INSTRUCTION MANUAL

# MODEL 460M
# NEMA OZONE MONITOR

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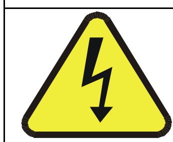
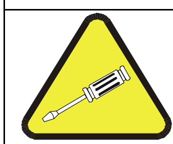
# SAFETY MESSAGES

Your safety and the safety of others is very important. We have provided many important safety messages in this manual. Please read these messages carefully.

A safety message alerts you to potential hazards that could hurt you or others. Each safety message is associated with a safety alert symbol. These symbols may be found in the manual and inside the monitor. The definition of these symbols is described below:

| | |
|---|---|
|  | **GENERAL SAFETY HAZARD: Refer to the instructions for details on the specific hazard.** |
|  | **CAUTION: Hot Surface Warning** |
|  | **CAUTION: Electrical Shock Hazard** |
|  | **TECHNICIAN SYMBOL: All operations marked with this symbol are to be performed by qualified maintenance personnel only.** |

**CAUTION**

**The monitor should only be used for the purpose and in the manner described in this manual. If you use the monitor in a manner other than that for which it was intended, unpredictable behavior could ensue with possible hazardous consequences.**

**NOTE**

**Technical Assistance regarding the use and maintenance of the Model 460M NEMA Ozone Monitor or any other Teledyne Instruments product can be obtained by:**

**Contacting Teledyne Instruments' Customer Service Department at 800-324-5190**

**or**

**Via the internet at http://www.teledyne-api.com/inquiries.asp**

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES



# LIST OF APPENDICES

# 1. INTRODUCTION

## 1.1. Preface

Teledyne Instruments is pleased that you have purchased the Model 460M NEMA Ozone Monitor. Included is a full one-year warranty (see Section 2.2) and we at Teledyne Instruments will be pleased to provide you with any support required so that you may utilize our equipment to the fullest extent.

The Model 460M is a microprocessor based medium range ozone monitor for monitoring process ozone in water treatment, food processing, and research applications. The design has been specifically optimized for applications requiring the measurement of ozone at near-ambient pressure such as water treatment contactor off-gas measurement. The Model 460M has been designed to give accurate and stable readings over long time periods with little or no maintenance or calibration.

The flexibility of the software as well as the analog and digital I/O allow the Model 460M to interface with a broad range of devices for process control and data logging.

We hope you will not experience any problems with the Teledyne Instruments Model 460M but if you do, our full time customer service department is always available to answer your questions.

## 1.2. 460M Documentation

The documentation for this monitor is available in several different formats:

- Printed format, part number 047130100
- Electronic format on a CD-ROM, part number 047130200

The electronic manual is in Adobe® Systems Inc. “Portable Document Format”. The Adobe® Acrobat Reader® software, which is necessary to view these files, can be downloaded for free from the internet at http://www.adobe.com/.

The electronic version of the manual has many advantages:

- Keyword and phrase search feature
- Figures, tables and internet addresses are linked so that clicking on the item will display the associated feature or open the website.
- A list of chapters and sections as well as thumbnails of each page are displayed to the left of the text.
- Entries in the table of contents are linked to the corresponding locations in the manual.
- Ability to print sections (or all) of the manual

# 1.3. Using This Manual

This manual has the following data structures:

**1.0 Table of Contents:**

Outlines the contents of the manual in the order the information is presented. This is a good overview of the topics covered in the manual. There is also a list of tables, a list of figures and a list of appendices. In the electronic version of the manual, clicking on any of these table entries automatically views that section.

**2.0 Specifications and Warranty**

This section contains a list of the monitor's performance specifications, a description of the conditions and configuration under which EPA equivalency was approved and Teledyne Instruments Incorporated warranty statement.

**3.0 Getting Started:**

A concise set of instructions for setting up, installing and starting your monitor for the first time. This includes unpacking; mechanical installation; attaching all pneumatic lines; attaching all electrical and electronic connections and; the physical configuration the RS-232/RS-485 port.

**4.0 FAQ:**

Answers to the most frequently asked questions about operating the monitor.

**5.0 Optional Hardware & Software**

A description of optional equipment to add functionality to your monitor.

**6.0 Operation Instructions**

Instructions for operating the monitor and using its basic features and functions.

**7.0 Serial Communications**

Information regarding the syntax and command definitions for the monitor's serial I/O interface.

**8.0 Calibration Procedures**

General information and step by step instructions for manually calibrating your monitor.

**9.0 Monitor Maintenance**

Description of certain preventative maintenance procedures that should be regularly performed on you monitor to keep it in good operating condition. This section also includes information on using the iDAS to record diagnostic functions useful in predicting possible component failures before they happen.

### 10.0 Theory of Operation

An in-depth look at the various principals by which your monitor operates as well as a description of how the various electronic, mechanical and pneumatic components of the monitor work and interact with each other. A close reading of this section is invaluable for understanding the monitor's operation.

### 11.0 Troubleshooting Section:

This section includes pointers and instructions for diagnosing problems with the monitor, such as excessive noise or drift, as well as instructions on performing repairs of the monitor's major subsystems.

### 12.0 Elector-Static Discharge (ESD) Primer:

This section describes how static electricity occurs; why it is a significant concern and; how to avoid it and avoid allowing ESD to affect the reliable and accurate operation of your monitor.

---

# User Notes:

# 2. SPECIFICATIONS AND WARRANTY

## 2.1. Specifications

**Table 2-1 460M Specifications**

| | |
|---|---|
| Measurement Principle | UV Absorption (Beer Lambert Law) |
| Ranges | 0-1000 PPM to 0-20,000 PPM<br>0-5 g/Nm$^3$ to 0-50 g/Nm$^3$<br>0-1 wt% to 0-5 wt% |
| Measurement Units | PPM, wt%, g/Nm3 |
| Accuracy | ± 1% of Full Scale |
| Precision/Repeatability | ±0.5% of Full Scale Range |
| Display Resolution | 1 PPM, 0.1 % wt, 0.01 g/Nm$^3$ |
| Rise/Fall Time (95%) | <45 sec to 95% |
| Compensation | Pressure, Temperature (NTP = 273.15K, 760mmHg) |
| Gas Inlet Pressure Range | 11.0 – 16.0 psia |
| Gas Flow Rate | 1.0 – 2.5 LPM |
| Temperature Range | 5-45$^o$C |
| Dimensions (H x W x D) | 12.64" x 11.19" x 6.08"<br>(321mm x 284mm x 154mm) |
| Weight | 9.40lb (4.27kg) |
| Power | 110-240V~, 50/60Hz, 2.5A |
| Environmental Conditions | Installation Category (Over Voltage Category) II<br>Pollution Degree 2 |
| Maximum Operating Altitude | 2000 meters |
| Analog Output Voltage | 0-5V, 4-20mA (Optional) |
| Isolated Analog Output 4-20mA Mode* | Maximum voltage between outputs and ground 60V peak |
| Degree of Protection (IP Code) | IP65 (NEMA 4X) |
| *Optional | |

# 2.2. Warranty

### Warranty Policy (02024)

Prior to shipment, Teledyne Instruments Incorporated equipment is thoroughly inspected and tested. Should equipment failure occur, Teledyne Instruments Incorporated assures its customers that prompt service and support will be available.

### Coverage

After the warranty period and throughout the equipment lifetime, Teledyne Instruments Incorporated stands ready to provide on-site or in-plant service at reasonable rates similar to those of other manufacturers in the industry. All maintenance and the first level of field troubleshooting is to be performed by the customer.

### Non-API Manufactured Equipment

Equipment provided but not manufactured by Teledyne Instruments Incorporated is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturer's warranty.

### General

Teledyne Instruments Incorporated warrants each product manufactured by Teledyne Instruments Incorporated to be free from defects in material and workmanship under normal use and service for a period of one year from the date of delivery. All replacement parts and repairs are warranted for 90 days after the purchase.

If a product fails to conform to its specifications within the warranty period, Teledyne Instruments Incorporated shall correct such defect by, in Teledyne Instruments' discretion, repairing or replacing such defective product or refunding the purchase price of such product.

The warranties set forth in this section shall be of no force or effect with respect to any product: (i) that has been altered or subjected to misuse, negligence or accident, or (ii) that has been used in any manner other than in accordance with the instruction provided by Teledyne Instruments Incorporated or (iii) not properly maintained.

THE WARRANTIES SET FORTH IN THIS SECTION AND THE REMEDIES THEREFORE ARE EXCLUSIVE AND IN LIEU OF ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR PARTICULAR PURPOSE OR OTHER WARRANTY OF QUALITY, WHETHER EXPRESSED OR IMPLIED. THE REMEDIES SET FORTH IN THIS SECTION ARE THE EXCLUSIVE REMEDIES FOR BREACH OF ANY WARRANTY CONTAINED HEREIN. TELEDYNE INSTRUMENTS INCORPORATED SHALL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF OR RELATED TO THIS AGREEMENT OF TELEDYNE INSTRUMENTS INCORPORATED'S PERFORMANCE HEREUNDER, WHETHER FOR BREACH OF WARRANTY OR OTHERWISE.

### Terms and Conditions

All units or components returned to Teledyne Instruments Incorporated should be properly packed for handling and returned freight prepaid to the nearest designated Service Center. After the repair, the equipment will be returned, freight prepaid.

# 3. GETTING STARTED

## 3.1. Unpacking

1. Inspect the received packages for external shipping damage. If damaged, please advise the shipper first, then Teledyne Instruments.

2. Loosen the 2 set screws located in the top and bottom left corners of the front and swing open the cover.

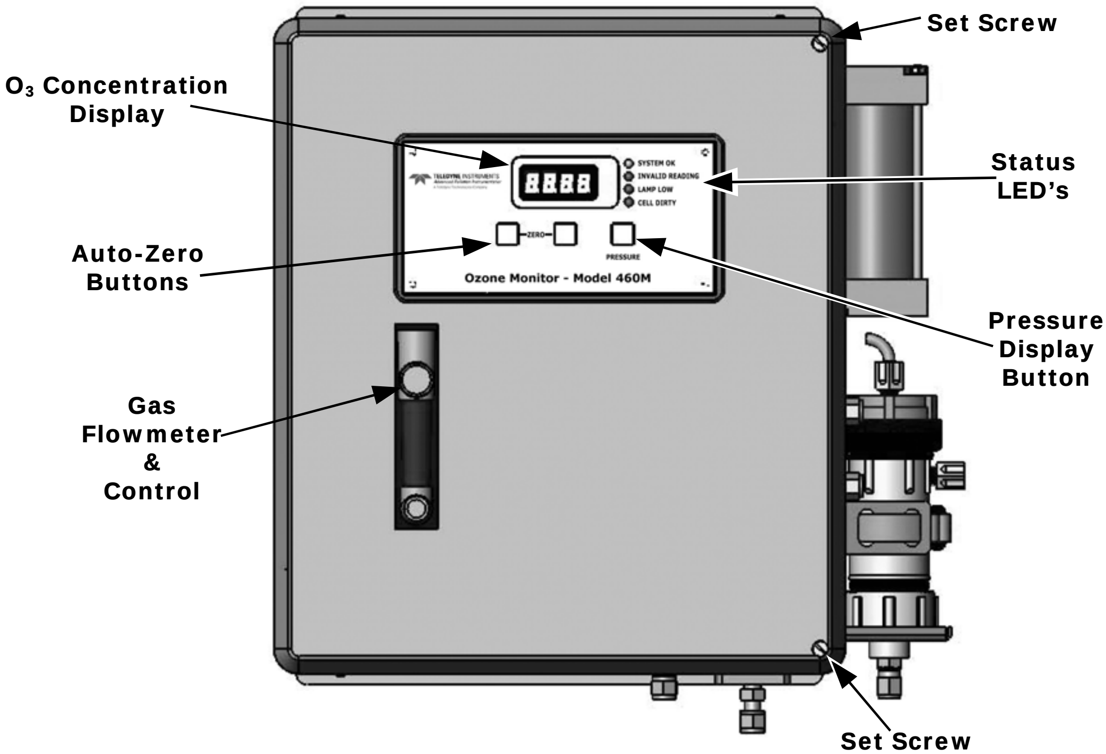



**Figure 3-1 M460M Front Cover Layout**

3. Inspect the interior of the monitor to make sure all circuit boards and other components are in good shape and properly seated.

**NOTE**

**Printed circuit assemblies (PCAs) are static sensitive. Electro-static discharges (ESD), often too small to be felt by the human nervous system, will still be large enough to destroy sensitive circuits.**

**Before touching PCAs, read Chapter 12 of this manual and follow the procedure described there for avoiding damage to your monitor due to ESD.**

| | CAUTION |
|---|---|
| | **Never disconnect electronic circuit boards, wiring harnesses or electronic subassemblies while the unit is under power.** |

4. Check the connectors of the various internal wiring harnesses and pneumatic hoses to make sure they are firmly and properly seated (see Figure 3-2).

5. Verify that all of the optional hardware ordered with the unit has been installed. These are listed on the paperwork accompanying the monitor.

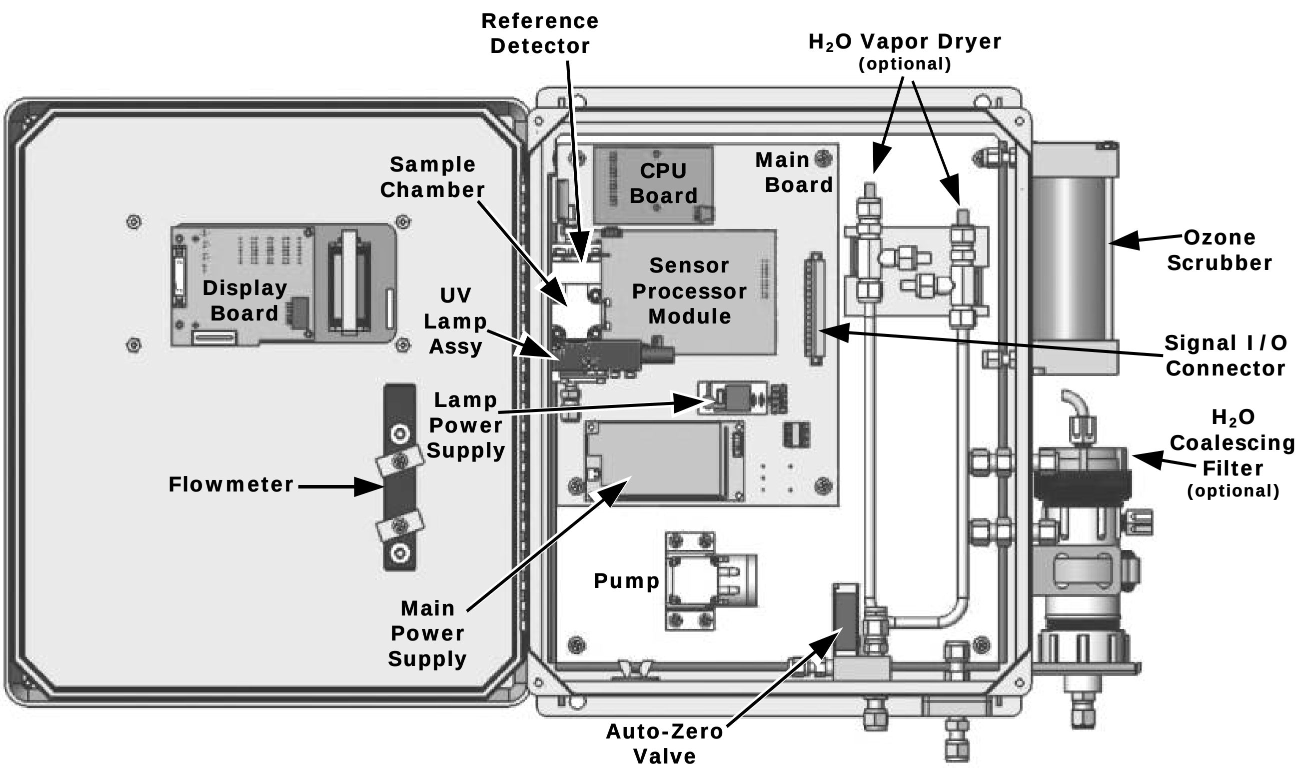



**Figure 3-2 460M Layout**

# 3.2. Mechanical Installation

Mount the enclosure securely to a vertical surface.

- Figure 3-3 below shows the locations of the four mounting holes.
- All four mounting holes should be used to secure the monitor.
- Use stainless steel, 5/16" diameter bolts.

**VENTILATION CLEARANCE:**

When installing the Monitor be sure to leave sufficient ventilation clearance.

**Table 3-1 460M Ventilation Clearances**

| AREA | MINIMUM REQUIRED CLEARANCE |
|---|---|
| Back of the monitor | 1/2 inch |
| Sides of the monitor | 1 inch |
| Above and below the monitor. | 1 inch |

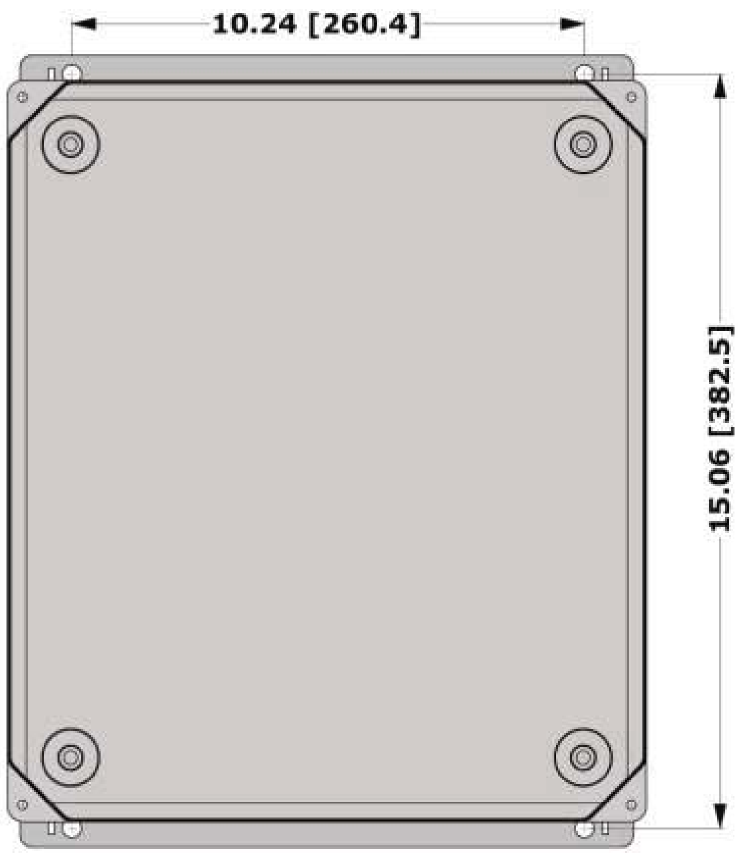



**Figure 3-3 460M Mounting Hole Locations and Dimensions**

# 3.3. Pneumatic Connections

1. Connect a ¼" exhaust line to the fitting labeled 'Exhaust.' This line should be vented to an outside area, since the exhaust gas may still contain trace levels of ozone that may not be completely removed by the built-in the ozone scrubber.

**CAUTION**

**Exhaust gas from the MODEL 460M may contain dangerous levels of ozone!**

2. Connect the ozone delivery line to the ¼" inlet fitting labeled "Ozone Inlet" on the bottom face of the enclosure (See Figure 3-4.)

**NOTE**

**The ozone delivery pressure should be at ambient pressure +/- 5 PSIG.**

**All tubing used should be made of ozone resistant material such as Stainless Steel, PTFE (Teflon™) or FEP. API can supply appropriate tubing for connecting the ozone supply line.**

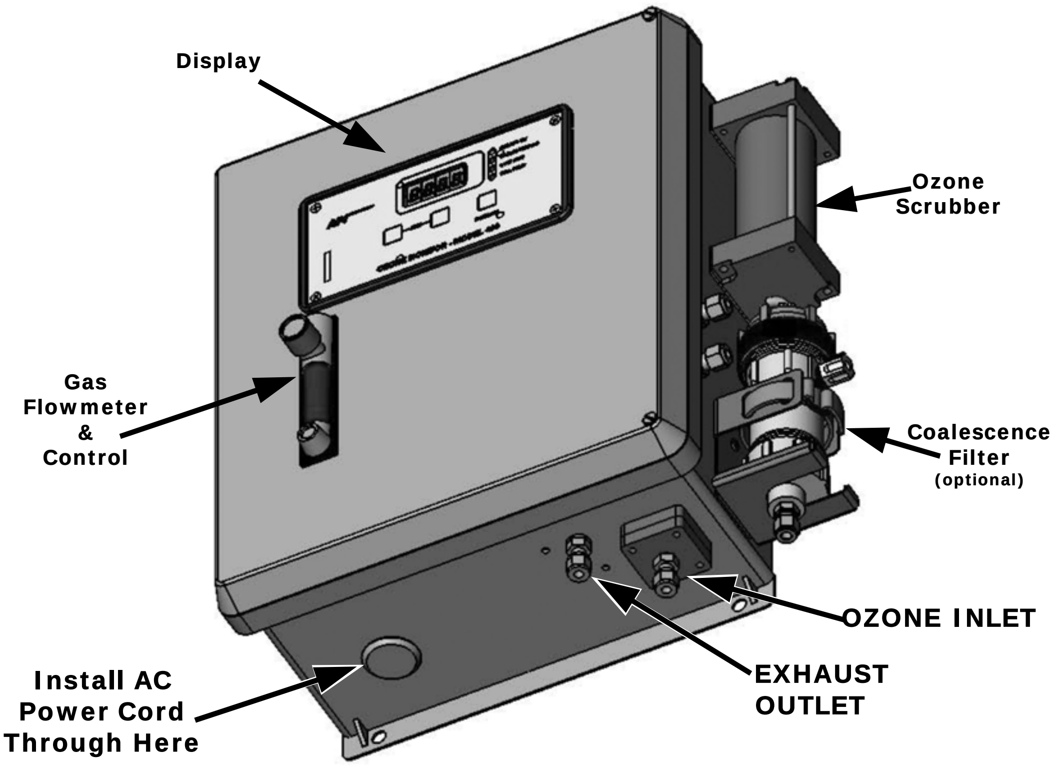



**Figure 3-4 460M Pneumatic Connections**

The gas flow rate through the monitor should be established between 0.5 and 2.0 L/min.

# 3.4. Electrical Connections

**NOTE**

**It is recommended that if multi-strand wires are used to the following electrical connections, the wire ends should first be "tinned" with solder to ensure that the terminals can make a reliable connection to the wires.**

## 3.4.1. AC Power Connection

**CAUTION**

**Disconnect power to the AC mains before making or removing any electrical connections to the 460M.**

**CAUTION**

**A proper earth ground connection must be made to the receptacle labeled "Earth Ground" on the 3 pin AC connector. Failure to do so may result in a shock hazard and malfunction of the monitor**

Connect AC power to the monitor.

1. Install a ½" conduit fitting for routing the electrical wiring into the monitor through the hole provided (see Figure 3-4). In order to maintain the IP (NEMA4X) rating of the enclosure, an appropriate sealed conduit connector should be used.

2. Attach the leads of the power line to the AC power connector (see Figure 3-5)

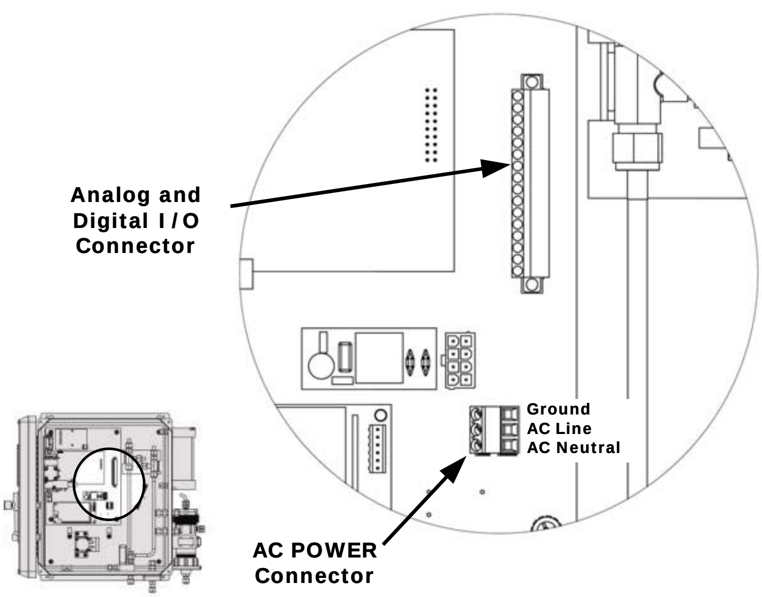



**Figure 3-5 Location of Electrical Connectors**

# 3.5. Signal I/O Connections

All digital and analog signal I/O connections are made via a 16 pin connector on the mainboard (See Figure 3-5 for the location of the connector.)

This connector can be unplugged from the header on the mainboard for easier access when wiring. To disconnect from mainboard, loosen the two retaining screws at either end of the connector.

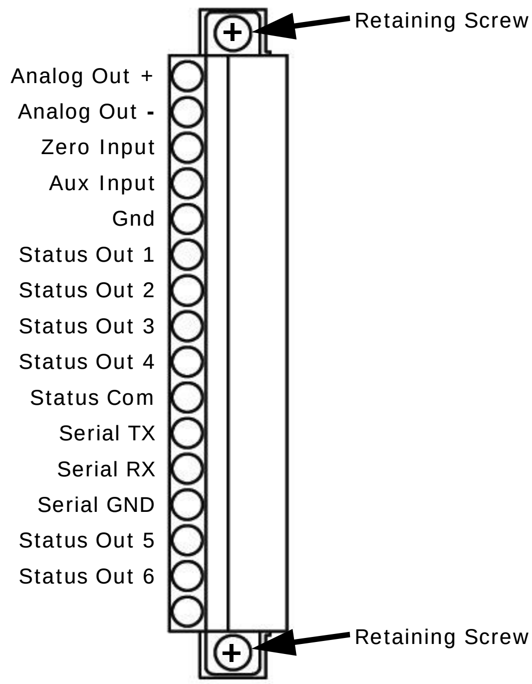



**Figure 3-6 Signal I/O Connector Pin Assignments**

## 3.5.1. Analog Output

The 460M is equipped with one analog output that is factory configurable as either a 0-5 VDC signal or a 4-20 mA signal. You may verify how your 406M is set up by checking the information on the monitor's serial number tag.

The analog output requires two connections: **ANALOG +**, the signal line, and **ANALOG–**, the ground connection. See Figure 3-6 for the locations of the **ANALOG OUT +** and **ANALOG OUT–** pins.

## 3.5.2. Digital Status Outputs

The 460M has five assigned and one spare digital status outputs for indicating error and operational status conditions (see Table 3-2). These outputs are in the form of opto-isolated open-collector transistors. They can be used to drive status LED's on a display panel or interface to a digital device such as a Programmable Logic Controller (PLC).

**Table 3-2 Digital Status Output Descriptions**

| LABEL | NAME | OPERATION |
|---|---|---|
| **STATUS OUT 1** | Sensor O.K. | Normally On |
| **STATUS OUT 2** | Invalid Reading | Normally Off |
| **STATUS OUT 3** | Lamp Low | Normally Off |
| **STATUS OUT 4** | Cell Dirty | Normally Off |
| **STATUS OUT 5** | Auto-Zero Error | Normally Off |
| **STATUS OUT 6** | Spare | Undefined |
| **STATUS COM** | Common Pin for all Status Outputs | N/A |
| • See Figure 3-6 for pin locations of the these output lines on the monitor's 16-pin I/O connector<br>• See Section 11-2 for definitions and interpretations of each output. | | |

Figure 3-7 shows the most common way of connecting the digital outputs to an external device such as PLC.

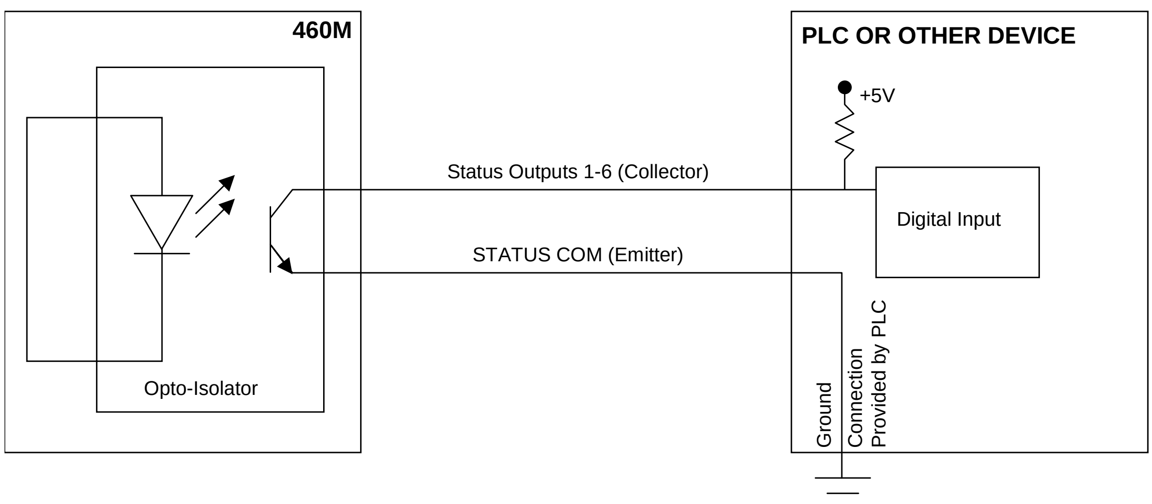



**Figure 3-7 Digital Status Output Connections**

> **Note**
>
> **Most devices, such as PLC's, have internal provision for limiting the current that the input will draw from an external device.**
>
> **When connecting to a unit that does not have this feature, external dropping resistors must be used to limit the current through the transistor output to 50mA or less.**
>
> **At 50 mA, the transistor will drop approximately 0.2V from its collector to emitter.**

The 460M's digital status outputs are useful tools for diagnosing sensor and system level malfunctions (see Section 11.2 for more information).

## 3.5.3. Control Inputs

Two digital control inputs are also available for use on the 460M. The control inputs are used for remote control of the 460M by a device such as a PLC. They are labeled **ZERO INPUT** and **AUX INPUT** (see Figure 3-6).

**Table 3-3 Control Inputs**

| INPUT | DESCRIPTION |
|---|---|
| **ZERO INPUT** | This input performs exactly the same function as the 'Zero' buttons on the front panel. |
| **AUX INPUT** | This input performs exactly the same function as the 'Pressure' buttons on the front panel. |

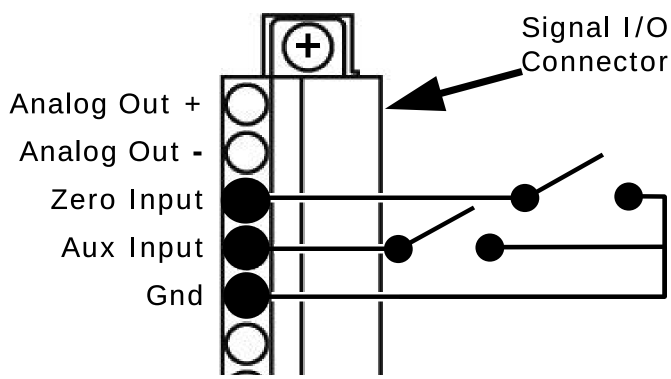



**Figure 3–8 Control Input Connections**

**NOTE:**

**Never connect a voltage level output from another device to these contacts.**

## 3.5.4. RS-232/RS-485 Serial Communications Port

The 460M's bi-directional RS-232/485 Serial Port Interface allows the user to communicate with the monitor via a computer over that computer's serial communications port (COM port). A terminal emulation program such as HyperTerminal is required to be installed and running on the host computer.

The following three pins are provided on the I/O connector for serial communications (see Figure 3-6).

**Table 3-4 Serial I/O Port Connection**

| LABEL | DESCRIPTION |
|---|---|
| **SERIAL TX** | Serial Transmit (RS-485 – A) |
| **SERIAL RX** | Serial Receive (RS-485 – B) |
| **SERIAL GND** | Serial Ground (RS-232 Only) |

While the standard factory configuration is for RS-232, the monitor's serial port can be configured for either RS-232 or RS-485 (see Section 3.5.4.1 for the procedure).

- Use RS-232 for direct connection to a nearby (no more than 6-8 feet cable length) PC or Laptop, RS-232 should be used.
- Use RS-485 for permanent connection to continuously operating data acquisition systems or connections over greater distances.

### 3.5.4.1. Serial Port Configuration

To configure the com port for RS-232 or RS-485, move the 4 shunts on JP3 of the CPU PCA (P/N #03492) to the proper position as shown in below.

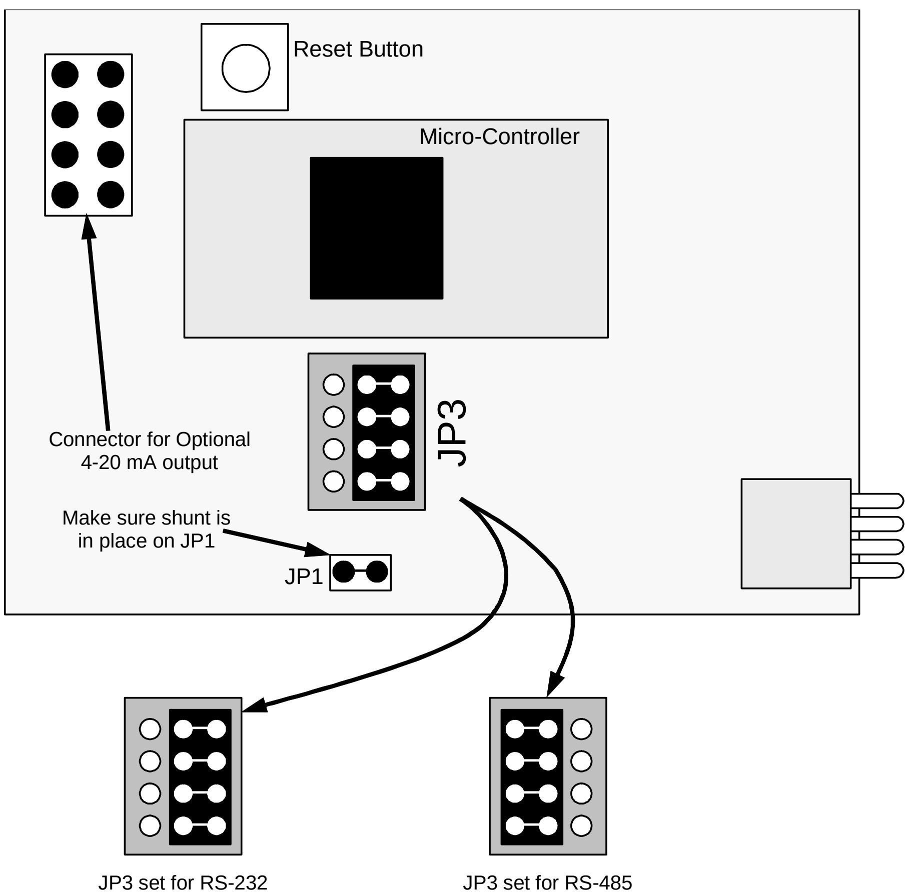



**Figure 3-9 RS-232/RS-485 Jumper Location and Settings**

The Serial Port of the device being used to communicate with the 460M should be configured as follows:

**Table 3-5 Serial Port Configuration**

| PARAMETER | VALUE |
|---|---|
| Baud Rate | 9600 bps |
| Data Bits | 8 |
| Stop Bits | 1 |
| Parity | None |

Figure 3.9 below illustrates how to construct wiring for both RS-232 and RS-485 connections.

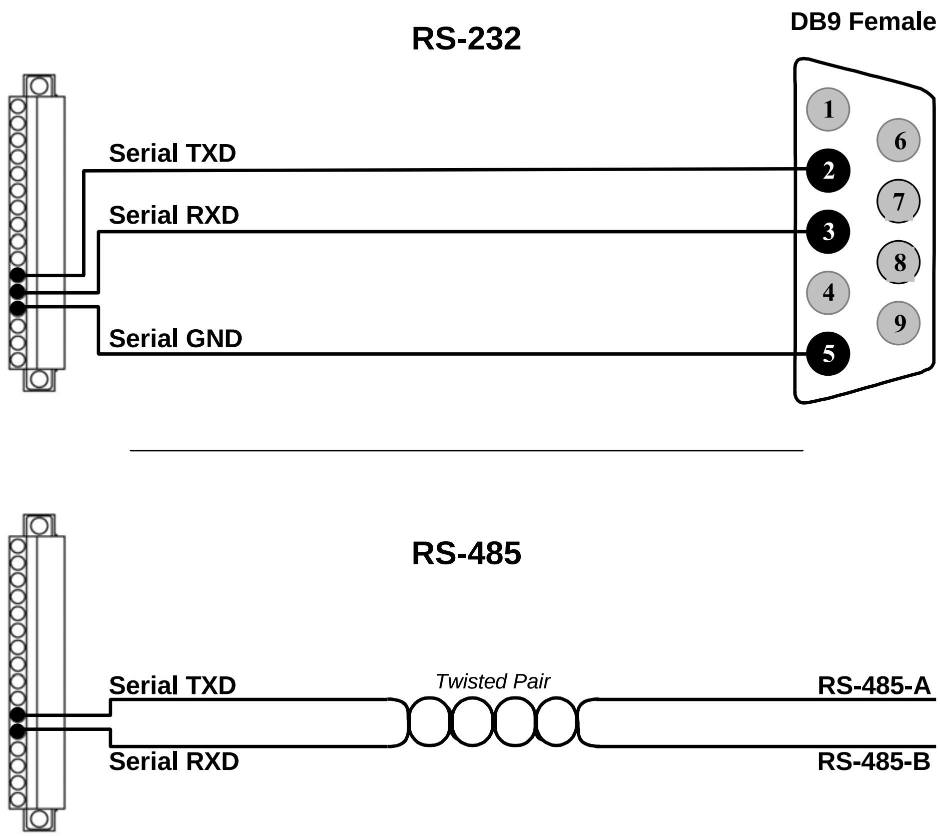



**Figure 3-10 Typical RS-232 and RS-485 Connections**

See Chapter 7 for information on the Serial Communications protocol used by the 460M.

# 3.6. Initial Startup

Perform the following steps when initially starting up the 460M or when bringing the monitor back into service it has been shut down for repair or maintenance.

1. Turn on power to the monitor.
    - The display will briefly display the "API" logo followed by the software version.
    - The display will then begin showing ozone concentration.
2. Establish a flow of ozone to the monitor.
    - Flow rate through monitor should be between 0.5 – 2.0 LPM (Liters per minute.)
    - Adjusts as needed using the needle valve of the flowmeter on the front panel (see Figure 3-1).
3. Let the monitor warm up for a minimum of 5 minutes.
4. Initiate the auto-zero function by simultaneously pressing the zero buttons on the front panel (see Figure 3-1). See Section 8.1 for a more detailed description of this automatic feature.
5. Check Status LED's on front panel;
    - Sensor OK led should be ON.
    - All other LED's should be OFF.
    - If the Status LED's are not in this state, refer to Chapter 11 for troubleshooting information.
6. Observe the monitor for several more minutes at zero to ensure that it is stable.

The monitor is now ready to measure ozone.

User Notes:

# 4. FREQUENTLY ASKED QUESTIONS

**Q:** What do I do if I smell Ozone and suspect a leak?

**A:** Ensure that all the fittings are tight.

If the fittings are tight and ozone is still detected send the monitor back for repair to Teledyne Instruments' customer service for repair.

**Q:** What do I do if my CPU status light stops flashing?

**A:** The CPU has stopped working. This is a major malfunction of the monitor. Return it to Teledyne Instruments' customer service for repair.

**Q:** What do I do if the Status OK light turns off or doesn't turn on after 30 min.?

**A:** If the status ok light is off and the Lamp low light is on then the monitor's UV lamp needs to be adjusted.

If the status ok light is off and the Lamp Low light is off then most likely the UV lamp output has drifted to >5000mv and needs to be adjusted.

**Q:** What does it mean if the Invalid Reading light turns on?

**A:** This will happen if the:

Ozone supply pressure exceeds 30 psi.

Ozone concentration exceeds the Range of the monitor then this light will turn on.

Ozone concentration goes excessively negative.

**Q:** What do I do if my Lamp Low light turns on?

**A:** If the Lamp low light turns on and the Status OK light is **ON**, the UV reference value has dropped to < 1000mv. The monitor will continue to run with no problems until the UV reference drops below 500mv.

If the Lamp low light turns on and the Status OK light is **OFF**, the UV reference has dropped below acceptable limits and will have to be adjusted.

**Q:** What do I do if the Cell Dirty Light turns on?

**A:** This light will turn on if the ratio between the $O_3$ reference reading and $O_3$ measure reading is less the 0.5. The most likely cause is that the windows inside the reaction cell are dirty. Return the monitor to Teledyne Instruments' customer service for repair.

---

# USER NOTES:

# 5. OPTIONAL HARDWARE AND SOFTWARE

This section includes a description of the hardware and software options available for the 460M monitor. For assistance with ordering these options please contact the sales department of Teledyne Instruments at:

**TOLL-FREE:** **800-324-5190**
**TEL:** **+1 858-657-9800**
**FAX:** **+1 858-657-9816**
**E-MAIL:** **apisales@teledyne.com**
**WEB SITE:** **http://www.teledyne-api.com/**

## 5.1. Sample Conditioning System

This option is required for 460M's that will be used in applications where the sample gas includes liquid or vaporous water. This option includes two major components:

- A coalescing water drop-out filter, and;
- A permeation tube dryer.

## 5.2. Current Loop Analog Output

This option adds isolated, voltage-to-current conversion circuitry to the monitor's CPU card. This option be installed at the factory or added later. Call Teledyne Instruments sales for pricing and availability.

The standard configuration of the current loop option is 4 – 20 mA.  0-20 mA is also available.

# 6. OPERATING INSTRUCTIONS

The 460M has been designed for simple and trouble-free operation. The Sections below detail the operational features of the 460M.

## 6.1. Front Panel Display

### 6.1.1. $O_3$ readout

The current ozone concentration is displayed in the 4 digit readout in the center of the display. The concentration is displayed in the currently selected units, either wt%, g/Nm3 or ppm.

### 6.1.2. Pressure Display

The pressure inside the measurement cell can be displayed on the readout by pressing and holding the 'Pressure' key on the front panel. The pressure is displayed in units of psia (pounds per square inch absolute.) The normal ambient pressure at sea level is about 14.7psia. Ambient pressure at higher elevations will be somewhat less.

The 460M can accurately measure ozone at cell pressures of 12 - 15psia. Care should be taken in setting up the monitor to avoid over-pressurizing the cell, as this will result in erroneous readings.

### 6.1.3. Auto-Zero Function

Normally the auto-zero function is triggered automatically by the monitor's software. In the rare event that it must be activated manually, such as during initial start-up after installation, it may be triggered by simultaneously pressing the two zero buttons on the face of the monitor. See Section 8.1 for more information

### 6.1.4. Status LED's

The four status LED's to the right of the display indicate the general status of the 460M Monitor. During normal operation, after the monitor has warmed up, the green 'Sensor OK' LED should be on and all other Status LED's should be off. For information on troubleshooting using the Status LED's, see Sections 11.3.

**Table 6-1 Status LED's**

| NAME | ON STATE | OFF STATE |
|---|---|---|
| SENSOR O.K. | Normal State | Reference or Measure > 4995mV; Reference < 1000mV |
| INVALID READING | Ozone Pressure > 45 psia, Negative Ozone Concentration, Concentration Over-Range | Normal State |
| LAMP LOW | Reference Detector<1000mV | Normal State |
| CELL DIRTY | Measure/Reference ratio < 0.5 (zero gas) | Normal State |

Definitions for these four LED's correspond to the definitions of the monitor's four digital status outputs with identical names. See Section's 11.2. & 11.3 for more detailed information.

# 7. SERIAL COMMUNICATIONS

The 460M comes equipped with a powerful digital Serial Communications Port that can be used for Data Acquisition and for changing monitor's configuration. This port can be configured for either RS-232 or RS-485 (half-duplex) operation. See Section 3.5.4.1 for details on configuring the port and connecting it to a computer or data acquisition system.

## 7.1. Serial Port Command Syntax

All characters sent and received are standard ASCII characters and all numbers are decimal numbers converted to ASCII text.

All commands are sent using the following syntax:

**<address><command>:<data1>,<data2>#<checksum><CR>**

Where:

- address is the monitor address(default =1)
- command is the command string being sent
- : (colon) is the data separator and is only included if data is being sent as part of the command (See Command Details below to see if a command requires data or not)
- data1 is the first data parameter, if required.
- data2 is the second data parameter, if required.
- # is the Checksum separator, sent only if optional checksum is included

  checksum is an ASCII checksum of all characters up to the # character. The checksum is optional, commands sent without the checksum (and checksum separator,) are also valid.
- CR is a carriage return, ASCII 13.

**Examples**

Valid Commands with no data:

- Checksum Included: **1CAUTO#179<CR>**
- No Checksum: **1CAUTO<CR>**

Valid Commands with data:

- Checksum Included: **1VSET:1,20#620<CR>**
- No Checksum: **1VSET:1,20<CR>**

# 7.2. Serial Port Command Summary

Table 7-1 below lists the commands available and a summary of their function.

**Table 7-1 Serial Port Command Summary**

| COMMAND | DESCRIPTION |
|---|---|
| CAUTO | Performs an auto-zero calibration. The monitor's internal valves are activated to route internally generated zero air through the $O_3$ measurement cell. |
| CZERO | Perform a manual zero calibration. The CZERO does not activate the zero-gas solenoid valve; therefore the calibration is calculated based on the current ozone content of the measurement cell. |
| DACSTEP | Analog Output Test Mode, Step Function |
| O3 | Returns O3 concentration currently being measured |
| SETADDR | Sets communication address for this 460M to a specific value |
| TDUMP | Returns the current values of a set of measurement parameters as a single data string |
| TLIST | Returns list of measurement parameters and their current values as a formatted list. |
| VGET | Returns the current value of a single VAR |
| VLIST | Lists all VARS and their current values |
| VSET | Sets value of internal VAR. |

# 7.3. Serial Port Command Reference

## 7.3.1. CAUTO

**SYNTAX**

<address>CAUTO<CR>

**DESCRIPTION**

Performs an auto-zero calibration using internally generated zero gas. For more information see Section 8.1

**DATA PARAMETERS SENT**

None

**RESPONSE**

<address>:<success_flag>#<checksum><CR>

**EXAMPLE**

Command:

**1CAUTO<CR>**

Response:

**1:OK#261<CR>** - Calibration Successful

**1:FAIL#391<CR>** - Calibration Failed

### 7.3.2. CZERO

**SYNTAX**

<address>CZERO<CR>

**DESCRIPTION**

Performs a zero calibration using gas sourced from the ozone gas inlet.

**DATA PARAMETERS SENT**

None

**RESPONSE**

<address>:<success_flag>#<checksum><CR>

**EXAMPLE**

Command:

**1CZERO<CR>**

Response:

**1:OK#261<CR>** - Calibration Successful

**1:FAIL#391<CR>** - Calibration Failed

**NOTE**

Once CZERO function is activated the monitor will briefly display dashes **('----')** after which the concentration should quickly go to zero.

The CZERO does not activate the zero-gas solenoid valve, therefore the gas flowing through the monitor is sourced from the ozone inlet and the zero calibration is calculated based on the current ozone content of that gas source.

Care must be taken to ensure that all ozone is purged from the monitor before activating the CZERO function. Before activating the CZERO function, disconnect the $O_3$ supply line from the monitor and allow room air to flow through the monitor for several minutes.

Use a shutoff valve to make sure that the $O_3$ source does not continue to feed $O_3$ into the supply line while it is disconnected

## 7.3.3. DACSTEP

**SYNTAX**

<address>DACSTEP<CR>

**DESCRIPTION**

Puts the monitor into Analog Output setup mode. The Analog Output steps from zero to full-scale in 25% increments, pausing for 10 seconds at each level. This repeats 5 times, after which the monitor returns to normal operation. This mode is useful for testing the Analog Output and the operation of any equipment measuring the Analog Output.

**DATA PARAMETERS SENT**

None

**RESPONSE**

<address>:<success_flag>#<checksum><CR>

**EXAMPLE**

Command:

**1DACSTEP<CR>**

Response:

**1:OK#261<CR>** - DACSTEP command acknowledged and initiated

**NOTES**

The DACSTEP function takes some time to complete.

When the command is sent to the monitor, it will immediately respond with the <address> and colon ':' as an acknowledgement that the message was received. After the function is complete the rest of the response will be sent.

No additional commands should be issued to the monitor until the function completes.

## 7.3.4. $O_3$

**SYNTAX**

<address>O3<CR>

**DESCRIPTION**

Returns the current ozone concentration measured by the monitor.

**DATA PARAMETERS SENT**

None

**RESPONSE**

<address>:<o3_conc>#<checksum><CR>

**EXAMPLE**

Command:

**1O3<CR>**

Response:

**1:12.01898#518<CR>** - Current O3 Concentration (reading 12.02 wt%)

**NOTES**

While the concentration value returned shows more digits after the decimal than the front panel (in the example above, 12.01898) display it is only valid to 4 significant digits (in the example above, 12.01).

# 7.3.5. SETADDR

**SYNTAX**

<address>SETADDR:<new_address><CR>

**DESCRIPTION**

Changes the communications address to a new value.

**DATA PARAMETERS SENT**

new_address is the new address for the monitor; Range for new_address is 1-9.

**RESPONSE**

<address>:<success_flag>#<checksum><CR>

**EXAMPLE**

Command:

**1SETADDR:2<CR>** - Change address from 1 to 2

Response:

**1:OK#261<CR>** - Change Address Successful

**1:FAIL#391<CR>** - Change Address Failed

**NOTES**

The monitor response is from the previous address (1 in the example shown above), but any further commands must be at new address (2 in the example shown above) .

If the address change was successful, after sending back the OK response, the monitor will no longer respond to commands with address 1.

## 7.3.6. TDUMP

**SYNTAX**

<address>TDUMP<CR>

**DESCRIPTION**

This command is best used if the response is intended as input for a database program or data acquisition system

It returns a string made up of the current values of the following parameters in the following order: O3 Concentration, Cell Pressure(psia,) Cell Temperature (K,) Lamp Temperature (K,) Measure Detector (mV,) Calibrated Reference Detector (mV,) Reference Detector (mV)

**DATA PARAMETERS SENT**

None

**RESPONSE**

<address>:<o3_conc>,<pressure>,<cell_temp>,<lamp_temp>,<measure>,<cal_ref>,<reference>#<checksum><CR>

**EXAMPLE**

Command:

**1TDUMP<CR>**

Response:

**1:0.0282144,14.77461,300.7179,324.7713,2881.437,2940.903,4412.52#3228<CR>**

**NOTES**

While the concentration value returned shows more digits after the decimal than the front panel (in the example above, 0.0282144) display it is only valid to 4 significant digits (in the example above, 0.028).

## 7.3.7. TLIST

**SYNTAX**

<address>TLIST<CR>

**DESCRIPTION**

Returns a formatted, easy to read list of the parameters by name with the current values for each.

**DATA PARAMETERS SENT**

None

**RESPONSE**

Test Parameter List (See Below)

**EXAMPLE**

Command:

**1TLIST<CR>**

Response:

**O3 = 0.0226168**
**Press = 14.7753**
**Cell Temp = 300.7116**
**Lamp Temp = 324.7965**
**Ref = 2881.52**
**Meas = 2941.092**
**Raw Ref = 4412.646**
**Azero Time = 720.0**
**Azero Day = 6**
**Current Time = 422.334**
**Current Day = 6**

**NOTES**

The set of parameters is not the same as those returned by the TDUMP command.

While the concentration value returned shows more digits after the decimal than the front panel (in the example above, 0.0226168) display it is only valid to 4 significant digits (in the example above, 0.022).

No checksum is sent in the response to the TLIST command.

## 7.3.8. VGET

### SYNTAX

<address>VGET:<var_index><CR>

### DESCRIPTION

Returns value of an internal configuration variable (VAR.)

### DATA PARAMETERS SENT

*var_index* is index number for internal VAR as follows:

**Table 7-2 VAR_INDEX List for VGET Command**

| *var_index* | Name | Description | Allowable Range |
|---|---|---|---|
| 0 | ANALOG_RANGE | Full-Scale concentration range for Analog Output scaling | 5.0 – 400.0 |
| 1 | AZERO_ENABLE | Auto-Zero Enable VAR. (only valid if Auto-Zero hardware is installed) | 0 = Off1 = On |
| 2 | AZERO_PERIOD | Period for Auto-Zero Calibration timer in seconds | 5.0 - 86400.0 |
| 3 | CARRIER_WEIGHT | Molecular weight of carrier gas for wt% calculations (32.0 = O2) | 27.0 – 32.0 |
| 4 | COMM_MODE | Not Used | N/A |
| 5 | IIR_FILT | Sets the sensitivity of the software filter used by the monitor to reduce noise and hysteresis in the reported $O_3$ concentration reading. | 0.05 – 1.0 |
| 6 | CONC_UNITS | $O_3$ concentration measurement units | 0 = wt%;<br>1 = g/nm3;<br>2 = ppm |
| **NOTE: Only one *var_index* is allowed per iteration of the VGET command** | | | |

### RESPONSE

<address>:<var_value>#<checksum><CR>

### EXAMPLE

Command:

**1VGET:0<CR>** - Request analog_range value

Response:

**1:15.0#303** - analog_range returned as 15.0 (wt%)

### NOTES

ANALOG_RANGE: Setting is in whatever units selected by the **CONC_UNITS** VAR

IIR_FILT: The lower the setting value the more significant the effect of the filter; 1.0 = No filtering; 0.05 = Maximum filtering. 0.0 is not allowed.

CARRIER_WEIGHT: The molecular weight of pure $O_2$ is 32. The nominal molecular weight of ambient air is 28.96

AZERO_PERIOD: 86,400 seconds = 24 hours

## 7.3.9. VLIST

**SYNTAX**

<address>VLIST<CR>

**DESCRIPTION**

Returns a formatted, easy to read list of an internal configuration variables (VAR's) and their current values.

**DATA PARAMETERS SENT**

None

**RESPONSE**

VAR List (See Below)

**EXAMPLE**

Command:

**1VLIST<CR>**

Response:

**#0 analog_range = 15.0**
**#1 azero_enable = 0.0**
**#2 azero_period = 720.0**
**#3 carrier_weight =32.0**
**#4 comm_mode = 0.0**
**#5 iir_filt = 0.4**
**#6 conc_units = 0.0**

**NOTES**

No checksum is sent in the response to the VLIST command.

The 460M does not use the comm_mode VAR, so its value will always be 0.

## 7.3.10. VSET

**SYNTAX**

<address>VSET:<var_index>,<new_value><CR>

**DESCRIPTION**

Sets value of an internal configuration variable (VAR.)

**DATA PARAMETERS SENT**

| | |
|---|---|
| var_index | is index number for internal VAR (See VGET for index list) |
| new_value | new value for VAR. |

**RESPONSE**

<address>:<var_value>#<checksum><CR>

**EXAMPLE**

Command:

**1VSET:0,15.0<CR>** - Set analog_range VAR to 15.0 (wt%)

Response:

**1:OK#261<CR>** **-** VSET Successful

**1:FAIL#391<CR>** - VSET Failed

**NOTES**

The 460M does not use the comm_mode VAR, so its value will always be 0.

# User Notes:

# 8. CALIBRATION

## 8.1. Auto-Zero Operation

The Auto-Zero feature allows the monitor to operate unattended for extended periods of time. This feature automatically activates a valve that routes internally generated zero air into the O3 measurement cell and performs a zero calibration at specific intervals (default interval is 6hrs.)

### 8.1.1. Auto-Zero Function

When the Auto-Zero function is triggered, the monitor performs the steps outlined in Table 8-1 below.

**Table 8-1 Display Readouts during Auto-Zero Function**

| STEP | FUNCTION | DISPLAY READS |
|---|---|---|
| 1 | Switch Auto-Zero valve on | N/A |
| 2 | Purge cell for 10 seconds | Holds and Flashes Concentration Value Analog output value is also held. |
| 3 | Perform Zero Calibration | Dashes: '----' |
| 4 | Switch Auto-Zero valve off | Dashes: '----' |
| 5 | Hold-Off for 4 sec to return Measurement Gas to cell | Dashes: '----' |
| 6 | Return to Measurement Mode | Both Display and analog output begin displaying current $O_3$ concentration. |

### 8.1.2. Auto Zero Error

When performing an auto-zero calibration, the monitor checks to make sure the ozone concentration is near zero before calibration. If the ozone concentration is above 0.5wt% (10.0 g/nm3; 50 ppm) the monitor will not perform the calibration and will display a **ZERO ERR** message on the display. The monitor will also turn on the auto-zero error status output signal (See Section 11.2). This status signal will remain on until another auto-zero calibration is successfully performed or a manual zero calibration is performed.

If an auto-zero error is detected, a manual zero calibration should be performed using the CZERO command over the serial I/O interface.

# 8.2. Adjusting the Optional Current Loop Output

If your monitor includes the option current loop output you may need to check or adjust the actual current levels of the output to ensure that it matches the input requirements of your recording device. See Section 3.5.1 for details on making connections to the 4-20mA output.

The zero and span points of the 4-20mA analog output can be manually adjusted by the user as follows:

1. Disconnect the monitor from AC power.

2. Connect current measuring meter in series with the 4-20mA output. For best results, the 4-20mA output should be calibrated with the actual load (measuring device) attached. If this cannot be done, then a 250 – 500 ohm resistor should be placed in series with the current meter to simulate a load.

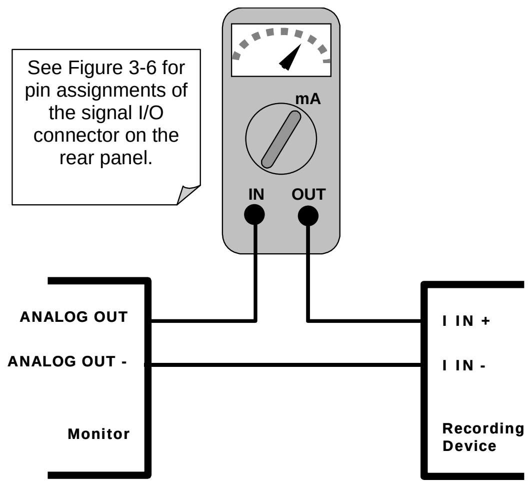



**Figure 8-1 Setup for Measuring Current Output Signal Level**

3. While reconnecting the monitor to AC power, press and hold the "Pressure" button on the front panel. This will cause the monitor to enter the analog output step mode. The display on the monitor will display "A 0" indicating that it is in the analog output step mode and at the 0% point.

4. At this point the analog output should read somewhere near 4.0 mA. Adjust the "Zero" potentiometer on the 4-20mA PCA (See Figure 8-2) as necessary.

5. To change the output signal level Press and release the "Pressure" button. Each time the "Pressure" button is pressed and released the monitor will now increment the current loop output by 25%.

   EXAMPLE

| OUTPUT LEVEL | NOMINAL SIGNAL LEVEL |
|---|---|
| 0% | 4mA |
| 25% | 8mA |
| 50% | 12mA |
| 75% | 16mA |

| | |
|---|---|
| 100% | 20mA |

6. Press the “Pressure” button until the display shows “A100” (four times). Adjust the “Span” potentiometer (See Figure 8.2) as necessary.

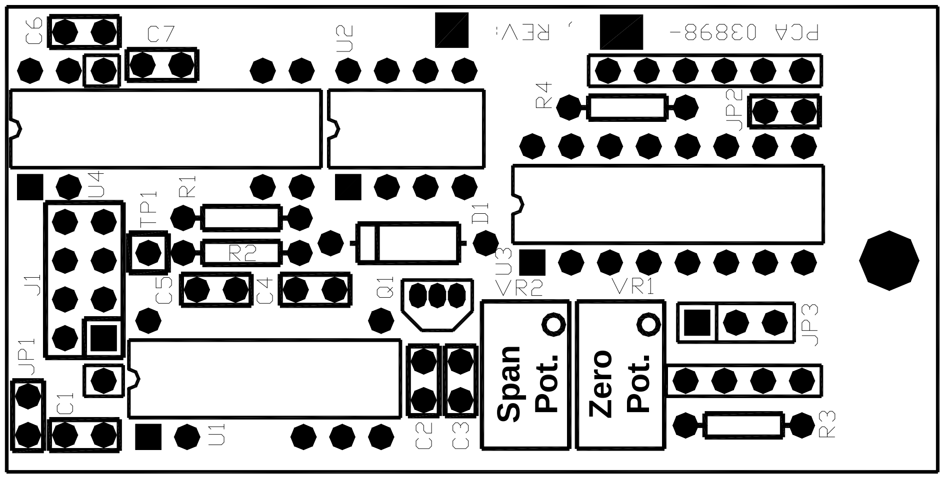



**Figure 8-2 Location Current Output Adjustment Potentiometers**

7. Note that the zero and span adjustments are not completely independent and adjusting one point may slightly affect on the other. Therefore steps 4-6 may need to be repeated several times in order to properly adjusted both points.

8. When the adjustment process is complete, disconnect the monitor from AC power then reconnect it without pressing the “Pressure” button. The monitor will restart in standard measurement.

# User Notes:

# 9. MAINTENANCE:

## 9.1. Replacing the Particulate Filter Element

The 460M is equipped with a particulate filter on the ozone inlet. These filters accept 25mm diameter glass fiber elements. Only filter elements of borosilicate glass or quartz fibers should be used. When the monitor is first installed, the sample filters should be checked at least once a week for particulate loading and replaced if necessary. Once the replacement frequency is determined, a regular schedule for filter replacement should be instituted.

For replacement 25mm filter elements, please contact Teledyne Instruments' sales department and request part number 02851.

**Filter Replacement Procedure:**

1. First ensure that the gas delivery line is not under pressure and has been purged of ozone.
2. Remove the four screws securing the gas filter assembly.
3. Remove the bottom half of the filter housing
4. Examine the internal sealing o-ring and replace if necessary.
5. Pull out the stainless steel screen securing the filter element.
6. The element can now be removed and replaced. When re-assembling filter, make sure that the top stainless steel screen is pushed into the filter cavity, securing the element in place.
7. After re-assembly, the gas line should be pressurized with oxygen or dry air and checked for leaks using a bubble solution.

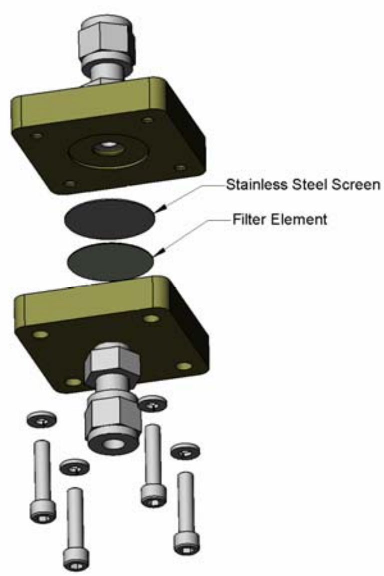



**Figure 9-1 Replacing the Particulate Filter Element**

# 9.2. Maintaining the Optional $H_2O$ Coalescing Filter

## 9.2.1. Draining the Optional Coalescing Filter

The coalescing filter component of the optional sample conditioning system may accumulate with water (see Figure 3-2 for filter location). It must be checked periodically and drained.

It is recommended that the filter be checked every 2 hours for the first several days of the monitor's operation to determine the fill rate of the filter's reservoir

To drain the filter:

1. Disconnect ozone supply line from monitor and shut off flow to the monitor using needle valve on front panel.
2. Remove the cap from the fitting on the bottom of the coalescing filter and allow the filter to drain.
3. Replace cap
4. Reconnect the O3 supply line adjust flow to the monitor.
5. Open the flowmeter valve and adjust the gas flow to the appropriate rate.

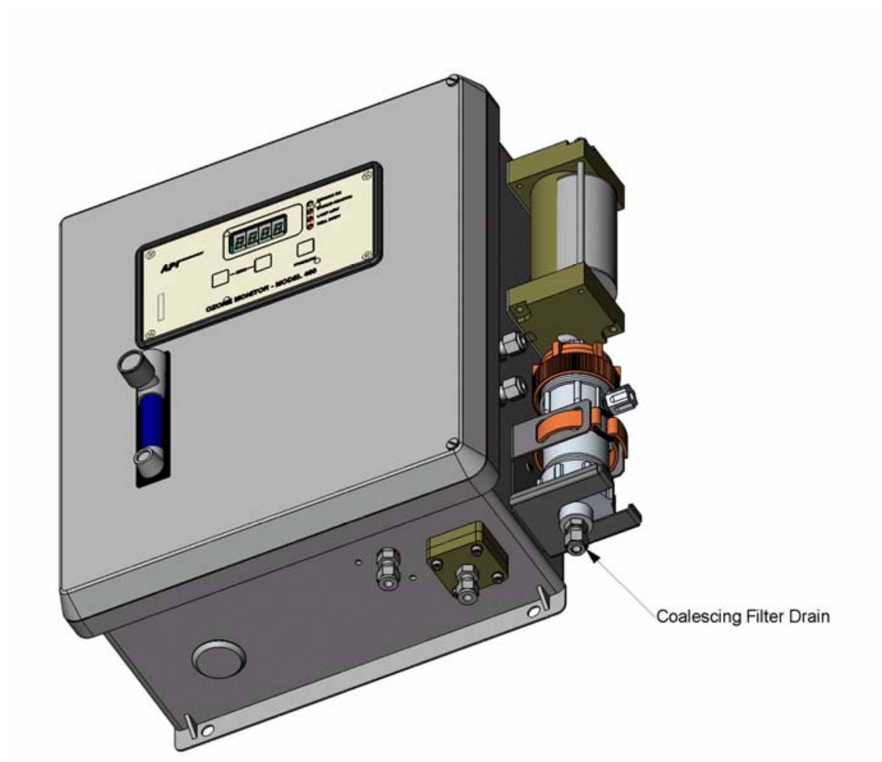



**Figure 9-2 Draining the Optional $H_2O$ Coalescing filter**

## 9.2.2. Replacing the Coalescing Membrane

The coalescing filter contains a replaceable Teflon coalescing membrane. Under normal operating conditions, this membrane should last for a long time, however a significant reduction in the gas pressure measured in the O3 cell might indicate that this membrane needs replacement. To replace the filter membrane:

1. Disconnect ozone supply line from the monitor and shut off flow to the monitor using needle valve on front panel.

2. Remove inlet and exit fittings from scrubber body and cap.

3. Remove the orange cap from the top of the coalescing filter.

4. Remove the old membrane. It is located on the underside of the cap assembly (see Figure 9-3).

5. Insert the new membrane into the cap assembly.

6. Tightly secure the cap back on the filter.

1. Reconnect the $O_3$ supply line adjust flow to the monitor.

2. Open the flow-meter valve and adjust the gas flow to the appropriate rate.

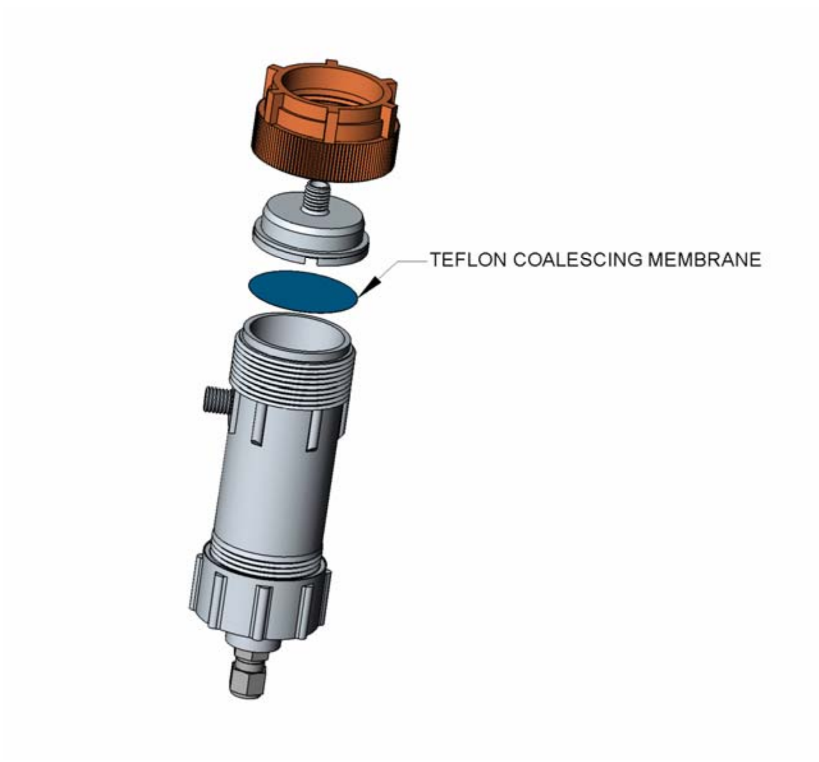



**Figure 9-3 Replacing the Membrane of the Optional $H_2O$ Coalescing filter**

Replacement filter elements can be ordered from API, use part number 03675.

# 9.3. UV Lamp Replacement

1. Disconnect power to the monitor and open cover.

2. Loosen, but do not remove, the two lamp set-screws (see Figure 9-4 below.)

3. Unplug lamp from power connector on Mainboard PCA.

4. Remove lamp from lamp housing. Dispose of lamp in accordance with local regulations regarding disposal of Mercury containing waste.

5. Install new lamp in housing and plug in to power connector on Mainboard PCA.

6. Connect ground lead of DVM to TP7 on Sensor PCA (Sensor PCA is directly behind sensor assembly.)

7. Connect positive lead of DVM to TP6 on Sensor PCA.

8. Re-Connect power to the monitor

   - Allow the instrument to warm up for 10 minutes.

9. TP6 voltage must read between –0.6 and –1.6Vdc. If TP6 voltage is outside this range, slowly rotate lamp and tighten lamp set-screws when the proper voltage is achieved.

10. Connect positive lead of DVM to TP2 (measure detector voltage) on Sensor PCA.

11. Adjust R43 (Adjacent to TP2) until TP2 voltage is 4.500 volts.

    - If it is not possible to adjust R43 until the measure detector voltage is 4.500 volts, the monitor's measurement cell is dirty and the instrument requires servicing.

12. Connect positive lead of DVM to TP1 (Reference Detector Voltage) on Sensor PCA.

13. Adjust R36 until TP2 voltage is 4.500 volts.

14. Wait for two minutes.

15. Initiate Auto-Zero function by pressing 'Zero' buttons on front panel.

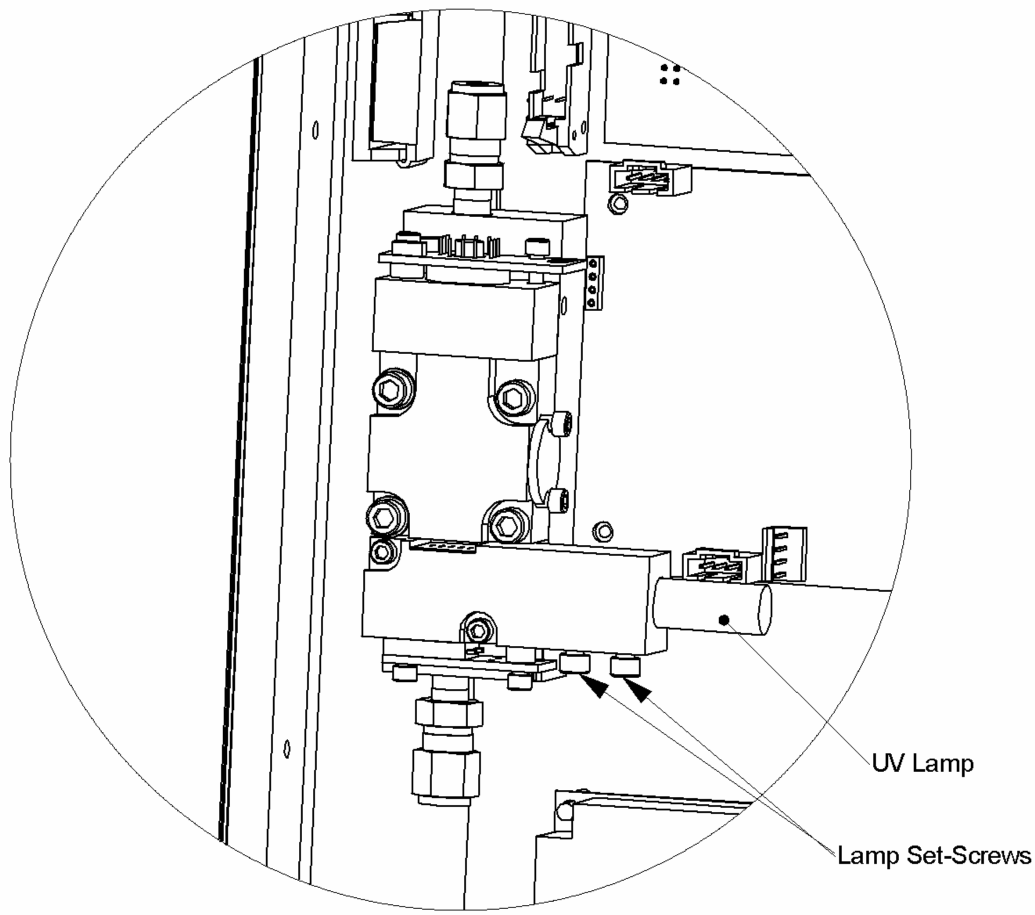



**Figure 9-4 Location of UV Lamp Set Screws**

# 9.4. Cleaning Exterior Surfaces of the 460M

If necessary, the exterior surfaces of the 460M can be cleaned with a damp cloth. Do not attempt to clean any of the other surfaces of the monitor. Do not submerge any part of the monitor in water or cleaning solution.

# 9.5. Degree of Protection

The Model 460M has a water ingress rating of IPX65 which indicates that it can withstand strong jets of water and is totally protected against dust.

User Notes:

# 10. THEORY OF OPERATION

## 10.1. Basic $O_3$ Measurement Principle

### 10.1.1. (Beer's Law)

The detection of ozone molecules in a gas is based on the principle that ozone is a very strong absorber of UV light with a wavelength of 254. If the distance that this light travels through the gas is always the same, the more ozone present in a gas, the more UV light is absorbed. If the distance the light travels through the gas, the intensity of light passing through the ozone containing gas, as well as the intensity of the light which does not pass through the gas are all known, the amount of ozone present can be calculated according to the following equation, called Beer's Law (also referred to as the Beer-Lambert equation).

$$I = I_O \, e^{-\alpha LC}$$

**Equation 10-1**

Where:

$I_O$ is the intensity of the light if there was no absorption.

$I$ is the intensity with absorption.

$L$ is the absorption path, or the distance the light travels as it is being absorbed. This distance determines how many molecules are present in the column of gas in the absorption cell.

$C$ is the concentration of the absorbing gas. In the case of the Model 460M, Ozone ($O_3$).

$\alpha$ is the absorption coefficient absorption coefficient, a number that reflects the inherent ability of ozone to absorb 254 nm light. Most current measurements place this value at 308 $cm^{-1}$ $atm^{-1}$ at Standard Temperature and Pressure (STP). The value of this number reflects the fact that ozone is a very efficient absorber of UV radiation which is why stratospheric ozone protects the life forms lower in the atmosphere from the harmful effects from solar UV radiation.

To solve this equation for **C**, the concentration of the absorbing gas (in this case $O_3$), the application of a little algebra is required to rearrange the equation as follows:

$$C = \ln\left(\frac{I_o}{I}\right) \times \left(\frac{1}{\alpha\, L}\right)$$

**Equation 10-2**

Unfortunately, both ambient temperature and pressure influence the density of the sample gas and therefore the number of ozone molecules present in the absorption path thus changing the amount of light absorbed.

In order to account for this effect the following addition is made to the equation:

$$C = ln\left(\frac{I_o}{I}\right) \times \left(\frac{1}{\alpha\ L}\right) \times \left(\frac{T}{273^o K} \times \frac{14.695psi}{P}\right)$$

**Equation 10-3**

Where:

T = sample ambient temperature in degrees Kelvin

P = ambient pressure in psi

Finally, to convert the result into Parts per Million (PPM), the following change is made:

$$C = ln\left(\frac{I_o}{I}\right) \times \left(\frac{10^{-6}}{\alpha\ L}\right) \times \left(\frac{T}{273^o K} \times \frac{14.695psi}{P}\right)$$

**Equation 10-4**

## 10.1.2. The Absorption Path

The Model 460M uses a high energy, mercury vapor lamp to generate a beam of UV light at 254 nm. This beam passes through a beam splitter that sends half the light through the sample gas in the $O_3$ measurement cell and on to a UV detector and half the light directly to a separate reference detector without passing through the sample gas (see Figure 10-1). The output voltages of these detectors are converted to digital values that represent ***I*** and ***I₀*** respectively. These digital values are used by the CPU to compute the concentration of $O_3$ present in the sample gas.

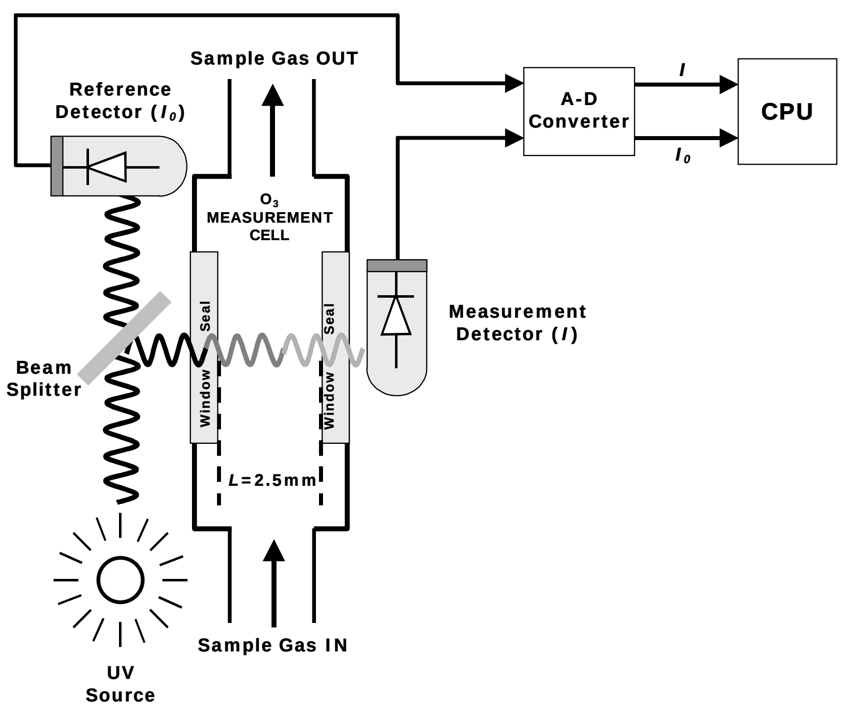


**Figure 10–1 $O_3$ Absorption Path**

## 10.1.3. Reference Detector Gain Adjustment Factor

For a variety of reasons (variation in detector efficiency, beam splitter accuracy, etc.) even if the sample gas contains no $O_3$ the values for $I$ and $I_0$ will not be exactly the same and can therefore introduce error into the $O_3$ calculation. This is called detector gain error.

The 460M corrects for detector gain error by periodically performing automatic zero calibration (see Chapter 8) and measuring the light intensity of the UV light passing through the sample gas when no $O_3$ is present and comparing that to the reference light intensity, the 460M can determine the amount of difference result ting from these sources of variation as follows:

$$\frac{I}{I'_o} = G_R$$

**Equation 10-5**

Where:

$I'_0$ = The light intensity measured by the reference detector

$I$ = The light intensity measured by the measurement detector though zero gas

$G_R$ = Gain Reference Factor

Since this equation can be algebraically rearranged as:

$$\frac{I'_0 G_R}{I} = 1 \qquad \textit{if } O_3 \textit{ concentration is zero}$$

**Equation 10-6**

This gain reference factor can be inserted into the $O_3$ concentration calculation thus correcting for any detector gain error.

$$C = ln\left(\frac{I'_o G_R}{I}\right) \times \left(\frac{10^{-6}}{\alpha L}\right) \times \left(\frac{T}{273^o K} \times \frac{14.695 psi}{P}\right)$$

**Equation 10-7**

## 10.1.4. Digital Noise Filter

The 460M software processes sample gas concentration data through a noise filter that stabilizes the concentration value reported to the display and via the monitor's analog outputs.

# 10.2. Pneumatic Theory of Operation

## 10.2.1. Basic Pneumatic Flow and Flow Control

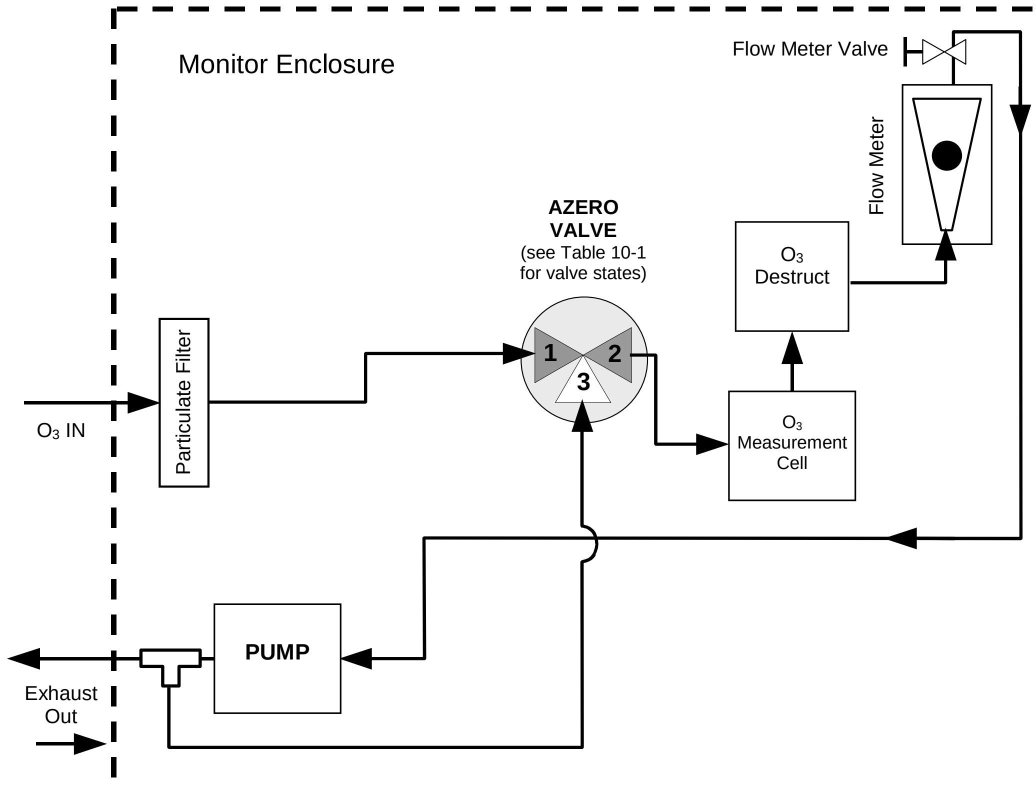



**Figure 10–2 460M Internal Pneumatic Diagram – Basic Configuration**

## 10.2.2. Internal Pump and Flow Control

Air flow through the M460M $O_3$ Monitor is supplied by a single-diaphragm, brushless DC pump that pulls air though the monitor. Since diaphragm pumps necessarily heat and compress the air they are pumping and since both temperature and pressure fluctuations can effect the $O_3$ measurement, the pump is placed down stream from the measurement cell to avoid any inadvertent effects resulting the from pumping action.

An adjustable needle-restrictor valve and flow gauge, located on the front panel of the monitor allow the user to manually adjust the gas flow rate through the monitor.

### Particulate Filter

To remove particles in the sample gas which might clog airways or foul the measurement cell optics, the monitor is equipped with a glass-fiber membrane filter of 25 mm diameter with a pore size of 0.1 microns. The filter is located inside the black housing on the bottom of the monitor. See Section 9-1 for location and instruction for replacing the filter element.

### 10.2.3. Internal Zero Air Supply

As described in Section 10.1.3 the 460M periodically performs an auto-zero calibration that requires zero air (air containing no $O_3$). Rather than rely on external tanks or zero air generators, the 460M produces its own zero air internally. All ozone is removed from the source gas, after it exits the measurement chamber by a special catalytic ozone scrubber that converts ozone ($O_3$) to ordinary oxygen molecules ($O_2$). As this is a true catalytic converter, there is no need to periodically replace the scrubbing material as is true for charcoal-based scrubbers. Also, unlike charcoal scrubbers there is no explosion hazard.

The $O_3$ scrubber is located on the right side of the monitor housing above the coalescing $H_20$ filter. A stainless Steel mesh filter is built into the scrubber to prevent any particulate byproducts of the $O_3 \rightarrow O_2$ conversion process from exiting getting into the gas stream and fouling either the pump or the measurement cell.

A beneficial side effect of this process is that the exhaust gas, leaving the monitor is free of any residual ozone which might require further handling or treatment.

**Azero Valve**

Once the $O_3$ has been removed from the source gas by the catalytic converter, a valve (see Figure 10-2) periodically redirects this $O_3$ free gas back into the measurement chamber according to the cycle described in Table 10-1

**Table 10-1: Zero/Span Valve Operating States**

| MODE | GAS FLOW PATH | VALVE PORTS OPEN (Fig. 9-2) | ACTIVITY |
|---|---|---|---|
| **AZERO**[1] | Zero air gas directed through measurement cell | **3 → 2** | 10 second wait period to ensures sample chamber has been flushed of $O_3$ bearing gas, then monitor makes zero gas measurement |
| **AZERO HOLDOFF**[1] | $O_3$ source gas directed through measurement cell | **1 → 2** | Holdoff period is 4 seconds allowing $O_3$ source gas to completely fill measurement cell. |
| **SAMPLE** | $O_3$ source gas directed through measurement cell | **1 → 2** | Monitor measures $O_3$ concentration for 12 minutes[2] |

[1] During these portions of the Azero cycle both the front panel display and the monitor's analog output hold the most recent, valid $O_3$ concentration.

[2] The length of the Sample period interval can be is adjusted by changing the value of the variable **AZERO_PERIOD** using the **VSET** command of the monitor's serial I/O interface (see Section 7.3.10).

## 10.2.4. Optional Sample Conditioning

The source air measured by the 460M needs to be as dry as possible. Significant amounts of liquid or vaporous water present in the source gas can foul the measurement cell optics and because water absorbs $O_3$ interfere with the 460M's ability to accurately measure the $O_3$ in the source gas. To counteract this problem, several optional components can be added to the 460M.

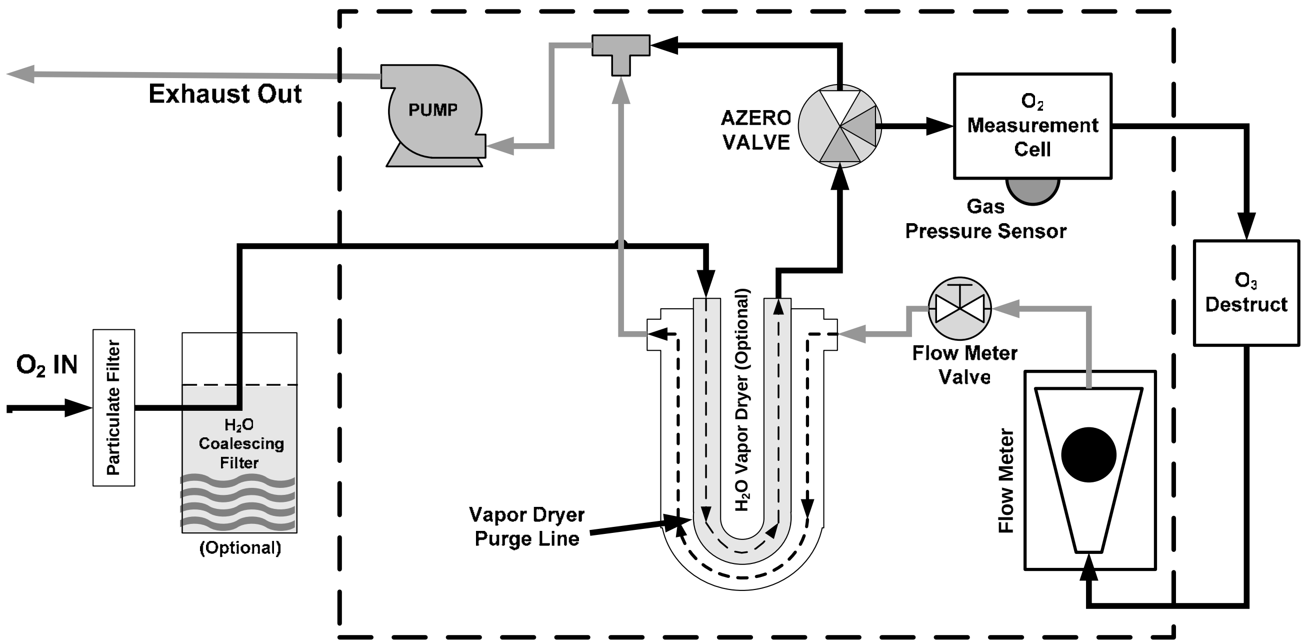



**Figure 10–3 460M Internal Pneumatic Diagram with Optional Sample Conditioning**

### $H_2O$ Coalescing Filter

The first step of this drying process is to remove any liquid water from the source gas. The 460M uses a Teflon® membrane, coalescing filter to accomplish this. This filter works in two ways. First, droplets of water that are large enough to precipitate out of the air on their own simply fall to the bottom of the filters container. Second, smaller droplets, small enough to stay combined and bourn along with the air encounter the Teflon® membrane (47 mm diameter; 20 micron pore size) at the top of the filter, and because Teflon is inherently water repellent, these tiny droplets collect along the Teflon fibers combining and growing until they are large enough to drip down into the reservoir.

### $H_2O$ Vapor Dryer

Once all of the liquid water is removed from the source gas, a separate, Perma Pure® single tube permeation tube dryer removes any vaporous water still present. The dryer consists of a single tube of Nafion®, a co-polymer similar to Teflon® that absorbs water very well but not other chemicals. The Nafion® tube is mounted within an outer, flexible plastic tube. As gas flows through the inner Nafion® tube, water vapor is absorbed into the membrane walls. The absorbed water is transported through the membrane wall and evaporates into the dry purge gas flowing through the outer tube, countercurrent to the gas in the inner tube. This process is called per-evaporation and is driven by the humidity gradient between the inner and outer tubes as well as the flow rates and pressure difference between inner and outer tubing.

To provide a dry purge gas for the outer side of the Nafion® tube, the 460M returns the dried $O_3$ free air from the measurement cell and $O_3$ destruct to the outer tube (see Figure 10-3). When the monitor is first started, the humidity gradient between the inner and outer tubes is not very large and the dryer's efficiency is low at first but improves as this cycle reduces the moisture in the sample gas and settles at a minimum humidity.

# 10.3. Electronic Theory of Operation

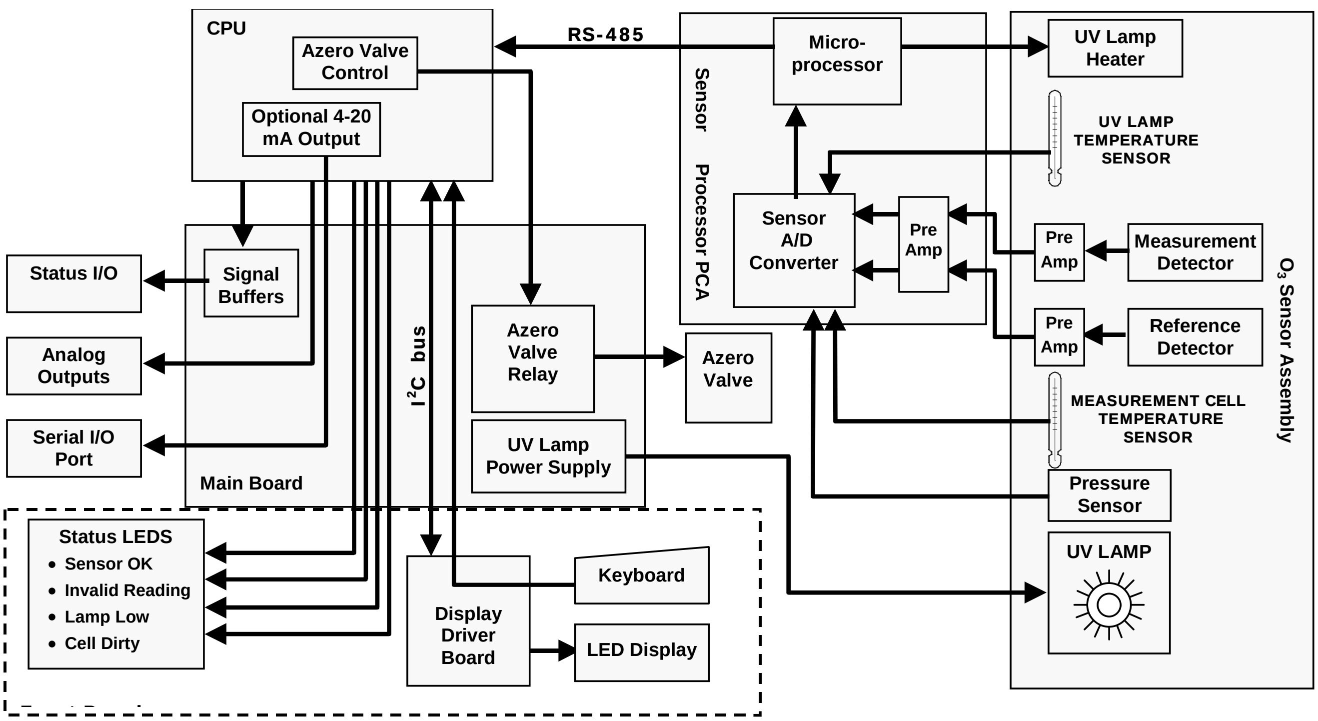



**Figure 10–4 460M Electronic Block Diagram**

Electronically, the 460M is of modular design (see Figure 10-4). Each Sub-module performs a specific set of functions as described in Sections 10.3.1 through 10.3.5.

## 10.3.1. Main Board

This printed circuit assembly provides interconnection between the monitor's other electronic modules as well as some opto-isolated signal buffers for the digital status outputs and control inputs.

The monitor's main power supply and the power supply for the monitor's UV Lamp are also located on this assembly (see Section 10.3.6)

**Azero Valve Control**

The auto zero valve is actuated by a 12 VDC solenoid valve driver located on the main board that is under CPU control.

## 10.3.2. CPU

The CPU card is the central module of the 460M's electronic design. Its micro-controller/processor and support circuitry receives digital data from the sensor processor module and performs all basic computational tasks related to determining the $O_3$ concentration of the source gas.

The CPU card also handles all I/O functions.

- **Status LED's:** Based on data received from the sensor processor module, it activates and deactivates the four status LED's located on the monitor's front panel (see Section 11.3).
- **Display Data:** Two-way communications between the CPU and the Display driver module is handled via an $I^2C$ interface. $I^2C$ is a two-wire, clocked, bi-directional, digital serial I/O bus that is used widely in commercial and consumer electronic systems.
- **Keyboard Input:** The three keys/buttons on the front panel (two zero keys and the pressure key) are sensed directly by the CPU as simple digital contact closures.
- **Status Outputs:** Logic-Level voltages are output through a connector J2 on the main board. These outputs convey good/bad information about key monitor operational conditions (see Section 11.2) via optically isolated NPN transistors, which sink up to 50 mA of DC current.

  These outputs can be used to interface with devices that accept logic-level digital inputs, such as programmable logic controllers (PLC's). Each Status bit is an open collector output that can withstand up to 40 VDC. All of the emitters of these transistors are tied together and available at the STATUS COM pin of J2 on the main board (see Figure 3-6). This pin is normally connected to the input ground of the external device.

> **NOTE**
>
> **Most PLC's have internal provisions for limiting the current that the input will draw from an external device. When connecting to a unit that does not have this feature, an external dropping resistor must be used to limit the current through the transistor output to less than 50 mA. At 50 mA, the transistor will drop approximately 1.2V from its collector to emitter.**

- **Control Inputs:** These inputs are used to initiate certain operations. (see Table 3-3). They are triggered by providing a contact closure or low impedance current path between the input and the ground pin (GND – see Figure 3-8). This can be done by using a mechanical switch or isolated transistor output from another device, such as a PLC.

- **Analog Outputs:** The 460M is equipped with one analog output which reports the current $O_3$ concentration currently being measured by the monitor. During auto zero operation the last valid concentration value is held until the auto zero procedure is completed. This output is factory configurable as either a 0-5 VDC signal or a 4-20 mA signal.

- **Serial I/O:** A standard RS-232 or RS-485 serial communications port. Section 3.5.4 describes how to configure and make connections to this port. Chapter 7 describes the syntax and commands available for use.

## 10.3.3. Sensor Processor PCA

The sensor processor module performs the real work of operating the $O_3$ sensor assemble and gathering the various measurements used to calculate the $O_3$ concentration. It includes:

- **Sensor Signal A/D Conversion**: The various analog voltages output by the monitor's $O_3$ sensor assembly are converted into digital signals that the CPU can understand and manipulate by an analog to digital converter (A/D) located on the sensor processor module.

  The A/D consists of an 80,000 count, voltage-to-frequency (V-F) converter, a programmable logic device (PLD), three multiplexers, several amplifiers and some other associated devices. The V-F converter produces a frequency proportional to its input voltage. The PLD counts the output of the V-F during a specified time period, and sends the result of that count, in the form of a binary number, to the CPU

  In the rare event that this converter requires recalibration, contact Teledyne Instruments' customer service department for instructions.

- **Sensor Microprocessor:** This IC provides two important functions.

  - A/D Converter Signal Selection: The A/D converter can only convert one signal at a time. The sensor microprocessor selects which of the various sensor inputs is to be converted, starts the conversion process, stops it, extracts the digital data and sends this to the main CPU via an internal RS-485 serial data bus.

  - UV Lamp Heater Control**:** The sensor microprocessor also provides direct control of the UV lamp heater by turning it on and off via a transistor using high frequency pulse width modulation. The output of the UV Lamp sensor is converted by the sensor processor module's A/D converter. Based on this digital value the sensor microprocessor sends out pulses that turn the heater ON/OFF. The more heat needed the longer the width of the ON (logic high) pulse and the shorter the width of the OFF (logic low) portion of the pulse.

## 10.3.4. $O_3$ Sensor Assembly

The heart of the 460M Monitor is the $O_3$ sensor assembly. This metal block located at the upper left hand side of the enclosure includes all of the electronic components needed to gather the data required to calculate the $O_3$ content of the source gas.

- **UV Lamp:** The ultraviolet light needed to detect $O_3$ is supplied by a mercury-vapor UV lamp. This lamp is coated in a material that optically screens the UV radiation output to remove the $O_3$ producing 185nm radiation. Only light at 254nm is emitted.

- **UV Lamp Heater**: to operate efficiently the UV lamp must be kept at a temperature of 52˚C or higher. While the heat created by the lamp itself is usually sufficient to cause this, under some ambient conditions additional heating is required. This additional heat is provided by a DC heater, controlled by the sensor microprocessor.

- **Temperature Sensors**: Two solid state temperature sensors are located in the $O_3$ sensor assembly. They are:

    - <u>Measurement Cell Temperature Sensor</u>: This sensor detects the temperature of the gas inside the measurement cell. This information is used by the CPU as part of the $O_3$ concentration calculation (see Formula 10-3 in Section 10.1).

    - <u>UV amp Temperature Sensor</u>: This sensor, attached to the UV lamp reports the current temperature of the Lamp to the sensor microprocessor via the sensor processor A/D converter.

- **UV detectors:** Two UV detectors measure the two primary variables, ***I*** and $I_0$ (See Section 10.1.1) needed to compute the $O_3$ concentration of the source gas. They are:

    - The measurement detector which detects the intensity of the UV light passing through the source gas(***I***) and;

    - The reference detector which measures the intensity of the light that is not affected by $O_3$ present in the measurement cell ($I_0$)

    Each detector is a specially designed vacuum diode that only reacts to radiation at or very near a wavelength of 254nm and outputs a voltage that varies in direct relationship with the light's intensity. The wavelength specificity of the detector is high enough that no extra optical filtering of the UV light is needed.

    Two stages of preamplifier are used to amplify the output signals of each detector to a level readable by the A/D Converter circuitry of the monitor's sensor processor module. In each case the first stage of amplification is located on each of the PCA's on which the detector itself is mounted. The second stage of amplification for both detectors is located on the sensor processor module.

- **Gas Pressure Sensor:** This absolute pressure sensor measures the gas pressure in the measurement cell upstream of the Pump. The sample pressure is used by the CPU to calculate $O_3$ Concentration (see Formula 10-3 in Section 10.1).

## 10.3.5. Display Driver and Keyboard Assembly

### Keyboard

The keyboard of the M460M is comprised of 3 contact closure button/keys that are directly sensed by the monitor's CPU: These Switches are:

- **Zero Switches:** When pressed simultaneously, these switches activate the monitor's auto zero calibration feature (see Section 8.1). Activating either switch independently has no affect on the monitor's' operation.
- **Pressure Switch:** Pressing and holding this switch causes the monitor to display the current gas pressure of the source gas as measured by the gas pressure sensor located on the measurement cell. Pressure is displayed in units of psia (pounds per square inch absolute)

### Display

The main display of the monitor is a 4-digit, 7-segment LED display with decimal point. Under normal operation it displays the current $O_3$ concentration of the source gas. It can also momentarily display the gas pressure of the source gas.

### Display Driver

The circuitry on the display driver several functions.

- Signal levels from the three front panel key/buttons are passed through the driver unaltered, directly to the CPU.
- Under command of the CPU a control chip located on this assembly turns the four status LED's(see Section 11.3) ON/OFF
- A bipolar integrated circuit decodes the serial data sent by the CPU via an I2C bus and the individual segments of the display ON/OFF. The clock signal used to decode this data is supplied by the monitor's main CPU.

  The four digits on the display are controlled by multiplexing between two pairs of 2 digits each. The display is operated in static mode. Each value sent by the CPU is held on the LED display until a new value is sent.

## 10.3.6. Power Distribution

The 460M operates on 90 to 260 VAC power at either 50Hz or 60Hz. As illustrated in Figure 10-5 below, power enters the monitor via a standard 3-conductor power cord through a hole provided in the bottom of the casing. In order to maintain the IP (NEMA4X) rating of the enclosure, an appropriate sealed conduit connector should be used.

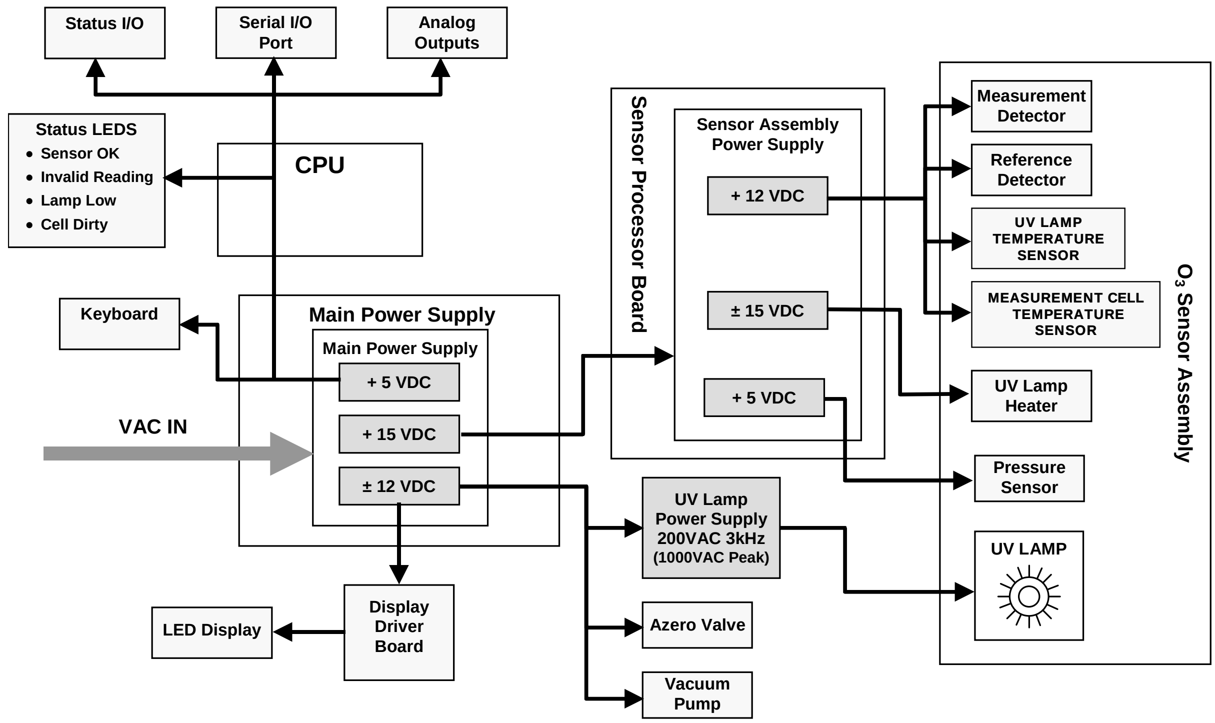



**Figure 10–5 460M Power Distribution Block Diagram**

- **Main Power Supply:** AC line power is converted and stepped down to several DC voltages by the main power supply:
  - +12 VDC: Powers the vacuum pump, the display driver and the Azero valve control relay. This voltage is also used as the source voltage for the UV Lamp Power supply
  - +5 VDC: The basic voltage on which the CPU and logic level circuitry operates.
  - +15 VDC: Source voltage for a secondary power supply located on the sensor processor module.
- **Sensor Processor Module Power Supply:** Using +15 VDC from the main power supply, this circuitry generates the +5, +12 & ±15 VDC supplies needed to operate its own on-board logic devices and the various components of the $O_3$ sensor assembly.
- **UV LAMP POWER SUPPLY:** Using +12 VDC supplied by the main power supply, this assembly generates the 30 kHz AC voltage for the monitor's mercury vapor UV lamp. The output of this power supply is variable. At startup voltage level of this output can reach as high a 1000 VAC. Once the lamp is warmed up and operating at peak efficiency, the output should be around 200 VAC

The 460M has no onboard ON/OFF switch. A hardwired 2 Amp fuse is located on the main power supply assembly to provide over voltage/current protection.

# User Notes:

# 11. TROUBLESHOOTING

## 11.1. Sensor and System Troubleshooting

This chapter gives guidelines for diagnosing system and sensor malfunctions using the five digital Status Outputs provided by the 460M. All troubleshooting should be done after the 460M has been turned on and allowed to warm up for at least 15 minutes.

## 11.2. Status Output Summary

Table 11-1 below gives a summary of the operation of the five Status Outputs on the 460M. See 2.4.2 Digital Status Outputs for information on connecting these outputs.

**Table 11-1: Digital Status Outputs and Front Panel Status LED Definitions**

| OUTPUT # | NAME | ON STATE | OFF STATE | LED on FRONT PANEL |
|---|---|---|---|---|
| 1 | Sensor O.K. | Normal State | Reference or Measure > 4995mV; Reference < 500mV | YES |
| 2 | Invalid Reading | Pressure > 30 psia, Negative Ozone Concentration, Concentration Over-Range | Normal State | YES |
| 3 | Lamp Low | Reference Detector <1000 mV | Normal State | YES |
| 4 | Cell Dirty | Measure/Reference ratio < 0.5 (zero gas) | Normal State | YES |
| 5 | Auto-Zero Error | Auto-Zero Failed: The zero value retuned is > 0.5wt%, 10.0 g/nm3 or 50 ppm. | Normal State | NO |
| 6 | SPARE | | | |

### 11.2.1. Sensor OK

The normal state for the Sensor OK output in ON. During the warm-up period on start-up this output will stay off until the UV lamp reaches a minimum intensity. If this output remains OFF after the 15 minute warm-up period, or goes off during normal operation the 460M is in need of servicing.

If the Sensor OK output turns OFF and the LAMP LOW output is ON, the lamp intensity has fallen below the minimum level required for proper operation.

If the Sensor OK output turns off and the Lamp Low output is also off, then one of the analog voltages output by the sensor processor module has exceeded the range of the internal A/D converter. Adjustment by qualified service personnel is required.

## 11.2.2. Invalid Reading

The normal state for the Invalid Reading output is OFF. When this output turns ON, the 460M is still operational, but a system fault or calibration fault exists that may make the current ozone reading invalid.

The Invalid Reading output is turned ON for any of the following conditions:

- The measured pressure in the measurement cell exceeds 30 psia.
- The measured concentration has exceeded the monitor's full-scale concentration range. Check the serial number tag for the full-scale concentration range.
- The measured concentration is an excessively negative reading.

## 11.2.3. Lamp Low

The normal state for the lamp low output is OFF. This output turns on when the UV lamp intensity, as measured by the reference detector, has dropped below 1000mV.

If the lamp low output turns ON and the Sensor OK, output is ON the lamp intensity is still adequate for measurement, but adjustment should be made when possible.

If the lamp low output turns ON and the Sensor OK output is OFF the lamp intensity has degraded to the point that an accurate measurement is no longer possible.

## 11.2.4. Cell Dirty

The normal state for the cell dirty output is OFF. This output turns ON when the ratio of the measure detector to the reference detector (at zero) is < 0.5. This value is calculated when the zero calibration is performed.

When this output is ON, the windows have become dirty or occluded to the point that optical transmission through the windows is too poor for a valid reading to be made or a calibration fault has occurred.

## 11.2.5. Auto Zero Error

The normal state for the auto zero output is OFF. This output turns ON when zero value returned during ether a manual zero calibration (using the CZERO command over the serial I/O interface - see Section 7.3.2), or an auto zero operation (see Section 8.1) is too high.

The Auto Zero Error output is turned ON for any of the following conditions:

- The auto zero valve has failed to activate.
- The $O_3$ scrubber is not adequately removing $O_3$

# 11.3. Front Panel Status LED Summary

Table 11-2 below is a logic truth table summarizing the recommended actions based on the states of the four status front panel status LED's. A '1' indicates the LED is ON, a '0' indicates the LED is OFF, and 'X' indicates the LED can be in either state.

**Table 11-2: Status Output Truth Table**

| SENSOR OK | INVALID READING | LAMP LOW | CELL DIRTY | ACTIONS |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | Normal operation, no action required |
| 0 | X | X | X | Service required |
| 1 | 1 | X | X | Check Pressure > 45 psia. Verify that concentration has not exceeded full scale range of sensor. Calibrate at Zero. |
| 1 | X | 1 | X | Lamp adjustment useful, though not required |
| 1 | X | X | 1 | Calibrate at zero.<br>Clean Cell[1]<br>Adjust Lamp[1] |
| [1] Contact Teledyne Instruments Customer Service dept. for instructions. | | | | |

Definitions for these four LED's correspond to the definitions of the four digital status outputs with identical names found in Section 11.2.

# 11.4. Poblems with Rs-232 or RS-485 communication ports.

If the monitor's RS-232 or RS-485 are not responding, check:

- The position of the 4 shunts on JP3 of the CPU board.
  - For RS-232 operation they should be connecting the right-most pins and the center pins of JP3.
  - For RS-485 operation they should be connecting the left-most pins and the center pins of JP3.
- Make sure a shunt is in place across the two pins of JP1 on the CPU board.

## **11.5.** Technical Assistance

If this manual and its trouble-shooting / repair sections do not solve your problems, technical assistance may be obtained from Teledyne Instruments, Customer Service, 6565 Nancy Ridge Drive, San Diego, CA 92121. Phone: +1 858 657 9800 or 1-800 324 5190. Fax: +1 858 657 9816. Email: api-customerservice@teledyne.com.

# User Notes:

# 12. A PRIMER ON ELECTRO-STATIC DISCHARGE

Teledyne Instruments considers the prevention of damage caused by the discharge of static electricity to be an xtremely important part of making sure that your monitor continues to provide reliable service for a long time. This section describes how static electricity occurs, why it is so dangerous to electronic components and assemblies as well as how to prevent that damage from occurring.

## 12.1. How Static Charges are Created

Modern electronic devices such as the types used in the various electronic assemblies of your monitor, are very small, require very little power and operate very quickly. Unfortunately the same characteristics that allows them to do these things also makes them very susceptible to damage from the discharge of static electricity. Controlling electrostatic discharge begins with understanding how electro-static charges occur in the first place.

Static electricity is the result of something called triboelectric charging which happens whenever the atoms of the surface layers of two materials rub against each other. As the atoms of the two surfaces move together and separate, some electrons from one surface are retained by the other.

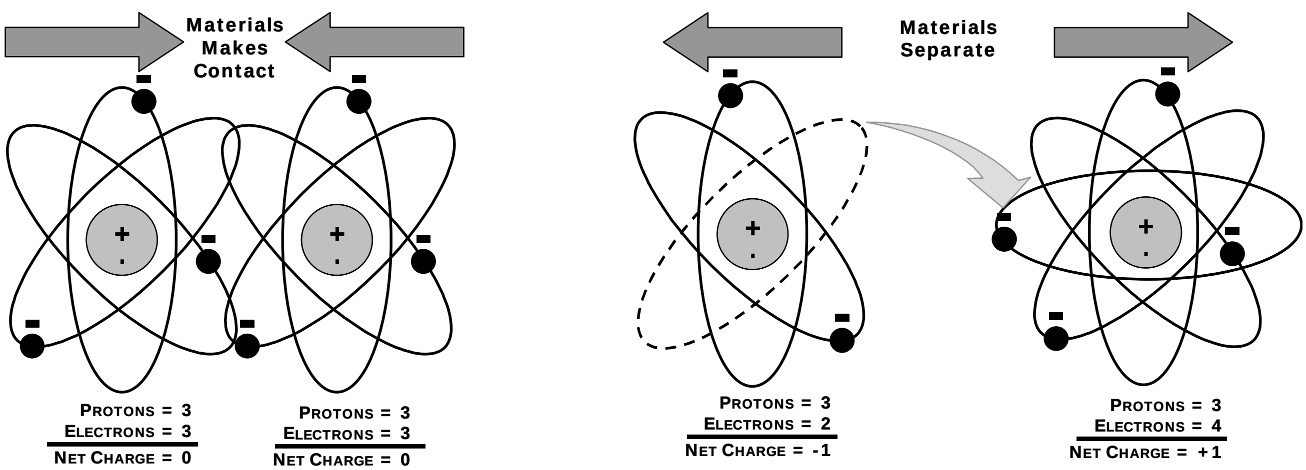



**Figure 12-1: Triboelectric Charging**

If one of the surfaces is a poor conductor or even a good conductor that is not grounded, the resulting positive or negative charge can not bleed off and becomes trapped in place, or static. The most common example of triboelectric charging happens when someone wearing leather or rubber soled shoes walks across a nylon carpet or linoleum tiled floor. With each step electrons change places and the resulting electro-static charge builds up, quickly reaching significant levels. Pushing an epoxy printed circuit board across a workbench, using a plastic handled screwdriver or even the constant jostling of Styrofoam™ pellets during shipment can also build hefty static charges

**Table 12-1: Static Generation Voltages for Typical Activities**

| MEANS OF GENERATION | 65-90% RH | 10-25% RH |
|---|---|---|
| Walking across nylon carpet | 1,500V | 35,000V |
| Walking across vinyl tile | 250V | 12,000V |
| Worker at bench | 100V | 6,000V |
| Poly bag picked up from bench | 1,200V | 20,000V |
| Moving around in a chair padded with urethane foam | 1,500V | 18,000V |

## 12.2. How Electro-Static Charges Cause Damage

Damage to components occurs when these static charges come in contact with an electronic device. Current flows as the charge moves along the conductive circuitry of the device and the typically very high voltage levels of the charge overheat the delicate traces of the integrated circuits, melting them or even vaporizing parts of them. When examined by microscope the damage caused by electro-static discharge looks a lot like tiny bomb craters littered across the landscape of the component's circuitry.

A quick comparison of the values in Table 12-1 with the those shown in the Table 12-2, listing device susceptibility levels, shows why *Semiconductor Reliability News* estimates that approximately 60% of device failures are the result of damage due to electro-static discharge.

**Table 12-2: Sensitivity of Electronic Devices to Damage by ESD**

| DEVICE | DAMAGE SUSCEPTIBILITY VOLTAGE RANGE | |
|---|---|---|
| | DAMAGE BEGINS OCCURRING AT | CATASTROPHIC DAMAGE AT |
| MOSFET | 10 | 100 |
| VMOS | 30 | 1800 |
| NMOS | 60 | 100 |
| GaAsFET | 60 | 2000 |
| EPROM | 100 | 100 |
| JFET | 140 | 7000 |
| SAW | 150 | 500 |
| Op-AMP | 190 | 2500 |
| CMOS | 200 | 3000 |
| Schottky Diodes | 300 | 2500 |
| Film Resistors | 300 | 3000 |
| This Film Resistors | 300 | 7000 |
| ECL | 500 | 500 |
| SCR | 500 | 1000 |
| Schottky TTL | 500 | 2500 |

Potentially damaging electro-static discharges can occur:

- Any time a charged surface (including the human body) discharges to a device. Even simple contact of a finger to the leads of a sensitive device or assembly can allow enough discharge to cause damage. A similar discharge can occur from a charged conductive object, such as a metallic tool or fixture.

- When static charges accumulated on a sensitive device discharges from the device to another surface such as packaging materials, work surfaces, machine surfaces or other device. In some cases, charged device discharges can be the most destructive.

  A typical example of this is the simple act of installing an electronic assembly into the connector or wiring harness of the equipment in which it is to function. If the assembly is carrying a static charge, as it is connected to ground a discharge will occur.

- Whenever a sensitive device is moved into the field of an existing electro-static field, a charge may be induced on the device in effect discharging the field onto the device. If the device is then momentarily grounded while within the electrostatic field or removed from the region of the electrostatic field and grounded somewhere else, a second discharge will occur as the charge is transferred from the device to ground.

## 12.3. Common Myths About ESD Damage

- **I didn't feel a shock so there was no electro-static discharge**: The human nervous system isn't able to feel a static discharge of less than 3500 volts. Most devices are damaged by discharge levels much lower than that.

- **I didn't touch it so there was no electro-static discharge**: Electro Static charges are fields whose lines of force can extend several inches or sometimes even feet away from the surface bearing the charge.

- **It still works so there was no damage**: Sometimes the damaged caused by electro-static discharge can completely sever a circuit trace causing the device to fail immediately. More likely, the trace will be only partially occluded by the damage causing degraded performance of the device or worse, weakening the trace. This weakened circuit may seem to function fine for a short time, but even the very low voltage and current levels of the device's normal operating levels will eat away at the defect over time causing the device to fail well before its designed lifetime is reached.

  These latent failures are often the most costly since the failure of the equipment in which the damaged device is installed causes down time, lost data, lost productivity, as well as possible failure and damage to other pieces of equipment or property.

- **Static Charges can't build up on a conductive surface**: There are two errors in this statement.

  Conductive devices can build static charges if they are not grounded. The charge will be equalized across the entire device, but without access to earth ground, they are still trapped and can still build to high enough levels to cause damage when they are discharged.

  A charge can be induced onto the conductive surface and/or discharge triggered in the presence of a charged field such as a large static charge clinging to the surface of a nylon jacket of someone walking up to a workbench.

- **As long as my monitor is properly installed it is safe from damage caused by static discharges**: It is true that when properly installed the chassis ground of your monitor is tied to earth ground and its electronic components are prevented from building static electric charges themselves. This does not, however, prevent discharges from static fields built up on other things, like you and your clothing, from discharging through the monitor and damaging it.

# 12.4. Basic Principles of Static Control

It is impossible to stop the creation of instantaneous static electric charges. It is not, however difficult to prevent those charges from building to dangerous levels or prevent damage due to electro-static discharge from occurring.

## 12.4.1. General Rules

**Only handle or work on all electronic assemblies at a properly set up ESD station.** Setting up an ESD safe work station need not be complicated. A protective mat properly tied to ground and a wrist strap are all that is needed to create a basic anti-ESD workstation (see figure 12-2).

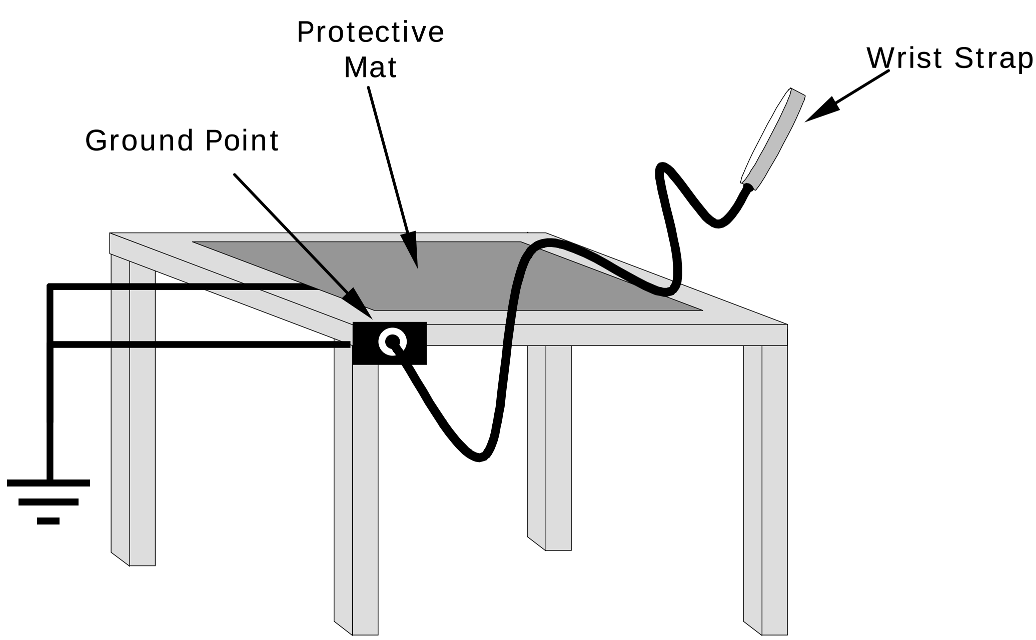



**Figure 12-2: Basic anti-ESD Work Station**

For technicians that work in the field, special lightweight and portable anti-ESD kits are available from most suppliers of ESD protection gear. These include everything needed to create a temporary anti-ESD work area anywhere.

- **Always wear an Anti-ESD wrist strap when working on the electronic assemblies of your monitor**. An anti-ESD wrist strap keeps the person wearing it at or near the same potential as other grounded objects in the work area and allows static charges to dissipate before they can build to dangerous levels. Anti-ESD wrist straps terminated with alligator clips are available for use in work areas where there is no available grounded plug.

  Also, anti-ESD wrist straps include a current limiting resistor (usually around one meg-ohm) that protects you should you accidentally short yourself to the monitor's power supply.

- **Simply touching a grounded piece of metal is insufficient**. While this may temporarily bleed off static charges present at the time, once you stop touching the grounded metal new static charges will immediately begin to re-build. In some conditions a charge large enough to damage a component can rebuild in just a few seconds.

- **Always store sensitive components and assemblies in anti-ESD storage bags or bins:** Even when you are not working on them, store all devices and assemblies in a closed anti-Static bag or bin. This will prevent induced charges from building up on the device or assembly and nearby static fields from discharging through it.

- **Use metallic anti-ESD bags for storing and shipping ESD sensitive components and assemblies rather than pink-poly bags.** The famous, pink-poly bags are made of a plastic that is impregnated with a liquid (similar to liquid laundry detergent) which very slowly sweats onto the surface of the plastic creating a slightly conductive layer over the surface of the bag.

  While this layer may equalize any charges that occur across the whole bag, it does not prevent the build up of static charges. If laying on a conductive grounded surface, these bags will allow charges to bleed away but the very charges that build up on the surface of the bag itself can be transferred through the bag by induction onto the circuits of your ESD sensitive device. Also, the liquid impregnating the plastic is eventually used up after which the bag is as useless for preventing damage from ESD as any ordinary plastic bag.

  Anti-Static bags made of plastic impregnated with metal (usually silvery in color) provide all of the charge equalizing abilities of the pink-poly bags but also, when properly sealed, create a Faraday cage that completely isolates the contents from discharges and the inductive transfer of static charges.

  Storage bins made of plastic impregnated with carbon (usually black in color) are also excellent at dissipating static charges and isolating their contents from field effects and discharges.

- **Never use ordinary plastic adhesive tape near an ESD sensitive device or to close an anti-ESD bag.** The act of pulling a piece of standard plastic adhesive tape, such as Scotch® tape, from its roll will generate a static charge of several thousand or even tens of thousands of volts on the tape itself and an associated field effect that can discharge through or be induced upon items up to a foot away.

## 12.4.2. Basic anti-ESD Procedures for Monitor Repair and Maintenance

### 12.4.2.1. Working on an Installed Monitor

When working on the monitor while it is installed and plugged into a properly grounded power supply

1. Attach your anti-ESD wrist strap to ground before doing anything else.
2. Pause for a second or two to allow any static charges to bleed away.
3. Open the casing of the monitor and begin work.
4. If you must remove a component from the monitor, do not lay it down on a non-ESD preventative surface where static charges may lie in wait.
5. Only disconnect your wrist strap after you have finished work and closed the case of the monitor.

### 12.4.2.2. Working at an Anti-ESD Work Bench.

When working on an instrument or an electronic assembly while it is resting on a anti-ESD work bench

1. Plug your anti-ESD wrist strap into the grounded receptacle of the work station before touching any items on the work station and while standing at least a foot or so away. This will allow any charges you are carrying to bleed away through the ground connection of the work station and prevent discharges due to field effects and induction from occurring.
2. Pause for a second or two to allow any static charges to bleed away.
3. Only open any anti-ESD storage bins or bags containing sensitive devices or assemblies after you have plugged your wrist strap into the work station.
   - Lay the bag or bin on the workbench surface.
   - Before opening the container, wait several seconds for any static charges on the outside surface of the container to be bled away by the work station's grounded protective mat.
4. Do not pick up tools that may be carrying static charges while also touching or holding an ESD Sensitive Device.
   - Only lay tools or ESD-sensitive devices and assemblies on the conductive surface of your workstation. Never lay them down on non-ESD preventative surfaces.
5. Place any static sensitive devices or assemblies in anti-static storage bags or bins and close the bag or bin before unplugging your wrist strap.
6. Disconnecting your wrist strap is always the last action taken before leaving the work bench.

### 12.4.2.3. Transferring Components from Installed Monitor to Bench and Back

When transferring a sensitive device from an installed monitor to an anti-ESD workbench or back:

1. Follow the instructions listed above for working on an installed monitor and for working at an anti-ESD work station.

2. Never carry the component or assembly without placing it in an anti-ESD bag or bin.

3. Before using the bag or container allow any surface charges on it to dissipate:

    - If you are at the monitor hold the bag in one hand while your wrist strap is connected to a ground point.

    - If you are at an anti-ESD work bench, lay the container down on the conductive work surface.

    - In either case wait several seconds.

4. Place the item in the container.

5. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape. Never use standard plastic adhesive tape as a sealer.

    - Folding the open end over isolates the component(s) inside from the effects of static fields.

    - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.

6. Once you have arrived at your destination, allow any surface charges that may have built up on the bag or bin during travel to dissipate:

    - Connect your wrist strap to ground.

    - If you are at the monitor hold the bag in one hand while your wrist strap is connected to a ground point.

    - If you are at a anti-ESD work bench, lay the container down on the conductive work surface

    - In either case wait several seconds

7. Open the container.

### 12.4.2.4. Opening Shipments from and Packing Components for Return to Teledyne Instruments Customer Service.

Packing materials such as bubble pack and Styrofoam pellets are extremely efficient generators of static electric charges. To prevent damage from ESD, Teledyne Instruments ships all electronic components and assemblies in properly sealed ant-ESD containers.

Static charges will build up on the outer surface of the anti-ESD container during shipping as the packing materials vibrate and rub against each other. To prevent these static charges from damaging the components or assemblies being shipped make sure that you:

- Always unpack shipments from Teledyne Instruments Customer Service by:
  - Opening the outer shipping box away from the anti-ESD work area
  - Carry the still sealed ant-ESD bag, tube or bin to the anti-ESD work area
  - Follow steps 6 and 7 of Section 12.4.2.3 above when opening the anti-ESD container at the work station
  - Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to Teledyne Instruments
- Always pack electronic components and assemblies to be sent to Teledyne Instruments Customer Service in anti-ESD bins, tubes or bags.
  - Do not use pink-poly bags.
  - If you do not already have an adequate supply of anti-ESD bags or containers available, Teledyne Instruments' Customer Service department) will supply them (see Section 11.5 for contact information.
  - Always follow steps 1 through 5 of Section 12.4.2.3

# User Notes:

# Appendix A - Spare Parts List

- 05127 Spare Parts List, M460M

# M460M Spare Parts List

| Part Number | Description |
|---|---|
| 000941000 | ORIFICE, 13 MIL (SAMPLE FLOW & OZONE GENERATOR) |
| 001760400 | ASSY, FLOW CONTROL, 800CC |
| 003290000 | ASSY, THERMISTOR |
| 005960000 | KIT, EXPENDABLES, ACTIVATED CHARCOAL |
| 006120100 | ASSY, UV LAMP, OZONE GENERATOR |
| 006190200 | KIT, EXPENDABLES, M400E |
| 009690000 | KIT, TFE FILTER ELEMENTS, 5 UM (100) |
| 009690100 | AKIT, TFE FLTR (FL6), 47MM, 5UM (30) |
| 016290000 | WINDOW, SAMPLE FILTER, 47MM (KB) |
| 016300700 | ASSY, SAMPLE FILTER, 47MM |
| 022710000 | ABSORPTION TUBE, QUARTZ, M400A/E (KB) |
| 037340200 | ASSY, AIR DRYER, SHORT CANISTER |
| 037860000 | ORING, TEFLON, RETAINING RING, 47MM (KB) |
| 039550100 | PCA, RELAY CARD, E SERIES, S/N'S <523 |
| 040010000 | ASSY, FAN REAR PANEL, E SERIES |
| 040030100 | PCA, PRESS SENSORS (1X), w/FM4, E SERIES |
| 040660000 | ASSY, REPLACEMENT CHARCOAL FILTER |
| 041200000 | PCA, DET PREAMP w/OP20, M400E/M700E/M703 |
| 041200200 | PCA, DET PREAMP w/OP20 M700E/ M400E/M703 |
| 041440000 | PCA, DC HEATER/TEMP SENSOR, OPTICAL BENCH |
| 041440100 | PCA, DC HEATER/TEMP SENSOR, OZONE GENERATOR |
| 041660100 | PCA, UV LAMP P/S, O3 GEN, M400E/M703E |
| 041660500 | PCA, UV LAMP P/S, OPT BENCH, M400E/M703E |
| 041710000 | ASSY, CPU, CONFIGURATION |
| 042010000 | ASSY, SAMPLE THERMISTOR, M400E |
| 042410200 | ASSY, PUMP, INT, SOX/O3/IR * |
| 042580000 | PCA, KEYBOARD, E-SERIES, W/V-DETECT |
| 042890100 | ASSY, PUMP CONFIG PLUG, 100-115V/60 HZ |
| 042890200 | ASSY, PUMP CONFIG PLUG, 100-115V/50 HZ |
| 042890300 | ASSY, PUMP CONFIG PLUG, 220-240V/60 HZ |
| 042890400 | ASSY, PUMP CONFIG PLUG, 220-240V/50 HZ |
| 042900100 | PROGRAMMED FLASH, E SERIES |
| 043160000 | MANUAL, OPERATION, M400E |
| 043820000 | KIT, SPARES |
| 043870100 | DOC, w/SOFTWARE, M400E |
| 043940000 | PCA, INTERFACE, ETHERNET, E-SERIES |
| 044730000 | KIT, IZS EXPENDABLES, M400E (KB) |
| 045230100 | PCA, RELAY CARD, E SERIES, S/N'S >522 |
| 048620200 | PCA, SERIAL INTERFACE, w/ MD, E SERIES |
| 048660000 | ASSY, THERMOCOUPLE, AG SCRUBBER, M400E |
| 048670000 | ASSY, HEATER, FIBER O3 SCRUBBER, 400E |
| 049290000 | CLIP, THERMISTOR HOLDER |
| 052400000 | ASSY, UV LAMP, OPTICAL BENCH (CR) |
| 052910000 | ASSY, OPTICAL BENCH, M400E/M700E/M703E |
| 055100200 | OPTION, PUMP ASSY, 240V * |
| 055560000 | ASSY, VALVE, VA59 W/DIODE, 5" LEADS |

# M460M Spare Parts List

| Part Number | Description |
|---|---|
| 058020100 | PCA, E-SERIES MOTHERBOARD, GEN 5 |
| CN0000458 | CONNECTOR, REAR PANEL, 12 PIN |
| CN0000520 | CONNECTOR, REAR PANEL, 10 PIN |
| DS0000025 | DISPLAY, E SERIES (KB) |
| FL0000001 | FILTER, SS |
| FL0000012 | SCRUBBER, OZONE, REFERENCE |
| FM0000004 | FLOWMETER (KB) |
| HW0000005 | FOOT, CHASSIS |
| HW0000020 | SPRING |
| HW0000036 | TFE TAPE, 1/4" (48 FT/ROLL) |
| KIT000219 | KIT, 4-20MA CURRENT OUTPUT (E SERIES) |
| KIT000246 | KIT, IZS RETROFIT, M400E |
| OP0000014 | QUARTZ DISC, OPTICAL BENCH |
| OP0000031 | WINDOW, OPTICAL BENCH & OZONE GEN FEEDBACK |
| OR0000001 | ORING, SAMPLE FLOW & OZONE GENERATOR |
| OR0000025 | ORING, AIR DRYER CANISTER |
| OR0000026 | ORING, ABSORPTION TUBE |
| OR0000039 | ORING, OPTICAL BENCH & OZONE GEN FEEDBACK |
| OR0000048 | ORING, OZONE GEN UV LAMP |
| OR0000089 | ORING, OPTICAL BENCH |
| OR0000094 | ORING, SAMPLE FILTER |
| PU0000022 | REBUILD KIT, FOR PU20 & 04241 (KB) |
| RL0000015 | RELAY, DPDT, (KB) |
| SW0000051 | SWITCH, POWER, CIRC BR |
| SW0000059 | PRESSURE SENSOR, 0-15 PSIA, ALL SEN |
| WR0000008 | POWER CORD, 10A |

# Appendix B – Electronic Schematics

**Table A-2 M460M List of Electronic Schematics**

| DOCUMENT # | DESCRIPTION |
|---|---|
| 03155 | PCA, SENSOR PROCESSOR |
| 03169 | PCA, FRONT PANEL DISPLAY |
| 03493 | PCA, CPU |
| 03897 | PCA, ISOLATED 4-20MA OUTPUT (OPTIONAL)" |
| 04992 | PCA, MAINBOARD |