is easily broken, and should not be touched with solid items (paper towels, rags, etc.)



4.7 Vacuum Pump temperature

Heat build-up occurs at the metal end of the Vacuum Pump. Keep plastic and insulation material away from contact with this part of the pump.



Section 5 – Initial System Prime

Follow these steps when filling the system with water for the first time.

- a. Calibrate DO₂ Meter & Probe

Follow **Appendix A - Recalibrate DO2 Meter & Probe** for calibration instructions



- b. Turn **ON** Control Box system power

- c. Turn **ON** Chiller/Pumps (*green switch*)



- d. Use arrow UP/DOWN keys on Pressure Control unit to adjust green number ('Set Value' or 'SV') to **115 mBar**

(This number is a guess, to correct for elevation difference from Utah to California. It will be further adjusted during full operation)



- e. Press SET key to confirm new Set Value



- f. Open Tank. Fill Tank with Distilled Water to Tank Fill line (see sticker inside Tank)

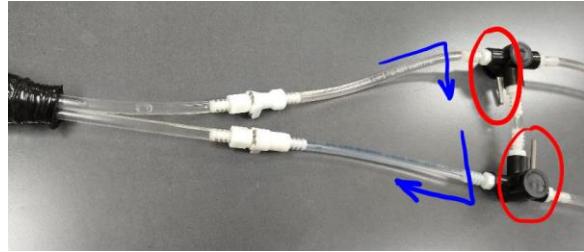


- g. Route insulated tubing lines on cart through a convenient side of the cart, depending on cart placement under the countertop and direction tubing will go toward the waveguide
- h. Attach ‘cart end’ of tubing extension lines to cart lines with quick-connect fittings



- i. Attach Cooling Pad assembly to ‘Patient End’ of tubing extension lines with quick-connect fittings. Ensure shunt valves are set to ‘Shunt’ position

(valve arms should point toward each other)



- j. Position the pad at a convenient location on the MRI Scanner table (i.e., near the ‘foot’ end) and secure the tubing lines with a sandbag
- k. Turn **ON** Supply Pump. Wait **2 minutes** for Pad lines to prime



- l. Start flow on Chiller by Pressing ‘Start’ on Chiller touchscreen



- m. If an Alarm message is displayed:
 1. Press ‘Accept’ on Chiller touchscreen
 2. Open Chiller Flush valve



3. Turn Chiller Prime valve to 'Prime' until water flows through Chiller Flush valve
4. Return Chiller Prime valve to 'Flow'
5. Close Chiller Flush valve



- n. Press 'Start' on Chiller touchscreen. Chiller should start operating normally. (If not, repeat steps 1-5 above)



- o. Hold down Return Pump Override button and turn ON Return Pump. Wait **10 seconds**
- p. Turn OFF Return Pump, and release Return Override button



- q. Turn Gauge Flush valve to "Drain" for **10 seconds**
- r. During this time, pinch tubing between Red tape marks multiple times to remove bubbles from valve
- s. Return to Gauge Flush valve to "Gauge"
- t. Pinch tubing between White tape marks (on the 'Drain' line) multiple times to remove trapped water from drain tubing
- u. Turn ON Vacuum



- v. Allow water to circulate for **45 minutes**
 - During this time, occasionally shake and tap Cooling Pad assembly shunt valves and to eliminate bubbles stuck inside



- w. Stop Chiller flow by pressing 'Stop' on touchscreen

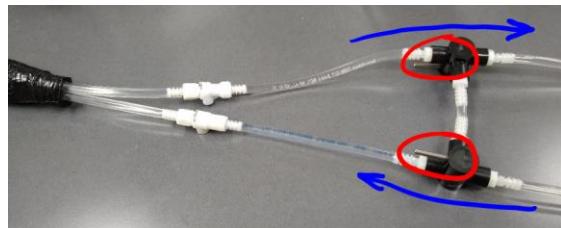


- x. Stop Turn **OFF** Supply Pump



- y. Turn shunt valves 90 degrees to 'Flow' position

(valve arms should be parallel each other)



- z. Turn **ON** Return Pump



- aa. Turn **ON** Supply Pump

- Allow Cooling Pad fill completely. System will oscillate briefly when maximum pad volume is reached, until target pressure is stabilized (*Return Pump Override feature will trigger at +15 mBar above target pressure, keeping the pad from bursting*)



- bb. Remove bubbles from Cooling Pad

- With both hands, tilt, massage, and flick the Cooling Pad to encourage bubbles toward the 'Return' tube (long tube inside pad).



- cc. Note pressure condition of Cooling Pad when fully inflated
 - Pad should be firm to the touch (somewhat yielding when compressed), but not over-inflated to the point of bursting
 - Try lifting pad 1 foot off the table to see if pad begins to deflate and become 'squishy'. If it doesn't, pad may be over-inflated



- dd. Use arrow UP/DOWN keys on Pressure Control unit to increase or decrease Set Value (Green number) by **10 mBar** at a time until Cooling Pad feels firm when pressure is stabilized

(Remember to press SET to confirm each adjustment)



- ee. Turn **OFF** Supply Pump
- ff. Turn **OFF** Return Pump

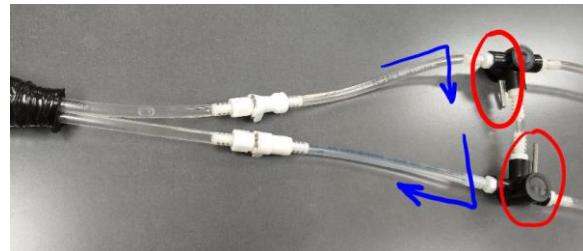


- gg. Turn **OFF** Vacuum



- hh. Allow pad to deflate for **5-10 seconds**, then turn Cooling Pad shunt valves 90 degrees to 'Shunt' position

(valve arms should point toward each other)



- ii. Place pad in a storage tray in a safe location with tubing lines still attached to minimize bubbles in lines for next use

- jj. Turn **OFF** Chiller/Pumps
- kk. Turn **OFF** Control Box Power
- ll. Turn **OFF** DO₂ Meter
- mm. Dispose of fluid in drain tray

– Initial Prime Complete –

Section 6 - Operation

Operation Overview

This section describes the procedure to prepare the Skin Cooling system for operation. Preparation must be started approximately **1 hour** before the patient is placed on the MRI table.

It is ideal to have a spare, primed Cooling Pad available at all times as a backup, in addition to the pad intended for use during the current procedure. Storing the spare pad inside a refrigerator will help reduce water chilling time when the spare pad is needed.

NOTE: Significant time is required to degas and prime a Cooling Pad. The best time to prime a Cooling Pad is at the end of the current patient's procedure, so that the pad can sit overnight. However, if emergency priming is required the day of the procedure, make sure to begin priming at least **1.5 hours** prior to placing the patient on the MRI table to allow extra water filling & degassing. See **Section 6.10: Prime Empty Cooling Pad** for priming procedure.

Operation Overview (details of each step follow this outline):

- 6.1 Start System
- 6.2 Initiate Chilling
- 6.3 Initiate Degassing
- 6.4 Inspect & Attach Primed Cooling Pad
- 6.5 Initiate Pad Pressurization

– Begin Patient Procedure –

- 6.6 Emergency / Stop Flow
- 6.7 Resume Flow
- 6.8 Adjust Pad Pressure (*if needed*)

– End Patient Procedure –

- 6.9 End Procedure
- 6.10 Prime Empty Cooling Pad
- 6.11 System Shut Down

6.1 Start System

- a. Turn **ON** Control Box system power
- b. Turn **ON** Chiller/Pumps (*green switch*)



6.2 Initiate Chilling

- a. Check water level in Tank, refill with Distilled Water if necessary



- b. Start flow on Chiller by pressing 'Start' on touchscreen

(The touchscreen often responds best to contact with both fingertip + fingernail. Pressing 'Start' activates both chilling and chiller water circulation functions.)



6.3 Initiate Degassing

- a. Slowly open Vacuum Depressurize Valve (turn blue knob 90 degrees so that it is in-line with the valve body). Close valve again.

(This eliminates any residual vacuum. If you attempt to turn on the Vacuum Pump while residual vacuum exists in the line, the Vacuum Pump will malfunction and burn out)



- b. Turn on Vacuum

(Allow Vacuum to degas water for at least 45 min., or approx. 0.6 ppm probe reading, before use with ultrasound)



- c. Recalibrate meter and probe following **Appendix A - Recalibrate DO2 Meter & Probe** instructions.

Temperature of water in Tank may be read on meter by pressing MODE button (press again to cycle back to 'mg/l' mode)

During next steps, monitor DO2 meter and turn ON/OFF Vacuum as needed to maintain approx. **0.6 ppm** dissolved oxygen reading. Reading should not be allowed above 1.0 ppm.



6.4 Inspect & Attach Primed Cooling Pad

NOTE: If emergency priming of a Cooling Pad is required (i.e., no pad is attached to tubing lines and no pad has been primed previously) skip to **Section 6.10: Prime Empty Cooling Pad**

- a. Inspect Primed Cooling Pad prior to installation and use. Contraindication for use include:
 - Outer rim weld separation
(The outer rim is composed of three concentric rings of welds. If there is a spot where the outer rim has separated down to ONE weld of approx. 5 mm thickness, see Photo 1, DO NOT REUSE)
 - Baffle weld separation (Photo 2)
 - Persistent dripping (from a puncture or leak)

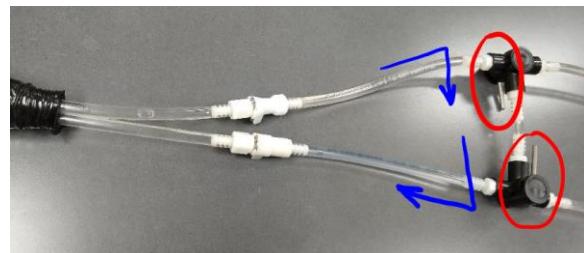


1.



2.

- b. Attach Cooling Pad to tubing lines, and ensure shunt valves are set to 'Shunt' position
(valve arms should point toward each other)



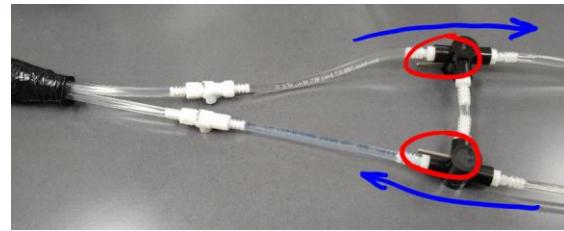
- c. Position the pad at a convenient location on the MRI Scanner table (i.e., near the 'foot' end) and secure the tubing lines with a sandbag

6.5 Initiate Pad Pressurization

- a. Turn **ON** Supply Pump
 - Allow water to circulate for approx. 5 minutes for bubbles to circulate through the lines
 - During this time, occasionally shake and tap Cooling Pad assembly shunt valves to eliminate bubbles stuck inside
- b. Turn **OFF** Supply Pump



- c. Turn shunt valves 90 degrees to 'Flow' position
(valve arms should be parallel each other)



- d. Turn **ON** Return Pump



- e. Turn **ON** Supply Pump

- Allow Cooling Pad fill completely. System will oscillate briefly when maximum pad volume is reached, until target pressure is stabilized (*Return Pump Override feature will trigger at +15 mBar above target pressure, keeping the pad from bursting*)



- f. Remove bubbles from Cooling Pad

- With both hands, tilt, massage, and flick the Cooling Pad to encourage bubbles toward the 'Return' tube (long tube inside pad).

- g. When bubbles are removed, place pad into position for ultrasound treatment



- h. Ensure water temperature is stabilized

- View water temperature display on Chiller touchscreen (Approx. 8 deg. Celsius has been typical lowest operating temperature) or D0₂ Meter (Press MODE button until 'T' appears in upper-right).

- i. Position patient on MRI table

– Begin Patient Procedure –

6.6 Emergency / Stop Flow (if necessary)

Press the **Emergency Stop** button if immediate interruption of flow is required:

- Pad puncture or leak
- Patient reposition
- Flow artifact issue
- Bubble in pad
- Etc.



6.7 Resume Flow

Release the **Emergency Stop** button by twisting the red knob

(System will oscillate for approx. 1 minute until target pressure is stabilized)



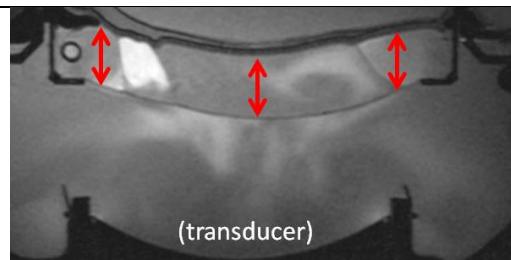
6.8 Adjust Pad Pressure (if necessary)

Proper Cooling pad pressure depends heavily on its relative elevation from the cart. Pressure adjustment on the Control Box may be necessary depending on the height of your scanner table + setup

Cooling Pad properly inflated:

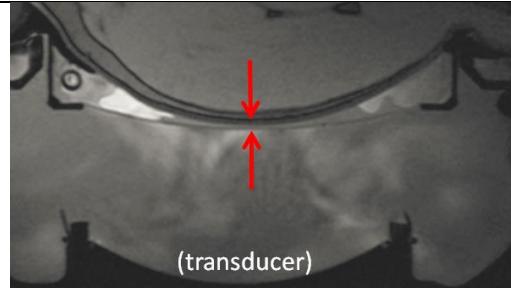
Pad should be of *uniform cross-sectional thickness* in MR image, see photo

- *No adjustment necessary*



Cooling Pad deflated:

Pad pressure is too low

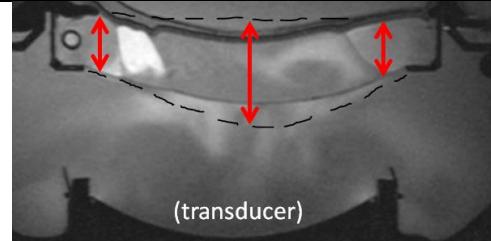


- Use arrow UP key on Pressure Control unit to INCREASE Set Value (Green number) by **10 mBar** (or intermediate amount if fine-tuning)
- Press SET button to confirm



Cooling Pad over-inflated:

Pad pressure is too high



- Use arrow DOWN key on Pressure Control unit to DECREASE Set Value (Green number) by **10 mBar** (or intermediate amount if fine-tuning)
- Press SET button to confirm



– End Patient Procedure –

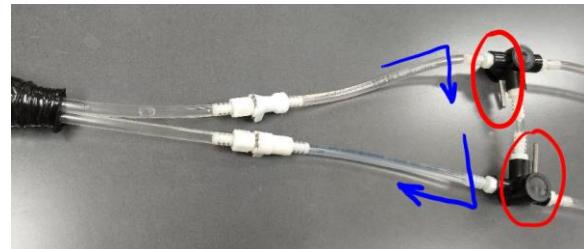
6.9 End Procedure

- Turn **OFF** Supply Pump
- Turn **OFF** Return Pump



- Allow pad to deflate for **5-10 seconds**, then turn Cooling Pad shunt valves 90 degrees to 'Shunt' position

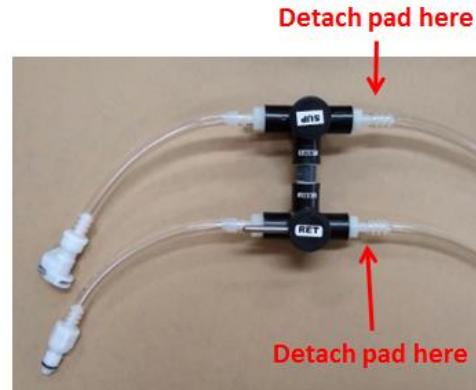
(valve arms should point toward each other)



- d. Inspect Cooling Pad for possible reuse.
 Contraindication for reuse include:
- Outer rim weld separation
 (The outer rim is composed of three concentric rings of welds. If there is a spot where the outer rim has separated down to ONE weld of approx. 5 mm thickness, see Photo 1, DO NOT REUSE)
 - Baffle weld separation (Photo 2)
 - Persistent dripping (from a puncture or leak)

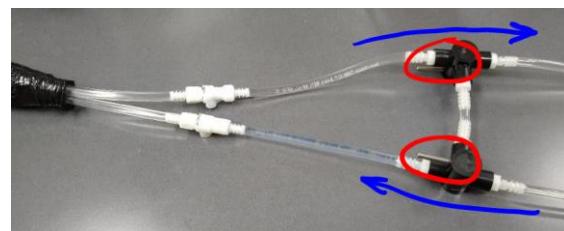


- e. **If pad CAN be reused, DO NOT** remove pad from tubing lines. Thoroughly dry and clean outside of pad with sanitation wipes, then place pad in a storage tray in a safe location with tubing lines still attached to minimize bubbles in lines. Skip to **Section 6.11: System Shut Down**
- f. **If pad CANNOT be reused**, remove pad from tubing lines and separate pad tubes from shunt valve assembly. Dispose of used pad and proceed to next **Section 6.10: Prime Empty Cooling Pad**



6.10 Prime Empty Cooling Pad

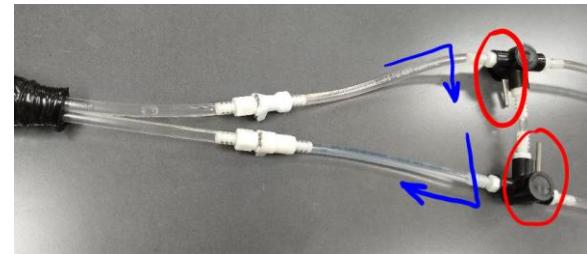
- Attach new Cooling Pad to shunt valves. Return Tube (long tube inside pad) should connect to 'Return' valve
- Make sure Tank is filled to 'Fill' Line
- Connect Cooling Pad assembly to tubing lines. Turn shunt valves 90 degrees to 'Flow' position
(valve arms should be parallel each other)



- d. Turn **ON** Return Pump
- e. Turn **ON** Supply Pump



- f. As the Cooling Pad is filling, actively collect and remove bubbles:
 - With both hands, tilt, massage, and flick the Cooling Pad to encourage bubbles toward the 'Return' tube (long tube inside pad).
- g. When pad is as bubble-free as possible, turn **OFF** Supply Pump
- h. Turn **OFF** Return Pump
- i. Allow pad to deflate for **5-10 seconds**, then turn Cooling Pad shunt valves 90 degrees to 'Shunt' position
(valve arms should point toward each other)
- j. If this pad is to be used during the next procedure, **DO NOT** remove pad from tubing lines. Place pad in a storage tray in a safe location, with tubing lines still attached. Skip to **Section 6.11: System Shut Down**
- k. If a spare pad is needed, remove this pad from tubing lines and place in a storage tray in the refrigerator. Repeat **Section 6.10: Prime Empty Cooling Pad** to prime a pad for use during the next procedure



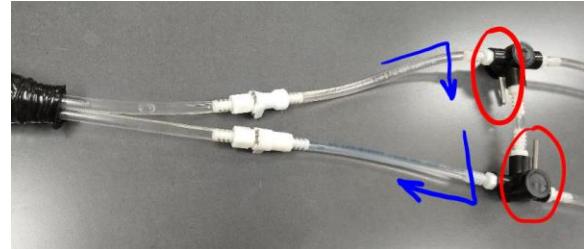
6.11 System Shut Down

If Weekly Maintenance is to be performed, skip to Section 7 – Weekly Maintenance. Then return to this section.

- I. Turn **OFF** Supply Pump
- m. Turn **OFF** Return Pump



- n. Turn Cooling Pad shunt valves 90 degrees to 'Shunt' position
(valve arms should point toward each other)



- o. Stop Chiller flow by pressing 'Stop' on touchscreen
- p. Turn **OFF** Chiller/Pumps
- q. Turn **OFF** Vacuum (if currently on)
- r. Turn **OFF** Control Box power
- s. Turn **OFF** D0₂ Meter
- t. Slowly open Vacuum Depressurize Valve (turn blue knob 90 degrees so that it is in-line with the valve body). Close valve again.



– End System Shut Down –

Section 7 - Weekly Maintenance

The following steps are ideally performed after a patient procedure, when the cart is still in operation mode.

A. Flush pressure gauge line

Bubbles collect inside the valve and may interfere with gauge operation

NOTE: Supply Pump should be ON for this operation

- a. Turn Gauge Flush valve to "Drain" for **10 seconds**
- b. During this time, pinch tubing between Red tape marks multiple times to remove bubbles from valve
- c. Return to Gauge Flush valve to "Gauge"
- d. Pinch tubing between White tape marks (on the 'Drain' line) multiple times to remove trapped water from drain tubing



B. Flush Chiller unit

Bubbles collect in the top of the internal Chiller reservoir and must be removed for maximum chilling to occur

- a. Pull out Reservoir drawer to expose Chiller Valve



- b. Open Chiller Valve (turn 90 degrees) until bubbles are removed

- c. Close Chiller Valve
- d. Slide Reservoir drawer closed



C. Inspect for algae growth / debris

- a. Open the Reservoir and check for signs of algae or floating debris. Remove debris.

*(if debris amounts are excessive, go to **Section 8.1 – Purge A, steps a – h** to clean tank)*

- b. Inspect exposed tubing in system for signs of algae growth

D. Empty

Section 8 - Quarterly Maintenance

Section Overview

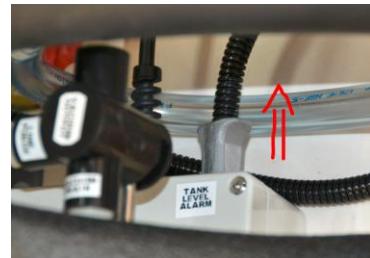
Quarterly Sanitization Protocol

- 8.1 Purge A
- 8.2 Sanitize (Hydrogen Peroxide)
- 8.3 Purge B
- 8.4 Rinse (Distilled Water)
- 8.5 Purge C
- 8.6 Prime (Distilled Water)
- 8.7 Replace MasterFlex Tubing

(This process may be performed more often as necessary)

8.1 Purge A

- a. Roll cart out from under counter
- b. Pull out drawer to expose Tank hook-ups
- c. Remove Supply hook-up from Tank and plug into "Line Purge" coupling
- d. Remove Return hook-up from Tank and set aside
- e. Remove D₂O Probe cable from D₂O Meter, and pull cable free
- f. Remove Tank Level Sensor cable from relay box
- g. Remove Tank from cart. Dump water while holding D₂O Probe in place so that the tip does not get damaged.
- h. Place protective cap on D₂O Probe. Scrub, clean & rinse Tank and Probe using soap & water and a toothbrush. (*Be careful not to get water into cable ends.*) Remove protective cap and set Tank aside



- i. Place Drain valve tube into external bucket

(At least 1 gallon bucket size)



- j. Open Drain Valve



- k. Turn **ON** Power

- l. Turn **ON** Chiller/Pumps



- m. Open Chiller Flush Valve



- n. Press 'Start' on Chiller Touchscreen.



- o. Wait until Chiller displays Alarm message, then press 'Accept'



- p. Turn Vacuum Output valve to “Line Purge”



- q. Open Vacuum Depressurize valve



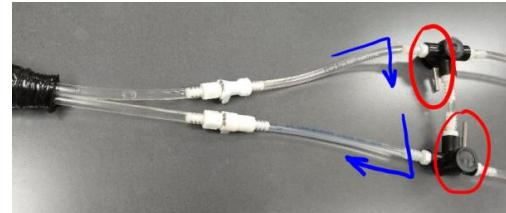
- r. Turn **ON** Vacuum. Wait **20 seconds** for water in Chiller and Membrane to pressurize



- s. Close Chiller Flush valve



- t. Make sure a Cooling Pad assembly is attached to the Cooling Pad lines, and turn Shunt Valves near Pad to “Shunt”



- u. Turn **ON** Supply Pump. Wait **2 minutes** for Pad lines to purge



- v. Hold down Return Pump Override button and turn ON Return Pump. Wait **10 seconds**
- w. Turn **OFF** Return Pump, and release Return Override button



- x. Turn Gauge Flush Valve to “Drain” for **5 seconds**, then return to “Gauge”



- y. Turn **OFF** Supply Pump
- z. Turn **OFF** Vacuum



- aa. Turn Vacuum Output valve to “Vacuum Drain”
- bb. Close Vacuum Depressurize valve



- cc. Close Drain valve and return tube to drain tray.
Dispose of water in drain tray and bucket



- dd. Return hook-ups to Tank

**Supply plug to Supply socket
Return plug to Return socket
Tank Level Sensor cable to relay box
(follow red routing lines)**



– Purge A Complete –

8.2 Sanitize

- a. Open Tank. Add **3 Liters** Hydrogen Peroxide

NOTE: Grocery store hydrogen peroxide concentration is typically 2% or 3%. Either concentration is OK. If dilution is necessary from a much larger concentration (i.e. 6%), see **Appendix G – Dilution Instructions.**



- b. Turn **ON** Supply Pump. Wait **2 minutes** for Pad lines to prime



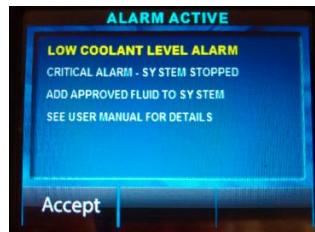
- c. Start flow on Chiller by Pressing 'Start' on Chiller touchscreen



- d. If an Alarm message is displayed:

6. Press 'Accept' on Chiller touchscreen

7. Open Chiller Flush valve



8. Turn Chiller Prime valve to 'Prime' until water flows through Chiller Flush valve

9. Return Chiller Prime valve to 'Flow'

10. Close Chiller Flush valve



- e. Press 'Start' on Chiller touchscreen. Chiller should start operating normally. (If not, repeat steps 1-5 above)



- f. Hold down Return Pump Override button and turn **ON** Return Pump. Wait **10 seconds**
- g. Turn **OFF** Return Pump, and release Return Override button



- h. Turn Gauge Flush valve to "Drain" for **10 seconds**
- i. During this time, pinch tubing between Red tape marks multiple times to remove bubbles from valve
- j. Return to Gauge Flush valve to "Gauge"
- k. Pinch tubing between White tape marks (on the 'Drain' line) multiple times to remove trapped water from drain tubing
- l. Allow Hydrogen Peroxide to circulate for **30 minutes**
- m. Stop Chiller flow by pressing 'Stop' on touchscreen



- n. Turn **OFF** Supply Pump
- o. Dispose of fluid in drain tray



– Sanitize Complete –

8.3 Purge B

- a. Pull out drawer to expose Tank hook-ups



- b. Remove Supply hook-up from Tank and plug into "Line Purge" coupling
- c. Remove Return hook-up from Tank and set aside



- d. Place Drain valve tube into external bucket

(At least 1 gallon bucket size)



- e. Open Drain Valve



- f. Open Chiller Flush Valve



g. Press ‘Start’ on Chiller Touchscreen.



h. Wait until Chiller displays Alarm message, then press ‘Accept’



i. Turn Vacuum Output valve to “Line Purge”



j. Open Vacuum Depressurize valve



k. Turn **ON** Vacuum. Wait **20 seconds** for Chiller and Membrane to evacuate



l. Close Chiller Flush valve



- m. Turn ON Supply Pump. Wait **2 minutes** for Pad lines to purge



- n. Hold down Return Pump Override button and turn ON Return Pump. Wait **10 seconds**

- o. Turn OFF Return Pump, and release Return Override button



- p. Turn Gauge Flush Valve to “Drain” for **5 seconds**, then return to “Gauge”



- q. Turn OFF Supply Pump
- r. Turn OFF Vacuum



- s. Turn Vacuum Output valve to “Vacuum Drain”
- t. Close Vacuum Depressurize valve



- u. Close Drain valve and return tube to drain tray. Dispose of water in drain tray and bucket



- v. Return hook-ups to Tank

**Supply – Supply
Return – Return**



– Purge B Complete –

8.4 Rinse

- a. Open Tank. Add **3 Liters** Distilled Water



- b. Turn **ON** Supply Pump. Wait **2 minutes** for Pad lines to prime



- c. Start flow on Chiller by Pressing 'Start' on Chiller touchscreen



- d. If an Alarm message is displayed:

11. Press 'Accept' on Chiller touchscreen
12. Open Chiller Flush valve



13. Turn Chiller Prime valve to ‘Prime’ until water flows through Chiller Flush valve

14. Return Chiller Prime valve to ‘Flow’

15. Close Chiller Flush valve



e. Press ‘Start’ on Chiller touchscreen. Chiller should start operating normally. (If not, repeat steps 1-5 above)



f. **Hold down** Return Pump Override button and turn **ON** Return Pump. Wait **10 seconds**

g. Turn **OFF** Return Pump, and release Return Override button



h. Turn Gauge Flush valve to “Drain” for **10 seconds**

i. During this time, pinch tubing between Red tape marks multiple times to remove bubbles from valve

j. Return to Gauge Flush valve to “Gauge”

k. Pinch tubing between White tape marks (on the ‘Drain’ line) multiple times to remove trapped water from drain tubing



l. Stop Chiller flow by pressing ‘Stop’ on touchscreen



- m. Turn **OFF** Supply Pump



- n. Dispose of fluid in drain tray

– Rinse Complete –

8.5 Purge C

- a. Pull out drawer to expose Tank hook-ups
- b. Remove Supply hook-up from Tank and plug into "Line Purge" coupling
- c. Remove Return hook-up from Tank and set aside



- d. Place Drain valve tube into external bucket

(At least 1 gallon bucket size)



e. Open Drain Valve



f. Turn **ON** Power

g. Turn **ON** Chiller/Pumps



h. Open Chiller Flush Valve



i. Press 'Start' on Chiller Touchscreen.



j. Wait until Chiller displays Alarm message, then press 'Accept'



k. Turn Vacuum Output valve to "Line Purge"



- I. Open Vacuum Depressurize valve



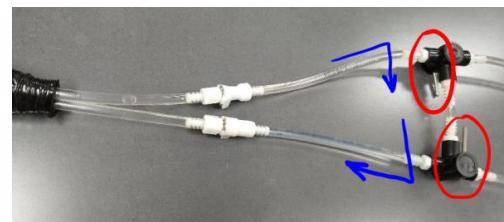
- m. Turn **ON** Vacuum. Wait **20 seconds** for Chiller and Membrane to evacuate



- n. Close Chiller Flush valve



- o. Make sure a Cooling Pad is attached to the Cooling Pad lines, and turn Shunt Valves near Pad to "Shunt"



- p. Turn **ON** Supply Pump. Wait **2 minutes** for Pad lines to purge



- q. **Hold down** Return Pump Override button and turn **ON** Return Pump. Wait **10 seconds**
- r. Turn **OFF** Return Pump, and release Return Override button



- s. Turn Gauge Flush Valve to “Drain” for **5 seconds**, then return to “Gauge”



- t. Turn **OFF** Supply Pump
- u. Turn **OFF** Vacuum



- v. Turn Vacuum Output valve to “Vacuum Drain”
- w. Close Vacuum Depressurize valve



- x. Close Drain valve and return tube to drain tray. Dispose of water in drain tray and bucket



- y. Return Tank hook-ups to proper positions

Supply – Supply

Return – Return

Level Sensor to Solenoid Valve box
(follow red guide lines)

D_O₂ Probe to Meter



– Purge C Complete –

8.6 Prime

- a. Open Tank. Fill Tank with Distilled Water to Tank Fill line (see sticker inside Tank)



- b. Turn **ON** Supply Pump. Allow water to circulate for **2 minutes** for bubbles to circulate through the lines



- c. Start flow on Chiller by Pressing 'Start' on Chiller touchscreen



- d. If an Alarm message is displayed:

16. Press 'Accept' on Chiller touchscreen

17. Open Chiller Flush valve



18. Turn Chiller Prime valve to 'Prime' until water flows through Chiller Flush valve

19. Return Chiller Prime valve to 'Flow'

20. Close Chiller Flush valve



- e. Press 'Start' on Chiller touchscreen. Chiller should start operating normally. (If not, repeat steps 1-5 above)



- f. Hold down Return Pump Override button and turn **ON** Return Pump. Wait **10 seconds**
- g. Turn **OFF** Return Pump, and release Return Override button



- h. Turn Gauge Flush valve to "Drain" for **10 seconds**
- i. During this time, pinch tubing between Red tape marks multiple times to remove bubbles from valve
- j. Return to Gauge Flush valve to "Gauge"
- k. Pinch tubing between White tape marks (on the 'Drain' line) multiple times to remove trapped water from drain tubing
- l. Allow water to circulate for **20 minutes**
 - During this time, occasionally shake and tap pad connectors and shunt valves and to eliminate bubbles stuck inside
- m. Stop Chiller flow by pressing 'Stop' on touchscreen



- n. Turn **OFF** Supply Pump



- o. Dispose of fluid in drain tray

– Prime Complete –

8.7 Replace MasterFlex Tubing

Replace MasterFlex tubing for both Supply and Return pumps, following steps in **Appendix B – MasterFlex Tubing Replacement**.

– Quarterly Maintenance Complete –

Appendix A - Recalibrate DO₂ Meter & Probe

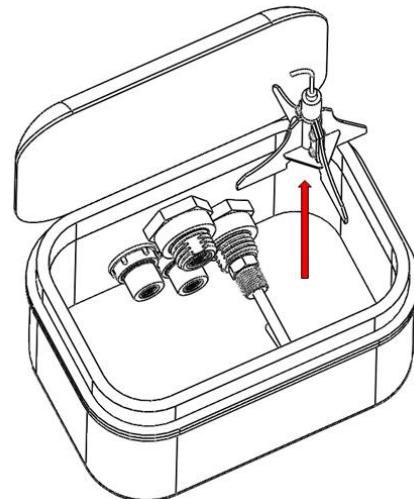
DO₂ Meter manual recommends the following:
'Perform daily calibration for best results.'

- a. Turn **ON** DO₂ Meter



- b. Open Tank and remove Probe Assembly (tilt the Probe Assembly as needed to move past Tank Level Sensor).

Shake gently to remove water from membrane tip



- c. Hold Probe Assembly above water level, with tip downward.



- d. Follow instructions in Probe Manual, **Section 3.3.1 100% Calibration** (p. 11).

- Step (1) may be skipped.
- Calibration Page is reproduced below for convenience.

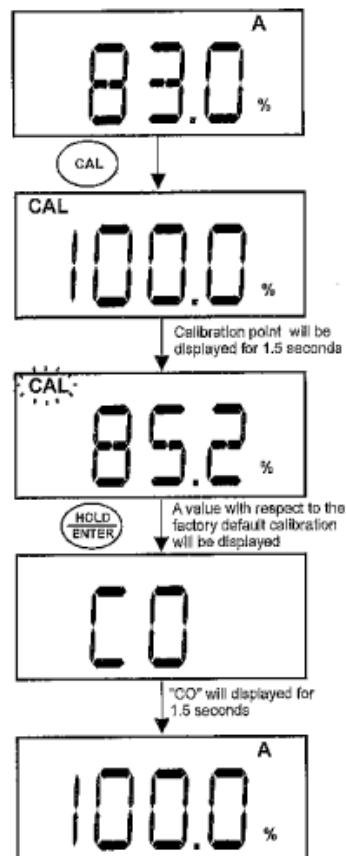
3.3 % Saturation Calibration

The DO6+ can be easily calibrated in air. For best DO accuracy, ensure that the barometric pressure value is accurate.

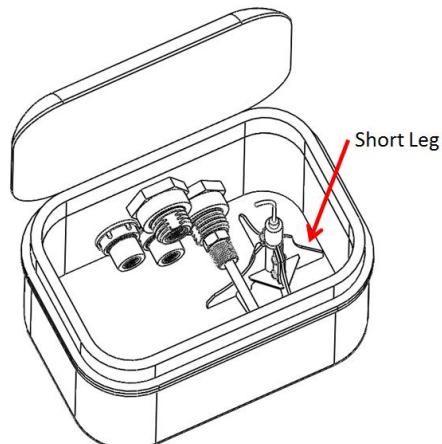
The barometric pressure factory default is 760 mm Hg, which results in a theoretical calibration value of 100% saturation in air. If the barometric pressure setting has been changed from 760 mm Hg, the meter will automatically adjust to a new % saturation calibration value instead of 100%. This new value is correct for the adjusted barometric pressure.

3.3.1 100% Calibration

- 1) Rinse the probe well with DI water or rinse solution.
- 2) Press **MODE** to select % saturation.
- 3) Hold the probe in the air with the tip facing downwards. Wait for the reading to stabilize.
- 4) Press **CAL**. The CAL indicator and intended percentage calibration point (100%) display briefly, before CAL flashes. The % value based on the factory default calibration is shown.
- 5) Press **HOLD/ENTER** to confirm the calibration. The meter displays "CO", automatically calibrates to 100.0% air saturation, then returns to measurement mode.



- e. Change Meter mode to 'mg/l' by pressing the **MODE** button
- f. Carefully return Probe Assembly to bottom of Tank, with 'short leg' away from the Tank Level Sensor
- g. Close Tank lid



– Meter & Probe Calibration Complete –

Appendix B - MasterFlex Tubing Replacement

B.1 Internet Video

<https://www.masterflex.com/tech-article/loading-tubing-masterflex-ls-standard-pump-heads>

(Please refer to this internet video if the written instructions below are not clear)



B.2 Supply Pump

- a. Remove head by loosening four screws, shown with arrows

(Be careful that the black rubber tab stays in pump, and does not get lost. Extras are provided in the system documentation kit)



- b. Push rotor with index finger while pulling off front bell cover. Pull out old tubing and discard, after removing connector ends



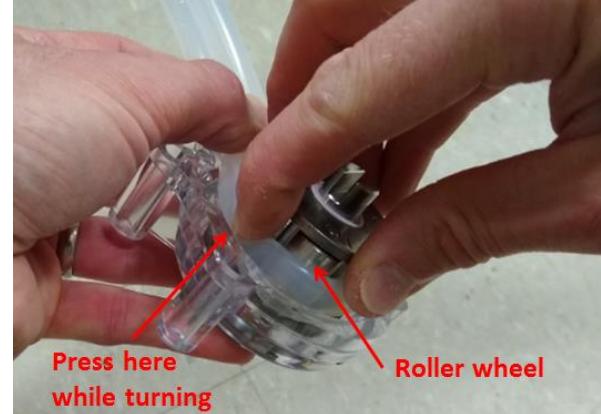
- c. Cut new tubing to **28 cm** length



- d. Insert tubing ends through tubing clamp and insert connector ends



- e. Wrap new tubing around rotor. Spin rotor by hand while pressing tubing into spaces between roller wheels



- f. Rotate rotor with rotor key while pressing two bell halves together



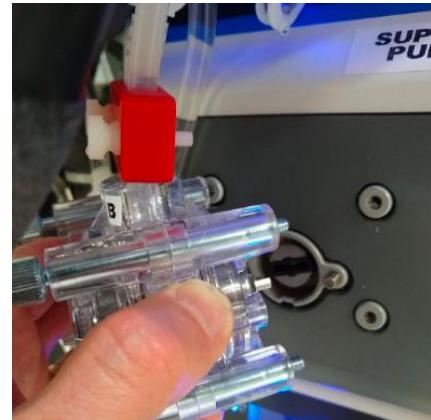
- g. Ensure tubing is not pinched in joint all the way around bell halves, and that tubing ends are still lined up (from Step 'c.')



- h. Tighten tubing clamp screws, making sure a small space is left between clamp and tubing connector barbed end



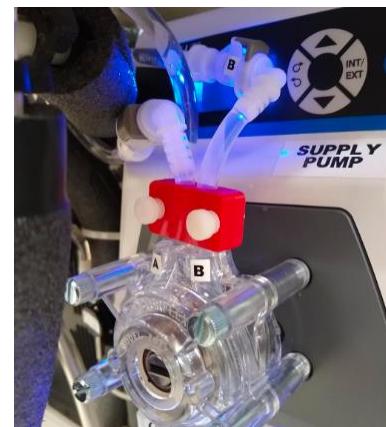
- i. Line up rotor drive tab, alignment pins, and screws with pump drive



- j. Turn rotor with rotor key to fit head into place, then tighten four screws (fingers only, do not use a screwdriver)



- k. Match tubing ends to corresponding labeled connectors



B.3 Return Pump

- a. Remove head by loosening four screws, shown with arrows

(Be careful that the black rubber tab stays in pump, and does not get lost. Extras are provided in the system documentation kit)



- b. Push rotor with index finger while pulling off front bell cover. Pull out old tubing and discard, after removing connector ends



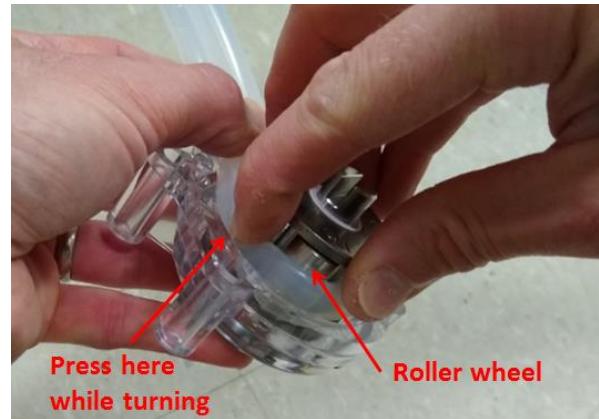
- c. Cut new tubing to **35 cm** length and insert tubing ends



- d. Insert connector ends into new tubing and wrap new tubing around rotor



- e. Spin rotor by hand while pressing tubing into spaces between roller wheels



- f. Rotate rotor with rotor key while pressing two bell halves together



- g. Ensure tubing is not pinched in joint all the way around bell halves, and that tubing ends are still lined up (from Step 'c.')



- h. Line up rotor tab, alignment pins, and screws with pump drive



- i. Turn rotor with rotor key to fit head into place, then tighten four screws (finger-tight only)

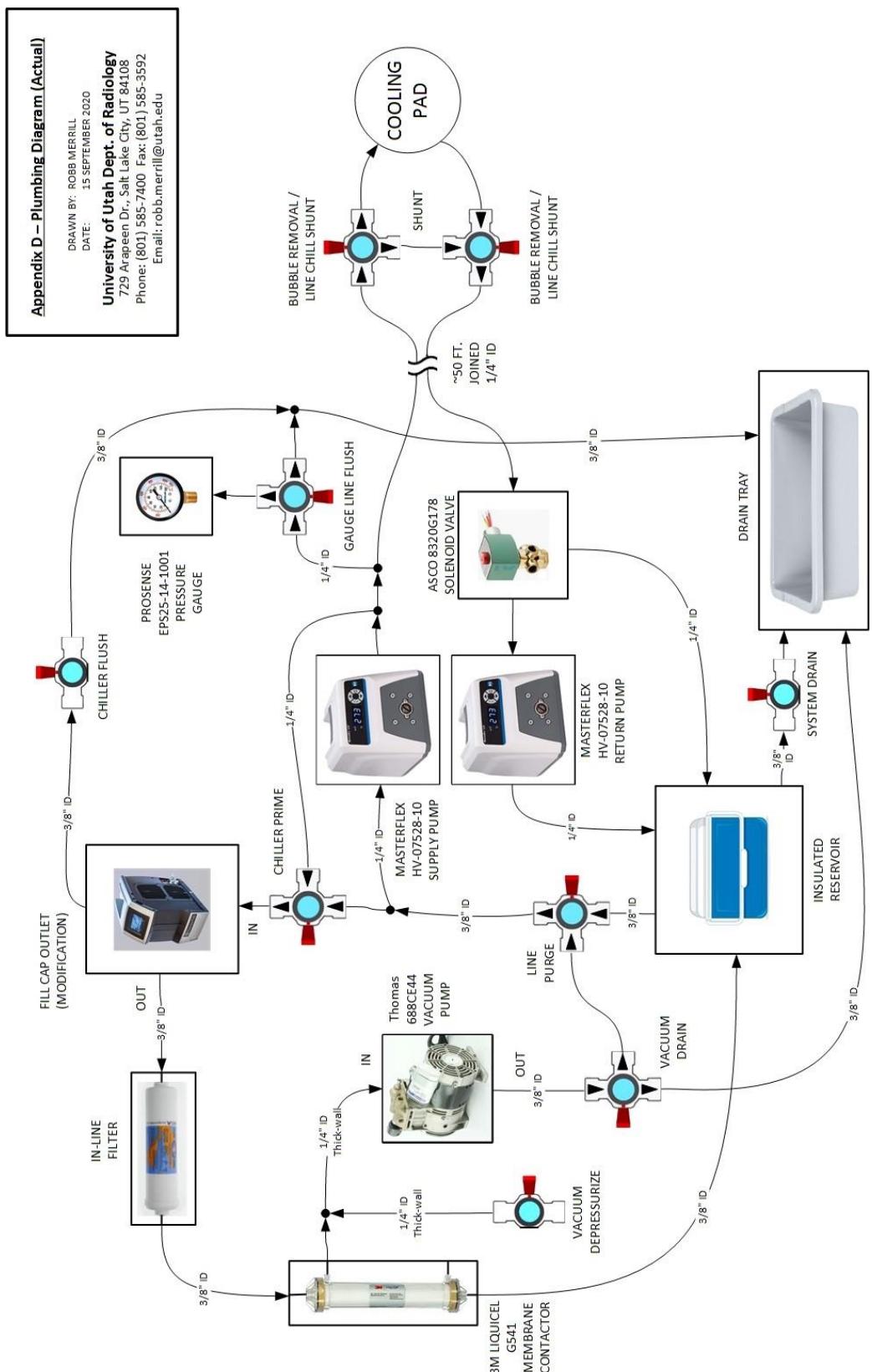


- j. Match tubing ends to corresponding labeled connectors

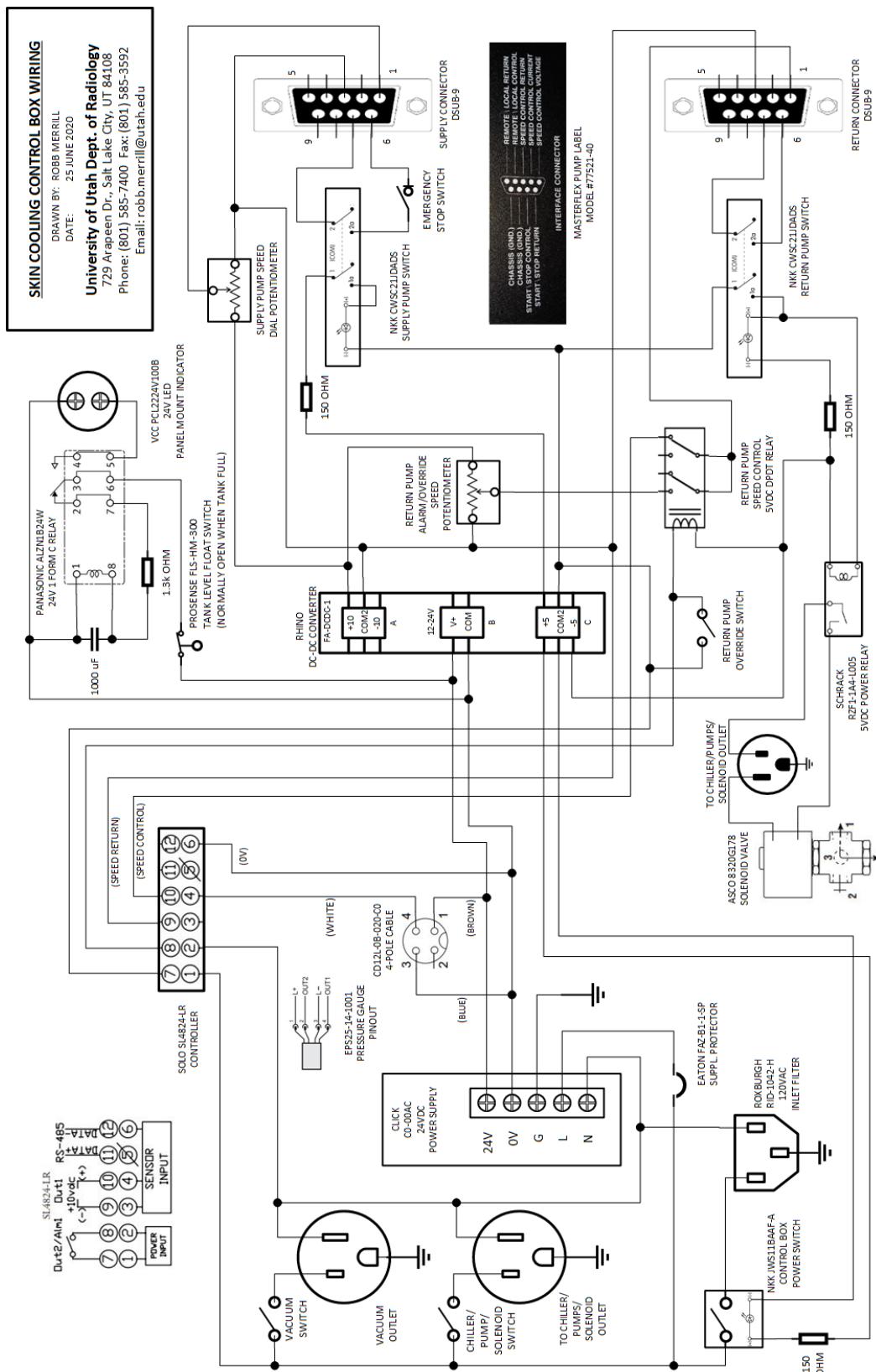


– Tubing Change Complete –

Appendix C - Plumbing Diagram



Appendix D – Control Box Wiring Diagram



Appendix E - Troubleshooting

Chiller/Pumps do not turn on, but switch lights up

Reset breaker switch on end of cart power strip

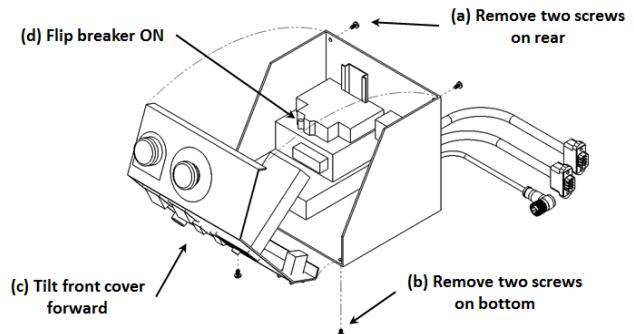


Chiller/Pumps do not turn on. Switch DOES NOT light up

Internal breaker switch inside Control Box has tripped

- h. Remove two screws from rear of the Control Box
- i. Remove two screws from bottom of the Control Box

(Screws are marked with arrows on Control Box)



- j. While looking at front of box, carefully tilt/rotate cover forward
- k. Flip breaker switch to **ON** position
- l. Carefully replace cover by first positioning lower tab into box, then rotate cover closed. Make sure no wires are pinched.
- m. Replace screws

Vacuum Pump making a strange humming noise

Residual vacuum in vacuum lines is causing Vacuum Pump to malfunction

- a. Slowly open Vacuum Depressurize Valve (turn blue knob 90 degrees so that it is in line with valve body). Wait until hissing stops.

- b. Close valve. Retry Vacuum switch.

Chiller message: "Low Coolant Level," but the system Tank is full

Chiller internal reservoir is empty. Bubbles collect in top of reservoir and displace water coolant

- a. Pull out Tank drawer to expose Chiller Valve



- b. Open Chiller Valve (turn 90 degrees) until water flows through drain tube
- c. Close Chiller Valve.



- d. Close drawer and Press 'Accept' on Chiller touchscreen.

If Error message is still displayed:

- a. Pull out Tank drawer again and open Chiller Valve
- b. Turn Chiller Prime valve to 'Prime'



- c. Turn **ON** Supply pump
- d. When water flows through Chiller Flush valve, turn **OFF** Supply pump



- e. Turn Chiller Prime valve to 'Flow'
- f. Close Chiller Flush valve
- g. Close drawer and Press 'Accept' on Chiller touchscreen.

SOLO Pressure Controller shows very low (single-digit) pressure when Supply Pump is ON; Pressure Gauge displays 'UL'

Supply Pump direction is reversed

- a. Turn OFF Supply Pump
- b. Press Flow Direction button on face of Supply Pump
- c. Turn ON Supply Pump

Tank Alarm is flashing, but Tank is full

An alarm cable is unplugged

- a. Check back of Control Box to make sure 'Tank' cable is plugged in fully
- b. Check the Relay Box (on the cart) to make sure the cable from the Tank is following the red routing line, and that it is plugged in fully



Appendix F – Membrane Cleaning Documentation

NOTE: The information in this section is incorporated into Section 7: Quarterly Maintenance



Liqui-Cel® Membrane Contactors CLEANING GUIDELINES

3.0 CHEMICAL COMPATIBILITY / SANITIZATION / DETERGENTS

For general questions about chemical resistance, refer to the Liqui-Cel® Membrane Contactor **Chemical Resistance Guide** available at www.liqui-cel.com or from your Membrana representative.

Table 1 shows the maximum recommended exposure times for several chemicals, which can be used to clean or sanitize a Liqui-Cel Membrane Contactor. To determine the total exposure time as a function of concentration, divide the value shown in column 2 of Table 1 by your actual chemical concentration. The resulting value is the total number of hours the contactor can be exposed to a specific chemical concentration.

Table 1: Sanitizing Guidelines

	Column 2	Column 3
Chemical	Concentration-hours at Room Temperature	Maximum Recommended Chemical Concentration *
Chlorine pH > 7	24000 ppm-hours	100 ppm
Hydrogen Peroxide	4800 % -hours	10% wt.
Peracetic acid	4800 ppm-hours	100 ppm

* Exposure times were determined when the fiber tensile strength and elongation values just began to decrease. The test conditions did not exceed these maximum concentrations, and testing was completed at 23°C. Using higher concentrations is not recommended, and at elevated temperatures the expected life is much shorter.

Exposure Time Calculations

Case 1: 2% hydrogen peroxide sanitization everyday for 30 minutes.

- a) What is the total exposure time for a solution of hydrogen peroxide at 2% concentration at room temperature?
- b) What is the maximum number of 30 minute cycles that the contactor can be subjected to using this solution at room temperature?
- c) Assume the desired number of cycles will be 365 times per year and the contactor will have a lifetime of 3 years.
Should this cleaning chemical protocol be used?

Solution

- a) Divide 4800 % - hours by 2%. Total exposure time = 2400 hours.
- b) Divide 2400 hours by 0.5 hours (30 minutes). Total number of cycles = 4800.
- c) Using 365 cycles per year and an expected lifetime of 3 years, the total number of exposure cycles is 1095 (365 * 3 years). It would be safe to use this chemical for daily cleaning for 30 minutes per day at 2% concentration at room temperature since 1095 cycles < 4800 cycles.

The total life expectancy of a Liqui-Cel Membrane Contactor is affected by many factors, one of which is the chemical cleaning cycle. Do not assume the total number of exposure cycles can be used to predict the ultimate lifetime of a contactor. Use this total number of cycles to judge whether the contactor lifetime will be affected by the cleaning cycle. In the case above, compare the number of theoretical cleaning cycles (4800 cycles) to the desired number of cleaning cycles over the expected lifetime of the contactor (1095 cycles). The conclusion in this example is that cleaning cycles will probably not reduce the 3-year lifetime of the membrane.

Case 2 illustrates a cleaning protocol that we **DO NOT RECOMMEND**.

Case 2: 200 ppm peracetic acid sanitization every day for 30 minutes.

- a) What is the total exposure time for a solution of peracetic acid at 200 ppm concentration at room temperature?
- b) What is the maximum number of 30 minute cycles that the contactor can be subjected to using this solution at room temperature?
- c) Assume the desired number of cycles will be 365 times per year and the contactor will have a lifetime of 3 years.
Should this cleaning chemical protocol be used?

Solution

- a) Divide 4800 ppm - hours by 200 ppm. Total exposure time = 24 hours.
- b) Divide 24 hours by 0.5 hours (30 minutes). Total number of cycles = 48.
- c) Using 365 cycles per year and an expected lifetime of 3 years, the total number of exposure cycles is 1095 (365 * 3 years).
It would NOT be safe to use this chemical for daily cleaning for 30 minutes per day at 200 ppm concentration at room temperature since the required number of cycles (1095) is much greater than the maximum number of 48 cycles.

However, the protocol could be used if the cleaning frequency was changed to 4 times per year for 3 years = 12 cycles, which is less than maximum number of 48 cycles.

IMPORTANT NOTES FOR CLEANING SOLUTION SELECTION:

DO NOT USE STRONG OXIDIZING AGENTS such as ozone.

Do NOT use any chemicals that contain DETERGENTS or surfactants.

Surfactants may allow liquids to pass through the membrane. This phenomenon is called break-through or wet-out. The membrane can be restored to a hydrophobic state by rinsing the detergent from the contactor and then drying it but this is a time consuming process.

Appendix G – Dilution Instructions

Question

Asked 9th Dec, 2015



Muhammad Saleem Kalhoro

Asian Institute of Technology

I need to convert 6% hydrogen peroxide (H₂O₂) into 3%. What diluent should I use?

16th Mar, 2016

Reena Sachan

Indian Institute of Technology Roorkee

Dear Muhammad Saleem Kalhoro,

You can use the formula C₁V₁=C₂V₂ where C₁ is the concentration of stock solution, V₁ is the volume of stock solution, C₂ is the concentration which you require and V₂ is the volume which you require. For example, you want to make 100mL of 3% H₂O₂ from 6% H₂O₂. Use this formula you will find to add 50 mL distilled water to 50 mL of 6% H₂O₂.

Good luck

Adapted from:

(https://www.researchgate.net/post/I_need_to_convert_6_hydrogen_peroxide_H2O2_into_3_What_diluent_should_I_use) Accessed July 2020.

Appendix H – Maintenance Schedule

Month	Week #	Maintenance Type	Date Performed	Name	Issues Encountered	Fixed?
	1	Weekly				
	2	Weekly				
	3	Weekly				
	4	Weekly				
	5	Weekly				
	1	Weekly				
	2	Weekly				
	3	Weekly				
	4	Weekly				
	5	Weekly				
	1	Weekly				
	2	Weekly				
	3	Weekly				
	4	Weekly				
	5	Quarterly				

Appendix I – Contact information

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