

# INSTRUCTION MANUAL

## ***MODEL 401*** ***O<sub>3</sub> CALIBRATOR***

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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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# 1 INTRODUCTION

## 1.1 Preface

Teledyne API is pleased that you have purchased the Model 401. We offer a full one year warranty (see Section 1.2) and we at Teledyne API will be pleased to provide you with any support required so that you may utilize our equipment to the fullest extent.

The Teledyne API Model 401 keyboard/operator interface with its "talking keys" makes the Teledyne API a very user-friendly system. We hope you will not experience any problems with the Teledyne API Model 401 but if you do, the built-in tests and diagnostics should allow you to quickly and easily find the problem. In addition, our full time customer service department is always available to answer your questions.

## 1.2 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.

## **1.3 Principle Of Operation**

M401 Ozone calibrator consist of two major parts; the ozone generating device and the photometer. Ozone generating device itself also consist of a pump, an air scrubber to self-generate zero air, a pressure regulator to control flow rate, an ozone generator using UV lamp, and a manifold. The pressure regulator provides very stable flow of zero air through the O<sub>3</sub> generator, while the light intensity of the UV lamp is controlled to generate accurate and stable ozone output.

The photometer is used as part of a feedback lamp control to assure stable O<sub>3</sub> output even during changing conditions. The photometer is compensated for both pressure and temperature variations. This true photometer operation along with self-generated zero air results in a completely self-contained O<sub>3</sub> generating system.

The detection of ozone molecules of the photometer is based on absorption of 254 nm UV light due to an internal electronic resonance of the O<sub>3</sub> molecule. The Model 401 Photometer 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 glass tube that is alternately filled with sample gas, then filled with zero air. The ratio of the intensity of light passing through the zero air to that of the sample forms a ratio  $I/I_0$ . This ratio forms the basis for the calculation of the ozone concentration.

**NOTE**

**Model 401 Photometric Calibrator is designed to be a dedicated calibrator. The M401 Photometer should not be used as a monitor.**

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

$$C_{O_3} = -\frac{10^9}{a \times \ell} \times \frac{T}{273^0 K} \times \frac{29.92 \text{ inHg}}{P} \times \ln \frac{I}{I_0}$$

Where:

$I$  = Intensity of light passed through the sample

$I_0$  = Intensity of light through sample free of ozone

$a$  = absorption coefficient

$\ell$  = path length

$C$  = concentration of ozone in ppm

$T$  = sample temperature in Kelvin

$P$  = pressure in inches of mercury

$\ln$  = natural logarithm

As you can see 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 impacts 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. 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  $308 \text{ cm}^{-1} \text{ atm}^{-1}$  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 pathlength 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 intensities, along with the other variables, are used by the CPU to compute the concentration using the above formula.

Every 8 seconds the M401 Photometer completes a measurement cycle consisting of a 2 second wait period for the sample tube to flush, followed by 2 seconds of measuring the average light intensity to determine  $I$ . The sample valve is switched to admit scrubbed sample gas for 2 seconds followed by 2 seconds measuring the average light intensity to obtain  $I_0$ . Measurement of the  $I_0$  every 8 seconds minimizes instrument drift due to changing intensity of the lamp due to aging and dirt. The 120 sec filter provides 32 averages.

### **1.3.1 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 401 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 401 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.

## 1.4 Specifications

### Photometer

Ranges	User selectable to any full scale range from 100 ppb to 20,000 ppb
Zero Noise	< 0.3 ppb (rms)
Span Noise	< 0.5% of reading (rms)
Lower Detectable Limit	< 0.6 ppb (rms)
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)	2% of reading *
Linearity	Better than 1% FS
Precision	1.0 ppb
Lag Time	10 sec
Rise/Fall Time (95%)	<20 sec
Sample Flow Rate	800 cc/min $\pm$ 10%
Temperature Range	5-40° C
Humidity Range	0-95% RH, Non-Condensing
Temp Coefficient	< 0.05 % per °C
Voltage Coefficient	< 0.05 % per V
Dimensions HxWxD	7" x 17" x 27" (178 mm x 432 mm x 686 mm)
Weight, Analyzer	60 lb. (27 kg)
Power, Analyzer	110v/60Hz, 220v/50Hz 250 watts
Environmental Conditions	Installation Category (Overvoltage Category) II Pollution Degree 2
Recorder Instantaneous	$\pm$ 100 mV, $\pm$ 1 v
(Bi-Polar)	$\pm$ 5 v, $\pm$ 10 v
Status	12 Status Outputs from Opto-Isolators

### Calibration Ozone Generator

Flow rate	2 to 5 LPM adjustable
Maximum concentration	1.0 ppm @ 5 LPM
Minimum concentration	0.050 ppm @ 2 LPM
Stability	$\pm$ 0.002 ppm (bench feedback)

\* at constant temperature and voltage

### **1.4.1 Noise (PPB RMS)**

The standard deviation of reported concentration calculated over 25 samples times 7 runs minimum, N-1 weighted.

### **1.4.2 Lower Detectable Limit (LDL) PPB**

LDL is defined as twice the (RMS) noise at the lower end of the most sensitive operating range.

### **1.4.3 Zero Drift (PPB)**

Zero drift is defined as unadjusted (automatic) operation maximum shift over the given period at constant temperature and pressure.

### **1.4.4 Span Drift**

Span drift is defined similarly to zero drift, requiring unadjusted operation at constant temperature and pressure.

### **1.4.5 Linearity**

< 1.0% of URL, best-straight-line deviation over range of LDL to URL.

### **1.4.6 Lag Time**

Lag time is defined as the time interval between a step change, at the sample inlet port, of input concentration and the first observable corresponding change in analyzer output.

### **1.4.7 Rise And Fall Times**

Rise/fall times are defined as the time interval between a step change in input concentration and 95% of final response unless otherwise noted.

### **1.4.8 Temperature Range**

5-40° C.

### **1.4.9 Humidity Range**

0 to 95% relative humidity, non-condensing.

### 1.4.10 Flow Rates

800 scc/min  $\pm$  10% (standard cubic centimeters/minute) sample flow rate.

2-5 l/min  $\pm$  10% (standard cubic liter/minute) O<sub>3</sub> generator flow rate.

### 1.4.11 Power

Standard input power: 120VAC rms, 60 Hz, 250 watts maximum and 220, 240 V, 50 Hz.  
5A resettable circuit breaker.

### 1.4.12 Weight

27 Kg (60 lb.) maximum.

## 1.5 Installation And Overview

The Model 401 is shipped with the following standard equipment:

1. Power cord.
2. Instruction manual.

**CAUTION**

**To avoid personal injury, always use two persons to lift and carry the Model 401.**



Upon receiving the Model 401 please do the following:

1. Verify no apparent shipping damage. (If damage has occurred please advise shipper first, then Teledyne API.)
2. Remove all red colored shipping screws from the underside of the instrument. Note: Save these shipping screws and re-install them whenever the unit is shipped to another location.
3. When installing the Model 401, allow a minimum of 4 inches (100mm) of clearance at the back of the instrument and 1 inch (25mm) of clearance on each side for proper ventilation.
4. Check that all options ordered are enclosed.
5. Connect analyzer' sample inlet line to the M401 sample port of manifold on rear panel.

**NOTE**

**See Figure 1-4 for rear panel pneumatic connections. Span gas should only come into contact with PTFE or glass. Leak check all fittings with soap solution.**

**Maximum pressure for leak check is 15 PSIG.**

6. Connect the pump exhaust to a suitable vent outside the analyzer area.

**CAUTION**

**Connect the exhaust fitting on the rear panel (see Figure 1-5) to a suitable vent outside the analyzer area.**



7. For internal pressurized zero air using an external dry air supply connect AIR IN port to a clean, dry air supply (see Figure 1-6).

**NOTE**

**For best O<sub>3</sub> generator stability and to avoid moisture condensation, it is recommended that zero air be dried to approximately -20°C dew point.**

For external pressurized dry zero air using an external dry pressurized source (see Figure 1-6) proceed as follows:

- a. Remove cap plug from the tee of zero air scrubber assembly and connect external dry zero air line instead (air pressure should be about 30-40 psi).
  - b. Install the cap plug to dry air inlet port.
  - c. Verify the power is off and unplug O<sub>3</sub> GENERATOR pump's power cable connector.
8. Connect a recording device to the terminal strip connections on the rear panel (see Figure 1-2). See Table 9-4 for setting proper analog output voltage jumpers.
  9. Connect the power cord to an appropriate power outlet (see the serial number tag for correct voltage and frequency).

**NOTE**

**Power plug must have ground lug.**



10. Turn on the M401 by switching the switch on the lower right corner of the front panel (See Figure 2-1). The front panel display should light with a sequence of messages, -API - M401 - software version number, then a normal display as shown in Figure 2-2.
11. Allow about 60 minutes for the temperatures to come up to their respective setpoints then press the leftmost button on the front keyboard to scroll through the TEST values. Compare these values to those noted during the final factory checkout listed in Table 1-1. The values observed should closely match the Table 1-1 values.

**NOTE**

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

12. Select the range the analyzer will be calibrated on.
  - a. From the MAIN menu press SETUP to enter the SETUP menu. (See Figure 2-2 for appearance of front panel.)
  - b. Press MISC.
  - c. Press D/A.
  - d. Enter the PASSWORD (818).
  - e. Press RNGE (RANGE).
  - f. Enter the derived full scale range for analog outputs and press ENTR. (Example: if full scale range is 500 ppb, then press corresponding digit's button until desired range is selected and press ENTR.)
  - g. Press EXIT 3 times to return to the MAIN menu.
13. O<sub>3</sub> generator flow adjustment. The O<sub>3</sub> generator flow is controlled by a precision pressure regulator and flow restrictor. Increasing upstream pressure of flow restrictor will increase flowrate and vice versa. In order to increase pressure, adjust knob clockwise as needed while monitoring the O<sub>3</sub> flow test measurement display. In general, the O<sub>3</sub> generator flow should be at least 1 L/MIN in addition of total flow demands for the Model 401 (800 cc/min) and remote analyzers.

**NOTE**

**Adjustment of the O<sub>3</sub> generator flow is to be performed by qualified maintenance personnel only.**



14. Generate the Zero Air.

- a. Press ZERO from the main menu and enter the password (512).
- b. Press STBY to terminate or press O<sub>3</sub>GN to continue to generate O<sub>3</sub> span gas.

15. Generate the O<sub>3</sub> Span Gas.

- a. Press O<sub>3</sub>GN from the main menu and enter the password (512).
- b. Enter the O<sub>3</sub> concentration value desired (0.05 - 1 ppm range).
- c. Press CONC in order to change O<sub>3</sub> gas concentration while generating specified O<sub>3</sub> gas.
- d. Press STBY to terminate O<sub>3</sub> gas generation or press zero to continue to generate zero air.

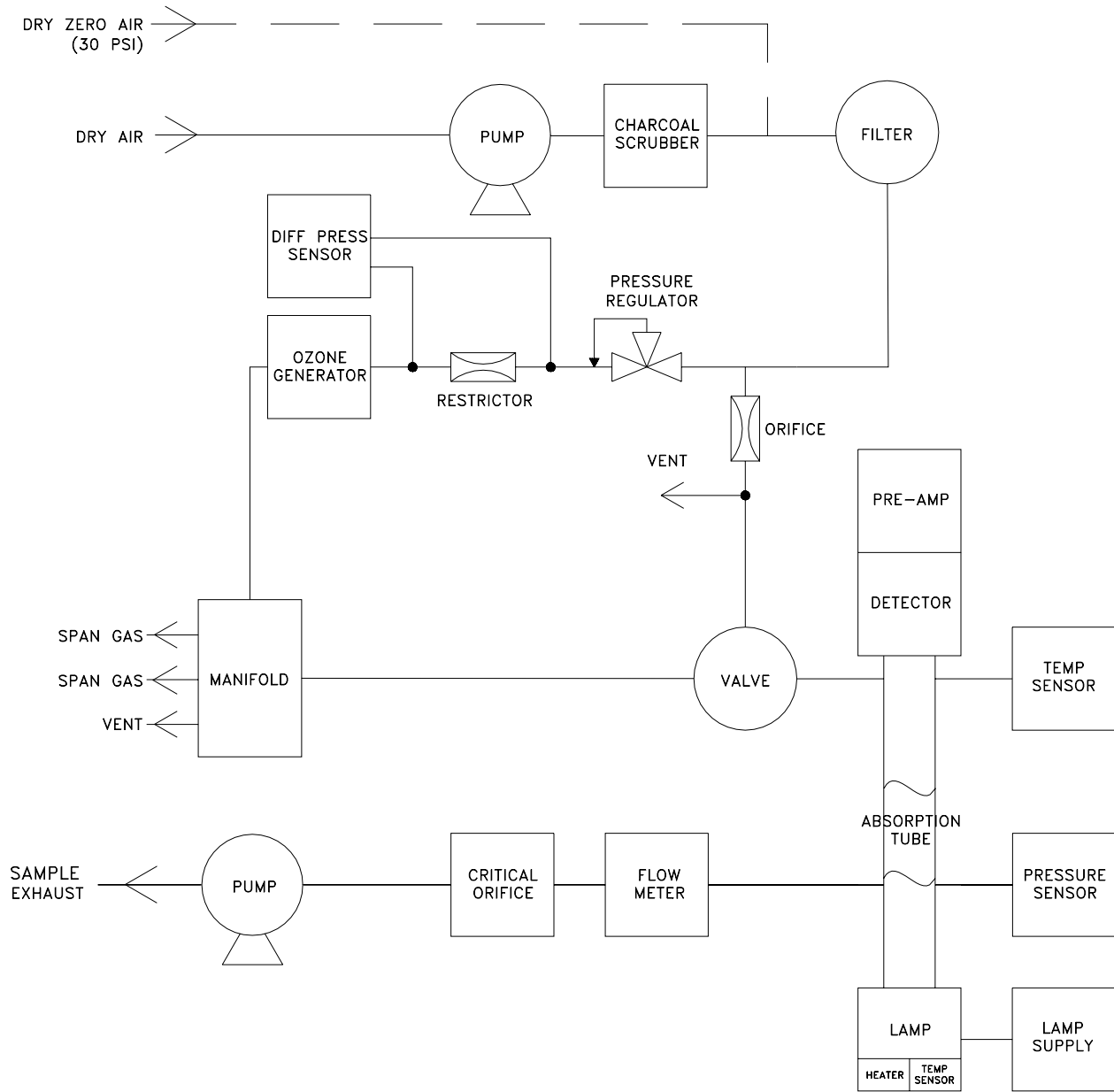


Figure 1-1: Model 401 Ozone Calibrator Block Diagram

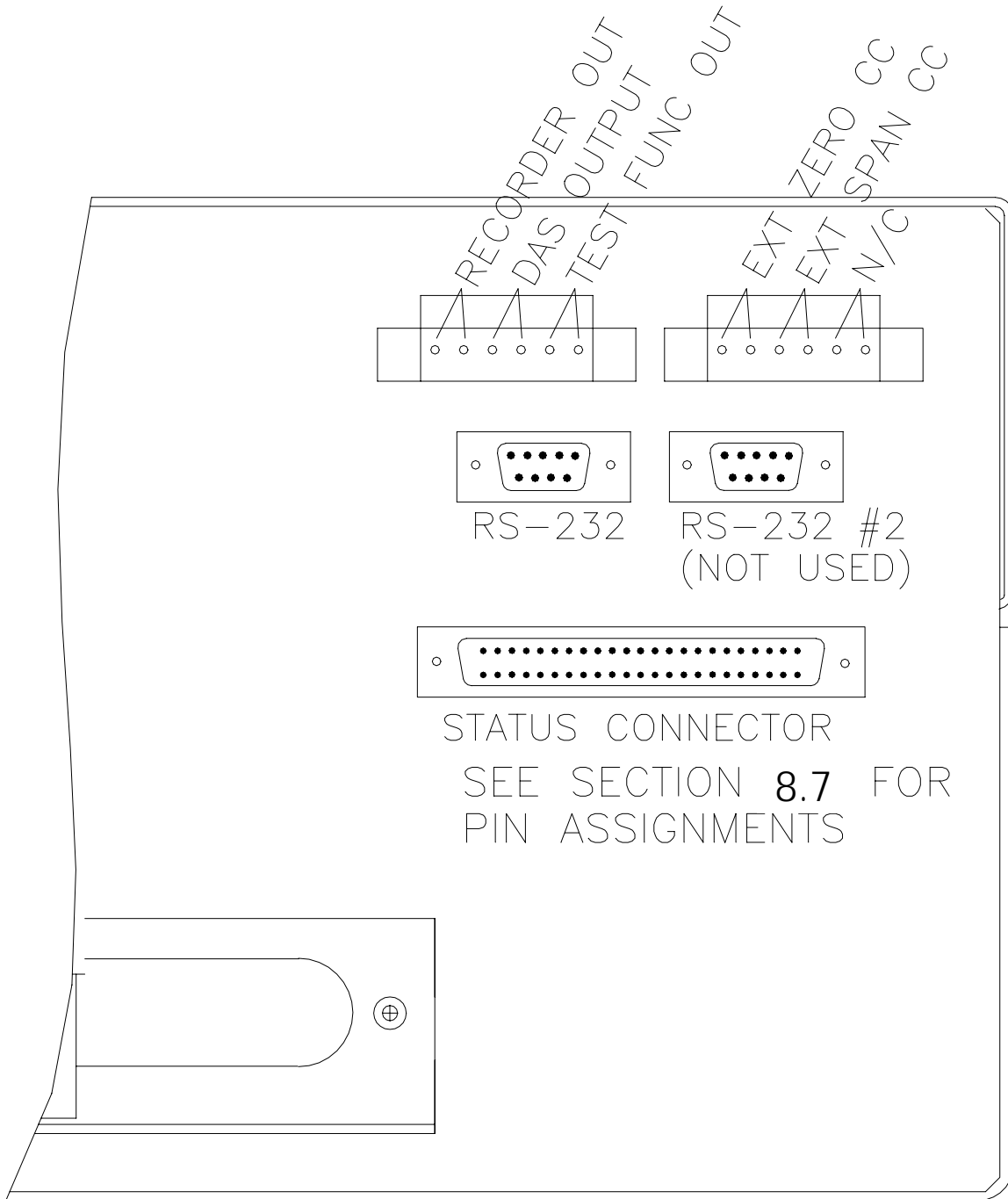


Figure 1-2: M401 Rear Panel Electrical Connections

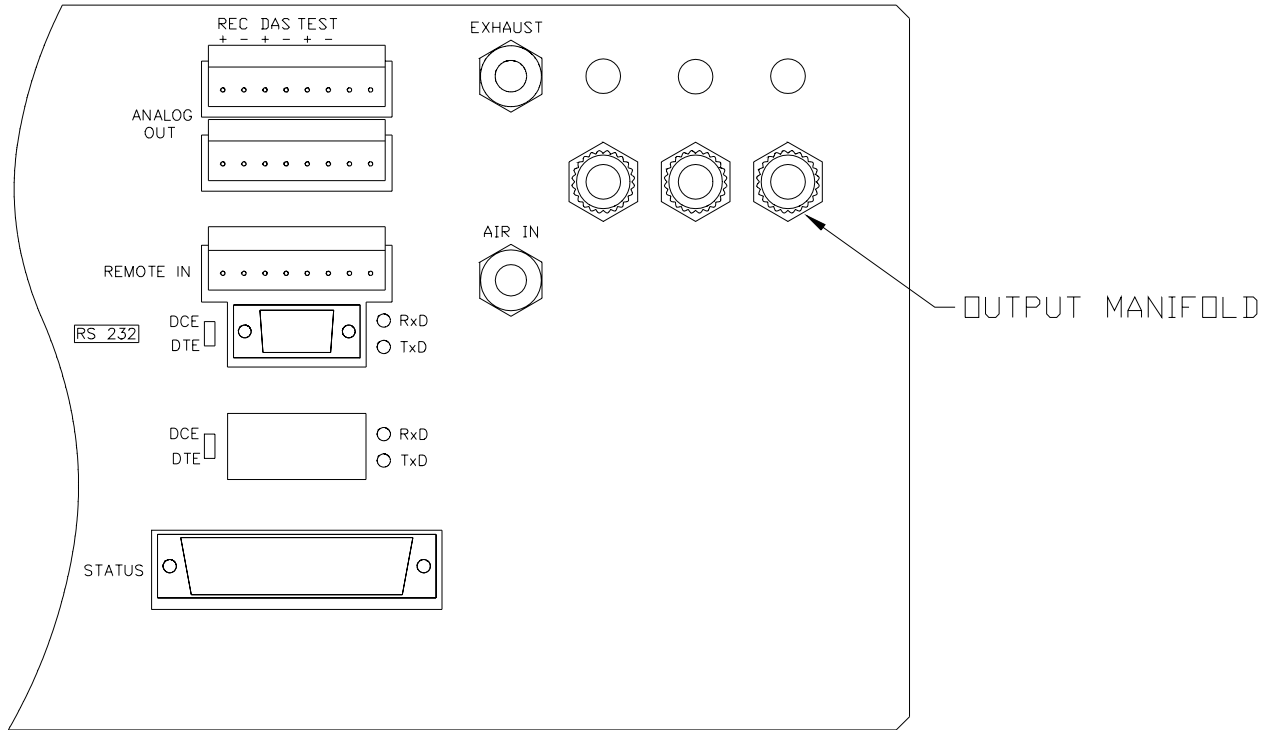


Figure 1-3: Rear Panel Electrical and Pneumatic Connections (CE Version)

## 1.6 Electrical And Pneumatic Connections

### 1.6.1 Electrical Connections

Output #1 Ozone concentration - chart recorder

Output #2 Ozone concentration - DAS

Output #3 Test function analog output

Input #4 Zero valve request

Input #5 Span valve request

Input #6 N/C

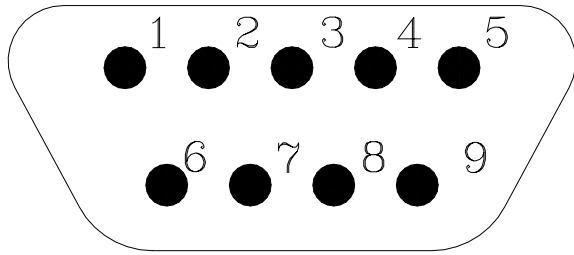
There are 2 six-pin connector strips on the rear panel shown in Figure 1-2. The pins are divided into 3-plus/minus pairs and have the functions shown above.

Outputs 1 and 2 have identical signals and electrical characteristics. Output 3 is the same as 1 and 2 electrically, but has analog TEST function signals routed to it. See Diagnostics in Section 5 for details.

### 1.6.2 RS-232

See Figure 1-4.

The RS-232 connection is a male 9-pin D-sub connector.



PIN 2 = TX DATA  
3 = RX DATA  
5 = SIGNAL GROUND  
6 = DSR  
7 = RTS  
8 = CTS  
1, 4, 9 = NOT USED

---

### RS-232 CONFIGURATION PARAMETERS

2400 BAUD DEFAULT \*  
8 DATA BITS  
1 STOP BIT  
NO PARITY

---

\* SETTABLE 300, 1200, 2400

**Figure 1-4: RS-232 Pin Assignments**

### 1.6.3 Pneumatic System

The Model 401 Photometric Calibrator is equipped with a compression pump to deliver up to 5 L/MIN for ozone generator system. It is also equipped with a second pump capable of pulling 800 cc/min across a critical flow orifice. This allows a smooth, stable flow of sample through the Photometer.

Compressed air is delivered through a charcoal scrubber. While one path is used as zero air reference, the other path of same zero air is used to generate the stable ozone output. This will ensure reliable ozone output as well as proper Photometer operation. Please see Figure 1-1 for flow diagram and Figure 1-5 for pneumatic connections.

#### NOTE

**The photometer output varies linearly with pressure and temperature. Temperature and pressure compensation is done automatically.**

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).

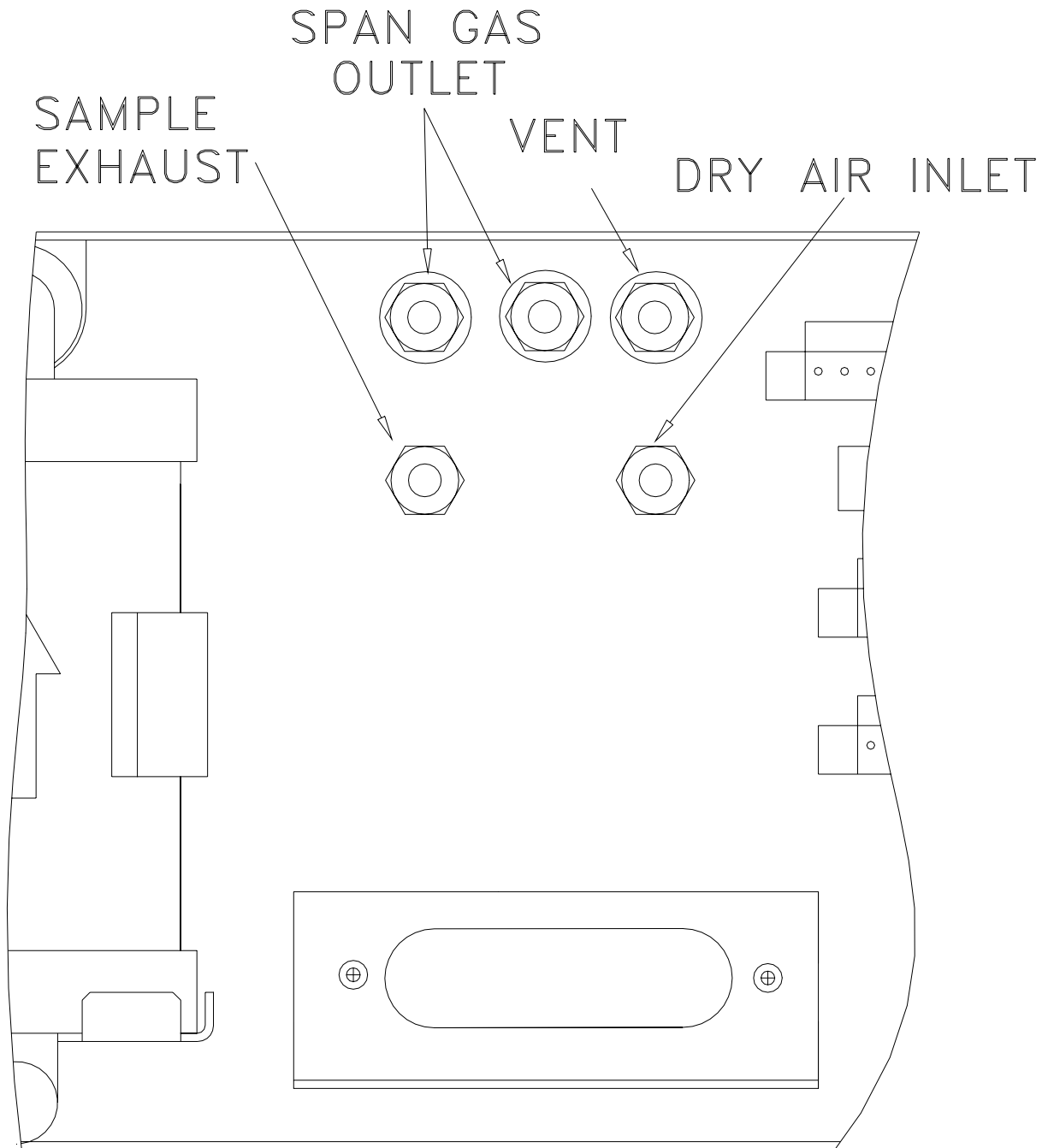
### 1.6.4 Exhaust Connections (See Figure 1-5)

A single 1/4" O.D. tube should be connected from the Analyzer sample exhaust to an area outside of the room the analyzer occupies. The maximum length of the exhaust line should not exceed 30 feet.

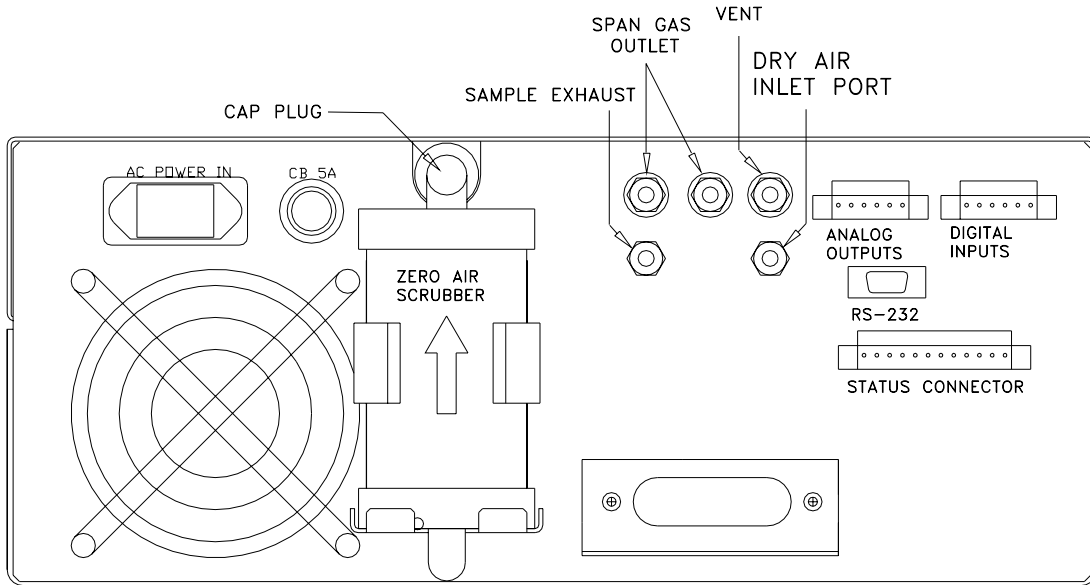
### 1.6.5 Output Flow Adjustment

The flow rate of gas supplied to the output manifold can be changed by adjusting the internal pressure regulator located on the top of the optical bench (see Figure 1-7). The output flow, O<sub>3</sub> FLOW, can be read on the front panel test functions. Adjust this flow rate to provide a minimum of 1 LPM for each analyzer being calibrated plus 1 LPM for the internal photometer in the M401. For example, when calibrating one analyzer the O<sub>3</sub> flow rate should be set to at least 2 LPM.

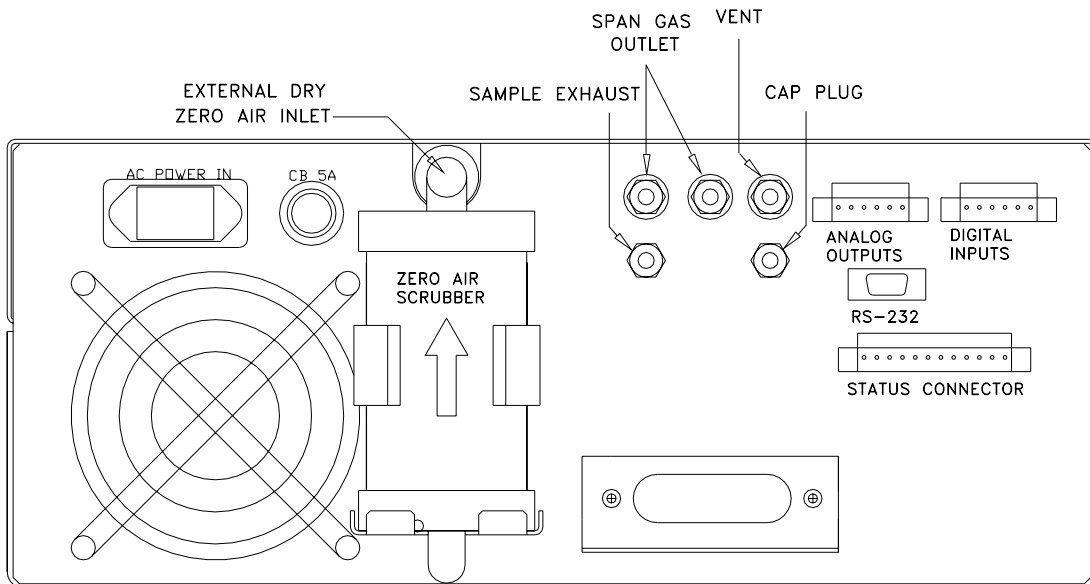




**Figure 1-5: M401 Calibrator Pneumatic Connections**



M401 REAR PANEL(INTERNAL ZERO AIR)



M401 REAR PANEL(EXTERNAL DRY ZERO AIR)

**Figure 1-6: M401 Rear Panel (External Dry Zero Air)**

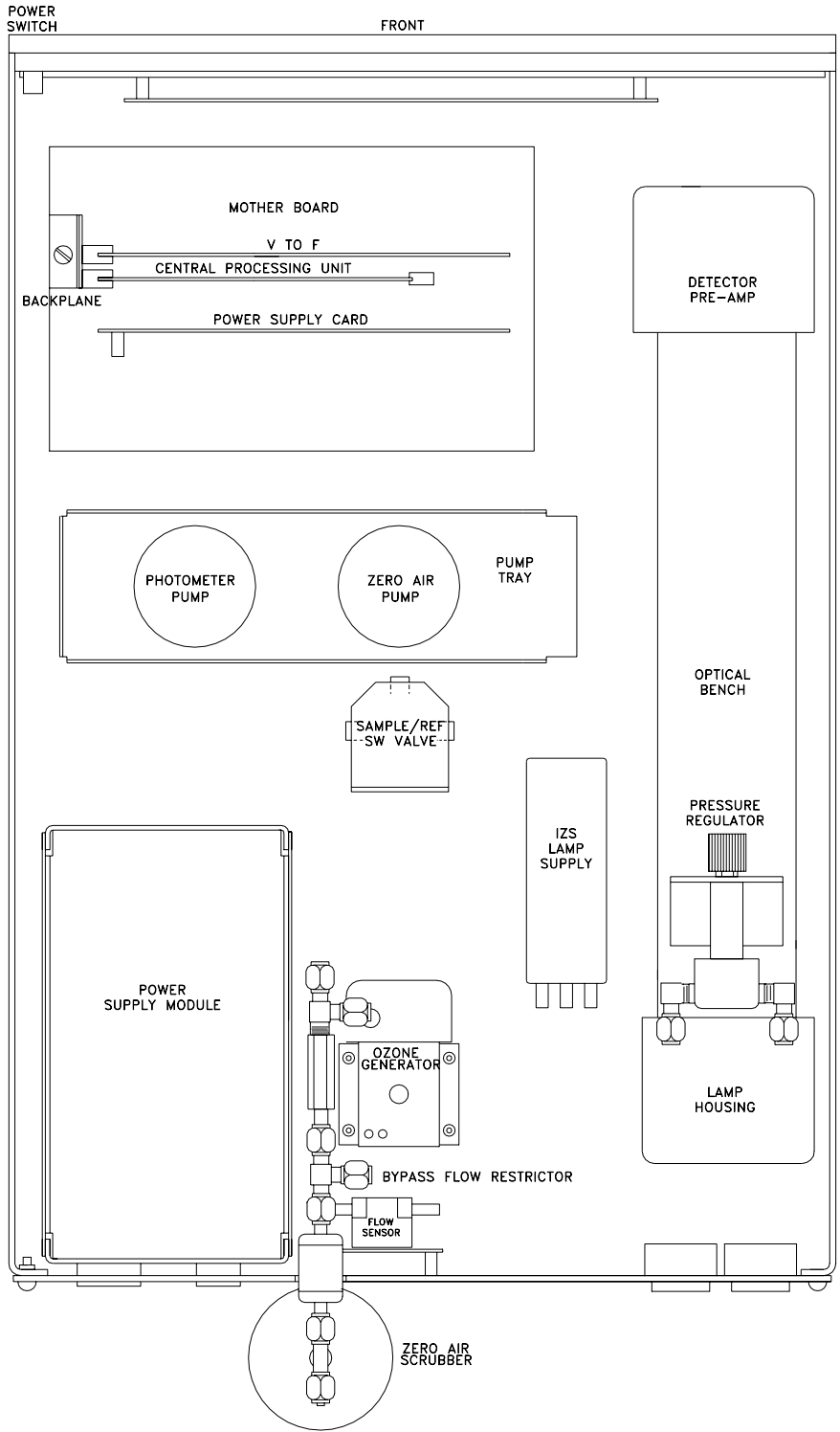


Figure 1-7: M401 Calibrator Chassis Layout

## 1.7 Operation Verification

The Model 401 Calibrator is now ready for operation.

1. Read Section 1.3 and all of Section 4 of the manual to understand the Calibrator operation.
2. Turn on the power by pressing the on/off switch on the front panel (see Figure 2-1). The display should turn on and green (sample) status LED should be energized. The green LED should blink indicating the instrument has entered the HOLD-OFF mode. The standby mode can be entered immediately by pressing the EXIT button on the front panel. The red "fault" light will also be on until the flows, temperatures and voltages are within operating limits. Clear the fault messages.
3. After a 60 minute warm-up, review the TEST function values in the front panel display by pushing the leftmost keyboard button labeled TEST. Not every TEST function is a diagnostic of correct analyzer operation, therefore TEST functions not covered below can be ignored for now.
4. O<sub>3</sub> REF, O<sub>3</sub> MEAS: TEST function values should be between 4200 mv and 4700 mv.
5. Pressure: 29 to 30 Inches-Mercury-Absolute at sea level. Other values will be displayed depending on altitude of analyzer.
6. Sample Flow: 800 cc/min  $\pm$  10 %.
7. Sample Temp: Ambient temperature +10° C.
8. Analytical Lamp Temp: 52° C  $\pm$  0.1 The computer drives the temp to this setpoint -it should be this value and not vary.
9. O<sub>3</sub> GEN Lamp Temp: 48° C  $\pm$  1° C.
10. Box Temp: Ambient  $\pm$  10° C.
11. DC Power Supply: 2500 mV  $\pm$  100 mv. This is a composite of all of the DC voltages in the instrument. The value is not important but it should be within the range indicated, and should be constant.
12. If the TEST functions are within the limits given above the instrument should function correctly. If there is a problem please read the manual and check your set-up. The Model 401 is now ready for calibration, see Section 3.

### 1.7.1 Final Test And Calibration Values

**Table 1-1: Test Values**

Test Parameter	Displayed Value	Units
TIME		HH:MM:SS
DCPS		MV
BOX TEMP		DEG C
O <sub>3</sub> OFFSET		PPB
O <sub>3</sub> SLOPE		-
REG PRESSURE		IN-HG-A
O <sub>3</sub> GEN TMP		DEG C
O <sub>3</sub> GEN FLOW		L/MIN
ANA LAMP TMP		DEG C
SAMPLE TEMP		DEG C
SAMPLE FLOW		SCC/MIN
SAMPLE PRESS		IN-HG-A
O <sub>3</sub> DRIVE		MV
O <sub>3</sub> GEN REF		MV
O <sub>3</sub> REF		MV
O <sub>3</sub> MEAS		MV
O <sub>3</sub> SET		PPB/PPM
<b>Options</b>		
RACK MOUNTS/SLIDES		
POWER VOLTS/Hz		
STATUS OUTPUT		
RS-232 OUTPUT		
<b>Calibration Settings</b>		
O <sub>3</sub> SPAN SETTING		PPB
O <sub>3</sub> ZERO SETTING		PPB
O <sub>3</sub> SLOPE		
O <sub>3</sub> OFFSET		

PROM # \_\_\_\_\_ Serial # \_\_\_\_\_  
 Date \_\_\_\_\_ Technician \_\_\_\_\_

## **1.8 Options**

### **1.8.1 Rack Mount With Slides**

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

### **1.8.2 Status Outputs**

The status output is an option that reports Analyzer conditions to a 50 pin connector from the mother board. The contacts are NPN transistors which can pass 50 ma of direct current. See Section 8.6 for status output pin assignments.

## 2 OPERATION

### 2.1 Key Features

The important features of the Teledyne API Model 401 Photometric Calibrator are listed below.

#### 2.1.1 O<sub>3</sub> Readout

The Teledyne API Model 401 Photometric Calibrator constantly displays the current ozone reading (in PPB) in the upper right hand corner of the alphanumeric display.

#### 2.1.2 O<sub>3</sub> Analog Output

The Teledyne API Photometric Calibrator provides a buffered analog output of the current O<sub>3</sub> readings on each of two pairs of outputs on the rear panel (see Figure 1-2) for DAS and recorder reporting. The analog outputs provide for 20% overrange. For example, on the 500ppb range the M401 will correctly report concentrations up to 600 ppb and output up to 6.00 volts to the DAS and recorder outputs. (See Table 9-4 for setting proper analog output voltage jumpers.)

In addition TEST function values can be routed to a third analog output.

#### 2.1.3 E<sup>2</sup> ROM Backup Of Software Configuration

The Teledyne API Photometric Calibrator has few DIP switches or jumpers that need to be set by the operator. Configuration of the calibrator is done under software control and the configuration options are stored in electrically erasable (E<sup>2</sup>) ROM. Thus, configuration options are saved even when the Analyzer is powered off.

There is one exception to this. The analog output voltage ranges are set by DIP switches on the A/D-I/O board as shown in Section 9.6.3.

#### 2.1.4 Adaptive Filter

The Teledyne API Photometric Calibrator 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.

### **2.1.5 Data Acquisition**

The Teledyne API Photometric Calibrator contains a built-in data acquisition system which keeps track of the average O<sub>3</sub> readings and the last 100 averages. This data is made available to other systems via the RS-232 interface. The Photometric Calibrator can be programmed to automatically output a 1 minute to 60 minute average. The last 100 averages can be called up through the remote RS-232 I/O or viewed on the display through keyboard call-up.

### **2.1.6 RS-232 Interface**

The Teledyne API Photometric Calibrator features an optional RS-232 interface which can output the instantaneous and/or average O<sub>3</sub> data to another computer. It can also be used as a command and status channel to allow another computer to control the Analyzer. Refer to Figure 1-4 for details on using the RS-232 interface.

### **2.1.7 Password Protection**

The Teledyne API Photometric Calibrator provides password protection of the calibration and setup functions to prevent incorrect adjustments to the Calibrator. There are three levels of passwords which correspond to operator, supervisor/maintenance, and dynamic span level 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. The table on the following page lists the password levels and the functions allowed for each level.



**Table 2-1: Password Levels**

<b>Password</b>	<b>Level</b>	<b>Functions Allowed</b>
No password required	0	TEST, MSG, CLR, SETUP-DAS-VIEW
Operator (512)	1	ZERO, 03GN, ASEQ
Setup (818)	2	SETUP-EVNT, SETUP-BCAL, SETUP-COMM, SETUP-MISC-O3 GEN, SETUP-MISC-DARK, SETUP-MISC-CLK, SETUP-MISC-D/A, SETUP-MISC-MORE, SETUP-PASS, SETUP-DIAG
Setup (717)	3	SETUP-MISC-O3-SLPE, SETUP-MISC-03-OFFS

**NOTE**

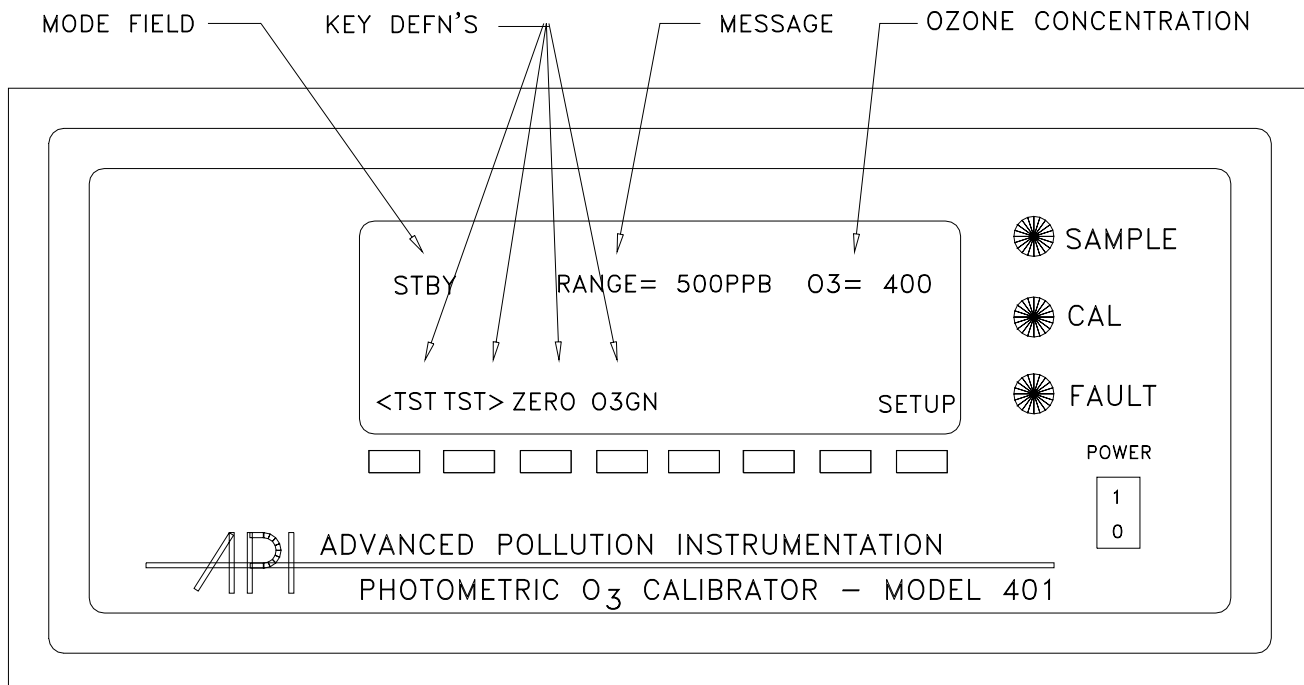
**All passwords can be disabled. To do this, enter setup-password, enter 818 and turn "enable" off. If the wrong password is entered, the analyzer will beep when enter is pressed.**

## 2.2 Front Panel

This section describes the operator interface from the point of view of the front panel. The front panel consists of a 2-line by 40-character alphanumeric display, 8 pushbuttons, and 3 status LEDs. Each of these features are described in Section 2.2.1.

### 2.2.1 Front Panel Display

The display is divided into 4 main "fields": the **mode** field in the upper left, the **message** field in the top center, the sample concentration field consisting of the most recent instantaneous ozone value field in the upper right, and the MENU field which occupies the entire bottom line of the display. A typical display is shown in Figure 2-1.



**Figure 2-1: Model 401 Front Panel**

The mode field indicates the current mode of the Analyzer. Usually, it shows "STBY ZS ", indicating that the instrument is in the standby mode and that automatic zero/span checking is enabled. Manual span checking or calibration can only be performed by pressing the buttons on the front panel labeled "ZERO", "O<sub>3</sub>GN" or "ASEQ." ASEQ is a sequence of multipoint calibration which is displayed only if automatic multipoint sequence is selected (see Section 3.3 for detailed information). Automatic span check only occurs at the preset time. Calibration and span adjustments are discussed in greater detail in Section 3.6. Table 2-2 lists all the possible modes in the Analyzer and their meanings.

**Table 2-2: System Modes**

Mode	Meaning
STBY xxxx (1)	Standby mode (Photometer is operating normally)
ZERO CAL x (2)	Zero check in progress
O <sub>3</sub> GN CAL x (2)	Span check in progress
ASEQ xxx (5) x (2)	Multi-point calibration in progress
HOLD OFF	Hold off delay after power reset
D/A OUTPUT (3)	Test analog output channels
BCAL ZERO	Bench zero calibration
BCAL SPAN	Bench span calibration
SETUP xxx (4)	Configuring analyzer (operation continues)
(1) xxxx = AZS ( Auto Zero & Span programmed), AZ2S (Auto Zero & 2 span points; 25% & 100% of O <sub>3</sub> set concentration) programmed AZ5S (Zero & 5 span points; 20%, 40%, 60%, 80% & 100% of O <sub>3</sub> set concentration) programmed. (2) x = M (manual), A (auto), R (remote) (3) diagnostic test modes (4) xxx = software revision (5) 0%, 20%, 25%, 40%, 60%, 80%, 100%	

The message field shows test measurements or warning messages. Table 2-3 and Table 2-4 summarize the test measurements and warning messages and their meanings. Refer to Sections 4 and 5 for detailed information on viewing test measurements and warning messages and clearing warnings.

**Table 2-3: Test Measurements**

Test Message	Meaning
TIME=xx:xx:xx	Current time-of-day (HH:MM:SS)
O <sub>3</sub> SET =xxxx PPB	Ozone generator set concentration
O <sub>3</sub> MEAS=xxxx MV	Current measure channel in mV
O <sub>3</sub> REF =xxxx MV	Current reference channel in mV
O <sub>3</sub> GEN =xxxx MV	O <sub>3</sub> GEN ref channel feedback voltage
PRES=xxx IN-HG-A	Absolute pressure : inches Hg
SMP FLW=xxx CC/M	Sample flow through Photometer (cc/min)
SAMPLE TEMP=xxx C	Temperature in the absorption tube
ANA LAMP TMP=xxx C	Analytical Lamp Housing Temperature
O <sub>3</sub> FLOW=x.x L/M	Gas flow through O <sub>3</sub> generator
O <sub>3</sub> LAMP TMP=xx C	O <sub>3</sub> GEN Lamp Housing temp. (deg. C)
REG = xx.x IN-HG-A	Regulator pressure - Inches Hg.
BOX TEMP=xxx C	Internal box temperature (deg. C)
DCPS=xxxxxx MV	DC power supply (mV)

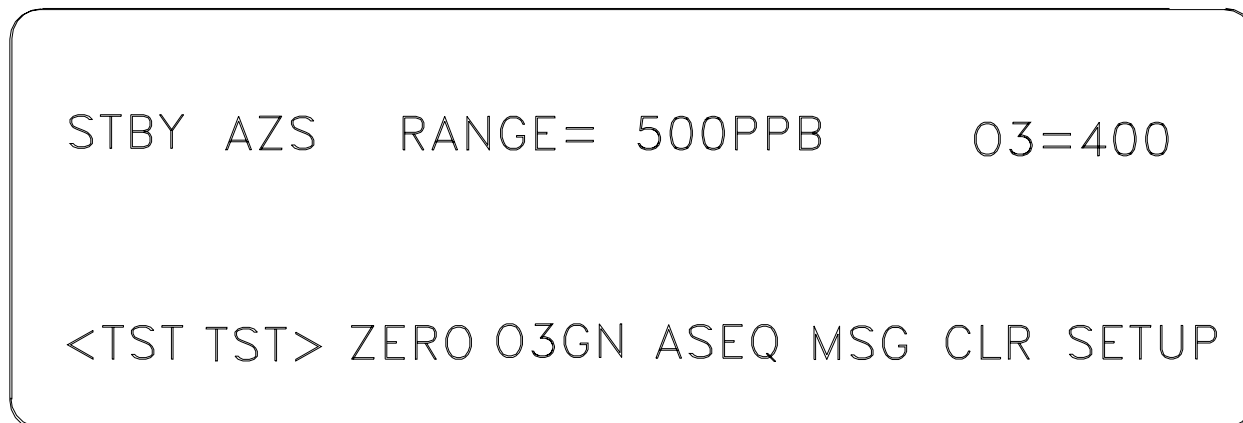
**Table 2-4: Warning Messages**

Warning Message	Meaning
SYSTEM RESET	Issued whenever Analyzer is powered on
RAM INITIALIZED	RAM was erased (including DAS reports)
ANA LAMP WARNING	Analyzer lamp < 40000 OR >= 80000 counts
O <sub>3</sub> LAMP SHUTDOWN	O <sub>3</sub> lamp temperature control not working
O <sub>3</sub> FLOW WARNING	O <sub>3</sub> GEN flow < 1.8 L/M or > 5.5 L/M
O <sub>3</sub> REF DET WARN	O <sub>3</sub> reference detector < 50 mV
SAMPLE FLOW WARNING	Sample flow < 500 cc/m or > 1000 cc/m
SAMPLE PRESSURE WARN	Sample pressure < 15 or > 35 In-Hg-A
SAMPLE TEMP WARNING	Sample temperature < 12 or > 48 deg. C
BOX TEMP WARNING	Box temp. < 12 deg. C or > 48 deg. C
O <sub>3</sub> GEN LAMP TEMP WARN	O <sub>3</sub> lamp < 43 or > 53 deg. C
ANA LAMP TEMP WARN	Analyzer lamp < 51 or > 61 deg. C
V/F NOT INSTALLED	A/D - I/O card not installed, bad, or no handshake.

The menu field changes depending on the mode of the Analyzer and the buttons that have been pressed. It indicates the current function of each of the 8 pushbuttons below the display. See Section 2.2.2 for information on using the pushbuttons.

### 2.2.2 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.



**Figure 2-2: Illustration Of Normal Display**

If TEST is pushed, the upper center display cycles through the menu of test parameters, e.g. Sample flow (see Table 2-3).

If STBY is pushed, the calibrator is in stand-by mode.

If ZERO is pushed, the sequence of operations for generating ZERO gas is initiated.

O<sub>3</sub>GN is used to initiate span setting using sample gas, such as during a formal calibration.

Pushing ASEQ will initiate multi-point calibration if it is preset. (see Section 3.4)

Pushing MSG will cause a message to appear on the upper center display if warning exists (also red status led will be blinking).

Pushing CLR will erase a message, provided the condition causing the message has ceased.

Pushing SETUP changes the function of the pushbuttons and is used for setting basic parameters as described in Section 4.

### 2.2.3 Status LEDs

The three status LEDs to the right of the display indicate the general status of the Model 401 Photometric Calibrator. The green SAMPLE LED indicates the sampling status. The yellow CAL LED indicates the calibration status. The red FAULT LED indicates the fault status. Table 2-5 summarizes the meanings of the status LEDs.

**Table 2-5: Status LEDs**

LED	State	Meaning
Green	Off On	Not monitoring (should never be off) Monitoring normally (STBY/ZERO/O <sub>3</sub> GN/ASEQ MODE)
Yellow	Off On Blinking	Auto cal. disabled Auto cal. enabled Calibrating
Red	Off Blinking	No warnings exist Warnings exist

INTENTIONALLY BLANK



## 3 CALIBRATION

The M401 is designed to be used as a dedicated ozone calibrator with built-in photometer. Zero/Span gas generation and calibration of Model 401 are discussed in Section 3. The emphasis in Section 3 is on the operation of the buttons and the internal adjustments they make in the instrument.

### 3.1 Manual Zero Air Supply

The Model 401 calibrator can generate zero air using the internal scrubbing module. Press zero and enter password (512) to generate zero air. The IZS pump will start to run and flow control system will maintain stable flowrate of zero air to both the photometer and the analyzer being calibrated. Supply flowrate should exceed demand flowrate to ensure good zero measurement. Dry air should be provided into the inlet of rear panel for internal zero air supply.

### 3.2 Manual O<sub>3</sub> Generation

Press O3GN, then enter the password (512), to generate the O<sub>3</sub> span gas. Specify O<sub>3</sub> gas concentration up to 1000 ppb and minimum of 50 ppb and press enter to select. Again, the O<sub>3</sub> generator pump will start to run and the flow control system will maintain stable flowrate through the O<sub>3</sub> generator. Supply flowrate should exceed demand flowrate to ensure good span measurement. Pressing CONC allows a change of O<sub>3</sub> gas concentration during specified O<sub>3</sub> gas generation.

#### NOTE

**The M401 software has a "Learning" feature that will remember the parameters from the last several concentrations that were generated by the instrument. The first time a specific concentration is requested, the response time may be somewhat slow. Any subsequent requests for that same concentration will be much faster since the instrument will remember the previous settings. This information remains in memory even when the instrument is turned off.**

### 3.3 Automatic Zero/Span (or Multipoint) Check

Automatic zero/span gas supply must be enabled in the setup mode. There are five parameters that affect zero/span checking: the zero and span duration, the time of day for calibration, the time shift, the zero and multipoint calibration switch, and the feedback mode. These are described individually below.

To set the duration of the zero/span check, press the following sequence of buttons from the STBY mode: **SETUP-EVNT-WAIT**. Enter the duration for the zero check and then press **ENTR**. Similarly enter the duration for the span check and then press enter. To shift the Z/S check time backwards each day, select "-" and enter a number from 1 to 60. To disable shifting of the check time (i.e. to Z/S check at the same time each day), enter a time shift of 0.

To enable automatic zero/span checking, press following sequence of **SETUP-EVNT-ASEQ**. The CPU will display the current setting in the menu field above the first button. Press "OFF" in order to disable automatic sequence, then press "ENTR". Likewise, select AZS for zero and span (See Section 3.2 or 3.4 How To preset O<sub>3</sub> concentration which is specified in O<sub>3</sub> GN or ASEQ of main menu.), AZ2S for zero and two span points, (25% AND 100% of preset O<sub>3</sub> concentration) and AZ5S for zero and five span multipoint (20%, 40%, 60%, 80%, and 100% of preset O<sub>3</sub> concentration) sequence.

O<sub>3</sub> generator has three different modes of lamp feedback control. Press sequence of **SETUP-MISC-O3-GEN-MODE** to select constant (CNST) lamp current control, reference (REF) detector feedback control, or bench (BNCH) feedback lamp control. **Bench feedback is recommended to generate fast response, stable, and accurate O<sub>3</sub> concentration in which the optical bench is used as a feedback detector to control O<sub>3</sub> generating lamp.**

### 3.4 Manual Zero/Span (or Multi-Point) Check

Manual zero/span (or multi-point) is activated by pressing "ASEQ" button from the main menu display. Then enter the password, specify full scale concentration between 50ppb - 1000ppb which would be 100% of span concentration, and press ENTER to select. This feature is identical to the automatic zero/span check sequence except it is activated manually. This ASEQ entry is not shown on display unless it is programmed. In order to enable this feature, automatic zero/span check parameters must be preset (See Section 3.3 or 4.2). While multipoint calibration is in progress pressing "STBY" will terminate "ASEQ".

### 3.5 Summary Of Front Panel Calibration Controls

The calibration controls are summarized below in terms of the button sequences used to access them.

**Table 3-1: Calibration Controls**

Button Sequence	Function	Default	Limits
STBY	Select stand by mode	-	-
ZERO-ENTR	Begin zero calibration	-	-
O3GN-ENTR	Begin span calibration	-	-
ASEQ-ENTR	Begin multi-point calibration	-	-
SETUP-WAIT	Zero/span/duration	15 min	1-20 min
SETUP-EVNT-TIME	Auto check time-of-day	23:30	00:00-23:59
SETUP-EVNT-ASEQ	En/disable auto multi-point check	OFF	OFF/ZS/Z2S/Z5S
SETUP-EVNT-SHFT	Auto check time shift	0 min	
SETUP-MISC-O3-GEN-MODE	Select lamp control mode	Bench	± 60 min CNST/REF/BNCH

### 3.6 Photometer Calibration

Model 401 is capable of accurately reproducing O<sub>3</sub> span gas. However, it should be quantitatively verified by relating to a master standard such as certified Model 400 O<sub>3</sub> photometric analyzer. The calibration of Model 401 photometer can be verified by periodic (recommended every 3 months) intercomparison between Model 401 photometer and a master standard.

#### Photometer Zero Calibration

1. Turn the power on for both Model 401 and Model 400 (as master standard) and allow them to stabilize for minimum of one hour.
2. Start to generate the zero gas by pressing "zero" button from the main menu and enter the password (512). In case of using external dry zero air, verify proper IZS flow and pressure of external air source. (See Figure 1-5 for pneumatic connections.)

3. Allow to sample zero gas for approximately 10 minutes.
4. Follow sequence of SETUP, BCAL, and ZERO. Then select "yes" to adjust zero.

NOTE: in case of using external dry zero air, check if dry zero air is supplied into the rear panel port (see Figure 1-5 for pneumatic connections) at about 30 - 40 PSI pressure. O<sub>3</sub> generator flow should be exceeding at least 1 l/min in addition of total flow demands. (See Section 1.6.5 for O<sub>3</sub> generator flow adjustment.)

### **Photometer Span Calibration**

1. Turn the power on for both Model M401 and Model M400 (master standard). Let them stabilize for minimum of one hour.
2. Start to generate the span (O<sub>3</sub>) gas by pressing O<sub>3</sub>GN from the main menu and enter the password (512). (In case of using external dry zero air, verify proper pressure of external air source.)
3. Allow to sample span gas for approximately 10 minutes.
4. Follow the sequence of SETUP, BCAL, and enter correct span concentration related to the Model M400 (master standard). Then select "yes" to set span.

## **3.7 Remote Zero/Span Check (Contact Closure)**

In addition to calibration check via the front panel buttons, the calibrator can be activated by means of two contact closures called EXT-ZERO-CAL and EXT-SPAN-CAL. (See Figure 1-2 for the location of the terminals for connection of the contacts on the rear panel.) The CPU monitors these two contact closures every 1 second and looks for a positive transition (i.e. 0 -> 1) on either signal. If a positive transition occurs on EXT-ZERO-CAL, the M401 will perform a zero check. If a positive transition occurs on EXT-SPAN-CAL, the M401 will perform a span check. If a positive transition occurs on both EXT-ZERO-CAL and EXT-SPAN-CAL simultaneously and ASEQ is preset, then the M401 will perform a multi-point sequence as selected in SETUP-EVNT-ASEQ menu (see Section 4.2.). When a negative transition (i.e. 1 -> 0) is detected, the CPU will go into standby mode.

Also, if a positive transition occurs on either signal while the M401 is in zero, span check or ASEQ mode, it will immediately switch to the specified mode. For example, if the analyzer is in zero check and a positive transition is detected on EXT\_SPAN\_CAL, then the instrument will immediately go into span check. To perform a zero check followed by a span check, first generate a positive transition on EXT-ZERO-CAL, and then when you want to do the span check, generate a positive transition on EXT-SPAN-CAL.

The remote calibration signals may be activated in any sequence, providing a virtually unlimited number of calibration types.

**NOTE**

**Teledyne API recommends that contact closures remain closed at least 10 minutes to allow for an accurate average zero or span value to be established.**

### **3.8 Remote Zero/Span Check Or Adjustment (RS-232)**

Besides Z/S checking from the front panel, automatic Z/S checking, and remote Z/S checking via the contact closure inputs, the Analyzer can also be checked via the RS-232 interface. Remote checking via the RS-232 interface supports zero, span, and zero followed by span check, and is identical to remote check via the contact closure inputs.

This RS-232 control feature is provided mainly so that a host computer at another location can control the Analyzer. See Section 7 for detailed information on using the RS-232 interface to do a remote Z/S check.

### **3.9 Hold Off**

Every type or check or adjustment (zero, span, manual, remote, etc.) is followed by a hold-off period of 30 seconds during which the internal data acquisition system (DAS) does not accumulate ozone readings into the DAS average.

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## 4 SETUP MODE

This section describes the setup variables which are used to configure the analyzer.

### 4.1 Setup Mode Operation

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.**

### 4.2 Setting Automatic Multipoint (ASEQ) Check

Automatic sequence of multipoint calibration can be programmed to select one zero and five span points 20%, 40%, 60%, 80%, and 100% of selected (see Section 3.4 How to set concentration) O<sub>3</sub> concentration by pressing sequence of **SETUP-EVNT-ASEQ-AZ5S**. Likewise, select **AZS** for zero and one span point (selected O<sub>3</sub> concentration), select **AS2S** for zero and two span points 25% and 100% of selected O<sub>3</sub> concentration, or press **OFF** to disable pre-programmed automatic sequence. If **ASEQ** is selected, then front panel's yellow status LED will be turned on.

### 4.3 Setting Automatic Zero/Span Duration

Duration of each zero/span calibration step can be programmed by selecting **SETUP-EVNT-WAIT**. Enter the duration between 1 - 20 minutes for the zero check and then press **ENTR**. similarly enter the duration for span check and press **ENTR**.

#### NOTE

**Teledyne API recommends that the durations are set at least 10 minutes to allow for an accurate and reliable ZERO or SPAN value to be established.**

Automatic zero/span calibration will be initiated once per day on a timed basis. Set starting time of the automatic calibration by selecting **SETUP-EVNT-TIME**. Time should be between 00:00 - 23:59.

Starting time of the automatic cal. can be shifted  $\pm 60$  min to avoid missing data of remote analyzer during same time of the day. Set desired shift time by selecting **SETUP-ENVNT-SHFT**.

## 4.4 Examining The Ozone Formula Slope And Offset

The slope and offset parameters can be examined (or changed) by **SETUP-MISC-O3-SLPE** or **SETUP-MISC-O3-OFFS**. 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 their exact values.

### NOTE

**Do not change slope or offset value unless it is absolutely necessary to restore the known original values. Take a note of new slope and offset values after each bench calibration for reference.**

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 401 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  $I_0$  in the ozone concentration equation.
4. The photometer 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-Lambert equation corrected for temperature and pressure.
7. Slope and offset corrections are made to the ozone concentration according to the equation:

$$\text{CorrectedConcentration} = \text{Slope} \times \text{MeasuredConcentration} + \text{Offset}$$

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.



## 4.5 Setting the O<sub>3</sub> Generation Mode

There are three modes of feedback operation that can be selected for the ozone generator. The mode can be changed by pressing **SETUP-MISC-O3-GEN-MODE**. The three modes are shown below. Please note that changing to any Mode other than **BNCH** may affect the concentration accuracy of the gas being produced.

### 4.5.1 BNCH Mode

This is the default mode. In Bench Feedback mode the ozone output is actively controlled by adjusting the UV lamp intensity in the ozone generator. The gas being produced is continuously sampled by the internal photometer and adjustments are continuously made to maintain the desired ozone concentration. The Bench Feedback mode produces the most accurate ozone concentration.

### 4.5.2 REF Mode

In Reference feedback mode, the ozone generator UV lamp intensity is controlled by using optical feedback from the reference detector mounted on the ozone generator.

### 4.5.3 CNST Mode

In Constant mode, no feedback is used to control the UV lamp in the ozone generator. The lamp is set to an initial drive value from the lamp power supply and is not changed.

## 4.6 Setting The Time-Of-Day

To set the current time-of-day, which is used for determining when to do an automatic calibration and for time-stamping the RS-232 reports, press **SETUP-MISC-CLK-TIME**. The CPU will display the current time-of-day as four digits in the format "H :M", where "H" is the hour in 24-hour format (i.e. hours range from 00 to 23) and "M" 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.

## 4.7 Setting The Date

To set the current date, which is used for time-stamping the RS-232 reports, press **SETUP-MISC-CLK-DATE**. The CPU will display the current date as "D MMM Y". For example, April 1, 1990 would be displayed as "0 1 APR 9 0". 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.

## 4.8 Adjusting The Clock Speed

In order to compensate for clocks which run a little bit fast or slow, there is a variable called **SETUP-MISC-CLK-ADJ**. This variable is set to the number of seconds per day by which to speed up or slow down the clock. 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**. (Note that -10 indicates that we want the clock to run 10 seconds slower each day.) If the clock is running 10 seconds slow each day, set the variable to +10, indicating that we want the clock to run 10 seconds faster each day.

If the clock speed adjust variable has already been set to a value other than 0 and the speed is still too fast or too slow, **ADD** the required adjustment to the current value of the variable. For example if the clock speed adjustment is already set to +10 and the clock is 5 seconds too slow per day, add +5 to the current value, yielding +15 as the new value.

## 4.9 Setting The O<sub>3</sub> Concentration Range

To set the range for the ozone reading to the D/A's press **SETUP-MISC-D/A-RNGE**. The operator can select any arbitrary full scale range between 100 and 20,000 ppb. Whatever range is selected, the value chosen will correspond to 5.00 volts on the analog outputs. For other analog voltage ranges check the jumper table for the V/F board schematic (drawing 00515 in the Appendix). The front panel display does not have a range setting due to the fact that it can display any concentration value up to 20,000 ppb.

## 4.10 Setting The Analog Output Offset

In order to permit the Analyzer to connect to a wider variety of strip chart recorders and other instruments, the analog output of the ozone readings can be adjusted by up to  $\pm 500$  mV for 0-5 V range (or  $\pm 10\%$  of current analog output range) in software. The default output offset is 0 mV. To change it, press **SETUP-MISC-D/A-OFFS** and 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 strip chart recorder or other instrument.

## 4.11 Setting The RS-232 Baud Rate

To set the baud rate for the RS-232 channel, press **SETUP-COMM-BAUD**. Press **300**, **1200**, or **2400**, followed by **ENTR** to accept the new baud rate, or **EXIT** to leave the baud rate unchanged.

## 4.12 Setting The Analyzer I.D.

Each Analyzer may be programmed with a unique I.D. number which appears on all RS-232 messages. To set the Analyzer I.D., press **SETUP-COMM-ID**. Enter a 4-digit number from 0000 to 9999, followed by **ENTR** to accept the new I.D., or **EXIT** to leave the I.D. unchanged. If changed, the new I.D. number will appear on all RS-232 reports from this Analyzer.

## 4.13 Disabling The Calibration Password

Normally, operators are required to enter the calibration password when doing a manual calibration via the **ZERO** or **O3GN** buttons. To allow calibration without entering the password, press **SETUP-PASS** and set it to OFF, and then press **ENTR** to accept the change, or **EXIT** to leave it unchanged. To require the calibration password, set the variable to ON.

## 4.14 Setting The Fault LED Timeout

The Model 401 can be set up so that the red fault LED on the front panel turns off automatically if no warning conditions persist. Any warning messages will still be displayed, however. To set the fault LED timeout, press **SETUP-MISC-MORE-FILT** and enter a value of from 0 to 300 seconds. A value of 0 disables the timeout, meaning that the fault will continue to blink as long as a warning message is displayed. For example, to cause the fault LED to turn off if no warning conditions have occurred for at least 5 minutes, set the variable to 300 sec.

### NOTE

**It is not advisable to set the timeout to an extremely short value such as 1 second. Doing this may make the fault LED behave strangely. This is because if a warning condition persists and the fault LED timeout is very short, then the warning condition will be trying to turn it off. The result will be an irregular blinking of the fault LED. You should set the timeout to a value of at least 15 seconds.**

## 4.15 Software Configuration

The software configuration can be displayed by entering the button sequence SETUP-CFG-LIST. For example the M401 could display:

```
"O3 CALIBRATOR"  
"SBC40 CPU"
```

Stating that the instrument was an Ozone Calibrator using the SBC40 computer. This feature is useful for showing any special features that are present in the currently installed PROM.

## 4.16 Summary Of Setup Variables

The setup variables are summarized in Table 4-1 in terms of the button sequences used to access them.

**Table 4-1: Setup Variables**

Button Sequence	Function	Default	Limits
SETUP-EVNT-WAIT	Zero cal. duration Span cal. duration	15 min. 15 min.	1-20 min. 1-20 min.
SETUP-EVNT-TIME	Cal. time-of-day	23:30	00:00-23:59
SETUP-EVNT-ASEQ	Auto. Multipoint cal. enable	OFF	OFF/ZS/Z2S/Z5S
SETUP-EVNT-SHFT	Auto check shift	0 min.	± 60 min.
SETUP-COMM-BAUD	RS-232 baud rate	2400 baud	300, 1200, 2400
SETUP-COMM-ID	Analyzer ID number	0000	0000-9999
SETUP-MISC-O3-SLPE	Slope adjust parameter	1.00	0.85 - 1.15
SETUP-MISC-O3-GEN-ADJ	O <sub>3</sub> GEN lamp setup/adjust	OFF	ON - OFF
SETUP-MISC-O3-GEN-CAL	O <sub>3</sub> GEN calibration	OFF	ON - OFF
SETUP-MISC-O3-GEN-MODE	Feedback mode selection	BNCH	
SETUP-MISC-O3-OFFS	Offset adjust parameter	0.0	± 1000.0
SETUP-MISC-DARK-VIEW	Dark current offset	0 mV	1000 mV
SETUP-MISC-CLK-TIME	Current time-of-day	00:00	00:00 - 23:59
SETUP-MISC-CLK-DATE	Current date	01 JAN 00	31 DEC 99
SETUP-MISC-CLK-ADJ	Clock speed adjust	0 sec/day	± 60 sec.
SETUP-MISC-D/A-RNGE	D/A output range	500 ppb	100-10000
SETUP-MISC-D/A-OFFS	D/A offset setting	0 mV	± 500 mV
SETUP-MISC-MORE-FLT	Fault LED timeout	5 min	0 - 10 min
SETUP-MISC-MORE-UNITS	O <sub>3</sub> conc. units	ppb	ppb/ppm/ug/mg
SETUP-MISC-MORE-TCHN	TEST to analog output	OFF	OFF-ON
SETUP-PASS	Cal. password enable	ON	OFF-ON
SETUP-CFG-LIST	Software configuration	O <sub>3</sub> CALIB.	Display

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## 5 DIAGNOSTICS

The Teledyne API ozone analyzer contains two levels of diagnostics: test measurements which can be viewed at all times (except when in setup) by pressing **TEST**, and lower level diagnostic operations which can only be performed by pressing **SETUP-DIAG**.

### 5.1 Test Measurements

As stated, test measurements can be viewed at any time except when in setup. To view a different test measurement, simply press the **TEST** button. Table 2-3 lists the test measurements which are available. Viewing these test measurements does not interfere with the operation of the Model 401 or the ozone reading of the photometer in any way, so they may be viewed freely.

Additionally, the values of most **TEST** functions can output as an analog voltage at the instrument's rear panel (see Figure 1-2). The **TEST** function to be output is selected by pressing **SETUP-MISC-MORE-TCHN**. Table 5-1 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=XXXXX.X MV".

### 5.2 Diagnostic Tests

The diagnostic tests are used to help diagnose a problem in the Analyzer and should only be used by skilled maintenance people. To get into the diagnostic test mode, press **SETUP-DIAG**. When the diagnostic mode is entered, a message is sent to the RS-232 channel indicating entry into the diagnostic mode.

The **TEST** button is used to scroll through the test measurements until the one of interest is displayed.

The **EXIT** button exits the diagnostic mode and turns all the diagnostic tests OFF. This ensures that a diagnostic test is not accidentally left ON. A message is also sent to the RS-232 channel to indicate that the diagnostic mode has been exited.

**Table 5-1: Test Channel Output**

Test #	Name	Purpose
1	NONE	No output
2	O3 DETECT	Outputs O <sub>3</sub> detector
3	REF DETECT	Outputs IZS ref. det.
4	SAMP PRESS	Outputs sample press.
5	SAMP FLOW	Outputs sample flow
6	SAMP TEMP	Outputs sample temp.
7	ALAMP TEMP	Outputs ana lamp temp.
8	O3 FLOW	Outputs O <sub>3</sub> flow
9	O3 LAMP TEMP	Outputs O <sub>3</sub> lamp temp
10	CHASSIS TEMP	Outputs chassis temp
11	DCPS VOLT	Outputs DC power

**Table 5-2: Diagnostic Tests**

Test #	Name	Type	Purpose
1	D/A OUTPUT	Analog	Tests analog outputs

### 5.2.1 D/A Output

This test cycles 3 of the analog output channels from 0% to 100% of Full Scale in 20% FS steps. It starts by outputting 0 volts to all four channels and displaying a 0% button. Then, every five seconds, the output is increased 20% FS and the button is changed accordingly. Thus, the button (and the analog outputs) will cycle through the following values:

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

To pause the output at the current voltage, press the **n%** button. To resume automatic cycling, press the **n%** button again.



## 6 HANDLING WARNINGS

When a system warning occurs, a warning message is displayed and the FAULT LED blinks. A warning indicates that something in the system needs to be checked or adjusted. Failure by the operator to respond to a warning may result in poor system performance and/or less accurate data acquisition. Warnings should be taken seriously.

When a warning is displayed, the **MSG** and **CLR** buttons will appear on the menu line (when not in setup mode). Pressing **MSG** will scroll through the warning messages if there is more than one. **CLR** will clear the currently displayed warning message, and if there are no more warning messages remaining, the **MSG** and **CLR** buttons will disappear and the FAULT LED will be turned OFF. If after pressing **CLR**, warning messages still exist, the FAULT LED will continue to blink and the **MSG** and **CLR** buttons will remain on the menu line.

If after clearing a message, the warning condition for that message still exists, the message will reappear after a period of time which depends on how frequently the condition is checked by the CPU (usually every few seconds). If a warning message reappears every time after **CLR** is pressed, the problem should be solved and the Analyzer restarted. Some problems may be temporary and may not reappear after **CLR** is pressed (e.g. temperature too high, too low, etc.).

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

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## 7 RS-232 COMMUNICATIONS

The Model 401 Photometric Calibrator features a powerful RS-232 interface which is used both for reporting test results and for controlling the Photometer 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.

All message outputs from the Model 401 Photometric Calibrator have the following format:

```
"X DDD:HH:MM I I I I MESSAGE<CRLF>"
```

The "X" is a character indicating the message type (see Table 7-1).

**Table 7-1: RS-232 Message Types**

Character	Message Type
R	DAS Report
W	Warning
C	Control/Status
D	Diagnostic
T	Test Measurement
V	Variable Value
?	HELP Screen

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.

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

Input messages to the Model 401 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 7-1 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.

## 7.1 DAS Reporting

Every N minutes (N is software selectable) the data acquisition system issues a report to the RS-232 interface. This report shows the average O<sub>3</sub> reading during the last N minutes, the range, and the number of 1-minute samples taken during that interval. The message format is:

```
"R DDD:HH:MM I III RANGE=xxxx O3=xxxx PPB SAMPLES=xx<CRLF>"
```

Whenever the Model 401 is in calibration or diagnostics mode, no O<sub>3</sub> readings are included in the average. Thus, it is possible for an average to contain 0 samples. If the number of samples in an average is 0, then "XXXX" is shown as the O<sub>3</sub> readings.

The host computer can request the DAS reports stored in the battery-backed RAM by means of the command:

```
"R NNN<CRLF>"
```

where "NNN" is the number of reports requested (starting from the most recent one). The CPU will output NNN reports to the RS-232 interface, each report having the following format:

```
"R DDD:HH:MM I III O3 PPB SAMPLES=xx<CRLF>"
```

where the fields have the same meaning as described above. For example, if the last DAS report was at 10:00 a.m. and the report frequency is 60 minutes and the host computer requests the most recent 3 reports by issuing the command:

```
"R 3<CRLF>"
```

and the CPU will respond by outputting something like the following:

```
"R 91:08:00 0000 O3= 0 PPB SAMPLES=60<CRLF>"
```

```
"R 91:09:00 0000 O3= 2 PPB SAMPLES=60<CRLF>"
```

```
"R 91:10:00 0000 O3= 0 PPB SAMPLES=60<CRLF>"
```

## 7.2 Warnings

Whenever a warning message is displayed on the display, it is also sent to the RS-232 output. See Table 2-4 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. The message format is:

```
"W DDD:HH:MM I III WARNING MESSAGE<CRLF>"
```

An example of an actual warning message is:

```
"W 194:11:03 0000 SAMPLE FLOW WARN<CRLF>"
```

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

```
"W COMMAND<CRLF>"
```

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 WSMPFLOW<CRLF>"
```

To clear all warning messages:

```
"W CLEAR ALL<CRLF>"
```

Attempting to clear a warning which is not active has no effect. Table 7-2 lists the command to use to clear each possible warning message.

**Table 7-2: Warning Message Clear Commands**

Command	Warning Message Cleared
"W WSYSRES<CRLF>"	SYSTEM RESET
"W WRAMINIT<CRLF>"	RAM INITIALIZED
"W WALMPINT<CRLF>"	ANA LAMP WARNING
"W WO3LMPHLT<CRLF>"	O3 GEN LAMP SHUTDOWN
"W WO3REFDET<CRLF>"	O3 GEN DETECTOR WARNING
"W WO3FLOW<CRLF>"	O3 GEN FLOW WARNING
"W WSMFLOW<CRLF>"	SAMPLE FLOW WARNING
"W WSMPPRES<CRLF>"	SAMPLE PRESSURE WARNING
"W WSMPTEMP<CRLF>"	SAMPLE TEMP WARNING
"W WBOXTEMP<CRLF>"	BOX TEMP WARNING
"W WO3LMPTMP<CRLF>"	O3 GEN LAMP TEMP WARNING
"W WALMPTMP<CRLF>"	ANA LAMP TEMP WARNING
"W WVFINS<CRLF>"	V/F NOT INSTALLED

## 7.3 Status/Control

This subset of messages is concerned with reporting the status of the calibrator and controlling the calibrator remotely. Whenever the calibrator does a calibration it issues a report to the RS-232 output. The table on the following page summarizes the status reports.

**Table 7-3: 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<CRLF>"

The commands are summarized in Table 7-4.

**Table 7-4: Control Commands**

Command Message	Meaning
"C ZERO<CRLF>"	Do a zero check
"C O <sub>3</sub> GEN<CRLF>"	Do a span check
"C ASEQ<CRLF>"	Do a multi-point check
"C STBY<CRLF>"	Exit zero, span, or ASEQ

**NOTE**

**The commands in Table 7-4 can only be entered via the RS-232 port when the calibrator is in the stand by mode. "C ASEQ" is enabled only if ASEQ is pre-selected.**

When a control command is issued, the CPU will respond by issuing a status report. For example if the host computer issues the command:

"C ZERO<CRLF>"

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

"C DDD:HH:MM IIII GENERATE ZERO"

to the RS-232 output.

## 7.4 Diagnostics

The diagnostics mode can be entered from the RS-232 port as well as from the front panel. The diagnostics commands available are listed below.

**NOTE**

**The diagnostics mode may only be entered via the RS-232 port when the calibrator is in stand by mode.**

**Table 7-5: Diagnostic Commands**

Command	Function
"D ENTER<CRLF>"	Enter diagnostics mode
"D EXIT<CRLF>"	Exit diagnostics mode
"D PREV<CRLF>"	Go to previous test
"D NEXT<CRLF>"	Go to next test
"D ON<CRLF>"	Turn test signal ON
"D OFF<CRLF>"	Turn test signal OFF
"D PAUSE<CRLF>"	Pause analog output test
"D RESUME<CRLF>"	Resume analog output test

These commands may be used whether the diagnostics have been entered from the keyboard (SETUP-DIAG) or the RS-232 ("D ENTER <CRLF>"). However, when the diagnostics are entered via the keyboard, no feedback is sent to the RS-232 channel. This prevents the RS-232 output from getting unnecessarily cluttered with diagnostic data.

In addition to the above commands, three special diagnostics commands have been added to provide complete control over a remote Analyzer. These commands may be executed no matter what mode the instrument is in.



**Table 7-6: Special Diagnostic Commands**

Command	Function
"D SYS-RESET<CRLF>"	Reset Calibrator (same as power off/on)
"D RAM-RESET<CRLF>"	Reset Calibrator and erase RAM
"D EE-RESET <CRLF>"	Reset Calibrator and erase RAM & EEPROM

Whenever the diagnostic mode is entered or exited, a report is issued to the RS-232 output. Table 7-7 summarizes the diagnostic reports.

**Table 7-7: Diagnostic Reports**

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

## 7.5 Test Measurements

All the test measurements which can be displayed by pressing the TEST button are also available to the host computer via the RS-232 interface. The host computer should issue a request for a test measurement, and then the CPU will send the current value of the test measurement to the RS-232 output. The format of the test measurement message is:

```
"T DDD:HH:MM IIII TEST MEASUREMENT<CRLF>"
```

For example, the format of the PMT output in millivolts would be:

```
"T 194:11:29 0000 PMT= 254 MV<CRLF>"
```

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

```
"T MEASUREMENT<CRLF>"
```

For a summary of all test functions issue the command "T LIST". Table 7-8 lists the commands and the corresponding test measurements which will be returned.

**Table 7-8: Test Measurement Request Commands**

Command	Test Measurement
"?<CRLF>"	RS-232 HELP screen
"T LIST<CRLF>"	Summary of all Tests
"T O3MEAS<CRLF>"	Current O <sub>3</sub> meas counts
"T O3REF<CRLF>"	Current O <sub>3</sub> reference counts
"T SPRESS<CRLF>"	Sample pressure
"T SFLOW<CRLF>"	Sample flow rate
"T STEMP<CRLF>"	Sample temperature
"T ALTEMP<CRLF>"	Analyzer lamp temperature
"T BOXTEMP<CRLF>"	Internal box temperature
"T DCPS<CRLF>"	DC power supply output
"T CLKTIME<CRLF>"	Current time-of-day

## 7.6 Viewing And Modifying Variables

The most powerful feature of the RS-232 interface is the ability of a host computer to view and modify the calibrator's internal variables. Just as the operator modifies the variables by means of the setup mode, the host computer modifies them by means of the RS-232 interface.

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

```
"V VARIABLE<CRLF> "
```

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

```
"V VARIABLE=VALUE WARNLO WARNHI <DATA LO-DATA HI> <CRLF> "
```

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. "DATA LO" and "DATA HI" 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 lamp temperature set point, the host computer would issue the command:

```
"V ALAMP_SET<CRLF> "
```

and the CPU would respond with something like:

```
"V   DDD:HH:MM   IIII   ALAMP_SET=25 20 30 <0-100><CRLF> "
```

indicating that the current set point is 25 degrees, the warning limits are 20 to 30 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<CRLF> "
```

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 which 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 ] <CRLF> "
```

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<CRLF> "
```

and the CPU should respond with:

```
"V   DDD:HH:MM   IIII   MACHINE_ID = 1234 (0-9999)<CRLF> "
```

Table 7-9 lists the variable names which are variable through the RS-232 interface and their corresponding button sequences.

**Table 7-9: RS-232 Variable Names**

<b>Var. Name</b>	<b>Button Sequence</b>	<b>Legal Values</b>
AUTO-TIME	SETUP-IZSC-TIME	00:00-23:59
AUTO-SHIFT	SETUP-IZSC-SHFT	-60 - +60
TIME-ZERO	SETUP-IZSC-WAIT	1-20
TIME-SPAN	SETUP-IZSC-WAIT	1-20
O3-SPAN	SETUP-IZSC-SPAN	0-9000
REPORT-FREQ	SETUP-DAS-FREQ	1-60
MACHINE-ID	SETUP-COMM-ID	0000-9999
BAUD-RATE	SETUP-COMM-BAUD	300, 1200, 2400
ILAMP-SET	(not available)	20-70
IZSLAMP-SET	(not available)	20-70
LAMP-PCT	SETUP-MISC-O3-GEN	0-100
CURR-TIME	SETUP-MISC-CLK-TIME	00:00-23:59
CURR-DATE	SETUP-MISC-CLK-DATE	01/01/00-12/31/99
CLOCK-ADJ	SETUP-MISC-CLK-ADJ	-60 - +60
DA-RANGE	SETUP-MISC-D/A-RNGE	0=100, 1=500, 2=1000, 3=5000, 4=10000
DA-OFFSET	SETUP-MISC-D/A-OFFS	-500 - +500
DARK-OFFSET	SETUP-MISC-DARK-VIEW	-1000 - +1000
PASS-ENABLE	SETUP-PASS	OFF, ON
FAULT-TIME	SETUP-MISC-MORE-FLT	0-300

## 8 ADJUSTMENTS

### NOTE

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



All adjustments to the Model 401 are easy to make. Pots and test points are readily accessible without removing any components.

Figure 1-7 is a plan view of the Model 401 Photometric Calibrator showing all the major components.

Figure 8-1 is an electrical diagram of Model 401 Photometric Calibrator.

### 8.1 Power Supply Board Adjustment

The power supply board provides  $\pm 15$  v + 12 v and + 5 v DC power to the Calibrator. Four temperature linearization circuits, for the Calibrator main lamp, Sample temp, Box temp, and IZS ozone generator are also located on the power supply board.

Each circuit is a whetstone bridge with the measuring thermistor being one leg. A feedback circuit performs the required linearization. Zero adjust pots have been factory set and no field adjustment should be required.

### NOTE

**The power supply board also contains a "Brown-Out" detector.**

#### 8.1.1 Box Temperature Limits

The box temperature is measured by a thermistor located on the motherboard. The box temperature is not controlled in the Model 401. The temperature is measured and displayed as a TEST function on the front panel (see Section 5.1). The alarm limits can be set via an RS-232 port command.

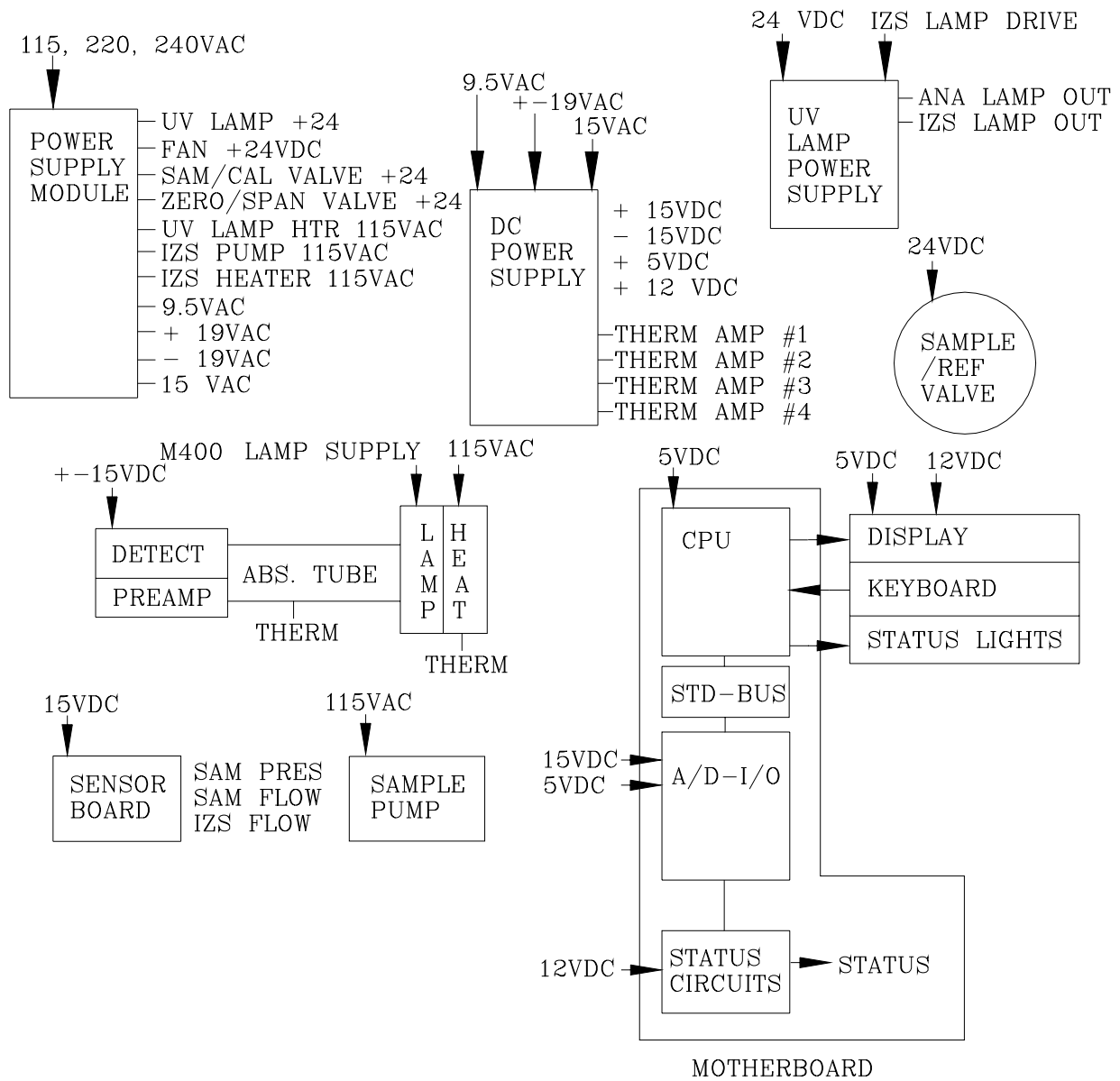


Figure 8-1: Electrical Block Diagram

## 8.2 A/D - D/A Calibration Procedure

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 ADC, do the following:

1. Press SETUP-MISC-D/A-CAL.
2. The M401 display will read "DAC #0: 60 mV", where 60 mV\* is the target voltage which should be coming out the DAC (it should be 60 mV). Put the probe of a voltmeter between TP3 (AGND) and TP9 (DAC #0) on the top of the V/F card (See Drawing 00514, Appendix E), then press the up/down buttons on the M400 front panel until the voltmeter displays the target voltage (60 mV on the 5 V range). Note that the value on the M401 display will not change. When the voltmeter shows the same value ( $\pm 3$  mV) as the M401 display, press ENTR.
- \* The reading will be close to 60 mV if the analyzer is setup for the 5 V range, 120 mV for the 10 V range, etc. DAC #0 is the recorder output, DAC #1 is the DAS output, and DAC #3 is the test output.
3. The M401 display will now show a new voltage in the same format as above. This voltage will be 90% of the full scale DAC output range (4500 mV on the 5 V range). As before, press the up/down buttons on the M401 front panel until the voltmeter displays the same ( $\pm 3$  mV) reading as the M400 display, then press ENTR. The first DAC is now calibrated and will be used as a voltage reference for calibrating the ADC.
4. The M401 display will now read ZR:60 = 60  $\pm$  3 mV, where 60 mV is the voltage being output from the DAC as input to the ADC, and 60  $\pm$  3 mV is the voltage as read from the ADC. The two values should be the same (60 = 60). If they are not, adjust the zero pot (R27) on the V/F card (as indicated by ZR on the display) until the two values are the same, then press ENTR.
5. The M401 display will now read GN:4500=4500  $\pm$  where 4500 is the voltage being output from the DAC as input to the ADC, and 4500  $\pm$  3 is the voltage as read from the ADC. The two values should be the same. If they are not, adjust the gain pot (R31) on the V/F card (as indicated by GN on the display) until the two values are the same (4500 = 4500  $\pm$  3 mV), then press ENTR. The ADC is now calibrated and M401 will automatically calibrate all the DAC's. The display will show the percent completion as the analyzer goes through the procedure.

Next, to automatically calibrate all the DACs, press SETUP-MISC-D/A-CAL-DAC. The display will show the percent completion as the analyzer goes through the procedure. You must calibrate the ADC before calibrating the DACs because the ADC is used during the DAC calibration procedure. Once the ADC is calibrated, you may recalibrate the DACs anytime simply by pressing SETUP-MISC-D/A-CAL, ENTR, ENTR, ENTR, ENTR.

## **8.3 Output Voltage Range Changes**

Output voltage ranges are set by jumper placement 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 top of the drawing using Figure 1-7.
2. Locate jumpers B6, B7, B9 along the top edge of the card. Select the desired range per the table in drawing 00515 located in Appendix D.

**NOTE**

**To adjust analog recorder offset, see Section 4.10.**

## **8.4 Flow Readout Adjustment**

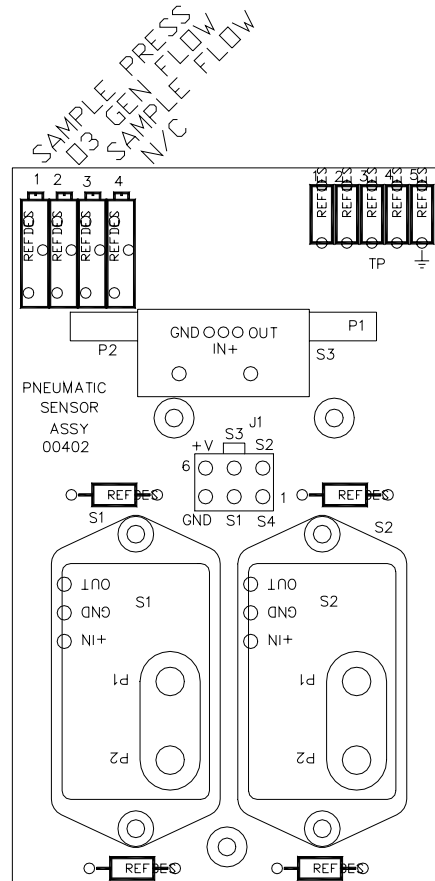
The sensor module in the M401 consists of one flow sensor and two pressure sensors. See Figure 8-2 for a diagram of this module. From these three sensors three values are computed and displayed on the front panel TEST function area. These are:

1. Sample flow
2. Sample cell pressure
3. O<sub>3</sub> GEN flow



FLOW AND PRESSURE  
READOUT ADJUSTMENT  
INSTRUCTIONS:

1. SELECT THE DESIRED TEST FUNCTION ON THE FRONT PANEL.
2. ADJUST THE APPROPRIATE POT PER THE TABLE BELOW UNTIL THE CORRECT READING IS OBSERVED ON THE FRONT PANEL.



SENSOR, TESTPOINT, ADJUSTMENT	M401 FUNCTION	VOLTAGE NOM.
S1, TP1, R1	SAMPLE PRESSURE	8V
S2, TP2, R2	O3 GEN PRESSURE	8V
S3, TP3, R3	SAMPLE FLOW	10V

**Figure 8-2: Flow And Pressure Readout Adjustment**

## 8.5 DC Power Supply

Overall performance of the DC power supply may be checked by observing the value displayed during test DCPS. If this value, a composite of the five (5) regulator outputs, deviates by more than 10% from the value recorded in Table 1-1 of this manual under Test Values, the outputs of the individual regulators should be measured.

Test points 1, 2, 3 and 4 provide connection to the temperature outputs on drawing no. 00016 in Appendix D.

## 8.6 CPU

If the display is operating and the green sample light is on, the CPU should be operating. If not, check the red LED on the CPU board itself, it should be blinking.

If the RED led on the CPU board is not blinking, make the following checks:

1. Verify the +5 Volt supply on the power connector to the CPU Backplane.
2. Check for any loose memory chips on the CPU board.
3. Try removing and reseating the CPU – V/F Card assembly in the motherboard.

## 8.7 Status Lines

**Table 8-1: The Calibrator Has The Following Status Conditions**

Output #	Pin Pair High/Low	Status	Condition
1	1, 2	ZERO CAL	In Zero Calibrate
2	3, 4	SPAN CAL	In Span Calibrate
3	5, 6	FLOW ALARM	Flow Warning
4	7, 8	TEMP ALARM	Any Temp Warning
5	9, 10	DIAG MODE	In Diagnostic Mode
6	11,12	POWER	On As Long As M401 Is Running
7	13,14	PRESS ALARM	Alarms On Low Pressure
8	15,16	IZS FLOW	Warn Alarms If No IZS Flow
9	17,18	SYSTEM OK	Alarms If Any Fault Is Present
10	19,20	LAMP WARNING	Alarms If The Calibrator Lamp Intensity Is Out Of Limits

## 8.8 UV Lamp Power Supply Adjustment

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 TP10, and adjust the pot (VR1) until the DVM reads 20 volts  $\pm$  1 volt.
2. Adjust the positioning of the source lamp, as follows:
  - a. At the front panel of the instrument, Press the **TEST** key until O<sub>3</sub> REF=XXXXXX is displayed.
  - b. Loosen the lamp retaining thumb-screw and rotate the lamp until the O<sub>3</sub> REF reading on display is 4500 mV  $\pm$  320 mV. Re-tighten the thumb-screw. (Note that the full range of lamp adjustment can be achieved within  $\frac{1}{4}$  revolution of the lamp. Note also that the O<sub>3</sub> REF display is updated approximately once every six seconds, and slow rotation of the lamp is needed for proper adjustment.)

**CAUTION**

**UV light present. Do not pull the lamp from the optical bench assembly.**



3. 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<sub>3</sub> REF reading on the display is 4500 mV  $\pm$  50 mV.
  - b. If it is still not possible to achieve a 4500 mV O<sub>3</sub> 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 TP10 to exceed 21 volts.)
4. Re-calibrate the automatic Detector Dark Current compensation by pressing **SETUP-MISC-DARK-CAL** at the front panel. See Section 9.3 for dark current adjustment procedure.

## 8.9 Ozone Generator Lamp Setup

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 O<sub>3</sub> generator and its feedback circuit.

1. Enter the SETUP menu by pressing SETUP-MISC-O3-GEN-ADJ. This causes the lamp drive circuit to output a constant 2.5 V.

If you are installing a new lamp, allow approximately 30 min for lamp output to stabilize.

2. Select the "O3 GEN" TEST function on the front panel display. Loosen the O<sub>3</sub> generating lamp and rotate until the reading on the display is 2500 mv  $\pm$  500 mV.

**CAUTION**

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



Re-tighten the hold-down screws securing the ozone lamp to the O<sub>3</sub> generator assembly.

3. Remove access cap from the O<sub>3</sub> generator preamp cover and adjust the pot to refine the front panel reading to 2500 mv  $\pm$  25.
4. The O<sub>3</sub> generator lamp and feedback circuit are now set up. Proceed to Section 8.11 to finish calibration of the O<sub>3</sub> generator.

## 8.10 Ozone Generator Calibration

The ozone generator can be calibrated against the analyzer calibration by using the analytical section of the M401 to determine the ozone generator's output. Calibration of the generator allows the operator to enter the desired calibration concentration directly in PPB's.

The M401 should be calibrated by relating to the master standard using the method described in Section 3 before doing this procedure.

Press SETUP-MISC-O3-GEN-CAL to start the calibration process, which works as follows:

1. The M401 will measure the O<sub>3</sub> generator reference signal and the O<sub>3</sub> concentration at 5 different O<sub>3</sub> concentrations.
2. For each test point, the machine outputs the drive setting and waits 10 minutes for the M401 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 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, the table will not be modified.

### NOTE

You can now use the O<sub>3</sub> generator. See Section 3 for details.



## 8.11 Dark Current Signal Adjust Procedure

The detector dark current changes little as the detector ages. Therefore this procedure should not need to be performed except whenever a major sub-assembly is changed (such as a new UV lamp or UV lamp power supply).

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

1. Turn the analyzer lamp off.
2. Average 6 successive O<sub>3</sub> 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<sub>3</sub> detector readings.

To view the current dark offset, press SETUP-MISC-DARK-VAL. Press EXIT when finished. No password is required to view the dark offset, only to change it.

## **8.12 Bench Feedback Option**

The Bench Feedback Option uses the Photometer to control the lamp drive current. This option assures very stable and repeatable ozone concentrations. Press SETUP-MISC-O3-GEN-MODE-BNCH to activate this option. It is recommended to select the bench feedback mode for stable and precise O<sub>3</sub> calibration gas.

## 9 TROUBLESHOOTING

### NOTE

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



### 9.1 Overview

The Model 401 Photometric Calibrator has been designed to rapidly detect possible problems and allow their quick evaluation and repair. During operation, the calibrator continuously performs self-check diagnostics and provides the ability to monitor the key operating parameters of the instrument without disturbing monitoring operations. These capabilities will usually allow the quick isolation and resolution of a problem.

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 corrective action as required.
4. Address any dynamic (Sample related) problems.

The following sections provide a guide for performing each of these steps. Figure 1-7 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.

### 9.2 Troubleshooting Fundamental Calibrator Operation

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

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

If these actions all occur, it is probable that the Calibrator's Power Supplies, CPU, and Display are working properly.

If any of these actions fail to occur, power and/or CPU operation should be checked as follows.

### **9.2.1 Checking The Power Sub-Systems**

1. Check incoming line power for proper Voltage and Frequency.
2. Check the Circuit breaker on the Calibrator's rear panel.
3. Check the 3-wire safety power-input plug on the Calibrator's rear panel.
4. Check for proper internal AC power by confirming that the Red(right-most) LED on the Power Supply Module is lit. If this LED is not lit, replace the fuse at the bottom center of the Power Supply Module.

**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.**



5. 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 as described in Section 9.6.4.



## 9.2.2 Checking The CPU And Display

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 9.2.1), the absence of these actions will usually indicate either a CPU or Display failure. To determine which module is defective, perform the following procedure:

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.

## 9.2.3 Checking The Keyboard

During normal Calibrator 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 9.2.2).

If these checks are satisfactory, it is probable that the keyboard is defective and should be replaced.

## 9.3 Troubleshooting Using Warning Messages

The most common and/or serious instrument failures will result in a warning message (or messages) being displayed on the front panel. Table 9-1 lists the warning messages which the Calibrator may display, along with their meaning and the 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 9.6.4) and the V/F Board (see Section 9.6.3) be confirmed before addressing the specific warning messages.

**Table 9-1: Warning Messages**

Warning Message	Meaning	Corrective Action
ANA LAMP WARNING	The O <sub>3</sub> REF value is greater than 5000 mV or less than 2500 mV.	Check and adjust Source Lamp and UV detector as described in Section 9.6.6.
ANA LAMP SHUTDOWN	Temperature control of the Source Lamp cannot be maintained at its 52°C set point.	Check source lamp heater and thermistor as described in Section 8.10.
O3 GEN LAMP WARNING	The Ozone Generator is unable to produce at least 1000 ppb at its maximum output or the O <sub>3</sub> GEN feedback control is adjusting the Ozone generator drive signal by more than a factor of two.	Check and adjust the O <sub>3</sub> GEN lamp and reference det as described in Section 9.6.8.
O3 GEN LAMP SHUTDOWN	Temperature control of the O <sub>3</sub> GEN Lamp cannot be maintained at its 48°C set point.	Check O <sub>3</sub> GEN lamp heater and thermistor as described in Section 8.10.
SAMPLE PRESSURE	The Sample Pressure is less than 15"Hg or is greater than 35"Hg.	Check for pressure transducer problems as described in Sections 9.6.1 and 9.6.5.
SAMPLE FLOW WARNING	The sample flow is less than 500 cc/min or greater than 1000 cc/min. Check for pneumatic system problems as described in Section 9.6.1.	Check for flow transducer problems as described in Section 9.6.5.
BOX TEMP WARNING	The inside chassis temp is less than 5°C or is greater than 50°C.	See Section 9.6.2.
SAMPLE TEMP WARNING	The Sample Temperature is less than 10°C or is greater than 50°C.	See Section 9.6.2.
V/F NOT INSTALLED	The CPU is unable to communicate with the V/F Board.	Check and re-seat CPU and V/F board. See Section 9.6.3.
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.
O3 FLOW WARNING	IZS flow rate is less than 1.8 L/M or >5.5 L/M.	Adjust pressure regulator to set proper flow rate.

## 9.4 Troubleshooting Using Test Function Values

The Model 401 Photometric Calibrator provides the capability to display, on operator demand, the values of Test Functions which allow the observation of key analyzer operating parameters. These Test Functions can be accessed by depressing the TEST Button on the instrument's front panel, with each depression of the button causing the next test function to be displayed. By comparing the values of Test Functions to acceptable operating limits, it is possible to quickly isolate and correct most problems.

Table 9-2 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 1-1 in this manual provides a list of the values of all Test Functions at the time the analyzer left the factory.

**Table 9-2: Test Function Values**

Test Function	Meaning	Acceptable Values	Corrective Action for Unacceptable Values
RANGE	The Full Scale Range of the analyzer's analog outputs in PPB.	Any between 100 - 10000 PPB	None required.
O <sub>3</sub> MEAS	The most recent detector reading taken in Measure mode (i.e. with sample gas bypassing the Ozone Scrubber).	2500-4700 mV	Check and adj source lamp and UV det as described in Section 9.6.6.
O <sub>3</sub> REF	The most recent detector reading taken in Reference mode (i.e. with sample gas passing through the Ozone Scrubber).	2500-4700 mV	Check and adj source lamp and UV det as described in Section 9.6.6.
O <sub>3</sub> GEN	The reading from the O <sub>3</sub> GEN lamp reference detector.	75-175 mV with O <sub>3</sub> gen off >75 mV with O <sub>3</sub> gen on.	Check and adjust the IZS lamp and reference detector as described in Section 8.10.
PRES	The absolute pres of the sample gas in the absorption cell.	0"-1.0" Hg below ambient pressure	Check for pneumatic system problems. See Section 9.6.1. Check for pressure transducer problems. See Section 9.6.5.

*(table continued)*

**Table 9-2: Test Function Values (Continued)**

Test Function	Meaning	Acceptable Values	Corrective Action for Unacceptable Values
SAMPLE FLOW	Sample mass flow rate.	700-900 cc./min	Check for pneumatic system problems. See Section 9.6.1. Check for flowmeter problems. See Section 9.6.5.
SAMPLE TEMP	The temperature of the sample gas in the absorption cell.	1°-5° C above ambient	See Section 9.6.2.
ANA LAMP TEMP	The temperature of the Source Lamp.	52° C (After warm-up)	See Section 9.6.2.
IZS LAMP	The temperature of the O <sub>3</sub> GEN Lamp.	48° C (After warm-up)	See Section 9.6.2.
BOX TEMP	The temperature inside the analyzer chassis.	1°-5° C above ambient	See Section 9.6.2.
DCPS	DC Power Supply reference-A composite of all voltages provided by the DC Power Supply.	2400-2600 mV	See Section 9.6.4.
O <sub>3</sub> FLOW	The flow rate of O <sub>3</sub> GEN.	2-5 L/M	Adjust pressure regulator to set proper flow rate.

## 9.5 Troubleshooting Dynamic 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.

### 9.5.1 Noisy Or Unstable Readings At Zero

1. Check for leaks in the pneumatic system as described in Section 10.3.
2. Confirm that the Zero gas is free of Ozone.
3. Confirm that the Source Lamp is fully inserted and that the lamp hold-down thumb- screw is tight.
4. Check for a dirty Absorption Cell and/or pneumatic lines. Clean as necessary as described in Section 10.4.
5. 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.

### 9.5.2 Noisy, Unstable, Or Non-Linear Span Readings

1. Check for leaks in the pneumatic systems as described in Section 10.3.
2. Check for proper operation of the Main Switching Valve as described in Section 9.6.7.
3. Check for dirty absorption cell and/or pneumatic system components and clean or replace as necessary as described in Section 10.4.
4. Check for proper adjustment of DAC and ADC electronics by performing the adjustment procedure in Section 8.2.
5. Confirm the Sample Temperature, Sample Pressure, and Sample Flow readings are correct. Check and adjust as required.
6. Verify sufficient flow from the O<sub>3</sub> generator in excess of the total flow needed. The total flow needed is the sum of the M401 sample flow and the remote analyzers sample flow.

### 9.5.3 Slow Response To Changes In Concentration

1. Check for dirty pneumatic components and clean or replace as necessary as described in Section 10.4.
2. Check for pneumatic leaks as described in Section 10.3.
3. Check for improper materials in the inlet manifold.

### 9.5.4 Analog Outputs Do Not Agree With Front Panel Readings

1. Confirm that the DAC offset (SETUP-MISC-D/A-OFFS) is set to zero.
2. Perform a DAC/ADC adjustment and Dark Signal adjustment by following the procedure described in Sections 8.2 and 8.3.

### 9.5.5 Cannot Zero

1. Check for leaks in the pneumatic system as described in Section 10.3.
2. Confirm that the Zero gas is free of Ozone.
3. Verify sufficient flow from the O<sub>3</sub> generator in excess of the total flow needed. The total flow needed is the sum of the M401 sample flow and the remote analyzers sample flow.

### 9.5.6 Cannot Span

1. Check for leaks in the pneumatic systems as described in Section 10.3.
2. Check for proper operation of the Main Switching Valve and Ozone Scrubber as described in Section 9.6.7.
3. Check for dirty pneumatic system components and clean or replace as necessary as described in Section 10.4.
4. Check for proper adjustment of DAC and ADC electronics by performing the adjustment procedure in Section 9.2.
5. Confirm the Sample Temperature, Sample Pressure, and Sample Flow readings are correct. Check and adjust as required.
6. Verify sufficient flow from the O<sub>3</sub> generator in excess of the total flow needed. The total flow needed is the sum of the M401 sample flow and the remote analyzers sample flow.

## 9.6 Troubleshooting Individual Sub-Assemblies And Components

The following sections provide troubleshooting/check-out methods for the specific sub-assemblies and components of the Calibrator.

### 9.6.1 Troubleshooting Flow Problems

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 available, use an independent flow meter (rotameter or mass flow meter) to measure flow(s). Sample flow can be measured at the inlet port at the optical bench and O<sub>3</sub> generator flow can be measured at the outlet of the O<sub>3</sub> generator. 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.

If the independent flowmeter shows the flow to be correct, check the Pneumatic Sensor Board as described in Section 9.6.5.

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.

Figure 1-1 in this Manual provides a schematic diagram of the Flow in a Model 401.

#### **Flow Is Zero**

1. Confirm that the sample pump (sample flow) and/or O<sub>3</sub> GEN pump, (O<sub>3</sub> GEN flow) are 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 10.3. Repair and re-check.
2. Check for dirty sample filter or dirty orifice filter(s).
3. Check for partially plugged pneumatic lines, orifices, or valves.

#### **High Flow**

1. The most common cause of high flow is a leak around an orifice.

## 9.6.2 Troubleshooting Temperature Problems

The Model 401 has been designed to operate at ambient temperatures between 5°C and 40°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 four temperatures:

1. Sample Temperature
2. Inside Chassis Temperature
3. Source Lamp Temperature
4. O<sub>3</sub> GEN Lamp Temperature

The instrument controls the temperatures of two components by heating:

1. Source Lamp
2. O<sub>3</sub> GEN Lamp

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. 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 J2 and measure across the leads.

### **Source Lamp Temperature**

Unplug the connector at Motherboard J4 and measure across the leads.

### **O<sub>3</sub> GEN Lamp Temperature**

Unplug the connector at Motherboard J6 and measure across the leads.



### Chassis Temperature

Turn the analyzer off and remove the DC Power Supply Board. Measure across Motherboard J21 pins A30 and C30.

If thermistor resistance(s) are within the proper range, check the temperature linearization circuits on the DC Power Supply Board as described in Section 9.6.4.

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 red (right-most) LED is lit, and that the "CEL HTR" and "O<sub>3</sub> GEN HTR" 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 9.2 and 9.6.3.
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.

**WARNING**

**Hazardous voltage present - use caution.**



### 9.6.3 Checking The V/F Card

A schematic and physical diagram of the V/F card are shown on Drawings 00514 and 00515 in Appendix D. Proper operation of the V/F board can be confirmed by performing an ADC calibration procedure as described in Section 8.2. If this calibration procedure can be performed correctly, it is probable that the V/F card is functioning properly. If the V/F does not function properly, check the following:

1. 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 in Section 9.6.4.

**NOTE**

**Do not disconnect CPU or other digital cards while under power.**

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

**Table 9-3: 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

**Table 9-4: V/F Board Dip Switches - Ranges For Analog Output**

User Set DIP Switches				
Switch	100 mV Full Scale	1 V Full Scale	5 V Full Scale	10 V Full Scale
S1(DAC 0)= "REC"	1,6 = ON	1,5 = ON	1,4 = ON	1,3 = ON
S2(DAC 1)= "DAS"	1,6 = ON	1,5 = ON	1,4 = ON	1,3 = ON
S3(DAC 2)= "TEST"	1,6,7 = ON	1,5,7 = ON	1,4,7 = ON	1,3,7 = ON
S3(DAC 2)= "O3 GEN"	N/A	N/A	1,4,7 = ON	N/A

3. If Voltages and Jumper settings are correct, the V/F card is faulty and should be replaced.

## 9.6.4 Checking The DC Power Supply Board

A schematic and physical diagram of the DC Power Supply Board are shown on Drawings 00015 and 00016 in Appendix D.

The overall performance of the DC Power Supply Board can be checked by observing the value of the DCPS test functions. If this value, a composite of five regulator outputs, deviates by more than 10% from the value recorded in Table 1-1 of this manual under Test Values, the outputs of the individual regulators should be checked by measuring for the following voltages:

1. Remove Plugs J8, J6, and J13 from the front of the Power Supply Module. Verify that the following voltages are present:

- +24 VDC between J8 pins 2 and 4
- +24 VDC between J6 pins 12 and 13
- 25 VAC between J13 pins 4 and 5
- 15 VAC between J13 pins 3 and 2
- 38VAC between J13 pins 6 and 7

**WARNING**

**Hazardous voltage present on the power supply module.**



If any of these voltages is not present, the Power Supply Module is defective and should be replaced.

2. Confirm that the following voltages are present on the V/F Board:

- +5V between V/F TP 4 and V/F TP 5
- +15V between V/F TP 1 and V/F TP 3
- 15V between V/F TP 2 and V/F TP 3
- +12V between Mother Board Pad J13,6 and J13,7

If any of these voltages is incorrect, it is probable that the DC Power Supply Board is faulty and should be replaced.

Four Temperature linearization circuits are contained on the DC Power Supply board. The outputs of these circuits can be checked by measuring the voltages at test points on the board as follows:

TP1	Sample Temp	30° C=2.5V, ± 0.125V/°C
TP2	Source Lamp Temp	50° C=2.5V, ± 0.125V/°C
TP3	IZS Lamp Temp	50° C=2.5V, ± 0.125V/°C
TP4	Chassis Temp	20° C=2.5V, ± 0.125V/°C

If any of these voltages is incorrect, check thermistor operation as described in Section 9.6.2. If thermistors are operating correctly, it is probable the DC Power Supply Board is defective and should be replaced.

### **9.6.5 Checking The Pneumatic Sensor Board**

A schematic and physical diagram of the Pneumatic Sensor Board are shown on Drawings 00402 and 00403 in Appendix D. Proper operation of the pneumatic sensor board can best be determined by comparing the values of Flow and Pressure Test functions to measurements obtained with independent flow and pressure meters. Flow and pressure readings can be adjusted as described in Section 8.5.

If it is not possible to adjust the pneumatic sensor board to agree with independent flow and pressure measurements, confirm the presence of +15 V at connector J1 pin 6. If this voltage is not present, check the DC Power Supply Board as described in Section 9.6.4. If +15 V is present, it is probable that the Pneumatic Sensor Board is defective and should be replaced.

### **9.6.6 Checking The Source Lamp And Detector**

Basic operation of the source lamp and detector can be determined by observing the value of the O<sub>3</sub> 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 follows.

**Table 9-5: UV Source Lamp And Detector Diagnostics**

<b>UV Source Lamp and Detector Diagnostics</b>	
<b>O<sub>3</sub> REF Value</b>	<b>Meaning</b>
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.

**WARNING**

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

**Adjustment Required or Adjustment Useful**

Adjust the Lamp and Detector Preamp as described in Section 8.8. If it is not possible to achieve an acceptable O<sub>3</sub> REF test value by means of adjustment, it is possible that the lamp has deteriorated beyond its useful range and should be replaced.

**Lamp or Detector Failure**

The O<sub>3</sub> REF value of approximately 125 mV 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 glass 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 Section 9.6.8. 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.**

**Detector Pre-Amp or V/F Failure**

The O<sub>3</sub> REF test value of less than 75 MV usually indicates a failure of the Detector Pre-Amp. Confirm that the V/F is operating properly as described in Section 9.6.3. If the V/F check is successful, the Detector pre-amp has failed and should be replaced.

**9.6.7 Checking Main Switching Valve**

Proper operation of the main Switching Valve can be determined by performing the following procedure:

1. Press Zero to generate the Zero gas and allow the analyzer to stabilize.
2. Observe the O<sub>3</sub> REF Test Function and make a note of its value.
3. Press span to generate approximately 400 ppb concentration and allow the analyzer to stabilize.
4. Observe the O<sub>3</sub> REF Test Function and note its value.

If the O<sub>3</sub> REF value has decreased by more than 5 MV from its value with Zero-gas, then 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<sub>3</sub> REF (in MV) should be no greater than  $5 \times \text{Actual Concentration}/400$ .)

**9.6.8 Checking The Lamp Power Supply**

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

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 voltage 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 9.6.4.
2. Remove the cover of the Lamp Power Supply and check for the presence of the following voltages:

+15VDC between TP14 and TP2

+20VDC +/-2VDC between TP14 and TP7

If these voltages are 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.

## 9.7 Warranty/Repair Questionnaire

CUSTOMER: \_\_\_\_\_ PHONE: \_\_\_\_\_

CONTACT NAME: \_\_\_\_\_ FAX NO. \_\_\_\_\_

SITE ADDRESS: \_\_\_\_\_

MODEL 401 SERIAL NO.: \_\_\_\_\_ FIRMWARE REVISION: \_\_\_\_\_

1. ARE THERE ANY FAILURE MESSAGES? \_\_\_\_\_

PLEASE COMPLETE THE FOLLOWING TABLE: (NOTE: *DEPENDING ON OPTIONS INSTALLED, NOT ALL TEST PARAMETERS SHOWN BELOW WILL BE AVAILABEL IN YOUR INSTRUMENT.*)

Parameter	Observed Value	Units	Normal Range
DCPS		MV	2300-2700mV
BOX TEMP		DEG C	Ambient +3-5° C
O <sub>3</sub> OFFSET		PPB	-10 - +20PPB
O <sub>3</sub> SLOPE		-	1.0 ± .15
REG PRESSURE		IN-HG-A	10 – 21”-Hg-A
O <sub>3</sub> GEN TMP		DEG C	48 ±1° C
O <sub>3</sub> GEN FLOW		L/MIN	2 – 5 LPM
ANA LAMP TMP		DEG C	52 ±1° C
SAMPLE TEMP		DEG C	10 - 50° C
SAMPLE FLOW		SCC/MIN	700-900 cc./min
SAMPLE PRESS		IN-HG-A	Ambient +0-2”-Hg-A
O <sub>3</sub> DRIVE		MV	0-5000mV
O <sub>3</sub> GEN REF		MV	120-5000mV
O <sub>3</sub> REF		MV	2500-4700mV
O <sub>3</sub> MEAS		MV	2500-4700 mV
O <sub>3</sub> SET		PPB/PPM	.05 PPM –1 PPM

2. HAS THE UNIT BEEN LEAK CHECKED? YES  NO

3. WHAT ARE THE FAILURE SYMPTOMS? \_\_\_\_\_

IF POSSIBLE, PLEASE INCLUDE A PORTION OF A STRIP CHART PERTAINING TO THE PROBLEM. CIRCLE PERTINENT DATA.

4. THANK YOU FOR PROVIDING THIS INFORMATION. YOUR ASSISTANCE ENABLES TELEDYNE API TO RESPOND FASTER TO THE PROBLEM THAT YOU ARE ENCOUNTERING



# 10 ROUTINE MAINTENANCE

**NOTE**

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



## 10.1 Maintenance Schedule

Table 10-1 shows a typical maintenance schedule for the Model 401. 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.

**Table 10-1: Maintenance Schedule**

Date Instrument Was Recieved: _____													
Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Recommended Action
Zero Air Scrubber													Replace charcoal quarterly.
Pump Diaphragms													Replace every 6 months.
DFU particulate filter for zero air													Replace annually.
Sample Cell													Inspect quarterly. Clean as necessary. (Section 10.3)
Sample Flow													Check annually 800 cc/min ± 80.
Leak Check													Check annually (Section 10.2) leak check after any maintenance.

## 10.2 Leak Checking

There are two methods of leak checking:

1. By vacuum: This is the simplest method but it does not show the location of a leak.
2. By pressure: By using bubble solution, this method shows a leak location.

### NOTE

**Be careful using the bubble solution. There is no internal pressure, the solution may enter and contaminate the cell. Use only bubbles, not liquid.**

If you know you have a leak, use pressure.

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

## 10.3 Cleaning Of Sample Cell

1. Remove the center cover from the optical bench.
2. Loosen the screws that hold the retaining rings at each end of the glass 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 glass tube may break and cause serious injury.**



4. Clean the tube with soapy water by running a swab from end-to-end. Rinse with de-ionized water, then isopropyl alcohol, then air dry. Check the cleaning job by looking down the bore of the tube. It should be free from dirt and lint.
5. Re-assemble the tube into the lamp housing and leak check the instrument.

## 10.4 Changing The Prom

1. Locate the CPU card by referring to Figure 1-7.
2. Remove the screws that hold the CPU card (SBC40 printed on the lever) top corner to the V/F card, then remove the card from the STD-BUS backplane.
3. Remove the two cables attached to the SBC40, taking note of the polarity.
4. Remove the card, laying it down on an insulating surface such that the card edge pins on the PCB are on the left. The PROM chip should be at the top center. The current chip should be labeled with something like "M401 411A0 - - -". 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. Replace the CPU board and re-attach the connectors, making sure to observe the polarity.
6. Re-attach the CPU card to the STD-BUS.
7. Move the power switch to the "ON" position 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.
8. Re-enter any non-default settings such as RANGE or AUTOCAL. Check all settings to make sure that expected setup parameters are present.

Re-calibrate the analyzer so that the default slope and intercept are overwritten with the correct values.

Perform Dark Calibration (see Section 8.11).

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# 11 MODEL 401 SPARE PARTS AND EXPENDABLES KITS

## 11.1 Spare Parts For CE Mark Units

**NOTE**

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

**Table 11-1: Spare Parts For CE Mark Units**

<b>Part No.</b>	<b>Description</b>
00015	Power Supply Board
00276-1401	CPU Board
00402-03	Sensor Board
00508	Absorption Tube
00514-03	V/F Board
00526-01	UV Lamp Assy, Source
00535	Pre-AMP Assy, M400 DET
00551-15	Power Supply Module - 230 V/50 Hz (EU)
00551-19	Power Supply Module - 230 V/50 Hz (UK)
00566-02	Assy, Optical Bench
00596	Activated Charcoal
00611	Assy, Bench Lamp Heater
00612-01	UV Lamp Assy, O <sub>3</sub> Gen
00628	Assy, Heater, 50W (IZS)
00644	M400 Zero Air Scrubber Charcoal
00690-01	Scrubber Filter Pads
00728	Display
00815	M400 Valve Module
01061	M401 Pump
01111	M401 Level 1 Spares Kit

*(table continued)*

**Table 11-1: Spare Parts For CE Mark Units (Continued)**

<b>Part No.</b>	<b>Description</b>
01112	M401 Expendables Kit
01509	UV Lamp Power Supply
01916-01	Rear Panel Connector Board
01930	Keyboard
01934	Assy, Sample Thermistor
CB004	Fuse, 3 AG 3 AMP, 250 V
FA004	Fan
FL003	Filter, DFU (036-040180)
FM004	Flow Meter, 0-1000 CC
FM05	Flow Restrictor (O <sub>3</sub> Generator)
FM06	Flow Restrictor (Zero Reference)
HW020	Spring, Flow Control
HW036	TFE Thread Tape (48 FT)
HW037	Tie, Cable
OP001	UV Detector
OR001	O-Ring, Flow Control
OR012	O-Ring, O <sub>3</sub> Gen Lamp
OR014	O-Ring, Optical Bench, Lamp Window
OR021	O-Ring, Scrubber
OR026	O-Ring, Absorption Tube
OR028	O-Ring, O <sub>3</sub> Gen Base
OR030	O-Ring, IZS Scrubber
OR048	O-Ring, UV Detector
SW006	Overheat SW, O <sub>3</sub> GEN
SW008	Vacuum Sensor
TU001	Tubing: 6', 1/8" Clr
TU002	Tubing: 6', 1/8" Blk
TU009	Tubing: 6', 1/4" Tygon
VA003	TFE, 24V, Sample/Ref. Valve

## 11.2 Spare Parts For Non-CE Mark Units

**Table 11-2: Spare Parts For Non-CE Mark Units**

<b>Part No.</b>	<b>Description</b>
00015	Power Supply Board
00276-0401	CPU Board
00402-03	Sensor Board
00508	Absorption Tube
00514-03	V/F Board
00526-01	UV Lamp Assy, Source
00535	Pre-Amp Assy, M400 DET
00551-03	Power Supply Module - 115 V/60 Hz
00551-13	Power Supply Module - 220 V/50 Hz
00551-19	Power Supply Module - 240 V/50 Hz
00566-02	Assy, Optical Bench
00596	Activated Charcoal
00611	Assy, Heater/Thermistor
00612-01	UV Lamp Assy, IZS Gen
00628	Assy, Heater, 50 W (IZS)
00690-01	Scrubber Pads
00704	Keyboard
00728	Display
00815	M400 Valve Module
01061	M401 Pump
01111	M401 Level 1 Spares Kit
01112	M401 Expendables Kit
01509	UV Lamp Power Supply
01934	Assy, Sample Thermistor
CB004	Fuse, 3 AG 3 AMP, 250 V
FA004	Fan
FL003	Filter, DFU (036-040180)

*(table continued)*

**Table 11-2: Spare Parts For Non-CE Mark Units (Continued)**

<b>Part No.</b>	<b>Description</b>
FM004	Flow Meter, 0-1000 CC
FM05	Flow Restrictor (O <sub>3</sub> Generator)
FM06	Flow Restrictor (Zero Reference)
HW020	Spring, Flow Control
HW036	TFE Thread Tape (48 FT)
HW037	Tie, Cable
OP001	UV Detector
OR001	O-Ring, Flow Control
OR012	O-Ring, O <sub>3</sub> Gen Lamp
OR014	O-Ring, Optical Bench, Lamp Window
OR018	O-Ring, Sample Filter
OR021	O-Ring, Scrubber
OR026	O-Ring, Absorption Tube
OR028	O-Ring, O <sub>3</sub> Gen Base
OR030	O-Ring, Zero Air Scrubber
OR048	O-Ring, UV Detector
SW006	Overheat SW, IZS OVEN
SW008	Vacuum Sensor
TU001	Tubing: 6', 1/8" Clr
TU002	Tubing: 6', 1/8" Blk
TU009	Tubing: 6', 1/4" Tygon
VA003	TFE, 24 V, Sample/Ref. Valve



## Appendix A LIST OF AVAILABLE MODEL 401 OPTIONS

Table A-1: Available Model 401 Options

	Option
1.	RS-232
2.	Status Outputs
3.	Rack Mount and Slides
4.	Rack Mount Only

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## Appendix B RECOMMENDED ZERO AIR SYSTEM

The following is from the TECHNICAL ASSISTANCE DOCUMENT FOR THE CALIBRATION OF AMBIENT OZONE MONITORS - Richard J. Paur and Frank F. McElroy (1979).

Zero air must be free of ozone and any other substance that might react with ozone (e.g. NO, NO<sub>2</sub>, various hydrocarbons, and particulates). Air from any source must be purified to remove such substances. Very dirty air may require a pre-cleaning process to remove large particles, oil mist, liquid water, etc. The primary purification process is based on mechanical and chemical filtering. While various schemes may be acceptable, systems similar to the following have been used successfully:

The air is first dried with a Perma-Pure type dryer followed by a column of indicating silica gel. The air is then irradiated with a UV lamp to generate ozone that converts existing NO to NO<sub>2</sub>, and a large column of activated charcoal removes NO<sub>2</sub>, O<sub>3</sub>, hydrocarbons, and various other substances. If desired, molecular sieve can be included for good measure.

A final particulate filter removes particulates which can originate in the scrubber columns. The removal of moisture may not be necessary, but fewer problems seem to be encountered when dry air is used.

The particulars of air purification are not well known, so some experimentation may be necessary to determine the appropriate size of volume for scrubber columns. Also, the capacity of the scrubber materials may not be accurately known, so frequent replacement or renewal of these materials is advisable. Additional information on air purification is available (APHA Intersociety Committee 1977, Section 20, Part I).

A very important requirement in photometer operation is the need for the zero air supplied to the photometer during the I<sub>0</sub> measurement to be obtained from the same source as that used for generation of ozone. The impurities present in zero air from different sources can significantly affect the transmittance of an air sample.

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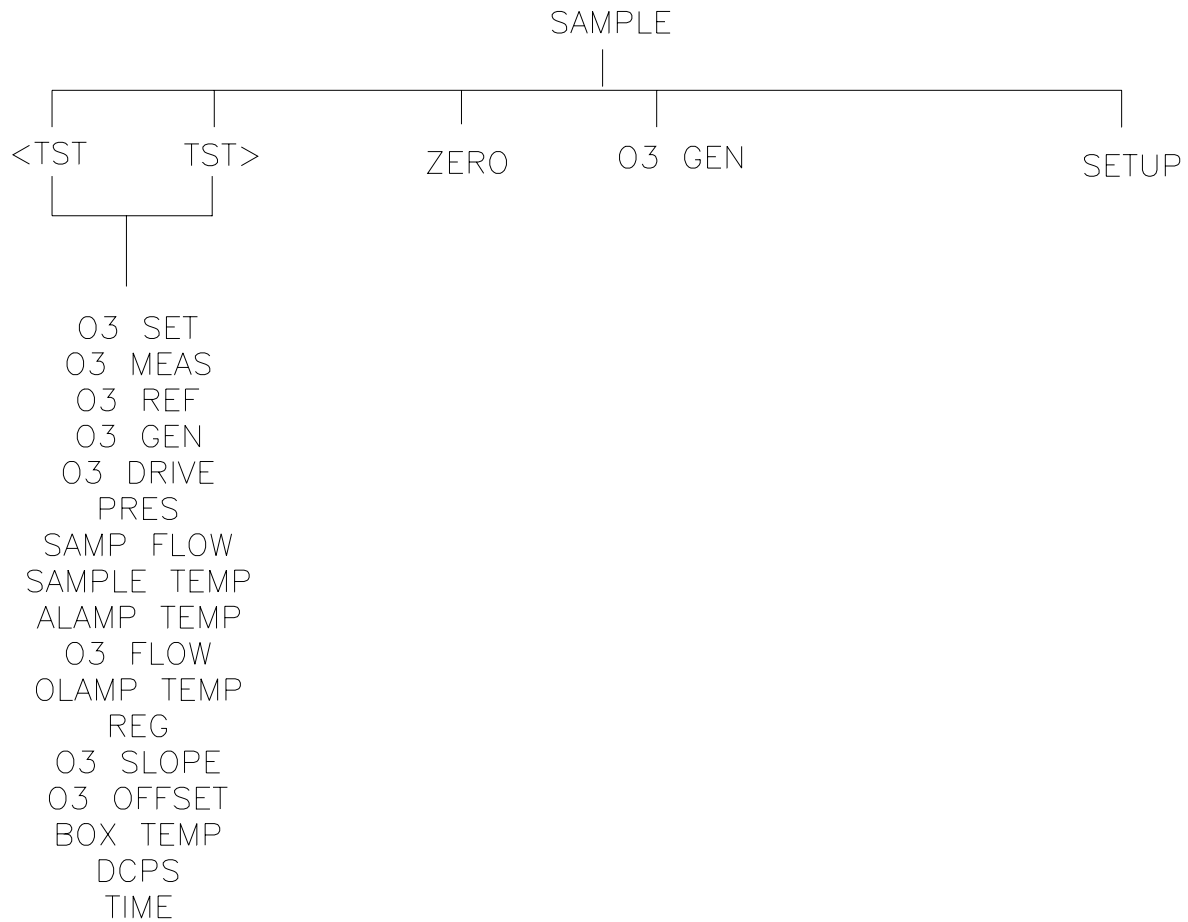
## Appendix C REFERENCES

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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.
12. Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, (abbreviated Q.A. Handbook Volume II). Available through USEPA Center for Environmental Research Information. Phone (513) 569-7562 EPA 600/4/77/027A.

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## Appendix D SOFTWARE MENU TREES

### API M401 SAMPLE MENU



**Figure A-1: Model 401 Sample Software Menu Tree**

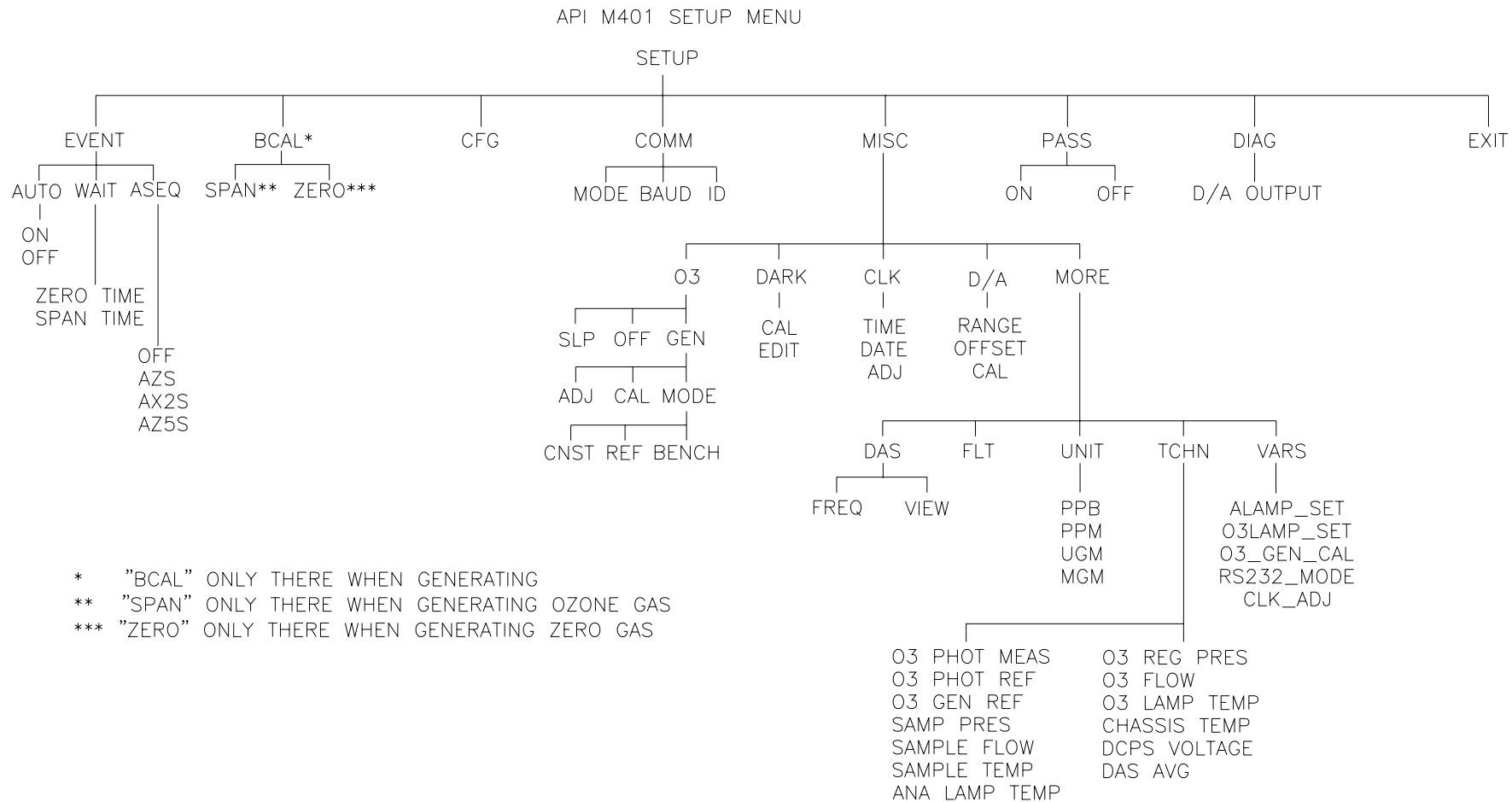


Figure A-2: Model 401 Setup Software Menu Tree



## Appendix E ELECTRICAL SCHEMATIC INDEX

**Table E-1: Electrical Schematic Index**

<b>Part No.</b>	<b>Name</b>
00015	Power Supply Board Assembly
00016	Power Supply Board Diagram
00402	Pneumatic Sensor Assembly
00403	Pneumatic Sensor Diagram
00514	V/F - I/O Card Assembly
00515	V/F - I/O Card Diagram
00517	Mother Board Assembly
00518	Mother Board Diagram
0053203	Power Supply PCA Assembly
0053303	Power Supply PCA Diagram
00535	UV Detector Assembly
00536	UV Detector Diagram
00704	Keyboard Assembly
00705	Keyboard Diagram
01217	UV Lamp Power Supply PCA
01218	UV Lamp Power Supply Diagram
01916	Rear Panel PCA Assembly
01917	Rear Panel PCA Diagram
02235	Transformer PTC Assembly
02236	Transformer PTC Diagram

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