

INSTRUCTION MANUAL

MODEL 9110AH
NITROGEN OXIDES ANALYZER

SERIAL NO. _____

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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.



Electrical Ground: This symbol inside the instrument marks the central safety grounding point for the instrument.

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.



TABLE OF CONTENTS

SAFETY MESSAGES	II
TABLE OF CONTENTS.....	III
LIST OF FIGURES	VII
LIST OF TABLES	VIII
1 HOW TO USE THIS MANUAL	1-1
2 GETTING STARTED.....	2-1
2.1 UNPACKING	2-1
2.2 ELECTRICAL AND PNEUMATIC CONNECTIONS	2-1
2.3 INITIAL OPERATION.....	2-6
3 SPECIFICATIONS, WARRANTY.....	3-1
3.1 SPECIFICATIONS.....	3-1
3.2 WARRANTY.....	3-2
4 THE M9110AH NO_x ANALYZER	4-1
4.1 PRINCIPLE OF OPERATION.....	4-1
4.2 OPERATION SUMMARY	4-4
4.2.1 Sensor Module, Reaction Cell, Detector	4-4
4.2.2 Pneumatic Sensor Board.....	4-4
4.2.3 Computer Hardware and Software	4-5
4.2.4 V/F Board.....	4-5
4.2.5 Front Panel	4-5
4.2.6 Power Supply Module.....	4-7
4.2.7 Pump, Valves, Pneumatic System.....	4-7
4.2.8 Ozone Generator	4-10
4.2.9 NO ₂ - NO Converter	4-10
5 SOFTWARE FEATURES.....	5-1
5.1 INDEX TO FRONT PANEL MENUS	5-1
5.1.1 Sample Menu.....	5-4
5.1.2 Set-Up Menu	5-5
5.2 SAMPLE MODE.....	5-9
5.2.1 Test Functions.....	5-9
5.2.2 CAL, CALS, CALZ, Calibration Functions	5-13

5.3 SET-UP MODE	5-15
5.3.1 Configuration Information (CFG)	5-15
5.3.2 Automatic Calibration (AutoCal)	5-15
5.3.3 Data Acquisition System (DAS)	5-16
5.3.4 Range Menu	5-18
5.3.5 Password Enable	5-21
5.3.6 Time of Day Clock.....	5-21
5.3.7 Diagnostic Mode	5-21
5.3.8 Communications Menu	5-21
5.3.9 Variables Menu (VARS)	5-22
5.4 M9110AH OPERATING MODES.....	5-22
5.4.1 NO/NO _x /NO ₂ Switching Mode	5-23
5.4.2 NO _x Only Mode.....	5-24
5.4.3 NO Only Mode.....	5-24
5.5 4-20 MA CURRENT LOOP.....	5-24
5.6 STATUS OUTPUT	5-25
5.7 RS-232 INTERFACE	5-25
5.7.1 Setting up the RS-232 Interface.....	5-26
5.7.2 Command Summary.....	5-29
5.7.3 TEST Commands and Messages.....	5-33
5.7.4 WARNING Commands and Messages.....	5-34
5.7.5 CALIBRATION Commands and Messages	5-35
5.7.6 DIAGNOSTIC Commands and Messages.....	5-36
5.7.7 DAS Commands and Messages.....	5-37
5.7.8 VARIABLES Commands and Messages.....	5-39
6 OPTIONAL HARDWARE AND SOFTWARE.....	6-1
6.1 RACK MOUNT OPTIONS	6-1
6.2 ZERO/SPAN VALVES OPTION.....	6-2
6.2.1 Autocal - Setup Zero/Span Valves	6-2
6.3 ISOLATED 4-20 MA CURRENT LOOP OPTION.....	6-4
6.4 MOLYBDENUM CONVERTER OPTION	6-5
6.5 EXTERNAL DESICCANT CANISTER OPTION	6-5
6.6 ALTERNATE BYPASS FLOW ORIFICE OPTION.....	6-5
6.7 EXTERNAL CONVERTER OPTION	6-5
7 CALIBRATION AND ZERO/SPAN CHECKS.....	7-1
7.1 MANUAL ZERO/SPAN CHECK OR CAL WITH ZERO/SPAN GAS IN THE SAMPLE PORT	7-3
7.2 MANUAL ZERO/SPAN CHECK WITH ZERO/SPAN VALVES OPTION	7-6
7.3 DYNAMIC ZERO/SPAN CALIBRATION USING AUTO CAL	7-7
7.4 USE OF ZERO/SPAN VALVES WITH REMOTE CONTACT CLOSURE.....	7-8
7.5 NO ONLY MODE CALIBRATION	7-9
7.6 NO _x ONLY MODE CALIBRATION	7-9

7.7 CALIBRATION REQUIREMENTS FOR AUTORANGE OR REMOTE RANGE.....	7-9
7.8 CALIBRATION REQUIREMENTS FOR INDEPENDENT RANGE.....	7-10
7.9 CALIBRATION QUALITY.....	7-10
7.10 CONVERTER EFFICIENCY COMPENSATION.....	7-11
7.11 RECOMMENDATIONS FOR CEM APPLICATIONS.....	7-12
7.11.1 Calibration Gasses.....	7-12
7.11.2 Calibration Frequency.....	7-13
7.11.3 Converter Efficiency.....	7-13
8 MAINTENANCE.....	8-1
8.1 MAINTENANCE SCHEDULE.....	8-1
8.2 REPLACING THE SAMPLE PARTICULATE FILTER.....	8-2
8.3 REPLACING THE CONVERTER.....	8-4
8.4 CLEANING THE REACTION CELL.....	8-6
8.5 PNEUMATIC LINE INSPECTION.....	8-10
8.6 LEAK CHECK PROCEDURE.....	8-13
8.7 LIGHT LEAK CHECK PROCEDURE.....	8-13
8.8 PROM REPLACEMENT PROCEDURE.....	8-14
9 TROUBLESHOOTING AND ADJUSTMENTS.....	9-1
9.1 OPERATION VERIFICATION - DIAGNOSTIC TECHNIQUES.....	9-3
9.1.1 Fault Diagnosis with TEST Variables.....	9-3
9.1.2 Fault Diagnosis with WARNING Messages.....	9-8
9.1.3 Fault Diagnosis using DIAGNOSTIC Mode.....	9-10
9.1.4 M9110AH Internal Variables.....	9-17
9.1.5 Test Channel Analog Output.....	9-19
9.1.6 Factory Calibration Procedure.....	9-20
9.2 PERFORMANCE PROBLEMS.....	9-24
9.2.1 AC Power Check.....	9-24
9.2.2 Flow Check.....	9-25
9.2.3 No Response to Sample Gas.....	9-25
9.2.4 Negative Output.....	9-26
9.2.5 Excessive Noise.....	9-26
9.2.6 Unstable Span.....	9-27
9.2.7 Unstable Zero.....	9-28
9.2.8 Inability to Span.....	9-28
9.2.9 Inability to Zero.....	9-28
9.2.10 Non-Linear Response.....	9-29
9.2.11 Slow Response.....	9-30
9.2.12 Analog Output Doesn't Agree With Display Concentration.....	9-30
9.3 SUBSYSTEM TROUBLESHOOTING AND ADJUSTMENTS.....	9-31
9.3.1 Computer, Display, Keyboard.....	9-31
9.3.2 RS-232 Communications.....	9-34

9.3.3 Voltage/Frequency (V/F) Board	9-37
9.3.4 Status/Temp Board	9-43
9.3.5 Power Supply Module.....	9-45
9.3.6 Ozone Generator	9-49
9.3.7 Flow/Pressure Sensor	9-53
9.3.8 NO _x Sensor Module	9-58
9.3.9 Z/S Valves	9-63
9.3.10 Pneumatic System	9-64
10 M9110AH SPARE PARTS LIST	10-1
APPENDIX A ELECTRICAL SCHEMATICS	A-1

LIST OF FIGURES

FIGURE 2-1: REMOVAL OF SHIPPING SCREWS & CHECK FOR CORRECT POWER	2-3
FIGURE 2-2: REAR PANEL.....	2-4
FIGURE 2-3: INLET AND EXHAUST VENTING RECOMMENDATIONS	2-5
FIGURE 2-4: FRONT PANEL.....	2-10
FIGURE 2-5: ASSEMBLY LAYOUT.....	2-12
FIGURE 4-1: BLOCK DIAGRAM	4-3
FIGURE 4-2: EXTERNAL PUMP PACK.....	4-9
FIGURE 5-1: SAMPLE MENU TREE	5-2
FIGURE 5-2: SETUP MENU TREE	5-3
FIGURE 8-1: REPLACING THE PARTICULATE FILTER	8-3
FIGURE 8-2: CONVERTER ASSEMBLY.....	8-5
FIGURE 8-3: REACTION CELL ASSEMBLY	8-8
FIGURE 8-4: SAMPLE/BYPASS FLOW CONTROL ASSEMBLY	8-9
FIGURE 8-5: PNEUMATIC DIAGRAM.....	8-11
FIGURE 8-6: PNEUMATIC DIAGRAM WITH ZERO/SPAN VALVES	8-12
FIGURE 9-1: SPAN CALIBRATION VOLTAGE.....	9-23
FIGURE 9-2: CPU BOARD JUMPER SETTINGS	9-33
FIGURE 9-3: RS-232 PIN ASSIGNMENTS.....	9-35
FIGURE 9-4: V/F BOARD JUMPER SETTINGS.....	9-42
FIGURE 9-5: POWER SUPPLY MODULE LAYOUT	9-47
FIGURE 9-6: ELECTRICAL BLOCK DIAGRAM	9-48
FIGURE 9-7: OZONE GENERATOR SUBSYSTEM.....	9-52
FIGURE 9-8: FLOW/PRESSURE SENSOR	9-55
FIGURE 9-9: NO _x SENSOR MODULE	9-56
FIGURE 9-10: NO _x SENSOR MODULE	9-57
FIGURE 9-11: PMT COOLER SUBSYSTEM	9-60
FIGURE 9-12: HIGH VOLTAGE POWER SUPPLY	9-62

LIST OF TABLES

TABLE 2-1: FINAL TEST AND CALIBRATION VALUES.....	2-13
TABLE 2-1: FINAL TEST AND CALIBRATION VALUES (CONTINUED).....	2-14
TABLE 4-1: SAMPLING MODES OF THE M9110AH	4-1
TABLE 4-2: FRONT PANEL STATUS LED'S	4-6
TABLE 4-3: OZONE GENERATOR START-UP TIMING	4-10
TABLE 5-1: M9110AH SAMPLE MENU STRUCTURE	5-4
TABLE 5-2: M9110AH SETUP MENU	5-5
TABLE 5-2: M9110AH SETUP MENU (CONTINUED)	5-6
TABLE 5-3: M9110AH SETUP MENU	5-7
TABLE 5-4: M9110AH SETUP MENU	5-8
TABLE 5-5: DAS DATA CHANNEL EDITING	5-17
TABLE 5-6: CALIBRATE, SETUP PASSWORDS	5-21
TABLE 5-7: M9110AH OPERATING MODES.....	5-23
TABLE 5-8: STATUS OUTPUT PIN ASSIGNMENTS	5-25
TABLE 5-9: RS-232 PORT SETUP - FRONT PANEL.....	5-26
TABLE 5-10: RS-232 SWITCHING FROM TERMINAL MODE TO COMPUTER MODE	5-28
TABLE 5-11: RS-232 TERMINAL MODE EDITING KEYS.....	5-28
TABLE 5-12: RS-232 COMMAND SUMMARY	5-30
TABLE 5-13: RS-232 COMMAND SUMMARY	5-31
TABLE 5-14: RS-232 INTERFACE COMMAND TYPES.....	5-32
TABLE 5-15: RS-232 TEST MESSAGES.....	5-33
TABLE 5-16: RS-232 WARNING MESSAGES.....	5-34
TABLE 5-17: RS-232 CALIBRATION MESSAGES.....	5-35
TABLE 5-18: RS-232 CALIBRATION COMMANDS.....	5-36
TABLE 5-19: RS-232 DIAGNOSTIC COMMAND SUMMARY	5-37
TABLE 6-1: ZERO/SPAN VALVE OPERATION	6-2
TABLE 6-2: SETUP AUTOMATIC ZERO/SPAN CHECKING OR CALIBRATION	6-3
TABLE 6-3: ACTION OF MODE FIELD IN AUTO CAL.....	6-4
TABLE 7-1: TYPES OF ZERO/SPAN CHECK AND CALIBRATION.....	7-2
TABLE 7-2: MANUAL ZERO CALIBRATION PROCEDURE - ZERO GAS THRU SAMPLE PORT	7-3
TABLE 7-3: ENTER EXPECTED SPAN GAS CONCENTRATIONS PROCEDURE	7-4
TABLE 7-4: MANUAL SPAN CALIBRATION PROCEDURE - SPAN GAS THRU SAMPLE PORT.....	7-5
TABLE 7-5: MANUAL ZERO CHECK PROCEDURE - Z/S VALVES.....	7-6
TABLE 7-6: MANUAL SPAN CHECK PROCEDURE - Z/S VALVES.....	7-7
TABLE 7-7: Z/S VALVE MODES WITH REMOTE CONTACT CLOSURE	7-8
TABLE 7-8: CALIBRATION REQUIREMENTS FOR AUTORANGE OR REMOTE RANGE.....	7-10
TABLE 7-9: CALIBRATION QUALITY CHECK	7-11
TABLE 7-10: CONVERTER EFFICIENCY - AUTOMATIC CALCULATION	7-12
TABLE 8-1: PREVENTATIVE MAINTENANCE SCHEDULE.....	8-1

TABLE 9-1: TEST FUNCTIONS	9-4
TABLE 9-1: TEST FUNCTIONS (CONTINUED)	9-5
TABLE 9-1: TEST FUNCTIONS (CONTINUED)	9-6
TABLE 9-1: TEST FUNCTIONS (CONTINUED)	9-7
TABLE 9-2: FRONT PANEL WARNING MESSAGES	9-9
TABLE 9-2: FRONT PANEL WARNING MESSAGES (CONTINUED)	9-10
TABLE 9-3: SUMMARY OF DIAGNOSTIC MODES	9-11
TABLE 9-4: DIAGNOSTIC MODE - SIGNAL I/O	9-12
TABLE 9-4: DIAGNOSTIC MODE - SIGNAL I/O (CONTINUED).....	9-13
TABLE 9-4: DIAGNOSTIC MODE - SIGNAL I/O (CONTINUED).....	9-14
TABLE 9-4: DIAGNOSTIC MODE - SIGNAL I/O (CONTINUED).....	9-15
TABLE 9-5: MODEL 9110AH VARIABLES.....	9-18
TABLE 9-6: TEST CHANNEL READINGS.....	9-19
TABLE 9-6: TEST CHANNEL READINGS (CONTINUED).....	9-20
TABLE 9-7: MOTHERBOARD JUMPER SETTINGS	9-39
TABLE 9-1: V/F BOARD SWITCH SETTINGS	9-39
TABLE 9-8: POWER SUPPLY MODULE SUBASSEMBLIES	9-46
TABLE 9-9: POWER SUPPLY MODULE LED OPERATION.....	9-49
TABLE 9-10: OZONE GENERATOR CONTROL CONDITIONS.....	9-50
TABLE 10-1: TELEDYNE M9110AH SPARE PARTS LIST.....	10-1
TABLE 10-1: TELEDYNE M9110AH SPARE PARTS LIST (CONTINUED).....	10-2
TABLE 10-1: TELEDYNE M9110AH SPARE PARTS LIST (CONTINUED).....	10-3
TABLE 10-2: TELEDYNE MODEL 9110AH EXPENDABLES KIT	10-4
TABLE 10-3: TELEDYNE MODEL 9110AH LEVEL 1 SPARES KIT WITH MINI-HICON CONVERTER	10-5
TABLE 10-4: TELEDYNE MODEL 9110AH LEVEL 1 SPARES KIT WITH MOLYBDENUM CONVERTER.....	10-6
TABLE A-1: ELECTRICAL SCHEMATICS	A-1

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1 HOW TO USE THIS MANUAL

The Model 9110AH has been designed to produce accurate data, be serviceable, reliable and easy to use. The M9110AH's microprocessor continually checks operating parameters such as temperature, flow, and critical voltages. The instruments design uses top mounted, modular components with captive screws to facilitate repair and ease of access. If you encounter any difficulty refer to the Troubleshooting Section 9 - General Hints.

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

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

Table of Contents:

Outlines the contents of the manual in the order the information is presented. This is a good overview of the topics covered in the manual. There is also a list of Tables and a list of Figures.

Index to M9110AH Front Panel Menus:

The Menu Index briefly describes the front panel menus and refers you to other sections of the manual that have a detailed explanation of each menu selection.

Troubleshooting Section 9:

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

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

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2 GETTING STARTED

2.1 Unpacking

CAUTION

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.

To avoid personal injury, always use two persons to lift and carry the Model 9110AH.



1. Before operation it is necessary to remove the shipping hold-down screws. Remove the instrument cover, then remove 2 screws as shown in Figure 2-1.
2. Also check for internal shipping damage, and generally inspect the interior of the instrument to make sure all circuit boards and other components are in good shape.
3. Please check the voltage and frequency label on the serial number tag on the rear panel. Compare that to your local power before plugging in the Instrument.

2.2 Electrical and Pneumatic Connections

1. Refer to Figure 2-2 to locate the rear panel electrical and pneumatic connections.
2. Attach the pump to the “Exhaust Out” port on the instrument rear panel. The exhaust from the pump should also be vented to atmospheric pressure.
3. Attach the sample inlet line to the sample inlet port. For initial testing, sample gas can be calibration gas or stack gas. The pressure of the sample gas at the inlet port should be at ambient pressure and constant. See Figure 2-3.
4. If desired, attach the analog output connections to a strip chart recorder and/or datalogger. Refer to Figure 9-4 - Analog Output Voltage Ranges - for switch settings. Factory default setting is 0-5 VDC.
5. Connect the power cord to the correct voltage line, then turn to Section 2.3 Initial Operation.

WARNING

**Analyzer Exhaust – O₃ Scrubber – Pump Pack
Danger – Analyzer exhaust contains ozone.**

**Ozone scrubber must always be present between
analyzer exhaust and pump.**

**Vent pump exhaust to well ventilated area at atmosphere
pressure FIRE or EXPLOSION HAZARD.**



WARNING

Lethal voltages present inside case.

Do not operate with cover off during normal operation.

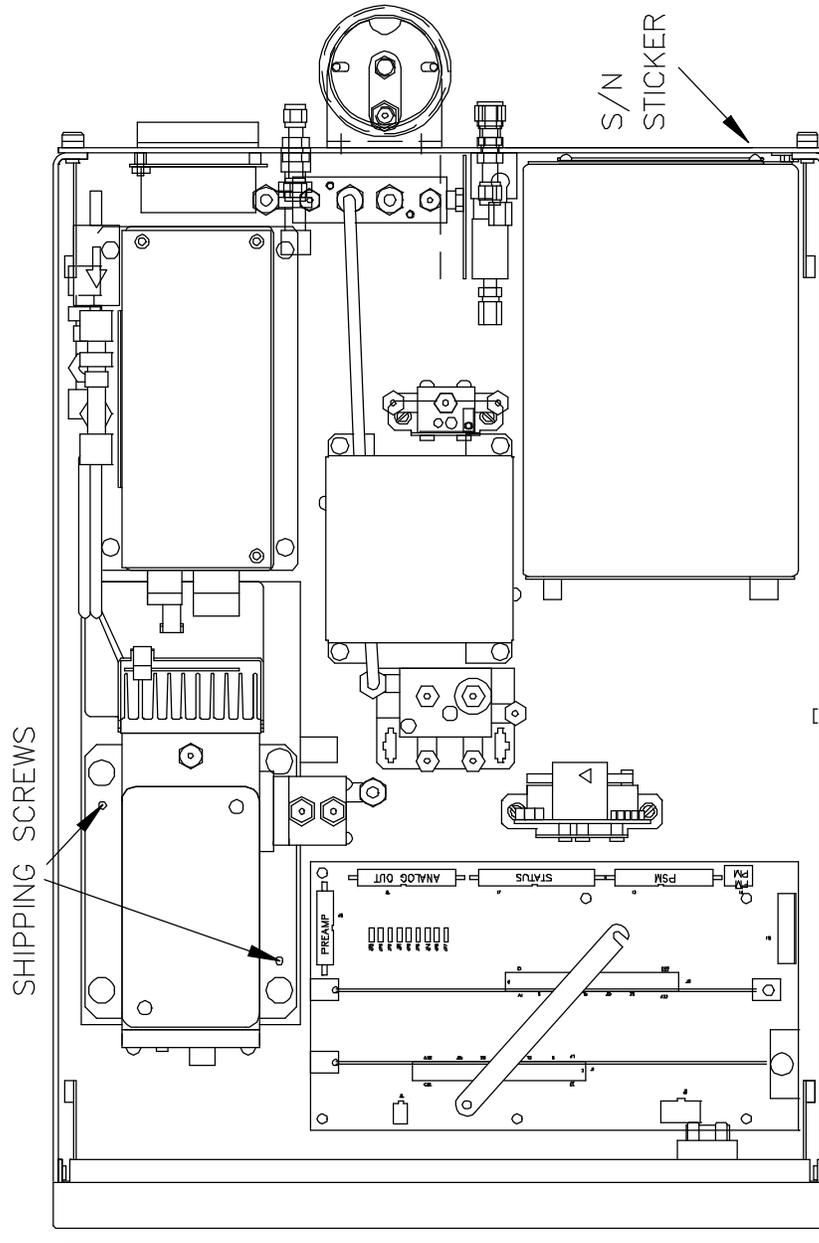
**Before operation check for correct
input voltage and frequency.**

Do not operate without proper chassis grounding.

Do not defeat the ground wire on power plug.

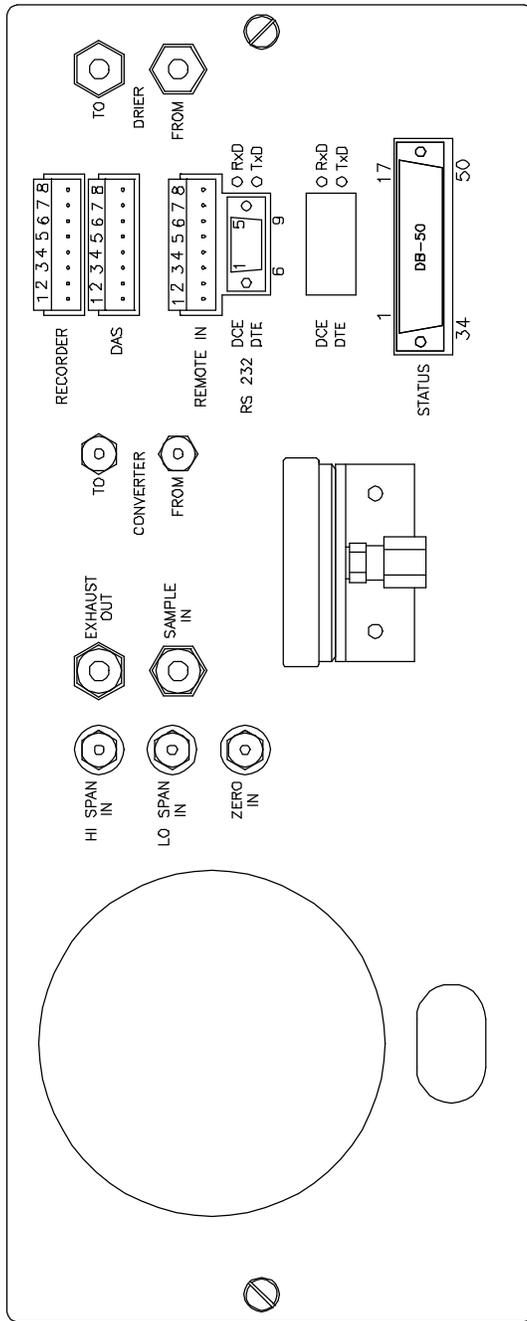
**Turn off analyzer power before disconnecting
electrical subassemblies.**





1. CHECK FOR INPUT POWER ON REAR PANEL TAG AND S/N STICKER
2. REMOVE SHIPPING SCREWS FOR NORMAL OPERATION
3. RE-INSTALL SHIPPING SCREWS IF INSTRUMENT IS TO BE TRANSPORTED OR RETURNED TO FACTORY

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



RECORDER AND DAS
PIN ASSIGNMENTS

PIN NO.	ASSIGNMENT
1	+ NO ₂ CONC
2	- NO ₂ CONC
3	+ NO _x CONC
4	- NO _x CONC
5	+ NO CONC
6	- NO CONC
7	+ TCHN
8	- TCHN

REMOTE IN
PIN ASSIGNMENTS

PIN NO.	ASSIGNMENT
1	+ REM ZERO CAL
2	- REM ZERO CAL
3	+ REM SPAN HI
4	- REM SPAN HI
5	+ REM SPAN LO
6	- REM SPAN LO
7	+ REM RANGE CTRL
8	- REM RANGE CTRL

RS-232 PORT
PIN ASSIGNMENTS

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

Figure 2-2: Rear Panel

NOTES:

1. SAMPLE INLET LINE 3 METERS MAXIMUM LENGTH
2. TUBING MATERIAL 1/4"PTFE
3. OTHER WETTED MATERIALS SHOULD BE PTFE, GLASS, STAINLESS ONLY
4. MUST BE EXCESS FLOW IN SAMPLE MANIFOLD
5. SAMPLE, CAL GAS, OR ZERO GAS INLET LINES AT ATMOSPHERIC PRESSURE.

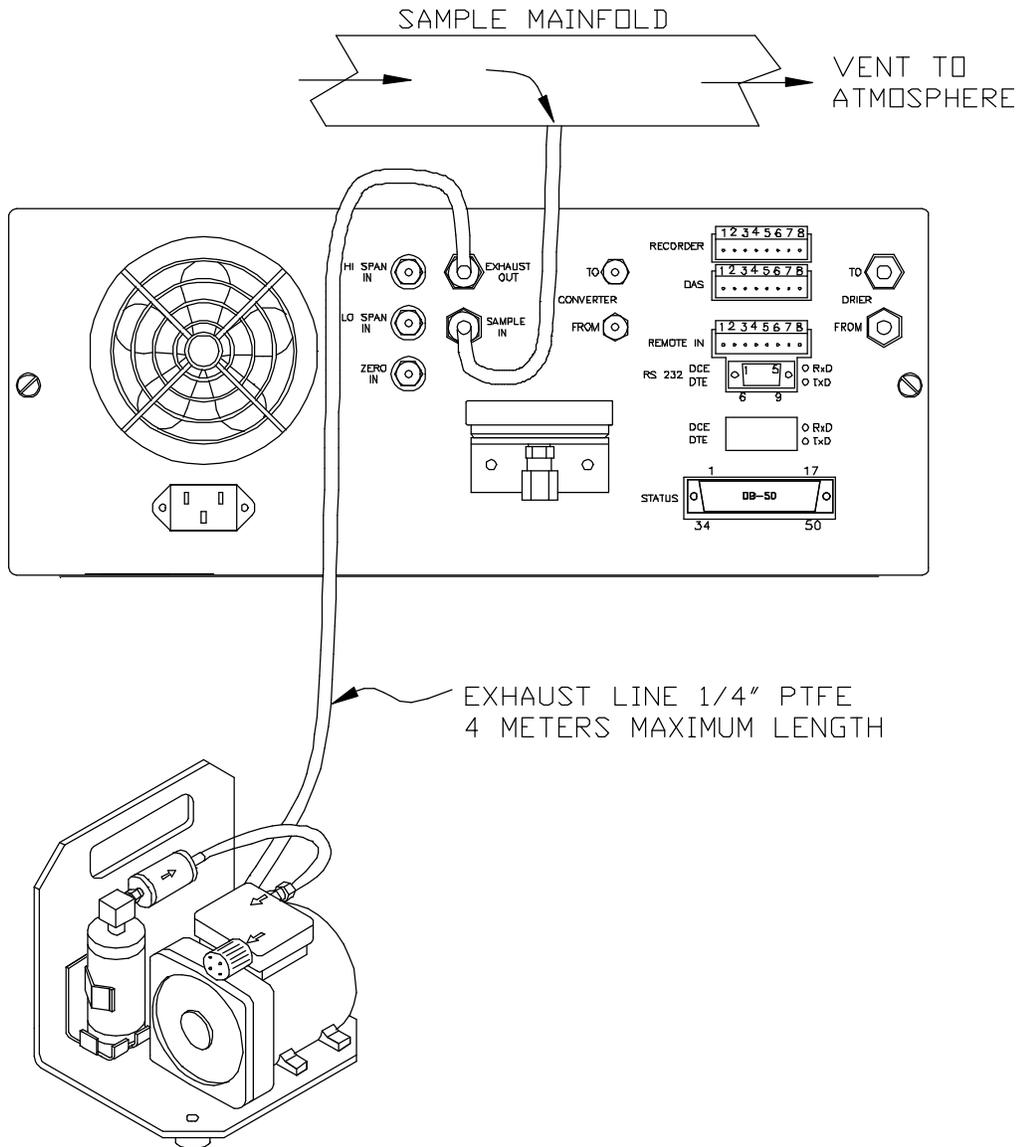


Figure 2-3: Inlet and Exhaust Venting Recommendations

2.3 Initial Operation

1. Turn on the instrument power.
2. The display should immediately light, showing the computer's memory configuration, then the instrument type - M9110AH. If you are unfamiliar with the M9110AH, we recommend that you read the overview Section 4 before proceeding. A diagram of the software menu trees is in Figure 5-1 and Figure 5-2.
3. The M9110AH requires about 30 minutes for all internal components to come to temperature. During this time the ozone generator power is OFF until the membrane dryer has time to purge itself, therefore there will be no response from the instrument, even if span gas is coming in the sample port. Many warning conditions are not displayed during this time, even though temperatures and other conditions are out of specification. All warning messages are enabled after 30 minutes of operation.
4. While waiting for instrument temperatures to stabilize, you can check for correct operation by using some of the M9110AH's diagnostic and test features.
5. Examine the TEST functions by comparing the values listed in Table 2-1 to those in the display. Remember that as the instrument warms up the values may not have reached their final values yet. If you would like to know more about the meaning and utility of each TEST function refer to Table 9-1. Also, now is a good time to verify that the instrument was shipped with the options you ordered. Table 2-1 also contains the list of options. Section 6 covers setting up the options.
6. Electric Test and Optic Test both generate simulated signals in the M9110AH.
 - A. Electric Test checks the electronics of the PMT signal path. To operate Electric Test from the front panel:
 - 1) Scroll the TEST function to PMT.
 - 2) Press SETUP-MORE-DIAG, then press ENTR to accept the default password. Scroll to Electric Test and press ENTR to turn it on. Instrument responses should come to the values indicated in Table 2-1. To turn off this test press EXIT. For more information on the circuitry being tested refer to the Troubleshooting Section 9.1.3.2.
 - B. Optic Test is an "end to end" test of the analyzer HVPS-PMT-detector-electronics-computer. It simulates a signal by turning on a LED in the Sensor Module. To operate Optic Test from the front panel:
 - 1) Scroll the TEST function to PMT.
 - 2) Press SETUP-MORE-DIAG, then press ENTR to accept the default password. Scroll to Optic Test and press ENTR to turn on optic test. Instrument response should come up to the values indicated in Table 2-1. To turn off this test press EXIT. To return to the SAMPLE mode press EXIT until SAMPLE is displayed in the upper left display. For more information about OT operation see Section 9.1.3.3.

7. When the instrument is warmed up, re-check the TEST functions against Table 2-1. All of the readings should compare closely with those in the table. If they do not see Section 9.1.1. The next task is to calibrate the analyzer. There are several ways to do a calibration, they are summarized in Table 7-1. For a preliminary checkout we recommend calibration with span gas coming in through the sample port. The procedure is:

Step 1 - Set the range, then enter the expected NO_x and NO span gas concentrations:

Step Nu mber	Action	Comment
1.	Press CAL-CONC-NOX	This key sequence causes the M9110AH to prompt for the expected span concentration. Enter the span value by pressing the key under each digit until the expected value is set.
2.	Press ENTR	ENTR stores the expected NO _x span value. The internal formulas are adjusted to compute this number when span gas concentration is input into the instrument.
3.	Press CAL-CONC-NO	In the same CAL-CONC sub menu press the NO button and enter the expected NO span value. As before this value will be used in the internal formulas to compute the NO concentration value.
4.	Press ENTR	ENTR stores the expected NO span value. The internal formulas are adjusted to compute this number when span gas concentration is input into the instrument.
5.	Press EXIT	Returns instrument to SAMPLE mode.
6.	Press SETUP-RNGE-MODE-SNGL	If necessary, you may want to change ranges. Normally the instrument is shipped in single range mode set at 100 ppm. We recommend doing the initial checkout on the 100 ppm range.
7.	Press SETUP-RNGE-SET	After SETUP-RNGE-SET, enter 100 and press ENTR. The instrument will now be in the 100 ppm range.

Step 2 - Calibrate the instrument:

Zero/Span Calibration Procedure

Step Number	Action	Comment
1.	Input Zero gas	Allow Zero gas to enter the sample port on the rear of the instrument.
2.	Press CAL	The M9110AH enters the calibrate mode from sample mode.
3.	Wait 10 min	Wait for reading to stabilize at the zero value. If you wait less than 10 minutes the final zero value may drift.
4.	Press ZERO	The ZERO button will be displayed.
5.	Press ENTR	Pressing ENTR actually changes the equations and zeros the instrument.
6.	Press EXIT, input Span gas	M9110AH returns to the CAL menu. Now switch gas streams to span gas.
7.	Wait 10 min	Wait for reading to stabilize at the span value.
8.	Press SPAN	The SPAN button should be displayed. If there is no SPAN button check the Troubleshooting Section 9.2.8 for instructions on how to proceed. In certain circumstances at low span gas concentrations both the ZERO and SPAN buttons will appear.
9.	Press ENTR	Pressing ENTR actually changes the equations so that the concentration displayed is the same as the expected span concentration you entered above, thus spanning the instrument.
10.	Press EXIT	Pressing EXIT returns the instrument to SAMPLE mode.

Step 3 - Review Quality of calibration:

Calibration Quality Check Procedure

Step Number	Action	Comment
1.	Scroll the TEST function menu until the NO _x SLOPE is displayed.	The SLOPE value for NO _x should be 1.0 ± 0.3. If the value is not in this range, check Section 7.1 or 9. If the SLOPE value is in the acceptable range the instrument will perform optimally.
2.	Scroll the TEST function menu until the NO SLOPE is displayed.	The SLOPE value for NO should be 1.0 ± 0.3. If the value is not in this range, check Section 7.1 or 9. If the SLOPE is in the acceptable range the instrument will perform optimally. NOTE: The NO and NO _x slopes should be equal within ± 0.3.
4.	Scroll the TEST function menu until the NO _x OFFS is displayed.	The M9110AH will display the OFFSET parameter for the NO _x equation. This number should be near zero. A value of 0.0 ± 50 indicates calibration in the optimal range. If the OFFSET value is outside this range, check Section 7.1 or 9.1 for procedures to correct the OFFSET value to near zero.
5.	Scroll the TEST function menu until the NO OFFS is displayed.	The Instrument will now display the NO OFFSET value. It should also have a value near zero (0.0 ± 50).

Step 4 - The M9110AH is now ready to measure sample gas.

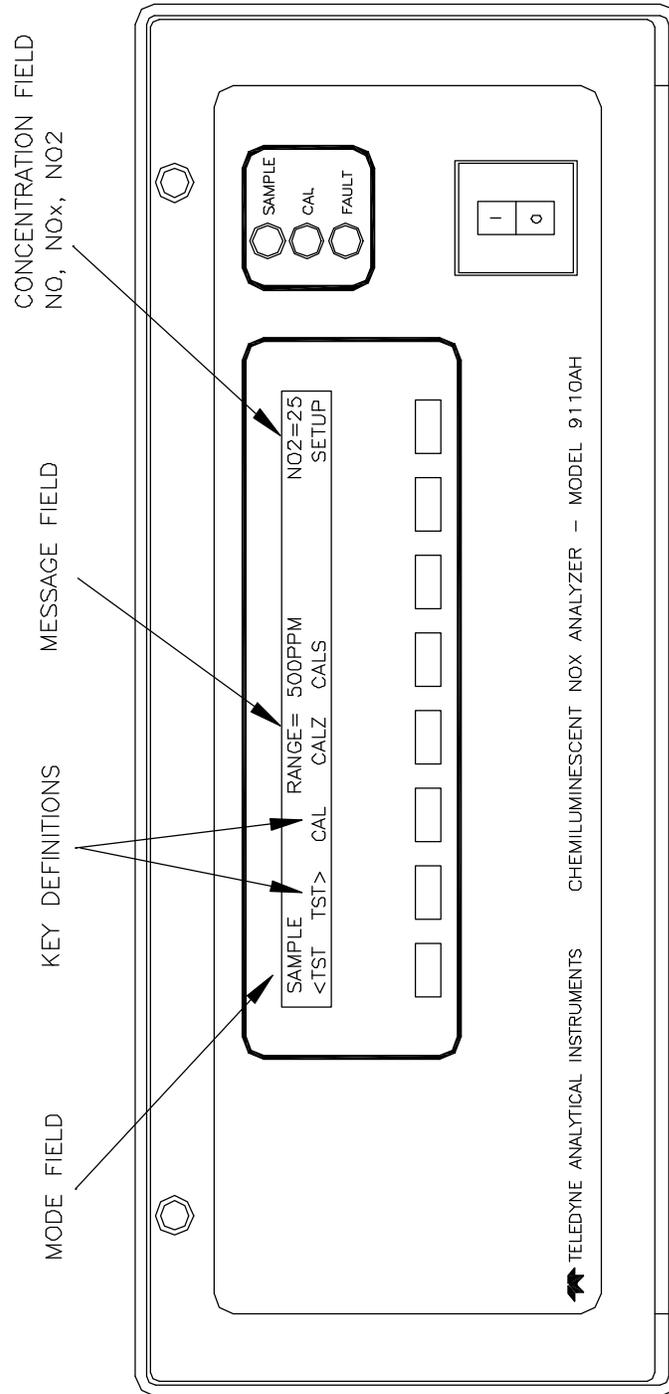


Figure 2-4: Front Panel

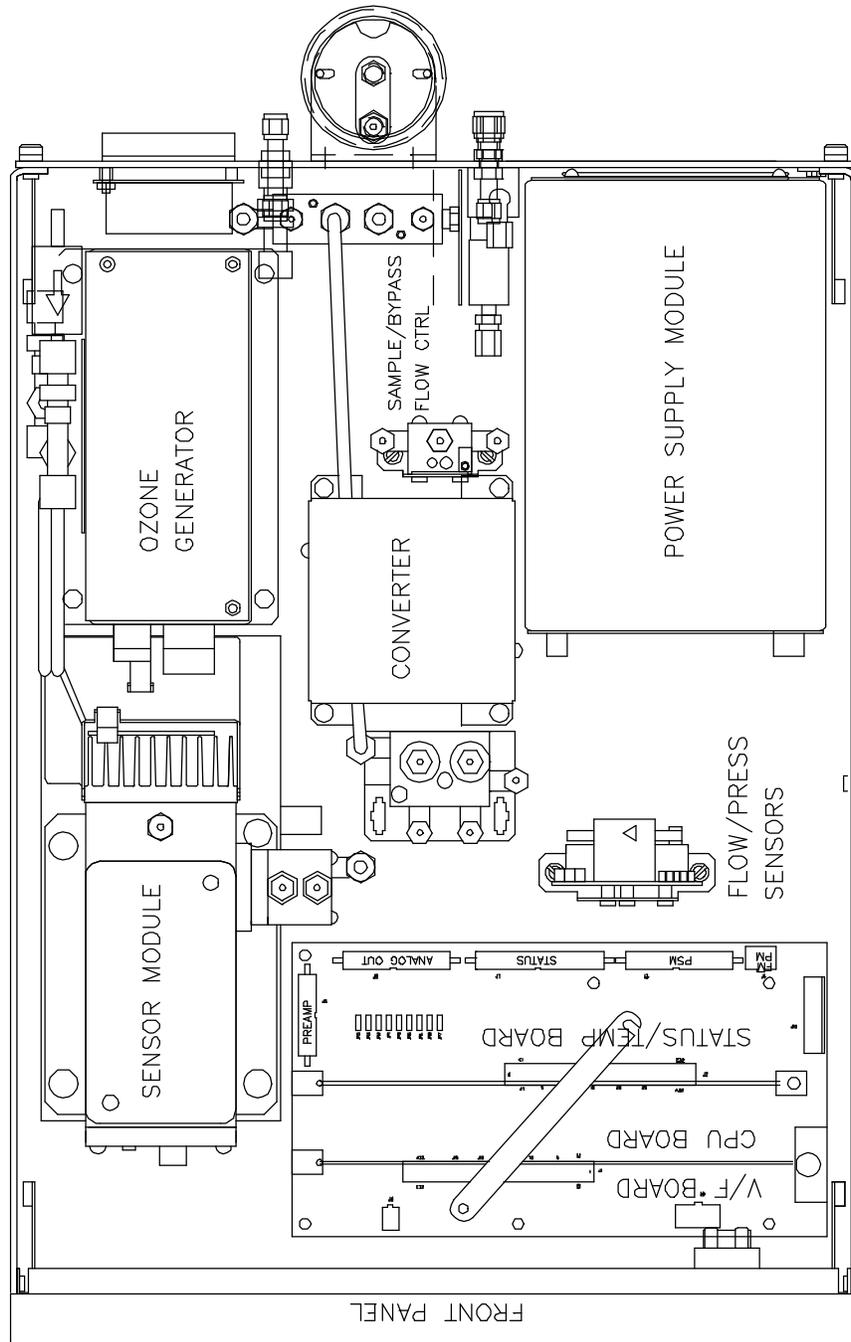


Figure 2-5: Assembly Layout

Table 2-1: Final Test and Calibration Values

TEST Values	Observed Value	Units	Nominal Range	Reference Section
RANGE		ppm	5-5000	5.3.4
NOISE		ppm	0.0 - 0.2	9.1.1, Table 9-1, 9.2.5
SAMP FLW		cc/min	300 50 (Default) 550 50 (Optional)	9.3.7, Table 9-1
OZONE FL		cc/min	250 15	9.3.6
PMT		mV	0-5000	9.3.8
AUTOZERO		mV	-10 to +50	4.1
HVPS		V	400 - 700 constant	9.3.8.5
DCPS		mV	2500 200	9.3.5
RCELL TEMP		°C	50 2	9.3.8.2
BLOCK TEMP		°C	50 2	9.3.4.1
BOX TEMP		°C	8-48	9.3.4.1
PMT TEMP		°C	7 1	9.3.8.4
CONV TEMP		°C	700 10 (Std) 315 5 (Moly)	9.3.4.1
RCEL PRES		IN-Hg-A	2 - 10 constant	9.3.7
SAMP PRES		IN-Hg-A	25 - 30 constant	9.3.7
Electric Test & Optic Test				
Electric Test				
PMT Volts		mV	2000 200	9.1.3.2
NO Conc		ppm	250 25	9.1.3.2
NO _x Conc		ppm	250 25	9.1.3.2
OPTIC TEST				
PMT Volts		mV	100 20	9.1.3.3
NO Conc		ppm	12.5 2	9.1.3.3
NO _x Conc		ppm	12.5 2	9.1.3.3

(table continued)

Table 2-1: Final Test and Calibration Values (Continued)

Parameter	Observed Value	Units	Nominal Range	Reference Section
NO Span Conc		ppm	0.5 - 5000	Table 7-3
NO _x Span Conc		ppm	0.5 - 5000	Table 7-3
NO Slope		-	1.0 - 0.3	7.1, 7.9
NO _x Slope		-	1.0 - 0.3	7.1
NO Offset		mV	25	7.1, 7.2
NO _x Offset		mV	25	7.1, 7.2
Conv Efficiency		%	0.75 - 1.10	7.10, 5.2.2.6
Noise at Zero		ppm	0.0 - 0.2	Table 9-1
Noise At Span		ppm	0.1 - 0.5	Table 9-1
Measured Flows				
Sample Flow		cc/min	50 - 20	9.3.7, Figure 9-8
Bypass Flow		cc/min	250 (Std) 500 (Optional)	Figure 8-4
Ozone Flow		cc/min	250 - 15	9.3.7, Figure 9-8
Factory Installed Options			Option Installed	
Power Voltage/Frequency				
Rack Mount, w/ Slides				
Rack Mount, w/ Ears Only				
Rack Mount, External Pump w/o Slides				
Stainless Zero/Span Valves				
4-20 mA Current Loop Output, Isolated				
Bypass flow 500 cc/min				
Molybdenum Converter				
Desiccant Canister - O ₃ generator				

PROM # _____ Serial # _____
 Date _____ Technician _____

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3 SPECIFICATIONS, WARRANTY

3.1 Specifications

Operating Modes	NO/NO _x switching mode, NO only mode, NO _x only mode
Ranges	In 1 ppm increments from 5 ppm to 5,000 ppm Single range, independent ranges or autoranging
Noise at zero	0.02 ppm RMS
Noise at span	<0.2% of reading RMS above 20 ppm
Detection Limit(Note 1)	0.04 ppm RMS
Zero Drift (Note 2)	<0.2% full scale/24 hours
Zero Drift (Note 2)	<0.4% full scale/7 days
Span Drift (Note 2)	<1% FS/24 hours
Lag Time	
Switching Mode	20 sec (Note 3)
NO _x mode	4 sec (Note 3)
Response Time	
Switching Mode	95% in < 40 sec (Note 3)
NO _x mode	95% in < 10 sec (Note 3)
Sample Flow Rate	290 10 cc/min (Including bypass)
Linearity	1% of full scale
Precision	0.5% of reading
Temperature Range	5-40 ^o C
Humidity	0-95% RH non-condensing
Temp Coefficient	< 0.1% per ^o C
Voltage Coefficient	< 0.1% per V
Dimensions HxWxD	7"x17"x23.6" (18 cm x 43 cm x 61 cm)
Weight, Analyzer	43 lbs (20 kg)
Weight, Pump Pack	16 lbs (7 kg)
Power, Analyzer	100 V~ 50/60 Hz, 120 V~ 60 Hz, 220 V~ 50 Hz, 240 V~ 50 Hz, 200 watts
Power, Analyzer ⁴	230 V~ 50 Hz, 2.5A
Power, Ext Pump	110 V~ 60 Hz, 220 V~ 50 Hz, 240 V~ 50 Hz, 295 watts
Power, Ext Pump ⁴	230 V~ 50 Hz, 2.5A
Environmental	Installation Category (Over-voltage Category) II Pollution Degree 2
Analog Resolution	1 part in 2048 of selected voltage or current range
Recorder Output	0-100 mV, 0-1, 5, 10v, bipolar
Current Loop Option	4-20ma isolated
Status	12 Status Outputs from opto-isolator
Measurement Units	ppm, mg/m ³

1. Defined as twice the zero noise level.
2. At constant temperature and voltage.
3. Lag & response times longer for external converter option.
4. Electrical ratings for CE Mark compliance.

3.2 Warranty

WARRANTY POLICY (02024c)

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

COVERAGE

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

Equipment provided but not manufactured by TELEDYNE 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 warrants each Product manufactured by TELEDYNE 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 shall correct such defect by, in TELEDYNE'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 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 SHALL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF OR RELATED TO THIS AGREEMENT OF TELEDYNE'S PERFORMANCE HEREUNDER, WHETHER FOR BREACH OF WARRANTY OR OTHERWISE.

TERMS AND CONDITIONS

All units or components returned to TELEDYNE 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.

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4 THE M9110AH NO_x ANALYZER

4.1 Principle of Operation

The TELEDYNE Model 9110AH Analyzer is designed to measure the concentration of nitric oxide [NO], total oxides of nitrogen [NO_x] and, by calculation, nitrogen dioxide [NO₂]. With the proper setup, it can operate in any of three sampling modes.

Table 4-1: Sampling Modes of the M9110AH

Mode	Description
NO/NO _x switching mode	Converter is switched, measures NO, NO _x , and NO ₂
NO only mode	Converter is switched out of sample stream. Nitric Oxide is only gas measured.
NO _x only mode	Converter is switched into the sample stream, NO _x is only gas measured.

Regardless of which sampling mode the instrument is operating in, the signal from the M9110AH comes from the light emitted from the chemiluminescent gas phase reaction of nitric oxide [NO] and ozone [O₃] as follows:



The reaction of NO with ozone results in electronically excited NO₂ molecules as shown in the first equation above. The excited NO₂ molecules release their excess energy by emitting a photon and dropping to a lower energy level as shown in the second equation. It has been shown that the light intensity produced is directly proportional to the [NO] concentration present.

In the NO mode, the sample gas is routed directly into the reaction cell. Any NO gas present reacts with ozone, producing light as described above.

In the NO_x mode, the sample gas is routed through a NO₂ to NO converter, and any NO₂ present is reduced to NO. The NO initially present remains as NO, therefore the signal is the sum of NO and NO₂ present in the sample gas stream.

In the NO/ NO_x switching mode the Analyzer samples the gas stream and measures [NO] concentration by digitizing the signal from the Analyzer's photomultiplier tube (PMT). The concentration is measured and stored internally. The valve is then switched, routing the sample gas through the converter, the signal measured is the NO_x concentration which is also stored in the computer.

The [NO₂] component is calculated by subtracting [NO_x] - [NO] = [NO₂] using the built-in computer. The three results [NO], [NO_x], and [NO₂] are then further processed and stored by the computer yielding several instantaneous and long term averages for all three components.

Periodically, the AutoZero valve switches allowing the analyzer to read zero background. The AutoZero readings are subtracted from all of the other readings. This improves zero baseline stability.

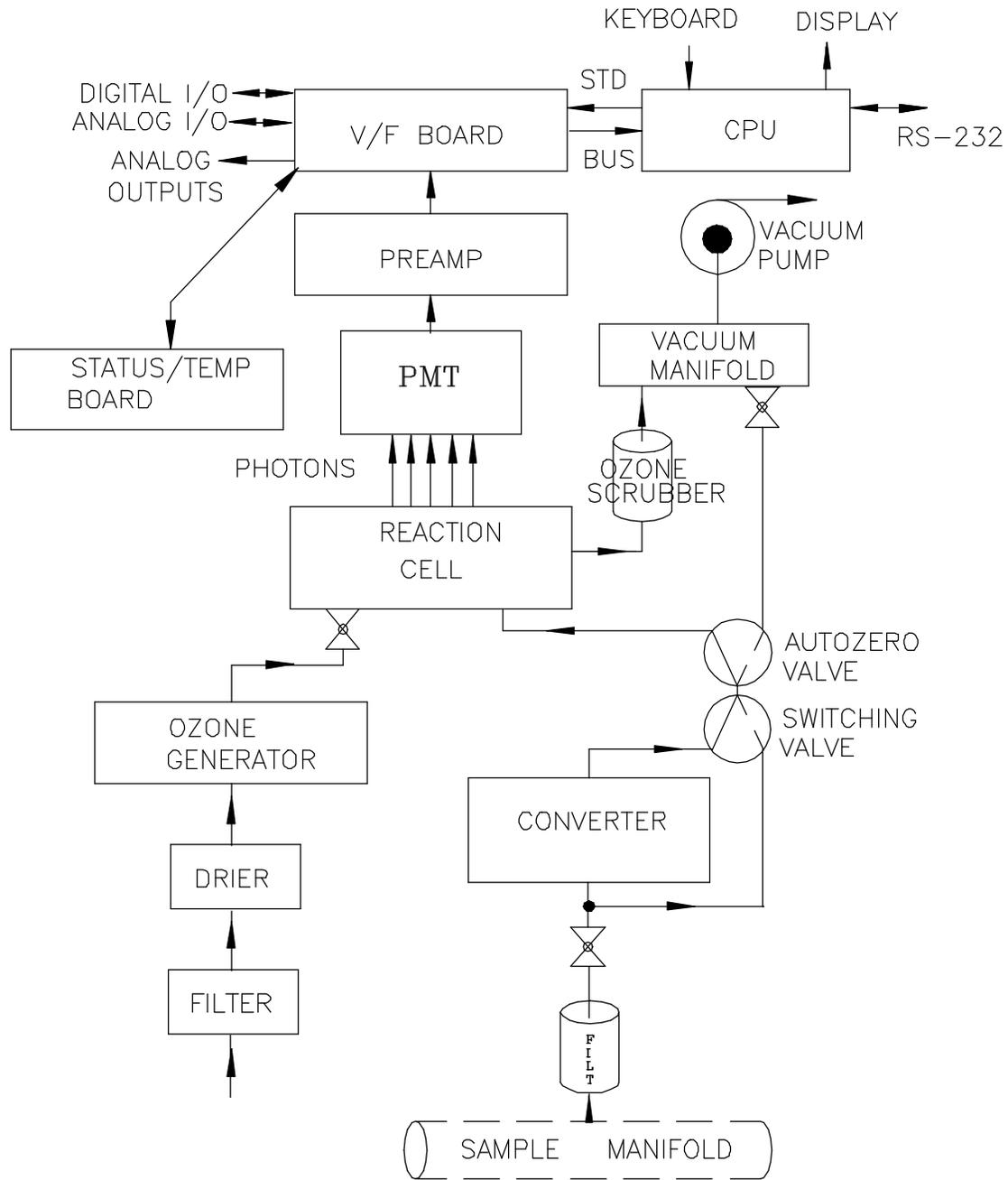


Figure 4-1: Block Diagram

4.2 Operation Summary

4.2.1 Sensor Module, Reaction Cell, Detector

The sensor module is where light from the chemiluminescent reaction is generated and detected. It is the most complicated and critical sub-assembly in the entire analyzer. It consists of the following assemblies and functions:

1. The reaction cell and ozone flow control module
2. Reaction cell heater/thermistor
3. PMT and High Voltage Power Supply
4. PMT cooler/cold block/heatsink/fan
5. Preamp assembly:
 - A. Preamp range control hardware
 - B. HVPS control
 - C. PMT cooler temp control
 - D. Electric test electronics
 - E. Optic test electronics

4.2.2 Pneumatic Sensor Board

The sensor board consists of 2 pressure sensors and a flow sensor. One pressure sensor measures the pressure in the reaction cell. The reaction cell is maintained at about one-quarter of atmospheric pressure. The second pressure sensor measures the pressure upstream of the reaction cell, which is near ambient pressure. From these two pressures the sample flow rate can be computed and is displayed as sample flow in the TEST menu. Finally, a solid state flow meter measures the ozone flow directly. Likewise, it is displayed as a TEST function.

The M9110AH displays all pressures in inches of mercury-absolute (in-Hg-A). Absolute pressure is the reading referenced to a vacuum or zero absolute pressure. This method was chosen so that ambiguities of pressure relative to ambient pressure can be avoided.

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

4.2.3 Computer Hardware and Software

The M9110AH Analyzer is controlled by a micro computer. The computers' multitasking operating system allows it to do instrument control, monitor test points, provide analog output and provide a user interface via the display, keyboard and RS-232 port. These operations appear to be happening simultaneously but are actually done sequentially based on priority queuing system maintained by the operating system. The jobs are queued for execution only when needed, therefore the system is very efficient with computer resources.

The M9110AH is a true computer based instrument. The microprocessor does most of the instrument control functions such as temperature control, valve switching. Data collection and processing are done entirely in the CPU with the final concentration values being sent to a D/A converter to produce the instrument analog output.

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

4.2.4 V/F Board

The computer CPU board communicates via 2 major hardware assemblies. These are the V/F board and the front panel display/keyboard. The V/F board communicates with the CPU via the STD-100 bus.

The V/F board includes of A/D input channels, digital I/O channels, and analog output channels. The computer receives all of the instrument data and provides all control functions through the V/F board.

4.2.5 Front Panel

The front panel of the M9110AH is shown in Figure 2-4. The front panel consists of a 2 line display and keyboard, 3 status LED's and power switch. Communication with the display, keyboard, and status LED's is done via the computers on-board parallel port. The M9110AH was designed as a computer controlled instrument, therefore all major operations can be controlled from the front panel display and keyboard.

The display consists of 2 lines of 40 characters each. The top line is divided into 3 fields, and displays information. The first field is the mode field.

The center field displays TEST values. The TEST functions allows you to quickly access many important internal operating parameters of the M9110AH. This provides a quick check on the internal health of the instrument. The right hand field shows current concentrations values of NO, NO_x, and NO₂.

The M9110AH can operate in any of 3 different sampling modes - NO only, NO_x only, and NO/NO_x switching mode. For the NO or NO_x only modes just the single gas being measured is displayed. For the NO/NO_x switching mode, the display scrolls between the NO, NO_x, and NO₂ concentration values every 4 seconds.

4.2.5.1 Keyboard

The second line of the display contains eight fields, each field defines the key immediately below it. By redefining the keys dynamically it is possible to simplify the instrument electronics and user interface.

4.2.5.2 Status LED's

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

Table 4-2: Front Panel Status LED's

LED	State	Meaning
Green	Off On Monitoring Blinking	NOT monitoring, DAS disabled Monitoring normally, taking DAS data Monitoring, DAS in HOLDOFF mode (1)
Yellow	Off On Blinking	AutoCal disabled AutoCal enabled Calibrating
Red	Off Blinking	No warnings exist Warnings exist
(1) This occurs during Calibration, DAS holdoff, after power-up and in Diagnostic mode.		

4.2.5.3 Power Switch

The power switch has two functions. The rocker switch controls overall power to the instrument, in addition it includes a circuit breaker. If attempts to power up the M9110AH result in a circuit breaker trip, the switch automatically returns to the OFF position, and the instrument will not power up.

4.2.6 Power Supply Module

The Power supply module supplies AC and DC power to the rest of the instrument. It consists of a 4 output linear DC power supply and a 15 volt switching supply. In addition, it contains the switching circuitry to drive the DC operated valves and several switched AC loads to operate the Rx cell heater, converter heaters and the ozone generator. The only voltages not generated in the PSM are the high voltage DC required by the PMT which is generated inside the sensor module and the high voltage AC used by the ozone generator.

4.2.7 Pump, Valves, Pneumatic System

A standard M9110AH comes with 2 valves, the NO/NO_x valve and the AutoZero valve, see Figure 4-1. Depending on the selected operating mode, the NO/NO_x valve:

1. NO only mode - routes sample gas continuously into the reaction cell.
2. NO_x only mode - routes sample gas continuously through the converter, then into the reaction cell.
3. NO/NO_x switching mode - switches gas alternately around, then through the converter to measure NO, NO_x, and by calculation NO₂.

The AutoZero valve provides a continuous zero reference. Periodically, the valve switches to turn off sample gas to the reaction cell. The ozone continues to flow. The zero reading is averaged and used to compensate subsequent readings for PMT zero offset.

An external pump comes as standard equipment. The Pump Pack includes a vacuum pump and ozone scrubber. It is supplied with 0.25" tube fitting to connect to the exhaust fitting on the M9110AH rear panel. See Figure 2-3 for hook-up information. The pump pack is turned on by plugging the power cord into an AC outlet, see Figure 4-2.

The pump is supplied as standard equipment, however if you are supplying a pump, it must have the following characteristics:

1. The pump must supply 2 slpm at 5"Hg-A.
2. The ozone scrubber must remove all ozone from the analyzer exhaust.
3. Connect the exhaust (Figure 2-3) to a pump with a <3 m length of 1/4" O.D. PTFE tubing.

Failure to meet the performance specifications will result in poor analyzer performance, damage to the pump, damage to the analyzer, and may jeopardize warranty repairs. TELEDYNE strongly recommends that the factory supplied pump be used with the M9110AH.

NOTE

On vacuum vs absolute pressure:

Many vacuum gauges read relative to ambient pressure, therefore a reading of 25" of mercury (Hg) at sea level (which would give an absolute pressure of about 5" Hg in the reaction cell) would read only 20" Hg at high altitude sites. Therefore in this manual the vacuum specification of 5" Hg pressure is given as an absolute pressure - 5" Hg-A - reference against zero absolute pressure (a perfect vacuum) thus removing ambiguities for high altitude sites.

A 47 mm diameter sample filter is provided as standard equipment to remove particulate matter from the sample gas. It is important that the filter be maintained at regular intervals because particulates trapped on the filter have been shown to alter the concentration of the sample. A suggested schedule is shown in Section 8 - Maintenance. It should be noted however that more or less frequent maintenance may be required depending on the situation.

CHANGE FILTER PER
MAINTENANCE SCHEDULE
IN SECTION 8.0

TO 9110AH
EXHAUST

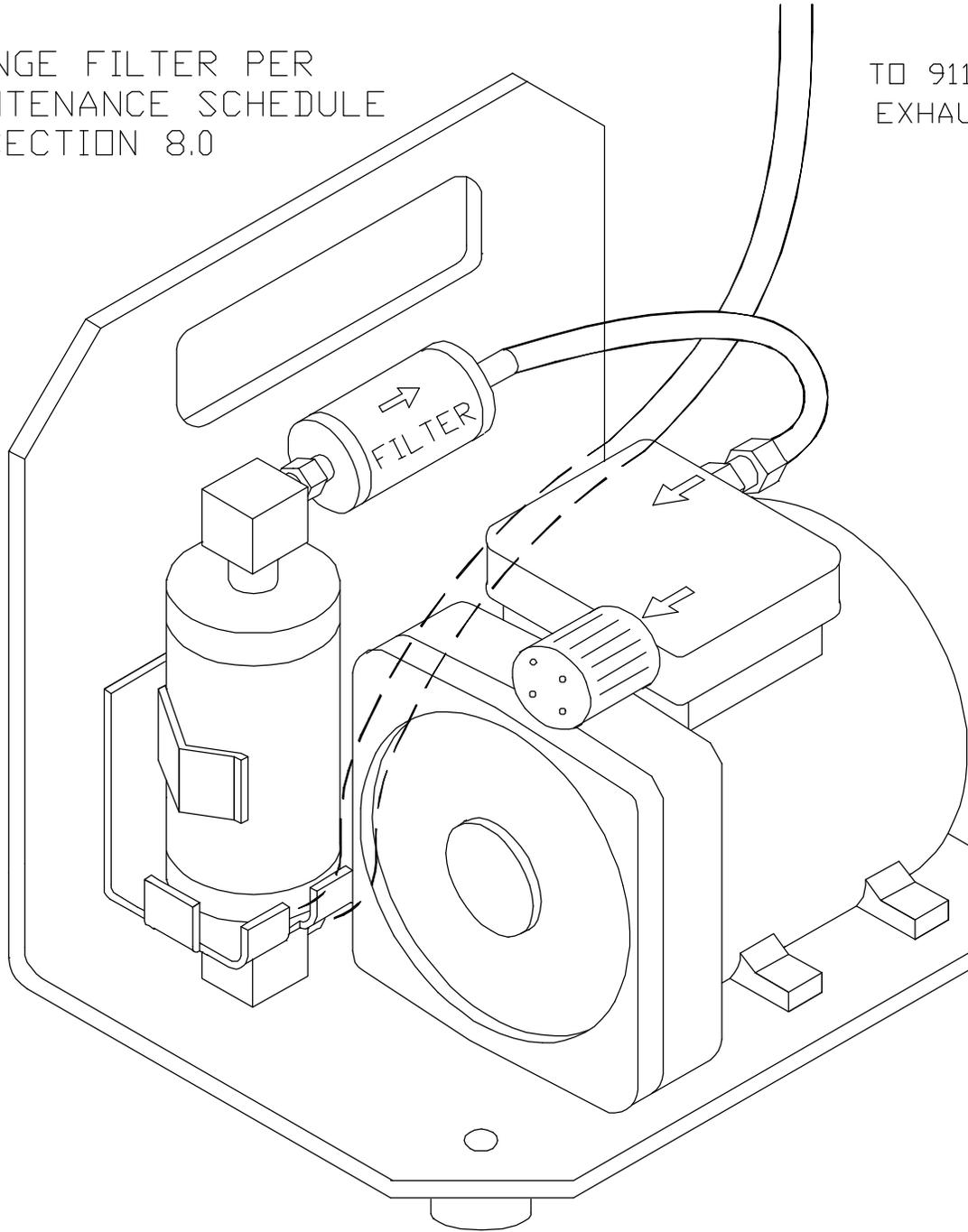


Figure 4-2: External Pump Pack

4.2.8 Ozone Generator

Because of the instability of ozone, it is necessary to generate this gas inside the analyzer. The ozone generation module consists of a switching power supply that drives a high voltage transformer and silent discharge tube. The generator's dry air supply uses a membrane drier to supply air with a dew point of 0° C or less. The exhaust side of the membrane is connected to the vacuum manifold at the rear of the instrument. A complete description and service requirements for this module can be found in Section 9.3.6.

Normal room air contains enough water vapor to damage the generator and components downstream, therefore the ozone GENERATOR MAY NOT TURN ON IMMEDIATELY AFTER POWER UP. The delay is built into the instrument to allow the dryer to start operating and purge the system with dry air. Table 4-3 details the conditions for turning on the ozone generator.

Table 4-3: Ozone Generator Start-up Timing

Time Since Last Power-up	Ozone Gen State	Program Action
< 1 hour	ON at power-up	Gen ON immediately after power-up.
> 1 hour	OFF at power-up	Wait 30 min, then turn gen ON.

4.2.9 NO₂ - NO Converter

The converter is a length of 1/8" tubing heated to 700 C. The converter's function is to reduce nitrogen dioxide (NO₂) to nitric oxide (NO). The temperature control for this module is done by the computer. To accurately measure converter efficiency, there should be oxygen present in the NO₂ calibration gas.

NOTE

For the converter to operate properly there should be a few percent oxygen present in the sample stream.

5 SOFTWARE FEATURES

The M9110AH control software has two major operating modes. The SAMPLE mode is the normal mode when the instrument is taking data. The software menu that covers the SAMPLE mode is diagrammed in Figure 5-1.

When the instrument is initially installed, or problems indicate a need for diagnostics, the SETUP menu is used. The SETUP menu is diagrammed in Figure 5-2.

5.1 Index to Front Panel Menus

The next several pages contain two different styles of indexes that will allow you to navigate the M9110AH software menus. The first two pages show a "tree" menu structure to let you see at a glance where each software feature is located in the menu. The second menu contains a brief description of each key mnemonic and a reference to the section of the manual that describes its purpose and function in detail.

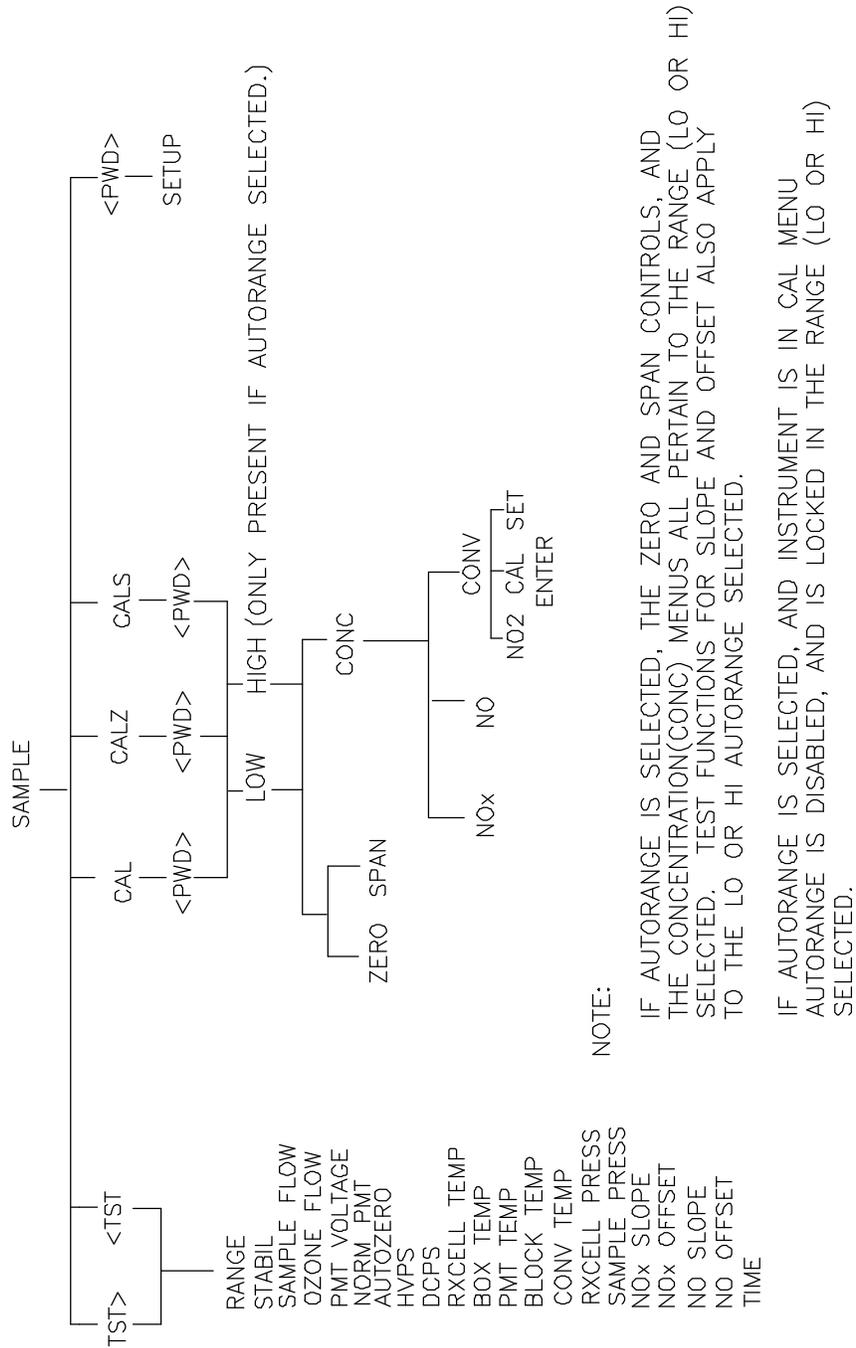


Figure 5-1: Sample Menu Tree

5.1.1 Sample Menu

Table 5-1: M9110AH Sample Menu Structure

Level 1	Level 2	Level 3	Level 4	Level 5	Description	Reference Section
TEST TST>					Test functions	5.2.1, Table 9-1
CAL					Zero/Span calibration w/ gas through sample port	5.2.2.1, 7.1
CALZ					Zero calibration w/ zero gas from zero valve option	5.2.2.2, 7.1, 7.2
CALS					Span calibration w/ span gas from low or high concentration span valve option	5.2.2.3, 7.1, 7.2
	LOW/ HIGH				Only present if AutoRange is selected. Used to select which range instrument will be calibrated in. Selects which slopes, offsets, expected span values, etc. will be updated and displayed.	5.3.4.2, 7.7
		ZERO			Press ZERO then ENTR will zero analyzer	5.2.2.2, 7.1, 7.2
		SPAN			Press SPAN then ENTR will span analyzer	5.2.2.4, 7.1, 7.2, 5.2, 2.3
		CONC			Expected NO/NO _x span concentrations and Conv efficiency setup	Table 7-3
			NOX CONC		Enter expected NO _x span concentration	5.2.2 Table 7-3
			NO CONC		Enter expected NO span concentration	5.2.2, Table 7-3
			CONV		Sub-menu for converter efficiency setup and verification	5.2.2.6, 7.10
				NO2	Expected NO ₂ concentration for converter efficiency calculation	5.2.2.6, 7.10
				CAL	Automatic converter efficiency calibration and entry	5.2.2.6, 7.10
				SET	Set the converter efficiency manually	5.2.2.6, 7.10
SETUP					The SETUP Menu - See next table.	Table 5-2

5.1.2 Set-Up Menu

Table 5-2: M9110AH Setup Menu

Level 1	Level 2	Level 3	Level 4	Description	Reference Section
CFG				CFG is primarily used for showing special configuration options and factory special software.	5.3.1
	PREV, NEXT, LIST			PREV, NEXT can be used to scroll through the configuration list. LIST automatically scrolls the list.	5.3.1
AUTOCAL				Automatic span check or calibration	5.3.2
	PREV SEQUENCE			Select a sequence of pre programmed calibration commands Scroll backwards	5.3.2
	NEXT SEQUENCE			Select a sequence of pre programmed calibration commands Scroll forwards	5.3.2
	MODE			Choose from a list of 7 modes plus disable	5.3.2
		PREV		Scroll back to choose type of calibration performed	5.3.2
		NEXT		Scroll forward to choose type of calibration performed	7.6
			DISABLE	Disable selected calibration sequence.	7.6
			ZERO	Do a zero calibrate	7.6
			ZERO-LO	Do a zero and low span calibrate	5.3.2, 6.2
			ZERO-HI	Do a zero and high span calibrate	5.3.2, 6.2

(table continued)

Table 5-2: M9110AH Setup Menu (Continued)

Level 1	Level 2	Level 3	Level 4	Description	Reference Section
			ZERO-LO-HI	Do a zero, low, and high span calibrate	5.3.2, 6.2
			LO	Do a low span calibrate	5.3.2, 6.2
			HI	Do a high span calibrate	5.3.2, 6.2
			LO-HI	Do a low and high span calibrate	5.3.2, 6.2
	SETTINGS				
		TIMER ENABLE		Enable/Disable chosen sequence	5.3.2,6.2
		START DATE		Start date of selected sequence	5.3.2, 6.2
		START TIME		Start time of selected sequence	5.3.2, 6.2
		DELTA DAYS		Number of days to shift start time each time sequence is run	5.3.2, 6.2
		DELTATIME		Number of hours to shift start time each time sequence is run	5.3.2, 6.2
		DURATION		Number of minutes to spend at each step in sequence	5.3.2, 6.2
		CALIBRATE		ON=compute new slope and/or offset OFF=do a span/zero check	5.3.2, 6.2
		RANGE TO CAL		If AutoRange is ON, select which range to calibrate LO or HI	5.3.2, 6.2

Table 5-3: M9110AH Setup Menu

Level 1	Level 2	Level 3	Level 4	Level 5	Description	Reference Section
DAS					Data Acquisition menu	5.3.3
	VIEW				Select which DAS data collector to view	5.3.3
			PREV-NEXT		Scroll through data collectors CONC, PNUMTC, CAL DAT	
		EDIT	UP		Examine the DAS data buffer	
			UP10		Move UP 10 averages in the DAS data buffer	
			DOWN		Examine the DAS data buffer - move down and display next average	
			DOWN10		Move DOWN 10 averages in the DAS data buffer	
RANGE					Sets the output range	5.3.4
	MODE				Type of range output	5.3.4
		SING			All 3 outputs are on the same single range	5.3.4.1
		AUTO			All 3 outputs AutoRange between 2 different ranges	5.3.4.2
		REM			Same as AutoRange, except external contacts set range	5.3.4.2
		IND			Each range can be set independently	5.3.4.3
	OFFS				Allows a offset bias voltage to all analog output channels	5.3.6
	UNIT				Unit selection menu	5.3.4.5
		PPM			Selects PPM units	5.3.4.5
		MGM			Selects milligrams per cubic meter units	5.3.4.5
	SET					
		IF SINGLE	SET		Sets the range of the instrument if in SINGLE range mode	5.3.4.1
		IF AUTO OR REM	LO/HI		Sets the low and high ranges for AUTORANGE or Remote Range.	5.3.4.2
		IF INDEP		NO NOX NO2	Sets each INDEPENDENT range.	
	DIL				Sets dilution factor.	5.3.4.4

Table 5-4: M9110AH Setup Menu

Level 1	Level 2	Level 3	Level 4	Level 5	Description	Reference Section
PASS					Password protection	5.3.5
	ON/OFF				Enable password protection of calibration and setup menus.	5.3.5
CLOCK					Time of day clock	5.3.6
	TIME				Set the time of day	5.3.6
	DATE				Set the date	5.3.6
MORE					Drop to next lower level of menus	
	COMM				Communications setup menu	5.3.8
		BAUD			Set the BAUD rate, there are more RS-232 options in the VARS menu.	5.3.8
		ID			Set the instrument ID	5.3.8
	VARS				Internal software variables	5.3.9
		PREV, NEXT, JUMP, EDIT			PREV, NEXT scroll up and down through the VARS menu. Jump will go to variable number selected, EDIT will allow changing the selected variable.	5.3.9
			VARs		User level variables.	5.3.9
	DIAG				Diagnostic menu	5.3.7, 9
		PREV, NEXT, JUMP			PREV, NEXT scroll up and down through the DIAG menu.	5.3.7, 9
			8 DIAG MODES		There are 8 diagnostic menus for testing various sections of the M9110AH	9.1.3
	EXIT				Exit from the SETUP menu	9.1

5.2 Sample Mode

5.2.1 Test Functions

NOTE

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

TEST functions allow the operator to examine several important operating parameters of the M9110AH to verify correct Analyzer operation. If faults are discovered, refer to Troubleshooting Section 9.

Range (RANGE)

This is the Range of the instrument. In single range mode there is one range for all 3 rear panel analog outputs.

The AutoRange option allows 2 different ranges for each channel, and will automatically switch to the other range dynamically as concentration values require. By selecting Remote AutoRange, the range change can be controlled remotely. The TEST values will show the range the instrument is currently operating in, and will dynamically display range change information when necessary.

Independent range option allows different ranges for each output. When enabled, there will be three range values displayed, NO, NO_x and NO₂.

NOTE

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

Signal Stability (STABIL)

The instrument noise is computed by calculating the standard deviation of the last 10 minutes of concentration data. If NO/ NO_x switching mode is selected, the noise reading is that of the NO_x channel. If NO only or NO_x only mode is selected the Noise applies to the mode selected. The noise value only becomes meaningful if sampling a constant concentration for more than 10 minutes. The noise value should be compared to the value observed in the factory check-out.

Sample Flow (SAMP FLW)

The SAMPLE FLOW test function is computed from the pressure measured up-stream of the sample flow orifice. The pressure down-stream of the orifice is also checked to assure the assumptions of the equation are valid. This will register variations in flow caused by changes in atmospheric pressure, but will not detect a plugged sample flow orifice. The sample flow into the reaction cell is 50 ± 10 cc/min with a bypass flow of 250 cc/min ± 50. The instrument reports a flow of 290 ± 50 cc/min.

Ozone Flow (OZONE FLW)

The OZONE FLOW test function is directly measured by a solid state flow meter. Variations in this value indicate variations in ozone flow. The nominal value for ozone flow is 250 ± 10 cc/min.

PMT Voltage (PMT)

The PMT VOLTAGE measures the PMT signal at the output of the preamp board. The waveform of the PMT voltage can be complex, and vary from near 0 mV when zero gas is in the reaction cell to 5000 mV when there is large amounts of NO being measured. If the PMT reading is consistently 5000 mV, that indicates an off-scale reading. Typical readings bounce around, which is normal.

AutoZero Voltage (AZERO)

The AutoZero Voltage is the PMT output when the AutoZero valve is actuated. It provides a zero reference which is subtracted from all NO and NO_x readings. The value typically will be near 0 mV. Readings in the range -10 to +50 mV are acceptable. High readings indicate a light leak in the reaction cell, recent exposure of the PMT to light, or contamination in the reaction cell.

High Voltage Power Supply Voltage (HVPS)

The HVPS reading is a measure of the scaled-up HVPS programming voltage. The voltage used to set the HVPS output is generated on the Preamp board. Its value is between 0 and 1 volt, corresponding to a voltage of 0 to 1000 volts out of the HVPS. The HVPS front panel TEST measurement should typically be in the range of 400-600V.

DC Power Supply Voltage (DCPS)

The DCPS voltage is a composite of the 5 and ± 15 VDC voltages in the Power Supply Module. This is meant to be a quick indicator to show if the PSM is working correctly. The nominal value is 2500 mV ± 200 mV.

Reaction Cell Temperature (RCEL TEMP)

This is a measurement of the temperature of the reaction cell. It is controlled by the computer to 50 ± 2 C. Temperatures outside this range will cause the M9110AH output to drift.

Box Temperature (BOX TEMP)

This TEST function measures the temperature inside the chassis of the M9110AH. The temperature sensor is located on the Status/Temp Board. Typically it runs 2 to 10 C higher than the ambient temperature. The M9110AH has been engineered to maintain stable output over 5 to 40 C ambient temperature range.

PMT Temperature (PMT TEMP)

The temperature of the PMT is closely controlled by a dedicated proportional temperature controller. The nominal set-point is 7 ± 1 C. Readings outside this range will cause instrument drift due to gain changes in the PMT detector.

Block Temperature (BLOCK TEMP)

The block temperature is the temperature of the sample flow orifice. The block is mounted near the rear of the instrument and is located upstream of the converter. Running the converter at low pressure improves its conversion efficiency. The normal temperature of the sample orifice block is 50 ± 2 C, and is controlled by the computer.

Converter Temperature (CONV TEMP)

The converter temperature monitors the temperature of the NO₂-to-NO converter and is controlled by the computer. The nominal set-point is 700 ± 10 C. The temperature sensor inside the converter is a type-K thermocouple. The thermocouple amplifier is located on the STATUS/TEMP board. If the thermocouple breaks, the circuit will turn off power to the heater.

If the analyzer is equipped with the molybdenum converter option the TEST function will report MOLY TEMP, the temperature setpoint will be 315 ± 10 C.

If the analyzer is equipped with the Model 501 external converter option, the converter temperature is shown on the front panel of the M501. The TEST function O3KL will report the temperature of the catalytic ozone killer located inside the converter can.

Reaction Cell Pressure (RCEL)

The pressure in the reaction cell is measured by a solid state pressure sensor which measures absolute pressure. Absolute pressure was chosen because it is an unambiguous measure of cell pressure. This pressure will vary depending on several things.

1. The type of pump attached to the analyzer.
2. Variations in local weather will cause a 0.3in-Hg change in pressure.
3. The altitude of the analyzer will cause the cell pressure to change.

Nominal values are 3 to 10 in-Hg-A. Typical reading is about 5 in-Hg-A at sea level for the standard pump.

Sample Pressure (SAMP)

The sample pressure is measured by one of the pressure sensors on the sensor board. The sample pressure typically runs slightly below atmospheric pressure. Sample pressure will change with varying atmospheric pressure (like the weather) because the sensor is an absolute pressure sensor. It will also change with altitude.

NO_x, NO Slope and Offset Values (NO_x SLOPE, NO_x OFFS, NO SLOPE, NO OFFS)

The slope (m) and intercept (b) coefficients of 2 (NO_x and NO) straight line equations ($y = mx + b$) determine the calibration of the M9110AH. The slope parameter(m) can be thought of as a gain term which determines the steepness of the calibration curve. The offset (b) parameter compensates for differences in the background signal of the NO and NO_x channels. This is primarily due to the background of the converter.

These parameters contain valuable information about the quality and validity of the calibration. For example the NO and NO_x slope values should not differ by more than 0.1 from each other. Larger values indicate a flow imbalance such as a leak or problems with the converter. Refer to Section 7.9 Calibration Quality for details on how to use these values.

Time (TIME)

This is the output of the internal time of day clock.

5.2.2 CAL, CALS, CALZ, Calibration Functions

The calibration and zero/span checking of the M9110AH analyzer is treated in detail in Section 7, Table 7-1 summarizes types of calibration.

5.2.2.1 CAL, CALS, CALZ

The CAL, CALS, and CALZ keys control the calibration functions of the analyzer. In the CAL mode the analyzer can be calibrated with zero/span gas coming in through the sample input port on the rear panel. If the analyzer is equipped with the Zero/Span valve option, the CALZ and CALS buttons operate the Zero/Span valves. The setup of this option is covered in Section 6.2, and operation is explained in Section 7.

5.2.2.2 Zero

Pressing the ZERO key along with ENTR will cause the instrument to adjust the OFFSET value of the internal formulas so that the instrument reads zero. The M9110AH allows zero adjustment over a limited range of signal levels, therefore the signal does not have to be exactly zero for the instrument to do a zero cal. The instrument will not, however, allow a zero cal on any signal level, therefore it is not possible to zero the instrument with high concentrations of span gas in the reaction cell. If the ZERO key does not come on as expected, check Section 9.2.9.

5.2.2.3 Span

Pressing the SPAN key along with ENTR will cause the instrument to adjust the SLOPE value of the internal formula so the instrument displays the span value. The expected NO_x and NO span concentrations must be entered before doing a SPAN calibration. See Table 7-3.

Like the Zero calibration, the Span cal cannot be done with any concentration of span gas. If signal level is outside certain limits the SPAN key will not be illuminated. If you encounter this condition see Section 9.2.8. It is also possible at low levels of span concentration that BOTH the ZERO and SPAN keys might be on, thus allowing you to either zero or span the instrument. In this case care must be taken to perform the correct operation or the analyzer can become miss-calibrated.

5.2.2.4 NO, NO_x Cal Concentration

Before the M9110AH can be spanned, it is necessary to enter the expected span concentrations for NO and NO_x. In single range mode there is one value each for the NO and NO_x expected span values. The span values are entered by pressing CAL-CONC-NO or CAL-CONC-NOX keys for NO_x and NO span concentrations respectively.

If AutoRange is enabled, there is a different slope and offset for each of the 2 ranges for a total of 4 expected span concentrations. Therefore there will be 2 span concentrations for NO and 2 span values for NO_x. When AutoRange is enabled, the path to the expected span concentrations contain an extra step. For the LOW concentration range the path is CAL-LOW-CONC-NO for NO, and CAL-LOW-CONC-NOX for NO_x. For the HIGH concentration range the pathways are CAL-HIGH-CONC-NO and CAL-HIGH-CONC- NO_x. These values must be entered to correctly calibrate the instrument.

5.2.2.5 Formula Values

The slope and offset terms should be checked after each calibration. The values for these terms contain valuable information about internal health of the analyzer. The range of acceptable values and their meanings is given in Section 7.9.

To compute the NO_x and NO concentrations, the formula for a straight line is used.

Where:

y = the NO_x or NO concentration

m = the slope

x = the conditioned PMT tube output

b = the offset

$y = mx + b$

In comparison with analog analyzers the slope term is equivalent to the "span pot" and the b term is equivalent to the "zero pot". Again, like an analog analyzer there is only a limited range of adjustment allowed for either term, and there are consequences of having the values near the high or low limits of their respective adjustment ranges.

The (x) term is the conditioned PMT signal. PMT signal is adjusted for current zero, AutoZero value, range, temperature, and pressure.

The offset (b) term is the total background light. Therefore in the case of the NO channel the b term should be very close to zero. The (b) for the NO_x channel is often slightly higher than the term for the NO channel. The extra background is mostly from the converter. The (b) term incorporates the PMT reading, the AutoZero value, the current span value, temperature and pressure compensation factors.

Because the span calibration calculation includes zero calibration data and zero calibration includes span calibration data, the zero and span calibrations can be performed in any order and the instrument will be accurately calibrated either way.

After every zero or span calibration, it is very important to check the QUALITY of the calibration. The calibration of the M9110AH involves balancing several sections of electronics and software to achieve an optimum balance of accuracy, noise, linearity and dynamic range.

See Section 7.9 for the calibration quality check procedure.

5.2.2.6 Automatic Converter Efficiency Compensation

The M9110AH can automatically compensate the NO_x and NO₂ readings for the converter efficiency. There are 2 ways to enter the converter efficiency into the instrument. If the instrument is in single or independent range modes, there is just one converter efficiency parameter. If the converter efficiency is determined by some outside method, the efficiency coefficient can be keyed in as a decimal fraction through the front panel. The path is CAL-CONC-CONV-SET. The second method is to have the M9110AH compute the efficiency using the CAL-CONC-CON-CAL menu. See the Calibration Section 7.10 - Converter Efficiency for details.

If AutoRange is enabled there will be 2 converter efficiencies, one for low range and one for high range. The procedure is identical for each range. To access the converter efficiency menu, the path is CAL-LOW-CONC-CONV for LOW range and CAL-HIGH-CONC-CONV for HIGH range. If NO_x or NO ONLY mode is set, the converter efficiency is disabled with the value set to 1.0000.

To disable the compensation, press CAL-CONV-SET and enter 1.0000 as the efficiency. Factory default is 1.0000.

5.3 Set-Up Mode

5.3.1 Configuration Information (CFG)

This menu item will tell if the installed software has factory special features or other non-standard features. If you call TELEDYNE service you may be asked for information from this menu.

5.3.2 Automatic Calibration (AutoCal)

The AutoCal feature allows the M9110AH to automatically operate the Zero/Span Valve option. This option allows a variety of periodic instrument calibrations and calibration checks. Information on setting up AutoCal is in Section 6.2.

5.3.3 Data Acquisition System (DAS)

The M9110AH contains a flexible and powerful built in data acquisition system (DAS) that enables the analyzer to store concentration data as well as diagnostic parameters in its battery backed memory. This information can be viewed from the front panel or printed out through the RS-232 port. The diagnostic data can be used for performing “Predictive Diagnostics” and trending to determine when maintenance and servicing will be required.

The logged parameters are stored in what are called “Data Channels.” Each Data Channel can store multiple data parameters. The Data Channels can be programmed and customized from the front panel. A set of default Data Channels has been included in the M200A software. For more information on programming custom Data Channels, a supplementary document containing this information can be requested from TELEDYNE.

5.3.3.1 Data Channels

The function of the Data Channels is to store, report, and view data from the analyzer. The data may consist of NO, NO_x, NO₂ concentration, or may be diagnostic data, such as the sample flow or reaction cell pressure.

The M9110AH comes pre-programmed with a set of useful Data Channels for logging concentration and predictive diagnostic data. The default Data Channels can be used as they are, or they can be changed by the user to fit a specific application. They can also be deleted to make room for custom user-programmed Data Channels.

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

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

- CONC:** Samples NO_x, NO and NO₂ concentration data at one minute intervals and stores an average every hour with a time and date stamp. Readings during calibration and calibration hold off are not included in the data. The last 800 hourly averages are stored.
- PNUMTC:** Collects sample flow and sample pressure data at five minute intervals and stores an average once a day with a time and date stamp. This data is useful for monitoring the condition of the pump and critical flow orifice(sample flow) and the sample filter(clogging indicated by a drop in sample pressure) over time to predict when maintenance will be required. The last 360 daily averages (about 1 year) are stored.
- CALDAT:** Logs new slope and offset every time a zero or span calibration is performed, also records the sample concentration reading just prior to performing a calibration.

NOTE:

This Data Channel collects data based on an event (a calibration) rather than a timer. This Data Channel will store data from the last 200 calibrations. This does not represent any specific length of time since it is dependent on how often calibrations are performed. As with all Data Channels, a time and date stamp is recorded for every data point logged.

Table 5-5: DAS Data Channel Editing

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

5.3.4 Range Menu

The instrument operates on any full scale range from 5 to 5,000 ppm. The range is the concentration value that equals the maximum voltage or current output on the rear panel of the instrument.

If the range you select is between 5 and 500 ppm the front panel will read the concentration anywhere from 0 to 500 ppm regardless of the range selected. If the range selected is from 501 to 5,000 ppm the front panel will read from 0 to 5,000 ppm. The apparently wider range of front panel readouts is because the M9110AH has 2 internal hardware ranges, namely 0-500 ppm and 0-5,000 ppm. The analog output is scaled for the range selected, however the front panel reading can display correct concentrations over the entire physical range.

NOTE

Only one of the following range choices can be active at any one time.

There are 3 range choices:

1. Single Range
2. Auto Range
 - A. Remote Range
3. Independent Ranges

5.3.4.1 Single Range

This range option selects a single range for all output channels (NO, NO_x, NO₂) of the M9110AH. To select Single Range press SETUP-RNGE-MODE-SING, then press ENTR. To set the value for the range press SETUP-RNGE-SET, and enter the full scale range desired from 5 ppm to 5,000 ppm.

5.3.4.2 Auto Range and Remote Range

Auto Range allows each of the 3 output signals (NO, NO_x, NO₂) to automatically range between a low value and a higher value. The Hi range mode is signaled by a bit on the STATUS connector see Table 5-8. When the instrument output increases to 98% of the low range value it will Auto Range into Hi range. In Hi range, when the output decreases to 75% of low range it will change to the lower range. If you select a Hi range that is less than Low range, the M9110AH will remain locked in Low range and behave as a Single Range instrument.

To set up Auto Range press SETUP-RNGE-MODE-AUTO, then press ENTR. To set the values press SETUP-RNGE-SET. The M9110AH will prompt you for LO, then HI which is the lower and upper ranges of Auto Range. Key in the value desired, then press ENTR.

Remote Range works the same as AutoRange except that the LO/HI range decision is made via remote status inputs on the rear panel, see Figure 2-2 for pinout. Calibration of Remote Range is also the same as for AutoRange see Section 7.7. To select Remote AutoRange press SETUP-RNGE-MODE-REM, then press ENTR.

5.3.4.3 Independent Ranges

Independent Ranges allows you to select different ranges for NO, NO_x, and NO₂.

To set up Independent Ranges press SETUP-RNGE-MODE-IND, then press ENTR. To set the values press SETUP-RNGE-SET. The M9110AH will prompt you for the range of NO, NO_x and NO₂ channels. Key in the desired range for each channel, then press ENTR after each value.

5.3.4.4 Dilution Ratio

The dilution feature allows the M9110AH to be used with a stack dilution probe. With the Dilution feature you can select the range and display the concentration at the value and units of the un-diluted gas in the stack. The dilution probe dilutes the gas by a fixed ratio so the analyzer is actually measuring a much lower concentration than is actually present in the stack.

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

To use the Dilution feature:

1. SELECT UNITS

For stack measurement, select PPM units. To set units, press SETUP-RANGE-UNIT-PPM. Press ENTR after the unit selection is made, then EXIT to return to upper level menus.

2. SET DILUTION RATIO

The dilution ratio of the probe is entered by SETUP-RANGE-DIL. Accepted values are 1 to 1000. Press ENTR, and EXIT to return to upper level menus. A value of 1 disables the dilution feature.

3. SELECT RANGE

The range selection is the same with dilution as with normal monitoring. See Section 5.3.4 for information on range selection. You should note however, the value entered should be the actual concentration of the calibration gas entering the dilution probe. The units of this number is ppm.

4. CALIBRATION

When the above selections have been made, the instrument now must be calibrated through the dilution probe.

NOTE

Units are now in PPM. See Section 7.1 for calibration methods.

5.3.4.5 Concentration Units

The M9110AH can display concentrations in ppm and mg/m³. To change the current units press SETUP-RANGE-UNIT. Select PPM or MGM, then press ENTR. Remember, you should now reset the expected span concentration values in the new units and re-calibrate the instrument using one of the methods in Section 7. The following equations give approximate conversion values. The exact values depend on the standard temperature and pressure used by your regulatory agency.

$$\text{NO ppm} \times 1.34 = \text{NO mg/m}^3$$

$$\text{NO}_2 \text{ ppm} \times 2.05 = \text{NO}_2 \text{ mg/m}^3$$

NOTE

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

Example:

If the current units are in ppm with the span value at 400 ppm, and the units are changed to mg/m³ the span value is NOT re-calculated to the equivalent value in mg/m³. Therefore the span value now becomes 400 mg/m³ instead of 400 ppm. Re-enter the expected span concentrations in mg/m³ units and recalibrate.

5.3.4.6 Recorder Offset

If necessary, a recorder offset can be introduced into the analog output voltages. This can be used to bias the output voltage or current 10%. It is intended for older design chart recorders that cannot show slightly negative readings. It can also be used to bias the input to a datalogger to offset small external ground loop voltages that are sometimes present in monitoring systems. To set the recorder offset, press SETUP-RANGE-OFFS and enter the offset voltage desired in percent. The recorder offset will bias both the recorder and DAS analog outputs.

5.3.5 Password Enable

If passwords are enabled, one of the values shown in Table 5-6 are required to calibrate or setup the instrument. If the 512 password is known, only calibrations can be performed. If the 818 password is known, the SETUP mode can be accessed. The 101 password can be used to enter both calibration and SETUP menus. A list of passwords is in Table 5-6.

Table 5-6: Calibrate, Setup Passwords

Password Usage		Password
Calibration Password	Use to get into CAL menus	512, 101
Setup Password	Use to get into SETUP menus	818, 101

5.3.6 Time of Day Clock

The instrument has an internal time of day clock. The time of day can be set by pressing SETUP-CLOCK-TIME and entering the time in 24hr format. In a similar manner the date can be entered by pressing SETUP-CLOCK-DATE and entering the date in a dd-mmm-yy format. If you are having trouble with the clock running slow or fast, the speed of the clock can be adjusted by selecting the CLOCK_ADJ variable in the SETUP-MORE-VARS menu.

5.3.7 Diagnostic Mode

The M9110AH Diagnostic Mode allows additional tests and calibrations of the instrument. These features are separate from the TEST functions because each DIAG function has the ability to alter or disable the output of the instrument. While in DIAG mode no data is placed in the DAS averages. Details on the use of Diagnostic mode are in Section 9.1.3.

5.3.8 Communications Menu

The COMM menu allows the RS-232 BAUD rate to be set. To set the BAUD rate press SETUP-MORE-COMM-BAUD, select the appropriate BAUD rate, then press ENTR.

The instrument ID number can also be set. This ID number is attached to every RS-232 message sent by the M9110AH. To set the ID press SETUP-MORE-COMM-ID and enter a 4 digit number from 0000-9999, then press ENTR. There are more RS-232 setups in the VARS menu Section 5.3.9.

5.3.9 Variables Menu (VARS)

This menu enables you to change the settings on certain internal variables. The VARS are defined in Table 9-5 which is located in the Troubleshooting Section 9.1.4.

5.4 M9110AH Operating Modes

The M9110AH has two main operating modes. The instrument is normally in SAMPLE mode when it is taking data or doing a calibration. The second main mode is the SETUP mode. In this mode the many features of the instrument can be altered, enabled or disabled. Within these two main modes there are many other operating modes which are shown in Table 5-7. The mode the instrument is operating in is shown in the upper left of the front panel display.

Table 5-7: M9110AH Operating Modes

Mode	Description
ZERO CAL D	Automatic dynamic zero calibration
ZERO CAL A	Automatic zero calibration
ZERO CAL R	Remote zero calibration
ZERO CAL M	Manual zero calibration
SPAN CAL D	Automatic dynamic span calibration
SPAN CAL A	Automatic span calibration
SPAN CAL R	Remote span calibration
SPAN CAL M	Manual span calibration
M-P CAL	Manual multi-point calibration
DIAG ELEC	Electrical diagnostic test
DIAG OPTIC	Optical diagnostic test
DIAG OZONE	Ozone generator diagnostic test
DIAG AOUT	D/A output diagnostic test
DIAG	Main diagnostic menu
DIAG I/O	Signal I/O diagnostic
DIAG RS232	RS232 output diagnostic
SETUP x.x	Setup mode (x.x is software version)
SAMPLE ZS	Sampling; automatic dynamic zero and span calibration enabled
SAMPLE Z	Sampling; automatic dynamic zero calibration enabled
SAMPLE S	Sampling; automatic dynamic span calibration enabled
SAMPLE A	Sampling; automatic cal. Enabled
SAMPLE	Sampling; automatic cal. Disabled

5.4.1 NO/NO_x/NO₂ Switching Mode

This is the most common mode of operation. It provides continuous output of NO, NO_x and NO₂ gas concentrations. To select switching mode press SETUP-MORE-VARS-ENTR and press NEXT to scroll to the MEASURE-MODE variable. Set the value of this variable to NO NO_x, then press ENTR. Press EXIT to return to SAMPLE mode.

5.4.2 NO_x Only Mode

In this mode only NO_x is measured. The converter is in the sample stream continuously. The output of the detector is sampled continuously. Since only NO_x is being measured, there are 2 advantages to this mode. First, it is possible to optimize for shortest response time. Second, NO_x is being continuously measured so that short transient events can be captured.

NOTE

It is not possible to apply converter efficiency compensation to the NO_x reading.

The NO_x reading is composed of a NO component and a NO₂ component. The NO₂ component is the only one impacted by the converter efficiency, and since the instrument is always in NO_x mode it is not possible to know the fraction of the NO_x reading that is NO₂.

To select NO_x only mode press SETUP-MORE-VARS and press NEXT to scroll to the MON_MODE variable. Set the value to NO_x, then press ENTR. Press EXIT to return to SAMPLE mode.

5.4.3 NO Only Mode

In this mode only NO is measured. The converter is always out of the sample stream. The output of the detector is sampled continuously. Since only NO is being measured, there are 2 advantages to this mode. First, it is possible to optimize for shortest response time. Second, NO is being continuously measured so that short transient events can be captured.

To select switching mode press SETUP-MORE-VARS and press NEXT to scroll to the MON_MODE variable. Set the value of this variable to NO, then press ENTR. Press EXIT to return to SAMPLE mode.

5.5 4-20 mA Current Loop

The analog signal output is available on the rear panel as a voltage or 4-20 mA current output. Optionally the current loop outputs can be isolated. See Section 6.3 for a description of isolated current loop outputs.

The current outputs come out on the same terminals that are used for voltage outputs see Figure 2-2. The NO, NO_x, NO₂ and Test Channel outputs have current loop capabilities. See Troubleshooting Section 9.3.4.4 for electrical specifications.

The factory default is voltage outputs. To convert from voltage to current loop, move the jumpers on the motherboard from the default B-C (rear pins) position to the A-B (forward pins) position. See the 01110 Motherboard schematic in the Appendix.

5.6 Status Output

The status output is an option that reports Analyzer conditions via contact closures on the rear panel. The closures are available on a 50 pin connector on the rear panel. The contacts are NPN transistors which can pass 50 ma of direct current. The pin assignments are listed in Table 5-8 below.

Table 5-8: Status Output Pin Assignments

Output #	Pin #	Definition	Condition
1	1,2	ZERO CAL	CLOSED IN ZERO CAL
2	3,4	SPAN CAL	CLOSED IN HIGH SPAN CALIBRATION
3	5,6	FLOW ALARM	CLOSED IF FLOW WARNING
4	7,8	TEMP ALARM	CLOSED IF ANY TEMP WARNING
5	9,10	DIAG MODE	CLOSED IN DIAG MODE
6	11,12	POWER OK	CLOSED IF SYSTEM POWER OK
7	13,14	CONC ALARM	CLOSED IF CONCENTRATION WARNING
8	27,28	LOW SPAN CAL	CLOSED IN LOW SPAN CALIBRATION
9		SPARE	
10	19,20	AUTORANGE - HI	CLOSED IF IN HIGH RANGE
11	21,22	SYSTEM OK	CLOSED IF NO FAULTS PRESENT
12	23,24	RX CELL PRESS	CLOSED IF ABS PRES > 15" HG

The Status Board schematic can be found in the Appendix Drawing 01087.

5.7 RS-232 Interface

The RS-232 communications protocol allows the instrument to be connected to a wide variety of computer based equipment. The interface provides two basic functions in the M9110AH.

1. First is a comprehensive command interface for operating and diagnosing the analyzer. The command set can be used interactively or operated via stored program. This interface has, in fact, more capabilities than the front panel keyboard.
2. The interface can provide an audit trail of analyzer events. In this function the port sends out messages about instrument events like calibration or warning messages. If these messages are captured on a printer or remote computer, they provide a continuous audit trail of the analyzers operation and status.

5.7.1 Setting up the RS-232 Interface

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

Second is physical wiring of the analyzer to the other unit. We have incorporated into the Analyzer LED's that signal the presence of data on the communications lines, and also a switch which can easily re-configure the analyzer from DCE to DTE if necessary. In addition, the front panel diagnostics allow test data streams to be sent out of the port on command. This flexibility and diagnostic capability should simplify attaching our equipment to other computers or printers. If problems occur, see the Troubleshooting Section 9.3.2.

Setup from the Front Panel

There are 3 additional RS-232 setups that can be done via the front panel.

1. Set the Instrument ID number by SETUP-MORE-COMM-ID, and enter a 4 digit number from 0000-9999. This ID number is part of every message transmitted from the port.
2. Set the BAUD rate by SETUP-MORE-BAUD, then select the desired BAUD rate.
3. Set the RS-232 mode bit field in the VARS menu. To get to the variable press, SETUP-MORE-VARS and scroll to RS-232_MODE, then press EDIT. The possible values are:

Table 5-9: RS-232 Port Setup - Front Panel

Decimal Value	Description
1	Turns on quiet mode (messages suppressed)
2	Places analyzer in computer mode (no echo of characters)
4	Enables Security Features (Logon, Logoff)
8	Enables RS-232 menus display on M9110AH front panel display
16	Enable alternate protocol
32	Enable RS-232 multidrop protocol

NOTE

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

Security Feature

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

1. A password is required before the port will operate.
2. If the port is inactive for 1 hour, it will automatically LOGOUT.
3. Repeat attempts at logging on with incorrect passwords will cause subsequent logins to be disabled for 1 hour.
4. If not logged on, the only command that is active is the '?'. If this command is issued the M9110AH will respond with MUST LOG ON.
5. The following messages will be given at logon.

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

The RS-232 LOGON feature must be enabled from the front panel by setting bit 4 from Table 5-9. Once the feature is enabled, to logon type:

```
LOGON 940331
```

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

```
V RS232_PASS=940331
```

which sets the password to the factory default.

Protocol of Port Communication

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

When an operator is communicating with the analyzer via a terminal, the analyzer should be placed into TERMINAL MODE, which echoes keystrokes, allows editing of the command line using the backspace and escape keys, and allows recall of the previous command. When a host computer or data logger is connected to the analyzer, it should be placed into COMPUTER MODE, which does not echo characters received or allow the special editing keys. See Table 5-10 for relevant commands.

Table 5-10: RS-232 Switching From Terminal Mode to Computer Mode

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

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

Entering Commands in Terminal Mode

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

Table 5-11: RS-232 Terminal Mode Editing Keys

Key	Function
CR (carriage return)	Execute command
BS (backspace)	Backspace one character to the left
ESC (escape)	Erase entire line
Control-R (ASCII 18 decimal)	Recall previous command
Control-E (ASCII 5 decimal)	Recall and execute previous command

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

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

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

5.7.2 Command Summary

The information contained in the rest of this section covers all of the normal commands that are required to operate the instrument from a remote terminal. If you are going to be writing computer programs to communicate with the M9110AH (i.e. operating the port in COMPUTER MODE) we suggest that you order a supplementary manual "The RS-232 Interface". This manual shows additional features of the port designed to support a computer driven interface program. Please, contact TAI for additional informations.

Table 5-12: RS-232 Command Summary

Commands	Definition
?	Print help screen
T SET ALL	Enable display of all test variables during T LIST
T SET name	Display only NAME during T LIST
T LIST [ALL]	Print all test variables enabled with T SET or ALL warnings
T name	Print single test, "name" from Table 5-15
T CLEAR ALL	Disable T LIST, use with T SET name
W SET ALL	Enable display of all warnings during W LIST
W LIST [ALL]	Print warnings enabled with W SET or ALL warnings
W name	Print individual "name" warning from Table 5-16
W CLEAR ALL	Disable W LIST, use with W SET
C LIST	Print calibration commands
C command	Execute calibration "command" from Table 5-18
D LIST	Prints all I/O signal values
D name	Prints single I/O signal value/state
D name=value	Sets variable to new "value"
D LIST NAMES	Lists diagnostic test names
D ENTER name	Enters and starts 'name' diagnostic test
D EXIT	Exits diagnostic mode
D SYS_RESET	Resets analyzer(same as power-on)
D RAM_RESET	System reset, plus erases RAM. Initializes DAS, NO, NO _x , NO ₂ conc readings, calib not affected.
D EE_RESET	System reset, plus erases EEPROM (RAM_RESET actions + setup variables, calibration to default values.
V LIST	Print all variable names
V name	Print individual "name" variable
V name=value	Sets variable to new "value"
V CONFIG	Print analyzer configuration
R count	Print last "count" DAS averages

Table 5-13: RS-232 Command Summary

Terminal Mode Editing Keys	Definition
V MODE	Print current analyzer mode
BS	Backspace
ESC	Erase line
^R	Recall last command
^E	Execute last command
CR	Execute command
^C	Switch to computer mode
Computer Mode Editing Keys	Definition
LF	Execute command
^T	Switch to terminal mode
Security Features	Definition
LOGON password	Establish connection to analyzer
LOGOFF	Disconnect from analyzer

General Output Message Format

Reporting of status messages for use as an audit trail is one of the two principal uses for the RS-232 interface. You can effectively disable the asynchronous reporting feature by setting the interface to quiet mode, see Table 5-9. All messages output from the analyzer (including those output in response to a command line request) have the format:

X DDD:HH:MM I III MESSAGE

X is a character indicating the message type, as shown in Table 5-14.

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.

III is the 4-digit machine ID number.

MESSAGE contains warning messages, test measurements, DAS reports, variable values, etc.

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

Table 5-14: RS-232 Interface Command Types

First Character	Message Type
C	Calibration status
D	Diagnostic
R	DAS report
T	Test measurement
V	Variable
W	Warning

There are 6 different types of messages output by the M9110AH. They are grouped below by type in Table 5-15 – Table 5-19. The meanings of the various messages are discussed elsewhere in the manual. The TEST, DIAGNOSTIC and WARNING messages are discussed in Sections 9.1.1, 9.1.2, 9.1.3. DAS and VARIABLES are discussed in Sections 5.3.3 and 5.3.9. CALIBRATE is discussed in Section 7.

5.7.3 TEST Commands and Messages

Table 5-15: RS-232 Test Messages

Name	Message	Description
NOXRANGE ¹	NOX RNG=xxxxx ppm	Indep. range for NO _x channel
NORANGE ¹	NO RNG=xxxxx ppm ³	Indep. range for NO channel
NO2RANGE ¹	NO2 RNG=xxxxx ppm ³	Indep. range for NO ₂ channel
RANGE ²	RANGE=xxxxx ppm ³	Analyzer range
STABIL	STABIL=xxxx.xx ppm	Std. Deviation of last 10 min of conc values.
FLOW	SAMPLE FL=xxx CC/M	Sample flow rate
OFLOW	OZONE FL=xxxx CC/M	Ozone flow rate
PMT	PMT=xxxxxx MV	PMT output
NORM PMT	NORM_PMT=xxxxxxx MV	PMT output adjusted for T/P compensation
AZERO	AZERO=xxxxxx MV	AutoZero offset value
HVPS	HVPS=xxxxx V	High voltage power supply
DCPS	DCPS=xxxxxx MV	DC power supply
RCTEMP	RCELL TEMP=xxx C	Reaction cell temperature
BOXTEMP	BOX TEMP=xxx C	Internal box temperature
PMTTEMP	PMT TEMP=xxx C	PMT temperature
BLOCKTEMP	BLOCK=xxx C	Sample flow control block temp
CONVTEMP	CONV TEMP=xxx C	Converter temperature
RCPRESS	RCEL=xxx.x IN-HG-A	Rx Cell Pressure
SMPPRESS	SAMP=xxx.x IN-HG-A	Sample Pressure
NOXSLOPE	NOXSLOPE=xxxxx	NO _x Slope Parameter
NOXOFFSET	NOXOFFS=xxxxx	NO _x Offset Parameter
NOSLOPE	NOSLOPE=xxxxxx	NO Slope Parameter
NOOFFSET	NOOFFS=xxxxxx	NO Offset Parameter
CLKTIME	TIME=HH:MM:SS	Time of day

¹Displayed when independent range is enabled.

²Displayed when single or AutoRange is enabled.

³Depends on which units are currently selected.

The **T command** lists TEST messages. Examples of the T command are:

- T LIST Lists test messages currently enabled with T SET
- T LIST ALL Lists all test messages
- T CONVTEMP Prints the temperature of the converter
- T LIST NOX Prints NO_x concentration message
- T NOX Prints concentration message

5.7.4 WARNING Commands and Messages

Table 5-16: RS-232 Warning Messages

Name	Message	Description
WSYSRES	SYSTEM RESET	Analyzer was reset/powerd on
WRAMINIT	RAM INITIALIZED	RAM was erased
WSMPFLOW	SAMPLE FLOW WARN	Sample flow out of spec.
WOZONEFLOW	OZONE FLOW WARNING	Ozone flow out of spec.
WRCELLP	RCELL PRESS WARNING	Rx cell pressure out of spec.
WBOXTEMP	BOX TEMP WARNING	Box temp. out of spec.
WRCELLT	RCELL TEMP WARNING	Reaction cell temp. out of spec.
WCONVTMP	CONV TEMP WARNING	Converter temp. out of spec.
WOBLKTMP	ORIFICE BLK TEMP WARN	Orifice block temp out of spec.
WDCPS	DC POWER SUPPLY WARN	DC Power voltage out of spec.
WDYNZERO	CANNOT DYN ZERO	Dynamic zero cal. out of spec.
WDYNSPAN	CANNOT DYN SPAN	Dynamic span cal. out of spec.
WBLKTEMP	SAMPLE FLOW ORIFICE BLOCK TEMP WARNING	Temperature out of spec.
WOZONEGEN	OZONE GEN OFF	Ozone generator is off
WAUTOZERO	AZERO WRN XXX.X MV	AutoZero reading out of spec.
WADINS	A/D NOT INSTALLED	A/D board not installed or broken

Whenever a warning message is reported on the analyzer display, if the RS-232 interface is in the normal mode(i.e. not in quiet mode) the warning message is also sent to the RS-232

interface. These messages are helpful when trying to track down a problem with the analyzer and for determining whether or not the DAS reports are actually valid. The warning message format is for example:

W 194:11:03 0000 SAMPLE FLOW WARN

The format of a warning command is W command. Examples of warning commands are:

W LIST List all current warnings

W CLEAR ALL Clear all current Warnings

Individual warnings may be cleared via the front panel or the command line interface. To clear the sample flow warning shown above the command would be:

W WSMPFLOW

5.7.5 CALIBRATION Commands and Messages

Table 5-17: RS-232 Calibration Messages

Message	Description
START ZERO CALIBRATION	Beginning zero calibration
FINISH ZERO CALIBRATION, NO ₂ =xxxxx ppm ¹	Finished zero calibration
START SPAN CALIBRATION	Beginning span calibration
FINISH SPAN CALIBRATION, NO ₂ =xxxxx ppm ¹	Finished span calibration
START MULTI-POINT CALIBRATION	Beginning multi-point calibration
FINISH MULTI-POINT CALIBRATION	Finished multi-point cal.

¹Depends on which units are currently selected.

Whenever the analyzer starts or finishes a calibration, it issues a status report to the RS-232 interface. If the RS-232 interface is in the normal mode, these reports will be sent. Otherwise, they will be discarded. The format of these messages is:

C DDD:HH:MM I III CALIBRATION STATUS MESSAGE

An example of an actual sequence of calibration status messages is:

C DDD:HH:MM I III START MULTI-POINT CALIBRATION

C DDD:HH:MM I III FINISH MULTI-POINT CALIBRATION

There are several methods of both checking the calibration and calibrating the M9110AH, these are discussed in Section 7. C LIST lists the calibration commands available. The C command executes a calibration command, which may be one of the following:

Table 5-18: RS-232 Calibration Commands

Command	Description
C LIST	List calibration commands
C ZERO	Enter zero calibration mode
C SPAN	Enter span calibration mode
C COMPUTE ZERO	Do a zero calibration
C COMPUTE SPAN	Do a span calibration
C EXITZ	Exit zero calibration
C EXITS	Exit span calibration
C EXIT	Exit zero or span calibration

5.7.6 DIAGNOSTIC Commands and Messages

When Diagnostic mode is entered from the RS-232 port, the diagnostic mode issues additional status messages to indicate which diagnostic test is currently selected. Examples of Diagnostic mode messages are:

D DDD:HH:MM I III ZERO VALVE=ON

D DDD:HH:MM I III ENTER DIAGNOSTIC MODE

D DDD:HH:MM I III EXIT DIAGNOSTIC MODE

The following is a summary of the Diagnostic commands.

Table 5-19: RS-232 Diagnostic Command Summary

Command	Description
D LIST	Prints all I/O signal values. See Table 9-4 for Sig I/O definitions.
D name=value	Examines or sets I/O signal. Must issue D ENTER SIG command before using this command
D LIST NAMES	Prints command names of all diagnostic tests
D ENTER SIG D ENTER OT D ENTER ET	Executes SIGNAL I/O diagnostic test. Executes Optic Test diagnostic test. Executes Elect Test diagnostic test. Use D EXIT to leave these diagnostic modes.
D EXIT	Must use this command to exit SIG, ET or OT Diagnostic modes
D SYS_RESET	Resets analyzer software (same as power on)
D RAM_RESET	Resets analyzer software and erases RAM. Erases NO, NO _x , NO ₂ conc values, erases all DAS data. Keeps setup variables and calibration. (same as installing new software version)
D EE_RESET	Resets analyzer software and erases RAM and EEPROM. Returns all setup variables to factory defaults, resets calibration values.

5.7.7 DAS Commands and Messages

The M9110AH contains a flexible and powerful built in data acquisition system (DAS) that enables the analyzer to store concentration data as well as diagnostic parameters in its battery backed memory. This information can be printed out through the RS-232 port. The diagnostic data can be used for performing “Predictive Diagnostics” and trending to determine when maintenance and servicing will be required.

To print out the properties of all of the data channels enter:

D PRINT

To print the properties of just a single data channel enter:

D PRINT "name"

For example to print the properties of the CONC data channel enter:

D PRINT "CONC"

To print records from a DAS data channel enter:

```
D REPORT "name" RECORDS=nnn COMPACT|VERBOSE
```

Examples of reports are:

```
D REPORT "CONC" RECORDS=35 VERBOSE
```

```
D REPORT "CALDAT" RECORDS=10
```

```
D REPORT "PNUMTC" RECORDS=155 VERBOSE
```

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

```
D 94:08:00 0200 CONC : AVG NXCNC1 = 1234.5 PPB
```

```
D 94:08:00 0200 CONC : AVG NOCNC1 = 1234.5 PPB
```

```
D 94:08:00 0200 CONC : AVG N2CNC1 = 1234.5 PPB
```

One CONC report consists of:

D	= Type of report (Diagnostic)
94:08:00	= Time and Date stamp (Julian day, Hr, Min)
0200	= Instrument ID number
CONC	= Data Channel name CONC = concentration data PNUMTC = pneumatic parameters CALDAT = calibration parameters
AVG	= Type of data AVG = average reading INST = instantaneous reading
NXCNC1 = 1234.5 PPB	= Name of the parameter NX = NO _x , NO = NO N2 = NO ₂ .

All of the default Data Channels sample more than one parameter, for these channels, each parameter is printed on a separate line.

There is also a compact format. If this attribute is enabled, all 3 concentration parameters are printed on one line as shown below:

```
D 94:08:00 0200 CONC : 120.0 100.0 20.0
```

The parameters are in the order of NO_x, NO, and NO₂.

To change any of the attributes of a particular data channel, the channel attributes are edited from the front panel. The following table uses the example of Automatic Reporting. Other attributes can be edited in a similar fashion

5.7.8 VARIABLES Commands and Messages

The M9110AH operational modes are listed above. To list the analyzer's current mode type:

```
V MODE      Lists M9110AH current operational mode
```

See Table 5-7 for list of operational modes and meanings.

Model M9110AH Internal variables

The M9110AH has a number of internal setup variables. Essentially all of these are set at time of manufacture and should not need to be changed in the field. A list of user accessible variables is shown in Table 9-5.

A list of variables and their settings can be requested over the RS-232 port by:

```
V LIST      Lists internal variables and values
```

The output from this command is quite long and will not be shown here. The general format of the output is:

```
name = value warning_lo warning_hi <data_lo> <data_hi>
```

Where:

name = name of the variable
value = current value of variable
warning_lo = lower limit warning (displayed if applicable)
warning_hi = upper limit warning (displayed if applicable)
data_lo = lower limit of allowable values
data_hi = upper limit of allowable values

Variables can be changed. Before changing the settings on any variables, please make sure you understand the consequences of the change. We recommend you call the factory before changing the settings on any variables. The general format for changing the settings on a variable is:

```
V LIST name[=value [warn_lo [warn_hi]]]
```

For example to change the warning limits on the box temperature type:

```
V BOX_SET 30 10 50
```

and the CPU should respond with:

```
V DDD:HH:MM I III BOX_SET=30 10 50(0-60)
```

The CONFIG command lists the software configuration.

For example:

```
V CONFIG list software configuration
```

The format of this listing is shown in the example below.

```
CONFIG[0] = Revision H.7
```

```
CONFIG[1] = NOx Analyzer
```

```
CONFIG[2] = SBC40 CPU
```

6 OPTIONAL HARDWARE AND SOFTWARE

Optional equipment offered with the M9110AH includes:

1. Rack mount with slides
2. Rack mount without slides, ears only
3. Rack mount for external pump
4. Stainless Steel zero/span valves
5. 4-20mA, isolated outputs
6. Molybdenum Converter
7. Model 501 External Stainless Steel/Molybdenum Converter
8. External Desiccant Canister
9. Alternate Bypass Flow Orifice - 500 cc/min

6.1 Rack Mount Options

Rack Mount including slides and ears, permits the Analyzer to be mounted in a standard 19" wide x 24" deep RETMA rack. This permits convenient slide out operation for servicing. It can also be ordered without slides for applications requiring the instrument to be rigidly mounted in a RETMA rack.

The external pump can be ordered in the following configurations:

1. External pump pack - this configuration comes standard with the M9110AH
2. Pump Pack with rack mount - fixed tray

6.2 Zero/Span Valves Option

The Zero/Span Valve option consists of a manifold of stainless steel valves plus drive electronics connected to the CPU. The Option consists of two variations. Option 50 has 2 - 2-way valves, 1 3-way valve and operates in 3 modes:

1. Sample mode, all 3 valves off, sample gas flows through the sample port to the instrument.
2. Zero mode, sample-cal valve is energized to shut off sample flow, zero valve is energized to input zero gas.
3. Span mode, sample-cal valve is energized to shut off sample flow, span valve is energized to input low concentration range span gas.

Option 52 consists of all of the features in Option 50 plus a second span valve to allow a low and high concentration of span gas.

See Figure 2-5 for valve location. Fittings on the rear panel are for two concentrations of span gas plus zero gas. (See Figure 2-2 and Figure 2-3) The valves are can be operated by several methods shown in Table 6-1.

Table 6-1: Zero/Span Valve Operation

Mode	Description	Reference Section
1.	Front panel operation via CALS and CALZ buttons.	Calibration Section 7 - Manual Zero/Span Check.
2.	Automatic operation using AUTOCAL	Setup and use of AUTOCAL is described in Table 6-2, and Section 7.2
3.	Remote operation using the RS-232 interface	Setup described in Section 6.2 Operation of AUTOCAL described in Section 7.2
4.	Remote operation using external contact closures	Section 7.4 - Automatic operation using external contact closures. Table 7-7 and Section 9.3.4.3

Zero and span gas inlets should supply their respective gases in excess of the demand of the Analyzer. Supply and vent lines should be of sufficient length and diameter to prevent back diffusion and pressure effects. See Figure 2-3 for fitting location and tubing recommendations.

6.2.1 Autocal - Setup Zero/Span Valves

The Zero/Span valves can be set up to operate automatically. Table 6-2 in this section describes Autocal setup.

Table 6-2: Setup Automatic Zero/Span Checking or Calibration

Step	Action	Comment
1.	Press SETUP-ACAL	This button sequence will cause the AUTOCAL menu to be displayed.
2.	Press PREV or NEXT	This selects a SEQUENCE. Up to 3 Sequences can be defined. A Sequence is a definition of zero/span calibrations along with timing information.
3.	Select MODE, then PREV or NEXT	MODE allows you to select the order of zero, low-span or high-span that will be performed, MODES are listed in Table 6-3. Use PREV - NEXT to scroll the list of choices, then press ENTR to select. To disable a sequence, select DISABLE from the menu.
4.	Press SET	<p>This menu sets up several timers and selects calibration or calibration check.</p> <ol style="list-style-type: none"> 1. TIMER ENABLE – If set to ON, the defined sequence will execute. If set to OFF, the sequence will remain in memory, but will not execute. 2. START DATE - calendar date to start sequence dd-mmm-yy, day-month-year format. 3. START TIME - time of day sequence will start. hh-mm, hours-minutes in 24 hr format. 4. DELTA DAYS and DELTA HOURS:MIN is the time between each activation of the sequence. By setting the Delta Hours variable to be other than an exact number of days, the sequence can move ahead or be delayed each time it is run. For example, by setting DELTA DAYS = 1 and DELTA HOURS = 1:00, the sequence will execute 1 hour later each day. To set it to move back ½ hour each day, DELTA DAYS = 0, DELTA HOURS = 23:30. 5. DURATION -Amount of time for each zero/span point. 6. CALIBRATE – If set to ON, will calibrate(adjust slope and offset). If OFF will check, but not change calibration. 7. RANGE-TO-CAL Selects the range to calibrate LO or HI. Applicable to AutoRange and RemoteRange modes.
5.	Press EXIT	The M9110AH now exits the AUTOCAL SETUP menu. For each enabled sequence, the M9110AH will now AUTOCAL at the defined times.

Table 6-3: Action of MODE Field in AutoCal

MODE	CALIBRATE = ON	CALIBRATE = OFF
ZERO	Zero calibrates LO or HI (depending on RANGE-TO-CAL), SINGLE or IND ranges.	Zero checks LO or HI (depending on RANGE-TO-CAL), SINGLE or IND range.
ZERO-LO	Zero and low span calibrates LO, SINGLE or IND ranges.	Zero and low span checks LO, SINGLE or IND ranges.
ZERO-HI	Zero calcs & span calcs HI, SINGLE or IND range with HI span gas	Zero checks & span checks on HI, SINGLE or IND range with HI span gas
ZERO-LO-HI	Zero calcs, span calcs LO and HI range. LO span gas for LO range, HI span gas for HI range. Zero calcs & span calcs in SINGLE or IND range using HI span gas. LO span is cal check only.	Zero checks, span checks both ranges. LO span gas for LO range, HI span gas for HI range. Does 3 point check in SINGLE or IND range modes.
LO-HI	Span calcs LO range with LO span gas, Span calcs HI range with HI span gas in AutoRange mode. Span calcs SINGLE or IND range with HI span gas. LO span is cal check only.	Span checks LO range with LO span gas, Span checks HI range with HI span gas. Does 2 point check in SINGLE or IND range mode.
LO	Span calcs LO range with LO span gas. Span calcs SINGLE or IND range with LO span gas.	Span checks LO range with LO span gas. Span checks SINGLE or IND range with LO span gas.
HI	Span calcs on HI range with HI span gas. Span calcs SINGLE or IND range with HI span gas.	Span checks on HI range with HI span gas. Span checks SINGLE or IND range with HI span gas.

6.3 Isolated 4-20 mA Current Loop Option

The M9110AH comes equipped with 4-20mA current loop. The electrical ground of this output is part of the instrument ground. In certain applications the instrument ground must be isolated from the external ground. For applications requiring electrical isolation, we offer optional isolated current loop outputs. With the exception of electrical isolation, the setup and usage is identical to the standard equipment current loop output. The calibration procedure is located in the Troubleshooting Section 9.

6.4 Molybdenum Converter Option

The Molybdenum Converter is used in applications where the NO₂ concentration will not be expected to exceed 5 ppm. In these applications it exhibits very high conversion efficiencies, thus enabling the accurate measurement of low concentrations of NO₂. Operating the Converter where the concentrations exceed 5 ppm will cause lower efficiencies and will shorten the life of the converter.

6.5 External Desiccant Canister Option

This Option is located between the PermaPure Dryer and the ozone flowmeter. See Figure 2-2 for location and Figure 8-5 for pneumatic schematic. It is mounted external to the analyzer. It should be used at extremely humid sites, or where the -70 C dewpoint air produced helps in reducing reaction cell contamination and window clouding.

6.6 Alternate Bypass Flow Orifice Option

The standard bypass flow is 250 cc/min. For those applications requiring a higher sample flow, this option provides a 500 cc/min bypass flow. The overall sample flow is 550 cc/min with this option installed. The orifice is located in the vacuum manifold at the rear of the instrument see Figure 2-5.

6.7 External Converter Option

The M9110AH can be ordered with an External Thermal Converter. Its conversion performance is very similar to the Mini HiCon. The advantage of this converter is that it is less prone to plugging because it is constructed of larger diameter tubing, also the conversion efficiency is very high because the thermal converter is followed by a molybdenum converter. Since the converter is external to the M9110AH the response of the instrument is considerably slower if operated in the NO/NO_x switching mode. This is due to the larger internal volume that must be purged during the NO/NO_x measurement cycle. This effect is less noticeable if the M9110AH is being operated in the NO_x only mode.

The External Thermal Module contains 2 converters, a high temperature stainless steel and a molybdenum converter. While this combination produces very high conversion efficiencies, the life of the moly must be considered. If high levels of NO₂ are expected in the sample stream, the high temperature converter converts only about 90 % of the total NO₂, the moly must convert the rest. Since the moly operates by reacting the molybdenum metal with the NO₂, its lifetime can be quite short if high levels (>50 ppm) of NO₂ are present.

In instruments that have the external converter option, the Mini HiCon housing assembly contains only the catalytic ozone killer and a heater to keep the ozone catalyst temperature at 200 C. Its temperature is monitored in the TEST function O3KL.

INTENTIONALLY BLANK

7 CALIBRATION AND ZERO/SPAN CHECKS

There are several ways to check and adjust the calibration of the M9110AH. These different methods are summarized in the following Table 7-1. In addition, all of the methods described in this section can be initiated and controlled via the RS-232 port, see Section 5.7 for details.

We strongly recommend that SPAN CALIBRATION be done with NO span gas. Since NO is unaffected by the converter, both channels can be accurately calibrated. It is also important that there be some oxygen in the span gas. Inaccurate calibration of the NO_x channel can result from calibration gasses containing no oxygen. All calibration gasses must have a dew point of < -20° C.

NOTE

The quality of calibration can be no better than the accuracy and quality of the calibration gasses used. See Section 7.9 Calibration Quality for recommendations on calibration gasses and Section 9.2. 0.

NOTE

If there are any problems completing any of the following procedures, refer to Section 9.2.8 and 9.2.9- Unable to Span or Zero.

Before Calibration

1. Use the SETUP-RNGE menu to set the range the instrument will be operated in.
2. If you are using any of the following features, they must be set up before calibration:
 - A. Autoranging or Remote Ranging - See Section 7.7
 - B. Independent Ranges - See Section 7.8
 - C. NO only or NO_x only mode, Section 7.5 and 7.6

Normal calibration assumes that these features are already set up.

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

Section	Type of Cal or Check	Description
7.1	Manual Z/S Check or Calibration with span gas in the sample port	This calibration method uses calibration gas coming in through the sample port. Zero/Span valves do not operate.
7.2	Manual Z/S Check or Calibration with Z/S Valve Option.	How to operate Zero/Span Valves Option. Can be used to check or adjust calibration.
7.3	Dynamic Z/S Calibration with Z/S Valves Option	Operates Z/S valves periodically and adjusts calibration.
7.4	Use of Z/S Valves with Remote Contact Closure	Operates Z/S valves with rear panel contact closures. Without valves, can be used to switch instrument into zero or span cal mode. Used for either checking or adjusting zero/span.
7.5	NO Only Mode Calibration	Covers requirements if calibrating in NO only mode.
7.6	NO _x Only Mode Calibration	Covers requirements if calibrating in NO _x only mode.
7.7	Calibration Requirements for AutoRange or Remote range	Covers special requirements if using AutoRange or Remote Range control.
7.8	Calibration Requirements for Independent Ranges	Covers special requirements if using Independent Range
7.9	Calibration Quality	Information on how to determine if the calibration performed will result in optimum instrument performance.
7.10	Converter Efficiency Compensation	Covers methods to automatically compensate for converter efficiency.

7.1 Manual Zero/Span Check or Cal With Zero/Span Gas in the Sample Port

The calibration of the instrument can be checked or adjusted using gas coming in the sample port. This method is often used when the calibration gas is supplied from the stack sample probe or external tank and valve system. This is the calibration method to use if the instrument is purchased without the Zero/Span Valve option.

Table 7-2 details the zero calibration procedure with zero gas coming in through the sample port.

Table 7-2: Manual Zero Calibration Procedure - Zero Gas Thru Sample Port

Step Number	Action	Comment
1.	Check "Before Calibration"	Check "Before Calibration" Section 7 above before proceeding.
2.	Press CAL	The M9110AH enters the calibrate mode from sample mode. The zero gas must come in through the sample port.
3.	Select LO or HI Range	If AutoRange is enabled you will be prompted for which range to calibrate. Select the LO or Hi range, then press ENTR.
4.	Wait 10 min	Wait for reading to stabilize at zero value.
5.	Press ZERO	If you change your mind after pressing ZERO, you can still press EXIT here without zeroing the instrument.
6.	Press ENTR	Pressing ENTR actually changes the calculation equations.
7.	Press EXIT	M9110AH returns to sampling. Immediately after calibration, data is not added to the DAS averages.

Enter the expected NO_x and NO span gas concentrations:

Table 7-3: Enter Expected Span Gas Concentrations Procedure

Step Number	Action	Comment
1.	Check "Before Calibration"	Check "Before Calibration" Section 7 before proceeding.
2.	Press CAL-CONC-NOX	This key sequence causes the M9110AH to prompt for the expected NO _x concentration. Enter the NO _x span concentration value by pressing the key under each digit until the expected value is set. This menu can also be entered from CALS or CALZ.
3.	Press ENTR	Pressing ENTR stores the NO span value and returns the prompt to the CONC menu.
4.	CAL-CONC-NO	This key sequence causes the M9110AH to prompt for the expected NO concentration. Enter the NO span concentration value by pressing the key under each digit until the expected value is set. This menu can also be entered from CALS or CALZ
5.	Press ENTR	Pressing ENTR stores the NO span value and returns the prompt to the CONC menu.
6.	Press EXIT	Returns instrument to SAMPLE mode.

If desired, compensation for converter efficiency (CE) can be included in the NO_x and NO₂ concentration calculation. The CE must be entered prior to calibration. Refer to Section 7.9 for the CE procedure

Table 7-4: Manual Span Calibration Procedure - Span Gas Thru Sample Port

Step Number	Action	Comment
1.	Check "Before Calibration"	Check "Before Calibration" Section 7 before proceeding.
2.	Press CAL	The M9110AH enters the calibrate mode. NO span gas should be fed to the sample port.
3.	Select LOW or HIGH	If AutoRange is selected, it is necessary to select which range to calibrate. This prompt will not be displayed unless Autorange or Remote range is selected.
4.	Wait 10 min	Wait for reading to stabilize at span value.
5.	Press SPAN	If you change your mind after pressing SPAN, you can still press EXIT here without spanning the instrument.
6.	Press ENTR	Pressing ENTR actually changes the calculation equations and causes the instrument to read the expected NO and NO _x span concentrations.
7.	Press EXIT	M9110AH returns to sampling. Immediately after calibration, data is not added to the DAS averages.

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

The Zero/Span valve option can be operated from the front panel keyboard as described below. The Zero/Span valves allow zero and span gas come in through ports on the rear panel of the instrument. The Zero/Span valves can be set up to operate automatically on a periodic schedule. See Section 6.2 to setup automatic zero/span feature.

Table 7-5: Manual Zero Check Procedure - Z/S Valves

Step Number	Action	Comment
1.	Check "Before Calibration"	Check "Before Calibration" Section 7 before proceeding.
2.	Press CALZ	The analyzer enters the zero calibrate mode. This switches the sample/cal and zero valve to allow zero gas to come in through the zero gas inlet port in the rear panel.
3.	Select LO or HI range	If AutoRange is enabled you will be prompted for which range to calibrate. Select the LO or HI range, then press ENTR.
4.	Wait 10 min	Wait for reading to stabilize at zero value.
5.	Press ZERO	If you change your mind after pressing ZERO, you can still press EXIT here without zeroing the instrument.
6.	Press ENTR	Pressing ENTR actually changes the calculation equations, forcing the reading to zero.
7.	Press EXIT	M9110AH returns to sample mode. Immediately after calibration, readings do not go into the DAS averages.

Refer to Table 7-3 to enter expected NO and NO_x values.

Table 7-6: Manual Span Check Procedure - Z/S Valves

Step Number	Action	Comment
1.	Press CALS	The M9110AH enters the span calibrate mode and switches the Z/S valves to admit NO span gas.
2.	Select LO or HI range	If AutoRange is enabled you will be prompted for which range to calibrate. Select the LO or HI range, then press ENTR
3.	Wait 10 min	Wait for reading to stabilize at span value.
4.	Press SPAN	If you change your mind after pressing SPAN, you can still press EXIT here without spanning the instrument.
5.	Press ENTR	Pressing ENTR actually changes the calculation equations and causes the instrument to read the expected NO and NO _x span concentrations.
6.	Press EXIT	The Zero/Span valves are switched back to admit gas through the sample port and instrument returns to SAMPLE mode. Immediately after calibration, data is not added to the DAS averages.

7.3 Dynamic Zero/Span Calibration Using AutoCal

The M9110AH can be automatically calibrated periodically using the Zero/Span Valve Option and features in the AUTOCAL menu. The Dynamic Zero/Span feature can be enabled when an AutoCal Sequence is set up. Refer to Section 6.2 for information.

With the Dynamic AutoCal in operation, the M9110AH is being continuously re-calibrated. We recommend that the quality of the calibrations be carefully monitored to assure that the instrument is performing correctly. Subtle fault conditions can sometimes be masked by continuous re-calibration.

7.4 Use of Zero/Span Valves with Remote Contact Closure

The Zero/Span valve option can be operated using Remote Contact Closures provided on the rear panel. See Figure 2-2 for connector location and pinout. There are 3 sets of contacts on the rear panel. They operate the zero valve, LO span valve, and HI span valve. To operate the valves, they must be held closed for at least 1 second. The valve will remain in operation for as long as the contacts are closed. In order to operate the valves again, the contact closures should be held open for at least 1 second, then may be closed again.

The default action is to do a span check when the valves are operated. A span check does not calibrate the instrument when the valves are operated. To calibrate the M9110AH when the valves are operated, go to the VARS section on the front panel menus. Press SETUP-MORE-VARS, then scroll to DYN_ZERO,

DYN_LO_SPAN or DYN_HIGH_SPAN, and set the variable to ON. With the variable in the ON state, the M9110AH will calibrate when the contact closure is released.

Table 7-7 shows what type of check is performed based on the settings of the three contact closures.

Table 7-7: Z/S Valve Modes with Remote Contact Closure

External Zero Contact Closure	External LO Span Contact Closure	External HI Span Contact Closure	Operation
Open	Open	Open	State when in SAMPLE mode, normal monitoring.
Open	Closed	Open	Low Span check or calibrate*
Open	Open	Closed	High Span check or calibrate*
Closed	Open	Open	Zero check or calibrate*

*Calibrate only if Dynamic Calibration Variable is ON

7.5 NO Only Mode Calibration

For details on the operation of this mode, check Section 5.4. In NO only mode, the span check or span calibration is operated using the same procedures covered in Sections 7.1 to 7.4. The main difference to note is that only one channel, namely the NO channel will be checked or calibrated. For example in Table 7-3 - Entering the Expected Span value, only the NO concentration is required. The NO/NO_x valve is continuously in the NO mode. And since the converter is never switched into the sample gas stream, none of the converter efficiency procedures apply.

7.6 NO_x Only Mode Calibration

For details on the operation of this mode, check Section 5.4. In NO_x only mode, the span check or span calibration is operated using the same procedures covered in Sections 7.1 to 7.4. The main difference to note is that only one channel, namely the NO_x channel, will be checked or calibrated. For example in Table 7-3 - Entering the Expected Span value, only the NO_x concentration is required. The NO/NO_x valve is continuously in the NO_x mode.

Since the instrument is always in NO_x mode it is not possible to apply converter efficiency compensation to the NO_x value. This is because the efficiency should only be applied to the NO₂ portion of the signal. The valve never switches to measure the proportion of NO in the sample gas, therefore the fraction of the sample that is NO₂ is unknown.

It is recommended that the converter efficiency be measured when the instrument is calibrated. This procedure is covered in Section 7.9.

7.7 Calibration Requirements for AutoRange or Remote Range

In AutoRange there are two separate calibrations for Low range and High range. That is there are 2 independent slopes and 2 offsets and 2 sets of converter efficiency parameters. The instrument applies the appropriate values depending on whether the instrument is in low range or high range.

Table 7-8: Calibration Requirements for AutoRange or Remote Range

No matter which calibration method you choose from this chapter, all of the following parameters must be set to properly calibrate the instrument on AutoRange or Remote range.

Parameter	Low Range	High Range
Range	Low Range is selected by pressing CONC-LO on the front panel.	High Range is selected by pressing CONC-HI on the front panel
Slope	NO _x and NO slopes for low range are set by span calibration	NO _x and NO slopes for high range are set by span calibration
Offset	NO _x and NO offsets for low range are set by zero calibration	NO _x and NO offsets for high range are set by zero calibration
Converter Efficiency	CE can be set by one of the procedures in Section 7.10. Converter efficiency is optional.	CE can be set by one of the procedures in Section 7.10. Converter efficiency is optional.

7.8 Calibration Requirements for Independent Range

In Independent Range mode there is one set of calibration parameters. That is, NO_x and NO slopes and NO_x and NO offsets, and one converter efficiency parameter. The calibration of the M9110AH using independent range is the same as calibration in single range. To achieve independent ranges, the computer scales the 3 outputs using the ranges keyed in by the operator.

7.9 Calibration Quality

After calibration is complete, it is very important to check the QUALITY of the calibration. The calibration of the M9110AH involves balancing several sections of electronics and software to achieve optimum accuracy, noise, linearity and dynamic range.

The slope and offset parameters are similar to the span and zero pots on an analog instrument. Just as in the analog instrument, if the slope or offset get outside of a certain range, the instrument will not perform as well.

The slope value will be slightly different on the NO and NO_x channels. This is due to slight differences in pneumatic resistance in each pathway. If the slopes are significantly different, there is a calibration error or a cross port leak in the switching valve. If there is a sudden change in slopes after a calibration, that usually indicates a change in reaction cell pressure. Check the Troubleshooting Section 9.

The offset value gives information about the background signal level. Check the observed offset value against the factory value in Table 2-1. If significantly higher, check Section 9.1.6. Increasing readings are a predictor of problems.

Table 7-9: Calibration Quality Check

Step Number	Action	Comment
1.	Scroll the TEST function menu until the NO _x SLOPE is displayed.	The SLOPE value for NO _x should be 1.0 ± 0.3. If the value is not in this range, check Section 9.1.6. If the SLOPE value is in the acceptable range the instrument will perform optimally.
2.	Scroll the TEST function menu until the NO _x OFFSET is displayed.	This number should be near zero. A value of 0.0 - 50 indicates calibration in the optimal range. This number already has the AutoZero value subtracted out and is mainly the background signal due to the molybdenum converter. If the OFFSET value is outside this range, check Section 9.1.6.
3.	Scroll the TEST function menu until the NO SLOPE is displayed.	The SLOPE value for NO should be 1.0 ± 0.3. If the SLOPE is in the acceptable range the instrument will perform optimally. If the value is not in this range, check Section 9.1.6. NOTE: The NO and NO _x slopes should be equal within ± 0.1.
4.	Scroll the TEST function menu until the NO OFFSET is displayed.	The instrument will now display the NO OFFSET value. It should also have a value near zero (0.0 - 50). This number already has the AutoZero reading subtracted out and should be near zero. If the OFFSET value is outside this range, check Section 9.1.6.

7.10 Converter Efficiency Compensation

The converter efficiency factor compensates NO₂ readings for converter efficiency. The NO₂ component of the NO_x reading is also compensated when instrument is in switching mode. An efficiency factor of 1.0 disables efficiency compensation, acceptable values are .80 to 1.20. There are some fault conditions that can be revealed by a NO₂ channel linearity check, such as a faulty switching valve or a partially plugged converter. For the converter to operate properly there should be at least a few percent oxygen present in the sample stream.

There are 2 ways to enter the NO₂ converter efficiency.

Method 1. is covered in Table 7-10.

Table 7-10: Converter Efficiency - Automatic Calculation

Step Number	Action	Comment
1.	Preparation	Make sure a calibration is completed before setting up Converter efficiency.
2.	Press CAL-CONC-CON-NO2	Enter the expected NO ₂ concentration, then press ENTR
3.	Input a known concentration of NO ₂ calibration gas.	Allow reading to stabilize for 10 minutes.
4.	Press CAL-ENTR	By pressing ENTR the M9110AH will calculate the ratio of the observed to expected NO ₂ and will use that ratio to compensate future NO ₂ readings. The calculated value can be seen by pressing the SET button. NOTE: The CAL button will come on only if the Instrument is measuring NO ₂ gas and ratio is between the limits of 0.80 - 1.20.
5.	Press EXIT	EXIT will return instrument to SAMPLE mode.

Method 2.

If the converter efficiency is determined by some external means, the value can be directly entered. Press CAL-CONC-CON-SET, then key in the ratio and press ENTR, then EXIT.

7.11 Recommendations for CEM Applications

7.11.1 Calibration Gasses

The following is our recommendation for calibration gasses and equipment for the M9110AH.

Regulator Specifications:

Ultra high purity, two-stage stainless steel body with stainless steel diaphragms, Tefzel and Teflon seats and seals, CGA 660 type. Gauges are 0-4000 psig inlet with 0-100 psig outlet.

Nitric Oxide Calibration Gas specifications:

Use NO in nitrogen, EPA protocol 1, NIST traceable (long lead item, order early) for CEMS Certification Test gas and acid rain applications.

Use NO in nitrogen at 80% of calibration range ± 2% for routine calibration.

Example: Order 80 ppm NO in N₂ if calibrating the 0-100 ppm range.

NOTE

It is important to note that if you are using blended calibration gases, other components of the blend can interfere with the NO concentration value. This can affect calibration accuracy and linearity. See Section 9.2.10 for additional details.

Zero Air:

Ultra Zero Grade Air, 99.999% pure

Nitrogen:

Ultra High purity Nitrogen, 99.999% pure

7.11.2 Calibration Frequency

Typically, the data acquisition system will perform a daily calibration. This consists of switching valves to have calibration gas introduced at the sample probe and passing through the entire sample induction system. The instrument or data acquisition system's slope and offset will be adjusted to produce the correct response of the system.

Once per quarter, the M9110AH should be calibrated using one of the procedures in Section 7. Also a 3 point linearity check (zero, low span, high span) will be performed to confirm system linearity.

It is important to note that when doing a linearity check, the calibration gasses have analysis errors. For example if ± 2% standards are being used, the linearity could be theoretically be as much as 4% in error, even if the instrument and sample induction system are "perfect". TELEDYNE recommends that EPA Protocol 1 (± 1%) gasses be used for linearity checks to minimize non-linear responses due to analysis errors of the gas bottles.

7.11.3 Converter Efficiency

In many applications the NO₂ concentration is low enough (<5%) that converter efficiency checks are not required. If your application requires an efficiency check, refer to 40 CFR, Part 60 Method 7E for the recommended procedure. Refer to Section 7.10 if automatic converter efficiency compensation is required.

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8 MAINTENANCE

8.1 Maintenance Schedule

NOTE

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



Table 8-1: Preventative Maintenance Schedule

Item	Maintenance Interval	Reference Section
TEST functions	6 - 12 month intervals	Table 9-1
Zero/Span Calibration	Annually or after repairs	Section 7
Zero/Span checks	Daily	Section 7, Table 6-2
Particulate Filter	Weekly as needed	Figure 8-1
Filter for PermaPure Drier	Replace every 24 months	Figure 9-7
Filter for Ozone Scrubber	Replace every 24 months	Figure 4-2
Drierite Canister	Replace when Drierite changes from blue to red.	Section 9.3.6
Reaction cell window	Clean annually or as necessary	Section 9.3.8, Figure 8-3
Ozone Flow	Check TEST function every year	Figure 9-7, Section 9.3.7
Sample Flow	Check TEST function every year	Figure 8-4, Figure 8-5 Section 9.3.7
Converter	Check efficiency every 6 months	Figure 8-2, Section 7.9
Pneumatic Lines	Examine every 12 months, clean if necessary	Figure 8-5, Figure 8-6
Factory Calibration	Calibrate each year or after repairs	Section 9.1.6
Leak Check	Check every year or after other maintenance.	Section 8.6, 9.3 10
Rx Cell O-rings	Replace every 12 months	Figure 8-3
O-rings	Replace every 12 months	Figure 9-9, Figure 9-10

8.2 Replacing the Sample Particulate Filter

The particulate filter should be inspected often for signs of plugging or contamination. It is also common for dirt particles to absorb NO₂, thus causing the reading to be low. A discoloration of the filter membrane indicates that the filter is dirty and should be changed.

To change the filter:

1. Locate the sample filter on the outside rear panel.
2. Unscrew the hold-down ring, remove the Teflon o-ring and then the filter disc. See Figure 8-1 for an exploded view of the filter assembly.
3. Replace the filter, being careful that the element is fully seated in the bottom of the holder. Replace the Teflon o-ring, then screw on the hold-down ring and hand tighten.

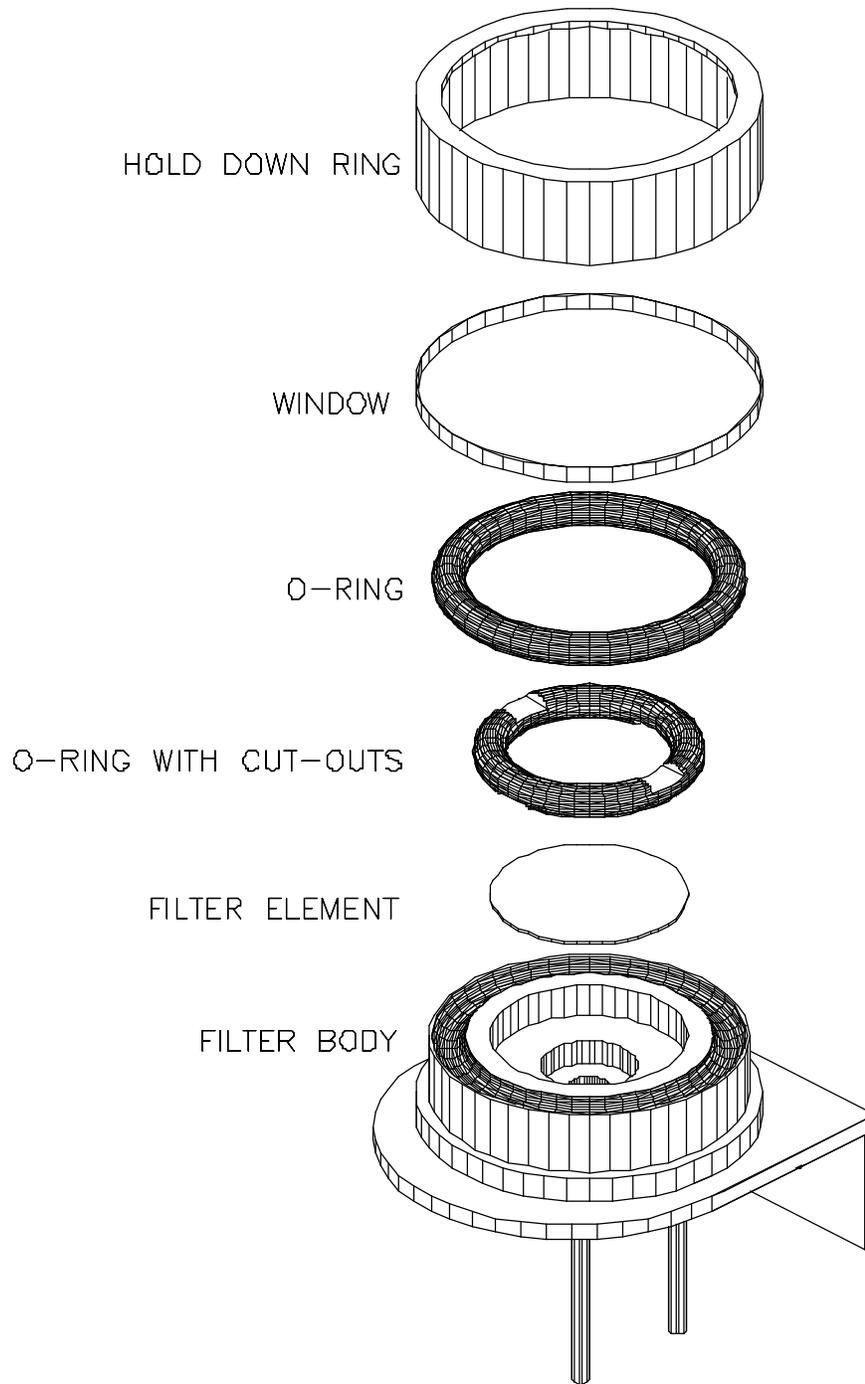


Figure 8-1: Replacing the Particulate Filter

8.3 Replacing the Converter

The Converter is located in the center of the instrument, refer to Figure 2-5 for its location. The heater, thermocouple, ozone scrubber and converter are designed to be replaced as a single unit.

1. Turn off the power to the M9110AH and allow the converter to cool.
2. Remove the entire assembly from the chassis:

CAUTION

The converter operates at about 700 C. Severe burns can result if not enough time is allowed for the assembly to cool. Do not handle assembly until it is at room temperature.



- A. Remove the pneumatic fittings from the valves.
 - B. Remove the Molex connectors to the valve bracket, thermocouple wire and cartridge heater.
 - C. Remove the converter assembly from the chassis by loosening the 4 captive screws that secure the assembly to the chassis.
3. Disconnect the gas fittings and power cable grounding from the can.
 4. Remove the valve assembly and bottom bracket and re-attach those two parts to the replacement converter assembly.
 5. Re-attach the pneumatic fittings and valve assembly to the can.
 6. Install the assembly back into the analyzer. Re-attach the electrical and pneumatic fittings. Leak check the assembly when completed.
 7. Turn the power back on. The insulation can emit a burnt odor for the first 24 hours, this is normal. Allow the converter to burn-in for 24 hours, then re-calibrate the instrument.

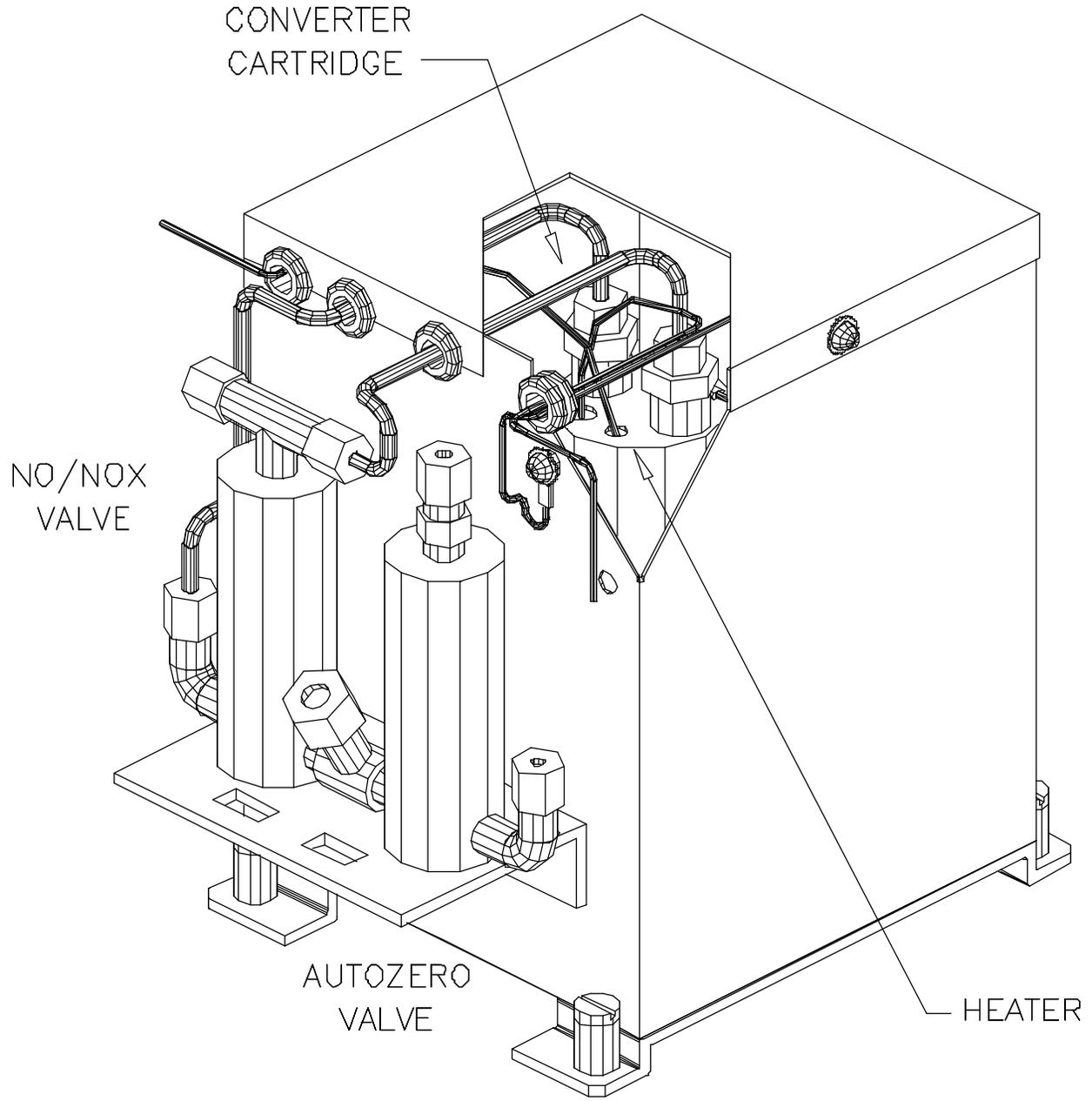


Figure 8-2: Converter Assembly

8.4 Cleaning the Reaction Cell

The reaction cell should be cleaned whenever troubleshooting points to it as the cause of the trouble. A dirty cell and window will cause excessive noise, unstable span or zero, or low response. To clean the reaction cell it is necessary to remove the reaction cell from the sensor housing. Use the following guide:

1. Turn off the instrument power and vacuum pump.
2. Loosen the hold down screws for pneumatic sensor assembly & move the assembly to the side.
3. Disconnect the exhaust fitting and inlet fittings. See Figure 8-3.
4. Loosen four screws holding the reaction cell to the sensor.
5. Disconnect heater/thermistor and lift the cell away.
6. The reaction cell will separate into two halves:
 - A. The manifold assembly
 - B. The reaction block with reaction sleeve and window
7. Push the reaction sleeve and window gently out of the reaction cell. Clean the assembly with any of the following:
 - A. Ammonia free glass cleaner.
 - B. Baking soda (sodium bicarbonate) and water solution.
 - C. Simple Green 10:1 dilution.

Rinse with distilled or de-ionized water, wipe with a clean tissue, and dry. It is normally not necessary to clean the ozone flow or sample flow orifices because they are protected by fritted filters. However, the following procedure is included here for completeness.

8. The manifold assembly should be cleaned by removing the o-ringed fittings, springs, fritted filter, orifices and O-rings from the ozone inlet. (NOTE: That the sample inlet does not contain a sample flow control orifice. The sample flow control orifice is located in a heated block at the rear of the instrument.) It is suggested that the orifice, filter and o-rings be replaced unless an ultrasonic cleaner and methanol or methylene chloride is available. Both orifice and sintered filter may be cleaned in either solvent by an ultrasonic bath for 30 minutes. Replace o-rings.
9. Do not remove the sample and ozone nozzles. They are Teflon threaded and require a special tool for re-assembly. If necessary, the manifold with nozzles attached can be cleaned in an ultrasonic bath.

10. Reassemble in the reverse order of disassembly, being sure to seat the paper gasket in the reaction cell before installing the window. After inserting the window, drop the o-ring in before inserting the sleeve. Reconnect pneumatics and heater connections, then re-attach the pneumatic sensor assembly.
11. Perform leak check procedure covered in Section 8.6. Perform light leak procedure covered in Section 8.7. The cleaning procedure is complete.
12. The analyzer span response will fall 10-12% in the first 1-2 days after cleaning due to the window re-conditioning.

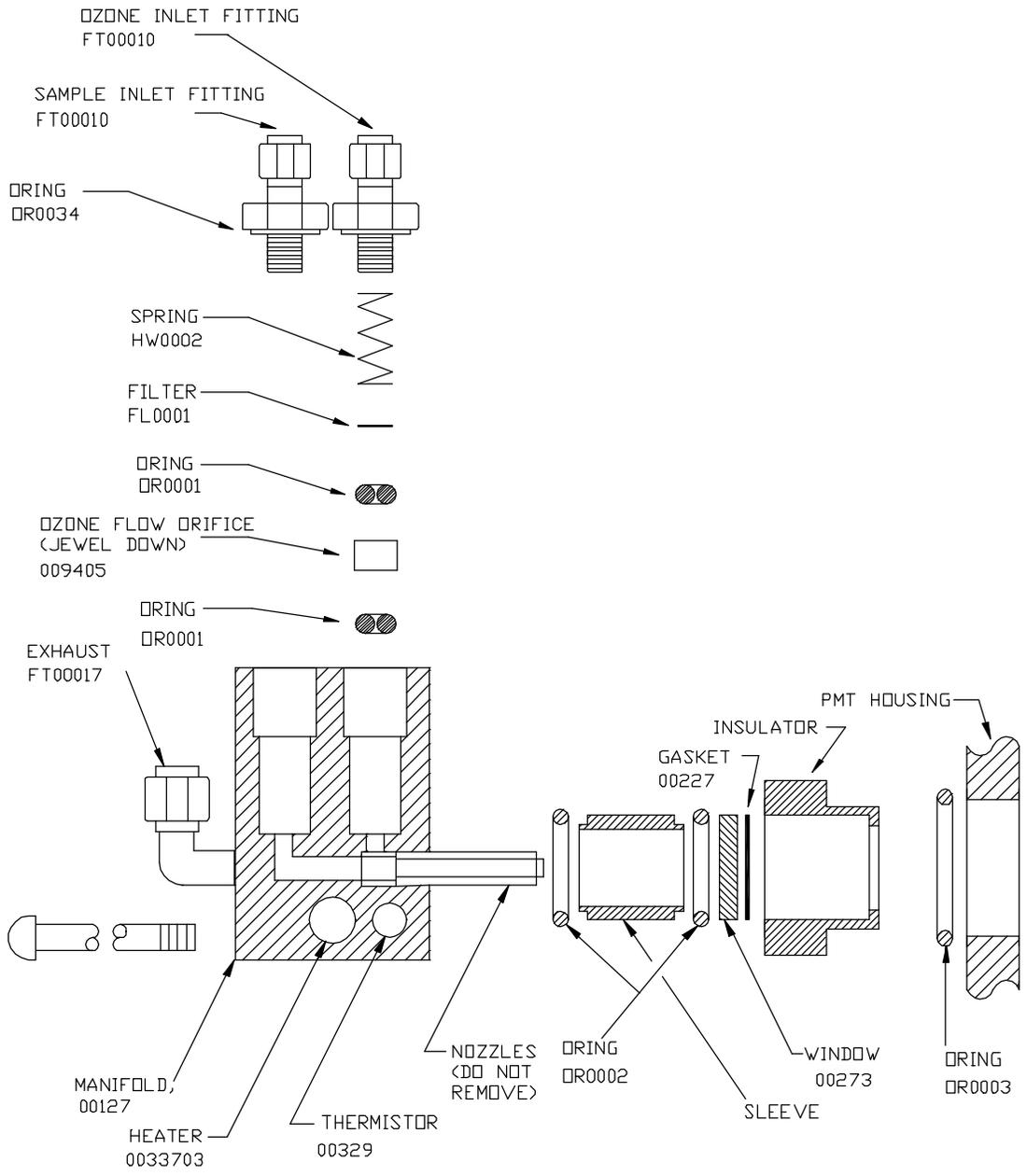


Figure 8-3: Reaction Cell Assembly

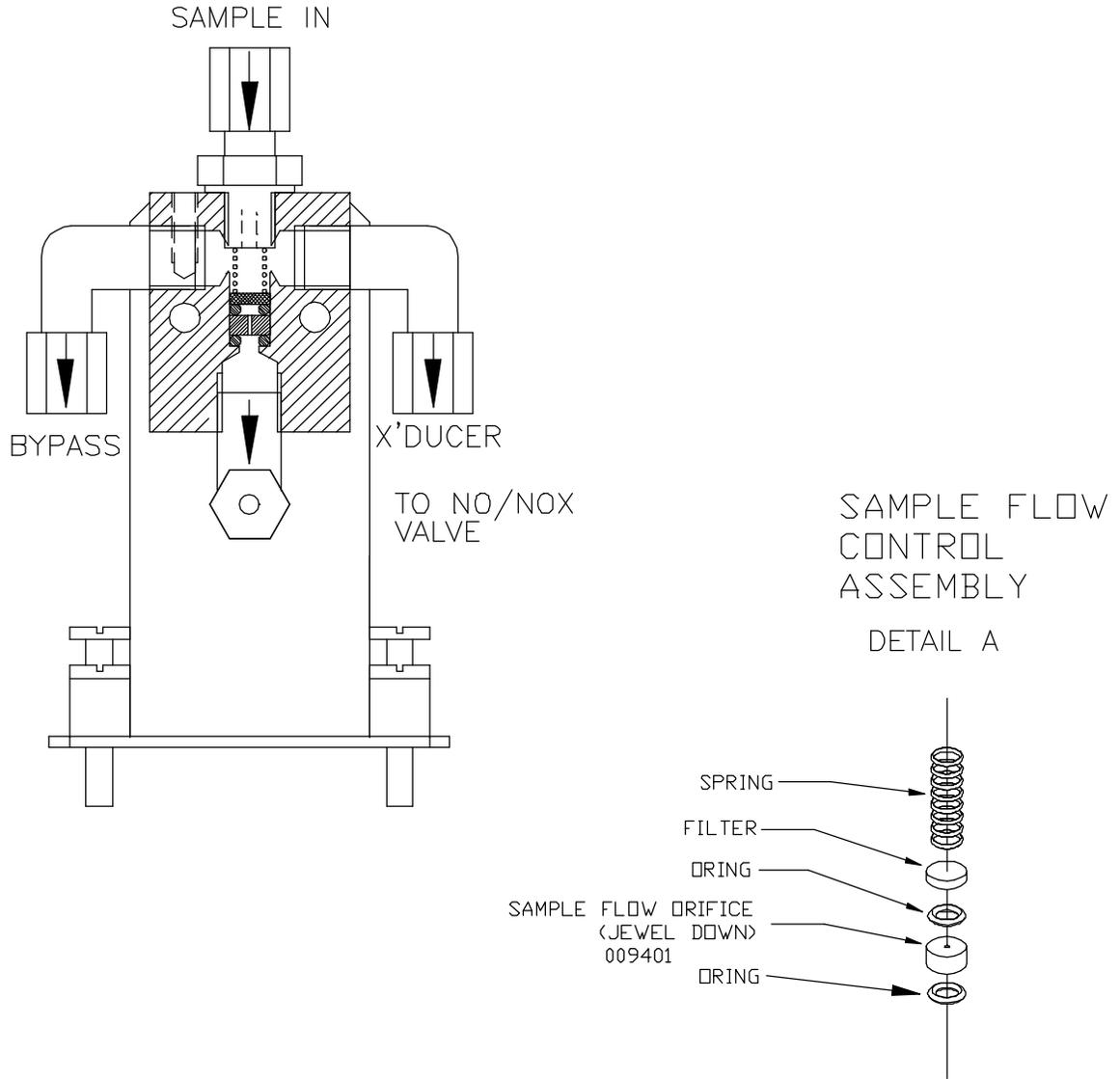


Figure 8-4: Sample/Bypass Flow Control Assembly

8.5 Pneumatic Line Inspection

Particulate matter in the pneumatic lines will affect both flow rate and response time. It is important that the pneumatic system be periodically inspected and thoroughly cleaned if necessary. Clean by disassembling and passing methanol through three times. Dry with nitrogen or suitable clean zero air.

Also inspect all pneumatic lines for cracks and abrasion on a regular basis. Replace as necessary. Refer to the pneumatic diagram in Figure 8-5, Figure 8-6.

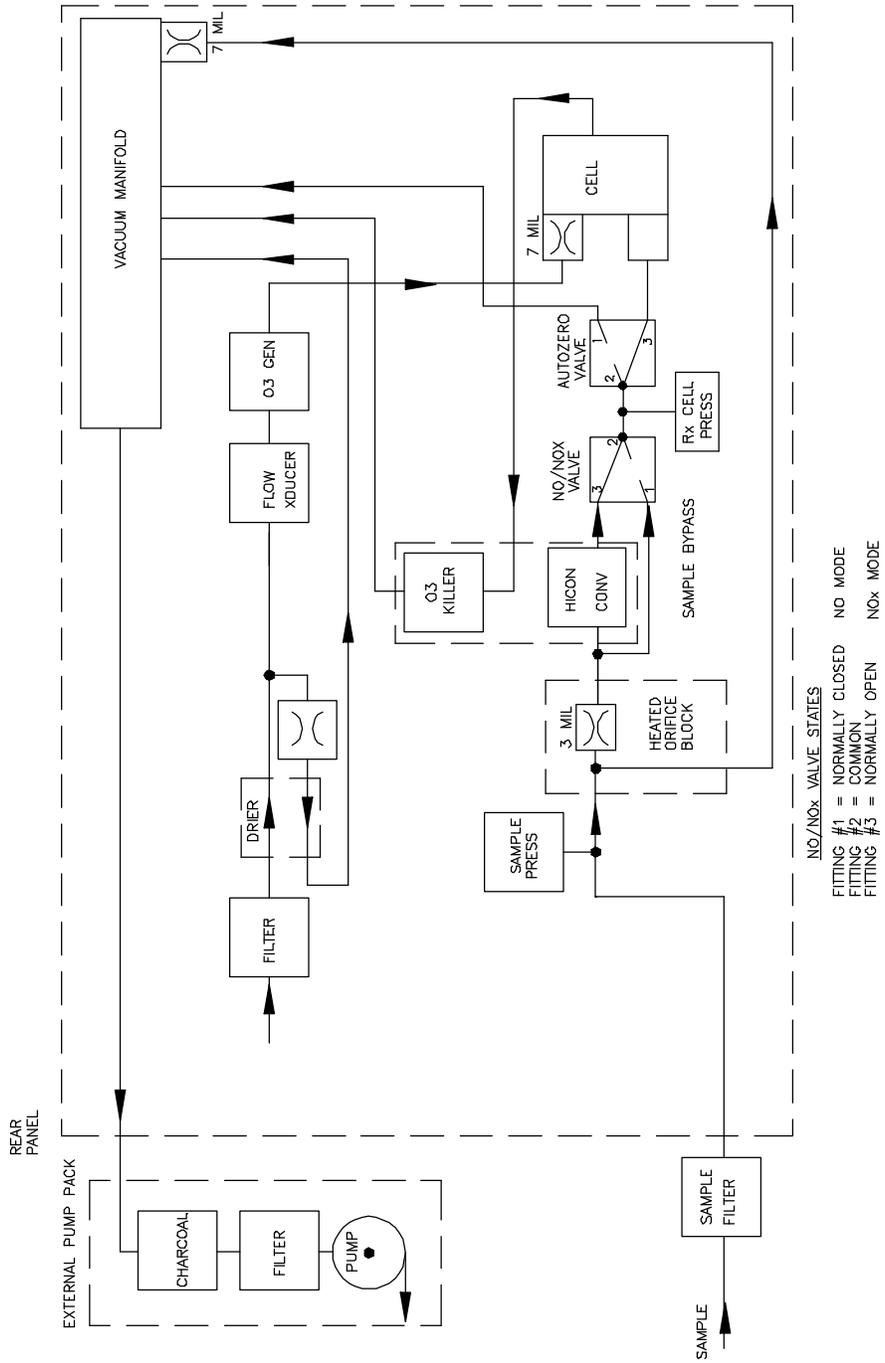


Figure 8-5: Pneumatic Diagram

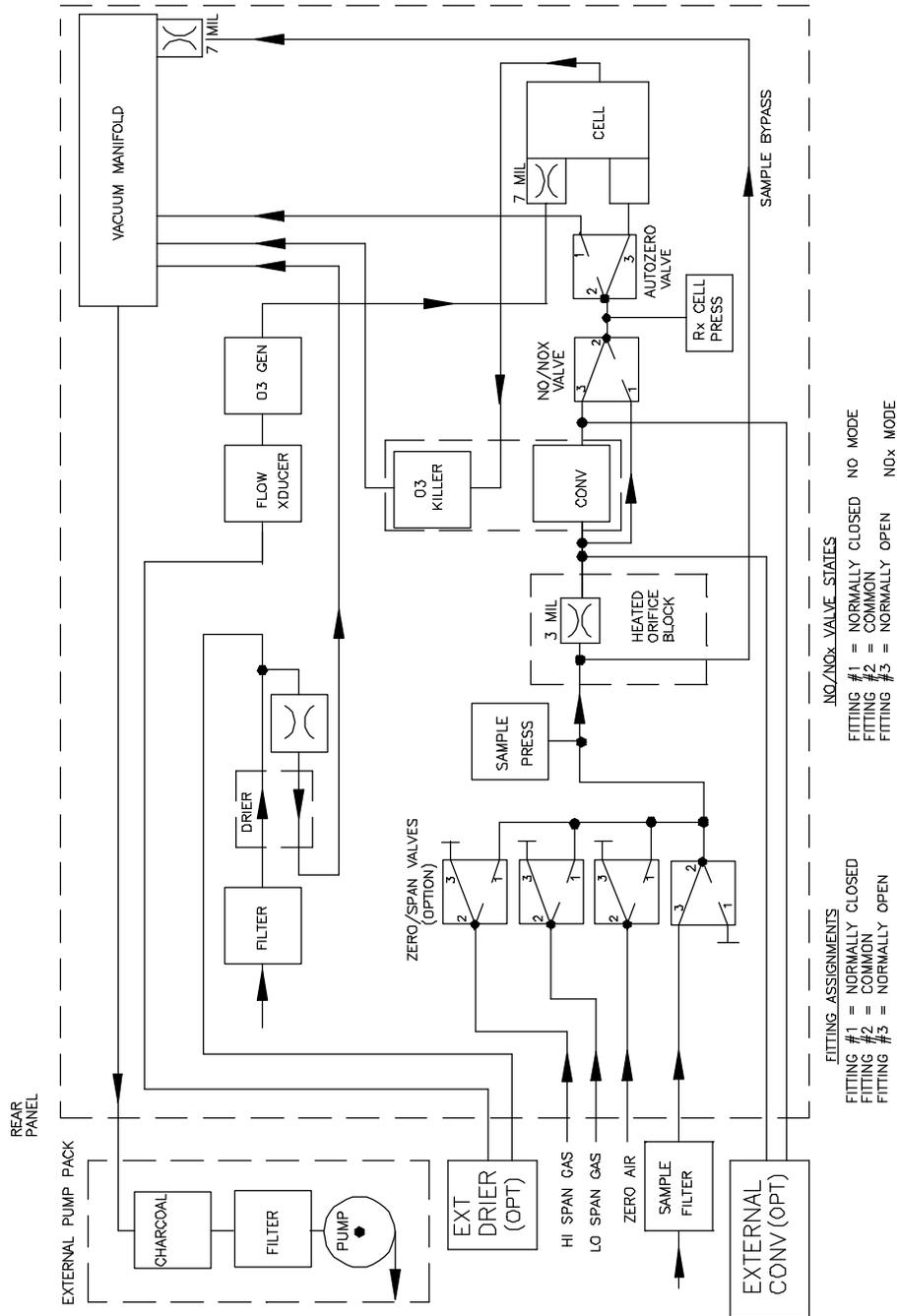


Figure 8-6: Pneumatic Diagram with Zero/Span Valves

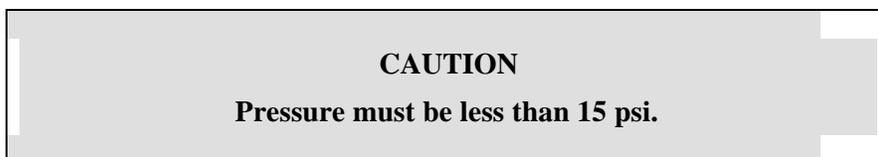
8.6 Leak Check Procedure

If a leak checker is not available, it is possible to leak check the instrument using the M9110AH's pump plus a shut-off valve.

1. Turn off instrument power and pump power.
2. Cap the sample inlet port, ozone generator air inlet, and zero air inlet (if Z/S valve option present).
3. Insert a shut-off valve between the sample pump and the vacuum manifold at the rear of the instrument.
4. Turn on the sample pump and set the TEST function to RCEL, which measures the reaction cell pressure. Turn off the shutoff valve and monitor the cell pressure. The pressure should not drop more than 1 PSI in 5 minutes.

If you have a leak checker:

1. Turn off instrument power and pump power.
2. Disconnect pump at rear panel. Cap the sample inlet port, ozone generator air inlet, and zero air inlet (if Z/S valve option present) and connect leak checker to exhaust port.



3. Pressurize system and check for leaks by watching overall pressure. The pressure should not drop more than 1 “-Hg in 5 minutes (0.5 PSIG in 5 min).

If instrument fails pressure test, each fitting needs to be leak checked with soap solution to find the location. Be careful that the system is always pressurized so as not to draw soap solution into the plumbing system. Make sure you dry off any accumulated soap solution. Refer to Figure 8-4, Figure 8-5 for pneumatic diagrams.

8.7 Light Leak Check Procedure

1. Scroll the TEST functions to PMT.
2. Input zero gas.
3. Shine a powerful flashlight or portable incandescent light at the inlet and outlet fitting, and at all the joints of the reaction cell. The PMT value should not respond to the light.

If there is a response, tighten the joints or replace the tubing with new black PTFE tubing. We often find light leaks are caused by o-rings being left out of the sensor assembly.

8.8 Prom Replacement Procedure

Preparation: If any setup changes such as RANGE, AUTOCAL, ON/OFF etc. have been made, record the changes because all settings should be checked after the PROM is changed. See Figure 9-2 for location of prom on CPU card.

1. Turn the machine off.

NOTE

The PROM is static sensitive, be sure that you are properly grounded before handling any of the electronics.



2. Remove the hold down screw that holds in the V/F-CPU assembly to the motherboard. Disconnect the J9 power connector from the motherboard. Gently lift the assembly far enough out of the instrument to remove the connector to the display and the RS-232 connector.
3. Locate the CPU board, which is attached to the larger V/F board.
4. Remove the CPU-V/F board assy, laying it down on an insulating surface such that the board edge pins on the PCB are on the left. The PROM chip will be at the top center. See Figure 9-2 for prom location. Gently pry the chip from its socket and replace it with the new chip. Install the chip in the left end of the socket with the notch facing to the right. Make sure that all of the legs insert into the socket correctly.
5. Re-attach the CPU board to the V/F board, re-connect the RS-232 and front panel display cables, and then re-attach the assembly to the motherboard.
6. Turn the M9110AH ON and observe the front panel display. As the machine goes through the setup the version number will be displayed on the front panel. It should read the same as the version number printed on the prom.
7. Check and re-enter if necessary any non-default settings such as RANGE or AUTOCAL. Re-enter the SPAN value. Check all settings to make sure that expected setup parameters are present.
8. Re-calibrate the machine so that the default slope and intercept are overwritten with the correct values.

9 TROUBLESHOOTING AND ADJUSTMENTS

NOTE

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



This section of the manual contains information on diagnosing and repairing instrument performance problems. It contains information on how to use and interpret TEST and DIAGNOSTIC data as well as WARNING messages the instrument generates. There is information on how to troubleshoot the instrument subsystems. Finally there is information on how to perform adjustments such as DAC calibration procedures.

This manual provides troubleshooting procedures that address problems to the board level. For component level troubleshooting, consult the schematics for the appropriate board in Appendix A.1.

NOTE

The values of the readings shown on the front panel of the instrument may at times read XXXXXX. This means that the reading is off scale and therefore meaningless.

General Troubleshooting Hints

1. Think of the analyzer as three sections:

Section 1: Pneumatics - Over 50% of all analyzer problems are traced to leaks in the pump, sample filter, instrument internal pneumatics, calibrator or external sample handling equipment. Suspect a leak first, and check Section 9.2.

Section 2: Electronics - data processing section. This can be readily checked out using Electric Test in Section 9.1.3.2.

Section 3: Optics - Optical section consisting of PMT, HVPS, Preamp, and signal processing. Refer to Section 9.1.3.3 on use of Optical Test.

2. Is the fault light on? If it stays on after your clear the warning messages, see Section 9.1.2
3. Compare the TEST functions to the factory values in Table 2-1, this will often provide important clues as to the problem. If discrepancies are noted see Table 9-1.

4. Pay special attention to the slopes, the slopes are the software equivalent of the span pot on an analog instrument. If the slopes are not 1.0 ± 0.3 the gain has changed, usually from a change in cell pressure (vacuum) - compare to value in Table 2-1. - possible causes:
 - A. Partially plugged ozone killer
 - B. Change of pump or malfunctioning pump
 - C. Plugged pneumatics
 - D. Miss-calibration
 - E. Change in altitude
5. Check the AutoZero reading in the TEST functions. Compare it to the value in the factory checkout Table 2-1. If it is significantly (>25 mV) higher, then:
 - A. Turn the ozone generator off (Use DIAG function). See if the AutoZero reading drops more than 25 mV.
 - B. If the reading drops, the reaction cell could be contaminated. Perform the cleaning procedure in Section 8.4.
 - C. If the reading remains high, there could be a light leak. Perform the procedure in Section 8.7. High readings also occur if the PMT has been recently exposed to high light levels, such as dis-assembly of the sensor assembly. This is normal. It usually requires 24 hours for levels to return to normal.
6. Check the Offset value in the TEST functions.

Compare it to the value in the factory checkout Table 2-1. If the reading is significantly greater than the factory test value, the reaction cell could be contaminated or there could be a light leak in the cell. Verify this fault by turning the ozone generator off and see if the AutoZero reading drops more than 25 mV.
7. Perform the leak check procedure in Section 8.6. If slopes are different from each other by > 0.3, this usually indicates a leak in the switching (NO/NO_x) valve, partially plugged converter, or improper calibration.
8. Incorrect span gas concentration - this could come either from wrong certificate on calibration gas bottle, incorrect flows or setup in the calibrator, or entering the expected span gas concentration incorrectly, see Table 7-3. If the instrument does not respond to span gas check 9.2.3.

The above should get you started in diagnosing and repairing the most common faults. If these reasons have been eliminated, the next thing to do is a Factory Calibration covered in Section 9.1.6 or check Section 9.2 for other fault diagnosis. If difficulties persist contact our service department. The toll free telephone number is on the cover page of this manual.

9.1 Operation Verification - Diagnostic Techniques

9.1.1 Fault Diagnosis with TEST Variables

The Table 9-1 indicates possible fault conditions that could cause the TEST functions to be outside the acceptable range.

Table 9-1: Test Functions

Test Function	Factory Set-Up	Comment
RANGE	500 PPM	<p>This is the Range of the instrument. In single range mode (standard configuration) all 3 outputs have the same range. If NO_x range-2 is enabled there will be an indication of the range for this output.</p> <p>Auto range option allows 2 different ranges for instrument output, and will automatically switch all outputs to the other range dynamically as concentration values require. The TEST values will show the range the instrument is currently operating in, and will dynamically display the alternate range as the range changes occur.</p> <p>Independent range option allows different ranges for each output. When enabled, there will be 3 range values displayed. If NO_x range-2 is enabled there will be an indication of the range for this output making a total of 4 range indications.</p>
STABIL	Check value in Final Test Values Table 2-1	<p>The instrument noise is determined by computing the standard deviation of the last 10 minutes of data. It is computed using NO_x channel data when in the NO/NO_x switching mode or NO_x only mode. When in the NO only mode it uses the NO data. The noise value only becomes meaningful if sampling a constant concentration for more than 10 minutes. The noise value should be compared to the value observed in the factory check-out.</p> <p>Faults that cause high noise values are:</p> <ol style="list-style-type: none"> 1. Gas leaks 2. Light leak 3. Faulty HVPS 4. Defective Preamp board 5. Outgassing Moly converter 6. PMT recently exposed to room light 7. Dirty/contaminated reaction cell 8. Mis-calibrated (slope - offset outside of limits)
SAMPLE FLW	290 cc/min 30	<p>This is the instrument flow. It is computed using the up stream and down stream pressures across the sample and bypass flow orifices. This method can give a false flow indication if the orifice is plugged and the sample pump is creating a pressure drop. It should be taken into account when diagnosing instrument faults.</p> <ul style="list-style-type: none"> - A rTeledyned method of determining if the orifice is plugged is to disconnect the sample, bypass or ozone tubes upstream of their respective locations, then briefly put your finger over the fitting. You should feel the vacuum build up. The bypass flow should be 250 cc/min, the ozone 250 cc/min, and sample flow of 50 cc/min. - Another reliable method is to attach a rotameter or soap bubble flowmeter to the fittings to measure the flow. <p>Flow rate will change a few cc/min due to changes in ambient air pressure such as cycling of air conditioning, or passing weather fronts. Changing altitude changes the ambient air pressure and therefore the sample flowrate. This effect is about 15-20 cc/min per 1000 feet of altitude change. If required, the output of the instrument can be compensated for pressure. See Section 5.3.9, Table 9-5.</p>

(table continued)

Table 9-1: Test Functions (Continued)

Test Function	Factory Set-Up	Comment
OZONE FL	250 cc/min 25	<p>This is the Ozone flow. It is measured by a solid state flow meter, and thus is a true indication of flow.</p> <p>If you suspect there is no ozone being generated, disconnect the tube at the reaction cell and rub the end of the tube on your fingertips, then sniff your fingers. The odor of ozone should be readily apparent.</p>
PMT	0-5000 mV	<p>This is the instantaneous output of the PMT. During normal operation the value varies widely as the M9110AH switches from NO to NO_x modes. Changes in reading will be synchronized with valve switching. The PMT voltage values will be relatively constant when:</p> <ol style="list-style-type: none"> 1. Electric test - variation in the 2000 mV signal observed will be sampling errors of the V/F board and preamp noise. See Section 9.1.3.2. 2. Optic test - variation in the 100 mV signal will be PMT dark current, preamp, HVPS plus item 1 above. See Section 9.1.3.3. 3. Sampling zero gas - signal from 1, 2 plus signal from ozone generator air 4. Sampling pure NO span gas - signal will be 1, 2, 3, above plus signal from chemiluminescent reaction. Slight pulsation's will be noticed as the M9110AH switches from NO to NO_x. This is due to differences in flowrates (Cv) in each channel. These differences are taken out in the calibration process resulting in slightly different slopes for the NO and NO_x channels. Large pulsation's when switching to the NO_x channel is indicative of a bad converter. 5. When sampling zero gas the PMT reading should be less than 50 mV and relatively constant. <p>High or noisy readings could be due to:</p> <ol style="list-style-type: none"> 1. Electric test - variation in the 2000 mV signal observed will be sampling errors of the V/F board and preamp noise. See Section 9.1.3.2. 2. Excessive background light which is caused by a possible contaminated reaction cell. 3. Humidity (undried ambient air) in the ozone generator feed air. 4. PMT recently exposed to room light. It takes 24-48 hours for the PMT to adapt to dim light. 5. Light leak in reaction cell. 6. Miswiring of the thermoelectric cooler causing the PMT to be heated.

(table continued)

Table 9-1: Test Functions (Continued)

Test Function	Factory Set-Up	Comment
NORM PMT	0-5000 mV	Normalized PMT voltage. Takes raw PMT voltage and applies temperature and pressure corrections. Use NORM PMT when doing the factory calibration procedure. A slope of 1.0 can be achieved for high altitude sites and pumps that are significantly down from their maximum vacuum.
AZERO	-20-100 mV Check value in Table 2-1	AZERO is the current value of the AutoZero circuit reading. The number typically should around zero. The value may be temporarily outside this range if the PMT has been recently been exposed to light or the instrument has been turned off for several days. If the value stays outside this range, check the AutoZero and NO/NO _x valve for a cross port leak. Use Diagnostic mode to manually check the AutoZero valve for correct operation.
HVPS	400-600 VDC	This represents the scaled-up HVPS programming voltage to the HVPS. The design of the HVPS precludes taking a single reading that indicates the health of the supply. Refer to the HVPS Troubleshooting Section 9.3.8.5 for a procedure for testing the HVPS. This TEST function is used primarily to set the HVPS voltage value. The supply will function over a voltage range of 375 to 1000 VDC. A value in the 400 to 600 volt range is common for the M9110AH.
DCPS	2500 ± 200 mV	DCPS is a composite of the +5 and ± 15 VDC supplies. It has been arbitrarily set at 2500 ± 200 mV. If it is not in this range one of the voltages in the supply is not working. Check the procedures for diagnosing the Power Supply Module.
RCELL TEMP	50 ± 2	The reaction cell temperature is controlled to 50 C ± 2 C by the computer. It should only read other values when the instrument is warming up. If the value is outside the acceptable range, go to the procedure for diagnosing the Reaction cell temp supply. The alarm limits are less than 45 C and greater than 55 C.
BOX TEMP	8-48 C	The Box Temp is read from a thermistor on the Status/Temp board (01086). It should usually read about 5 C above room temp. The M9110AH is designed to operate from 5 to 40 C ambient. Therefore the box temperature should be in the range of about 10 to 50 C. Temperatures outside this range will cause premature failures of components, and poor data quality. Warning limits are < 8 C and > 48 C.
PMT TEMP	7 ± 1 C	The PMT detector is very temperature sensitive. The PMT temperature should always be 7 C, except at power-up. Temperatures more than ± 1 C from the set point indicate problems with the cooler circuit. See Section 9.3.8.4 for PMT cooler diagnostic and troubleshooting. Warning limits are < 5 C and > 14 C.
BLOCK TEMP	50 C ± 2	Temperature of the orifice block that houses the sample flow orifice. Should be 50 C except when the instrument is warming up.

(table continued)

Table 9-1: Test Functions (Continued)

Test Function	Factory Set-Up	Comment
CONV TEMP O3KL TEMP	700 C ± 10 C 315 C ± 5 C 200 ± 10 C	The CPU controls the converter temp to 700 C. After cold start it requires about 30 min to come to temperature. After temperature is reached, it should not vary more than ± 10 C. See Section 9.3.4 for troubleshooting. Warning limits are < 690 C and > 720 C. The M9110AH can be equipped with a molybdenum converter as an option. The troubleshooting is the same as listed above except the warning limits are <290 C and > 320 C. If the M9110AH is equipped with the M501 external converter option, the converter housing is equipped with a heater to warm the ozone killer catalyst to 200 C.
RCEL PRESS	3 – 10 “-Hg-A (Thomas 607)	RCEL is the pressure in the Reaction Cell. The instrument is very sensitive to variations in reaction cell pressure. 10% change in output per 1"Hg pressure is typical. Higher altitudes will decrease cell pressure due to lower pump back pressure. Pressures higher than the acceptable range will decrease instrument sensitivity and increase noise.
SAMP PRESS	29.5"Hg at sea level	The sample pressure is taken upstream of the reaction cell. It usually runs about 0.5" less than ambient pressure due to the restrictions in the sample intake tubing. Sample pressure should be within ± 1"Hg of atmospheric pressure. The pressure sensor used reports absolute pressure and therefore is sensitive to altitude, weather fronts, and room air conditioning. Change due to altitude is about 1" per 1000 ft., other changes are ± 0.4" maximum. Pressurizing the sample inlet will cause the M9110AH to be noisy and to shift its reading.
SLOPE	1.0 ± 0.3	NO and NO _x SLOPE. The slope is a software gain factor used to calibrate the analyzer. When the instrument is span calibrated, this parameter is set so the analyzer front panel and analog output show the expected span gas concentration. There can be 2 values for SLOPE if AutoRange is enabled.
OFFSET	0 ± 25	NO and NO _x OFFSET. The offset is used to zero the analyzer. When the instrument is zeroed, the offset term is set so the concentration reads 0 ppm. There can be 2 values for OFFSET if AutoRange is enabled.
TIME		This is the time of day clock readout. It is used to time the AutoCal cycles. The speed of the clock can be adjusted by the CLOCK_ADJ variable in the VARS menu. The clock can be set via SETUP-CLOCK-TIME from the front panel.

9.1.2 Fault Diagnosis with WARNING Messages

The M9110AH monitors several internal values for alarm conditions. If the condition for an alarm is met, the alarm is displayed on the front panel and the warning is transmitted out the RS-232 port. Any time the instrument is powered up the SYSTEM RESET alarm will be displayed. Generally, it is ok to ignore warnings that are displayed shortly after power-up only if they persist should they be investigated.

Table 9-2 shows the warning messages and gives some possible causes.

Table 9-2: Front Panel Warning Messages

Message	Description
SYSTEM RESET	Analyzer was reset/powered on. This warning occurs every time the instrument is powered up, as in a power failure. It also occurs if the RAM or EEPROM is reset.
RAM INITIALIZED	RAM was erased. The RAM contains the DAS averages, which get erased when the RAM is initialized. It also contains temporary data used by the M9110AH to calculate concentrations. No setup variables are stored in the RAM.
SAMPLE FLOW WARN	The calculated sample flow is outside the hi/low limits. Since the flow is calculated, it probably means the pressure has gotten too low. This warning can be caused by a plugged sample inlet.
AZERO WRN XXX.X MV	AutoZero reading out of specification, XXX.X is actual reading.
OZONE FLOW WARNING	Ozone flow out of spec, warnings occur most often due to loss of vacuum, which causes the ozone flow to go to zero. They also can occur due to a flow sensor failure.
VACUUM WARNING	Vacuum out of spec. warnings are caused by leaks, pump failure or disconnected pump.
BOX TEMP WARNING	Box temp out of spec. Instrument fan failure, enclosure temperature failure. Operation of the M9110AH in a too warm or cold environment will cause degradation of data quality and shorten the life of the instrument.
RCELL TEMP WARNING	Reaction cell temp. out of spec. The warning message is most often present during initial warm-up or if the connector to the heaters is not plugged in after dis-assembly. It can also occur if the thermistor is not in position in the reaction cell.
PMT TEMP WARNING	PMT temp out of spec. The PMT temp has its own proportional controller on the preamp board. Warnings sometimes occur during initial operation. The warning can occur if the 7 pin connector to the interior of the sensor is not plugged in. The test points on the TEC control board should be checked for proper voltage (+15 VDC ± 0.5)
CONV TEMP WARNING	Converter temp. out of spec. The Converter temp is controlled by the CPU. It has a thermocouple with amplifier on the Status/Temp board. Because of the high temperature of the converter (700 C) the temp warning will tend to be the last warning to clear as the instrument is powered on.

(table continued)

Table 9-2: Front Panel Warning Messages (Continued)

Message	Description
BLOCK TEMP WARNING	The sample flow orifice is located in a separate temperature controlled block near the rear of the instrument. This message is most often present during warm-up. It can also occur if heater is not plugged in, or if thermistor has fallen out of block.
DCPS WARNING	DCPS is out of specification 2500 mV ± 200 mV. Check each DCPS voltage per Section 9.3.5.
OZONE GEN OFF	Ozone generator is turned off. See Table 9-10 for conditions.
CANNOT DYN ZERO	Dynamic zero cal. out of spec. The reading of the PMT was too high for the ZERO button to appear. Make sure the instrument is receiving zero gas. Check for dirty reaction cell. Do the factory calibration procedure located in Section 9.1.6.
CANNOT DYN SPAN	Dynamic span cal. out of spec. The reading of the PMT was too high or low for the SPAN button to appear. Make sure the instrument is receiving correct concentration span gas. Make sure the expected span concentration is entered. Check for dirty reaction cell. Do the factory calibration procedure located in Section 9.1.6.
A/D NOT INSTALLED	V/F board has failed. The V/F board did not respond to commands from the CPU. This probably means 1. Board not seated in socket, 2. defective board, 3. defective back plane connector.

9.1.3 Fault Diagnosis using DIAGNOSTIC Mode

Diagnostic mode can be looked at as a tool kit of diagnostics to help troubleshoot the instrument.

To enter DIAG mode press:

SETUP-MORE-DIAG

The diagnostic modes are summarized in Table 9-3. To access these functions, after you have pressed SETUP-MORE-DIAG, then press NEXT, PREV to select the desired mode, then press ENTR to select the desired mode. This section is a detailed description of the test and suggestions for its use.

Table 9-3: Summary of Diagnostic Modes

DIAG Mode	Description
SIGNAL I/O	<p>Gives access to the digital and analog inputs and outputs on the V/F board. The status or value of all of the signals can be seen. Some of the signals can be controlled from the keyboard. Table 9-4 gives details on each signal and information on control capabilities.</p> <p>NOTE: Some signals can be toggled into states that indicate warnings or other faults. These settings will remain in effect until DIAG mode is exited, then the M9110AH will resume control over the signals.</p>
ANALOG OUTPUT	<p>Causes a test signal to be written to the analog output DAC's. The signal consists of a scrolling 0%, 20%, 40%, 60%, 80%, 100% of the analog output value. The scrolling may be stopped by pressing the key underneath the % display to hold the displayed value. The exact voltage values depend on the jumper settings on the analog output buffer amplifiers on the V/F card.</p>
DAC CALIBRATION	<p>The analog output is created by 4 digital-to-analog converters located on the V/F card. This selection starts a procedure to calibrate these outputs. Refer to Section 9.3.3.1 for a detailed procedure.</p>
TEST CHANNEL	<p>Using the test channel, it is possible to route some of the internal analog signals out of the 4th analog output port. This Diagnostic mode is useful for intermittent problems, since the signal can be captured on a strip chart recorder and examined for periods of fault conditions.</p>
OPTICAL TEST	<p>Sets the M9110AH into a known state and turns on an LED near the PMT to test the instrument signal path. See Section 9.3.3.1 for details on using this test.</p>
ELECTRICAL TEST	<p>Tests just the electronic portion of the PMT signal path. Used in conjunction with optic test, see Section 9.1.3.2.</p>
O3 GEN OVERRIDE	<p>This function controls the power to the ozone generator. Unlike the other Diagnostic tests, O3 Gen Power remains in the state (ON/OFF) you set it to even when Diagnostic mode is exited. Function does not indicate status of generator.</p>
RS-232	<p>Causes a 1-second burst of data to be transmitted from the RS-232 port. Used to diagnose RS-232 port problems. See Section 9.1.3.7, 9.3.2 for RS-232 port diagnostic techniques.</p>

9.1.3.1 Signal I/O Diagnostics

Table 9-4: Diagnostic Mode - Signal I/O

No.	Signal	Control	Description
0	DSP_BROWNOUT	NO	Display brownout is used to keep the display from getting corrupted during low line voltage conditions. Circuitry on the Status/Temp board senses low line voltage and sets this bit. The CPU reads this and generates the BROWNOUT_RST signal described below.
1	EXT_ZERO_CAL	NO	Shows state of status input bit to cause the M9110AH to enter Zero Calibration mode. Use to check external contact closure circuitry.
2	EXT_SPAN_CAL	NO	Shows state of status input bit to cause the M9110AH to enter the Span Calibration mode. Use to check external contact closure circuitry.
3	EXT_LOW_SPAN	NO	Shows state of status input bit to switch the low span concentration valve in the zero/span valve option
4	REMOTE_RANGE_HI	NO	Shows state of status input bit to switch the remote range control from low to high range.
5	SPAN_VALVE	YES	Switches the Span valve. Use this bit to test the valve function.
6	CAL_VALVE	YES	Switches the Cal valve. Use this bit to test the valve function.
7	NOX_VALVE	YES	Switches the NO/NO _x valve. Use this bit to test the valve function.
8	RCELL_HEATER	YES	Shows the status of the reaction cell heater. This has the same function as the LED in the PSM.
9	BLOCK_HEATER	YES	Shows the status of the sample flow orifice block heater. This has the same function as the LED in the PSM.
10	ELEC_TEST	YES	Turns on electric test bit in preamp. Should be used for troubleshooting Preamp logic lines. We recommend you use the ET button in the DIAG menu to operate electric test.

Table 9-4: Diagnostic Mode - Signal I/O (Continued)

No.	Signal	Control	Description
11	OPTIC_TEST	YES	Turns on optic test bit in preamp. Should be used for troubleshooting Preamp logic lines. We recommend you use the OT button in the DIAG menu to operate optic test.
12	BROWNOUT_RESET	YES	Brownout reset works in conjunction with DSP_BROWNOUT. When DSP_BROWNOUT is set the CPU sends a signal to reset the display and clear the DSP_BROWNOUT.
13	CONV_HEATER	NO	Shows the status of the converter heater. This has the same function as the LED in the PSM.
14	O3GEN_STATUS	YES	Switches power to the ozone generator. Can be used to force the ozone generator to turn on.
15	ST_LOW_SPAN_CAL	YES	Status Bit - state of the low concentration span valve Logic high = valve open to admin span gas Logic low = valve closed
16	AUTOZERO_VALVE	YES	Switches the AutoZero valve. Use this bit to test the valve function.
17	ST_RCELL_PRESS	YES	Status Bit - Reaction Cell Pressure alarm Logic high = pressure out of acceptable range Logic low = pressure inside acceptable range
18	PREAMP_RANGE_HI	YES	Switches the preamp hardware range. Standard ranges are 500 and 5,000 ppm. Logic high = 5,000 ppm; logic low = 500 ppm. M9110AH will reset range to correct value based on user set range value.
19	ST_CONC_ALARM	YES	
20	ST_ZERO_CAL	YES	Status Bit - Zero Calibration mode Logic high = M9110AH in Zero cal mode Logic low = Not in Zero cal mode
21	ST_SPAN_CAL	YES	Status Bit - Span Calibration mode Logic high = M9110AH in Span cal mode Logic low = Not in Span cal mode

(table continued)

Table 9-4: Diagnostic Mode - Signal I/O (Continued)

No.	Signal	Control	Description
22	ST_FLOW_ALARM	YES	Status Bit - Flow alarm Logic High = Sample/Ozone flow out of spec Logic Low = Flows within spec
23	ST_TEMP_ALARM	YES	Status Bit - Temperature alarm Logic High = Rxcell, Conv, Box temps out of spec Logic Low = Temps within spec
24	ST_DIAG_MODE	YES	Status Bit - In Diagnostic mode Logic High = M9110AH in Diagnostic mode Logic Low = Not in Diag mode
25	ST_POWER_OK	YES	Status Bit - Power OK Logic High = Instrument power is on Logic Low = Instrument power is off
26	ST_SYSTEM_OK	YES	Status Bit - System OK Logic High = No instrument warnings present Logic Low = 1 or more alarms present
27	ST_HIGH_RANGE	YES	Status Bit - Autorange High Range Logic High = M9110AH in high range of autorange mode Logic Low = M9110AH in low range of autorange mode
28	PMT_SIGNAL	NO	Current PMT voltage. Same as PMT voltage in TEST menu. Bi-polar, typically in 0-5000 mV range. A constant value of 5000 mV indicates offscale.
29	SAMPLE_PRES	NO	Sample pressure in mV. Typical sea level value = 4300 mV for 29.9" Hg-A.
30	RCELL_TEMP	NO	Reaction Cell temperature. Typically 3500 mV for 50 C.
31	BOX_TEMP	NO	Box Temperature. Typically 1800 mV for 25 C
32	BLOCK_TEMP	NO	Temperature of the sample flow control orifice. Typically 3500 mV for 50 C.

(table continued)

Table 9-4: Diagnostic Mode - Signal I/O (Continued)

No.	Signal	Control	Description
33	PMT_TEMP	NO	PMT cold block temperature. Typically 4300 mV for 7 C.
34	DCPS_VOLTAGE	NO	DC power supply composite voltage output. Typically 2500 mV
35	RCELL_PRESS	NO	Reaction Cell Pressure in mV. Typically 1270 mV for 5" Hg-A at sea level. Is an absolute pressure so higher values means higher absolute pressures.
36	OZONE_FLOW	NO	Ozone flowmeter voltage. Typically 3200 mV at 250 cc/min.
37	CONV_TEMP	NO	Converter temp. Typically XXXX mV at 700 C
38	HVPS_VOLTAGE	NO	HVPS programming voltage. Output of HVPS is 1000x value present. 700 mV = 700 VDC output.
39	DAC_CHAN_0	NO	Output of NO _x channel in mV.
40	DAC_CHAN_1	NO	Output of NO channel in mV.
41	DAC_CHAN_2	NO	Output of NO ₂ channel in mV.
42	DAC_CHAN_3	NO	Test Channel output. Also second NO _x output.
43	NOX_CONC	YES	NO _x DAC programming voltage. The following 3 signals can be set to output specific voltages to each DAC. Use in conjunction to ANALOG OUTPUT test to check each DAC output channel. The value keyed in should appear on the appropriate analog output channel. This value overrides data being written from the analyzer. Value reverts to instrument output when function is exited.
44	NO_CONC	YES	NO DAC programming voltage. See above for description.
45	NO2_CONC	YES	NO ₂ DAC programming voltage. See above for description.
46	TEST_OUTPUT	NO	Displays voltage of selected analog signal

9.1.3.2 Electric Test

This function injects a constant voltage between the preamplifier and the buffer amplifier on the preamp board. Electric test checks part of the preamp, the V/F and computer for proper functioning. The result of electric test should be a smooth quiet signal as shown by constant values for the NO, NO_x concentrations, the NO₂ concentration should be near zero. Likewise the analog outputs should produce a smooth quiet trace on a strip chart.

Procedure:

1. Scroll the TEST function to PMT.
2. Press SETUP-MORE-DIAG, then scroll to ELECT TEST by pressing the NEXT button. When ET appears, press ENTR to turn it on.
3. The value in PMT should come up to 2000 mV ± 200 mV in less than 15 sec.

If the HVPS or the span gain adjust on the preamp card has been changed without doing a FACTORY CALIBRATION, the reading in step 3 may be different than 2000 mV, since the overall calibration affects ELECTRIC TEST. See Section 9.1.6 for factory calibration procedure.

4. To turn off ET, press EXIT.

If ET is a steady, that means the Power Supply Module, Preamp buffer amplifier, V/F, CPU, and display are all working properly.

9.1.3.3 Optic Test

Optic test turns on a small LED inside the PMT housing which simulates the signal from the reaction cell. OT tests the entire signal detection subsystem. By observing the level, noise and drift of this test, correct operation of many sections of the analyzer can be verified.

The implementation of OT involves several changes to instrument operating conditions. The M9110AH does the following when switching to optic test:

1. Save the current instrument setup as to AutoRange, indep range, current range and place the instrument into the 500 ppm range.
2. Turn off power to the ozone generator to assure there is no interfering light from the reaction cell.
3. Turns off the AutoZero valve switching.
4. Turn on the OT LED, the PMT reading in TEST functions should be 100 ± 20 mV.

If the HVPS or the span gain adjust on the preamp card has been changed without doing a FACTORY CALIBRATION, the reading in step 3 may be different than 100 mV, since the overall calibration affects OPTIC TEST. See Section 9.1.6 for factory calibration procedure.

9.1.3.4 Ozone Gen Power

This diagnostic manually turns the power off and on to the ozone generator. When the M9110AH is powered up from a cold start the ozone generator is not immediately started. This is due to the fact that humid air may be present in the generator cartridge. Humid air can produce nitric acid aerosol which can permanently damage parts of the instrument down stream of the generator. Using this diagnostic, it is possible to turn on the generator before the warmup time has elapsed. If you turn the power on it will remain on after you exit the diagnostic.

9.1.3.5 Analog Output Step Test

The Step Test is used to test the functioning of the 4 DAC outputs on the V/F board. The test consists of stepping each analog output 0-20-40-60-80-100% of the output. If the analog outputs are set for 0-5V full scale the outputs would step 0-1-2-3-4-5 VDC. The stepping can be halted at any value by pressing the key under the percentage on the front panel. When the test is halted, square brackets are placed around the percentage value in the display. Pressing the key again resumes the test. This test is useful for testing the accuracy/linearity of the analog outputs.

9.1.3.6 DAC Calibration

The Digital to Analog Converters (DAC) are calibrated when the instrument is set up at the factory. Re-calibration is usually not necessary, but is provided here in case the V/F board needs to be replaced and re-calibrated. The procedure for using the DAC Calibration routines is in the Troubleshooting Section 9.3.3.1.

9.1.3.7 RS-232 Port Test

This test is used to verify the operation of the RS-232 port. When started, it outputs the ASCII letter X for about 2 seconds. During the test it should be possible to detect the presence of the signal with a DVM. A detailed procedure is given in the Troubleshooting Section 9.3.2.

9.1.4 M9110AH Internal Variables

The M9110AH software contains many adjustable parameters. Many of the parameters are set at time of manufacture and do not need to be adjusted for the lifetime of the instrument. It is possible to change these variables either through the RS-232 port or the front panel. Altering the values of many of the variables will adversely affect the performance of the instrument. Therefore it is recommended that these variables not be adjusted unless you have a clear understanding of the effects of the change. Table 9-5 contains a description of each variable and a brief description of its function.

Table 9-5: Model 9110AH Variables

No.	Name	Units	Default Value	Value Range	Description
0	DAS_HOLDOFF	min	15	0.5 - 20	Time, in minutes, that data is not stored in the DAS after calibration or power-up.
1	MEASURE MODE	text	NONOX	NO, NO _x , NONOX	NO = only mode NO _x = only mode NO/NO _x = switching mode
2	TPC_ENABLE	Logic	ON	ON-OFF	Temp/Pres compensation enable.
3	DYN_ZERO	Logic	OFF	ON-OFF	Calibrates instrument during AutoCal Sequence or external contact closure or RS-232 command
4	DYN_SPAN	Logic	OFF	ON-OFF	Calibrates instrument during AutoCal Sequence or external contact closure or RS-232 command
5	CONC_LIM_ENA	LOGIC	NO	NO/YES	Enable concentration limit alarms
6	NO _x _CONC_LIM	PPM	0	5000	NO _x concentration limit alarm
7	NO_CONC_LIM	PPM	0	5000	NO concentration limit alarm
8	NO ₂ _CONC_LIM	PPM	0	5000	NO ₂ concentration limit alarm
9	SFLOW_SET	cc/min.	290	0-1000	Nominal sample flow rate
10	OFLOW_SET	cc/min.	250	0-500	Nominal ozone flow rate
11	RS232_MODE	Bit Field	8	0-99999	RS-232 port 1 mode flags. Add values to combine flags. 1 = quiet mode 2 = computer mode 4 = enable security 8 = enable TELEDYNE protocol 16 = enable alternate protocol 32 = enable multidrop 64 = enable modem 128 = ignore RS-232 line errors 4096 = enable command prompt
12	CLOCK_ADJ	Sec.	0	+60	Real-time clock speed adjustment

9.1.5 Test Channel Analog Output

Many of the TEST functions have an analog voltage associated with them. As a diagnostic aid it is possible to route the various test voltages out the 4th analog output port. Details on using the test channel analog output are in the Troubleshooting Section.

Table 9-6: Test Channel Readings

TEST Channel	Min μ m*	Max μ m*	Description
PMT DETECTOR	0 mV	5000 mV	PMT detector output from the preamp. This signal has been amplified and filtered. Since the instrument is switched and uses AutoZero, normal values can vary from -100 to 5000 mV. Wide variations in this signal are normal. Values should be around 0 mV when sampling zero air.
OZONE FLOW	0 cc/min	1000 cc/min	This signal is the output from the ozone flowmeter. Values around 1150 mV indicate zero flow. Typical values for 80 cc/min ozone flow are around 1800 mV. Voltage should be steady, indicating stable flow.
SAMPLE FLOW	0 cc/min	1000 cc/min	The sample flow is calculated from the upstream pressure as measured by the SAMPLE PRESSURE transducer.
SAMPLE PRESSURE	0 " Hg-Abs	40 " -Hg-Abs	The sample pressure is measured by an absolute pressure meter. The absolute pressure at sea level is 29.92" -Hg. The exact reading will vary a few tenths due to passing weather fronts and daily temperature cycling. The reading will decrease about 1" -Hg with each 1000 ft gain in altitude. For example, the absolute pressure at 10,000-ft (3000 m) is about 20" -Hg-A. A typical value near sea level would be about 4200 mV.
RCELL PRESSURE	0 " Hg-Abs	40 " -Hg-Abs	Like the SAMPLE PRESSURE the RCELL pressure is an absolute pressure measurement. With the sample pump off, it should read about atmospheric pressure. With the pump operating, a typical value is 1300 mV for about 5" -Hg-A reaction cell pressure.

(table continued)

Table 9-6: Test Channel Readings (Continued)

TEST Channel	Min μ m*	Max μ m*	Description
RCELL TEMP	0° C	70° C	Reaction Cell temperature is set to 50° C. At the setpoint, a typical reading is 3600 mV.
BLOCK TEMP	0° C	70° C	The Block temperature is set to 50° C. At the setpoint, a typical reading is 3600 mV.
IZS TEMP	0° C	70° C	The IZS temperature is set to 50° C. At the setpoint, a typical reading is 3600 mV.
CONV TEMP	0° C	1000° C	The Converter temperature is 315° C. At the setpoint, a typical voltage is 3150 mV.
PMT TEMP	0° C	70° C	The PMT temperature is unique in that the voltage is inverse to the temperature. A typical reading for 8° C would be 4200 mV.
CHASSIS TEMP	0° C	70° C	The Chassis (Box) temperature is variable due to variable ambient air temperature. The Box temp generally runs about 5° C above the surrounding air temp. Thus in a 25° C room, the Box temp would be about 30° C and have a TEST channel voltage of about 2000 mV.
DCPS VOLTAGE	0 mV	5000 mV	The DCPS is a composite of several DC power supply voltages in the instrument. It has been arbitrarily set at 2500 mV, which is typical.
HVPS VOLTAGE	0 V	5000 V	The HVPS voltage is a scaled up reading of the programming voltage going to the HVPS. Zero to 1000 mV corresponds 0-1000 VDC for the HVPS, which is the maximum voltage possible. A typical reading would be 700 mV corresponding to 700 VDC for the HVPS.

*Minimum and Maximum readings depend on the DAC 3 switch settings of the V/F board. For the standard 5 VDC range, minimum corresponds to 0 VDC and maximum corresponds to 5 VDC.

9.1.6 Factory Calibration Procedure

The Factory Cal procedure balances the PMT, preamp, and software gain factors so the instrument has optimum noise, linearity, and dynamic range. It should be used in the cases where you were unable to zero or span the instrument or slope and offset values were outside of the acceptable range and other more obvious reasons for problems have been eliminated.

PMT Calibration Procedure:

NOTE

In this procedure a range of 100 ppm and a span gas concentration of 80 ppm is used as an example. Other values can be used.

1. On the Preamp board, set S2 to 6, set S1 to 8. Turn R19 25 turns counter-clockwise, then 12 turns clockwise.
2. Set RANGE MODE to SING by pressing SETUP-RNGE-SET-MODE to select single range operation.
3. Set the RANGE to 100 ppm by SETUP-RNGE-SET and key in 100, then press ENTR.
4. Input Zero gas into the sample port, and Scroll to the TEST function labeled NORM PMT. The reading should be near 0 mV. Readings above 50 mV indicate a pneumatic leak, light leak, contaminated reaction cell, bad zero gas, or wet air coming into the ozone generator. If readings are greater than 50 mV the instrument will not zero or span properly see Sections 9.2.8, 9.2.9.
5. Allow the instrument to sample zero gas for at least 10 minutes to fill the internal data filters with zero readings. The reading is stable when the STABIL – TEST function drops to 2.0 or less. Then zero the instrument by CAL-ZERO-ENTR.
6. Set the expected span concentration to 80 ppm. Enter the expected NO_x concentration of 80 ppm by pressing CAL-CONC-NOX. Then press CAL-CONC-NO, to enter the expected NO concentration of 80 ppm. Then press EXIT to return to the CAL menu.
7. Input 80 ppm of NO span gas in the sample inlet port.
8. Scroll to the NORM PMT - TEST function.
9. Calculate the expected PMT mV reading.

For ranges up to 500 ppm, multiply the expected span value by 8 to get the mV reading.

For ranges 501 to 5000 ppm, multiply the expected span value by .8 to get the mV reading.

In this example the expected span gas concentration is 80 ppm and therefore the expected voltage is $80 \text{ ppm} \times 8 = 640 \text{ mV}$. As an alternate method, the voltage can be determined from the graph in Figure 9-1. On the Y-axis find the calibration concentration in PPM, then determine the expected voltage from the X-axis.

10. Adjust S2, the HVPS coarse adjustment, on the preamp board to the setting that produces a signal that is closest to 640 mV. Adjust S1, the HVPS fine adjustment, to the setting that produces a signal that is closest to 640 mV. Use R19 to trim the reading to 640 ± 50 mV. The readings will periodically go to zero as the AutoZero circuit operates, ignore the zero readings.
11. Allow the instrument to sample span gas for 10 minutes. The reading is stable when the STABIL – TEST function drops to 2.0 or less. Then do a span calibration by CAL-SPAN-ENTR. After the span is completed, do the span quality check procedure in Table 7-9. This procedure is extremely important to assure that the instrument will operate with optimum noise, linearity, and dynamic range.

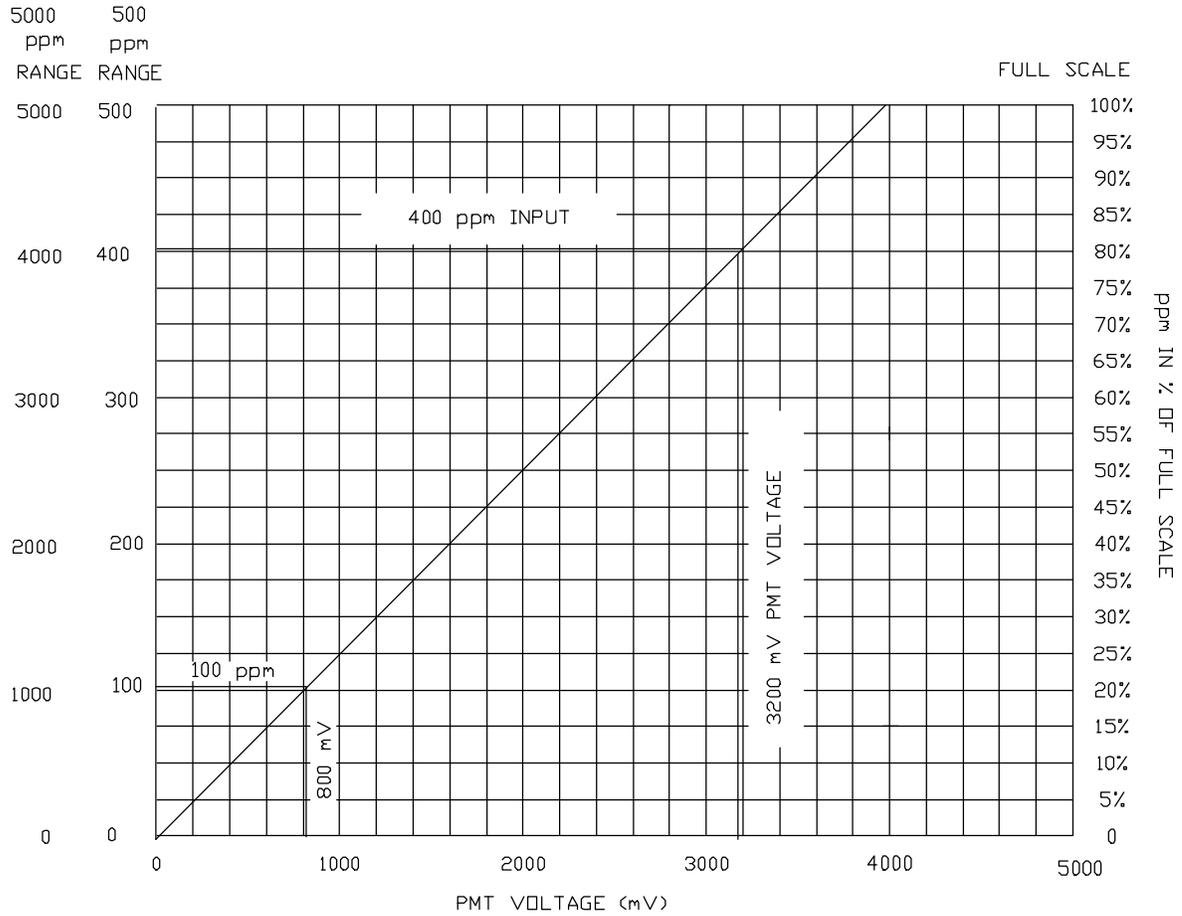
Electric Test (ET) Procedure:

1. Any time the gain of the PMT buffer amplifier circuit (R19) is changed, that will change the ET reading. Since the gain was adjusted in the above procedure do the following to re-adjust the ET signal.
2. To re-adjust ET press SETUP-MORE-DIAG, then scroll to ELEC TEST and press ENTR.
3. Scroll the TEST functions until PMT is displayed.
4. Adjust R27 until 2000 mV ± 50 is displayed.
5. Press EXIT to return to SAMPLE mode.

Optic Test (OT) Procedure:

1. Any time the PMT buffer amplifier circuit (R19) gain and/or the PMT high voltage setting is changed the OT reading will also change. The Factory Cal procedure can change both of these values.
2. To re-adjust OT press SETUP-MORE-DIAG, then scroll to OPTIC TEST and press ENTR.
3. Scroll the TEST functions until PMT is displayed.
4. Adjust R25 until 100 mV ± 5 is displayed.
5. Press EXIT to return to SAMPLE mode.

If this procedure does not produce an instrument that will properly span please contact your local distributor or the TELEDYNE factory. TELEDYNE's phone number is on the front page of this manual.



FOR ANY RANGE 0 - 500 PPM MULTIPLY THE EXPECTED SPAN CONC BY 8 TO GET PMT MILLIVOLT SETTING

FOR RANGES 501 TO 5000 PPM MULTIPLY THE EXPECTED SPAN CONC SETTING BY .8 TO GET PMT MILLIVOLT SETTING

FOR INFORMATION ON USING THIS FIGURE SEE SECTION 9.1.6 FACTORY CALIBRATION PROCEDURE

Figure 9-1: Span Calibration Voltage

9.2 Performance Problems

When the response from a span check is outside the control limits, the cause for the drift should be determined, and corrective action should be taken. Some of the causes for drift are listed below:

NOTE

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

1. Fluctuations in flow, caused by leaks or plugged orifices.
2. Lack of preventive maintenance.
3. Change in zero air source.
 - A. Air containing NO leaking into zero air line.
4. Change in span gas concentration.
 - A. Zero air or ambient air leaking into span gas line.
 - B. Calibration gas tank exhaustion.
5. Leak in the NO/NO_x or AutoZero switching valves.

9.2.1 AC Power Check

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

9.2.2 Flow Check

1. Check TEST function RCEL - this is the absolute pressure in the reaction cell. It should be 3 - 10 in-Hg-A.
2. Check that pump is running. Observe pump for proper operation.
3. Check that pump tubing is connected to rear of analyzer.
4. Confirm that the sample pump is producing vacuum by removing fitting at rear of analyzer and checking for suction at fitting.
5. Check for correct flows.

The M9110AH has a flow splitter. The flow into the reaction cell is 50 cc/min, and the flow through the bypass is 250 cc/min. It is best to use a calibrated flow meter to do the following tests. It is assumed, however that no flow meter is available.

- A. To test the bypass orifice, remove the 1/8" tube that comes from the heated orifice block to the vacuum manifold. Briefly plug the fitting on the vacuum manifold with your finger. You should notice a vacuum build up.
 - B. To test the sample flow orifice, remove the tube that connects the orifice block to the vacuum manifold (bypass flow tube). Plug the fitting on the orifice block. Remove the fitting that connects the orifice block to the sample inlet on the rear panel. Briefly plug the fitting on the orifice block with your finger. You should notice a vacuum build up.
 - C. Remove the ozone fitting and compare relative flow rates shown in the TEST menu under OZONE FL. It should read about 250 cc/min.
 - D. Re-connect the sample and ozone lines, then check RCEL TEST function for proper vacuum reading. Should be 3 - 10 in-Hg-A.
6. Broken flow or pressure sensor.
 7. Leak check analyzer. See Section 8.6 for leak check procedure.

9.2.3 No Response to Sample Gas

1. Confirm general operation of analyzer.
 - A. Check for AC Power, Section 9.2.1.
 - B. Do flow checks, Section 9.2.2.
 - C. Confirm that sample gas contains NO or NO₂.

2. Check instrument electronics.
 - A. Do ELEC TEST procedure in DIAGNOSTIC menu Section 9.1.3.2.
 - B. Do OPTIC TEST procedure in the DIAGNOSTIC menu Section 9.1.3.3.

If the M9110AH passes ET and OT that means the instrument is capable of detecting light and processing the signal to produce a reading. Therefore the problem is in the pneumatics.

3. Check ozone generator subsystem. Do diagnostic test of ozone generator subsystem, see Section 9.3.6.

9.2.4 Negative Output

1. Miss-calibration. The 'zero' gas that was used to zero the M9110AH contained some NO gas - that is it had more NO gas than that of the sample air. Also, doing a zero calibration using sample air.
2. Reaction cell contamination - If NO/NO_x OFFSET - TEST functions are greater than 50 mV, this indicates reaction cell contamination.
3. Check for leaks.
4. Corruption of the AutoZero filter. If a significant signal was detected during the AutoZero cycle, that higher reading can enter the AutoZero filter. The value of the AutoZero filter is subtracted from the current reading, thus producing a negative reading. High AutoZero readings can be caused by:
 - A. Leaking AutoZero valve.
 - B. Electronic fault in the preamp causing it to have a voltage on the PMT output pin during the AutoZero cycle.
 - C. Reaction cell contamination causing high background (>40 mV) light readings.
 - D. Broken PMT temperature control circuit, allowing a high zero offset.

After fixing the cause of the high AutoZero readings, the M9110AH will take 15 minutes for the filter to clear itself.

9.2.5 Excessive Noise

Common reasons for excessive noise are:

1. Leak in pneumatic system.
2. Light leak - check the sensor module with strong light. Check for missing O-rings in Sensor Assembly.

3. HVPS noisy - see HVPS test procedure. See Section 9.3.8.5.
4. Defective electronic components on preamp board. - use optic test and electric test to check electronics, optics and observe noise.
5. Contamination of ozone generator and/or reaction cell - This can be wet air or impurities. This can be detected by high PMT readings with zero air as sample gas. Verify this condition by turning off the ozone generator using the DIAG mode command and observing a drop in PMT reading of more than 25 mV. If the ozone generator or reaction cell is contaminated, disassemble and clean.
6. Broken PMT temperature control circuit. Check PMT TEMP - TEST function.
7. Miss-calibration. Check SLOPES in TEST function.
8. Reaction cell pressure too high. Check RCEL - TEST function.

9.2.6 Unstable Span

Common causes are:

1. Leak in pneumatic system.
2. Light leak - check the sensor module with strong light. Check for missing O-rings in Sensor Assembly.
3. Sample lines or sample filter dirty - clean or replace.
4. Plugged sample inlet orifice - clean with methanol and sonic cleaner.
5. Defective HVPS - see HVPS test procedure.
6. Bad or defective PMT detector – replace.
7. Reaction cell temp not stable - observe warning messages, or RCELL TEMP in TEST functions. Check diagnostic LED in Power Supply Module for normal cycling.
8. Large variations in ambient temperature - observe warning messages, or BOX TEMP in TEST functions.
9. Pump not maintaining steady vacuum - observe warning messages, or RCEL in TEST functions.
10. Sample vent line too short, allowing room air to mix with span gas - should be a minimum of 15" long.
11. Calibration gas source unstable.

9.2.7 Unstable Zero

Common causes are:

1. Leak in pneumatic system.
2. Light leak - check the sensor module with strong light.
3. Sample lines or sample filter dirty - clean or replace.

9.2.8 Inability to Span

If the SPAN button is not illuminated when attempting to span, that means the reading is outside of the software gain ranges allowed. In an analog instrument it would be the equivalent to the span pot hitting the rotation stop.

Here are some things to check:

1. Check the expected span concentration values in CAL-CONC-NOX and CAL-CONC-NO, and compare them to the concentration of the calibrator span gas being input. They should be equal.
2. When sampling span gas, check the PMT - TEST function reading. The mV reading should be 8x the expected span concentration in step 1. above for range settings up to 500 ppm. If over 500 ppm the value should be 0.8x the expected span concentration.

For example, if the expected span gas concentration is 80 ppm, the PMT reading should be $8 * 80 = 640$ mV 30%.

3. Check ET and OT for the correct response.
4. If the above do not check out, perform the Factory Calibration Procedure Section 9.1.6.

9.2.9 Inability to Zero

If the ZERO button is not displayed when attempting to zero, that means the reading is outside of the software gain ranges allowed. In an analog instrument it would be the equivalent to the zero pot hitting the rotation stop.

Here are some things to check:

1. Select the PMT - TEST function. With zero gas going into the instrument, the value should be less than 25 mV, a number close to 0 mV is common. If you are getting a high reading here the probable reasons are:

- A. A leak that admits gas containing NO.
- B. Contaminated reaction cell. Remove and clean cell.
- C. Wet (i.e. undried ambient air) air into the ozone generator. Check the PermaPure drier and associated plumbing for leaks and correct operation.
- D. Zero gas that isn't really zero. Make sure you're not trying to zero the machine with sample air or span gas.
- E. AutoZero filter is corrupted with high readings. Fix the cause of the high readings, then input zero gas and wait for 15 minutes for the filter to clear.

9.2.10 Non-Linear Response

Common causes are:

- 1. Leak in pneumatic system.
- 2. Calibration gas tanks concentration in error.
 - A. Tanks certification test in error.
 - B. Even if the NO concentration is correct, different tanks may have variable concentrations of interfering gasses. CO₂ is often blended in the NO tanks, and is a known interferent with chemiluminescent NO_x analyzers. If the CO₂ concentration is markedly different between tanks, the CO₂ quenching effect on NO will produce non-linearities. This effect may also be present with gas standards that blend SO₂/N₂/NO. The problem arises because the gas manufacturer uses FT-IR to do the analysis. FT-IR does not have the same interaction between components as do chemiluminescent analyzers.
- 3. Variation in sample inlet pressure due to sample manifold inlet flow changes.
- 4. High zero background - The PMT TEST function should be near 0 mV with zero gas. Readings above 25 mV indicate a light leak, contaminated reaction cell, bad zero gas, or wet air coming into the ozone generator. If the reading is not less than 20 mV the instrument will not zero or span properly. Check Section 9.2.9.
- 5. Calibration device in error, re-check flowrates and concentrations. This is especially true at low concentrations. Mass Flow calibrators often become non-linear if the flow is < 1% of the full scale flow.
- 6. Contamination in sample delivery system:
 - A. Dirt in sample lines or reaction cell.
 - B. Contaminated cal gas source (NO₂ in NO cal gas is common).
 - C. Dilution air contains sample or span gas.

7. Ozone concentration too low:
 - A. Wet air in generator - need to disassemble, clean, dry.
 - B. Electrical short circuit.
 - C. Transformer partial failure.
8. Sample inlet vent line too short - should be at least 15".
9. Sample exhaust not properly vented, creating a backpressure at the sample inlet port of the instrument. See Figure 2-3 for venting recommendations.

9.2.11 Slow Response

1. Contaminated or dirty sample delivery pneumatics:
 - A. Dirty/plugged sample filter or sample lines.
 - B. Dirty reaction cell.
2. Sample inlet line too long.
3. Wrong materials in contact with sample - use glass, stainless steel or Teflon
4. Sample vent line located too far from instrument sample inlet. - Locate sample inlet vent as close as possible to analyzer.
5. Insufficient time allowed for purging of lines upstream of analyzer.
6. Leaking NO/NO_x or AutoZero valve. The leak can either be external or cross-port.
7. Insufficient time allowed for calibration cal gas source to become stable.
8. Converter temperature too low.

9.2.12 Analog Output Doesn't Agree With Display Concentration

1. V/F board DAC's out of calibration. Do DAC calibration and Factory Calibration.
2. Analog outputs electrically loaded down causing voltage to sag. Could be due to input impedance to chart recorder or data logger being too low or improper grounding. The Recorder and DAS outputs do not have separate output drivers, the problem could be the combined load of both could be too high.

9.3 Subsystem Troubleshooting and Adjustments

9.3.1 Computer, Display, Keyboard

The purpose of this section is to determine if the computer subsystem electronics hardware are working properly. Assessment will be made at the board level.

9.3.1.1 Front Panel Display

The front panel display is a 2 line by 40 character display. It has its own microprocessor to decode commands and display characters. It contains a self test feature. To test the display:

1. Turn off the power to the instrument.
2. Fold down the M9110AH front panel.
3. Disconnect the 24 line flat ribbon cable (J2) that connects the computer parallel port to the keyboard.
4. Turn on the M9110AH power switch.
5. Observe the front panel display. If the display successfully completes its power on self test it will display a single underline character "_" in the left most character of the top line of the display. If this character is present, the display is working properly.
6. Power down the analyzer, and re-attach the 24 line cable to J2, and proceed to the next test.

9.3.1.2 Single Board Computer

The SBC40 is a full function computer designed for instrument control applications. It consists of a 16 bit 8080 microprocessor, 2 serial and one parallel ports, standard bus interface, and 4 sockets for memory. The memory sockets consist of 256k ROM containing the multitasking operating system and application code. 32k EE prom containing the setup variables. 128k RAM containing data collected by the instrument, and a time-of-day clock to provide event timing services. The overall function of this board is quite complex. Complete testing of this board's functions is not possible in the field. If component level troubleshooting of this board is necessary contact the factory for schematics.

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

1. Locate the CPU board on the motherboard by referring to Figure 2-5.
2. Power the instrument on.
3. Locate the red LED at the top left edge of the board.
4. It should be flashing at a frequency of about once per second.
5. This flashing indicates the board is powered up and is executing instructions.

Testing and operation of the CPU RS-232 port is described in Section 9.3.2.

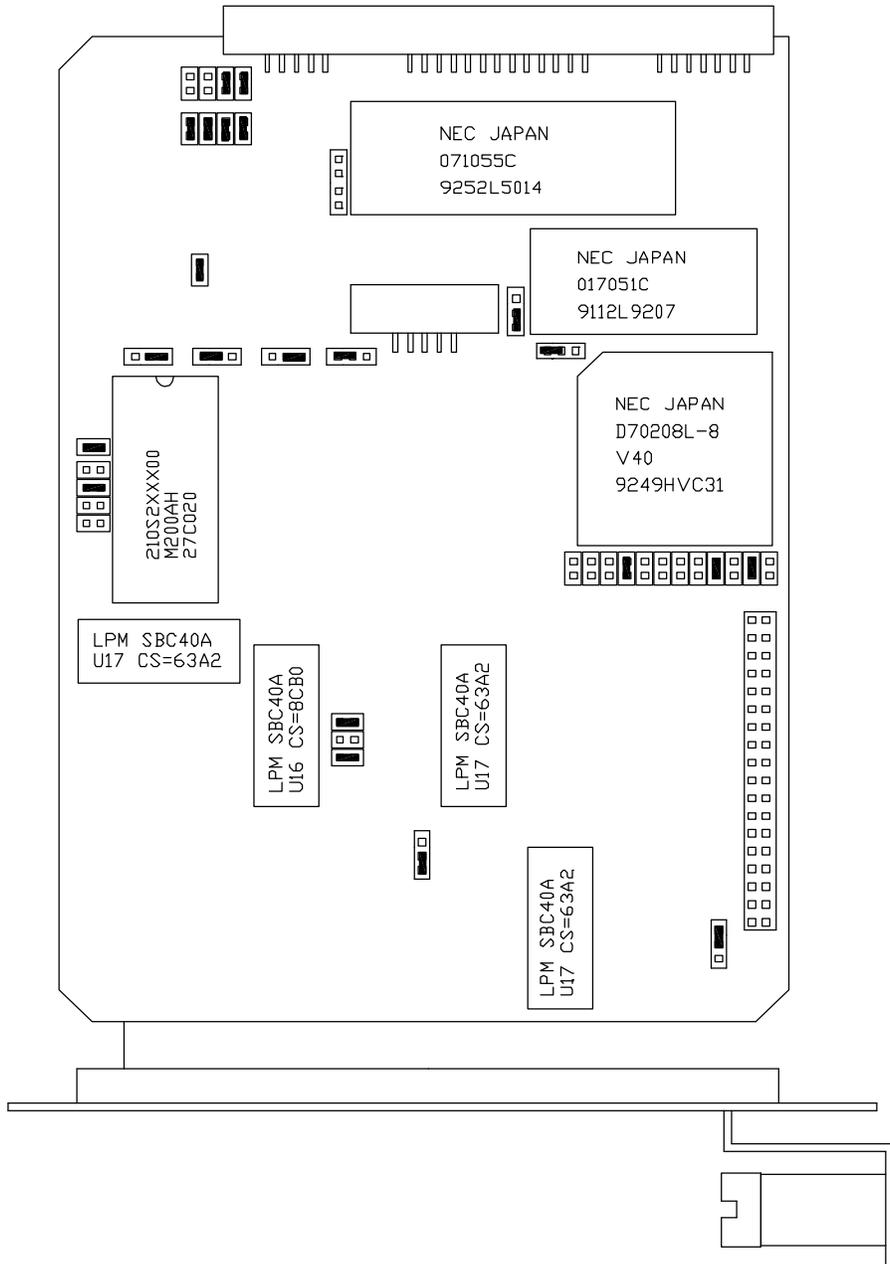


Figure 9-2: CPU Board Jumper Settings

9.3.1.3 Front Panel Keyboard

The keyboard consists of 8 keys and 3 LED's. Key strokes are sent to the SBC40 computers' parallel port. The computer software detects the key strokes via CPU interrupts. The bottom line of the display consists of 40 characters which is divided into 8 - 5 character fields. Each field defines the function of the key immediately below it. The definition of the keys is variable and depends on the menu level of the software.

To check the operation of the keyboard, each key should perform an operation indicated by its current definition shown on the second line of the display.

Example #1 - testing key#1 (left most key).

At the top level menu key #1 is defined as the TEST function. Pressing this key should cause the middle field of the top line of the display to show the various test functions.

Example #2 - testing key #8 (right most key). At the top level menu Key #8 is defined as the SETUP key. Pressing key #8 should cause the SETUP menu to be displayed.

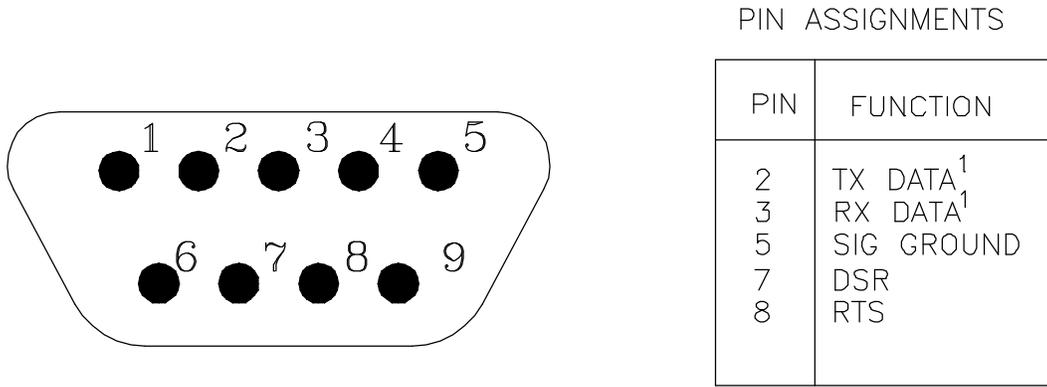
Example #3 - If the 5 character field above any key is blank, the key is not defined, pressing the key has no effect.

The 3 status LED's indicate several functional states of the instrument such as calibration, fault, and sample modes. The state of the LED's is controlled by 3 lines on the parallel port of the SBC40. Functioning of the LED's can be checked by:

1. Turn off the M9110AH power.
2. While watching the LED's, turn on the instrument power.
3. When the power comes up, the computer momentarily applies power to all 3 LED's for approximately 1 sec. If all the LED's are observed to light, they are working properly.

9.3.2 RS-232 Communications

The M9110AH uses the RS-232 communications protocol to allow the instrument to be connected to a variety of computer based equipment. RS-232 has been used for many years and is well documented. Generally, The M9110AH uses the RS-232 communications protocol to allow the instrument to be connected to a variety every manufacturer observes the signal and timing requirements of the protocol very carefully. Problems arise when trying to specify connectors, and wiring diagrams that attach the analyzer to various devices.



RS-232 CONFIGURATION PARAMETERS

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

*
SETTABLE 300, 1200, 2400, 4800, 9600, 19200 BAUD

¹ SWITCH SETTABLE ON REAR PANEL CONNECTOR BOARD

Figure 9-3: RS-232 Pin Assignments

9.3.2.1 RS-232 Port

If the RS-232 port is not working, check the following:

Physical Wiring

Refer to Figure 9-3 for the wiring diagram of the DB-9 plug on the M200A rear panel. There are 2 features that make connecting the wiring easier. First is the red/green LED's on the rear panel. One device (such as the M9110AH) provides the power to run the red LED, the other device will provide the power for the green LED. If the wiring is hooked up correctly both LED's will be illuminated. There is a DTE-DCE switch, this switch interchanges pin 2 & 3 on the DB-9 connector. Set the DTE-DCE switch so that both LED's are illuminated.

RS-232 Protocol (BAUD rate, Data bits, Parity)

The communication protocol for each instrument must match. In Figure 9-3 the default RS-232 parameters are listed. The BAUD rate can be changed in the software menus under SETUP-MORE-COMM-BAUD.

Data Communications Software for a PC

You will need to purchase a software package so your computer can transmit and receive on its serial port. There are many such programs, we use PROCOMM at TELEDYNE. Once you set up the variables in PROCOMM and your wiring connections are correct, you will be able to communicate with the analyzer.

If connecting to a modem, check the following:

Modems are especially difficult because they may have pins that need to be at certain EIA RS-232 levels before the modem will transmit data. The most common requirement is the Ready to Send (RTS) signal must be at logic high (+5V to +15V) before the modem will transmit. The TELEDYNE analyzer sets pin 8 (RTS) to 10 volts to enable modem transmission.

To troubleshoot a modem connection first disconnect the RS-232 cable from the Analyzer and verify (use a DVM) that you are getting a signal on Pin 2 of the RS232 port on the Analyzer. The signal will be between -5V and -15V with respect to signal ground (pin 5). If not, there is a problem with the CPU board or the cable. This is the transmit (TD) signal out of the Analyzer. This should then be connected to TD input on the modem, normally Pin 2. You may need to change the DTE/DCE switch on the M9110AH so the signal is on Pin 2 of the modem.

Go to the cable connected to the modem/terminal and verify (use a DVM) that you are getting a -5V to -15V signal on Pin 3 of the cable. This pin should be connected to Pin 3 of the TELEDYNE Analyzer.

Check that the voltage level on Pin 8 of the Analyzer is between +5V and +15V. This pin should be connected (through the cable) to Pin 4 of the modem.

Now set the baud rate of the Analyzer to the speed required by the modem and it should work. If you are still experiencing problems, a cable adapter may be needed. Please contact the factory for assistance.

9.3.3 Voltage/Frequency (V/F) Board

The V/F Board consists of 16 analog input channels, each software addressable, 8 digital inputs, and 24 digital outputs, each independently addressable, and 4 independent analog output channels. The analog input channels are connected to a V/F converter capable of 80,000 counts, which is approximately 16 bit resolution. The integration period is software selectable from 40 msec to 2.4 secs. Commands from the SBC40 computer and digitized values from the V/F section of the board are sent via the STD bus interface. The schematic for the board is in the Appendix.

The overall operation of this board is quite complex, to fully check it out in all of its operational modes is not possible in the field. Therefore a few of simple tests are described here that test one analog input channel, the 4 analog output channels, one digital input, and one digital output.

1. V/F board analog input test.

Each analog channel is routed through a programmable 16 channel multiplexer. Chances are that if one channel works, they all work.

- A. Turn on instrument.
- B. Press TEST key on front panel keyboard until DCPS test is displayed.
- C. The value displayed should read 2500 ± 200 mV.

If the M9110AH passes this test, it has successfully digitized a 2500 mV composite voltage output from the Power Supply Module. The signal should also be quiet ± 25 mV.

2. Analog output channel test.

In the DIAGNOSTIC menu on the front panel, there is a test that outputs a step voltage to the 4 analog outputs. This test is useful for calibrating chart recorders and dataloggers attached to the M9110AH. The test can also be useful in diagnosing faults in the V/F board.

- A. Turn on the instrument.
- B. Enter the SETUP-MORE-DIAG menu.
- C. Select the ANALOG OUTPUT test. This causes the M9110AH to output a 5 step voltage pattern to the 4 analog outputs on the rear panel. The status of the test is shown on the front panel display. The scrolling can be stopped at any voltage by pressing the key below the changing percentage display. The values are 0-20-40-60-80-100% of whatever voltage range has been selected. For example the voltages would be 0, 1, 2, 3, 4, 5V if the 5V range had been selected.
- D. Use a DVM on each of the analog output channels to confirm the correct voltages.

If the voltages step, but are the wrong values, the V/F board may be out of calibration.

3. Digital input channel test.

The digital I/O section of the V/F board has 8 input bits and 24 output bits. Two of the 8 input bits are assign as calibration controls. See Section 7.4 for information calibration using external contact closures.

To test the digital inputs:

- A. Turn on the M9110AH.
- B. Connect a jumper wire across pins 1 and 2 of the "REMOTE IN" rear panel connector as shown in Figure 2-2.
- C. Shortly after closure is made the instrument should switch into zero mode as indicated on the front panel display.
- D. Remove the jumper. Shortly after the jumper is removed the instrument should exit the zero calibrate mode.

4. Digital output channel test.

There are 24 output bits on the V/F board. The 24 bits are made up of 3 - 8 bit ports. It is possible for a single 8 bit port or even a single bit within a port to fail.

A quick observational test of the digital outputs is to observe the LED's in the Power Supply Module (Refer to Figure 9-5 for the location of the LED's in the PSM). The state of the LED's can be checked from the Table 9-9. The comment section assumes the M9110AH has been running for at least 45 minutes.

A more detailed test is in the DIAGNOSTIC menu. See Diagnostic tests in Section 9.1.3.

9.3.3.1 ADC/DAC Calibration Procedure

Due to the stability of modern electronics, this procedure should only need to be performed if a major sub-assembly is exchanged or when the display voltage does not match the input voltage or current to the V/F card. After completion, a Factory Calibration Procedure should be performed, see Section 9.1.6.

Before the actual calibration is performed, switches on the V/F card must be correctly set and jumpers set on the motherboard. **Jumper and switch setting changes must be performed with the instrument power OFF.**

Motherboard Jumpers

The motherboard contains 4 pairs of jumpers JP1 - JP8, one pair for each analog output channel. Each channel can be configured for either voltage or current output. Use Table 9-7 to configure the jumpers.

Table 9-7: Motherboard Jumper Settings

Analog Output	Terminal Pair Rear Panel	Jumper Pair	Jumper Setting for Voltage Mode	Jumper Setting for Current Mode
DAC 0 - NO _x	3-4	JP3 - JP4	B-C	A-B
DAC 1 - NO	5-6	JP1 - JP2	B-C	A-B
DAC 2 - NO ₂	1-2	JP5 - JP6	B-C	A-B
DAC 3 - TEST	7-8	JP7 - JP8	B-C	A-B

V/F Board Switch Settings

There are 2 different types of current outputs, Non-Isolated (std equipment) and Isolated. Each requires a different switch setting shown below. If you are operating the instrument in voltage output mode, the switches should be set to the desired voltage range.

Table 9-1: V/F Board Switch Settings

D/C #	Sw 1	Sw 2	Sw 3	Sw 4	Sw 5	Sw 6	Sw 7
0	ON*	OFF*					OFF*
1	ON*	OFF*					OFF*
2	ON*	OFF*					OFF*
3	ON*	OFF*					OFF*

*Required settings

10 V output or non-isolated current loop

Switch	State	Comment
3	ON	Use for non-isolated current loop or 10 V output
4	OFF	Use for non-isolated current loop or 10 V output
5	OFF	Use for non-isolated current loop or 10 V output
6	OFF	Use for non-isolated current loop or 10 V output

5 V output or isolated current loop

Switch	State	Comment
3	OFF	Use for isolated current loop or 5 V output
4	ON	Use for isolated current loop or 5 V output
5	OFF	Use for isolated current loop or 5 V output
6	OFF	Use for isolated current loop or 5 V output

1 V output

Switch	State	Comment
3	OFF	Use for 1 V output
4	OFF	Use for 1 V output
5	ON	Use for 1 V output
6	OFF	Use for 1 V output

100 mV output

Switch	State	Comment
3	OFF	Use for 100 mV output
4	OFF	Use for 100 mV output
5	OFF	Use for 100 mV output
6	ON	Use for 100 mV output

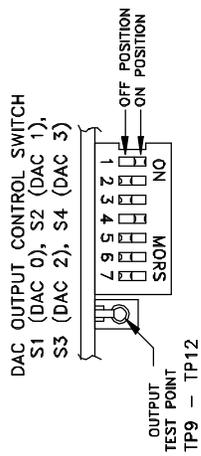
1. After the switches and jumpers are set, turn on instrument power and complete the following:
 - A. Press SETUP-MORE-DIAG, then press ENTR. Scroll to D/A CALIBRATION, press ENTR. Press A/D to select the first task, which is to calibrate the A/D converter.
 - B. Connect a DVM ground lead to TP3-AGND on the V/F board. Connect the positive lead to TP9-DAC0.
 - C. The M9110AH will display a voltage near 1% of the voltage range set in the above procedure. Adjust R27 until the displayed voltage matches the DVM voltage, then press ENTR.
 - D. The M9110AH will display a voltage near 90% of the voltage range set in the above procedure. Adjust R31 until the displayed voltage matches the DVM voltage, then press ENTR. This step calibrates the instrument A/D converter to the external DVM.

The next task is to calibrate each of the 4 DAC output channels. The NEXT - PREV buttons allows selection of any of the 4 D/A channels. DAC0 - the NO_x channel - is displayed first.

- E. The SET button has 2 functions, first to select the output mode - voltage or current. Press VOLT and CURR depending on the type of output desired. - **Remember, the VOLT or CURR setting must match the switch and jumper settings made previously.** Second, the voltage output can be biased up to 10% of the selected range with the OFFSET parameter. Just key in the desired offset, or press EXIT to leave the OFFSET at zero.
- F. For DAC channels in VOLTAGE mode, press CAL. This will cause the instrument to automatically calibrate the channel.
- G. For DAC channels in current mode, first connect a 250 ohm resistor in series with a current meter to the correct pair of terminals on the rear panel, see Table 9-6 for terminal assignments. Press CAL. The instrument will output 4 mA to the rear panel terminals. UP, DOWN and ENTR buttons will be displayed. Press the UP - DOWN buttons until the correct reading is displayed on the meter, then press ENTR. 20 mA is then output to the rear panel. As before, press the UP, DOWN buttons to get the correct reading, then press ENTR.
- H. To go the next channel press the NEXT button and follow the previous steps starting with step - f. Proceed through all 4 DAC channels, then exit. To back up to previously calibrated channels, press the PREV button.

9.3.3.2 Changing Output Voltage Ranges

Several different output voltage ranges can be selected by switch settings on the V/F board. See Figure 9-4. If you change the analog output voltage range, the power to the instrument should be turned off, then on and a DAC calibration performed (Section 9.3.3.1).



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

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

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

- 1 ON
- 2 OFF
- 7 OFF

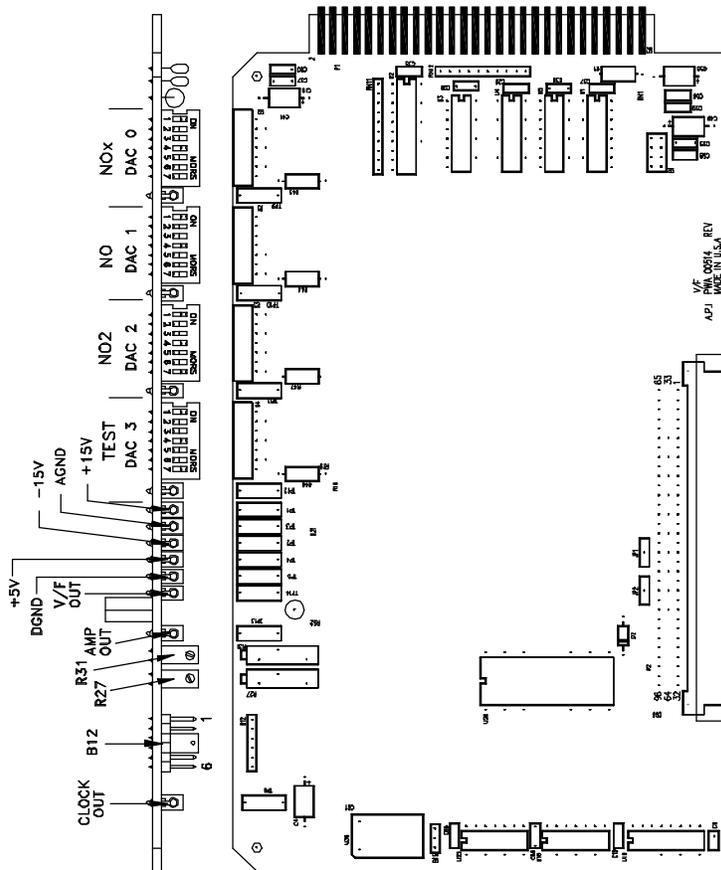


Figure 9-4: V/F Board Jumper Settings

9.3.4 Status/Temp Board

The Status/Temp Board is a multifunction board that:

1. Converts the resistance readings of the thermistors to a voltage
2. Amplifies and scales the thermocouple voltage for the V/F card
3. Provides status output circuitry
4. Provides circuitry for contact closure inputs
5. Provides circuitry for display brown-out/reset at low line voltage
6. Provides circuitry for 4-20 mA outputs

9.3.4.1 Temperature Amplifier Section

The 4 thermistor amplifiers that convert resistance into voltage monitor:

1. Reaction Cell temperature
2. Heated Orifice block
3. Box temperature
4. Spare

The voltages of the thermistor and thermocouple amplifier outputs are brought out to test points on the edge of the board. Refer to the schematic in the Appendix for details. The voltages can also be read using the DIAGNOSTIC - SIGNAL I/O feature. See Table 9-4 for details.

Thermistor Temperature Amplifier Adjustments

The 4 temperature amplifiers are controlled by a common pot (R34) on the upper edge of the card.

If the temperature readouts are in error:

1. Locate the Box temp thermistor on the board and place a thermometer near the thermistor.
2. Select the BOX TEMP - TEST function on the front panel.
3. Adjust R34 until the front panel readout matches the thermometer readout. This will cause all of the readouts to accurately measure their respective temperatures.

Converter Thermocouple Amplifier Adjustments

The converter temperature is sensed by a Type K thermocouple. The cold junction compensation and signal conditioning are done on the Temp/Status board.

The thermocouple amplifier for the converter temperature has a gain adjustment. The voltage across J2 reads 27.5 mV when the converter temperature is 700 C. The CPU is programmed to always drive the temp to 700 C, so the thermocouple voltage must be used as the absolute reference as to the correct temperature.

The temperature can be adjusted by the R6 pot. To adjust the converter temperature:

1. Select the CONV TEMP - TEST function on the front panel.
2. Wait until the converter is up to temperature, usually 30-45 min after a cold start.
3. Adjust R6 until the front panel readout equals 700 C for the CONV TEMP and the voltage at J2 is 27.5 mV.
4. Recheck the two readings 15 min later and re-adjust if necessary.

9.3.4.2 Display Brownout

During low AC line conditions the display can lock up due to insufficient voltage. When low line conditions are approaching, this circuit senses the condition by monitoring the un-regulated +5 VDC in the Power Supply Module. If brownout conditions are met, the DISP_BROWNOUT line is asserted and the CPU sends a hardware RESET command to the display and sends a BRNOUT RESET pulse back to U4. Brownout conditions will be noticed by the display flashing every 8 seconds.

9.3.4.3 Status Output Lines, External Contact Closures

The Status lines consist of 4 active input lines, and 12 active output lines. Individual lines are set or cleared under CPU control depending on the assigned alarm condition. The CPU also monitors the 4 input lines for remote calibration and range control commands. The status inputs and outputs are terminated at the rear panel, see the schematic in the Appendix.

The output lines are opto-coupled NPN transistors which can pass 50 ma max of direct current with a voltage of 30 VDC max.

The input lines are optically coupled with inputs pulled up to +5 VDC. External contacts can be contact closures or open collector transistor contacts. DO NOT apply any voltage, since +5 VDC is supplied internally.

Individual status lines can be set or cleared using the DIAGNOSTIC mode SIGNAL I/O. This can be useful for simulating fault conditions in the analyzer to see if external circuitry is working correctly. See Table 5-8 for pin assignments.

9.3.4.4 4-20 mA Current Output

There are two types of current loop outputs available for the M9110AH, non-isolated (standard equipment) and isolated (optional). These outputs may be used in place of the analog voltage signals that appear at the rear panel connector. See Section 9.3.3.1 for setup and calibration procedure.

Non-isolated 4-20 mA or 0-20 mA Output

Non-isolated 4-20 mA is recommended for applications requiring a current loop and the current loop receiver has an isolated input stage. It can also be used when there a potential difference does not exist between the ground connections of the two instruments.

Recommended load (R_L) = 100 - 600 (Max. 600)

V/F analog output voltage setting = +10V Full Scale

Default Setting = 4-20 mA

To convert from 4-20 mA to 0-20 mA output, refer to Status/Temp Schematic 01087 sheet 2, and the procedure in Section 9.3.3.1.

Isolated 4-20 mA or 0-20 mA Option

This option is recommended where maximum isolation from ground loops is required. Specifications include up to 1500 V rms common mode voltage isolation (transformer coupled input to output galvanic isolation) and 240 Vrms normal mode voltage output protection.

Recommended load (R_L) = 200 - 1000 (Max. 1200)

V/F analog output voltage setting = +5V Full Scale

Default Setting = 4-20 mA

To convert from 4-20 mA to 0-20 mA output, refer to Status/Temp Schematic in the Appendix, and the procedure in Section 9.3.3.1.

9.3.5 Power Supply Module

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

Table 9-8: Power Supply Module Subassemblies

Module	Description
Linear Power Supply Board	The linear power supply board takes multiple voltage inputs from the power transformer and produces +5, +15, -15, +12 VDC outputs. The outputs are routed to two external connectors, P2 and P3. See Figure 9-5. The +5 is used for operating the CPU. The -15 is used in several locations for running op-amps and IC's. The +12 is used for operating fans and valves.
Switching Power Supply	The switching power supply supplies +15 VDC at 4 A to the PMT cooler control on the Sensor Module and input power for the ozone generator. The output is made available through J10 on the Switch Board. There is a load resistor on the Switch Board to keep the output stable when little current is required from the supply.
Switch Board	The Switch Board has many different functions. It takes logic signals from the V/F board and uses them to switch 4-115 VAC and 4-12 VDC loads. The board also contains the instrument central grounding tie point. It routes unswitched AC and DC power as needed. Connector P2 programs the power transformers to take 115, 220, 230 or 240 VAC inputs
Power Transformers	There are potentially 2 input power transformers in the PSM. The multitap transformer T1 is in every M9110AH and supplies input power for the Linear Power Supply board described above. A second transformer T2 is added if 220, 230 or 240 VAC input is required. This transformer steps down the 220/230/240 VAC to 115 VAC/50Hz for heaters and other components. Input power selection is done via a programming connector P2 which provides the proper connections for either foreign or domestic power.
Circuit Breaker/Power Switch	The front panel contains a combination circuit breaker - input power switch. It is connected to the PSM through J6 on the Switch Board. If an overload is detected the switch goes to the OFF position. Switching the power back on resets the breaker also.

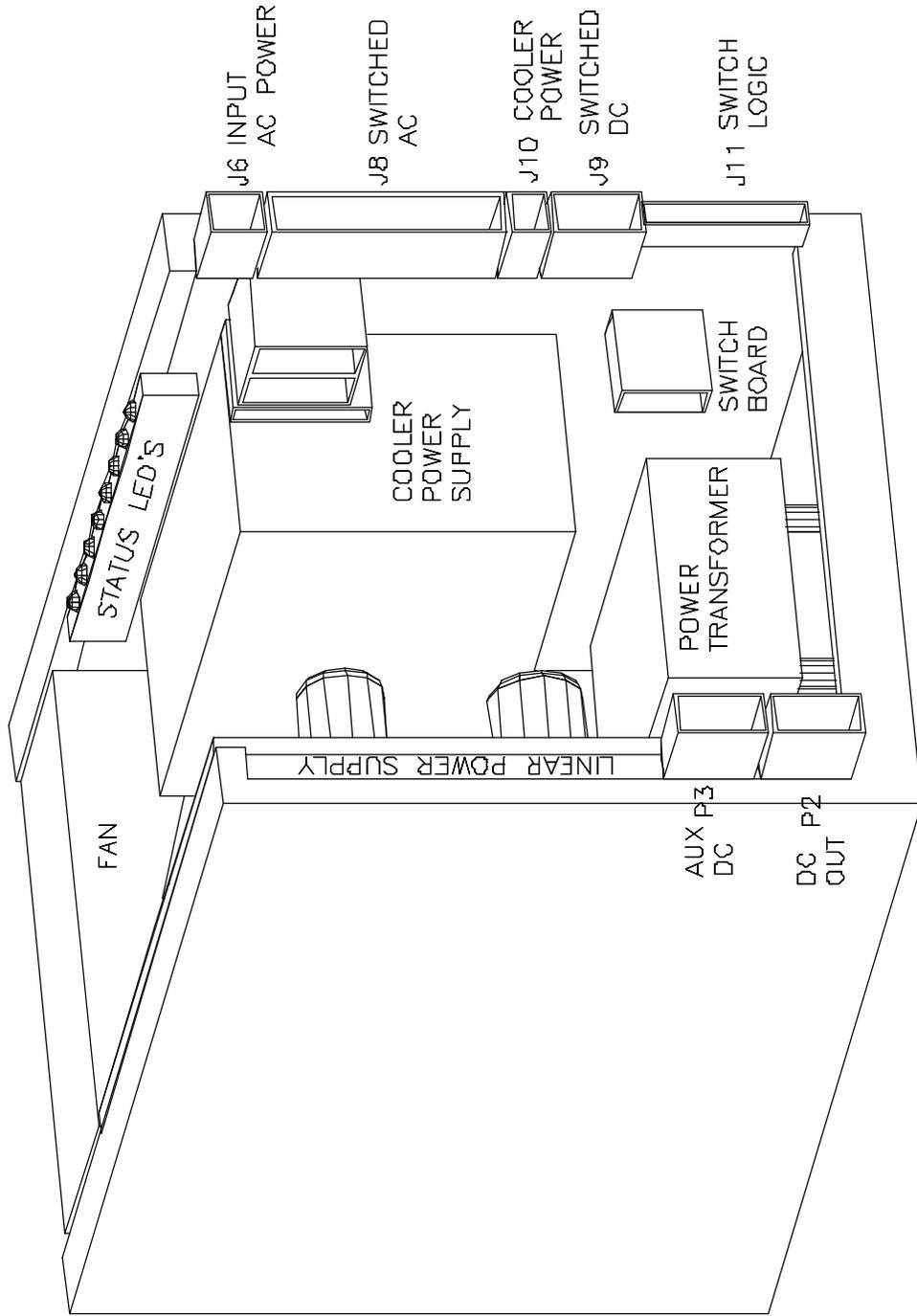


Figure 9-5: Power Supply Module Layout

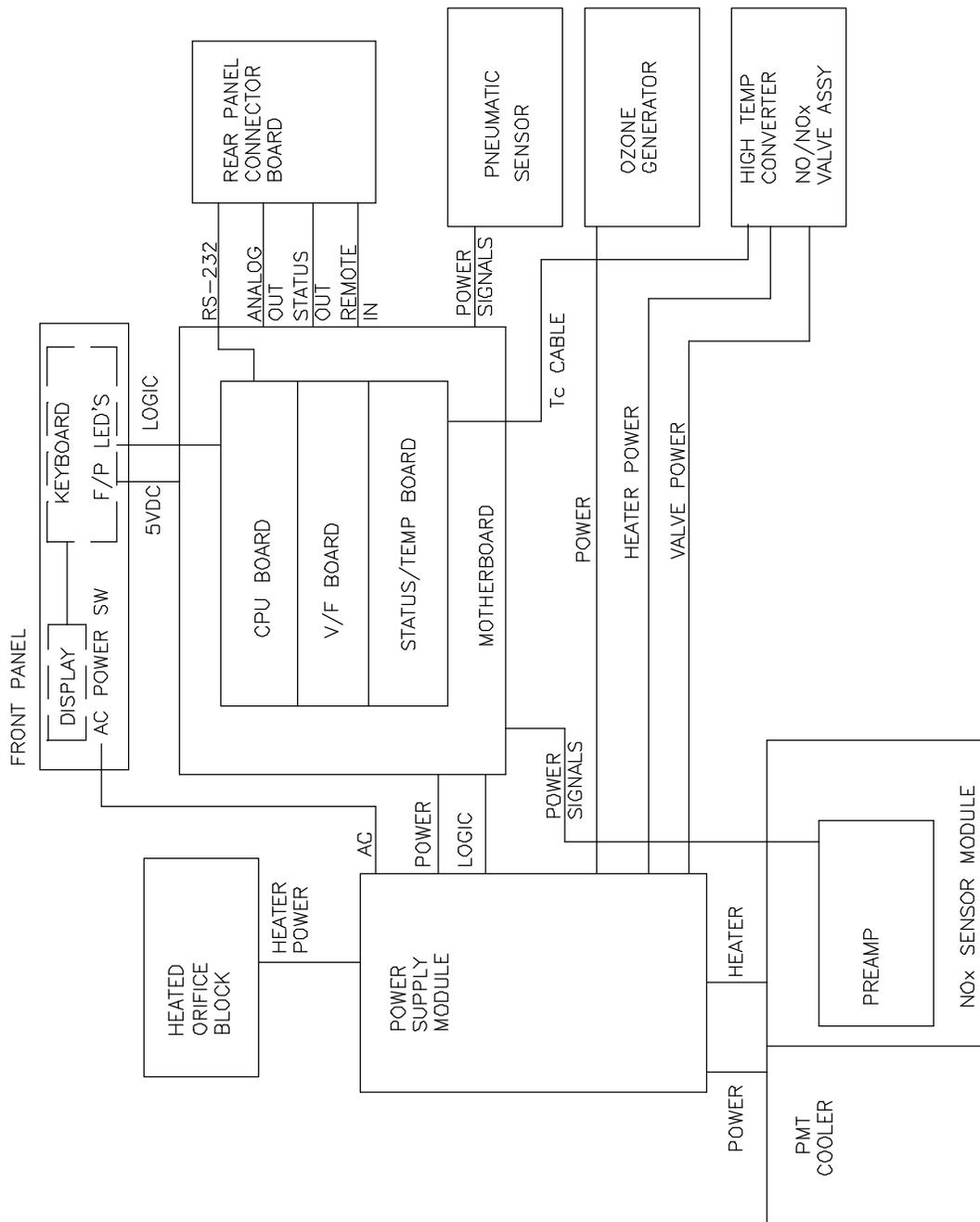


Figure 9-6: Electrical Block Diagram

PSM Diagnostic procedures

The Linear Power Supply board can be tested by checking the DCPS - TEST function on the front panel. It should read 2500 mV ± 200 mV. If the value is outside this range, individual output voltages can be tested on connector P3, see the schematic in the Appendix for pinouts.

The Switching Power Supply output can be tested by observing the red LED on the TEC control board attached to the inside of the fan duct on the Sensor Module. If the LED is on, +15 VDC is being supplied to the cooler. The current draw through the cooler can be measured across TP1 and TP2. The value of the current in amps is 10x the voltage measured, and is typically 1.5 to 2.0 amps at room temperature.

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

Table 9-9: Power Supply Module LED Operation

No.	Function	Description
1.	NO/NO _x Valve	Should switch about every 6 sec. On = NO _x mode Off = NO mode.
4.	AutoZero Valve	Should switch every 2 minutes. On = Azero Off = Sample mode
5.	Ozone Generator Power	Power to ozone generator is off for 30 minutes after turning on an instrument that has been off for a long time. If the instrument has been turned off for less than 60 minutes, the ozone generator is immediately turned on.
6.	Block Heater	Should cycle ON-OFF every 20 sec to 2 min. On continuously until up to temp.
7.	Conv Heater	Should cycle ON-OFF every 20 sec to 2 min. On continuously until up to temp.
8.	Reaction Cell Heater	Should cycle ON-OFF every 20 sec to 2 min. On continuously until up to temp.

9.3.6 Ozone Generator

The ozone generator subsystem consists of a permeation drier, flowmeter, transformer - generator assembly, and driver board. The location of the components is illustrated in Figure 9-7. Ozone is generated by drying ambient air, then passing the air between two electrodes that have a large oscillating electric field generated by a high voltage transformer.

The generator cartridge - transformer assembly is potted to eliminate corona and increase safety. The module cannot be disassembled.

Common faults in the ozone generator are:

1. A leak or some other failure in the drier will let ambient air into the generator. There is enough water vapor in room air to cause the generator to make nitric acid aerosol. It is very corrosive and causes the generator cartridge to short out, and plug up due to salt build-up. This reduces the ozone concentration generated, which can cause the analyzer to be non-linear due to insufficient ozone concentration. Also, the nitric acid can destroy parts down stream of the generator.
2. Contaminated ozone generator cartridge. Disconnect fittings and run water through the cartridge to clean.
3. Failure of the driver board.

Table 9-10: Ozone Generator Control Conditions

Condition	Description	Ozone Generator
1	Manual override off (SETUP-MORE-DIAG-OZONE GEN).	OFF
2	Manual override on.	ON
3	Ozone flow below low warning limit for 5 minutes (<i>OFLOW_SET</i> setup variable).	OFF
4	Instrument powered on for more than 30 minutes.	ON
5	Instrument powered off for less than 1 hour <i>and</i> ozone generator was on when instrument was powered off.	ON
6	Ozone flow above low warning limit for 0.5 minutes <i>and</i> condition 4 or 5 is true.	ON

NOTE

The ozone generator is independently controlled in the *SIGNAL I/O*, *O₂TIC TEST*, and *ELECTRICAL TEST* diagnostics. After exiting these diagnostics, the ozone generator is restored to the state specified by the above conditions.

9.3.6.1 The PermaPure Drier

The PermaPure drier is constructed of 2 concentric tubes. The inner tube is a special material that has an affinity for water vapor. The outer annulus is evacuated by the instrument pump. This creates a concentration gradient causing water in ambient air to diffuse into the outer annulus, thus the air in the inner tube becomes progressively drier as it progresses down the tube.

Due to the large number of connections and fittings on the drier, the most common drier fault is leaks. Before proceeding with any other procedures check the drier for leaks.

Occasionally the drier gets contaminated. The manufacturer of the drier recommends replacing the drier rather than trying to clean it. If cleaning is chosen, the following options are available:

1. Dirt - Clean any solids from dryer inlet by brushing. Use clean dry air to blow any loose particles from the inlet. De-ionized water or dilute (5-10% conc HCl in de-ionized water) hydrochloric acid can be passed thru the dryer. This should be done only with the dryer and HCl at room temperature.
2. Contamination with organic liquids and Freons - rinse the inner and outer tubes using 1,1,1 trichlorethane. Follow the solvent with dry air to purge the solvent.
3. Inorganic salts and oxgenated hydrocarbons can be removed by rinsing with 10% nitric acid at 50 C.

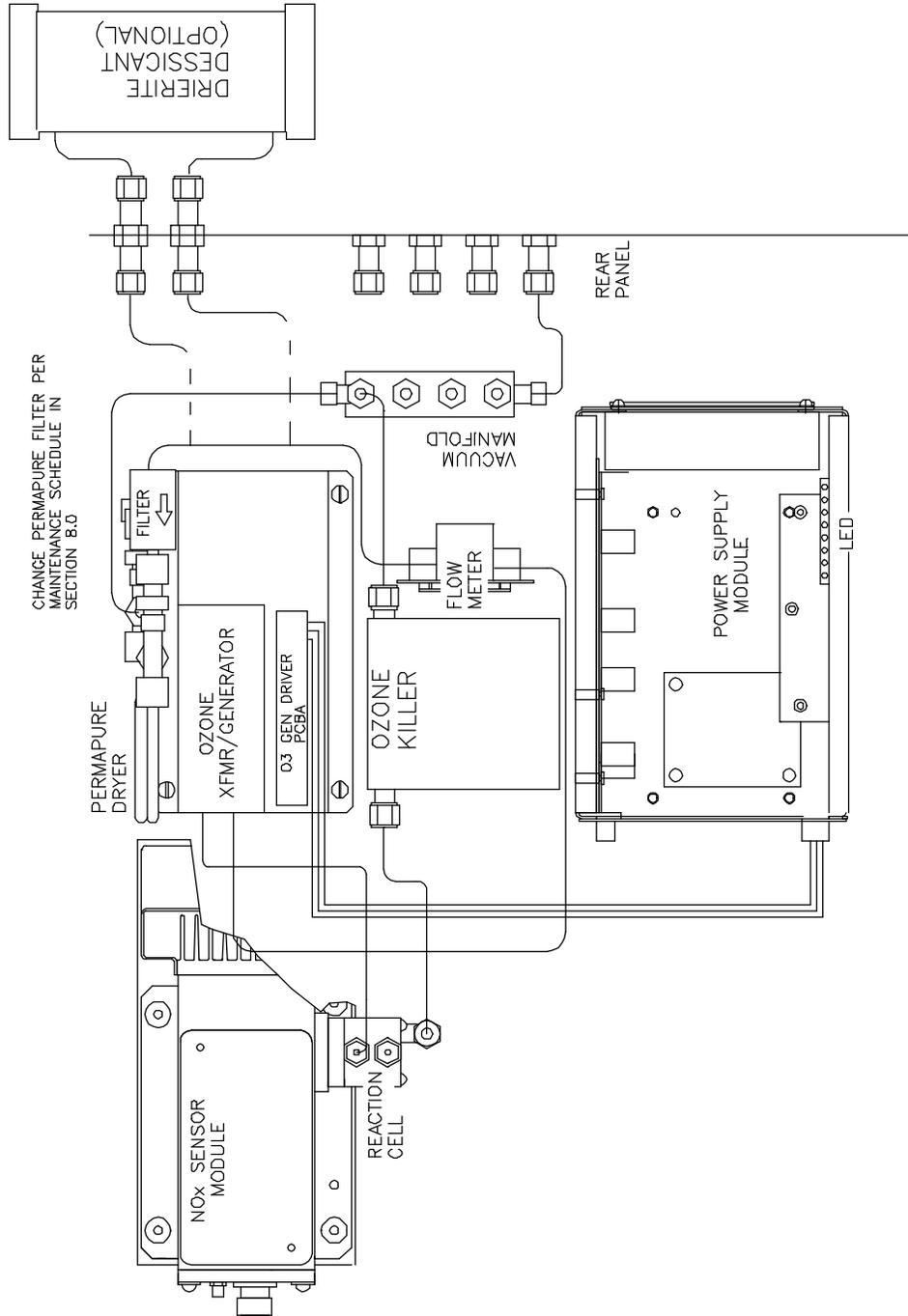


Figure 9-7: Ozone Generator Subsystem

9.3.7 Flow/Pressure Sensor

The flow/pressure sensor board consists of 2 pressure sensors and a flow sensor. See Figure 9-8 for a diagram of this board. From these three sensors four values are computed and displayed on the front panel TEST functions. They are:

1. Ozone flow - measured directly - S3, R3
2. Reaction Cell Pressure - measured directly - S2, R2
3. Sample gas pressure - measured directly S1, R1
4. Sample Flow - computed from sample pressure and reaction cell pressure S1, S2

The above pressures and flows are filtered to produce the front panel readings. There is a small delay after adjustment for a steady reading when observing the TEST functions.

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4. Sample Flow - computed from sample pressure and reaction cell pressure S1, S2

The above pressures and flows are filtered to produce the front panel readings. There is a small delay after adjustment for a steady reading when observing the TEST functions.

To adjust the OZONE flow:

1. Go to DIAG mode by pressing SETUP-MORE-DIAG, then select SIGNAL I/O, and press ENTR. Select OZONE_FLOW by using NEXT-PREV keys.
2. Adjust R3 so that OZONE_FLOW reads 2000 mV. This is the coarse adjustment.
3. Press EXIT to return to the SAMPLE mode. Select the OZONE FL - TEST function. Plumb a calibrated flow measuring device upstream of the ozone generator (See Figure 9-7). Use the external device reading to make small adjustments in R3 to dial in correct flow readout on the front panel.

To adjust the SAMPLE PRESSURE

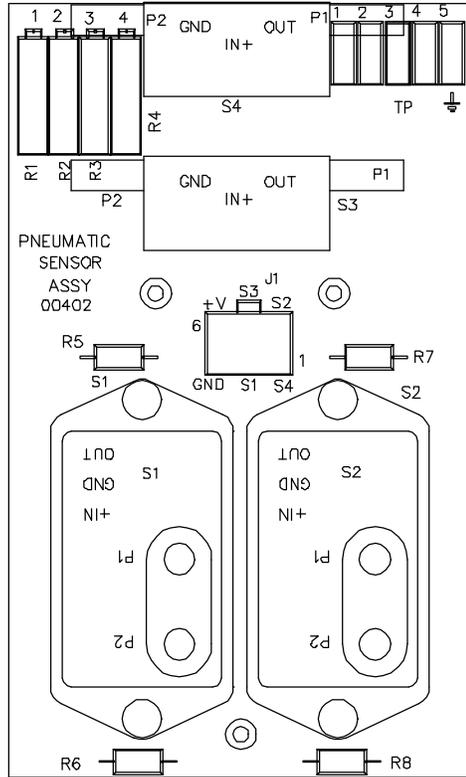
1. Go to DIAG mode by pressing SETUP-MORE-DIAG, then select SIGNAL I/O, and press ENTR. Select SAMPLE_PRESS by using NEXT-PREV keys.
2. Adjust R1 to read 4100 mV. This is the coarse adjustment.
3. Press EXIT to return to the SAMPLE mode. Select SAMP - TEST function. Use a calibrated absolute pressure meter to make small adjustments to R1 until the correct absolute pressure is displayed. 29.92 in-Hg-A is the target value at sea level. The rate of decrease is about 1"-Hg per 1000 ft of altitude.

To adjust the REACTION CELL PRESSURE

1. Go to DIAG mode by pressing SETUP-MORE-DIAG, then select SIGNAL I/O, and press ENTR. Select RCELL_PRESS by using the NEXT-PREV keys.
2. Disconnect the vacuum pump at the Sample Exhaust port on the instrument rear panel.
3. Press EXIT to return to the SAMPLE mode. Select RCEL - TEST function. Use a calibrated absolute pressure meter to make small adjustments to R1 until the correct absolute pressure is displayed. 29.92 in-Hg-A is the target value at sea level. The rate of decrease is about 1"-Hg per 1000 ft of altitude.
4. Re-connect the sample pump. The RCELL reading should now display the reaction cell absolute pressure of approximately 5 in-Hg-A.

To adjust the SAMPLE FLOW

1. In SAMPLE mode, scroll the TEST functions to SAMP FLW. Observe the reading. Then subtract the observed reading from the desired reading.
2. Go to the VARS menu by SETUP-MORE-VARS, then pressing ENTR. Scroll to SFLOW_SET and press EDIT. The first value displayed is the SFLOW_SET:VALUE reading, ADD the value from step 1 to the reading shown and key in the new reading, then press ENTR. Check the low and high warning limits, which are displayed as the next 2 values to make sure the new value does not exceed the warning limits. Press exit to return to SAMPLE mode.
3. Observe the SAMP FLW value. If necessary repeat step 2 to adjust the reading again to match the desired flow rate.



SENSOR, TESTPOINT, ADJUSTMENT	M200A FUNCTION
S1, TP1, R1	SAMPLE PRES, FLOW
S2, TP2, R2	CELL PRESSURE
S3, TP3, R3	OZONE FLOW

Figure 9-8: Flow/Pressure Sensor

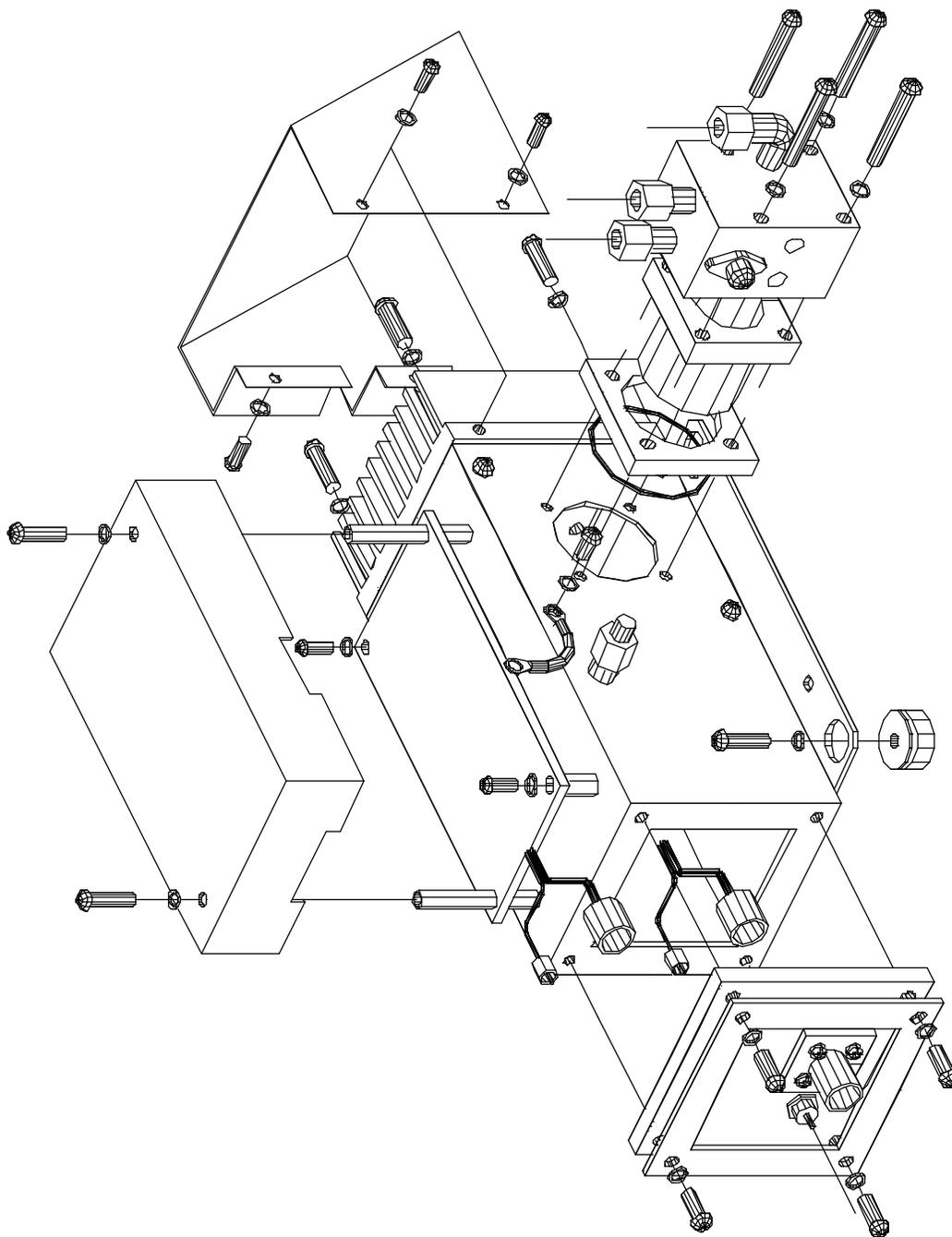


Figure 9-9: NO_x Sensor Module

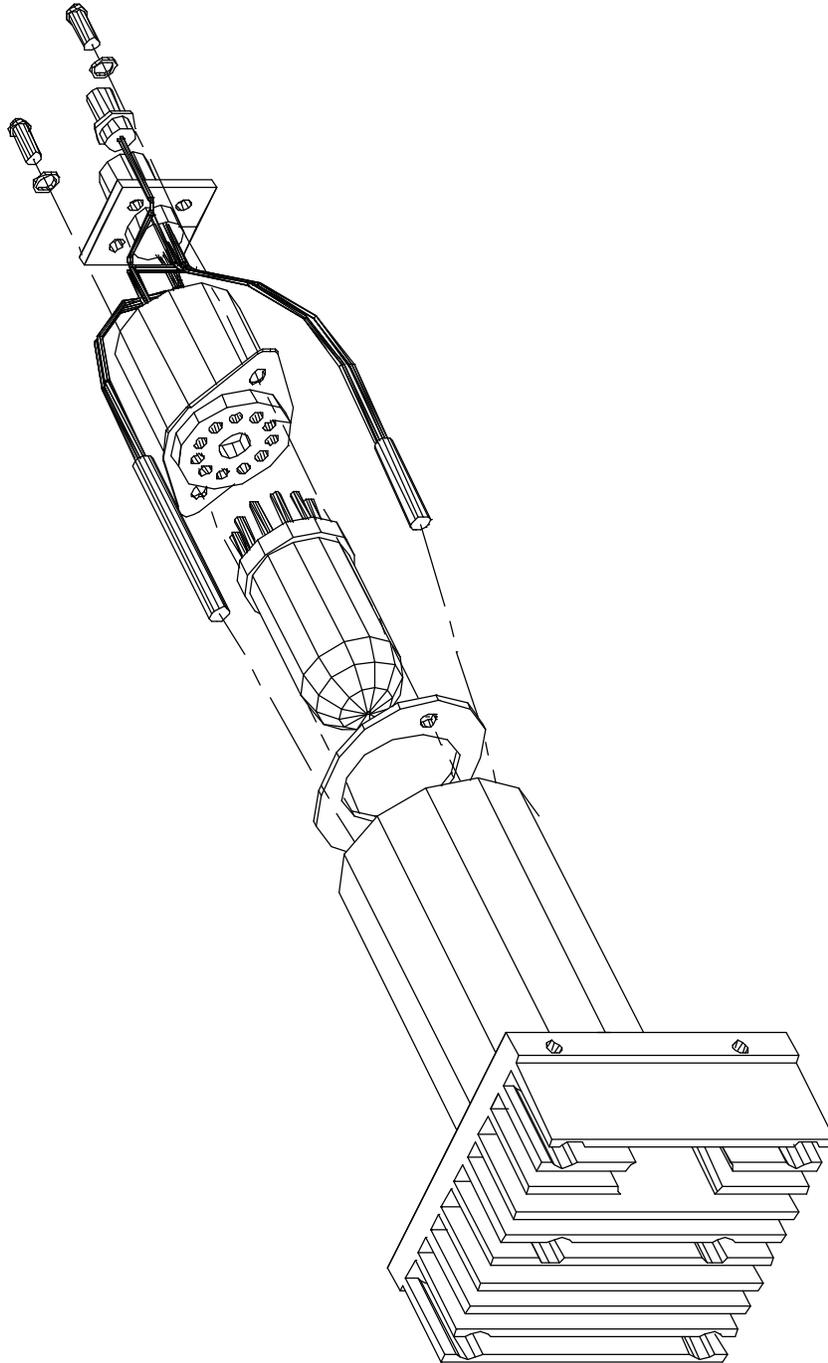


Figure 9-10: NO_x Sensor Module

9.3.8 NO_x Sensor Module

Figure 9-9 and Figure 9-10 show the assembly of the NO_x sensor module.

9.3.8.1 PMT

The PMT detects the light emitted by the reaction of NO with ozone. It has a gain of about 500,000 to 1,000,000. Because of its high sensitivity to light, it is not possible to test the detector outside of the instrument in the field. The best way to determine if the PMT is working is by using Optic test. OT operation is described in Section 9.1.3.3.

The basic method to diagnose a PMT fault is to eliminate the other components using ET, OT and specific tests for other sub-assemblies.

9.3.8.2 Reaction Cell Temperature

The reaction cell temperature is controlled by the CPU. It operates by reading a thermistor amplifier on the Status/Temp board. The CPU controls the temperature by toggling a bit on the V/F board. The V/F board TTL logic controls a solid state switch on the Switch Board in the PSM. The switched 115 VAC comes out of the PSM to a connector near the underside of the reaction cell. A warning message may be present during initial warm-up due to the temperature being below the 50 C setpoint.

9.3.8.3 Preamp Board

The NO_x Preamp Board is a multifunction board providing circuitry to support the following functions.

1. Preamp, buffer amplifier, physical range control hardware for the PMT detector.
2. Precision voltage reference and voltage generation, and control for the PMT - HVPS inside the sensor module.
3. Constant current generator and adjustment for the Optic Test LED.
4. Voltage generation and adjustment for Electric Test.
5. Thermistor amplifier, control signal generation for the PMT cooler.

The setup and adjustment of items 1-4 above is covered in the Factory Calibration procedure in Section 9.1.6. Item 5 has no adjustable features.

9.3.8.4 PMT Cooler

The PMT cooler uses a Peltier cooler supplied with DC current from the switching power supply in the Power Supply Module. An overall view is shown in Figure 9-11. The temperature is controlled by a proportional temperature controller located on the Preamp board. The input voltage from the supply is 15 VDC. Typical current through the cooler at room temp is about 1.5 to 2 A. At normal room temperatures the 7 C set point should be maintained within 0.1 C. The current and voltage can be measured at test points on the fan shroud at one end of the NO_x sensor module. See the Schematic in the Appendix.

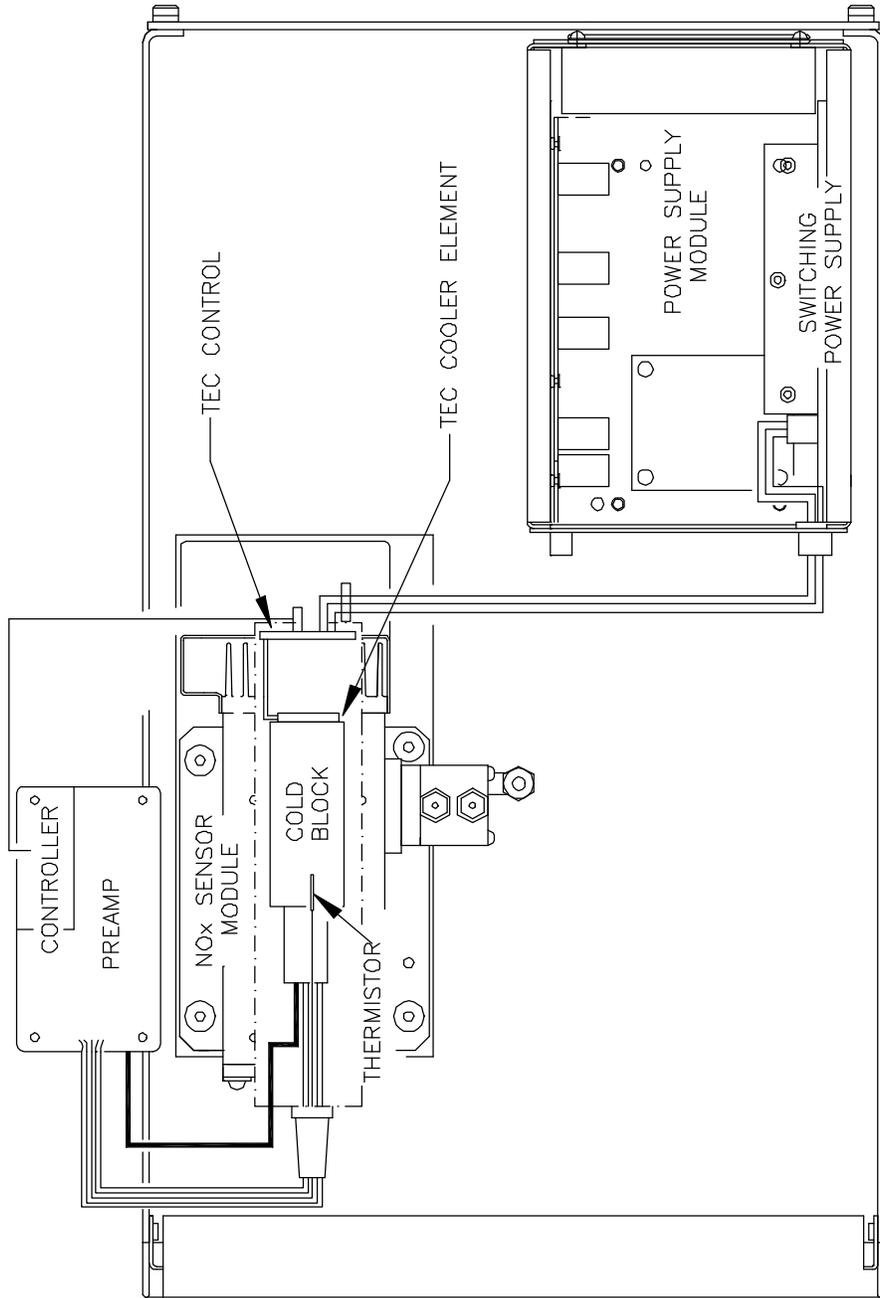


Figure 9-11: PMT Cooler Subsystem

9.3.8.5 High Voltage P.S.

The HVPS is located in the interior of the Sensor Module, and is plugged into the PMT tube. It requires 2 voltage inputs. The first is +15 VDC, which powers the supply. The second is the programming voltage, which is generated on the Preamp Board. This power supply is unlike a traditional PMT HVPS. It is like having 10 independent power supplies, one to each pin of the PMT. The test procedure below allows you to test each supply.

Adjustment of the HVPS is covered in the Factory Calibration Procedure in Section 9.1.6.

To troubleshoot the HVPS:

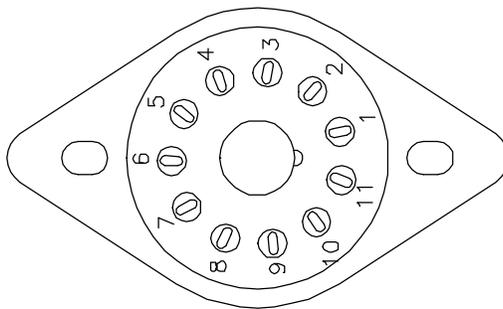
1. Turn off the instrument.
2. Remove the cover and disconnect the 2 connectors at the front of the NO_x Sensor Module.
3. Remove the end cap from the sensor.
4. Remove the HVPS/PMT assembly from the cold block inside the sensor. Un-plug the PMT tube.
5. Re-connect the 7 pin connector to the Sensor end cap, and power-up the instrument.
6. Use Figure 9-12 to check the voltages at each pin of the supply.
7. Turn off the instrument power, and re-connect the PMT tube, then re-assemble the sensor.

If any faults are found in the test, you must obtain a new HVPS as there are no user serviceable parts inside the supply.

To test the HVPS, follow the procedure outlined in Section 9.3.8.5 of the manual. Then:

1. With the instrument disassembled as described and the power turned on, check the HVPS – TEST function on the front panel.

2. Divide the observed HVPS voltage by 10 and test the following pairs of points. The voltage should be 1/10 of the HVPS voltage for each pair.
 For Example: If the voltage was 700VDC, the voltage at each stage would be 70VDC.



HVPS PINS	VOLTAGE
11-1	70
1-2	70
2-3	70
3-4	70
4-5	70
5-6	70
6-7	70
7-8	70
8-9	70

3. Each stage should have the same voltage. If so the HVPS is working.

Figure 9-12: High Voltage Power Supply

9.3.9 Z/S Valves

The Z/S Valves is an option in the instrument. Before troubleshooting this sub-assembly, check that the options were ordered, and that they are enabled in the software. Section 7.2 shows how the Z/S valve option should be set-up.

Check for the Z/S valves.

1. Check for the physical presence of the valves. See Figure 2-5 for Z/S Valve location.
2. Check that the option has been enabled in the software. The front panel display, when the instrument is in SAMPLE mode, should display CALS and CALZ buttons on the second line of the display. The presence of the buttons indicates that the option has been enabled in software. If the valves are present but CALS/CALZ is not displayed, call the factory.

Troubleshooting the Z/S valves.

1. Turn the instrument and sample pump on. Locate the valve module on the rear panel.
2. There is a red LED associated with each of the 4 valve positions, when the LED is ON the valve is OPEN. Each LED corresponds top-to-bottom to each valve.
3. Correct operation of each valve can be checked as follows:
 - A. In sample mode, the bottom sample valve is open and the LED is ON. Check flow through the sample inlet port on the rear panel.
 - B. In CALZ mode, the second from the bottom zero gas valve is open and the LED is ON. Check flow through the zero gas port on the rear panel.
 - C. In CALS - LOW SPAN mode, the third from the bottom span gas valve is open and the corresponding LED is ON. Check flow through the low span gas port on the rear panel.
 - D. In CALS - HI SPAN mode, the top gas valve is open and the top LED is ON. Check flow through the high span gas port on the rear panel.

If the LED's fail to light, check the iSBX board on the CPU board and cable for 0-5 VDC logic signals.

If the LED's light, but the valves do not operate, check the 12 VDC cable from the power supply module.

The valve may be operating, but may be plugged. If that is suspected, dis-assemble the manifold and inspect for signs of plugging. While the valves can be removed from the manifold, it is NOT recommended that the valves be dis-assembled as there are several small spring loaded parts inside.

It is also possible to manually toggle each of the valves in the DIAGNOSTIC mode. Refer to Section 9.1.3 for information on using the DIAG mode. Also refer to Figure 8-4, Figure 8-5 for a pneumatic diagram of the system. Check for fitting leaks and crimped tubing.

9.3.10 Pneumatic System

The pneumatic system is diagrammed in Figure 8-4, Figure 8-5, depending on which options the instrument was ordered with.

9.3.10.1 Leak Check

CAUTION

**When doing a leak check do not pressurize
the M9110AH to greater than 15psi.**

**Damage to internal components will
occur at higher pressures.**



The root cause of many performance problems is a leak. Refer to Section 8.6 for the leak check procedure.

9.3.10.2 Pump

The external sample pump is capable of maintaining the cell pressure at 5"-Hg-A. If higher pressures are noted, the pump may need servicing. Common pump problems and causes are:

1. Failure of ozone scrubber, thus allowing ozone into the pump. Ozone is very corrosive and causes failure of the diaphragm. Replace catalytic ozone scrubber in the NO₂-to-NO converter, replace charcoal scrubber on pump pack, and rebuild the pump.
2. Sometimes the felt pads in the charcoal ozone scrubber plug up, thus restricting flow, and decreasing effective vacuum even if pump is good.
3. Failed pump. The pump has a finite lifetime. There is a re-build kit, see the spare parts list.

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