TELEDYNE
ADVANCED POLLUTION INSTRUMENTATION
A Teledyne Technologies Company

INSTRUCTION MANUAL

MODEL 460L
Nema Ozone Monitor

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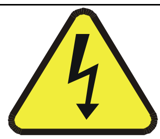
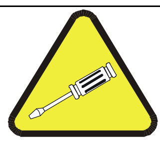
SAFETY MESSAGES

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 460L 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

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1. INTRODUCTION

1.1. Preface

Teledyne Instruments is pleased that you have purchased the Model 460L 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 460L is a microprocessor based low range ozone monitor for safety monitoring of ozone levels in a variety of applications such as water treatment, food processing, and research. The design has been specifically optimized for applications requiring the measurement of ozone at the typically low concentration levels encountered when tracking ambient conditions. The Model 460L 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 460L 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 460L but if you do, our full time customer service department is always available to answer your questions.

1.2. 460L Documentation

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

- Printed format, part number 050120100
- Electronic format on a CD-ROM, part number 050120200

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 Teledyne Instruments Incorporated warranty statement applies.

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 your monitor to keep it in good operating condition.

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 Electro-Static Discharge (ESD) Primer:

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

USER NOTES:

USER NOTES:

2. SPECIFICATIONS AND WARRANTY

2.1. Specifications

Table 2-1 460L Specifications

Measurement Principle	UV Absorption (Beer Lambert Law)
Ranges	1ppm to 500 ppm: User selectable
Measurement Units	ppm; ppb
Accuracy	± 1% of Full Scale
Zero Noise	< 0.0015 ppm (rms)
Span Noise	< 0.5% of reading (rms) (above 0.1 ppm)
Lower Detectable Limit	< 0.003 ppm (rms)
Linearity	Better than 1% of selected range
Response Time (95%)	<30 sec
Repeatability	±0.5% of selected range
Display Resolution	0001 ppm, 1 ppb
Gas Flow Rate	1.0-2.0 LPM
Compensation	Pressure, Temperature (NTP = 273.15K, 760mmHg)
Gas Inlet Pressure Range	11.0 – 16.0 psia
Temperature Range	5-45 °C
Humidity Range	10-90% RH, Non-Condensing
Dimensions (H x W x D)	12.64" x 11.19" x 6.08" (321mm x 284mm x 154mm)
Weight	9.40lb (4.27kg)
Power	110-240V~, 50/60Hz, 200 VA
Environmental Conditions	Installation Category (Over Voltage Category) II Pollution Degree 2
Maximum Operating Altitude	2000 meters
Analog Voltage Output	Single output: 0-5V, Option available converting voltage output to 4-20mA output with maximum voltage between outputs and ground 60V peak
Relay Outputs	3 relay outputs: Sensor OK and two concentration alarms (HI & Hi-Hi)
Relay type & Output Rating	SPDT: 250V AC, 3A
Degree of Protection (IP Code)	IP65 (NEMA 4X)

2.2. Warranty

WARRANTY POLICY (02024D)

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

COVERAGE

After the warranty period and throughout the equipment lifetime, T-API 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 T-API is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturers warranty.

GENERAL

During the warranty period, T-API warrants each Product manufactured by T-API to be free from defects in material and workmanship under normal use and service. Expendable parts are excluded.

If a Product fails to conform to its specifications within the warranty period, API shall correct such defect by, in API's 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 T-API, 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. API SHALL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF OR RELATED TO THIS AGREEMENT OF T-API'S PERFORMANCE HEREUNDER, WHETHER FOR BREACH OF WARRANTY OR OTHERWISE

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 setscrews located in the top and bottom left corners of the front and swing open the cover.

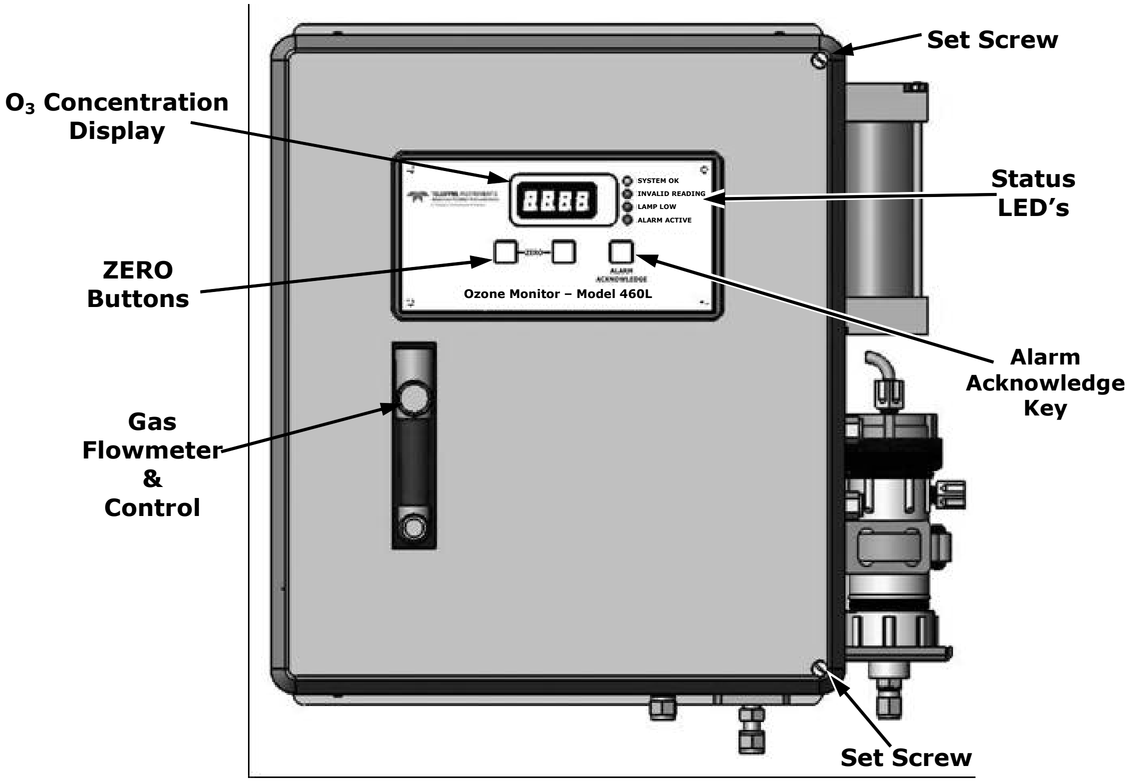

Figure 3-1 M460L Front Cover Layout

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), too small to be felt by the human nervous system, are 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.

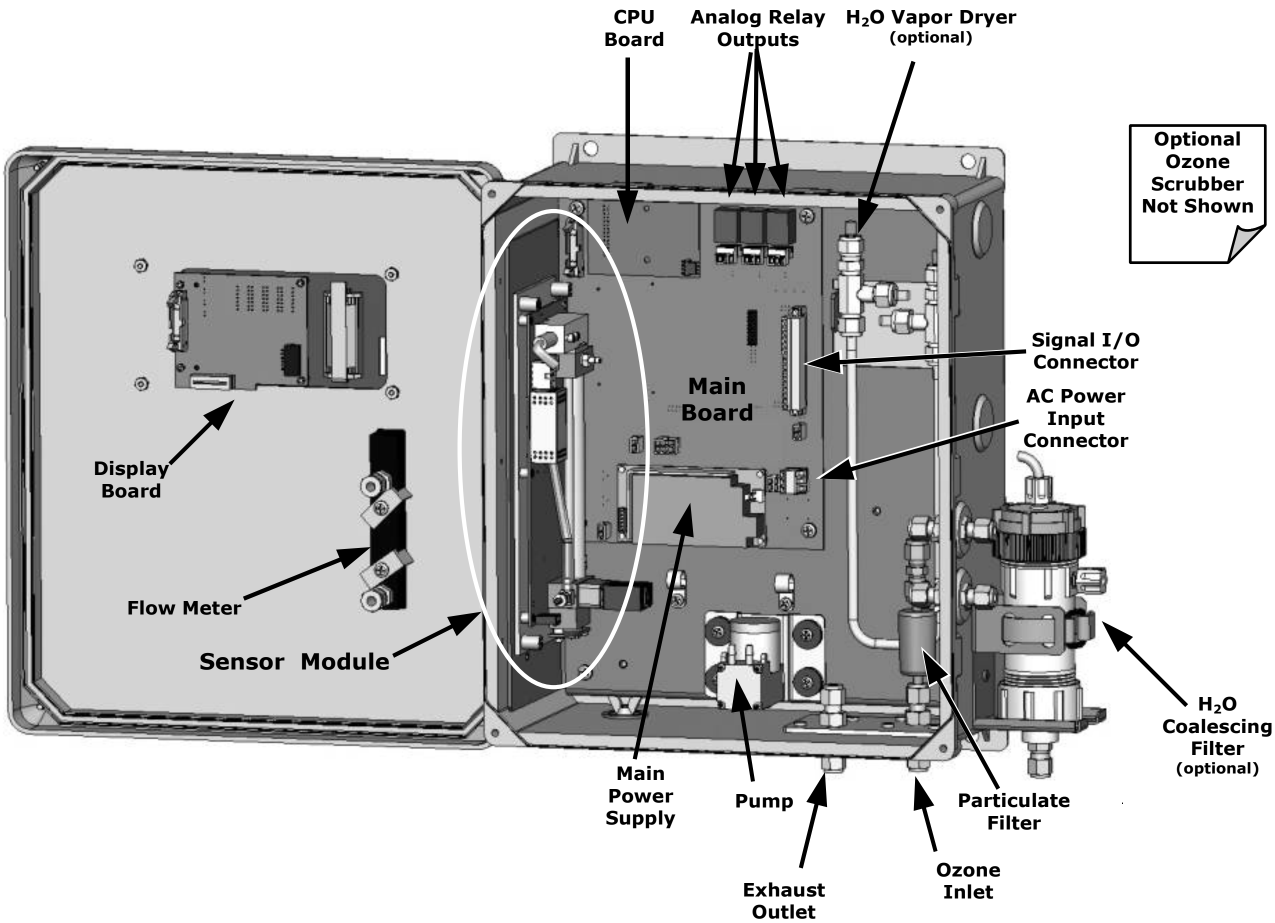

Figure 3-2 460L Layout

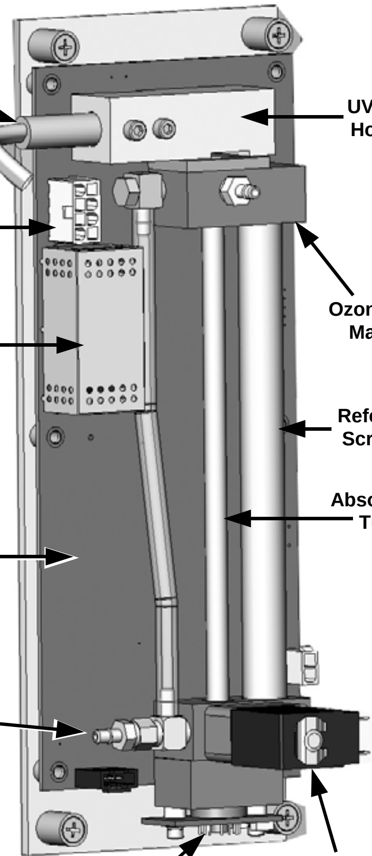

Figure 3-3 460L Sensor Module Layout

3.2. Mechanical Installation

Mount the enclosure securely to a vertical surface.

- Figure 3-4 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 460L Ventilation Clearances

AREA	MINIMUM REQUIRED CLEARANCE
Sides of the monitor	1 inch
Above and below the monitor.	1 inch

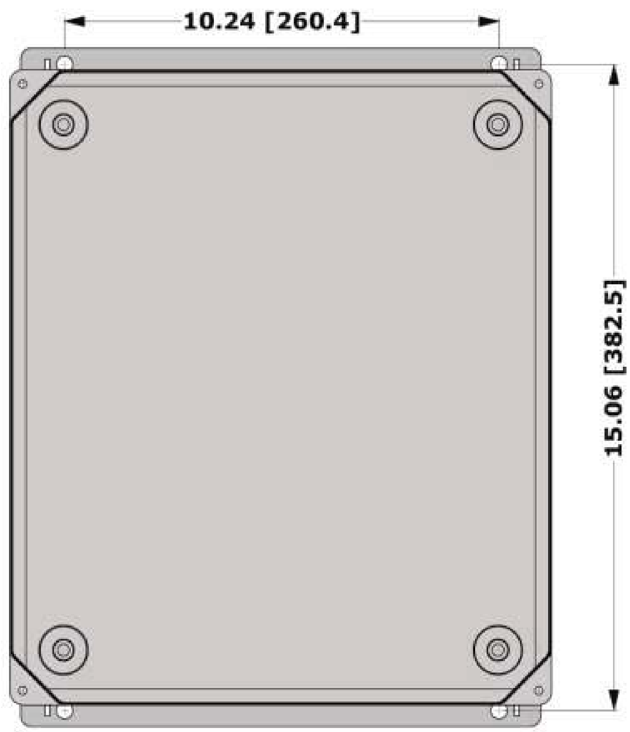

Figure 3-4 460L Mounting Hole Locations and Dimensions

3.3. Pneumatic Connections

1. Connect a ¼" exhaust line to the fitting labeled 'Exhaust.'

	**CAUTION** **If using the 460L to measure O_3 levels that are ≥100 ppb exhaust gas from the MODEL 460L may contain dangerous levels of ozone!** **The optional ozone destruct (see Section 5.3) should be installed** **and** **Make sure that the exhaust line is vented to an outside area.**

2. Connect the ozone delivery line to the ¼" inlet fitting labeled "Ozone Inlet" on the bottom face of the enclosure (See Figure 3-5.)

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.

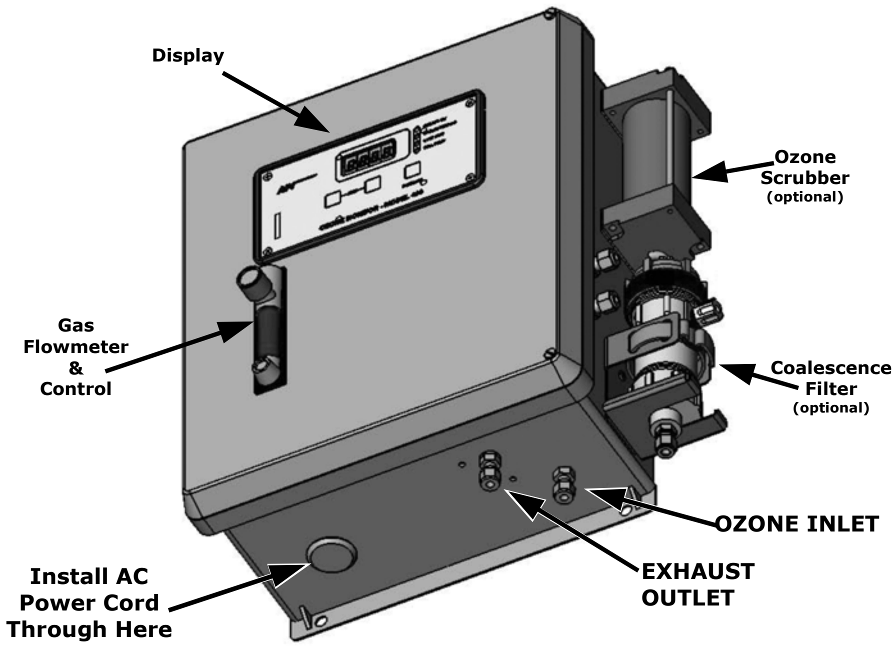

Figure 3-5 460L Pneumatic Connections

The gas flow rate through the monitor should be established between 1.0 and 2.0 L/min.

3.4. Electrical Connections

NOTE

It is recommended that if multi-strand wires are used for the following electrical connections. To ensure a reliable connection the wires should be:

- **"Tinned" with solder or;**
- **Terminated with insulated crimped ferrules, such as Entrelec® P/N 304.456.02 (18 gauge) or 304.558.10 (22 gauge)**

3.4.1. AC Power Connection

CAUTION

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

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.

3. Install a ½" conduit fitting for routing the electrical wiring into the monitor through the hole provided (see Figure 3-5). In order to maintain the IP (NEMA4X) rating of the enclosure, an appropriate sealed conduit connector should be used.
4. Attach the leads of the power line to the AC power connector (see Figure 3-6)

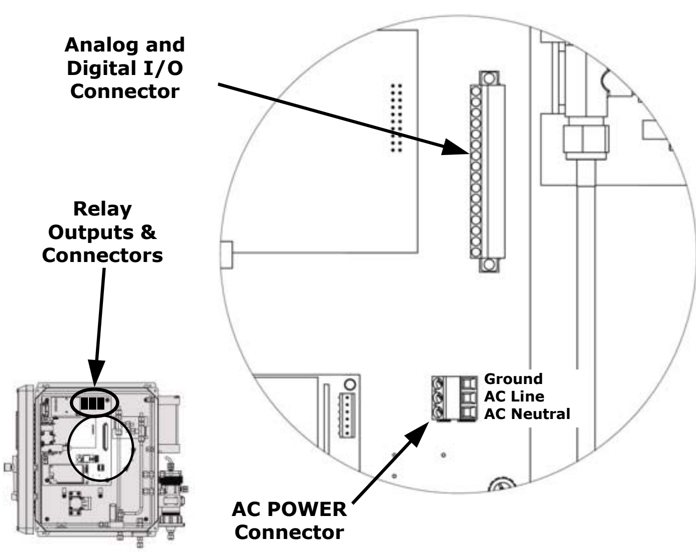

Figure 3-6 Location of Electrical Connectors

3.5. Signal I/O Connections

All digital and analog signal I/O connections are made via a 16-pin connector on the main board (See Figure 3-6 for the location of the connector.)

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

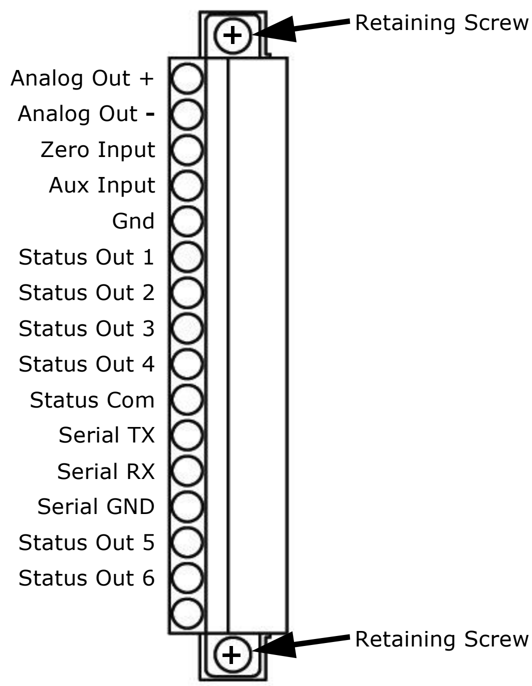

Figure 3-7 Signal I/O Connector Pin Assignments

3.5.1. Analog Output

The 460L 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 460L 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 3-7 for the locations of the **ANALOG OUT +** and **ANALOG OUT–** pins.

3.5.2. Digital Status Outputs

The 460L has six assigned digital status outputs for indicating error and operational status conditions of the monitor as well as the status of its O_3 concentration alarms (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). Several of the status outputs are useful tools for diagnosing sensor and system level malfunctions (see Section 11.2 for more information).

Table 3-2 Digital Status Output Descriptions

LABEL[1]	NAME	OPERATION
STATUS OUT 1[2]	Sensor O.K.	Normally On
STATUS OUT 2[2]	Invalid Reading	Normally Off
STATUS OUT 3[2]	Lamp Low	Normally Off
STATUS OUT 4	Alarm Active	Normally Off
STATUS OUT 5	HI Alarm Status	Normally Off
STATUS OUT 6	HI-HI Alarm Status	Normally Off
STATUS COM	Common Pin for all Status Outputs	N/A

[1] See Figure 3-7 for pin locations of the these output lines on the monitor's 16-pin I/O connector

[2] See Section 11-2 for definitions and interpretations of these output.

Figure 3-8 shows the most common way of connecting the digital outputs to an external device such as PLC.

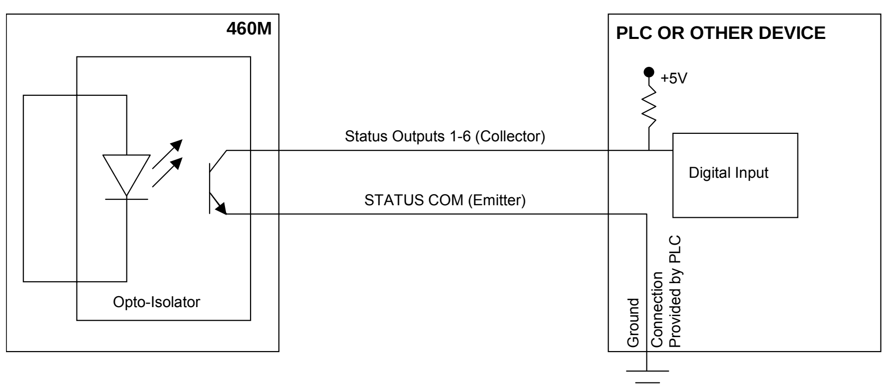

Figure 3-8 Digital Status Output Connections

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.

3.5.3. Control Inputs

Two digital control inputs are also available for use on the 460L. The control inputs are used for remote control of the 460L by a device such as a PLC. They are labeled **ZERO INPUT** and **AUX INPUT** (see Figure 3-9).

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 can be used to clear active concentration alarms in similar fashion as the serial communications ALMACK.

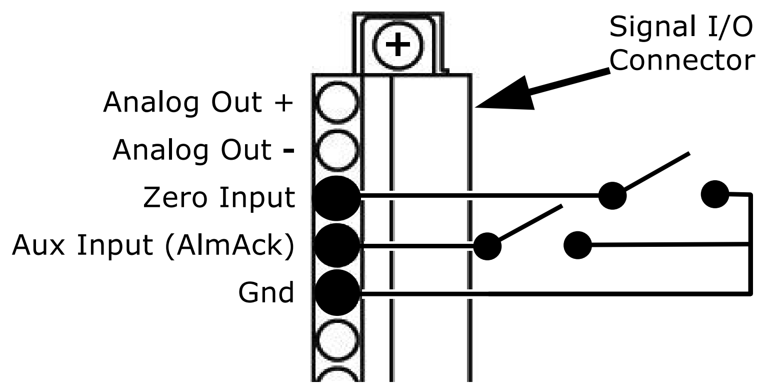

Figure 3-9 Control Input Connections

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

3.5.4. Relay Outputs

The 460L is equipped with three SPDT relays. They are located at the top right hand side of the main board and are labeled **RELAY 1**, **RELAY 2** & RELAY **3.**

- **RELAY 1** corresponds to the Sensor OK status output and LED;
- **RELAY 2** corresponds to the HI concentration alarm, and;
- **RELAY 3** corresponds to the HI-HI concentration alarm

See Section 11.2.1 for more information on the Sensor OK status output.

See Section 6.2 for more information on these alarms.

Below each relay is a 3-pin connector that allows the relay to be connected for either normally open or normally closed operation.

Table 3-4 describes how to connect the alarm relays.

> **NOTE**
>
> **The relay contacts are rated to 3A at 240VAC. Do not exceed these ratings when connecting equipment to the instrument.**

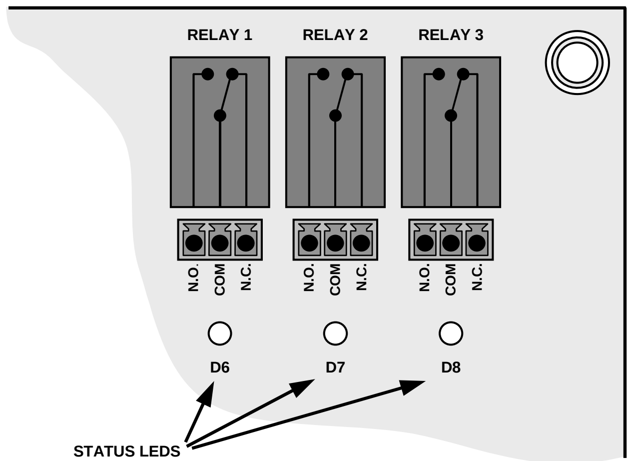

Figure 3-10 Alarm Output Relays

Table 3-4 Relay Output Operation

RELAY	FUNCTION	RELAY PIN STATE[2]			STATUS LED[1]	COMMENTS
		N.O.	COM	N.C.		
1	SENSOR OK **ON**	●—●			**D6 ON**	460L is operating normally
	SENSOR OK **OFF**		●—●		**D6 OFF**	Problem with the O_3 sensor module. See Section 11.2.
2	**HI** Alarm **ON**	●—●			**D7 ON**	O_3 concentration > HI alarm limit
	HI Alarm **OFF**		●—●		**D7 OFF**	O_3 concentration < HI alarm limit
3	**HI-HI** Alarm **ON**	●—●			**D8 ON**	O_3 concentration > HI-HI alarm limit
	HI-HI Alarm **OFF**		●—●		**D8 OFF**	O_3 concentration < HI-HI alarm limit

1 Located just below each relay connector (see Figure 3-10)
2 N.O. = Normally Open operation.
N.C. = Normally Closed operation.

3.6. Initial Startup

Perform the following steps when initially starting up the 460L 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 the monitor should be between 0.5 – 2.0 LPM (Liters per minute.)
   - Adjust as needed using the needle valve of the flow meter on the front panel (see Figure 3-1).
3. Let the monitor warm up for a minimum of 5 minutes.
4. 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.
5. Observe the monitor for several more minutes at zero to ensure that it is stable.

THE MONITOR IS NOW READY TO MEASURE OZONE.

3.7. Setting up the Serial Communications Port

The 460L'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 3-12).

Table 3-5 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 3.7.1 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.

3.7.1. Physical Serial Port Configuration

6. 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.
   - The jumpers may already be in this position but this still needs to be verified.
   - Also make sure that JP1 is jumpered. It may be hanging off of one pin, make sure it is jumpered together as in Figure 3-11.
   - JP2 can either be jumpered or not as it is already shorted on the board.

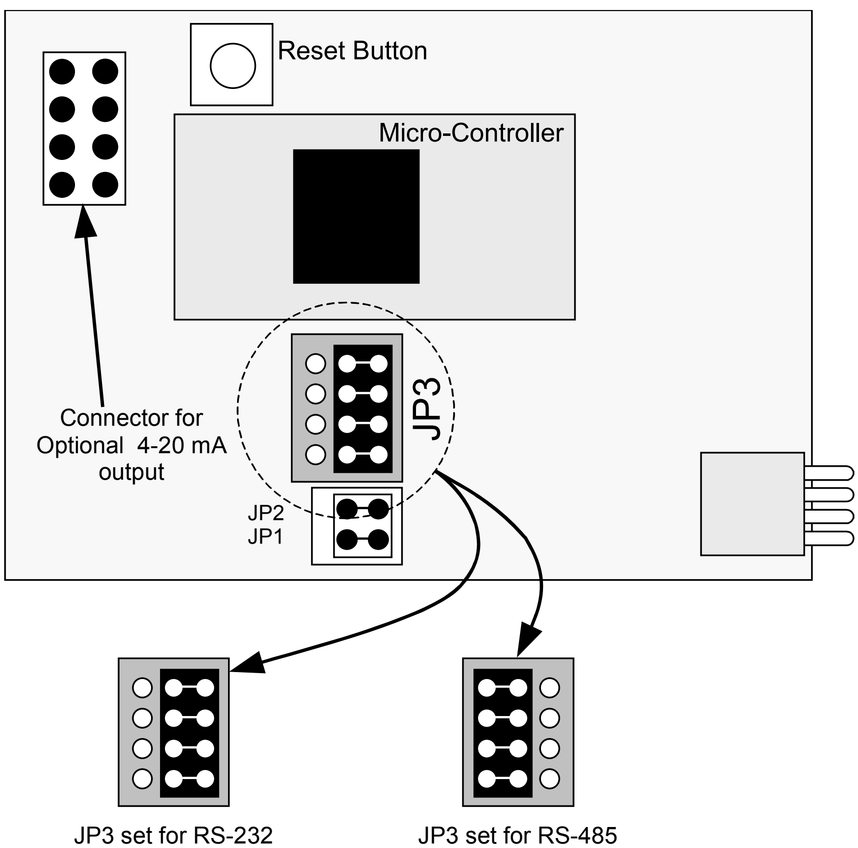

Figure 3-11 RS-232/RS-485 Jumper Location and Settings

7. Connect the appropriate type of cable to the 16 pin Signal I/O connector inside the analyzer.
8. A cable may be included with you instrument. If not, Figure 3-12 below illustrates how to construct wiring for both RS-232 and RS-485 connections.

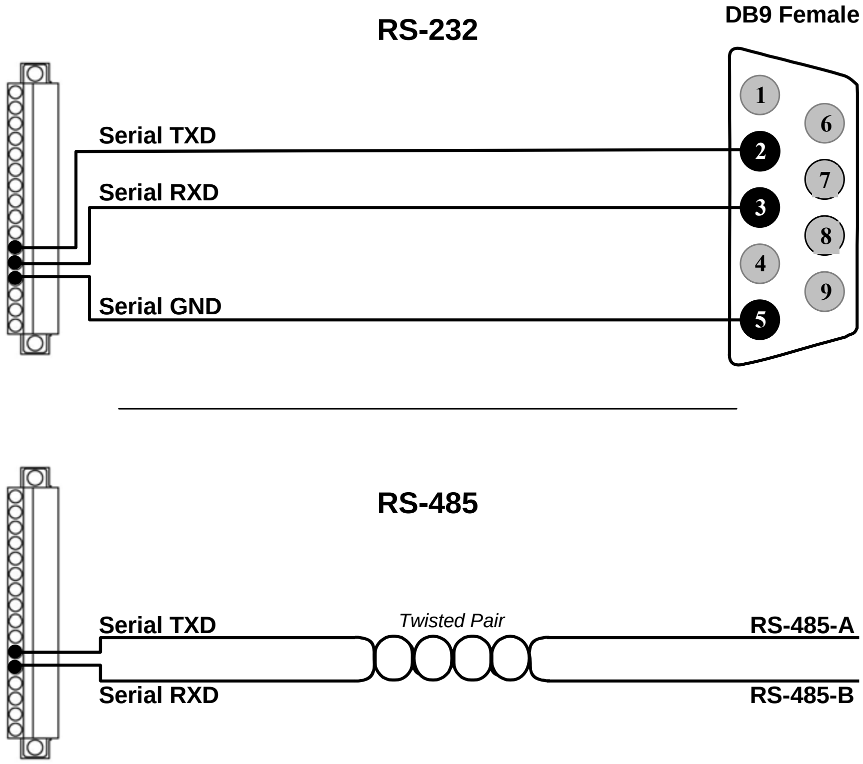

Figure 3-12 Typical RS-232 and RS-485 Connections

3.7.2. Software Setup for Serial Port Communications

NOTE

This section refers to various serial communication commands for the M460M. For detailed information regarding these commands see Chapter 7.

1. Connect the other end of the cable to your serial Com port on your computer
2. Open up Hyper-terminal or another terminal program and set up a connection with the settings below. Your com port is most likely COM1.

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

Table 3-6 Serial Port Configuration

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

3. Find the address of the 460L.
   - This can be accomplished by repeating the **O3** command (see Section 7.3.5) for each possible address (0-9) until the M460M responds:

   EXAMPLE: 0O3<CR>
   1O3<CR>
   2O3<CR>
   …
   9O3<<CR>

   - When the instrument responds record the first number in the response line
   - This is the address of the analyzer.
4. To determine if the M460L is operating correctly type:

   1TLIST<CR>

   This analyzer will respond with a list of the current values of its test functions. See Section 7.3.8 for a list of the nominal values for these functions
5. Check the analyzer's operation variables (VARS). These describe certain application specific conditions such as units of measure, measurement ranges, etc.
   - To check the current state of the VARS, type:

   1VLIST<CR>

   This analyzer will respond with a list of the current values of its VARS. See Section 7.3.10 for a list of the nominal values for these functions
6. If you need to change one of the VARS settings, see the VSET command (see Table 7-3 of Section 7.3.11)
7. After viewing the data you can return the analyzer to normal operation.
   - After changing the value of any of the VARS return the analyzer to normal operation.
   - The simplest way to do this is to turn the analyzer off and back on. User Notes:

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 14.9 psia.
- 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: When should I change the Particulate Filter and how do I change it?

A: The Particulate filter should be changed monthly. See Section 9.1 for instructions on performing this replacement.

USER NOTES:

5. OPTIONAL HARDWARE AND SOFTWARE

This section includes descriptions of the hardware and software options available for the 460L 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 460L'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.

5.3. Ozone Destruct Option

An externally mounted scrubber (see Figure 3-5) is available for the 460L monitor for use when measuring O_3 levels that are ≥100 ppb. Ozone levels this high will damage several of the components of the monitor downstream of the sensor module such as the flow meter and the pump. High levels of O_3 are hazardous and should be removed from the gas stream exhaust.

CAUTION

Make sure that the exhaust line is vented to an outside area.

USER NOTES:

6. OPERATING INSTRUCTIONS

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

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, ppb.

6.1.2. Zero Point Calibration

The 460L needs little or no calibration in the field; however sometimes minor measurement offsets can occur. To compensate for this a zero point calibration can be initiated by using the two **ZERO** buttons. See Section 8.1 for more information.

6.1.3. Status LED’s

The four status LED’s to the right of the display indicate the general status of the 460L 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 11.2.4.

Table 6-1 Status LED’s

NAME	ON STATE	OFF STATE
SENSOR O.K.	Normal State is **STEADY GLOW**	**OFF** when • Reference or Measure > 4995mV; • Reference < 1000mV
INVALID READING	**STEADY GLOW** if: • Ozone Pressure > 14.9 psia, • Negative Ozone Concentration, • Concentration Over-Range	Normal State
LAMP LOW	**STEADY GLOW** if Reference Detector<2500mV	Normal State
ALARM ACTIVE	**BLINKS** whenever the measured O_3 concentration exceeds either the alarm limits.	Normal State

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

6.2. Concentration Alarms

There are two O_3 concentration alarms, **HI** and **HI-HI**. Both alarms are triggered when the measured O_3 concentration equals or rises above the set limit for that alarm. The set limit for **HI** alarm must always be a lower value than that of the **HI-HI** alarm. If the O_3 concentration is between the **HI** limit and the **HI-HI** limit, the **HI** alarm will be active, but the **HI-HI** alarm will be inactive.

When either the **HI** or the **HI-HI** alarms are active the **ALARM ACTIVE** status LED on the front panel (see Figure 3-1) will blink. In addition when the **HI** alarm is active alarm trigger LED D7 (on the main PCA, see Figure 3-12) will glow and when the **HI-HI** alarm is active alarm trigger LED D8 will glow.

6.2.1.1. Concentration Alarm Configuration

Either of the concentration alarms can be independently configured via the 460L's serial communication port (see Section 7.3.11).

The user can set the alarms to operate in either the latching or non-latching as well as independently adjust the trigger levels of the alarm limits.

In non-latching mode, the alarms will be triggered when O_3 concentration equals or exceeds the associated limit is reached and will automatically return to an inactive state if the O_3 concentration falls below the limit level. In latching mode once an alarm is triggered it will stay active until cleared by the user regardless of how the O_3 concentration measurement changes.

6.2.1.2. Remotely Sensing the Status of the Alarm

Besides the LEDs located on the front panel and on the monitor's main PCA, the status of each alarm can be sensed externally via a single-pull, double-throw relay (see Section 3.5.4) or determined from a remote location via the monitor's serial communication port (See Chapter 7).

6.2.1.3. Clearing Alarms

When set for non-latching mode the alarms will only clear when the alarm condition disappears and will do so automatically. When in latching mode, the concentration alarms may be cleared in several ways:

- **FRONT PANEL**: Pressing the **ALARM ACKNOWLEDGE** key on the monitor's front panel will clear all active alarms.
- **SERIAL COMMUNICATION PORT**: The ALMACK command to clear all active alarms (see Section 7.3.1)

Table 6-2 Concentration Alarm Default Settings

ALARM	CONDITION	MODE	TRIGGER LIMIT
HI	Enabled	Latching	100 ppb
HI-HI			300 ppb

7. SERIAL COMMUNICATIONS

The 460L comes equipped with a powerful digital Serial Communications Port that can be used for Data Acquisition and for changing the monitor's configuration. This port can be configured for either RS-232 or RS-485 (half-duplex) operation. See Section 3.7.1 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 (optional)**><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

  The 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: **1ALMACK#474<CR>**
- No Checksum: **1ALMACK<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
ALMACK	Acknowledges and clears any active concentration alarms
ALMSTAT	Returns the current state of the concentration alarms
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 460L 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. ALMACK

SYNTAX

<address>ALMACK<CR>

DESCRIPTION

Acknowledges any active concentration alarm and clears them if possible For more information see Section 6.2.

DATA PARAMETERS SENT

None

RESPONSE

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

EXAMPLE

Command:

1ALMACK<CR>

Response:

1:OK#261<CR> - Command successfully received. All alarms capable of being cleared have been.

NOTE

The alarm(s) will only clear if the condition causing the alarm no longer exists,

EXAMPLE

If the current O_3 concentration rises above the trigger levels for both the **HI** and **HI-HI** alarms, both alarms will activate. If the O_3 level falls below the **HI-HI** alarm limit, but is still above the is still above the **HI** limit, the ALMACK command will only clear the **HI-HI** alarm.

7.3.2. ALMSTAT

SYNTAX

<address>ALSTAT<CR>

DESCRIPTION

Returns the current status of both of the concentration alarms.

0= Inactive

1= Active

DATA PARAMETERS SENT

None

RESPONSE

<address>:<HI alarm state>,<HI-HI alarm state>#<checksum><CR>

EXAMPLE

Command:

1ALMSTAT<CR>

Response:

1:0,0#247<CR> - Both concentration alarms are INACTIVE

1:1,0#248<CR> - The **HI** alarm is ACTIVE and the **HI-HI** alarm is INACTIVE

1:1,1#249<CR> - Both concentration alarms are ACTIVE

7.3.3. 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 the 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

7.3.4. 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.

7.3.5. 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:

1:250.1898#522<CR> - Current O3 Concentration (reading 250.2 ppb)

NOTES

While the concentration value returned shows more digits after the decimal than the front panel (in the example above, 250.1898) display it is only valid to 4 significant digits (in the example above, 250.2).

The returned value will be in whichever units of measure for which the monitor is set.

7.3.6. 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.

7.3.7. 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>,<al-hi-stat>,<al-hi-hi-stat>#<checksum><CR>

EXAMPLE

Command:

1TDUMP<CR>

Response:

1:0.0282144,14.77461,300.7179,324.7713,2881.437,2940.903,4412.52,1,0#3413 <CR>

NOTES

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

7.3.8. 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
HI Alarm = ON
HI-HI Alarm = OFF

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 display (in the example above, 0.0226168), 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.

7.3.9. 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**
0	ANALOG_RANGE	Full-Scale concentration range for Analog Output scaling
1	ALARM_ENABLE	0 = disabled 1 = enabled
2	ALARM_MODE	0 = latching 1 =non-latching
3	CARRIER_WEIGHT	Molecular weight of carrier gas(e.g. 32.0 = O2). Only used by 460L's with ppmw capability
4	COMM_MODE	Not Used
5	IIR_FILT	The sensitivity of the software filter used by the monitor to reduce noise and hysteresis in the reported O_3 concentration reading.
6	CONC_UNITS	2 =ppb 3 = ppm
7	HI_ALARM_LEVEL	Sets the trigger limit of the HI alarm
8	HI-HI_ALARM_LEVEL	Sets the trigger limit of the HI-HI alarm
NOTE: Only one *yar_index* is allowed per iteration of the VGET command		

RESPONSE

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

EXAMPLE

Command:

1VGET:8<CR> - Request limit value for HI concentration Alarm

Response:

1:300.0#348<CR> - HI alarm limit is 300.0 ppb

NOTE

Response is in units of measure for which the monitor is set.

7.3.10. 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 = 1000.0
#1 alarm_enable = 1.0
#2 alarm_mode = 0.0
#3 carrier_weight =32.0
#4 comm_mode = 0.0
#5 iir_filt = 0.25
#6 conc_units = 2.0
#7 hi_al_level = 100.0
#8 hihi_al_level = 300.0

NOTES

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

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

hi_al_level and hihi_al_level are returned in the units of measure for which the monitor is set.

7.3.11. VSET

SYNTAX

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

DESCRIPTION

Sets value of an internal configuration variable (VAR.)

DATA PARAMETERS SENT

var_index index number for internal VAR (See VGET for index list)

new_value new value for VAR.

RESPONSE

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

Table 7-3 VAR_INDEX List for VSET Command

var_index	Name	Description	Allowable Range
0	ANALOG_RANGE	Sets the full-scale concentration range for Analog Output scaling	1 ppb – 1000 ppb 0.001 ppm – 1.000 ppm
1	ALARM_ENABLE	Enables or disables the Concentration alarms	0 = disabled 1 = enabled
2	ALARM_MODE	Selects latching mode or non-latching mode for both alarms.	0 = latching 1 =non-latching
3	CARRIER_WEIGHT	Sets the molecular weight of carrier gas for wt% calculations (e.g. 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	2 =ppb 3 = ppm
7	HI_AL_LEVEL	Sets the trigger limit of the HI alarm	10 ppb < x < 1000 ppb 0.010 ppm < x < 1.000 ppm
8	HIHI_AL_LEVEL	Sets the trigger limit of the HI-HI alarm	10 ppb < x < 1000 ppb 0.010 ppm < x < 1.000 ppm
NOTE: Only one *yar_index* is allowed per iteration of the VSET command			

EXAMPLE1

Command:

1VSET:8,275.0<CR> - Set HI-HI concentration alarm to 275.0 ppb

Response:

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

1:FAIL#391<CR> - VSET Failed

EXAMPLE2

Command:

1VSET:6,1<CR> - Set CONC_UNITS VAR to ppm

Response:

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

1:FAIL#391<CR> - VSET Failed

NOTES

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

ALARM_ENABLE: The concentration alarms cannot be enable/disabled independently.

ALARM_MODE: The mode of the concentration alarms cannot be set independently.

CARRIER_WEIGHT: This variable is only used by 460L's with ppm by weight capability (ppmw).

- The molecular weight of pure O_2 is 32.
- The nominal molecular weight of ambient air is 28.96

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

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.

HIHI_AL_LEVEL must be greater than HI_AL_LEVEL. New_value should be in the units of measure the monitor for which the monitor is set.

EXAMPLE:

1VSET:8,275.0<CR> - Set HI-HI concentration alarm to 275.0 ppb

1VSET:8,0.275<CR> - Set HI-HI concentration alarm to 0.275 ppm

USER NOTES:

8. CALIBRATION

8.1. Zero Point calibration

Variations in ambient conditions, most notably changes in ambient humidity, and minor changes in the performance of certain electronic components over time may cause slight offsets in the zero point measurement of the monitor. To check for and compensate for these minor offsets use the following procedure.

1. Supply zero air to the monitor by inserting a O_3 scrubber filled with activated charcoal into the ozone supply gas line just before it enters the monitor.
   - A scrubber of this type is available from Teledyne Instruments (Carbon Filter, DAU, 000 Grade; P/N FL0000020).

NOTE

Since variations in humidity is a common cause of these types of offsets, use of bottled O_2, which is extremely dry, as zero air is not recommended particularly in areas where the ambient humidity is high.

2. Once the scrubber is installed, allow the monitor to operate until the O_3 reading stabilizes. This may take approximately 15 minutes
3. Check the O_3 reading.
   - If the reading is within the repeatability specification of the monitor (see Section 2.1), no adjustment is needed.
   - If the reading is higher than the repeatability specification of the monitor but still relatively minor (10 to 20 ppb for example), press the two **ZERO** keys on the front panel and hold them for 3 seconds.
   - If the offset is greater than 30 ppb or pressing the zero key has no effect, contact Teledyne Instruments' customer service department.

8.2. Span Point Calibration

1. Connect the M40M to a computer running a terminal emulation program such as Hyper-terminal. See Section 3.7 for instructions.
2. Flow zero air, or pure O_2 through the analyzer and wait 15minutes.
3. After the analyzer has stabilized, perform a zero calibration by pressing both zero buttons on the front panel at the same time.

4. Type:

   <address>LOGIN:929<CR>

Where

- <address> is the network address of the M460M being calibrated.
- 929 is a special password allowing you to calibrate the analyzer.

5. List the current values of the M460M's VARS. Type:

   <address>VLIST<CR>

   - Look through the list for one with the a special VARS named either **O3 SLOPE**, or **O3 SPAN SLOPE**. This VAR is only available using the 929 password.
   - Record both the slope value and the VAR Number it corresponds with.

6. Make sure your ozone standard and analyzer are both reading the same span gas or ozone concentration.
7. Calculate the slope using the following equations:

Equation 8-1

(O3 concentration on analyzer) ÷ (O3 Slope) = (True O3 value of analyzer)

Equation 8-2

(O3 concentration on standard) ÷ (True O3 value of analyzer) = (New slope)

EXAMPLE

Where:

- Slope of analyzer = 1.013
- Current O3 reading of analyzer = 8.70%
- Current O3 reading of standard = 9.00%

a) (O3 concentration on analyzer) ÷ (O3 Slope) = (True O3 value of analyzer

8.70% ÷ 1.013 = 8.59%

b) (O3 concentration on standard) ÷ (True O3 value of analyzer) = (New slope)

9.00% ÷ 8.59% = 1.048

- 1.048 would be the New Slope Value that needs to be entered in the next step.

8. Enter the New Slope into the M460M's memory enter it in. Type:

   <address>VSET:<VAR Number>,<New Slope Value><CR>

   EXAMPLE

   3VSET:16,1.048<CR>

   Where:

   - The address of the M460M is 3
   - The **O3 SLOPE** VAR is number 16
   - The New Slope is = 1.013

8.3. 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.

To manually adjust the zero and span points of the 4-20mA analog output:

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.

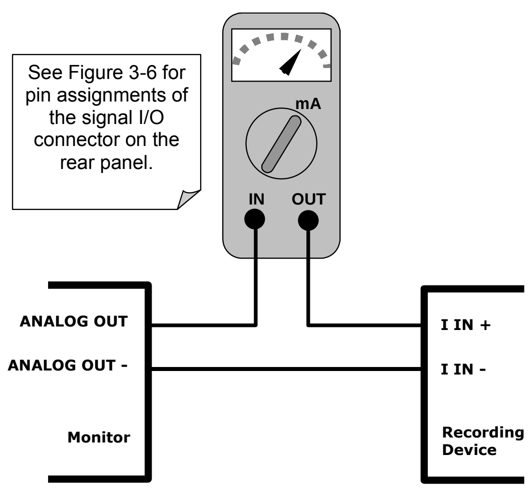

Figure 8-1 Setup for Measuring Current Output Signal Level

3. While reconnecting the monitor to AC power, press and hold the "Alarm Reset" 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 (see Section 7.3.4).

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

5. The monitor will automatically generate the nominal signal level by producing a 25% increment output level on the current loop.

   EXAMPLE

OUTPUT LEVEL	NOMINAL SIGNAL LEVEL
0%	4mA
25%	8mA
50%	12mA
75%	16mA
100%	20mA

6. The display will then show "A100" (four times). Adjust the "Span" potentiometer (See Figure 8.2) as necessary.

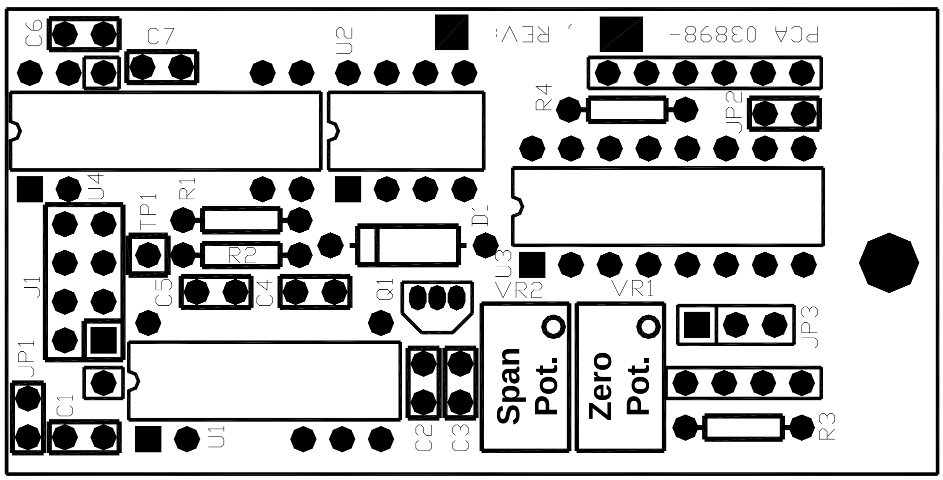

Figure 8-2 Location Current Output Adjustment Potentiometers

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, the monitor will automatically restart in standard measurement after 5 cycles.

USER NOTES:

9. MAINTENANCE:

9.1. Replacing the Particulate Filter Element

The 460L is equipped with a particulate filter on the ozone inlet. Only Teledyne Instruments filter elements 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 filter, please contact Teledyne Instruments' sales department and request part number 05017.

9.1.1. Filter Replacement Procedure

1. Turn the Monitor off and ensure that the gas delivery line is not under pressure
2. Purge the gas delivery line of ozone.
3. Unscrew the pressure fitting at the top of the filter (Fitting B in Figure 9-1) from the union fitting.
4. Unscrew the pressure fitting at the bottom of the filter (Fitting C in Figure 9-1) from the ozone Inlet.
5. Discard the filter.
6. Attach the new filter using the fittings supplied with it.
7. After reassembly, the gas line should be pressurized with oxygen or dry air and checked for leaks using a bubble solution.

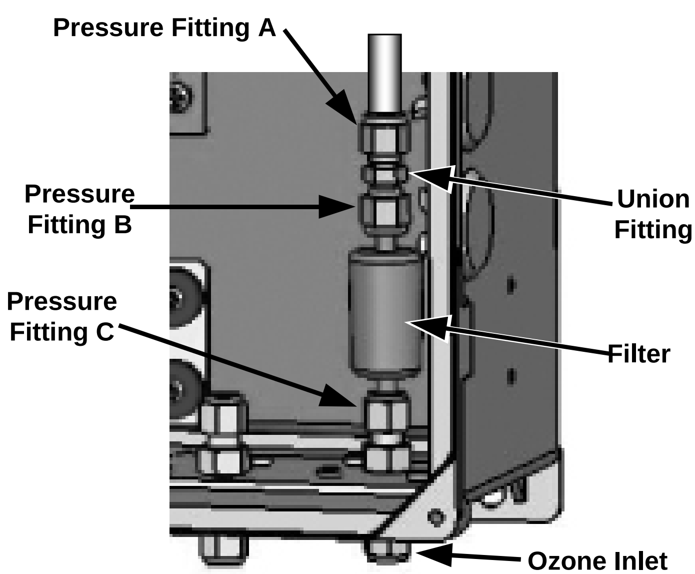

Figure 9-1 Changing the Particulate Filter

9.1.2. Mounting the Particulate Filter Externally

In applications where the 460L is sampling ambient air at its own location and no inlet gas line is being used, the particulate filter can be mounted on the outside of the instrument so that it may be replaced without turning off the monitor or opening the case.

To mount the particulate filter outside the monitor enclosure:

1. Turn the monitor off and ensure that the gas delivery line is not under pressure
2. Purge the gas delivery line of ozone.
3. Unscrew the pressure attached to the internal gas line (Fitting A in Figure 9-2) from the union fitting.
4. Unscrew the union fitting from the fitting at the top of the filter (fitting B in Figure 9-2). Although the union fitting is no longer needed, save it in case you wish to return the particulate filter to the inside of the monitor at a later date.
5. Unscrew the pressure fitting at the bottom of the filter (Fitting C in Figure 9-2) from the ozone inlet.
6. Reattach the filter to the external side of the ozone inlet.
7. Attach the internal gas line to the internal side of the ozone inlet using Fitting A.
8. After reassembly, the gas line should be pressurized with oxygen or dry air and checked for leaks using a bubble solution.

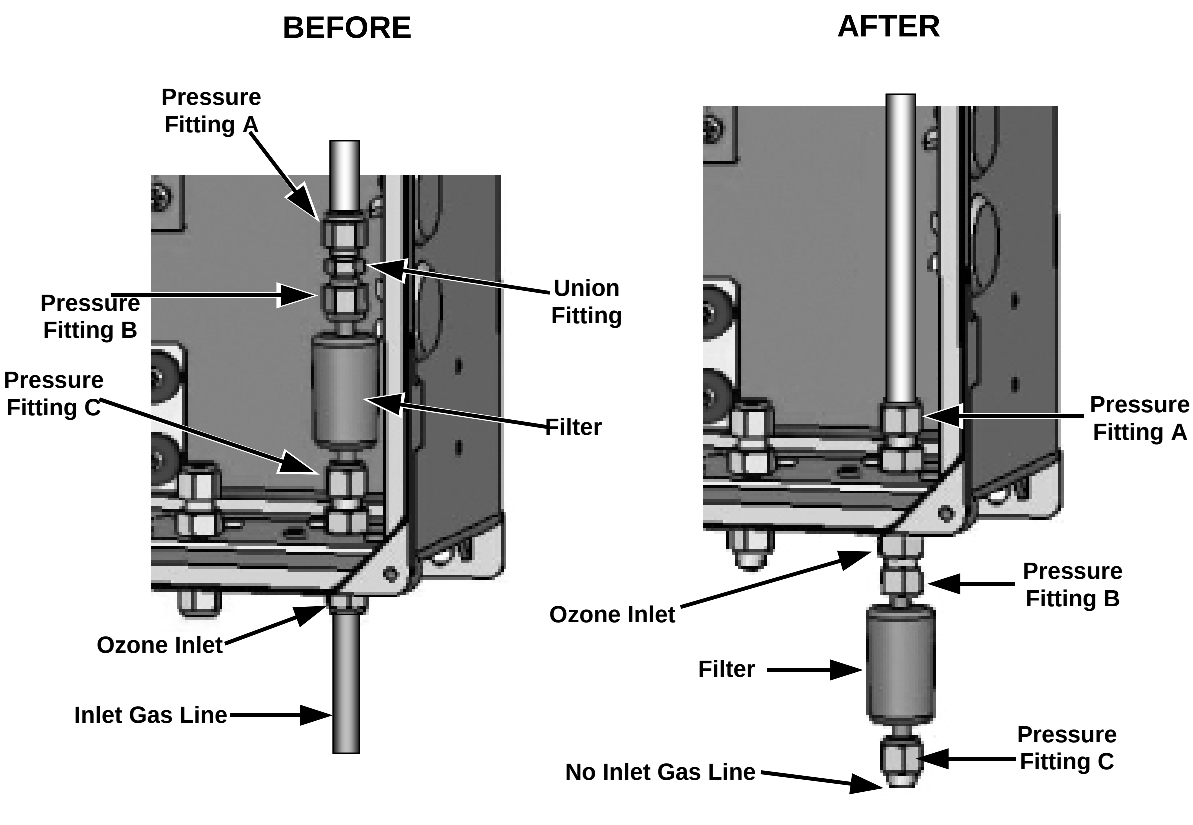

Figure 9-2 Changing the Particulate Filter

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 9-3 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 O_3 supply line and adjust flow to the monitor.
5. Open the flow meter valve and adjust the gas flow to the appropriate rate.

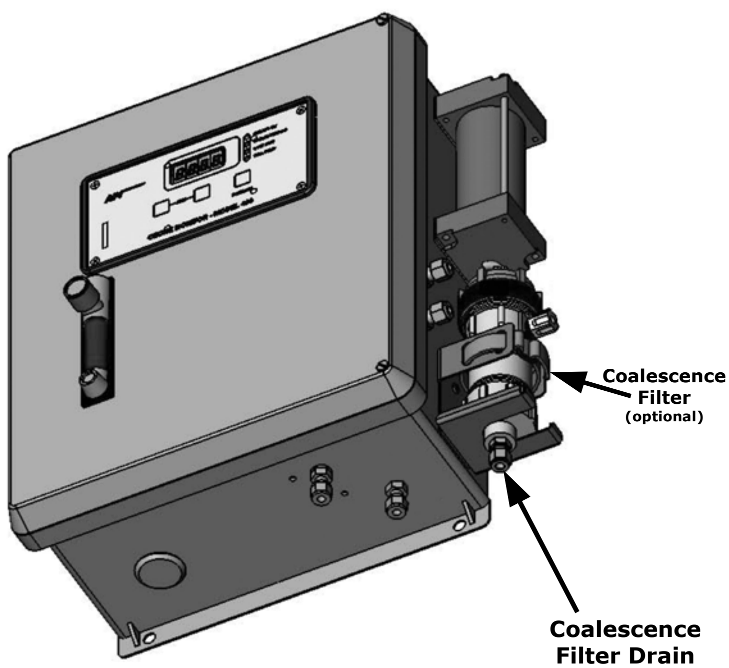

Figure 9-3 Draining the Optional H_2O Coalescing filter

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 9-4).
5. Insert the new membrane into the cap assembly.
6. Tightly secure the cap back on the filter.
7. Reconnect the O_3 supply line adjust flow to the monitor.
8. Open the flowmeter valve and adjust the gas flow to the appropriate rate.

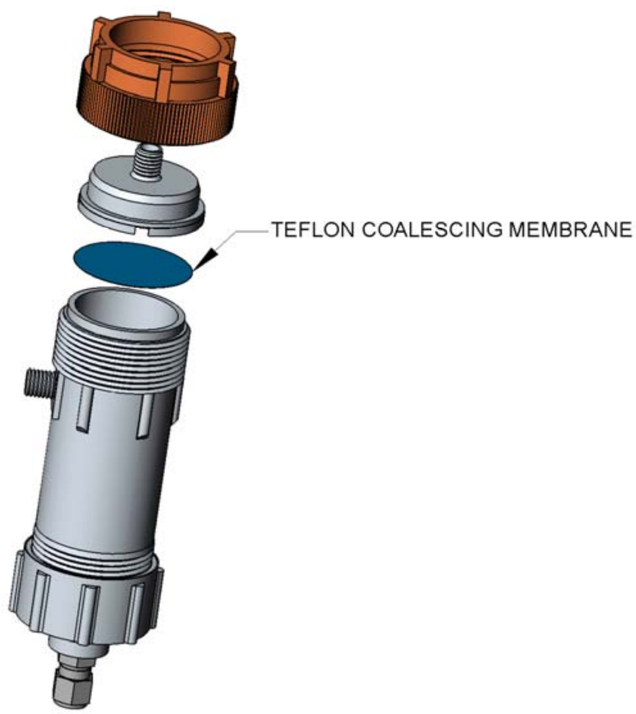

Figure 9-4 Replacing the Membrane of the Optional H_2O Coalescing filter

Replacement filter elements can be ordered from TAPI (P/N 036750000).

9.3. UV Lamp Replacement

1. Disconnect power from the monitor and open cover.
2. Loosen, but do not remove, the two lamp set-screws (see Figure 9-5 below).
3. Unplug lamp from the UV lamp power connector on Sensor Module 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 into the UV lamp power connector.
6. Connect the ground lead of a voltmeter to TP4.
7. Connect the positive lead of voltmeter to TP10.
8. Reconnect power to the monitor.
9. The voltage on TP10 must read between –0.6 and –1.6Vdc. If this voltage is outside that range, slowly rotate the lamp until the proper voltage is achieved, then tighten the lamp set-screws.
10. Connect the positive lead of a voltmeter to TP11 (Measure Detector Voltage).
11. Adjust R26 until the voltage on TP11 is as high as possible within the range of 0.60 –1.00 volts.

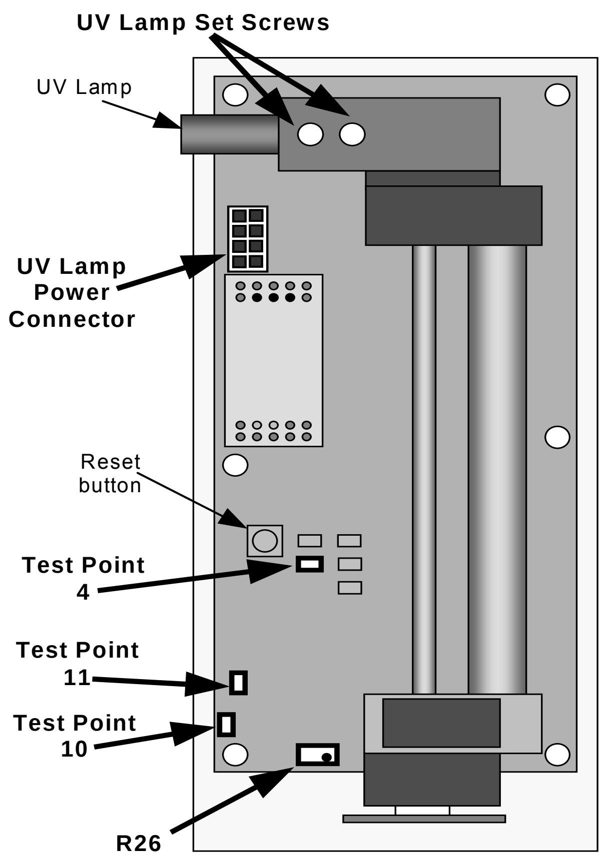

Figure 9-5 UV Lamp Set Screws and Calibration Test Points

9.4. Cleaning Exterior Surfaces of the 460L

If necessary, the exterior surfaces of the 460L 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 460L has a water ingress rating of IP65 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 nm. 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 460L, Ozone (O_3).

α 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:

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

Equation 10-3

Where:

T = sample ambient temperature in degrees Kelvin

P = ambient pressure in pound per square inch (psi),

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

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

Equation 10-4

10.1.2. The Absorption Path

In the most basic terms, the Model 460L uses a high energy, mercury vapor lamp to generate a beam of UV light. This beam passes through a window of material specifically chosen to be both non-reactive to O_3 and transparent to UV radiation at 254nm and into an absorption tube filled with Sample Gas.

Because ozone is a very efficient absorber of UV radiation the Absorption Path Length required to create a measurable decrease in UV intensity is short enough (approximately 16 cm) that the light beam is only required to make pass through the Absorption Tube. Therefore no complex mirror system is needed to lengthen the effective path by bouncing the beam back and forth.

Finally, the UV then passes through a similar window at the other end of the Absorption Tube and is detected by a specially designed vacuum diode that only detects radiation at or very near a wavelength of 254nm. The specificity of the detector is high enough that no extra optical filtering of the UV light is needed.

The detector reacts to the UV light and outputs a voltage that varies in direct relationship with the light's intensity. This voltage is digitized and sent to the instrument's CPU to be used in computing the concentration of O_3 in the absorption tube.

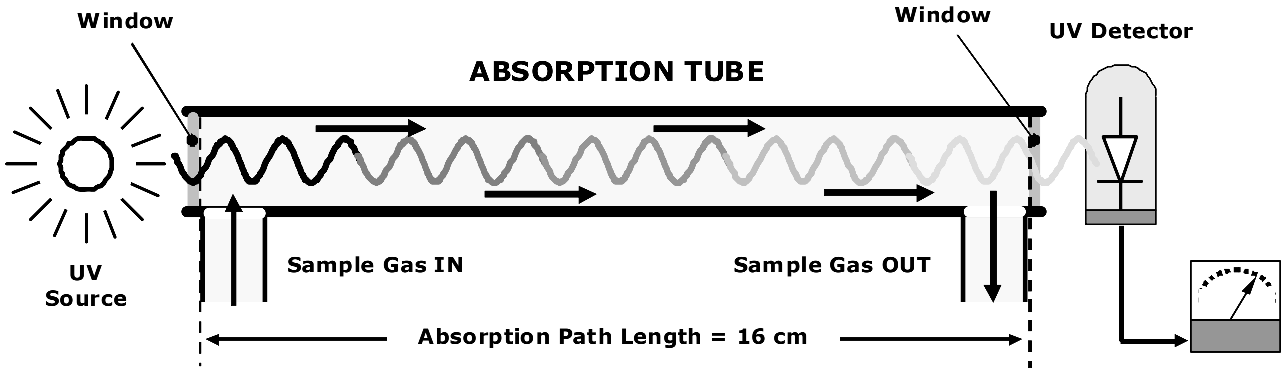

Figure 10-1 O_3 Absorption Path

10.1.3. The Reference / Measurement Cycle

In order to solve the Beer-Lambert equation it is necessary to know the intensity of the light passing through the absorption path both when O_3 is present and when it is not. The Model 460L accomplishes this by alternately passing the sample gas through a chemical scrubber that removes any O_3 present and sending it directly to the absorption tube.

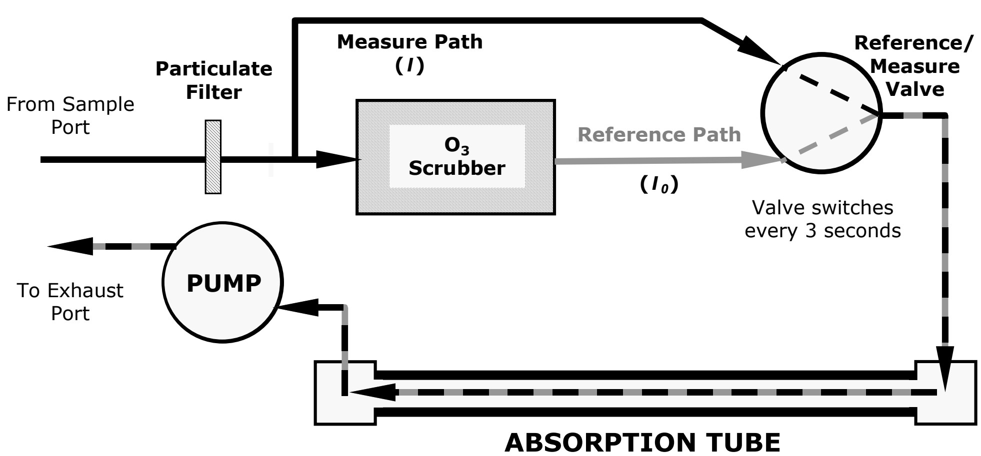

Figure 10-2 Reference / Measurement Gas Cycle

The Measurement / Reference Cycle consists of:

Table 10-1 Measurement / Reference Cycle

CYCLE STATUS	DURATION	ACTIVITY	VALVE STATE (FIG. 10-3)
MEASURE PERIOD	- -	Measure/Reference Valve Opens to the Measure Path.	**1 → 3**
	0.50 sec.	Wait Period. Ensures that the Absorption tube has been adequately flushed of any previously present gasses.	
	0.15 sec.	Analyzer measures the average UV light intensity of O_3 bearing Sample Gas (***I***) during this period.	
REFERENCE PERIOD	- -	Measure/Reference Valve Opens to the Reference Path.	**2 → 3**
	0.50 sec.	Wait Period. Ensures that the Absorption tube has been adequately flushed of O_3 bearing gas.	
	0.15 sec.	Analyzer measures the average UV light intensity of Non-O_3 bearing Sample Gas (I_0) during this period.	
1 min 30 sec		**TOTAL CYCLE TIME**	

10.1.4. Digital Noise Filter

The 460L 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

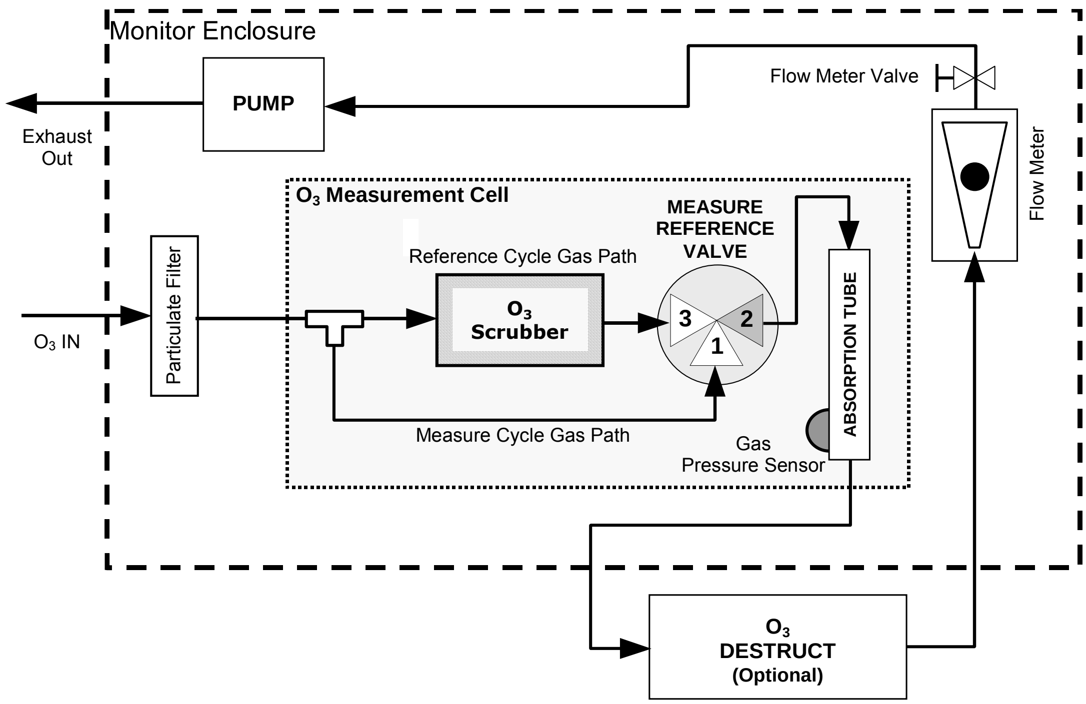

Figure 10-3 460L Internal Pneumatic Diagram – Basic Configuration

10.2.2. Internal Pump and Flow Control

Air flow through the M460L 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 from the 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 1.5 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. Optional Sample Conditioning

The source air measured by the 460L 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. Also, water absorbs O_3 and interferes with the 460L's ability to accurately measure the O_3 in the source gas. To counteract this problem, several optional components can be added to the 460L.

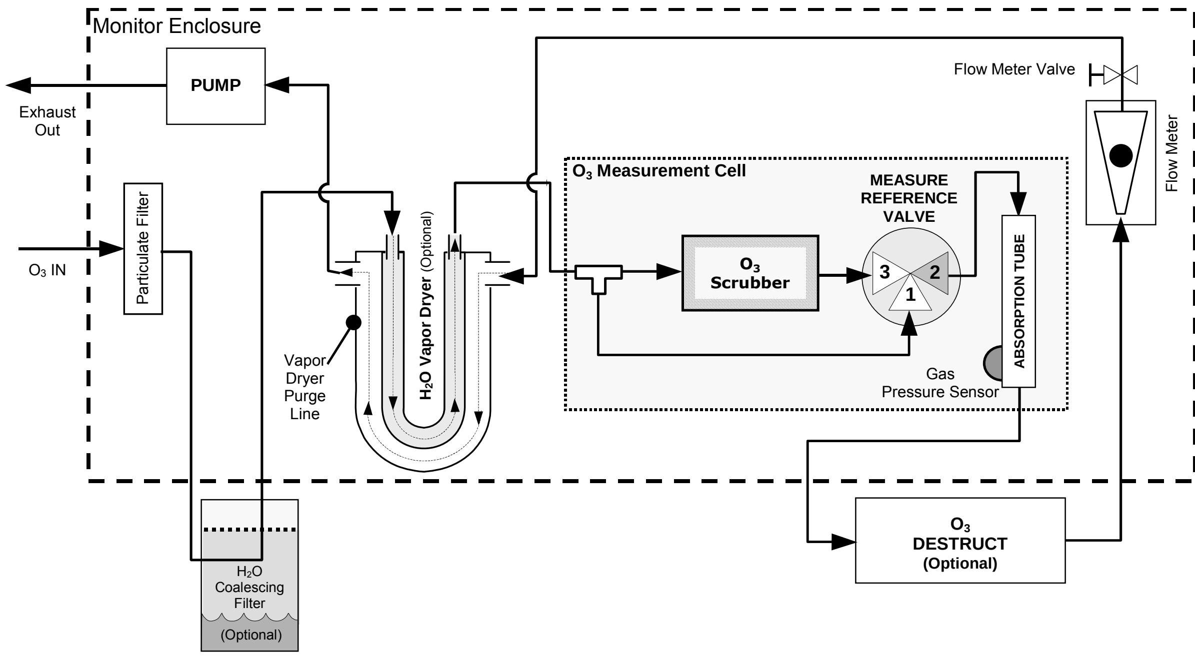

Figure 10-4 460L Internal Pneumatic Diagram with Optional Sample Conditioning

10.2.3.1. H_2O Coalescing Filter

The first step of this drying process is to remove any liquid water from the source gas. The 460L 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.

10.2.3.2. 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 pervaporation 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 460L returns the dried O_3 free air from the measurement cell and O_3 destruct to the outer tube (see Figure 10-4). 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.

10.2.3.3. Ozone Destruct Scrubber

The ozone destruct scrubber removes O_3 from the exhaust gas stream of the monitor after it exits the instrument's absorption tube but before it can damage the 460L's flow meter and pump. It also prevents hazardously high levels of O_3 from exiting the monitors exhaust outlet.

When installed, the O_3 scrubber is located outside the monitor's NEMA housing, on the right side at the top (see Figure 3-5). It is filled with a special catalytic ozone scrubbing material that removes all of the O_3 from the sample gas exiting the sensor module's absorption tube. The catalyst used in the scrubber only converts ozone to oxygen and does not produce any toxic or hazardous gases.

The catalyst is 100% efficient at scrubbing ozone at room temperature. It is a true catalytic converter, therefore there are no maintenance requirements such as changing the scrubbing material as is required for charcoal-based scrubbers.

10.3. Electronic Theory of Operation

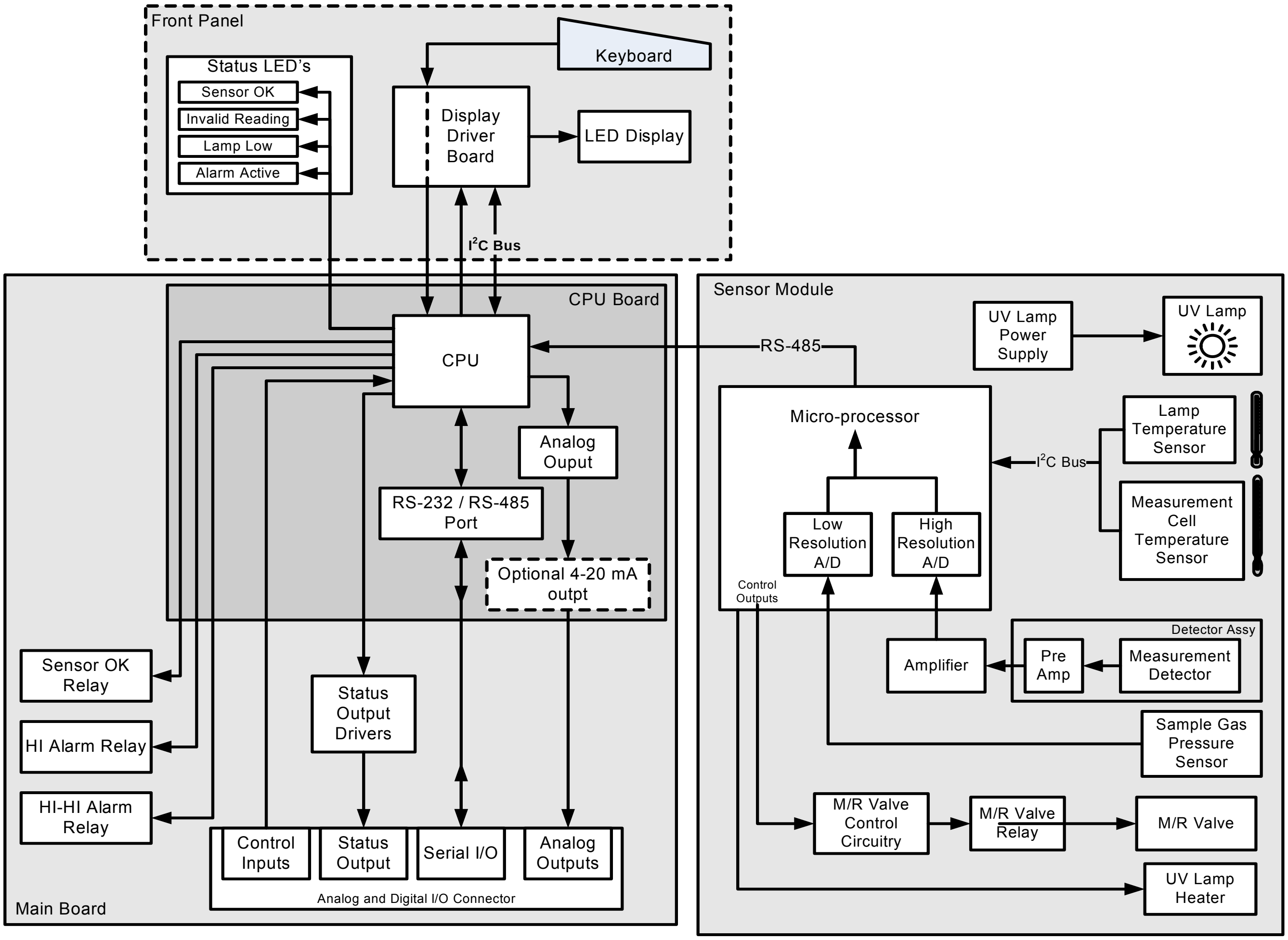

Figure 10-5 460L Electronic Block Diagram

Electronically, the 460L is of modular design (see Figure 10-5). 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; some opto-isolated signal buffers for the digital status outputs and control inputs and is the location of the three solid state output relays (see Section 3.5.5).

The monitor's main power supply (see Section 10.3.5) is also located on this assembly.

10.3.2. O_3 Sensor Module

The heart of the 460 Monitor is the O_3 sensor module. This electromechanical assembly located at the left hand side of the enclosure includes all of the pneumatic, mechanical and electronic components needed to gather the data required to calculate the O_3 content of the source gas.

10.3.2.1. O_3 Sensor Components

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

  Both Sensors have built-in A/D converters and send digitized data directly to the monitors CPU.

- **UV detector:** A UV detector measures the two primary variables, ***I*** and $\boldsymbol{I_0}$ (See Section 10.1.1) needed to compute the O_3 concentration of the source gas. They are:

  - The first measurement (***I***) is taken during the measure period of the measure/ reference cycle (see Table 10-1) and records the intensity of the UV light passing through the O_3 bearing source gas.

  - The second measurement ($\boldsymbol{I_0}$) occurs during the reference period of the cycle and records the intensity of the light passing though gas from which the O_3 has been removed.

  This 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 the preamplifier are used to amplify the output signals of the detector to a level readable by the A/D Converter circuitry of the monitor's sensor module. The first stage of amplification is located on the PCA's on which the detector itself is mounted. The second stage of amplification is located on the sensor module PCA.

- **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). This sensor outputs an analog signal to the sensor microprocessor.
- **Measure / Reference Valve:** This valve alternates the O_3 gas stream between a direct path to the absorption tube and a path that first passes it the O_3 scrubber. The state of this valve is the Sensor Module PCA (see Section 10.3.2.2).

10.3.2.2. Sensor Module PCA

The sensor module PCA performs the real work of operating the O_3 sensor module. It gathers the various measurements used to calculate the O_3 concentration and performs all basic computations related to determining the O_3 concentration of the source gas.

It includes:

- **Sensor Signal A/D Conversion**: The output of the monitor's O_3 sensor and the pressure sensor are converted into digital signals that the CPU can understand by two analog to digital converters (A/D) located on the sensor PCA.
  - LOW RESOLUTION A/D: A 12-bit, SAR converter that digitizes the output of the monitors pressure sensor.
  - HIGH RESOLUTION A/D: This component digitizes the signal output by the UV detector of the monitor's measurement detector. Since the reference detector output requires a large dynamic range and superior noise rejection, a Delta-Sigma type A/D Converter is used here.
- **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 sensor inputs is to be converted(pressure sensor or measurement detector), starts the conversion process, stops it and extracts the digital data.

  Data Output: The sensor microprocessor collects data from the various digital sensors as well as the data converted by its internal A/D and sends it 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 micrprocessor'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.
- **Measure / Reference Valve Control:** The Measure/Reference valve is actuated by a 12 VDC solenoid valve driver that is controlled by timing circuitry built into the sensor module board.

10.3.3. CPU Board

In addition to being responsible for all I/O functions and managing the state of the monitors various status indicators and alarms (see below), the 460L's CPU also calculates the monitor's offset during zero point calibration (see Section 8.1) and converts O_3 concentration data from ppb units into ppm units if necessary.

10.3.3.1. I/O Functions

- **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 Alarm Resert key) are sensed directly by the CPU as simple digital contact closures.
- **Analog Output:** The 460L 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.
- **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 3-9). This can be done by using a mechanical switch or isolated transistor output from another device, such as a PLC.

10.3.3.2. Status and Alarm Functions

- **Relay Outputs:** The 460L is equipped with three relay three SPDT relay. They are located at the top right hand side of the main board and are labeled RELAY 1, RELAY 2 & RELAY 3.
  - RELAY 1 corresponds to the Sensor OK status output and LED;
  - RELAY 2 corresponds to the HI concentration alarm, and;
  - RELAY 3 corresponds to the HI-HI concentration alarm
- **Status LED's:** Based on data received from the sensor module, it activates and deactivates the four status LED's located on the monitor's front panel (see Section 11.2.4).
- **Status Outputs:** Logic-Level voltages are output via optically isolated NPN transistors, which sink up to 50 mA of DC current. They are accessed through connector J2 on the main board. Several of these outputs convey good/bad information about key monitor operational conditions (see Section 11.2). Others reflect the status of the monitors O_3 concentration alarms.

  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 3-7). 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.

10.3.4. Display Driver and Keyboard Assembly

10.3.4.1. Keyboard

The keyboard of the M460L 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).

10.3.4.2. 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.

10.3.4.3. Display Driver

The circuitry on the display has 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 112 & 11.3) ON/OFF
- A bipolar integrated circuit decodes the serial data sent by the CPU via an I^2C 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.

10.3.5. Power Distribution

The 460L operates on 90 to 260 VAC power at either 50Hz or 60Hz. As illustrated in Figure 10-6 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.

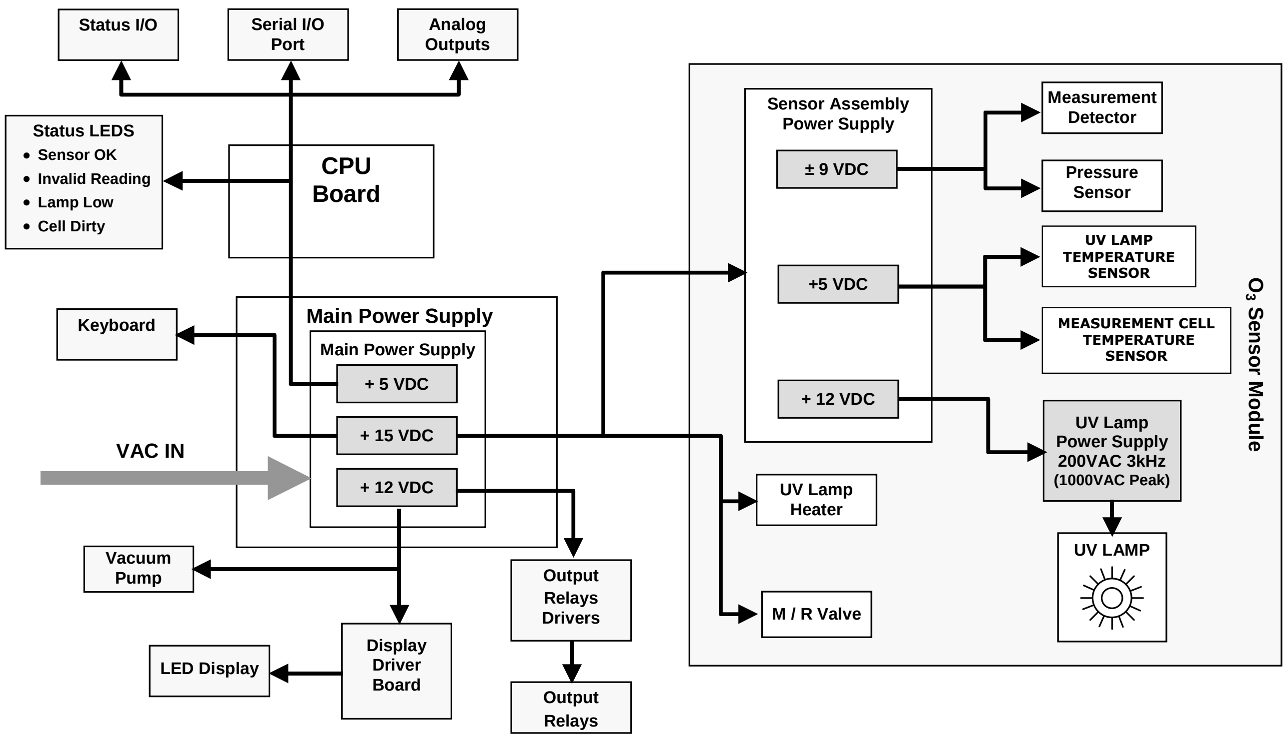

Figure 10-6 460L Power Distribution Block Diagram

- **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 alarm relay outputs.
  - +5 VDC: The basic voltage on which the CPU and logic level circuitry operates.
  - +15 VDC: Source voltage for the keyboard (where it is regulated down to +5 VDC), the UV lamp heater; the measure / reference valve a secondary power supply located on the sensor module assembly.
- **SENSOR MODULE POWER SUPPLY:** Using +15 VDC from the main power supply, this circuitry generates the +5, +12 & ±9 VDC supplies needed to operate its own on-board logic devices and the various components of the O_3 sensor module.

- **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 460L 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

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

11.1. Status Output Summary

Table 11-1 below gives a summary of the operation of the Status Outputs on the 460L. See Section 3.5.2 Digital Status Outputs for information on connecting these outputs.

Table 11-1 Digital Status Outputs Definitions

OUTPUT #	NAME	ON STATE	OFF STATE	LED on FRONT PANEL
1	Sensor O.K.	**Normal State**	Measure > 1230mV; Reference > 1230mV; UV Lamp Off (Reference < 250 mV); No data from The O_3 sensor	YES
2	Invalid Reading	Pressure > 14.9 psia; Pressure < 9 psia; Negative Ozone Concentration; Concentration Over-Range	**Normal State**	YES
3	Lamp Low	Reference <375 mV	**Normal State**	YES
4	Alarm Active	Either the HI or the HI-HI O_3 concentration alarm is active	No O_3 Concentrati0on alarms are active	YES
5	HI Alarm	Measured O_3 concentration is ≥ than the **HI** alarm set point	**Normal State**	NO
6	HI-HI Alarm	Measured O_3 concentration ≥ the **HI-HI** alarm set point	**Normal State**	NO

11.2. Troubleshooting Using Status Outputs

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 460L is in need of servicing.

If the Sensor OK output turns OFF

- One of the analog voltages output by the sensor module (reference / measure) is too high. This could mean that the lamp output has drifted high
- The reference voltage output by the sensor module (reference / measure) is too low. This could mean that the lamp intensity has drifted very low or the lamp is completely off.

- The O3 sensor is not responding to CPU requests for data. This could represent a variety of electronic problems with the sensor module or internal communication between the CPU and the sensor module.

11.2.2. Invalid Reading

The normal state for the Invalid Reading output is OFF. When this output turns ON, the 460L 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 too high indicating that the O_3 supply is under pressure.
- The measured pressure in the measurement cell exceeds too low indicating that there could be a blockage in the monitor's internal pneumatic lines.
- The measured concentration has exceeded the measurement range selected for the monitor.
- The measured concentration is an excessively negative reading (less than -0.10 ppm or –10.0 ppb).

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 375mV. This could mean that the lamp has drifted has started to drift low and that the lamp output should be adjusted.

11.2.4. Status LED / Status Output Troubleshooting 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 LED / Output Trouble shooting Truth Table

SENSOR OK	INVALID READING	LAMP LOW	ACTIONS
1	0	0	Normal operation, no action required.
0	0	0	• The Lamp intensity has drifted and is too high for proper operation. → Adjust the lamp. • The O_3 sensor is not responding to request from the CPU for data.
1	X	1	• UV Lamp output is starting to drift low. → Adjust the lamp output.
0	X	1	• The UV lamp is either completely off or its intensity has drifted so low that the monitor can not reliable measure O_3. → Replace the UV lamp (see Section 9.3).
X	1	X	• O_3 reading is above the upper limit of the range selected for the monitor. → Check or change the range setting (see Sections 7.3.9 to 7.3.11). • O_3 reading is too negative. → Calibrate zero point (see Section 8.1). • Possible Internal blockage. → check or replace the filter (see Section 9.1.1). • O_3 supply under high pressure. → Check gas lines from O_3 source.

11.3. Concentration Alarm Outputs

Table 11-3 Alarm Output Troubleshooting

FAULT CONDITION	POSSIBLE CAUSES
Pressing **ALARM ACKNOWLEDGE** button does not clear alarm or turn off Alarm Active LED.	• Alarm mode is set for Non-Latching and Concentration value is ≥ relevant alarm set point. • **ALARM ACKNOWLEDGE** button is bad.
Using the **ALMACK** command over the serial port does not clear alarm or turn off Alarm Active LED.	• Alarm mode is set for Non-Latching and Concentration value is ≥ relevant alarm set point.
Alarm Active LED doesn't blink when one or both Alarms are active	• LED has Failed. • Display driver PCA malfunction
Alarm does not activate at expected O_3 concentration	• Set point for alarm is set incorrectly
Alarm Active Status Output OFF when HI alarm or HI-HI Alarm is active	• Electronic failure of Alarm Active status output.
Hi alarm or HI-HI alarm status output is OFF when O_3 concentration is ≥ related set point value	• Electronic failure of status output.

11.4. Technical Assistance

If this addendum and its trouble-shooting / repair sections do not solve your problems, technical assistance may be obtained from:

Teledyne Instruments
Advanced Pollution Instrumentation Division
(TAPI)
Customer Service
9480 Carroll Park Drive
San Diego, California 92121-5201USA

Toll-free Phone:	800-324-5190
Phone:	858-657-9800
Fax:	858-657-9816
Email:	API-CustomerService@Teledyne.com
Website:	http://www.Teledyne-API.com

Before you contact Teledyne Instruments' Customer service, fill out the problem report form in Appendix C, which is also available online for electronic submission at http://www.Teledyne-API.com/forms/p-fmapicom.asp.

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 extremely important part of making sure that your analyzer 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 analyzer, are very small, require very little power and operate very quickly. Unfortunately, the same characteristics that allow them to do these things also make 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.

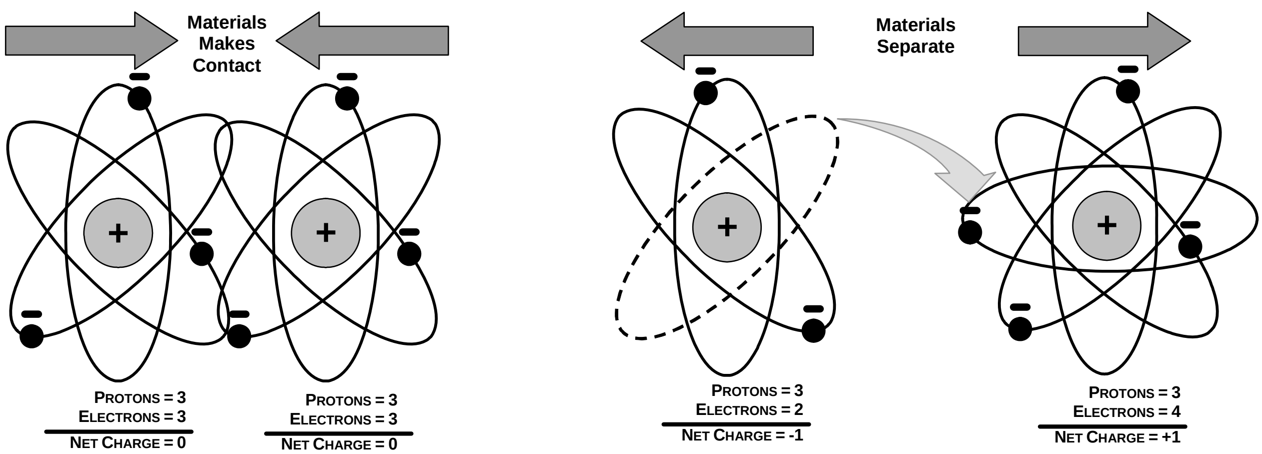

Figure 12-1 Triboelectric Charging

If one of the surfaces is a poor conductor or even a good conductor that is not grounded, the resulting positive or negative charge cannot 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 into 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 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 analyzer is properly **installed, it is safe from damage caused by static discharges**: It is true that when properly installed the chassis ground of your analyzer is tied to earth ground and its electronic components are prevented from building static electric charges themselves. This does not prevent discharges from static fields built up on other things, like you and your clothing, from discharging through the instrument 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 workstation 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.

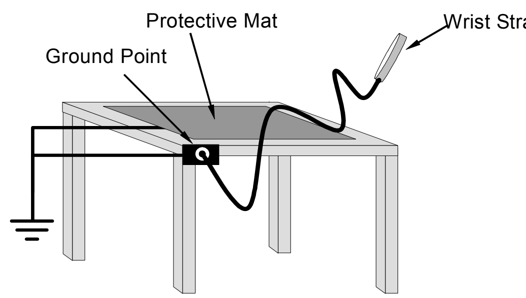

Figure 12-2 Basic anti-ESD Workbench

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 analyzer. 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 instrument'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 equalizes 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 Analyzer Repair and Maintenance

12.4.2.1. Working at the Instrument Rack

When working on the analyzer while it is in the instrument rack and plugged into a properly grounded power supply

1. Attach you anti-ESD wrist strap to ground before doing anything else.

- Use a wrist strap terminated with an alligator clip and attach it to a bare metal portion of the instrument chassis.
- This will safely connect you to the same ground level to which the instrument and all of its components are connected.

2. Pause for a second or two to allow any static charges to bleed away.
3. Open the casing of the analyzer and begin work. Up to this point, the closed metal casing of your analyzer has isolated the components and assemblies inside from any conducted or induced static charges.
4. If you must remove a component from the instrument, 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 analyzer.

12.4.2.2. Working at an Anti-ESD Work Bench.

When working on an instrument of an electronic assembly while it is resting on a anti-ESD workbench

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 workstation 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 workstation.
   - 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 workstation'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.
5. Only lay tools or ESD-sensitive devices and assemblies on the conductive surface of your workstation. Never lay them down on any non-ESD preventative surface.
6. 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.
7. Disconnecting your wrist strap is always the last action taken before leaving the workbench.

12.4.2.3. Transferring Components from Rack to Bench and Back

When transferring a sensitive device from an installed Teledyne Instruments analyzer to an Anti-ESD workbench or back:

1. Follow the instructions listed above for working at the instrument rack and workstation.
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 instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
   - If you are at an anti-ESD workbench, 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.
   - 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:
7. Connect your wrist strap to ground.
   - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
   - If you are at a anti-ESD workbench, lay the container down on the conductive work surface.
   - In either case wait several seconds.
8. Open the container.

12.4.2.4. Opening Shipments from 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:

1. Always unpack shipments from Teledyne Instruments Customer Service by.
2. Open the outer shipping box away from the anti-ESD work area.
3. Carry the still sealed ant-ESD bag, tube or bin to the anti-ESD work area.
4. Follow steps 6 and 7 of Section 12.4.2.3 above when opening the anti-ESD container at the work station.
5. Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to Teledyne Instruments.

12.4.2.5. Packing Components for Return to Teledyne Instruments Customer Service

Always pack electronic components and assemblies to be sent to Teledyne Instruments Customer Service in anti-ESD bins, tubes or bags.

CAUTION
ESD Hazard

- **DO NOT use pink-poly bags.**
- **NEVER allow any standard plastic packaging materials to touch the electronic component/assembly directly**
  - **This includes, but is not limited to, plastic bubble-pack, Styrofoam peanuts, open cell foam, closed cell foam, and adhesive tape**
- **DO NOT use standard adhesive tape as a sealer. Use ONLY anti-ESD tape**

1. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
2. Before using the bag or container allow any surface charges on it to dissipate:
   - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
   - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
   - In either case wait several seconds.
3. Place the item in the container.

4. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
   - 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.

NOTE

If you do not already have an adequate supply of anti-ESD gags or containers available, Teledyne Instruments' Customer Service department will supply them (see Section 11.4 for contact information).

Follow the instructions listed above for working at the instrument rack and workstation.

USER NOTES:

Appendix A - Spare Parts list

- **05128 – Spare Parts List M460L**

M460L Spare Parts List

Part Number	Description
025710100	PCA, UV DETECTOR PREAMP, M454/M460
030500400	OVERLAY, FRONT PANEL, O3 SENSOR, M460L
031680100	PCA, FRONT PANEL, M454 PRODUCTS
034920000	PCA, EXPANSION BD, M554/M460X/03/CAL
036280000	ASSY, WATER DROP OUT FILTER, PFA, M450
036750000	AKIT, ELEMENTS, 47MM, 30 MICRON (10 PCS)
037420000	ASSY, UV LAMP (BIR) M452/454/460X/465L *
037490100	ASSY, FLOWMETER, 0-2.5L, M460M/L
040530000	CBL, PS AC IN, M454 NEMA
040540100	CBL, DC POWER, M460L NEMA
041980000	CBL ASSY, GROUND STRAP, 4.5"
046170000	ABSORPTION TUBE, M460L
046740000	ASSY, PUMP, 12VDC, M460M/M700E
047110000	ASSY, VALVE, M460L
048490100	PCA, O3 BENCH, M460L/M465L
049680000	ASSY, SENSOR, HI-CONC, M460L/M465L
049910100	PCA, MAINBOARD, M460L
050120000	MANUAL, OPERATORS, M460L
050170000	ASSY, DFU SAMPLE FILTER
050300000	ASSY, REF SCRUBBER, HI-CONC, M460L/M465L
053010000	AKIT, EXP KIT, CARULITE 200
CN0000350	CONNECTOR, 16 PIN, W/SCREW FLANGE
DR0000006	DRYER, 24", 1/4" SS FITTINGS
HW0000120	SHOCKMOUNT, GROMMET ISOLATOR
OP0000031	WINDOW, QUARTZ, 1/2"DIA, .063" THICK (KB
OR0000039	ORING, BENCH
OR0000050	ORING, BENCH
OR0000098	ORING, BENCH
OR0000099	ORING, WATER DROP OUT FILTER
PS0000035	EOS SWITCHING PS, 15V, 40W

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Appendix B – Electronic Schematics

Table B-1 M460L List of Electronic Schematics

DOCUMENT #	DESCRIPTION
03169	PCA, FRONT PANEL DISPLAY
04992	PCA, MAINBOARD
03493	PCA, CPU