Maintenance Supplement

1.1. Scheduled Maintenance

The Green Machine requires regular maintenance every 2200 hours of operation. For the specific procedures required at a given interval, check Table 1.1-1 below. At each maintenance, perform all procedures with an interval that is a multiple of the current run time hours. For example, at 8800 hours runtime, perform all of the 2200 hour and 4400 hour maintenance items in addition to the 8800 hour items. Alternatively, refer to the Maintenance Schedule in Appendix A.

Record all work performed on the Green Machine in the Machine Maintenance Log. At the specified maintenance intervals, copy and submit a Maintenance Checklist (Appendix B) to ElectraTherm Customer Service.

Table 1.1-1: Maintenance Intervals

MAINTENANCE	MAINTENANCE INTERVAL (HOURS)	INSTRUCTIONS
Inspect all plumbing, flanges, and valves for leaks	2200	See Section 1.2.
Inspect hardware for wear/damage	2200	See Section 1.3.
Gates 20mm belt tension/inspection	2200	See Section 1.4.
Check oil drain catch bottle	2200	See Section 1.5.
Grease pump motor bearings	2200	See Section 1.6.
Gates 20mm belt replacement	4400	See Section 1.7.
Inspect and grease generator bearings	4400	Grease at scheduled interval or after 6+ months idle. See Section 1.8.
Clean cabinet filters, verify fan operation	4400	See Section 1.9.
Inspect for electrical wear/damage	4400	See Section 1.10.
Check HX water-side pressure difference	8800	See Section 1.11
Test working fluid acidity	8800	See Section 1.12
Check for non-compressible gases (NCGs)	8800	See Section 1.13
Clean enclosure	8800	See Section 1.14
Test oil concentration	8800	See Section 1.15
Check operation of compressed air system	8800	See Section 1.16
Verify operability of safety equipment (buttons, lights, labels)	8800	See Section 1.17
Replace PRVs	17600	May require more frequent replacement. See Section 1.18
Replace PLC and HMI batteries	17600	See Section 1.19
Howden expander rebuild	19800	Contact ElectraTherm Customer Service or your local Distributor to schedule. See Section 1.20
Replace filter-dryer	19800	See Section 1.20
Replace VFD internal cooling fan	26400	See Section 1.21

NOTICE: Current maintenance intervals are conservative and may be extended based on field experience. Consult your local distributor or ElectraTherm Customer Service if you have any questions about maintenance procedures.

 Block 3 Supplement, December 2013

1.2. Plumbing Inspection

It is very important that the Green Machine be regularly inspected for leaks. In particular, leaks in the working fluid loop can result in a costly loss of working fluid. When the working fluid evaporates, it will leave the oil behind. This oily residue is a clear indication of a leak. Look for puddles of oil or water on the floor of the enclosure, and locate their source. A small leak can be identified using a liquid leak detector.

1) Check that the bolts on the pipe flanges are tight and the gaskets are not leaking.
2) Check the pipe threads at sensors, copper tubing, and test valves.
3) Pay particular attention to the Kitz bypass and blocking valve packing (Figure 1.2-1). If the valve packing is determined to be leaking, tighten the valve packing **only enough to stop the leak.**
4) While the Green Machine is off, manually actuate the bypass and blocking valves using the Test Functions on the touch panel. Ensure that the valves cycle fully and smoothly, and that the actuators are not leaking air.

CAUTION: Over-tightening of Kitz valve packing may cause the valve to stick. Once packing has been over-tightened, the valve seal has been compromised and will need replacement.

NOTICE: Every 8800 hours of operation, a complete inspection should be performed using liquid leak detector. At this interval, check every gasket and threaded fitting on the GM.

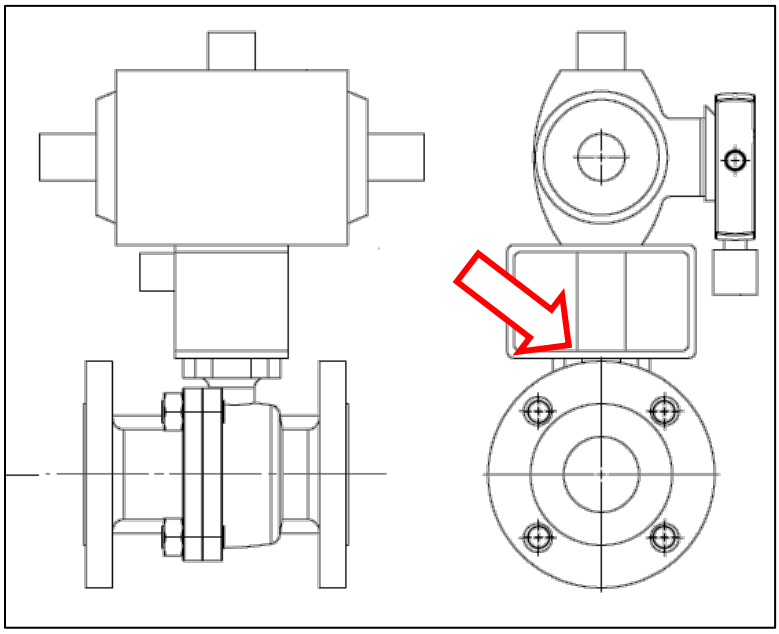

FIGURE 1.2-1: KITZ VALVE PACKING

1.3. Hardware Inspection

The Green Machine is subject to mechanical vibration which, over time, can loosen bolts and fasteners. Excessive vibration of the moving components can cause severe damage to the Green Machine. If bolts are found to be loose, they should be tightened to the torque specifications listed in Table 1.3-1.

1) Check the expander mounting bolts.
2) Check the generator mounting bolts to the tilt table, the jacking screws, and the tilt table to generator table bolts.
3) Check other major components (heat exchangers, WF tank, support tables) for motion.
4) Check for any other physical damage to the Green Machine.

NOTICE: Every 8800 hours of operation, a complete inspection should be performed. At this interval, check every bolt on the GM and tighten as necessary.

Table 1.3-1: Torque Specifications

PART LOCATION	SIZE	GRADE (METRIC)	TYPE	TORQUE (lb·ft)	TORQUE (N·m)
Tank to Tank Table	M12x1.75x35L	8.8	hex head	60	81
Pump to Base	M12x1.75x50L	8.8	hex head	60	81
Expander to Expander Table	M12x1.75x50L	8.8	hex head	60	81
Generator to Pivot Table	M12x1.75x50L	8.8	hex head	60	81
Expander taper Lock	7/16-14 x 7/8	SAE Grade 5	Cap Screws	23	31
Generator Taper Lock	1/2-13 x 1 1/2	SAE Grade 5	Cap Screws	83	113
Evaporator to Table	M12x1.75x35L	8.8	hex head	60	81
Pre-Heater to Base	M12x1.75x35L	8.8	hex head	60	81
Condenser to Table	M12x1.75x35L	8.8	hex head	60	81
Expander Inlet Flange	M10x1.5x35L	N/A	Cap Screws	40	54
Expander Outlet Flange	M20x2.5x55L	N/A	Cap Screws	115	156
Pump Flanges	M16x2.00x80L	8.8	hex head	70	95
Pump Base	M12x1.75x100L	8.8	hex head	37	50
1 1/4" Class 150 Flange	M14x2.00x60L	8.8	hex head	45	61
1 1/2" Class 150 Flange	M14x2.00x60L	8.8	hex head	45	61
2" Class 150 Flange	M16x2.00x80L	8.8	hex head	90	122
2 1/2" Class 150 Flange	M16x2.00x80L	8.8	hex head	90	122
3" Class 150 Flange	M16x2.00x80L	8.8	hex head	115	156
Belt Shroud to Base and Expander Table	M12x1.75x35L	8.8	hex head	60	81

1.4. Belt Inspection

DANGER: Be aware that even though the Green Machine may be disconnected and locked out, the expander and generator can still spin without warning. This is caused by a change in temperature and/or pressure within the machine. Take special care when the belt guard is removed while performing maintenance.

The Gates 20mm belt should be checked for excessive wear and proper tension at every maintenance interval. Before removing the belt shroud, ensure that all energy sources for the Green Machine are shut off and locked out. This includes the electrical and water sources.

1) Remove the belt shroud as described in Section 2.15 of the manual. *The shroud is heavy; two people may be necessary to lift it.*

2) Verify smooth rotation of the pulleys and check for wear of the belt.

3) Check the alignment of the pulleys

4) Check belt tension as described in Section 2.5.

5) Adjust belt tension if necessary (based on the "Used" specification in Table 1.4-1).

Table 1.4-1: Gates Belt Tension Specifications

PULLEY TEETH		BELT WIDTH [mm]	BELT LENGTH [mm]	FREQUENCY [Hz]		DEFLECTION [in]		FORCE [lbf]	
EXPANDER	GENERATOR			NEW	USED*	NEW	USED*	NEW	USED*
28	90	20	2100	78-82	67-71	0.325	0.325	25	20
28	75	20	1960	79-83	67-72	0.325	0.325	25	20

PULLEY TEETH		BELT WIDTH [mm]	BELT LENGTH [mm]	FREQUENCY [Hz]		DEFLECTION [cm]		FORCE [kgf]	
EXPANDER	GENERATOR			NEW	USED*	NEW	USED*	NEW	USED*
28	90	20	2100	78-82	67-71	1.0	1.0	11.5	9
28	75	20	1960	79-83	67-72	1.0	1.0	11.5	9

*BELTS ARE CONSIDERED "NEW" FOR THE FIRST 15 MINUTES THEY ARE IN ACTIVE SERVICE. AFTER THAT, TENSION TO THE "USED" SPECIFICATION

1.5. Oil Drain Rate

There is a weep hole located below the expander pulley to prevent excess oil from collecting in the expander housing. The oil drains from this hole to a catch bottle attached to the leg of the expander table ((Figure 1.5-1). The bottle must be periodically checked and emptied. Results should be logged in the MHL.

1) Record the date and GM run hours in the log.
2) If there is not any oil in the bottle, record this information in the log. If there is, continue with this procedure.
3) Pull the bottle out of the spring clips, and unscrew the bottle from the lid, leaving the hose attached to the lid.
4) Measure and record the amount of oil in the drain bottle.
5) Dispose of the drained oil as required by local code.
6) Installation of the bottle is the reverse of removal. Attach it to the table leg and push the tube back into the fitting

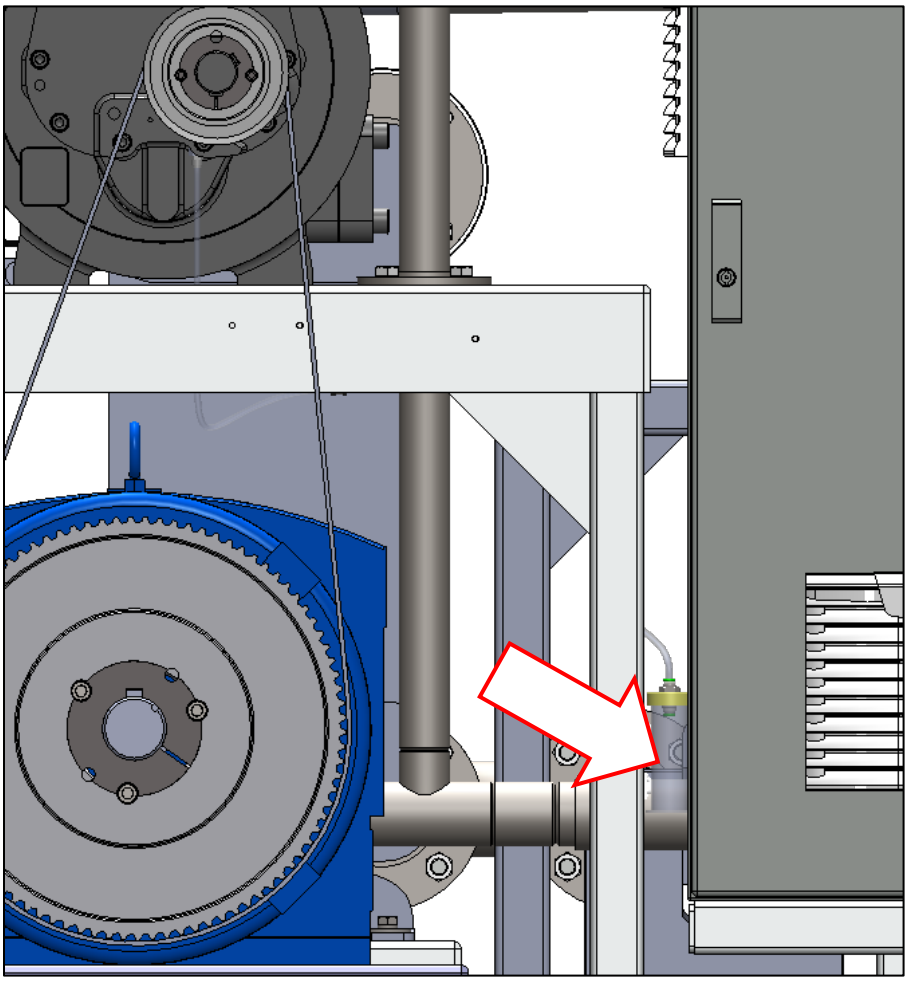

FIGURE 1.5-1: HOWDEN SNOUT DRAIN BOTTLE

1.6. Pump Motor

The Baldor pump motor requires regular lubrication to achieve optimum bearing life.

Note: If the motor is not equipped with grease fittings, the bearings are sealed and do not need greasing.

1) Clean grease fittings and outlet plugs (Locations shown on Figure 1.6-1).

CAUTION: Never add more than 1.5x the amount of grease specified to each bearing. Adding too much or too little grease to the bearings can damage them and reduce pump life.

2) Measure the amount of grease your grease gun injects with each pump.
3) Add 17g (20 mL) of Exxon Mobil Polyrex EM grease to each Zerk fitting on the pump motor.
4) Add grease SLOWLY. It should take about a minute before new grease appears at the outlet plug.

NOTICE: If new grease does not appear at the outlet plug, the bearings will need to be repacked at the next service interval. Contact ElectraTherm Customer Service.

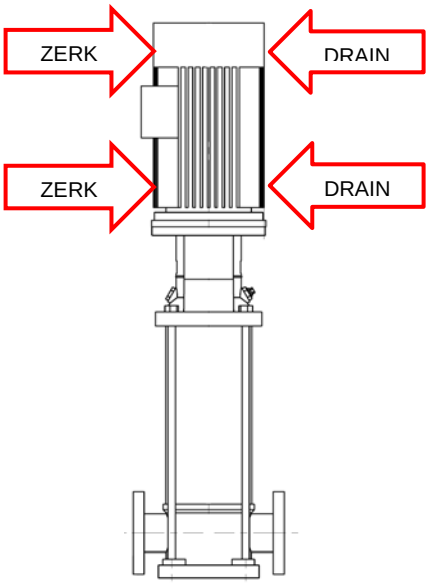

FIGURE 1.6-1: PUMP GREASE FITTINGS

FIGURE 1.6-2: PREFERRED GREASE

1.7. Belt Replacement

DANGER: Before removing the belt shroud, disconnect and lock out all energy sources to the machine. These included electrical and water sources. Be aware that even though the Green Machine may be disconnected and locked out, the expander and generator can still spin without warning. This is caused by a change in temperature and/or pressure within the machine. Take special care when the belt shroud is removed while performing maintenance.

The Gates 20mm belt has an expected service life of 4400 hours of run time. Before removing the belt shroud, ensure that all energy sources for the Green Machine are shut off and locked out. This includes the electrical and water sources.

1) Remove the belt guard shroud by removing the three bolts indicated in Figure 1.7-1. Slide the guard towards you, out from under the table. It can then be lifted and set aside out of the way. *The guard is heavy and may require two people to lift.*
2) With the guard out of the way, loosen the nuts on the generator table (shown in Figure 1.7-2) that tighten the belt.
3) Raise table with a pry bar until there is enough slack in the belt to remove it from the pulleys.
4) Remove the old belt.
5) While the belt is off, reference Section 1.8 for generator maintenance instructions.

6) After the generator has been serviced, install the new belt and set tension to the “New” belt specification (Table 1.4-1). A belt is considered “New” if it has been in service less than 15 minutes.

7) Verify the alignment by manually spinning the generator pulley. The belt should remain centered on the pulley (Figure 1.7-3).

8) Tighten bolts per torque specifications in Table 1.3-1.

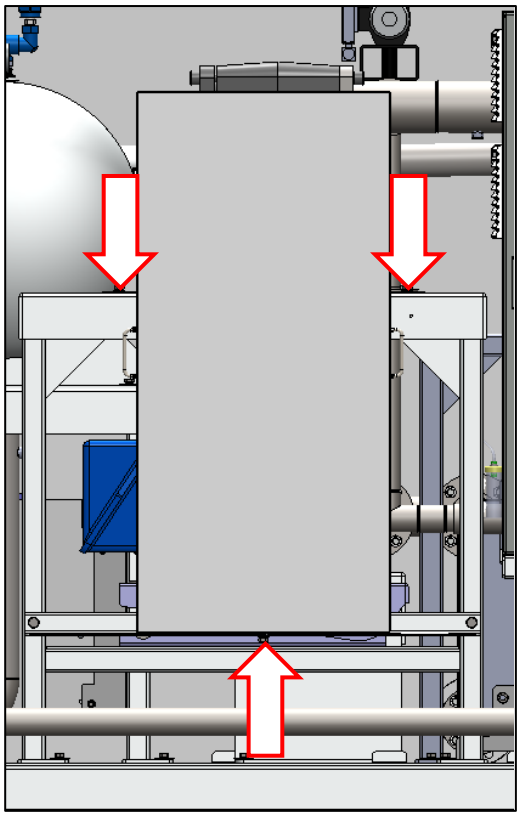

FIGURE 1.7-1: BELT SHROUD MOUNT BOLTS

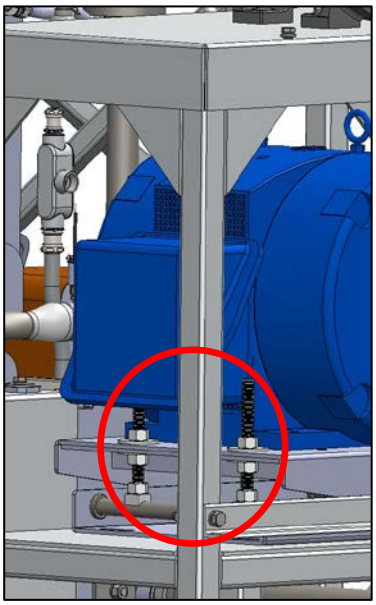

FIGURE 1.7-2: GENERATOR TABLE NUTS

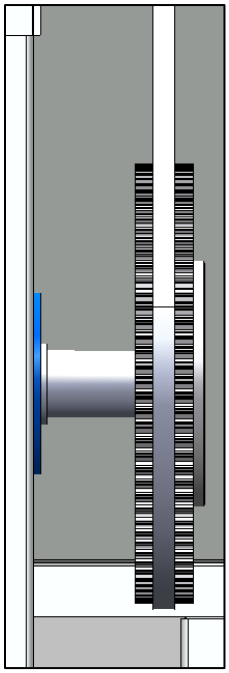

FIGURE 1.7-3: BELT ALIGNMENT

1.8. Generator Bearings

The generator bearings need regular greasing for optimal operation and life span. They should be inspected whenever the generator is greased to ensure that they are sufficiently lubricated and not wearing excessively.

1.8.1. INSPECTION

1) With the belt removed, rotate the generator pulley by hand.

2) Listen and feel for any noise such as grinding or clunking that could indicate uneven wearing of the bearing races or foreign material contamination.

3) Consult ElectraTherm Customer Service with any concerns about the bearing performance.

1.8.2. LUBRICATION

4) Clean Zerk fittings on top of bearing housings and spring-loaded drain on bottom of housings (Figure 1.8-1).

5) Add the same grease used on the pump motor using a low pressure grease gun.

Table 1.8-1: Required Generator Grease			
	GREASE TYPE	VOLUME (mL)	MASS (g)
DRIVE SHAFT END	EXXON MOBIL POLYREX EM	28.8	25.5
OPPOSITE DRIVE SHAFT END	EXXON MOBIL POLYREX EM	21.8	19.3

CAUTION: Never add more grease than specified to each bearing. Adding too much or too little grease to the bearings can damage them and reduce generator life.

6) Replace the belt shroud.
7) Run generator for 30 minutes.
8) Wipe off any grease that has drained.

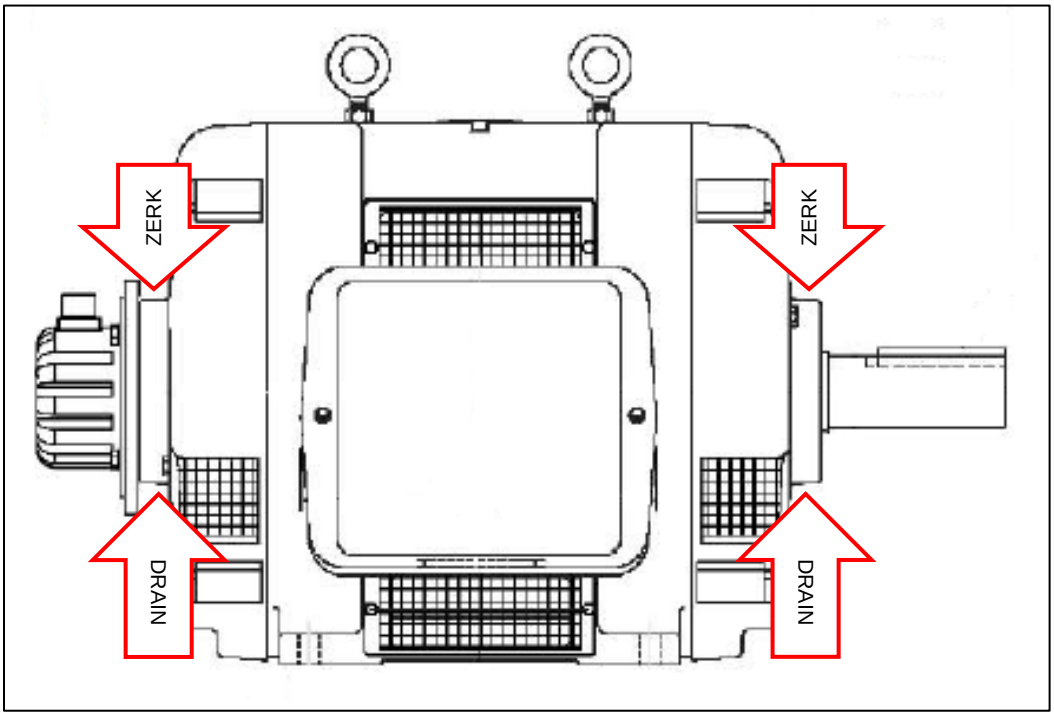

FIGURE 1.8-1: GENERATOR GREASE FITTINGS

1.9. Cabinet Cooling Fans/Filters

The electrical components that power and control the Green Machine need sufficient air flow to remain within their operating temperatures. Cooling fans are installed in each cabinet door, and filters in the cabinet wall, to provide this air flow. Periodic maintenance is required to ensure that the fans continue to circulate air and the filters are not choked with debris.

1) In the C-more Test Functions menu, toggle Panel Fan Test to ON.
2) Verify that the fans operate smoothly, without grinding or rattling, and that they pull air in to the cabinet.
3) In the C-more Test Functions menu, toggle Panel Fan Test back to NORMAL.
4) Open the filter housing(s) by pulling firmly on the bottom edge of the blue tab (Figure 1.9-1) on the outside of the housing.

5) Remove the filters and clean them with compressed air. If compressed air is unavailable, wash them in water and allow them to dry completely before replacing them.

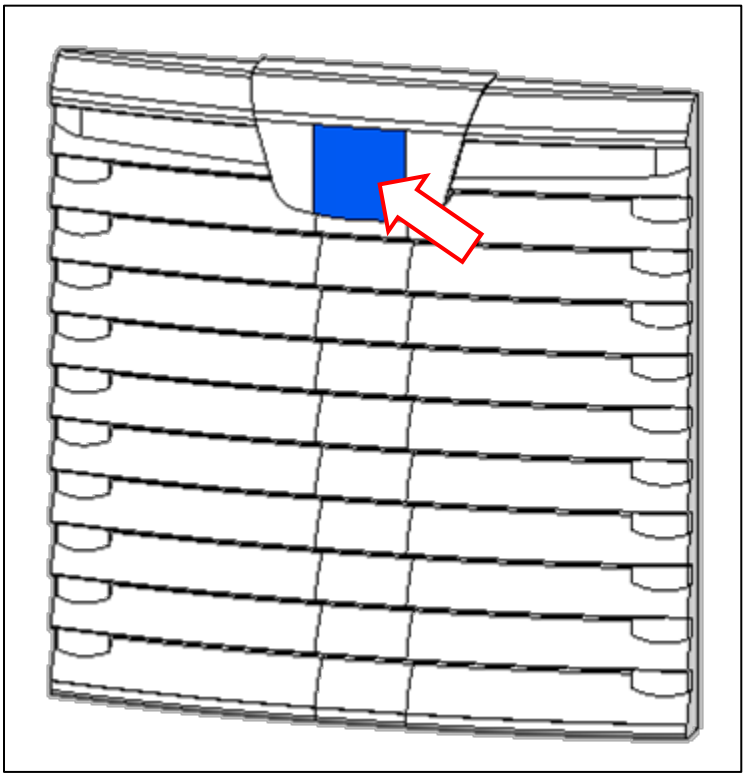

FIGURE 1.9-1: FAN/FILTER HOUSING

1.10. Electrical Inspection

Regular inspection of the electrical components and connections is an import part of preventative maintenance. Scorched or discolored wiring can be one of the first indications of an electrical problem, and merits further examination to determine the root cause. Poor electrical connections can generate excessive heat and become a fire hazard.

1) Visually inspect the wiring connections in the power cabinet, ensuring that terminals are tight and wires are securely connected.
2) Check the connections in the control cabinet. Incorrect or missing information from sensor inputs can cause undesirable operation of the Green Machine, or prevent startup entirely.
3) Look specifically for any discoloration or scorching that could indicate a connection or component nearing failure.

1.11. Heat Exchanger Pressure Difference

Pressure difference on the water side of each set of heat exchangers should be measured at startup to provide a baseline. This information should be recorded in the Baseline Commissioning Data sheet.. If the pressure difference across a heat exchanger has significantly increased, it is an indication that flow through the heat exchanger is obstructed. This can significantly reduce the power output of the Green Machine. Contact ElectraTherm Customer Service if you have any questions about clearing obstructed heat exchangers.

1) Locate the heat exchanger vent (A) and drain (B) on the hot water loop, Figure 1.11-1.
2) Install pressure sensors at each valve, or a differential pressure sensor between them.
3) With normal water flow, measure the differential pressure, and compare it to the baseline data.
4) Repeat this process for the cold water loop. Cold water vent is behind sensor (C) (water-cooled machines only).

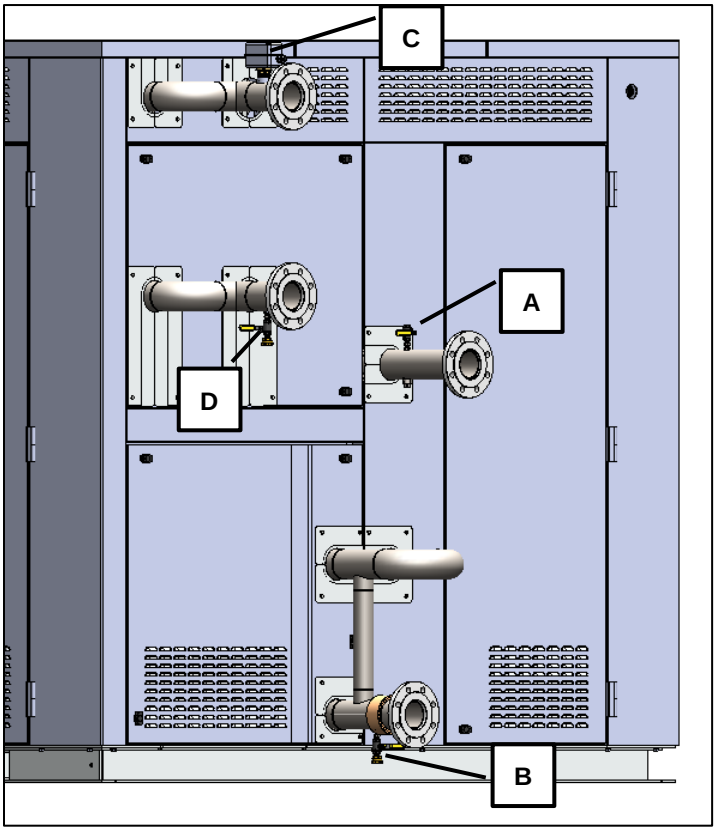

FIGURE 1.11-1: WATER-SIDE VENTS AND DRAINS

1.12. Working Fluid Acidity

DANGER: Discharge of a large volume of working fluid in an enclosed space may displace oxygen and lead to asphyxiation. Conduct this procedure with adequate ventilation and avoid inhalation of working fluid vapors. Wear safety glasses meeting or exceeding ANSI Z87.1 specification.

CAUTION: If the temperature of working fluid is below 60°F (16°C), the system pressure will be below one atmosphere. Opening an access valve under these circumstances will draw air into the machine, necessitating a non-condensable gas purge. Do not open a valve if ambient temperature is below this threshold.

It is unlikely that the working fluid or oil will decompose to form acids under normal operating conditions. However, due the risk of damage from any acid in the working fluid system, regular tests must be performed. Acid in the working fluid can corrode the plumbing, creating a potentially hazardous leak or machine damage.

1) With the Green Machine warm (>60°F [16°C]), test the working fluid vapor at the condenser Schrader valve (water-cooled) or the top of the ACC (air-cooled) using a standard refrigerant acidity tester (Figure 1.12-1).
2) Follow the instructions on the refrigerant acidity test.
3) In the case of any color change, **do not add neutralizers mentioned on test packaging**. Photograph the result and contact ElectraTherm Customer Service for instruction.

FIGURE 1.12-1: TYPICAL REFRIGERATION ACID TEST

1.13. Non-Condensable Gases

Check for the presence of non-condensable gases (NCGs) annually, or if maintenance could have introduced such contaminants to the system. NCGs can reduce output and efficiency of the Green Machine and in sufficient percentage can react adversely with the working fluid and/or lubrication oil.

1) Shut down the Green Machine and allow it to sit for 10 minutes.
2) Without providing hot water flow, run the VFD in test mode to stir the working fluid for 5 minutes.
3) Read the Expander Low Pressure and WF Tank Outlet Temperature from the PLC I-O Rack 0 screen described in the distributor manual.
4) Plot the point on Figure 1.13-1.
5) If the point is above the red purge line, the Green Machine should be purged.

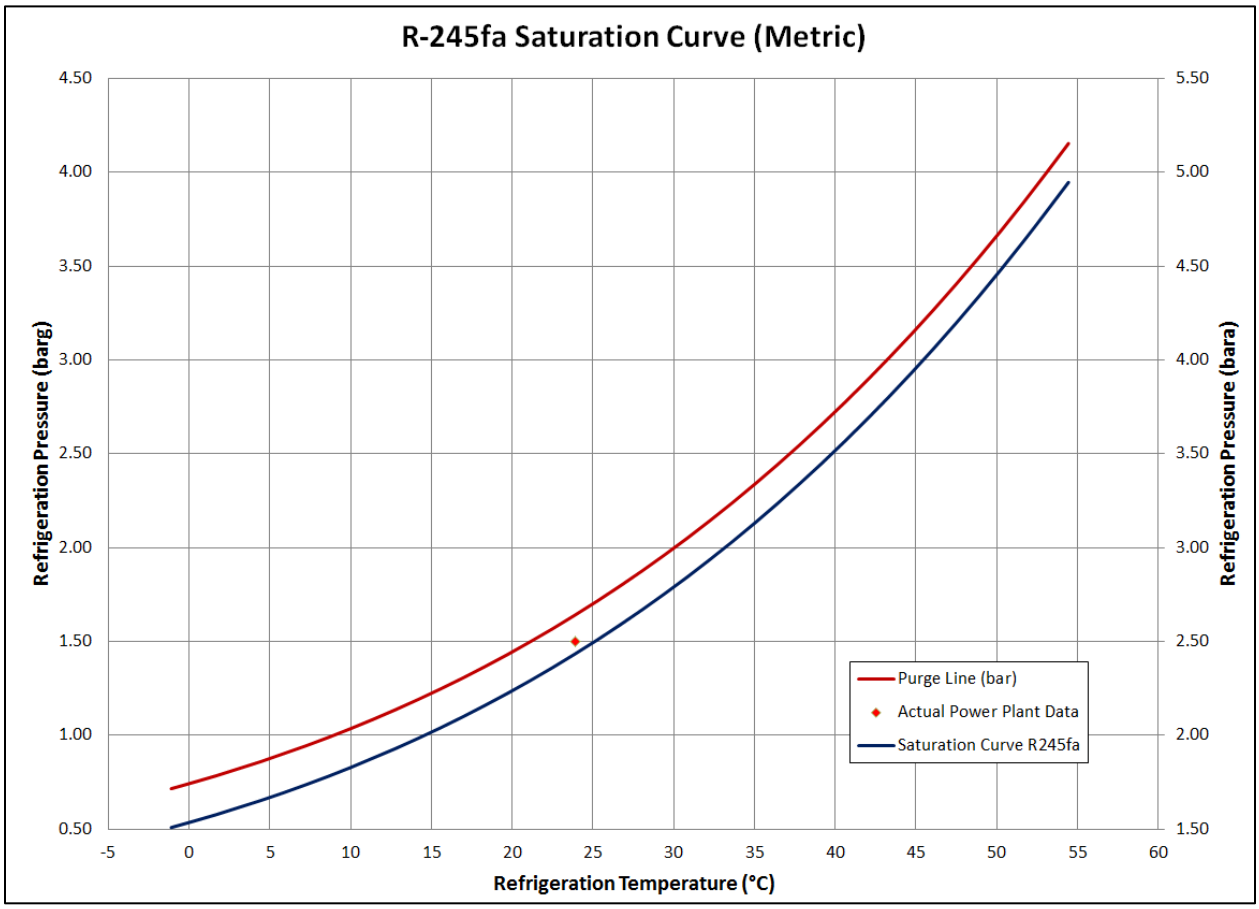

FIGURE 1.13-1: WORKING FLUID SATURATION CURVE

1.14. Clean Enclosure

Keeping the Green Machine clean makes it much easier to spot leaks and other potential problems, both during maintenance and during normal operation.

1) Vacuum loose dirt and debris from the enclosure.
2) Use a soap and water solution or mild cleaner to remove dust and dirt.
3) Denatured alcohol works well to remove oil residue.
4) Make sure to identify the source of any oil found in the enclosure. Use liquid leak detector if needed to find the source of the leaked oil.

1.15. Working Fluid Oil Concentration

It is vital to the life of the expander and the performance of the Green Machine that the working fluid contains the proper amount of oil. The Green Machine is initially filled with over 5% (by mass of the working fluid) of mineral oil. During operation, the oil and working fluid mix. To ensure proper lubrication, this circulating mixture should contain between 1 and 2% oil.

CAUTION: At temperatures below 60°F (16°C) the Green Machine will be at a pressure below one atmosphere. Do not attempt this procedure below this temperature. At an ambient temperature above 90°F (32°C), vapor expansion of the working fluid may pop the tops off of the test tubes. Always wear eye protection.

NOTICE: The small amount of working fluid released during this test is considered a *de minimis* release and is not a code violation. Remember that the working fluid is non-toxic, non-flammable, and non-ozone-depleting.

1.15.1. PREPARATION

1) Remove the labels from the Vacutainer sample tubes and wipe off dirt/oils as much as possible with a dry rag.
2) Label the test tubes with numbers 1 through 4.
3) Weigh the tubes using the balance and record the weight of each tube. Be careful not to touch the tubes with your bare hands too frequently as it will leave excess skin oils on the tube, corrupting the weight measurements.
4) Record the test date and run hours on the Oil Concentration Data form.

1.15.2. GATHERING SAMPLES

1) The Green Machine should be running for 60 minutes before this test. This will mix the working fluid and allow a positive pressure to develop in the receiver tank.
5) Verify that the lower working fluid valve (at the pump outlet) is closed and remove the valve access cap.
6) Cover the fitting with a rag and slightly open the valve to purge the line of stagnant liquid (about 2 seconds).
7) Close the valve again and screw on the septum adapter loosely. Before tightening the adapter completely, open the valve slightly to purge it.
8) When the line has purged, screw down the septum adapter, stopping the fluid flow. Fully open the liquid access valve and verify there is no leakage.
9) Insert the needle holder. A thin stream of fluid will spray out the end of the needle; this will purge the needle.
10) Insert the Vacationer tube onto the syringe barrel, penetrating the red stopper with the needle. Liquid will start to flow into the vial.
11) Collect a sample to fill the vial ~1/2 full of liquid.
12) Withdraw the filled tube from the needle holder.
13) Place each tube in the cup of cold water if ambient temperature is above 80°F (26.7°C) to prevent the tops popping off.
14) Collect a total of four samples. The samples should be a milky-white mixture of working fluid and oil.
15) Close the liquid access valve, remove the septum adapter and replace the original valve cap.

1.15.3. OIL PERCENTAGE CALCULATION

16) Weigh the test tube containing the working fluid/oil mixture and record the value.
17) After weighing, set the test tube in a tube rack and carefully remove the rubber stopper, allowing the working fluid to evaporate.
18) Be careful that no liquid escapes due to boiling over; this will corrupt the results from that tube.

19) After sitting for a couple hours the volume in the tube should be reduced by about 90%.
20) The solution should now appear clear (almost pure oil).
21) Bubbles must stop completely. A good test is to tip the tube on its side in your hand and allow the mixture to run along the inside edges of the glass. If no bubbles are visible, move on to the next step.
22) Carefully dry the tube with a dry rag, and weigh it again. Record this value, along with any observations on residue appearance (color, debris, etc.).
23) Repeat this procedure for each test tube.

1.15.4. EXAMPLE OF CALCULATIONS

Original tube weight: 11.963 g

Tube with oil & working fluid (1/2 full): 19.956 g

Tube with residual oil only: 12.242 g

Weight of oil: (tube with residual oil only – original tube weight) = 0..279 g

Weight of the working fluid/oil solution: (Tube with oil & working fluid – original weight) = 7.933 g

Calculating the percentage oil:

$$\%\ oil = \frac{(\text{mass of oil})}{(\text{mass of working fluid} + \text{oil solution})} \times 100\%$$

For this case we have:

$$\frac{0.279\text{g}}{7.933\text{g}} * 100\% \ = \ 3.5\%\ \text{oil by mass}$$

Calculate the average of the four tubes.

If oil concentration is less than 1%, consult ElectraTherm Service for instructions on adding oil.

1.16. Compressed Air System

The air compressor provides air at 90 psig (7.6 barg) to actuate the bypass and blocking valves. The compressed air system includes a solenoid valve to purge water from the air tank. This valve actuates automatically every 24 hours. This system is rated for the life of the Green Machine, assuming normal operating cycles.

1) Manually actuate the purge valve using the function on the test screen. Allow the air pressure to drop low enough that it triggers the HMI alarm for low air pressure.
2) While the purge valve is open, observe the air pressure, (gauge indicated in Figure 1.16-1) in the tank. The compressor should switch on below 70 psig (4.7 barg).
3) Allow the valve to close. The compressor should shut off at 90 psig (6.2 barg). If it does not, contact ElectraTherm for adjustment instructions.
4) Check the Preslok fittings and verify that the tubing is held firmly and sealed.
5) Check the tubing for signs of abrasion or heat damage.
6) Using liquid leak detector, check the fittings on the air system for leaks.

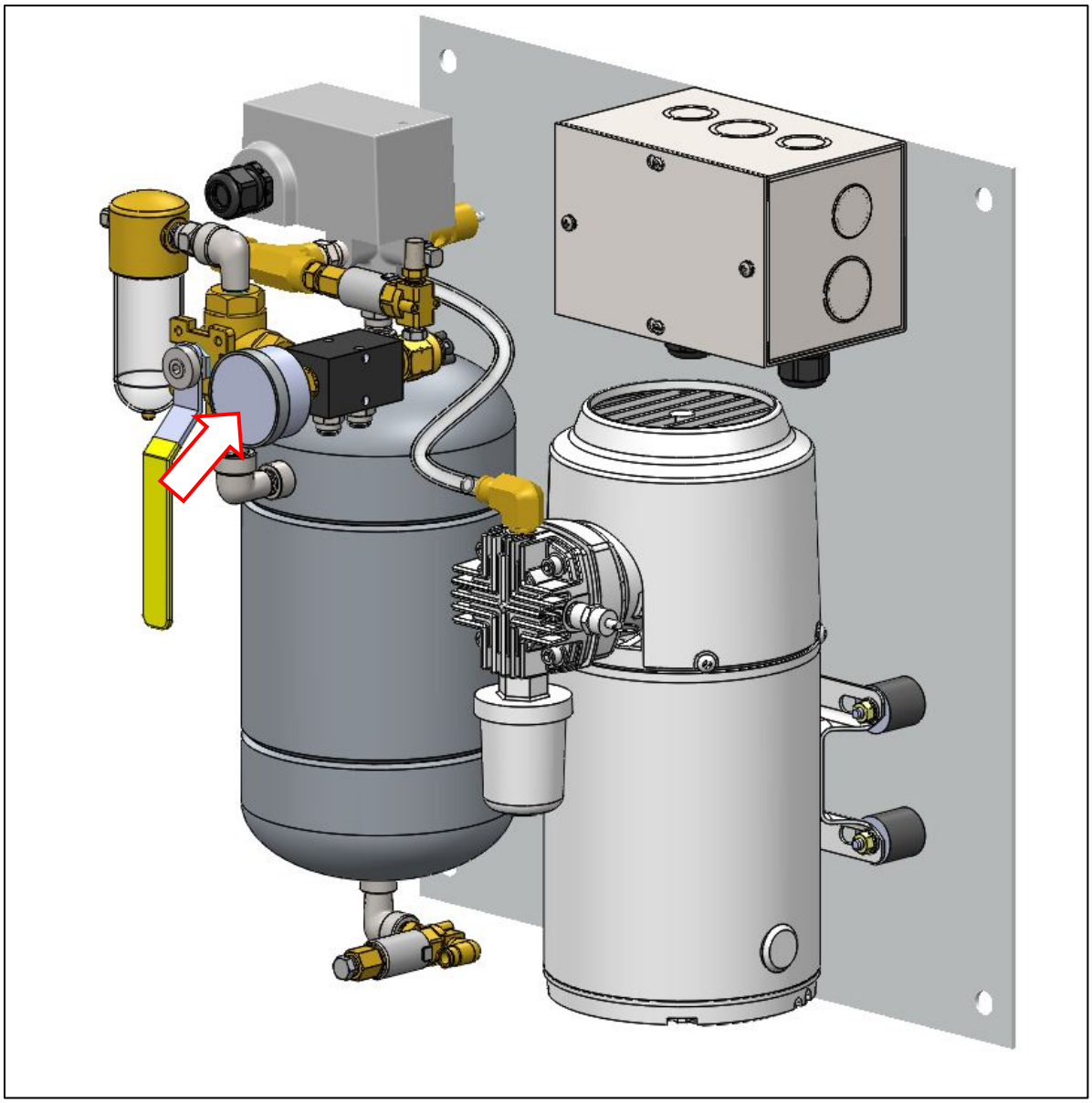

FIGURE 1.16-1: AIR COMPRESSOR ASSEMBLY

1.17. Safety and Warning Indicators

This procedure provides guidance through a thorough test of all user inputs to the machine. If any of these controls fail to operate as specified, follow appropriate troubleshooting steps or contact ElectraTherm Customer Service.

1) With the Green Machine powered off and the disconnect switch open, test all of the buttons on the control pendant (Figure 1.17-1) to confirm that they operate smoothly.
2) Verify that all safety stickers are in place and visible as required per local code and regulation.
3) Turn power on, and start the Green Machine as normal.

1.17.1. LIGHT AND BUTTON TEST

4) With the Green Machine running [green indicator light on], stop it using the red STOP button on the panel (not the HMI). The green light will turn off, and once the Green Machine is ready to restart the red indicator will light.
5) Start the Green Machine using the green START button on the panel (not the HMI). The red light will go out, and the amber indicator will begin flashing. When all startup conditions are met (water temperatures, flows, etc.), the amber light will turn solid on during actual startup. When the Green Machine goes on grid, the amber indicator will turn off, and the green light will turn on.

1.17.2. EMERGENCY SYSTEMS TEST

6) Stop the Green Machine using the E-STOP button. Verify that this button latches in and trips the MCR, and that the GM cannot be restarted. All indicator lights should turn off, and the C-more screen will show an alarm that the MCR is off.
7) Reset the E-STOP button. All lights should stay off, and the GM should not be able to start.
8) Use the black POWER ON button to reset the MCR. The red indicator light should turn on, and the C-more alarm should clear. The GM is now ready for restart.

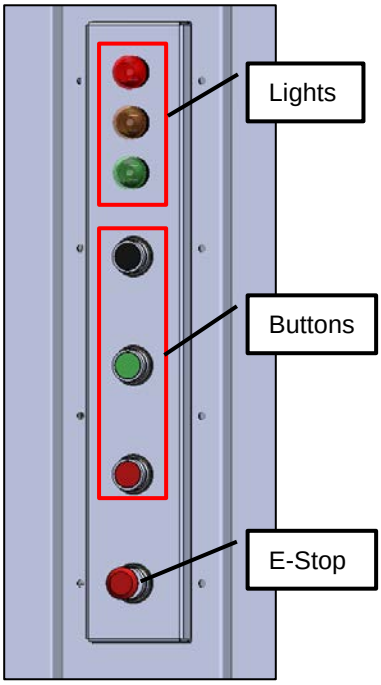

FIGURE 1.17-1: CONTROL PENDANT

1.18. Pressure Relief Valves

There are two ASHRAE-approved pressure relief valves (PRVs) installed on a 3-way dual shutoff safety valve on top of the working fluid tank. ElectraTherm requires replacement of these valves every 2 years. If local codes specify a more frequent replacement interval, this must be observed. The PRVs are rated for 150 psig (10.3 barg). If either valve releases, it must be immediately replaced.

1) Remove the valve stem cap [A] on the 3-way valve.
2) Turn the valve counter-clockwise to close the near PRV (Figure 1.18-1, [B]).
3) Unthread the union [C], and carefully remove the PRV from the manifold [D]. Some residual pressure may be present. Discard the PRV, and replace it.
4) Once the first PRV is tightly reinstalled, turn the valve fully clockwise, and replace the other PRV as in Step 2.
5) Return the valve to a full counter-clockwise position and replace the valve stem cap.

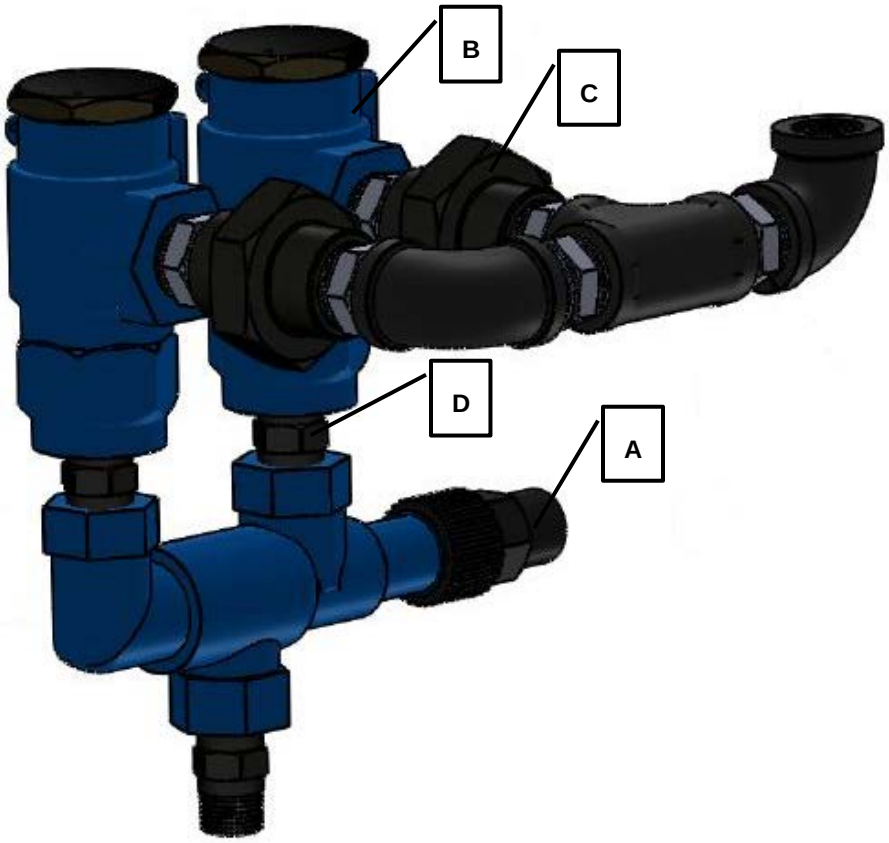

FIGURE 1.18-1: PRV ASSEMBLY

1.19. Batteries

The PLC and the HMI both use a standard CR2354 type battery to store their programming when power is lost.

1.19.1. HMI

1) Lock out the hot and cold water supplies.
2) Ensure that the GM has power from the grid. DO NOT shut off the electrical when replacing the battery. This will erase the operating software, requiring reinstall by ElectraTherm Service personnel.

DANGER: Exposed line voltages are present inside the power cabinet, and in the control cabinet, whenever the machine is energized. Electrical service must only be done by qualified personnel.

3) Open the power panel with the cabinet key and press the release latch on the base of the disconnect switch indicated in Figure 1.19-1. Use a pencil or piece of wire to press the recessed button.

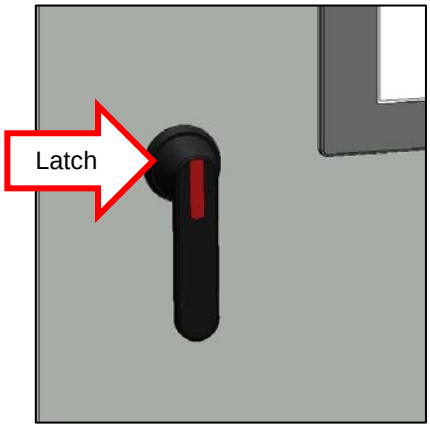

FIGURE 1.19-1: MAIN DISCONNECT LATCH

4) The C-more battery is located below and to the left of the DC power connector (Figure 1.19-2).

5) Open the battery door and remove the battery using the slot in the door to pry it out (Figure 1.19-3).

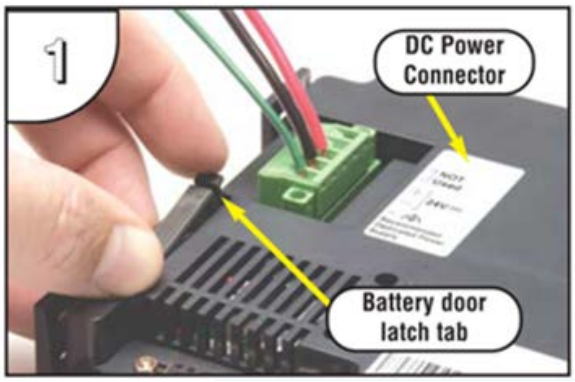

FIGURE 1.19-2: OPEN BATTERY DOOR

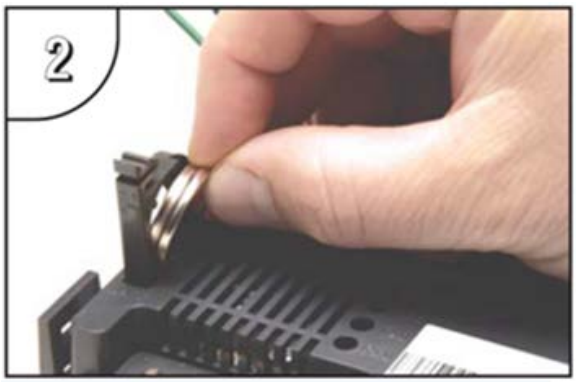

FIGURE 1.19-3: REMOVE BATTERY

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6) Insert the new battery with the positive (+) side to the right. Set the battery inside the retainer tab (Figure 1.19-4), and press the top in to the holder.

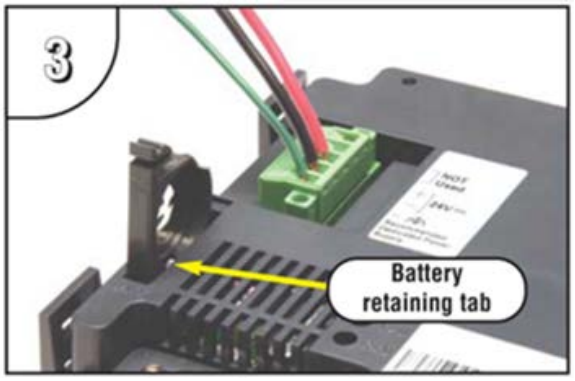

FIGURE 1.19-4: RETAINING TAB

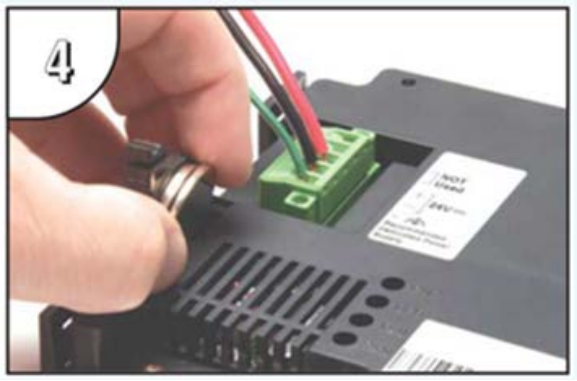

FIGURE 1.19-5: INSERT BATTERY

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7) Close the battery holder, making sure that the latch tab locks in place.

8) If the C-more date and time are incorrect following battery replacement, contact your local distributor or ElectraTherm Customer Service.

1.19.2. PLC

1) Locate the CPU card on PLC Rack 0, shown in Figure 1.19-6.

2) Release the retaining clip and open the battery holder. (Figure 1.19-7)

3) Remove the old battery and install the new one with the positive (+) side to the right.

4) Close the battery door. Make sure the tab locks securely in place.

FIGURE 1.19-6: PLC CPU MODULE

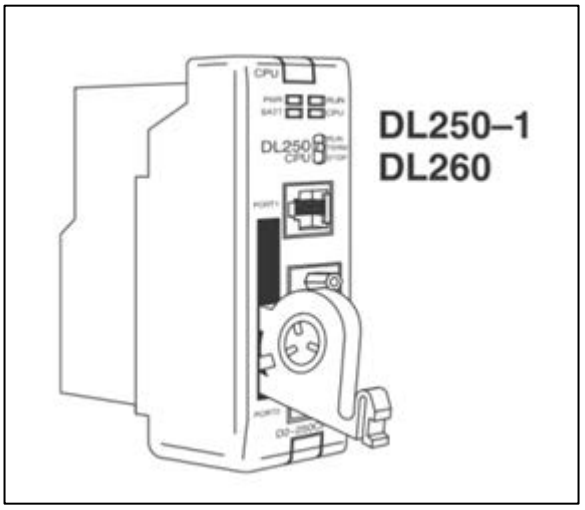

FIGURE 1.19-7: BATTERY HOLDER

1.20. Howden Expander

The Howden expander requires a factory rebuild to replace bearings and seals. This process will be conducted through a core exchange program. As you near the specified maintenance interval, contact ElectraTherm Customer Service to arrange shipment of a replacement expander to your site. Once that expander arrives, swap out the expanders using the procedure below, and return the old expander for a refund of your core charge.

DANGER: Be aware that even though the Green Machine may be disconnected and locked out, the expander and generator can still spin without warning. This is caused by a change in temperature and/or pressure within the machine. Take special care when the belt shroud is removed while performing maintenance.

DANGER: Discharge of a large volume of working fluid in an enclosed space may displace oxygen and lead to asphyxiation. Conduct this procedure with adequate ventilation and avoid inhalation of working fluid vapors. Do not loosen any flanges until the working fluid has been recovered to the receiver tank or an external vessel.

1.20.1. WORKING FLUID RECOVERY

Before disconnecting the expander, the working fluid must be isolated in the receiver tank. This procedure will require several hours to complete, although most of it will not require regular monitoring.

1) Lock out and isolate all energy sources for the green machine. This usually includes electrical, hot water flow, and cold water flow or the ACC electrical.
2) Begin the working fluid recovery procedure detailed in Section 5.7. Isolating the working fluid in the tank will take several hours.
3) Follow the procedure in Section 1.4 to remove the belt shroud. Before removing the belt, measure and record the belt tension. Then remove the belt.
4) Remove the expander pulley by unscrewing the two bolts on the face. Insert the bolt in the third hole and tighten it until the outer pulley has dislodged itself from the taper lock.

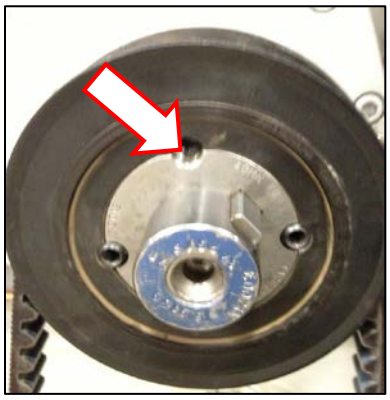

FIGURE 1.20-1: EXPANDER PULLEY REMOVAL

5) Remove the taper lock from the shaft. It will be necessary to insert a wedge into the slot on the taper lock to spread it so it will slide off the shaft. Remove the pulley once the taper lock is off.

CAUTION: Do not proceed with the next steps until the working fluid is isolated in the tank! A very expensive and hazardous loss of working fluid will occur if either WF isolation valve is open.

1.20.2. EXPANDER REMOVAL

Once the working fluid has been isolated, the expander can be disconnected and removed.

6) Disconnect the front lubrication line, leaving all adapters installed in the expander housing.
7) Do the same with the rear lubrication line.
8) Unplug and remove the expander rear temperature RTD from the housing.
9) Remove the oil drain tube from the brass fitting, and remove the fitting from the housing.

10) Install a support for the low pressure pipe. Disconnecting this pipe from the expander without supporting it may cause damage to the working fluid piping or condenser pack (if equipped).
11) Unbolt the low pressure flange from the expander housing. Be careful not to lose the gasket.
12) Unbolt the high pressure flange from the expander housing. Be careful not to lose the gasket.
13) Unbolt the expander from the table.
14) The expander weighs over 500 lb (227 kg). Use an appropriate lifting device to remove the expander from the Green Machine.

CAUTION: When moving the expander, be very careful to avoid damaging the copper lubrication lines.

15) Installation of the new expander is the reverse of removal.
16) Putting a small amount of oil on the table before installing the new expander can make it much easier to adjust the placement.
17) Install the expander mounting bolts loose.
18) Reattach both flanges to the expander. Be sure to install the gaskets on the flange faces. Hand-tighten the flange bolts.
19) Torque the mounting bolts first. Torque specifications can be found in Table 1.3-1.
20) After the expander is torqued to the table, torque the flanges to the expander housing.
21) Reinstall the front and rear lubrication lines, the rear housing RTD, and the snout drain tube.
22) Following the procedure in Chapter 5, begin pumping the system down to a vacuum for leak testing.
23) Reinstall the taper lock on the expander. A small wedge (like a screwdriver) will be necessary to spread the taper lock so it fits on the shaft.
24) Install and align the pulley using an appropriate pulley alignment technique.
25) Reinstall the belt and shroud using the procedure in Section 2.15 of the manual. Tension the belt to its previous value.
26) Before releasing the working fluid back to the system, perform pressure and vacuum tests to check for leaks, as described in Chapter 5.

CAUTION: Failure to test for leaks and verify system integrity could lead to a costly loss of working fluid.

27) Contact ElectraTherm Customer Service to coordinate the return of the old expander and refund of the core charge.

1.21. VFD Cooling Fan

The cooling fan in the ABB ACS355 VFD is rated for 3 years of service. Replace the fan using the following procedure.

1) Shut off the power panel and open the disconnect switch.
2) Locate the VFD in the power cabinet.
3) Wait for all of the lights on the VFD to turn off, indicating that the capacitor has discharged.

CAUTION: The VFD contains large capacitors that present a significant electrical hazard. Ensure they are discharged before servicing the drive.

4) Lever the fan holder out of the VFD housing using a screwdriver [A].
5) Tilt the fan holder up to disengage the back hinge [B].
6) Free the fan wire from the clip [C], and unplug it [D].

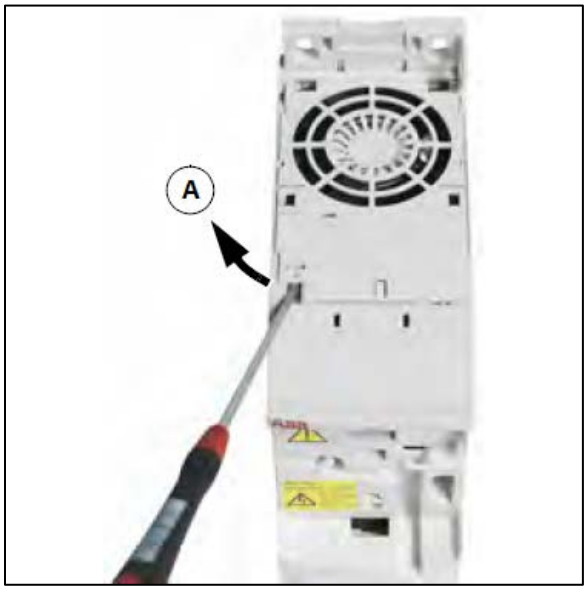

FIGURE 1.21-1: VFD HOUSING

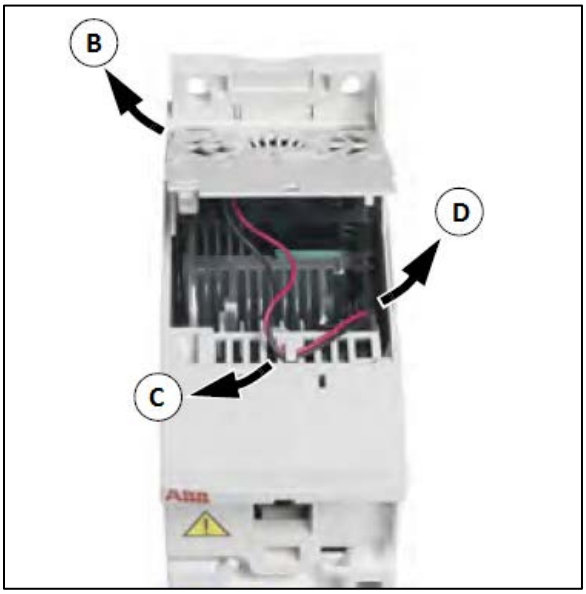

FIGURE 1.21-2: FAN CONNECTION

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7) Install the new fan at an angle to engage the back hinge [B].

FIGURE 1.21-3: REPLACEMENT FAN

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8) Slide the fan wire under the clip [C], and plug it in [D].
9) Lower the fan into the housing. Be careful to avoid pinching the wire.
10) When the fan is properly seated, press down on the cover (A) to snap it into place.

APPENDIX A: MAINTENANCE SCHEDULE

MAINTENANCE INTERVAL: 2200 HOURS (3 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
MAINTENANCE INTERVAL: 4400 HOURS (6 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Gates 20mm belt replacement	See Section 5.7.
		Inspect and grease generator bearings	Grease at scheduled interval or after 6+ months idle. See Section 5.8.
		Clean cabinet filters, verify fan operation	See Section 5.9
		Inspect for electrical wear/damage	See Section 5.10
MAINTENANCE INTERVAL: 6600 HOURS (9 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6

MAINTENANCE INTERVAL: 8800 HOURS (12 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Gates 20mm belt replacement	See Section 5.7.
		Inspect and grease generator bearings	Grease at scheduled interval or after 6+ months idle. See Section 5.8.
		Clean cabinet filters, verify fan operation	See Section 5.9
		Inspect for electrical wear/damage	See Section 5.10
		Check HX water-side pressure difference	See Section 5.11
		Test working fluid acidity	See Section 5.12
		Check for non- condensable gases (NCGs)	See Section 5.13
		Clean enclosure	See Section 5.14
		Test oil concentration	See Section 5.15
		Check operation of compressed air system	See Section 5.16
		Verify operability of safety equipment (buttons, lights, labels)	See Section 5.17
MAINTENANCE INTERVAL: 11000 HOURS (15 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6

MAINTENANCE INTERVAL: 13200 HOURS (18 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Gates 20mm belt replacement	See Section 5.7.
		Inspect and grease generator bearings	Grease at scheduled interval or after 6+ months idle. See Section 5.8.
		Clean cabinet filters, verify fan operation	See Section 5.9
		Inspect for electrical wear/damage	See Section 5.10
MAINTENANCE INTERVAL: 15400 HOURS (21 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6

MAINTENANCE INTERVAL: 17600 HOURS (24 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Gates 20mm belt replacement	See Section 5.7.
		Inspect and grease generator bearings	Grease at scheduled interval or after 6+ months idle. See Section 5.8.
		Clean cabinet filters, verify fan operation	See Section 5.9
		Inspect for electrical wear/damage	See Section 5.10
		Check HX water-side pressure difference	See Section 5.11
		Test working fluid acidity	See Section 5.12
		Check for non- condensable gases (NCGs)	See Section 5.13
		Clean enclosure	See Section 5.14
		Test oil concentration	See Section 5.15
		Check operation of compressed air system	See Section 5.16
		Verify operability of safety equipment (buttons, lights, labels)	See Section 5.17
		Replace PRVs	May require more frequent replacement. See Section 5.18
		Replace PLC and HMI batteries	See Section 5.19
MAINTENANCE INTERVAL: 19800 HOURS (27 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Howden expander rebuild	Contact ElectraTherm Customer Service to schedule. See Section 5.20

MAINTENANCE INTERVAL: 22000 HOURS (30 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Gates 20mm belt replacement	See Section 5.7.
		Inspect and grease generator bearings	Grease at scheduled interval or after 6+ months idle. See Section 5.8.
		Clean cabinet filters, verify fan operation	See Section 5.9
		Inspect for electrical wear/damage	See Section 5.10
MAINTENANCE INTERVAL: 24200 HOURS (33 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6

MAINTENANCE INTERVAL: 26400 HOURS (36 MONTHS)			
DATE	HOURS	DESCRIPTION	DETAILS
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Gates 20mm belt replacement	See Section 5.7.
		Inspect and grease generator bearings	Grease at scheduled interval or after 6+ months idle. See Section 5.8.
		Clean cabinet filters, verify fan operation	See Section 5.9
		Inspect for electrical wear/damage	See Section 5.10
		Check HX water-side pressure difference	See Section 5.11
		Test working fluid acidity	See Section 5.12
		Check for non- condensable gases (NCGs)	See Section 5.13
		Clean enclosure	See Section 5.14
		Test oil concentration	See Section 5.15
		Check operation of compressed air system	See Section 5.16
		Verify operability of safety equipment (buttons, lights, labels)	See Section 5.17
		Replace VFD internal cooling fan	See Section 5.21
MAINTENANCE INTERVAL: 28600 HOURS (39 MONTHS)			
DATE	HOURS	DESCRIPTION	DETAILS
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6

MAINTENANCE INTERVAL: 30800 HOURS (42 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Gates 20mm belt replacement	See Section 5.7.
		Inspect and grease generator bearings	Grease at scheduled interval or after 6+ months idle. See Section 5.8.
		Clean cabinet filters, verify fan operation	See Section 5.9
		Inspect for electrical wear/damage	See Section 5.10
MAINTENANCE INTERVAL: 33000 HOURS (45 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6

MAINTENANCE INTERVAL: 35200 HOURS (48 MONTHS)			
DATE	HOURS	DESCRIPTION	DETAILS
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Gates 20mm belt replacement	See Section 5.7.
		Inspect and grease generator bearings	Grease at scheduled interval or after 6+ months idle. See Section 5.8.
		Clean cabinet filters, verify fan operation	See Section 5.9
		Inspect for electrical wear/damage	See Section 5.10
		Check HX water-side pressure difference	See Section 5.11
		Test working fluid acidity	See Section 5.12
		Check for non-condensable gases (NCGs)	See Section 5.13
		Clean enclosure	See Section 5.14
		Test oil concentration	See Section 5.15
		Check operation of compressed air system	See Section 5.16
		Verify operability of safety equipment (buttons, lights, labels)	See Section 5.17
		Replace PRVs	May require more frequent replacement. See Section 5.18
		Replace PLC and HMI batteries	See Section 5.19
MAINTENANCE INTERVAL: 37400 HOURS (51 MONTHS)			
DATE	HOURS	DESCRIPTION	DETAILS
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6

MAINTENANCE INTERVAL: 39600 HOURS (54 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Gates 20mm belt replacement	See Section 5.7.
		Inspect and grease generator bearings	Grease at scheduled interval or after 6+ months idle. See Section 5.8.
		Clean cabinet filters, verify fan operation	See Section 5.9
		Inspect for electrical wear/damage	See Section 5.10
MAINTENANCE INTERVAL: 41800 HOURS (57 MONTHS)			
DATE	**HOURS**	**DESCRIPTION**	**DETAILS**
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6

MAINTENANCE INTERVAL: 44000 HOURS (60 MONTHS)			
DATE	HOURS	DESCRIPTION	DETAILS
		Inspect all plumbing, flanges, and valves for leaks	See Section 5.2
		Inspect hardware for wear/damage	See Section 5.3
		Gates 20mm belt tension/inspection	See Section 5.4
		Check oil drain catch bottle	See Section 5.5
		Grease pump motor bearings	See Section 5.6
		Gates 20mm belt replacement	See Section 5.7.
		Inspect and grease generator bearings	Grease at scheduled interval or after 6+ months idle. See Section 5.8.
		Clean cabinet filters, verify fan operation	See Section 5.9
		Inspect for electrical wear/damage	See Section 5.10
		Check HX water-side pressure drop	See Section 5.11
		Test working fluid acidity	See Section 5.12
		Check for non-compressible gases (NCGs)	See Section 5.13
		Clean enclosure	See Section 5.14
		Test oil concentration	See Section 5.15
		Check operation of compressed air system	See Section 5.16
		Verify operability of safety equipment (buttons, lights, labels)	See Section 5.17

Appendix B: Maintenance Checklist

SUBMIT TO ELECTRATHERM CUSTOMER SERVICE AT EACH SPECIFIED MAINTENANCE INTERVAL: CSM@ELECTRATHERM.COM				
GM SERIAL #:		DATE:		MAINTENANCE INTERVAL:
MAINTENANCE INTERVAL (HOURS)	MAINTENANCE ITEM	COMPLETE		NOTES
		DATE	INITIALS	
2200	Gates 20mm belt tension/inspection			
2200	Inspect all plumbing, flanges, and valves for leaks			
2200	Inspect hardware for wear/damage			
2200	Grease pump motor bearings			
2200	Check oil catch bottle			
4400	Gates 20mm belt replacement			
4400	Clean cabinet filters, verify fan operation			
4400	Inspect for electrical wear/damage			
4400	Grease & inspect generator bearings			
8800	Check HX water-side pressure drop			
8800	Test working fluid acidity			
8800	Check for non-compressible gases (NCGs)			
8800	Clean enclosure			
8800	Test oil concentration			
8800	Check operation of compressed air system			
8800	Verify operability of safety equipment (buttons, lights, labels)			
17600	Replace PRVs			
17600	Replace PLC and HMI batteries			
19800	Howden expander rebuild			
26400	Replace VFD internal cooling fan			
Technician Name and Signature				