INSTRUCTION MANUAL

MODEL 400A
OZONE ANALYZER

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SAFETY MESSAGES

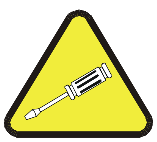
Your safety and the safety of others is very important. We have provided many important safety messages in this manual. Please read these messages carefully.

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 are found in the manual and inside the instrument. The definition of these symbols is described below:

GENERAL WARNING/CAUTION: Refer to the instructions for details on the specific danger.

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 analyzer should only be used for the purpose and in the manner described in this manual.

If you use the analyzer in a manner other than that for which it was intended, unpredictable behavior could ensue with possible hazardous consequences.

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LIST OF FIGURES

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1 HOW TO USE THIS MANUAL

Teledyne API is pleased that you have purchased the Model 400A UV Photometric Ozone Analyzer. The keyboard, with it's "talking keys", allows you to quickly and easily set up the instrument. The built-in tests and diagnostics make problem location and diagnosis easy. In addition, our customer service department is available to assist with any problems you may have.

The M400A's microprocessor continually checks operating parameters such as temperature, flow, and critical voltages. If you encounter any difficulty refer to Section 9 General Troubleshooting Hints.

We recognize that the need for information in this manual changes as time passes. When the instrument first arrives, it is necessary to get it up and running quickly and verify its correct operation. As time passes, more detailed information is often required on special configurations, calibration alternatives and other operational details. Finally there is the need for periodic maintenance and to quickly troubleshoot problems to assure maximum reliability and data integrity.

To address these needs, we have created three indexes to the information inside. They are:

<u>Table of Contents:</u>

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 and a list of Figures.

<u>Index to M400A Front Panel Menus:</u>

The Menu Index (Figure 5-1 and Figure 5-2, Table 5-1 and Table 5-2) briefly describes the front panel menus and refers you to other sections of the manual that have a detailed explanation of each menu selection.

<u>Troubleshooting Section 9:</u>

The Troubleshooting Section, outlined in the Table of Contents, allows you to diagnose and repair the instrument based on variables in the TEST menu, the results of DIAGNOSTIC tests, and PERFORMANCE FAULTS such as excessive noise or drift. The troubleshooting section also explains the operation, adjustment, diagnosis and testing of each instrument subsystem.

If you are unpacking the instrument for the first time, please refer to "Getting Started" in Section 2.

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2 GETTING STARTED

2.1 Unpacking

1. Verify that there is no apparent external shipping damage. If damage has occurred, please advise the shipper first, then Teledyne API.

> **CAUTION**
>
> **To avoid personal injury, always use two persons to lift and carry the Model 400A.**

2. Also check for internal shipping damage, and generally inspect the interior of the instrument to make sure all circuit boards and other components are in good shape.

3. Locate the instruction manual that is shipped with the instrument. Remove all red colored shipping screws shown in the Figure 2-1. Also remove the four red shipping screws from the optical bench assembly on the inside of the instrument.

> **NOTE**
>
> **Save these shipping screws and re-install them whenever the unit is shipped to another location.**

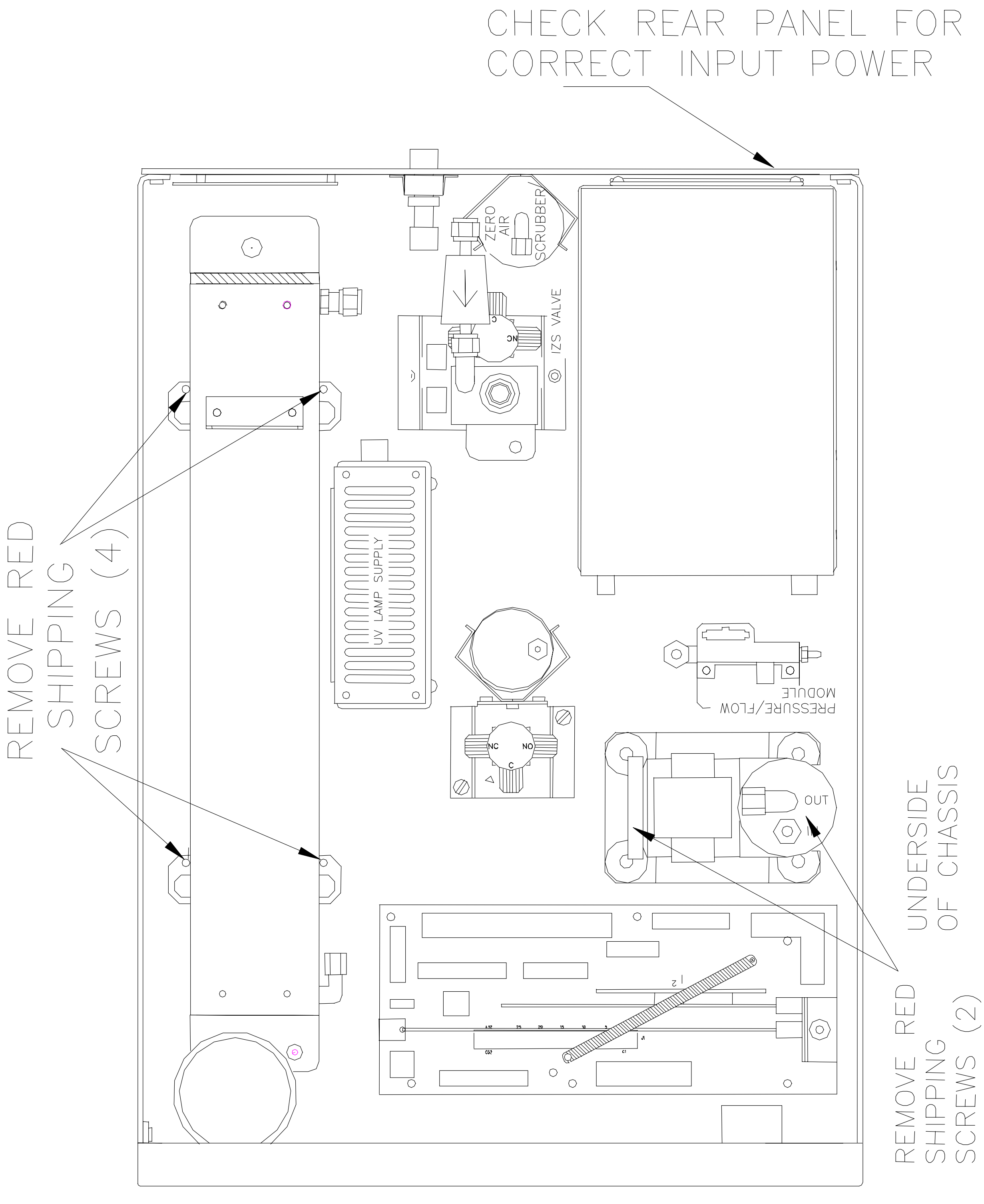


Figure 2-1: Removal of Shipping Screws & Check for Correct Power

2.2 Electrical and Pneumatic Connections

1. Refer to Figure 2-2 to locate the rear panel electrical and pneumatic connections.
2. Locate the power cord that is shipped with the instrument. Before plugging the instrument in, check the voltage and frequency label on the rear panel of the instrument for compatibility with the local power.
3. If you are connecting to a calibrator, attach a vented sample inlet line to the sample inlet port. The pressure of the sample gas at the inlet port should be at ambient pressure. The exhaust from the pump should be vented to atmospheric pressure using maximum of 10 meters of ¼" tubing.
4. Attach the analog output connections to a strip chart recorder and/or datalogger. Refer to Figure 9-1 for the jumper settings for the desired analog output voltage range.
5. When installing the Model 400A, allow a minimum of 4 inches of clearance at the back of the instrument and 1 inch of clearance on each side for proper ventilation.

CAUTION

Connect the exhaust fitting on the rear panel to a suitable vent outside the analyzer area. Use vent line when sampling from pressurized manifolds. Sample pressure should not exceed 1.5 in-$H_2$0 over ambient.

NOTE

See Figure 2.2 for rear panel pneumatic connections. Sample gas should only come into contact with PTFE, quartz or glass. Leak check all fittings with soap solution. Maximum pressure for leak check is 15 PSI.

6. Connect IZS air inlet, labeled DRY AIR on the rear panel, to a clean, dry air supply.

NOTE

The IZS system can be operated successfully at ambient humidity levels. However, for best stability, the imput air should be dried to approximately a –20^{O}C dew point.

NOTE

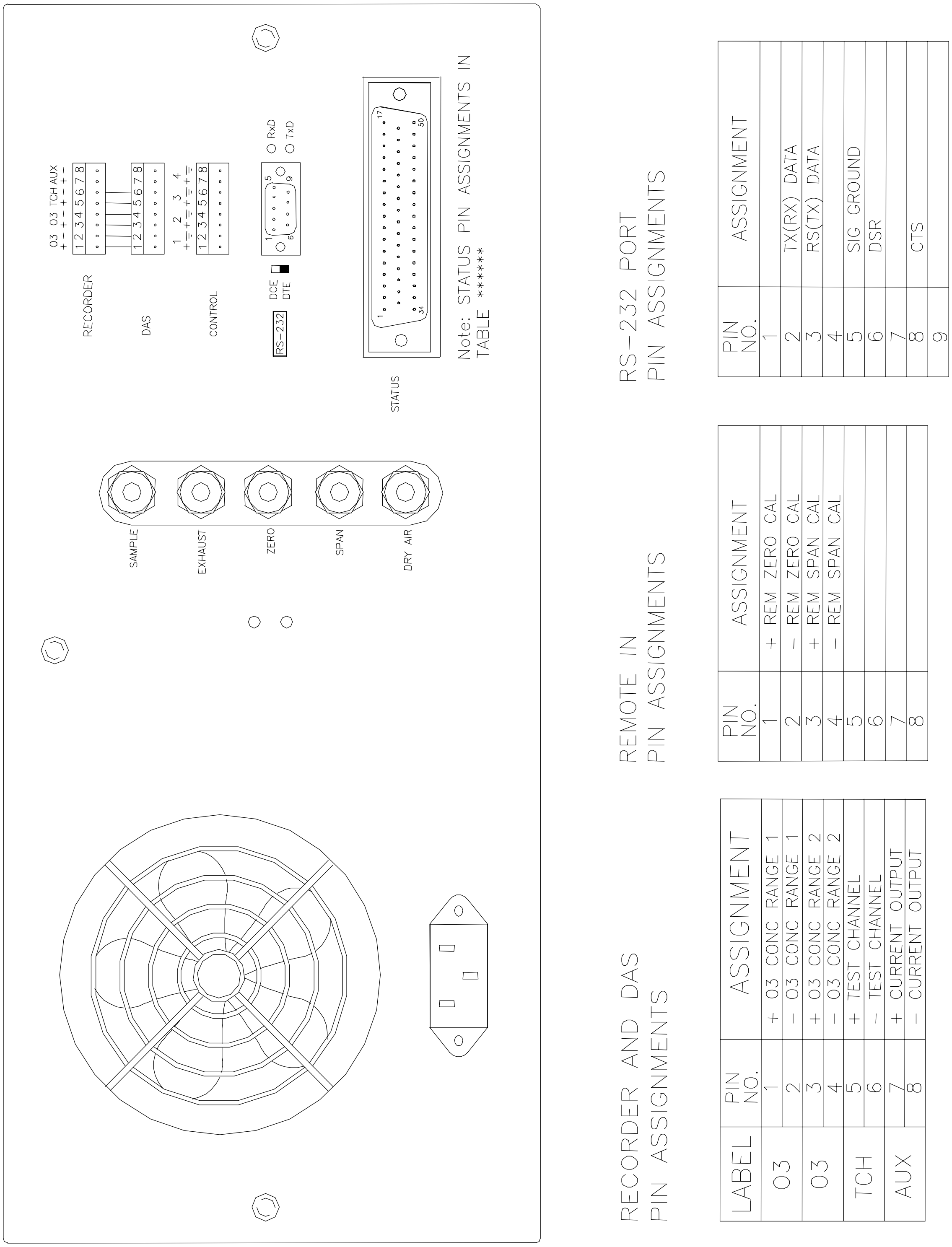
Check that analyzer is set up for proper voltage and frequency.

CAUTION

Power plug must have ground lug.

NOTE

Never disconnect CPU or other PCB cards while under power.



RS-232 PORT PIN ASSIGNMENTS

PIN NO.	ASSIGNMENT
1	
2	TX(RX) DATA
3	RS(TX) DATA
4	
5	SIG GROUND
6	DSR
7	
8	CTS
9	

REMOTE IN PIN ASSIGNMENTS

PIN NO.	ASSIGNMENT
1	+ REM ZERO CAL
2	− REM ZERO CAL
3	+ REM SPAN CAL
4	− REM SPAN CAL
5	
6	
7	
8	

RECORDER AND DAS PIN ASSIGNMENTS

LABEL	PIN NO.	ASSIGNMENT
O3	1	+ O3 CONC RANGE 1
	2	− O3 CONC RANGE 1
O3	3	+ O3 CONC RANGE 2
	4	− O3 CONC RANGE 2
TCH	5	+ TEST CHANNEL
	6	− TEST CHANNEL
AUX	7	+ CURRENT OUTPUT
	8	− CURRENT OUTPUT

Figure 2-2: Rear Panel

2.3 Initial Operation

1. Turn on the instrument power.
2. The display should immediately light, displaying the instrument type - M400A and the computer's memory configuration. If you are unfamiliar with the M400A theory of operation, we recommend that you read Section 4 before proceeding. A diagram of the software menu trees is in Figure 5-1 and Figure 5-2.
3. The M400A requires about 30 minutes for all internal components to come up to temperature. During this time temperatures and other conditions are out of specification. The software will suppress most warning conditions for 30 minutes after power up. After 30 minutes, warning messages will be displayed until the respective warning conditions are within specifications. Use the CLR key on the front panel to clear warning messages.
4. While waiting for instrument temperatures to come up, you can check for correct operation by using some of the M400A's diagnostic and test features.
5. Check the TEST functions by comparing the values listed in Table 2-1 to those in the display. Remember that as the instrument warms up the values may not have reached their final values yet. If you would like to know more about the meaning and utility of each TEST function, refer to Table 9-1. Also, now is a good time to verify that the instrument was shipped with the options you ordered. Table 2-1 also contains the list of options. Section 6 covers setting up the options.
6. When the instrument is warmed up, re-check the TEST functions against Table 2-1. All of the readings should compare closely with those in the table. If they do not, see Section 9.
7. The next task is to calibrate the analyzer. There are several ways to do a calibration, they are summarized in Table 7-1. For a preliminary checkout we recommend calibration with zero air and span gas coming in through the sample port. The procedure is:

NOTE

Words in all caps are messages on the analyzer front panel.

Step 1 - Enter the expected O_3 span gas concentration:

Set the Expected Span Gas Concentration

Step Number	Action	Comment
1.	Press CAL-CONC	This key sequence causes the M400A to prompt for the expected O_3 concentration. Enter the O_3 span concentration value by pressing the key under each digit until the expected value is set.
2.	Press ENTR	ENTR stores the expected O_3 span value. This value will be used in the internal formulas to compute subsequent O_3 concentration values.
3.	Press EXIT-EXIT	Returns instrument to SAMPLE mode.

Step 2 – Set the Range of the M400A:

Set the Range

Step Number	Action	Comment
1.	Press SETUP-RNGE- MODE-SING-ENTR	If necessary you may want to change ranges. Normally the instrument is shipped in single range mode set at 500 ppb. We recommend doing the initial checkout on the 500 ppb range.
2.	Press SETUP-RNGE-SET	After SETUP-RNGE-SET, enter 500 and press ENTR. The instrument will now be in the 500 ppb range.
3.	Press EXIT, EXIT	Returns instrument to SAMPLE mode.

Step 3 - Calibrate the instrument:

Zero/Span Calibration Procedure

Step Number	Action	Comment
1.	Input Zero gas	Allow Zero gas to enter the sample port on the rear of the instrument.
2.	Press CAL	The M400A enters the calibrate mode from sample mode.
3.	Wait 10 min	Wait for reading to stabilize at the zero value. If you wait less than 10 minutes the final zero value may drift.
4.	Press ZERO	The ZERO button will be displayed.
5.	Press ENTR	Pressing ENTR actually changes the calculation equations and zeroes the instrument.
6.	Input Span Gas	Switch gas streams to span gas.
7.	Wait 10 min	Wait for reading to stabilize at the span value. If you wait less than 10 minutes the final span value may drift.
8.	Press SPAN	The SPAN button should be displayed. If it is not, check the Troubleshooting Section 9.2.6 for instructions on how to proceed. In certain circumstances at low span gas concentrations (<100ppb), both the ZERO and SPAN buttons will appear.
9.	Press ENTR	Pressing ENTR actually changes the calculation equations so that the concentration displayed is the same as the expected span concentration you entered above, thus spanning the instrument.
10.	Press EXIT	Pressing EXIT returns the instrument to SAMPLE mode.

The Model 400A Analyzer is now ready for operation.

Table 2-1: Final Test and Calibration Values

Test Values	Observed Value	Units	Nominal Range
RANGE		PPB	100 - 10,000
STABIL		PPB	0.2 - 1.0
O3 MEAS		mV	4200 - 4700
O3 REF		mV	4200 - 4700
O3 GEN		mV	0 - 5000
O3 DRIVE		mV	0 - 5000
VAC		in-Hg-A	8.0 - 14.0
PRESS		in-Hg-A	25 - 35
SAMP FL		cc/min	800 ± 80
SAMPLE TEMP		°C	20 - 45
PHOTO LAMP		°C	52 ± 0.5
O3 GEN TEMP		°C	48 ± 0.5
BOX TEMP		°C	8 - 50
DCPS		mV	2500 ± 100
SLOPE		N/A	1.0 ± 0.1
OFFSET		PPB	0.0 ± 5
Span and Cal Values			
O3 Span Conc		PPB	50 - 10,000
Noise at Zero (rms)		PPB	0.2 - 0.3
Noise at Span (rms)		PPB	0.5% of reading
Measured Flows			
Sample Flow		cc/min	800 ± 80
Factory Installed Options		**Option Installed**	
Power Voltage/Frequency			
Rack Mount, w/ Slides			
Internal Zero/Span - IZS			
Zero/Span Valves			
REC Voltage Range		0 - V	
DAS Voltage Range		0 - V	
TCHAN Voltage Range		0 - V	

PROM # ____________ Serial # ____________

Date ____________ Technician ____________

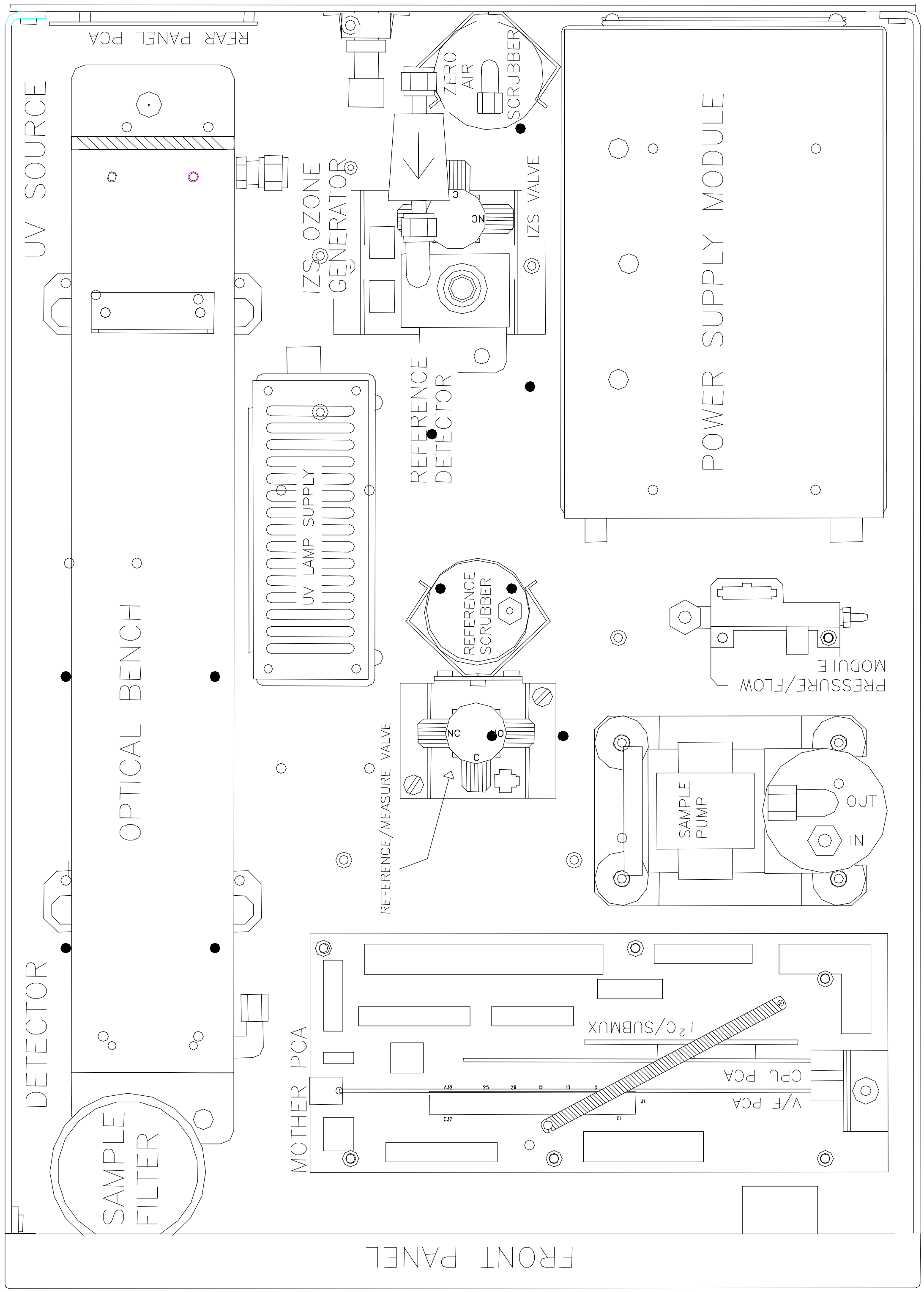


Figure 2-3: Assembly Layout

3 SPECIFICATIONS, AGENCY APPROVALS, WARRANTY

3.1 Specifications

Ranges	User selectable to any full scale range from 100 ppb to 10 ppm
Measurement Units	ppb, ppm, µg/m^3 (user selectable)
Zero Noise	< 0.3 ppb RMS per EPA definition
Span Noise	< 0.5% of reading RMS per EPA definition (above 100 ppb)
Lower Detectable Limit	< 0.6 ppb per EPA definition
Zero Drift (24 hours)**	< 1.0 ppb
Zero Drift (7 days)**	< 1.0 ppb
Span Drift (24 hours)**	< 1% of reading
Span Drift (7 days)**	< 1% of reading
Linearity	Better than 1% full scale
Precision*	0.5% reading
Lag Time	<10 sec per EPA Definition
Rise/Fall Time	<20 sec to 95% per EPA Definition
Sample Flow Rate	800 scc/min. ± 10%
Temperature Range*	5 - 40^{o}C
Humidity Range	10-90% RH, Non-Condensing
Temp Coefficient	< 0.05 % per ^{o}C
Voltage Coefficient	< 0.05 % per V
Dimensions (H x W x D)	7" x 17" x 24" (178 mm x 432 mm x 610 mm)
Weight	37 lb (17 kg) standard unit 39 lb (17.6 kg) w/IZS
Power	110V/60 Hz, 220V/50 Hz, 240 V/50 Hz 250 watts 230 V~, 50 Hz, 2.5A
Environmental Conditions	Installation Category (Overvoltage Category) II Pollution Degree 2, 2000m maximum altitude
Recorder/DAS Output	± 100 mV, ± 1 V, ± 5 V, ± 10 V (Bi-Polar), 0-20 or 4-20 mA current loop
Analog Output Resolution	1 part in 1024 of selected full-scale voltage
Status	12 Status outputs from opto-isolators

* As defined by the USEPA
** at constant temperature and voltage

3.2 EPA Equivalency Designation

Teledyne Advanced Pollution Instrumentation Devision, Model 400A Ozone Analyzer is designated as Reference Method Number EQOA-0992-087 as defined in 40 CFR Part 53, when operated under the following conditions:

1. Range: Any range from 100 parts per billion (ppb) to 1 ppm.
2. Ambient temperature range of 5 to 40^{o} C.
3. Line voltage range of 105-125 VAC, 60 Hz; 220-240 VAC, 50 Hz.
4. With 5-micron TFE filter element installed in the internal filter assembly.
5. Sample flow of 800 ± 80 cc/min.
6. Internal or External sample pump
7. Software settings:

A.	Dilution factor	1.0
B.	AutoCal	ON or OFF
C.	Dual range	ON or OFF
D.	Autorange	ON or OFF
E.	Temp/Pres compensation	ON

Under the designation, the Analyzer may be operated with or without the following options:

1. Rack mount with slides
2. Rack mount without slides, ears only
3. Rack mount for external pump w/o tray
4. Sample/Cal valve
5. Internal zero/span
6. 4-20mA, isolated output
7. Internal pump or external pump

3.3 Warranty

WARRANTY POLICY (02024c)

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

COVERAGE

After the warranty period and throughout the equipment lifetime, Teledyne 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-TELEDYNE API MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by Teledyne 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

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

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

TERMS AND CONDITIONS

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

4 THE M400A OZONE ANALYZER

4.1 Principle of Operation

The detection of ozone molecules is based on absorption of 254 nm UV light due to an internal electronic resonance of the O_3 molecule. The Model 400A uses a mercury lamp constructed so that a large majority of the light emitted is at the 254nm wavelength. Light from the lamp shines down a hollow quartz tube that is alternately filled with sample gas, then filled with gas scrubbed to remove ozone. The ratio of the intensity of light passing through the scrubbed gas to that of the sample forms a ratio I/I_o. This ratio forms the basis for the calculation of the ozone concentration.

The Beer-Lambert equation, shown below, calculates the concentration of ozone from the ratio of light intensities.

$$C_{O_3} = -\frac{10^9}{\alpha \times \ell} \times \frac{\mathrm{T}}{273^o\mathrm{K}} \times \frac{29.92\,inHg}{\mathrm{P}} \times \ell n \frac{\mathrm{I}}{\mathrm{I}_o}$$

Where:

I = Intensity of light passed through the sample

I_o = Intensity of light through sample free of ozone

α = absorption coefficient

ℓ = path length

C_{O_3} = concentration of ozone in ppb

T = sample temperature in degrees Kelvin

P = pressure in inches of mercury

As can be seen the concentration of ozone depends on more than the intensity ratio. Temperature and pressure influence the density of the sample. The density changes the number of ozone molecules in the absorption tube, which changes the amount of light removed from the light beam.

These effects are addressed by directly measuring temperature and pressure and including their actual values in the calculation. Temperature and pressure compensation are done automatically.

The absorption coefficient is 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 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. Lastly, the absorption path length determines how many molecules are present in the column of gas in the absorption tube.

The intensity of light is converted into a voltage by the detector/preamp module. The voltage is converted into a number by a voltage-to-frequency (V/F) converter capable of 80,000 count resolution. The digitized signal, along with the other variables, are used by the CPU to compute the concentration using the above formula.

Every 6 seconds the M400A completes a measurement cycle consisting of a 2 second wait period for the sample tube to flush, followed by a 1 second measurement of the UV light intensity to obtain I. The sample valve is switched to admit scrubbed sample gas for 2 seconds followed by a 1 second measurement of the UV light intensity to obtain I_o. Measurement of I_o every 6 seconds minimizes instrument drift due to changing intensity of the lamp due to aging and dirt.

4.1.1 Adaptive Filter

The Teledyne API O_3 Analyzer is able to provide a smooth, stable output by means of an adaptive filter. During conditions of constant or nearly constant concentration the filter is allowed to grow to 32 samples (2 minutes) in length, providing a smooth, stable reading. If a rapid change in concentration is detected, the filter is cut to 6 samples to allow the Analyzer to quickly respond to rapidly varying signals.

4.1.2 Examining the Ozone Formula Slope and Offset

The slope and offset parameters can be examined by pressing the **<TST** or **TST>** buttons until the slope and offset TEST functions appear**.** The slope and offset parameters are set only during zero and span calibration routines. These parameters are used to adjust the span and zero values to the expected values entered in the CAL menu.

If the instrument's range mode is set to Dual or Auto, then a second set of slope and offset parameters is used for computing the concentration for the high range.

The current value of the ozone reading that is displayed on the front panel and output on the D/A terminals on the back panel is computed as follows:

1. The Model 400A Analyzer switches into reference mode.

2. The Analyzer waits 2 seconds to purge the sample tube.

3. The instrument measures the intensity of light striking the detector during the next 1.067 sec. This reading forms the reference intensity I_o in the ozone concentration equation.

4. The analyzer now switches to the sample mode and waits 2 seconds as in step 2 above.

5. The instrument measures the intensity of light striking the detector during the next 1.067 sec. This reading forms the sample concentration intensity I in the ozone concentration equation.

6. The concentration of ozone is computed using the Beer-Lambent equation corrected for temperature and pressure.

7. Slope and offset corrections are made to the ozone concentration according to the equation:

   Corrected Concentration = Slope * Measured Concentration + Offset

8. An average of the last 32 samples is computed and converted to the number displayed on the front panel.

   This is the ozone concentration. The number is also routed to the D/A converter and the resulting voltage is output to the back panel.

4.2 Interferent Rejection

It should be noted that the UV absorption method for detecting ozone is subject to interference from a number of sources. The Model 400A has been successfully tested for its ability to reject interference from sulfur dioxide, nitrogen dioxide, nitric oxide, water, and meta-xylene.

While the instrument rejected interference from the aromatic hydrocarbon meta-xylene, it should be noted that there are a very large number of volatile aromatic hydrocarbons that could potentially interfere with ozone detection. If the Model 400A is installed in an environment where high aromatic hydrocarbon concentrations are suspected, specific tests should be conducted to reveal the amount of interference these compounds may be causing.

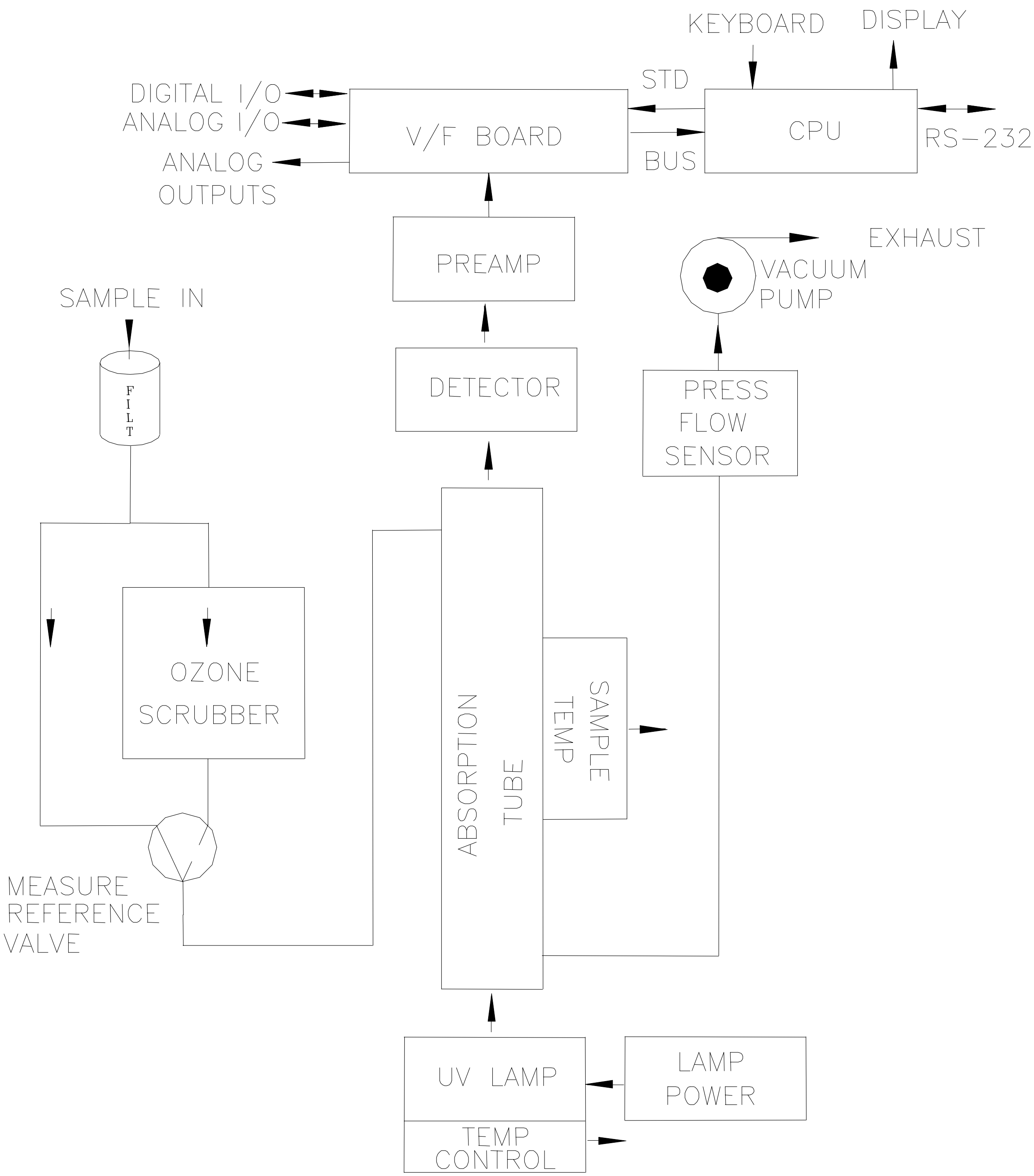


Figure 4-1: Block Diagram

4.3 Operation Summary

4.3.1 Optical Bench Assembly

The Optical Bench, see Figure 8-2, is where the absorption of UV light by ozone is measured and converted into a voltage. It consists of several sub-assemblies:

1. A mercury UV lamp, lamp block/sample exhaust assembly, and heater.
2. 40 cm long quartz absorption tube located in a temperature controlled aluminum channel. A thermistor attached to the quartz tube for measuring sample temperature.
3. Quartz tube mounting block which routs sample gas into the bench assembly.
4. The UV detector/preamplifier. The detector converts UV light to a current, which is amplified and scaled by the preamp.

4.3.2 Pneumatic Sensor Board

The pneumatic sensor board measures the absolute pressure of the sample gas up-stream and down-stream of an orifice. The up-stream pressure is used to calculate the sample flow through the orifice, based on a nominal 800 scc/min flow. There is a TEST function reported for:

1. Sample flow - reported in scc/min
2. Sample pressure - reported in in-Hg-Absolute
3. Sample vacuum - reported in in-Hg-Absolute

The M400A displays all pressures in inches of mercury-absolute (in-Hg-A). Absolute pressure is the reading referenced to a vacuum or zero absolute pressure. This method was chosen so that ambiguities of pressure relative to ambient pressure can be avoided.

For example, if the vacuum reading is 25" Hg relative to room pressure at sea level the absolute pressure would be 5" Hg. If the same absolute pressure was observed at 5000 ft altitude where the atmospheric pressure was 5" lower, the relative pressure would drop to 20" Hg, however the absolute pressure would remain the same 5" Hg-A.

4.3.3 Computer Hardware and Software

The M400A Analyzer is operated by an NEC V40 micro computer. The computer's multitasking operating system allows it to do instrument control, monitor test points, provide analog output and provide a user interface via the display, keyboard and RS-232 port. These operations appear to be happening simultaneously but are actually done sequentially based on a priority queuing system maintained by the operating system. The jobs are queued for execution only when needed, therefore the system is very efficient with computer resources.

The M400A is a true computer based instrument. The microprocessor does most of the instrument control functions such as temperature control, valve switching. Data collection and processing are done entirely in the CPU with the final concentration values being sent to a D/A converter to produce the instrument analog output.

The computer memory is divided into 3 sections: ROM memory contains the multi-tasking operating system code plus the instructions that run the instrument. The RAM memory is used to hold temporary variables and current concentration data. The EEPROM memory contains the instrument set-up variables such as range and instrument ID number. The EEPROM data is non-volatile so the instrument can lose power and the current set-up information is preserved.

4.3.4 V/F Board

Computer communication is done via 2 major hardware assemblies. These are the V/F board and the front panel display/keyboard.

The V/F board is multi-functional, consisting of A/D input channels, digital I/O channels, and analog output channels. Communication with the computer is via a STD bus interface. The computer receives all of the instrument data and provides all control functions through the V/F board.

4.3.5 Front Panel

The front panel of the M400A is shown in Figure 4-2. The front panel consists of a 2 line display, keyboard, 3 status LED's and power switch. Communication with the display, keyboard, and status LED's is done via the computer's on-board parallel port. All major operations can be controlled from the front panel display and keyboard.

4.3.5.1 Display

The top line of the display is divided into 3 fields, and displays information. The first field is the mode field. A list of operating modes is given in Table 4-1. The center field displays TEST values or WARNING messages. The TEST functions are described in Table 9-1. The meaning of the WARNING messages is given in Table 9-2. In DIAGNOSTIC mode the center field is used to report the results of the diagnostic tests. The right hand field shows current ozone concentration.

Table 4-1: System Modes

Mode	Meaning
SAMPLE	Sampling normally, flashing indicates adaptive filter is on
SAMPLE xx (1)	Sampling normally with AutoCal enabled
ZERO CAL x (2)	Doing a zero check or adjust
SPAN CAL x (2)	Doing a span check or adjust
MP CAL	Doing a multi-point calibration
SETUP xxx (3)	Configuring analyzer (sampling continues)
DIAG I/O	Diagnostic Mode, Test digital I/O signals
DIAG AOUT	Diagnostic Mode, Test analog output channels
DIAG D/A	Diagnostic Mode, Configure and Calibrate D/A outputs
DIAG O3GEN	Diagnostic Mode, Ozone Generator Calibration
DIAG TCHN	Diagnostic Mode, Configure Test Channel output
(1) xx = A (AutoCal enabled) (2) x = M (manual cal), A (cal with AutoCal sequence), R (cal using remote contact closure or RS-232) (3) xxx = software revision	

4.3.5.2 Programmable Pushbuttons

The 8 pushbuttons below the display are programmable by the CPU in that their functions change depending on the mode of the Analyzer or the operations being performed. The legend above a button identifies its current function. If there is no legend above a button, it has no function and will be ignored if pressed.

4.3.5.3 Keyboard

The second line of the display contains eight fields. Each field defines the key immediately below it. By redefining the keys dynamically it is possible to simplify the instrument electronics and user interface. Figure 5-1 and Figure 5-2 show all of the functions of the keyboard.

When entering data in the keyboard, if the entered value is not accepted, the M400A will "beep" to notify the user that the value keyed in was not accepted. The original value remains unchanged.

4.3.5.4 Status LED's

At the right of the display there are 3 status LED's. They can be in three states, OFF, ON, and BLINKING. The meanings of the LED's are given in Table 4-2.

Table 4-2: Status LED’s

LED	State	Meaning
Green (Sample)	On Off Blinking	Monitoring normally, taking DAS data NOT monitoring, DAS disabled Monitoring, DAS in HOLDOFF mode (1)
Yellow (Cal)	Off On Blinking	Auto cal. Disabled Auto/Dynamic cal. Enabled Calibrating
Red (Fault)	Off Blinking	No warnings exist Warnings exist
(1) This occurs during Calibration, DAS holdoff, Power-up Holdoff,and when in Diagnostic mode.		

4.3.5.5 Power Switch

The power switch has two functions. The rocker switch controls overall power to the instrument, in addition it includes a circuit breaker. If attempts to power up the M400A result in a circuit breaker trip, the switch automatically returns to the off position, and the instrument will not power up.

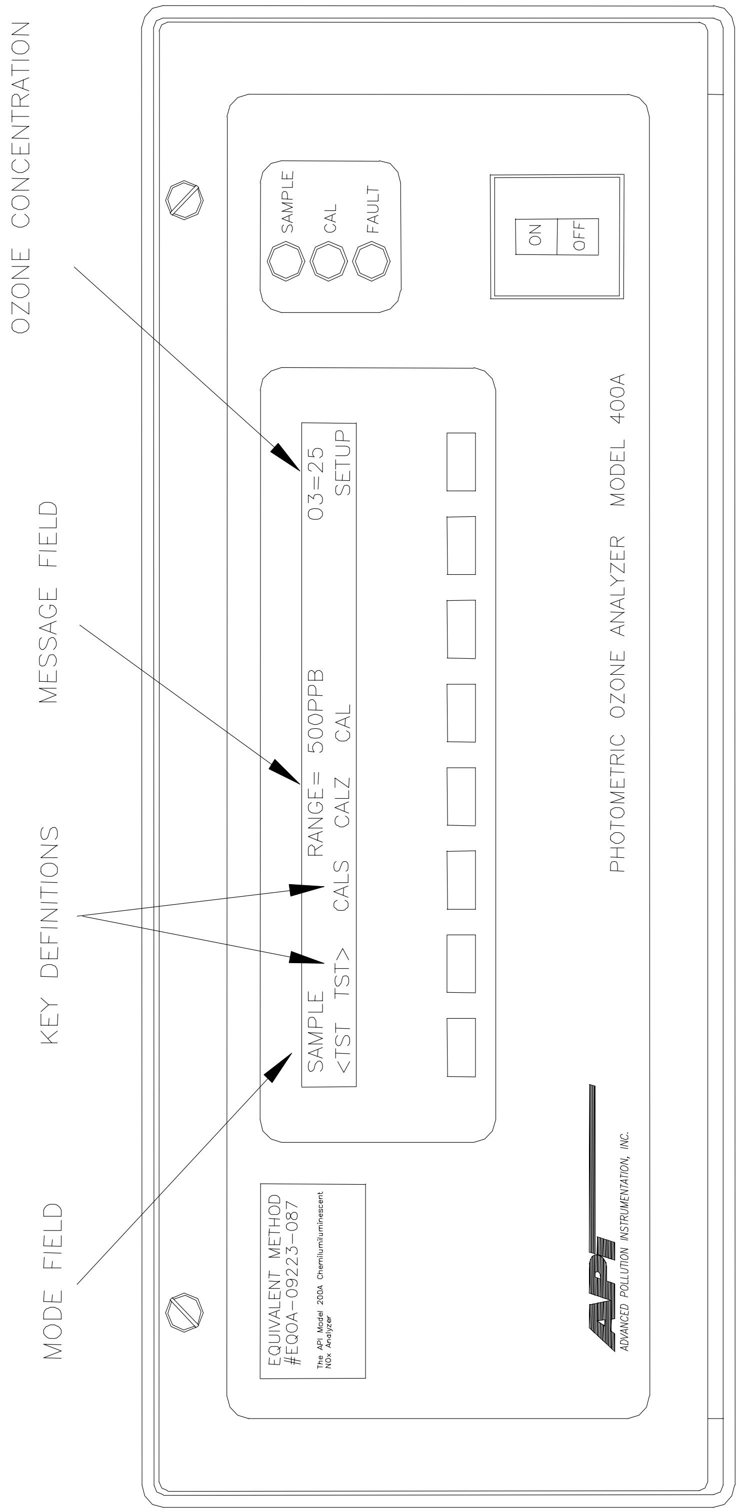


Figure 4-2: Front Panel

4.3.6 Power Supply Module

The Power supply module supplies AC and DC power to the rest of the instrument. It consists of a 4 output linear DC power supply and a 24 volt switching supply. In addition, it contains the switching circuitry to drive the DC operated valves and several switched AC loads to operate the Bench, IZS, and UV lamp heaters.

4.3.7 Pump, Valves, Pneumatic System

The M400A is equipped with a vacuum pump capable of pulling 800 cc/min across a critical flow orifice. This allows a smooth, stable flow of sample through the Analyzer.

An internal pump comes as standard equipment with the M400A. As an option, the M400A can be supplied with an external sample pump.

A critical flow orifice is used to control the sample flow. The orifice is a precision-drilled sapphire jewel protected by a 20 micron sintered filter. The critical flow orifice never needs adjustment and maintains precise flow control as long as the ratio of the up-stream to down-stream pressures is greater than 0.53 (sonic flow conditions).

A standard M400A comes with 1 valve. The Sample/Reference valve switches sample gas either directly from the sample inlet port or gas from the ozone scrubber into the Optical Bench Assembly. An optional second valve can be supplied either as part of the IZS option or to supply external calibration gas.

Sample enters the Analyzer through a 5 micron TFE particulate filter element (37 mm dia. Std. or 47 mm dia. optional) located behind the fold down front panel. The sample then enters directly into the sample cell. Flow diagrams are shown in Figure 8-3 and Figure 8-4.

5 SOFTWARE FEATURES

5.1 Index To Front Panel Menus

Figure 5-1 and Figure 5-2 show a "tree" menu structure to let you see at a glance where each software feature is located in the front panel menus.

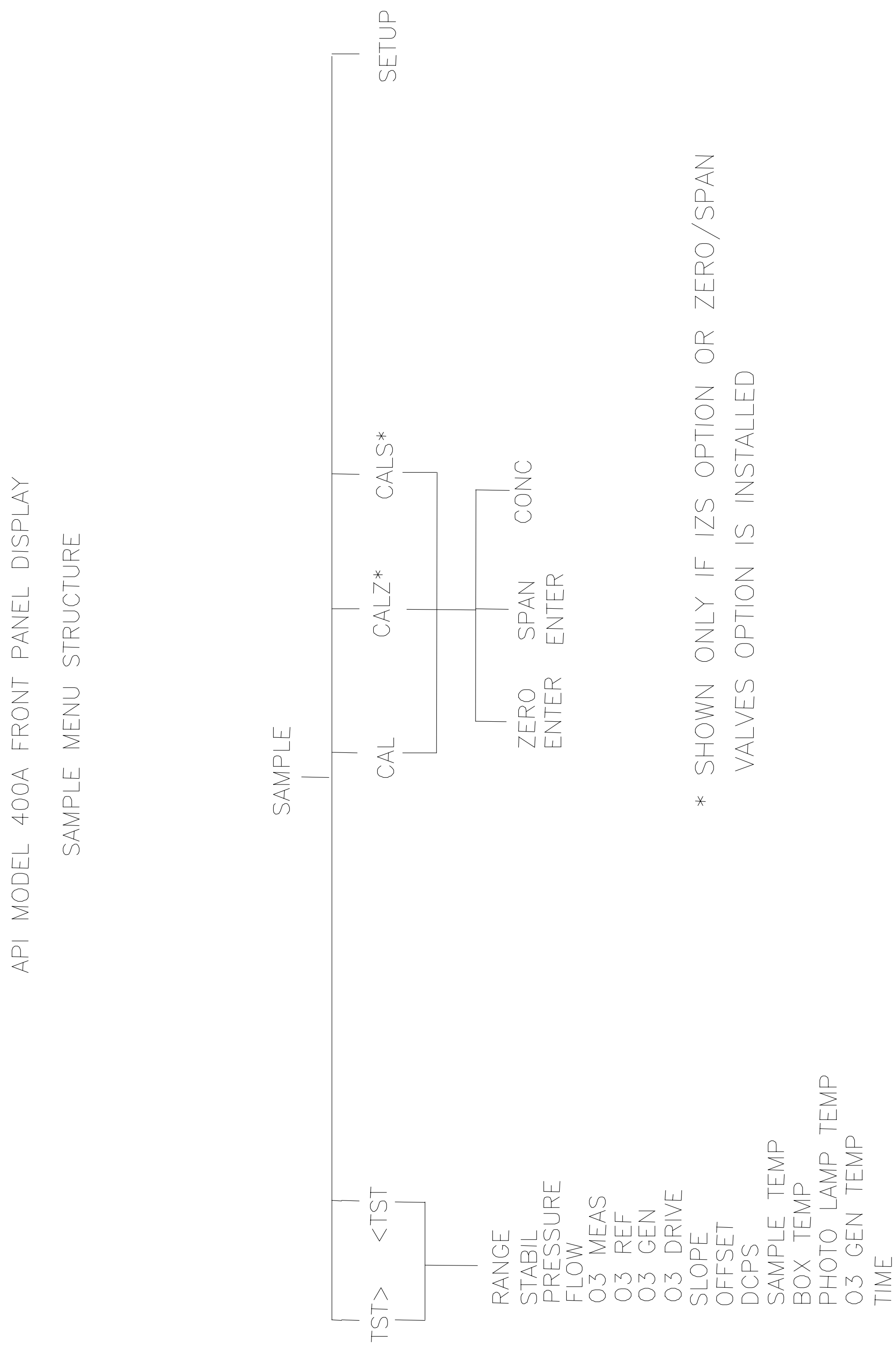


Figure 5-1: Sample Menu Tree

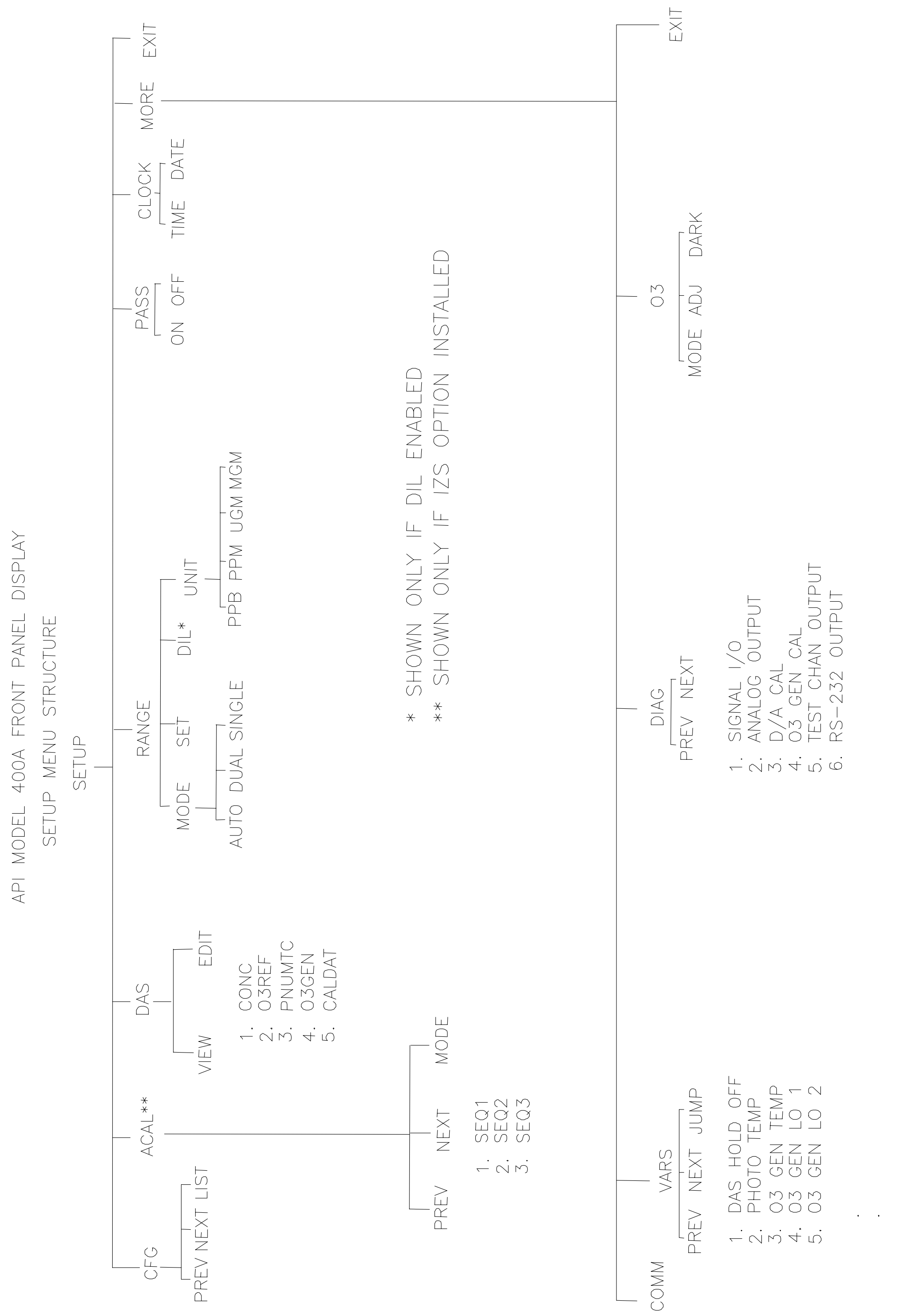


Figure 5-2: Setup Menu Tree

5.2 Sample Mode

5.2.1 Test Functions

NOTE

In any of the following TEST functions, if a value of XXXX is displayed, that indicates an off scale and therefore meaningless reading.

To use the TEST functions to diagnose instrument faults, refer to Troubleshooting Section 9.

Range

This is the range of the instrument. The M400A has one physical range that covers the entire concentration range from 100 to 20,000 ppb full scale. The front panel display will always show the concentration correctly no matter what range the instrument is operating in. The rear panel analog output for each range is scaled to fit the range of voltage or current the instrument is set up for.

There are 3 range modes to choose from:

1. **Single range** mode sets a single maximum range for the instrument analog output.

2. **Autorange** mode allows a low range and high range. The M400A will automatically switch to the other range dynamically as concentration values require. The TEST values will show the range the instrument is currently operating in, and will dynamically display the alternate range as the range changes occur.

3. **Dual range** provides 2 continuous analog outputs on the rear panel, each output is scaled to the range selected by the user.

NOTE

Each of the range modes Single range, Autorange, and Independent ranges are mutually exclusive.

Stability

The instrument noise is computed using the standard deviation of the last 10 minutes of data, with the value being updated at the end of each measure/reference cycle. The value only becomes meaningful if sampling a constant concentration for more than 10 minutes. The value should be compared to the value observed in the factory checkout.

O_3 Measure Voltage

The O_3 Measure Signal is the intensity of light when sample gas was in the Optical Bench during the most recent measurement cycle. This voltage is the digitized mV reading measured by the V/F board.

O_3 Reference Voltage

The O_3 Reference Signal is the intensity of light when reference gas was in the Optical Bench during the most recent measurement cycle. This voltage is the digitized mV reading measured by the V/F board.

O_3 Generator Reference Detector (IZS option only)

This is the Ozone Generator UV lamp intensity measured by the Reference Detector option in the IZS ozone generator. This signal is used to control the drive current to the lamp, thus improving the stability of the IZS ozone output.

O_3 Generator Drive Voltage (IZS option only)

The Drive Voltage a DC voltage used to program the power supply for the ozone generating UV lamp in the IZS option. The value of this voltage determines the concentration of ozone generated by the IZS.

Vacuum

Vacuum is the absolute pressure measured down stream of the sample flow orifice. Typical readings are 12 in-Hg-Abs.

Sample Pressure

The pressure in the sample inlet line is measured by a solid state pressure sensor, which measures absolute pressure. Absolute pressure was chosen because it is an unambiguous measure of sample pressure. This pressure typically runs 0.5" or so below atmospheric pressure due to the pressure drop in the sample inlet lines.

Absolute atmospheric pressure is about 29.92 in-Hg-A at sea level. It decreases about 1” per 1000 ft gain in altitude. Several additional factors cause changes in atmospheric pressure. Air conditioning systems, passing storms, and air temperature can change the absolute pressure by a few tenths of an inch of Hg.

Sample Flow

The SAMPLE FLOW test function is computed from the pressure measured up-stream of the sample flow orifice. The pressure down-stream of the orifice is also checked to assure the assumptions of the equation are valid. The Sample Flow TEST function will register variations in flow caused by changes in ambient pressure, but will not detect a plugged sample flow orifice. The nominal value is 800 ± 80 cc/min.

Sample Temperature

Sample temperature is measured in the optical bench assembly at the midpoint of the quartz absorption tube. It is used in the computation of the ozone concentration.

Photo Lamp Temperature

The source lamp in the optical bench is temperature controlled to 52 deg C to maintain a stable UV output. Once the instrument temperatures have stabilized, the photometer lamp temperature should be 52 ± 0.5 deg C.

O_3 Generator Temperature (IZS option only)

The ozone generator housing containing the ozone generating lamp is temperature controlled at 48 deg C to maintain a stable output from the ozone generator. Once the instrument temperatures have stabilized, the ozone generator temperature should be 48 ± 0.5 deg C.

Orifice Temperature

This TEST function monitors the orifice temperature. The value of the orifice temperature is used in the calculation of the sample flow to correct for air density changes due to the sample temperature inside the orifice manifold. For instruments with the IZS option, the orifice is temperature controlled to 45 deg C to maintain very stable sample flow, which is necessary for stable operation of the IZS ozone generator.

Box Temperature

This TEST function measures the temperature inside the M400A chassis. The temperature sensor is located on the I^2C adapter card on the CPU board.

DC Power Supply (DCPS)

The DCPS voltage is a composite of the 5 and ± 15 VDC voltages in the Power Supply Module. This is meant to be a quick indicator to show if the PSM is working correctly. The nominal value is 2500 mV ± 100 mV.

O_3 Slope Value

The slope is the ‘m’ coefficient of the straight line equation (y = mx + b). The value of the slope term sets the calibration of the M400A. The slope can be thought of as a gain term which determines the steepness of the calibration curve. If DUAL RANGE is enabled there are 2 slope terms, one for each range.

O_3 Offset Value

The offset term is the ‘b’ coefficient of the straight line equation (y = mx + b). The value of the offset term sets the zero point of the M400A.

Test Value

Many of the internal voltages measured by the M400A can be routed to this analog output channel for test purposes. See Trouble shooting Section 9 for details on using this function.

Time

This is the output of the M400A's internal time of day clock.

5.2.2 CAL, CALS, CALZ, Calibration Functions

5.2.2.1 CAL, CALS, CALZ

The CAL button switches the M400A into calibration mode. CAL mode allows the instrument to be calibrated with zero or span gas coming in through the sample port. When in calibration mode, the expected span gas concentration can be entered. See Section 7 for details on instrument calibration.

The CALS and CALZ buttons control the operation of the IZS option or Zero/Span Valves option. CALS switches the IZS valve to admit span gas into the Optical Bench. Span checks or span calibrations can be done in CALS mode.

CALZ switches the IZS valve to admit zero gas into the Optical Bench. Zero checks or zero calibration can be done in CALZ mode.

NOTE

When operating the M400A with the IZS option, the CALZ and CALS operations should be used only to perform zero and span checks and should not be used to calibrate the instrument.

5.2.2.2 Zero

Pressing the ZERO key along with ENTR will cause the instrument to adjust the OFFSET value of the calibration equation. The M400A will only allow zero adjustment over a limited range of signal levels, therefore the signal does not have to be exactly zero for the instrument to do a zero cal. The instrument will not, however allow a zero cal on any signal level, therefore it is not possible to zero the instrument with span gas in the optical bench. If the ZERO key does not come on as expected, check Section 9.2.7.

5.2.2.3 Span

Pressing the SPAN key along with ENTR will cause the instrument to adjust the SLOPE value of the calibration equation. The concentration value will be adjusted to the value entered for the expected span concentration.

Like ZERO calibration, the instrument will not allow span on any ozone concentration. If the SPAN key is not illuminated as expected, see Section 9.2.6. It is also possible that at low levels of ozone that BOTH the ZERO and SPAN keys will be illuminated. If this condition occurs, use extra caution so the correct operation is done so the M400A does not become mis-calibrated.

5.2.2.4 Ozone Calibration Concentration

Before the M400A can be span calibrated, the expected ozone span concentration must be entered. This is done by entering CAL-CONC-SPAN, then keying in the expected span value.

5.3 Set-Up Mode

This section describes how to configure the Analyzer.

The setup variables are summarized in Table 5-1 in terms of the button sequences used to access them.

Table 5-1: Setup Variables

Button Sequence	Function	Default	Limits
CAL-CONC-SPAN	Set O_3 span value	400 ppb	0-10000 ppb
CALS-CONC-O3GEN	IZS O_3 concentration	400 ppb	0-1500 ppb
SETUP-ACAL-SEQ1	Setup auto-cal sequence	Disabled	
SETUP- ACAL -SEQ2	Setup auto-cal sequence	Disabled	
SETUP- ACAL -SEQ3	Setup auto-cal sequence	Disabled	
SETUP-DAS-VIEW	View DAS data		
SETUP-MORE-COMM-BAUD	RS-232 baud rate	19,200 baud	300, 1200, 2400, 9600, 19.2
SETUP-MORE-COMM-ID	Analyzer ID number	0400	0000-9999
SETUP-MORE-O3- ADJ	IZS lamp setup/adj		
SETUP-MORE-O3-DARK-CAL	Detector dark offset calibration		
SETUP-MORE-O3-DARK-EDIT	Dark signal offset	125 mV	75-175 mV
SETUP-MORE-O3-MODE	IZS feedback enable		
SETUP-CLK-TIME	Current time-of-day	00:00	00:00-23:59
SETUP-CLK-DATE	Current date	01 JAN 00	01 JAN 00 - 31 DEC 99
SETUP-RNGE-SET	D/A output range	500 ppb	100-20000
SETUP-RNGE-MODE	D/A output range mode	SNGL	SNGL, DUAL, AUTO
SETUP-RNGE-UNITS	O_3 conc. units	ppb	ppb/ppm/ug/mg
SETUP-PASS	Cal. Password enab.	OFF	OFF-ON
SETUP-CFG	Software config.		

ALL the setup variables are stored in the Analyzer's EEPROM and are retained during power off and even when new software revisions are installed.

NOTE

If a variable is modified, but ENTR is not pressed, the variable will not be changed and the analyzer will beep when EXIT is pressed.

5.3.1 Configuration Information (CFG)

The software configuration can be displayed by entering the button sequence SETUP-CFG. PREV/NEXT buttons allow scrolling through the configuration parameters. For example the M400A should display:

```
M400A O3 ANALYZER

SBC40 CPU
```

This feature is useful for showing any special features that are present in the currently installed PROM.

5.3.2 Automatic Calibration (ACAL)

The AutoCal feature allows the M400A to automatically operate the Zero/Span Valve or IZS option to periodically check its calibration. Information on setting up AutoCal is in Section 6.4.

5.3.3 Data Acquisition System (DAS)

The Model 400A contains a flexible and powerful built in data acquisition system (DAS) that enables the analyzer to store concentration data as well as many diagnostic parameters in its battery backed memory. This information can be viewed from the front panel or printed out through the RS-232 port. The diagnostic data can be used for performing “Predictive Diagnostics” and trending to determine when maintenance and servicing will be required.

The logged parameters are stored in what are called “Data Channels.” Each Data Channel can store multiple data parameters. The Data Channels can be programmed and customized from the front panel. A set of default Data Channels has been included in the Model 400A software. These are described Section 5.3.3.1. For more information on programming custom Data Channels, a supplementary document containing this information can be requested from Teledyne API.

5.3.3.1 Data Channels

The function of the Data Channels is to store, report, and view data from the analyzer. The data may consist of ozone concentration, or may be diagnostic data, such as the sample flow or detector output.

The M400A comes pre-programmed with a set of useful Data Channels for logging ozone concentration and predictive diagnostic data. The default Data Channels can be used as they are, or they can be changed to fit a specific application. They can also be deleted to make room for custom user-programmed Data Channels.

The data in the default Data Channels can be viewed through the **SETUP-DAS-VIEW** menu. Use the **PREV** and **NEXT** buttons to scroll through the Data Channels and press **VIEW** to view the data. The last record in the Data Channel is shown. Pressing **PREV** and **NEXT** will scroll through the records one at a time. Pressing **NX10** and **PV10** will move forward or backward 10 records. For Data Channels that log more than one parameter, such as PNUMTC, buttons labeled **<PRM** and **PRM>** will appear. These buttons are used to scroll through the parameters located in each record.

The function of each of the default Data Channels is described below:

CONC: Samples ozone concentration (Low Range) at one minute intervals and stores an average every hour with a time and date stamp. Readings during calibration and calibration hold off are not included in the data. The last 800 hourly averages are stored.

O3REF: Samples detector reference value at five minute intervals and stores an average once a day with a time and date stamp. This data is useful for monitoring lamp intensity over time to predict when adjustment or replacement of the lamp will be required. The last 730 daily averages (about 2 years) are stored.

PNUMTC: Collects sample flow and sample pressure data at five minute intervals and stores an average once a day with a time and date stamp. This data is useful for monitoring the condition of the pump and critical flow orifice(sample flow) and the sample filter(clogging indicated by a drop in sample pressure) over time to predict when maintenance will be required. The last 360 daily averages (about 1 year) are stored.

O3GEN: Samples ozone generator lamp drive voltage at five minute intervals and stores an average once a day with a time and date stamp. This data is useful for monitoring the condition of the ozone generating lamp in the IZS option. A rise in lamp drive voltage when the ozone generator is being operated in REF mode is a measure of lamp decay. The last 360 daily averages are stored.

CALDAT: Logs new slope and offset every time a zero or span calibration is performed. This Data Channel also records the instrument reading just prior to performing a calibration. ***Note:*** this Data Channel collects data based on an event(a calibration) rather than a timer. This Data Channel will store data from the last 200 calibrations. This does not represent any specific length of time since it is dependent on how often calibrations are performed. As with all Data Channels, a time and date stamp is recorded for every data point logged.

5.3.4 Range Menu (RNGE)

The O_3 concentration range is the concentration value that corresponds to the maximum voltage output at the rear panel. The M400A can operate in one of three analog output Range Modes. The Range Mode can be changed through the **SETUP-RNGE-MODE** menu. The modes are described below:

5.3.4.1 Single Range Mode

In this mode, both analog outputs (REC and DAS) are set to the same range. This range can be set to any value between 100 and 20,000 ppb and is accessed through the **SETUP-RNGE-SET** menu. This is the default range mode for the analyzer.

5.3.4.2 Dual Range Mode

Selecting dual range mode will allow you to select different ranges for the REC and DAS analog outputs. The two ranges are called Low and High. The REC output at the rear panel is used for the Low range and the DAS output is used for the High range. To set the ranges press **SETUP-RNGE-SET** and select which range you want to edit followed by **ENTR**. The High and Low ranges have separate slopes and offsets for computing the ozone concentration. Therefore, the two ranges must be independently calibrated. See Section 7.7 for details on calibrating the two ranges.

5.3.4.3 Auto Range Mode

In auto range mode, the analyzer automatically switches between the Low and High range depending on the concentration. When the O_3 concentration increases to 98% of the Low range value, the analyzer will switch to the High range. The analyzer will remain in the High range until the O_3 concentration drops to 75% of the Low range value. It will then switch back to the Low range. Auto ranging changes the range for the REC and DAS outputs simultaneously. To set the ranges press **SETUP-RNGE-SET** and select which range you want to edit followed by **ENTR**.

The High and Low ranges have separate slopes and offsets for computing the ozone concentration. Therefore, the two ranges must be independently calibrated. See Section 7.7 for details on calibrating the two ranges.

5.3.4.4 Concentration Units

The M400A can display concentrations in ppb, ppm, ug/m^3, mg/m^3 units. Concentrations displayed in mg/m^3 and ug/m^3 use 0° C, 760 mmHg for STP. Consult your local regulations for the STP used by your agency. The following equations give approximate conversions:

O_3 ppb x 2.14 = O_3 ug/m^3

O_3 ppm x 2.14 = O_3 mg/m^3

To change the current units press **SETUP-RNGE-UNIT** from the SAMPLE mode and select the desired units.

NOTE

The expected span concentration values in the new units must be re-entered into the analyzer and the unit re-calibrated using one of the methods in Section 7.

Changing units affects all of the RS-232 values, all of the display values, and all of the calibration values.

Example: If the current units are in ppb and the O_3 span value is 400 ppb, and the units are changed to ug/m^3 the span value is NOT re-calculated to the equivalent value in ug/m^3. The new value of 856 ug/m^3 must be entered for the expected span concentration.

5.3.4.5 Dilution Ratio

The dilution feature allows you to use the M400A with an additional external system that dilutes the sample gas. With the Dilution feature you can select the range and display the concentration at the value and units of the un-diluted gas.

The software scales the diluted sample gas concentration readings so that the outputs show the un-diluted concentrations. Also, when calibrating the instrument or setting the ranges the values selected are scaled to reflect the actual un-diluted concentrations. The scaled readings are sent to the display, analog outputs, and RS-232 port.

To use the Dilution feature:

1. SELECT UNITS. To set units, press **SETUP-RANGE-UNIT**. Press **ENTR** after the unit selection is made, then **EXIT** to return to upper level menus.
2. SET DILUTION RATIO The dilution ratio of the probe is entered by **SETUP-RANGE-DIL**. Accepted values are 1 to 1000. Press **ENTR**, and **EXIT** to return to upper level menus. A value of 1 disables the dilution feature.

3. SELECT RANGE The range selection is the same with dilution as with normal monitoring. See Section 5.3.4 for information on range selection. You should note however, the value entered should be the actual concentration of the un-diluted calibration gas. The units of this number is ppm.
4. CALIBRATION When the above selections have been made, the instrument now must be calibrated with the dilution system in place. See Section 7 for calibration methods.

5.3.5 Password Enable (PASS)

The M400A provides password protection of the calibration and setup functions to prevent incorrect adjustments. There are three levels of password protection, which correspond to operator, supervisor/maintenance, and configuration functions. When prompted for a password, any of the valid passwords can be entered, but the CPU will limit access to the functions allowed for that password level. Each level allows access to the functions of all the levels below plus some additional functions. Table 5-2 lists the password levels and the functions allowed for each level.

To disable passwords, press **SETUP-PASS** and select **OFF**.

Table 5-2: Password Levels

Password Levels		
Password	**Level**	**Functions Allowed**
No password	0	TEST MSG CLR
Operator - 101	1	CALZ CALS CAL
Setup - 818	2	SETUP SETUP-VARS SETUP-DIAG

5.3.6 Time of Day Clock (CLK)

The M400A has a time of day clock that supports the AutoCal timer, time of day TEST function, and time stamps on most RS-232 messages.

To set the time-of-day, press **SETUP-CLK-TIME.** The CPU will display the current time-of-day as four digits in the format "HH:MM", where "HH" is the hour in 24-hour format (i.e. hours range from 00 to 23) and "MM" is the minute (00 - 59). The operator may change the time-of-day and then press **ENTR** to accept the new time, or press **EXIT** to leave the time unchanged.

To set the current date, press **SETUP-CLK-DATE**. The CPU will display the current date as "DD MMM YY". For example, April 1, 1997 would be displayed as "01 APR 97". Change the date by pressing the button under each field until the desired date is shown. Then press **ENTR** to accept the new date or press **EXIT** to leave the date unchanged.

In order to compensate for clocks which run a fast or slow, there is a variable to speed up or slow down the clock by a fixed amount every day. To change this variable, press **SETUP-MORE-VARS**. Press **NEXT** until the CLOCK_ADJ variable is displayed. To change the setting, press the **EDIT** key and enter the value from the keyboard. Press **ENTR** to accept the change. The value entered represents the number of seconds per day the clock gains or loses. It should only need to be set once for each Analyzer. For example, if the clock is running 10 seconds fast each day, set the variable to -10 and press **ENTR.** This will cause the clock to run slower by 10 seconds each day.

5.3.7 Communications Menu (COMM)

The COMM menu allows you to set the Baud Rate for RS232 communications and the instrument ID.

To select the Baud Rate, press **SETUP-MORE-COMM-BAUD** and select from the available baud rates and press **ENTR**.

To select the Instrument ID, press **SETUP-MORE-COMM-ID** and enter a four digit ID number for the instrument.

NOTE

Multidrop RS232 operation only supports the use of a three digit ID number. In this case, set the first digit in the ID to 0.

See Section 5.5 for more details on the operation of the RS232 interface.

5.3.8 Variables Menu (VARS)

Table 5-3 lists the variable names which are present in the Variables Menu. Variables are also accessible through the RS-232 interface.

Table 5-3: RS-232 Variable Names

Variable Name	Legal Values
DAS_HOLD_OFF	0.5 – 20 min
PHOTO_LAMP	0.0 to 100.0^{o} C
O3_GEN_LAMP	0.0 to 100.0^{o} C
O3_GEN_LOW1	0 – 1500 ppb
O3_GEN_LOW2	0 – 1500 ppb
ORIFICE_SET	0 – 100^{o} C
SAMPLE_FLOW_SET	100 – 1000 cc/min
RS232_MODE	0 to 32767 Bit
CLOCK_ADJ	-60 to 60 sec/day

5.3.9 Diagnostic Mode (DIAG)

The Diagnostic menu contains several diagnostic tests and setup menus for diagnosing operational problems and performing setup functions that are not part of routine operation. The Diagnostic menu is accessed by pressing **SETUP-MORE-DIAG** from the front panel and entering the diagnostic password. Note: The Diagnostic password is always enabled, even when the other setup passwords are disabled. The diagnostic tests and setup are described in detail in Section 9.1.3 of this manual.

5.4 Status Outputs

Status outputs report analyzer conditions via contact closures located on the DB-50 connector on the rear panel. The pin assignments are listed in Table 5-4:

Table 5-4: Status Outputs

Output #	PIN Pair (low/high)	Status	Condition
1	1, 2	ZERO CAL	ON IN ZERO CALIBRATE
2	3, 4	SPAN CAL	ON IN SPAN CALIBRATE
3	5, 6	FLOW ALARM	ON IF FLOW WARNING
4	7, 8	TEMP ALARM	ON ANY TEMP WARNING
5	9, 10	DIAG MODE	ON IN DIAGNOSTIC MODE
6	11,12	POWER ON	ON IF M400A IS RUNNING
7	13,14	PRESS ALARM	ON IF LOW PRESSURE
8	15,16	LOW SPAN CAL	ON IF IN LOW SPAN CALIBRATE
9	17,18	SYSTEM OK	ON IF NO FAULTS PRESENT, OFF IF FAULT CONDITION EXISTS
10	19,20	LAMP WARNING	ON IF UV LAMP INTENSITY IS OUT OF LIMITS
11	21,22	HIGH RANGE	ON IF UNIT IS IN HIGH RANGE

5.5 RS-232 Interface

The Model 400A ozone Analyzer features a powerful RS-232 interface which is used both for reporting test results and for controlling the Analyzer from a host computer. Because of the dual nature of the RS-232 interface, the message format has been carefully designed to accommodate both printers and host computers. Tips on connecting the RS-232 port can be found in the Section 9.3.3.

All message outputs from the Model 400A have the following format:

```
X DDD:HH:MM IIII MESSAGE<CRLF>
```

The **"X"** is a character indicating the message type shown in Table 5-5.

Table 5-5: RS-232 Message Types

First Character	Message Type
C	Calibration
D	Diagnostic
L	Logon
T	Test measurement
V	Variable
W	Warning

The "**DDD:HH:MM**" is a time-stamp indicating the day-of-year ("**DDD**") as a number from 1 to 366, the hour of the day ("**HH**") as a number from 00 to 23, and the minute ("**MM**") as a number from 00 to 59.

The "**IIII**" is a 4-digit Analyzer I.D. number.

The "**MESSAGE**" field contains variable information such as warning messages, test measurements, DAS reports, etc.

The "<**CRLF**>" is a carriage return-line feed combination which terminates the message and also makes the messages appear neatly on a printer. All RS-232 messages from the analyzer are terminated in this manner.

The uniform nature of the output messages makes it easy for a host computer to parse them.

Input messages to the Model 400A have a format which is similar to that for output messages:

"X command<CRLF>"

The "**X**" indicates the message type as shown above in Table 5-5 and "**command**" is the command type, each of which is described individually below.

The "<**CRLF**>" is used to terminate the command. Typing "<**CRLF**>" a few times by itself is a good way to clear the input buffer of any extraneous characters.

5.5.1 Setting Up the RS-232 Interface

The RS-232 communications protocol allows the instrument to be connected to a wide variety of computer based equipment. The interface provides two basic functions in the M400A.

1. First is a comprehensive command interface for operating and diagnosing the analyzer.
2. The interface can also provide an audit trail of analyzer events. In this function the port sends out messages about instrument events like calibration or warning messages. If these messages are captured on a printer or remote computer, they provide a continuous audit trail of the analyzers operation and status.

The baud rate is set from the front panel by SETUP-MORE-COMM-BAUD. Select the baud rate appropriate for your application, 300, 1200, 2400, 4800, 9600, or 19,200. It is important to note that the other device must have identical settings in order for the communications to work correctly.

Second is physical wiring of the analyzer to the other unit. We have incorporated into the Analyzer LED's that signal the presence of data on the communications lines, and also switches to easily re-configure the analyzer from DCE to DTE if necessary. In addition the front panel diagnostics allow test data streams to be sent out of the port on command. This flexibility and diagnostic capability should simplify attaching our equipment to other computers or printers. If problems occur, see the Troubleshooting Section 9.3.3.

Setup from the Front Panel

There are 2 additional RS-232 setups that can be done via the front panel.

1. Set the instrument ID number by SETUP-MORE-COMM-ID, and enter a 4-digit number from 0000-9999. This ID number is part of every message transmitted from the port.
2. Set the RS-232 mode bit field in the VARS menu. To get to the variable press, SETUP-MORE-VARS, then ENTR and scroll to RS232_MODE, then press EDIT. The possible values are shown in Table 5-6. Typical RS-232 configurations are shown in Table 5-7.

Table 5-6: RS-232 Mode Setup - Front Panel

Decimal Value	Description
1	Turns on quiet mode (messages supressed)
2	Places analyzer in computer mode (no echo of chars)
4	Enables Security Features (Logon, Logoff)
8	Enables Teledyne API protocol and setup menus
16	Enable alternate protocol
32	Enable multidrop protocol

NOTE

To enter the correct value, ADD the decimal values of the features you want to enable. For example if LOGON and front panel RS-232 menus are desired, the value entered would be 4 + 8 = 12.

Table 5-7: Typical RS-232 Configurations

Configuration	RS232_MODE Setting
Normal Status, warning, DAS messages reported. Characters echoed. Line editing allowed. No security or multidrop.	8
Computer Status, warning, DAS messages suppressed. Characters not echoed. Line editing disabled. No security or multidrop.	11
Security Status, warning, DAS messages reported. Characters echoed. Line editing allowed. No multidrop.	12
Hessen protocol (optional) Status, warning, DAS messages suppressed. Characters not echoed. Line editing disabled. Alternate protocol enabled; native protocol disabled. No security or multidrop.	19
Multidrop Status, warning, DAS messages suppressed. Characters not echoed. Line editing disabled. Commands must include ID number. No security. Multidrop.	43

Security Feature

The RS-232 port is often connected to a public telephone line, which could compromise instrument security. If the LOGON feature is implemented, the port has the following attributes:

1. A password is required before the port will operate.
2. If the port is inactive for 1 hour, it will automatically LOGOFF.
3. Repeat attempts at logging on with incorrect passwords will cause subsequent logins (even with the correct password) to be disabled for 1 hour.
4. If not logged on, the only command that is active is the '?'.

5. The following messages will be given at logon.

`LOG ON SUCCESSFUL`	Correct password given
`LOG ON FAILED`	Password not given or incorrect
`LOG OFF SUCCESSFUL`	Logged off

The RS-232 LOGON feature must be enabled from the front panel by setting bit 4. See Table 5-6. Once the feature is enabled, to logon type:

`LOGON 940331` or

`LOGON 0400 940331` - if instrument ID is used

940331 is the default password. The password can be changed to any number from 0 to 999999 by the variable RS232_PASS. To change the password enter the command

```
V RS232_PASS=NNNNNN
```

which sets the password to the value NNNNNN.

Protocol of Port Communication

The RS-232 interface has two protocols of communication, because if the port is attached to a computer it needs to have different characteristics than if used interactively. Consequently, there are two primary styles of operation: terminal mode and computer mode.

When an operator is communicating with the analyzer via a terminal, the analyzer should be placed into TERMINAL MODE, which echoes keystrokes, allows editing of the command line using the backspace and escape keys, and allows recall of the previous command. When a host computer or data logger is connected to the analyzer, it should be placed into COMPUTER MODE, which does not echo characters received or allow the special editing keys. See Table 5-8 and Table 5-9 for relevant commands.

Table 5-8: RS-232 Switching from Terminal Mode to Computer Mode

Key	Function
Control-T (ASCII 20 decimal)	Switch to terminal mode (echo, edit)
Control-C (ASCII 3 decimal)	Switch to computer mode (no echo, no edit)

If the command line doesn't seem to respond to keystrokes or commands, one of the first things you should do is send a Control-T to switch the command line interface into terminal mode. Also, some communication programs remove CTRL-T and CTRL-C characters from the byte stream, therefore these characters will not be sent to the analyzer. Check your communications program owners manual.

Entering Commands in Terminal Mode

In terminal mode, all commands must be terminated by a carriage return; commands are not processed until a carriage return is entered. While entering a command you may use the following editing keys:

Table 5-9: RS-232 Terminal Mode Editing Keys

Key	Function
CR (carriage return)	Execute command
BS (backspace)	Backspace one character to the left
ESC (escape)	Erase entire line

Commands are not case-sensitive; you should separate all command elements (i.e. keywords, data values, etc.) by spaces.

Words such as T, SET, LIST, etc. are called keywords and are shown on the help screen in uppercase, but they are not case-sensitive. You must type the entire keyword; abbreviations are not accepted.

NOTE

To open the help screen, Type "?" and press the Enter key.

5.5.1.1 Protocol Selection

The RS-232 interface will support more than one command protocol. Decimal flags 8 and 16 select which protocol is active.

5.5.1.2 Multidrop Mode

The RS-232 interface supports a multidrop configuration (by means of additional external hardware to handle the line arbitration) which allows multiple instruments to be connected to the same RS-232 “bus.” The principal difference between multidrop and non-multidrop mode is that the RS-232 RTS signal is used to turn the drivers in the external hardware on prior to transmitting messages, and turn the drivers off again shortly after transmitting. This multidrop protocol assumes that only one instrument will be transmitting at a time. It is up to the controlling host computer to ensure that this protocol is adhered to.

In addition to hardware-level support, all of the RS-232 interface commands allow an instrument ID number as part of the command. Regardless of whether multidrop mode is enabled, if you include an ID number in a command, the instrument will only process the command if the ID number matches the instrument’s ID number.

In general, the ID number should appear in a command after the first token in the command and preceded by a space. The printout below shows several commands, each with and without ID numbers.

```
?
? 100
logon 940331
logon 100 940331
c zero
c 100 zero
v baud_rate=”2400”
v 100 baud_rate=”2400”
```

Notice in all of the commands, the ID number of “100” appears after the first token in the command. The commands including ID numbers would be executed only if the instrument’s ID number was set to “100”.

5.5.2 Command Summary

Table 5-10 contains a summary of the RS-232 port commands.

Table 5-10: RS-232 Command Summary

Commands	Definition
? [id]	Print help screen. ID is an optional instrument ID number.
T [id] LIST	Print all active test messages
T [id] LIST name or T [id] name	Print single test message "name" from Table 5-13
W [id] LIST	Print all active warnings
W [id] CLEAR name or W [id] name W [id] CLEAR ALL	Clear single warning message "name" from Table 5-14 Clears all warning messages
C [id] ZERO [1|2]	Start remote zero calibration
C [id] LOWSPAN [1|2]	Start remote low span calibration
C [id] SPAN [1|2]	Start remote span calibration
C [id] ASEQ number	Start remote calibration sequence number (1-3)
C [id] EXIT	Terminate remote zero or span calibration
C [id] ABORT	Abort rest of calibration sequence and immediately resume sampling
C [id] COMPUTE ZERO	Calculates a new slope and offset during zero calibration. Must be in zero calibration first.
C [id] COMPUTE SPAN	Calculates a new slope and offset during span calibration. Must be in span calibration first.
D [id] LIST	Prints all I/O signal values
D [id] name	Print single I/O signal value/state
D [id] name=value	Sets I/O signal to new "value"
D [id] LIST NAMES	Lists diagnostic test names
D [id] ENTER name	Enters and starts 'name' diagnostic test
D [id] EXIT	Exits diagnostic mode
D [id] RESET	Resets analyzer(same as power-on)
D [id] RESET RAM	System reset, plus erases RAM. Initializes DAS, O_3, conc readings, calib not affected.

(table continued)

Table 5-10: RS-232 Command Summary (Continued)

Commands	Definition
D [id] RESET EEPROM	System reset, plus erases EEPROM (RESET RAM actions + setup variables, calibration to default values). Restores all factory defaults.
D [id] PRINT	Prints properties for all data channels (DAS)
D [id] PRINT "name”	Prints properties for single data channel. Quotes around name are required.
D [id] REPORT "name" [RECORDS=number] [COMPACT|VERBOSE]	Prints DAS records for a data channel. Quotes around name are required. Parameters in brackets are optional.
LOGON [ID] NNNNNN	Login with password NNNNNN
LOGOFF	Logoff – terminate RS-232 session
V [id] LIST	Print all setup variable names and values
V [id] name	Print individual setup variable value
V [id] name=value	Sets setup variable to new "value"
V [id] CONFIG	Print analyzer configuration
V [id] MODE	Print current analyzer mode

Table 5-11: RS-232 Command Summary

Terminal Mode Editing Keys	Definition
BS	Backspace
ESC	Erase line
CR	Execute command
^C	Switch to computer mode
Computer Mode Editing Keys	**Definition**
LF	Execute command
^T	Switch to terminal mode
Security Features	**Definition**
LOGON [id] password	Establish connection to analyzer
LOGOFF [id]	Disconnect from analyzer

5.5.3 TEST Commands and Messages

To request a test measurement, the host must issue a command of the form:

T *measurement*

For example, the format of the O_3 Reference reading in millivolts would be:

```
T 194:11:29 0400 O3 REF= 2520mV
```

For a summary of all test functions issue the command T LIST. Test measurements request commands are shown in Table 5-12. All the TEST measurements displayed on the front panel display are also available via the RS-232 interface.

Table 5-12: Test Measurements Request Commands

Command	Test Measurement
?	RS-232 HELP screen
T LIST	Summary of all TEST parameters
T O3	Current O_3 reading
T RANGE1	Analog output low range
T RANGE2	Analog output high range
T PHOTOMEAS	Current O_3 meas reading
T PHOTOREF	Current O_3 reference reading
T O3GENREF	Ozone generator reference reading
T O3GENDRIVE	Ozone generator lamp drive voltage
T PHOTOSPRESS	Sample pressure
T PHOTOSFLOW	Sample flow rate
T PHOTOSTEMP	Sample temperature
T PHOTOLTEMP	Analyzer lamp temperature
T O3GENTEMP	IZS lamp temperature
T BOXTEMP	Internal box temperature
T DCPS	DC power supply output
T PHOTOSLOPE	Slope value for Low Range
T PHOTOOFFSET	Offset value for Low Range
T CLOCKTIME	Current time-of-day

5.5.4 WARNING Commands and Messages

Warning messages are sent both to the display and to the RS-232 output. See Table 5-13 for a list of the warning messages. These messages are very helpful when trying to track down a system problem and for determining whether or not DAS average data is actually valid. An example of an actual warning message is:

```
W 194:11:03 0000 SAMPLE FLOW WARN
```

Warnings may be cleared via the RS-232 interface by issuing a command of the form:

`W command`

where "***command***" indicates which warning message to clear. For example, to clear the "SAMPLE FLOW WARN" message, the host computer can issue the command:

```
W WSAMPFLOW
```

Attempting to clear a warning which is not active has no effect. Table 5-13 lists the command to use to clear each possible warning message. W CLEAR ALL clears all warning messages.

Table 5-13: Warning Message Clear Commands

Command	Warning Message Cleared
W CLEAR ALL	CLEARS ALL WARNING MESSAGES
W WSYSRES	SYSTEM RESET
W WRAMINIT	RAM INITIALIZED
W WPHOTOREF	PHOTO REF WARNING
W WILMPHLT	O3 GEN LAMP SHUTDOWN
W WALMPHLT	PHOTO LAMP SHUTDOWN
W WSAMPFLOW	SAMPLE FLOW WARNING
W WSAMPRES	SAMPLE PRESSURE WARNING
W WSAMPTEMP	SAMPLE TEMP WARNING
W WBOXTEMP	BOX TEMP WARNING
W WO3GENTEMP	O3 GEN TEMP WARNING
W WPHOTOLTEMP	PHOTO LAMP TEMP WARNING
W WVFINS	V/F NOT INSTALLED

5.5.5 CALIBRATION Commands and Messages

This subset of messages is concerned with reporting the status of the Analyzer and controlling the Analyzer remotely. Whenever the Analyzer does a calibration it issues a report to the RS-232 output. Table 5-14 lists the status reports.

Table 5-14: Status Reports

Report
C DDD:HH:MM IIII START ZERO CALIBRATION
C DDD:HH:MM IIII FINISH ZERO CALIBRATION
C DDD:HH:MM IIII START SPAN CALIBRATION
C DDD:HH:MM IIII FINISH SPAN CALIBRATION
C DDD:HH:MM IIII START MULTI-POINT CALIBRATION
C DDD:HH:MM IIII FINISH MULTI-POINT CALIBRATION
C DDD:HH:MM IIII START CALIBRATION HOLD
C DDD:HH:MM IIII FINISH CALIBRATION HOLD

To do a remote adjustment via the RS-232 interface, the host computer should issue a message with the following format:

`C command`

Table 5-15: Calibration Commands

Command	Description
C [id] ZERO [1|2][1]	Start remote zero calibration.
C [id] LOWSPAN [1|2][1]	Start remote low span calibration.
C [id] SPAN [1|2][1]	Start remote span calibration.
C [id] ASEQ number	Start remote calibration sequence number (1-3).
C [id] EXIT	Terminate remote zero or span calibration.
C [id] ABORT	Abort rest of calibration sequence and immediately resume sampling.
C [id] COMPUTE ZERO	Calculates a new slope and offset during zero calibration. Must be in zero calibration first.
C [id] COMPUTE SPAN	Calculates a new slope and offset during span calibration. Must be in span calibration first.
[1] This parameter selects the range to calibrate. Nothing or a value of 1 selects the low range; a value of 2 selects the high range.	

Calibration commands are shown on Table 5-15. When a calibration command is issued, the CPU will respond by issuing a status report. For example if the host computer issues the command:

```
C SPAN
```

to do a zero check, the CPU will send the status report

```
C DDD:HH:MM IIII START SPAN CALIBRATION
```

to the RS-232 output.

5.5.6 DIAGNOSTIC Commands and Messages

The diagnostic Signal I/O mode and Ozone Generator Calibration (IZS option) can be entered from the RS-232 port as well as from the front panel. The diagnostics commands available are listed in Table 5-16.

Table 5-16: Diagnostic Commands

Command	Function
D ENTER SIG	Enter diagnostic Signal I/O mode
D ENTER O3GEN	Perform ozone generator calibration
D EXIT	Exit diagnostics mode
D LIST	Prints all Signal I/O values. See Table 9-3 for Signal Definitions
D name[=value]	Examines or sets I/O signal. See Table 9-3 for a list of signals. Must issue D ENTER SIG before using this command.
D RESET	Reset analyzer(same as power on)
D RESET RAM	Resets analyzer and erases RAM. Erases all DAS data. Keeps setup variables and calibration
D RESET EEPROM	Resets analyzer and erases RAM and EEPROM. Erases all DAS data. Resets all setup variables to factory default. Resets calibration values.

These commands may be used whether the diagnostics have been entered from the keyboard (SETUP-DIAG) or the RS-232 (D ENTER).

Whenever the diagnostic mode is entered or exited, a report is issued to the RS-232 output. Table 5-17 summarizes the diagnostic reports.

Table 5-17: Diagnostic Reports

Report
C DDD:HH:MM IIII ENTER DIAGNOSTIC MODE
C DDD:HH:MM IIII EXIT DIAGNOSTIC MODE

5.5.7 DAS Commands and Message

Data from individual Data Channels in the DAS system can be retrieved through the RS-232 interface. The command format for printing the data for a Data Channel is shown below:

`D [id] REPORT "name" [RECORDS=number] [COMPACT|VERBOSE]`

parameters in [ ] are optional

id is the analyzers ID number (**SETUP-MORE-COMM-ID**)

name is the Data Channel name(must be enclosed in quotes)

number is the number of records to print, beginning with the most recent(if this parameter is not specified then all available records for the Data Channel are printed)

COMPACT|VERBOSE refers to the report format.

5.5.7.1 Average Concentration Report

To report the last record from the CONC1 Data Channel in VERBOSE format, type:

```
D REPORT "CONC1" RECORDS=1 VERBOSE
```

```
D 63:11:40 0400 CONC : AVG CONC1 = 482.7 PPB<CRLF>
```

CONC is a user-defined name used to identify the data channel. Following the colon, the report indicates that the average concentration of range 1 ("CONC1") is 482.7 PPB.

5.5.7.2 Calibration Parameter Report

The following DAS report shows the calibration parameters measured during the last span calibration. Notice that there are three lines of output in the report; this is because three data parameters are monitored by this data channel. The name used to identify the channel is "CALDAT," which stands for *calibration data*.

In the first line, after the colon, the report indicates that the new slope ("SLOPE1") calculated is 0.976. In the second line the report indicates that the new offset ("OFSET1") calculated is 0.0 mV. And in the third line the report indicates that the instantaneous concentration ("ZSCNC1") prior to calculating a new slope and offset was 409.9 ppb.

To report the last record from the CALDAT Data Channel in VERBOSE format, type:

```
D REPORT "CALDAT" RECORDS=1 VERBOSE

D 63:11:45 0400 CALDAT: INST SLOPE1= 0.976<CRLF>

D 63:11:45 0400 CALDAT: INST OFSET1= 0.0mV<CRLF>

D 63:11:45 0400 CALDAT: INST ZSCNC1= 409.9 PPB<CRLF>
```

The same calibration parameter report may also appear in *compact* format, with all the parameters on one line, as shown below. This format reduces the amount of output, and is well suited for parsing by a host computer.

```
D 63:11:45 0400 CALDAT: 1 0.976 0.0 409.9<CRLF>
```

Verbose Data Report Format

There are two kinds of data reports: verbose (with a lot of detail) and compact (with just the data point values). The verbose format looks like the following:

```
D 31:10:06 0412 CONC : AVG O3CNC1=6.8 PPB
```

This report uses the format of a leading first character ("D" in this example), a time stamp ("31:10:06"), and the instrument ID ("0412").

The other fields in the report are the data collector name ("CONC"), the sampling mode ("AVG"), the data point ("O3CNC1"), the data point value ("6.8"), and the units ("PPB"). Due to the length of the message, only one data point may be printed per line.

Compact Data Report Format

The compact format looks like the following:

```
D 31:10:06 0412 CONC : 1 6.8
```

The fields up to the colon are the same as for the verbose format, but the next fields are different. The fields following the colon are the line number ("1" in the example), and the data point value ("6.8"). Presumably the user (or remote computer) knows all of the other information about the data point value.

This report format is particularly useful when you are sampling more than one data point because up to five data points may be printed per line. The line number field is necessary because a single report may span multiple lines. A compact report with two data points, such as the PNUMTC Data Channel, looks like this:

```
D 31:10:06 0412 PNUMTC: 1 800.0 29.7
```

Example 1: To report the last 100 records from the CONC Data Channel in Verbose format type:

```
D REPORT "CONC" RECORDS=100 VERBOSE
```

Example 2: To report all the records from the PNUMTC Data Channel in Compact format type:

```
D REPORT "PNUMTC" COMPACT
```

Automatic DAS Report Generation

Automatic RS-232 reporting can be independently enabled and disabled for each Data Channel. For all default data channels, automatic reporting is initially set to "OFF." If this property is turned on, the Data Channel will issue a report with a time and date stamp to the RS-232 port every time a data point is logged. The report format is shown below:

```
D 31:10:06 0412 CONC : AVG O3CNC1=6.8 PPB
```

To enable RS-232 reporting for a specific Data Channel follow the procedure in Table 5-18.

Table 5-18: Setup DAS Data Channel

Step	Action	Comment
1.	Press SETUP-DAS-EDIT	Enter DAS menu to edit Data Channels
2.	Press PREV/NEXT	Select Data Channel to edit
3.	Press EDIT	Edit selected Data Channel
4.	Press SET> (5 times)	Scroll through setup properties until RS-232 REPORT: OFF is displayed
5.	Press EDIT	Edit selected setup property
6.	Toggle OFF to ON	Change RS-232 REPORT property
7.	Press ENTR	Accepts change
8.	Press EXIT (4 times)	Exits back to sample menu

5.5.8 Internal Variables

The M400A's internal variables can be viewed and modified via the RS-232 port, just as the operator modifies the variables using the SETUP mode.

To view a variable's value, the host computer issues a command of the following format:

```
V variable
```

The CPU will respond by sending a message of the following format to the RS-232 output:

```
V VARIABLE=VALUE WARNLO WARNHI <DATALO-DATAHI>
```

In both cases "**VARIABLE**" is the name of the variable that is being viewed. "**VALUE**" is the current value of the variable. "**WARNLO**" and "**WARNHI**" are the low and high warning limits, respectively, but may not appear for all variables since some variables do not have warning limits. "**DATALO**" and "**DATAHI**" are the low and high data entry limits, respectively, and are given for all variables. The CPU will not set a variable's value or warning limits to values, which are outside of the data entry limits.

For example, to see the analyzer UV lamp temperature set point, the host computer would issue the command:

```
V PHOTO_LAMP
```

and the CPU would respond with something like:

```
V DDD:HH:MM 0400 PHOTO_LAMP=52.0 51.0 61.0 (0.0 TO 100.0) DEGC
```

indicating that the current set point is 52.0 degrees, the warning limits are 51.0 to 61.0 degrees, and the data entry limits are 0 to 100 degrees.

To modify a variable's value, almost the same format of command is used:

```
V variable=value warnlo warnhi
```

The "***variable***" field is the name of the variable being modified, and the "***value***" field is the new value. "***warnlo***" and "***warnhi***" are the low and high warning limits, respectively, and may only be given if the variable uses warning limits. They are optional for variables that use warning limits and, if not given, the warning limits are not changed.

After changing the variable's value, the CPU will respond with:

```
V VARIABLE=VALUE WARNLO WARNHI [DATALO-DATAHI]
```

which should reflect the new value. The values in square brackets are not required for all variables. If needed, the values are included on the command line, separated by spaces. For example, to change the instrument ID, the host computer would issue a command like this:

```
V MACHINE_ID=1234
```

and the CPU should respond with:

```
V DDD:HH:MM IIII MACHINE_ID = 1234 (0-9999)
```

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6 OPTIONAL HARDWARE AND SOFTWARE

6.1 Rack Mount Option

This option, including slides and rack mounting ears, permits the Analyzer to be mounted in a standard 19" wide x 30" deep RETMA rack.

6.2 Zero/Span Valve Option

The Zero/Span Valve option consists of two PTFE solenoid valves inside the instrument that admit sample gas or externally generated calibration gas. The valves are controlled from the front panel push-buttons, an AutoCal sequence, RS-232 commands, or by remote contact closure.

See Figure 2-2 for details on the pneumatic connections to the zero/span valves. Zero air and span gas should be supplied in excess of 800 cc/min demand of the Analyzer. The manifold should be vented outside the enclosure and be of sufficient length and diameter to prevent back diffusion and pressure effects.

Span gas can by generated by a M700 Mass Flow Calibrator equipped with appropriate options or an M401 UV Photometric Ozone Calibrator. Zero air can be supplied by the Teledyne API M701 Zero Air Module.

6.3 Internal Zero/Span (IZS) Option

The IZS option includes a Sample/Cal valve, a Zero Air Scrubber, and a temperature-controlled ozone generator. The concentration of ozone can be set through front panel controls or the RS-232 port. The ozone generator lamp intensity can be monitored and fed back via the CPU for very accurate and stable ozone concentration if the feedback detector option is purchased.

In the Zero mode, ambient air is drawn through the charcoal scrubber and filter, through the un-energized ozone generator, the energized sample/cal valve and into the Analyzer (see Figure 8-4).

In the Span mode, the ozone generator is energized and the resulting span gas is drawn through the energized sample/cal valve into the analyzer.

To set the ozone concentration for the IZS ozone generator, press **CALS-CONC-O3GEN** and enter a value from 50 to 1500 in the current units. A value of 0 turns the lamp OFF. See Section 9.3.9 for information on how to calibrate the IZS concentration setting.

If the IZS feedback option is purchased the ozone generator feedback mode should be set to REF. To set the feedback mode to REF, press **SETUP-MORE-O3-MODE-REF** and press **ENTR.** The IZS ozone lamp drive circuit will be actively adjusted to maintain the IZS reference set point.

Setup the IZS Option

To set the Low Span concentration (precision point) for Auto-Cal Sequences, press SETUP-MORE-VARS. Press NEXT until the O3_GEN_LOW1 variable is displayed. To change the concentration, press EDIT and enter the desired concentration. If the analyzer is being operated in Dual or Auto-Range mode then there is a second variable named O3_GEN_LOW2 that sets the Low Span concentration for the High range. This variable can be changed using the method described above.

When the **CALS** button is pressed, the ozone generator is turned on and the lamp drive is determined by looking up the user-specified concentration in the table computed during the calibration procedure, and interpolating between the two nearest concentration readings in the table. This yields the initial lamp drive setting and the IZS reference set point.

6.4 Autocal Setup to Support IZS and Z/S Valve Option

The AutoCal system allows unattended periodic operation of the IZS and Z/S valve options by using the M400A’s internal time of day clock. A variety of zero or span checks can be programmed.

The Autocal system operates by executing SEQUENCES. It is possible to program and run up to 3 sequences, each sequence operates in one of 8 MODES as shown in Table 6-1 to Table 6-4.

Table 6-1: AutoCal MODE Setup Parameters

Mode No.	Mode Name	Action
1.	Disabled	Disables the Sequence
2.	Zero	Does a Zero check
3.	Zero-Lo	Does a Zero and low concentration Span check
4.	Zero-Hi	Does a Zero and a high concentration Span check
5.	Zero-Lo-Hi	Does a Zero check
6.	Lo	Does a low concentration Span check
7.	Hi	Does a high concentration Span check
8.	Lo-Hi	Does a low and high concentration span Check

For each mode there are seven attributes that the MODE can have that control operational details of the SEQUENCE. They are:

Table 6-2: AutoCal ATTRIBUTE Setup Parameters

Attribute No.	Attribute Name	Action
1.	Timer Enabled	Turns on the Sequence timer
2.	Starting Date	Sequence will operate after Starting Date
3.	Starting Time	Time of day sequence will run
4.	Delta Days	Number of days to skip between each Seq. execution
5.	Delta Time	Number of hours later each “Delta Days” Seq is to be run.
6.	Duration	Number of minutes the sequence operates

Example of enabling sequence #2, keystroke sequence is in Table 6-2:

Do a span check ½ hour later every other day, lasting 15 minutes, without calibration.

Table 6-3: AutoCal Example SEQUENCE Setup

Mode and Attribute	Value	Comment
Mode and Attribute	Value	Comment
Sequence	2	Define Seq. #2
Mode	4	Select Span Mode
Timer Enable	ON	Enable the timer
Starting Date	Sept. 4, 1996	Start after Sept 4
Starting Time	01:00	First Span starts at 1:00AM
Delta Days	2	Do Seq #2 every other day
Delta Time	00:30	Do Seq #2 ½ hr later each time
Duration	15.0	Operate Span valve for 15 min
Calibrate	NO	Do not calibrate at end of Seq

Table 6-4: AutoCal Example SEQUENCE Keystrokes

Step	Action	Comment
1.	Press SETUP-ACAL	This button sequence will cause the AUTOCAL menu to be displayed.
2.	Press PREV-NEXT	Press PREV-NEXT until SEQ 2 is displayed
3.	Press MODE	Select the MODE menu
3.	Press PREV-NEXT	Press PREV NEXT to scroll to SPAN
4.	Press ENTR	ENTR selects the SPAN MODE
5.	Press SET	Select the SET menu to change the sequence attributes
6.	Press PREV-NEXT	Scroll the SET menu to TIMER ENABLE
7.	Press EDIT	Allows changing the TIMER ENABLE attribute, select ON
8.	Press ENTR	ENTR changes TIMER ENABLE to ON
9.	Press PREV-NEXT	Repeat steps 6-9 for each attribute
10.	Press EXIT	Press the EXIT key to return to upper level menus

6.5 Current Loop Option

The M400A can be configured with a voltage-to-current converter for 0-20mA or 4-20mA current loop output on the REC analog output channel. REC current loop channel is calibrated independently of the voltage output channel (DAS). This calibration must be repeated every time an A/D - D/A calibration is performed. To calibrate the current output, see Section 9.3.4.

NOTE

Do not exceed 60 V peak voltage between current loop outputs and instrument ground.

6.6 Metal Wool Scrubber Option

The measurement technique in a M400A is to measure the ratio of light absorbed by sample gas with and without ozone. A scrubber is used to remove ozone from the sample stream during the reference cycle. This scrubber option is desirable in some high humidity sites.

The Metal Wool Scrubber uses fine metal wire to create a large surface area to catalytically scrub ozone. To work effectively, the scrubber must be heated. The temperature is not critical, therefore the scrubber is continuously heated with a 12 watt heater, which produces a typical temperature of about 70^{o} C at an ambient temperature of 25^{o} C.

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7 CALIBRATION AND ZERO/SPAN CHECKS

There are several ways to check and adjust the calibration of the M400A. These different methods are summarized in Table 7-1. Calibration controls are shown in Table 7-2. In addition, all of the methods described in this section can be initiated and controlled via the RS-232 port.

Zero air is used for all calibration procedures, less than 1 ppb of major interferents, and a dew point of -5^{o} C or less. Ozone should be generated by a stable source and its concentration verified with an Ozone Primary Standard or Transfer Standard.

Before Calibration

1. Use the SETUP-RNGE menu to set the range the instrument will be operated in.
2. If you are using any of the following features, they must be set up before calibration:
   A. Autoranging or Remote Ranging - See Section 7.7
   B. Independent Ranges - See Section 7.7
   C. Normal calibration assumes that these features are already set up.

> **NOTE**
>
> **If you are using the M400A for EPA monitoring, only the calibration method described in Section 7.6 should be used.**

> **NOTE**
>
> **If there are any problems completing the following procedures, refer to Section 9.2.6 and 9.2.7 – Inability to Span and Zero.**

Table 7-1: Types of Zero/Span Check and Calibration

Section	Type of Cal or Check	Description
7.1	Manual Z/S Check or Calibration through the sample port	This calibration option uses calibration gas coming in through the sample port. IZS and Zero/Span valves, if present, do not operate.
7.2	Manual Z/S Check or Calibration with Z/S Valves Option.	How to operate Zero/Span Valves Option. Can be used to check or adjust calibration.
7.3	Manual Z/S Check with IZS Option	How to operate IZS option. Can be used to check or adjust calibration.
7.4	Automatic Z/S Check with Z/S Valves or IZS Options	Use of AutoCal to operate Z/S valves or IZS once per day to check the calibration.
7.5	Use of Z/S Valves or IZS with Remote Contact Closure	Operates Z/S valves or IZS with rear panel contact closures. Without valves or IZS, can be used to switch instrument into zero or span cal mode. Used for either checking or adjusting zero/span.
7.6	EPA Protocol Calibration	Covers methods to be used if data is for EPA equivalency monitoring.
7.7	Special Calibration Requirements for Independent Ranges or AutoRanging	Covers special requirements if using Independent Range or AutoRange
7.8	References	Contains a list of references on quality control and calibration.

Table 7-2: Calibration Controls

Button Sequence	Function
CALZ	Begin zero check
CALZ-ZERO-ENTR	Adjust O_3 conc to zero
CALS	Begin span check
CALS-CONC-SPAN	Set O_3 span cal target value
CALS-CONC-O3GEN	Set O_3 generator setpoint
CALS-SPAN-ENTR	Adj O_3 conc to span value
CAL	Begin M-P cal.
CAL-ZERO-ENTR	Adjust O_3 conc zero value
CAL-SPAN-ENTR	Adjust O_3 conc span value
CAL-CONC-SPAN	Set O_3 span cal target value
SETUP-ACAL-SEQ1	Setup auto-cal SEQ1
SETUP-ACAL-SEQ2	Setup auto-cal SEQ2
SETUP-ACAL-SEQ3	Setup auto-cal SEQ3
EXIT	Exit calibration mode

7.1 Manual Zero/Span Check or Cal with Input from Sample Port

Operators can manually check the zero and span set-points of the Analyzer while in sample mode by allowing the instrument to sample calibration gas and pressing the **CAL** button. This is also referred to as a multi-point calibration. To do this type of calibration, refer to Table 7-3, Table 7-4 and Table 7-5. Figure 7-1 shows the pneumatic diagram for calibration.

Table 7-3: Manual Zero Calibration Procedure - Zero Gas Thru Sample Port

Step Number	Action	Comment
1.	Press CAL	The M400A enters the calibrate mode from sample mode. The zero gas must come in through the sample port.
2.	Wait 10 min	Wait for reading to stabilize at zero value.
3.	Press ZERO	If you change your mind after pressing ZERO, you can still press EXIT here without zeroing the instrument.
4.	Press ENTR	Pressing ENTR actually changes the calculation equations.
5.	Press EXIT	M400A returns to sampling. Immediately after calibration, data is not added to the DAS averages.

If the **ZERO** button is not displayed, this means that the zero reading is too far out of adjustment to do a reliable calibration. The reason for this must be determined before the analyzer can be calibrated. See Section 9.2 for troubleshooting calibration problems. Pressing **EXIT** will bring you back to the Sample menu or you can leave the instrument in CAL mode if you are also going to make a span check.

Table 7-4: Enter Expected Span Gas Concentrations Procedure

Step Number	Action	Comment
1.	Press CAL-CONC	This key sequence causes the M400A to prompt for the expected ozone concentration. Enter the ozone span concentration value by pressing the key under each digit until the expected value is set. This menu can also be entered from CALS or CALZ.
2.	Press ENTR	ENTR stores the expected ozone span value.
3.	Press EXIT	Returns instrument to SAMPLE mode.

Table 7-5: Manual Span Calibration Procedure - Span Gas thru Sample Port

Step Number	Action	Comment
1.	Press CAL	The M400A enters the calibrate mode. Ozone span gas should be entering the sample port.
2.	Wait 10 min	Wait for reading to stabilize at span value.
3.	Press SPAN	If you change your mind after pressing SPAN, you can still press EXIT here without spanning the instrument.
4.	Press ENTR	Pressing ENTR actually changes the calculation equations and causes the instrument to read the ozone span value entered in Table 7-4.
5.	Press EXIT	M400A returns to sampling. Immediately after calibration, data is not added to the DAS averages.

If the **SPAN** button is not displayed, this means that the span reading is too far out of adjustment to do a reliable calibration. The reason for this must be determined before the analyzer can be calibrated. See Section 9.2 for troubleshooting calibration problems.

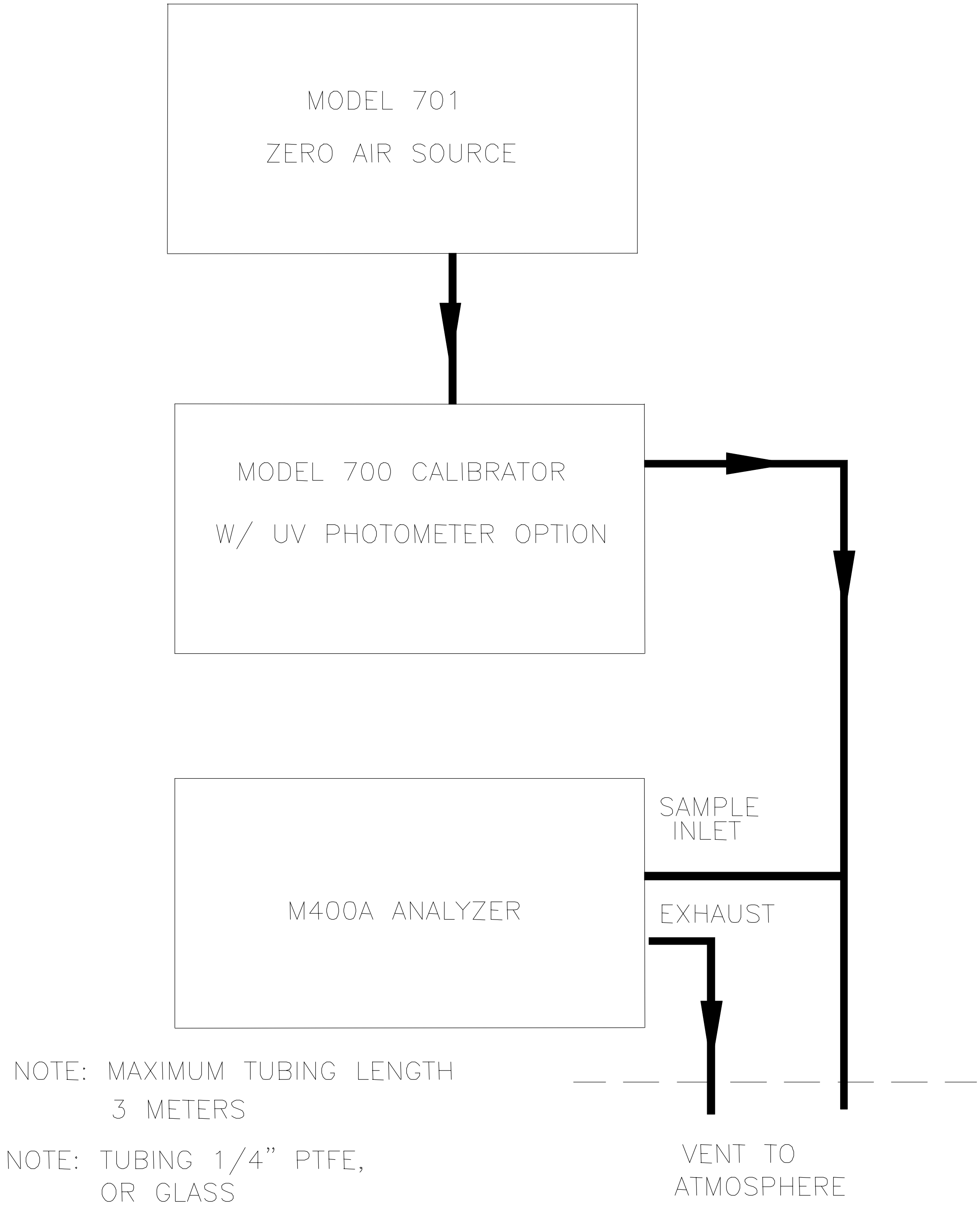

Figure 7-1: Calibration Pneumatic Diagram

7.2 Manual Zero/Span Check or Cal with Zero/Span Valves Option

Zero and Span checks using the Zero/Span Valves option is similar to that described in Section 7.1, except that external zero and span gas is supplied to the analyzer through the zero/span valves rather than through the sample inlet port. Procedures are covered in Table 7-6 and Table 7-7.

The Zero/Span valve option can be operated from the front panel keyboard. With the Zero/Span valve option the zero and span gas come enters through ports on the rear panel of the instrument.

Table 7-6: Manual Zero Calibration Procedure - Z/S Valves

Step Number	Action	Comment
1.	Press CALZ	The analyzer enters the zero calibrate mode. This switches the sample/cal and zero/span valves to allow zero gas to come in through the zero gas inlet port in the rear panel.
2.	Wait 10 min	Wait for reading to stabilize at zero value.
3.	Press ZERO	If you change your mind after pressing ZERO, you can still press EXIT here without zeroing the instrument.
4.	Press ENTR	Pressing ENTR actually changes the calculation equations, forcing the reading to zero.
5.	Press EXIT	M400A returns to sample mode. Immediately after calibration, readings do not go into the DAS averages.

Refer to Table 7-4 to enter expected ozone span concentration values.

Table 7-7: Manual Span Calibration Procedure - Z/S Valves

Step Number	Action	Comment
1.	Press CALS	The M400A enters the calibrate mode from sample mode. This operates the sample/cal and zero/span valves to allow span gas to come in through the cal gas inlet port in the rear panel.
2.	Wait 10 min	Wait for reading to stabilize at span value.
3.	Press SPAN	If you change your mind after pressing SPAN, you can still press EXIT here without spanning the instrument.
4.	Press ENTR	Pressing ENTR actually changes the calculation equations.
5.	Press EXIT	M400A returns to sampling. Immediately after calibration, data is not added to the DAS averages.

7.3 Manual Zero/Span Check with IZS Option

Using the IZS option, the operator can check the zero and span points of the analyzer by pressing the **CALZ** or **CALS** button. With the IZS Option installed, the CALZ and CALS buttons operate the ozone generator/ zero air system.

Pressing **CALZ** switches the Sample/Cal valve to allow the analyzer to draw air through the zero air scrubber and the un-energized ozone generator. The zero point can be just checked or the instrument can be zeroed when in this mode. See Table 7-6 for the procedure.

Pressing **CALS** switches the Sample/Cal valve so that air is drawn through the zero air scrubber and the energized ozone generator. After a few minutes the O_3 reading should approach the span level. The span point can be checked or adjusted when in this mode. See Table 7-7 for the procedure.

The IZS ozone generator concentration setpoint can be changed by pressing **CALS-CONC-O3GEN**, and entering the desired ozone concentration. Calibration of the IZS ozone generator is covered in Section 9.3.9.2.

7.4 Automatic Zero/Span Check

Automatic zero/span checking (Z/S check) must be enabled in the setup mode. The Teledyne API model 400A Photometric Ozone Analyzer with IZS or Zero/Span Valves option offers capability to check one zero and two span points automatically on a timed basis, or through remote RS-232 operation (see Section 5.5).

If the IZS option is installed its concentration must be set separately. Refer to Section 9.3.9 for information on adjusting the IZS concentration.

Under the **SETUP-ACAL** menu, there are three separate auto-sequences called SEQ1, SEQ2, and SEQ3. Under each SEQ, there are five setup parameters that affect zero/span checking: the mode, the starting date of the check, the time of day for check, the number of days delay between checks, and time shift each check is executed. These are described individually below. Use the **PREV** and **NEXT** buttons to scroll through the three sequences. The mode for each sequence is displayed. To change the mode for any of the sequences, scroll to the desired sequence and press the **MODE** button. Use the **PREV** and **NEXT** buttons to select one of the modes shown below and press **ENTR**.

Sequence Mode:

1. DISABLED (Sequence is disabled)
2. ZERO
3. ZERO-LO
4. ZERO-HI
5. ZERO-LO-HI
6. LO
7. HI
8. LO-HI

To change the setup parameters for a sequence, press the **SET** button. Pressing the **<SET** and **SET>** buttons allows you to scroll through the setup parameters and edit them by pressing the **EDIT** button. The function of each setup parameter is described below:

Starting Date: The starting date for the sequence is entered in the format of MM/DD/YY, where MM is the month, DD is the date, and YY is the year. Enter starting date and press **ENTR** or **EXIT** to leave the date unchanged.

Starting Time: To set the time of day for the sequence, enter in the format HH:MM, where HH is the hour in 24-hour format (i.e. hours range from 00 to 23) and MM is the minute (00 - 59). Enter the time of day for calibration check and then press **ENTR** to accept the new time or **EXIT** to leave the time unchanged.

> **NOTE**
>
> **The programmed start time must be a minimum of 5 minutes later than the real time clock (See Section 5.3.6 for setting real time clock).**

Delta Days: The number of delta days is the number of days between each auto-sequence. Enter desired number of delay days (0-365) and press **ENTR**.

Delta Time: The delta time allows the automatic Z/S check time-of-day to be delayed in the format of HH:MM, where HH is the hour from 00 to 23 and MM is the minutes (00-59). The delta days and delta time are added together to determine the total delay between sequences. The delta time parameter allows you to advance or retard the starting time by a fixed amount each time the sequence is run. For example: Setting the delta days to 1 day and the delta time to 15 minutes will delay the starting time for the sequence by 15 minutes each day. If you want to have the sequence run at the same time every day, simply set the delta time to zero.

NOTE

Avoid setting two or more sequences at the same time of the day. Any new sequence which is initiated whether from a timer, the RS-232, or the contact closure inputs will override any sequence which is in progress.

Duration: The duration of each step of the sequence. Enter the duration in minutes(1-60) and press **ENTR**.

Range to cal: This setup parameter is enabled only if the range mode is set to Dual or Auto. This parameter determines which range the sequence will check.

Examples of possible sequences are as following under any one of three available SEQx.

Example 1: to perform a 15 minute zero-span(100 %) check once per day at 10:30 pm, 12/20/97.

1. MODE: ZERO-HI
2. STARTING DATE: 12/20/97
3. STARTING TIME: 22:30
4. DELTA DAYS: 1
5. DELTA TIME: 00:00
6. DURATION: 15

Example 2: to perform a 15 min zero-low span check once per day retarding 15 minutes everyday starting at 11:30 pm, 12/20/97.

1. MODE: ZERO-LO
2. STARTING DATE: 12/20/97
3. STARTING TIME: 23:30
4. DELTA DAYS: 0
5. DELTA TIME: 23:45
6. DURATION: 15

Example 3: to perform zero-low-high span check once per week starting at 11:30 pm, 12/20/97

1. MODE: ZERO-LO-HI
2. STARTING DATE: 12/20/97
3. STARTING TIME: 23:30
4. DELTA DAYS: 7
5. DELTA TIME: 00:00
6. DURATION: 15

Example 4: to perform zero-span check once per day at 10:30 pm and zero-low-high span check once per week starting at 11:30 pm, 12/20/97.

1. Select any one of SEQx and program as example 1.
2. Select any other SEQx and program as example 3. Avoid setting two or more sequences at the same time of the day.

7.5 Use of Zero/Span Valves or IZS with Remote Contact Closure

A span or zero check may be initiated by means of two rear panel contact closures. See Figure 2-2 for connector location. The CPU monitors logic signals once each second and looks for a positive level on either signal. The instrument responses are shown in Table 7-8. The external contact closure should be closed for at least 1 second. When both states go to 0 (open) the CPU will go into DAS hold-off. The remote calibration signals may be activated in any sequence. It is recommended that contact closures remain closed for at least 10 minutes to establish a reliable reading. See Section 6.2 and 6.3 for further details.

Table 7-8: Remote Contact Closure Truth Table

Contact Closure States		
EXT_ZERO_CAL	EXT_SPAN_CAL	Instrument State
0 (open)	0	Sample Mode
1 (closed)	0	Zero check
0	1	Span check
1	1	Low span check

7.6 EPA Protocol Calibration

In order to insure that high quality, accurate measurement information is obtained at all times, the Model 400A O_3 Analyzer must be calibrated prior to use. A quality assurance program centered on this aspect and including attention to the built-in warning features of the Model 400A, periodic inspection, regular zero/span checks and routine maintenance is paramount to achieving this. See Table 7-9.

In order that the users have a more complete appreciation and better understanding of the factors involved in assuring continuous and reliable information from the Model 400A it is strongly recommended that the publication Quality Assurance Handbook for Air Pollution Measurement Systems (abbreviated, Q.A. Handbook Volume II) be purchased from the National Technical Information Service[11] (phone 703-487-4650) or Center for Environmental Research Information[11] or the U.S. Government Printing Office (phone 202-783-3238). Special attention should be paid to Section 2.7 which deals with O_3 analyzers and ozone photometers and upon which most of this section is based. Specific regulations regarding the use and operation of ambient O_3 analyzers can be found in Reference 1 at the end of this Section.

References given in Sections 7.6 and 7.7 are listed in Section 7.8.

7.6.1 M400A Calibration – General Guidelines

In general, calibration is the process of adjusting the gain and offset of the M400A against some recognized standard. The reliability and usefulness of all data derived from any analyzer depends primarily upon its state of calibration. In this section the term dynamic calibration is used to express a multipoint check against known standards and involves introducing gas samples of known concentration into the instrument in order to adjust the instrument to a predetermined sensitivity and to produce a calibration relationship. This relationship is derived from the instrumental response to successive samples of different known concentrations. As a minimum, three reference points and a zero point are recommended to define this relationship. The true values of the calibration gas must be traceable to an ozone primary standard.

All monitoring instrument systems are subject to some drift and variation in internal parameters and cannot be expected to maintain accurate calibration over long periods of time. Therefore, it is necessary to dynamically check the calibration relationship on a predetermined schedule. Zero and span checks must be used to document that the data remains within control limits. These checks are also used in data reduction and validation.

To ensure accurate measurements of the O_3 levels, the Model 400A must be calibrated at the time of installation and re-calibrated as necessary (Section 2.7.2 of the Q.A. Manual [11]).

Care must be exercised to ensure that the calibration system meets the guidelines outlined in the revised Appendix D, 40 CFR 50.[1] Detailed calibration procedures are also discussed in the Technical Assistance Document (TAD).[2] Dynamic multipoint calibration of the M400A must be conducted by using either the UV photometric calibration procedure or a certified transfer standard. The equipment (i.e. calibrator and UV photometer) that is needed to carry out the calibration is commercially available, or it can be assembled by the user.

Calibrations should be carried out at the field monitoring site. The Analyzer should be in operation for at least several hours (preferably overnight) before calibration so that it is fully warmed up and its operation has stabilized. During the calibration, the M400A should be in the CAL mode, and therefore sample the test atmosphere through all components used during normal ambient sampling and through as much of the ambient air inlet system as is practicable. If the instrument will be used on more than one range, it should be calibrated separately on each applicable range (See Section 7.7). Calibration documentation should be maintained with each analyzer and also in a central backup file.

Personnel, equipment, and reference materials used in conducting audits must be independent from those normally used in calibrations and operations. Ozone audit devices must be referenced to a primary UV photometer or one of the Standard Reference Photometers maintained by NIST and the USEPA.

Table 7-9: Activity Matrix for Procurement of Equipment and Supplies

Equipment/ Supplies	**Acceptance Limits**	**Frequency and Method of Measurement**	**Action if Requirements are not Met**
Model 400A	Performance according to specifications in Table 4-1, Sec. 2.0.4 (Ref 11)	Manufacturer strip chart recording of analyzer's performance or equipment documentation	Have the manufacturer adjust and rerun the performance checks
Strip chart recorder	Compatible with output signal of analyzer; recommended chart width of 15cm (6 inches)	Visually observe upon receipt	Return to supplier
Sampling lines and manifold	Constructed of Teflon, quartz, glass; fittings may be S/S	As above	As above
Calibration system	Meets the guidelines of Section 2.7.9 (Ref 11) and TAD-2 or TAD-3	Check upon receipt	As above

7.6.2 Calibration Equipment, Supplies, and Expendables

The measurement of O_3 in ambient air requires a certain amount of basic sampling equipment and supplemental supplies. These include, but are not limited to, the following:

1. Equivalent Method UV Photometric O_3 analyzer, such as the Teledyne API Model 400A
2. Strip chart recorder and/or data logging system
3. Sampling lines
4. Sampling manifold
5. UV (ultraviolet) photometric calibration system
6. Certified calibration transfer standards
7. Zero-air source
8. Ozone generation device ("calibrator")
9. Spare parts and expendable supplies
10. Record forms
11. Independent audit system

When purchasing these materials, a log book should be maintained as a reference for future procurement needs and as a basis for future fiscal planning.

Spare Parts and Expendable Supplies

In addition to the basic equipment discussed above, it is necessary to maintain an inventory of spare parts and expendable supplies. Section 8 describes the parts that require periodic replacement and the frequency of replacement. Section 10 contains a list of spare parts and kits of expendables. Based on these requirements, the management of the monitoring network can determine which parts and the quantity of each that should be available at all times.

7.6.3 Calibration Gas and Zero Air Sources

Production of Zero Air

Devices that condition ambient air by drying and removal of pollutants are available on the commercial market such as the Teledyne API Model 701 Zero Air Module. We recommend this type of device for generating zero air. Detailed procedures for generating zero air are in TAD[2].

Production of Span Gas

Because of the instability of O_3, the certification of O_3 concentrations as Standard Reference Materials (SRMs) is impractical, if not impossible. Thus, when O_3 concentration standards are required, they must be generated and certified locally. Ozone concentration standards may also be required at the monitoring site to check the span and precision of ambient O_3 monitors between calibrations.

Ozone standards can be classified into two basic groups: primary standards and transfer standards.

1. A primary O_3 standard is an O_3 concentration standard that has been dynamically generated and assayed by UV photometry in accordance with the procedures prescribed by the U.S. Environmental Protection Agency (EPA) under Title 40 of the Code of Federal Regulations, Part 50, Appendix D (40 CFR Part 50).
2. An O_3 transfer standard is a transportable device or apparatus, which, together with associated operational procedures, is capable of accurately reproducing O_3 concentration standards or producing accurate assays of O_3 concentrations which are quantitatively related to a primary O_3 standard.

A Standard Reference Photometer (SRP) has been developed as a primary O_3 standard by the U.S. National Institute of Standards and Technology (NIST) and the EPA. It is a highly stable, highly precise, computer-controlled instrument for assaying O_3 concentrations. NIST maintains one or more “master” SRP’s in lieu of an SRM for ozone. A nationwide network of regionally located SRPs enables State and local air monitoring agencies to compare their O_3 standards with authoritative O_3 standards maintained and operated under closely controlled conditions. Other SRPs are located in foreign countries.

Currently, the U.S. SRP Network consists of SRP's located at:

1. EPA's National Exposure Research Laboratory (NERL), in Research Triangle Park, North Carolina
2. EPA's Region I Environmental Services Division in Lexington, Massachusetts
3. EPA's Region II Environmental Services Division in Edison, New Jersey
4. EPA's Region IV Environmental Services Division in Athens, Georgia
5. EPA's Region V Environmental Science Division in Chicago, Illinois
6. EPA's Region VI Environmental Services Division in Houston, Texas
7. EPA's Region VII Environmental Services Division in Athens, Georgia
8. EPA's Region VIII Environmental Services Division in Denver, Colorado
9. The State of California Air Resources Board (CARB) in Sacramento, California

Commercial UV photmeters meeting the requirements of a primary ozone standard as set forth in 40 CFR Part 50 are available and are currently being used by air monitoring agencies. Agencies have been encouraged to intercompare their primary O_3 standards (and O_3 transfer standards) as part of their routine quality assurance (QA) programs.

7.6.4 Data Recording Device

Either a strip chart recorder, data acquisition system, digital data acquisition system should be used to record the data from the M400A RS-232 port or analog outputs. If analog readings are being used, the response of that system should be checked against a NIST referenced voltage source or meter. Data recording device should be capable of bi-polar operation so that negative readings can be recorded. Strip chart recorder should be at least 6" (15 cm) wide.

7.6.5 Record Keeping

Record keeping is a critical part of all quality assurance programs. Standard forms similar to those that appear in this manual should be developed for individual programs. Three things to consider in the development of record forms are:

1. Does the form serve a necessary function?
2. Is the documentation complete?
3. Will the forms be filed in such a manner that they can easily be retrieved when needed?

7.6.6 Dynamic Multipoint Calibration Procedure

The EPA-prescribed calibration procedure is based on photometric assays of O_3 concentrations in a dynamic flow system. It is based on the same principles that the M400A uses to measure ozone. The theory is covered in Section 4.1 of this manual.

Since the accuracy of the calibration standards obtained by this calibration procedure depends entirely on the accuracy of the photometer, it is very important that the photometer is operating properly and accurately. The fact that the photometer makes a ratio measurement (I/I_o) rather than an absolute measurement eases this task.

The checks described in this section, if carried out carefully, will provide reasonable confidence that a photometer which has the required inherent capability is operating properly. Checks should be carried out frequently on a new calibrator, and a chronological record of the results should be kept. If the record of the photometer performance shows continued adequacy and reliability, the frequency of the checks can be reduced with no loss of confidence in the photometer. (The record, however, may indicate the need for continued frequent verification of the system condition.) Even where the record shows excellent stability, the checks should still be carried out monthly as the possibility of malfunction is always present.

A well-designed properly built photometer is a precision instrument, and once it is operating adequately, it is likely to continue to do so for some time, particularly if the photometer is stationary and is used intermittently under ideal laboratory conditions. If the photometer is commercially manufactured, it should include an operation/instruction manual. Study the manual thoroughly and follow its recommendations carefully and completely.

7.6.6.1 Linearity test

Because the required photometric measurement is a ratio, a simple linearity check of the photometer is a good indication of accuracy. Linearity of commercially made photometers may be demonstrated by the manufacturer. The linearity test is conducted by first generating and assaying an ozone concentration near the upper range limit (i.e., 0.1, 0.5 or 1.0 ppm) of the system. Then dilute the concentration using a configuration similar to that shown in Figure 7-1. Add a flow of zero-air (F_d) to the flow of original generated concentration (F_o) and pass the mixture through a mixing chamber to ensure a homogeneous concentration at the output manifold. For this test, the flow rates F_o and F_d must be accurately measured within ±2% of the true value. To help ensure accurate flow measurements, the two flowmeters should be of the same general type and one should be standardized against the other. The dilution ratio R is calculated as the flow of the original concentration (F_o) divided by the total flow ($F_o + F_d$),

$$R = \frac{F_o}{(F_o + F_d)}$$

With stable, high resolution flowmeters and with careful technique, R should be accurate to within ± 1%. When F_d has been adjusted and R has been calculated, assay the diluted concentration with the photometer and then compare the diluted assay (A_2) with the original undiluted assay (A_1) by calculating the percentage of linearity error (E) according to the following equation.

$$E = \frac{A_1 - (A_2 / R)}{A_1} \times 100$$

This linearity error must be <5% in magnitude and should be <3% for a well-performing system.

> **NOTE**
>
> **The result is not the true linearity error because it includes possible errors in the flow measurements, the test is only an indicator.**

If the linearity error is >5% or is greater than you expect it to be, check and verify the accuracy of the flow dilution carefully before assuming that the photometer is inaccurate. The test should be carried out several times at various dilution ratios, and an averaging technique should be used to determine the final result. If the linearity error is excessive and cannot be attributed to flow measurement inaccuracy, check the photometer system for:

1. Dirty or contaminated cell, lines, or manifold
2. Inadequate "conditioning" of the system
3. Leaking of two-way valve or other system components
4. Contaminated zero-air
5. Non-linear detectors in the photometer
6. Faulty electronics in the photometer

7.6.6.2 O_3 Loss Correction Factor

In spite of scrupulous cleaning and preconditioning, some O_3 may be lost on contact with the photometer cell walls and the gas-handling components. Any significant loss of O_3 must be quantitatively determined and used to correct the output concentration assay. In any case, the O_3 loss must not exceed 5%. To determine O_3 loss, calibrate a stable ozone analyzer with the UV calibration system, assuming no losses. Then generate an O_3 concentration, and measure it with the analyzer as close as possible to the actual inlet of the photometer cell. Similarly, measure the concentration as close as possible to the outlet of the cell. Repeat each measurement several times to get a reliable average, and measure the concentration at the output manifold. The tests should be repeated at several different O_3 concentrations.

The percentage of O_3 loss is calculated as,

$$\%O_3 loss = \frac{C_m - \frac{(C_i + C_o)}{2}}{C_m} \times 100$$

where

C_i = O_3 concentration measured at cell inlet, ppm

C_o = O_3 concentration measured at cell outlet, ppm, and

C_m = O_3 concentration measured at output manifold, ppm.

For other configurations, the % O_3 loss may have to be calculated differently. The ozone loss correction factor is calculated as,

L = 1 - 0.01 × % O_3 loss.

7.6.7 Multipoint Calibration

The procedures for multipoint calibration of an O_3 analyzer by UV photometry or a transfer standard have been specified in the Federal Register.[1] To facilitate these procedures, operational and calculation data forms have been developed. These forms will aid in conducting calibrations and quality assurance checks. A detailed description of the calibration theory and procedures for UV photometry and transfer standards is in the Federal Register[1] and TAD.[2,3] Table 7-15 is a matrix for the actual dynamic calibration procedure.

In general, ambient monitors are always calibrated in situ without disturbing their normal sampling setup, except for transferring the sample inlet from the ambient sampling point to the calibration system.

7.6.7.1 The Calibration Procedure

Calibration should be performed with a primary UV photometer or by a transfer standard. The user should be sure that all flow-meters are calibrated under the conditions of use against a reliable standard such as a soap bubble meter or wet test meter. All volumetric flow rates should be corrected to 25°C and 760 mm Hg. A discussion of the calibration of flow-meters is in Section 2.1.2 (Ref. 11).

A newly installed M400A should be operated for several hours or preferably overnight before calibration to allow it to stabilize. A brand new M400A (fresh from the factory) may require several days of operation to fully stabilize. Allow the photometer or transfer standard to warm up and stabilize before use, particularly if stored or transported in cold weather.

7.6.7.2 Zero Calibration Procedure

Since the zero gas concentration is defined as 0 ppb, it is not necessary to enter the expected zero value. The following Table 7-10 details the zero calibration procedure.

Table 7-10: Zero Calibration Procedure

Step Number	Action	Comment
1.	Press CAL	The M400A enters the calibrate mode from sample mode. Note: The analyzer does not operate the zero/span valves in this mode, the zero gas enters through the sample port.
2.	Wait 10 min	Wait for reading to stabilize at the zero value.
3.	Press ZERO	If you change your mind after pressing ZERO, you can still press EXIT here without zeroing the instrument.
4.	Press ENTR	Pressing ENTR actually changes the calculation equations.
5.	Press EXIT	M400A returns to the SAMPLE mode.

7.6.7.3 Span Calibration Procedure.

Adjust the ozone generation system to produce 80% of the URL. Enter the ozone span gas concentration using the procedure in Table 7-11. The expected span concentrations need not be re-entered each time a calibration is performed unless they are changed.

Table 7-11: Expected Span Gas Concentration Procedure

Step Number	Action	Comment
1.	Press CAL-CONC-SPAN	This key sequence causes the M400A to prompt for the expected ozone span concentration. Enter the span concentration value by pressing the key under each digit until the expected value is set. This menu can also be entered from CALS or CALZ.
2.	Press ENTR	ENTR stores the expected span value.
3.	Press EXIT	Returns instrument to SAMPLE mode.

Span the instrument by following the procedure in Table 7-12.

Table 7-12: Span Calibration Procedure

Step Number	Action	Comment
1.	Press CAL	The M400A enters the calibrate mode from sample mode.
2.	Wait 10 min	Wait for readings to stabilize at span values.
3.	Press SPAN	If you change your mind after pressing SPAN, you can still press EXIT here without spanning the instrument.
4.	Press ENTR	Pressing ENTR actually changes the calculation equations.
5.	Press EXIT	M400A returns to SAMPLE mode.

The analog voltage output should measure 80% of the voltage range selected. (e.g. 4.00VDC if 0-5V output is selected.) The readings on the front panel display should be equal to the expected span concentration entered in the procedure given in Table 7-11. See the Troubleshooting Section 9.2.8 if there are problems.

After the zero and the 80% URL points have been set, generate five approximately evenly spaced calibration points between zero and 80% URL without further adjustment to the instrument. Allow the instrument to sample these intermediate concentrations for about 10 minutes each and record the instrument responses.

Plot the analyzer responses versus the corresponding calculated concentrations to obtain the calibration relationships. Determine the straight line of best fit ($y = mx + b$) determined by the method of least squares (e.g., see Appendix J of Volume I of the Q.A. Handbook[6]).

After the best-fit line has been drawn, determine whether the analyzer response is linear. To be considered linear, no calibration point should differ from the best-fit line by more than 2% of full scale.

7.6.7.4 Span Drift Check

The first level of data validation should accept or reject monitoring data based upon routine periodic analyzer checks. It is recommended that results from the Level 1 span checks (Section 2.7.2 (Ref. 11)) be used as the first level of data validation. This means up to two weeks of monitoring data may be invalidated if the span drift for a Level 1 span check is ≥ 25%. For this reason, it may be desirable to perform Level 1 checks more often than the minimum recommended frequency of every 2 weeks.

7.6.8 Auditing Procedure

An audit is an independent assessment of the accuracy of data. Independence is achieved by having the audit made by an operator other than the one conducting the routine field measurements and by using audit standards and equipment different from those routinely used in monitoring. The audit should be a true assessment of the measurement process under normal operations without any special preparation or adjustment of the system. Routine quality control checks (such as zero and span checks in Section 7.1) conducted by the operator are necessary for obtaining and reporting good quality data, but they are not considered part of the auditing procedure.

Three audits are recommended: two performance audits and a systems audit. These audits are summarized in Table 7-15 at the end of this section. See Sections 2.0.11 and 2.0.12 of the Q.A. Manual (Ref. 11) for detailed procedures for a systems audit and for a performance audit, respectively.

Proper implementation of an auditing program will serve a twofold purpose: (1) to ensure the integrity of the data and (2) to assess the data for accuracy. The technique for estimating the accuracy of the data is given in Section 2.0.8 of the Q.A. Manual (Ref 11).

7.6.9 Multipoint Calibration Audit

A performance audit consists of challenging the continuous analyzer with known concentrations of O_3 within the measurement range of the analyzer. The difference between the known concentration and the analyzer response is obtained, and an estimate of the analyzer's accuracy is determined.

7.6.9.1 Multipoint Audit Procedure

Known concentrations of O_3 must be generated by a stable O_3 source and assayed by the primary UV photometric procedure or may be obtained using a certified O_3 transfer standard. Procedures used to generate and assay O_3 concentrations are the same as those described in Section 7.6.6. If during a regular field audit, the differences recorded for most analyzers are either negatively or positively biased, a check of the calibrator used in routine calibrations of the analyzers may be advisable.

The test atmosphere must pass through all filters, scrubbers, conditioners, and other components used during normal ambient sampling and through as much of the ambient air inlet system as practical. Be sure the manifold includes a vent to assure that the M400A inlet is at atmospheric pressure.

Audit Procedure:

1. Turn on the zero-air flow in the audit device.
2. After stabilization, record the analyzer zero.
3. Generate an up-scale audit point.
4. After stabilization, record the O_3 analyzer response.
5. Assay the audit concentration using an audit UV photometer or certified transfer standard.
6. Repeat steps 4 and 5 for the two remaining up-scale audit points. If analyzer is operated on 0-1.0 ppm range, four up-scale audit points must be used.

Results:

Results of the audit will be used to estimate the accuracy of the ambient air quality data. Calculation of accuracy is described in Section 2.0.8 of the Q.A. Manual.

7.6.9.2 Data Processing Audit

Data processing audit involves reading a strip chart record, calculating an average, and transcribing or recording the results on the SAROAD form. The data processing audit should be performed by an individual other than the one who originally reduced the data. Initially, the audit should be performed 1 day out of every 2 weeks of data. For two 1-hour period within each day audited, make independent readings of the strip chart record and continue through the actual transcription of the data on the SAROAD form. The 2 hours selected during each day audited should be those for which either the trace is most dynamic (in terms of spikes) or the average concentration is high.

The data processing audit is made by calculating the difference, $\mathbf{d} = [O_3]_R - [O_3]_A$

where

d = the difference between measured and audit values, ppm,

$[O_3]_R$ = the recorded analyzer response, ppm, and

$[O_3]_A$ = the data processing O_3 concentration, ppm.

If d exceeds ± 0.02 ppm, check <u>all</u> of the remaining data in the 2 week period.

7.6.10 System Audit

A system audit is an on-site inspection and review of the quality assurance activities used for the total measurement system (sample collection, sample analysis, data processing, etc.); it is a qualitative appraisal of system quality.

Conduct the system audit at the startup of a new monitoring system and periodically (as appropriate) as significant changes in system operations occur.

The recommended audit schedule depends on the purpose for which the monitoring data are being collected. For example, Appendix A, 40 CFR 58[8] requires that each analyzer in State and Local Air Monitoring Networks (SLAMS) be audited at least once a year. Each agency must audit 25% of the reference or equivalent analyzers each quarter. If an agency operates less than four reference or equivalent analyzers, it must randomly select analyzers for re-auditing so that one analyzer will be audited each calendar quarter and so that each analyzer will be audited at least once a year.

Appendix B, 40 CFR 58[9] requires that each PSD (prevention of significant deterioration) reference or equivalent analyzer be audited at least once a sampling quarter. Results of these audits are used to estimate the accuracy of ambient air data.

7.6.11 Calibration Frequency

To ensure accurate measurements of the ambient O_3 concentrations, calibrate the M400A at the time of installation, and recalibrate it:

1. No later than 3 months after the most recent calibration or performance audit which indicated the M400A response to be acceptable; or
2. Following any one of the activities listed below:
   A. An interruption of more than a few days in M400A operation,
   B. Any repairs which might affect its calibration,
   C. Physical relocation of the M400A
   D. Any other indication (including excessive zero or span drift) of possible significant inaccuracy of the unit.

Following any of the activities listed in above, perform Level 1 zero and span checks to determine if a calibration is necessary. If the zero and span drifts do not exceed the calibration limits in Section 2.0.9 Q.A. Manual (Ref. 11) (or limits set by the local agency), a calibration need not be performed.

7.6.12 Summary of Quality Assurance Checks

Essential to quality assurance are scheduled checks for verifying the operational status of the monitoring system. The operator should visit the site at least once each week. Every two weeks a Level 1 zero and span check must be made on the analyzer. Level 2 zero and span checks should be conducted at a frequency desired by the user. Definitions of these terms are given in Table 7-13.

In addition, an independent precision check between 0.08 and 0.10 ppm may be required at least once every two weeks. Table 7-16 summarizes the quality assurance activities for routine operations. A discussion of each activity appears in the following sections.

To provide for documentation and accountability of activities, a checklist should be compiled and then filled out by the field operator as each activity is completed.

Table 7-13: Definition of Level 1 and Level 2 Zero and Span Checks

from Section 2.0.9 of Q.A. Handbook (Ref. 11)

LEVEL 1 ZERO AND SPAN CALIBRATION	LEVEL 2 ZERO AND SPAN CHECK
A Level 1 zero and span calibration is a simplified, two-point analyzer calibration used when analyzer linearity does not need to be checked or verified. (Sometimes when no adjustments are made to the analyzer, the Level 1 calibration may be called a zero/span check, in which case it must not be confused with a Level 2 zero/span check.) Since most analyzers have a reliably linear or near-linear output response with concentration, they can be adequately calibrated with only two concentration standards (two-point concentration). Furthermore, one of the standards may be zero concentration, which is relatively easily obtained and need not be certified. Hence, only one certified concentration standard is needed for the two-point (Level 1) zero and span calibration. Although lacking the advantages of the multipoint calibration, the two-point zero and span calibration--because of its simplicity--can be (and should be) carried out much more frequently. Also, two-point calibrations are easily automated. Frequency checks or updating of the calibration relationship with a two-point zero and span calibration improves the quality of the monitoring data by helping to keep the calibration relationship more closely matched to any changes (drifts) in the analyzer response.	A Level 2 zero and span check is an "unofficial" check of an analyzer's response. It may include dynamic checks made with uncertified test concentrations, artificial stimulation of the analyzer's detector, electronic or other types of checks of a portion of the analyzer, etc. Level 2 zero and span checks are not to be used as a basis for analyzer zero or span adjustments, calibration updates, or adjustment of ambient data. They are intended as quick, convenient checks to be used between zero and span calibrations to check for possible analyzer malfunction or calibration drift. Whenever a Level 2 zero or span check indicates a possible calibration problem, a Level 1 zero and span (or multipoint) calibration should be carried out before any corrective action is taken. If a Level 2 zero and span check is to be used in the quality control program, a "reference response" for the check should be obtained immediately following a zero and span (or multipoint) calibration while the analyzer's calibration is accurately known. Subsequent Level 2 check responses should then be compared to the most recent reference response to determine if a change in response has occurred. For automatic Level 2 zero and span checks, the first scheduled check following the calibration should be used for the reference response. It should be kept in mind that any Level 2 check that involves only part of the analyzer's system cannot provide information about the portions of the system not checked and therefore cannot be used as a verification of the overall analyzer calibration.

Table 7-14: Daily Activity Matrix

Characteristic	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements are not Met
Shelter Temperature	Mean temperature between 22º C and 28º C (72º F and 82º F), daily fluctuations not greater than ± 2º C	Check thermograph chart daily for variations not greater than ± 2ºC (4ºF)	1. Mark strip chart for the affected time period 2. Repair/adj temp control
Sample Introduction System	No moisture, foreign material, leaks, obstructions; sample line connected to manifold	Weekly visual inspection	Clean, repair or replace as needed
Recorder	1. Adequate ink supply and chart paper 2. Legible ink traces 3. Correct settings of chart speed and range switches 4. Correct time	Weekly visual inspection	1. Replenish and chart paper supply 2. Adjust recorder time to agree with clock note on chart
Analyzer Operational Settings	1. Flow and regulator indicators at proper settings 2. Temperate indicators cycling or at proper levels 3. Analyzer in samp mode 4. Zero/span controls locked	Weekly visual inspection	Adjust or repair as needed
Analyzer Operational Check	Zero and span within tolerance limits as described in Subsec. 9.1.3 of Sec. 2.0.9 (Ref. 11)	Level 1 zero and span every 2 weeks; Level 2 between Level 1 checks at frequency desired by user	1. Isolate source error, and repair 2. After corrective action recalibrate analyzer
Precision Check	Assess precision as described in Sec. 2.0.8 (Ref. 11)	Every 2 weeks, Sec. 2.0.8 (Ref. 11)	Calculate, report precision, Sec. 2.0.8 (Ref. 11)

Table 7-15: Activity Matrix for Audit Procedure

Audit	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements are not Met
Multipoint calibration audit	The difference between the measured and the audit values as a measure of accuracy (Sec. 2.0.8 of Ref. 11)	At least once a quarter (Sec. 2.0.8 of Ref. 11)	Re-calibrate the analyzer
Data processing audit	Adhere to stepwise procedure for data reduction (Sec. 8.4); no difference exceeding ± 0.02 ppm	Perform independent check on a sample of recorded data, e.g., 1 day out of every 2 weeks of data, 2 hours for each day	Check all remaining data if one or more audit checks exceeds ± 0.02 ppm
Systems audit	Method described in this section of the Handbook	At the startup of a new monitoring system, and periodically as appropriate; observation and checklist	Initiate improved methods and/or training programs

Table 7-16: Activity Matrix for Data Reduction, Validation and Reporting

Activity	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements are not Met
Data reduction	Stepwise procedure, Sec. 2.7.4 Ref. 11	Follow the method for each strip chart.	Review the reduction procedure
Span drift check	Level 1 span drift check <25%, Sec. 2.7.3 Ref 11	Check at least every 2 weeks; Sec. 2.7.3, Ref. 11.	Invalidate data; take corrective action; increase frequency of Level 1 checks until data is acceptable
Strip chart edit	No sign of malfunction	Visually check each strip chart.	Void data for time interval for which malfunction is detected
Data reporting	Data transcribed to SAROAD hourly data form; Ref. 10	Visually check	Review the data transcribing procedure

Table 7-17: Activity Matrix for Calibration Procedures

Calibration Activities	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements are not Met
Zero-air	Zero-air, free of contaminants (Sec. 2.0.7 Ref. 11.)	Compare the new Zero-air against Source known to Be free of Contaminants	Return to supplier, or take corrective action with generation system as appropriate
Calibrator	Meet all requirement for UV photometer as specified in Sec. 2.7.2 Q.A. Manual, TAD[2] and the Fed. Reg.[1] or approve Transfer Standard Sec. 2.7.1, Q.A. Manual and TAD[3].	Re-certify transfer Standard against Primary UV Photometer at least Twice each quarter	Return to supplier, or take corrective action with system as appropriate
Multipoint	According to Calibration procedure (Sec. 2.7.2 Q.A. Manual Ref 11) and Federal Register; data recorded.	Calibrate at least Once, quarterly; Anytime an audit Indicates discrepancy; After maintenance that May affect the Calibration (Subsec 2.1) Federal Register[1]	Repeat the calibration

7.6.13 ZERO and SPAN Checks

A system of Level 1 and Level 2 zero span checks (see Table 7-13) is recommended. These checks must be conducted in accordance with the specific guidance given in Subsection 9.1 of Section 2.0.9 (Ref. 11). Level 1 zero and span checks should be conducted at least every two weeks. Level 2 checks should be conducted in between the Level 1 checks at a frequency determined by the user. Span concentrations for both levels should be between 70 and 90% of the measurement range.

7.6.13.1 Assessment of Monitoring Data for Precision and Accuracy

A periodic check is used to assess the data for precision. A one-point precision check must be carried out at least once every 2 weeks on each analyzer at an O_3 concentration between 0.08 and 0.10 ppm. The analyzer must be operated in its normal sampling mode, and the precision test gas must pass through all filters, scrubbers, conditioners, and other components used during normal ambient sampling. Those standards used for calibration or auditing may be used.

Estimates of single instrument accuracy for ambient air quality measurements from continuous methods are calculated according to the procedure in Section 2.0.8 (Ref 11). The audit procedure is described in Section 7.6.8.

7.6.14 Recommended Standards for Establishing Traceability

Ozone is the only criteria pollutant for which standard concentrations for calibration cannot be directly traceable to an NIST-SRM (National Institute of Standards - Standard Reference Material).

7.6.14.1 Ozone Working Standard Traced to NIST Ozone Standard

To maintain a uniform and consistent set of references, the USEPA maintains 9 Standard Reference Photometers (SRP) around the US. It is suggested that the regional office of the EPA be contacted for the location of a SRP nearby and that the standards be intercompared. This assures a uniform standard for ozone concentration is applied everywhere.

7.6.14.2 Other Methods of Establishing Traceability

To provide a reference against which calibration standards for O_3 must be compared, the U.S. EPA has prescribed a reference calibration procedure based on the principle of UV light absorption by ozone at a wavelength of 254 nm.[1] This procedure provides an authoritative standard for all O_3 measurement. Ozone transfer standards may also be used for calibration if they have been certified against the UV calibration procedure.[3]

7.7 Calibration of Independent Ranges or Autoranging

7.7.1 Zero/Span Calibration on Autorange or Dual Ranges

If the analyzer is being operated in Dual Range mode or Auto-Ranging mode, then the High and Low ranges must be independently calibrated. When the analyzer is in Dual or Auto Range mode you will be prompted to enter the range to calibrate whenever you enter a calibration command from the front panel. Press **HIGH** or **LOW** followed by the **ENTR** button to proceed with the calibration. To calibrate the other range you must exit to the sample menu and restart the calibration. See Section 5.3.4 for more information on the Range Modes. Table 7-18 shows an example of how to calibrate the two ranges with calibration gas coming in through the sample port:

Table 7-18: Calibration of AutoRange or Dual Range

Step Number	Action	Comment
0.	Setup	AutoRange or Dual Range features must be selected from the SETUP-RNGE menu before calibration.
1.	Press CAL	Analyzer enters M-P calibration mode. Calibration gas source should be set to deliver zero gas to the sample port.
2.	Press LOW-ENTR	Select range to calibrate. This will enable zero calibration on the low range.
3.	Wait 15 min.	Wait for O_3 reading to stabilize at zero value.
4.	Press ZERO-ENTR	Changes calibration equations for Low range so analyzer will read zero.
5.	Press CONC-SPAN	Enter span gas concentration for Low range.
6.	Key in span concentration	Enter span gas concentration for Low Range. Set calibration gas source to deliver span concentration.
7.	Press ENTR	
8.	Wait 15 min.	Wait for O_3 reading to stabilize at Low span value.
9.	Press SPAN-ENTR	Changes calibration equations for Low range so analyzer will read span value.
10.	Press EXIT	Exits back to sample menu.
11.	Cal High Range	Repeat Steps 1-10 for High Range.

7.8 References

1. Calibration of Ozone Reference Methods, Code of Federal Regulations, Title 40, Part 50, Appendix D.
2. Technical Assistance Document for the Calibration of Ambient Ozone Monitors, EPA publication available from EPA, Department E (MD-77), Research Triangle Park, N.C. 27711. EPA-600/4-79-057, September 1979.
3. Transfer Standards for Calibration of Ambient Air Monitoring Analyzers for Ozone, EPA publication available from EPA, Department E (MD-77), Research Triangle Park, N.C. 27711. EPA-600/4-79-056, September 1979.
4. Ambient Air Quality Surveillance, Code of Federal Regulations, Title 40, Part 58.
5. U.S. Environmental Protection Agency. Evaluation of Ozone Calibration Procedures. EPA-600/S4-80-050, February 1981.
6. Quality Assurance Handbook for Air Pollution Measurement Systems. Vol. I. EPA-600/9-76-005. March 1976.
7. Field Operations Guide for Automatic Air Monitoring Equipment, U.S. Environmental Protection Agency, Office of Air Programs; October 1972. Publication No. APTD-0736, PB 202-249, and PB 204-650.
8. Appendix A - Quality Assurance Requirements for State and Local Air Monitoring Stations (SLAMS), Code of Federal Regulations, Title 40, Part 58.
9. Appendix B - Quality Assurance Requirements for Prevention of Significant Deterioration (PSD) Air Monitoring, Code of Federal Regulations, Title 40, Part 50, Appendix D.
10. Aeros Manual Series Volume II: Aeros User's Manual. EPA-450/2-76-029, OAQPS No. 1.2-039. December 1976.
11. Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, (abbreviated Q.A. Handbook Volume II) National Technical Information Service (NTIS). Phone (703) 487-4650 part number PB 273-518 or the USEPA Center for Environmental Research Information (513) 569-7562 part number EPA 600/4/77/027A.

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8 MAINTENANCE

8.1 Maintenance Schedule

Table 8-1 shows a typical maintenance schedule for the Model 400A. Please note that in certain environments (i.e. dusty, very high ambient pollutant levels) some maintenance procedures may need to be performed more often than shown.

NOTE
The M400A must be re-calibrated after any of the maintenance procedure are performed.

Table 8-1: M400A Maintenance Schedule

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Action
Sample Filter Element													Replace weekly or as needed
IZS Zero Air Scrubber													Replace every 6 months
Pump Diaphragm													Replace every 12 months
ZERO Air Filter													Replace every 12 months
O_3 Scrubber													Replace every 2 years
Sample Cell													Inspect annually. Clean as necessary
Sample Flow													Check annually
Leak Check													Check after maintenance
IZS Zero Air Filter													Replace every two years

8.2 Replacing the Sample Particulate Filter

Procedure - Refer to Figure 8-1:

The particulate filter should be inspected often for signs of plugging or contamination. It is also common for dirt particles to absorb O_3, thus causing those readings to be low.

Any contamination on particulate filter or its holder can affect the output of the analyzer for 15 min. to an hour. This contamination can be as little as fingerprints on the filter element or on the wetted surfaces of the housing. We recommend that when you change the filter, handle it and the wetted surfaces of the filter housing as little as possible. Try not to touch any part of the housing, filter element, teflon retaining ring, glass cover and the Viton o-ring. The analyzer might show a slight decrease in span concentration after changing the filter. If this is the case, allow the unit to run until the concentration comes up to the expected span value, this usually takes 15 min to 1 hour.

To check and change the filter:

1. Fold down the M400A front panel.
2. Locate the filter on the left side of the analyzer front panel. See Figure 8-1 for an exploded view of the filter assembly.
3. Visually inspect the filter through the glass window.
4. If the filter appears dirty, unscrew the hold-down ring, remove the teflon o-ring and then the filter.
5. Replace the filter, being careful that the element is fully seated in the bottom of the holder.
6. Replace the teflon o-ring with the notches up, then screw on the hold-down ring and hand tighten.

8.3 Cleaning Exterior Surfaces of the M400A

If necessary, the exterior surfaces of the M400A can be cleaned with a clean damp cloth. Do not submerge any part of the instrument in water or cleaning solution.

CAUTION

Risk of electrical shock. Disconnect power before performing the following operations.

NOTE

The operations outlined in this chapter are to be performed by qualified maintenance personnel only.

8.4 Replacing the IZS Zero Air Scrubber

Procedure:

1. Turn off the analyzer.
2. Fold down the Instrument rear panel.
3. Remove the old scrubber by disconnecting the 9/16” fitting at the top of the O_3 gen tower, then removing the DFU filter and scrubber.
4. Replace the DFU filter, if necessary – see Table 8-1 Maintenance Schedule.
5. Unscrew the top of the scrubber canister and replace the activated charcoal.
6. Tighten the cap on the scrubber - **HAND TIGHTEN ONLY!**
7. Replace the scrubber in its clip on the rear panel.
8. Re-connect the 9/16” fitting to the top of the O_3 gen tower.

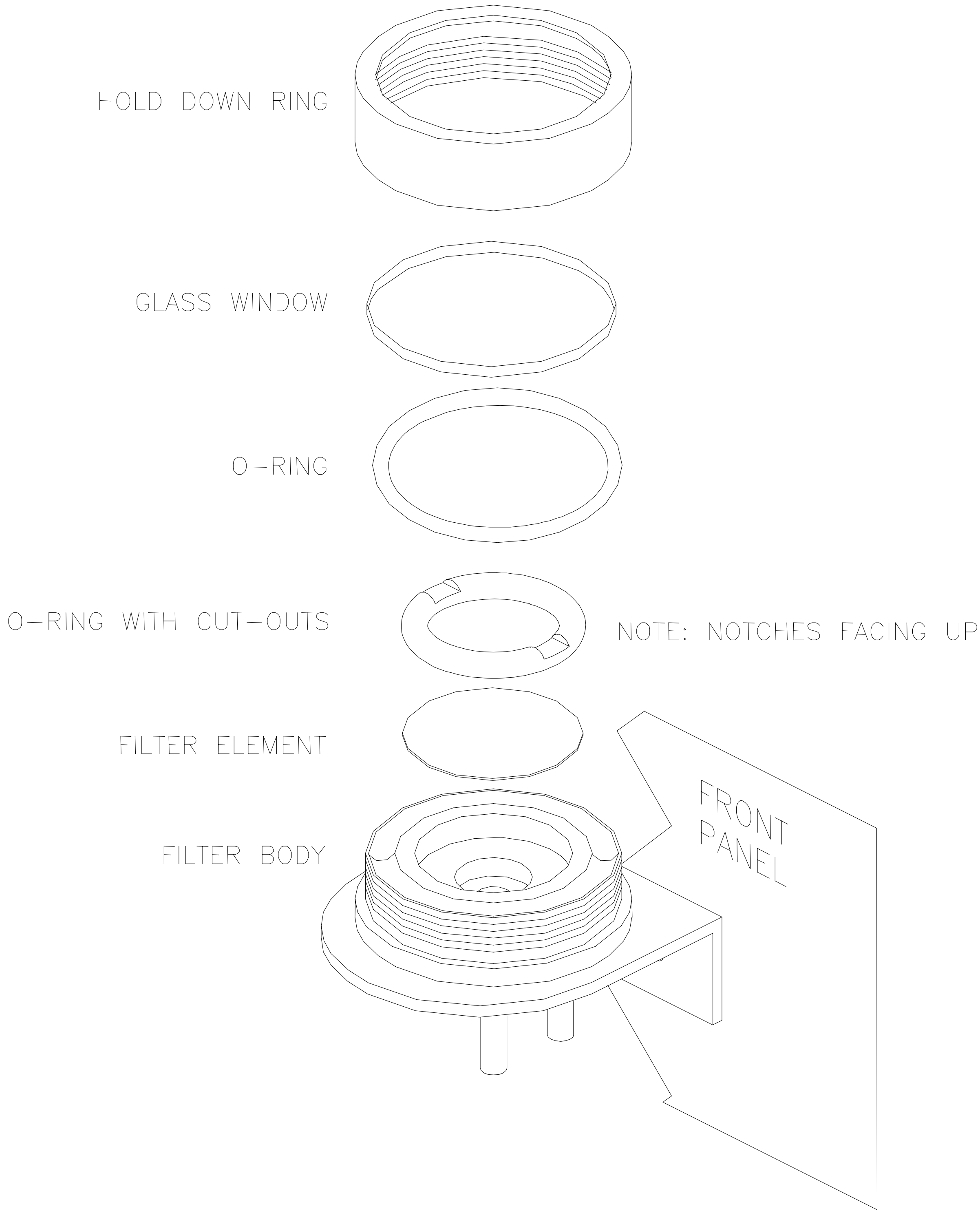


Figure 8-1: Replacing the Particulate Filter

8.5 Cleaning the Absorption Tube

1. Remove the center cover from the optical bench.
2. Loosen the knurled nuts at each end of the quartz tube.
3. Using both hands, rotate the tube to free it, then slide the tube towards the back of the instrument (towards the lamp housing). The front of the tube can now be slid past the detector block and out of the instrument.

CAUTION

**Do not cause the tube to bind against the metal housings.
The tube may break and cause serious injury.**

4. Clean the tube with soapy water by running a swab from end-to-end. Rinse with isopropyl alcohol, de-ionized water, then air dry. Check the cleaning job by looking down the bore of the tube. It should be free from dirt and lint.
5. Inspect the o-rings that seal the ends of the optical tube (these o-rings may stay seated in the manifolds when the tube is removed.) If there is any noticeable damage to these o-rings, they should be replaced. See Section 8.5 for instructions.
6. Re-assemble the tube into the lamp housing and leak check the instrument. Note: It is important for proper optical alignment that the tube be pushed all the way towards the front of the optical bench when it is re-assembled. When tightening the knurled nuts, tighten the nut with one hand and with the other hand pull the tube gently towards the front of the optical bench as the nut is tightened. This will ensure that the tube is assembled with the forward end against the stop inside the detector manifold.

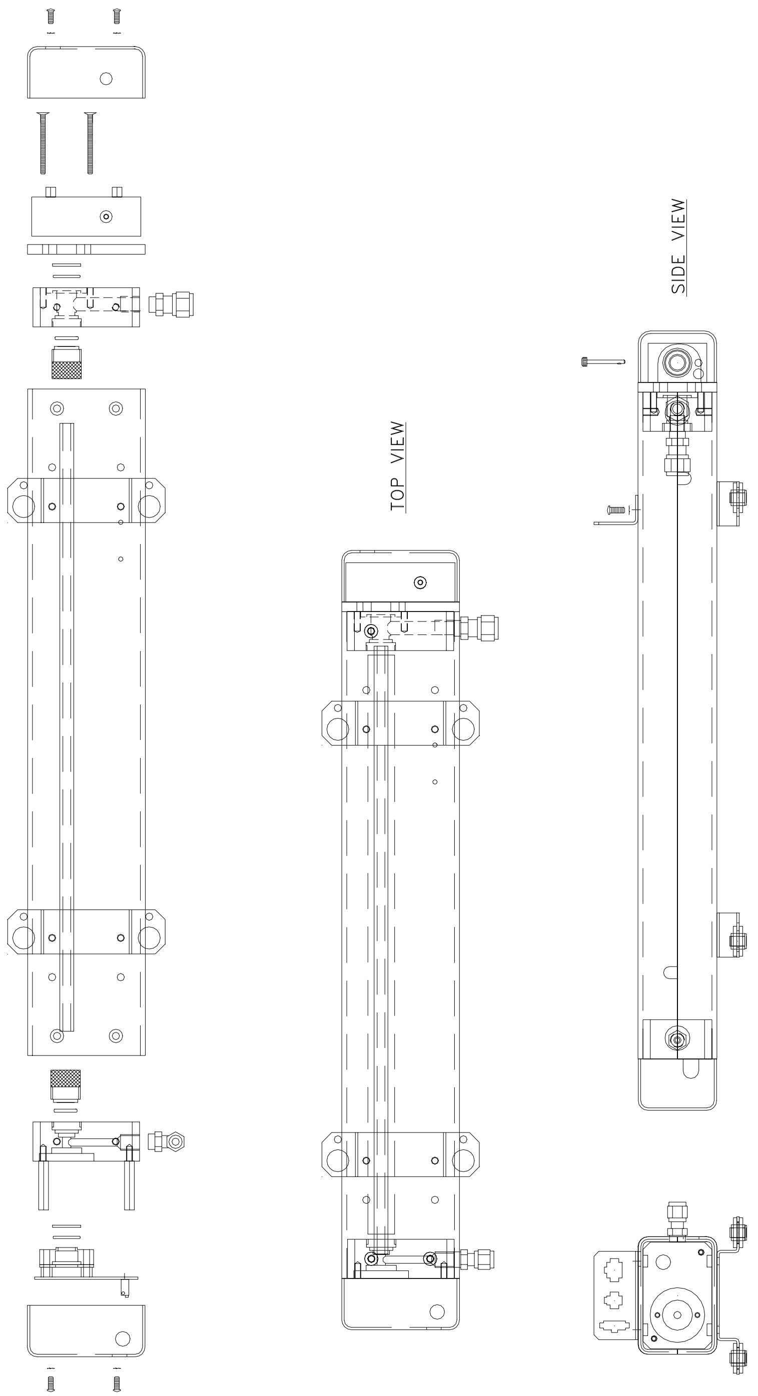


Figure 8-2: Optical Bench Assembly

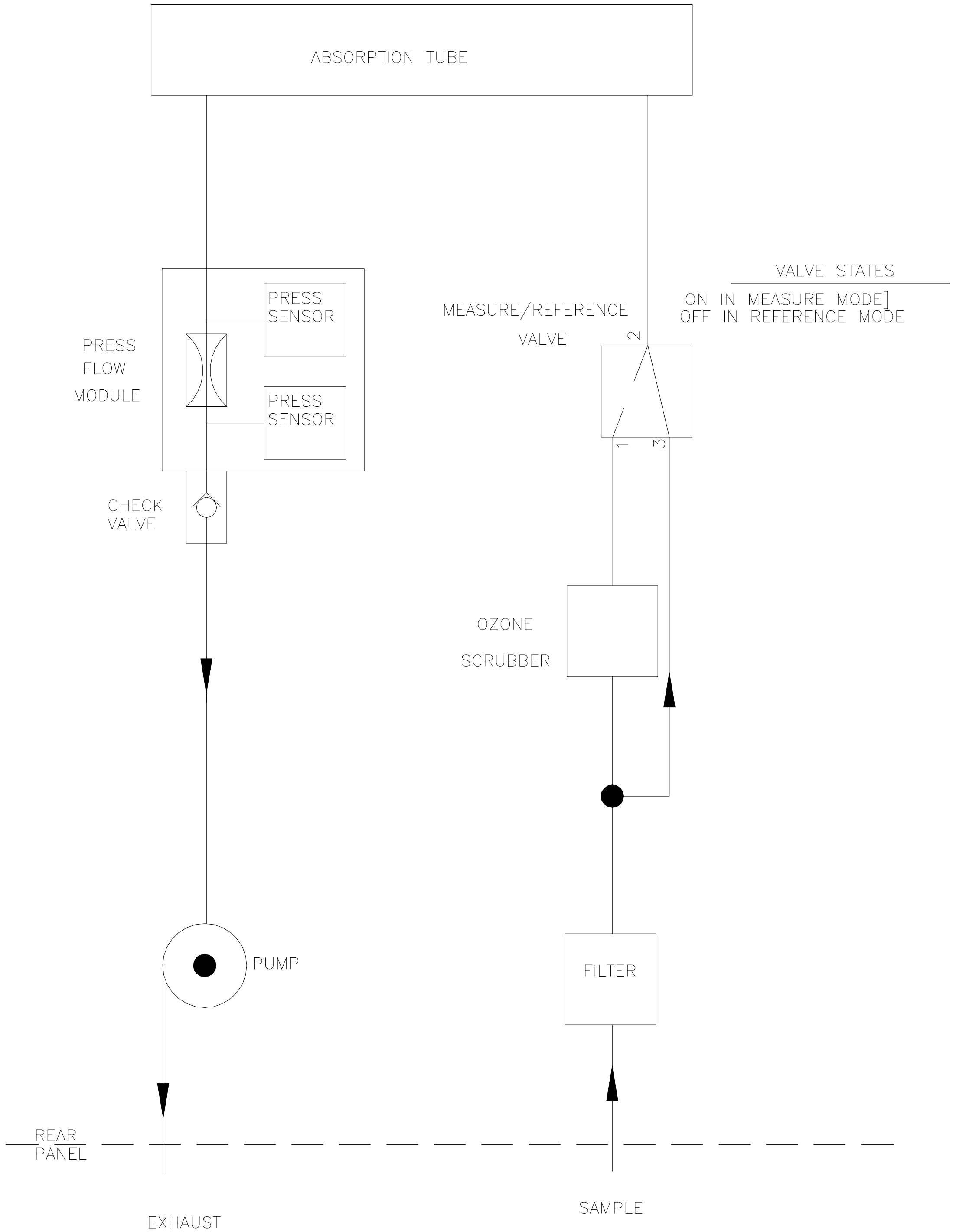


Figure 8-3: Pneumatic Diagram – Standard Configuration

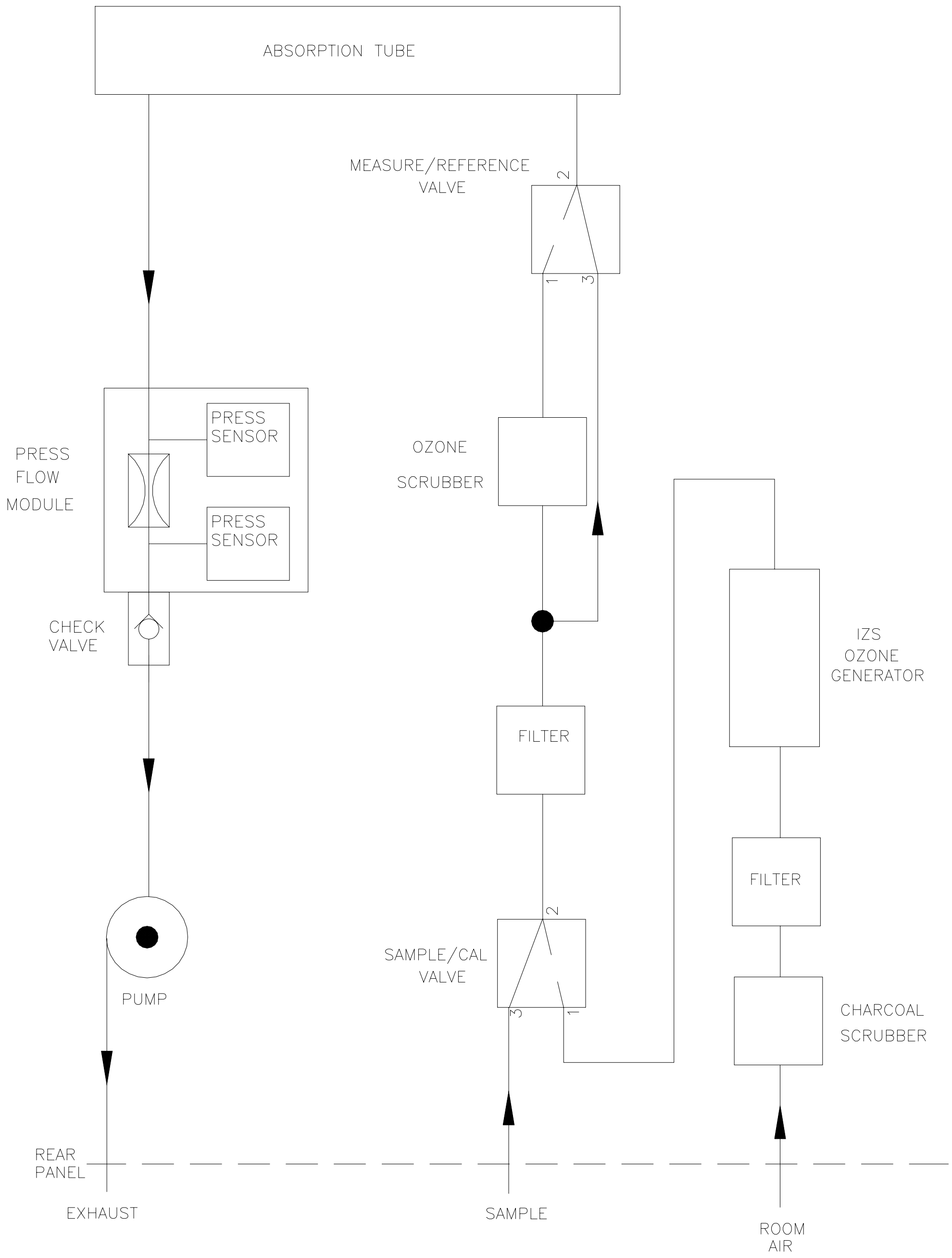


Figure 8-4: Pneumatic Diagram – Zero/Span Valves & IZS Option

8.6 Leak Check Procedure

There are two methods of leak checking:

By vacuum: This is the simplest method but it does not show the location of a leak.

If you want to confirm that you do not have a leak, use vacuum.

By pressure: By using bubble solution, this method shows a leak location.

If you know you have a leak, use pressure.

CAUTION

Do not use bubble solution with vacuum. The solution may contaminate the instrument. Do not exceed 15 PSI pressure.

8.6.1 Auto Leak Check

A quick automatic leak check can be done by the instrument as follows:

1. Press **SETUP-MORE-DIAG** and enter password.
2. Press **NEXT** until AUTO LEAK CHECK appears on the top line of the display.
3. Press **ENTR**.
4. Follow the prompts on the display. You will be asked to cap the sample inlet port (standard configuration) or the Dry Air Inlet port (units with IZS option.) The rest of the leak check will be performed automatically and the results of the test will be displayed when it is complete.

If the instrument fails this test, proceed with a manual leak check as described in the sections below to pinpoint the leak source.

8.6.2 Leak Check Procedure for Standard Unit

1. See Figure 8-3. Disconnect the tubing between the Pressure/Flow Module and the Pump and cap the tubing end.
2. Cap the end of the Critical Flow Orifice assembly that you just removed.
3. Connect leak checker to sample inlet. Using pressure or vacuum, check for leaks. When applying pressure or vacuum, be sure to allow enough time (30 sec minimum) for air to bleed through the critical flow orifice located in the Pressure/Flow Module.
4. The leak-down rate should be less than 1” drop in pressure in 5 min.

8.6.3 Leak Check Procedure for Units with IZS Option

1. See Figure 8-4. Disconnect the nut from the inlet fitting to the sample pump.
2. Cap the end of the tubing that you just removed.
3. Connect leak checker to sample inlet. Using pressure or vacuum, check for leaks as described above. When applying pressure or vacuum, be sure to allow enough time (30 sec minimum) for air to bleed through the critical flow orifice located in the Pressure/Flow Module.
4. To leak check the IZS assembly, connect leak checker to Dry Air Inlet port on the rear panel of the instrument. Leak check as described above. The leak-down rate should be less than 1” drop in pressure in 5 min.

8.6.4 Leak Check Procedure for Units with Zero/Span Valves

1. Disconnect the nut from the inlet fitting to the sample pump.
2. Cap the end of the tubing that you just removed.
3. Connect leak checker to sample inlet. Using pressure or vacuum, check for leaks as described above. When applying pressure or vacuum, be sure to allow enough time (30 sec minimum) for air to bleed through the critical flow orifice located in the Pressure/Flow Module.
4. The zero and span gas inlets should also be individually checked. Since both of these ports are normally closed, simply connect the leak checker and apply pressure or vacuum.

8.7 Prom Replacement Procedure

1. Locate the CPU/V-F card assembly by referring to Figure 2-3.
2. Remove the screw that hold the CPU/V-F card assembly in place and remove the assembly from the motherboard.
3. Disconnect the three cables that attach the CPU/V-F assembly to the rest of the instrument, taking note of the polarity.
4. Remove the assembly laying it down on an insulating surface such that the CPU is face up and the backplane card is on the left. The PROM chip should be at the top center of the CPU. See Figure 9-1 for component location. The current chip should be labeled with something like "41AB7STD.1_1". Gently pry the chip from its socket and replace it with the new chip. Install the chip in the left end of the socket with the notch facing to the right. Make sure that all of the legs insert into the socket correctly.
5. Re-attach all cables making sure to observe the polarity, then replace the CPU/V-F assembly, and tighten the screw on the backplane bracket.
6. Turn instrument power "ON" and observe the front panel display. As the analyzer goes through the setup the version number will be displayed on the front panel. It should read the same as the version number that was located on the top right corner of the label on the PROM.
7. Re-enter any non-default settings such as RANGE or AUTOCAL. Check all settings to make sure that expected setup parameters are present.
8. Re-calibrate the analyzer so that the default slope and intercept are overwritten with the correct values.

9 TROUBLESHOOTING, ADJUSTMENTS

NOTE

The operations outlined in this chapter are to be performed by qualified maintenance personnel only.

CAUTION

Risk of electrical shock. Disconnect power before performing the following operations.

General Troubleshooting Hints

The Model 400A has been designed so that problems can be rapidly detected, evaluated and repaired. During operation, the analyzer continuously performs self-check diagnostics and provides the ability to monitor the key operating parameters of the instrument without disturbing monitoring operations.

A systematic approach to troubleshooting will generally consist of the following four steps, performed in order:

1. Confirm the proper operation of fundamental instrument sub-systems (power supplies, CPU, display).
2. Note any warning messages and take corrective action as required.
3. Examine the values of all TEST functions and compare to Factory values. Note any major deviations from the factory values and take correction action as required.
4. Address any dynamic (sample related) problems.
5. Data from our Service Department indicates that 50% of ALL problems are eventually traced to leaks in the analyzer, calibrator, zero air system, or sample delivery system. Suspect a leak first.

The following sections provide a guide for performing each of these steps. Figure 2-3 in this manual shows the general layout of components and sub-assemblies in the analyzer and can be referenced in performing the checks described in the following sections.

9.1 Operation Verification-M400A Diagnostic Techniques

When the Analyzer is turned on, several actions will normally occur which indicate the proper functioning of basic instrument sub-systems. These actions are:

1. The sample pump should start.
2. The Display should light and display a log-on message followed by a standard "Sample" display (See Figure 4-2 for illustration of a normal display.)
3. The green sample light on the front panel should turn on.

If these actions all occur, it is probable that the Analyzer's Power Supplies, CPU, and Display are working properly. If any of these actions fail, this Section contains procedures for diagnosing the above mentioned subsytems.

9.1.1 Fault Diagnosis with TEST Variables

The Model 400A provides the capability to display the values of TEST functions, which show key analyzer operating parameters. These TEST functions can be accessed by depressing the **<TST** and **TST>** buttons on the front panel. By comparing the values of TEST functions to acceptable operating limits, it is possible to quickly isolate and correct most problems.

Table 9-1 provides a list of available Test Functions along with their meaning, their range of acceptable values, and the recommended corrective actions if the value is not in the acceptable range. Additionally, Table 2-1 provides a list of TEST values during factory checkout.

Table 9-1: Test Function Values

Test Function	Meaning	Acceptable Values	Corrective Action for Unacceptable Values
RANGE	The full scale range of the analyzer's analog outputs.	100 to 10,000 ppb	None required
STABIL	Standard deviation of noise reading for last 10 min of data	Check Table 2-1 for noise readings at factory checkout	Check Section 9.2.3 for causes and remedies for excess noise.
O_3 MEAS	The most recent detector reading taken in Measure mode.	2500-4700mV	Check and adjust source lamp and UV detector as described in Section 9.3.5
O_3 REF	The most recent detector reading taken in Reference mode.	2500-4700mV	Check and adjust source lamp and UV detector as described in Section 9.3.5
O_3 GEN	The reading from the IZS feedback reference detector option.	75-175mV - O_3 generator off. >75mV - O_3 Gen on.	Check and adjust the IZS lamp and reference detector as described in Section 9.3.9
O_3 GEN DRIVE	Drive voltage that programs the IZS ozone generator.	0-5000mV	
VACUUM	Absolute pressure down stream of the sample flow control orifice.	Less than ½ of SAMPLE PRES reading.	Most common cause for incorrect readings is faulty sample pump or leaks.
SAMPLE PRES	The absolute pressure of the sample gas in the absorption cell	0"-2.0" Hg below ambient pressure	Check for pneumatic system problems. See Section 9.3.12. Check for pressure transducer problems. See Section 9.3.10

(table continued)

Table 9-1: Test Function Values (Continued)

Test Function	Meaning	Acceptable Values	Corrective Action for Unacceptable Values
SAMPLE FLOW	Sample mass flow rate	720-880 cc./min	Check for pneumatic system problems. See Section 9.3.12 Check for flowmeter problems. See Section 9.3.10
SAMPLE TEMP	The temperature of the sample gas in the absorption cell	10º-15ºC above ambient	See Section 9.2.3
PHOTO LAMP	The temperature of the UV Source Lamp	52ºC	See Section 9.3.5
O_3 GEN TEMP	The temperature of the IZS ozone generator lamp option	48ºC	See Section 9.3.9
ORIFICE TEMP	Orifice manifold temperature	48ºC	
BOX TEMP	The temperature inside the analyzer chassis	1º-5ºC above ambient	If > 5C above ambient, check fan in the Power Supply Module. Areas to the side and rear of instrument should allow adequate ventilation.
DCPS	DC Power Supply reference. A composite of voltages provided by the DC Power Supply	2250-2750mV	Composite of +5 and ±15VDC. Values outside range indicate failure of DCPS.
SLOPE	Software gain term	1.0 ± 0.1	Values outside range indicate contamination, miscalibration or flow blockage
OFFSET	Software zero offset term	0 ± 20 ppb	Values outside range indicate contamination.
TIME	Time-of-day clock	00:00 – 23:59	Fast or slow clocks can be adjusted. See VARS CLOCK_ADJ. Battery in clock chip on CPU board may be dead.

9.1.2 Fault Diagnosis with WARNING Messages

The most common and/or serious instrument failures will result in a warning message being displayed on the front panel. Table 9-2 lists warning messages, along with their meaning and recommended corrective action. It should be noted that if multiple (more than 2 or 3) warning messages occur at the same time, it is often an indication that some fundamental analyzer sub-system (power supply, V/F board, CPU) has failed rather than an indication of the multiple failures referenced by the warnings. In this situation, it is recommended that proper operation of power supplies (see Section 9.3.8) and the V/F Board (see Section 9.3.4) be confirmed before addressing the specific warning messages.

Table 9-2: Warning Messages

Warning Message	Meaning	Corrective Action
PHOTO REF WARNING	The O_3 REFERENCE value is greater than 5000mV or less than 2500mV	Check and adjust Source Lamp and UV detector as described in Section 9.3.5
PHOTO LAMP TEMP WARNING	Temperature control of the Source Lamp cannot be maintained at its 52^{o}C set point.	Check source lamp heater and thermistor as described in Section 9.3.5
O3 GEN REFERENCE WARNING	Unable to adjust UV lamp intensity.	Section 9.3.9
O3 GEN LAMP WARNING	The IZS Ozone Generator is unable to produce at least 1000 ppb at its maximum output or the IZS feedback control is adjusting the Ozone generator drive signal by more than a factor of two	Check and adjust the IZS lamp and reference detector as described in Section 9.3.9
O3 GEN TEMP WARNING	Temperature control of the IZS O_3 Gen Lamp cannot be maintained at its 48^{o}C set point.	Check source lamp heater and thermistor as described in Section 9.3.9
SAMPLE PRESSURE WARNING	The Sample Pressure is less than 15"Hg or is greater than 35"Hg	Check for pressure transducer problems as described in Section 9.3.10
SAMPLE FLOW WARNING	The sample flow is less than 500 cc/min or greater than 1000 cc/min.	Check pressure sensor assembly using Section 9.3.10 Check pneumatic system using Section 9.3.12
SAMPLE TEMP WARNING	The Sample Temperature is less than 10^{o}C or is greater than 50^{o}C	See Section 9.3.2
BOX TEMP WARNING	The inside chassis temp is less than 10^{o}C or is greater than 50^{o}C	See Section 9.3.2
ORIFICE TEMP WARNING	Orifice manifold temp cannot be maintained at 48^{o}C, check heater or thermistor	
SYSTEM RESET	A power Off-On cycle has occurred	None required
RAM INITIALIZED	Dynamic memory has been re-initialized in response to the installation of a new PROM or memory chip	None required

When certain monitored values get outside of normal limits. a WARNING occurs. A warning message is displayed on the front panel, and a message is sent out the RS-232 port, the FAULT LED blinks. For certain WARNINGS, a STATUS bit is set. A warning indicates that something in the system may need to be checked or adjusted. Failure to respond to a warning may result in poor system performance and/or less accurate data acquisition.

When a warning is displayed, **MSG** and **CLR** buttons will appear on display. Pressing **MSG** will scroll through the warning messages if there is more than one. **CLR** will clear the currently displayed warning message.

If a warning message reappears every time after **CLR** is pressed, the problem should be corrected and the Analyzer restarted. Some problems may be temporary and may not reappear after **CLR** is pressed, for example the SYSTEM RESET message when the instrument is powered up.

To ignore the warning messages and display the test measurement again, simply press **TST>**. The warning messages will remain active and may be viewed again by pressing **MSG**.

9.1.3 Fault Diagnosis using DIAGNOSTIC Mode

Diagnostic mode can be thought of as a tool kit to help troubleshoot the instrument.

To access DIAG mode, press SETUP-MORE-DIAG, then press NEXT, PREV to select the desired mode, then press ENTR. The diagnostic modes are summarized in Table 9-3.

9.1.3.1 Signal I/O

The signal I/O diagnostic mode gives the user access to the digital and analog inputs and outputs on the V/F board. The digital outputs can be controlled through the keyboard. Any signals manually changed through the signal I/O menu will remain in effect until you leave the signal I/O menu. At that time the analyzer will regain control of these signals. To enter the signal I/O test mode, press **SETUP-MORE-DIAG-ENTR**. When the diagnostic mode is entered, a message is sent to the RS-232 channel indicating entry into the diagnostic mode. Use the **PREV** and **NEXT** buttons to scroll through the signals. Edit buttons will appear for the signals that can be controlled by the user. Press **JUMP** to skip to a specific I/O Signal.

Table 9-3: Diagnostic Mode I/O Signals

No.	Signal	Control	Description
0	SPAN_VALVE	YES	Switches the Zero/Span valve. Use this bit to test the valve function.
1	CAL_VALVE	YES	Switches the Sample/Cal valve. Use this bit to test the valve function.
2	PHOTO_REF_VALVE	YES	Switches the photometer ref/meas valve. Use this bit to test the valve function.
3	PHOTO_LAMP_HTR	YES	Shows the status of the photometer lamp heater. This has the same function as the LED in the power supply module.
4	O3_GEN_HTR	YES	Shows the status of the ozone generator heater. This has the same function as the LED in the power supply module.
5	LAMP_POWER	YES	Controls input power to the lamp power supply
6	O3_PUMP	YES	Sample pump power
7	ORIFICE_HEATER	YES	Switches orifice mainfold heater
8	PHOTO_DET	NO	Photometer UV detector reading. Typically 2500-4500mV
9	O3_GEN_DET	NO	O_3 Generator UV detector reading. Typically 2500-4500mV
10	PHOTO_SAMP_PRES	NO	Sample pressure in mV. Typical sea level value = 4300mV for 29.9" HG-A.
11	VACUUM_PRESSURE	NO	Pressure reading down stream of orifice
12	DCPS_VOLTAGE	NO	DC power supply composite voltage output. Typically 2500mV.
13	DAC_CHAN_0	NO	Output of DAC 0 (REC) in mV.
14	DAC_CHAN_1	NO	Output of DAC 0 (DAS) in mV.
15	DAC_CHAN_2	NO	Output of DAC 0 (TEST) in mV.
16	DAC_CHAN_3	NO	Output of DAC 0 (O_3 GEN DRIVE) in mV.
17	REF_TEMP	NO	Calibration voltage for thermistor (0^oC)
18	BOX_TEMP	NO	Internal analyzer temp in mV
19	ORIFICE_TEMP	NO	Orifice manifold temperature in mV
20	O3_GEN_TEMP	NO	O_3 Generator temp. Typically 2270mV for 48C

(table continued)

Table 9-3: Diagnostic Mode I/O Signals (Continued)

No.	Signal	Control	Description
21	SAMPLE_TEMP	NO	Sample temp in mV
22	PHOTO_LAMP_TEMP	NO	Photometer Lamp temp. Typically 2740 mV for 52 C
23	REF_TEMP_70	NO	Calibration voltage for thermistors (70^o C)
24	CONC_OUT_1	YES	O_3 Reading (REC) in mV
25	CONC_OUT_2	YES	Reading (DAS) in mV
26	O3_GEN_DRIVE	YES	O_3 Generator Drive in mV
27	TEST_OUTPUT	YES	Test Channel in mV
28	EXT_ZERO_CAL	NO	Shows state of status input bit to cause the M400A to enter Zero Calibration mode. Use to check external contact closure circuitry.
29	EXT_LO_SPAN	NO	Shows state of status input bit to cause the M400A to enter the precision point Calibration mode. Use to check external contact closure circuitry.
30	EXT_SPAN_CAL	NO	Shows state of status input bit to cause the M400A to enter the Span Calibration mode. Use to check external contact closure circuitry.
31	CONTROL_IN_1	YES	Shows state of control input bit for low span check
32	CONTROL_IN_2	YES	Unused control input bit (spare)
33	CONTROL_IN_3	YES	Unused control input bit (spare)
34	ST_SYSTEM_OK	YES	Status Bit - System OK Logic High = No instrument warning present Logic Low = 1 or more alarm present
35	ST_LAMP_ALARM	YES	Status Bit - UV Lamp alarm Logic High = UV lamp output too low Logic Low = Lamp output normal
36	ST_HIGH_RANGE	YES	Status Bit - Autorange High Range Logic High = M400A in high range Logic Low = M400A in low range
37	STATUS_OUT_1	YES	Spare status output

(table continued)

Table 9-3: Diagnostic Mode I/O Signals (Continued)

No.	Signal	Control	Description
38	ST_ZERO_CAL	YES	Status Bit - Zero Calibration mode Logic high = M400A in Zero cal mode Logic low = Not in Zero cal mode
39	ST_SPAN_CAL	YES	Status Bit - Span Calibration mode Logic high = M400A in Span cal mode Logic low = Not in Span cal mode
40	ST_FLOW_ALARM	YES	Status Bit - Flow alarm Logic High = Sample flow out of spec Logic Low = Flows within spec
41	ST_TEMP_ALARM	YES	Status Bit - Temperature alarm Logic High = One or more temps out of spec Logic Low = Temps within spec
42	ST_DIAG_MODE	YES	Status Bit - In Diagnostic mode Logic High = M100A in Diagnostic mode Logic Low = Not in Diag mode
43	ST_POWER_OK	YES	Status Bit - Power OK Logic High = Instrument power is on Logic Low = Instrument power is off
44	ST_PRESS_ALARM	YES	Status Bit - Flow alarm Logic High = Sample pressure out of spec Logic Low = pressure within spec
45	ST_LOW_SPAN_CAL	YES	Status Bit - Zero Calibration mode Logic high = M400A in Low Span cal mode Logic low = Not in Zero cal mode
46	SAMPLE_LED	YES	Controls state of green SAMPLE LED on the front panel
47	CAL_LED	YES	Controls state of yellow CAL LED on the front panel
48	FAULT_LED	YES	Controls state of red FAULT LED on the front panel

9.1.3.2 Analog Output Step Test

This test steps the analog output channels from 0% to 100% of Full Scale in 20% steps. To enter the analog output test press **SETUP-MORE-DIAG**. Scroll using **PREV/NEXT** until ANALOG OUTPUT appears, then press **ENTR**.

It starts by outputting 0 volts then, every five seconds the output is increased 20%. The analog outputs will cycle through the following values. The display will indicate the current step.

0%, 20%, 40%, 60%, 80%, 100%, 0% ...

Pressing the key under the display will halt the stepping. To resume automatic cycling, press the button again.

9.1.3.3 Setting the Analog Output Offset

The analog outputs can be biased to offset the output voltage of each channel ±10% of the output voltage setting. The default offset is 0mV. To change it, press **SETUP-MORE-DIAG,** press **NEXT** until D/A CALIBRATION is displayed and press **ENTR.** Press **CFG** to enter the D/A configuration menu. Use the **NEXT** and **PREV** buttons to select the desired analog output and press **SET**. Enter a value of from –500 mV to +500 mV (other ranges will ratio accordingly), followed by **ENTR** to accept the change, or **EXIT** to leave it unchanged. The offset will be reflected immediately on the analog output.

9.1.3.4 Test Channel Output

Additionally, the values of most TEST functions can output as an analog voltage at the instrument's rear panel (see Figure 2-2). The TEST function to be output is selected by pressing **SETUP-MORE-DIAG**. Press **NEXT** until TEST CHANNEL OUTPUT appears. Press **ENTR**. Select test channel function and press **ENTR**. Table 9-4 lists the Test functions available for analog output. In addition to outputting a value to the analog output channel, these tests activate a new test measurement which displays the analog voltage reading on the front panel as: "**TEST=XXXX.X MV**".

Table 9-4: Test Channel Outputs

Test Channel	Zero	Full Scale
O3 PHOTO MEAS	0 mV	5000 mV
O3 PHOTO REF	0 mV	5000 mV
O3 GEN REF	0 mV	5000 mV
SAMPLE PRESS	0 "Hg	40 "Hg
SAMPLE FLOW	0 cc/m	1000 cc/m
SAMPLE TEMP	0 DegC	70 DegC
ANA LAMP TEMP	0 DegC	70 DegC
O3 LAMP TEMP	0 DegC	70 DegC
CHASSIS TEMP	0 DegC	70 DegC
DCPS VOLTAGE	0 mV	5000 mV

9.1.3.5 RS-232 Port Test

This test is used to verify the operation of the RS-232 port. It outputs a 1 second burst of the ASCII letter 'w'. During the test it should be possible to detect the presence of the signal with a DVM on pin 2 or 3 (depending on the DTE/DCE switch setting) or by the flickering of the red test LED. A detailed procedure is given in the Section 9.3.3.

9.1.3.6 V/F Board Calibration

The V/F Board is calibrated when the instrument is set up at the factory. Re-calibration is usually not necessary, but is provided here in case the V/F board needs to be replaced and re-calibrated. The procedure for using the V/F Calibration routines is in the Section 9.3.4.

9.1.4 M400A Internal Variables

The M400A software contains many adjustable parameters. Most of the parameters are set at time of manufacture and do not need to be adjusted for the lifetime of the instrument. Some of the variables are user adjustable, they are listed in Table 9-5.

To access the VARS menu press SETUP-MORE-VARS-ENTR. Use the PREV-NEXT buttons to select the variable of interest, then press EDIT to examine/change the value, then press ENTR to save the new value and return to the next higher menu. If no change is required, press EXIT.

Table 9-5: MODEL 400A Variables

No.	Name	Units	Default Value	Value Range	Description
0	DAS_HOLD_OFF	min	15	0-60	Time that data is not put into DAS after CAL or DIAG modes
1	PHOTO_LAMP	^oC	52	0-60	UV Lamp Temperature
2	O3_GEN_LAMP	^oC	48	0-60	Ozone Generator Lamp Temperature
3	O3_GEN_LOW1	ppb	100	0-1500	Ozone Generator Low Concentration Setpoint (Precision point) for Range 1
4	O3_GEN_LOW2	ppb	100	0-1500	Ozone Generator Low Concentration Setpoint (Precision point) for Range 2
5	ORIFICE_SET	^oC	48	0-60	Setpoint for orifice manifold temp control
6	SFLOW_SET	cc/min	500	400-1000	Nominal sample flow rate
7	RS232_MODE	Bit Field	0	0-99999	Value is SUM of following decimal numbers: 1=enable quiet mode 2=enable computer mode 4=enable security feature 8=enable front panel RS-232 menus 16=enable alternate protocol 32=enable multidrop protocol
8	CLOCK_ADJ	sec	0	+-60	Real-time clock speed adjustment

9.2 Performance Problems

Dynamic problems (i.e. problems which only manifest themselves when the analyzer is monitoring sample gas) can be the most difficult and time consuming to isolate and resolve. Additionally, analyzer behavior which appears to be a dynamic problem is often a symptom of a seemingly unrelated static problem. For these reasons, it is recommended that dynamic problems not be addressed until all static problems and warning conditions, as described in the preceding sections, have been isolated and resolved.

If all the checks described in the preceding sections have been successfully performed, the following will provide an itemization of the most common dynamic problems with recommended troubleshooting checks and corrective actions.

NOTE

It has been our experience that about 50% of all analyzer performance problems are sooner or later traced to leaks in some part of the system.

1. Fluctuations in flow, such as leaks or plugged orifices.
2. Lack of preventive maintenance – dirty/plugged sample filter.
3. Change in zero air source.
   A. Air containing ozone leaking into zero air line.
   B. Saturation of IZS zero air scrubbers.
4. Change in span gas concentration.
   A. Zero air or ambient air leaking into span gas line.
5. Leak in Ref/Measure switching valve.
6. Loose pneumatic fittings.

9.2.1 AC Power Check

1. Check that power is present at main line power input. Verify that correct voltage and frequency is present. If unit is set for 240VAC and is plugged into 115VAC it will appear as no power fault.
2. Check that the unit is plugged into a good socket. Analyzer must have 3-wire safety power input.
3. Check circuit breaker. Circuit breaker is part of the front panel power switch. It is set each time the instrument power is turned on. If there is an internal short causing a trip, the switch will automatically return to the OFF position when an attempt is made to turn it on.

9.2.2 Temperature Problems

The Model 400A has been designed to operate at ambient temperatures between 5^{o}C and 40^{o}C. As a first step in troubleshooting temperature problems, confirm the ambient temperature is within this range and that the air inlets slots on the sides of the cover and the fan exhaust on the rear panel are not obstructed.

The instrument monitors five temperatures:

1. Sample Temperature
2. Inside Chassis Temperature
3. Source Lamp Temperature
4. IZS Lamp Temperature (Option)
5. Orifice Manifold Temperature

and controls the temperatures of three components by heating:

1. Orifice Manifold
2. Source Lamp
3. IZS Lamp (Option)

If any of the temperature readings appear to be incorrect, check for proper thermistor operation by measuring the resistance of the thermistor(s). This resistance should be in the range of 7.6K ohms to 95K ohms, a resistance of 27k ohms corresponds to a temperature of 27^{o}C. If it is not, the thermistor is defective and should be replaced. Points for measuring thermistor resistance are as follows:

Sample Temperature

Unplug the connector at Motherboard J14 and measure across the leads.

Photometer Lamp Temperature

Unplug the connector at Motherboard J15 and measure across the leads.

IZS Lamp Temperature

Unplug the connector at Motherboard J16 and measure across the leads.

If thermistor resistance(s) are within the proper range, check the temperature linearization circuits on the I2C Submux Board, see Section 9.3.2.

If temperature sensor readings appear accurate but control temperatures are not being maintained at their proper value, check the operation of the heaters as follows:

1. Observe the indicator LED's on the Power Supply Module and confirm that the "PHOTOMETER LAMP HEATER" and "O3 GEN HEATER" LED's are lit or cycling (turning off and on). If these indicators are not correct, it is probably that the Power Supply Module, or the V/F Board is at fault. Check as described in Sections 9.3.8.
2. Unplug the heater element from Power Supply Module and confirm that 115VAC is present. If 115VAC is present, the heater element has failed and should be replaced.
3. Measure heater resistance lead-to-lead and lead-to chassis. Heater resistance should be in the range 200 – 2000 ohms depending on the wattage of the heater. Resistance of heater-to-chassis should be infinite.

WARNING

Hazardous voltages present – use CAUTION!

9.2.3 Excessive Noise

1. Check for leaks in the pneumatic systems as described in Section 9.3.12.
2. Confirm the Sample Temperature, Sample Pressure, Photo Lamp Temperature, and Sample Flow readings are correct. Check and adjust as required.
3. UV Lamp may need replacement. If spare lamp is available, replace lamp and check noise. If spare lamp is not available, consult factory for assistance.
4. Unplug lamp and plug back in. If noise goes away, change lamp or power supply, change PROM to updated software.

9.2.4 Unstable Span

1. Check for leaks in the pneumatic systems as described in Section 9.3.12.
2. Check for proper operation of the Main Switching Valve and Ozone Scrubber as described in Section 9.3.6.
3. Check for a dirty particulate filter and replace as necessary as described in Section 8.2.
4. Check for dirty pneumatic system components and clean or replace as necessary as described in Section 9.3.12.
5. Check for proper adjustment of DAC and ADC electronics by performing the adjustment procedure in Section 9.3.4.
6. Confirm the Sample Temperature, Sample Pressure, and Sample Flow readings are correct. Check and adjust as required.

9.2.5 Unstable Zero

1. Check for leaks in the pneumatic system as described in Section 9.3.12.
2. Confirm that the Zero gas is free of Ozone.
3. Check for a dirty particulate filter and replace as necessary as described in Section 8.2.
4. Confirm that the Source Lamp is fully inserted and that the lamp hold-down thumb- screw is tight.
5. Check for a dirty Absorption Cell and/or pneumatic lines. Clean as necessary as described in Section 8.4.
6. Disconnect the exhaust line from the optical bench (the pneumatic line at the lamp end of the bench) and plug the port in the bench. If readings remain noisy, the problem is in one of the electronic sections of the instrument. If readings become quiet, the problem is in the instrument's pneumatics.

9.2.6 Inability to Span

1. Confirm that the ozone span gas source is accurate – this is the #1 problem reported by our service department.
2. Check for leaks in the pneumatic systems as described in Section 9.3.12.
3. Check for proper operation of the Main Switching Valve and Ozone Scrubber as described in Section 9.3.6.
4. Check for a dirty particulate filter and replace as necessary as described in Section 8.2.
5. Check for dirty pneumatic system components and clean or replace as necessary as described in Section 9.3.12.
6. Check for proper adjustment of DAC and ADC electronics by performing the adjustment procedure in Section 9.2.
7. Confirm the Sample Temperature, Sample Pressure, and Sample Flow readings are correct. Check and adjust as required.

9.2.7 Inability to Zero

1. Check for leaks in the pneumatic system as described in Section 9.3.12.
2. Confirm that the zero gas is free of ozone. Place a charcoal scrubber in sample inlet line.
3. Check for a dirty particulate filter and replace as necessary as described in Section 8.2.

9.2.8 Analog Output Doesn't Agree with Display Concentration

1. Confirm that the DAC offset is set to zero. See Section 9.1.3.3.
2. Perform a DAC calibration and Dark Signal adjustment by following the procedures described in Sections 9.2 and 9.3.5.
3. Perform analog output step test by pressing SETUP-MORE-DIAG, then scroll to the analog output step test.

9.3 Subsystem Troubleshooting and Adjustments

9.3.1 Computer, Display, Keyboard

When the analyzer is turned on, the front panel display should energize and the green "Sample" LED should light. If proper DC power is present (see Section 9.3.8), the absence of these will usually indicate either a CPU or Display failure. To determine which module is defective, perform the following procedure:

9.3.1.1 Front Panel Keyboard

During normal Analyzer operation, depressing the right-most key of the keyboard should cause a change of display modes. If it does not, check:

1. Cable connections
2. CPU and Display operation (see Section 9.3.1)
3. If these checks are satisfactory, it is probable that the keyboard is defective and should be replaced.

9.3.1.2 Front Panel Display

1. Turn off power
2. Remove the ribbon cable from the CPU board to the Display
3. Turn Power on
4. A cursor character should appear in the upper left corner of the display. If it does not, the display is defective and should be replaced. If the cursor does appear, it is probable that the CPU is faulty.

9.3.1.3 Single Board Computer

The SBC40 is a full function computer designed for instrument control applications. It consists of a 16 bit 8080 microprocessor, 2 serial and one parallel ports, standard bus interface, and 4 sockets for memory. The memory sockets consist of: 256k ROM containing the multitasking operating system and application code, 8k EE prom containing the setup variables, 256k RAM containing data collected by the instrument, and a time-of-day clock to provide event timing services. The overall function of this board is quite complex. Complete testing of this board's functions is not possible in the field. The board outline is shown in Figure 9-1.

Like the display, the overall functioning of the CPU can be confirmed by a simple test.

1. Locate the CPU board on the mother board by referring to Figure 2-3.
2. Power the instrument on.
3. Locate the red LED at the top left edge of the board.
4. It should be flashing at a frequency of about once per second.
5. This flashing indicates the board is powered up and is executing instructions.
6. Upon power-up, the CPU does a self-test checking RAM, EEPROM and other functions. If there is a fault, it will be shown on the front panel display.

Testing and operation of the CPU RS-232 port is described in Section 9.3.3. It is possible for the UART driver chip to malfunction in either or both of the input or output ports.

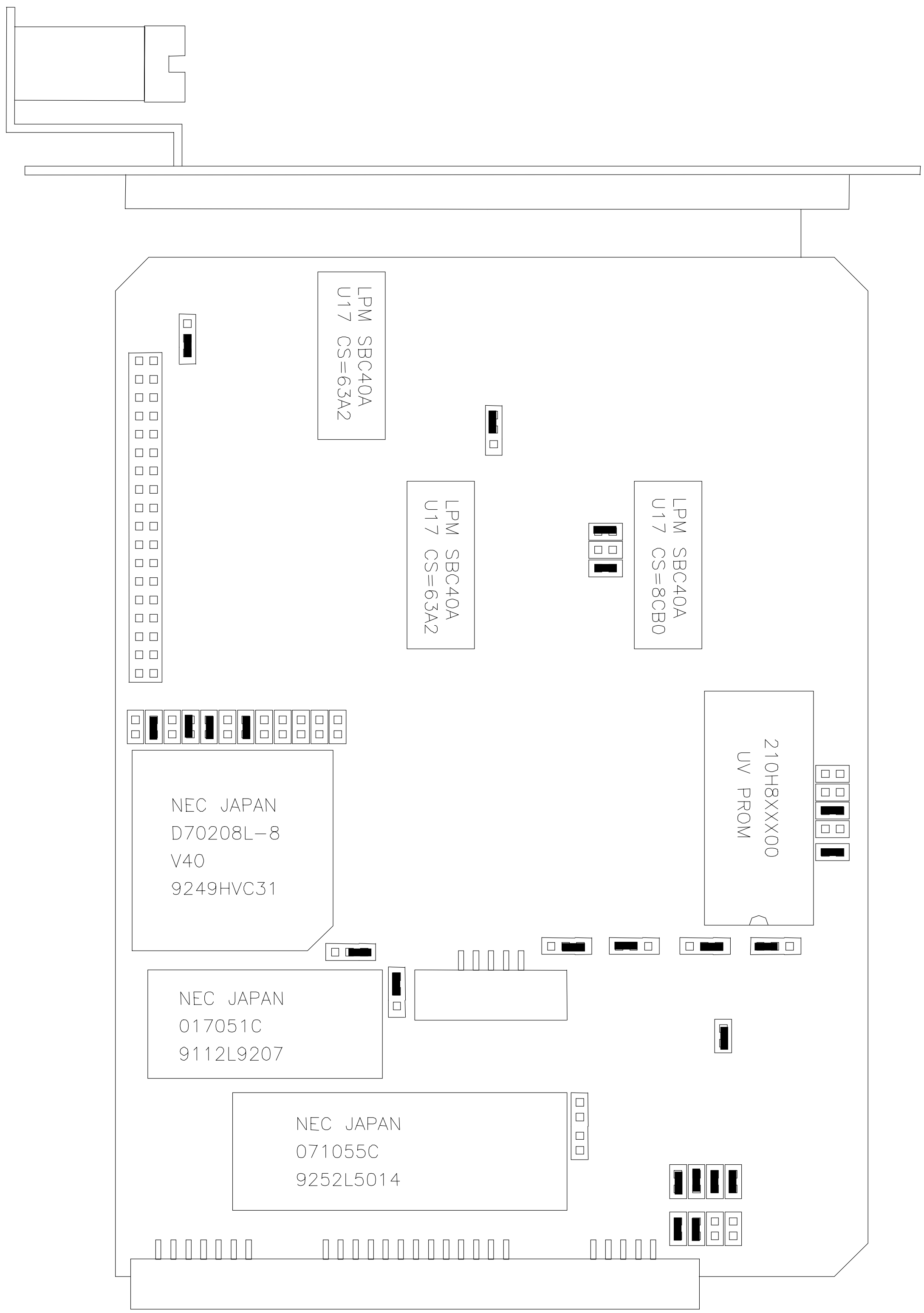


Figure 9-1: CPU Board Jumper Settings

9.3.2 I2C / Submux Board

This board is mounted as a mezzanine board on the CPU card. It serves two purposes, the first is to transmit digital signals from the CPU to the rear panel status board, and secondly to convert the thermistor resistance into a voltage which goes to the mother board, then to the V/F board. The digitized number is sent to the CPU via the STD bus for scaling and linearization.

9.3.2.1 Temperature Amplifier Section

Four thermistors are brought onto the board through connector P2. A single thermistor is selected from the P1 MSC1 & MSC0 lines, which are then decoded by U2. The analog mux U4 selects the appropriate signal, which is then routed to U7 for conditioning and scaling, then routed back off the board via P2 to the V/F board.

The temperatures measured are:

1. Box Temp
2. Sample Temp
3. Ozone Generator Temp
4. Block Temp

Proper functioning of this part of the board can be verified by looking at the temperatures using the front panel TEST functions. Each voltage being read by the V/F board can be checked by using the SIGNAL I/O feature in the DIAGNOSTIC menu.

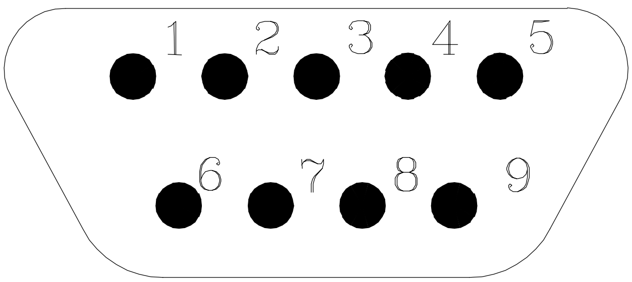
9.3.2.2 I2C Serial Bus Section

The second section of this board takes CPU board digital signals from the P1 connector and passes them to U1, which serializes the signal and sends them to the rear panel board via P2.

The CPU continually monitors the integrity of the I2C bus by sending commands to the rear panel “slave device” every 30 sec and checking for a valid reply. If the check fails a warning message is sent to the front panel and RS-232 port.

Front Panel Warning Message: `REAR PANEL NOT DETECTED`

RS-232 Message: `WRPANELDET – REAR PANEL NOT DETECTED`



PIN ASSIGNMENTS

PIN	FUNCTION
2	TX DATA[1]
3	RX DATA[1]
5	SIG GROUND
7	DSR
8	RTS

RS-232 CONFIGURATION PARAMETERS

19,200 BAUD DEFAULT*
8 DATA BITS
1 STOP BIT
NO PARITY

*SETTABLE 300-19,200 BAUD

1 SWITCH SETTABLE ON REAR PANEL CONNECTOR BOARD

Figure 9-2: RS-232 Pin Assignments

9.3.3 RS-232 Communications

9.3.3.1 RS-232 Diagnostic Procedures

Teledyne API analyzers use the RS-232 communications protocol to allow the instrument to be connected to a variety of computer based equipment. RS-232 has been used for many years and as equipment has become more advanced, connections between various types of hardware have become increasingly difficult. Generally, every manufacturer observes the signal and timing requirements of the protocol very carefully. Problems arise when trying to specify connectors, and wiring diagrams that attach the analyzer to various devices. See Figure 9-2 for pin-out.

9.3.3.2 RS-232 Connections

Connectors:

The problem centers around two areas. First is the physical incompatibility of connectors. Second is the wiring of the connectors. We will attempt to provide some guidelines for connecting the Teledyne API analyzers to other equipment.

There are a wide variety of connectors and cables that are specified to operate with the RS-232 protocol. This is because electronics have decreased in size over the years and connectors have been downsized to match the electronics.

Cables & Adapters come in the following 4 general types:

1. Cables - cables are provided in various lengths from 6 to 50 feet. In most cases they have a male connector at one end and a female at the other. Variations on this are ones that provide both a cable and adapter. For example the cable provided with our analyzer adapts a female DB-9 to a male DB-25 connector. Most cables do not contain a Null modem.
2. Gender changers - convert a male connector to a female connector or vice versa. They do so WITHOUT changing the pin-to-pin wiring.
3. Adapters - these change from one type plug (DB-9) to another type plug (DB-25). They do so WITHOUT changing the wiring.
4. Null modems - here the connector changes the internal wiring so that DTE devices can become DCE or vice versa. The main internal change is swapping pin 2 and 3 so that data is transmitted and received on opposite pins.

CAUTION

Null modems can also combine gender changer or adapter features in the design. When making up an adapter cable be EXTREMELY CAREFUL to note what you are using, especially with combination null modem – adapter connectors.

DTE – DCE Wiring:

As technology has progressed it has become ambiguous which equipment should be DCE or DTE. The M400A has a switch that allows you to switch between DTE and DCE. Once your equipment is plugged in and turned on, correct wiring can be confirmed if BOTH red and green LED's are illuminated on the instrument rear panel. If only one LED is on, switch the DTE-DCE switch.

9.3.3.3 Connecting the Analyzer to a Modem

Modem's are configured as Data Communications Equipment (DCE). All that is needed is a straight through adapter to connect from the analyzer to the modem. Make sure that none of the adapters contain a null modem.

In addition to DTE-DCE wiring, modems have pins that need to be at certain logic levels before the modem will transmit data. The most common requirement is the Ready to Send (RTS) signal must be at logic high before the modem will transmit. The M400A sets pin 7 (RTS) to 10 volts to enable modem transmission. DSR and CTS are at ground.

Make sure the BAUD rate, word length, and stop bit settings between modem and analyzer match, see Figure 9-2.

In DIAGNOSTIC mode, use the RS-232 test function to send a 1 sec burst of "w" characters out the port. You can verify that the M400A is transmitting data by looking at the red LED on the rear panel. It will flicker when data is being transmitted.

Get your modem to transmit data to the analyzer, the green LED should flicker as the instrument is receiving data.

Data Communications Software for a PC

You will need to purchase a software package so your computer can transmit and receive on its serial port. There are many such programs, internally we use Hyperterminal. Once you set up the variables in PROCOMM and your wiring connections are correct, you will be able to communicate with the analyzers. Make sure the analyzer BAUD rate matches PROCOMM. Check in SETUP-MORE-COMM-BAUD, also check the other details covered in Figure 9-2.

9.3.4 Voltage/Frequency (V/F) Board Diagnosis and Calibration

The 00515 V/F board is a complex board, complete testing of all of its functions in the field are not possible. The following is a few simple tests that will confirm the general operation of the board:

1. Observe the DCPS - TEST function on the front panel. The reading should be near 2500 ±100mV. If it is, this means that the V/F converter is probably working properly.
2. Perform the Analog Output Step Test DIAGNOSTIC test covered in Section 9.1.3. The output voltages should cycle correctly according to the test. If the board fails the Analog Output Step test above, the board may be out of calibration. The V/F board calibration procedure is covered below
3. Confirm the presence of appropriate power by checking for:

   +5V between TP 4 and TP 5

   +15V at TP 1 and TP 3

   -15V at TP 2 and TP 3

   If any of these voltages are incorrect, check the DC Power Supply as described inSection 9.3.8.

4. Confirm that all jumpers on the V/F board are set properly, as follows:

Table 9-6: V/F Board Jumpers – Factory Settings

Factory Set Jumpers	
Jumper	**Setting**
B1	1
B2	1-2
B12	3-4 (0-5V)
B14	2-3 (Enabled)
B15	Set to match power line frequency
JP1	1-2
JP2	1-2

5. Confirm that the V/F board DIP switches are set correctly by referring to Figure 9-3.

> **NOTE**
>
> **If you change the dip switches for analog output range then you must do an V/F calibration per this section.**

Due to the stability of modern electronics, this procedure should not have to be performed more than once a year or whenever a major sub-assembly is exchanged or whenever analog output voltage range is changed.

To calibrate the Analog-toDigital converter on the V/F board, do the following:

> **NOTE**
>
> **The accuracy of this calibration will only be as accurate as the DVM you use.**

1. Press **SETUP-MORE-DIAG**.
2. Enter Diagnostic password and press **NEXT** until D/A CALIBRATION appears in the display and press **ENTR**.
3. Press **ADC** to calibrate the V/F converter.
4. The M400A display will read "ADJUST ZERO:A/D=xx.x MV.” Put the probe of a voltmeter between TP3 (AGND) and TP9 (DAC #0) on the top of the V/F board (See Drawing 00514, Appendix E)
5. The value displayed by the voltmeter should be close (± 20mV) to the value on the M400A display. If they are not close then the V/F card has probably been configured improperly.
6. Adjust the Zero pot (R27) on the V/F card until the value on the M400A display matches the value on the voltmeter to within ± 2mV.

> **NOTE**
>
> **When adjusting R27, the value on the M400A display will change, the value on the voltmeter will remain constant.**

7. Press **ENTR**.
8. The M400A display will now read "ADJUST GAIN:A/D=xx.x MV."
9. Adjust the Span pot (R31) on the V/F card until the value on the M400A display matches the value on the voltmeter to within ± 20mV.
10. Press **ENTR**.
11. The ADC is now calibrated and the M400A will automatically calibrate all the DAC's. This process takes only a few seconds
12. Press **EXIT** 4 times to return to the sample menu.

9.3.4.1 Output Voltage Range Changes

Output voltage ranges are set by DIP switches on the V/F board. To change the range for the analog outputs:

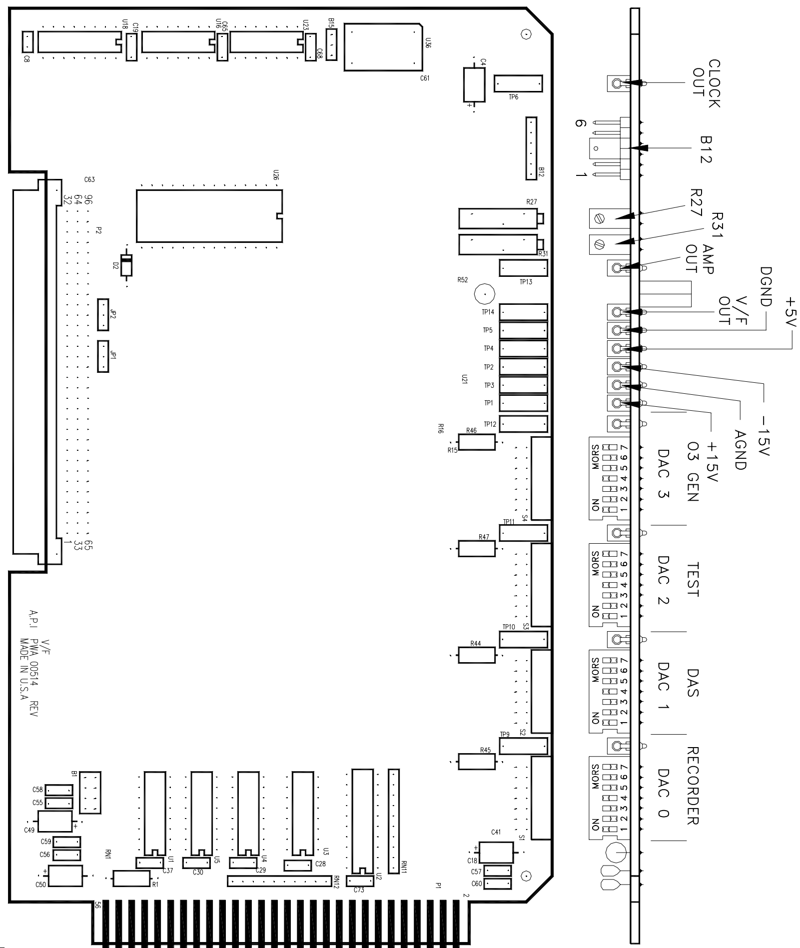
1. **Turn off instrument power.** Remove instrument cover. Locate the V/F board near the front of the analyzer using Figure 2-3.
2. Locate switches along the top edge of the card. Select the desired range per Figure 9-3.
3. Recalibrate the ADC as described in this section.

NOTE

To adjust the recorder offset, see Section 9.1.3.3.

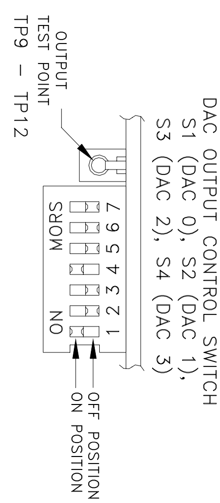
NOTE

Do not attempt to change the voltage range for DAC3 (S4).
Doing so will result in malfunction of the IZS ozone generator.



EXAMPLE: BIPOLAR, 5VOLT FULLSCALE WITH OVERRANGE
SWITCH POSITIONS = 1 AND 4 ON,
ALL OTHER SWITCH POSITIONS OFF.

NOTE: SWITCHES 1,2,7 MUST HAVE THE FOLLOWING SETTINGS.
1 ON
2 OFF
7 OFF



SWITCH POSITION	FUNCTION	SWITCH SETTINGS
1 & 2	BIPOLAR/ UNIPOLAR	BIPOLAR 1=ON, 2=OFF UNIPOLAR 2=ON, 1=OFF
3,4,5,6	FULLSCALE OUTPUT RANGES	10V 3=ON 4,5,6=OFF 5V 4=ON 3,5,6=OFF 1V 5=ON 3,4,6=OFF 100mV 6=ON 3,4,5=OFF
7	GAIN LIMIT	FULLSCALE OUT 7=ON OVERRANGE OUT 7=OFF

APPROXIMATE TARGET VOLTAGES FOR V/F CALIBRATION

OUTPUT RANGE	10% OF SCALE	90% OF SCALE
100mV	1.2 mV	90 mV
1V	12 mV	900 mV
5V	60 mV	4500 mV
10V	120 mV	9000 mV

ANALOG OUTPUT	SIGNAL	REAR PANEL PIN #	SWITCH SETTING ON	SWITCH SETTING OFF
DAC0	REC	1,2	1,4	2,3,5,6,7
DAC1	DAS	2,3	1,4	2,3,5,6,7
DAC2	O3GEN	N/A	1,4,7	2,3,5,6
DAC3	TEST	3,4	1,4,7	2,3,5,6

Figure 9-3: V/F Board Settings

9.3.5 Optical Bench Assembly

9.3.5.1 Source Lamp Power Supply Diagnosis and Adjustment

Basic operation of the source lamp and detector can be determined by observing the value of the O_3 REF test function. After the analyzer is warmed-up (15 min. to 30 min. after power-on), this value will give a good indication of the state of Lamp and Detector operation as shown on Table 9-7.

Table 9-7: UV Source Lamps and Detector Diagnostics

O_3 REF Value	**Meaning**
4700 mV to 5000 mV	The Source Lamp and Detector are operating, but adjustment is required
4000 mV to 4700 mV	The Source Lamp and Detector are operating properly; no adjustment is needed
2500 mV to 4000 mV	The Source Lamp and Detector are operating. Adjustment is useful but not required
175 mV to 2500 mV	The Source Lamp and Detector are operating, but adjustment is required
75 mV to 175 mV	Either the Source Lamp or the UV detector is not functioning
Less than 75 mV	The Detector Pre-Amp or V/F Board has failed or is disconnected

Checking the Lamp Power Supply

A schematic and physical diagram of the Lamp Power Supply are shown on drawings 01217 and 01218 in Appendix E.

It is not always possible to determine with certainty whether a problem is the result of the UV Lamp or the Lamp Power Supply. However, the following steps will provide a reasonable confidence test of the Lamp Power Supply.

WARNING

Hazardous voltages present – use CAUTION!

1. Unplug the cable connector at J1 on the Lamp Power Supply and confirm that +24VDC is present between Pins 1 and 2 on the cable connector. If this voltage is incorrect, check the Power Supply Module as described in Section 9.3.8.
2. Remove the cover of the Lamp Power Supply and check for the presence of the following voltage:

   +24VDC between TP1 and TP14
3. If this voltage is incorrect, the Lamp Power Supply is faulty and should be replaced.

If the above checks are successful, it is more likely that a problem is due to the UV Lamp than due to the Lamp Power Supply. Replace the Lamp and if the problem persists, replace the Lamp Power Supply.

Adjustment Required or Adjustment Useful

Adjust the Lamp and Detector Preamp as described in Section 9.3.5. If it is not possible to achieve an acceptable O_3 REF test Value by means of adjustment, it is possible that the lamp has deteriorated beyond its useful range and should be replaced.

WARNING

UV light present. Do not look directly at the UV lamp since UV light could cause eye damage. Always use UV filtering glasses or view through glass.

Lamp or Detector Failure

An O_3 REF value of approximately 125mV usually indicates a total failure of either the source lamp or the detector. To determine which component is at fault, remove the top cover of the optical bench and observe the "lamp end" of the quartz absorption tube. If a blue-white light is visible, the lamp is operating and the detector is at fault and should be replaced. If no light is visible, the lamp power supply should be checked as described in this Section. If the Lamp Power Supply check is satisfactory, then the lamp has failed and should be replaced.

NOTE

In cold ambient conditions, it may require 5 to 15 minutes of warm-up before the source lamp initially fires. Be sure to wait for this period before troubleshooting the lamp/detector.

Adjust the drive power of the lamp power supply as follows:

1. Remove the cover of the lamp power supply. Attach a DVM across TP7 and TP14, and adjust the pot (RV1) until the DVM reads 20 volts ± 1 volt.
2. Remove the cap on the detector preamp cover. Turn pot 25 turns CW, then 5 turns CCW.
3. Adjust the positioning of the source lamp, as follows:
   A. At the front panel of the instrument, Press the **TEST** key until O_3 REF=XXXXX is displayed.

   B. Loosen the lamp retaining thumb-screw and rotate the lamp until the O_3 REF reading on display is 4500 mV ± 320 mV. Re-tighten the thumb-screw. (Note that the full range of lamp adjustment can be achieved within ¼ revolution of the lamp. Note also that the O_3 REF display is updated approximately once every six seconds, and slow rotation of the lamp is needed for proper adjustment.)
4. Adjust the UV Detector Pre-Amp gain as follows:
   A. Remove the access cap on the Detector cover at the front end of the optical bench, and adjust the pot (R7) until the O_3 REF reading on the display is 4500mV ± 50mV.

WARNING

UV light present. Do not remove lamp from housing when adjusting.

   B. If it is still not possible to achieve a 4500 mV O_3 REF reading, increase the UV lamp drive power by adjusting the lamp power supply as described in Step 1. (DO NOT, however, allow the voltage measured across the TP7 and TP14 to exceed 21 volts.)

5. Re-calibrate the automatic Detector Dark Current compensation by pressing **SETUP-MORE-O3-DARK-CAL**. See Section 9.3.5.3 for dark current adjustment procedure.

9.3.5.2 Detector Pre-Amp

A O_3 REF test value of less than 75mV usually indicates a failure of the Detector Pre-Amp. Confirm that the V/F is operating properly as described in Section 9.3.4. If the V/F check is successful, the Detector pre-amp has failed and should be replaced.

9.3.5.3 Dark Current Signal Adjust Procedure

The detector dark current changes little as the detector ages. Therefore this procedure should not need to be performed more than once per year or whenever a major sub-assembly is changed (such as a new UV lamp or UV lamp power supply) or gain pot on the preamp board is adjusted.

To calibrate the dark current signal, press **SETUP-MORE-O3-DARK-CAL** and the analyzer will do the following:

1. Turn the analyzer lamp off
2. Average 6 successive O_3 detector readings, taken 1 second apart
3. Turn the analyzer lamp back on

This offset will then be stored and subtracted from all future O_3 detector readings.

To view the current dark offset, press **SETUP-MORE-O3-DARK-EDIT**. Press **EXIT** when finished. No password is required to view the dark offset, only to change it. CAUTION: Do not change the DARK value once it has been calibrated. Doing so will give erroneous readings.

9.3.5.4 Source Lamp Temp

The UV lamp on the Optical Bench is temperature controlled to 52^{o} C. The heater is a ¼” dia heater, the temperature is measured by a thermistor. The most common problem is that the temperature will become too high because the Box Temperature is greater than 52^{o} C.

1. Check the TEST functions to see if the heater is controlling to the correct temperature.
2. Check Optical Bench to see that both the heater and thermistor are fully seated in their respective holes.
3. Check the cycling of power to the heater by observing the “Photometer Lamp Heater” LED on the top of the Power Supply Module.
4. Use a DVM to see if heater is getting power. The voltage across the heater should be 115 VAC regardless of the instrument in input voltage. The voltage should cycle between 0 and 115 VAC, synchronized with the LED on the PSM. If no power is observed at the heater, the solid state switch in the PSM could be bad.

9.3.6 Checking the Ozone Scrubber and Main Switching Valve

Proper operation of the selective Ozone Scrubber and main Switching Valve can be determined by performing the following procedure:

1. Introduce Zero-gas at the sample inlet port using either the optional IZS or an external zero-gas source, and allow the analyzer to stabilize.
2. Observe the O_3 REF Test Function and make a note of its value.
3. Introduce Span-gas of approximately 400 ppb concentration at the sample inlet port using either the optional IZS or an external Span-gas source and allow the analyzer to stabilize.
4. Observe the O_3 REF Test Function and note its value. If the O_3 REF value has decreased by more than 5mV from its value with Zero-gas, then either the Ozone Scrubber has failed or there is a "cross-port" leak in the main switching valve.

NOTE

If desired, this check can be performed using Ozone concentrations higher than 400 ppb. In this case, the drop in O_3 REF (in mV) should be no greater than: O_3 REV < 5 * (actual concentration)/400.

To determine which, pneumatically bypass the main switching valve by disconnecting the sample line between the valve and the optical bench from the valve's common port and reconnect it directly to the output port of the Ozone Scrubber.

Repeat Steps 1 through 4 above. If the decrease in the O_3 REF value is now within tolerance, then the main switching valve is defective and should be replaced or rebuilt. If an out-of-tolerance decrease in the O_3 REF value persists, the Ozone scrubber should be replaced.

9.3.7 Rear Panel Status/Analog Output PCA

The Rear Panel Status/Analog Output PCA, is a multifunction board. The functions are:

1. Provide 3 channels of analog voltage/current loop output
2. Provide instrument status bits through the 50 pin connector
3. Provide contact closure inputs to control calibration
4. Provide RS-232 communications

The sections below provide an operational test for each one of these functions.

9.3.7.1 Analog Outputs

There are 4 analog output channels. Channel assignments are:

0. Ozone output (O31)
1. Output (O32)
2. Ozone Generator Drive
3. TEST Output (TCH)

In the DIAGNOSTIC menu, there is an Analog Output Step Test, which writes stepped voltages to the DAC's. This test will verify the correct operation of the analog outputs, refer to Section 9.1.3.

9.3.7.2 Status Output Lines, External Contact Closures

The status output function reports Analyzer conditions to a 50 pin connector on the rear panel. The status data is generated in the CPU, routed to a mezzanine board attached to the CPU where it is serialized and formatted for I2C. The signals travel to the rear panel status board where they are received and decoded. They are then routed to NPN transistors, which can pass 50 ma of direct current. See Section 5.4 for status output pin assignments.

Remote contact closures can be used to provide the following functions:

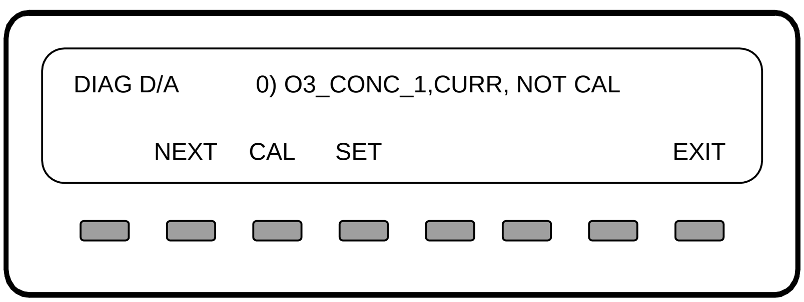
1. If no IZS or Z/S valves option is present, the contact closures will switch the instrument into zero or span calibration mode if closed.
2. If Z/S valves option is present, the contact closures operate the valves and switch the instrument into zero or span mode if closed.
3. If the IZS option is present, the contact closures operate the valves and ozone generator/zero air system plus switch the instrument into zero or span mode if closed

The external circuitry should be capable of switching 12VDC at 50 ma.

9.3.7.3 -20 mA Current Output (Optional)

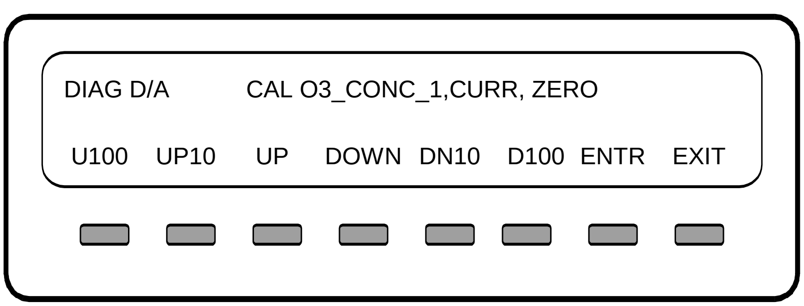
A current loop option can be ordered that will provide 0-20mA or 4-20mA analog output on the REC channel. The current loop channel can be independently calibrated without affecting the voltage output. This calibration must be repeated every time an A/D - D/A calibration is performed. To calibrate the current output, perform the following steps:

1. Perform an A/D - D/A calibration as outlined in Section 9.3.4.
2. Connect a Multimeter capable of measuring milliamperes to the current loop output. The current output connector is located on pins 7 and 8 of the connector labeled “RECORDER” on the rear panel. Note: When measuring the current output with a multimeter or similar low-impedance current measuring device, a 500-1K ohm resistor must be placed in series with the meter to simulate a load. Failure to do this will result in erroneous readings.
3. From the front panel, press SETUP-MORE-DIAG. Press NEXT until D/A CALIBRATION appears and press ENTR. Press CFG and the properties for analog output channel 0 will be displayed on the top line. The display should show something like:



   This indicates that channel 0 is setup for current output and has not been calibrated. If the display shows VOLT instead of CURR then the channel must be setup for current output. To do this, press **SET**, select **CURR** as the output type and press **ENTR**.

4. Next press **CAL** to begin the calibration. At this point the display should show:



The zero point for current output can now be set. Pressing UP, UP10 and U100 will step the zero point up in increments of 1, 10 and 100 steps. The zero point can be adjusted anywhere between 0 and 4 milliamps. Press **ENTR** when you have reached the desired zero point as measured by your test meter.

5. The display will now prompt you to adjust the Gain, or full-scale output of the current loop. Using the UP and DOWN buttons as in step 4, adjust the full-scale (usually 20ma) and press **ENTR**. This completes the current loop calibration. Press **EXIT** several times until you are back at the sample menu.

9.3.7.4 RS-232 Port

An RS-232 port is provided on the board. See Section 5.5 for setup and diagnosis.

9.3.8 Power Supply Module

The Power Supply Module consists of several subassemblies described in Table 9-8.

Table 9-8: Power Supply Module Subassemblies

Module	Description
Linear Power Supply Board	The linear power supply board takes multiple voltage inputs from the power transformer and produces +5, +15, -15, +12 VDC outputs. The outputs are routed to two external connectors, P2 and P3. See Figure 9-4. The +5 is used for operating the CPU. The ± 15 is used in several locations for running op-amps and IC's. The +12 is used for operating fans and valves.
Switching Power Supply	The switching power supply supplies +24 VDC at 2 A to the UV Source lamp power supply. The output is made available through J10 on the Switch Board. There is a load resistor on the Switch Board to keep the output stable when little current is required from the supply.
Switch Board	The Switch Board has many different functions. It takes logic signals from the V/F board and uses them to switch 4-115 VAC and 4-12VDC loads. The board also contains the instrument central grounding tie point. It routes unswitched AC and DC power as needed. Connector J2 programs the power transformers to take 115, 220, 230, and 240 VAC inputs.
Power Transformers	There are potentially 2 input power transformers in the instrument. The multitap transformer T1 is in every M400A and supplies input power for the Linear Power Supply board described above. A second transformer T2 is added if 220 or 240 VAC input is required. Input power selection is done via a programming connector P2 which provides the proper connections for either foreign or domestic power.
Circuit Breaker/Power Switch	The front panel contains a combination circuit breaker - input power switch. It is connected to the PSM through J6 on the Switch Board. If an overload is detected the switch goes to the OFF position. Switching the power back on resets the breaker also.

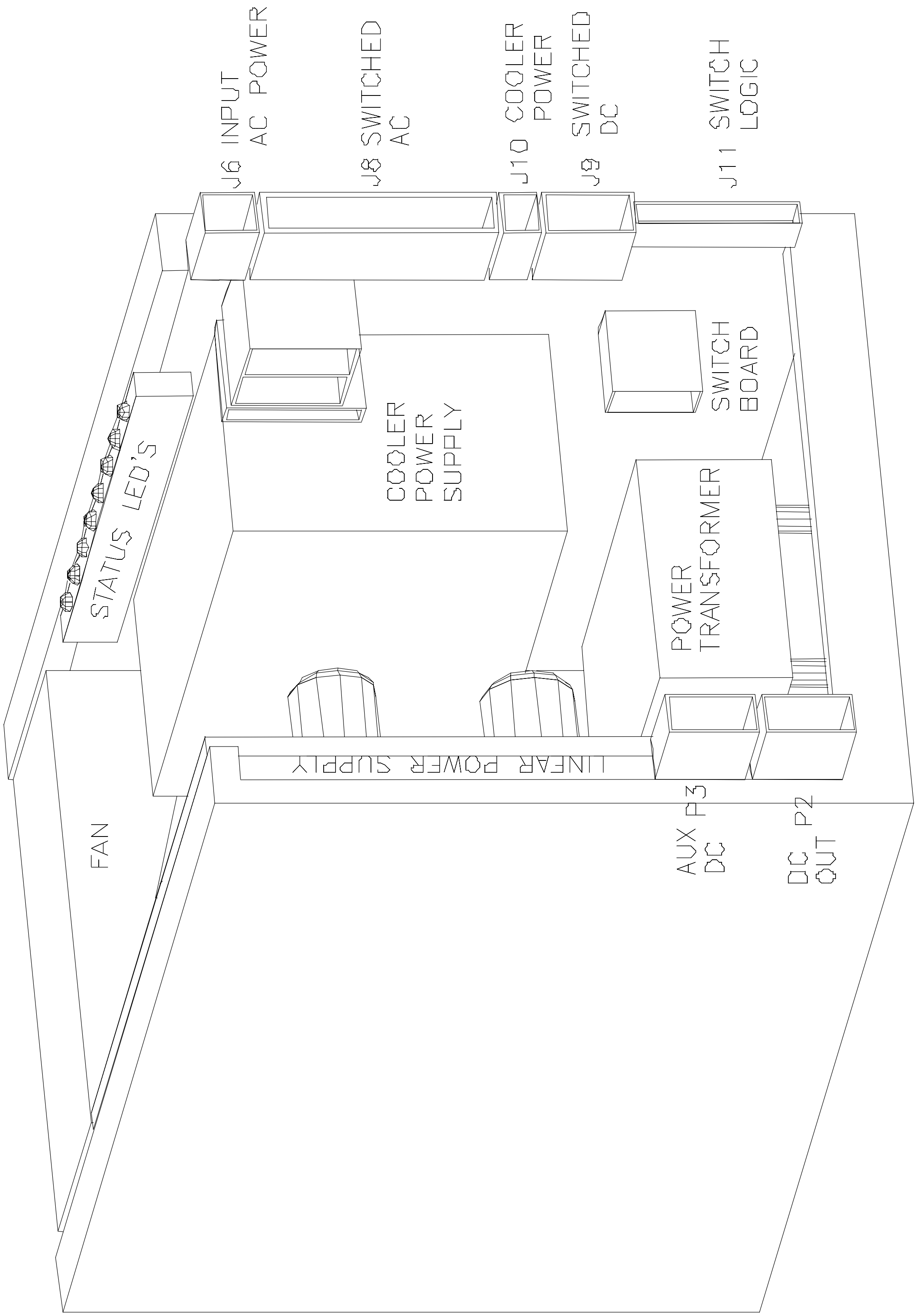


Figure 9-4: Power Supply Module Layout

PSM Diagnostic Procedures

The Linear Power Supply board can be tested by checking the DCPS - TEST function on the front panel. It should read 2500mV ±100mV. If the value is outside this range, individual output voltages can be tested on connector P3, see Schematic in the Appendix for pinouts.

The Switching Power Supply output can be tested by observing the REF VOLTAGE – TEST function on the front panel. It should be between 2500 and 4500mV.

The Switch Board can be tested by observing the diagnostic LEDS along the top edge of the board. The following Table 9-9 describes the typical operation of each LED.

Table 9-9: Power Supply Module LED Operation

No.	Function	Description
1.	Measure/Reference Valve	Should switch about every 3 sec. On = Measure mode Off = Reference mode
2.	Sample/Cal Valve	Should switch ON when CALZ or CALS button is pressed.
3.	No function	
4.	Zero/Span Valve	Should switch ON when CALS button is pressed.
5.	Pump power	Switches the power to the sample pump. On if instrument is powered up.
6.	Source lamp heater	Should cycle ON-OFF every 5 sec to 1 min. On continuously until up to temp.
7.	Sample flow control block heater	Should cycle ON-OFF every 5 sec to 1 min. On continuously until up to temp.
8.	Ozone Generator heater	Should cycle ON-OFF every 5 sec to 1 min. On continuously until up to temp.

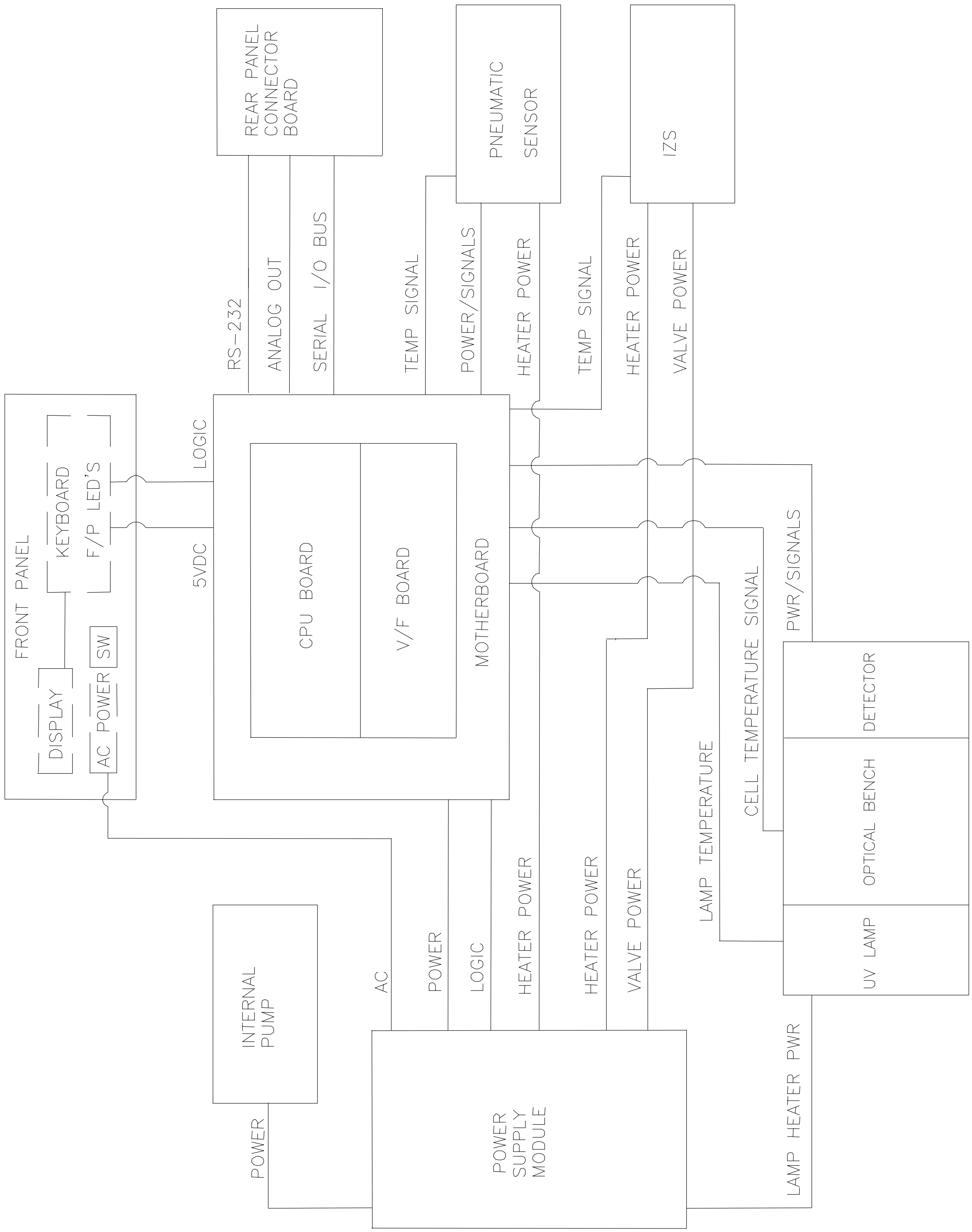


Figure 9-5: Electrical Block Diagram

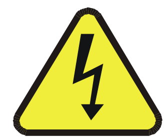
Checking the Power Sub-Systems

Refer to the electrical block diagram in Figure 9-5 for help.

1. Check incoming line power for proper Voltage and Frequency.
2. Check the Circuit breaker on the Analyzer's rear panel.
3. Check the 3-wire safety power-input plug on the Analyzer's rear panel.

CAUTION

Hazardous voltages are present on the power supply module. Always remove AC power cord from instrument before attempting to remove or replace any parts.



Check for proper DC Voltages by measuring for the following voltages on the V/F Board:

+5V between TP4 and TP5

+15V between TP1 and TP3

-15V between TP2 and TP3

If any of these voltages are incorrect, check the DC Power Supply schematic in Appendix 11.1.

9.3.9 IZS Option Diagnosis and Troubleshooting

9.3.9.1 IZS Ozone Generator Lamp

This procedure only needs to be done if the lamp is replaced or if the lamp is accidentally moved. The procedure adjusts the lamp for optimum operation of the IZS and its feedback circuit. Reference Figure 9-6 – IZS Module.

1. Enter the SETUP menu by pressing SETUP-MORE-O3-ADJ. This causes the lamp drive circuit to output a constant 2.5 V.
2. If you are installing a new lamp, allow approximately 30 min for lamp output to stabilize.
3. Select the "O3 GEN" Test function on the front panel display. Loosen the IZS lamp and rotate until the reading on the display is 2500 mV ± 500 mV.

CAUTION

UV light present. Do not pull the lamp from the IZS assembly.

4. Re-tighten the hold-down screws securing the ozone lamp to the IZS generator assembly.
5. Remove access cap from the IZS preamp cover and adjust the pot to refine the front panel reading to 2500 mV ± 25.
6. The IZS lamp and feedback circuit are now set up. Proceed to Section 9.3.9.2 to finish calibration of the IZS.

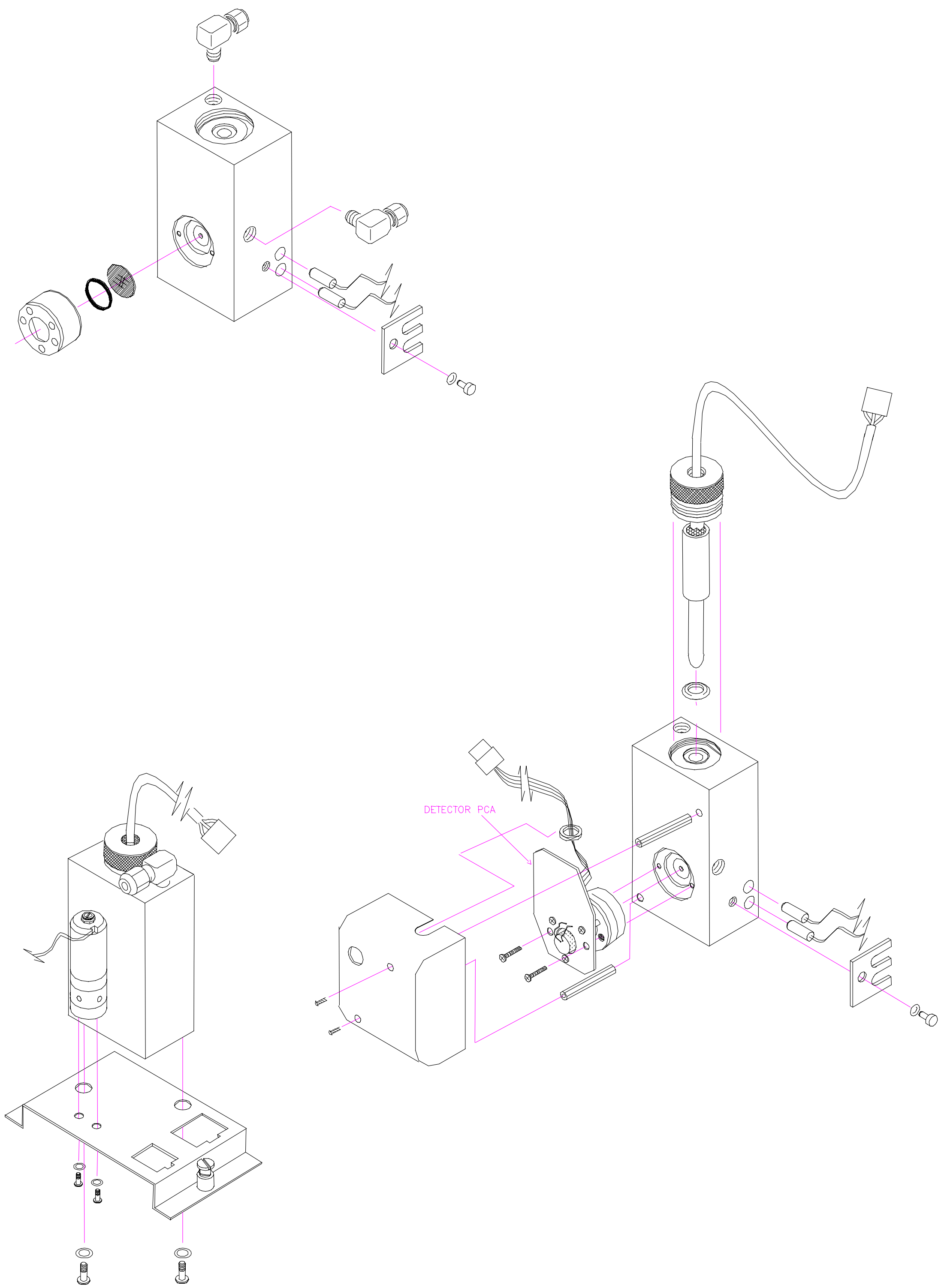


Figure 9-6: IZS Module

9.3.9.2 IZS Ozone Generator Calibration

The IZS ozone generator can be calibrated against the analyzer calibration by using the analytical section of the M400A to determine the ozone generator's output. Calibration of the generator allows the operator to enter the desired calibration concentration directly in ppb.

The M400A should be calibrated from an external ozone source using one of the methods described in Section 7 before doing this procedure.

Press **SETUP-MORE-DIAG** and scroll to **O3 GEN CALIBRATION** to start the calibration process, which works as follows:

1. The M400A will measure the IZS reference signal and the O_3 concentration at 6 different IZS lamp drive points: 400, 600, 800, 1000, 2000, and 5000 mV.
2. For each test point, the machine outputs the drive setting and waits 10 minutes for the M400A to stabilize. Then it takes two readings and stores them in a table for future use.
3. During calibration, the analyzer displays % completion so that you can monitor the progress of the calibration. Full calibration will take 1 hour (6 points x 10 minutes/point).
4. You can abort calibration by pressing EXIT. This will not restore the table contents already computed, however. If you EXIT within the first 10 minutes of the calibration, none of the calibration points will be modified.
5. If the procedure is allowed to complete, the IZS is ready for use.

9.3.9.3 IZS Reference Feedback Option

The Internal Zero/Span Feedback Option senses the output of the IZS ozone generating lamp and uses this signal to control the lamp drive current. This option assures very stable and repeatable ozone concentrations. If the IZS reference detector feedback option is present press **SETUP-MORE-O3-MODE-REF-ENTR** to activate this option.

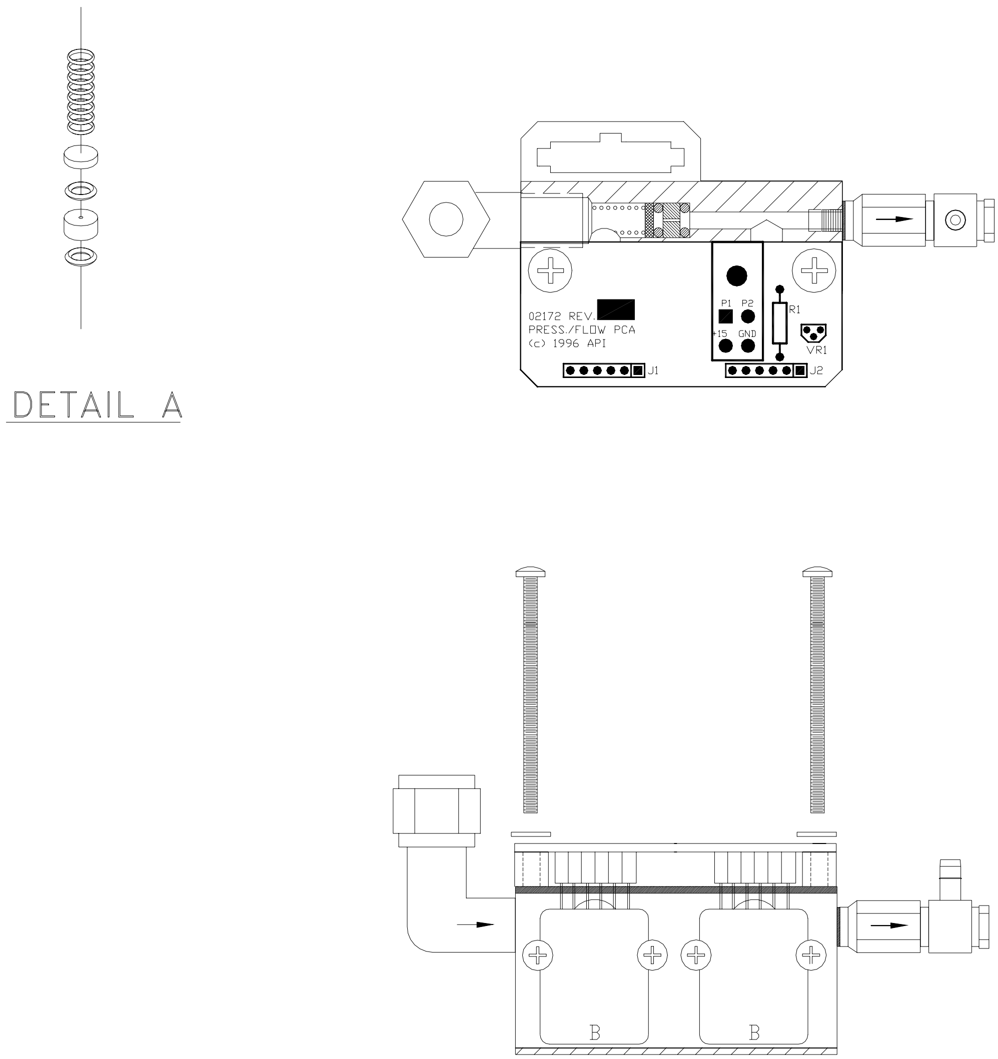


Figure 9-7: Pressure/Flow Sensor Module

9.3.10 Flow/Pressure Sensor

The Model 400A uses a critical flow orifice upstream of the sample pump to provide stable flow through the analyzer. The module is shown in Figure 9-7. Flow is calculated by measuring the pressure and temperature on the upstream side of the critical flow orifice and performing an ideal gas law correction on the nominal flow through the orifice. The downstream pressure is also measured to ensure that the conditions for critical flow are met.

When any flow problem is being diagnosed, the actual sample flow should be measured by connecting an independently calibrated flowmeter to the sample inlet and measuring the actual flow. Below are listed some of the possible fault conditions and their solution:

Displayed flow = "XXXX"

This warning means that the condition for critical flow are not being maintained. This condition is that the ratio of the downstream pressure to the upstream pressure must be 0.53 or higher. There are two conditions which might cause this, a flow obstruction upstream of the orifice or a loss of vacuum downstream of the orifice. To determine which is the case, scroll to the Sample Pressure and Vacuum test functions on the front panel. If the sample pressure is reading abnormally low, then the cause is likely a flow obstruction upstream of the orifice. First, check the sample filter and make sure it is not plugged and then systematically check all the other components upstream of the orifice to ensure that they are not obstructed. If the sample pressure is reading normal but the vacuum pressure is reading more than half the sample pressure value, it is likely that the pump diaphragm is worn and it should be replaced.

Actual Flow Does Not Match Displayed Flow

If the actual flow measured does not match the displayed flow, but is within the limits of 720-880 cc/min, the flow measurement can be calibrated from the front panel per Section 9.3.10.1.

9.3.10.1 Flow Calibration

To calibrate the flow measurement, connect an independently calibrated flowmeter to the sample inlet. From the front panel, press **SETUP-MORE-DIAG**. Press **NEXT** until FLOW CALIBRATION appears and press **ENTR**. Using the keyboard, enter the measured flow and press **ENTR**. The Sample Flow test function should now closely match the measure flow.

9.3.11 Z/S Valves Option

The Z/S Valves Option allows customer provided zero gas or span gas to be connected to separate ports on the rear panel. The calibration gasses are routed into the instrument by 2 valves.

Testing these valves can be done by:

1. Pressing the CALZ button on the front panel energizes the Sample/Cal valve, shutting off sample flow and admitting zero air to the instrument through the unenergized Zero/Span valve.

2. Pressing the CALS button on the front panel energizes the Sample/Cal valve and the Zero/Span valve shutting off sample flow and admitting cal gas to the instrument through the energized Zero/Span valve.

3. These two valves can be also tested by using the SIGNAL I/O part of the DIAGNOSTIC menu.

9.3.12 Pneumatic System

9.3.12.1 Troubleshooting Flow Problems

In general, flow problems can be divided into 3 categories:

1. Flow is zero (no flow)
2. Flow is greater than zero, but is too low, and/or unstable
3. Flow is too high

When troubleshooting flow problems, it is a good idea to first confirm that the actual flow and not the flow meter is in error. If the independent flowmeter shows the flow to be correct, check the Pneumatic Sensor Board as described in Section 9.3.10.

Use an independent flow meter (rotameter or mass flow meter) to measure sample flow at the sample inlet port at the instrument's rear panel. If no independent flow meter is available, placing a finger over an inlet port and feeling for a vacuum will at least give an indication whether flow is present.

Figure 1.3 in this Manual provides a schematic diagram of the Flow in a Model 400A and its optional IZS subsystem.

Flow is Zero

Confirm that the sample pump is operating (turning). If not, check the 115V power to the pump. If the pump does not operate with 115V present at its terminal, replace the pump. Check for plugged pneumatic lines, filters, or orifices.

Low Flow

1. Check for leaks as described in Section 8.5. Repair and re-check.
2. Check for dirty sample filter or dirty orifice filter. Replace filters.
3. Check for partially plugged pneumatic lines, orifices, or valves. Clean or replace lines.
4. Check if the pump diaphragm is in good condition. If not, rebuild pump.

High Flow

The most common cause of high flow is a leak around the sample flow orifice. To correct, remove the orifice, replace O-rings, and re-assemble.

9.3.12.2 Leak Check

An important source of analyzer performance problems is leaks. Fifty percent of all service problems reported to Teledyne API are eventually traced to leaks in some part of the system. Please refer to Section 8.5 for a leak check procedure.

9.3.12.3 Pump

The pump causes sample to pulled through the instrument. To check for proper operation:

1. Check that the pump is operating (turning).
2. Do flow check described in Section 9.3.12.1.
3. If the flow check fails, and the pump appears to be otherwise in good condition, rebuild it. Check the Spare Parts List for pump rebuild kit part number.

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10 M400A SPARE PARTS LIST

NOTE

Use of replacement parts other than those supplied by Teledyne API may result in non-compliance with European Standard EN 61010-1.

Table 10-1: Teledyne API M400A Spare Parts List

Part No.	Description
02230-0000	DC POWER SUPPLY BOARD
00094-10	ORIFICE, 13 MIL
00276-0140	CPU BOARD
00369	FILTER, TFE, 37 MM, QTY 100 (872-006400)
00369-01	FILTER, TFE, 37 MM, QTY 25 (872-006300)
00420-3000	O_3 PROM W/SOFTWARE
02271	ABSORPTION TUBE
00514-0200	V/F BOARD
00526-0100	UV LAMP ASSY, SOURCE
02028	PRE-AMP ASSY, M400A DET
01139-XX00	POWER SUPPLY MODULE
02241	ASSY, OPTICAL BENCH
00596	ACTIVATED CHARCOAL
02419	ASSY, UV LAMP, HEATER, THERMISTOR
00612-01	UV LAMP ASSY, IZS GEN
02818	M400A LEVEL 1 SPARES KIT
02819	M400A EXPENDABLES KIT-IZS
00619-02	M400A SPARES KIT FOR 1 UNIT
02260	ISTRUCTION MANUAL FOR M400A
02254	M400A ZERO AIR SCRUBBER (IZS) CHARCOAL
01190-01	SAMPLE FILTER ASSY
00690	SCRUBBER PADS

(table continued)

Table 10-1: Teledyne API M400A Spare Parts List (Continued)

Part No.	Description
02061	REAR PANEL CONNECTOR BOARD
01930	KEYBOARD
00728	DISPLAY
02240	M400A SWITCHING VALVE ASSY, W/SCRUBBER
00969	FILTER, TFE, 47 MM, QTY 100
00969-01	FILTER, TFE, 47 MM, QTY 25
01509	UV LAMP POWER SUPPLY
02414-01	ASSY, SAMPLE THERMISTOR
FA010	FAN
FL001	SINTERED FILTER (002-024900)
FL003	FILTER, DFU (036-040180)
FL012	M400A REFERENCE SCRUBBER
02255	ASSY, HEATER, THERMISTOR (IZS)
HW020	SPRING, FLOW CONTROL
HW036	TFE THREAD TAPE (48 FT)
HW037	TIE, CABLE
OP012	UV DETECTOR
OR001	O-RING, FLOW CONTROL
OR012	O-RING, O_3 GEN LAMP
OR014	O-RING, OPTICAL BENCH, LAMP WINDOW
OR018	O-RING, SAMPLE FILTER
OR021	O-RING, SCRUBBER
OR026	O-RING, ABSORPTION TUBE
OR030	O-RING, IZS SCRUBBER
OR048	O-RING, UV DETECTOR
PU020	PUMP 115V 50/60 Hz
PU022	PUMP REBUILD KIT
SW006	OVERHEAT SW, IZS OVEN, OPTICAL BENCH

(table continued)

Table 10-1: Teledyne API M400A Spare Parts List (Continued)

Part No.	Description
SW026	VACUUM SENSOR
TU001	TUBING: 6’, 1/8” CLR
TU002	TUBING: 6’, 1/8” BLK
TU009	TUBING: 6’, 1/4” TYGON
VA033	TFE, 12V, SAMPLE/REF. VALVE
VA028	IZS, ZERO/SPAN VALVE

Table 10-2: Teledyne API MODEL 400A Level 1 Spares Kit

Part No.	Description	
028180000	M400A LEVEL 1 SPARES KIT	
Includes:		**Qty**
000941000	ORIFICE, 13 MIL	1
005260100	UV LAMP ASSY, SOURCE	1
002028000	PRE-AMP ASSY, M400A DET	1
024190000	ASSY, HEATER/THERMISTOR, OPTICAL BENCH	1
006120100	UV LAMP ASSY, IZS GEN	1
022400000	M400A VALVE MODULE	1
015090000	UV LAMP POWER SUPPLY	1
024140100	ASSY, SAMPLE THERMISTOR, M400A	1
022710000	ABSORPTION TUBE, M400A	1
FL0000005	M400 OZONE SCRUBBER (INTERNAL)	2
022550000	ASSY, IZS HEATER/THERMISTOR M400A	1
PU0000022	PUMP REBUILD KIT	2

Table 10-3: Teledyne API MODEL 400A Expendables Kit For IZS

Part No.	Description	
028190000	M400A EXPENDABLES KIT - IZS	
Includes:		**Qty**
005960000	ACTIVATED CHARCOAL	1
006900000	RETAINER PADS	2
FL0000001	SINTERED FILTER (002-024900)	2
FL0000003	FILTER, DFU (036-040180)	1
PU0000022	PUMP REBUILD KIT	1

Table 10-4: Teledyne API MODEL 400A Spares Kit for 1 Unit

Part No.	Description	
028180100	M400A SPARES KIT FOR 1 UNITS	
Includes:		**Qty**
024190000	ASSY, HEATER/THERMISTOR, OPTICAL BENCH	1
022550000	ASSY, IZS HEATER/THERMISTOR M400A	1
FA0000010	FAN	1

APPENDIX A ELECTRICAL SCHEMATICS

Table A-1: Electrical Schematics

Drawing No.	Title
005140200	V/F Board Assembly
005150000	V/F Board Schematic
007040000	Keyboard Assembly
007050000	Keyboard Schematic
011391400	Power Supply Module Wiring Schematic
012170000	UV Lamp Power Supply Assembly
012180000	UV Lamp Power Supply Schematic
014780100	Motherboard Assembly
014790000	Motherboard Schematic
015610000	I2C/SubMux Assembly
015620000	I2C/SubMux Schematic
019300000	Keyboard Assembly (CE)
019310000	Keyboard Schematic (CE)
020280000	IZS UV Detector Preamp Assembly
020290000	IZS UV Detector Preamp Schematic
020610000	Rear Panel Assembly
020620000	Rear Panel Schematic
021720000	Pressure/Flow Sensor Assembly
021730000	Pressure/Flow Sensor Schematic
022220100	Power Supply Switch Board Assembly
022230300	Power Supply Switch Board Schematic
022300000	DC Power Supply Assembly
022310000	DC Power Supply Schematic
029820000	M400A Interconnect Diagram

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