

DEL OZONE QUANTUM™

CD SERIES OZONE GENERATORS OWNER'S MANUAL



Shown: CD-400F

EPA Estab. No. 071472-CA-001

Table of Contents

| | |
|--|-----------|
| SECTION 1. General Information | 1 |
| 1A. Ozone Application | 1 |
| 1B. Ozone Generator Overview..... | 1 |
| 1C. Warranty Summary | 1 |
| SECTION 2. Installation..... | 3 |
| 2A. System Overview | 3 |
| 2B. Unpacking and Inspection | 3 |
| 2C. Location | 3 |
| 2D. Transportation..... | 3 |
| 2E. Mounting..... | 3 |
| 2F. Connections..... | 3 |
| 2G. User I/O Panel | 4 |
| 2H. Pre-Commissioning Checklist..... | 7 |
| SECTION 3. Commissioning..... | 7 |
| 3A. Ozone Generator Check..... | 7 |
| 3B. Support Systems Check | 7 |
| 3C. Initial Start-Up | 7 |
| 3D. Supply Voltage Check..... | 8 |
| 3E. Vacuum Regulator Check | 8 |
| 3F. External Control Check..... | 8 |
| 3G. Ready for Normal Operation | 8 |
| SECTION 4. operation | 8 |
| 4A. System Overview | 8 |
| 4B. System Power Up | 11 |
| 4C. System States | 11 |
| SECTION 5. Maintenance & Service | 13 |
| 5A. Preventative Maintenance Schedule | 13 |
| 5B. Electrode and Ground Tube Cleaning – Module in Place | 13 |
| 5C. Ozone and Module Inspection and Service | 14 |
| 5D. Air Filter Cleaning | 16 |
| 5E. Oxygen Filter Cleaning | 17 |
| 5F. Replacement Parts and Order Information | 18 |
| 5G. Standard Replacement Parts List | 18 |


Table of Contents

| | |
|---|-----------|
| SECTION 6. Troubleshooting | 19 |
| 6A. System will not start..... | 19 |
| 6B. Low Ozone Output | 19 |
| 6C. Module Current Does Not Correspond to Power Setting | 19 |
| 6D. Fault Message: BFPD | 19 |
| 6E. Fault Message: LOW O2 PRESSURE..... | 20 |
| 6F. Fault Message: LOW O2 %..... | 20 |
| 6G. Fault Message: COOLANT TEMP | 20 |
| 6H. Fault Message: LOW COOLANT FLOW | 20 |
| 6I. Fault Message: AMBIENT AIR TEMP | 20 |
| 6J. Fault Message: TRANSFORMER TEMP | 21 |
| 6K. Fault Message: LOW VACUUM | 21 |
| 6L. Fault Message: HIGH VACUUM | 21 |
| 6M. Fault Message: PROCESS FLOW | 21 |
| 6N. Fault Message: AMBIENT OZONE | 22 |
| 6O. Fault Message: 4-20mA SIGNAL LOSS | 22 |
| 6P. Fault Message: INVERTER | 22 |
| 6Q. Fault Message: PHASE LOSS | 22 |
| 6R. System Pauses | 23 |
| SECTION 7. Warranty | 24 |
| APPENDIX | 25 |
| APPENDIX A: OUTPUT CURVES..... | 26 |
| APPENDIX B: SPECIFICATIONS..... | 27 |
| APPENDIX C: PRE-COMMISSIONING CHECKLIST | 28 |
| APPENDIX D: OZONE PROCESS SYSTEM LAYOUT..... | 29 |
| APPENDIX E: SYSTEM/CONTROLS BLOCK DIAGRAM..... | 30 |
| APPENDIX F: WIRING DIAGRAM | 31 |
| APPENDIX G: PLC FUNCTIONAL SPECIFICATION | 33 |
| APPENDIX H: MAINTENANCE LOG SHEET | 47 |
| APPENDIX I: PRESSURE CONVERSION TABLE | 48 |
| APPENDIX J: OPTION -98 INSTALLATION NOTES..... | 49 |
| APPENDIX K: MATERIAL SAFETY DATA SHEETS (MSDS) | 49 |

IMPORTANT SAFETY INSTRUCTIONS

READ AND FOLLOW ALL INSTRUCTIONS

Read this manual completely before attempting installation, operation or servicing.

- Follow all applicable electrical codes.
- A ground terminal marked  is located inside the Control Enclosure near the Main Disconnect. To reduce the risk of electric shock, this terminal must be connected to the grounding means provided in the electrical supply service panel with a continuous copper wire equivalent in size to the circuit conductors supplying this equipment. For Autotransformer equipped models (-98 option), the Control Enclosure Ground Terminal is prewired to the Autotransformer. Make ground connection on the designated Terminal Block inside the Autotransformer.
- Electric shock hazard. Be sure to turn power OFF before servicing. Failure to do so could result in serious injury or death.
- Hazardous voltages may still be present inside cabinet when main disconnect switch is off.
- Do not operate with any panels or covers removed.
- Hazardous levels of ozone may be trapped in the system after a fault condition or when power is turned off during operation. Always ensure ozone has been purged by allowing Ozone Generator to complete its shutdown sequence before servicing.
- Short term inhalation of high concentrations of ozone and long term inhalation of low concentrations of ozone can cause serious harmful physiological effects. DO NOT inhale ozone gas produced by this device. Review MSDS sheets for Gaseous and Aqueous Ozone in Appendix K.
- A spontaneous and violent ignition may occur if oil, grease or contaminants come in contact with oxygen under pressure. Keep these substances away from oxygen regulators, cylinder valves, tubing and connections and all other oxygen equipment.
- Do not store or use gasoline, chemicals or other flammable liquids or vapors near this or any other appliance.

SAVE THESE INSTRUCTIONS

CAUTIONS AND GENERAL NOTES

This manual covers all DEL Ozone Quantum Series Corona Discharge Ozone Generators, Models CD-XX.

Any variations in system operation or configuration between models are noted in the text.

DEL Ozone reserves the right to make changes to the product covered in this manual. Use this manual only with its original product. Although every effort has been made to ensure accuracy of the information contained in this manual, DEL Ozone assumes no responsibility for inadvertent errors.

SECTION 1. General Information

1A. Ozone Application

The Quantum™ Series Ozone Generators described in this manual utilize high voltage corona discharge technology to generate ozone gas in high concentrations. They are designed to operate under vacuum, typically using suction provided by a venturi injector in a side stream of the process flow.

Follow the instructions in this manual carefully to ensure safe and reliable operation of the Ozone Generator.

1B. Ozone Generator Overview

Refer to Figure 1 for an overview of the Ozone Generator and system connections. Labels are provided on the Ozone Generator near selected connections to assist in proper installation.

a. Connections

- i. **Oxygen In-** ½" Female NPT Brass for oxygen supply line.
- ii. **Ozone Out-** ¾" Female NPT Stainless Steel for ozone output line.
- iii. **Coolant In/Coolant Out-** ¾" Female NPT PVC for coolant lines in and out of the Ozone Generator (labeled "Water In" and "Water Out".)
- iv. **Electrical-** Power and Ground Connections are made inside the Control Enclosure. A hole is provided next to Specification Label for a ¾" conduit fitting. For Autotransformer equipped models (-98 option), all electrical connections are made at the Autotransformer. Refer to Instruction Sheet 4-0902-01 in Appendix J.
- v. **User I/O Panel-** Provides terminal blocks for all user control signal connections. A ½" conduit fitting knockout is provided above the panel for control signal wires.

b. Operator Interface

- i. **Operator Interface Panel (OIP)** - The OIP consists of a four line LCD Display to report status, and Function Keys to allow control of Ozone Generator functions. See Section 4 for a complete description of Ozone Generator functionality and control.
- ii. **Oxygen Flowmeter** - Displays the gas flow into the Ozone Generator. Refer to Table 1 for appropriate flow range. (Use Suction Control Valve or Injector By-pass Valve to control flow as described in Section 3.)
- iii. **Coolant Flowmeter** - Displays the coolant flow through the Ozone Generator in gallons per minute (GPM). Make fine adjustments to the cooling water flow by adjusting the ball valve mounted on the Ozone Generator. Recommended flow rates for each model are shown on the Specification Drawings within Appendix B.
- iv. **Vacuum Regulator** - The Vacuum Regulator is factory set to provide optimal control over a wide vacuum range and **does not require adjustment**. Do not adjust unless directed to do so by DEL Ozone.
- v. **Disconnect Switch** - The Disconnect Switch toggles power to the Ozone Generator. When turned to the ON position, the OIP will initiate and system Fans will start up. For user safety, the Control Enclosure door will not open until the Disconnect Switch is turned to the OFF position.

Important – The Disconnect Switch may also be used as an emergency stop switch.

1C. Warranty Summary

- i. Two (2) years on entire Ozone Generator.
- ii. Three (3) years on High Voltage Electrodes
- iii. To prevent voiding warranty, follow all installation instructions and ensure that an authorized DEL technician has commissioned the unit prior to first start-up. After commissioning, the end user is responsible for all routine maintenance outlined in Section 5 of this manual.
- iv. For complete Warranty details see Section 7 of this manual.
- v. Extended Warranty and Service Agreements are available. Please contact DEL Ozone Warrent Department for quotes.

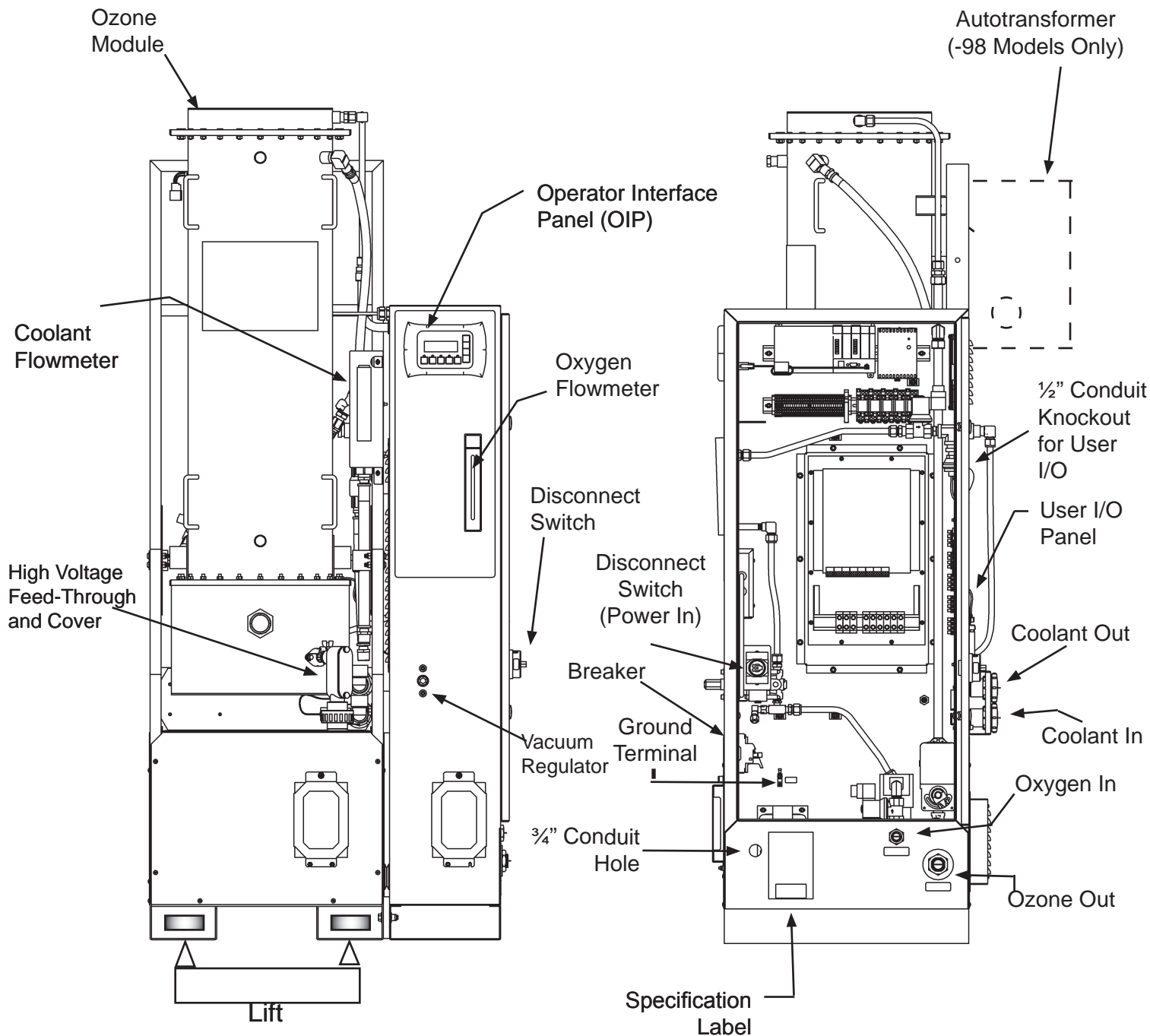


Figure 1. Quantum™ Ozone Generator Overview
(CD-400 F Shown)

| Model Number | Voltage | Number of Modules | Autotransformer |
|--------------|---------------------------|-------------------|-----------------|
| CD-250F | 207-253 VAC, 50/60 Hz, 3Ø | 1 | No |
| CD-250F-98 | 360-440 VAC, 50 Hz, 3Ø | 1 | Yes |
| CD-400F | 432-528 VAC, 50/60 Hz, 3Ø | 1 | No |
| CD-400F-98 | 360-440 VAC, 50 Hz, 3Ø | 1 | Yes |
| CD-800F | 432-528 VAC, 50/60 Hz, 3Ø | 2 | No |
| CD-800F-98 | 360-440 VAC, 50 Hz, 3Ø | 2 | Yes |
| CD-1200F | 432-528 VAC, 50/60 Hz, 3Ø | 3 | No |
| CD-1200F-98 | 360-440 VAC, 50 Hz, 3Ø | 3 | Yes |

Table 1. Model Number Identification

SECTION 2. Installation

2A. System Overview

Quantum™ series Ozone Generators accept externally supplied oxygen (O_2) under pressure and transition the gas to vacuum prior to ozone (O_3) generation.

Vacuum is typically provided by a venturi injector installed directly (within a Bypass manifold) in the process flow or in a side stream of the process flow (see Typical Ozone Delivery System Overview Diagram in Appendix C.) The injector “pulls” the ozone into the water flow, wherein a high percentage of the gas is dissolved. Note that the process water is not treated *within* the Ozone Generator, although the process water may be used for coolant in some cases.

The ozone/water mixture then moves to the Contact Tank or Mixing Tower giving the ozone time to react with impurities. Excess gas (high in ozone concentration) leaves the top of the Contact Tank through a Degas Valve and moves to an Ozone Destruct. The Ozone Destruct catalytically converts the excess ozone back to oxygen so it can be safely exhausted.

Each of the system components has its own installation instructions and maintenance requirements that must be followed closely for safe operation of the ozone system. The Sections below describe the connections made directly to the Ozone Generator and may refer to these other system components as needed.

2B. Unpacking and Inspection

- a. Upon receipt, remove all crate panels and inspect Ozone Generator for evidence of shipping damage. **Immediately report any damage to the shipping company.**
- b. Remove bolts and crate material securing the Ozone Generator to the bottom of the crate.

2C. Location

- a. Mount Ozone Generator indoors only. Location should be cool, clean and dry.
- b. Recommended Clearances
 - i. Ceiling clearance of 48 inches above the Ozone Generator will allow servicing of the High Voltage Electrodes without Ozone Module removal.
 - ii. Clearance of approximately 6 inches behind the unit and 30 inches in front is required for full tilting of the Ozone Module.
 - iii. 21 inches of clearance to the right of the unit allows full swing of the Enclosure Door.
- c. Ambient Temp – Mount Ozone Generator in a climate-controlled location. Area must not exceed 100°F with Generator operating at full capacity.

2D. Transportation

- a. Whenever possible, lift and move the Ozone Generator with lifting forks inside of the Ozone Module Base Channels. If necessary, the unit may also be lifted in between Channels or using the Shipping Crate pallet.

2E. Mounting

- a. Prepare the mounting surface and install appropriate anchor hardware.
- b. Mount using a minimum of 2 hold-down bolts in front and 2 in back, through the ½” bolt clearance holes in the Module Base Channels. The four holes in the Enclosure base are optional.
- c. Observe the recommended clearances in Section 2C where possible.


2F. Connections

- a. **Oxygen-** ½” Female NPT Brass. Connect external oxygen supply at the pressure and concentration shown in Table 1.
- b. **Ozone-** ¾” Female NPT Stainless Steel. Connect vacuum source (injector) from Process Line. Use only properly sized Stainless Steel or rigid Teflon® tubing. Install ozone compatible Suction Control Valve and Check Valve near the injector as shown in System Diagram (see Appendix C.)

Note: Use appropriate oxygen-safe grease on Stainless Steel pipe threads to avoid galling.

- c. **Coolant-** ¾” Female NPT PVC. Connect coolant line into and out of the Ozone Generator. Use only clean, filtered and non-corrosive coolant at the flows and pressures shown in Appendix B.

d. **Electrical**

- i. For units **without** Autotransformers, connect power conductors directly to the bottom terminals of the Disconnect Switch inside the Control Enclosure. Connect earth ground conductor to the Ground Terminal (identified by the  symbol.) Run wires through appropriate 3/4" conduit fitting installed in the hole next to the Specification Label.
- ii. For Autotransformer equipped models (-98 option), all electrical connections including ground are made at the Autotransformer. **Do not modify wiring within the Control Enclosure.** Refer to the Instruction sheet 4-0902-01 for further details.

CAUTION – Potentially lethal voltages. All electrical connections must be made by a licensed electrician. Follow all applicable local and national electrical codes.

2G. User I/O Panel

See Figure 2 for an overview of the User I/O Panel.

The User I/O Panel is located on the back wall inside the Control Enclosure. Signal wires may be run through the 1/2" conduit fitting knockout provided just above the Panel.

Note: Remove existing jumpers as needed to install Control Signals. Jumpers must be left in place for unused Relay Input signals.

a. **Relay Inputs**

The first six inputs (starting from the top) are Relay Input connections. All connections should be made so that a **closed contact indicates normal operation** (open contact indicates fault condition.) For example, use the Normally Open contacts from a Flow Switch so that sufficient water flow closes the switch.

Relay Input signals will affect Ozone Generator operation differently depending on the type of Input and the current State of the Ozone Generator. See Section 4 for a complete description of States and Ozone Generator Operation.

External (customer supplied) relays and/or switches must meet the following minimum ratings:

| EXTERNAL RELAY MINIMUM RATINGS | |
|--------------------------------|---------|
| VOLTAGE | CURRENT |
| 24 VDC | 100 mA |

Table 2. Electrical Ratings of Relay Inputs

- i. **ORP** – If applicable, connect the signal from an ORP Controller to cycle ozone production on and off based on process demand. If a second ORP input is required, the Stand-By or Stop Inputs may be used depending on the system requirements.
- ii. **Dissolved Ozone** – If applicable, connect the signal from a Dissolved Ozone Controller to cycle ozone production on and off based on process demand.
- iii. **Remote Stand-By** – Connect a switch or relay signal to place the Ozone Generator in Stand-By mode from a remote location. Ozone Generator will not start until Remote Stand-By switch is closed.
- iv. **Remote Stop** – Connect a switch or relay signal to stop the Ozone Generator from a remote location. Ozone Generator will not restart until Remote Stop switch is closed and the Fault is cleared at the Operator Interface Panel.

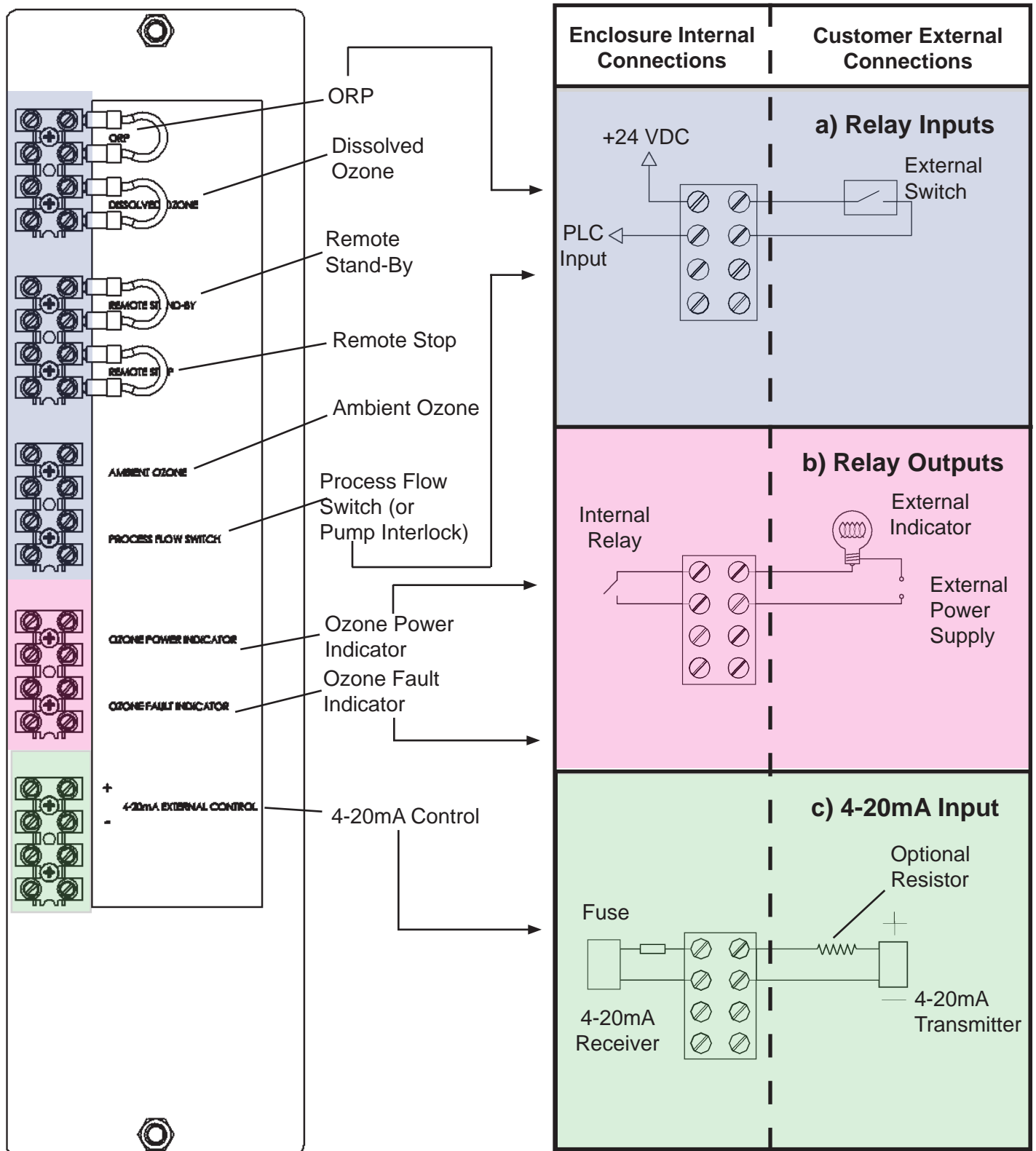


Figure 2. User I/O Panel

2G. User I/O Panel, Cont.

WARNING – For user safety and Ozone Generator protection, Ambient Ozone and Process Flow Switch connections are required. Do not operate Ozone Generator with over-ride jumpers in these locations.

- v. **Ambient Ozone** – Connect signal from Ambient Ozone Monitor to immediately stop ozone production in the event of an ozone leak.
 - vi. **Process Flow Switch** – Install a Water Flow Switch in the Process Line near the ozone Injector. Install and calibrate the switch so that the switch closes only when sufficient water is flowing to generate appropriate vacuum at the Ozone Generator. This will provide optimum protection against water back-flow to the Ozone Generator, as well as fault-avoidance due to vacuum loss during filter backwash.
- b. **Relay Outputs**
Two Relay Outputs are provided to communicate the status of the Ozone Generator. These signals may be run to a remote status display, for example, or connected to local signal lights. **External power is required** and must meet the following ratings:

| RELAY OUTPUT RATINGS | | |
|--|------------------|-----------------|
| | AC | DC |
| MAX RESISTIVE LOAD (p.f. = 1.0) | 10 A at 110 VAC | 10 A at 24 VDC |
| MAX INDUCTIVE LOAD (p.f. = 0.4) | 7.5 A at 110 VAC | 5 A at 24 VDC |
| MAX OPERATING VOLTAGE | 250 VAC | 125 VDC |
| MINIMUM REQUIRED LOAD | --- | 100 mA at 5 VDC |

Table 3. Electrical Ratings of Relay Outputs

- i. **Ozone Power Indicator** – A closed Output Relay indicates ozone production is on.
 - ii. **Ozone Fault Indicator** – An open Output Relay indicates that the Ozone Generator has encountered a Fault condition as described in Section 6 (or has been powered off). Ozone production will cease and user intervention is required.
- c. **4-20mA**
i. A standard 2-wire 4-20 mA input is provided for optional external control of ozone output. Enable the external control function through the Operator Interface Panel (see Section 4A)

4-20mA Input:

| SPECIFICATION | VALUE |
|-----------------|-------------------|
| INPUT IMPEDANCE | 125 Ω |
| MAX CURRENT | 30 mA |
| FUSE RATING | FAST-ACTING 31 mA |

Table 4.1 Electrical Ratings for 4-20 mA External Control Signal

- Connect the 2 wire 4-20 mA signal to the 4-20 mA input + and – terminals on User I/O Panel.
- Use shortest wire route possible.
- Use shielded wire.
- Ground the shield at the transmitter source only.
- Do not* ground the shield at the terminal block input.
- Avoid noise problems by routing cable away from noise sources such as motors, high current switches, transformers and AC wires.

7. The input signal must not exceed a maximum of 30 mA. Install an optional series resistor as needed to match the 4-20 mA transmitter output voltage and impedance to the input impedance.
8. The 4-20 mA signal is interpreted as follows:

| CURRENT (mA) | RESULT |
|--------------|-------------------------------|
| < 4 | SIGNAL LOSS |
| 4 - 20 | 0-100% OZONE POWER |
| 21 - 30 | 100 % OZONE POWER |
| > 30 | MAXIMUM INPUT RATING EXCEEDED |

Table 4.2 Signal for 4-20 mA External Control Signal

2H. Pre-Commissioning Checklist

Upon completing all of the generator system connections outlined in Section 2, complete the PRE-COMMISSIONING CHECKLIST in Appendix B and SEND TO DEL OZONE by fax at 805-541-5452 or e-mail to o3info@delozone.com. Once form has been sent, contact DEL Ozone 805-541-1601 to schedule commissioning.

SECTION 3. Commissioning

Perform commissioning prior to initial start up of Ozone Generator and upon re-starting after service.

Note: If necessary, use the Disconnect Switch to shut down power at any point during Commissioning.

NOTE – Initial commissioning to be performed by Authorized DEL technical **ONLY**.

3A. Ozone Generator Check.

- a. Review Pre-Commissioning Checklist (Appendix B) and correct any non-conformities.
- b. Verify that Ozone Generator is mounted in an appropriate (cool, clean, indoor) location.

3B. Support Systems Check

- a. Start-up Oxygen Preparation system and verify that proper pressure (30psi) is available at the Ozone Generator.
- b. Start-up Cooling system and/or open appropriate cooling line valves.
- c. Start Process circulation system and adjust injector bypass to pull a strong vacuum. The injector should cavitate causing a rattling sound. This is normal.
- d. Verify proper supply voltage at the Ozone Generator.

3C. Initial Start-Up

- a. With the Enclosure Door open, override the disconnect switch by turning the shaft extending from the switch.
- b. Turn on breaker.

DANGER – LETHAL VOLTAGES PRESENT. KEEP UNAUTHORIZED PERSONNEL AWAY FROM ENCLOSURE WHEN DISCONNECT SWITCH IS OVER-RIDDEN.

- c. PLC will automatically run through its start up and begin sequentially verifying sensor inputs in order to proceed.
- d. If applicable, Flow and Vacuum fault messages will appear on the OIP Display. Use Injector Bypass and Suction Control Valve to balance gas flow, DO NOT ADJUST VACUUM REGULATOR. See Section 4 (Operation) or Section 6 (Troubleshooting) for further instructions. Once gas system is adjusted properly, the Ozone Generator will progress to the STOPPED State.

- e. Press F1 to start Ozone Generator. If gas flow is balanced, coolant flow is sufficient and external contacts (ORP, Dissolved Ozone, etc) are closed, the generator will start.
- f. Verify that Ozone Generator Power Level is set to 100% as indicated on the OIP Display.
- g. For multiple Module models, verify proper balance of Oxygen and Coolant flow between Modules. Since balance is pre-set at the factory, only slight adjustments should be necessary.
- h. Check for water leaks in coolant plumbing. Shut down Ozone Generator and fix leaks as required.

3D. Supply Voltage Check

- a. Allow Ozone Generator to warm up for several minutes and re-check supply voltage. If supply voltage is not within specifications, shut down and notify facility manager.
- b. If supply voltage is within specifications, press F2 to stop. Wait for the Ozone Generator to complete its SHUTTING DOWN sequence.
- c. Carefully turn Disconnect Switch back to OFF position.
- d. Close and latch Enclosure Door.

3E. Vacuum Regulator Check

- a. Turn Disconnect Switch back to ON position.
- b. Bring Ozone Generator back to READY State. Ensure that "Oxygen Save Mode" and "Auto Mode" are OFF to allow gas flow (see Section 4.)
- c. Use the Suction Control Valve to choke off vacuum to the Ozone Generator. Verify that the Ozone Generator continues to run when flow drops to approximately 50cfh per module.

3F. External Control Check

- a. From READY State, re-enable Auto Mode (press F3) and press F1 to start ozone production. Verify that ORP/Dissolved ozone level rises. Wait for level to reach set point (or bring set point down) to verify that ozone turns off.
- b. Check other external controls as required.

3G. Ozone Generator is now ready for normal operation. Review Section 4 for details on control system operation and user settings. After start up, the control system will automatically cycle the generator on and off as needed to maintain required ozone level. Initial system start up procedures need to be followed again in the event of a safety interlock system shut down or an interruption in the main power.

SECTION 4. Operation

For first time startup: Perform Commissioning as outlined in Section 3.

4A. System Overview

The Ozone Generator is controlled by a programmable logic controller (PLC). An LCD screen provides user feedback on the status of the Ozone Generator and a keypad allows input of user settings and control of the Ozone Generator.

a. Operator Interface Panel (OIP)

- i. The Operator Interface Panel on the front of the Controls Enclosure consists of a four line LCD display to report essential user information and a keypad to allow control of Ozone Generator functions.
- ii. The OIP has two screen modes: "PLC Message" and "Diagnostics and Settings". Functions and Display information will change with each mode as noted below.

Note: The PLC Message Screen has priority over the Diagnostics and Settings Screen. When an Ozone Generator State change occurs, the display will automatically switch to the PLC Message screen. Press ESC to return to the Diagnostics and Settings Screen.

- b. **PLC Message Screen** - In this mode, the PLC will update the screen with current information about the Ozone Generator's State of operation. The "PLC Message" LED is illuminated when the screen is in this mode. See Table 5 for function of Keys in this mode.

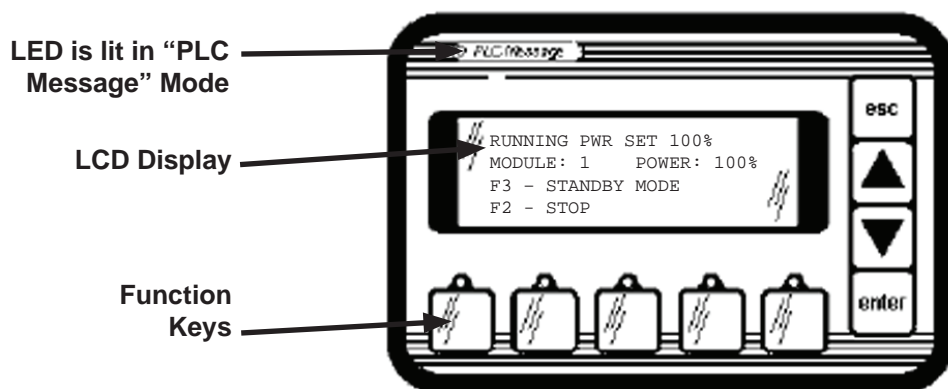


Figure 3a. Typical OIP Display in “PLC Message” Mode

| KEY | FUNCTION |
|---------|---|
| F1 – F5 | SOFT KEYS. FUNCTIONS DEFINED ON SCREEN MENU |
| ESC | SWITCH TO DIAGNOSTICS AND SETTINGS MENU |
| UP/DOWN | NONE |
| ENTER | NONE |

Table 5. Function of OIP Keys in “PLC Message” Mode

- c. **Diagnostics and Settings Menu** - The Diagnostics and Settings menu consists of six main folder items as shown in Figure 3b. Each folder contains user settings or diagnostic information. Use the UP/DOWN arrow keys to scroll to the desired folder and press the ENTER key to open the folder. Use the ESC key to exit a folder. Table 6 describes the key functions in this mode.

| KEY | FUNCTION |
|---------|---|
| F1 – F5 | SOFT KEYS FUNCTION AS DEFINED ON THE CURRENT (ALTHOUGH NOT VISIBLE) PLC MESSAGE SCREEN MENU |
| ESC | EXIT MENU LEVELS OR SWITCH TO PLC MESSAGE MODE |
| UP/DOWN | SCROLL THROUGH MENU AND CHANGE SETTINGS |
| ENTER | ENTER FOLDERS AND EDIT SETTINGS |

Table 6. Function of OIP Keys in “Diagnostics and Settings” Mode

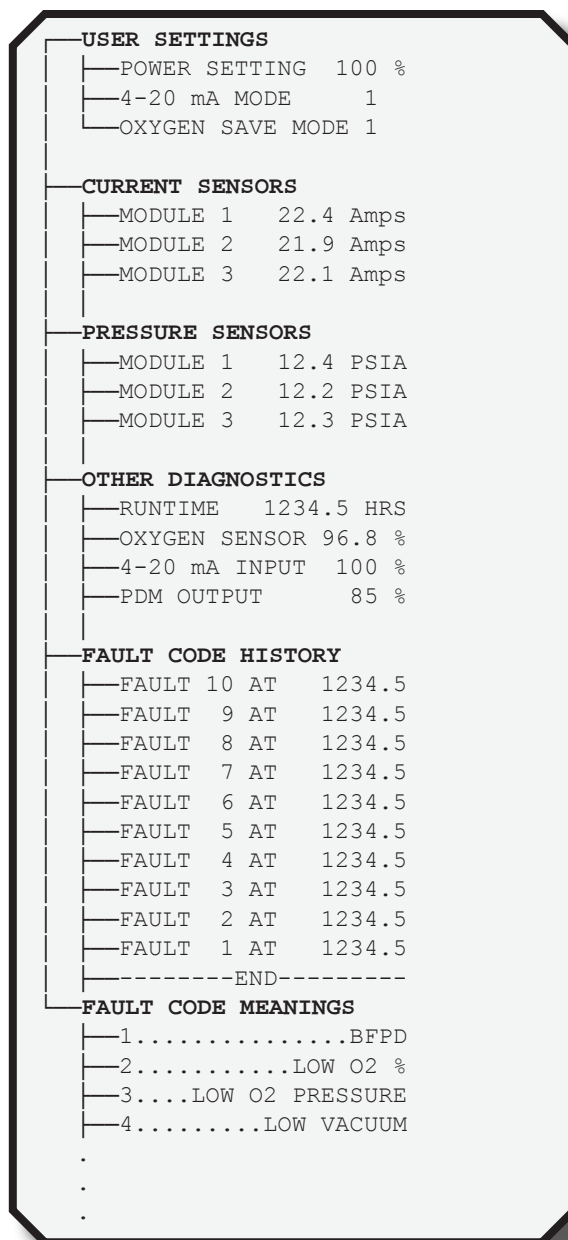


Figure 3b. Diagnostics and Settings Menu Tree

- i. **USER SETTINGS** – This folder contains all available user settings. To change any of these settings:
 - Use the UP/DOWN arrow keys to scroll to the desired setting and press ENTER.
 - Use the UP/DOWN arrow keys to change the setting to the desired value.
 - Press ENTER to complete the change, or ESC to cancel.
 1. **POWER SETTING** – Use Power Setting to scale ozone generation between 0 and 100%. Functions only when 4-20 mA mode is NOT enabled.
 2. **4-20 mA MODE** – This setting may either be ON (setting = 1) or OFF (setting = 0). When this mode is turned on, an external 4-20mA signal will scale ozone generation between 0 and 100%. *Note: If 4-20mA mode is turned on, a fault message will appear unless an appropriate 4-20mA signal is present.*
 3. **OXYGEN SAVE MODE** – This setting may either be ON (setting = 1) or OFF (setting = 0). When this mode is on, gas flow valves will be closed during the READY state. This reduces the duty cycle of the oxygen system, but will result in a delay during restart of ozone production. If this mode is off, oxygen will continue to flow during the READY state and ozone production will begin without delay.
- ii. **CURRENT SENSORS** – This folder contains sensor readings for the electrical current (Amps RMS) being delivered to each Ozone Module. Only installed Modules will be listed, depending on model.

- iii. **PRESSURE SENSORS** – This folder contains sensor readings for the vacuum/pressure in each Ozone Module. Nominal Value is 12.7 PSIA (lb/in² absolute) at Rated Flow. Refer to **Appendix H** for conversion to other units. Only installed Modules will be displayed, depending on model.
- iv. **OTHER DIAGNOSTICS** – This folder contains various other system diagnostic values.
 - 1. **RUNTIME** – Total ozone production time in hours. This timer is only incremented when ozone is on.
 - 2. **OXYGEN SENSOR** – Oxygen feedgas concentration (%).
 - 3. **4-20 mA INPUT** – Input value of the external 4-20 mA signal (%). This will correspond to the desired power level setting if the 4-20 mA mode is used.
 - 4. **PDM OUTPUT** – Percentage to which the system is being driven to achieve the desired output power setting. This value will vary automatically as the system controls the electrical current to the Ozone Modules.
- v. **FAULT CODE HISTORY** – The last 10 fault codes are logged in this folder along with a time stamp. The most recent fault is on top of the list. Refer to the FAULT CODE MEANINGS folder for definition of fault codes.
- vi. **FAULT CODE MEANINGS** – A reference list of the various fault codes and their meanings.

4B. System Power Up

Caution: Before starting the Ozone Generator ensure that:

- ☐ Commissioning has been successfully completed.
 - ☐ All electrical connections are secure and properly installed per applicable electrical codes.
 - ☐ All plumbing connections are secure and no leaks are present.
 - ☐ Breaker inside Control Enclosure is on
 - ☐ Enclosure door is closed
 - ☐ All Ozone Generator covers and panels are in place.
- a. Turn the main disconnect switch to the ON position. The PLC control system and Operator Interface Panel (OIP) will boot up.
 - b. The OIP will perform a self test then show the Welcome Screen. The Welcome screen will pause for 30 seconds while displaying the Model Number and Software revision.
 - c. When the boot sequence is complete, the Ozone Generator will enter the STOPPED State as indicated on the LCD Display.

4C. System States

Control logic is performed through States. Each State has particular menu control choices and specific PLC message screens to display relevant sensor readings and progress information. Responses to input conditions and output behavior are dependant on the current State of the Ozone Generator. For detailed information refer to Appendix F.

- a. **STOPPED**
 - i. Once the OIP has completed its self test and Welcome Screen pause, the Ozone Generator will automatically enter the STOPPED State. The Ozone Generator will remain in this State until a START is initiated by pressing the F1 key. Any interlocks preventing the Ozone Generator from starting are displayed on the screen. Pressing F1 will have no effect until all the interlocks are cleared.
 - ii. When interlocks are cleared and START has been initiated, the Ozone Generator will verify system vacuum, gas flow and oxygen concentration (by incrementally opening Solenoid Valves) through the following three sequential States.
- b. **CHECKING VACUUM**
 - i. If sufficient vacuum is available, the Ozone Generator will proceed to the CHECKING FLOW State.
- c. **CHECKING FLOW**
 - i. If system flow is balanced, the Ozone Generator will proceed to the CHECKING O2% State

d. INSUFFICIENT VACUUM/INSUFFICIENT FLOW

- i. If proper flow conditions are not attained within **2 minutes**, all valves will close as a precaution against water backflow. One of the following messages will appear:
 1. INSUFFICIENT VACUUM if vacuum is too low or not present. Establish proper vacuum to continue.
 2. INSUFFICIENT FLOW if system flow is unbalanced. Correct vacuum and/or oxygen flow to continue.

e. CHECKING O2 %

- i. Once gas flow through the Ozone Generator is balanced, the system will pause to verify that oxygen concentration is steadily greater than 85% for **2 minutes** in order to proceed.
- ii. As long as no other fault occurs, the system will remain in the CHECKING O2% State until correct oxygen concentration is detected.
- iii. Once the above system checks have been completed successfully, the Ozone Generator will proceed to the READY State.

f. READY

- i. Once gas flow and vacuum balancing has been completed, the Ozone Generator will enter the READY State. The system will behave differently in this State depending on previously discussed settings (Section 4A):
 1. If "Oxygen Save Mode" is enabled, all valves will be closed and gas will not flow.
 2. If "Oxygen Save Mode" is disabled, valves will remain open and gas will continue to flow.
- ii. Process Flow Switch – The Ozone Generator may also enter the READY State from the RUNNING State if the Process Flow switch opens. All gas flow valves will be closed and vacuum will be locked in the Ozone Generator. When process flow returns, the generator will resume normal operation.
- iii. AUTO MODE
 1. In the READY State, the F3 key will toggle "AUTO MODE" On/Off.
 2. In AUTO MODE, the Ozone Generator will automatically start or stop ozone production as required by external control signals such as ORP, Dissolved Ozone and Remote Standby. If ORP is high, for example, the Ozone Generator will switch to the READY State (ozone off). When ORP drops it will return to the RUNNING State (ozone on).

g. STARTING

This is a transition State from READY to RUNNING. Gas flow valves are re-opened (if applicable) and the Coolant Valve is opened. If vacuum and flow balance have been maintained and sufficient Coolant flow is detected, the Ozone Generator enters the RUNNING State.

h. RUNNING

In this State, feed gas is flowing, coolant is flowing, and ozone is being produced. Ozone production will continue until input signal(s) indicate no demand for ozone, a fault is encountered or the user presses F2 to STOP.

i. SHUTTING DOWN

In this State, Ozone is off and feed gas flows through the system to purge residual ozone from the module and gas lines. Time remaining is displayed on the LCD screen.

CAUTION – When shutting the Ozone Generator down for maintenance or servicing, always allow the SHUTTING DOWN State to complete. Failure to do so may trap high concentrations of ozone gas in the system, presenting a safety hazard. When shutdown is complete the "STOPPED" message will be displayed on the LCD screen.

j. FAULT

Fault conditions require the Ozone Generator to shutdown immediately to prevent potential equipment damage and/or protect from a hazardous condition.

The condition that caused the Fault will be displayed on the screen. Ozone, oxygen and coolant flow are all stopped.

The situation that caused the fault must be corrected before resuming operation. Once the source of the fault is corrected, press F4 to acknowledge and clear the Fault Screen. The Ozone Generator will then return to the STOPPED State. Refer to Troubleshooting Section 6, if necessary.

CAUTION – Ozone gas may be trapped in the Module and gas lines after a Fault. Do not disconnect gas lines until a SHUTTING DOWN sequence has been successfully completed.

SECTION 5. Maintenance & Service

5A. Preventative Maintenance Schedule

Note: Refer to Figure 4 on Page 15 of this manual. A Maintenance Log Sheet is provided in Appendix G. Record all maintenance and service activity for warranty purposes.

WARNING – Disconnect and lock out power to the Ozone Generator prior to opening doors or removing panels.

- a. Daily
 - i. Verify that no Fault messages are displayed on the Operator Interface Panel.
 - ii. Check Gas Flowmeter(s) and Coolant Flowmeter(s) for proper level. For multiple Module models, verify proper balance between Modules.
 - iii. On the Operator Interface Panel, check Module Pressure(s) Level and Current(s) for proper levels.
- b. Weekly
 - i. Visually inspect cabinet Air Filters for foreign objects or obstructions. Clean as needed (see Section 5D.)
 - ii. Visually inspect Oxygen Filter. Clean or replace filter element as required (see Section 5E.)
 - iii. Look through Ozone Module Sight Glass to verify that all electrodes are lit and that no moisture has accumulated in High Voltage Housing.
 - iv. Check for proper operation of the Ozone Destruct Unit and Water Dump Valve.
- c. Monthly
 - i. Perform a function test of ambient ozone monitor (if installed).
- d. Three Months
 - i. Verify proper operation of cooling fans.
 - ii. Test all PLC safety interlocks.
- e. Six Months
 - i. Verify that High Voltage Transformer and Inductor thermal switches are glued in place. Check that power connections are secure.
 - ii. Check that the high voltage cable is not chafing on any surfaces.
 - iii. Verify that High Voltage Feed-Through is secure and free of corrosion. Remove dust buildup.
 - iv. Inspect areas near coolant plumbing for evidence of any water leaks and resulting damage or corrosion.
 - v. Perform general cleaning throughout the Enclosure.
 - vi. Inspect electrical system for corroded contacts or chafed wires. Clean/repair.
 - vii. Remove Zinc Anodes and inspect for wear. Replace as needed.
- f. Twelve Months
 - i. Disassemble, inspect and clean Ozone Generator Module. Refer to Section 5C for instructions.

5B. Electrode and Ground Tube Cleaning – Module in Place

- a. If there is at least 48 inches of clearance between the top of the Ozone Module and the Ceiling, Electrodes may be serviced with the Module in place. Otherwise, Module will need to be removed as described in Section 5C.
- b. To service Electrodes with the Module in place, remove the ¼-20 hex bolts securing the Top Endcap of the Ozone Module.
- c. Disconnect ozone output line by loosening nut on compression fitting. Move tubing out of the way.
- d. Remove and set aside the Endcap and Gasket. The ends of the High Voltage Electrodes are now exposed.
- e. The electrodes can be removed by gripping the exposed ends firmly and carefully pulling the electrodes out. Twisting the electrodes slightly will help with removal.
- f. Clean and reinstall electrodes and reattach Top Endcap using the procedure described in Section 5Cd.

5C. Ozone Module Inspection and Service

WARNING – Ozone Module is extremely heavy. Support module with proper rigging prior to loosening bolts. Keep clear of module front while tilting.

CAUTION – When shutting the Ozone Generator down for maintenance or servicing, always allow the SHUTTING DOWN State to complete. Failure to do so may trap high concentrations of ozone gas in the system, presenting a safety hazard. When shutdown is complete, the “STOPPED” message will be displayed on the LCD.

- a. Ozone Module Removal
 - i. Perform normal system shut down procedure.
 - ii. Turn off and lock out main electrical service.
 - iii. Remove High Voltage Feedthrough Assembly
 1. Remove Cover from Conduit Fitting.
 2. Remove nut and washer securing Ring Lug to High Voltage Feed-Through.
 3. Loosen the Hose Clamp and pull the Conduit fitting free of the High Voltage Feedthrough. (The grommet on the Top Panel may be pushed into the Transformer Enclosure if necessary.)
 4. Remove the Feedthrough Ring Clamp and disconnect the Feedthrough by gently pulling it from the module. Set the Feedthrough and Sealing Ring aside to avoid damage.
 - iv. Find the Thermal Switch at the top-rear of the Ozone Module. Disconnect the Switch at the Sealed Connector.
 - v. Drain Module
 1. Close the Coolant Ball Valve located behind the lower left side of the Ozone Module.
 2. Disconnect the Coolant line entering the top of the Flowmeter at the Quick Disconnect fitting. A small amount of coolant will spill out, catch as much as possible to limit spills on the Transformer Enclosure.
 3. Move the hose to a convenient location for draining (add extension hose as required), and reopen the Coolant Ball Valve.
 4. Disconnect the Brass swivel fitting from the top of the Module. Wait for all coolant to drain from the Module.
 - vi. Disconnect the oxygen inlet and ozone output lines by removing the stainless steel compression nuts (located at the bottom and top of the Module, respectively.) Move tubing out of the way.
 - vii. Disconnect the module ground wire from the rear-lower flange of the CD Module.
 - viii. With proper Ozone Module support in place, remove the two bolts that secure the module to the Frame.
 - ix. Remove Safety Cable from the left module support.

WARNING – The Ozone Module can now rotate on the Support Pins and may fall forward if not properly restrained.

- x. Carefully move Module onto a work bench with the Sight Glass facing up for further disassembly.
- b. Ozone Module Disassembly
 - i. Remove the ¼-20 hex bolts securing the Top Endcap of the Ozone Module **Note:** Mark orientation of Ozone Fitting for re-assembly.
 - ii. Remove and set aside the Endcap and Gasket. The ends of the High Voltage Electrodes are now exposed.
 - iii. Grip the exposed Electrode ends firmly and carefully pull the Electrodes out. Twisting the Electrodes slightly will help with removal. Set the Electrodes aside to avoid damage.
 - iv. Remove the ¼-20 hex nuts securing the bottom High Voltage Housing to the generator. Carefully remove and set aside the High Voltage Housing and gasket.
 - v. The Electrodes, generator housings, and gaskets are now exposed for inspection, cleaning, and/or replacement. See the end of this Section for Replacement parts list.
- c. Ozone Module Component Inspection
 - i. High Voltage Housing
 - 1. Inspect High Voltage Sockets (on High Voltage Plate) for proper tightness, damage, or corrosion. Clean, repair or replace as needed.
 - 2. Inspect Sight Glass for cracks, replace if necessary.
 - 3. Inspect bottom of Housing for evidence of water intrusion and excessive corrosion. This may indicate a Water Jacket Failure or Backflow problem. Troubleshoot cause and replace parts as needed.
 - 4. Inspect Gasket for damage. Replace as needed.
 - ii. Top Endcap
 - 1. Inspect Top Endcap for evidence of water intrusion and excessive corrosion. Clean/replace as needed
 - 2. Inspect Gasket for Damage. Replace as needed.
 - iii. Electrodes – Inspect for deposit buildups, pitting or cracks. Replace as needed.
 - iv. Water Jacket – Clean thoroughly then inspect all weld seams. Replace Water Jacket if necessary.
- d. Ozone Module Re-Assembly

Note: It is imperative that all Ozone Module components be free of contaminants during re-assembly. Remove all surface corrosion, grease, oil, lint, dirt, etc.

 - i. Clean Water Jacket Ground Tubes by swabbing the inside of the tubes with an alcohol-soaked, clean, lint-free cloth (using rifle cleaner or equivalent tool.)
 - ii. Reinstall the lower Gasket and High Voltage Housing (sight glass should be facing up.) Apply anti-seize compound to two opposite studs. Install washers and nuts hand tight.
 - iii. Clean Electrodes using an alcohol-soaked, clean, lint-free cloth.
 - iv. Look into the Sight Glass using a flashlight. Insert Electrodes into Ground Tubes starting at the bottom. Line up Electrode with corresponding socket and carefully push/twist into the socket. If an Electrode fails to line up with a socket, swap with a different electrode. If socket is damaged, remove Housing and replace it. Continue inserting the remaining electrodes in the same manner.

Note: Do not touch Electrode Glass during installation. Handle with a clean, dry, lint-free cloth.

 - v. Apply anti-seize compound to remaining studs on High Voltage Housing. Install washers and nuts and tighten in groups of three in an alternating pattern using two passes. First Pass: torque to 25in•lbs. Second pass: torque to 37+/-3 in•lbs.
 - vi. Reinstall the Top Endcap using the same technique above (note proper orientation.)

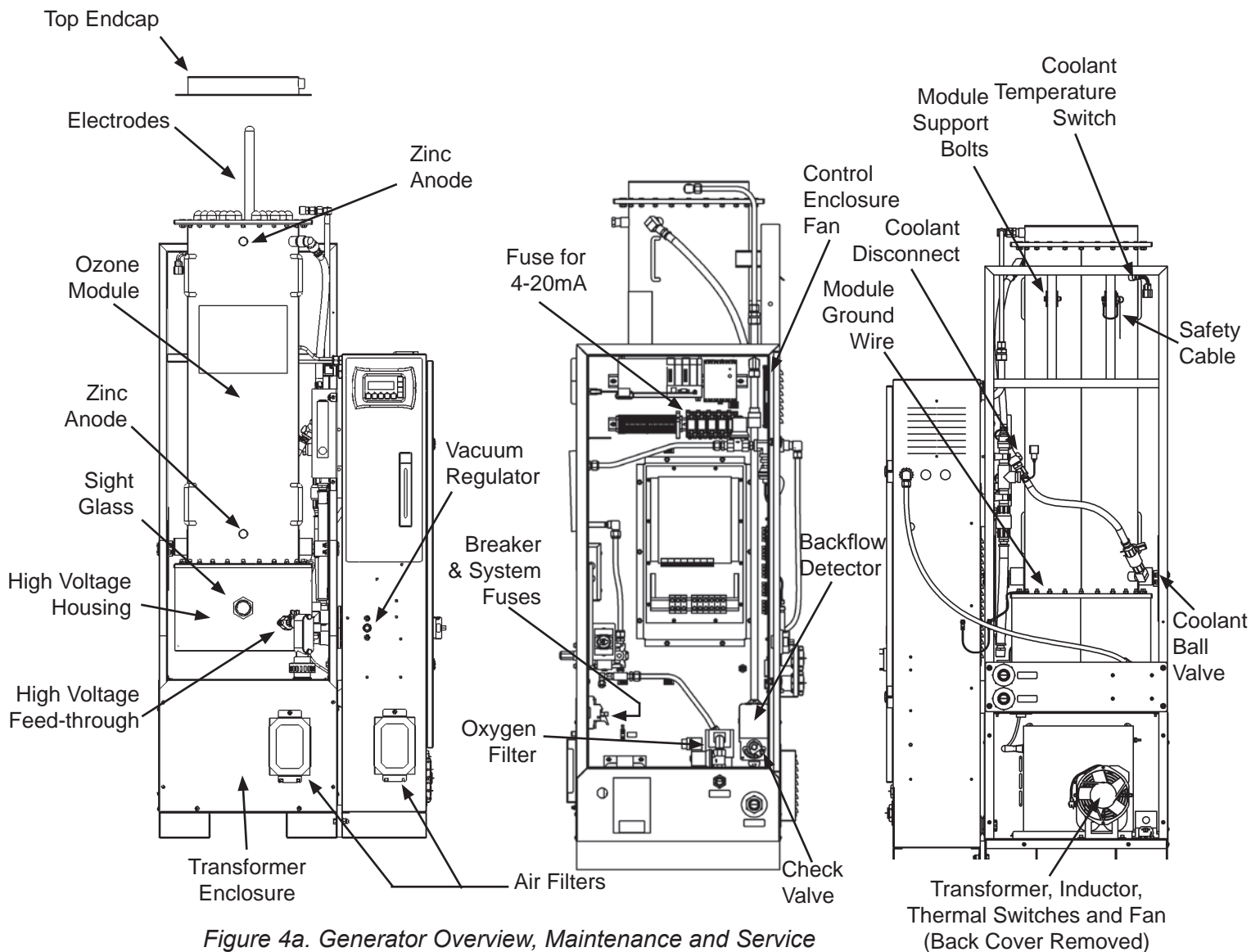


Figure 4a. Generator Overview, Maintenance and Service
CD-400F Shown (CD-800F and CD-1200F Typical)

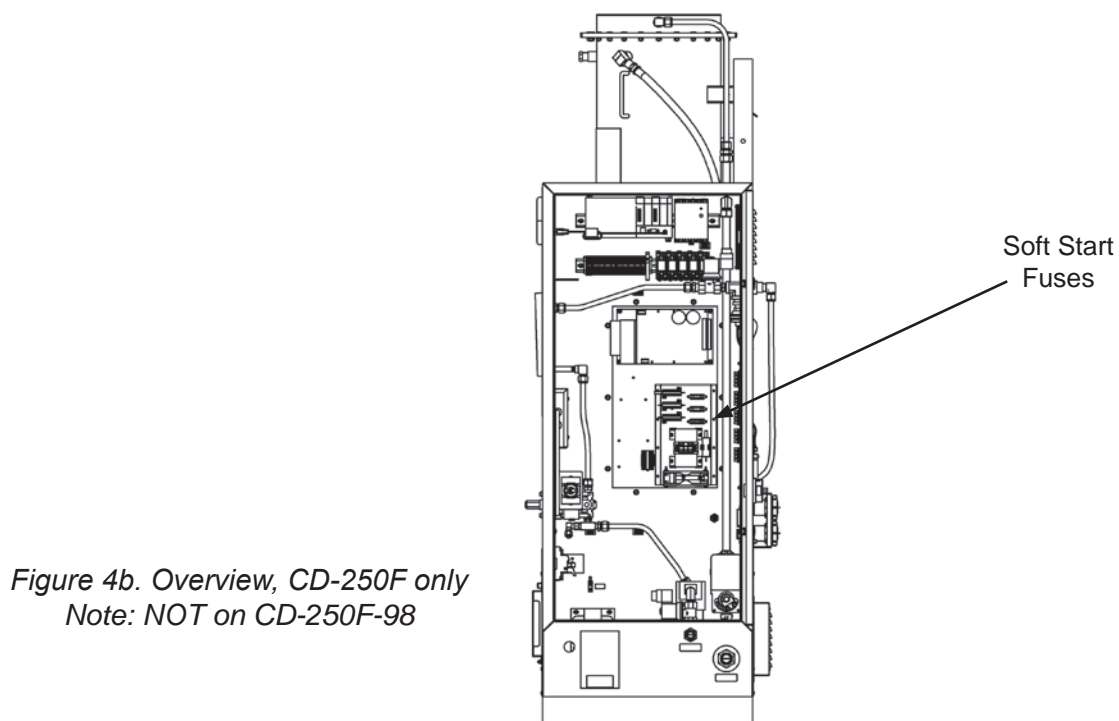


Figure 4b. Overview, CD-250F only
Note: NOT on CD-250F-98

5C. Ozone Module Inspection and Service, Cont.

- e. Ozone Module Reinstallation
 - i. Move the Ozone Module to the Frame and rest on Support Brackets. Line up mounting brackets on the back of the Water Jacket with the Frame and rotate into place. Reinstall Module Support Bolts.
 - ii. Reconnect Thermal Switch connector.
 - iii. Connect Oxygen Inlet and Ozone Outlet lines. (Use a back up wrench on the Compression fitting body when tightening the Compression Nut.)
 - iv. Carefully insert the High Voltage Feedthrough into the High Voltage Housing with Sealing Ring first. Feedthrough will need to align with socket on High Voltage Plate. View alignment through Sight Glass if necessary and press in until secure.
 - v. Reattach and tighten Feedthrough Ring Clamp.
 - vi. Place High Voltage Cover over Feedthrough. Verify that Grommet is properly installed on Top Panel of Transformer Enclosure.
 - vii. Reinstall High Voltage Cable ring lug on High Voltage Feed-Through using star washers and nut.
 - viii. Tighten hose clamp and reinstall conduit fitting cover.
 - ix. Reconnect Coolant in and out lines

Note: Coolant must enter at the bottom of the module and exit at the top.

- x. Reconnect ground wire to Module.

5D. Air Filter Cleaning

- a. Perform normal system shutdown procedure
- b. Air Filters are located on lower front of Controls Enclosure and (each) Transformer Enclosure. There are two to four filters depending on Ozone Generator model.
- c. Back out thumb screw on top of Filter Support Bracket.
- d. Filter Bracket should slide up and free of the lower nuts. If lower nuts are too tight, back them out slightly until Bracket slides out with Filter.
- e. Inspect Filter and Gasket for damage. Order replacement Filter as needed (see the end of this Section for Replacement Parts list.)
- f. If Filter and Gasket are in good condition, the Filter may be cleaned by rinsing with warm water and mild detergent in opposite direction of air flow (into the gasket side.)
- g. Allow Filter to dry completely and reinstall.

5E. Oxygen Filter Cleaning

- a. Perform normal system shutdown procedure.
- b. Depressurize Oxygen line.
- c. Filter is located inside Controls Enclosure immediately after Oxygen inlet.
- d. Remove Bowl by depressing red button at the top while turning the Bowl. (Red button may be out of direct view.) Drop bowl down and pull out of Enclosure.
- e. Unscrew Filter Element Retainer, and remove Filter Element. O-ring should also drop out.
- f. Inspect Filter Element and O-ring. Filter Element can be cleaned by Tapping on a hard surface and using compressed air to blow out residual dirt. If a new Filter or O-Ring is required, see end of this section for Replacement Parts list.
- g. Wipe Bowl with soft cloth. Note: If excessive moisture is present in the Bowl, check Oxygen Preparation System for proper operation.
- h. If Automatic Drain in the Bowl appears dirty, disassemble and clean using compressed air.
- i. Reassemble Bowl, reinstall Filter Element (with O-ring first) and Reattach Bowl. Be sure that Bowl locks into place.

5F. Replacement Parts and Order Information

For Replacement Parts call DEL at 1-800-676-1335 with the following information:

- a. Customer Name
- b. Customer Address
- c. DEL Model Number
- d. DEL Serial Number
- e. Date of Purchase

5G. Standard Replacement Parts List

- | | |
|--|-----------|
| a. Cabinet Air Filter with Gasket | 9-0666-01 |
| b. Control System Fuses (1Amp, type FLQ) | 5-1557-01 |
| c. Soft Start Fuses (3Amp, type 3AG Slow) | 5-9019 |
| d. 4-20mA External Control Fuse (31mA, type 3AG) | 5-1576-01 |
| e. Check Valve, ¾" SS | 8-0697 |
| f. Check Valve rebuild kit | 8-0333 |
| g. Oxygen Filter Element & O-ring | 7-0125 |
| h. Electrode Assembly | 9-0420 |
| i. Water Jacket Gasket | 7-0772 |
| j. 12kVA Transformer Assembly | 9-0660 |
| k. Zinc Anodes, ½" MNPT | 2-0150 |

SECTION 6. Troubleshooting

Introduction: The Operator Interface Panel (OIP) will provide immediate text notification of all system faults detected by the PLC. The sections below list various system and PLC faults that may be encountered during normal operation, along with typical causes and potential corrections. Other error messages may occur on start-up that are not listed here. See Section 4 for start-up details.

The PLC also maintains a Fault History which can be accessed through the Diagnostics and Settings screen of the OIP. See Section 4 for details on Fault Messages and accessing Fault History.

WARNING – Shut down system and lock out power before opening Enclosure Door or removing Panels.

6A. System will not start

| CAUSE | SOLUTION |
|-------------|---|
| No Power | Verify that main supply conductors are properly connected and that correct voltage is present. |
| Breaker Off | Reset Breaker inside Control Enclosure. Reset any external Breakers. |
| Bad Fuse(s) | Check Control Circuit Fuses (2 ea) inside the Control Enclosure. For CD-250F models, also check Soft Start Fuses (3 ea). Replace as needed (see Replacement parts list at the end of Section 5.) |

6B. Low Ozone Output

| CAUSE | SOLUTION |
|-----------------------------|--|
| Ozone Power Setting too low | Turn up Power as described in Section 4. |
| Bad Electrodes | With Ozone Generator running, use a flashlight to look through the Ozone Module Sight Glass. Note any Electrodes that are not glowing and service as described in Section 5. |
| Warm Coolant | Lower coolant temperatures and higher coolant flow rates will yield higher ozone output. Nominal coolant inlet temperature is 60°F. However, temperature can be as low as 50°F to further increase Ozone Output. |
| Low Coolant Flow Rate | |

6C. Module Current does not correspond to Power Setting

| CAUSE | SOLUTION |
|----------------|--|
| Bad Electrodes | With Ozone Generator running, use a flashlight to look through the Ozone Module Sight Glass. Note any Electrodes that are not glowing and service as described in Section 5. |

6D. Fault Message: BFPD

| CAUSE | SOLUTION |
|--------------------------|--|
| Water Back Flow Detected | <ol style="list-style-type: none"> 1. Identify and correct source of water backflow. 2. Clean or replace any faulty check valves. 3. Remove, clean and thoroughly dry all gas plumbing exposed to water backflow. |

6E. Fault Message: LOW O2 PRESSURE

| CAUSE | SOLUTION |
|--|---|
| No oxygen pressure | Check Oxygen Preparation system for proper operation. |
| | With system running, check pressure regulator for proper setting. |
| | Correct leaks or clogs in oxygen lines. |
| Oxygen Filter in Ozone Generator clogged | Clean filter element as described in Section 5. |

6F. Fault Message: LOW O2 %

| CAUSE | SOLUTION |
|---|---|
| Oxygen Preparation System not operating properly. | Use handheld Oxygen Meter to verify that Oxygen System is providing at least 90% pure Oxygen. |
| No flow through Oxygen Sensor | Check that all tubing connections leading to Oxygen Sensor are secure and that there are no clogs or leaks. |
| | Remove Orifice Fitting and check for clog. Clean carefully with pin or small wire (~.010" diameter). |

6G. Fault Message: COOLANT TEMP

| CAUSE | SOLUTION |
|--|--|
| Coolant flow too low (< 1gpm) | Increase coolant flow. |
| | Correct any coolant line clogs or leaks. |
| Coolant temperature too high (>150 °F) | Lower incoming coolant temperature. |
| Closed-Loop cooling system not functioning | Check chiller for proper operation. |
| Closed-Loop cooling system undersized | Increase chilling capacity. |
| | If allowed, turn down Ozone Generator power. |

6H. Fault Message: LOW COOLANT FLOW

| CAUSE | SOLUTION |
|-------------------------|--|
| Coolant flow too low | Increase coolant flow at the flow meter or at source as required. |
| Plumbing lines reversed | Check that coolant line connections at the Enclosure are plumbed so that flow is in the correct direction. |
| No coolant Flow | Correct any clogs or leaks in the coolant lines. |
| | Check chiller pump (if applicable). |

6I. Fault Message: AMBIENT AIR TEMP

| CAUSE | SOLUTION |
|-------------------------------------|---|
| Room Temperature has exceeded 100°F | Reduce ambient temperature. |
| Enclosure Fan not operating | Restart system and check for air flow through louvers behind Enclosure. Replace fan if necessary. |
| Enclosure Air Filter dirty | Clean or replace filter (see Section 5.) |

6J. Fault Message: TRANSFORMER TEMP

| CAUSE | SOLUTION |
|---------------------------|---|
| Room Temperature too high | Reduce ambient temperature. |
| Current too high | Restart system and check current value on OIP. If value consistently exceeds 22.4 A, call DEL for assistance. |
| Fan Failure | Check for fan operation in the transformer cabinet. Replace fan if necessary. |

6K. Fault Message: LOW VACUUM

| CAUSE | SOLUTION |
|--|---|
| Injector not pulling sufficient vacuum | Increase water flow through injector (close Bypass Valve). |
| | Check process water pump and filters for proper operation. |
| Vacuum not reaching Ozone Generator | Clear any clogs in the injector throat. |
| | Check any valves installed in ozone line for proper setting. |
| | Correct any clogs or leaks in ozone line. |
| Vacuum Regulator not set properly | Contact DEL for assistance. |
| Ozone Ball Valve not opening | Valve must be serviced or replaced. Contact DEL for assistance. |
| Check Valve not opening | Valve must be serviced or replaced. Contact DEL for assistance. |

6L. Fault Message: HIGH VACUUM

| CAUSE | SOLUTION |
|------------------------------------|--|
| Injector pulling excessive vacuum | Decrease water flow through injector (open Bypass Valve) and/or partially close Suction Control Valve in ozone line. |
| Vacuum Regulator not set properly. | Contact DEL for assistance. |

6M. Fault Message: PROCESS FLOW

| CAUSE | SOLUTION |
|-------------------------------|---|
| Process water is not flowing. | Start Process pumps. |
| Flow Switch is not closed | Verify that Flow Switch is installed properly (proper depth in pipe, no air bubbles, etc). |
| | Verify that switch function is normally open (water flow closes switch). |
| Flow Switch not installed | Install Flow Switch and connect Normally Open signal to User I/O Terminal Block. |
| | If Flow Switch is not required, install jumper across Flow Switch Terminals on User I/O Terminal Block. |

6N. Fault Message: AMBIENT OZONE

| CAUSE | SOLUTION |
|---|--|
| Ambient Ozone Monitor detecting high levels of ozone in the air | <ol style="list-style-type: none"> 1. Ventilate area until ambient ozone drops to safe level. 2. Check all external ozone lines for leaks, particularly those leading to the Ozone Destruct from the Contact Tank 3. Verify that water has not entered the Ozone Destruct unit. 4. Restart Ozone Generator. If Ambient Ozone fault reoccurs, turn off and lock out Ozone Generator and contact DEL |
| Ambient Ozone Monitor not installed | Install Ambient Ozone Monitor and connect signal lines to User I/O Terminal Block as described in Section 2. |
| | If Ambient Ozone Monitor is not required, install jumper across Ambient Ozone Terminal on User I/O Terminal Block. |
| Dirty or non-operational sensor producing faulty reading on Ambient Ozone Monitor | Refer to Ambient Ozone Monitor manual for instructions regarding sensor service/calibration. |

6O Fault Message: 4-20mA SIGNAL LOSS

| CAUSE | SOLUTION |
|------------------------------------|--|
| 4-20mA signal lost or not present. | Check current source for proper operation. |
| | Verify that current source is connected to User I/O Terminal Block |
| | Check 4-20mA External Control Fuse |
| | If 4-20mA signal is not required, turn off 4-20mA function using Operator Interface Panel as described in Section 4. |

6P. Fault Message: INVERTER.

| CAUSE | SOLUTION |
|---|--|
| Supply Voltage is outside of allowable operating range. | Verify that incoming voltage is within acceptable limits (see Table 1). Voltage must remain within range with Ozone Generator running at full power. |
| One or more power supply phases lost | Verify and correct incoming power for proper voltage on all legs. |
| | Check internal breaker. |
| Inverter malfunction | Contact DEL for assistance. |

6Q. Fault Message: PHASE LOSS

| CAUSE | SOLUTION |
|--------------------------------------|--|
| One or more power supply phases lost | Check incoming power for proper voltage on all legs. |
| Relay Sensitivity too high | Contact DEL for assistance. |

6R. System Pauses

All pauses identified below are part of normal operation. However, there are situations in which a pause may take too long or hold indefinitely and the system will not progress to a running State. The Operator Interface Panel will display one of the System Pause messages below and await user intervention. In some cases it may be necessary to re-commission and restart the system as outlined in Sections 3 and 4.

| PAUSE | RESOLUTION |
|-------------------|--|
| COOLANT | Verify that coolant is plumbed properly and flowing at least 1gpm. Note: If Ozone Module is empty, it will take several minutes to fill with coolant. |
| O2 CONCENTRATION | Check Oxygen Preparation System for proper operation. Use an oxygen sensor to verify that oxygen concentration into the Ozone Generator is consistently above 85%. |
| PROCESS FLOW | Flow Switch in Process pipe detects loss of water flow. Reestablish water flow and/or check Flow Switch wiring and connections. |
| HIGH VACUUM | It is possible for the Ozone Generator to develop a High Vacuum in the READY State and may take a few moments to drop back to operating level when restarted. Watch for the vacuum reading to drop on the LCD display. If the vacuum is steadily too high, readjust vacuum as described in Section 4C. |
| REMOTE STANDBY | The Ozone Generator has been placed in Standby mode through the external control contacts on the User I/O terminal block. Disengage Remote switch to regain local control. |
| | If Remote Standby switch is not used, verify that there is jumper across the Remote Standby terminals on the User I/O Terminal Block. |
| DISSOLVED OZONE | This message is normal if Dissolved Ozone Controller is installed. Ozone Generator will cycle ozone on and off as required to maintain the set point programmed into the Dissolved Ozone Controller. |
| | If Dissolved Ozone Controller is not installed, verify that there is a jumper across the Dissolved Ozone terminals on the User I/O Terminal Block. |
| | If Dissolved Ozone Controller is installed but ozone does not cycle, there may be a problem with the Dissolved Ozone Controller Output or Sensor. See Dissolved Ozone Controller/Sensor Operation Instructions. |
| ORP | This message is normal if ORP Controller is installed. Ozone Generator will cycle ozone on and off as required to maintain the set point programmed into the ORP Controller |
| | If ORP Controller is not installed, verify that there is a jumper across the ORP terminals on the User I/O Terminal Block. |
| | If ORP Controller is installed but ozone does not cycle, there may be a problem with the ORP Controller Output or Sensor. See ORP Controller/Sensor Operation Instructions. |
| INADEQUATE VACUUM | During Ozone Generator startup, there is a time limit of 2 minutes to establish correct vacuum levels. Follow instructions on screen to retry. |
| INADEQUATE FLOW | During Ozone Generator startup, there is a time limit of 2 minutes to establish correct flow parameters. Follow instructions on screen to retry. |

SECTION 7. Warranty**DEL OZONE
TWO YEAR LIMITED WARRANTY**

The limited warranty set forth below applies to the CD-400F Ozone Generator manufactured by DEL Ozone – 3428 Bullock Lane, San Luis Obispo, California 93401, and sold by DEL Ozone and its authorized dealers. This limited warranty is given only to the first retail purchaser of such products and is not transferable to any subsequent owners or purchasers of such products.

DEL Ozone warrants that DEL Ozone or a DEL Ozone authorized service provider will repair or replace, at its option, any part of such products proven to be defective in materials or workmanship within two (2) years of the date of final commissioning by DEL Ozone or its authorized agent. Warranties on systems not commissioned by an authorized DEL Ozone representative shall be deemed null and void. This policy pertains to all installations. This warranty is extended to three (3) years on high voltage electrodes. All parts are covered under two (2) year warranty when and only when required maintenance requirements are met. For DEL Ozone Systems with Compressors, the Compressor(s) must be maintained per the Compressor operation and maintenance manual. All work performed without the permission of DEL Ozone or by an authorized DEL Ozone representative shall be deemed null and void the warranty. DEL Ozone reserves all rights to determine and authorize DEL Ozone representatives. Warranty does not include parts for compressor rebuild (when applicable). This Warranty specifically excludes any components not manufactured by DEL Ozone which are external to the products covered, such as pumps, air compressors, monitors or related components. DEL Ozone will assist with all warranty claims for such components purchased through DEL Ozone; limited to the extent of the manufacturer's standard warranty. ANY REPAIR OR REPLACEMENT WILL BE WARRANTED ONLY FOR THE BALANCE OF THE ORIGINAL TWO (2) YEAR WARRANTY PERIOD.

NOTE: USE ONLY DEL OZONE AUTHORIZED REPLACEMENT AND MAINTENANCE PARTS. USE OF ANY OTHER PART(S) WILL AUTOMATICALLY VOID THIS WARRANTY.

Any replaced parts must be returned to DEL OZONE for warranty evaluation.

THIS LIMITED WARRANTY DOES NOT INCLUDE ANY OF THE FOLLOWING: (a) any repair or replacement of such parts necessitated by faulty installation, or improper maintenance, improper operation, misuse, abuse, negligence, accident, fire, flood, repair materials, and/or unauthorized accessories; (b) any such products installed without regard to required local codes and accepted trade practices; (c) ANY IMPLIED WARRANTY OF MERCHANTABILITY OR IMPLIED WARRANTY OF FITNESS FOR PARTICULAR PURPOSE, AND SUCH WARRANTIES ARE HEARBY DISCLAIMED; AND (d) DEL OZONE SHALL NOT BE LIABLE UNDER ANY CIRCUMSTANCES FOR LOSS OF USE OF SUCH PRODUCTS, LOST PROFITS, DIRECT DAMAGES, INDIRECT DAMAGES, CONSEQUENTIAL DAMAGES AND/OR INCIDENTAL DAMAGES.

This warranty gives you specific legal rights. You may have other rights which vary from state to state.

Returning Defective Parts Under Warranty

Any product and/or part not performing satisfactorily may be returned to DEL Ozone for evaluation. A Return Material Authorization (RMA) number must first be obtained by either calling or emailing DEL Ozone with the product/part number and a description of the problem prior to shipping the product. The RMA number must appear prominently on the exterior of the shipped box(es). Returned parts without an RMA number will be rejected and returned to the sender. The product and/or part must be packaged either in its original packing material or in comparable and suitable packaging material to prevent shipping damage. It is your responsibility for charges incurred in shipping the product and/or part back to DEL Ozone and for any damages that may occur during shipment.

If, after the product and/or part is returned prepaid and evaluated by DEL Ozone it is determined to be defective within the scope of this limited warranty, DEL Ozone will either repair or replace the defective product and/or part and will return ship at lowest cost transportation prepaid. If upon inspection, it is determined that there is no defect or that the damage to the product and/or part is a result of causes not within the scope of this limited warranty, then you are responsible for all costs for repair or replacement of damaged product and/or part and all return freight charges.

To Obtain Warranty Service, Please Contact:

DEL Ozone Warranty Department
3428 Bullock Lane, San Luis Obispo, CA 93401
Customer Service Number: (800) 676-1335 (805) 541-1601
Fax Number: (805) 541-8459

For Warranty Service, Please Provide:

1. Project, contact name, mailing address and telephone
2. Installer/Mechanical Contractor
3. Model # and Serial # of Ozone Generator
4. The date of failure
5. A description of the failure
6. Properly obtained RGA number if returning parts

DEL Ozone also offers Extended Warranties and Service Agreements for a nominal charge. Please contact the Warranty Department for a Quote.

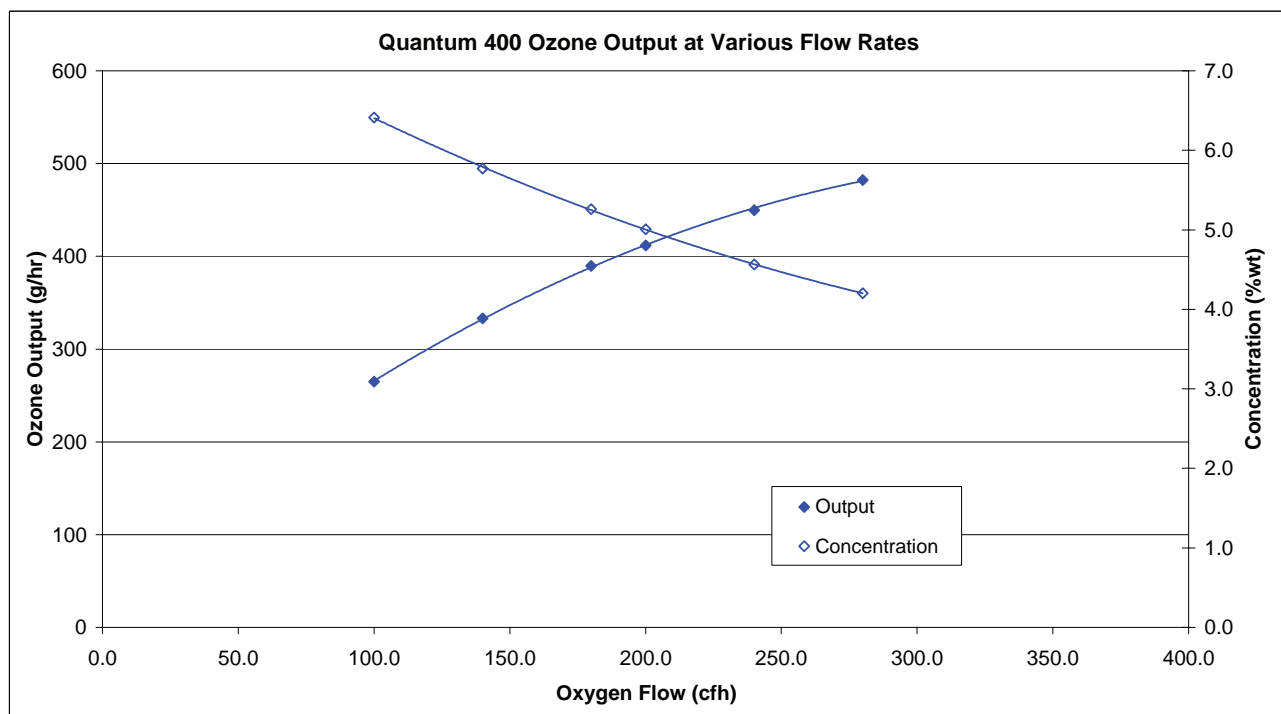
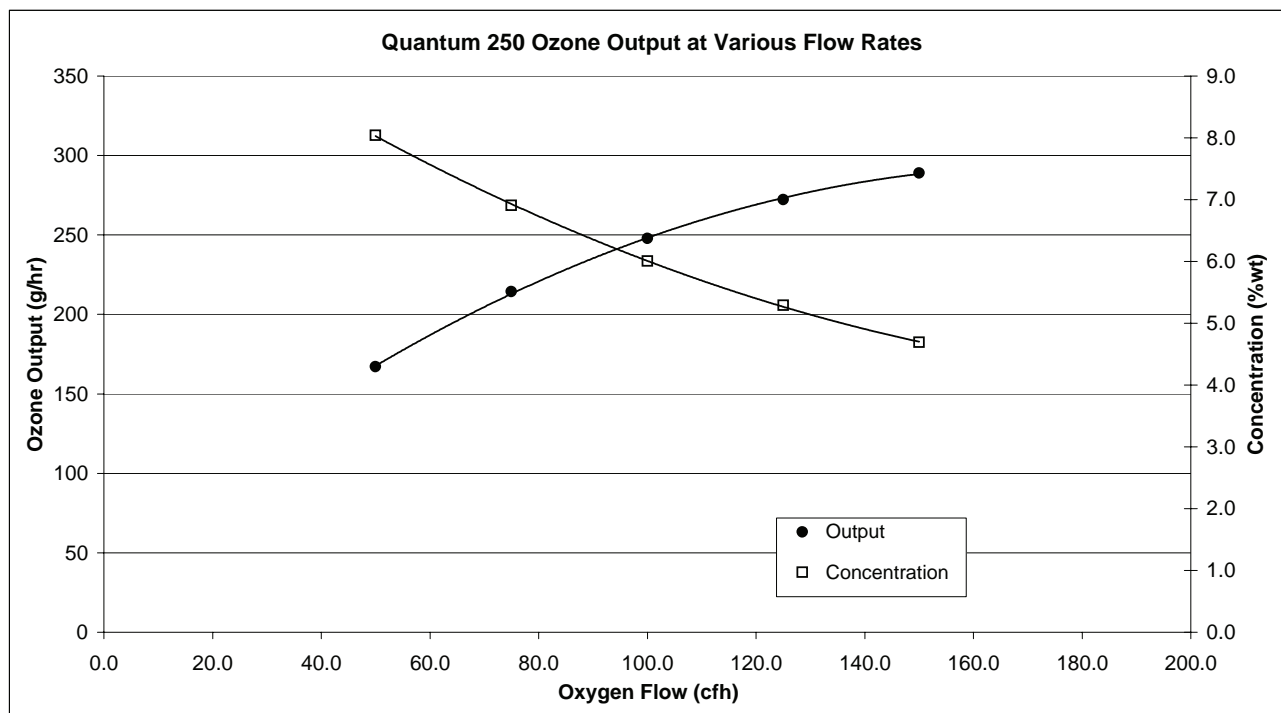
APPENDIX

APPENDIX A: Output Flow Rates

Ozone Output Performance - Quantum Series Ozone Generators



Note – Curves reflect nominal output rates. Actual output will depend on coolant flow rate, coolant temperature, run time, power settings and other factors.

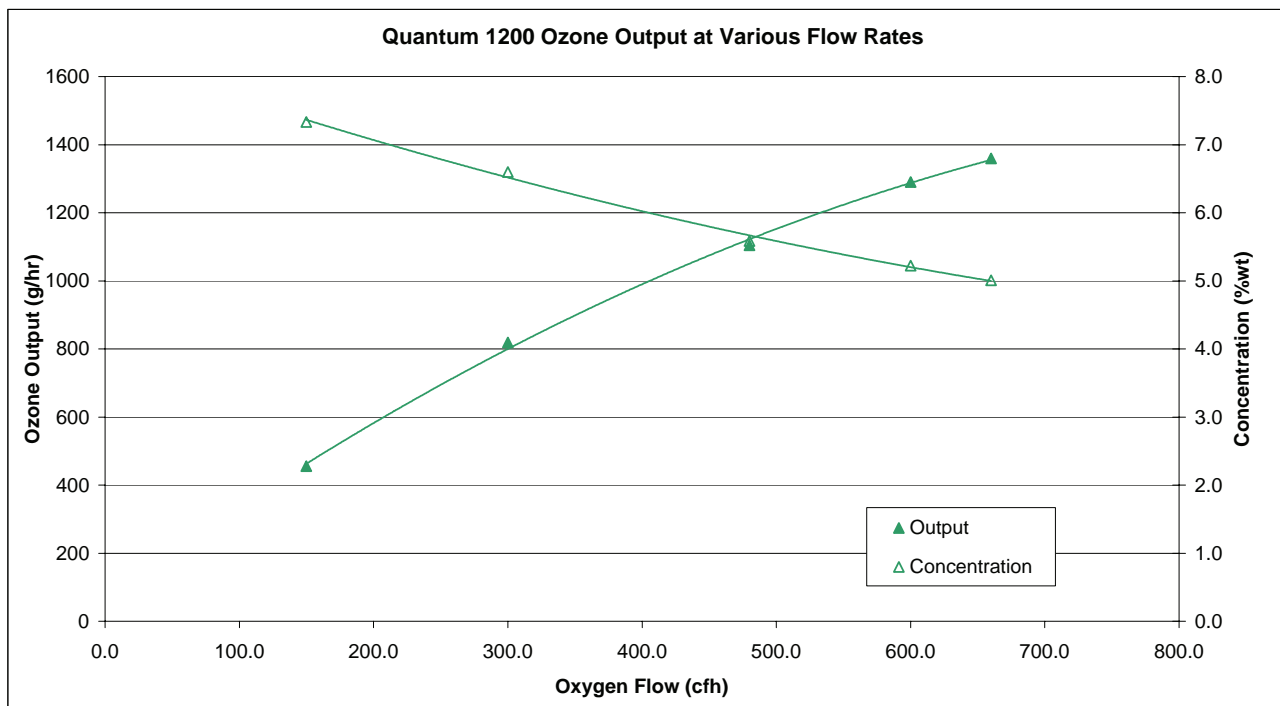
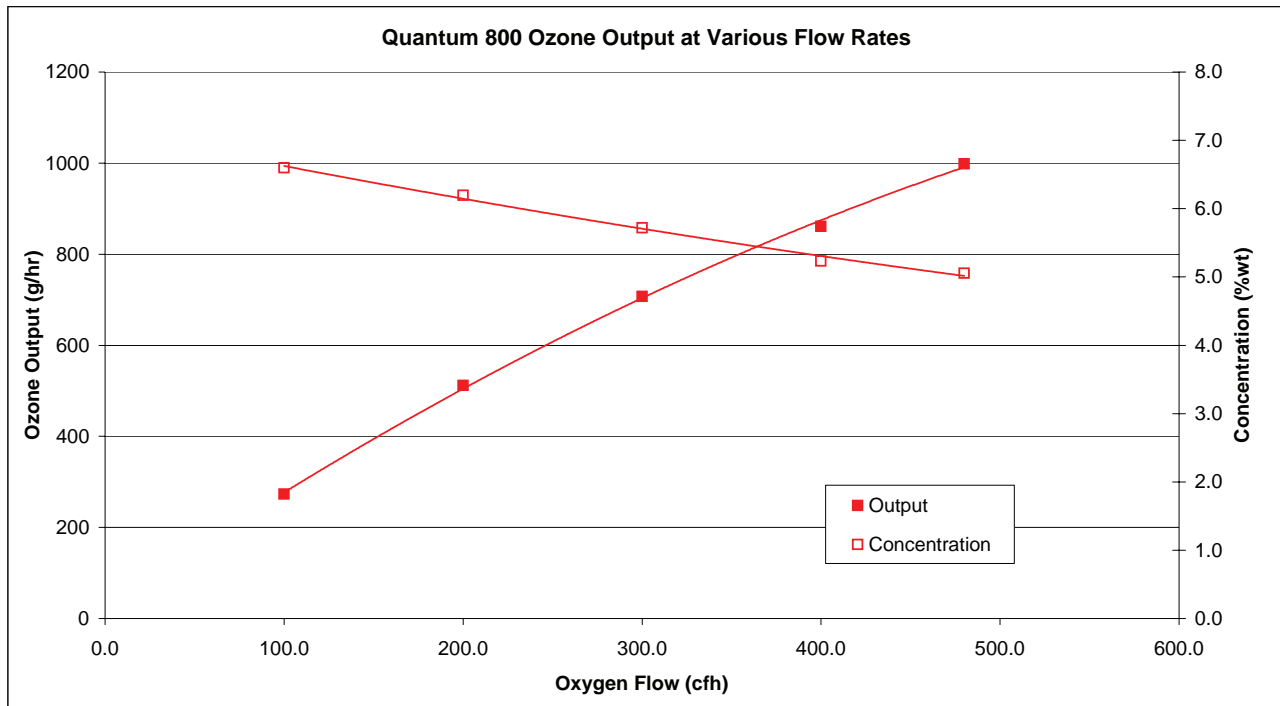


APPENDIX A: Output Flow Rates

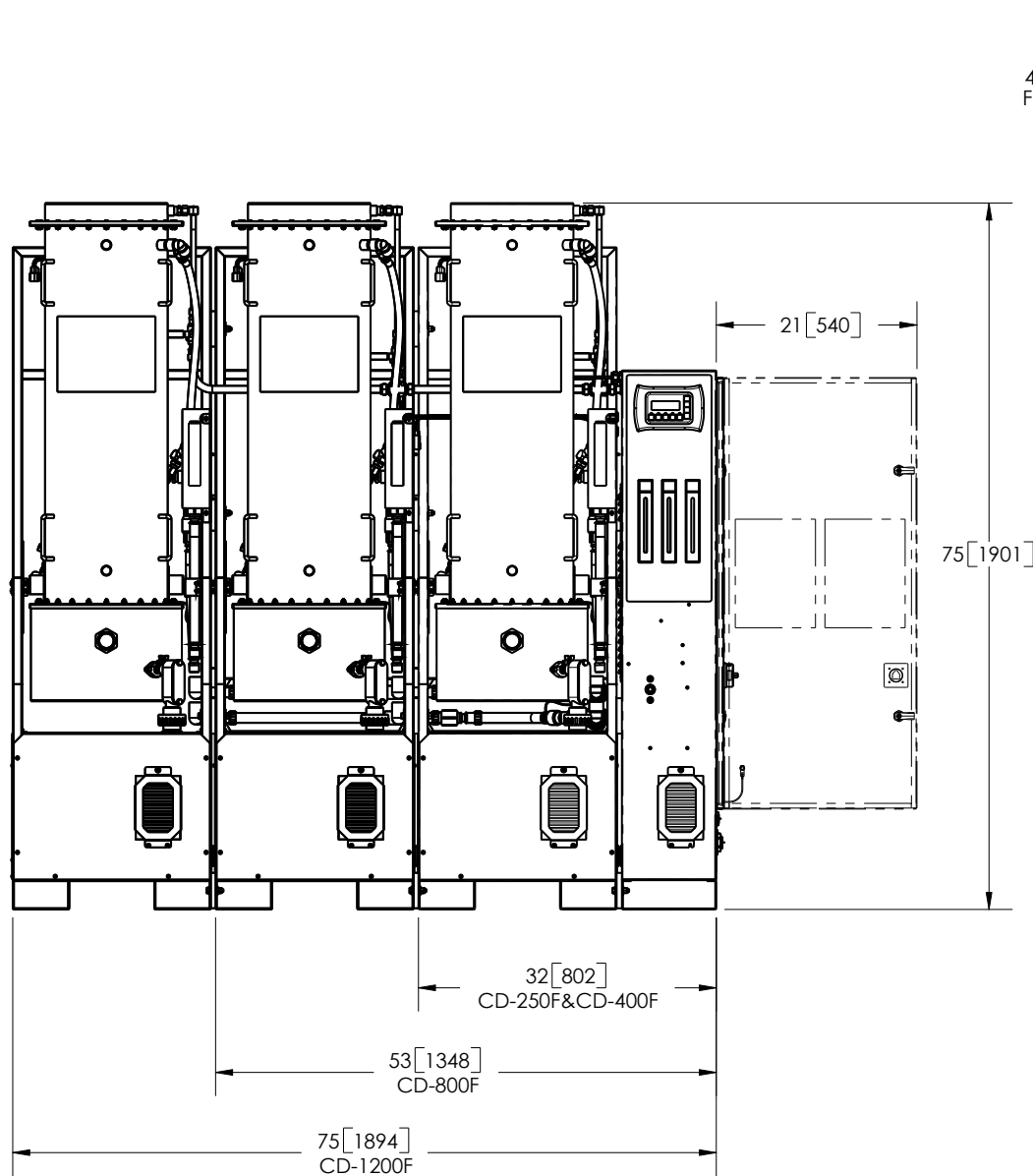
Ozone Output Performance - Quantum Series Ozone Generators



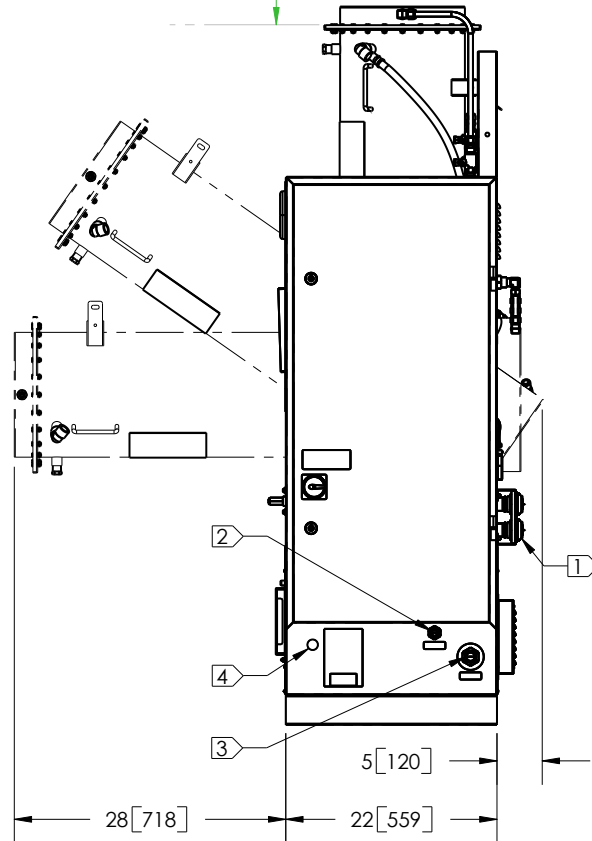
Note – Curves reflect nominal output rates. Actual output will depend on coolant flow rate, coolant temperature, run time, power settings and other factors.



APPENDIX B: Specification Drawings



48[1219] CLEARANCE RQD
FOR ELECTRODE REMOVAL
WITH MODULE IN PLACE



- 1 COOLING WATER IN&OUT, 3/4" FNPT, PVC
2 OXYGEN INLET, 1/2" FNPT, BRASS
3 OZONE OUTLET, 3/4"FNPT, SS
4 POWER INLET, Ø 1.09 FOR 3/4"NPT FITTING

SPECIFICATIONS

| | CD-250F | CD-400F | CD-800F | CD-1200F |
|-------------------------|--|--|---|---|
| OZONE OUTPUT (+/-10%) | 250 g/hr (13.2 lb/day) | 400 g/hr (21.2 lb/day) | 800 g/hr (42.3 lb/day) | 1200 g/hr (63.5 lb/day) |
| FLOW RATE (MAX) | 3.7 m ³ /hr (130 ft ³ /hr) | 6.8 m ³ /hr (240 ft ³ /hr) | 13.0 m ³ /hr (460 ft ³ /hr) | 18.7 m ³ /hr (660 ft ³ /hr) |
| NOMINAL CONCENT | 73 g/Nm ³ (5.0% wt) | 73 g/Nm ³ (5.0% wt) | 73 g/Nm ³ (5.0% wt) | 73 g/Nm ³ (5.0% wt) |
| POWER REQUIREMENTS | 240VAC, 50/60Hz, 3Ø, 5.6kVA | 480VAC, 50/60Hz, 3Ø, 7.5kVA | 480VAC, 50/60Hz, 3Ø, 15.0kVA | 480VAC, 50/60Hz, 3Ø, 22.5kW |
| COOLING WATER | | | | |
| FLOW* | 0.5 m ³ /hr (2.0 gpm) | 0.7 m ³ /hr (3.0 gpm) | 1.4 m ³ /hr (6.0 gpm) | 2.0 m ³ /hr (9.0 gpm) |
| INLET TEMPERATURE** | 10-32°C (50-90°F) | 10-32°C (50-90°F) | 10-32°C (50-90°F) | 10-32°C (50-90°F) |
| INLET PRESSURE (MAX) | 103 kPa (15 psi) | 103 kPa (15 psi) | 103 kPa (15 psi) | 138 kPa (20 psi) |
| HEAT REJECTION (TO AIR) | 1.4 kW (4781 BTU/hr) | 1.7 kW (5806 BTU/hr) | 3.4 kW (11600 BTU/hr) | 5.1 kW (17400 BTU/hr) |
| WEIGHT | 294 kg (650 lb) | 318 kg (700 lb) | 680 kg (1500 lb) | 1043 kg (2300 lb) |
| LOCATION REQUIREMENTS | | | | |
| MOUNTING | Indoor Only. Floor mount in a clean, protected area. | | | |
| AMBIENT TEMPERATURE | 4-38°C (40-100°F) | 4-38°C (40-100°F) | 4-38°C (40-100°F) | 4-38°C (40-100°F) |

* Cooling water flow for approximate temperature rise of 8°C (15°F). Lower flows may be used if larger temperature differentials can be tolerated.

** Potable water may be used for cooling. Specified ozone output is at 16°C (60°F.) Generator efficiency and life will be improved with water inlet temperatures of 27°C (80°F) or less.

STANDARD FEATURES

Control Enclosure built to NEMA 3R standards
Ozone Transformer Enclosure built to NEMA 12 standards
Programmable Logic Controller with LCD equipped User Interface Panel
Protection from
-Low Vacuum -Low Cooling Water flow
-High Vacuum -Ozone Module Overheat
-Pressure Loss -Transformer Overheat
-Water Backflow -Low Oxygen Concentration
24VDC Control System
Complete Ozone Isolation during shutdown
All Stainless Steel Water Cooled Generator Module
Electrodes
-Cold Plasma
-Medium Frequency
-Vertical tube and shell
-Glass Tube Dielectric
Variable Ozone Output (0-100%)
4-20mA External Ozone Output Control
Vacuum Operation with Built-in Vacuum Regulation
User Contacts for External Shut-down or Stand-by
2 year Parts and Labor Warranty

OPTIONAL FEATURES

ORP Monitor / Controller
Ambient Ozone Monitor / Controller
Dissolved Ozone Monitor / Controller
Closed Loop Cooling System

ALL DIMESIONS IN INCHES [mm]

APPROVALS:

DATE:

PROPERTY OF DEL OZONE

DRAWN: FM

03/25/05

THIS DOCUMENT AND THE
DATA DISCLOSED HEREIN
IS PROPRIETARY. IT IS NOT
TO BE REPRODUCED,
USED, OR OTHERWISE
DISCLOSED IN WHOLE,
OR IN PART, TO ANYONE,
WITHOUT WRITTEN CONSENT
FROM DEL OZONE.



3428 Bullock Ln. San Luis Obispo, CA 93401
(800)676-1335, email: info@delozone.com

PROJECT: **QUANTUM**

TITLE: **SPECIFICATION**

PART NUMBER: **4-0816**

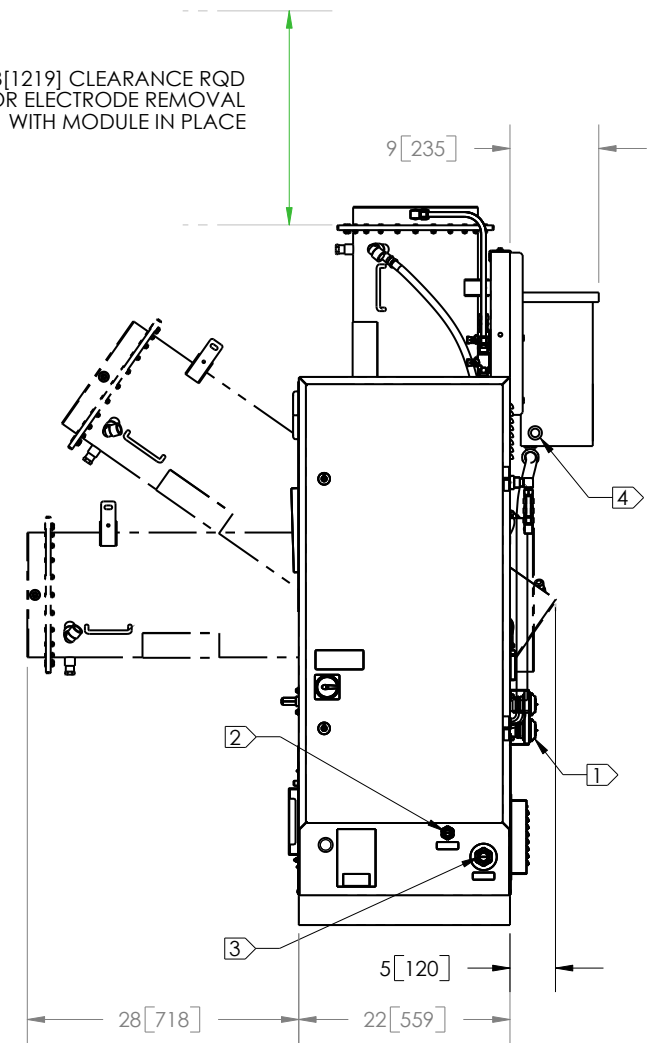
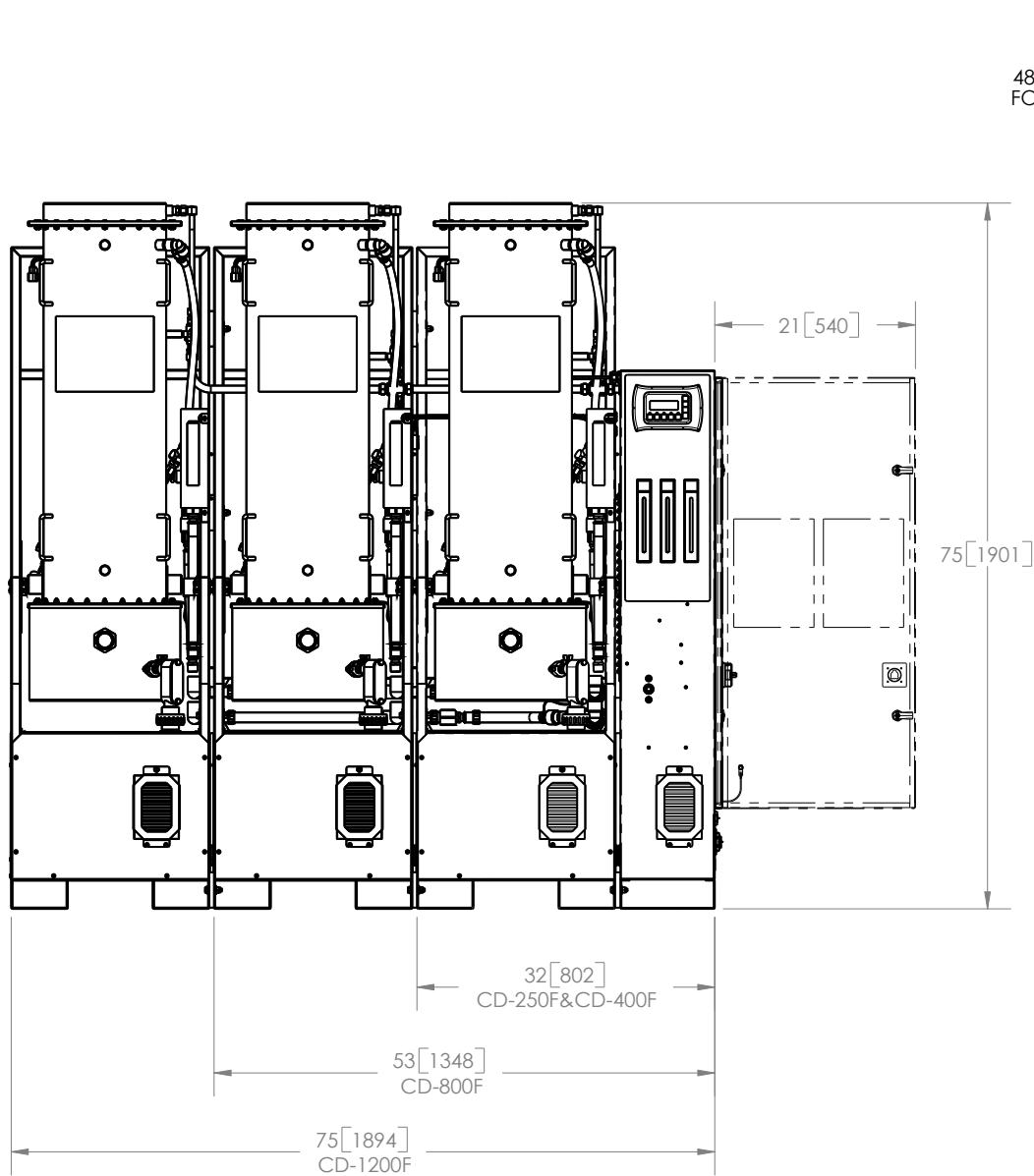
REV. **C**

SHEET: **1 OF 1**

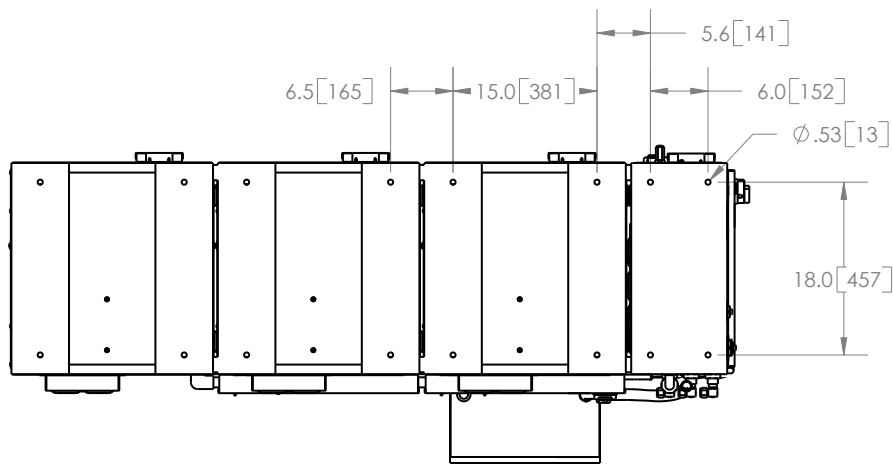
| | | | |
|---|------|-----------------------------------|----------|
| C | 2688 | REVISE MODEL 250F SPECS | 08/01/06 |
| B | 2623 | REVISE O2 FLOW, PWR, WT, H2O FTGS | 06/23/06 |
| A | 2520 | PRODUCTION RELEASE | 11/22/05 |

| | | | |
|------|------|--------------|-------|
| LTR: | ECN: | DESCRIPTION: | DATE: |
|------|------|--------------|-------|


REVISIONS:



- 1> COOLING WATER IN&OUT, 3/4" FNPT, PVC
- 2> OXYGEN INLET, 1/2" FNPT, BRASS
- 3> OZONE OUTLET, 3/4"FNPT, SS
- 4> POWER INPUT, MULTIPLE KNOCKOUTS PROVIDED



| SPECIFICATIONS | | | | |
|--|--|--------------------------|--------------------------------------|---------------------------|
| | CD-250F-98 | CD-400F-98 | CD-800F-98 | CD-1200F-98 |
| OZONE OUTPUT (+/-10%) | 250 g/hr (13.2 lb/day) | 400 g/hr (21.2 lb/day) | 800 g/hr (42.3 lb/day) | 1200 g/hr (63.5 lb/day) |
| FLOW RATE (max) | 4.2 m³/hr (150 ft³/hr) | 6.8 m³/hr (240 ft³/hr) | 13.0 m³/hr (460 ft³/hr) | 18.7 m³/hr (660 ft³/hr) |
| NOMINAL CONCENT | 73 g/Nm³ (5.0% wt) | 73 g/Nm³ (5.0% wt) | 73 g/Nm³ (5.0% wt) | 73 g/Nm³ (5.0% wt) |
| POWER REQUIREMENTS | 400VAC, 50Hz, 3Ø, 6.5kVA | 400VAC, 50Hz, 3Ø, 7.5kVA | 400VAC, 50Hz, 3Ø, 15.0kVA | 400VAC, 50Hz, 3Ø, 22.5kVA |
| COOLING WATER | | | | |
| FLOW* | 0.5 m³/hr (2.0 gpm) | 0.7 m³/hr (3.0 gpm) | 1.4 m³/hr (6.0 gpm) | 2.0 m³/hr (9.0 gpm) |
| INLET TEMPERATURE** | 10-32°C (50-90°F) | 10-32°C (50-90°F) | 10-32°C (50-90°F) | 10-32°C (50-90°F) |
| INLET PRESSURE | 103-276 kPa (15-40 psi) | 103-276 kPa (15-40 psi) | 103-276 kPa (15-40 psi) | 103-276 kPa (15-40 psi) |
| HEAT REJECTION (TO AIR) | 1.0 kW (3415 BTU/hr) | 1.7 kW (5806 BTU/hr) | 3.4 kW (11600 BTU/hr) | 5.1 kW (17400 BTU/hr) |
| WEIGHT | 294 kg (650 lb) | 318 kg (700 lb) | 680 kg (1500 lb) | 1043 kg (2300 lb) |
| LOCATION REQUIREMENTS | | | | |
| MOUNTING | Indoor Only. Floor mount in a clean, protected area. | | | |
| AMBIENT TEMPERATURE | 4-38°C (40-100°F) | 4-38°C (40-100°F) | 4-38°C (40-100°F) | 4-38°C (40-100°F) |
| * Cooling water flow for approximate temperature rise of 8°C (15°F). Lower flows may be used if larger temperature differentials can be tolerated. | | | | |
| ** Potable water may be used for cooling. Specified ozone output is at 16°C (60°F.) Generator efficiency and life will be improved with water inlet temperatures of 27°C (80°F) or less. | | | | |
| STANDARD FEATURES | | | OPTIONAL FEATURES | |
| Control Enclosure built to NEMA 3R standards | | | ORP Monitor / Controller | |
| Ozone Transformer Enclosure built to NEMA 12 standards | | | Ambient Ozone Monitor / Controller | |
| Programmable Logic Controller with LCD equipped User Interface Panel | | | Dissolved Ozone Monitor / Controller | |
| Protection from | | | Closed Loop Cooling System | |
| -Low Vacuum | | | | |
| -High Vacuum | | | | |
| -Pressure Loss | | | | |
| -Water Backflow | | | | |
| -Low Cooling Water flow | | | | |
| -Ozone Module Overheat | | | | |
| -Transformer Overheat | | | | |
| -Low Oxygen Concentration | | | | |
| 24VDC Control System | | | | |
| Complete Ozone Isolation during shutdown | | | | |
| All Stainless Steel Water Cooled Generator Module | | | | |
| Electrodes | | | | |
| -Cold Plasma | | | | |
| -Medium Frequency | | | | |
| -Vertical tube and shell | | | | |
| -Glass Tube Dielectric | | | | |
| Variable Ozone Output (0-100%) | | | | |
| 4-20mA External Ozone Output Control | | | | |
| Vacuum Operation with Built-in Vacuum Regulation | | | | |
| User Contacts for External Shut-down or Stand-by | | | | |
| 2 year Parts and Labor Warranty | | | | |

| | | | | | | | | | | | | |
|---|--|--|--|---|--|-------------|--|----------|--|---|--|--|
| <div>B2623REVISE O2 FLOW,PWR,WT,H2O FTGS06/23/06</div> <div>ARELEASE02/14/06</div> <div>LTR:ECN:DESCRIPTION:DATE:</div> <div>REVISIONS:</div> | | | | <div>ALL DIMESIONS IN INCHES [mm]</div> <div>MATERIAL:</div> <div>FINISH:</div> | | APPROVALS: | | DATE: | <div>PROPERTY OF DEL OZONE</div> <div>THIS DOCUMENT AND THE DATA DISCLOSED HEREIN IS PROPRIETARY. IT IS NOT TO BE REPRODUCED, USED, OR OTHERWISE DISCLOSED IN WHOLE, OR IN PART, TO ANYONE, WITHOUT WRITTEN CONSENT FROM DEL OZONE.</div> <div></div> <div>3428 Bullock Ln. San Luis Obispo, CA 93401 (800)676-1335, email: info@delozone.com</div> | <div>PROJECT: QUANTUM</div> <div>TITLE: SPECIFICATION</div> | | |
| | | | | | | DRAWN: FM | | 03/25/05 | | | | |
| | | | | | | ENGR. APPR: | | | | | | |
| | | | | | | CHECKED: | | | | | | |
| | | | | | | MFG. APPR: | | | | | | |
| Q.A. APPR: | | | <div>PART NUMBER: SP-CDF-98</div> <div>REV. B</div> <div>SHEET: 1 OF 1</div> | | | | | | | | | |

APPENDIX C: Pre-Commissioning Checklist

| | | | |
|----------|--|------------|--|
| Customer | | Date | |
| Job Name | | Model No. | |
| Location | | Serial No. | |

Please complete one checklist for each Ozone Generator to be commissioned. Initial all items, note any exceptions/deviations observed and detail any corrective action taken or recommended.

Ozone Generator

- ☐ Properly anchored to mounting surface.
- ☐ Correct voltage supplied and connected.
- ☐ Coolant supply and return connected from proper source.
- ☐ Ozone line (stainless steel or Teflon) connected to outlet fitting.
- ☐ Flow switch (or pump interlock) connected.

Injectors

- ☐ Correct orientation with water flow direction.
- ☐ Ozone line (stainless steel or Teflon) connected with stainless steel ball valve and check valve near injector.

Ozone Destructs

- ☐ Securely mounted.
- ☐ Inlet, vent and drain connections correct.
- ☐ 110 VAC outlet provided (catalytic destruct only)

User I/O

- ☐ ORP and/or dissolved monitor(s) and probe(s) properly installed in accessible location for maintenance.
- ☐ ORP, Dissolved Ozone, Remote Standby, Remote Stop inputs properly connected (jumped out if not used).
- ☐ 4-20 mA signal properly connected if used. Input left open if unused.
- ☐ If used, "Ozone On" and "Fault" output signals connected correctly.

Ambient Ozone Monitor

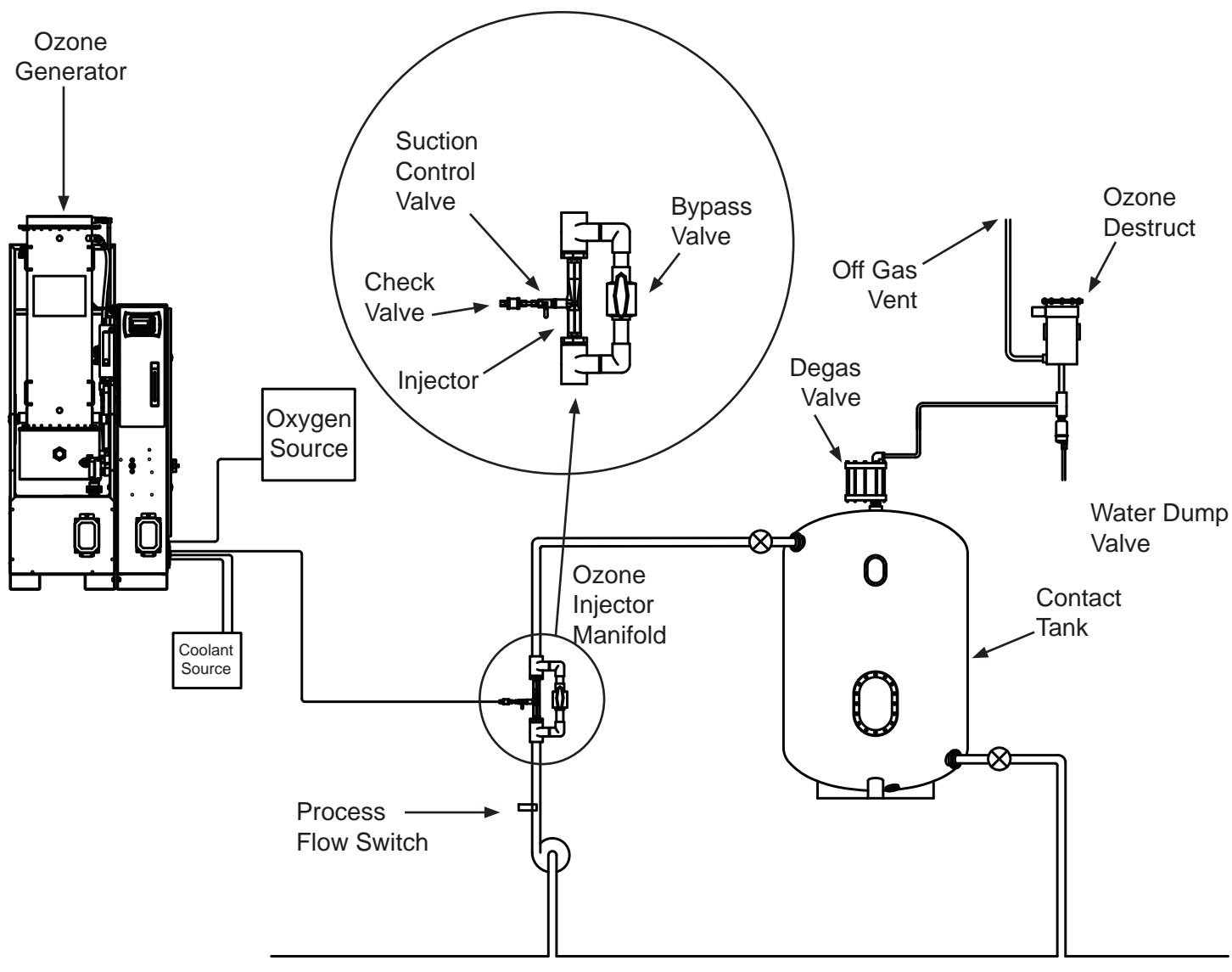
- ☐ Ambient Ozone monitor interlock properly connected to user input terminal.
- ☐ Sensor installed per manufacturer's instructions.

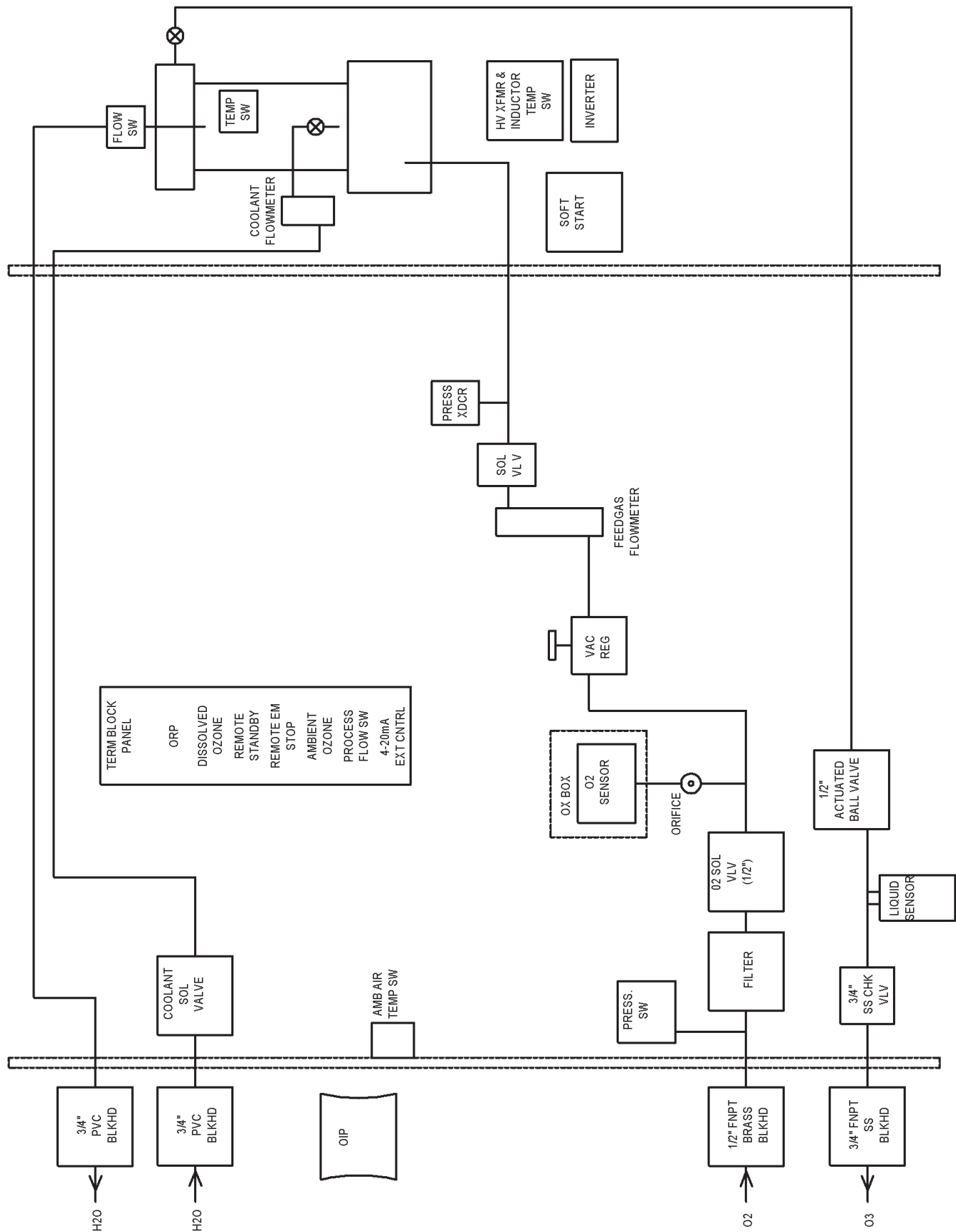
System Plumbing

- ☐ Contact tank(s) or mixing tower(s) properly mounted and plumbed.
- ☐ Degas valve(s) installed properly and plumbed to ozone destruct inlet.
- ☐ Main circulation system in working order including pumps, filters, heater, ...
- ☐ Booster pump operational and ozone side-stream plumbing complete and in proper operating order.

Signed: _____

APPENDIX D: Ozone Process System Typical Layout



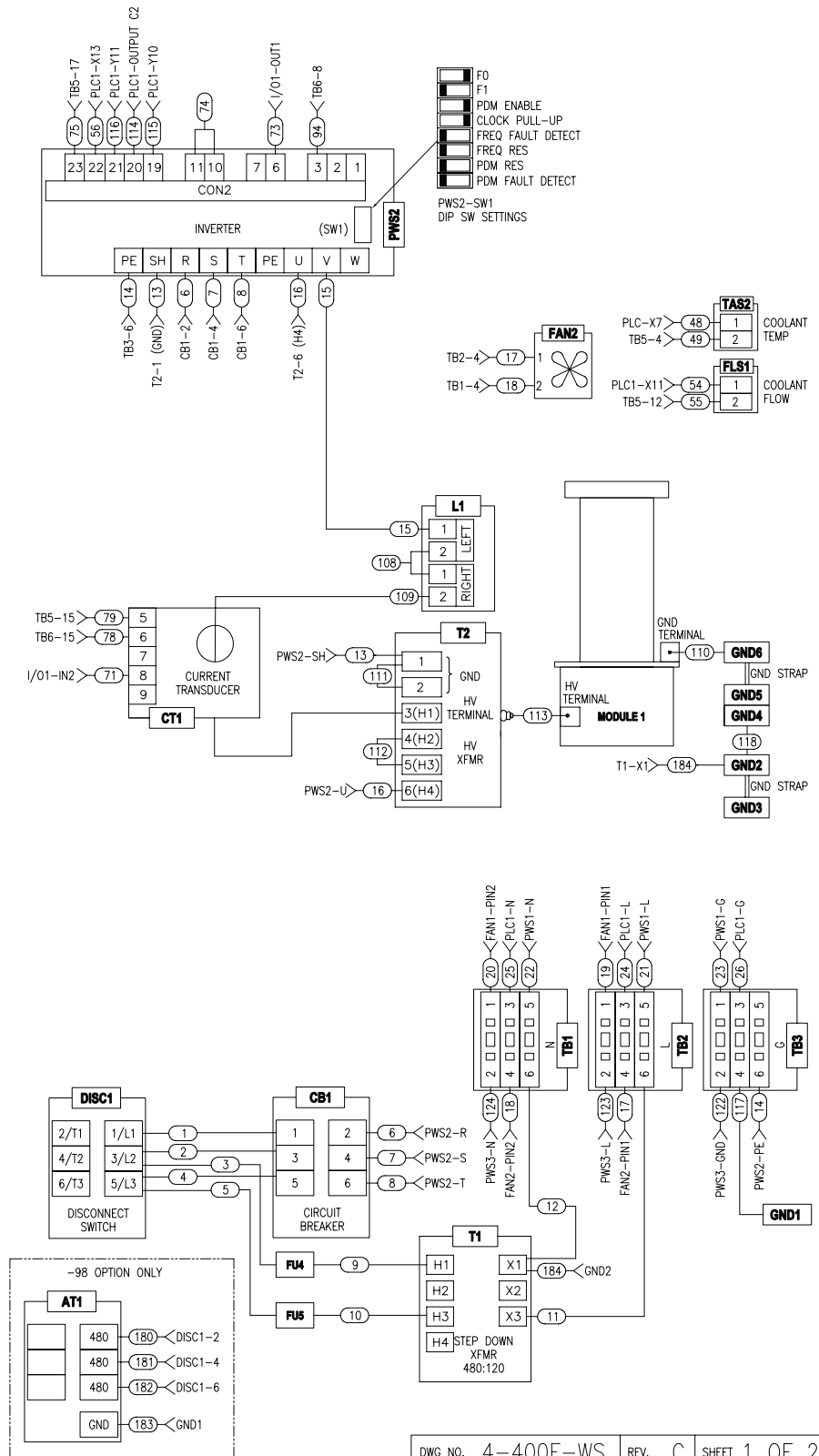
APPENDIX E: System/Controls Block Diagram

APPENDIX F: Wiring Diagram

NOTES:

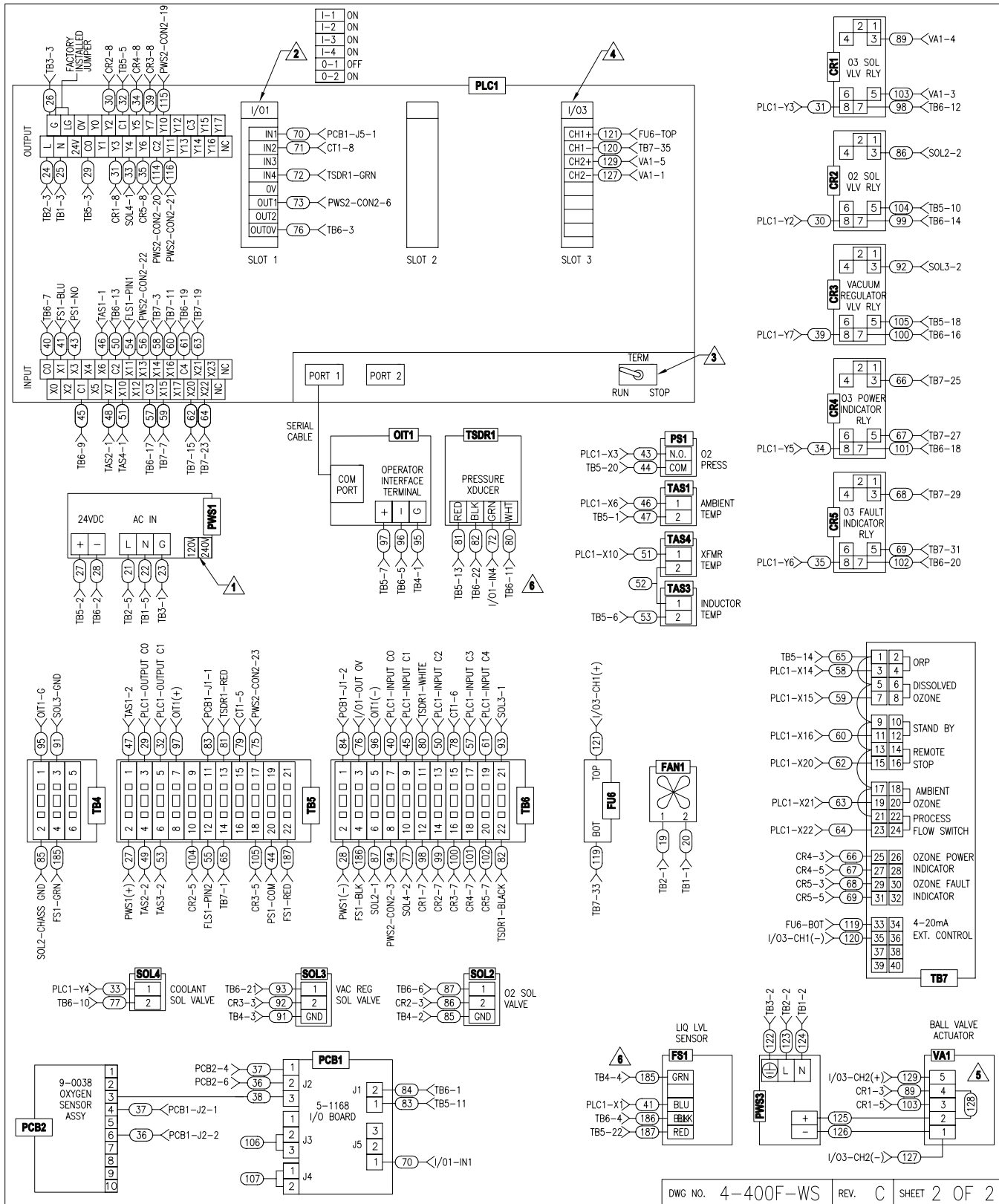
- ▲ SELECT 120V SWITCH SETTING ON PWS1.
- ▲ I/O1 JUMPER SETTINGS. INSTALL IN SLOT 1.
- ▲ TOGGLE SWITCH TO "RUN" MODE.
- ▲ I/O3: NO JUMPER ON J3. INSTALL IN SLOT 3.
- ▲ SET VA1 DIP SWITCHES FOR 2 POSITION CONTROL. SEE DATA SHEET INSTRUCTIONS.
- ▲ MATES TO WIRE HARNESS THROUGH EXTERNAL CONNECTOR. REFER TO ASSEMBLY DRAWING.
- 7. NOMINAL INVERTER PWS2 OUTPUT FREQUENCY 700Hz. ADJUST PER PRODUCTION TEST PROCEDURE.

| REF DES | DEVICE DESCRIPTION |
|---------|--|
| AT1 | AUTOTRANSFORMER, 400:480VAC |
| CB1 | CIRCUIT BREAKER, MAINS |
| CR1 | CONTROL RELAY, OZONE SOLENOID VALVE |
| CR2 | CONTROL RELAY, OXYGEN SOLENOID VALVE |
| CR3 | CONTROL RELAY, VACUUM REGULATOR SOLENOID VALVE |
| CR4 | CONTROL RELAY, OZONE POWER INDICATOR |
| CR5 | CONTROL RELAY, OZONE FAULT INDICATOR |
| CT1 | CURRENT TRANSDUCER |
| DISC1 | DISCONNECT SWITCH, 3 PHASE MAINS |
| FAN1 | FAN, CONTROL BOX |
| FAN2 | FAN, TRANSFORMER BOX |
| FLS1 | FLOW SWITCH, COOLANT FLOW |
| FS1 | LIQUID LEVEL SWITCH |
| FU1 | N/A |
| FU2 | N/A |
| FU3 | N/A |
| FU4 | FUSE, STEP-DOWN TRANSFORMER INPUT |
| FU5 | FUSE, STEP-DOWN TRANSFORMER INPUT |
| FU6 | FUSE, 4-20mA INPUT |
| GND1 | GROUND LUG, CUSTOMER GND LOCATION |
| GND2 | GROUND LUG, CABINET NEAR DOOR |
| GND3 | GROUND LUG, DOOR |
| GND4 | GROUND STUD, OPPOSITE SIDE OF GND 5 |
| GND5 | GROUND LUG, CABINET EXTERIOR |
| GND6 | GROUND LUG, EXTERNAL MODULE FRAME |
| I/O1 | ANALOG I/O MODULE 1 (F0-4AD2DA-2 CARD) |
| I/O2 | N/A |
| I/O3 | 4-20mA INPUT MODULE (F0-04AD-1 CARD) |
| L1 | INDUCTOR |
| MODULE1 | OZONE REACTION CHAMBER 1 |
| OIT1 | OPERATOR INTERFACE TERMINAL |
| PCB1 | I/O DISTRIBUTION BOARD |
| PCB2 | OXYGEN SENSOR BOARD |
| PLC1 | PROGRAMMABLE LOGIC CONTROLLER |
| PS1 | PRESSURE SWITCH, OXYGEN PRESSURE |
| PWS1 | POWER SUPPLY, 24 VDC |
| PWS2 | POWER SUPPLY, INVERTER |
| PWS3 | POWER SUPPLY, 30VDC (FOR VA1) |
| SOL1 | N/A |
| SOL2 | SOLENOID VALVE, OXYGEN |
| SOL3 | SOLENOID VALVE, VAC REGULATOR |
| SOL4 | SOLENOID VALVE, COOLANT FLOW |
| T1 | TRANSFORMER, STEP-DOWN TO 120V |
| T2 | TRANSFORMER, HIGH VOLTAGE |
| TAS1 | TEMPERATURE ACTUATED SWITCH, AMBIENT AIR |
| TAS2 | TEMPERATURE ACTUATED SWITCH, COOLANT |
| TAS3 | TEMPERATURE ACTUATED SWITCH, INDUCTOR |
| TAS4 | TEMPERATURE ACTUATED SWITCH, TRANSFORMER |
| TB1 | TERMINAL BLOCK, 120V NEUTRAL |
| TB2 | TERMINAL BLOCK, 120V LINE |
| TB3 | TERMINAL BLOCK, CHASSIS GROUND |
| TB4 | TERMINAL BLOCK, CHASSIS GROUND |
| TB5 | TERMINAL BLOCK, 24 VDC |
| TB6 | TERMINAL BLOCK, DC GND |
| TB7 | TERMINAL BLOCK, EXTERNAL I/O |
| TSDR1 | TRANSDUCER, PRESSURE |
| VA1 | ACTUATOR, OZONE BALL VALVE |



DWG NO. 4-400F-WS REV. C SHEET 1 OF 2

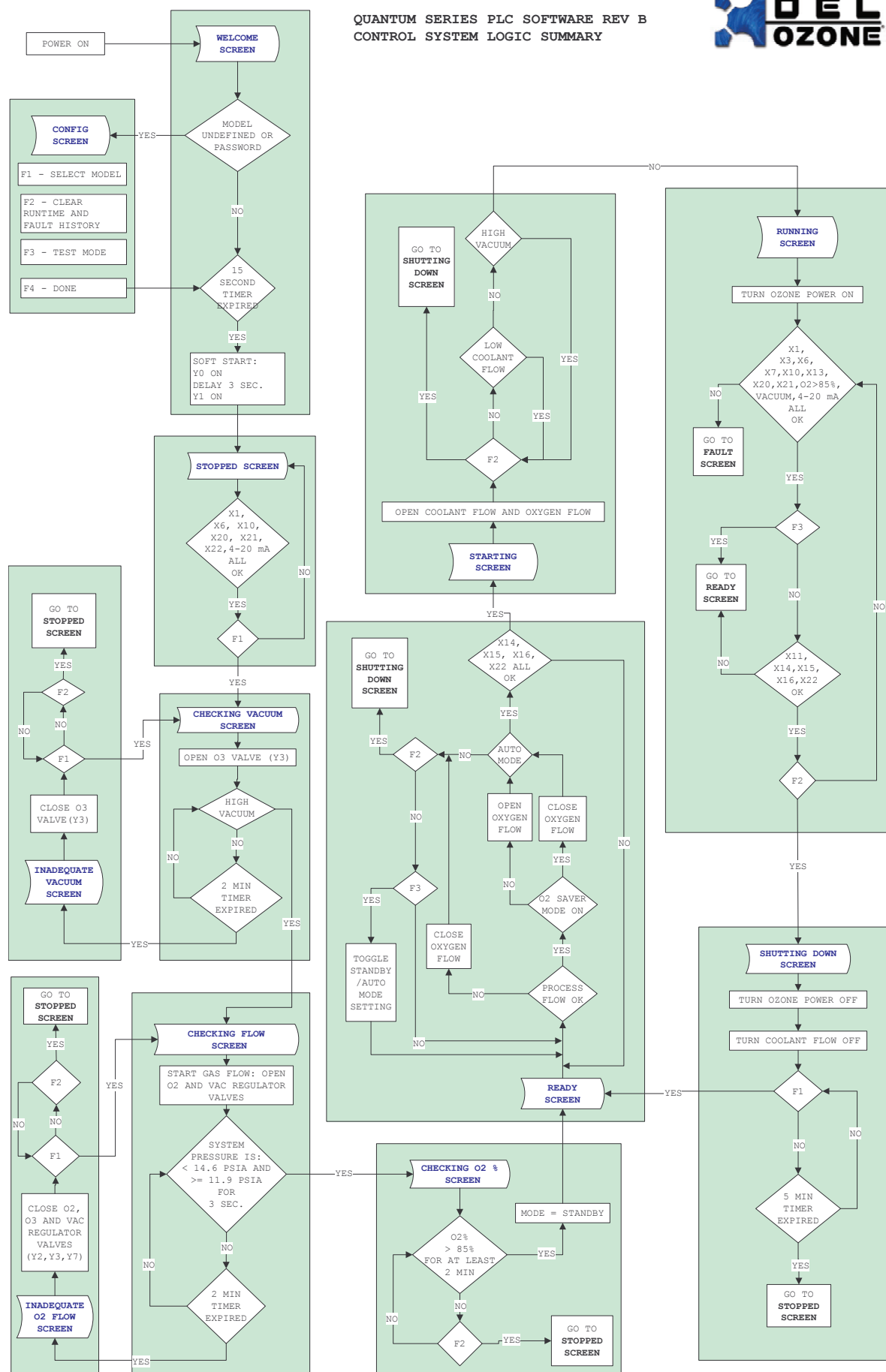
APPENDIX F: Wiring Diagram, Cont.



DWG NO. 4-400F-WS REV. C SHEET 2 OF 2

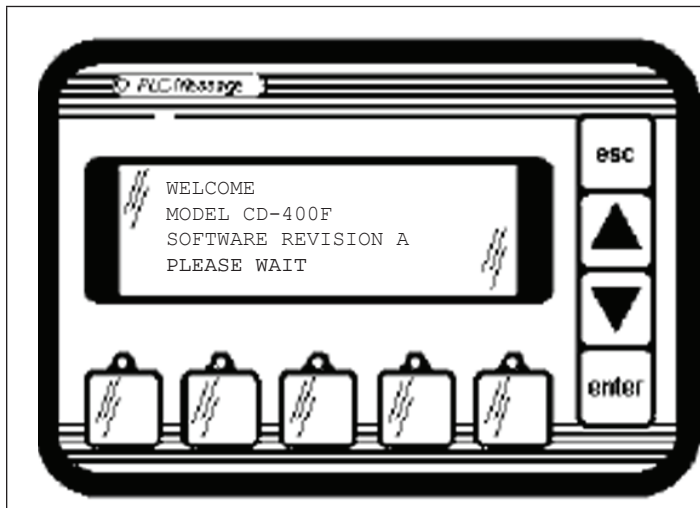
APPENDIX G: PLC Functional Specification

QUANTUM SERIES PLC SOFTWARE REV B
CONTROL SYSTEM LOGIC SUMMARY



APPENDIX G: PLC Functional Specification

WELCOME



- All valves are closed.
- Inverter output is off.
- Soft-start sequence is applied for inverters that require it.
- Model Number and Software Revision are displayed.
- Welcome screen is displayed for 20 seconds, followed by an inverter soft start, and then the STOPPED screen is entered.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|---------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 0 | VALVE CLOSED |
| Y3 | OZONE SOLENOID VALVE | 0 | VALVE CLOSED |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 0 | VALVE CLOSED |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

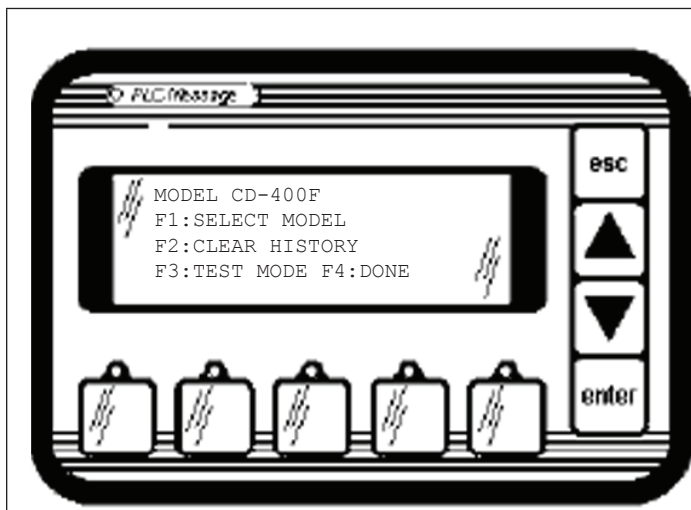
| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | - | - |
| X3 | OXYGEN PRESSURE | - | - |
| X6 | AMBIENT AIR TEMP | - | - |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | - | - |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | - | - |
| X15 | DISSOLVED OZONE | - | - |
| X16 | REMOTE STANDBY | - | - |
| X20 | REMOTE STOP | - | - |
| X21 | AMBIENT O3 | - | - |
| X22 | PROCESS FLOW | - | - |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-5 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

| FUNCTION KEYS | |
|---------------|--|
| KEY | ACTION |
| F1 | IGNORE, EXCEPT FOR PASSWORD KEY SEQUENCE |
| F2 | IGNORE, EXCEPT FOR PASSWORD KEY SEQUENCE |
| F3 | IGNORE, EXCEPT FOR PASSWORD KEY SEQUENCE |
| F4 | IGNORE, EXCEPT FOR PASSWORD KEY SEQUENCE |
| F5 | IGNORE, EXCEPT FOR PASSWORD KEY SEQUENCE |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|--------|
| HIGH VACUUM | IGNORE |
| LOW VACUUM | IGNORE |

| TIMERS | |
|------------|-----------------------------|
| VALUE | DESCRIPTION |
| 20 SECONDS | WELCOME SCREEN DISPLAY TIME |
| 2 SECONDS | SOFT START SEQUENCE TIMING |

APPENDIX G: PLC Functional Specification**CONFIG**

- All valves are closed.
- Inverter output is off.
- Model can be configured
- Fault code history table can be cleared and total runtime can be zeroed.
- Test mode can be enabled to ignore low vacuum.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|--------------|---------------------|
| OUTPUT | DESCRIPTION | SET- TING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 0 | VALVE CLOSED |
| Y3 | OZONE SOLENOID VALVE | 0 | VALVE CLOSED |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 0 | VALVE CLOSED |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | - | - |
| X3 | OXYGEN PRESSURE | - | - |
| X6 | AMBIENT AIR TEMP | - | - |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | - | - |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | - | - |
| X15 | DISSOLVED OZONE | - | - |
| X16 | REMOTE STANDBY | - | - |
| X20 | REMOTE STOP | - | - |
| X21 | AMBIENT O3 | - | - |
| X22 | PROCESS FLOW | - | - |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-5 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

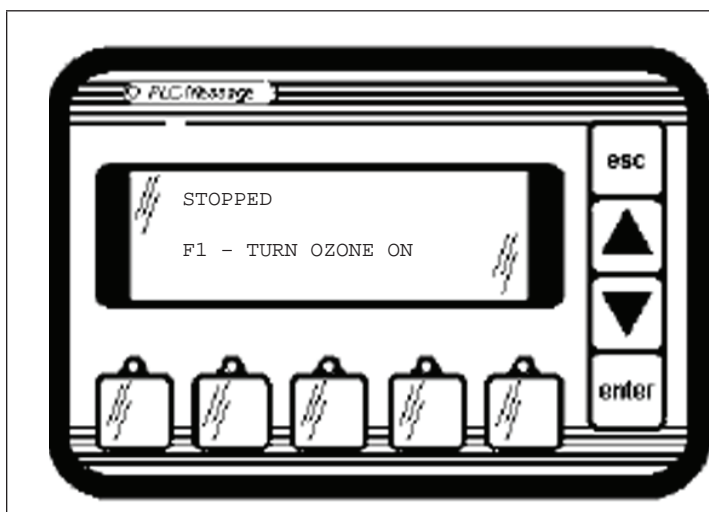
| FUNCTION KEYS | |
|---------------|---|
| KEY | ACTION |
| F1 | CYCLE THROUGH MODEL SELECTIONS |
| F2 | CLEAR FAULT CODE TABLE AND ZERO OUT RUNTIME |
| F3 | SET TEST MODE (LOW VAC WILL BE IGNORED) |
| F4 | DONE |
| F5 | IGNORE |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|--------|
| HIGH VACUUM | IGNORE |
| LOW VACUUM | IGNORE |

| TIMERS | |
|--------|-------------|
| VALUE | DESCRIPTION |
| NONE | - |

APPENDIX G: PLC Functional Specification

STOPPED



- All valves are closed.
- Inverter output is off.
- Any inputs that are not as expected will be displayed on Line 2
- Line 2 must be clear of any messages before F1 can proceed.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|---------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 0 | VALVE CLOSED |
| Y3 | OZONE SOLENOID VALVE | 0 | VALVE CLOSED |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 0 | VALVE CLOSED |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | 1 | CANNOT PROCEED |
| X3 | OXYGEN PRESSURE | 1 | CANNOT PROCEED |
| X6 | AMBIENT AIR TEMP | - | - |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | 1 | CANNOT PROCEED |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | - | - |
| X15 | DISSOLVED OZONE | - | - |
| X16 | REMOTE STANDBY | - | - |
| X20 | REMOTE STOP | 1 | CANNOT PROCEED |
| X21 | AMBIENT O3 | 1 | CANNOT PROCEED |
| X22 | PROCESS FLOW | 1 | CANNOT PROCEED |

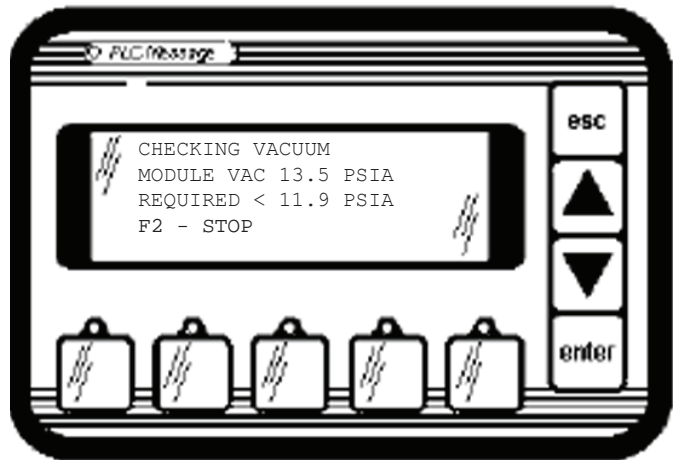
| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| SIGNAL | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

| FUNCTION KEYS | |
|---------------|---|
| KEY | ACTION |
| F1 | IF INPUTS ARE AS EXPECTED, PROCEED TO THE "CHECKING VACUUM" STATE |
| F2 | - |
| F3 | - |
| F4 | - |
| F5 | - |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|--------|
| HIGH VACUUM | IGNORE |
| LOW VACUUM | IGNORE |

| TIMERS | |
|--------|-------------|
| VALUE | DESCRIPTION |
| NONE | - |

APPENDIX G: PLC Functional Specification**CHECKING VACUUM**



- All valves are closed, except for ozone solenoid valve.
- Inverter output is off.
- Sufficient vacuum must be drawn before proceeding.
- There is a time limit for achieving sufficient vacuum, after which the "INSUFFICIENT VACCUM" state is entered.
- Test for sufficient vacuum by allowing system to draw a high vacuum threshold level.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|---------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 0 | VALVE CLOSED |
| Y3 | OZONE SOLENOID VALVE | 1 | VALVE OPEN |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 0 | VALVE CLOSED |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | 1 | PROCEED TO "FAULT" STATE |
| X3 | OXYGEN PRESSURE | - | - |
| X6 | AMBIENT AIR TEMP | 1 | PROCEED TO "FAULT" STATE |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | 1 | PROCEED TO "FAULT" STATE |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | - | - |
| X15 | DISSOLVED OZONE | - | - |
| X16 | REMOTE STANDBY | - | - |
| X20 | REMOTE STOP | 1 | PROCEED TO "FAULT" STATE |
| X21 | AMBIENT O3 | 1 | PROCEED TO "FAULT" STATE |
| X22 | PROCESS FLOW | 1 | PROCEED TO "FAULT" STATE |

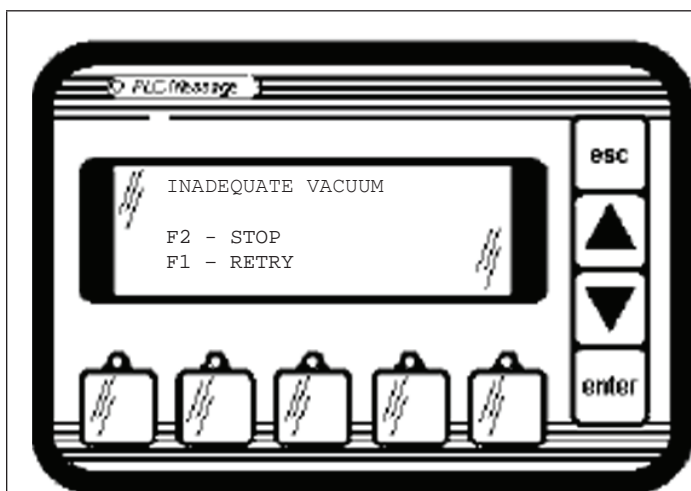
| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

| FUNCTION KEYS | |
|---------------|----------------------------|
| KEY | ACTION |
| F1 | - |
| F2 | PROCEED TO "STOPPED" STATE |
| F3 | - |
| F4 | - |
| F5 | - |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|------------------------------|
| HIGH VACUUM | PROCEED TO "CHECKING FLOW" * |
| LOW VACUUM | IGNORE |

* IGNORE IN TEST MODE

| TIMERS | |
|-----------|--|
| VALUE | DESCRIPTION |
| 2 MINUTES | MAX TIME TO ACHIEVE CORRECT VACUUM |
| 1 SECOND | TIME VAC READING MUST BE OK BEFORE BEING CONSIDERED WITHIN RANGE |

APPENDIX G: PLC Functional Specification**INADEQUATE VACUUM**

- All valves are closed.
- Inverter output is off.
- This state protects the system from being left open indefinitely to potential water backflow.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|---------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 0 | VALVE CLOSED |
| Y3 | OZONE SOLENOID VALVE | 0 | VALVE CLOSED |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 0 | VALVE CLOSED |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

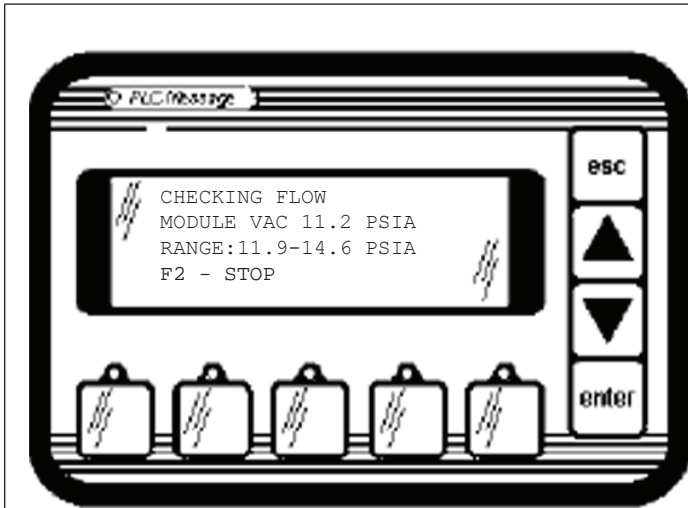
| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPPD | 1 | PROCEED TO "FAULT" STATE |
| X3 | OXYGEN PRESSURE | - | - |
| X6 | AMBIENT AIR TEMP | 1 | PROCEED TO "FAULT" STATE |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | 1 | PROCEED TO "FAULT" STATE |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | - | - |
| X15 | DISSOLVED OZONE | - | - |
| X16 | REMOTE STANDBY | - | - |
| X20 | REMOTE STOP | 1 | PROCEED TO "FAULT" STATE |
| X21 | AMBIENT O3 | 1 | PROCEED TO "FAULT" STATE |
| X22 | PROCESS FLOW | 1 | PROCEED TO "FAULT" STATE |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

| FUNCTION KEYS | |
|---------------|------------------------------------|
| KEY | ACTION |
| F1 | PROCEED TO "CHECKING VACUUM" STATE |
| F2 | PROCEED TO "STOPPED" STATE |
| F3 | - |
| F4 | - |
| F5 | - |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|--------|
| HIGH VACUUM | IGNORE |
| LOW VACUUM | IGNORE |

| TIMERS | |
|--------|-------------|
| VALUE | DESCRIPTION |
| NONE | - |

APPENDIX G: PLC Functional Specification**CHECKING FLOW**

- All 3 oxygen flow valves are open (oxygen, ozone and vacuum regulator valves) to allow oxygen flow.
- Inverter output is off.
- Correct flow range must be established before proceeding.
- Flow range is correlated to a range of vacuum reading.
- There is a time limit for achieving correct flow, after which the "INADEQUATE FLOW" state is entered.
- Once correct sufficient vacuum has been obtained, automatically proceed to the "CHECKING OXYGEN FLOW" state.
- In Test Mode, vacuum reading is ignored and assumed good.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|---------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 1 | VALVE OPEN |
| Y3 | OZONE SOLENOID VALVE | 1 | VALVE OPEN |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 1 | VALVE OPEN |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | 1 | PROCEED TO "FAULT" STATE |
| X3 | OXYGEN PRESSURE | - | - |
| X6 | AMBIENT AIR TEMP | 1 | PROCEED TO "FAULT" STATE |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | 1 | PROCEED TO "FAULT" STATE |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | - | - |
| X15 | DISSOLVED OZONE | - | - |
| X16 | REMOTE STANDBY | - | - |
| X20 | REMOTE STOP | 1 | PROCEED TO "FAULT" STATE |
| X21 | AMBIENT O3 | 1 | PROCEED TO "FAULT" STATE |
| X22 | PROCESS FLOW | 1 | PROCEED TO "FAULT" STATE |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| SIGNAL | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

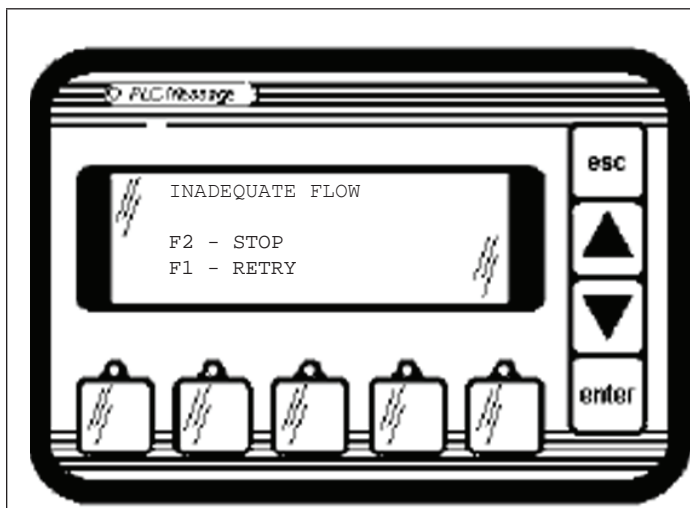
| FUNCTION KEYS | |
|---------------|----------------------------|
| KEY | ACTION |
| F1 | - |
| F2 | PROCEED TO "STOPPED" STATE |
| F3 | - |
| F4 | - |
| F5 | - |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|-------------------------|
| HIGH VACUUM | WAIT FOR CORRECT VACUUM |
| LOW VACUUM | WAIT FOR CORRECT VACUUM |

| TIMERS | |
|-----------|--|
| VALUE | DESCRIPTION |
| 2 MINUTES | MAX TIME TO ACHIEVE CORRECT VACUUM |
| 3 SECONDS | TIME VAC READING MUST BE OK BEFORE BEING CONSIDERED WITHIN RANGE |

APPENDIX G: PLC Functional Specification

INADEQUATE FLOW



- All valves are closed.
- Inverter output is off.
- This state protects the system from being left open indefinitely to potential water backflow.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|---------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 0 | VALVE CLOSED |
| Y3 | OZONE SOLENOID VALVE | 0 | VALVE CLOSED |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 0 | VALVE CLOSED |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

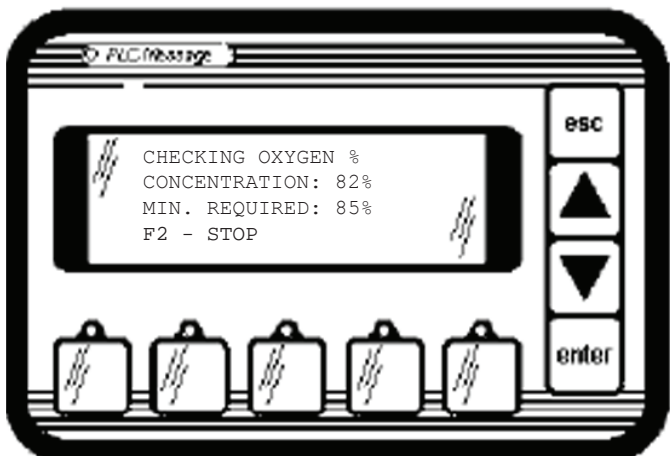
| FUNCTION KEYS | |
|---------------|----------------------------------|
| KEY | ACTION |
| F1 | PROCEED TO "CHECKING FLOW" STATE |
| F2 | PROCEED TO "STOPPED" STATE |
| F3 | - |
| F4 | - |
| F5 | - |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|--------|
| HIGH VACUUM | IGNORE |
| LOW VACUUM | IGNORE |

| TIMERS | |
|--------|-------------|
| VALUE | DESCRIPTION |
| NONE | - |

| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | 1 | PROCEED TO "FAULT" STATE |
| X3 | OXYGEN PRESSURE | - | - |
| X6 | AMBIENT AIR TEMP | 1 | PROCEED TO "FAULT" STATE |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | 1 | PROCEED TO "FAULT" STATE |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | - | - |
| X15 | DISSOLVED OZONE | - | - |
| X16 | REMOTE STANDBY | - | - |
| X20 | REMOTE STOP | 1 | PROCEED TO "FAULT" STATE |
| X21 | AMBIENT O3 | 1 | PROCEED TO "FAULT" STATE |
| X22 | PROCESS FLOW | 1 | PROCEED TO "FAULT" STATE |

APPENDIX G: PLC Functional Specification**CHECKING O2 %**



- All 3 oxygen flow valves are open (oxygen, ozone and vacuum regulator valves) to allow oxygen flow.
- Inverter output is off.
- Minimum oxygen concentration must be maintained continuously for 2 minutes before proceeding.
- Once oxygen concentration check has completed successfully, the "READY" state is entered.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|---------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 1 | VALVE OPEN |
| Y3 | OZONE SOLENOID VALVE | 1 | VALVE OPEN |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 1 | VALVE OPEN |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|----------------------------|--------|--------------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | MONITOR |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/ PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

| FUNCTION KEYS | |
|---------------|----------------------------|
| KEY | ACTION |
| F1 | - |
| F2 | PROCEED TO "STOPPED" STATE |
| F3 | - |
| F4 | - |
| F5 | - |

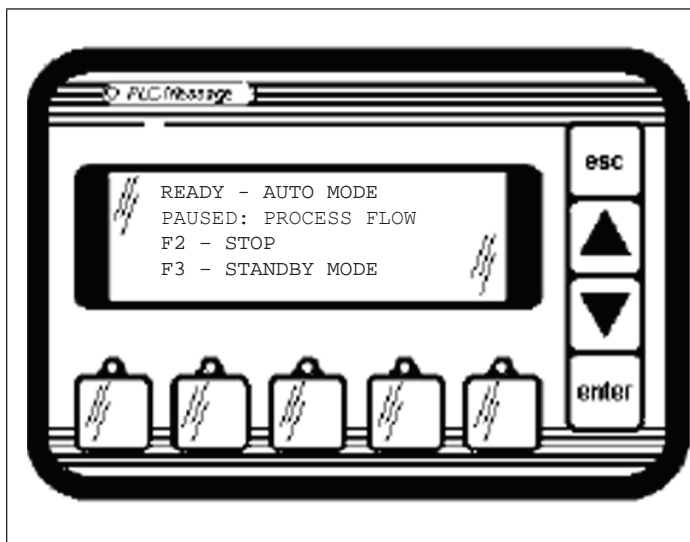
| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|--------|
| HIGH VACUUM | IGNORE |
| LOW VACUUM | IGNORE |

| TIMERS | |
|-----------|-------------------------------|
| VALUE | DESCRIPTION |
| 2 MINUTES | DURATION O2% MUST REMAIN GOOD |

| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | 1 | PROCEED TO "FAULT" STATE |
| X3 | OXYGEN PRESSURE | 1 | PROCEED TO "FAULT" STATE |
| X6 | AMBIENT AIR TEMP | 1 | PROCEED TO "FAULT" STATE |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | 1 | PROCEED TO "FAULT" STATE |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | - | - |
| X15 | DISSOLVED OZONE | - | - |
| X16 | REMOTE STANDBY | - | - |
| X20 | REMOTE STOP | 1 | PROCEED TO "FAULT" STATE |
| X21 | AMBIENT O3 | 1 | PROCEED TO "FAULT" STATE |
| X22 | PROCESS FLOW | 1 | PROCEED TO "FAULT" STATE |

APPENDIX G: PLC Functional Specification

READY



- Depending on O2 saver mode setting, oxygen flow valves are either all open or all closed.
- If Process Flow is lost, oxygen flow will be closed, while pausing in this state until process flow returns.
- Inverter output is off.
- Standby or Auto Mode
- Standby will wait indefinitely.
- Auto mode will allow ozone production based on ORP, Remote Standby and Dissolved O3 signals.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|-------------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | DEPENDS | O2 SAVER MODE DEPENDANT |
| Y3 | OZONE SOLENOID VALVE | DEPENDS | O2 SAVER MODE DEPENDANT |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | DEPENDS | O2 SAVER MODE DEPENDANT |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

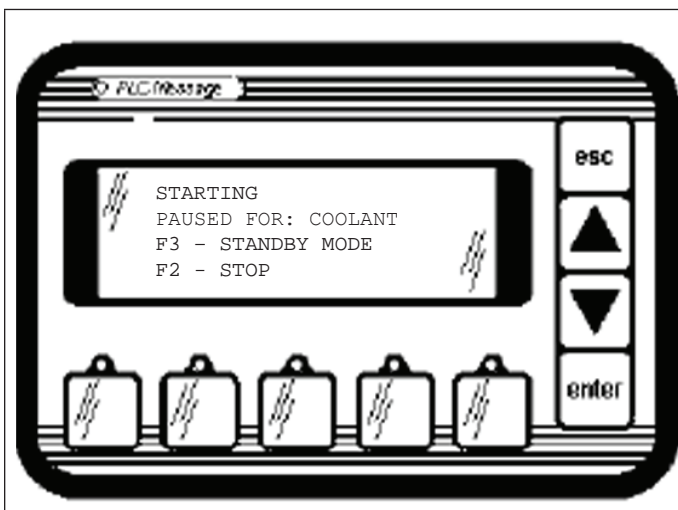
| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | 1 | PROCEED TO "FAULT" STATE |
| X3 | OXYGEN PRESSURE | 1 | PROCEED TO "FAULT" STATE |
| X6 | AMBIENT AIR TEMP | 1 | PROCEED TO "FAULT" STATE |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | 1 | PROCEED TO "FAULT" STATE |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | DEPENDS | PROCEED TO "STARTING" IF |
| X15 | DISSOLVED OZONE | DEPENDS | IN AUTO MODE AND ALL 3 |
| X16 | REMOTE STANDBY | DEPENDS | SIGNALS ARE CLOSED |
| X20 | REMOTE STOP | 1 | PROCEED TO "FAULT" STATE |
| X21 | AMBIENT O3 | 1 | PROCEED TO "FAULT" STATE |
| X22 | PROCESS FLOW | 1 | PROCEED TO "FAULT" STATE |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

| FUNCTION KEYS | |
|---------------|----------------------------------|
| KEY | ACTION |
| F1 | - |
| F2 | PROCEED TO "SHUTTING DOWN" STATE |
| F3 | TOGGLE STANBY/AUTO MODE |
| F4 | - |
| F5 | - |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|---------------------|
| HIGH VACUUM | IGNORE |
| LOW VACUUM | GO TO "FAULT" STATE |

| TIMERS | |
|--------|-------------|
| VALUE | DESCRIPTION |
| NONE | - |

APPENDIX G: PLC Functional Specification**STARTING**

- Oxygen flow valves are all open.
- Coolant flow valve is open.
- Inverter output is off.
- Waiting for coolant flow ok and any high vacuum condition to return to normal.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|---------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 1 | VALVE OPEN |
| Y3 | OZONE SOLENOID VALVE | 1 | VALVE OPEN |
| Y4 | COOLANT SOLENOID VALVE | 1 | VALVE OPEN |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 1 | VALVE OPEN |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

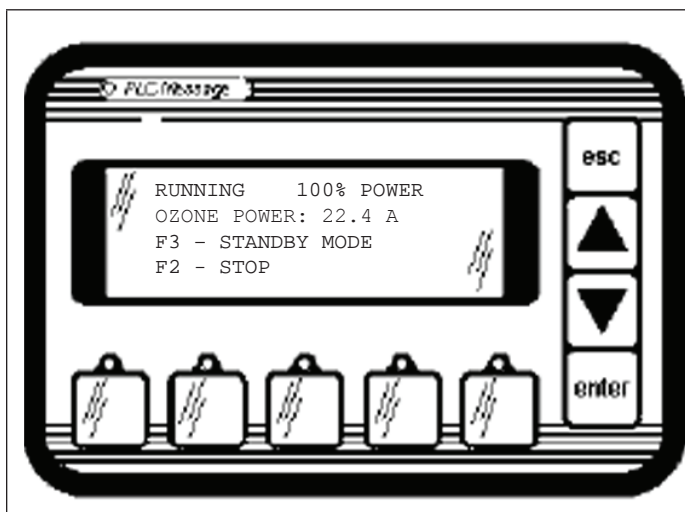
| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | 1 | PROCEED TO "FAULT" STATE |
| X3 | OXYGEN PRESSURE | 1 | PROCEED TO "FAULT" STATE |
| X6 | AMBIENT AIR TEMP | 1 | PROCEED TO "FAULT" STATE |
| X7 | COOLANT TEMP | 1 | PROCEED TO "FAULT" STATE |
| X10 | TRANSFORMER TEMP | 1 | PROCEED TO "FAULT" STATE |
| X11 | COOLANT FLOW | 1 | WAIT FOR SIGNAL |
| X13 | INVERTER ON | - | - |
| X14 | ORP | 1 | PROCEED TO "READY" STATE |
| X15 | DISSOLVED OZONE | 1 | |
| X16 | REMOTE STANDBY | 1 | |
| X20 | REMOTE STOP | 1 | PROCEED TO "FAULT" STATE |
| X21 | AMBIENT O3 | 1 | PROCEED TO "FAULT" STATE |
| X22 | PROCESS FLOW | 1 | PROCEED TO "FAULT" STATE |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

| FUNCTION KEYS | |
|---------------|----------------------------------|
| KEY | ACTION |
| F1 | - |
| F2 | PROCEED TO "SHUTTING DOWN" STATE |
| F3 | PROCEED TO "READY" STATE |
| F4 | - |
| F5 | - |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|----------------------------|
| HIGH VACUUM | WAIT FOR VACUUM TO CORRECT |
| LOW VACUUM | GO TO "FAULT" STATE |

| TIMERS | |
|--------|-------------|
| VALUE | DESCRIPTION |
| NONE | - |

APPENDIX G: PLC Functional Specification**RUNNING**

- Oxygen flow valves are all open.
- Coolant flow valve is open.
- Inverter output is ON.
- Ozone is being produced at a power setting that is controlled by PID loop control on the transformer/inductor current as a percentage of maximum current.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|--------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 1 | VALVE OPEN |
| Y3 | OZONE SOLENOID VALVE | 1 | VALVE OPEN |
| Y4 | COOLANT SOLENOID VALVE | 1 | VALVE OPEN |
| Y5 | OZONE POWER INDICATOR | 1 | INVERTER ON |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 1 | VALVE OPEN |
| Y10 | INVERTER OFF | 0 | INVERTER OUTPUT ON |
| Y11 | INVERTER ON | 1 | INVERTER OUTPUT ON |

| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | 1 | PROCEED TO "FAULT" STATE |
| X3 | OXYGEN PRESSURE | 1 | PROCEED TO "FAULT" STATE |
| X6 | AMBIENT AIR TEMP | 1 | PROCEED TO "FAULT" STATE |
| X7 | COOLANT TEMP | 1 | PROCEED TO "FAULT" STATE |
| X10 | TRANSFORMER TEMP | 1 | PROCEED TO "FAULT" STATE |
| X11 | COOLANT FLOW | 1 | PROCEED TO "READY" STATE |
| X13 | INVERTER ON | 1 | PROCEED TO "FAULT" STATE |
| X14 | ORP | 1 | PROCEED TO "READY" STATE |
| X15 | DISSOLVED OZONE | 1 | |
| X16 | REMOTE STANDBY | 1 | |
| X20 | REMOTE STOP | 1 | PROCEED TO "FAULT" STATE |
| X21 | AMBIENT O3 | 1 | PROCEED TO "FAULT" STATE |
| X22 | PROCESS FLOW | 1 | PROCEED TO "READY" STATE |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|--------------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | FAULT IF LOW |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | PID CONTROL |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | PID CONTROL |
| OUT 2 | - | - | - |

| FUNCTION KEYS | |
|---------------|----------------------------------|
| KEY | ACTION |
| F1 | - |
| F2 | PROCEED TO "SHUTTING DOWN" STATE |
| F3 | PROCEED TO "READY" STATE |
| F4 | - |
| F5 | - |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|---------------------|
| HIGH VACUUM | GO TO "FAULT" STATE |
| LOW VACUUM | GO TO "FAULT" STATE |

| TIMERS | |
|------------|--|
| VALUE | DESCRIPTION |
| 1 SECOND | INVERTER ON DELAY TO AVOID POSSIBLE TIMING FAULT (OFF/ON TOO FAST) |
| 1 SECOND | O2 PRESSURE SWITCH DEBOUNCE FILTER |
| 1 SECOND | WAIT FOR VALID INVERTER RELAY OUTPUT |
| 10 SECONDS | TIME BEFORE LOW O2% CONSIDERED TRUE |

APPENDIX G: PLC Functional Specification**SHUTTING DOWN**

- Oxygen flow valves are all open.
- Coolant flow valve is OFF.
- Inverter output is off.
- During this state, ozone is being purged from the machine.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|---------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 1 | VALVE OPEN |
| Y3 | OZONE SOLENOID VALVE | 1 | VALVE OPEN |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 0 | NO FAULTS |
| Y7 | VAC REGULATOR VALVE | 1 | VALVE OPEN |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | 1 | PROCEED TO "FAULT" STATE |
| X3 | OXYGEN PRESSURE | 1 | PROCEED TO "FAULT" STATE |
| X6 | AMBIENT AIR TEMP | 1 | PROCEED TO "FAULT" STATE |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | 1 | PROCEED TO "FAULT" STATE |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | - | - |
| X15 | DISSOLVED OZONE | - | - |
| X16 | REMOTE STANDBY | - | - |
| X20 | REMOTE STOP | 1 | PROCEED TO "FAULT" STATE |
| X21 | AMBIENT O3 | 1 | PROCEED TO "FAULT" STATE |
| X22 | PROCESS FLOW | 1 | PROCEED TO "FAULT" STATE |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | INACTIVE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

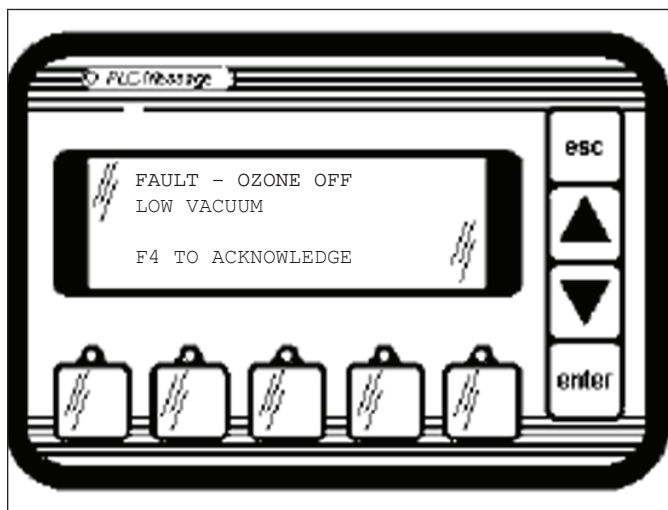
| FUNCTION KEYS | |
|---------------|--------------------------|
| KEY | ACTION |
| F1 | PROCEED TO "READY" STATE |
| F2 | - |
| F3 | - |
| F4 | - |
| F5 | - |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|--------|
| HIGH VACUUM | IGNORE |
| LOW VACUUM | IGNORE |

| TIMERS | |
|-----------|------------------|
| VALUE | DESCRIPTION |
| 5 MINUTES | OZONE PURGE TIME |

APPENDIX G: PLC Functional Specification

FAULT



- All valves are all CLOSED.
- Coolant flow valve is OFF.
- Inverter output is off.
- Specific fault condition is indicated on Line 2.
- The way to clear this state is by a manual user acknowledgement (press F4).
- Fault code and runtime are logged in the fault history table.

| DIGITAL OUTPUTS | | | |
|-----------------|------------------------|---------|---------------------|
| OUTPUT | DESCRIPTION | SETTING | FUNCTION |
| Y0 | SOFT START RELAY1 | 1 | POWER TO INVERTER |
| Y1 | SOFT START RELAY2 | 1 | POWER TO INVERTER |
| Y2 | OXYGEN SOLENOID VALVE | 0 | VALVE CLOSED |
| Y3 | OZONE SOLENOID VALVE | 0 | VALVE CLOSED |
| Y4 | COOLANT SOLENOID VALVE | 0 | VALVE CLOSED |
| Y5 | OZONE POWER INDICATOR | 0 | INVERTER OFF |
| Y6 | OZONE FAULT INDICATOR | 1 | INDICATE A FAULT |
| Y7 | VAC REGULATOR VALVE | 0 | VALVE CLOSED |
| Y10 | INVERTER OFF | 1 | INVERTER OUTPUT OFF |
| Y11 | INVERTER ON | 0 | INVERTER OUTPUT OFF |

| DIGITAL INPUTS | | | |
|----------------|------------------|----------|--------------------|
| INPUT | FUNCTION | EXPECTED | IF NOT AS EXPECTED |
| X1 | BFPD | - | - |
| X3 | OXYGEN PRESSURE | - | - |
| X6 | AMBIENT AIR TEMP | - | - |
| X7 | COOLANT TEMP | - | - |
| X10 | TRANSFORMER TEMP | - | - |
| X11 | COOLANT FLOW | - | - |
| X13 | INVERTER ON | - | - |
| X14 | ORP | - | - |
| X15 | DISSOLVED OZONE | - | - |
| X16 | REMOTE STANDBY | - | - |
| X20 | REMOTE STOP | - | - |
| X21 | AMBIENT O3 | - | - |
| X22 | PROCESS FLOW | - | - |

| ANALOG MODULE, SLOT 1 | | | |
|-----------------------|------------------------|--------|-----------|
| | DESCRIPTION | RANGE | ACTION |
| IN 1 | OXYGEN CONCENTRATION | 0-1 V | IGNORE |
| IN 2 | TRANSFORMER 1 CURRENT | 0-5 V | IGNORE |
| IN 3 | - | - | - |
| IN 4 | SYSTEM VACUUM/PRESSURE | 0-10 V | SEE BELOW |
| OUT 1 | PDM TO INVERTER | 0-10 V | INACTIVE |
| OUT 2 | - | - | - |

| FUNCTION KEYS | |
|---------------|----------------------------|
| KEY | ACTION |
| F1 | - |
| F2 | - |
| F3 | - |
| F4 | PROCEED TO "STOPPED" STATE |
| F5 | - |

| SYSTEM VACUUM/PRESSURE CONDITION | |
|----------------------------------|--------|
| HIGH VACUUM | IGNORE |
| LOW VACUUM | IGNORE |

| TIMERS | |
|--------|-------------|
| VALUE | DESCRIPTION |
| NONE | - |

APPENDIX H: Maintenance Log Sheet

A copy of this log must be submitted to DEL Ozone upon request in order to validate the warranty agreement.

| | |
|-----------|--------|
| Date: | Notes: |
| Initials: | |
| Hours: | |
| Date: | Notes: |
| Initials: | |
| Hours: | |
| Date: | Notes: |
| Initials: | |
| Hours: | |
| Date: | Notes: |
| Initials: | |
| Hours: | |
| Date: | Notes: |
| Initials: | |
| Hours: | |
| Date: | Notes: |
| Initials: | |
| Hours: | |
| Date: | Notes: |
| Initials: | |
| Hours: | |
| Date: | Notes: |
| Initials: | |
| Hours: | |
| Date: | Notes: |
| Initials: | |
| Hours: | |
| Date: | Notes: |
| Initials: | |
| Hours: | |
| Date: | Notes: |
| Initials: | |
| Hours: | |

APPENDIX I: Pressure Conversion Table

| | psia | inHg* | kPa* | atm* |
|-------------------|------|-------|------|------|
| Low Vacuum Limit | 14.6 | 0.2 | 0.7 | 0.01 |
| | 14.5 | 0.4 | 1.4 | 0.01 |
| | 14.4 | 0.6 | 2.1 | 0.02 |
| | 14.3 | 0.8 | 2.8 | 0.03 |
| | 14.2 | 1.0 | 3.4 | 0.03 |
| | 14.1 | 1.2 | 4.1 | 0.04 |
| | 14.0 | 1.4 | 4.8 | 0.05 |
| | 13.9 | 1.6 | 5.5 | 0.05 |
| | 13.8 | 1.8 | 6.2 | 0.06 |
| | 13.7 | 2.0 | 6.9 | 0.07 |
| | 13.6 | 2.2 | 7.6 | 0.07 |
| | 13.5 | 2.4 | 8.3 | 0.08 |
| | 13.4 | 2.6 | 9.0 | 0.09 |
| | 13.3 | 2.9 | 9.7 | 0.10 |
| | 13.2 | 3.1 | 10.3 | 0.10 |
| | 13.1 | 3.3 | 11.0 | 0.11 |
| | 13.0 | 3.5 | 11.7 | 0.12 |
| | 12.9 | 3.7 | 12.4 | 0.12 |
| | 12.8 | 3.9 | 13.1 | 0.13 |
| | 12.7 | 4.1 | 13.8 | 0.14 |
| | 12.6 | 4.3 | 14.5 | 0.14 |
| | 12.5 | 4.5 | 15.2 | 0.15 |
| | 12.4 | 4.7 | 15.9 | 0.16 |
| | 12.3 | 4.9 | 16.5 | 0.16 |
| | 12.2 | 5.1 | 17.2 | 0.17 |
| | 12.1 | 5.3 | 17.9 | 0.18 |
| | 12.0 | 5.5 | 18.6 | 0.18 |
| High Vacuum Limit | 11.9 | 5.7 | 19.3 | 0.19 |

* Below ambient (negative)

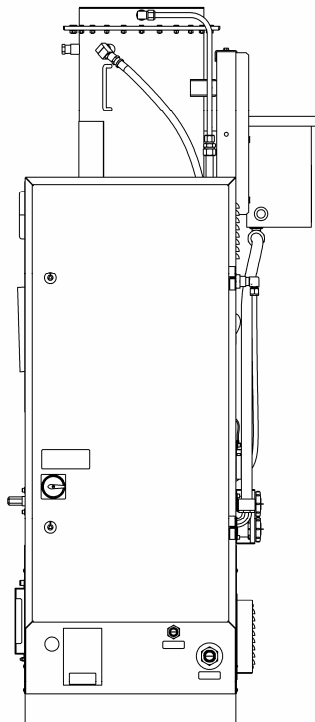


APPENDIX J: Option - 98 Installation Notes

Power connections for Quantum™ model Ozone Generators with a Buck/Boost Autotransformer.

Quantum™ Ozone Generators with a -98 option in the model number (i.e. CD-400F-98) have a factory installed buck/boost autotransformer located externally, behind Ozone Module 1 as shown in the diagram below.

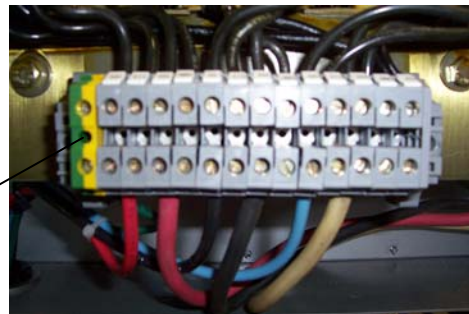
Electrical power connections are made inside the buck/boost autotransformer enclosure. The transformer output is factory pre-wired to the correct locations inside the ozone generator's electronics cabinet. Do not modify wiring inside of the electronics cabinet.



INSTALLATION:

- Wiring to be installed by a qualified electrician only. Always follow all applicable electrical codes.
- Connect each of the incoming 3 phase wires to the desired tap locations as labeled on the terminal block. Select the voltage closest to the available facility voltage.
- All 3 phase wires must be connected to three consistent voltage tap locations. Do not mix voltage tap values.
- **IMPORTANT: BE SURE TO CONNECT GROUND WIRE TO GROUND LOCATION INSIDE THE BUCK/BOOST AUTOTRANSFORMER CABINET.**
- Do not remove the factory pre-installed wiring.

Ground
Block



OZONE

Material Safety Data Sheet

SECTION I: MATERIAL IDENTIFICATION

IDENTITY: OZONE (Gaseous)

ISSUED: February, 1992

FORMULA: O₃

REVISED: September, 2001

Description (origin/uses): Occurs in atmosphere from UV light action on oxygen at high altitude. Commercially obtained by passing air between electrodes carrying a high voltage alternating current. Also found as a by-product in welding areas, high voltage equipment, or UV radiation.

Ozone is used as an oxidizing agent in air and water disinfection: for bleaching textiles, oils, and waxes; organic synthesis as in processing certain perfumes, vanillin, camphor; for mold and bacteria control in cold storage.

Cautions: A powerful oxidizing agent, ozone generally exists as a gas and is highly chemically reactive. Inhalation produces various degrees of respiratory effects from irritation to pulmonary edema (fluid in lungs) as well as affecting the eyes, blood, and central nervous system.

Manufacturer/Supplier: On-site generation, equipment available from various suppliers, including:

DEL Industries

Phone: (805) 541-1601

3428 Bullock Ln.

FAX: (805) 541-8459

San Luis Obispo, CA 93401

SECTION II: INGREDIENTS AND HAZARDS

Ozone, CAS No. 10028-15-6: NIOSH RTECS No. RS8225000

1991 OSHA PELs

8-hr TWA: 0.1 ppm vol. (0.2 mg/m³)15-min STEL: 0.3 ppm vol (0.6 mg/m³)

1991-1992 ACGIH TLV

Ceiling: 0.1 ppm (0.2 mg/m³)

1996 IDLH

5 ppm

1990 DFG (Germany) MAK

TWA: 0.1 ppm (0.2 mg/m³)

Category 1: Local Irritant

Peak Exposure Limit: 0.2 ppm

5 min momentary value, 8 per shift

1990 NIOSH REL

Ceiling: 0.1 ppm vol. (0.2 mg/m³)

Other Designations: Triatomic oxygen: CAS No. 10028-15-6, NIOSH RTECS No. RS8225000

SECTION III: PHYSICAL DATA

Boiling Point: -169° F

Vapor Pressure: >1 ATM

Vapor Density (AIR = 1): 1.6

Solubility in Water: ... 0.49 ml @ 32° F (0° C),
30 ppm @ 68° (20° C)

Melting Point: -315.4° F (-193° C)

% Volatile by Volume: .. 100%

Molecular Weight: 48 Grams/Mole

pH: Not Listed

Critical Temperature: .. 10.22° F (-12.1° C)

Appearance and Odor: Colorless to blue gas (greater than -169° F): characteristic odor often associated with electrical sparks or lightning in concentrations of less than 2 ppm and becomes disagreeable above 1-2 ppm. CAUTION: Olfactory fatigue develops rapidly, so do not use odor as a preventative warning device.

SECTION IV: FIRE AND EXPLOSION HAZARD DATA

Flash Point: Nonflammable

Extinguishing Media: Use large amounts of water spray or fog to put out fires involving ozone. Use appropriate fire-fighting techniques to deal with surrounding material.

Special Fire Fighting Procedures: Wear a self contained breathing apparatus with full facepieces operated in a pressure-demand or other positive-pressure mode.

Unusual Fire/Explosion Hazards: Decomposition of ozone into oxygen gas, (O₂), can increase strength of fire.

SECTION V: REACTIVITY DATA

Stability: Ozone is not stable. Hazardous polymerization cannot occur.

Chemical Incompatibilities: Ozone is chemically incompatible with all oxidizable materials, both organic and inorganic.

Conditions to Avoid: Ozone is unstable at room temperatures and spontaneously decomposes to oxygen gas. Avoid ignition sources such as heat, sparks, and open flame. Keep away from strong reducing agents and combustible materials such as grease, oils, and fats.

Products of Hazardous Decomposition: Ozone spontaneously decomposes to oxygen gas, even at room temperatures.

SECTION VI: HEALTH HAZARD DATA

Carcinogenicity: Ozone is not listed as a carcinogen by the NTP, IARC, or OSHA.

Primary Entry: Inhalation

Target Organs: Respiratory system, eyes, blood.

Summary of Risks: There is no true threshold limit and so no exposure (regardless of how small) is theoretically without effect from ozone's strong oxidative ability. Ozone passes straight to the smallest bronchioles and alveoli and is not absorbed by mucous membranes along the way. Initial small exposure may reduce cell sensitivity and/or increase mucous thickness producing a resistance to low ozone levels. Short exposure to 1-2 ppm concentrations causes headache as well as irritation to the respiratory tract, but symptoms subside when exposure ends. High concentrations of ozone produce severe irritation of the eyes and respiratory tract. Exposure above the ACGIH/OSHA limits produce nausea, chest pain, coughing, fatigue, reduced visual acuity, and pulmonary edema. Symptoms of edema from excessive exposure can be delayed one or more hours. Inhalation of >20 ppm for an hour or more (>50 ppm for 1/2 hour) can be fatal.

Acute Effects: Acute damage from ozone appears to be mainly from its oxidizing effect on contact with tissue.

Chronic Effects: Respiratory disease. Deleterious effects on lungs and acceleration of tumors have been reported.

Medical Conditions Generally Aggravated by Long-Term Exposure: History of respiratory or heart disorders.

First Aid: Remove from ozone containing air, get prompt medical help*, administer oxygen if necessary.

Eye Contact - Gently lift eyelids and flush eyes continuously with flooding amounts of water for 15 minutes or until transported to a medical facility*.

Inhalation - Remove exposed person to fresh air, support breathing, administer humidified oxygen as needed, get medical help*.

Ingestion - Highly unlikely since ozone is a gas until -169° F,

* **GET MEDICAL ASSISTANCE = APPROPRIATE IN-PLANT, PARAMEDIC, or COMMUNITY.** Get prompt medical assistance for further treatment, observation, and support after first aid.

SECTION VII: PRECAUTIONS FOR SAFE HANDLING AND USE**Steps to be Taken in Case of Spill/Leak:**

1. Discontinue production
2. Isolate and vent area
3. Immediately notify personnel
4. Deny entry
5. Follow applicable OSHA regulations

Disposal: Provide ventilation to dilute and disperse small amounts of ozone (below OSHA PELs) to outside atmosphere. Follow federal, state, and local regulations.

Handling/Storage Precautions: Ensure proper personnel training and establish emergency procedures.

SECTION VIII: CONTROL MEASURES

Respiratory Protection: High Level (>10ppm) - Self Contained Breathing Apparatus: MISH/NIOSH approved.
Low Level (0.3 - 10 ppm) - Canister Type (carbon) respirator may be used.

Eye Protection: Wear chemical safety goggles if necessary to work in high ozone (>10 ppm).

Skin Gloves: Effects of ozone on skin are minimal to non-existent.

Ventilation: Provide general and local exhaust ventilation to dilute and disperse small amounts of ozone into the outside atmosphere.

SECTION IX: SPECIAL PRECAUTIONS AND COMMENTS

Storage Segregation: Prevent ozone from coming into direct physical contact with strong acids or bases or with strong oxidizing/reducing agents.

Engineering Controls: Install ventilation systems capable of maintaining ozone to concentrations below the ACGIH/OSHA exposure limits (see sect. II). Install ambient ozone monitor(s) configured to shut down ozone equipment and turn high speed ventilation on.

Material Safety Data Sheet

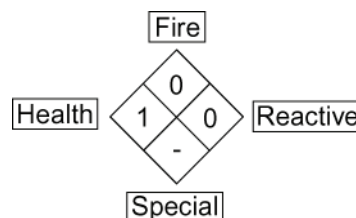
This MSDS complies with OSHA's Hazardous Communication Standard 29 CFR 1910.1200 and OSHA form 174.

DEL Ozone
3428 Bullock Lane
San Luis Obispo, CA 93401

Product Information 805-541-1601

NFPA 704 Designation
Hazard Rating

4 = Extreme
3 = High
2 = Moderate
1 = Slight
0 = Insignificant



| | | | | | |
|------------------------------------|--|---------------------|-----------------|-----------|----------|
| Product Name | AQUEOUS OZONE SOLUTION | | | | |
| Chemical Name | DISSOLVED OZONE GAS IN WATER 0 TO 2 PPM | | | | |
| Product Description | AQUEOUS SOLUTION OF OZONE DISSOLVED IN POTABLE WATER | | | | |
| D.O.T. Shipping Classification | NON REGULATED | | | | |
| I PHYSICAL DATA | | | | | |
| Boiling Point | 212 F | Freezing Point | 32 F | | |
| Specific Gravity | 1.0 | Solubility in Water | COMPLETE | | |
| Evaporation Rate | APPROX 1 | Physical Form | LIQUID | | |
| Appearance & Odor | COLORLESS (CLEAR) WATER WITH FRESH, ASEPTIC ODOR | | | | |
| II HAZARDOUS INGREDIENTS | | | | | |
| MATERIAL | HAZARD | CAS # | % BY WT | ACGIH TLV | OSHA PEL |
| None | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| III FIRE AND EXPLOSION HAZARD DATA | | | | | |
| Flash Point | NA Method NA | | Auto Ign. Temp. | | NA |
| Flammable Limits in Air | NON APPLICABLE | | Lower NA | | Upper NA |
| Extinguishing Media | NON APPLICABLE | | | | |
| Unusual Fire & Explosion Hazards | NONE | | | | |
| Special Fire Fighting Procedures | NONE | | | | |

Material Safety Data Sheet Cont.

Product Name **AQUEOUS OZONE SOLUTION**

| IV HEALTH HAZARD DATA | |
|--------------------------------------|---|
| Threshold Limit Value | NOT DETERMINED |
| Route of Exposure | <input type="checkbox"/> Inhalation <input type="checkbox"/> Ingestion <input type="checkbox"/> Skin <input checked="" type="checkbox"/> Eye <input checked="" type="checkbox"/> Not Hazardous |
| Eye Contact Hazard | Exposure may cause mild eye irritation, but is not expected. |
| Ingestion Hazard | Not Hazardous |
| Inhalation Hazard | Inhalation is not likely to be a primary route of exposure but could become irritating if aerosols are exposed to individual for extended period of time. |
| Skin Contact Hazard | No skin irritation is expected from short term exposure. |
| Skin Absorption Hazard | No published data indicates this product is absorbed through the skin. |
| Effects of Acute Exposure | Mild skin or eye irritation. |
| Effects of Chronic Exposure | Repeated exposure of the skin to concentrated product should be avoided to prevent irritation and drying of the skin. |
| V EMERGENCY AND FIRST AID PROCEDURES | |
| Eye Contact | If exposure to water containing aqueous solution of ozone causes irritation to eyes, flush eyes with plenty of clean, ozone free, running water for at least 15 minutes, lifting the upper and lower lids occasionally. Remove contact lenses if worn. Seek medical attention if irritation persists. |
| Skin Contact | Not likely to become irritated unless repeatedly exposed to large volumes of material. If irritation develops, rinse affected area with ozone free potable water. If irritation continues seek medical advice. |
| Inhalation | Inhalation of mists could lead to irritation of lungs. If symptoms develop, move individual away from exposure and into fresh air. If symptoms persist, seek medical attention. |
| Ingestion | NA |
| VI REACTIVITY DATA | |
| Incompatibility (Materials to Avoid) | Natural rubber (may degrade, or "dry", rubber components over extended periods of exposure) |
| Conditions to Avoid | NONE KNOWN |
| Hazardous Decomposition | NONE |
| Stability | <input checked="" type="checkbox"/> STABLE <input type="checkbox"/> UNSTABLE Hazardous Polymerization <input type="checkbox"/> MAY OCCUR <input checked="" type="checkbox"/> WILL NOT OCCUR |

Material Safety Data Sheet Cont.

Product Name **AQUEOUS OZONE SOLUTION**

| VII SPILL OR LEAK PROCEDURES | | | | |
|--|-------------------------|--|---------|----|
| Steps To Be Taken If Material Is Released Or Spilled | | NONE | | |
| Waste Disposal Method | | DISPOSE OF THE SAME AS POTABLE RINSE WATER | | |
| VIII SPECIAL PROTECTIVE INFORMATION | | | | |
| Respiratory Protection (Specify Type) | | NOT REQUIRED FOR NORMAL USE OF THIS PRODUCT | | |
| Ventilation | Local Exhaust | PREFERABLE | Special | NA |
| | Mechanical (general) | OK | Other | NA |
| Protective Gloves | | NOT REQUIRED | | |
| Eye Protection | | NOT REQUIRED | | |
| Other Protective Equipment | | NOT REQUIRED | | |
| IX SPECIAL PRECAUTIONS | | | | |
| Precautionary Labeling | | Certified testing of DEL Ozone systems by NSF (National Sanitation Foundation) has shown that under normal conditions of use, aqueous solutions containing low levels of ozone gas dissolved in potable water do not present a safety hazard when contact to the individual is incidental. When used in room with normal ventilation, levels of ozone gas being released into the air have been shown by NSF to be well below the periodic exposure levels established by OSHA for worker safety through the use of DEL's ozone management technology. | | |
| Precautions To Be Taken In Handling | | Aqueous solutions of ozone in potable water should not be sprayed as an aerosol (i.e. >20psi) to avoid releasing higher levels of ozone gas into the work area. The decay rate of ozone gas is a function of temperature and exposure to organic material. Certified testing has shown that when ozone gas has been properly dissolved in ambient temperature potable water at a level not exceeding 2 mg/l (ppm) using DEL's ozone management technology, the rate at which ozone is released from the water as ozone gas is below the PEL established for gaseous ozone. | | |
| Rev. Date 10/14/03 | | | | |
| This material safety data sheet is provided as an information resource only. It should not be taken as a warranty or representation for which the preparer assumes legal responsibility. While we believe the information contained herein is accurate and compiled from sources believed to be reliable, it is the responsibility of the user to investigate and verify its validity. The buyer assumes all responsibility of using and handling the product in accordance with applicable federal, state, and local regulations. | | | | |