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INSTRUCTION MANUAL

Model 9110TH *Nitrogen Oxides Analyzer*



P/N M9110TH
DATE 10/11/13

TELEDYNE ELECTRONIC TECHNOLOGIES *Analytical Instruments*

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Important Notice

This instrument provides measurement readings to its user, and serves as a tool by which valuable data can be gathered. The information provided by the instrument may assist the user in eliminating potential hazards caused by his process; however, it is essential that all personnel involved in the use of the instrument or its interface be properly trained in the process being measured, as well as all instrumentation related to it.

The safety of personnel is ultimately the responsibility of those who control process conditions. While this instrument may be able to provide early warning of imminent danger, it has no control over process conditions, and it can be misused. In particular, any alarm or control systems installed must be tested and understood, both as to how they operate and as to how they can be defeated. Any safeguards required such as locks, labels, or redundancy, must be provided by the user or specifically requested of Teledyne at the time the order is placed.

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INFORMATION ABOUT THE SPECIFIC CONFIGURATION OF YOUR MODEL 9110T NO_x ANALYZER

Note: All instruments must include the standard hardcopy manual.

SELECTED VERSIONS OF THE MODEL 9110T

Model 9110T— Standard Touch Screen Version

This Model 9110E NO_x Analyzer is a touch screen version designed for analyzing the NO_x concentration in a background gas specified by the customer. It has a minimum settable range of 0-50 ppb and a maximum settable range of 0-10 ppm. The standard version is designed for ambient pressure applications. The analyzer may have one or two analysis ranges with or without auto-ranging as listed below. It includes an internal Moly converter and an external pump. Alarm relays are optional and if included, that option will be checked below.

Model 9110TH — High Range Touch Screen Version

The Model 9110EH NO_x Analyzer is a touch screen version designed for analyzing higher NO_x concentration (from 0-5 ppm to 0-5000 ppm) than the standard model. It includes an internal Hicon converter and an external pump. Alarm relays are optional and if included, that option will be checked below. There is no internal zero/span gas/oven option available for this model. The analyzer may have one or two analysis ranges with or without autoranging as listed below.

This version is available with internal or external Hicon or Moly converters.

Model 9110TM — Mid-Range Touch Screen Version

The Model 9110EA NO_x Analyzer is a touch screen version designed for analyzing a mid-range NO_x concentration. It has a minimum settable range of 0-1 ppm and a maximum settable range of 0-200 ppm. It includes an internal Moly converter and an external pump. Alarm relays are optional and if included, that option will be checked below. There is no internal zero/span gas/oven option available for this model. The analyzer may have one or two analysis ranges with or without autoranging as listed below.

This model is similar to the EH version but does not have a sample bypass line. An optional paramagnetic oxygen sensor is available for oxygen analysis in this version.

Converter Options

The 9110 is equipped with an internal Hicon thermal converter as standard equipment. Other converters are available for the EH version as follows:

- | | |
|--|--|
| <input type="checkbox"/> Internal Hicon (standard) | <input type="checkbox"/> External Hicon (2 nd set of rack mounts req'd) |
| <input type="checkbox"/> Internal Moly | <input type="checkbox"/> External Moly (2 nd set of rack mounts req'd) |

Power Requirements

This Model 9110E is configured to operate from the following AC Power source:

- | | | |
|--|--|-------------------------------------|
| <input type="checkbox"/> 100-120 VAC 60 Hz | <input type="checkbox"/> 220-240 VAC 60 Hz | <input type="checkbox"/> 100V 60 Hz |
| <input type="checkbox"/> 100-120 VAC 50 Hz | <input type="checkbox"/> 220-240 VAC 50 Hz | <input type="checkbox"/> 100V 50 Hz |

Analog Output Signals

Analog output signals are available at A1, A2, and A3 on the rear panel. This instrument is configured with the following analog outputs:

- | | |
|---|--|
| <input type="checkbox"/> A1(NOx): 4-20 mA | |
| <input type="checkbox"/> A2 (NO): 0-5 V | <input type="checkbox"/> A2(NO): 4-20 mA |
| <input type="checkbox"/> A3 (NO ₂): 0-5 V | <input type="checkbox"/> A2(NO ₂): 4-20 mA |

Range Mode

The analyzer can be designed with a single or dual analysis ranges with auto-ranging or dual independent ranges. This analyzer is configured with the following range mode:

- | | |
|--|---|
| <input type="checkbox"/> Single Range: _____ | |
| <input type="checkbox"/> Dual Range/Auto-ranging: | <input type="checkbox"/> Dual Range/Independent: |
| Low Range: _____ | Low Range: _____ |
| High Range: _____ | High Range: _____ |
| | Gas: _____ |

Selected Options for the Model 9110T

Mounting Options

- 19" rack mounting with 26" sliders with ears
- 19" rack mounting with ears only

Pump Mounting Options

- None
- Rack mounting hardware

Rear Panel Gas Fittings

- 1/4" SS Standard
- 6 mm SS Optional

Valve Options

- No Valves
- Internal SS Zero/Span Valves
- Second Range Span Valve
- Internal Zero/Span Valves with Oven (Not available for 9110EH/EM)
- Internal Zero/Span Valves with Oven and Permeation Tube (Not available for 9110EH)

The permeation tube option installed depends on the sample gas and the effusion rate. The specific permeation tube in this instrument is listed below:

Permeation tube Installed: _____

Alarm Relay Option

This option includes two concentration alarm relays.

Oxygen Sensor

This analyzer is equipped with a paramagnetic oxygen sensor for measuring the oxygen concentration over the range of 0-25%

Gas Conditioner

A gas conditioner/dryer permeation gas exchange tube is installed for removing H₂O and ammonia from the sample stream. This item is required for EN certification.

Oxygenator

For applications where background gas less than 2% oxygen and using a Moly converter.

Remote Operation for Purged Enclosure

The operator interface is duplicated with switches mounted on the front door of the enclosure allowing operation without compromising purge integrity.

Background Gas: _____

Notes:

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SAFETY MESSAGES

Important safety messages are provided throughout this manual for the purpose of avoiding personal injury or instrument damage. Please read these messages carefully. Each safety message is associated with a safety alert symbol, and are placed throughout this manual; the safety symbols are also located inside the instrument. It is imperative that you pay close attention to these messages, the descriptions of which are as follows:



WARNING: Electrical Shock Hazard



HAZARD: Strong oxidizer



GENERAL WARNING/CAUTION: Read the accompanying message for specific information.



CAUTION: Hot Surface Warning



Do Not Touch: Touching some parts of the instrument without protection or proper tools could result in damage to the part(s) and/or the instrument.



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



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

NEVER use any gas analyzer to sample combustible gas(es)!

Note: Technical Assistance regarding the use and maintenance of the Model 9110TH or any other Teledyne product can be obtained by contacting Teledyne Customer Service Department:

Phone: 888-789-8168

Email: ask_tai@teledyne.com

or by accessing various service options on our website at

<http://www.teledyne-ai.com/>

CONSIGNES DE SÉCURITÉ

Des consignes de sécurité importantes sont fournies tout au long du présent manuel dans le but d'éviter des blessures corporelles ou d'endommager les instruments. Veuillez lire attentivement ces consignes. Chaque consigne de sécurité est représentée par un pictogramme d'alerte de sécurité; ces pictogrammes se retrouvent dans ce manuel et à l'intérieur des instruments. Les symboles correspondent aux consignes suivantes :



AVERTISSEMENT : Risque de choc électrique



DANGER : Oxydant puissant



AVERTISSEMENT GÉNÉRAL / MISE EN GARDE : Lire la consigne complémentaire pour des renseignements spécifiques



MISE EN GARDE : Surface chaude



Ne pas toucher : Toucher à certaines parties de l'instrument sans protection ou sans les outils appropriés pourrait entraîner des dommages aux pièces ou à l'instrument.



Pictogramme « technicien » : Toutes les opérations portant ce symbole doivent être effectuées uniquement par du personnel de maintenance qualifié.



Mise à la terre : Ce symbole à l'intérieur de l'instrument détermine le point central de la mise à la terre sécuritaire de l'instrument.

MISE EN GARDE



Cet instrument doit être utilisé aux fins décrites et de la manière décrite dans ce manuel. Si vous utilisez cet instrument d'une autre manière que celle pour laquelle il a été prévu, l'instrument pourrait se comporter de façon imprévisible et entraîner des conséquences dangereuses.

NE JAMAIS utiliser un analyseur de gaz pour échantillonner des gaz combustibles!

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ABOUT THIS MANUAL

This manual describes operation, specifications, and maintenance for the Model 9110TH.

In addition this manual contains important SAFETY messages for this instrument. It is strongly recommended that you read that operation manual in its entirety before operating the instrument.

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1. INTRODUCTION, FEATURES, AND OPTIONS

1.1. OVERVIEW

The Models 9110TH and 9110TM (also referred to in this manual as 9110TH/M when applicable to both models) use the proven chemiluminescence measurement principle, coupled with state-of-the-art microprocessor technology for monitoring high and medium levels of nitrogen oxides. User-selectable analog output ranges and a linear response over the entire measurement range make them ideal for a wide variety of applications, including extractive and dilution CEM, stack testing, and process control.

1.2. FEATURES

The Models 9110TH and 9110TM include the following features:

- LCD Graphical User Interface with capacitive touch screen
- Bi-directional RS-232, and 10/100Base-T Ethernet (optional USB and RS-485) ports for remote operation
- Front panel USB ports for peripheral devices
- 9110TH: 0-5 ppm to 0-5000 ppm, user selectable
- 9110TM: 0-1 to 0-200 ppm, user selectable
- Independent ranges for NO, NO₂, NO_X
- Auto ranging and remote range selection
- NO_X-only or NO-only modes
- Microprocessor controlled for versatility
- Multi-tasking software allows viewing of test variables while operating
- Continuous self checking with alarms
- Permeation drier on ozone generator
- Digital status outputs provide instrument condition
- Adaptive signal filtering optimizes response time
- Temperature & pressure compensation, automatic zero correction
- Converter efficiency correction software
- Minimum CO₂ and H₂O interference
- Catalytic ozone scrubber
- Internal data logging with 1 min to 365 day multiple averages

1.3. USING THIS MANUAL

The flowcharts in this manual contain typical representations of the analyzer's display during the various operations being described. These representations are not intended to be exact and may differ slightly from the actual display of your instrument.

1.4. OPTIONS

Option	Option Number	Description/Notes	Reference
Pumps		Pumps meet all typical AC power supply standards while exhibiting same pneumatic performance.	
	11A	Ship without pump	N/A
	11B	Pumpless Pump Pack	N/A
	12A	Internal Pump 115V @ 60 Hz	N/A
	12B	Internal Pump 220V @ 60 Hz	N/A
	12C	Internal Pump 220V @ 50 Hz	N/A
Rack Mount Kits		Options for mounting the analyzer in standard 19" racks	
	20A	Rack mount brackets with 26 in. (660 mm) chassis slides	N/A
	20B	Rack mount brackets with 24 in. (610 mm) chassis slides	N/A
	21	Rack mount brackets only (compatible with carrying strap, Option 29)	N/A
	23	Rack mount for external pump pack (no slides)	N/A
Carrying Strap/Handle		Side-mounted strap for hand-carrying analyzer	
	29	Extends from "flat" position to accommodate hand for carrying. Recesses to 9mm (3/8") dimension for storage. Can be used with rack mount brackets, Option 21. Cannot be used with rack mount slides.	N/A
		CAUTION – GENERAL SAFETY HAZARD	
		THE 9110TH OR 9110TM ANALYZER WEIGHS ABOUT 18 KG (40 POUNDS).	
		TO AVOID PERSONAL INJURY WE RECOMMEND THAT TWO PERSONS LIFT AND CARRY THE ANALYZER. DISCONNECT ALL CABLES AND TUBING FROM THE ANALYZER BEFORE MOVING IT.	
Analog Input and USB port		Used for connecting external voltage signals from other instrumentation (such as meteorological instruments).	
	64B	Also can be used for logging these signals in the analyzer's internal DAS	Section 3.4.2
Current Loop Analog Outputs		Adds isolated, voltage-to-current conversion circuitry to the analyzer's analog outputs.	
	41	Can be configured for any output range between 0 and 20 mA. May be ordered separately for any of the analog outputs. Can be installed at the factory or retrofitted in the field.	Section 3.4.5
Parts Kits		Spare parts and expendables	
	42A	Expendables Kit includes a recommended set of expendables for one year of operation of this instrument including replacement sample particulate filters.	Appendix B
Calibration Valves		Used to control the flow of calibration gases generated from external sources, rather than manually switching the rear panel pneumatic connections.	
	50A	AMBIENT ZERO AND AMBIENT SPAN VALVES Zero Air and Span Gas input supplied at ambient pressure. Gases controlled by 2 internal valves; SAMPLE/CAL & ZERO/SPAN.	Section 3.5.3.1
	50D	ZERO SCRUBBER AND DUAL PRESSURIZED SPAN VALVES Zero Air Scrubber produces/supplies zero air to the ZERO inlet port. Dual Pressurized Span Valves for two gas mixtures to separate inlet ports, HIGH SPAN and LOW SPAN.	Section 3.5.3.2



Option	Option Number	Description/Notes	Reference
Communication Cables		For remote serial, network and Internet communication with the analyzer.	
		Type	Description
	60A	RS-232	Shielded, straight-through DB-9F to DB-25M cable, about 1.8 m long. Used to interface with older computers or code activated switches with DB-25 serial connectors.
	60B	RS-232	Shielded, straight-through DB-9F to DB-9F cable of about 1.8 m length.
	60C	Ethernet	Patch cable, 2 meters long, used for Internet and LAN communications.
	60D	USB	Cable for direct connection between instrument (rear panel USB port) and personal computer.
USB Port		For remote connection	
	64A	For connection to personal computer. (Separate option only when Option 64B, <i>Analog Input and USB Com Port</i> not elected).	Sections 3.4.8.2 and 4.11.8
Concentration Alarm Relays		Issues warning when gas concentration exceeds limits set by user.	
	61	Four (4) "dry contact" relays on the rear panel of the instrument. This relay option is different from and in addition to the "Contact Closures" that come standard on all TAPI instruments.	Section 3.4.7
RS-232 Multidrop		Enables communications between host computer and up to eight analyzers.	
	62	Multidrop card seated on the analyzer's CPU card. Each instrument in the multidrop network requires this card and a communications cable (Option 60B).	Sections 3.4.8.3 and 4.11.9
Other Gas Options		Second gas sensor and gas conditioners	
	65A	Oxygen (O ₂) Sensor	Figure 3-23, Figure 3-24 and Sections 3.7.2 and 8.4
	86A	Sample Gas Conditioner (Dryer/NH ₃ Removal) for sample gas stream only. Converts analyzer to dual-conditioner instrument.	(contact Sales)
	87	Sample Oxygenator for proper operation of the NO ₂ -to-NO catalytic converter. Injects oxygen into sample gas that is depleted of oxygen.	(contact Sales)
Special Features		Built in features, software activated	
	N/A	Maintenance Mode Switch , located inside the instrument, places the analyzer in maintenance mode where it can continue sampling, yet ignore calibration, diagnostic, and reset instrument commands. This feature is of particular use for instruments connected to Multidrop or Hessen protocol networks. Call Customer Service for activation.	N/A
	N/A	Second Language Switch activates an alternate set of display messages in a language other than the instrument's default language. Call Customer Service for a specially programmed Disk on Module containing the second language.	N/A
	N/A	Dilution Ratio Option allows the user to compensate for diluted sample gas, such as in continuous emission monitoring (CEM) where the quality of gas in a smoke stack is being tested and the sampling method used to remove the gas from the stack dilutes the gas. Call Customer Service for activation.	Section 4.8.2

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2. SPECIFICATIONS AND APPROVALS

2.1. 9110TH/M OPERATING SPECIFICATIONS

Table 2-1: Model 9110TH/M Basic Unit Specifications

Min/Max Range (Physical Analog Output)	9110TH: Min: 0-5 ppm; Max: 0-5000 ppm	9110TM: Min: 0-1 ppm; Max: 0-200 ppm
Measurement Units	ppm, mg/m ³ (user selectable)	
Zero Noise	<20 ppb (RMS)	
Span Noise	<0.2% of reading above 20 ppm	
Lower Detectable Limit	40 ppb (2x noise as per USEPA)	
Zero Drift (24 hours)	<20 ppb (at constant temperature and voltage.)	
Zero Drift (7 days)	<20 ppb (at constant temperature and voltage.)	
Span Drift (7 Days)	<1% of reading (at constant temperature and voltage.)	
Linearity	1% of full scale	
Precision	0.5% of reading	
Lag Time	20 s	
Rise/Fall Time	95% in <60 s (~10 s in NO only or NO _x only modes)	
Gas Flow Rates	9110TH: <ul style="list-style-type: none"> • 40 cm³/min sample gas through NO₂ converter & sensor module • 250 cm³/min ± 10% through bypass manifold • 290 cm³/min total flow O ₂ Sensor option adds 80 cm ³ /min to total flow though 9110TH/M when installed.	9110TM: 250 cm ³ /min sample gas through NO ₂ converter & sensor module
Temperature Range	5 - 40 °C operating range	
Humidity Range	0-95% RH non-condensing	
Dimensions H x W x D	18 cm x 43 cm x 61 cm (7" x 17" x 23.6")	
Weight, Analyzer	18 kg (40 lbs) without options	
Weight, Ext Pump Pack	7 kg (16 lbs)	
AC Power	9110TH: 100V-120V, 60 Hz (175W) 220V-240V, 50 Hz (155W)	9110TM: 100V-120V, 60 Hz (55W) 220V-240V, 50 Hz (75W)
Power, Ext Pump	100 V, 50 Hz (300 W); 100 V, 60 Hz (255 W); 115 V, 60 Hz (285 W); 220 - 240 V, 50 Hz (270 W); 230 V, 60 Hz (270 W)	
Environmental	Installation category (over-voltage category) II; Pollution degree 2	
Analog Outputs	4 user configurable outputs	
Analog Output Ranges	All Outputs: 0.1 V, 1 V, 5 V or 10 V Three outputs convertible to 4-20 mA isolated current loop. All Ranges with 5% under/over-range	
Analog Output Resolution	1 part in 4096 of selected full-scale voltage (12 bit)	
Status Outputs	8 Status outputs from opto-isolators, 7 defined, 1 spare	
Control Inputs	6 Control inputs, 4 defined, 2 spare	
Alarm outputs	2 relay alarms outputs (Optional equipment) with user settable alarm limits - 1 Form C: SPDT; 3 Amp @ 125 VAC	
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 8 opto-isolated digital outputs 6 opto-isolated digital inputs 4 analog outputs	
Optional I/O	1 USB com port 1 RS485 8 analog inputs (0-10V, 12-bit) 4 digital alarm outputs Multidrop RS232 3 4-20mA current outputs	

2.2. APPROVALS AND CERTIFICATIONS

The TAI Nitrogen Oxides Analyzers 9110TH and 9110TM were tested and certified for Safety and Electromagnetic Compatibility (EMC). This section presents the compliance statements for those requirements and directives.

2.2.1. SAFETY

IEC 61010-1:2001, Safety requirements for electrical equipment for measurement, control, and laboratory use.

CE: 2006/95/EC, Low-Voltage Directive

North American:

cNEMKO (Canada): CAN/CSA-C22.2 No. 61010-1-04

NEMKO-CCL (US): UL No. 61010-1 (2nd Edition)

2.2.2. EMC

EN 61326-1 (IEC 61326-1), Class A Emissions/Industrial Immunity

EN 55011 (CISPR 11), Group 1, Class A Emissions

FCC 47 CFR Part 15B, Class A Emissions

CE: 2004/108/EC, Electromagnetic Compatibility Directive

3. GETTING STARTED

3.1. UNPACKING AND INITIAL SETUP

CAUTION



THE 9110TH AND THE 9110TM EACH WEIGH ABOUT 18 KG (40 POUNDS) WITHOUT OPTIONS INSTALLED. TO AVOID PERSONAL INJURY, WE RECOMMEND USING TWO PERSONS TO LIFT AND CARRY THE ANALYZER.

CAUTION – Avoid Warranty Invalidation



Printed circuit assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Damage resulting from failure to use ESD protection when working with electronic assemblies will void the instrument warranty.

See *A Primer on Electro-Static Discharge* section in this manual for more information on preventing ESD damage.

Note

TAI recommends that you store shipping containers/materials for future use should the instrument need be returned to the factory for repair and/or calibration service. See Warranty section in this manual and our Website at <http://www.teledyne-api.com> for a Return Authorization form.

WARNING



NEVER DISCONNECT ELECTRONIC CIRCUIT BOARDS, WIRING HARNESSSES OR ELECTRONIC SUBASSEMBLIES WHILE THE UNIT IS UNDER POWER.

1. Inspect the received packages for external shipping damage. If damaged, please advise the shipper first, then TAI.
2. Included with your analyzer is a printed record of the final performance characterization performed on your instrument at the factory. This record, titled *Final Test and Validation Data Sheet* (P/N 04413) is an important quality assurance and calibration record for this instrument. It should be placed in the quality records file for this instrument.
3. Carefully remove the top cover of the analyzer and check for internal shipping damage, as follows:
 - a. Remove the set-screw located in the top, center of the front panel.

- b. Remove the 2 screws fastening the top cover to the unit (one per side towards the rear).
 - c. Slide the cover backwards until it clears the analyzer's front bezel.
 - d. Lift the cover straight up.
4. Inspect the interior of the instrument to make sure all circuit boards and other components are in good shape and properly seated.
 5. Check the connectors of the various internal wiring harnesses and pneumatic hoses to make sure they are firmly and properly seated.
 6. Verify that all of the optional hardware ordered with the unit has been installed. These are checked on the paperwork (Form 04490) accompanying the analyzer.

3.2. VENTILATION CLEARANCE

Whether the analyzer is set up on a bench or installed into an instrument rack, be sure to leave sufficient ventilation clearance.

AREA	MINIMUM REQUIRED CLEARANCE
Back of the instrument	10 cm / 4 inches
Sides of the instrument	2.5 cm / 1 inch
Above and below the instrument.	2.5 cm / 1 inch

3.3. 9110TH/M LAYOUT

Figure 3-1 shows the front panel layout of the analyzer, and Figure 3-4 shows the rear panel with optional zero-air scrubber mounted to it and two optional fittings for the IZS option. Figure 3-5 shows a top-down view of the analyzer. This configuration includes the IZS option, zero-air scrubber and an additional sample dryer (briefly described in Section 1.4).

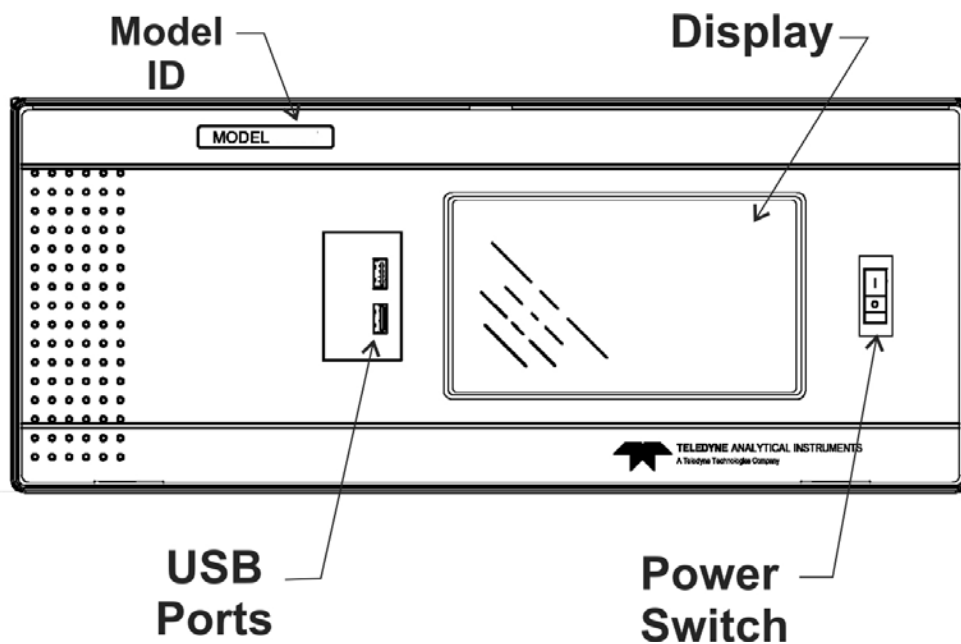


Figure 3-1: 9110TH Front Panel



Figure 3-2: Display Screen and Touch Control



CAUTION – Avoid Damaging Touch screen

Do not use hard-surfaced instruments such as pens to operate the touch screen.

The front panel liquid crystal display screen includes touch control. Upon analyzer start-up, the screen shows a splash screen and other initialization indicators before the main display appears, similar to Figure 3-2 above (may or may not display a Fault alarm). The LEDs on the display screen indicate the Sample, Calibration and Fault states; also on the screen is the gas concentration field (Conc), which displays real-time readouts for the primary gas and for the secondary gas if installed. The display screen also shows what mode the analyzer is currently in, as well as messages and data (Param). Along the bottom of the screen is a row of touch control buttons; only those that are currently applicable will have a label. Table 3-1 provides detailed information for each component of the screen.

Table 3-1: Display Screen and Touch Control Description

Field	Description/Function			
Status	LEDs indicating the states of Sample, Calibration and Fault, as follows:			
	Name	Color	State	Definition
	SAMPLE	Green	Off	Unit is not operating in sample mode, DAS is disabled.
			On	Sample Mode active; Front Panel Display being updated; DAS data being stored.
			Blinking	Unit is operating in sample mode, front panel display being updated, DAS hold-off mode is ON, DAS disabled
CAL	Yellow	Off	Auto Cal disabled	
		On	Auto Cal enabled	
		Blinking	Unit is in calibration mode	
FAULT	Red	Off	No warnings exist	
		Blinking	Warnings exist	
Conc	Displays the actual concentration of the sample gas currently being measured by the analyzer in the currently selected units of measure			
Mode	Displays the name of the analyzer's current operating mode			
Param	Displays a variety of informational messages such as warning messages, operational data, test function values and response messages during interactive tasks.			
Control Buttons	Displays dynamic, context sensitive labels on each button, which is blank when inactive until applicable.			

Figure 3-3 shows how the front panel display is mapped to the menu charts illustrated in this manual. The Mode, Param (parameters), and Conc (gas concentration) fields in the display screen are represented across the top row of each menu chart. The eight touch control buttons along the bottom of the display screen are represented in the bottom row of each menu chart.

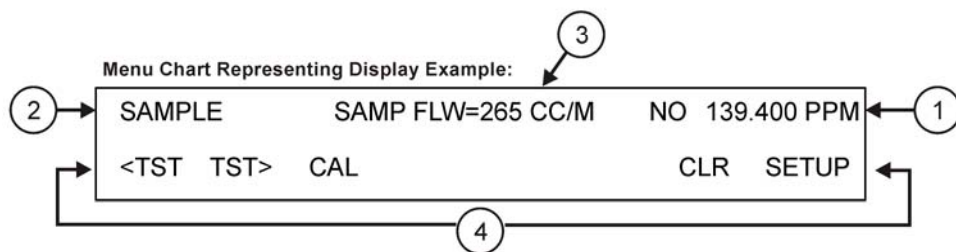
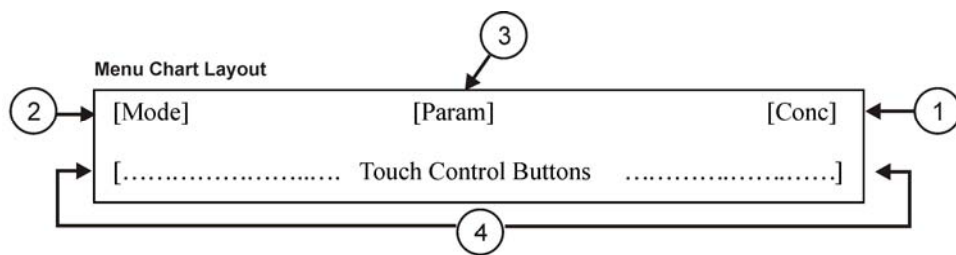


Figure 3-3: Display/Touch Control Screen Mapped to Menu Charts

The rear panel is illustrated in Figure 3-4 and described in Table 3-2.

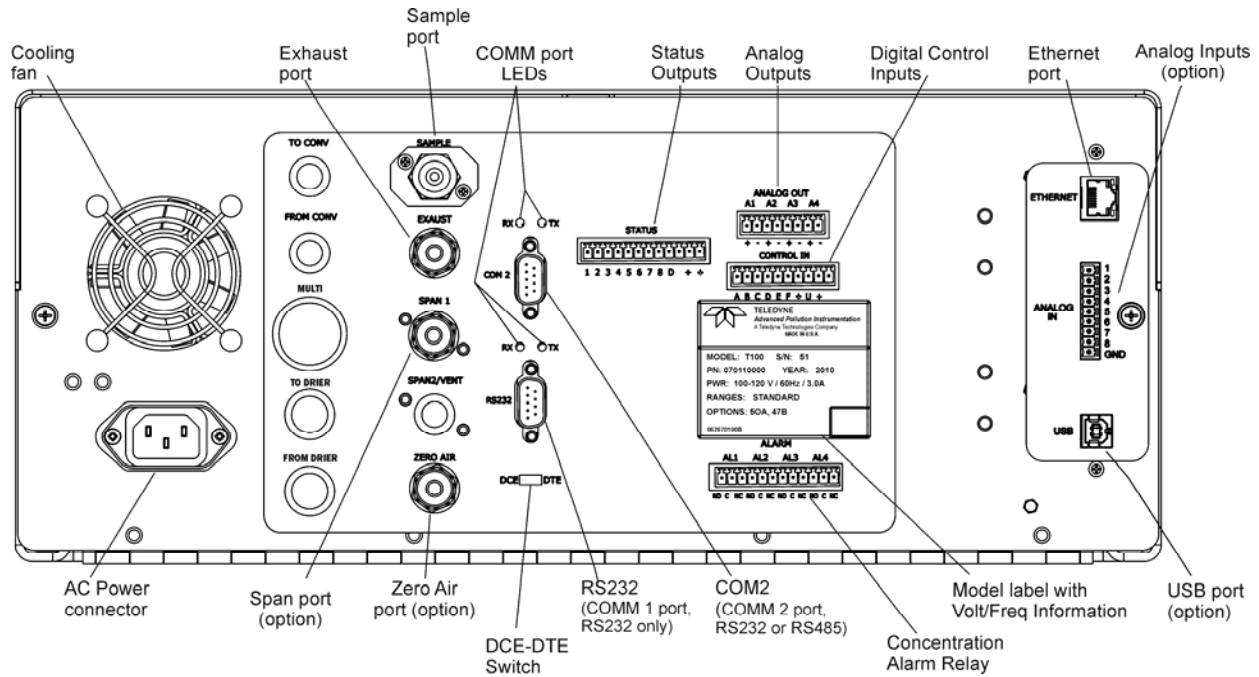



Figure 3-4: 9110TH/M Rear Panel Layout

Table 3-2: Rear Panel Description

Component	Function
Cooling Fan	Pulls ambient air into chassis through side vents and exhausts through rear.
 AC power connector	Connector for three-prong cord to apply AC power to the analyzer. CAUTION! The cord's power specifications (specs) MUST comply with the power specs on the analyzer's rear panel Model number label
Model label	Identifies the analyzer model number and provides voltage and frequency specs
SAMPLE	Connect a gas line from the source of sample gas here. Calibration gases are also inlet here on units without zero/span valve options installed.
EXHAUST	Connect an exhaust gas line of not more than 10 meters long here that leads outside the shelter or immediate area surrounding the instrument.
SPAN 1	On units with zero/span valve options installed, connect a gas line to the source of calibrated span gas here.
ZERO AIR (option)	Internal Zero Air: On units with zero/span valve options installed but no internal zero air scrubber attach a gas line to the source of zero air here.
RX TX	LEDs indicate receive (RX) and transmit (TX) activity on the when blinking.
COM 2	Serial communications port for RS-232 or RS-485.
RS-232	Serial communications port for RS-232 only.
DCE DTE	Switch to select either data terminal equipment or data communication equipment during RS-232 communication.
STATUS	For outputs to devices such as Programmable Logic Controllers (PLCs).
ANALOG OUT	For voltage or current loop outputs to a strip chart recorder and/or a data logger.
CONTROL IN	For remotely activating the zero and span calibration modes.
ALARM	Option for concentration alarms and system warnings.
ETHERNET	Connector for network or Internet remote communication, using Ethernet cable
ANALOG IN	Option for external voltage signals from other instrumentation and for logging these signals.
USB	Option for direct connection to laptop computer, using USB cable.

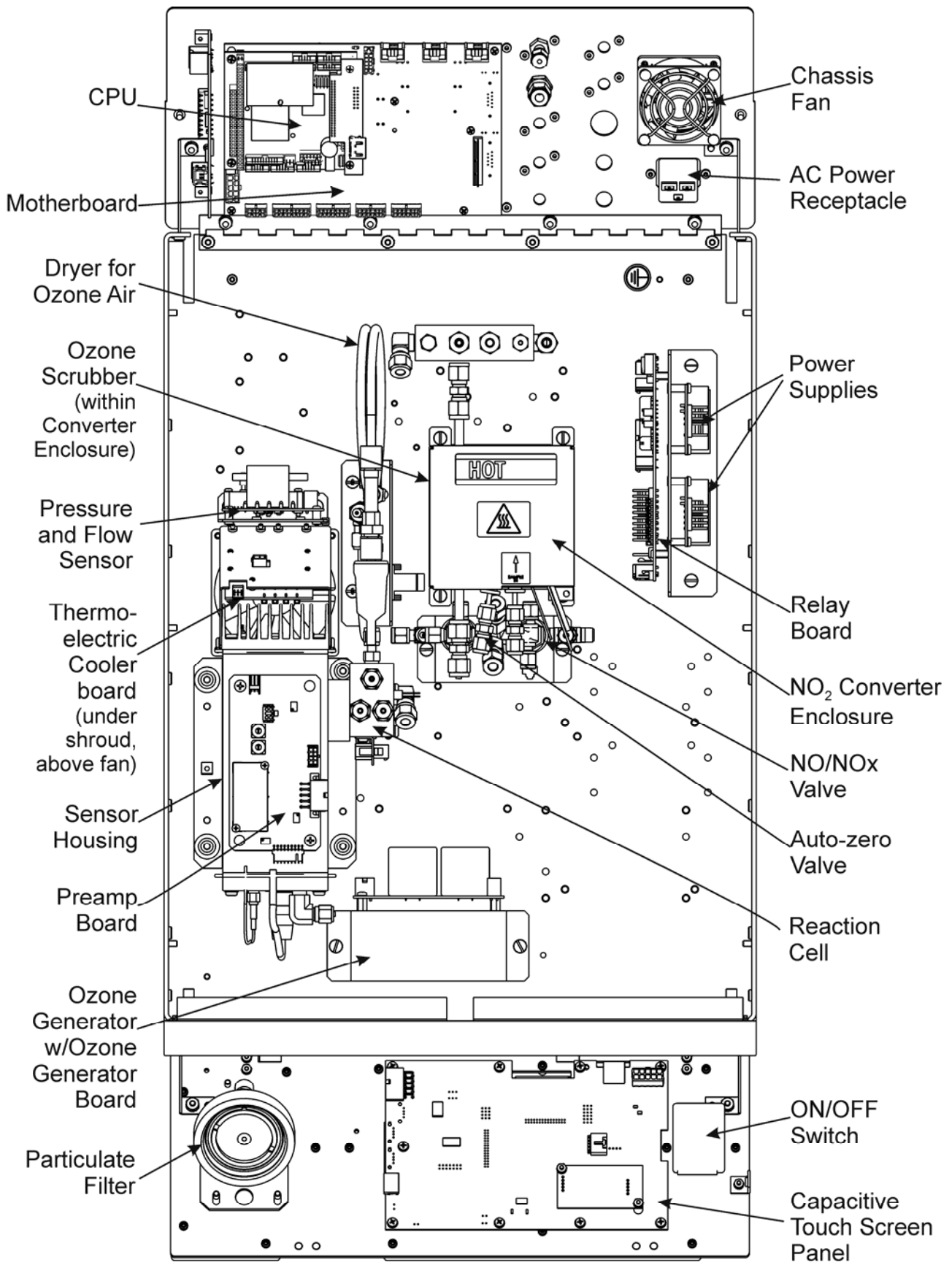


Figure 3-5: 9110TH/M Internal Layout

3.4. ELECTRICAL CONNECTIONS

Note

To maintain compliance with EMC standards, it is required that the cable length be no greater than 3 meters for all I/O connections, which include Analog In, Analog Out, Status Out, Control In, Ethernet/LAN, USB, RS-232, and RS-485.

Refer to Figure 3-4 for the location of the rear panel electrical and pneumatic connections.

3.4.1. POWER CONNECTION

Attach the power cord to the analyzer and plug it into a power outlet capable of carrying at least 10 A current at your AC voltage and that it is equipped with a functioning earth ground.

CAUTION



CHECK THE VOLTAGE AND FREQUENCY SPECIFICATIONS ON THE REAR PANEL LABEL SHOWING THE MODEL NAME AND NUMBER OF THE INSTRUMENT FOR COMPATIBILITY WITH THE LOCAL POWER BEFORE PLUGGING THE 9110TH/M INTO LINE POWER.

Do not plug in the power cord if the voltage or frequency is incorrect.

WARNING – RISK OF ELECTRIC SHOCK



HIGH VOLTAGES ARE PRESENT INSIDE THE INSTRUMENT'S CHASSIS.

POWER CONNECTION MUST HAVE FUNCTIONING GROUND CONNECTION.

DO NOT DEFEAT THE GROUND WIRE ON POWER PLUG.

TURN OFF ANALYZER POWER BEFORE DISCONNECTING OR CONNECTING ELECTRICAL SUBASSEMBLIES.

DO NOT OPERATE WITH COVER OFF.

The 9110TH/M analyzer can be configured for both 100-130 V and 210-240 V at either 50 or 60 Hz. To avoid damage to your analyzer, make sure that the AC power voltage matches the voltage indicated on the rear panel serial number label and that the frequency is between 47 and 63 Hz.

3.4.2. ANALOG INPUTS (OPTION 64) CONNECTIONS

The Analog In connector is used for connecting external voltage signals from other instrumentation (such as meteorological instruments) and for logging these signals in the analyzer's internal DAS. The input voltage range for each analog input is 0-10 VDC, and the input impedance is nominally 20k Ω in parallel with 0.1 μ F.

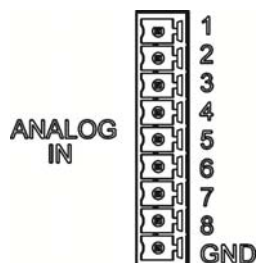


Figure 3-6: Analog In Connector

Pin assignments for the Analog In connector are presented in Table 3-3.

Table 3-3: Analog Input Pin Assignments

PIN	DESCRIPTION	DAS PARAMETER ¹
1	Analog input # 1	AIN 1
2	Analog input # 2	AIN 2
3	Analog input # 3	AIN 3
4	Analog input # 4	AIN 4
5	Analog input # 5	AIN 5
6	Analog input # 6	AIN 6
7	Analog input # 7	AIN 7
8	Analog input # 8	AIN 8
GND	Analog input Ground	N/A

¹ See Section 4.7 for details on setting up the DAS.

3.4.3. ANALOG OUTPUT CONNECTIONS

The 9110TH/M is equipped with four analog output channels accessible through a connector on the back panel of the instrument. Each of these outputs may be set to reflect the value of any of the instrument's DAS data types. (see Table A-6 of 9110TH/M Appendix A – P/N 05147).

The following table lists the default settings for each of these channels. To change these settings, see Sections 6.13.4

Table 3-1: Analog Output Data Type Default Settings

PARAMETER	CHANNEL DEFAULT SETTING			
	A1	A2	A3	A4 ³
DATA TYPE ¹	NXCNC1	NOCNC1	N2CNC1	NXCNC2
RANGE	0 - 5 VDC ²			
REC OFS	0 mVDC			
AUTO CAL.	ON			
CALIBRATED	NO			
OUTPUT	ON			
SCALE	100 ppm			
UPDATE	5 sec			
¹ See Table A-6 of 9110TH/M Appendix A for definitions of these DAS data types ² Optional current loop outputs are available for analog output channels A1-A3. ³ On analyzers with O ₂ sensor options installed, DAS parameter O2CONC is assigned to output A4.				

To access these signals attach a strip chart recorder and/or data-logger to the appropriate contacts of the analog output connector on the rear panel of the analyzer.

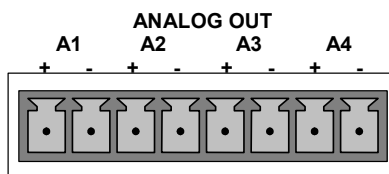


Figure 3-7: Analog Output Connector

Table 3-4: Analog Output Pin-Outs

PIN	ANALOG OUTPUT	VOLTAGE SIGNAL	CURRENT SIGNAL
1	A1	V Out	I Out +
2		Ground	I Out -
3	A2	V Out	I Out +
4		Ground	I Out -
5	A3	V Out	I Out +
6		Ground	I Out -
7	A4	V Out	Not Available
8		Ground	Not Available

3.4.4. CONNECTING THE STATUS OUTPUTS

The analyzer’s status outputs to interface with a device that accepts logic-level digital inputs, such as programmable logic controller (PLC) chips, are accessed through a 12 pin connector labeled STATUS on the analyzer’s rear panel.

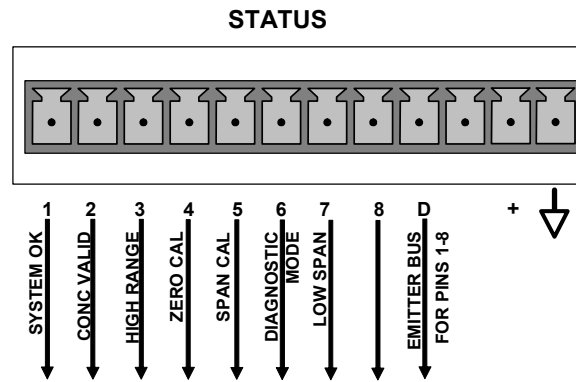


Figure 3-8: Status Output Connector

Note

Most PLCs have internal provisions for limiting the amount of current the input will draw. When connecting to a unit that does not have this feature, external resistors must be used to limit the current through the individual transistor outputs to $\leq 50\text{mA}$ ($120\ \Omega$ for 5V supply).

Table 3-5: Status Output Signals

PIN #	STATUS	CONDITION (ON = CONDUCTING)
1	SYSTEM OK	ON if no faults are present.
2	CONC VALID	ON if concentration measurement (NO, NO ₂ or NO _x) is valid. OFF any time the hold-off feature is active.
3	HIGH RANGE	ON if unit is in high range of the Auto Range Mode.
4	ZERO CAL	ON whenever the instrument is in ZERO point calibration mode.
5	SPAN CAL	ON whenever the instrument is in SPAN point calibration mode.
6	DIAG MODE	ON whenever the instrument is in diagnostic mode.
7	LOW SPAN CAL	ON when in low span calibration (optional equipment necessary)
8	Not Used	
D	EMITTER BUS	The emitters of the transistors on pins 1-8 are tied together.
	Not Used	
+	DC POWER	+ 5 VDC, 300 mA (combined rating with Control Output, if used).
⚡	Digital Ground	The ground level from the analyzer's internal DC power supplies

3.4.5. CURRENT LOOP ANALOG OUTPUTS (OPT 41) SETUP

This option adds isolated, voltage-to-current conversion circuitry to the analyzer's analog outputs. This option may be ordered separately for the first three of the analog outputs and can be installed at the factory or added later. Call TAI sales for pricing and availability.

The current loop option can be configured for any output range between 0 and 20 mA (for example 0-20, 2-20 or 4-20 mA). Information on calibrating or adjusting these outputs can be found in Section 4.13.6.3.

CAUTION – Avoid Warranty Invalidation

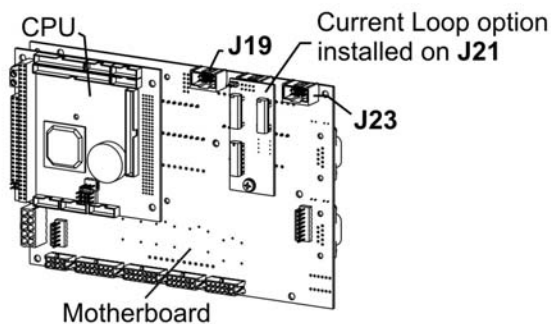
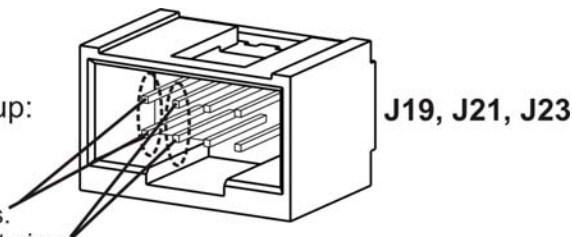


Printed circuit assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Damage resulting from failure to use ESD protection when working with electronic assemblies will void the instrument warranty.

See *A Primer on Electro-Static Discharge* in this manual for more information on preventing ESD damage.

J19, J21, J23 Analog Output Setup:

- For **voltage** output of any one, two, or all:
 1. Jumper two leftmost pins.
 2. Jumper next two leftmost pins.
 3. Calibrate per Analog I/O Configuration menu.
- For **current** output of any one, two, or all:
 1. Remove jumper shunts.
 2. Install Current Loop option.
 3. Calibrate per Analog I/O Configuration menu.



Example setup: install jumper shunts for voltage output on J19 and J23; remove jumper shunts and install Current Loop option for current output on J21.

Figure 3-9: Current Loop Option Installed on the Motherboard

3.4.5.1. Converting Current Loop Analog Outputs to Standard Voltage Outputs.

CAUTION – Avoid Warranty Invalidation



Printed circuit assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Damage resulting from failure to use ESD protection when working with electronic assemblies will void the instrument warranty.

See *A Primer on Electro-Static Discharge* in this manual for more information on preventing ESD damage.

To convert an output configured for current loop operation to the standard 0 to 5 VDC output operation:

1. Turn off power to the analyzer.
2. If a recording device was connected to the output being modified, disconnect it.
3. Remove the top cover:
 - Remove the set screw located in the top, center of the rear panel
 - Remove the screws fastening the top cover to the unit (four per side).
 - Lift the cover straight up.
4. Disconnect the current loop option PCA from the appropriate connector on the motherboard.
5. Place a shunt between the leftmost two pins of the connector (see Figure 3-9).
6. Reattach the top case to the analyzer.

The analyzer is now ready to have a voltage-sensing, recording device attached to that output.

3.4.6. CONNECTING THE CONTROL INPUTS

Control Inputs are used to remotely activate the zero and span calibration modes. Locate the 10-pin connector labeled CONTROL IN on the analyzer’s rear panel.

There are two methods for energizing the control inputs. The internal +5V available from the pin labeled “+” is the most convenient method. However, if full isolation is required, an external 5 VDC power supply should be used.

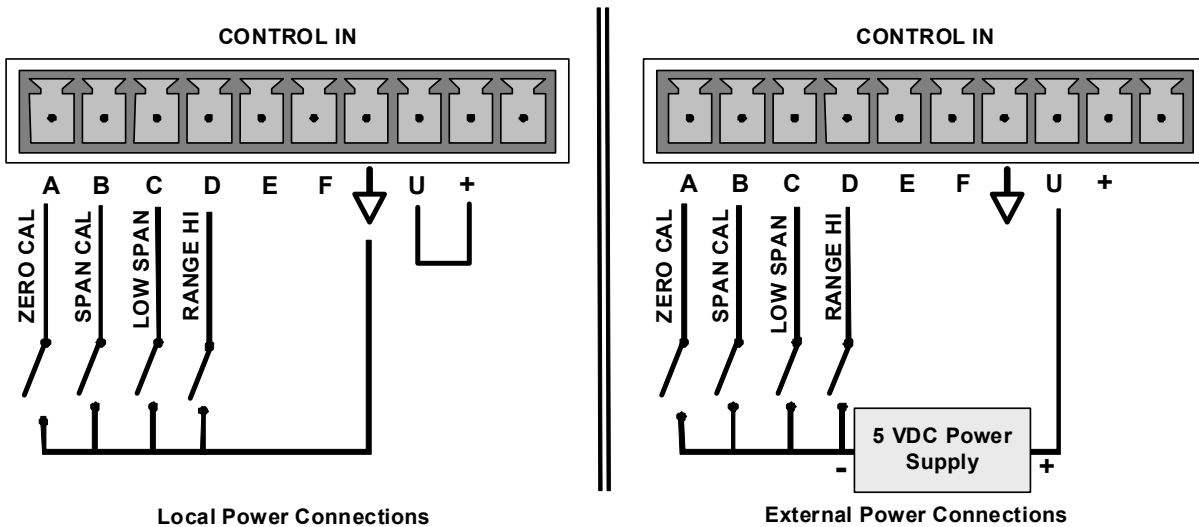


Figure 3-10: Control Input Connector

Table 3-6: Control Input Signals

INPUT #	STATUS DEFINITION	ON CONDITION
A	REMOTE ZERO CAL	The analyzer is placed in Zero Calibration mode. The mode field of the display will read ZERO CAL R.
B	REMOTE SPAN CAL	The analyzer is placed in Span Calibration mode. The mode field of the display will read SPAN CAL R.
C	REMOTE LO SPAN CAL	The analyzer is placed in low span calibration mode as part of performing a low span (midpoint) calibration. The mode field of the display will read LO CAL R.
D	REMOTE RANGE HI	The analyzer is placed into high range when configured for dual ranges..
E	SPARE	
F	SPARE	
⏚	Digital Ground	The ground level from the analyzer’s internal DC power supplies (same as chassis ground).
U	External Power input	Input pin for +5 VDC required to activate pins A - F.
+	5 VDC output	Internally generated 5V DC power. To activate inputs A - F, place a jumper between this pin and the “U” pin. The maximum amperage through this port is 300 mA (combined with the analog output supply, if used).

3.4.7. CONNECTING THE ALARM RELAY OPTION (OPT 61)

The 9110TH/M can be equipped with a set of 2 concentration alarms. Each alarm can be independently enabled or disabled as well as programmed with its own, individual alarm limit point (see Section 4.14 for details on programming the alarms).

The status of each alarm is available via a set of alarm relay outputs located on the lower right hand corner of the analyzer's rear panel (see Figure 3-4). While there are four relay outputs on the back of the analyzer, only Two of the outputs correspond to the instrument's two concentration alarms.

Table 5-5: Alarm Relay Output Assignments

RELAY NAME	AL1	AL2	AL3	AL4
ASSIGNED ALARM	ST_SYSTEM_OK2 ¹	CONCENTRATION ALARM 1	CONCENTRATION ALARM 2	SPARE

¹ST_SYSTEM OK2 is a second system OK status alarm available on some analyzers.

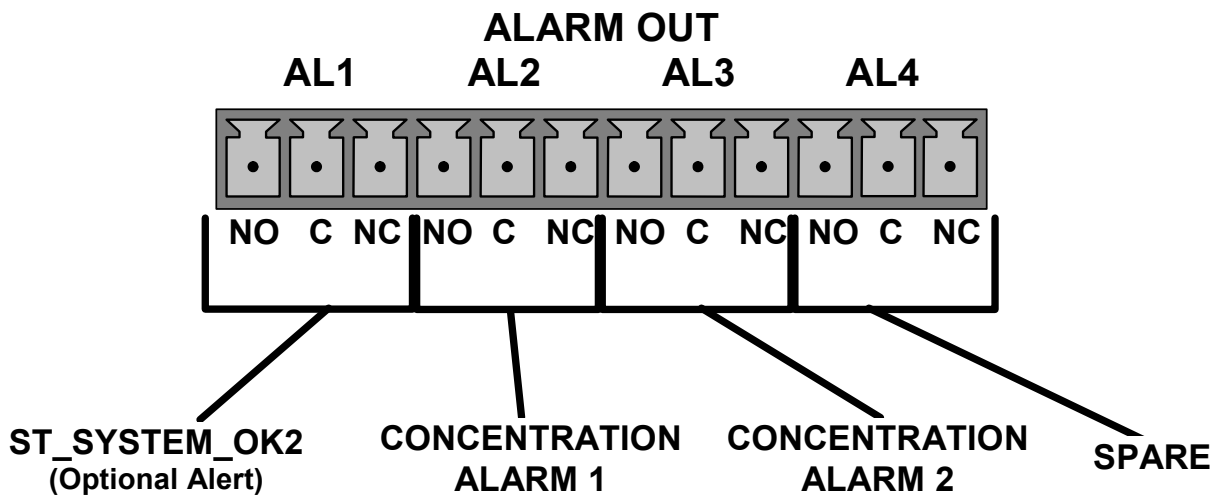






Figure 3-11: Alarm Relay Output Pin Assignments

Each of the two concentration relay outputs has 3-pin connections that allow the relay to be connected for either normally open or normally closed operation. Table 3-7 describes how to connect the alarm relays.

Table 3-7: Concentration Alarm Relay Output Operation

RELAY	FUNCTION	RELAY PIN STATE ¹			COMMENTS
		N O	C	N C	
AL2	Concentration Alarm 1 Active				Gas concentration level is above the trigger limit set for CONC_ALARM_1 <ul style="list-style-type: none"> • DAS Trigger CONCW1 ACTIVATED • CONC ALARM1 WARN appears on Analyzer Display
	Concentration Alarm 1 Inactive				Gas concentration level is below the trigger limit set for CONC_ALARM_1
AL3	Concentration Alarm 2 Active				Gas concentration level is above the trigger limit set for CONC_ALARM_2 <ul style="list-style-type: none"> • DAS Trigger CONCW2 ACTIVATED • CONC ALARM2 WARN appears on Analyzer Display
	Concentration Alarm 2 Inactive				Gas concentration level is below the trigger limit set for CONC_ALARM_2

¹ NO = Normally Open operation.
C = Common
NC = Normally Closed operation.

3.4.8. CONNECTING THE COMMUNICATIONS PORTS

For RS-232 or RS-485 (option) communications through the analyzer’s two serial interface ports, refer to Section 4.11 for information and connection instructions.

3.4.8.1. Connecting to a LAN or the Internet

For network or Internet communication with the analyzer, connect an Ethernet cable from the analyzer’s rear panel Ethernet interface connector to an Ethernet port. See Section 4.11.7 for configuration instructions.

Note

The 9110TH/M firmware supports dynamic IP addressing or DHCP. If your network also supports DHCP, the analyzer will automatically configure its LAN connection appropriately. If your network does not support DHCP, see Section 4.11.7.2 for instructions on manually configuring the LAN connection.

3.4.8.2. Connecting to a Personal Computer (PC)

If the USB port is configured for direct communication between the analyzer and a desktop or a laptop PC, connect a USB cable between the analyzer and the PC or laptop USB ports, and follow the set-up instructions in Section 4.11.8. (RS-485 communication is not available with the USB com port option).

3.4.8.3. Connecting to a Multidrop Network

The multidrop option is used with RS-232 and utilizes both com port DB-9 connectors (RS-232 and COM2) on the rear panel to enable communications of up to eight analyzers with the host computer over a chain of RS-232 cables. It is subject to the distance limitations of the RS 232 standard.

The option consists of a small printed circuit assembly, which is seated on the analyzer's CPU card (see Figure 3-12). One Option 62 is required for each analyzer along with one 6' straight-through, DB9 male → DB9 Female cable (P/N WR0000101).

If your unit has a TAI RS-232 multidrop card (Option 62), see Section 4.11.9 for instructions on setting it up.

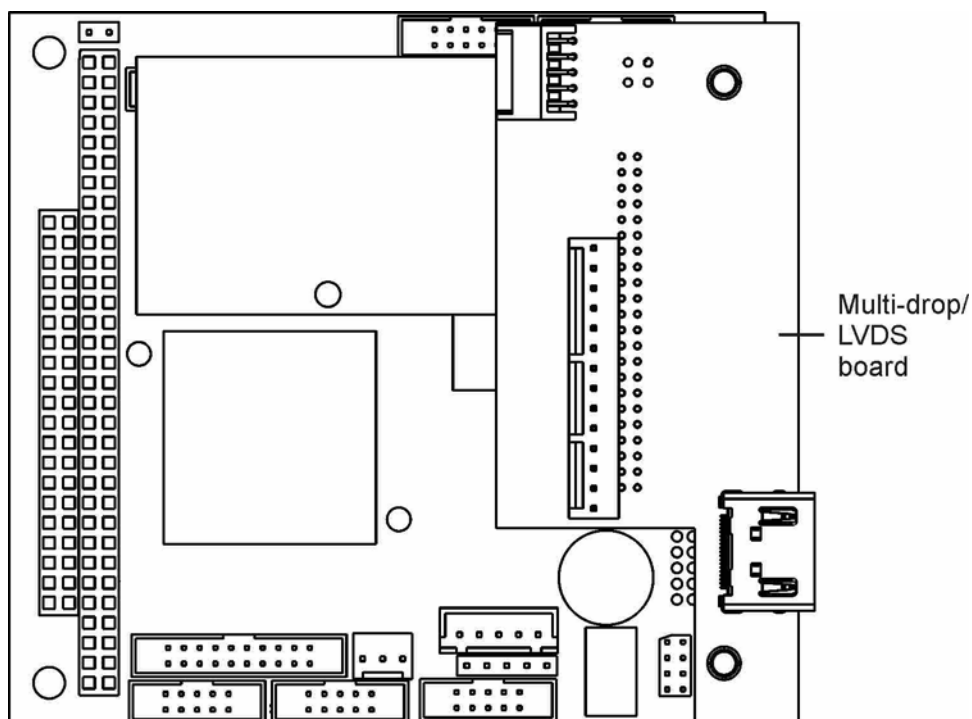


Figure 3-12: 9110TH/M Multidrop Card

3.5. PNEUMATIC CONNECTIONS

Note

To prevent dust from getting into the analyzer, it was shipped with small plugs inserted into each of the pneumatic fittings on the rear panel. Remove and store the dust plugs for future use, such as storage, moving, shipping.



CAUTION!

Do not operate this instrument until you've removed dust plugs from SAMPLE and EXHAUST ports on the rear panel!

Table 3-8: Inlet / Outlet Connector Descriptions

REAR PANEL LABEL	FUNCTION
SAMPLE	Connects the sample gas to the analyzer. When operating the analyzer without zero span option, this is also the inlet for any calibration gases.
EXHAUST	Connects the exhaust of the analyzer with the external vacuum pump.
SPAN	On Units with a zero/span valve, this port connects the external calibration gas to the analyzer.
ZERO AIR	On Units with a zero/span valve, this port connects the zero air gas or the zero air cartridge to the analyzer.

3.5.1. ABOUT ZERO AIR AND CALIBRATION (SPAN) GASES

3.5.1.1. Zero Air

Zero air or zero calibration gas is defined as a gas that is similar in chemical composition to the measured medium but without the gas to be measured by the analyzer, in this case NO and NO₂. If your analyzer is equipped with an external zero air scrubber option, it is capable of creating zero air from ambient air.

If your application is not a measurement in ambient air, the zero calibration gas should be matched to the matrix of the measured medium. Pure nitrogen could be used as a zero gas for applications where NO_x is measured in nitrogen. Special considerations apply if measuring NO_x in a matrix that does not contain oxygen, see Section 8.3.11 for more information.

3.5.1.2. Calibration (Span) Gas

Calibration (or Span) gas is a gas specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired measurement range. In this case, NO_x, NO and NO₂ measurements made with the 9110TH/M, it is recommended that you use a span gas with an NO concentration equal to 80% of the measurement range for your application.

EXAMPLE: If the application is to measure between 0 ppm and 500 ppm, an appropriate span gas concentration would be 400 ppm NO_x.

Even though NO gas in nitrogen could be used as a span gas, the matrix of the balance gas is different and may cause interference problems or yield incorrect calibrations. The same applies to gases that contain high concentrations of other compounds (for example, CO₂ or H₂O). The span gas should match all concentrations of all gases of the measured medium as closely as possible.

Cylinders of calibrated NO gas traceable to NIST-standard reference materials specifications (also referred to as EPA protocol calibration gases) are commercially available.

Table 3-9: NIST-SRM's Available for Traceability of NO_x Calibration Gases

NIST-SRM ⁴	TYPE	NOMINAL CONCENTRATION
2627a	Nitric Oxide (NO) in N ₂	5 ppm
2628a	Nitric Oxide (NO) in N ₂	10 ppm
2629a	Nitric Oxide (NO) in N ₂	20 ppm
1683b	Nitric Oxide (NO) in N ₂	50 ppm
1684b	Nitric Oxide (NO) in N ₂	100 ppm
1685b	Nitric Oxide (NO) in N ₂	250 ppm
1686b	Nitric Oxide (NO) in N ₂	5000 ppm
1687b	Nitric Oxide (NO) in N ₂	1000 ppm
2630	Nitric Oxide (NO) in N ₂	1500 ppm
2631a	Nitric Oxide (NO) in N ₂	3000 ppm
2635	Nitric Oxide (NO) in N ₂	800 ppm
2636a	Nitric Oxide (NO) in N ₂	2000 ppm
2631a	Oxides of Nitrogen (NO _x) in N ₂	3000 ppm
1684b	Oxides of Nitrogen (NO _x) in N ₂	100 ppm

Note

If a dynamic dilution system such as the TAI Model T700 is used to dilute high concentration gas standards to low, ambient concentrations, make sure that the NO concentration of the reference gas matches the dilution range of the calibrator. Choose an NO gas concentration that is in the middle of the dilution system's range.

3.5.2. PNEUMATIC CONNECTIONS TO 9110TH/M BASIC CONFIGURATION

Figure 3-13 and Figure 3-14 show the most common configurations for gas supply and exhaust lines to the Model 9110TH/M analyzer. Please refer to Figure 3-4 for the locations of pneumatic connections on the rear panel and Table 3-2 for the descriptions.

Note

Sample and calibration gases should only come into contact with PTFE (Teflon) or glass or materials. They should not come in contact with FEP or stainless steel materials.

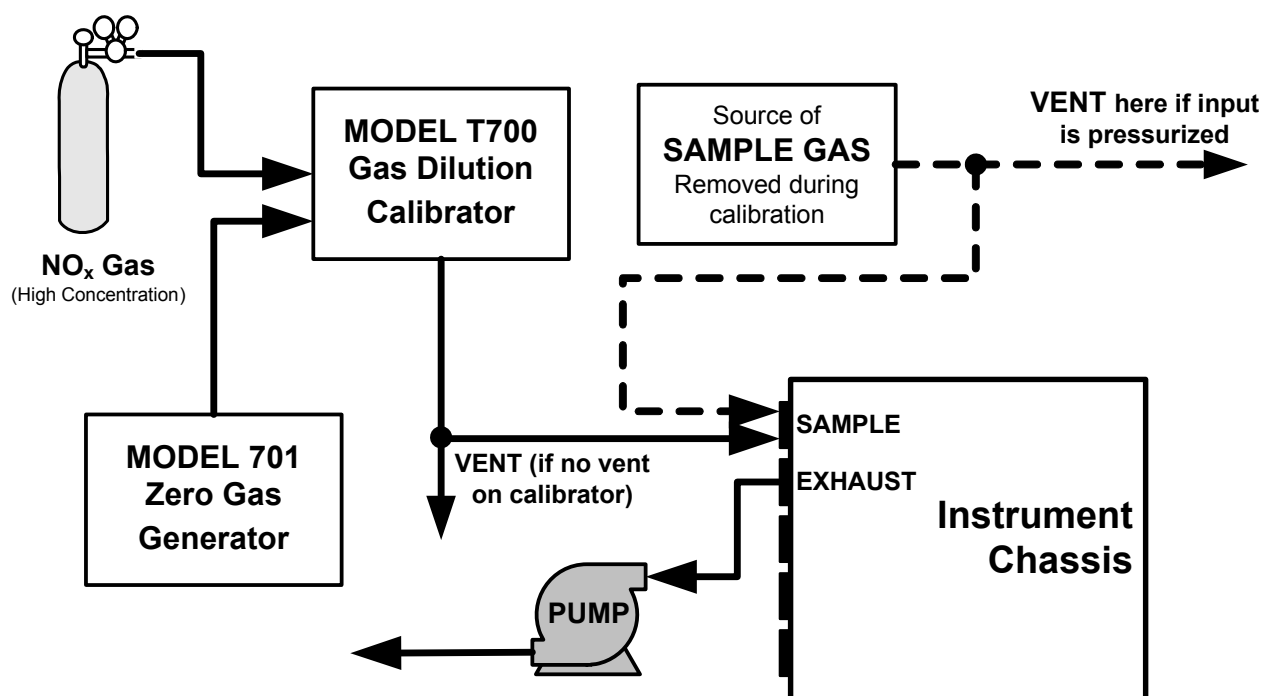


Figure 3-13: Pneumatic Connections—Basic Configuration—Using Gas Dilution Calibrator

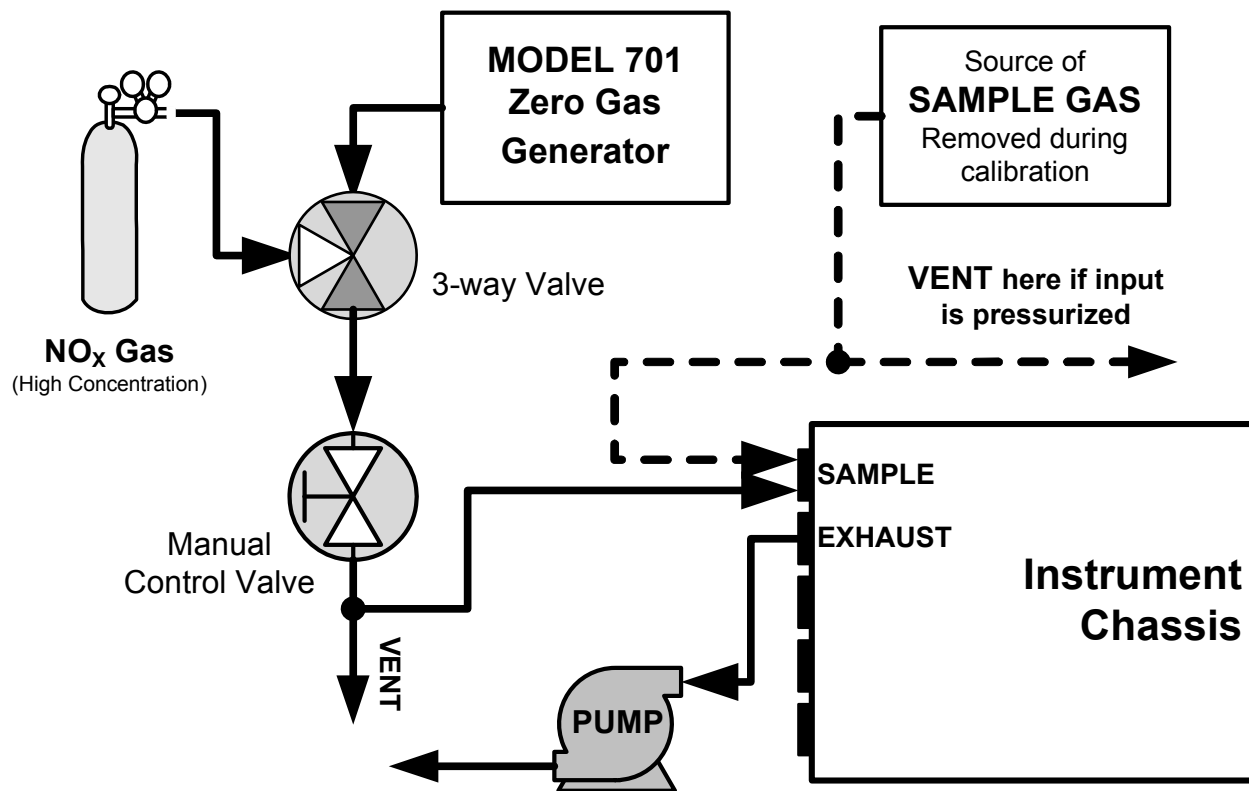


Figure 3-14: Pneumatic Connections–Basic Configuration–Using Bottled Span Gas

1. Attach a 1/4" exhaust line between the external pump and the EXHAUST port of the analyzer.
2. Attach an additional 1/4" exhaust port of the pump.

**CAUTION**

The exhaust from the analyzer must be vented outside the shelter or immediate area surrounding the instrument and conform to all safety requirements using a maximum of 10 meters of 1/4" PTFE tubing.

3. Attach a sample inlet line to the SAMPLE inlet port. Ideally, the pressure of the sample gas should be equal to ambient atmospheric pressure.

Note

Maximum pressure of any gas at the SAMPLE inlet should not exceed 1.5 in-Hg above ambient pressure and ideally should equal ambient atmospheric pressure.

In applications where the sample gas is received from a pressurized manifold, a vent must be provided to equalize the sample gas with ambient atmospheric pressure before it enters the analyzer.

The vented gas must be routed outside the immediate area or shelter surrounding the instrument.

4. Once the appropriate pneumatic connections have been made, check all pneumatic fittings for leaks using procedures defined in Section 7.5.1.

Figure 3-15 and Figure 3-16 show the internal pneumatic flow of the standard configuration of the 9110TH and 9110TM respectively.

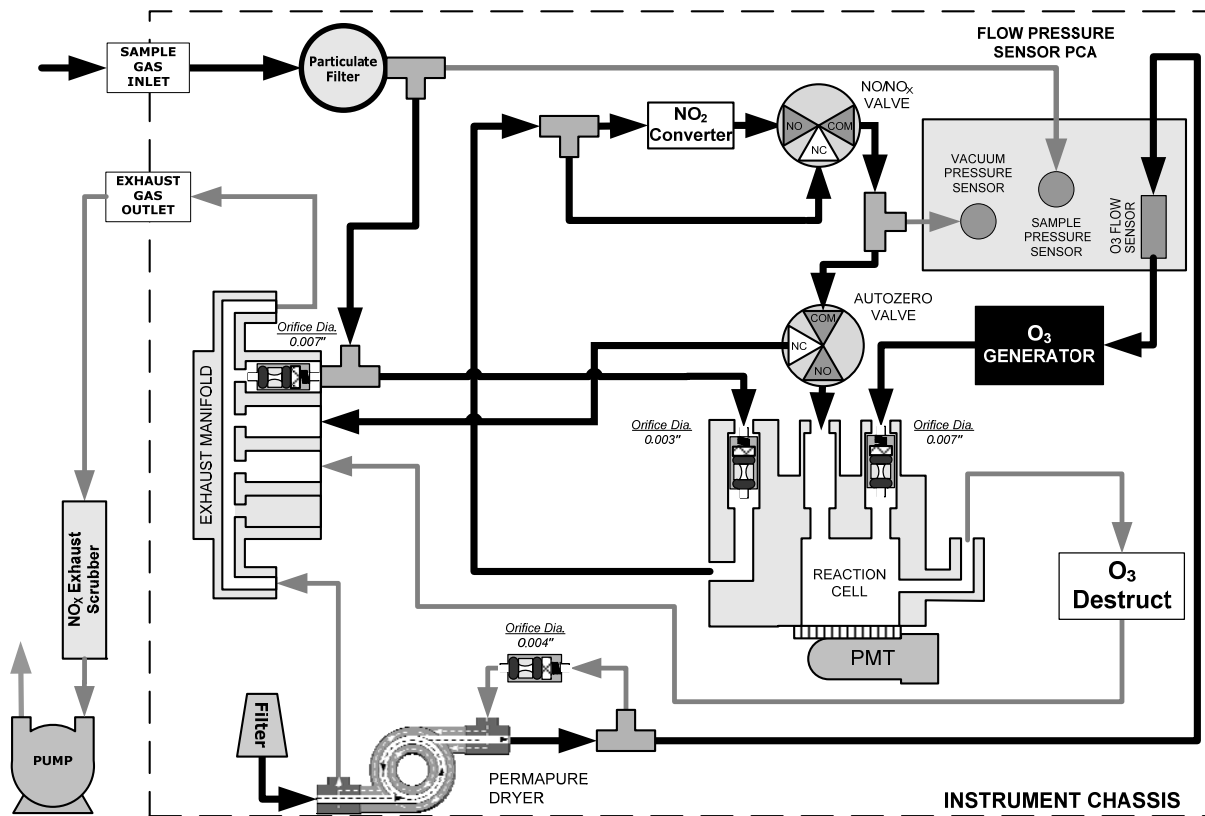


Figure 3-15: 9110TH Internal Pneumatic Block Diagram - Standard Configuration

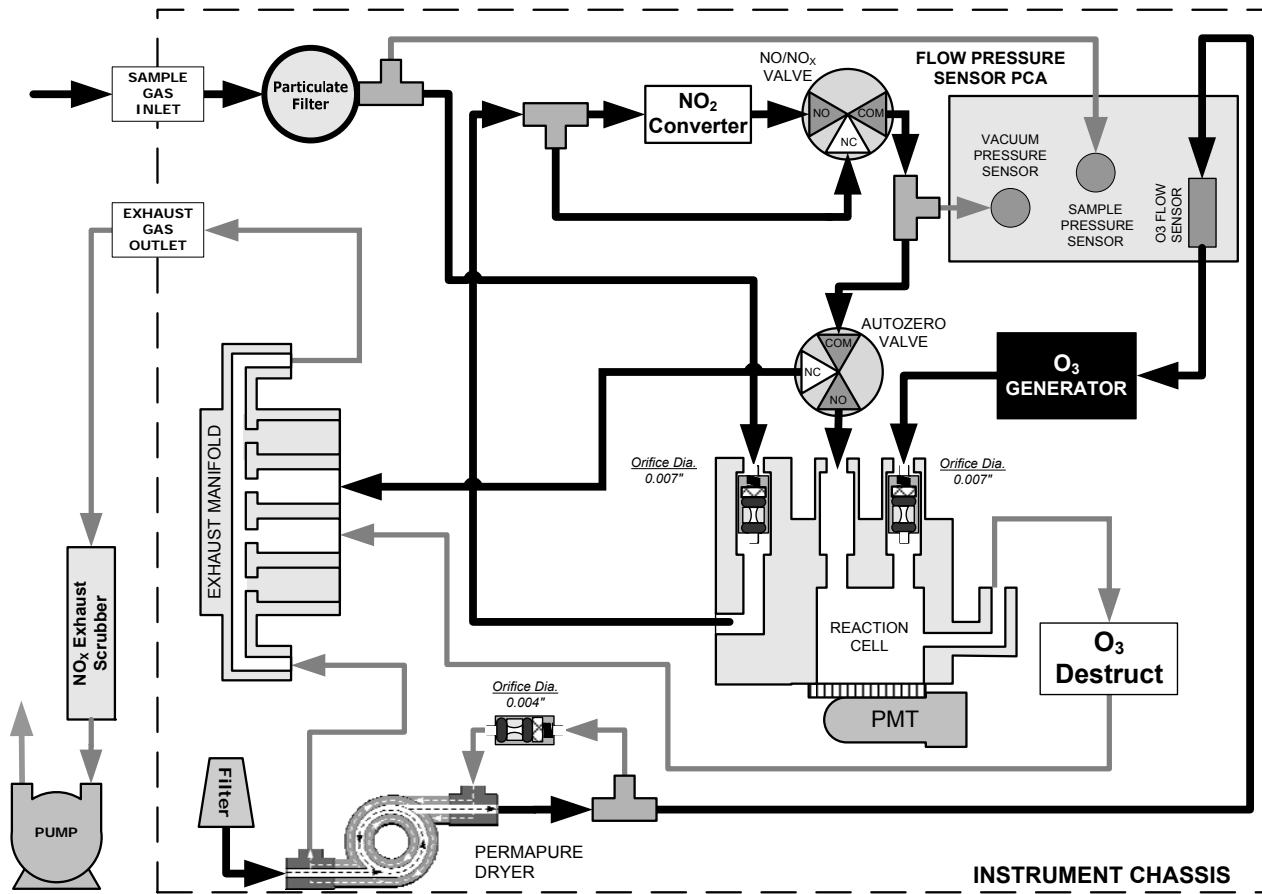


Figure 3-16: 9110TM Internal Pneumatic Block Diagram - Standard Configuration

Note

Pneumatic Diagrams do not reflect the physical layout of the instrument.

The most significant differences between the 9110TH and 9110TM versions in regards to pneumatic flow are:

- A bypass line leading directly from the particulate filter to the exhaust manifold is present on the 9110TH, but not in the 9110TM.
- The diameter of the critical flow orifice controlling the gas flow into the sample chamber is smaller and therefore the flow rate of sample gas through the instrument is lower.

3.5.3. CONNECTIONS WITH INTERNAL VALVE OPTIONS INSTALLED

If your analyzer is equipped with either the zero/span valve option (50A) or the 2-span point valve option (50D), the pneumatic connections should be made as shown in Figure 3-17 and Figure 3-18:

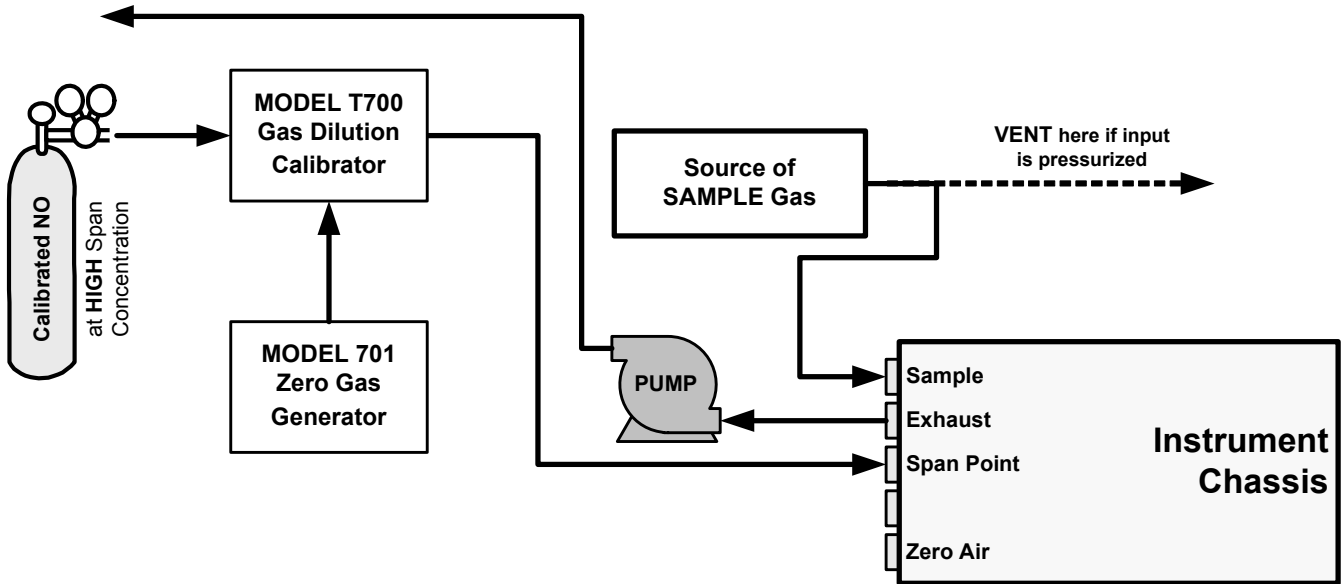


Figure 3-17: Pneumatic Connections—With Zero/Span Valve Option (50A)

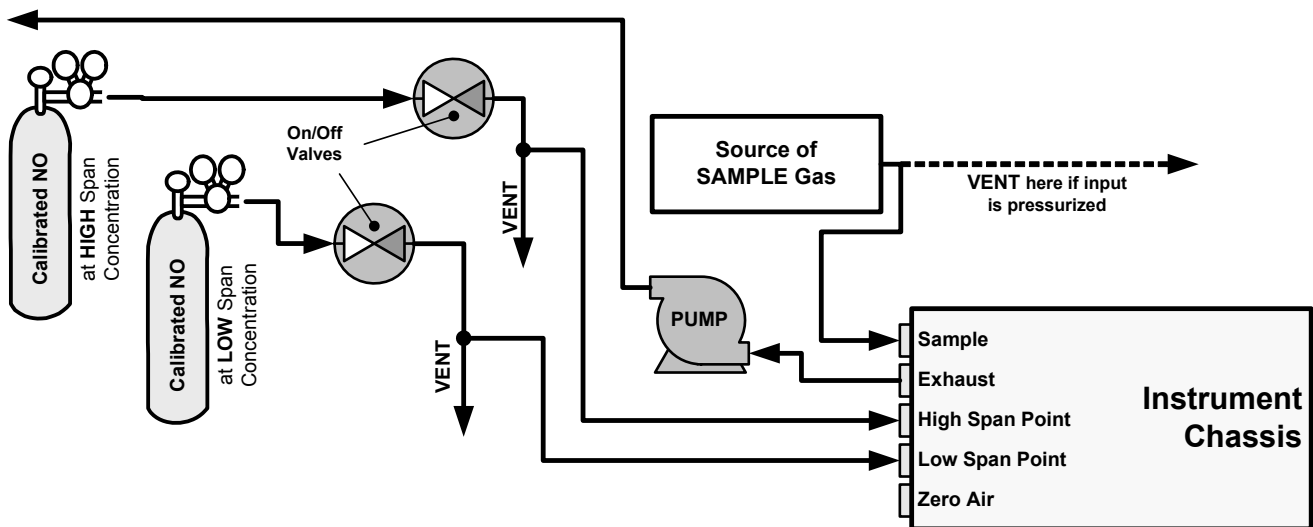


Figure 3-18: Pneumatic Connections—With 2-Span Point Option (50D) –Using Bottled Span Gas

Once the appropriate pneumatic connections have been made, check all pneumatic fittings for leaks using the procedures defined in Section 7.5.

3.5.3.1. Ambient Zero/Ambient Span Valves (OPT 50A)

The Model 9110TH/M NO_x analyzer can be equipped with a zero/span valve option for controlling the flow of calibration gases generated from external sources. This option contains two solenoid valves located inside the analyzer that allow the user to switch either zero, span or sample gas to the instrument's sensor.

The user can control these valves from the front panel keyboard either manually or by activating the instrument's CAL or AutoCal features (Section 5.8). The valves may also be opened and closed remotely through the serial ports (Section 4.11) or through the external, digital control inputs (Section 4.15).

This option also includes a two-stage, external zero air scrubber assembly that removes all NO and NO₂ from the zero air source (ambient air). The scrubber is filled with 50% Purafil Chemisorbant[®] (for conversion of NO to NO₂) and 50% activated charcoal (for removal of NO₂). This assembly also includes a small particle filter to prevent scrubber particles to enter the analyzer as well as two more rear panel fittings so each gas can enter the analyzer separately.

Figure 3-19 and Figure 3-20 show the internal, pneumatic layouts with the zero/span valve option installed for a Model 9110TH and 9110TM respectively.

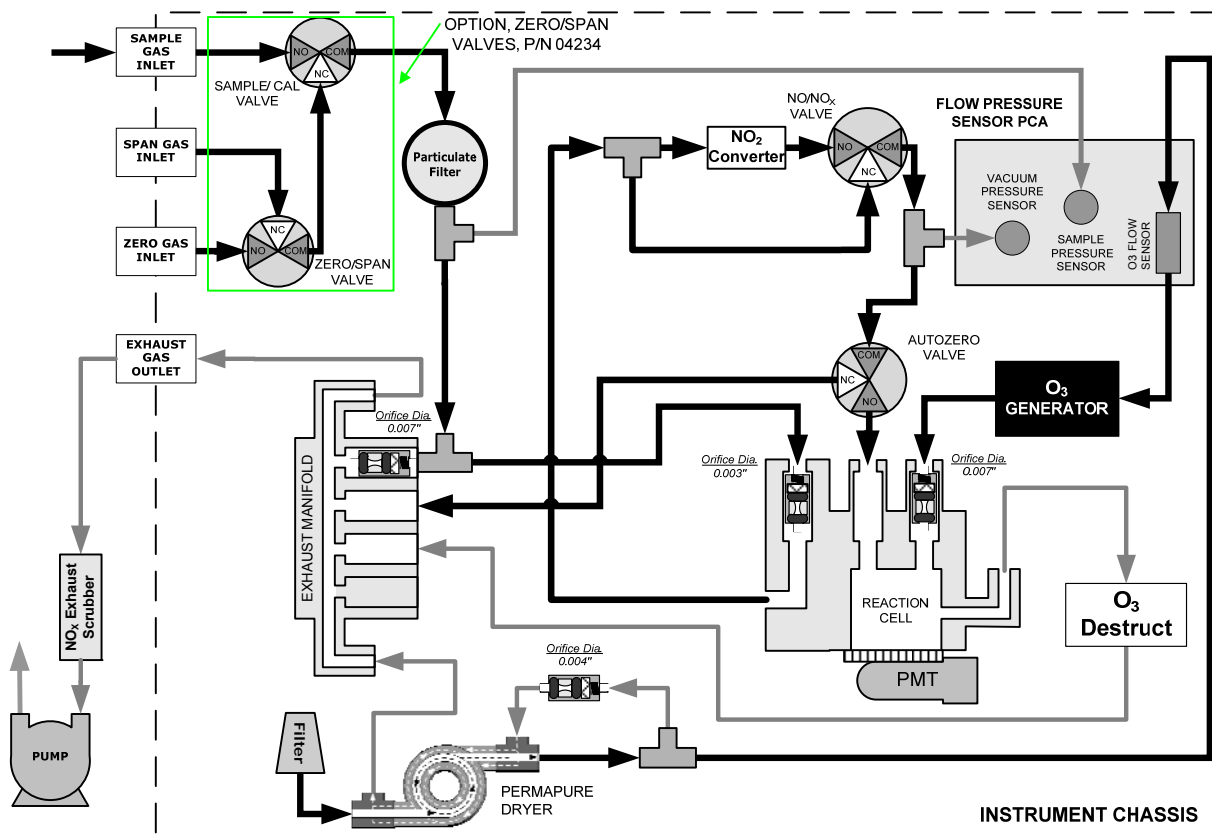


Figure 3-19: 9110TH – Internal Pneumatics with Ambient Zero-Span Valve Option 50A

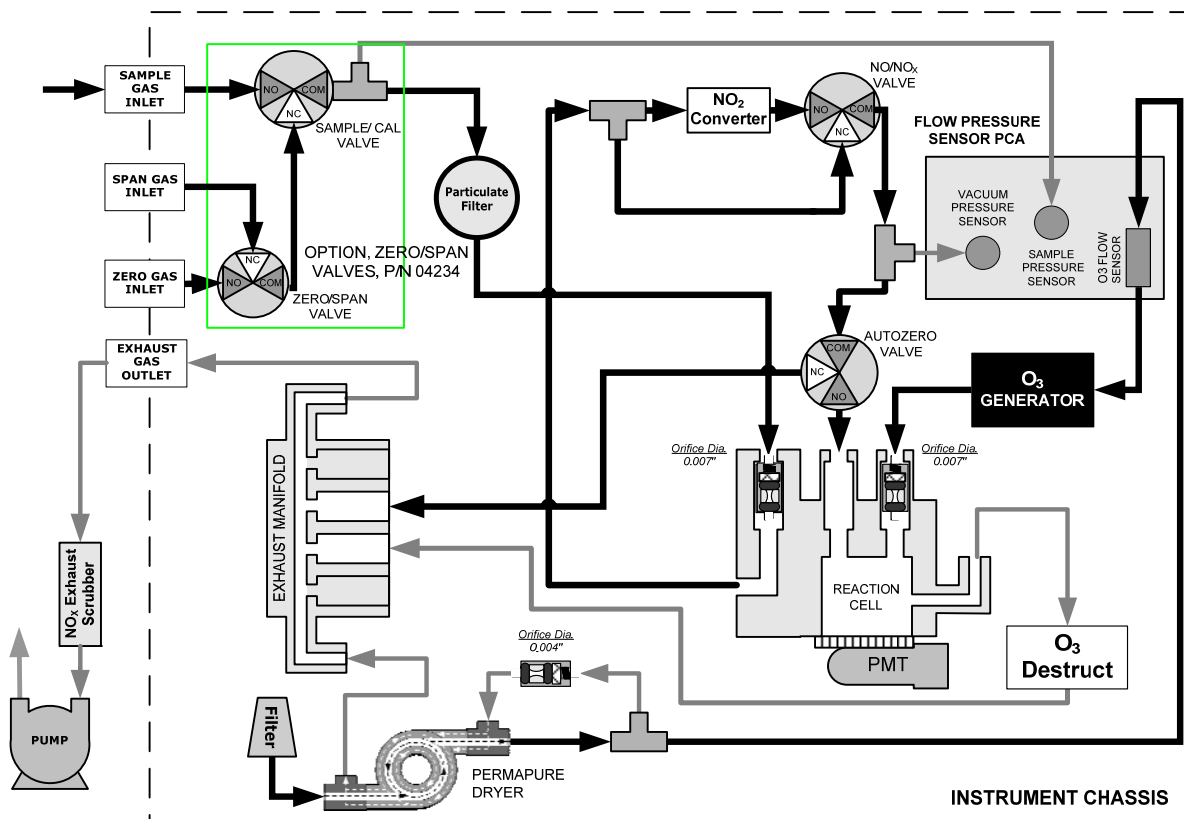


Figure 3-20: 9110TM – Internal Pneumatics with Ambient Zero-Span Valve Option 50A

Table 3-10: Zero/Span Valve States

MODE	VALVE	CONDITION
SAMPLE	Sample/Cal	Open to sample gas inlet
	Zero/Span	Open to zero air inlet
ZERO CALIBRATION	Sample/Cal	Open to zero/span inlet (activated)
	Zero/Span	Open to zero air inlet
SPAN CALIBRATION	Sample/Cal	Open to zero/span inlet (activated)
	Zero/Span	Open to span gas inlet / IZS gas (activated)

The state of the zero/span valves can also be controlled:

- Manually from the analyzer’s front panel by using the **SIGNAL I/O** controls located under the **DIAG** Menu (Section 4.13.2),
- By activating the instrument’s AutoCal feature (Section 5.8),
- Remotely by using the external digital control inputs (Section 4.15.1.2) or Ethernet option.
- Remotely through the RS-232/485 serial I/O ports (Section 4.11).

All supply lines should be vented outside of the analyzer's enclosure. In order to prevent back-diffusion and pressure drop effects, these vent lines should be between 2 and 10 meters in length.

3.5.3.2. Zero Scrubber/Dual Pressurized Span Valve (OPT 50D)

The zero air scrubber of Option 50D is a cartridge, which is used to produce and supply zero air to the analyzer's ZERO inlet port. The cartridge mounts to the outside rear panel and contains two chemicals: 50% volume of Purafil Chemisorbant to convert NO to NO₂, followed by 50% volume of charcoal to absorb NO₂.

The dual pressurized span valves of Option 50D are a special set of valves that allows two separate NO_x mixtures to enter the analyzer from two independent sources. Typically these two gas mixtures will come from two, separate, pressurized bottles of certified calibration gas: one mixed to produce a NO, NO₂ or NO_x concentration equal to the expected span calibration value for the application and the other mixed to produce a concentration at or near the midpoint of the intended measurement range. Individual gas inlets, labeled HIGH SPAN and LOW SPAN are provided at the back on the analyzer.

The valves allow the user to switch between the two sources via the front panel touch screen control buttons or from a remote location by way of either the analyzer's digital control inputs or by sending commands over its serial I/O port(s).

Note

The analyzer's software only allows the SLOPE and OFFSET to be calculated when sample is being routed through the HIGH SPAN inlet. The LOW SPAN gas is for midpoint reference checks only.

The state of the optional valves can be controlled:

- Manually from the analyzer's front panel by using the **SIGNAL I/O** submenu located under the **DIAG** menu (Section 4.13.2),
- By activating the instrument's CAL or AutoCal features (Section 5.8),
- Remotely by using the external digital control inputs (Section 4.15.1.2) or Ethernet.
- Remotely through the RS-232/485 serial I/O ports (Section 4.11).

Table 3-11: Two-Point Span Valve Operating States

MODE	VALVE	CONDITION
SAMPLE	Sample/Cal	Open to SAMPLE inlet
	Zero Gas Valve	Closed to ZERO AIR inlet
	High Span Valve	Closed to HIGH SPAN inlet
	Low Span Valve	Closed to LOW SPAN inlet
ZERO CAL	Sample/Cal	Closed to SAMPLE inlet
	Zero Gas Valve	Open to ZERO AIR inlet
	High Span Valve	Closed to HIGH SPAN inlet
	Low Span Valve	Closed to LOW SPAN inlet
HIGH SPAN CAL	Sample/Cal	Closed to SAMPLE inlet
	Zero Gas Valve	Closed to ZERO AIR inlet
	High Span Valve	Open to HIGH SPAN inlet
	Low Span Valve	Closed to LOW SPAN inlet
Low Span Check	Sample/Cal	Closed to SAMPLE inlet
	Zero Gas Valve	Closed to ZERO AIR inlet
	High Span Valve	Closed to HIGH SPAN inlet
	Low Span Valve	Open to LOW SPAN inlet

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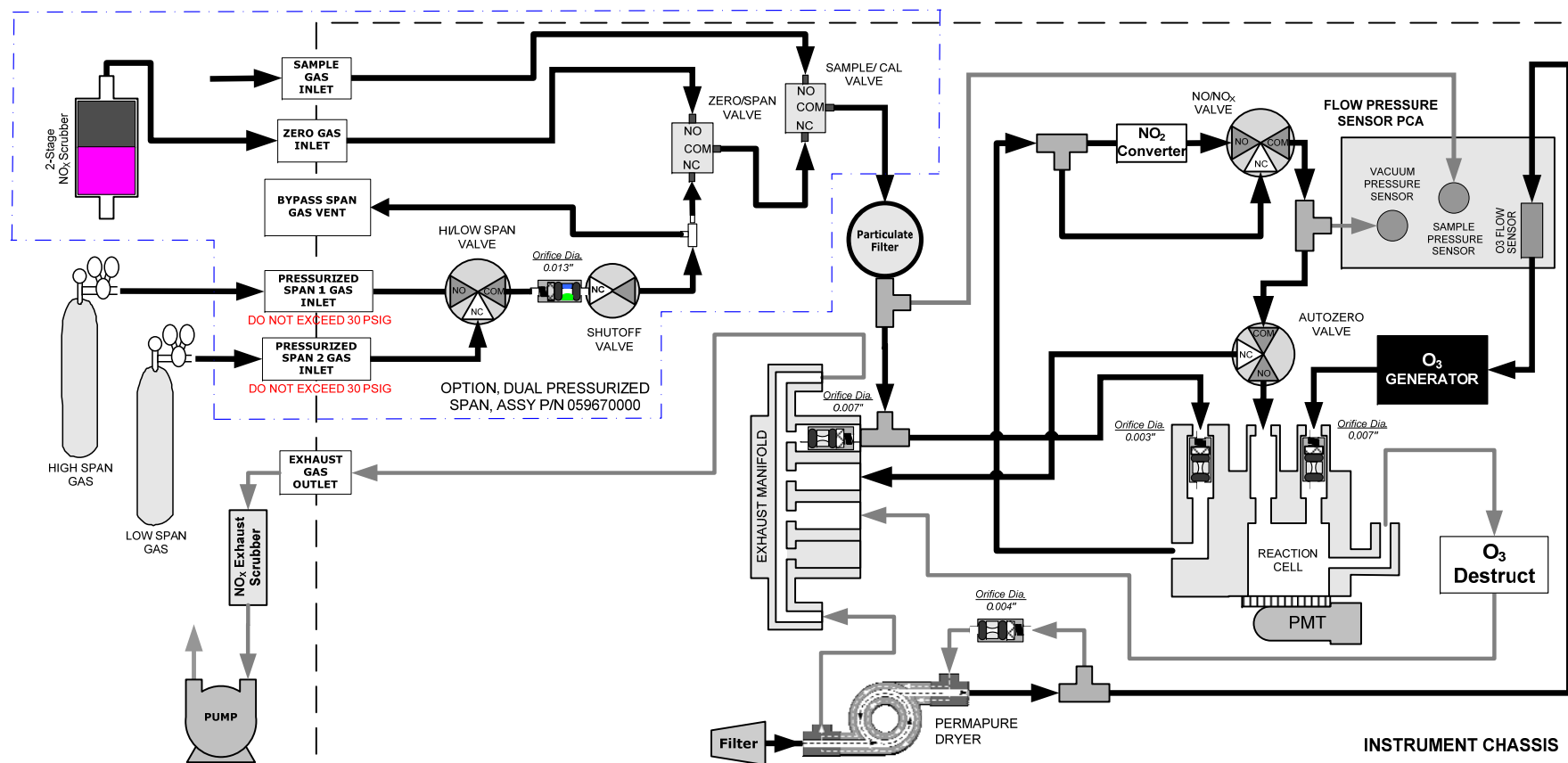


Figure 3-21: 9110TH - Internal Pneumatics for Zero Scrubber/Dual Pressurized Span, Option 50D

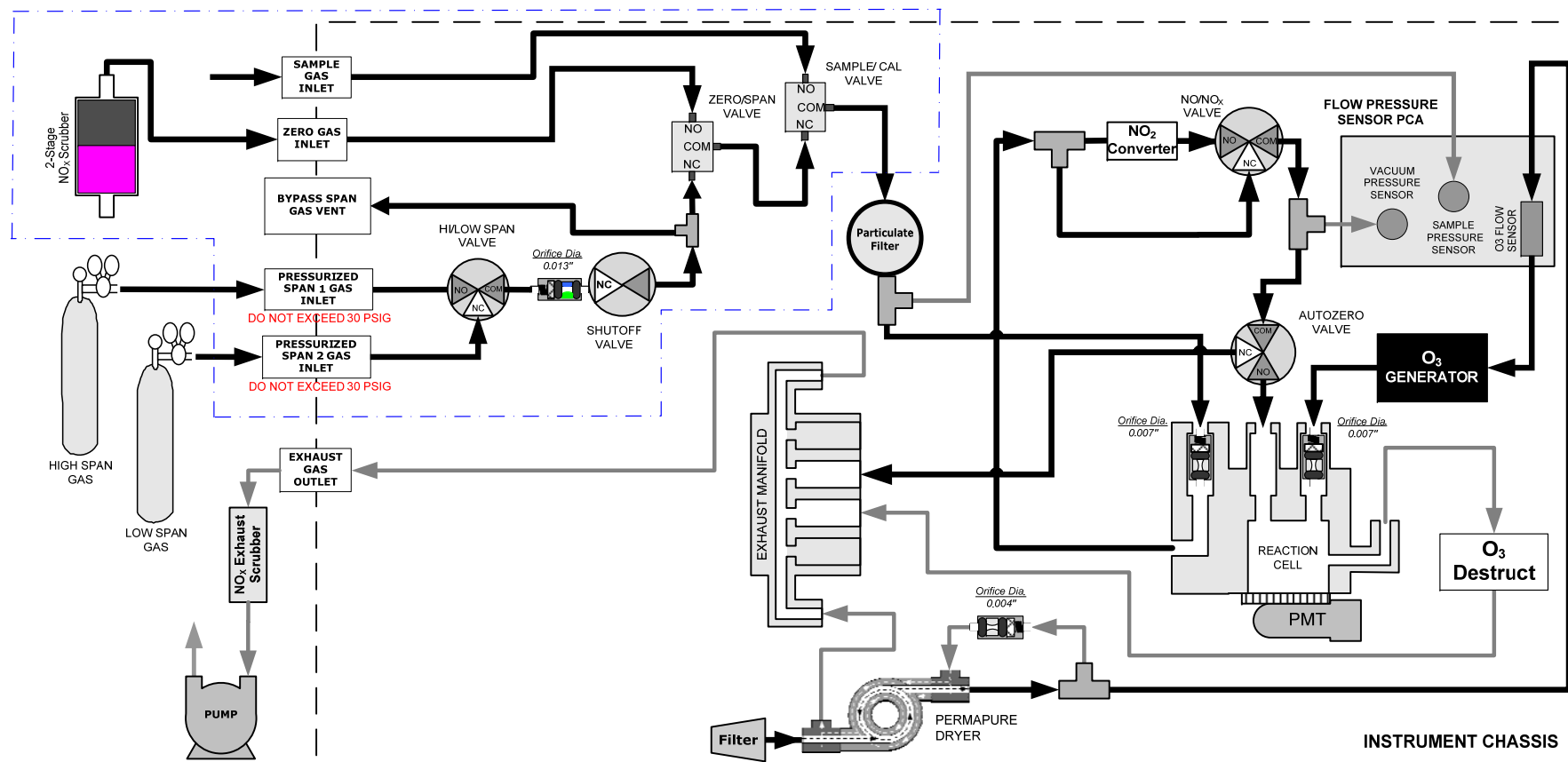


Figure 3-22: 9110TM - Internal Pneumatics for Zero Scrubber/Dual Pressurized Span, Option 50D

3.5.3.3. Internal Flow for O₂ Sensor Option 65A

Please see Section 3.7.2 for calibration connections and method.

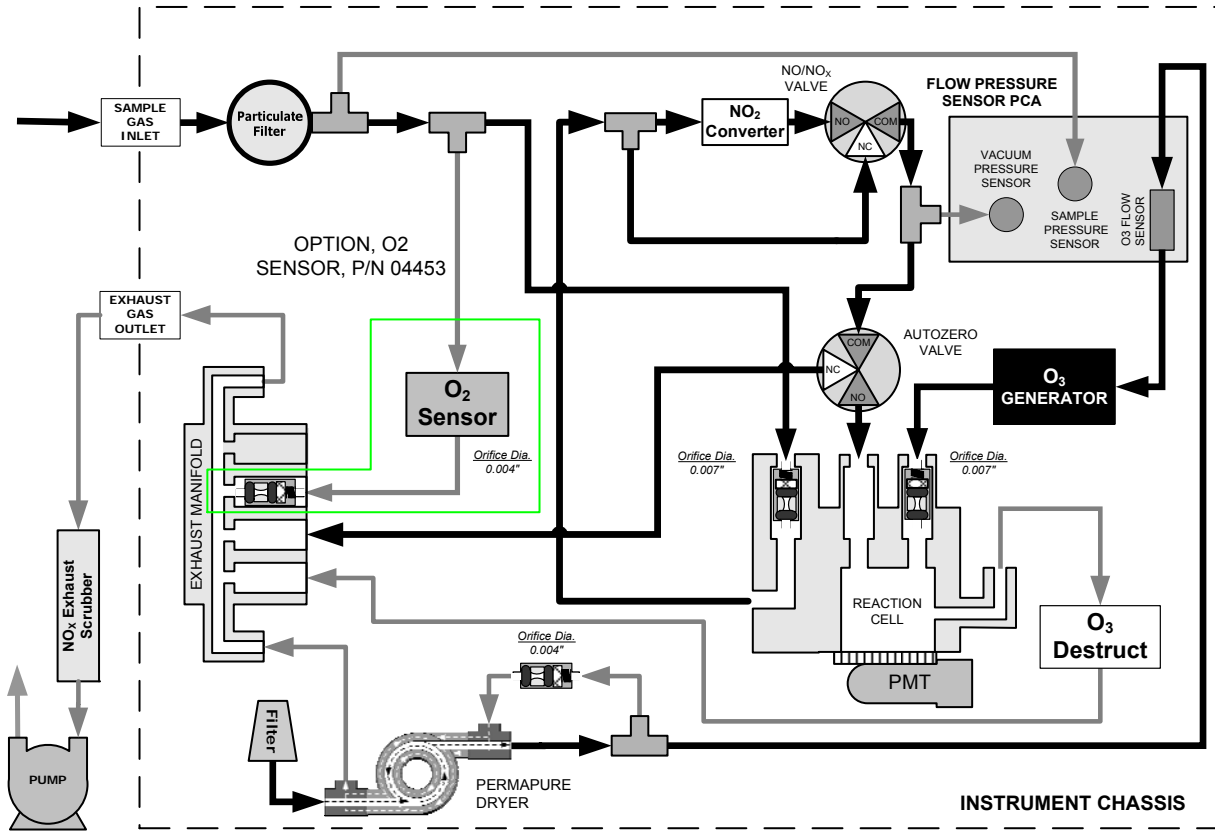


Figure 3-23: 9110TH – Internal Pneumatics with O₂ Sensor Option 65A

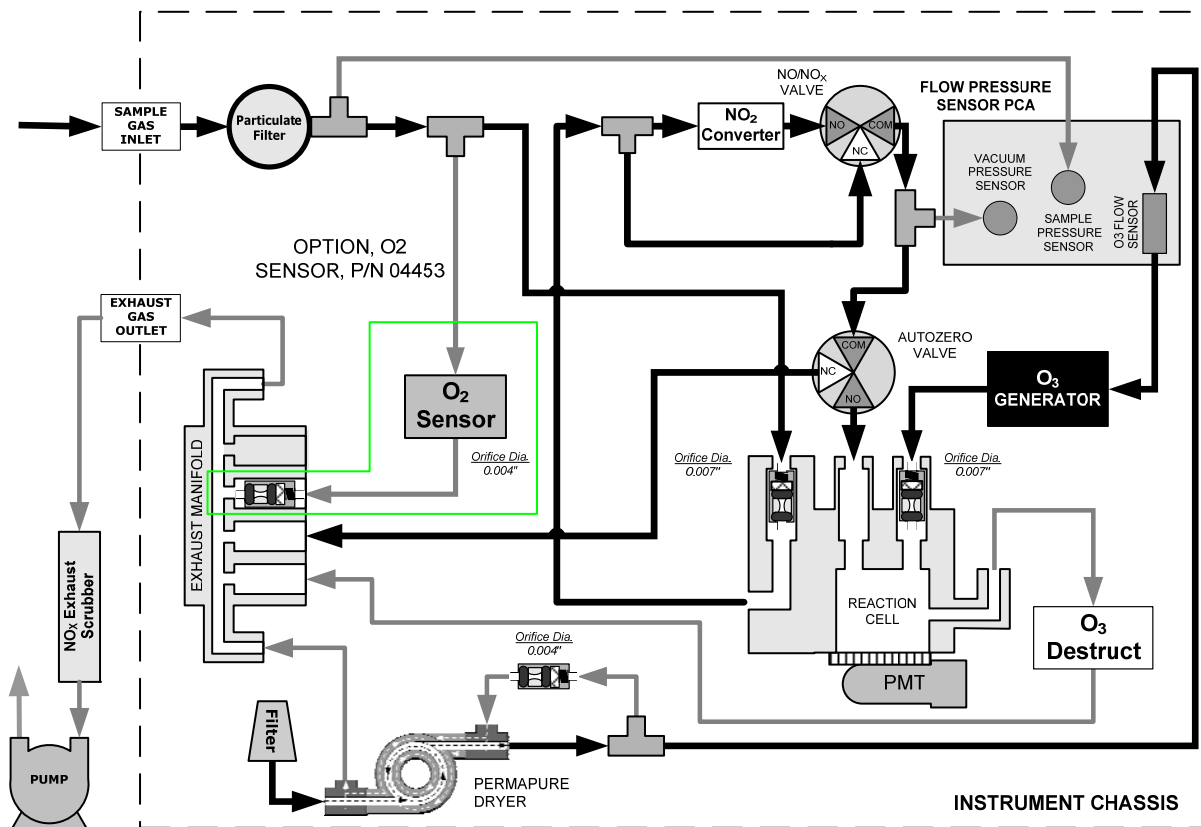


Figure 3-24: 9110TM – Internal Pneumatics with O₂ Sensor Option 65A

3.6. INITIAL OPERATION



CAUTION!

If the presence of ozone is detected at any time, call TAI Technical Support as soon as possible:

Tel: 626-934-1673 or email: TETCI_customerservice@teledyne.com

If you are unfamiliar with the theory of operation of the 9110TH/M analyzer, we recommend that you read Section 8 before proceeding. For information on navigating the analyzer's software menus, see the menu trees described in Appendix A.

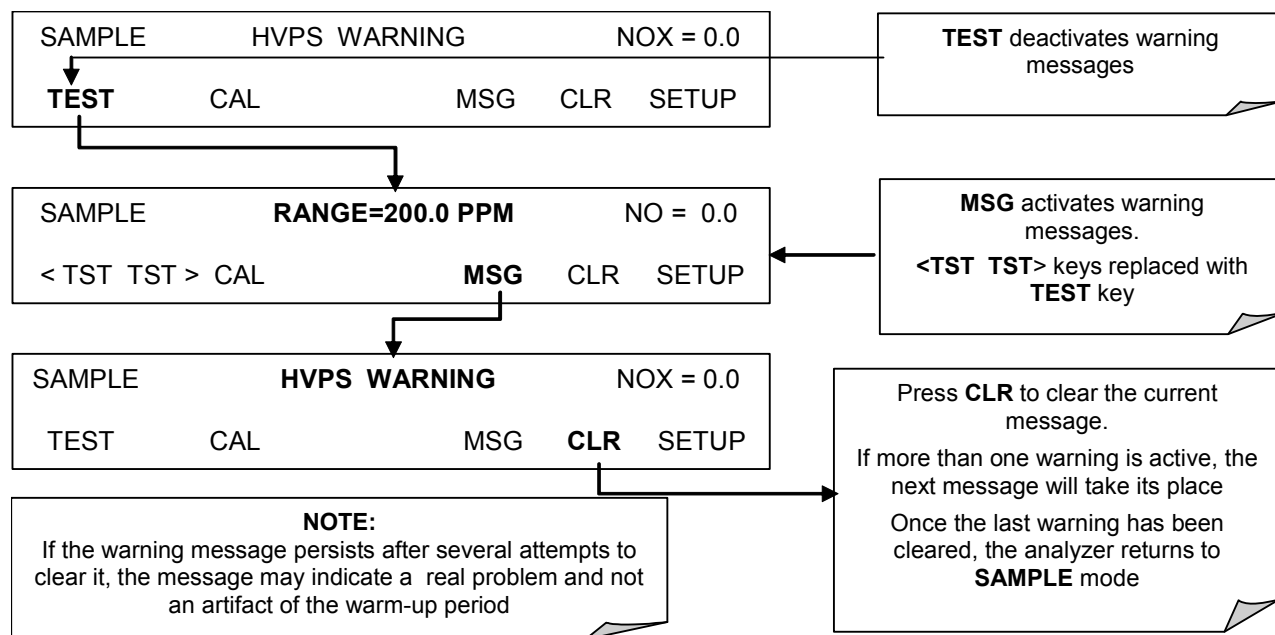
3.6.1. STARTUP

After the electrical and pneumatic connections are made, an initial functional check is in order. Turn on the instrument. The pump and exhaust fan should start immediately. The display will briefly show a logo splash screen at the start of initialization.

The analyzer should automatically switch to Sample Mode after completing the boot-up sequence and start monitoring NO_x, NO, NO₂ gases. Allow a one-hour warm-up period. During the warm-up period, the front panel display may show messages in the Parameters field, such as WARNING messages.

3.6.2. WARNING MESSAGES

During warm-up, internal temperatures and other parameters may be outside of specified limits. The software will suppress most warning conditions for 30 minutes after power up.

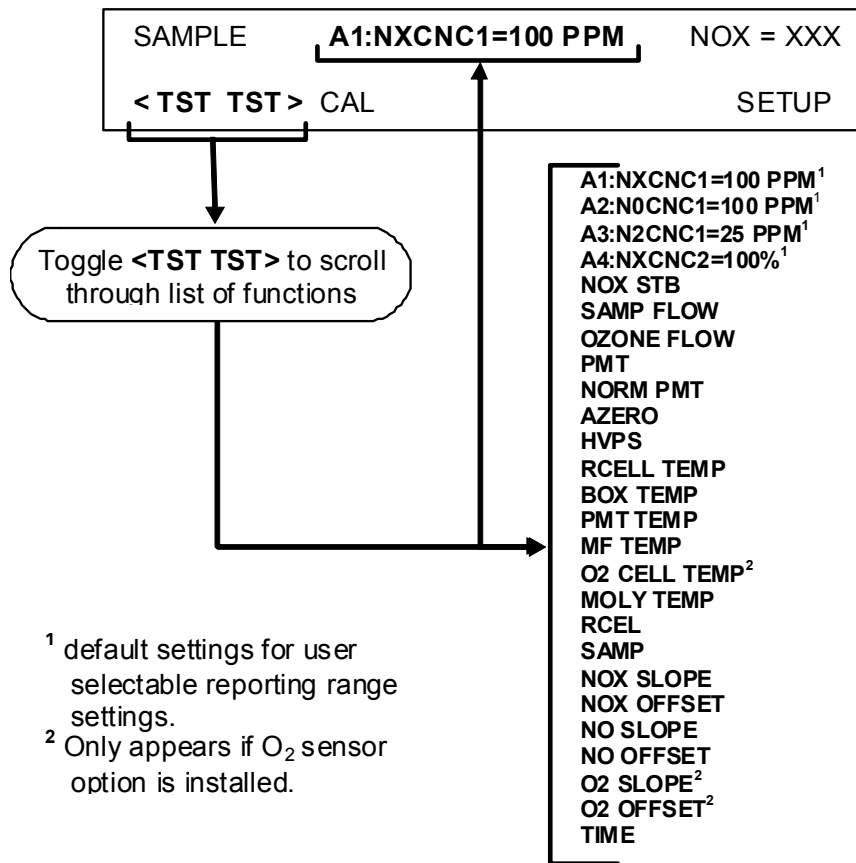


Section 4.2.2 provides a table of warning messages with their definitions and the steps to view and clear them. If warning messages persist after 30 minutes, investigate their cause using the troubleshooting guidelines in Section 7.

3.6.3. FUNCTIONAL CHECK

After the analyzer's components have warmed up for at least 30 minutes, verify that the software properly supports any hardware options that were installed.

Check to make sure that the analyzer is functioning within allowable operating parameters. Appendices A and C include a list of test functions viewable from the analyzer's front panel as well as their expected values. These functions are also useful tools for diagnosing performance problems with your analyzer (Section 7). The enclosed *Final Test and Validation Data Sheet* (part number 04490) lists these values before the instrument left the factory. To view the current values of these test functions press the <TST TST> buttons:



3.7. CALIBRATION

An initial calibration and functional check should be conducted upon first-time startup.

Note

Once you have completed the following set-up procedures, please fill out the quality questionnaire that was shipped with your unit and return it to TAI.

This information is vital to our efforts in continuously improving our service and our products. Thank you.

3.7.1. BASIC NO_x CALIBRATION PROCEDURE

The initial calibration should be carried out using the same reporting range set up as used during the analyzer's factory calibration. This will allow you to compare your calibration results to the factory calibration as listed on the *Final Test and Validation Data Sheet*.

The following procedure assumes that the instrument does not have any of the available valve options installed. Section 5 contains instructions for calibrating instruments with these options.

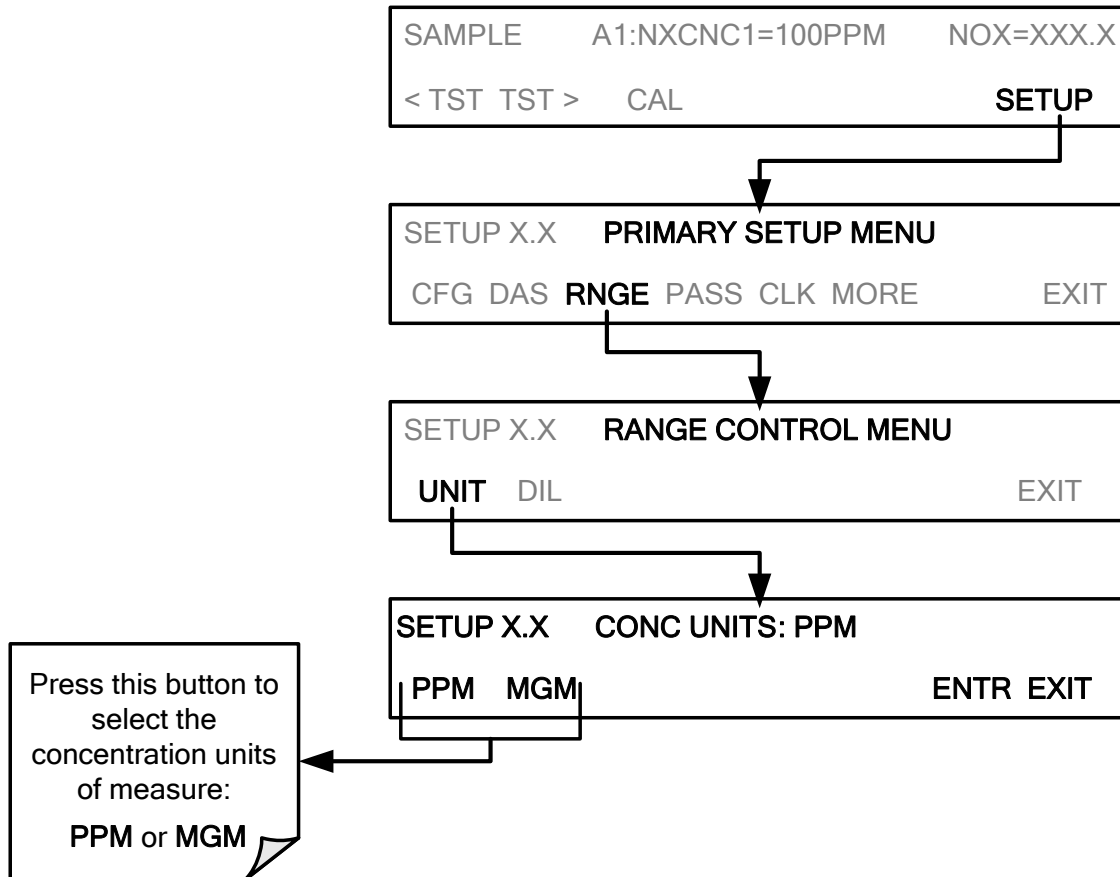
If both available DAS parameters for a specific gas type are being reported via the instrument's analog outputs e.g. NXCNC1 and NXCNC2, separate calibrations should be carried out for each parameter.

- Use the LOW button when calibrating for NXCNC1
- Use the HIGH button when calibrating for NXCNC2.

See Sections 4.13.3 and 4.13.4 for more information on analog output reporting ranges.

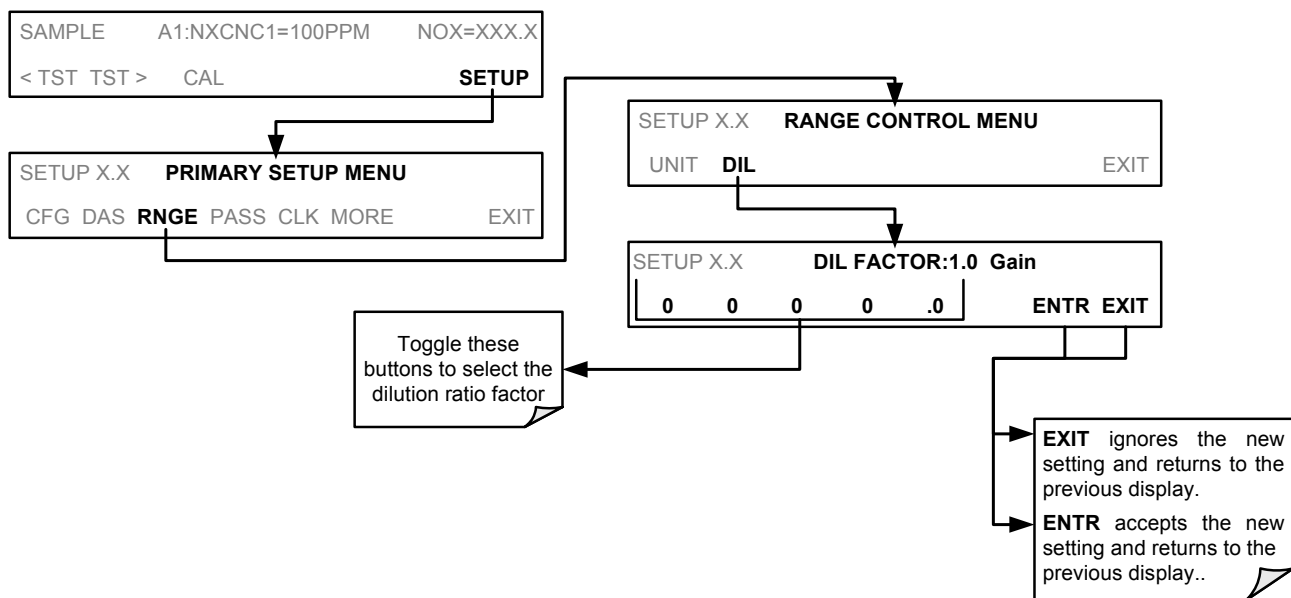
STEP 1 - Set Units:

To select the concentration units of measure press:



STEP 2 - Dilution Ratio:

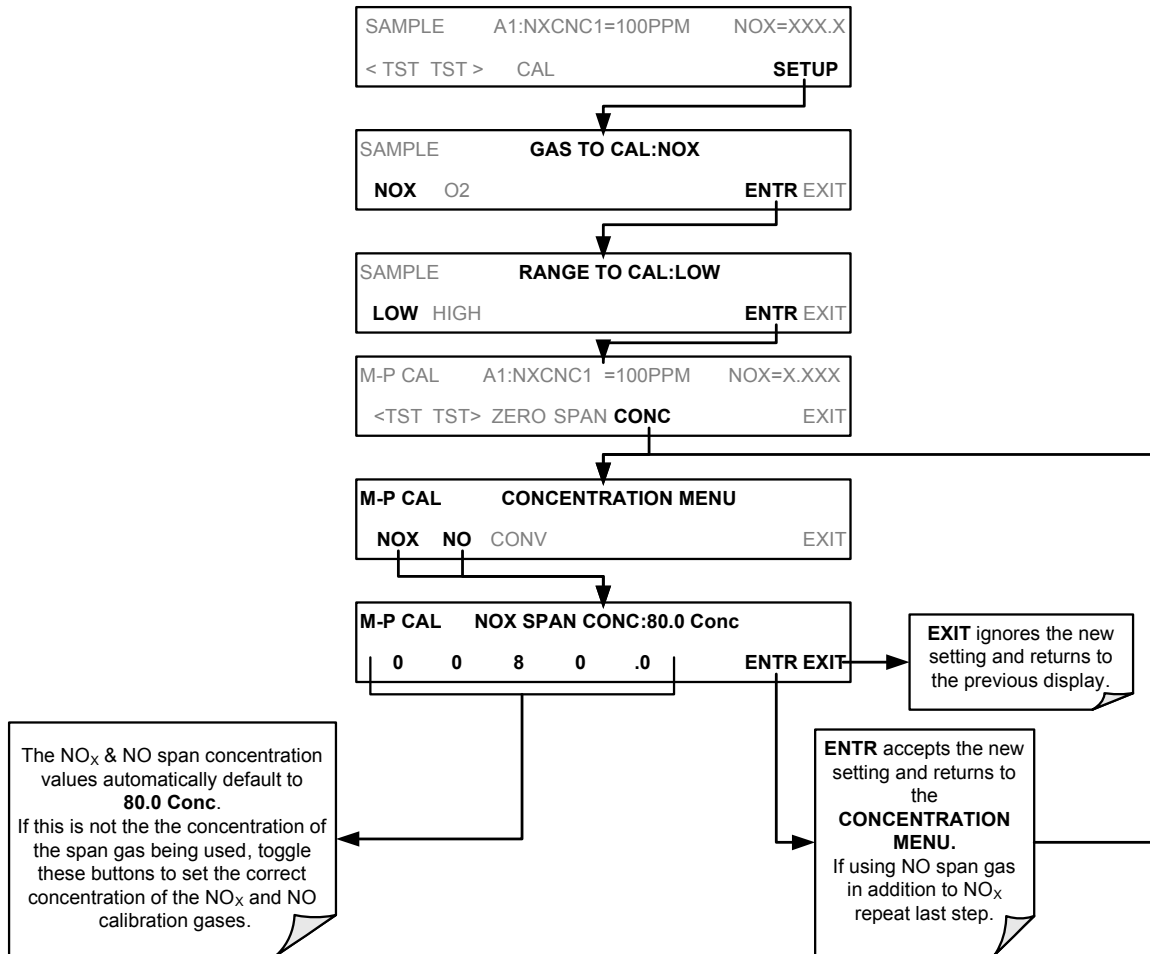
If the dilution ratio option is enabled on your 9110TH/M and your application involves diluting the sample gas before it enters the analyzer, set the dilution ratio as follows:



STEP 3 – Set NO_x and NO span gas concentrations :

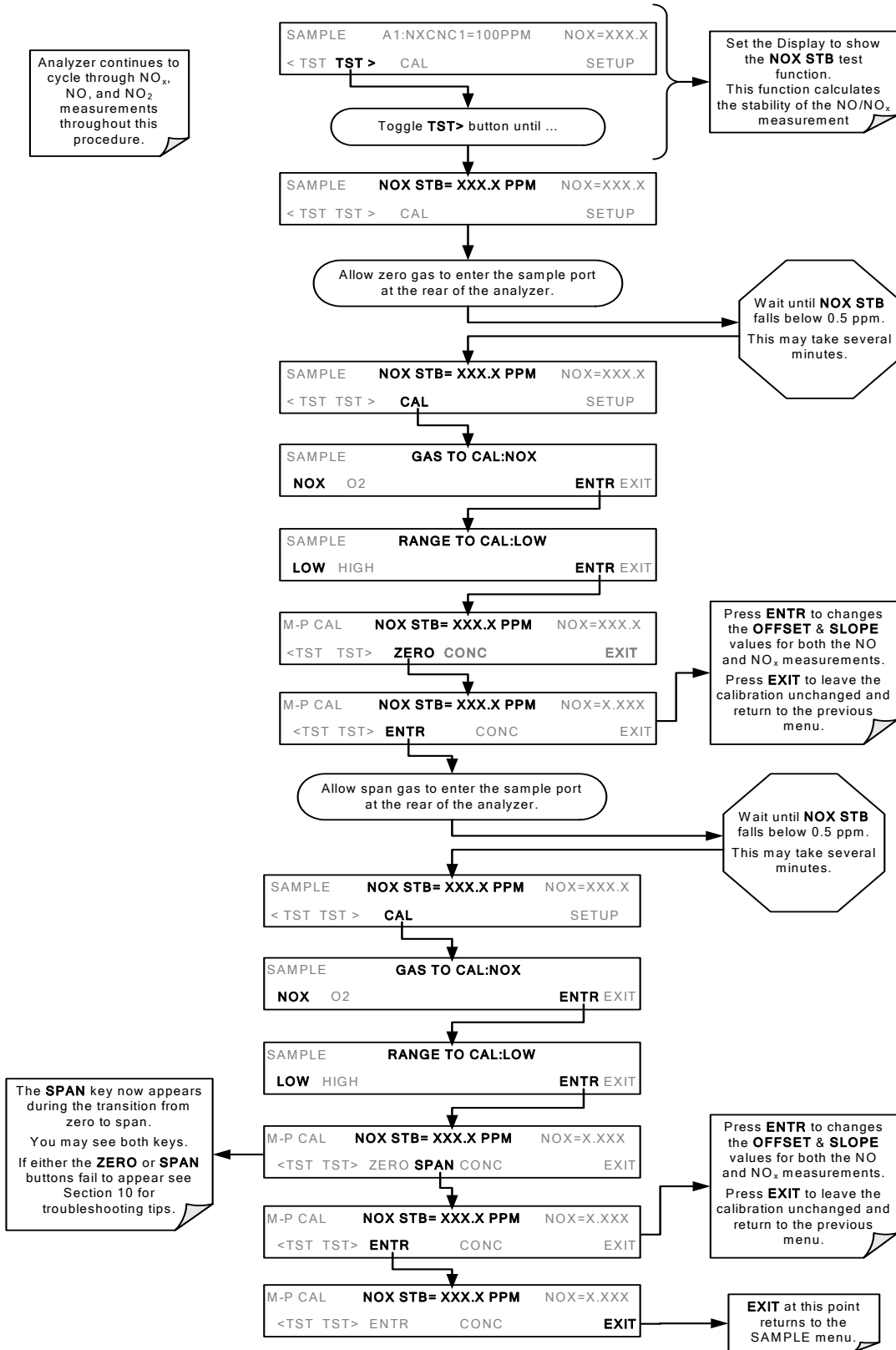
Set the expected NO and NO_x span gas concentration. These should be 80% of range of concentration values likely to be encountered in this application. The default factory setting is 100 ppm. If one of the configurable analog outputs is to be set to transmit concentration values, use 80% of the reporting range set for that output (see Section 4.13.4)

If you supply NO span gas to the analyzer as well as NO_x, the values for expected NO and NO_x span gas concentrations need to be identical.



STEP 4 – Zero/Span Calibration :

To perform the zero/span calibration procedure:



3.7.2. BASIC O₂ SENSOR CALIBRATION PROCEDURE

If your instrument has an O₂ sensor option installed, that should be calibrated as well.

3.7.2.1. O₂ Calibration Setup

The pneumatic connections for calibrating are as follows:

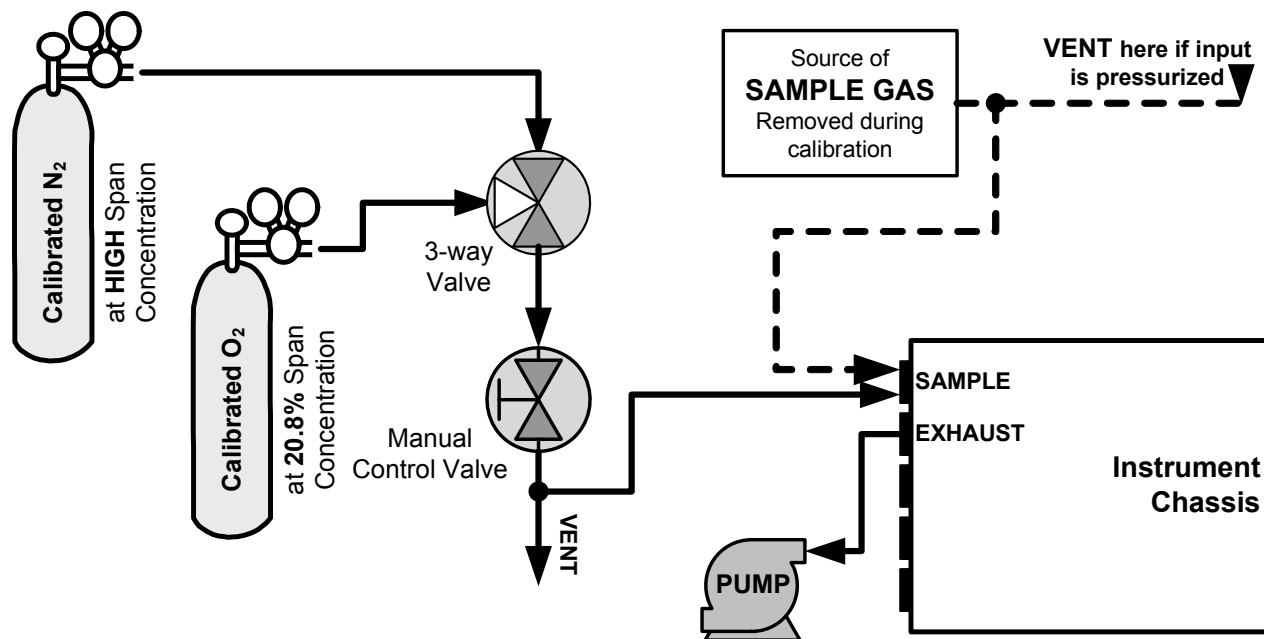


Figure 3-25: O₂ Sensor Calibration Set Up

O₂ SENSOR ZERO GAS: TAI recommends using pure N₂ when calibration the zero point of your O₂ sensor option.

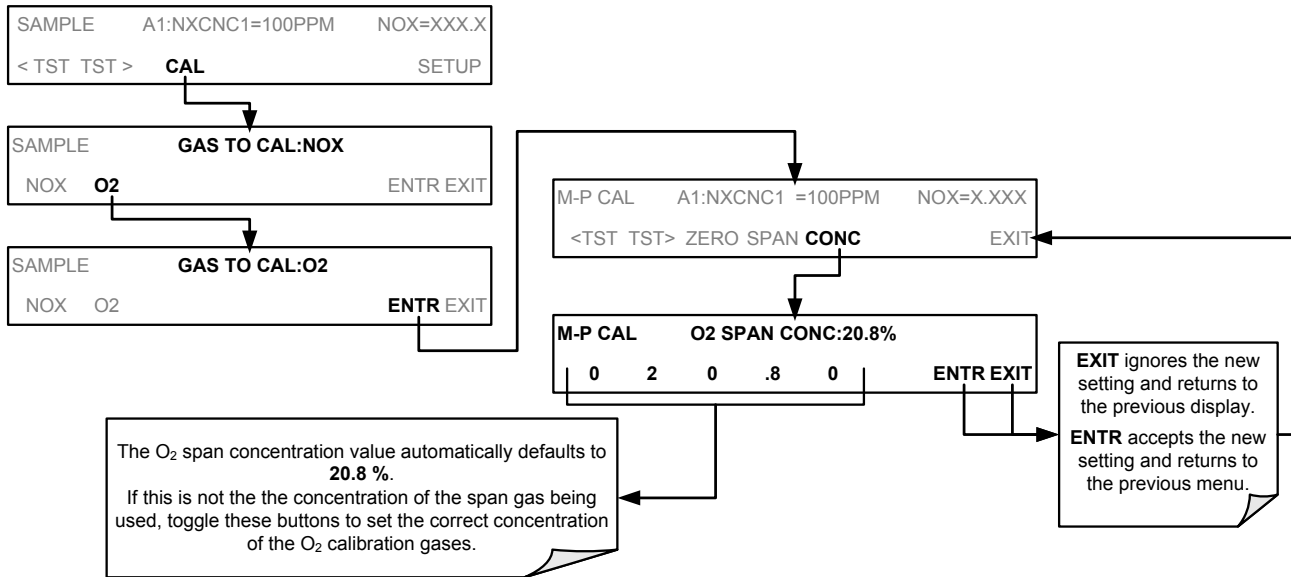
O₂ SENSOR SPAN GAS: TAI recommends using 21% O₂ in N₂ when calibration the span point of your O₂ sensor option.

3.7.2.2. O₂ Calibration Method

STEP 1 – Set O₂ span gas concentration :

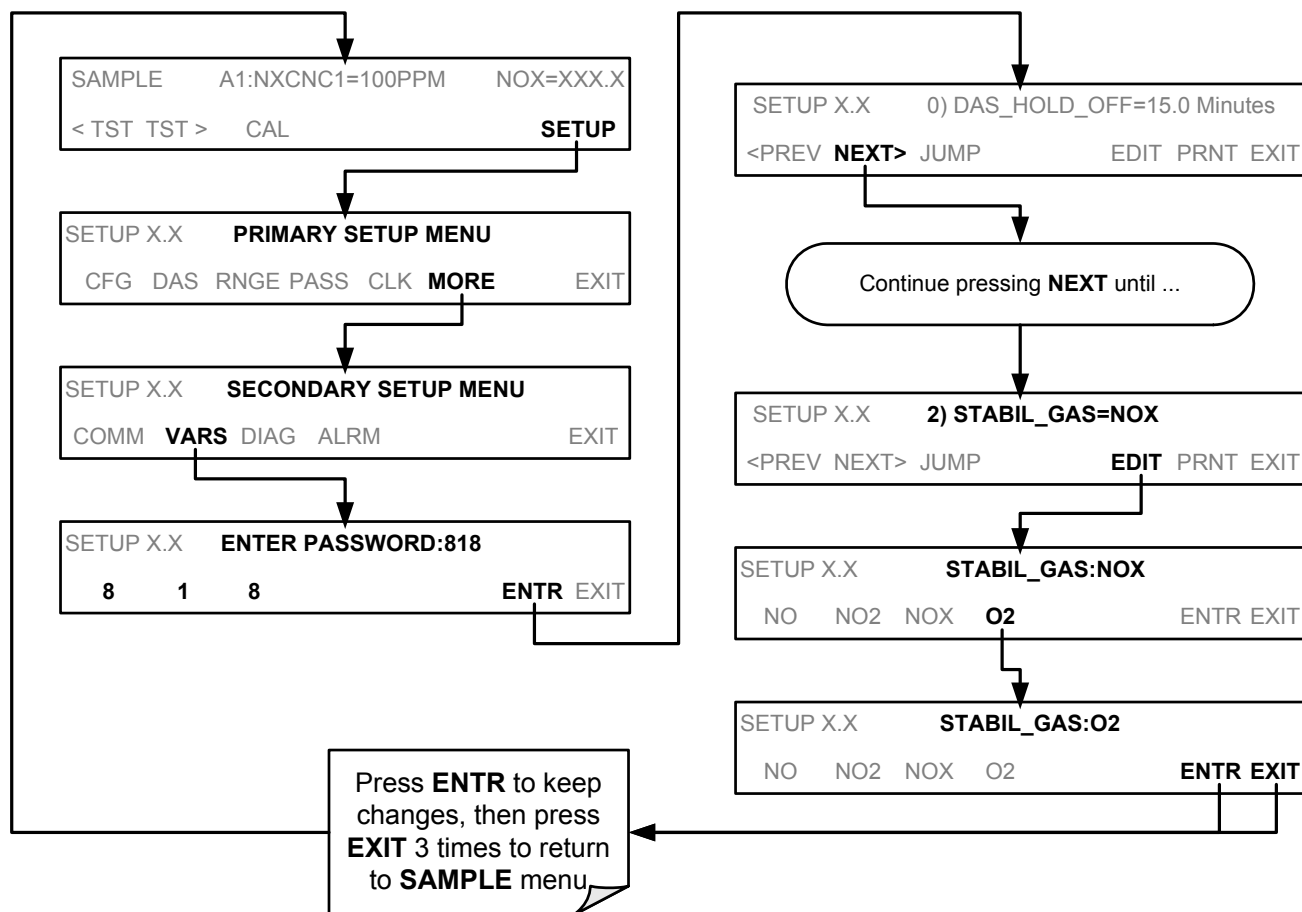
Set the expected O₂ span gas concentration.

This should be equal to the percent concentration of the O₂ span gas of the selected reporting range (default factory setting = 20.8%; the approximate O₂ content of ambient air).



STEP 2 – Activate O₂ sensor stability function

To change the stability test function from NO_x concentration to the O₂ sensor output, press:

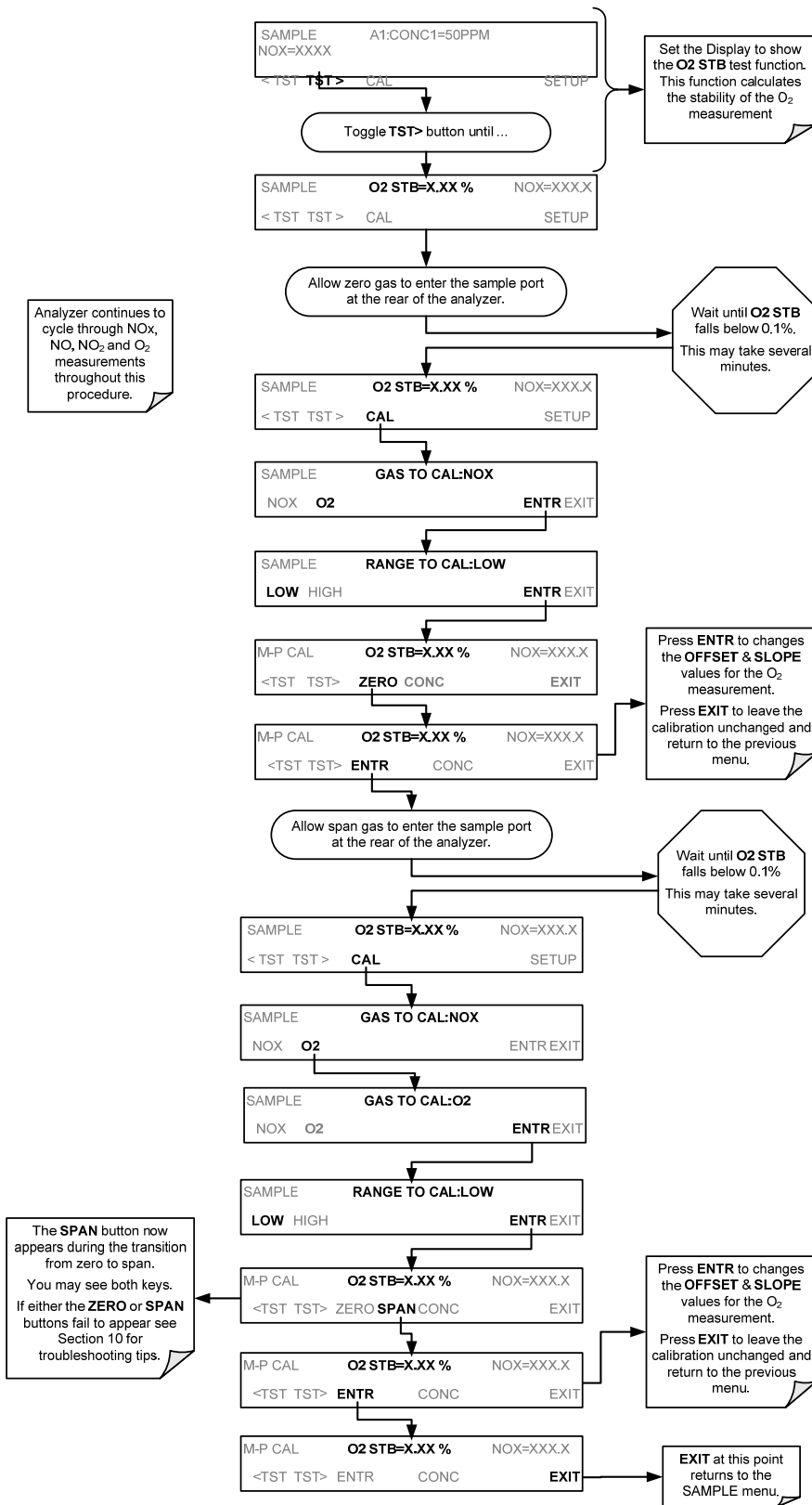


Note

Use the same procedure to reset the STB test function to NO_x when the O₂ calibration procedure is complete.

STEP 4 – O₂ ZERO/SPAN CALIBRATION :

To perform the zero/span calibration procedure:



The Model 9110TH/M analyzer is now ready for operation.

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4. OPERATING INSTRUCTIONS

To assist in navigating the analyzer's software, a series of menu trees can be found in Appendix A of this manual.

Note

The flow charts appearing in this section contain typical representations of the analyzer's display during the various operations being described. These representations may differ slightly from the actual display of your instrument.

The ENTR button may disappear if you select a setting that is invalid or out of the allowable range for that parameter, such as trying to set the 24-hour clock to 25:00:00. Once you adjust the setting to an allowable value, the ENTR button will re-appear.

4.1. OVERVIEW OF OPERATING MODES

The 9110TH/M software has a variety of operating modes. Most commonly, the analyzer will be operating in **SAMPLE** mode. In this mode, a continuous read-out of the NO, NO₂ and NO_x concentrations are displayed on the front panel and are available to be output as analog signals from the analyzer's rear panel terminals. Also, calibrations can be performed, and **TEST** functions and **WARNING** messages can be examined.

The second most important operating mode is **SETUP** mode. This mode is used for performing certain configuration operations, such as for the DAS system, configuring the reporting ranges, or the serial (RS-232/RS-485/Ethernet) communication channels. The **SET UP** mode is also used for performing various diagnostic tests during troubleshooting.



Figure 4-1: Front Panel Display with "SAMPLE" Indicated in the Mode Field

The mode field of the front panel display indicates to the user which operating mode the unit is currently running.

In addition to **SAMPLE** and **SETUP**, other modes the analyzer can be operated in are:

Table 4-1: Analyzer Operating modes

MODE	EXPLANATION
SAMPLE	Sampling normally, flashing text indicates adaptive filter is on.
M-P CAL	This is the basic calibration mode of the instrument and is activated by pressing the CAL key.
SETUP X.#²	SETUP mode is being used to configure the analyzer. The gas measurement will continue during this process.
SAMPLE A	Indicates that unit is in SAMPLE mode and AUTOCAL feature is activated.
ZERO CAL M¹	Unit is performing ZERO calibration procedure initiated manually by the user.
ZERO CAL A¹	Unit is performing ZERO calibration procedure initiated automatically by the AUTOCAL feature.
ZERO CAL R¹	Unit is performing ZERO calibration procedure initiated remotely through the COM ports or digital control inputs.
LO CAL A	Unit is performing LOW SPAN (midpoint) calibration initiated automatically by the analyzer's AUTOCAL feature.
LO CAL R	Unit is performing LOW SPAN (midpoint) calibration initiated remotely through the COM ports or digital control inputs.
SPAN CAL M¹	Unit is performing SPAN calibration initiated manually by the user.
SPAN CAL A¹	Unit is performing SPAN calibration initiated automatically by the analyzer's AUTOCAL feature.
SPAN CAL R¹	Unit is performing SPAN calibration initiated remotely through the COM ports or digital control inputs.
DIAG	One of the analyzer's diagnostic modes is active (Section 4.13).
¹ Only Appears on units with Z/S valve or IZS options.	
² The revision of the analyzer firmware is displayed following the word SETUP , e.g., SETUP F.0 .	

The very important **CAL** mode, which allows calibration of the analyzer in various ways, is described in detail in Section 7.

4.2. SAMPLE MODE

This is the analyzer's standard operating mode. In this mode, the instrument is analyzing NO and NO_x and calculating NO₂ concentrations.

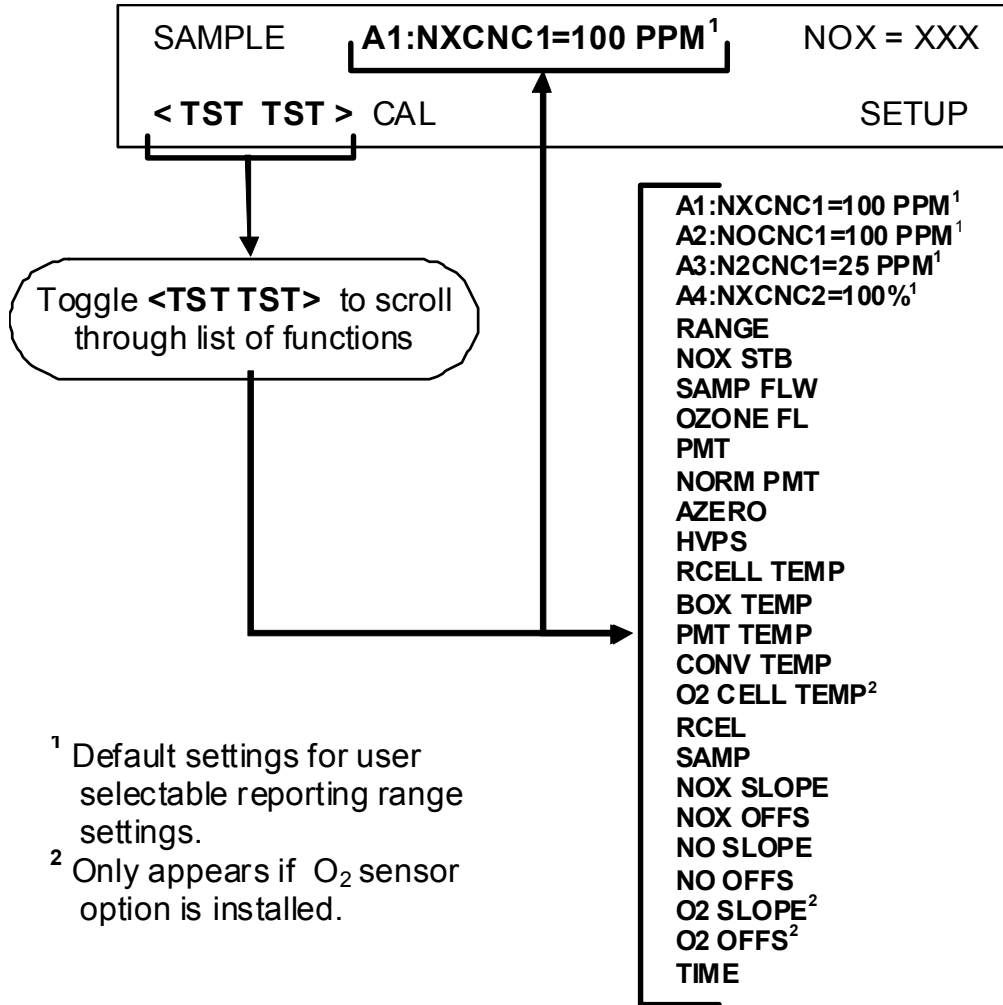
4.2.1. TEST FUNCTIONS

A series of test functions is available at the front panel while the analyzer is in SAMPLE mode. These parameters provide information about the present operating status of the instrument and are useful during troubleshooting (Section 7). They can also be recorded

in one of the DAS channels (Section 4.7) for data analysis or output on one of the configurable analog outputs.

Table 4-2: Test Functions Defined

DISPLAY	PARAMETER	UNITS	DESCRIPTION
Analog output range configuration	A1:NXCNC1=100 PPM A2:N0CNC1=100 PPM A3:N2CNC1=25 PPM A4:NXCNC2=100%		These functions show the default settings for the enabled analog output channels. See section 4.13.4 for more information.
NOX STB	STABILITY	PPM, MGM	The stability is a standard deviation of the NO _x concentration over 25 samples, each recorded every 10 seconds. A low NOX STB value indicates low variability in NO _x .
SAMP FLW	SAMPLE FLOW	cm ³ /min (cc/m)	The flow rate of the sample gas through the reaction cell. This value is not measured but calculated from the sample pressure.
OZONE FL	OZONE	cm ³ /min (cc/m)	Flow rate of the O ₃ gas stream as measured with a flow meter
PMT	PMT Signal	MV	The raw output voltage of the PMT.
NORM PMT	NORMALIZED PMT Signal	MV	The output voltage of the PMT after normalization for auto-zero offset and temperature/pressure compensation (if activated).
AZERO	AUTO-ZERO	MV	The PMT signal with zero NO _x , which is usually slightly different from 0 V. This offset is subtracted from the PMT signal and adjusts for variations in the zero signal.
HVPS	HVPS	V	The PMT high voltage power supply.
RCELL TEMP	REACTION CELL TEMP	°C	The current temperature of the reaction cell.
BOX TEMP	BOX TEMPERATURE	°C	The ambient temperature of the inside of the analyzer case.
PMT TEMP	PMT TEMPERATURE	°C	The current temperature of the PMT.
CONV TEMP	CONVERTER TEMPERATURE	°C	The current temperature of the NO ₂ converter.
RCEL	REACTION CELL PRESSURE	in-Hg-A	The current gas pressure of the reaction cell as measured at the vacuum manifold. This is the vacuum pressure created by the external pump.
SAMP	SAMPLE PRESSURE	in-Hg-A	The current pressure of the sample gas as it enters the reaction cell, measured between the NO/NO _x and Auto-Zero valves.
NOX SLOPE	NO _x SLOPE	--	The slope of the current NO _x calibration as calculated from a linear fit during the analyzer's last zero/span calibration.
NOX OFFS	NO _x OFFSET	MV	The offset of the current NO _x calibration as calculated from a linear fit during the analyzer's last zero/span calibration.
NO SLOPE	NO SLOPE	--	The slope of the current NO calibration as calculated from a linear fit during the analyzer's last zero/span calibration.
NO OFFS	NO OFFSET	MV	The offset of the current NO calibration as calculated from a linear fit during the analyzer's last zero/span calibration.
NO2	NO ₂ concentration	PPM, MGM	The current NO ₂ concentration in the chosen unit.
NOX	NO _x concentration	PPM, MGM	The current NO _x concentration in the chosen unit.
NO	NO concentration	PPM, MGM	The current NO concentration in the chosen unit.
TEST	TEST SIGNAL ²	MV	Signal of a user-defined test function on output channel A4.
TIME	CLOCK TIME	hh:mm:ss	The current day time for DAS records and calibration events.



¹ Default settings for user selectable reporting range settings.

² Only appears if O₂ sensor option is installed.

Figure 4-2: Viewing 9110TH/M TEST Functions

Note

A value of “XXXX” displayed for any of the TEST functions indicates an out-of-range reading or the analyzer’s inability to calculate it. All pressure measurements are represented in terms of absolute pressure. Absolute, atmospheric pressure is 29.92 in-Hg-A at sea level. It decreases about 1 in-Hg per 300 m gain in altitude. A variety of factors such as air conditioning and passing storms can cause changes in the absolute atmospheric pressure.

4.2.2. WARNING MESSAGES

The most common instrument failures will be reported as a warning on the analyzer’s front panel and through the COM ports. Appendix A provides the recommended action and explains how to use these messages to troubleshoot problems. 7.1.1 shows how to view and clear warning messages.

Table 4-3: List of Warning Messages

MESSAGE	DEFINITION
ANALOG CAL WARNING	The instrument's analog-to-digital converter (A/D) circuitry or one of the analog outputs are not calibrated.
AZERO WRN XXX.X MV	The reading taken during the Auto-zero cycle is outside the specified limits. The value shown here as "XXX.X" indicates the actual auto-zero reading at the time of the warning.
BOX TEMP WARNING	The temperature inside the 9110TH/M chassis is outside the specified limits.
CANNOT DYN SPAN	Remote span calibration failed while the dynamic span feature was ON.
CANNOT DYN ZERO	Remote zero calibration failed while the dynamic zero feature was ON.
CONFIG INITIALIZED	Configuration storage was reset to factory configuration or was erased.
CONV TEMP WARNING	NO ₂ converter temperature is outside of specified limits.
DATA INITIALIZED	DAS data storage was erased.
HVPS WARNING	High voltage power supply for the PMT is outside of specified limits.
OZONE FLOW WARNING	Ozone flow is outside of specified limits.
OZONE GEN OFF	Ozone generator is off. This is the only warning message that automatically clears itself when the ozone generator is turned on.
PMT TEMP WARNING	PMT temperature is outside of specified limits.
RCELL PRESS WARN	Reaction cell pressure is outside of specified limits.
RCELL TEMP WARNING	Reaction cell temperature is outside of specified limits.
REAR BOARD NOT DET	The firmware is unable to communicate with the motherboard.
RELAY BOARD WARN	The firmware is unable to communicate with the relay board.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.
SYSTEM RESET	The computer rebooted or was powered up.

To view and clear warning messages

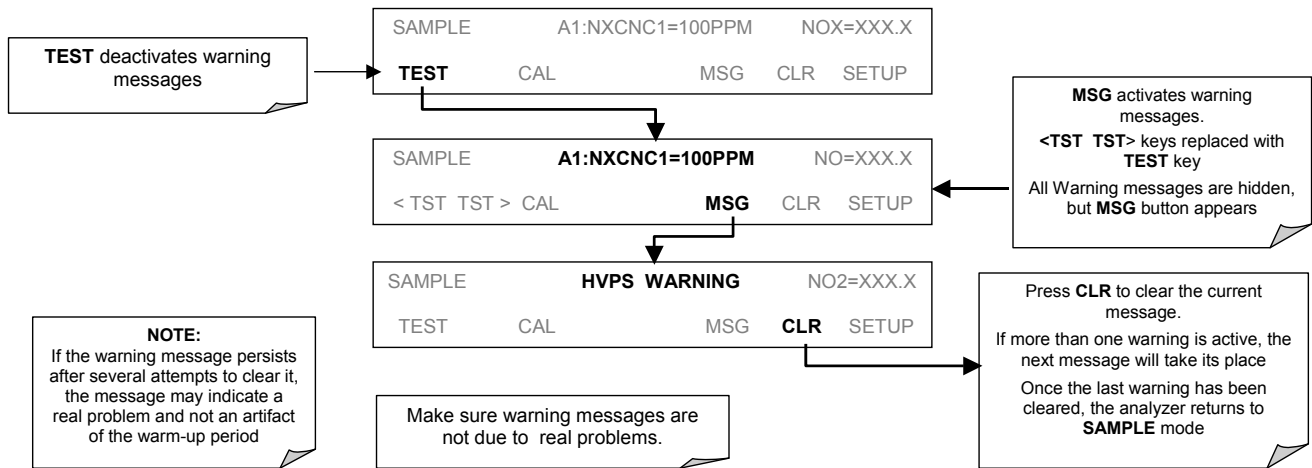


Figure 4-3: Viewing and Clearing 9110TH/M WARNING Messages

4.3. CALIBRATION MODE

4.3.1. CALIBRATION FUNCTIONS

Pressing the **CAL** key switches the 9110TH/M into calibration mode. In this mode, the user can calibrate the instrument with the use of calibrated zero or span gases.

If the instrument includes the zero/span valve option, the display will also include **CALZ** and **CALS** buttons. Pressing either of these buttons also puts the instrument into multipoint calibration mode.

- The **CALZ** button is used to initiate a calibration of the zero point.
- The **CALS** button is used to calibrate the span point of the analyzer. It is recommended that this span calibration is performed at 90% of full scale of the analyzer's currently selected reporting range.

Because of their critical importance and complexity, calibration operations are described in detail in Section 5.

4.4. SETUP MODE

The **SETUP** mode contains a variety of choices that are used to configure the analyzer's hardware and software features, perform diagnostic procedures, gather information on the instruments performance and configure or access data from the internal data acquisition system (DAS). The areas access under the Setup mode are:

Table 4-4: Primary Setup Mode Features and Functions

MODE OR FEATURE	MENU BUTTON	DESCRIPTION
Analyzer Configuration	CFG	Lists key hardware and software configuration information
Auto Cal Feature	ACAL	Used to set up an operate the AutoCal feature. Only appears if the analyzer has one of the internal valve options installed
Internal Data Acquisition (DAS)	DAS	Used to set up the DAS system and view recorded data
Analog Output Reporting Range Configuration	RNGE	Used to set the units of measure for the display and set the dilution ratio on instruments with that option active.
Calibration Password Security	PASS	Turns the password feature ON/OFF
Internal Clock Configuration	CLK	Used to Set or adjust the instrument's internal clock
Advanced SETUP features	MORE	This button accesses the instruments secondary setup menu

Table 4-5: Secondary Setup Mode Features and Functions

MODE OR FEATURE	KEYPAD LABEL	DESCRIPTION	MANUAL SECTION
External Communication Channel Configuration	COMM	Used to set up and operate the analyzer's various external I/O channels including RS-232; RS 485, modem communication and/or Ethernet access.	6.11 & 6.15
System Status Variables	VARS	Used to view various variables related to the instruments current operational status	6.12
System Diagnostic Features and Analog Output Configuration	DIAG	Used to access a variety of functions that are used to configure, test or diagnose problems with a variety of the analyzer's basic systems. Most notably, the menus used to configure the output signals generated by the instruments Analog outputs are located here.	6.13
Alarm Limit Configuration ¹	ALRM	Used to turn the instrument's two alarms on and off as well as set the trigger limits for each.	6.14

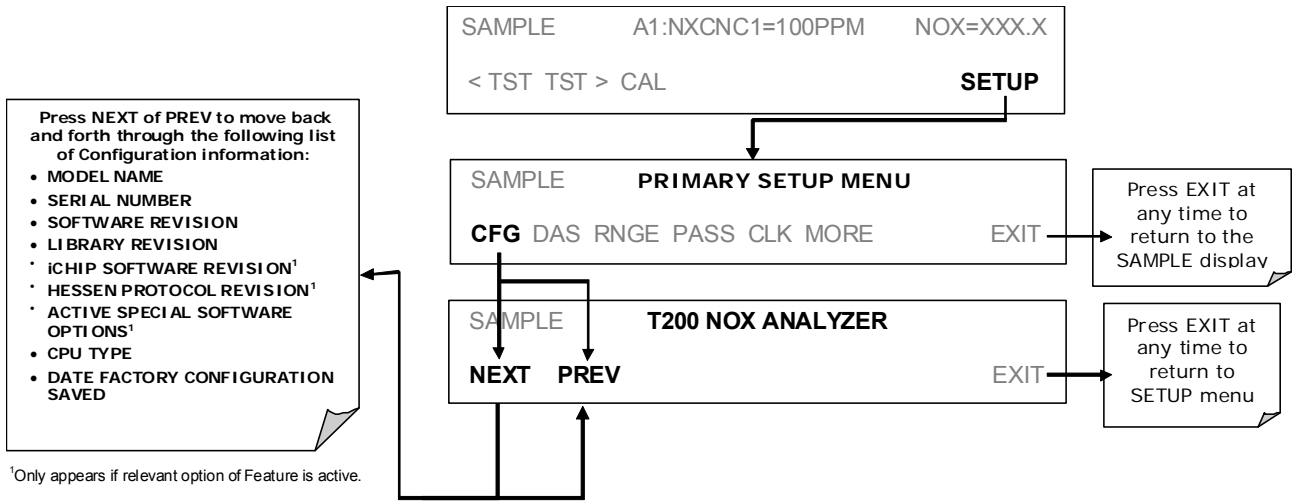
¹ Only present if the optional alarm relay outputs (Option 61) are installed.

Note

Any changes made to a variable during one of the following procedures is not acknowledged by the instrument until the ENTR button is pressed. If the EXIT button is pressed before the ENTR button, the analyzer will beep, alerting the user that the newly entered value has not been accepted.

4.5. SETUP → CFG: VIEWING THE ANALYZER'S CONFIGURATION INFORMATION

Pressing the CFG key displays the instrument configuration information. This display lists the analyzer model, serial number, firmware revision, software library revision, CPU type and other information. Use this information to identify the software and hardware when contacting Technical Support. Special instrument or software features or installed options may also be listed here.



4.6. SETUP → ACAL: AUTOMATIC CALIBRATION

Instruments with one of the internal valve options installed can be set to automatically run calibration procedures and calibration checks. These automatic procedures are programmed using the submenus and functions found under the **ACAL** menu.

A menu tree showing the **ACAL** menu’s entire structure can be found in Appendix A-1 of this manual.

Instructions for using the **ACAL** feature are located in the Section 7.7 of this manual along with all other information related to calibrating the 9110TH/M analyzer.

4.7. SETUP → DAS - USING THE DATA ACQUISITION SYSTEM (DAS)

The 9110TH/M analyzer contains a flexible and powerful, internal data acquisition system (DAS) that enables the analyzer to store concentration and calibration data as well as a host of diagnostic parameters. The data points can cover days, weeks or months of valuable measurements, depending on how the DAS is configured. The data are stored in non-volatile memory and are retained even when the instrument is powered off. Data are stored in plain text format for easy retrieval and use in common data analysis programs (such as spreadsheet-type programs).

Note

Please be aware that all stored data will be erased if the analyzer's disk-on-module, CPU board or configuration is replaced/reset.

The DAS is designed to be flexible. Users have full control over the type, length and reporting time of the data. The DAS permits users to access stored data through the instrument's front panel or its communication ports. TAI also offers APICOM, a program that provides a visual interface for configuration and data retrieval of the DAS or using a remote computer. Additionally, the analyzer's four analog output channels can be programmed to carry data related to any of the available DAS parameters.

The principal use of the DAS is logging data for trend analysis and predictive diagnostics, which can assist in identifying possible problems before they affect the functionality of the analyzer. The secondary use is for data analysis, documentation and archival in electronic format.

DAS STATUS

The green SAMPLE LED on the instrument front panel, which indicates the analyzer status, also indicates certain aspects of the DAS status:

Table 4-6: Front Panel LED Status Indicators for DAS

LED STATE	DAS STATUS
Off	System is in calibration mode. Data logging can be enabled or disabled for this mode. Calibration data are typically stored at the end of calibration periods, concentration data are typically not sampled, diagnostic data should be collected.
Blinking	Instrument is in hold-off mode, a short period after the system exits calibrations. DAS channels can be enabled or disabled for this period. Concentration data are typically disabled whereas diagnostic should be collected.
On	Sampling normally.

The DAS can be disabled only by disabling or deleting its individual data channels.

4.7.1. DAS STRUCTURE

The DAS is designed around the feature of a “record”, an automatically stored single data point. (e.g. concentration, PMT signal level, etc.). Records are organized into data channels which are defined by properties that characterize the:

- Type of data recorded (e.g. concentration, PMT signal level, etc.);
- Trigger event that causes the record to be made (e.g. every minute, upon exiting calibration mode, etc.);
- How many records to be stored, as well as;
- How the information is to be stored (e.g. average over 1 hour, individual points, minimum value over last 5 minutes, etc.).

The configuration of each DAS channel is stored in the analyzer’s memory as a script, which can be edited from the front panel or downloaded, edited and uploaded to the instrument in form of a string of plain-text lines through the communication ports.

4.7.1.1. DAS Channels

The key to the flexibility of the DAS is its ability to store a large number of combinations of triggering events and data parameters in the form of data channels. Users may create up to 20 data channels. For each channel one triggering event is selected and one or all of the 9110TH/M’s 25 data parameters are allowed. The number of parameters and channels is limited by available memory.

The properties that define the structure of an DAS data channel are:

Table 4-7: DAS Data Channel Properties

PROPERTY	DESCRIPTION	DEFAULT	SETTING RANGE
NAME	The name of the data channel.	“NONE”	Up to 6 letters or digits ¹ .
TRIGGERING EVENT	The event that triggers the data channel to measure and store the datum	ATIMER	Any available event (see Appendix A-5).
NUMBER AND LIST OF PARAMETERS	A User-configurable list of data types to be recorded in any given channel.	1 - PMTDET	Any available parameter (see Appendix A-5).
REPORT PERIOD	The amount of time between each channel data point.	000:01:00	000:00:01 to 366:23:59 (Days:Hours:Minutes)
NUMBER OF RECORDS	The number of reports that will be stored in the data file. Once the limit is exceeded, the oldest data is over-written.	100	1 to 1 million, limited by available storage space.
RS-232 REPORT	Enables the analyzer to automatically report channel values to the RS-232 ports.	OFF	OFF or ON
CHANNEL ENABLED	Enables or disables the channel. Allows a channel to be temporarily turned off without deleting it.	ON	OFF or ON
CAL HOLD OFF	Disables sampling of data parameters while instrument is in calibration mode ² .	OFF	OFF or ON

¹ More with APICOM, but only the first six are displayed on the front panel).

² When enabled records are not recorded until the **DAS HOLD OFF** period is passed after calibration mode. **DAS HOLD OFF** set in the VARS menu (see Section 4.12.)

4.7.1.2. DAS Parameters

Data parameters are types of data that may be measured by the analyzers instrumentality concentrations of measured gases, temperatures of heated zones,, pressures and flows of the pneumatic subsystem as well as calibration data such as slope and offset for each gas. For each TAI analyzer model, the list of available data parameters is different, fully defined and not customizable (see Appendix A for a list of 9110TH/M parameters).

Most data parameters have associated measurement units, such as mV, ppm, cm³/min, etc., although some parameters have no units. The only units that can be changed are those of the concentration readings according to the **SETUP-RANGE** settings.

Note

The DAS does not keep track of the unit of each concentration value and DAS data files may contain concentrations in multiple units if the unit was changed during data acquisition.

Each data parameter has user-configurable functions that define how the data are recorded.

Table 4-8: DAS Data Parameter Functions

FUNCTION	EFFECT
PARAMETER	Instrument-specific parameter name.
SAMPLE MODE	INST: Records instantaneous reading. AVG: Records average reading during reporting interval. MIN: Records minimum (instantaneous) reading during reporting interval. MAX: Records maximum (instantaneous) reading during reporting interval. SDEV: Records the standard deviation of the data points recorded during the reporting interval.
PRECISION	Decimal precision of parameter value(0-4).
STORE NUM. SAMPLES	OFF: stores only the average (default). ON: stores the average and the number of samples in each average for a parameter. This property is only useful when the AVG sample mode is used. Note that the number of samples is the same for all parameters in one channel and needs to be specified only for one of the parameters.

4.7.1.3. DAS Triggering Events

Triggering events define when and how the DAS records a measurement of any given data channel. Triggering events are firmware-specific and are listed in Appendix A-5. The most common triggering events are:

- **ATIMER:** Sampling occurs at regular intervals specified by an automatic timer. Trending information is often stored via such intervals, as either individual datum or averaged.
- **EXITZR, EXITSP, SLPCHG** (exit zero, exit span, slope change): Sampling at the end of an irregularly occurring event such as calibration or when the slope changes. These events create individual data points. Zero and slope values can be used to monitor response drift and to document when the instrument was calibrated.

- **WARNINGS:** Some data may be useful when stored if one of several warning messages appears. This is helpful for trouble-shooting by monitoring when a particular warning occurred.

4.7.2. DEFAULT DAS CHANNELS

The 9110TH/M is configured with a basic DAS configuration, which is enabled by default. New data channels are also enabled by default but each channel may be turned off for later or occasional use. Note that DAS operation is suspended while its configuration is edited through the front panel. To prevent such data loss, it is recommended to use the APICOM graphical user interface for DAS changes.

A set of default data channels has been included in the analyzer's software for logging nitrogen oxides concentrations, calibration and predictive diagnostic data. They are:

- **CONC:** Samples NO_x, NO and NO₂ concentration at one minute intervals and stores an average every hour with a time and date stamp along with the number of (1-minute) samples within each average (for statistical evaluation). Readings during calibration and calibration hold off are not included in the data. By default, the last 800 hourly averages are stored.
- **CALDAT:** Every time a zero or span calibration is performed **CALDAT** logs concentration, slope and offset values for NO_x and NO with a time and date stamp. The NO_x stability (to evaluate calibration stability) as well as the converter efficiency (for reference) are also stored. This data channel will store data from the last 200 calibrations and can be used to document analyzer calibration. The slope and offset data can be used to detect trends in (instrument response).
- **CALCHECK:** This channel logs concentrations and the stability each time a zero or span *check* (not calibration) is finished. This allows the user to track the quality of zero and span responses over time and assist in evaluating the quality of zero and span gases and the analyzer's noise specifications. The last 200 data points are retained.
- **DIAG:** Daily averages of temperature zones, flow and pressure data as well as some other diagnostic parameters (HVPS, AZERO). These data are useful for predictive diagnostics and maintenance of the 9110TH/M. The last 1100 daily averages are stored to cover more than four years of analyzer performance.
- **HIRES:** Records one minute, instantaneous data of all active parameters in the 9110TH/M. Short-term trends as well as signal noise levels can be detected and documented. Readings during calibration and the calibration hold off period are included in the averages. The last 1500 data points are stored, which covers a little more than one day of continuous data acquisition. This data channel is disabled by default but may be turned on when needed such as for trouble-shooting problems with the analyzer.

The default data channels can be used as they are, or they can be customized from the front panel or through APICOM to fit a specific application. The TAI website contains this default and other sample DAS scripts for free download. We recommend that the user backs up any DAS configuration and its data before altering it.

Note

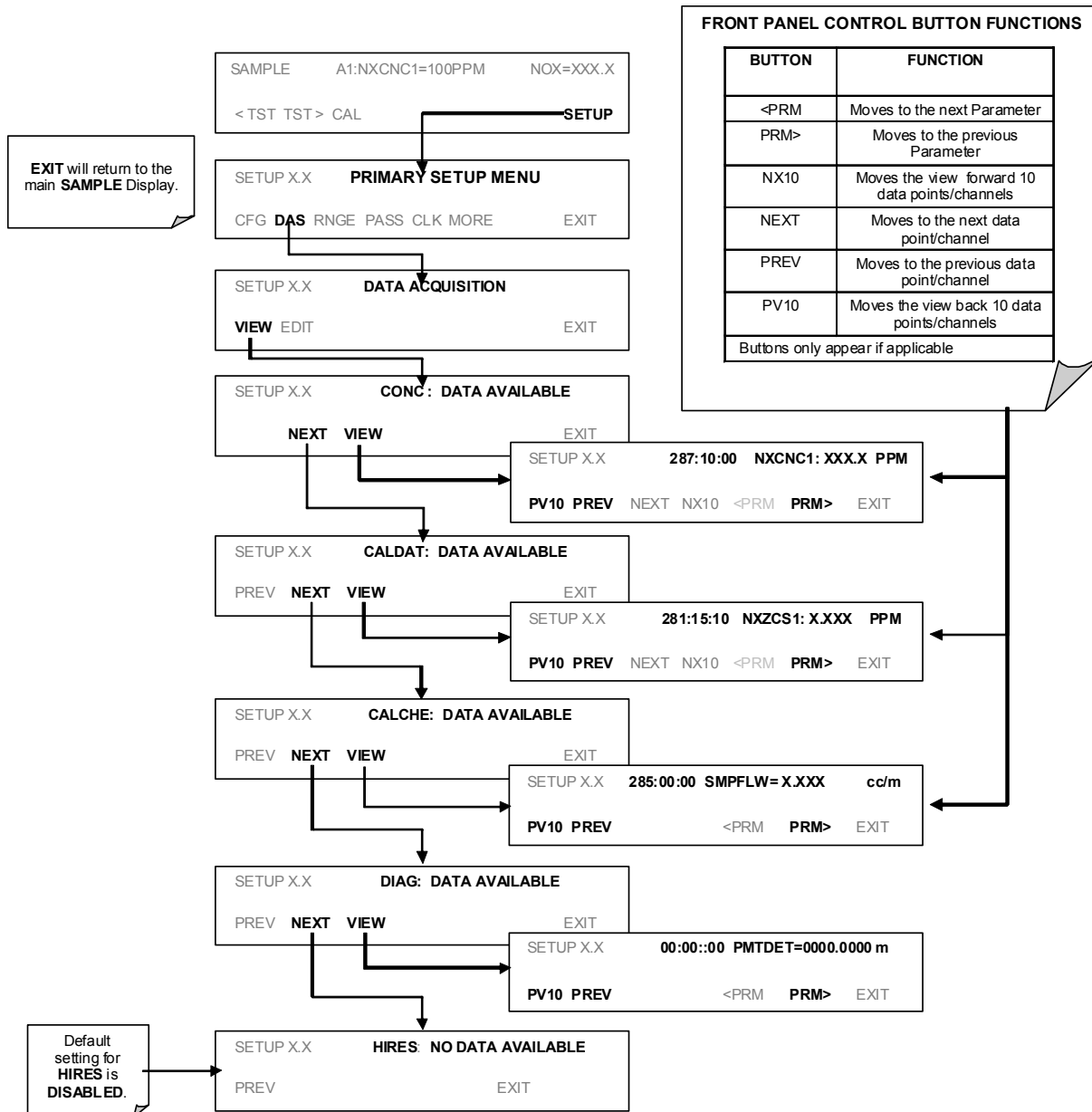
Teledyne recommends downloading and storing existing data and the DAS configurations regularly for permanent documentation and future data analysis. Sending a DAS configuration to the analyzer through its COM ports will replace the existing configuration and will delete all stored data.

Table 4-9: 9110TH/M Default DAS Configuration

CHANNELS with PROPERTIES	PARAMETERS				
	NAME	MODE	EVENT	PRECISION	NUM SAMPLES
Name: CONC Event: ATIMER Sample Period: 000:00:01 Report Period: 000:01:00 Number of Records: 800 RS-232 report: OFF Channel enabled: ON DAS HOLDOFF: ON	NOXCNC1	AVG	--	4	ON
	NOCNC1	AVG	--	4	OFF
	N2CNC1	AVG	--	4	OFF
	STABIL	AVG	--	4	OM
Name: CALDAT Event: SLPCHG Number of Records: 200 RS-232 report: OFF Channel enabled: ON DAS HOLDOFF: OFF	NXZSC1	--	SLPCHG	4	OFF
	NOXSPL1	--	SLPCHG	4	OFF
	NOXOFFS1	--	SLPCHG	4	OFF
	NOZSC1	--	SLPCHG	4	OFF
	NOSPL1	--	SLPCHG	4	OFF
	NOOFFS1	--	SLPCHG	4	OFF
	N2ZSC1	--	SLPCHG	4	OFF
	CNVEF1	--	SLPCHG	4	OFF
STABIL	--	SLPCHG	4	OFF	
Name: CALCHECK Event: EXITMP Number of Records: 200 RS-232 report: OFF Channel enabled: ON DAS HOLDOFF: OFF	NXZSC1	--	EXITMP	4	OFF
	NOZSC1	--	EXITMP	4	OFF
	N2ZSC1	--	EXITMP	4	OFF
	STABIL	--	EXITMP	4	OFF
Name: CALCHECK Event: EXITMP Number of Records: 200 RS-232 report: OFF Channel enabled: ON DAS HOLDOFF: OFF	SMPFLW	AVG	--	2	OFF
	O3FLOW	AVG	--	2	OFF
	RCPRESS	AVG	--	2	OFF
	SMPPRES	AVG	--	2	OFF
	RCTEMP	AVG	--	2	OFF
	PMTTMP	AVG	--	2	OFF
	CNVTMP	AVG	--	2	OFF
	BOXTMP	AVG	--	2	OFF
	HVPS	AVG	--	2	OFF
AZERO	AVG	--	2	OFF	
Name: HIRES Event: ATIMER Sample Period: 000:00:01 Report Period: 000:00:01 Number of Records: 1500 RS-232 report: OFF Channel enabled: OFF DAS HOLDOFF: OFF	NOXCNC1	AVG	--	4	OFF
	NOCNC1	AVG	--	4	OFF
	N2CNC1	AVG	--	4	OFF
	STABIL	AVG	--	4	OFF
	SMPFLW	AVG	--	2	OFF
	O3FLOW	AVG	--	2	OFF
	RCPRESS	AVG	--	2	OFF
	SMPPRES	AVG	--	2	OFF
	RCTEMP	AVG	--	2	OFF
	PMTTMP	AVG	--	2	OFF
	CNVTMP	AVG	--	2	OFF
	BOXTMP	AVG	--	2	OFF
	HVPS	AVG	--	1	OFF
	AZERO	AVG	--	2	OFF
REFGND	AVG		1	OFF	
REF4096	AVG		1	OFF	

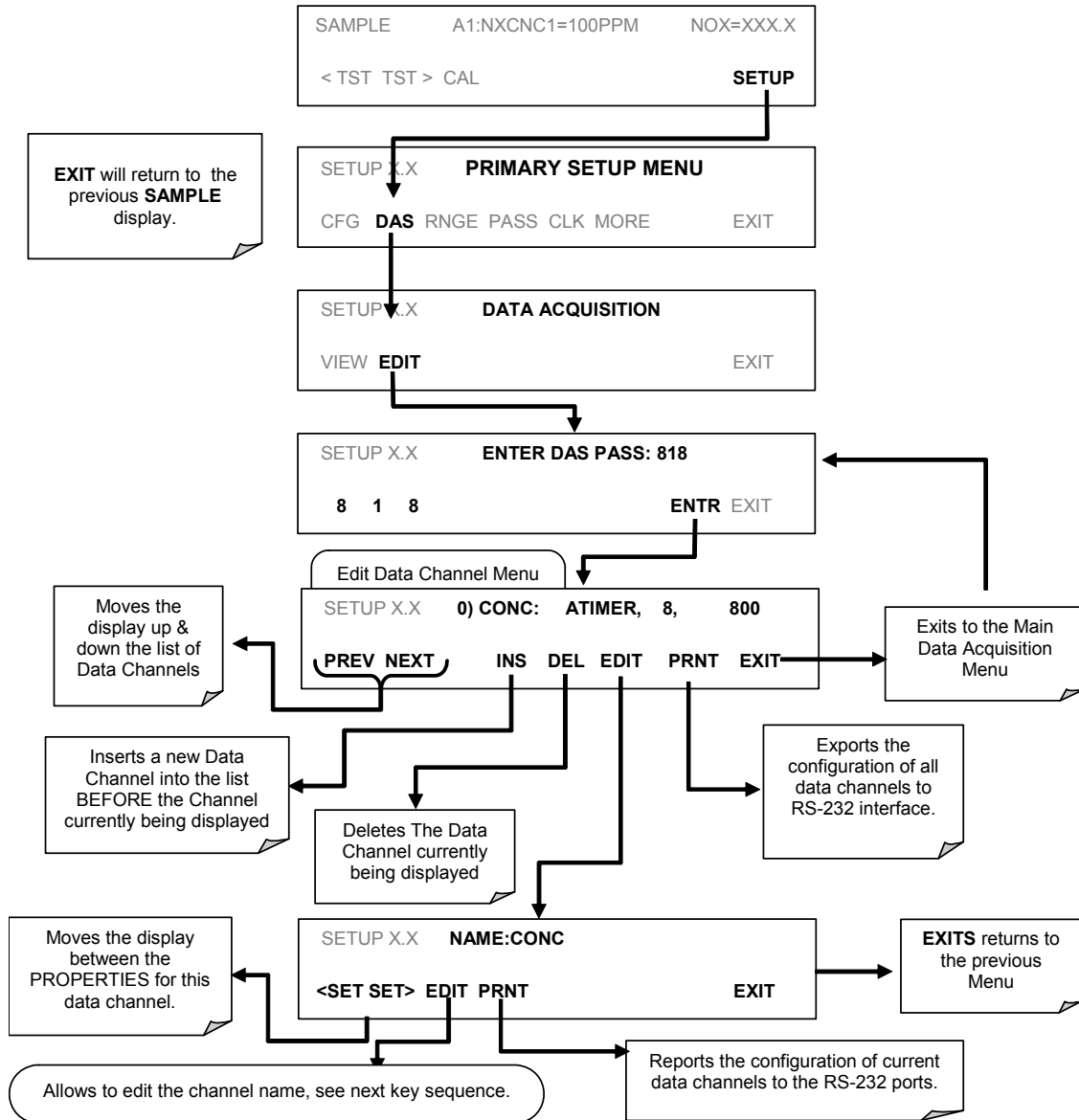
4.7.2.1. Viewing DAS Data and Settings

DAS data and settings can be viewed on the front panel through the following keystroke sequence.



4.7.2.2. Editing DAS Data Channels

DAS configuration is most conveniently done through the APICOM remote control program. The following sequence of touch screen button presses shows how to edit using the front panel.



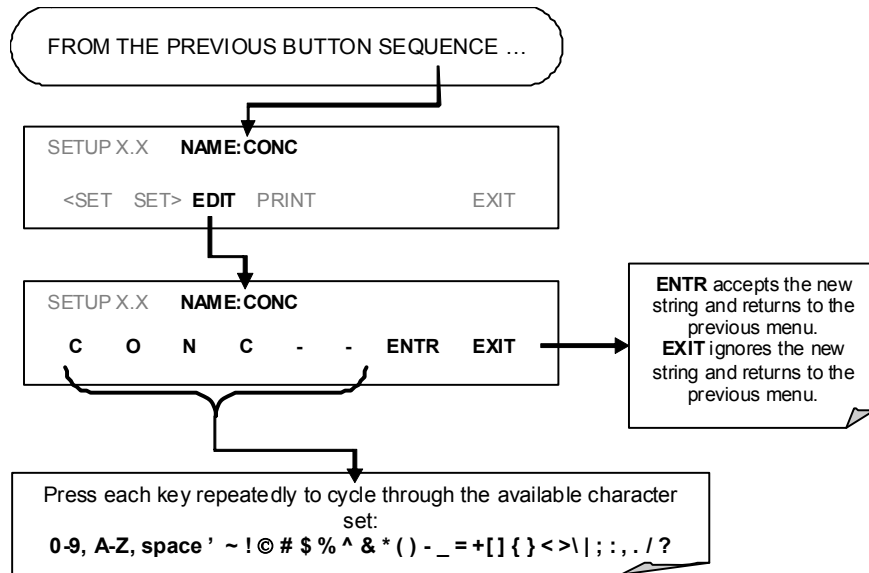
When editing the data channels, the top line of the display indicates some of the configuration parameters. For example, the display line:

0) CONC : ATIMER, 4, 800

Translates to the following configuration:

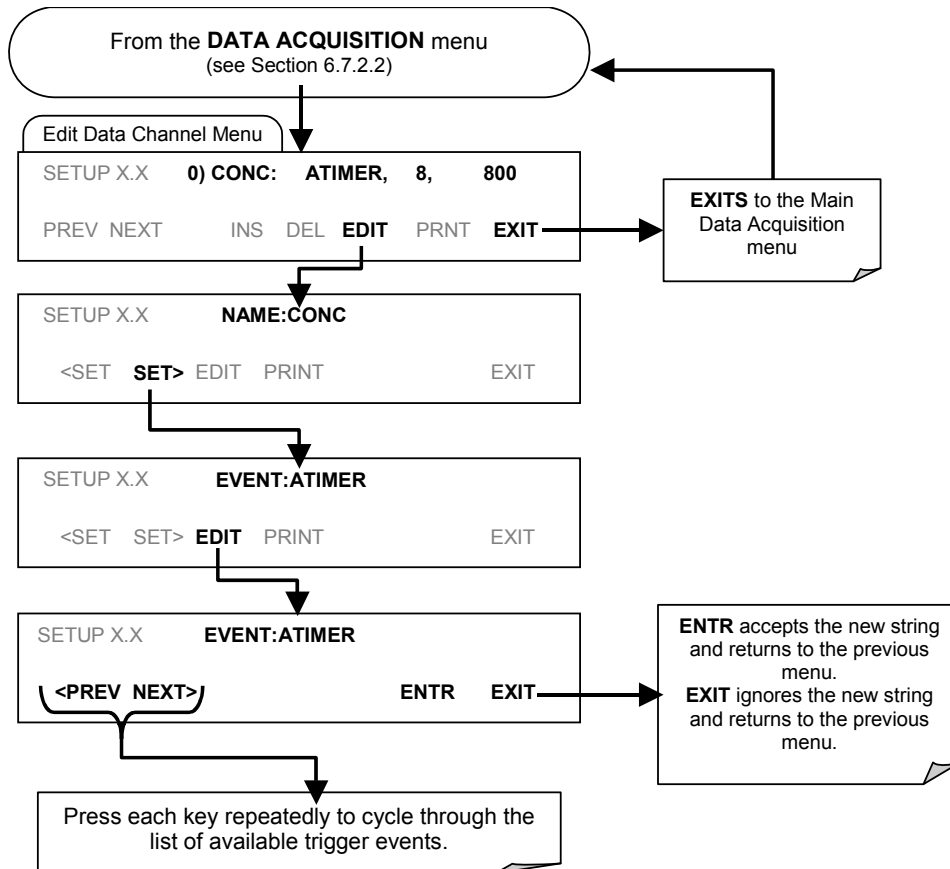
Channel No.: 0
 NAME: CONC
 TRIGGER EVENT: ATIMER
 PARAMETERS: Four parameters are included in this channel
 EVENT: This channel is set up to record 800 data points.

To edit the name of a data channel, follow the above key sequence and then press:



4.7.2.3. Trigger Events

To edit the list of data parameters associated with a specific data channel, press:

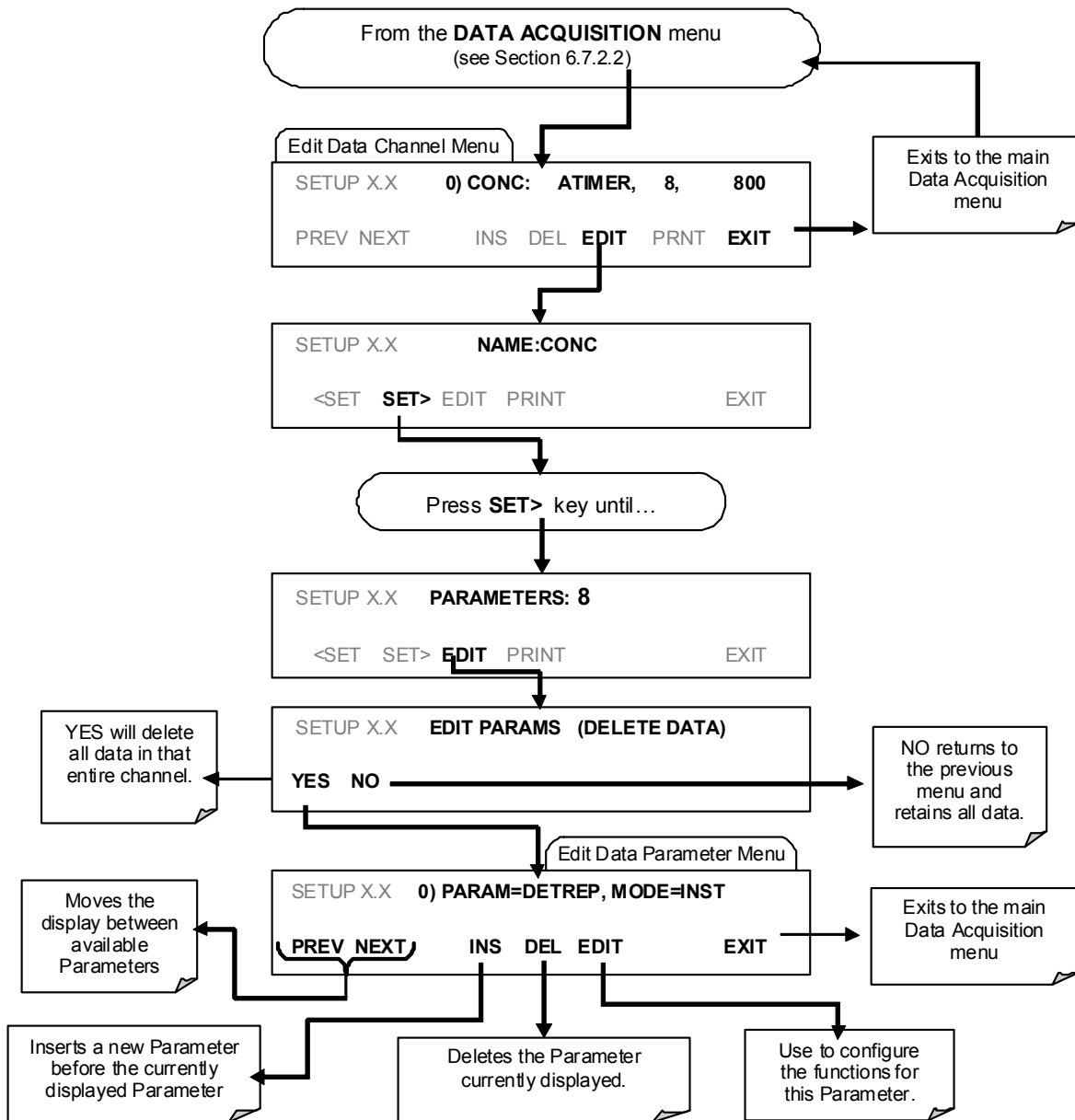


See Appendix A for list of DAS trigger events available on the 9110TH/M.

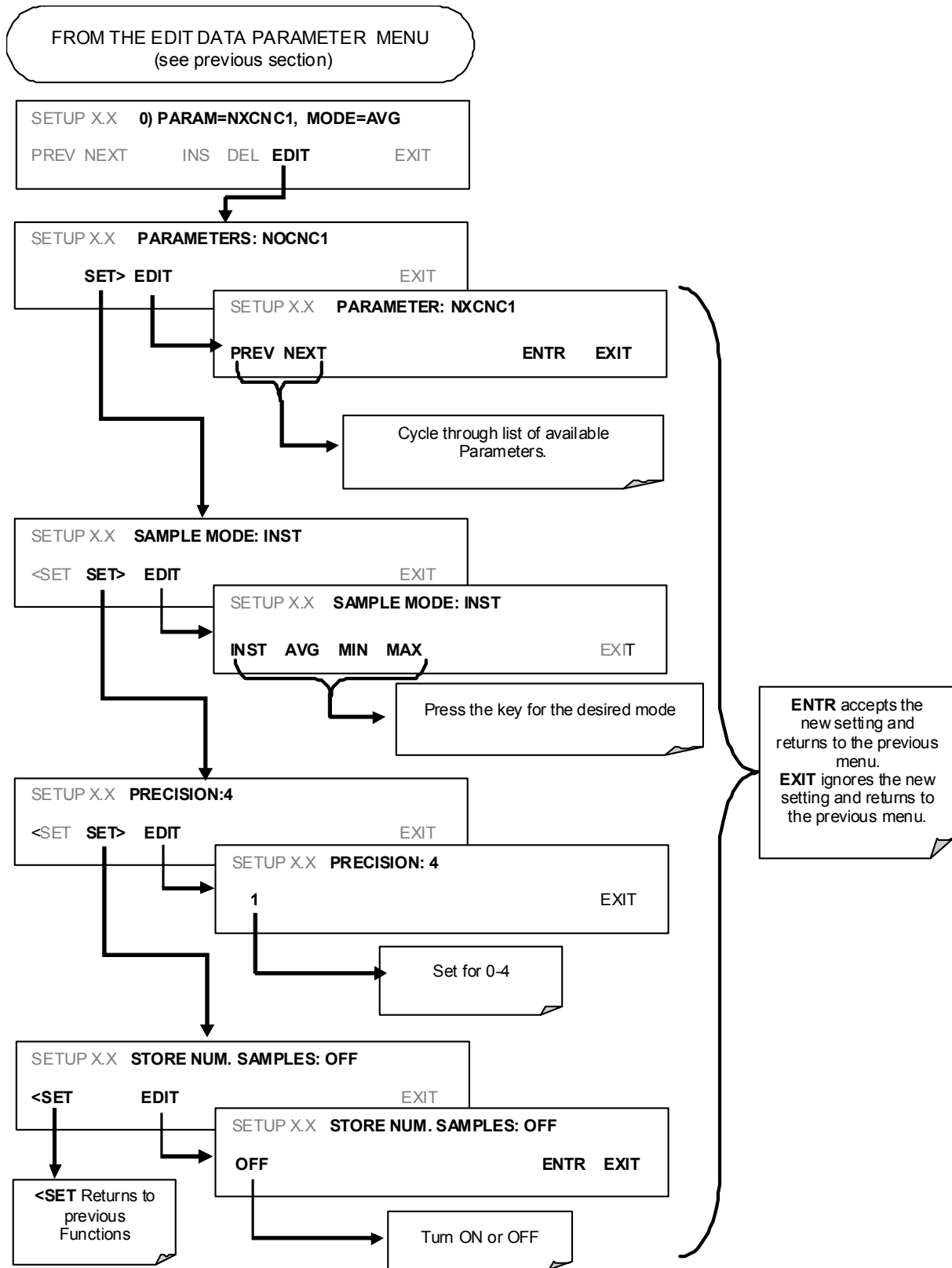
4.7.2.4. Editing DAS Parameters

Data channels can be edited individually from the front panel without affecting other data channels. However, when editing a data channel, such as during adding, deleting or editing parameters, all data for that particular channel will be lost, because the DAS can store only data of one format (number of parameter columns etc.) for any given channel. In addition, an DAS configuration can only be uploaded remotely as an entire set of channels. Hence, remote update of the DAS will always delete all current channels and stored data.

To modify, add or delete a parameter, follow the instruction shown in section 4.7.2.2 then press:



To configure the parameters for a specific data parameter, press:



See Appendix A-5 for list of DAS parameters available on the 9110TH/M.

4.7.2.5. Sample Period and Report Period

The DAS defines two principal time periods by which sample readings are taken and permanently recorded:

- **SAMPLE PERIOD:** Determines how often DAS temporarily records a sample reading of the parameter in volatile memory. The **SAMPLE PERIOD** is set to one minute by default and generally cannot be accessed from the standard DAS front panel menu, but is available via the instruments communication ports by using APICOM or the analyzer's standard serial data protocol.

SAMPLE PERIOD is only used when the DAS parameter's sample mode is set for **AVG, MIN** or **MAX**.

- **REPORT PERIOD:** Sets how often the sample readings stored in volatile memory are processed, (e.g. average, minimum or maximum are calculated) and the results stored permanently in the instrument's Disk-on-Module as well as transmitted via the analyzer's communication ports. The **REPORT PERIOD** may be set from the front panel.

If the **INST** sample mode is selected the instrument stores and reports an instantaneous reading of the selected parameter at the end of the chosen **REPORT PERIOD**

In **AVG, MIN** or **MAX** sample modes, the settings for the **SAMPLE PERIOD** and the **REPORT PERIOD** determine the number of data points used each time the average, minimum or maximum is calculated, stored and reported to the com ports. The actual sample readings are not stored past the end of the of the chosen **REPORT PERIOD**.

Also, the **SAMPLE PERIOD** and **REPORT PERIOD** intervals are synchronized to the beginning and end of the appropriate interval of the instruments internal clock.

- If **SAMPLE PERIOD** were set for one minute the first reading would occur at the beginning of the next full minute according to the instrument's internal clock.
- If the **REPORT PERIOD** were set for of one hour the first report activity would occur at the beginning of the next full hour according to the instrument's internal clock.

EXAMPLE: Given the above settings, if DAS were activated at 7:57:35 the first sample would occur at 7:58 and the first report would be calculated at 8:00 consisting of data points for 7:58, 7:59 and 8:00.

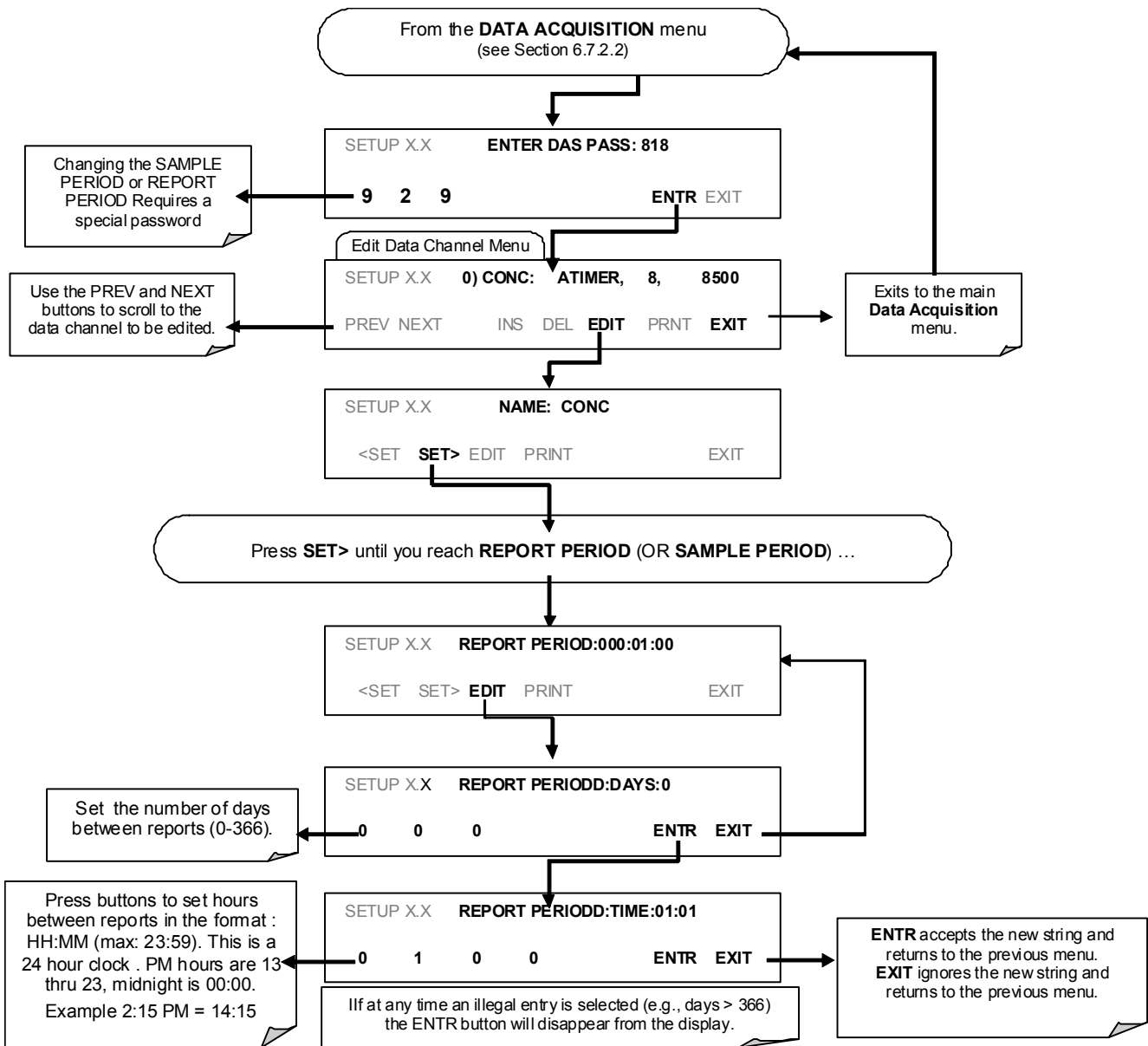
During the next hour (from 8:01 to 9:00) the instrument will take a sample reading every minute and include 60 sample readings.

When the **STORE NUM. SAMPLES** feature is turned on the instrument will also store how many sample readings were used for the **AVG, MIN** or **MAX** calculation but not the readings themselves.

4.7.2.6. Report Periods in Progress when Instrument Is Powered Off

If the instrument is powered off in the middle of a **REPORT PERIOD**, the samples accumulated so far during that period are lost. Once the instrument is turned back on, the DAS restarts taking samples and temporarily them in volatile memory as part of the **REPORT PERIOD** currently active at the time of restart. At the end of this **REPORT PERIOD** only the sample readings taken since the instrument was turned back on will be included in any **AVG**, **MIN** or **MAX** calculation. Also, the **STORE NUM. SAMPLES** feature will report the number of sample readings taken since the instrument was restarted.

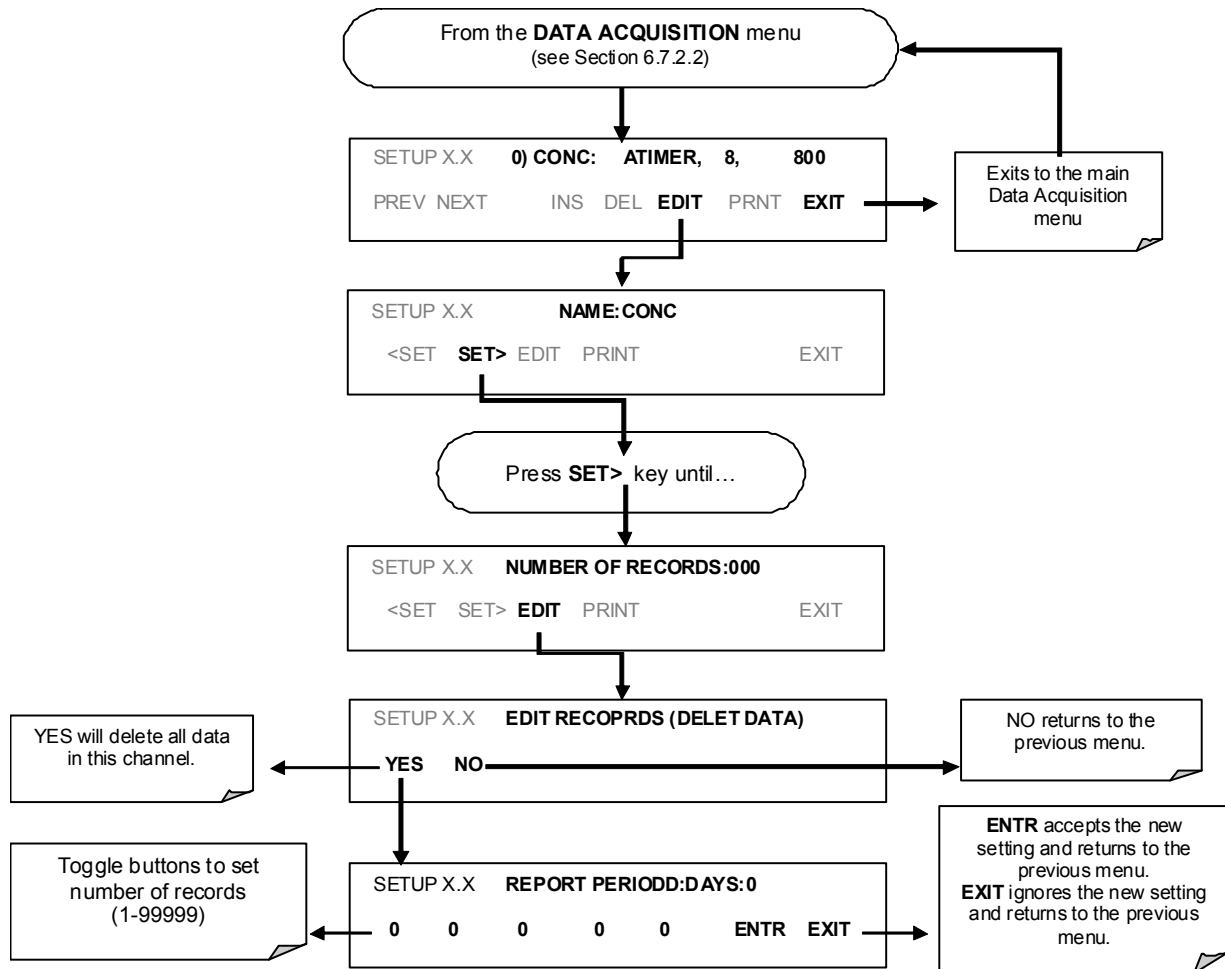
To define the **REPORT PERIOD**, follow the instruction shown in Section 4.7.2.2 then press:



4.7.2.7. Number of Records

The DAS is capable of capturing several months worth of data, depending on the configuration. Every additional data channel, parameter, number of samples setting etc. will reduce the maximum amount of data points somewhat. In general, however, the maximum data capacity is divided amongst all channels (max: 20) and parameters (max: 50 per channel).

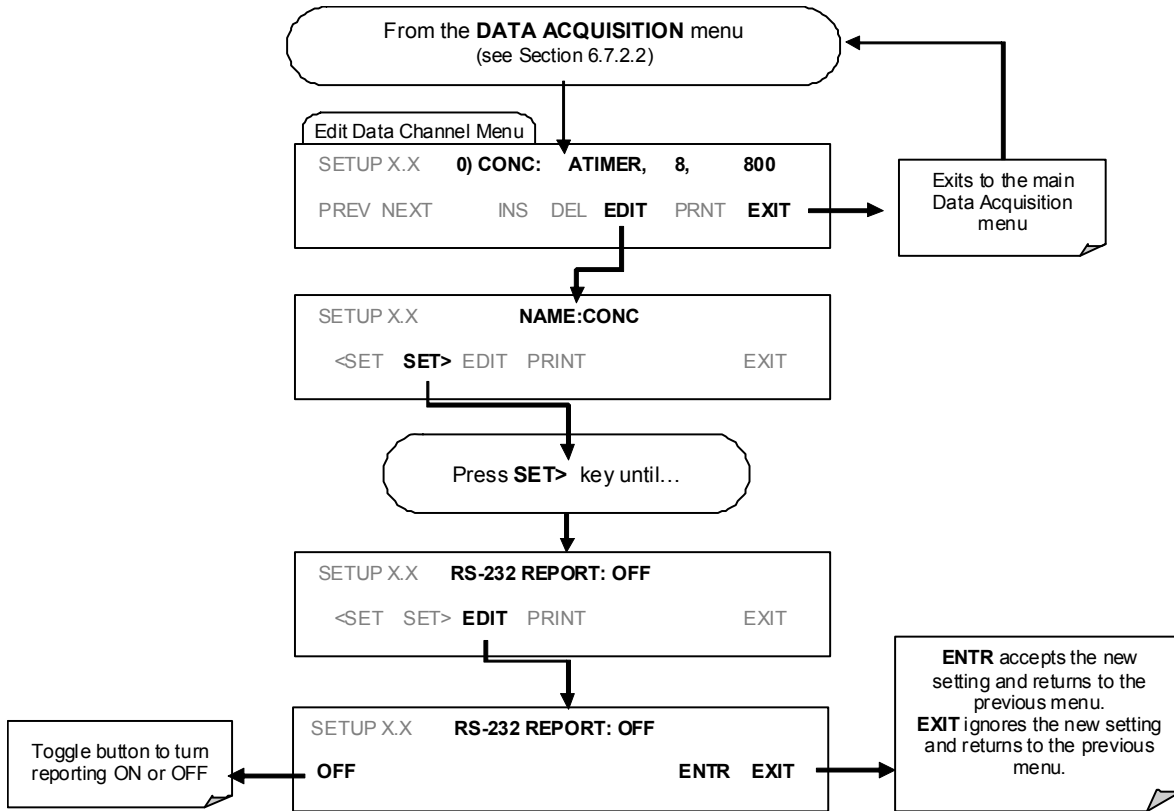
The DAS will check the amount of available data space and prevent the user from specifying too many records at any given point. If, for example, the DAS memory space can accommodate 375 more data records, the ENTR key will disappear when trying to specify more than that number of records. This check for memory space may also make an upload of an DAS configuration with APICOM or a Terminal program fail, if the combined number of records would be exceeded. In this case, it is suggested to either try from the front panel what the maximum number of records can be or use trial-and-error in designing the DAS script or calculate the number of records using the DAS or APICOM manuals. To set the number of records for one channel from the front panel, follow the instruction shown in section 4.7.2.2 then press.



4.7.2.8. RS-232 Report Function

The 9110TH/M DAS can automatically report data to the communications ports, where they can be captured with a terminal emulation program or simply viewed by the user.

To enable automatic COM port reporting, follow the instruction shown in section 4.7.2.2 then press:



4.7.2.9. Compact Report

When enabled, this option avoids unnecessary line breaks on all RS-232 reports. Instead of reporting each parameter in one channel on a separate line, up to five parameters are reported in one line, instead. For example, channel DIAG would report its record in two lines (10 parameters) instead of 10 lines. Individual lines carry the same time stamp and are labeled in sequence.

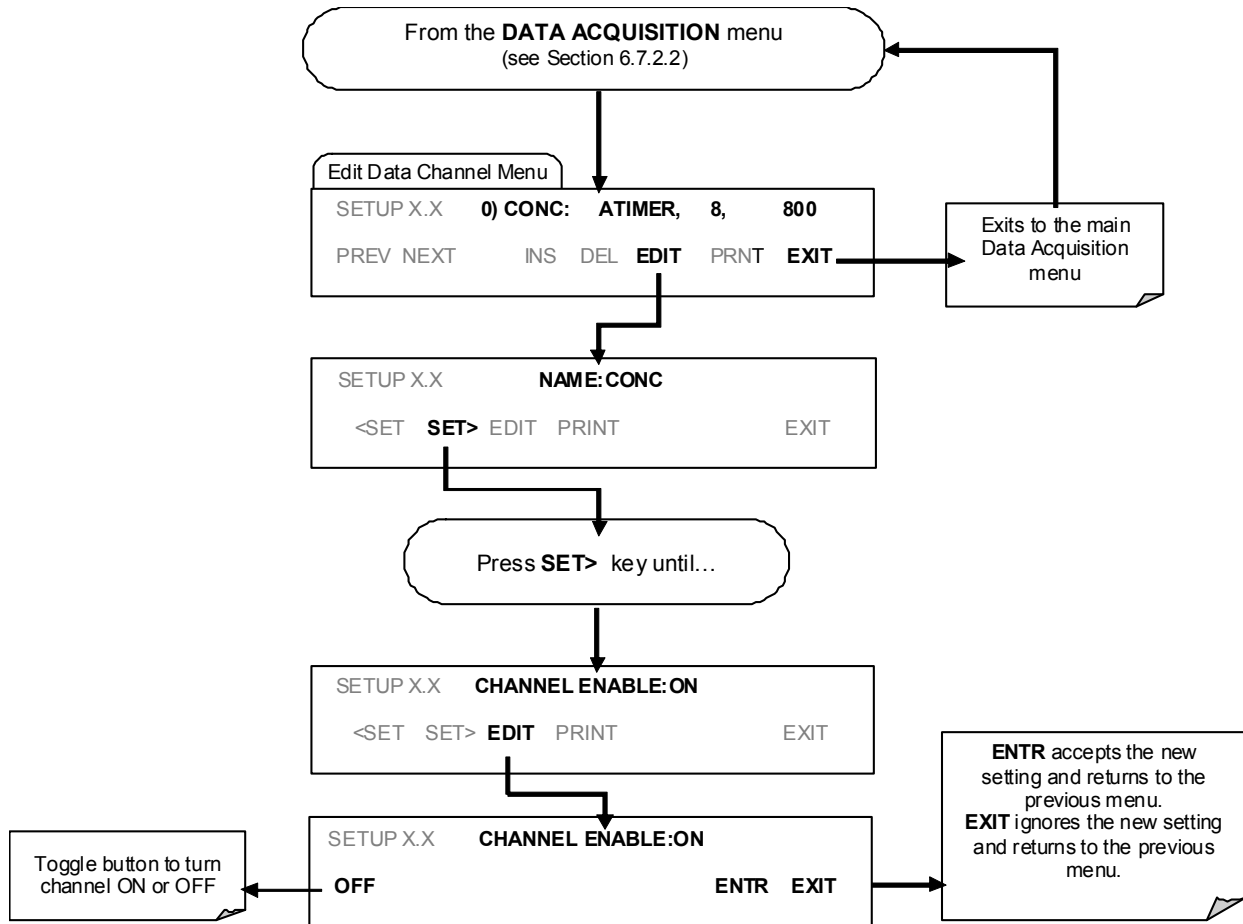
4.7.2.10. Starting Date

This option allows to specify a starting date for any given channel in case the user wants to start data acquisition only after a certain time and date. If the **Starting Date** is in the past, the DAS ignores this setting.

4.7.2.11. Disabling/Enabling Data Channels

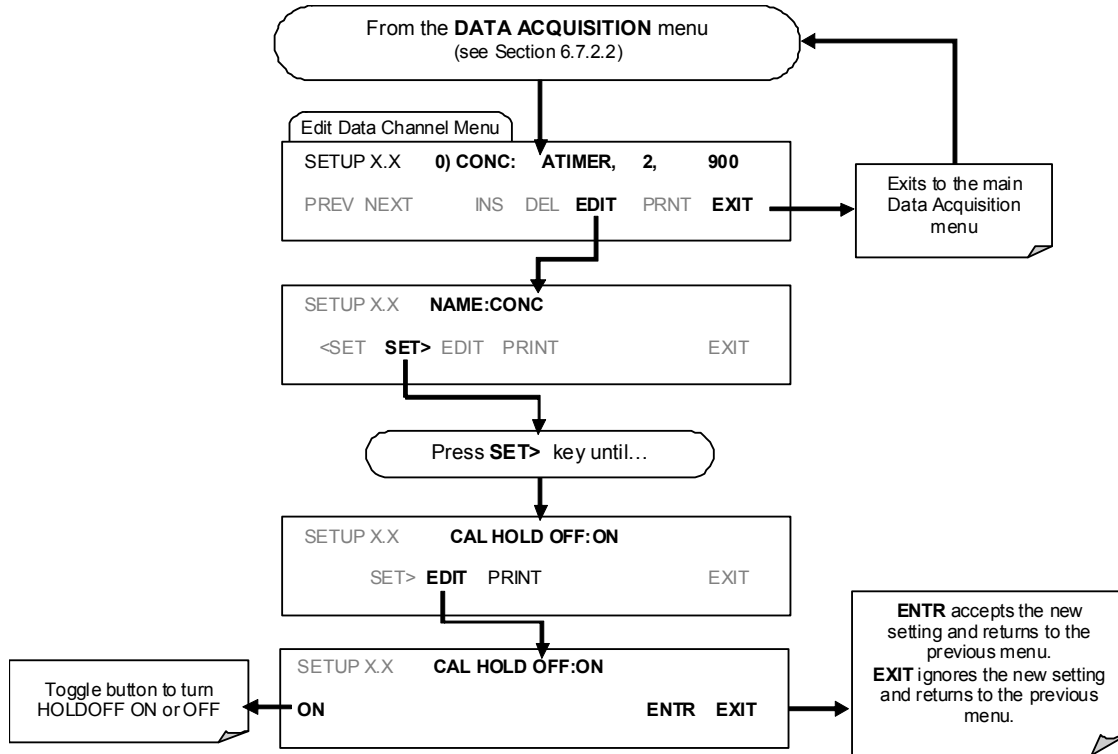
Data channels can be temporarily disabled, which can reduce the read/write wear on the disk-on-chip. The HIRES channel of the 9110TH/M, for example, is disabled by default.

To disable a data channel, follow the instruction shown in section 4.7.2.2 then press:



4.7.2.12. HOLDOFF Feature

The DAS HOLDOFF feature allows to prevent data collection during calibrations and during the DAS_HOLDOFF period enabled and specified in the VARS (Section 4.12). To enable or disable the HOLDOFF for any one DAS channel, follow the instruction shown in section 6.7.2.2 then press:



4.7.3. REMOTE DAS CONFIGURATION

Editing channels, parameters and triggering events as described in 6.7 is much more conveniently done in one step through the APICOM remote control program using the graphical interface shown in Figure 4-4. Refer to Section 4.15 for details on remote access to the 9110TH/M analyzer.

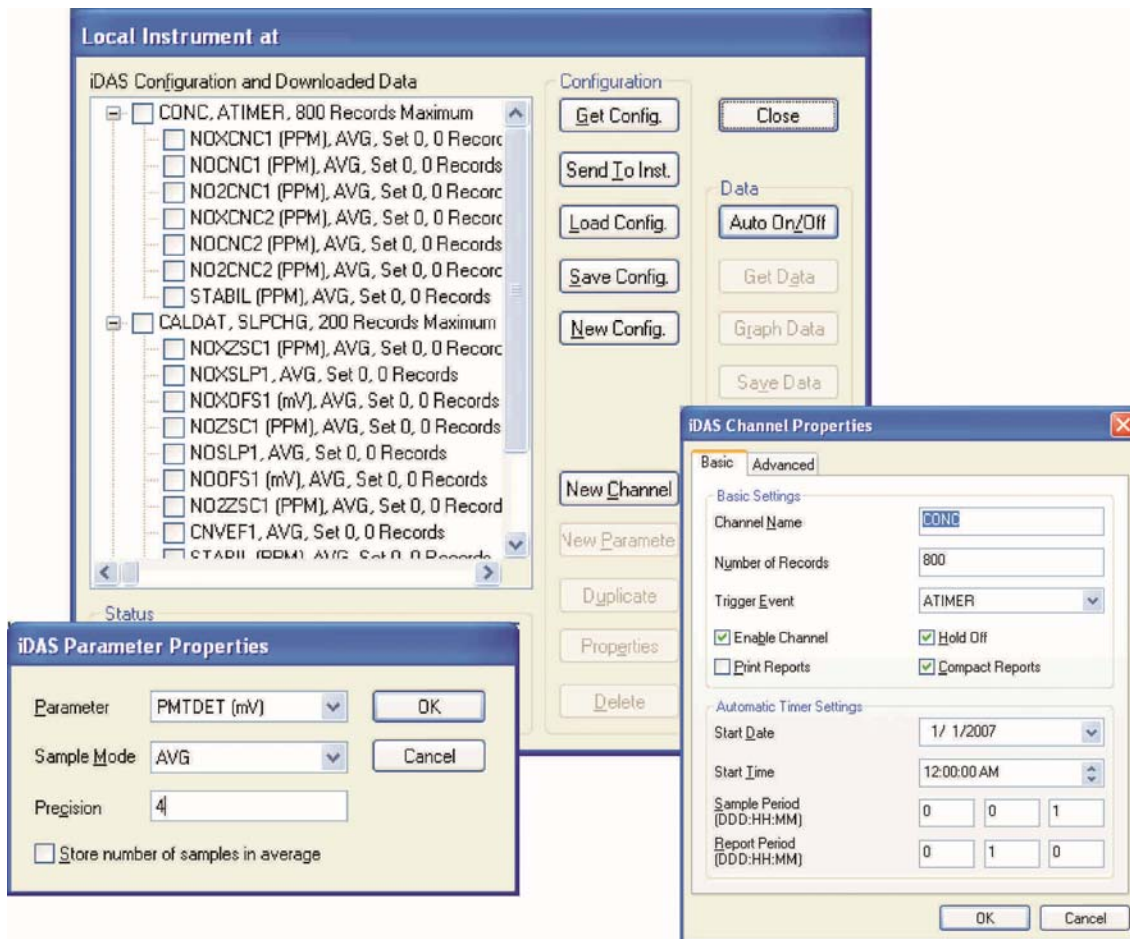


Figure 4-4: APICOM Graphical User Interface for Configuring the DAS

Once a DAS configuration is edited (which can be done offline and without interrupting DAS data collection), it is conveniently uploaded to the instrument and can be stored on a computer for later review, alteration or documentation and archival. Refer to the APICOM manual for details on these procedures. The APICOM user manual is included in the APICOM installation file, which can be downloaded at <http://www.teledyne-api.com/software/apicom/>.

Note

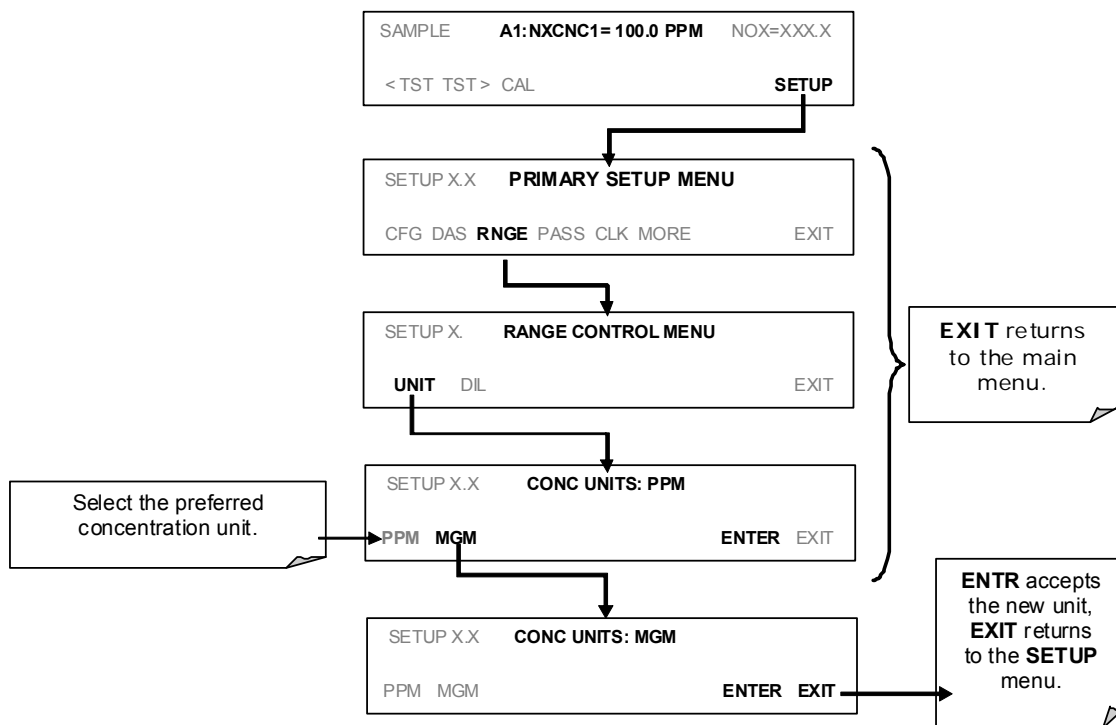
Whereas the editing, adding and deleting of DAS channels and parameters of one channel through the front-panel touch screen can be done without affecting the other channels, uploading a DAS configuration script to the analyzer through its communication ports will erase ALL data, parameters and channels by replacing them with the new DAS configuration. It is advised to download and backup all data and the original DAS configuration before attempting any DAS changes.

4.8. SETUP → RNGE: RANGE UNITS AND DILUTION CONFIGURATION

This Menu is used to set the units of measure to be associated with the analyzer’s reporting ranges (see Section 4.13.4.2. for more information on reporting ranges vs. physical ranges) and for instruments with the sample gas dilution option operating, to set the dilution ratio.

4.8.1. RANGE UNITS

The 9110TH/M can display concentrations in parts per million (10^6 mols per mol, PPM) or milligrams per cubic meter (mg/m^3 , MGM). Changing units affects all of the display, COM port and DAS values for all reporting ranges regardless of the analyzer’s range mode. To change the concentration units:



Conversion factors from volumetric to mass units used in the 9110TH/M:

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

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

Concentrations displayed in mg/m^3 and $\mu\text{g}/\text{m}^3$ use 0°C and 760 Torr as standard temperature and pressure (STP). Consult your local regulations for the STP used by your agency. EPA protocol applications, for example, use 25°C as the reference temperature. Changing the units may cause a bias in the measurements if standard temperature and pressure other than 0°C and 760 Torr are used. This problem can be avoided by recalibrating the analyzer after any change from a volumetric to a mass unit or vice versa.

Note

In order to avoid a reference temperature bias, the analyzer must be recalibrated after every change in reporting units.

4.8.2. DILUTION RATIO

The dilution ratio is a software option that allows the user to compensate for any dilution of the sample gas before it enters the sample inlet.

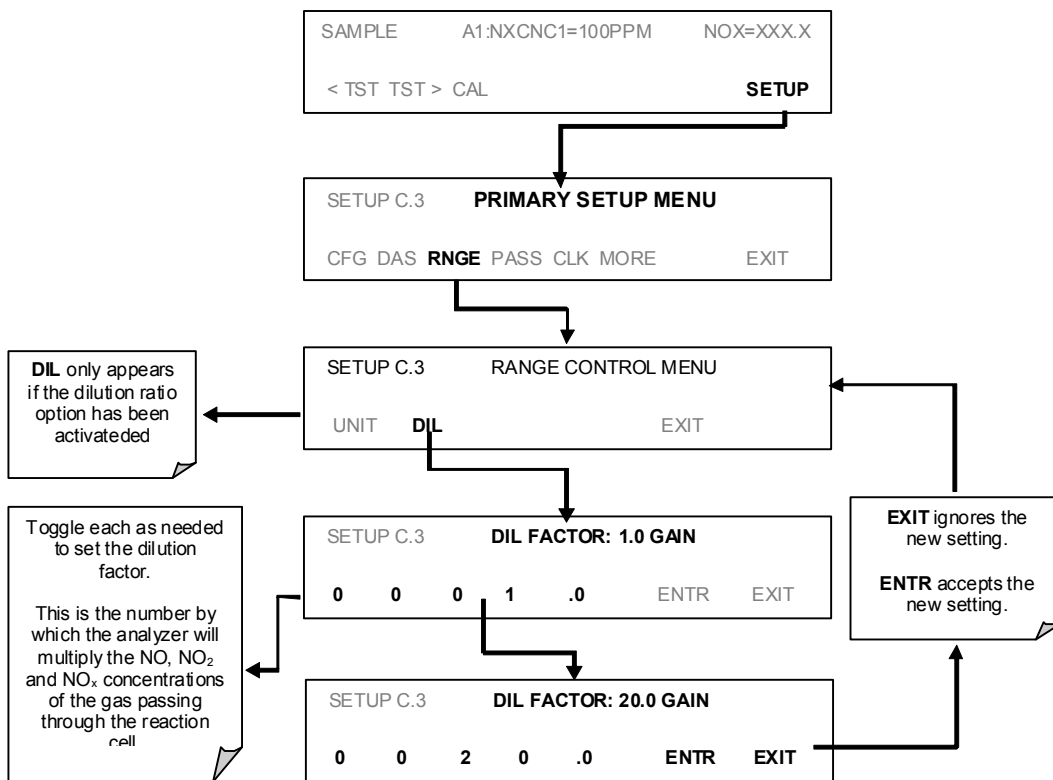
1. The **SPAN** value entered during calibration is the maximum expected concentration of the undiluted calibration gas
2. The span gas should be either supplied through the same dilution inlet system as the sample gas or be supplied at an appropriately lower actual concentration.

For example, with a dilution set to 100, a 1 ppm gas can be used to calibrate a 100 ppm sample gas if the span gas is not routed through the dilution system.

On the other hand, if a 100 ppm span gas is used, it needs to pass through the same dilution steps as the sample gas.

3. Set the dilution factor as a gain (e.g., a value of 20 means 20 parts diluent and 1 part of sample gas):

The analyzer will multiply the measured gas concentrations with this dilution factor and displays the result.



The analyzer multiplies the measured gas concentrations with this dilution factor and displays the result.

Calibrate the analyzer. Once the above settings have been entered, the instrument needs to be recalibrated using one of the methods discussed in Section 5.

4.9. SETUP → PASS: PASSWORD FEATURE

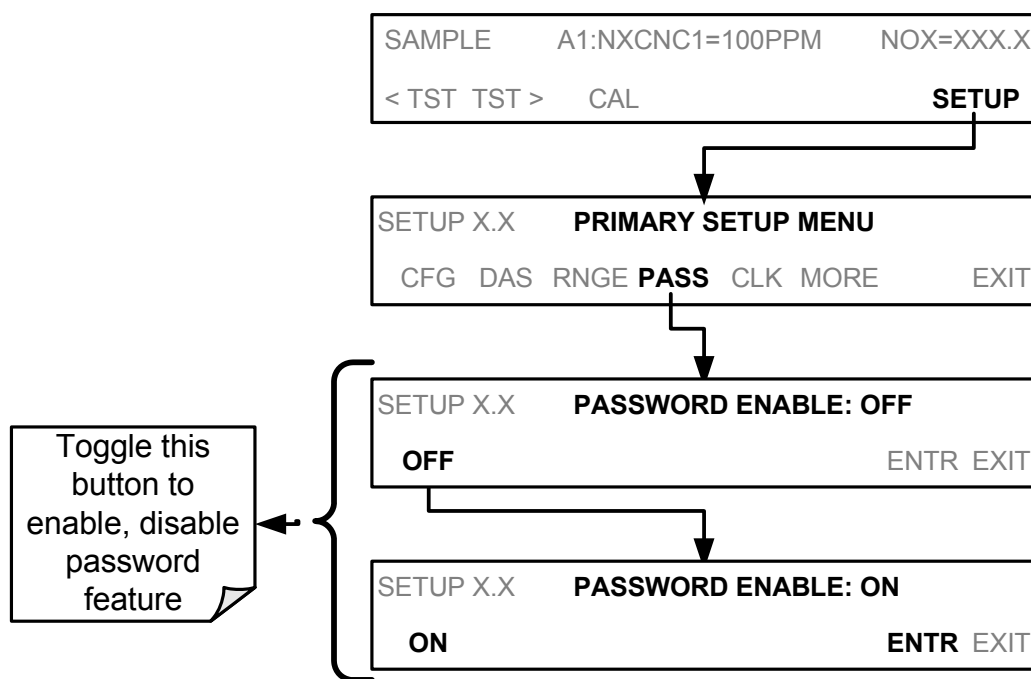
The 9110TH/M provides password protection of the calibration and setup functions to prevent unauthorized adjustments. When the passwords have been enabled in the **PASS** menu item, the system will prompt the user for a password anytime a password-protected function (e.g., SETUP) is selected. This allows normal operation of the instrument, but requires the password (101) to access to the menus under SETUP. When PASSWORD is disabled (SETUP>OFF), any operator can enter the Primary Setup (SETUP) and Secondary Setup (SETUP>MORE) menus. Whether PASSWORD is enabled or disabled, a password (default 818) is required to enter the VARS or DIAG menus in the SETUP>MORE menu.

There are three levels of password protection, which correspond to operator, maintenance, and configuration functions. Each level allows access to all of the functions in the previous level.

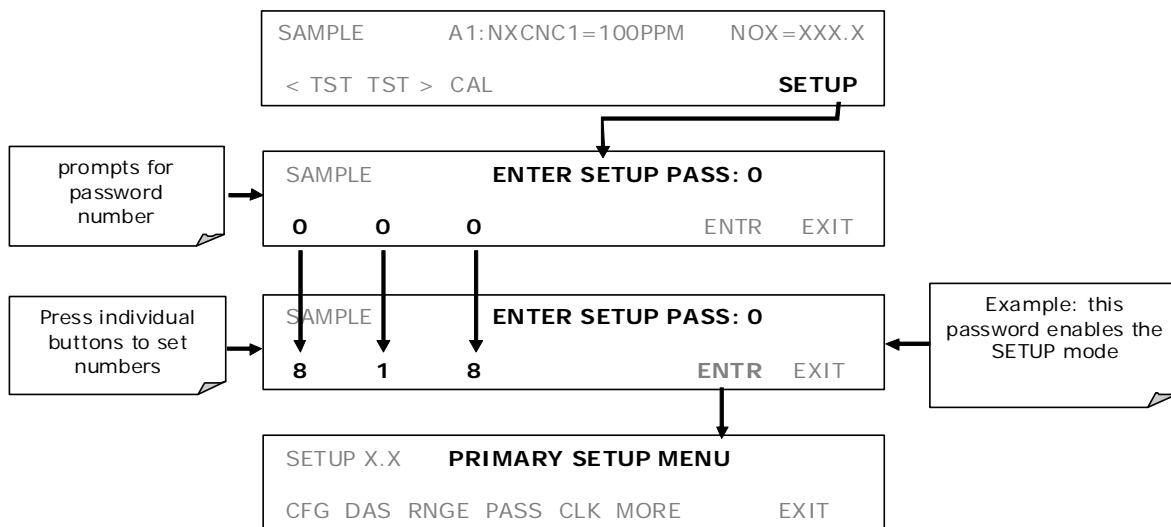
Table 4-10: Password Levels

Password	Level	Menu Access Allowed
Null (000)	Operation	All functions of the MAIN menu: TEST, GEN, initiate SEQ , MSG, CLR
101	Configuration/Maintenance	Access to Primary Setup and Secondary SETUP Menus when PASSWORD is enabled.
818	Configuration/Maintenance	Access to Secondary SETUP Submenus VARS and DIAG whether PASSWORD is enabled or disabled.

To enable or disable passwords, press the following menu button sequence:



Example: If all passwords are enabled, the following menu button sequence would be required to enter the SETUP menu:

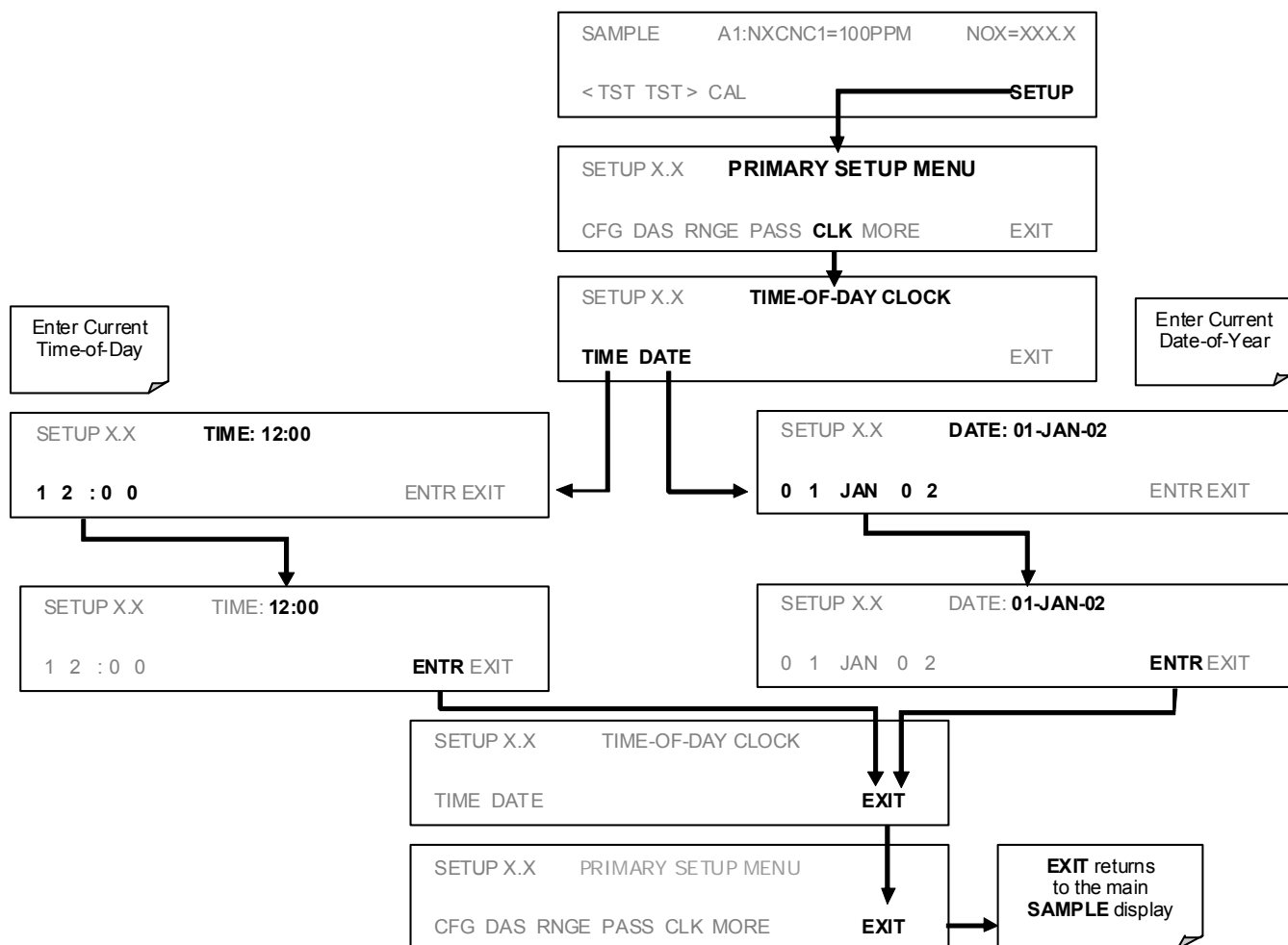


Note that the instrument still prompts for a password when entering the VARS and DIAG menus, even if passwords are disabled, but it displays the default password (818) upon entering these menus. The user only has to press ENTR to access the password-protected menus but does not have to enter the required number code.

4.10. SETUP → CLK: SETTING THE INTERNAL TIME-OF-DAY CLOCK

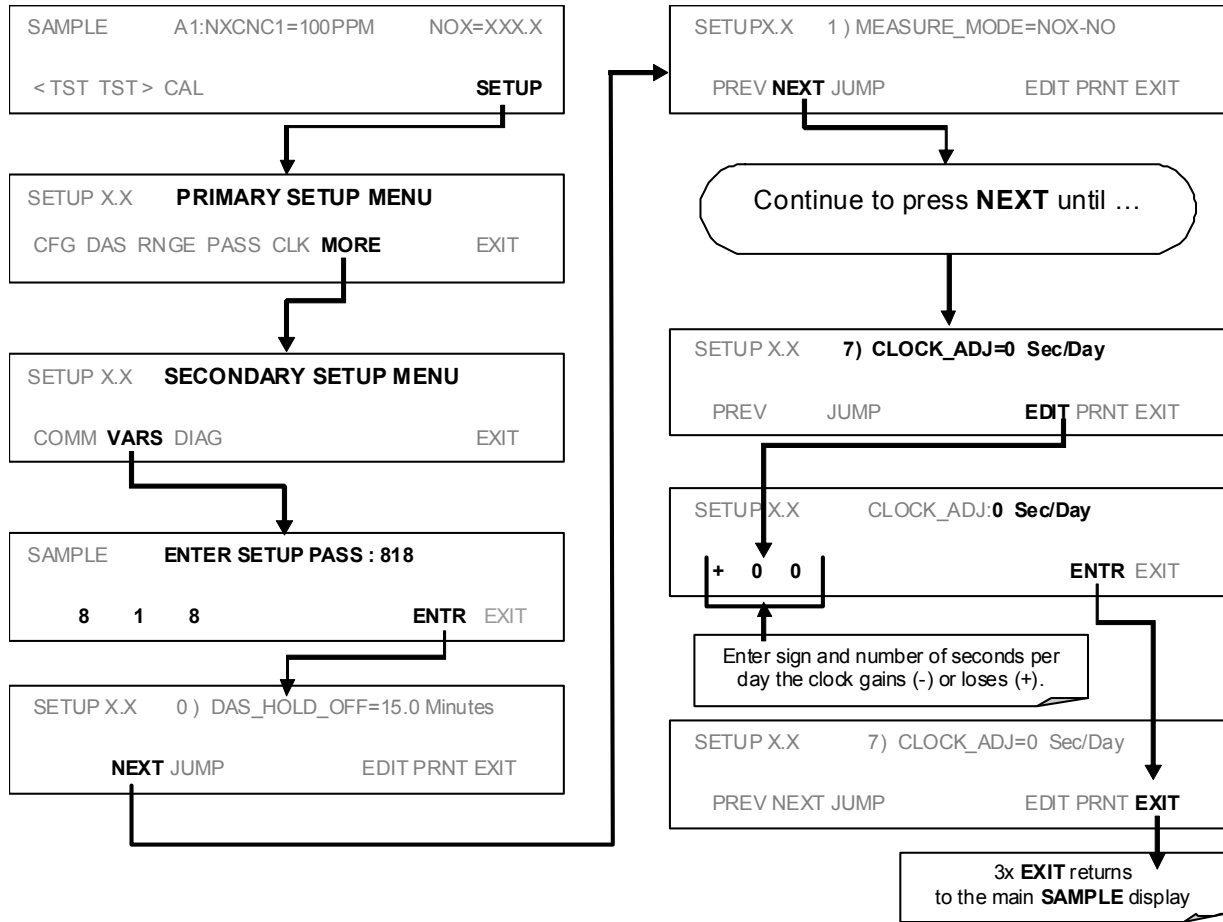
The 9110TH/M has a built-in clock for the Auto Cal timer, Time **TEST** function, and time stamps on COM port messages and DAS data entries.

To set the time-of-day, press:



In order to compensate for CPU clocks which run fast or slow, there is a variable to speed up or slow down the clock by a fixed amount every day.

To change this variable, press:



4.11. SETUP → MORE → COMM: SETTING UP THE ANALYSER'S COMMUNICATION PORTS

The 9110TH/M is equipped with an Ethernet port, a USB port and two serial communication (COMM) ports located on the rear panel (see Figure 3-2). Both com ports operate similarly and give the user the ability to communicate with, issue commands to, and receive data from the analyzer through an external computer system or terminal. By default, both ports operate on the RS-232 protocol.

The **RS232** port (used as COM1) can also be configured to operate in single or RS-232 multidrop mode (option 62; See Section 5.9.2 and 4.11.8).

The **COM2** port, can be configured for standard RS-232 operation or for half-duplex RS-485 communication (RS485 configuration disables the USB communication port).

A code-activated switch (CAS), can also be used on either port to connect typically between 2 and 16 send/receive instruments (host computer(s) printers, data loggers, analyzers, monitors, calibrators, etc.) into one communications hub. Contact TAI sales for more information on CAS systems.

4.11.1. DTE AND DCE COMMUNICATION

RS-232 was developed for allowing communications between data terminal equipment (DTE) and data communication equipment (DCE). Basic terminals always fall into the DTE category whereas modems are always considered DCE devices. The difference between the two is the pin assignment of the Data Receive and Data Transmit functions.

- DTE devices receive data on pin 2 and transmit data on pin 3.
- DCE devices receive data on pin 3 and transmit data on pin 2.

To allow the analyzer to be used with terminals (DTE), modems (DCE) and computers (which can be either), a switch mounted below the serial ports on the rear panel allows the user to set the configuration of COM1 for one of these two modes. This switch exchanges the receive and transmit lines on COM1 emulating a cross-over or null-modem cable. The switch has no effect on COM2.

4.11.2. COM PORT DEFAULT SETTINGS

As received from the factory, the analyzer is set up to emulate a DCE or modem, with Pin 3 of the DB-9 connector designated for receiving data and Pin 2 designated for sending data.

- **RS232:** (used as COM 1) RS-232 (fixed), DB-9 male connector.
 - **Baud rate:** 115200 bits per second (baud).
 - **Data Bits:** 8 data bits with 1 stop bit.
 - **Parity:** None.
- **COM2:** RS-232 (configurable to RS-485), DB-9 female connector.
 - **Baud rate:** 19200 bits per second (baud).
 - **Data Bits:** 8 data bits with 1 stop bit.
 - **Parity:** None.

4.11.3. COMMUNICATION MODES, BAUD RATE AND PORT TESTING

Use the SETUP>MORE>COMM menu to configure COM1 (labeled **RS232** on instrument rear panel) and/or COM2 (labeled **COM2** on instrument rear panel) for communication modes, baud rate and/or port testing for correct connection.

4.11.3.1. COM Port Communication Modes

Each of the analyzer's serial ports can be configured to operate in a number of different modes, which are listed in the following table. Each COM port needs to be configured independently.

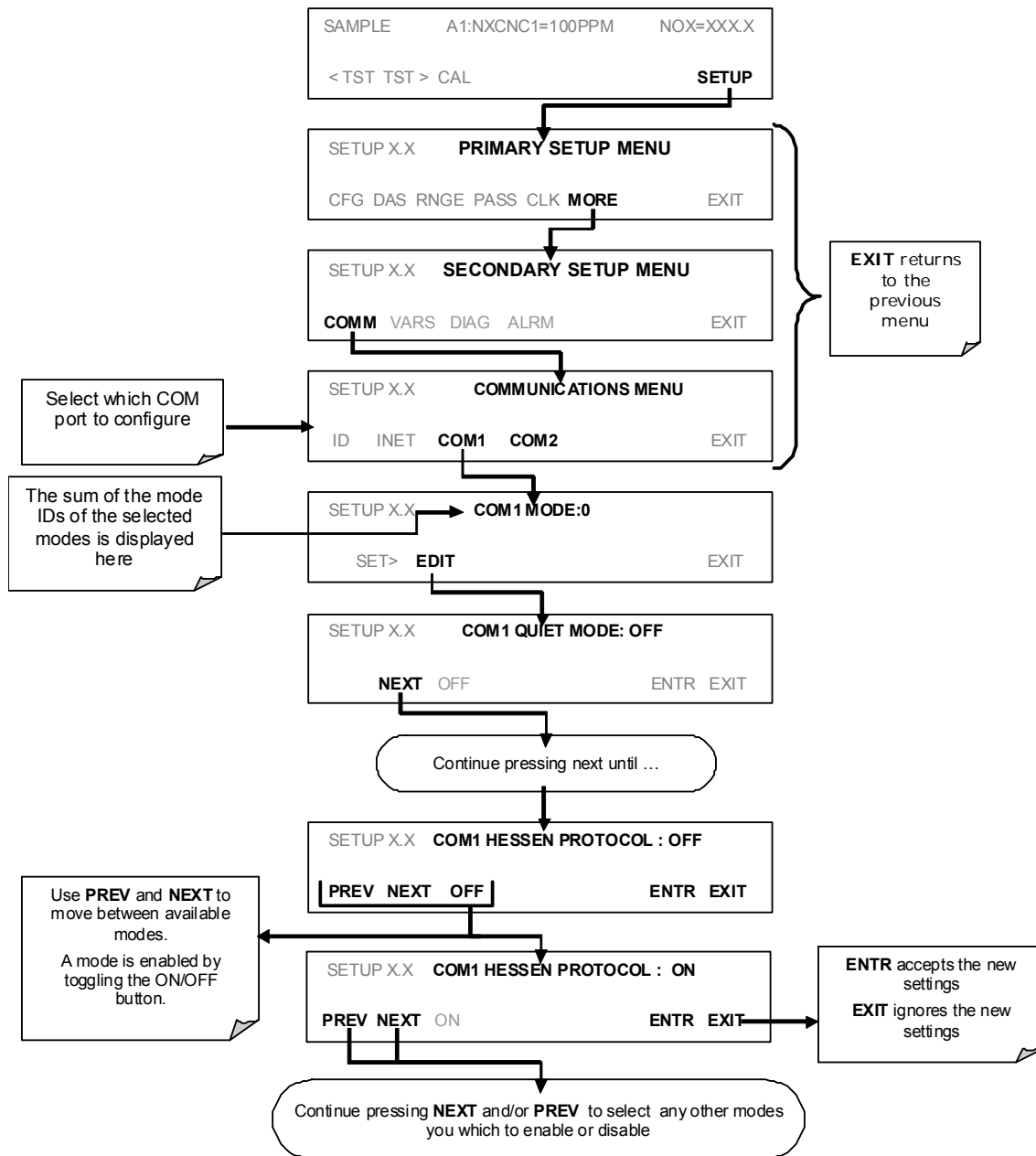
Table 4-11: COM Port Communication modes

MODE ¹	ID	DESCRIPTION
QUIET	1	Quiet mode suppresses any feedback from the analyzer (DAS reports, and warning messages) to the remote device and is typically used when the port is communicating with a computer program such as APICOM. Such feedback is still available but a command must be issued to receive them.
COMPUTER	2	Computer mode inhibits echoing of typed characters and is used when the port is communicating with a computer program, such as APICOM.
SECURITY	4	When enabled, the serial port requires a password before it will respond. The only command that is active is the help screen (? CR).
HESSEN PROTOCOL	16	The Hessen communications protocol is used in some European countries. TAI part number 02252 contains more information on this protocol.
E, 7, 1	2048	When turned on this mode switches the com port settings from No parity; 8 data bits; 1 stop bit to Even parity; 7 data bits; 1 stop bit
RS-485	1024	Configures the COM2 Port for RS-485 communication. RS-485 mode has precedence over multidrop mode if both are enabled. When the COM2 port is configured for RS-485 communication, the rear panel USB port is disabled.
MULTIDROP PROTOCOL	32	Multidrop protocol allows a multi-instrument configuration on a single communications channel. Multidrop is an option requiring a special PCA and the use of instrument IDs.
ENABLE MODEM	64	Enables sending a modem initialization string at power-up. Asserts certain lines in the RS-232 port to enable the modem to communicate.
ERROR CHECKING ²	128	Fixes certain types of parity errors at certain Hessen protocol installations.
XON/XOFF HANDSHAKE ²	256	Disables XON/XOFF data flow control also known as software handshaking.
HARDWARE HANDSHAKE	8	Enables CTS/RTS style hardwired transmission handshaking. This style of data transmission handshaking is commonly used with modems or terminal emulation protocols as well as by Teledyne Instrument's APICOM software.
HARDWARE FIFO ²	512	Improves data transfer rate when on of the com ports.
COMMAND PROMPT	4096	Enables a command prompt when in terminal mode.

¹ Modes are listed in the order in which they appear in the
SETUP → MORE → com → COM[1 OR 2] → MODE menu

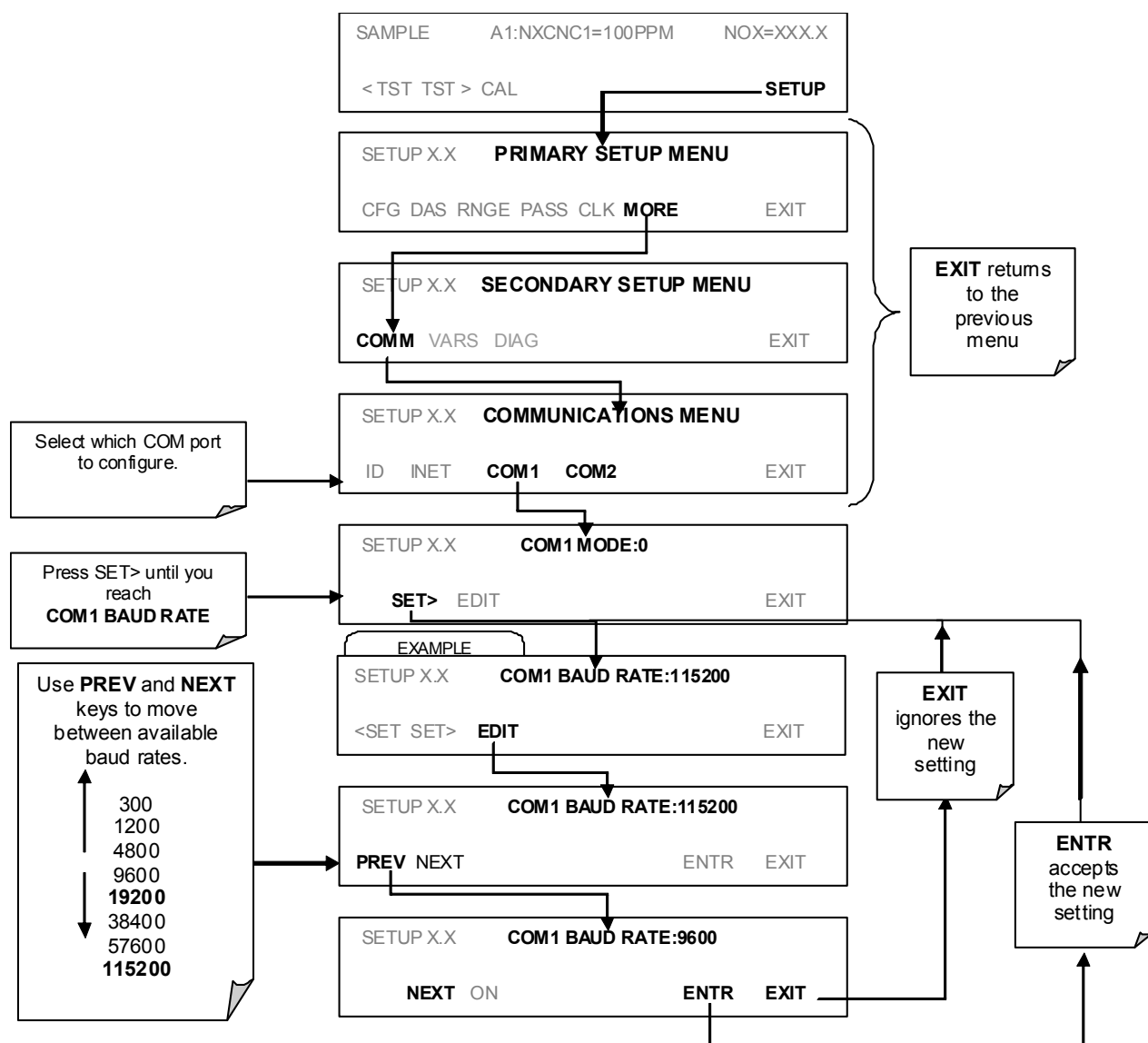
² The default sting for this feature is **ON**. Do not disable unless instructed to by TAI Technical Support personnel.

Press the following buttons to select a communication mode for a one of the com ports, such as the following example where **HESSEN PROTOCOL** mode is enabled:



4.11.3.2. COM Port Baud Rate

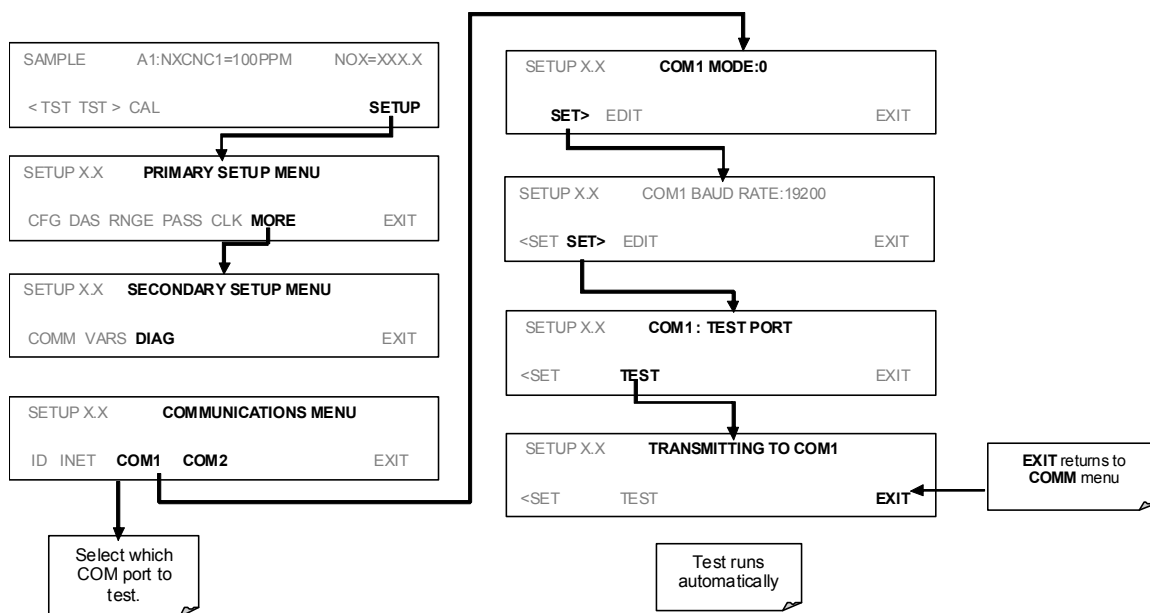
To select the baud rate of one of the COM Ports, press:



4.11.3.3. COM Port Testing

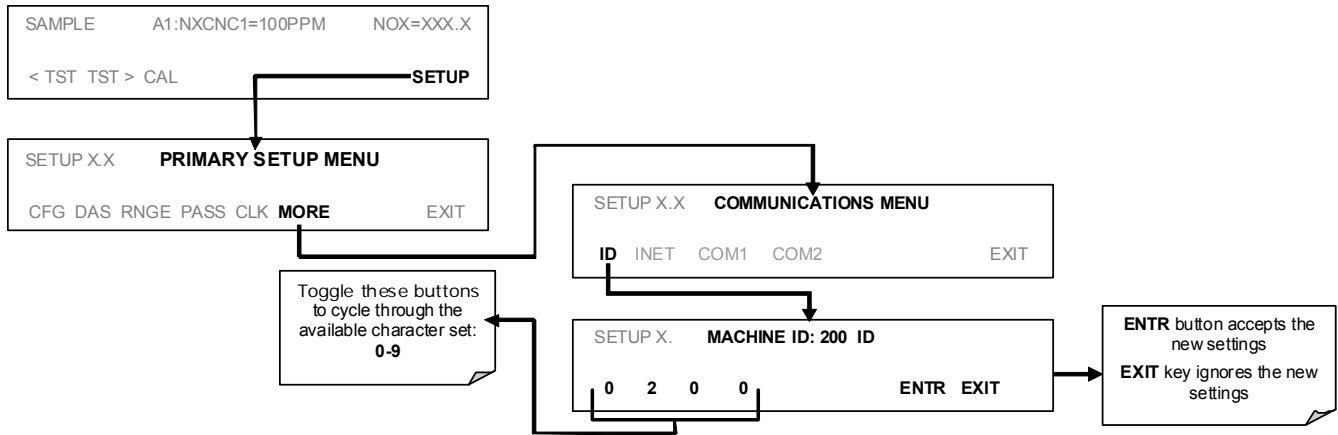
The serial ports can be tested for correct connection and output in the com menu. This test sends a string of 256 'w' characters to the selected COM port. While the test is running, the red LED on the rear panel of the analyzer should flicker.

To initiate the test press the following key sequence.



4.11.4. ANALYZER ID

Each type of TAI analyzer is configured with a default ID code. The default ID code for all 9110TH/M analyzers is either **0** or **200**. The ID number is only important if more than one analyzer is connected to the same communications channel such as when several analyzers are on the same Ethernet LAN (see Section 4.11.7); in a RS-232 multidrop chain (see Section 4.11.9) or operating over a RS-485 network (see Section 4.11.6). If two analyzers of the same model type are used on one channel, the ID codes of one or both of the instruments needs to be changed so that they are unique to the instruments. To edit the instrument’s ID code, press:



The ID can be any 4 digit number and can also be used to identify analyzers in any number of ways (e.g. location numbers, company asset number, etc.)

4.11.5. RS-232 COM PORT CABLE CONNECTIONS

In its default configuration, the 9110TH/M analyzer has two available RS-232 com ports accessible via 2 DB-9 connectors on the back panel of the instrument. The COM1 connector, labeled **RS232**, is a male DB-9 connector and the **COM2** is a female DB9 connector.

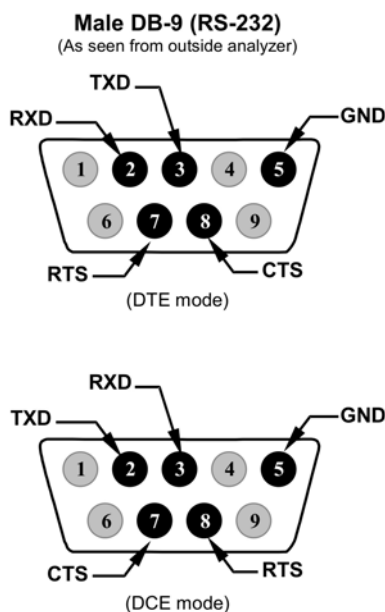


Figure 4-5: Default Pin Assignments for Rear Panel com Port Connectors (RS-232 DCE & DTE)

The signals from these two connectors are routed from the motherboard via a wiring harness to two 10-pin connectors on the CPU card, J11 (COM1) and J12 (COM2).

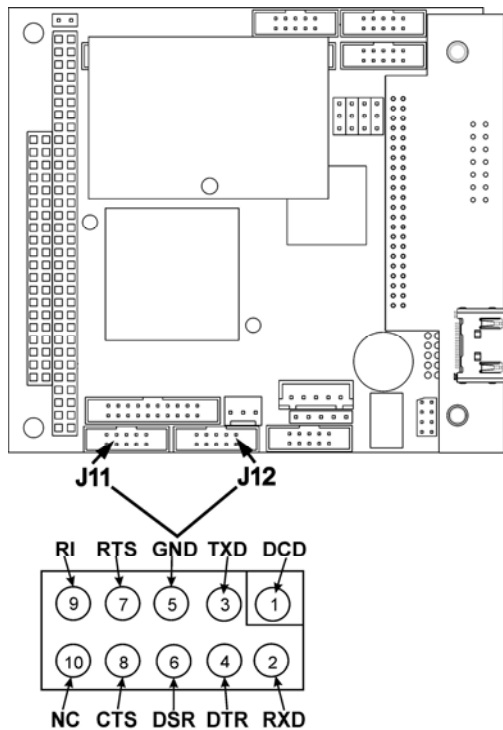


Figure 4-6: CPU COM1 & COM2 Connector Pin-Outs for RS-232 Mode

TAI offers two mating cables, one of which should be applicable for your use.

- Part number WR000077, a DB-9 female to DB-9 female cable, 6 feet long. Allows connection of COM1 with the serial port of most personal computers. Also available as Option 60 (see Section 5.9.1).
- Part number WR000024, a DB-9 female to DB-25 male cable. Allows connection to the most common styles of modems (e.g. Hayes-compatible) and code activated switches.

Both cables are configured with straight-through wiring and should require no additional adapters.

Note

Cables that appear to be compatible because of matching connectors may incorporate internal wiring that make the link inoperable. Check cables acquired from sources other than TAI for pin assignments before using.

To assist in properly connecting the serial ports to either a computer or a modem, there are activity indicators LEDs (labeled RX and TX) just above the rear panel RS-232 port. Once a cable is connected between the analyzer and a computer or modem, both the red and green LEDs should be on. If the RX TX LEDs for **RS232** are not lit, change position of rear panel DCE DTE mode switch (see 4.11.1). If both LEDs are still not illuminated, check the cable for proper wiring.

4.11.6. RS-485 CONFIGURATION OF COM2

Opting to use RS-485 communications for the COM2 port will disable the USB port. To configure your instrument for RS-485 communications, please consult the factory.

4.11.7. ETHERNET INTERFACE CONFIGURATION

When using the Ethernet interface, the analyzer can be connected to any standard 10BaseT or 100BaseT Ethernet network via low-cost network hubs, switches or routers. The interface operates as a standard TCP/IP device on port 3000. This allows a remote computer to connect through the network to the analyzer using APICOM, terminal emulators or other programs.

The Ethernet cable connector on the rear panel has two LEDs indicating the Ethernet's current operating status.

Table 4-12 Ethernet Status Indicators

LED	FUNCTION
amber (link)	On when connection to the LAN is valid.
green (activity)	Flickers during any activity on the LAN.

The analyzer is shipped with DHCP enabled by default. This allows the instrument to be connected to a network or router with a DHCP server. The instrument will automatically be assigned an IP address by the DHCP server (Section Configuring Ethernet Communication Using DHCP). This configuration is useful for quickly getting an instrument up and running on a network. However, for permanent Ethernet connections, a static IP address should be used. Section 4.11.7.2 below details how to configure the instrument with a static IP address.

4.11.7.1. Configuring Ethernet Communication Using DHCP

1. Consult with your network administrator to affirm that your network server is running DHCP.
2. Access the Ethernet Menu (SETUP>MORE>COMM>INET).
3. After pressing ENTR at the password menu, press SET> to view the DHCP settings:

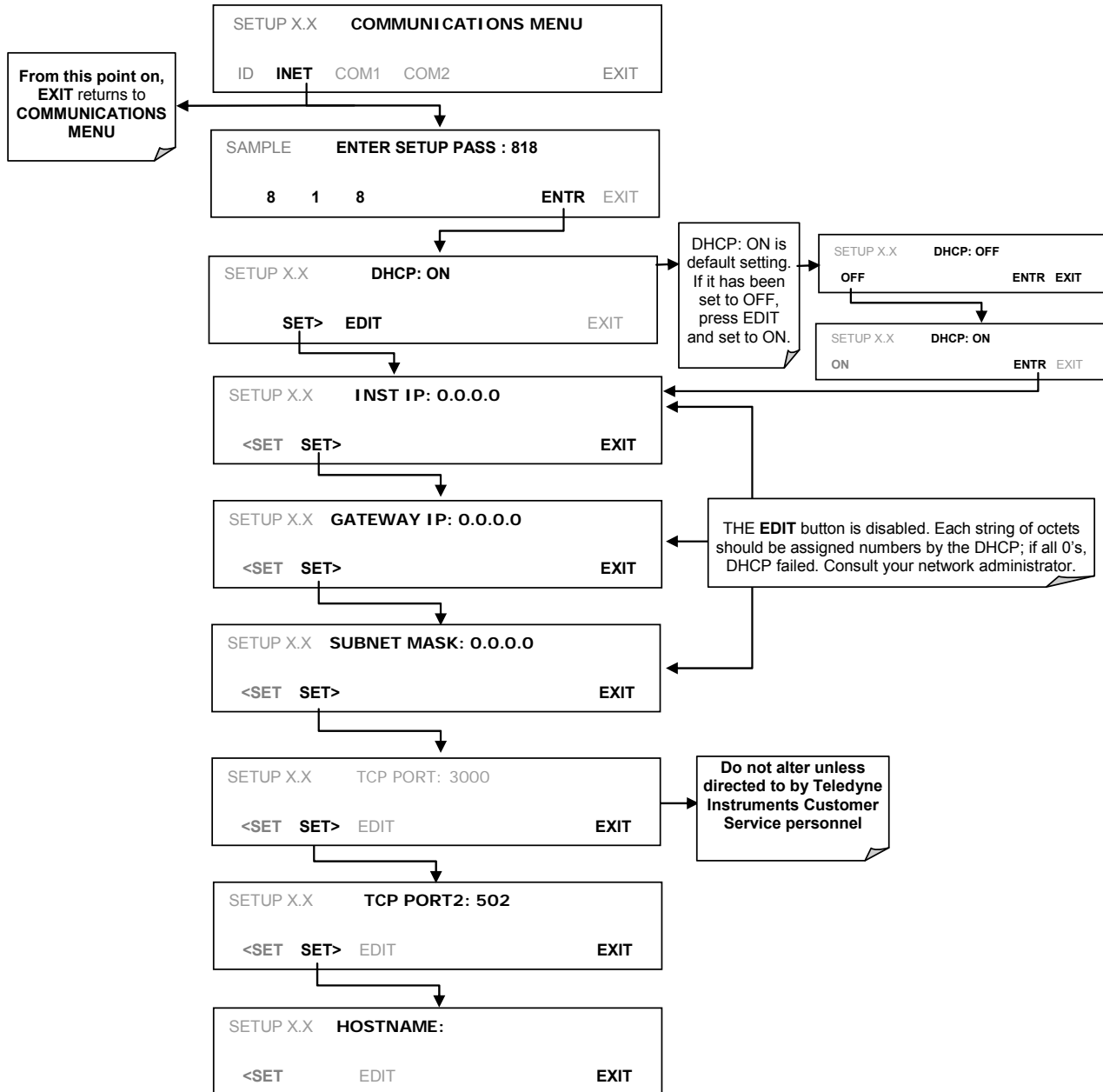


Table 4-13: LAN/Internet Configuration Properties

PROPERTY	DEFAULT STATE		DESCRIPTION
DHCP STATUS	On	Editable	This displays whether the DHCP is turned ON or OFF.
INSTRUMENT IP ADDRESS	Configured by DHCP	EDIT key disabled when DHCP is ON	This string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55.) is the address of the analyzer itself.
GATEWAY IP ADDRESS	Configured by DHCP	EDIT key disabled when DHCP is ON	A string of numbers very similar to the Instrument IP address (e.g. 192.168.76.1.) that is the address of the computer used by your LAN to access the Internet.
SUBNET MASK	Configured by DHCP	EDIT key disabled when DHCP is ON	Also a string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) that defines that identifies the LAN the device is connected to. All addressable devices and computers on a LAN must have the same subnet mask. Any transmissions sent devices with different assumed to be outside of the LAN and are routed through gateway computer onto the Internet.
TCP PORT¹	3000	Editable	This number defines the terminal control port by which the instrument is addressed by terminal emulation software, such as Internet or Teledyne API APICOM.
HOST NAME	[initially blank]	Editable	The name by which your analyzer will appear when addressed from other computers on the LAN or via the Internet. While the default setting for all TAI analyzers is the model number, the host name may be changed to fit customer needs.
¹ Do not change the setting for this property unless instructed to by TAI Technical Support personnel.			

Note

It is recommended that you check these settings the first time you power up your analyzer after it has been physically connected to the LAN/Internet to confirm that the DHCP server has successfully downloaded the appropriate information from you network. If the gateway IP, instrument IP and subnet mask are all zeroes (e.g. "0.0.0.0"), the DHCP was not successful. It may be necessary to manually configure the analyzer's Ethernet properties. Consult your network administrator.

4.11.7.2. Configuring Ethernet Communication Manually (Static IP Address)

1. Connect a cable from the analyzer's Ethernet port to a Local Area Network (LAN) or Internet port.
2. From the analyzer's front panel touch screen, access the Ethernet Menu: (SETUP>MORE>COMM>INET).
3. Follow the setup sequence as shown in Figure 4-7, and edit the Instrument and Gateway IP addresses and the Subnet Mask to the desired settings.
4. From the computer, enter the same information through an application such as HyperTerminal.
5. Table 4-13 shows the default Ethernet configuration settings.

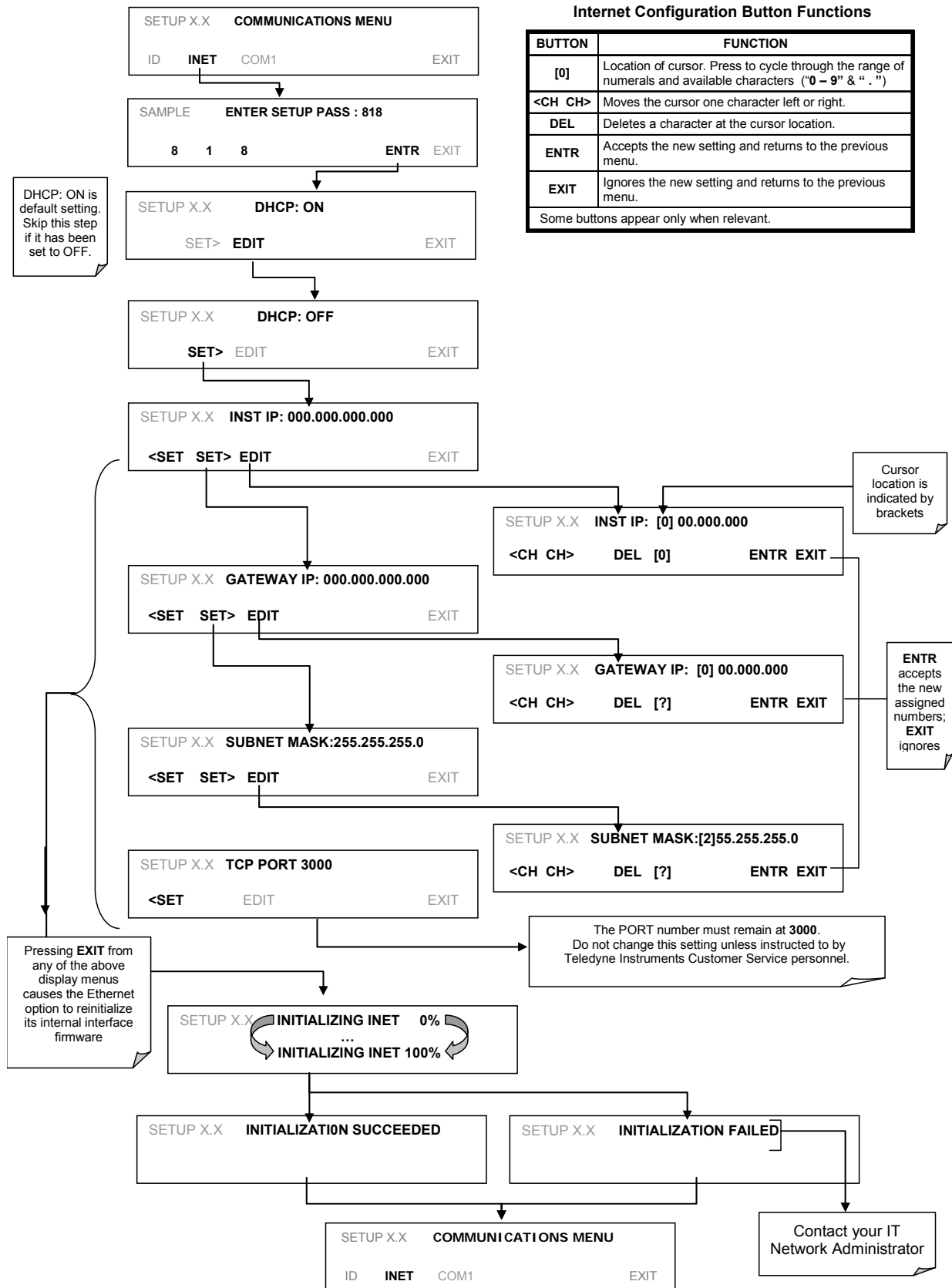


Figure 4-7: COM – LAN / Internet Manual Configuration

4.11.7.3. Changing the Analyzer's HOSTNAME

The **HOSTNAME** is the name by which the analyzer appears on your network. The default name for all TAI Model 9110TH/M analyzers is initially blank. To create or later change this name (particularly if you have more than one analyzer on your network), press.

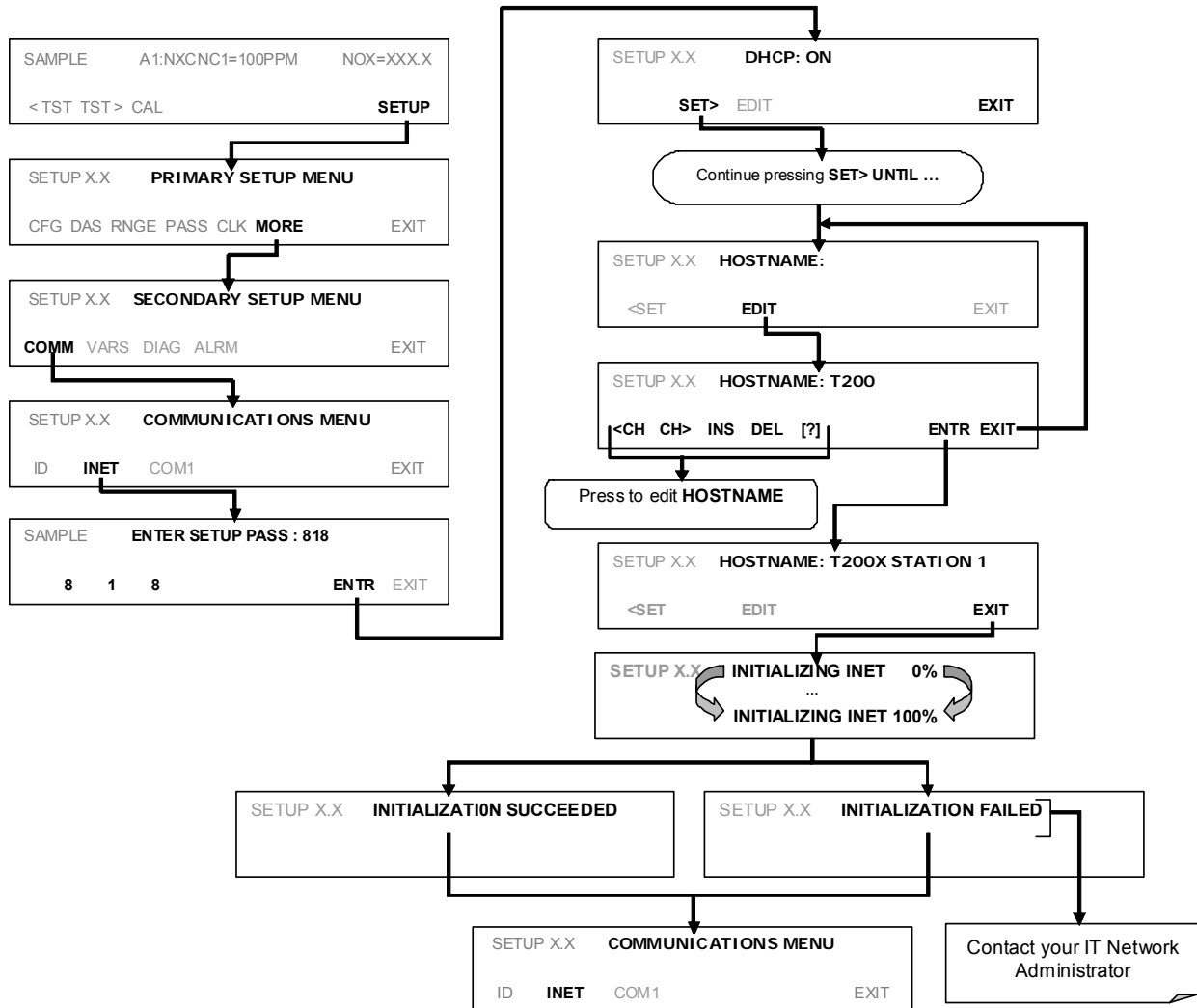


Table 4-14: Internet Configuration Menu Button Functions

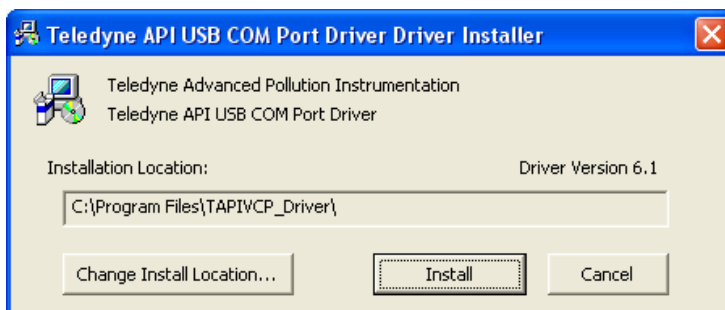
BUTTON	FUNCTION
<CH	Moves the cursor one character to the left.
CH>	Moves the cursor one character to the right.
INS	Inserts a character before the cursor location.
DEL	Deletes a character at the cursor location.
[?]	Press this key to cycle through the range of numerals and characters available for insertion. 0-9, A-Z, space ' ~ ! © # \$ % ^ & * () - _ = + [] { } < > \ ; : , . / ?
ENTR	Accepts the new setting and returns to the previous menu.
EXIT	Ignores the new setting and returns to the previous menu.

Some keys only appear as needed.

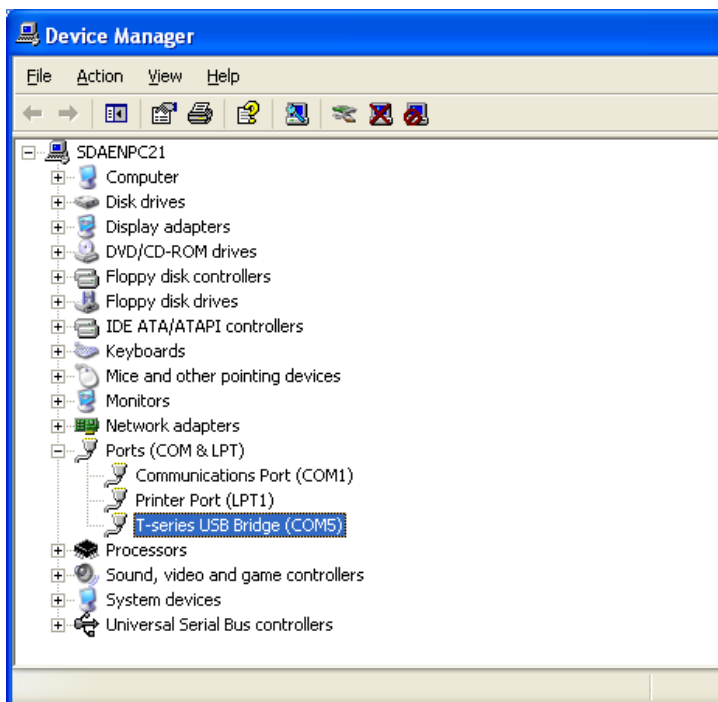
4.11.8. USB PORT SETUP

The analyzer can be operated through a personal computer by downloading the Teledyne USB driver and directly connecting their respective USB ports.

1. Install the Teledyne T-Series USB driver on your computer, downloadable from the Teledyne API website under Help Center>Software Downloads (www.teledyne-api.com/software).
2. Run the installer file: "TAPIVCPInstaller.exe"



3. Connect the USB cable between the USB ports on your personal computer and your analyzer. The USB cable should be a Type A – Type B cable, commonly used as a USB printer cable.
4. Determine the Windows XP Com Port number that was automatically assigned to the USB connection. (Start → Control Panel → System → Hardware → Device Manager). This is the com port that should be set in the communications software, such as APIcom or Hyperterminal.



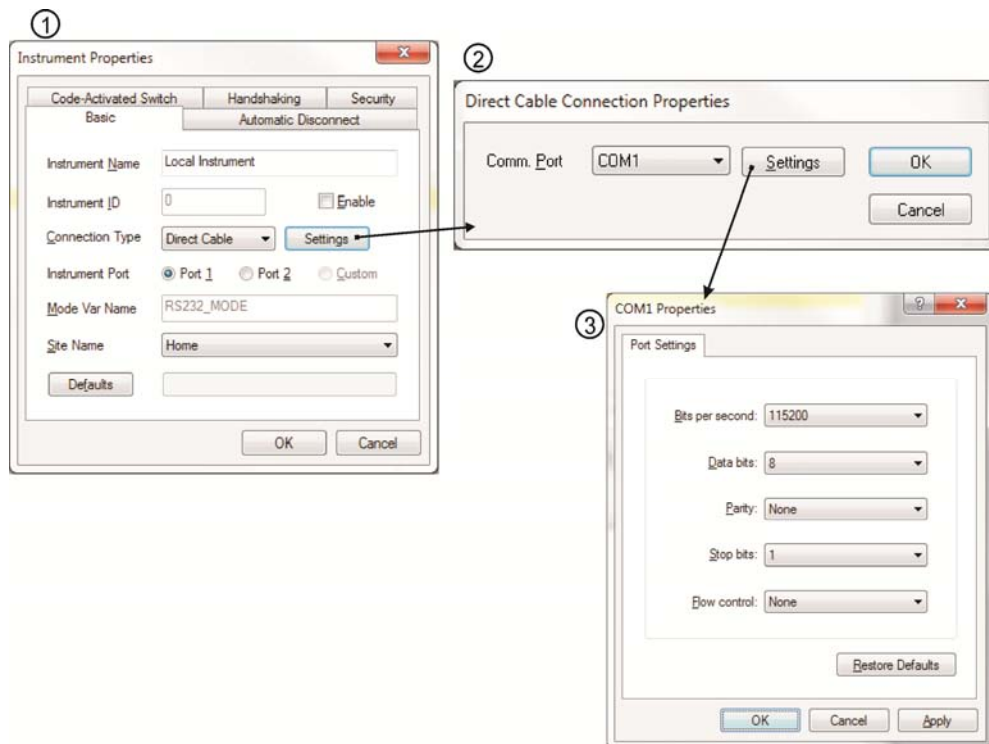
Refer to the Quick Start (*Direct Cable Connection*) section of the Teledyne APIcom Manual, PN 07463.

- In the instrument's SETUP>MORE>COMM>COM2 menu, make the following settings:

Baud Rate: 115200
 COM2 Mode Settings:

Quiet Mode	ON
Computer Mode	ON
MODBUS RTU	OFF
MODBUS ASCII	OFF
E,8,1 MODE	OFF
E,7,1 MODE	OFF
RS-485 MODE	OFF
SECURITY MODE	OFF
MULTIDROP MODE	OFF
ENABLE MODEM	OFF
ERROR CHECKING	ON
XON/XOFF HANDSHAKE	OFF
HARDWARE HANDSHAKE	OFF
HARDWARE FIFO	ON
COMMAND PROMPT	OFF

- Next, configure your communications software, such as APIcom. Use the COM port determined in Step 4 and the baud rate set in Step 5. The figures below show how these parameters would be configured in the Instrument Properties window in APIcom when configuring a new instrument. See the APIcom manual (PN 07463) for more details.



Note

USB configuration requires that instrument and PC baud rates match; check the PC baud rate and change if needed. Using the USB port disallows use of the rear panel COM2 port except for multidrop communication.

4.11.9. MULTIDROP RS-232 SET UP

When the RS-232 Multidrop option is installed, connection adjustments and configuration through the menu system are required. This section provides instructions for the internal connection adjustments, then for external connections, and ends with instructions for menu-driven configuration.

Note that because the RS-232 Multidrop option uses both the **RS232** and **COM2** DB9 connectors on the analyzer's rear panel to connect the chain of instruments, **COM2** port is no longer available for separate RS-232 or RS-485 operation.



CAUTION – Risk of Instrument Damage and Warranty Invalidation

Printed circuit assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Damage resulting from failure to use ESD protection when working with electronic assemblies will void the instrument warranty. See *A Primer on Electro-Static Discharge* section in this manual for more information on preventing ESD damage.

In each instrument with the Multidrop option there is a shunt which jumpers two pins on the serial Multidrop and LVDS printed circuit assembly (PCA), as shown in Figure 4-8. This shunt must be removed from all instruments except that designated as last in the multidrop chain, which must remain terminated. This requires powering off and opening each instrument and making the following adjustments:

1. With **NO power** to the instrument, remove its top cover and lay the rear panel open for access to the multidrop PCA, which is seated on the CPU.
2. On the Multidrop/LVDS PCA's JP2 connector, remove the shunt that jumpers Pins 21 ↔ 22 as indicated in Figure 4-8. (Do this for all but the last instrument in the chain where the shunt should remain at Pins 21 ↔ 22).
3. Check that the following cable connections are made in *all* instruments (again refer to Figure 4-8).
 - J3 on the Multidrop/LVDS PCA to the CPU's COM1 connector
(Note that the CPU's COM2 connector is not used in Multidrop)
 - J4 on the Multidrop/LVDS PCA to J12 on the motherboard
 - J1 on the Multidrop/LVDS PCS to the front panel LCD

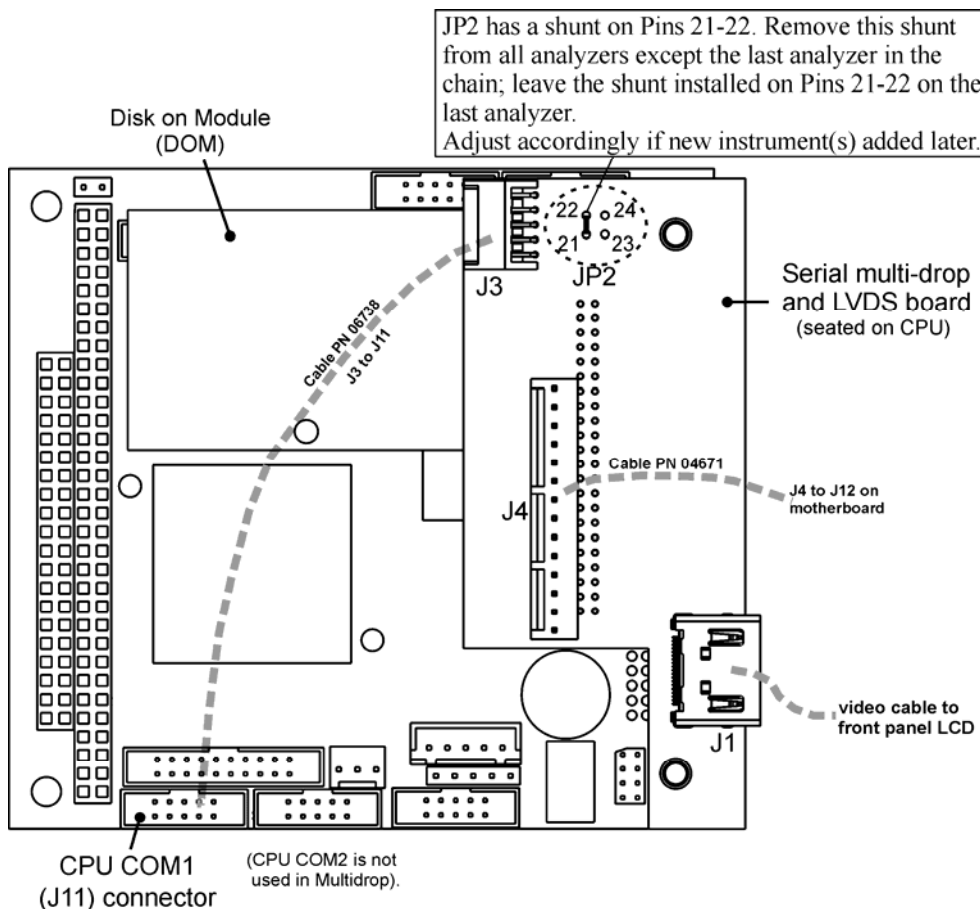


Figure 4-8: Jumper and Cables for Multidrop Mode

Note: If you are adding an instrument to the end of a previously configured chain, remove the shunt between Pins 21 ↔ 22 of the Multidrop PCA in the instrument that was previously the last instrument in the chain.

4. Close the instrument.
5. Referring to Figure 4-9, use straight-through DB9 male-DB9 female cables to interconnect the host RS232 port to the first analyzer's RS232 port; then from the first analyzer's COM2 port to the second analyzer's RS232 port; from the second analyzer's COM2 port to the third analyzer's RS232 port, etc., connecting in this fashion up to eight analyzers, subject to the distance limitations of the RS-232 standard.
6. On the rear panel of each analyzer, adjust the DCE DTE switch so that the green and the red LEDs (RX and TX) of the COM1 connector (labeled RS232) are both lit. (Ensure you are using the correct RS-232 cables that are internally wired specifically for RS232 communication).

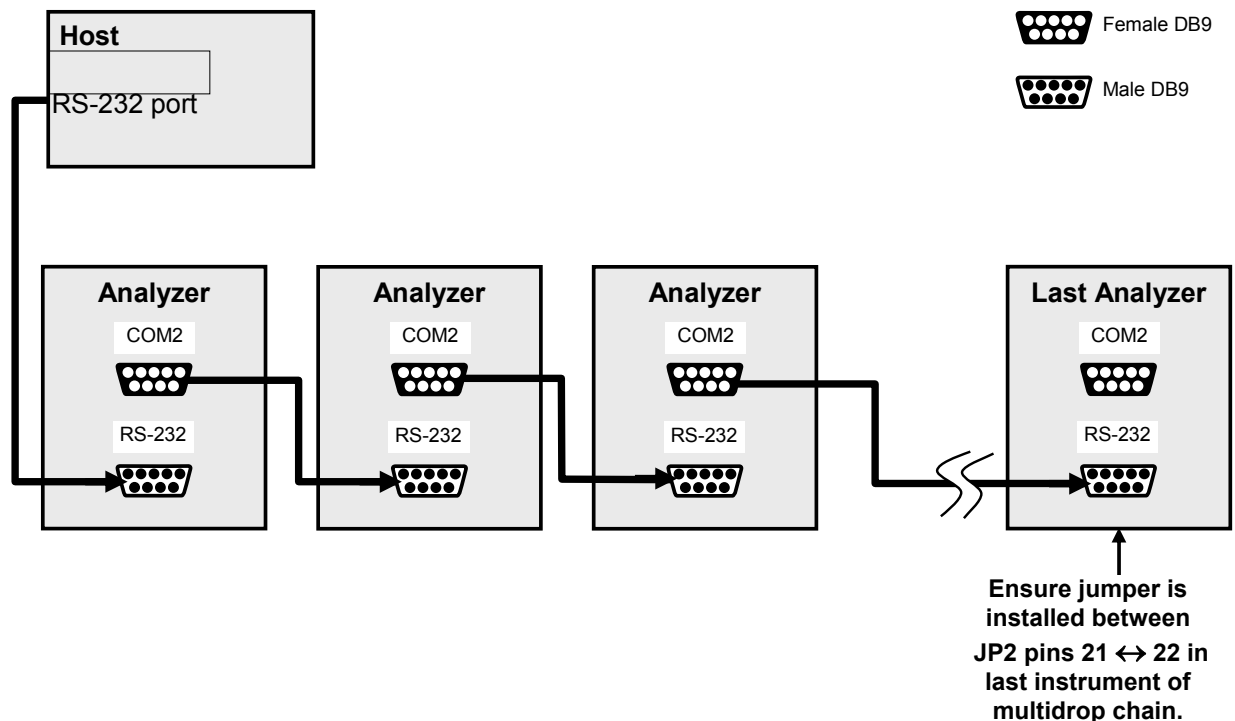


Figure 4-9: RS-232-Multidrop Host-to-Analyzer Interconnect Diagram

7. BEFORE communicating from the host, power on the instruments and check that the Machine ID (Section 4.11.1) is unique for each. On the front panel menu, use SETUP>MORE>COMM>ID. The default ID is typically the model number or "0"; to change the 4-digit identification number, press the button below the digit to be changed; once changed, press/select ENTER to accept the new ID for that instrument.
8. Next, in the SETUP>MORE>COMM>COM1 menu (do not use the COM2 menu for multidrop), edit the COM1 MODE parameter as follows: press/select EDIT and set only QUIET MODE, COMPUTER MODE, and MULTIDROP MODE to ON. Do not change any other settings.
9. Press/select ENTER to accept the changed settings, and ensure that COM1 MODE now shows 35.
10. Press/select SET> to go to the COM1 BAUD RATE menu and ensure it reads the same for all instruments (edit as needed so that all instruments are set at the same baud rate).

NOTES:

- The (communication) Host instrument can address only one instrument at a time, each by its unique ID (see Step 7 above).
- TAI recommends setting up the first link, between the Host and the first analyzer, and testing it before setting up the rest of the chain.

4.11.10. MODBUS SETUP

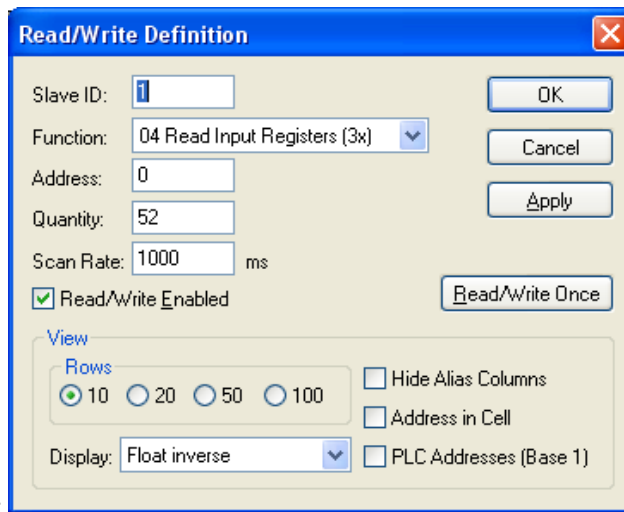
The following set of instructions assumes that the user is familiar with MODBUS communications, and provides minimal information to get started. For additional instruction, please refer to the Teledyne API MODBUS manual, PN 06276. Also refer to www.modbus.org for MODBUS communication protocols.

MINIMUM REQUIREMENTS

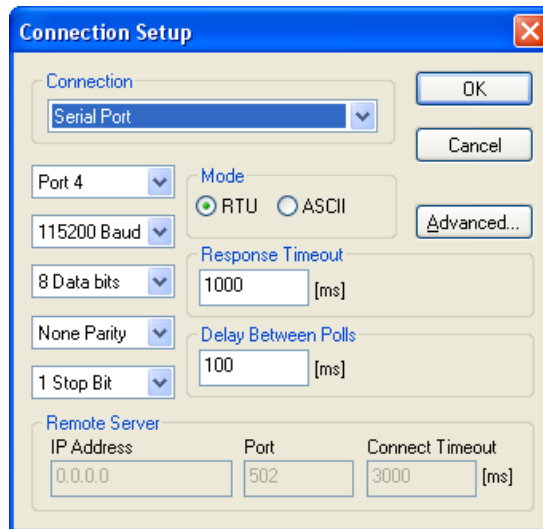
- Instrument firmware with MODBUS capabilities installed.
- MODBUS-compatible software (TAPI uses MODBUS Poll for testing; see www.modbustools.com)
- Personal computer
- Communications cable (Ethernet or USB or RS232)
- Possibly a null modem adapter or cable

ACTIONS

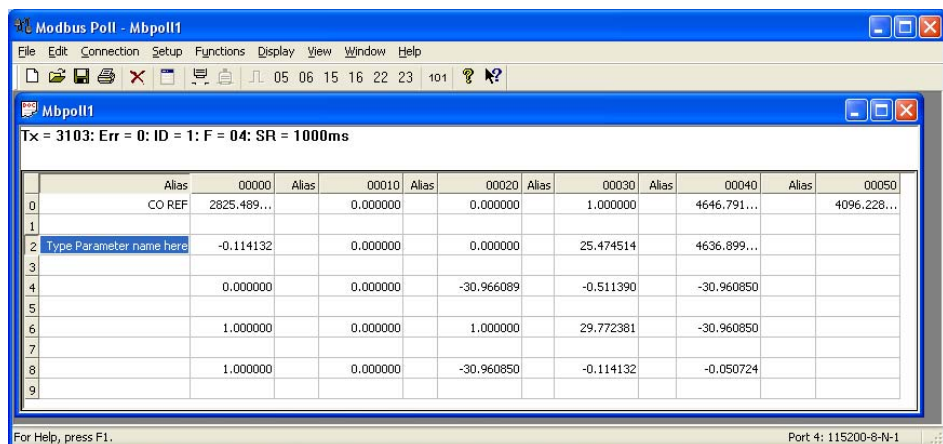
Set Com Mode parameters Comm Slave ID	<p>Ethernet: Using the front panel menu, go to SETUP – MORE – COMM – INET; scroll through the INET submenu until you reach TCP PORT 2 (the standard setting is 502), then continue to TCP PORT 2 MODBUS TCP/IP; press EDIT and toggle the menu button to change the setting to ON, then press ENTR. (Change Machine ID if needed: see “Slave ID”).</p> <p>USB/RS232: Using the front panel menu, go to SETUP – MORE – COMM – COM2 – EDIT; scroll through the COM2 EDIT submenu until the display shows COM2 MODBUS RTU: OFF (press OFF to change the setting to ON. Scroll NEXT to COM2 MODBUS ASCII and ensure it is set to OFF. Press ENTR to keep the new settings. (If RTU is not available with your communications equipment, set the COM2 MODBUS ASCII setting to ON and ensure that COM2 MODBUS RTU is set to OFF. Press ENTR to keep the new settings).</p> <p>If your analyzer is connected to a network with at least one other analyzer of the same model, a unique Slave ID must be assigned to each. Using the front panel menu, go to SETUP – MORE – COMM – ID. The MACHINE ID default is the same as the model number. Toggle the menu buttons to change the ID.</p>
Reboot analyzer	For the settings to take effect, power down the analyzer, wait 5 seconds, and power up the analyzer.
Make appropriate cable connections	Connect your analyzer either: <ul style="list-style-type: none"> • via its Ethernet or USB port to a PC (this may require a USB-to-RS232 adapter for your PC; if so, also install the software driver from the CD supplied with the adapter, and reboot the computer if required), or • via its COM2 port to a null modem (this may require a null modem adapter or cable).
Specify MODBUS software settings (examples used here are for MODBUS Poll software)	<ol style="list-style-type: none"> 1. Click Setup / [Read / Write Definition] /. <ol style="list-style-type: none"> a. In the Read/Write Definition window (see example that follows) select a Function (what you wish to read from the analyzer). b. Input Quantity (based on your firmware’s register map). c. In the View section of the Read/Write Definition window select a Display (typically Float Inverse). d. Click OK. 2. Next, click Connection/Connect. <ol style="list-style-type: none"> a. In the Connection Setup window (see example that follows), select the options based on your computer. b. Press OK.
Read the Modbus Poll Register	Use the Register Map to find the test parameter names for the values displayed (see example that follows). If desired, assign an alias for each.



Example Read/Write Definition window:



Example Connection Setup window:



Example MODBUS Poll window:

4.12. SETUP → MORE → VARS: INTERNAL VARIABLES (VARS)

The 9110TH/M has several-user adjustable software variables, which define certain operational parameters. Usually, these variables are automatically set by the instrument's firmware, but can be manually re-defined using the VARS menu. Table 4-15 lists all variables that are available within the 818 password protected level. See Appendix A2 for a detailed listing of all of the 9110TH/M variables that are accessible through the remote interface.

Table 4-15: Variable Names (VARS)

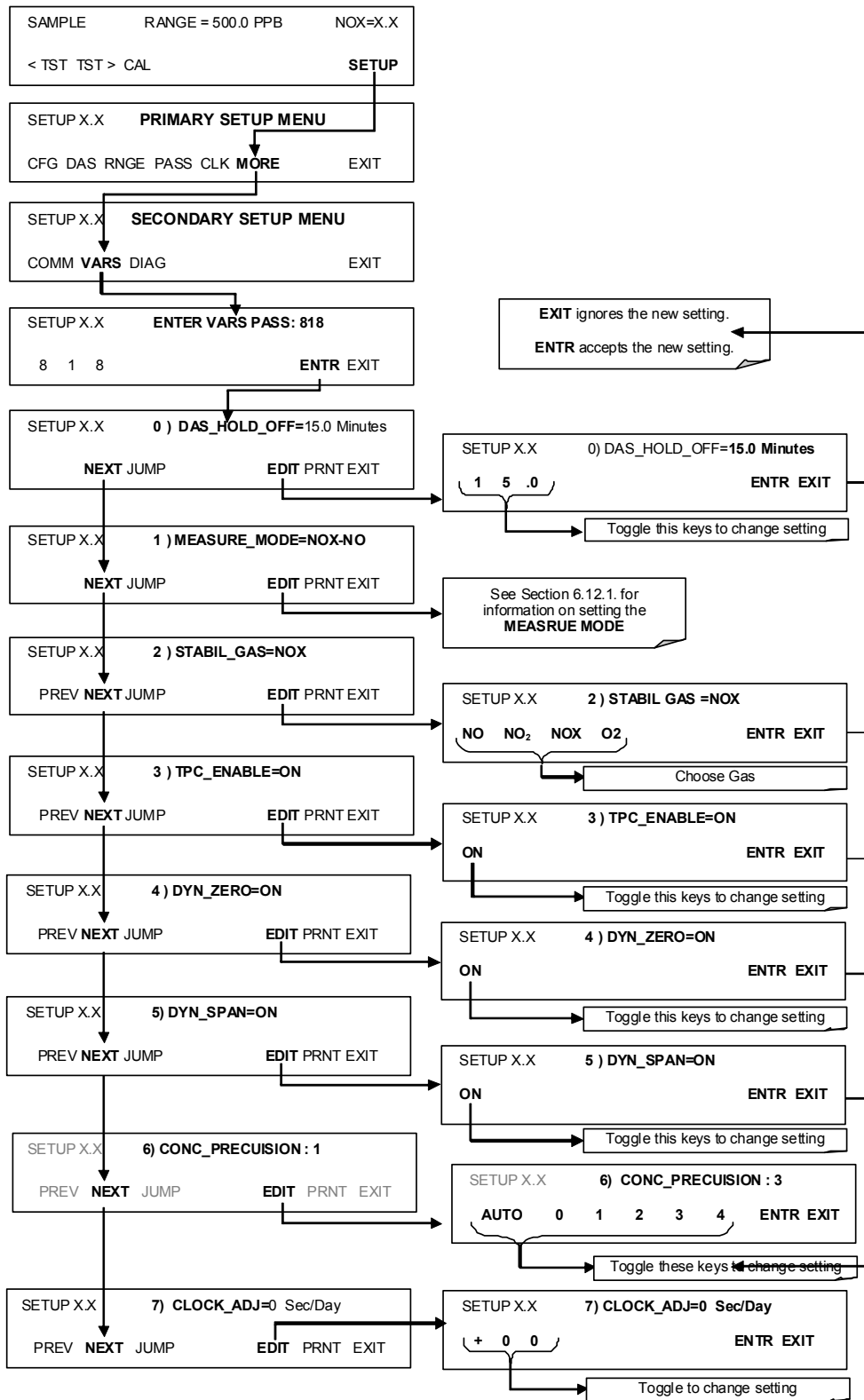
NO.	VARIABLE	DESCRIPTION	ALLOWED VALUES
0	DAS_HOLD_OFF	Duration of no data storage in the DAS. This is the time when the analyzer returns from one of its calibration modes to the SAMPLE mode. The DAS_HOLD_OFF can be disabled in each DAS channel.	Can be between 0.5 and 20 minutes Default=15 min.
1	MEASURE_MODE	Selects the gas measurement mode in which the instrument is to operate. NO _x only, NO only or dual gas measurement of NO _x and NO simultaneously. Dual gas mode requires that a special switching optional be installed.	NO; NO _x ; NO _x -NO
2	STABIL_GAS	Selects which gas measurement is displayed when the STABIL test function is selected.	NO; NO _x ; NO ₂ ; O ₂ ¹
3	TPC_ENABLE	Enables or disables the temperature and pressure compensation (TPC) feature (Section 8.8.3).	ON/OFF Default=ON
4	DYN_ZERO	Dynamic zero automatically adjusts offset and slope of the NO and NO _x response when performing a zero point calibration during an AutoCal (Section 7.7).	ON/OFF Default=OFF
5	DYN_SPAN	Dynamic span automatically adjusts the offsets and slopes of the NO and NO _x response when performing a zero point calibration during an AutoCal (Section 7.7). Note that the DYN_ZERO and DYN_SPAN features are not allowed for applications requiring EPA equivalency.	ON/OFF Default=OFF
6	CONC_PRECISION	Allows to set the number of decimal points of the concentration and stability parameters displayed on the front panel.	AUTO, 1, 2, 3, 4 Default=AUTO
7	CLOCK_ADJ	Adjusts the speed of the analyzer's clock. Choose the + sign if the clock is too slow, choose the - sign if the clock is too fast.	-60 to +60 s/day Default=0
8	SERVICE_CLEAR	Resets the service interval timer. (Changing the setting to ON resets the timer and then returns the setting back to default OFF).	ON/OFF Default=OFF
9	TIME_SINCE_SVC	Tracks the time since last service (restarts the time when the service interval timer, SERVICE_CLEAR, is reset).	0-500000 Default=0
10	SVC_INTERVAL	Sets the interval between service reminders.	0-100000 Default=0

¹ Only available in analyzers with O₂ sensor options installed.

Note

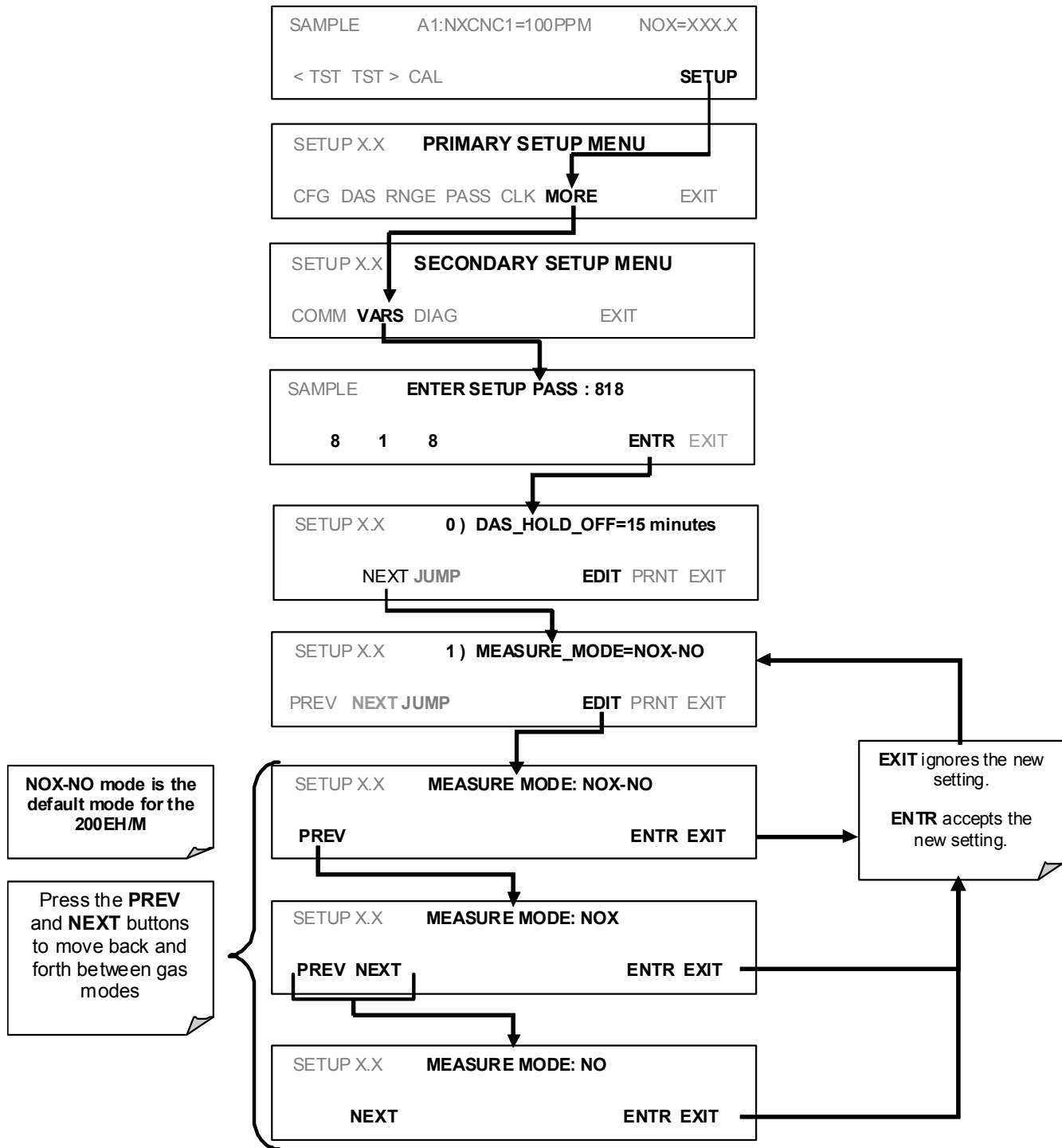
There is a 2-second latency period between the time a VARS value is changed and the time the new value is stored into the analyzer's memory. DO NOT turn the analyzer off during this period or the new setting will be lost.

To access and navigate the VARS menu, use the following touch screen button sequence:



4.12.1. SETTING THE GAS MEASUREMENT MODE

In its standard operating mode the 9110TH/M measures NO, NO₂ and NO_x. It can also be set to measure only NO or only NOX. To select one of these three measurement modes, press:



4.13. SETUP → MORE → DIAG: DIAGNOSTICS MENU

A series of diagnostic tools is grouped together under the **SETUP-MORE-DIAG** menu. These parameters are dependent on firmware revision. These tools can be used in a variety of troubleshooting and diagnostic procedures and are referred to in many places of the maintenance and trouble-shooting sections.

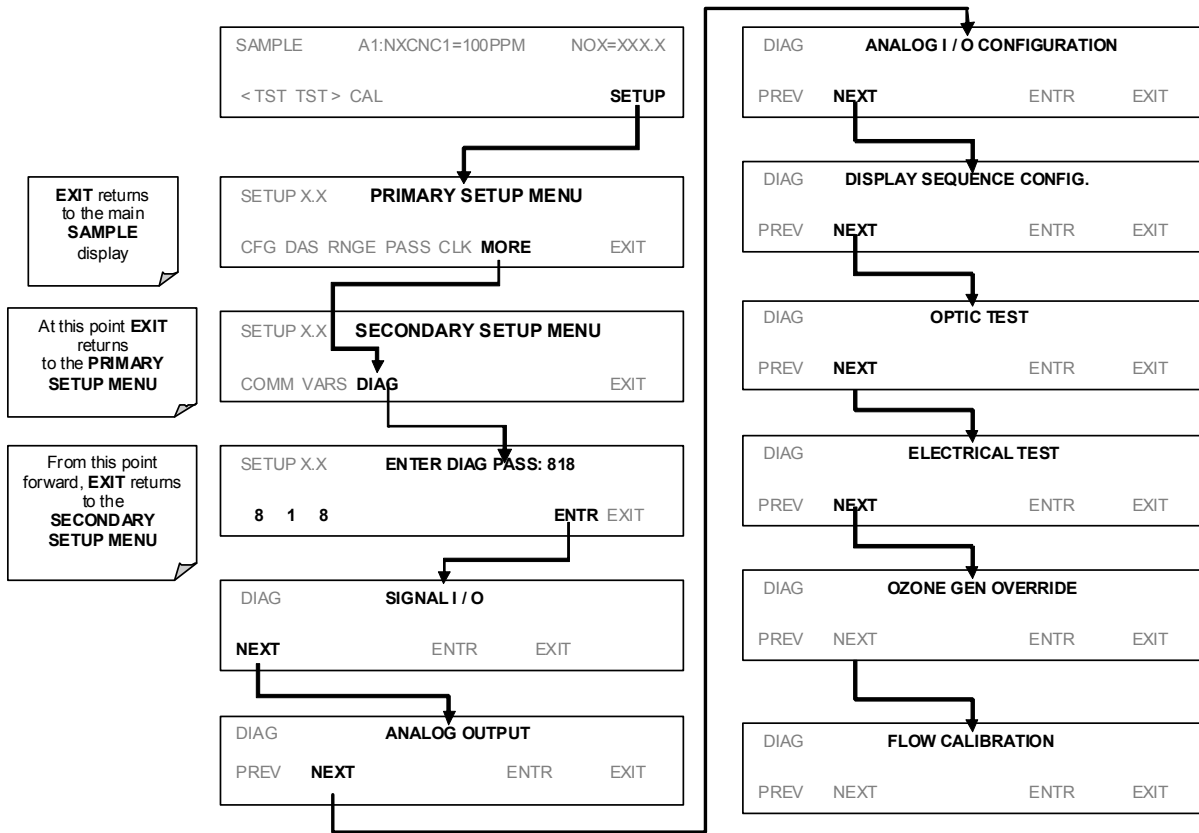
An overview of the entire **DIAG** menu can be found in menu tree A-6 of Appendix A.1.

Table 4-16: 9110TH/M Diagnostic (DIAG) Functions

DIAGNOSTIC FUNCTION AND MEANING	FRONT PANEL MODE INDICATOR	SECTION
SIGNAL I/O: Allows observation of all digital and analog signals in the instrument. Allows certain digital signals such as valves and heaters to be toggled ON and OFF.	DIAG I/O	4.13.2
ANALOG OUTPUT: When entered, the analyzer performs an analog output step test. This can be used to calibrate a chart recorder or to test the analog output accuracy.	DIAG AOUT	4.13.3
ANALOG I/O CONFIGURATION: This submenu allows the user to configure the analyzer's four analog output channels, including choosing what parameter will be output on each channel. Instructions that appear here allow adjustment and calibration the voltage signals associated with each output as well as calibration of the analog to digital converter circuitry on the motherboard.	DIAG AIO	6.13.4, through 6.13.6
DISPLAY SEQUENCE CONFIGURATION: Allows the user to program which concentration values are displayed in the .	DIAG DISP	6.13.7.1
OPTIC TEST: When activated, the analyzer performs an optic test, which turns on an LED located inside the sensor module near the PMT (Fig. 10-15). This diagnostic tests the response of the PMT without having to supply span gas.	DIAG OPTIC	6.13.7.2
ELECTRICAL TEST: When activated, the analyzer performs an electric test, which generates a current intended to simulate the PMT output to verify the signal handling and conditioning of the PMT preamp board.	DIAG ELEC	6.13.7.3
OZONE GEN OVERRIDE: Allows the user to manually turn the O ₃ generator on or off. This setting is retained when exiting DIAG . During initial power up TMR (timer) is displayed while the Ozone brick remains off for the first 30 minutes.	DIAG OZONE	6.13.7.4
FLOW CALIBRATION: This function is used to calibrate the gas flow output signals of sample gas and ozone supply. These settings are retained when exiting DIAG .	DIAG FCAL	6.13.7.5

4.13.1. ACCESSING THE DIAGNOSTIC FEATURES

To access the DIAG functions press the following keys:



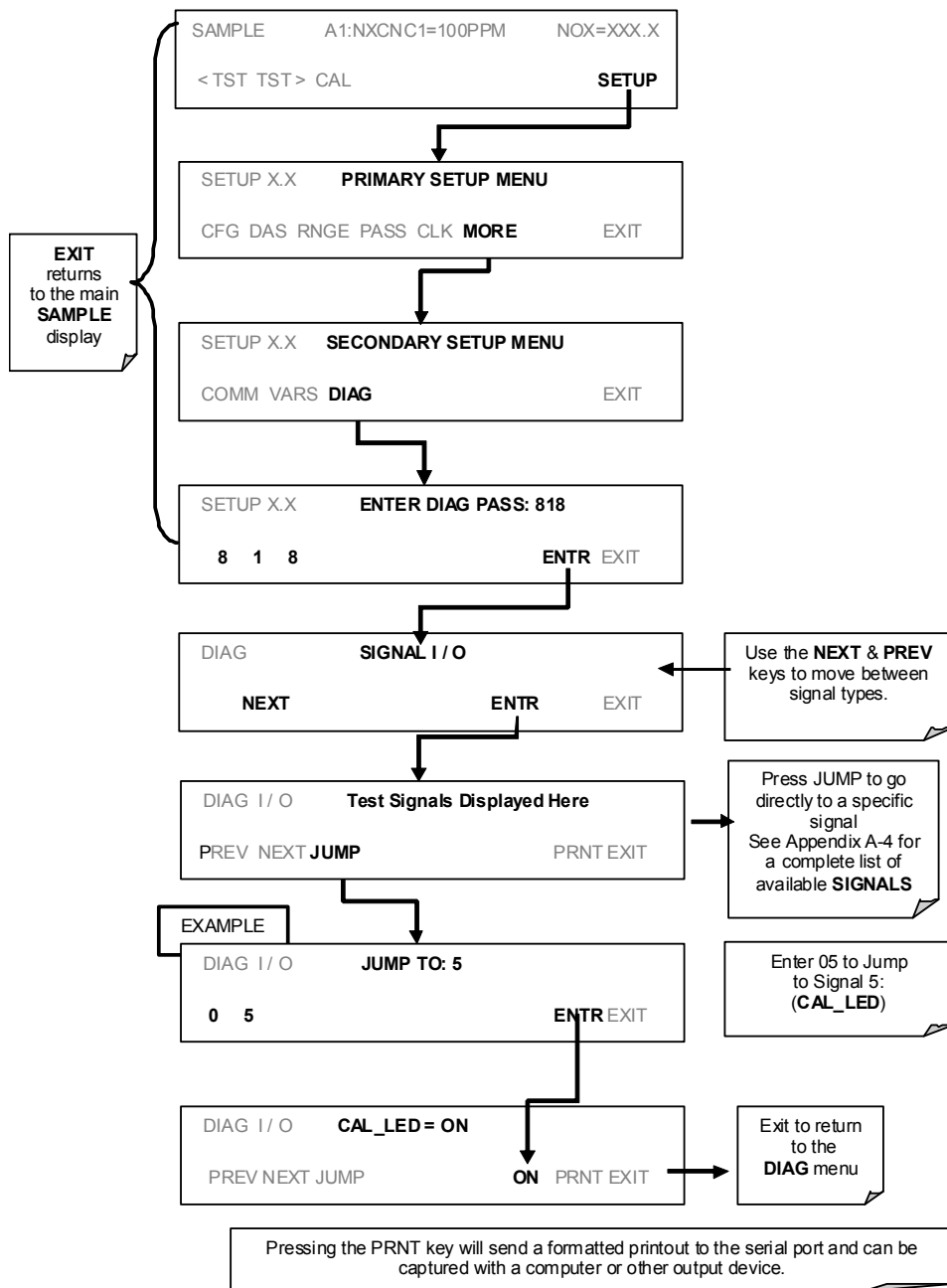
4.13.2. SIGNAL I/O

The signal I/O diagnostic mode allows to review and change the digital and analog input/output functions of the analyzer. See Appendix A-4 for a complete list of the parameters available for review under this menu.

Note

Changes to signal I/O settings will remain in effect only until the signal I/O menu is exited. Exceptions are the ozone generator override and the flow sensor calibration, which remain as entered when exiting.

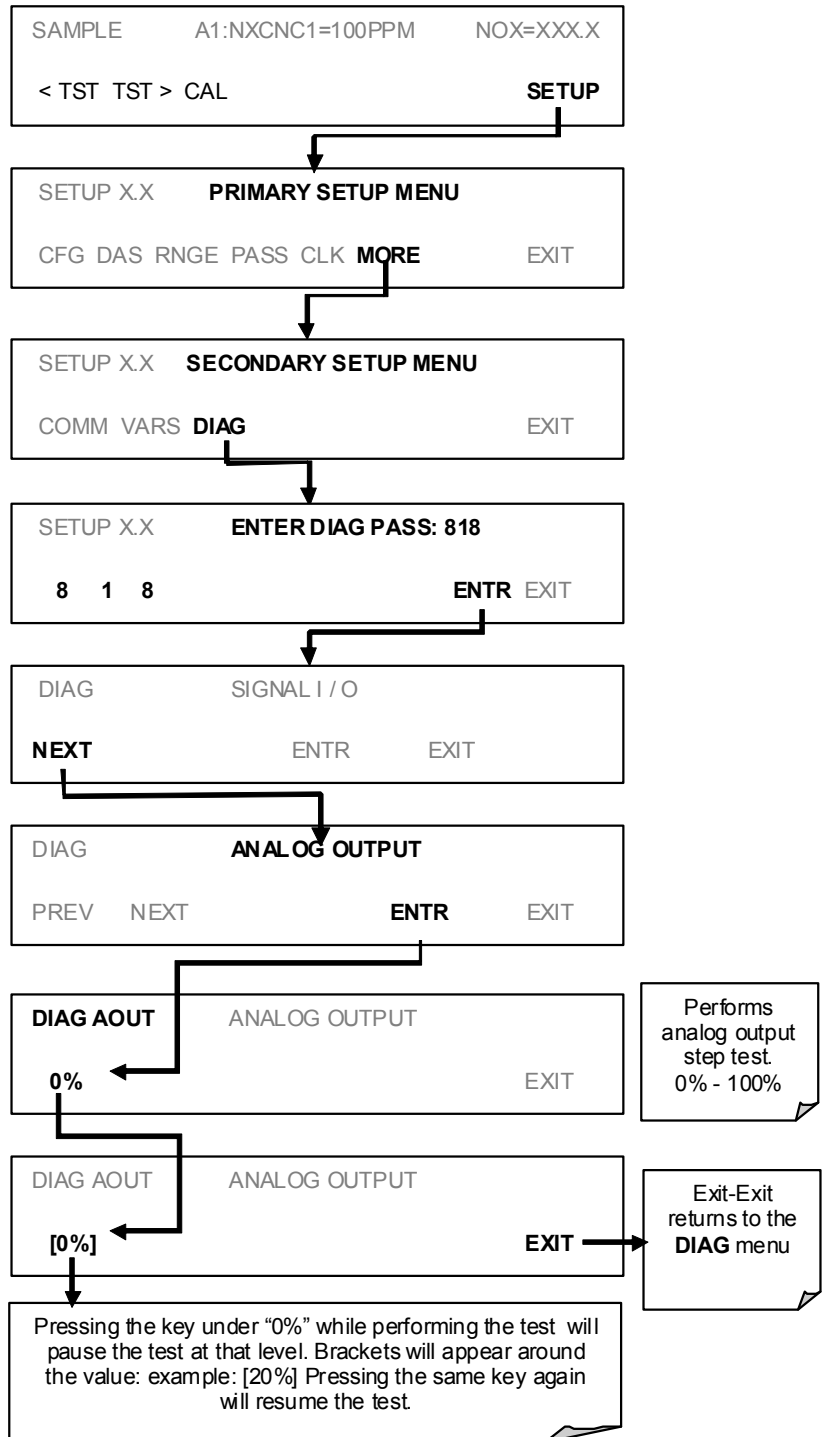
To enter the signal I/O test mode, press:



4.13.3. ANALOG OUTPUT STEP TEST

This test can be used to check the accuracy and proper operation of the analog outputs. The test forces all four analog output channels to produce signals ranging from 0% to 100% of the full scale range in 20% increments. This test is useful to verify the operation of the data logging/recording devices attached to the analyzer.

To begin the Analog Output Step Test press:



4.13.4. ANALOG OUTPUTS AND REPORTING RANGES

4.13.4.1. Analog Output Signals Available on the 9110TH/M

The analyzer has four analog output signals, accessible through a connector on the rear panel.

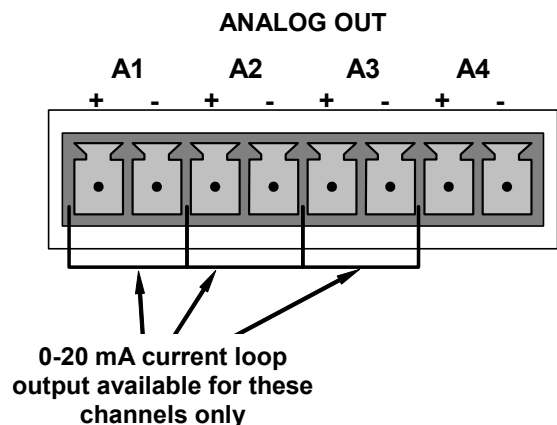


Figure 4-10: Analog Output Connector Key

The signal levels of each output can be independently configured as follows. An over-range feature is available that allows each range to be usable from -5% to + 5% of its nominal scale:

Table 4-17: Analog Output Voltage Ranges with Over-Range Active

RANGE	MINIMUM OUTPUT	MAXIMUM OUTPUT
0-0.1 V	-5 mV	+105 mV
0-1 V	-0.05 V	+1.05 V
0-5 V	-0.25 V	+5.25 V
0-10 V	-0.5 V	+10.5 V

The default offset for all ranges is 0 VDC.

Pin assignments for the ANALOG output connector at the rear panel of the instrument:

Table 4-18: Analog Output Pin Assignments

PIN	ANALOG OUTPUT	VOLTAGE SIGNAL	CURRENT SIGNAL
1	A1	V Out	I Out +
2		Ground	I Out -
3	A2	V Out	I Out +
4		Ground	I Out -
5	A3	V Out	I Out +
6		Ground	I Out -
7	A4	V Out	Not Available
8		Ground	Not Available

Additionally **A1**, **A2** and **A3** may be equipped with optional 0-20 mA current loop drivers. **A4** is not available for the current loop option.

Table 4-19: Analog Output Current Loop Range

RANGE	MINIMUM OUTPUT	MAXIMUM OUTPUT
0-20 mA	0 mA	20 mA
These are the physical limits of the current loop modules, typical applications use 2-20 or 4-20 mA for the lower and upper limits. Please specify desired range when ordering this option. The default offset for all ranges is 0 mA.		

All of these outputs can be configured output signals representing any of the DAS parameters available on this model (See Table A-6 of Appendix A.5 for a complete list).

The ability to select any one of the 9110TH/M's 40+ DAS data types coupled with the ability to select from a variety of signal ranges and scales makes the analog outputs of the 9110TH/M extremely flexible.

Table 4-20: Example of Analog Output Configuration for 9110TH/M

OUTPUT	DAS PARAMETER ASSIGNED	SIGNAL SCALE
A1	NXCNC1	0-5 V
A2	N2CNC2	4-20 mA ¹
A3	PMTDET	0 - 1 V
A4	O2CONC	0-10 V
¹ With current loop option installed		

4.13.4.2. Physical Range versus Analog Output Reporting Ranges

The entire measurement range of the analyzer is quite large, 0 – 5,000 ppm for the 9110TH and 0-200 PPM for the 9110TM, but many applications use only a small part of the analyzer's full measurement range. This creates two performance challenges:

1. The width of the analyzer's physical range can create data resolution problems for most analog recording devices. For example, in an application where a 9110TH is being used to measure an expected concentration of typically less than 200 ppm NO_x, the full scale of expected values is only 4% of the instrument's full 5000 ppm measurement range. Unmodified, the corresponding output signal would also be recorded across only 4% of the range of the recording device.

The 9110TH/M solves this problem by allowing the user to select a scaled reporting range for the analog outputs that only includes that portion of the physical range relevant to the specific application. Only the reporting range of the analog outputs is scaled, the physical range of the analyzer and the readings displayed on the front panel remain unaltered.

2. Applications where low concentrations of NO, NO₂ and NO_x are measured require greater sensitivity and resolution than typically necessary for measurements of higher concentrations.

The 9110TH/M solves this issue by using two hardware physical ranges that cover the instruments entire measurement range The analyzer's software automatically

selects which physical range is in effect based on the analog output reporting range selected by the user:

FOR THE 9110TM:

- Low range spans 0 to 20 ppm NO_x (20 ppm = 5 V);
- High range spans 0-200 ppm NO_x (200 ppm = 5 V).

If the high end of the selected reporting range is \leq 20 ppm. The low physical range is selected. If the high end of the selected reporting range is $>$ 20 ppm. The high physical range is selected.

FOR THE 9110TH:

- Low range spans 0 to 500 ppm NO_x (500 ppm = 5 V);
- High range spans 0-5000 ppm NO_x (5000 ppm = 5 V).
- If the high end of the selected reporting range is \leq 500 ppm. The low physical range is selected. If the high end of the selected reporting range is $>$ 500 ppm. The high physical range is selected.

Once properly calibrated, the analyzer's front panel will accurately report concentrations along the entire span of its 0 and 200 ppm or 5,000 ppm physical range regardless of which reporting range has been selected for the analog outputs and which physical range is being used by the instruments software.

Both reporting ranges need to be calibrated independently to the same span gas concentrations in order to allow switching back and forth between high and low ranges.

4.13.5. ANALOG I/O CONFIGURATION

4.13.5.1. The Analog I/O Configuration Submenu.

Table 4-21 lists the analog I/O functions that are available in the 9110TH/M.

Table 4-21: DIAG - Analog I/O Functions

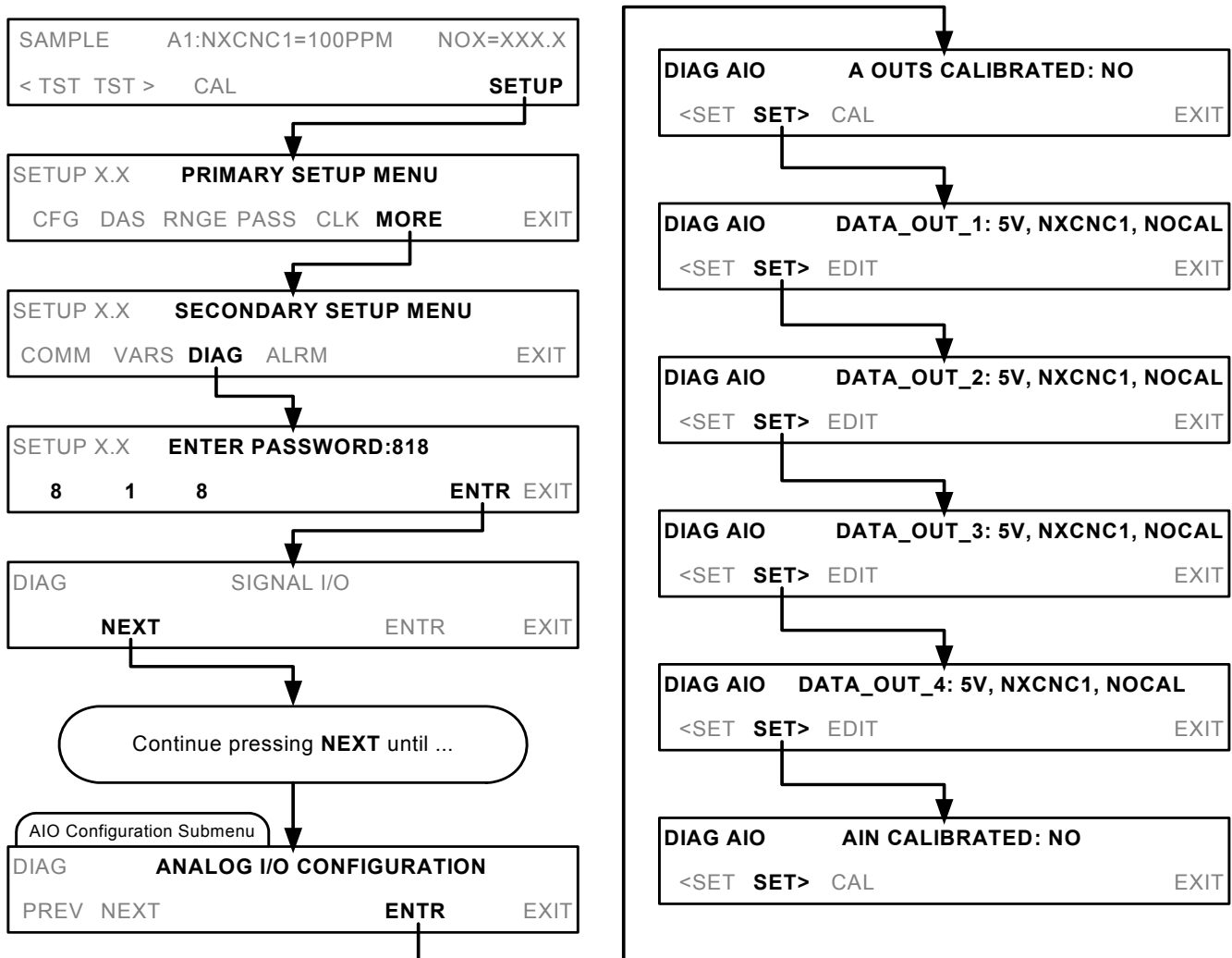
SUB MENU	FUNCTION
AOUTS CALIBRATED:	Shows the status of the analog output calibration (YES/NO) and initiates a calibration of all analog output channels.
DATA_OUT_1:	Configures the A1 analog output: RANGE ¹ : Selects the signal type (voltage or current loop) and full scale value of the output. OVERRANGE : Turns the ± 5% over-range feature ON/OFF for this output channel. REC_OFS ¹ : Sets a voltage offset (not available when RANGE is set to CURRENT loop. AUTO_CAL ¹ : Sets the channel for automatic or manual calibration CALIBRATED ¹ : Performs the same calibration as AOUT CALIBRATED , but on this one channel only. OUTPUT : Turns the output channel ON/OFF. A signal. Equal to the low end of the output scale (zero point) is still output by the analyzer, but no data is sent. DATA : Allows the user to select which DAS parameter to be output. SCALE : Sets the top end of the reporting range scale for this channel. The analyzer automatically chooses the units of measure appropriate for the DAS parameter chosen (e.g. ppm for concentration parameters; in-Hg-A for pressure measurements, etc.) UPDATE : Sets the time interval at which the analyzer updates the data being output on the channel.
DATA_OUT_2	Same as for DATA_OUT_1 but for analog channel 2 (NO)
DATA_OUT_3	Same as for DATA_OUT_1 but for analog channel 3 (NO ₂)
DATA_OUT_4	Same as for DATA_OUT_1 but for analog channel 4 (O ₂)
AIN CALIBRATED	Shows the calibration status (YES/NO) and initiates a calibration of the analog to digital converter circuit on the motherboard.
XIN1 . . . XIN8	For each of 8 external analog input channels, shows the gain, offset, engineering units, and whether the channel is to show up as a Test function.
¹ Changes to RANGE or REC_OFS require recalibration of this output.	

To configure the analyzer’s four analog outputs, set the electronic signal type of each channel and calibrate the outputs. This consists of:

1. Selecting an output type (voltage or current, if an optional current output driver has been installed) and the signal level that matches the input requirements of the recording device attached to the channel.
2. Determine if the over-range feature is needed and turn it on or off accordingly.
3. If a Voltage scale is in use, a bipolar recorder offset may be added to the signal if required (Section 4.13.5).
4. Choose an DAS parameter to be output on the channel.

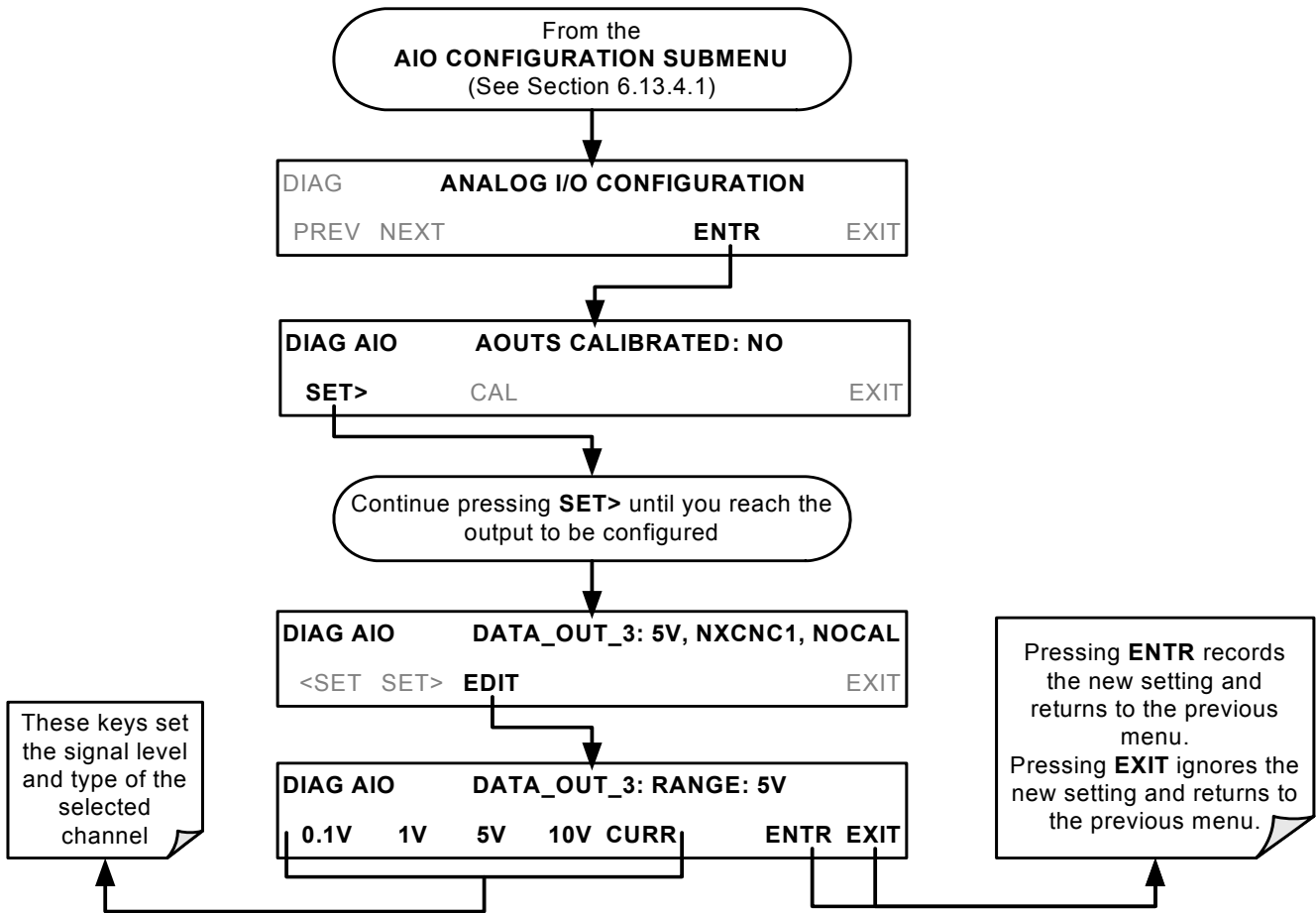
5. Set the reporting range scale for the data type chosen.
6. Set the update rate for the channel.
7. Calibrating the output channel. This can be done automatically or manually for each channel (see Sections 4.13.6).

To access the analog I/O configuration sub menu, press:



4.13.5.2. Analog Output Signal Type and Range Selection

To select an output signal type (DC Voltage or current) and level for one output channel press:



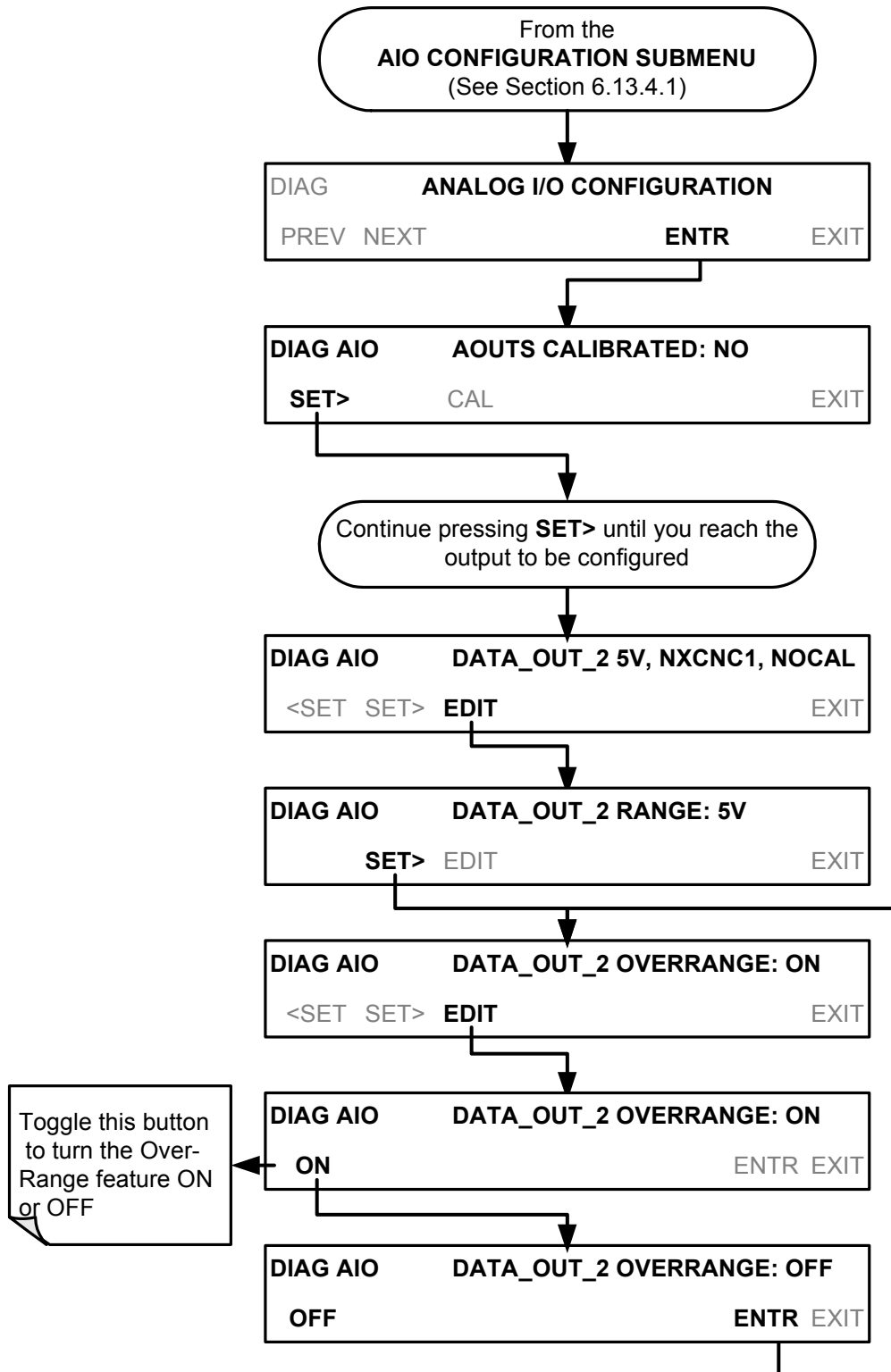
4.13.5.3. Turning the Analog Output Over-Range Feature ON/OFF

In its default configuration a $\pm 5\%$ over-range is available on each of the 9110TH/M's analog output channels. This over-range can be disabled if your recording device is sensitive to excess voltage or current.

Note

Instruments with current range options installed on one or more of the outputs often are delivered from the factory with the over-range feature turned OFF on those channels.

To Turn the over-range feature on or off, press:

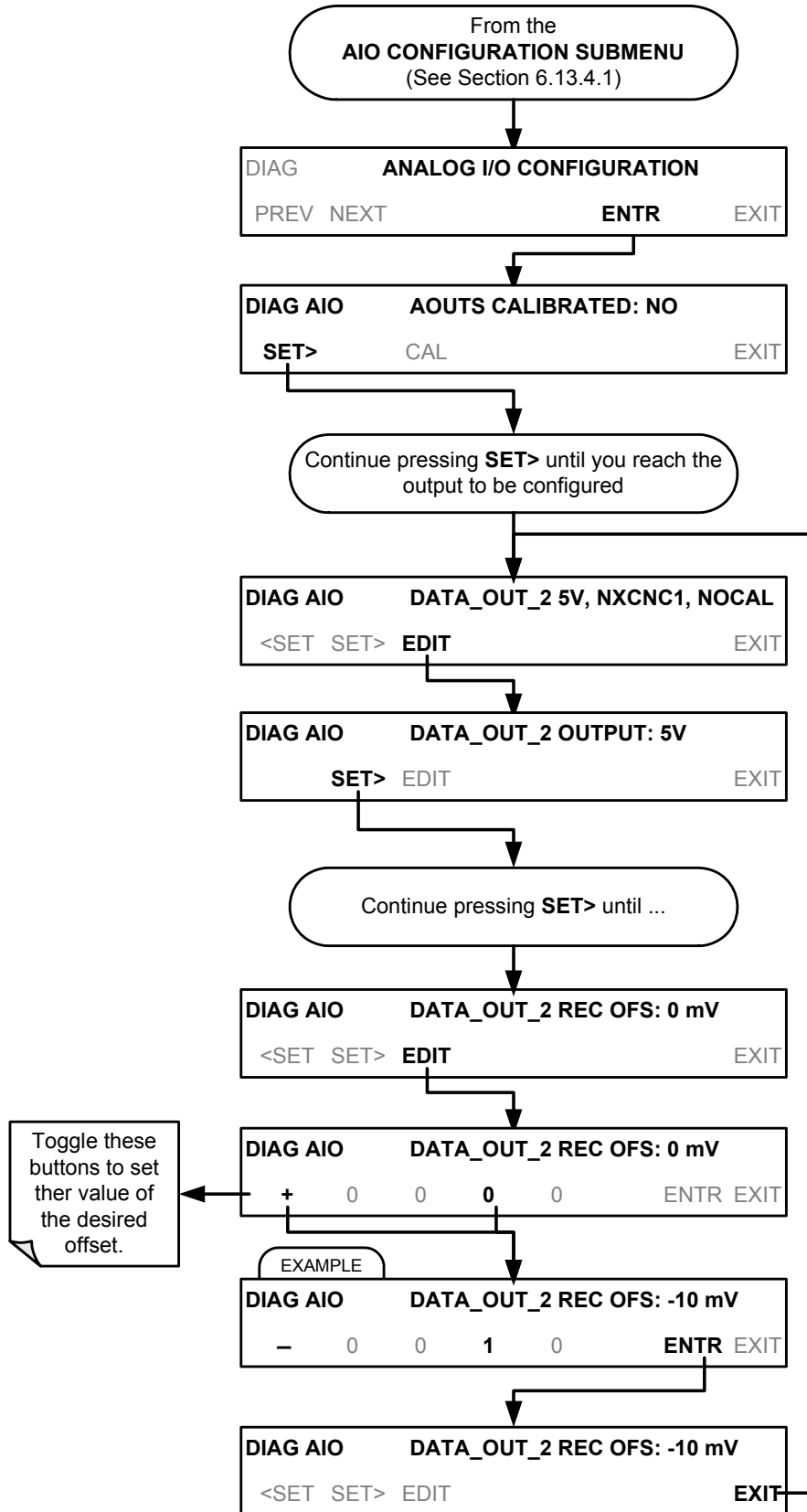


4.13.5.4. Adding a Recorder Offset to an Analog Output

Some analog signal recorders require that the zero signal is significantly different from the baseline of the recorder in order to record slightly negative readings from noise

around the zero point. This can be achieved in the 9110TH/M by defining a zero offset, a small voltage (e.g., 10% of span).

To add a zero offset to a specific analog output channel, press:



4.13.5.5. Assigning a DAS Parameter to an Analog Output Channel

The 9110TH/M analog output channels can be assigned to output data from any of the 40+ available DAS parameters (see Table A-6 of Appendix A.5). The default settings for the four output channels are:

Table 4-22: Analog Output Data Type Default Settings

PARAMETER	CHANNEL DEFAULT SETTING			
	A1	A2	A3	A4 ³
DATA TYPE ¹	NXCNC1	NOCNC1	N2CNC1	NXCNC2
RANGE	0 - 5 VDC ²			
REC OFS	0 mVDC			
AUTO CAL.	ON			
CALIBRATED	NO			
OUTPUT	ON			
SCALE	100 ppm			
UPDATE	5 sec			
¹ See Table A-6 of 9110TH/M Appendix A for definitions of these DAS data types				
² Optional current loop outputs are available for analog output channels A1-A3.				
³ On analyzers with O ₂ sensor options installed, DAS parameter O2CONC is assigned to output A4.				

4.13.5.6. DAS Configuration Limits

The number of DAS objects are limited by the instrument's finite storage capacity. For information regarding the maximum number of channels, parameters, and records and how to calculate the file size for each data channel, refer to the DAS manual downloadable from the Teledyne API website at <http://www.teledyne-api.com/manuals/> under Special Manuals.

4.13.5.7. Reporting Gas Concentrations via the 9110TH/M Analog Output Channels

While the DAS parameters available for output over via the analog channels A1 thru A4 include a wide variety internal temperatures, gas flows and pressures as well as certain key internal voltage levels, most of the DAS parameters are related to gas concentration levels.

Two parameters exist for each gas type measured by the 9110TH/M. They are generally referred to as range 1 and range 2 (e.g. NXCNC1 and NXCNC2; NOCNC1 and NOCNC2; etc.). These take the place of the high and low concentration ranges of previous versions of the analyzer software. Concentrations for each range are computed using separate slopes and offsets which are also stored via separate DAS parameters.

Note

If an analog output channel is set to report a gas concentration (e.g. NXCNC1; NO_x concentration; Range 1) it is generally a good idea to use 80% of the reporting range for that channel for the span point calibration. If both available parameters for a specific gas type are being reported (e.g. NXCNC1 and NXCNC2) separate calibrations should be carried out for each parameter.

The available gas concentration DAS parameters for output via the 9110TH/M analog output channels are:

Table 4-23: Analog Output DAS Parameters Related to Gas Concentration Data

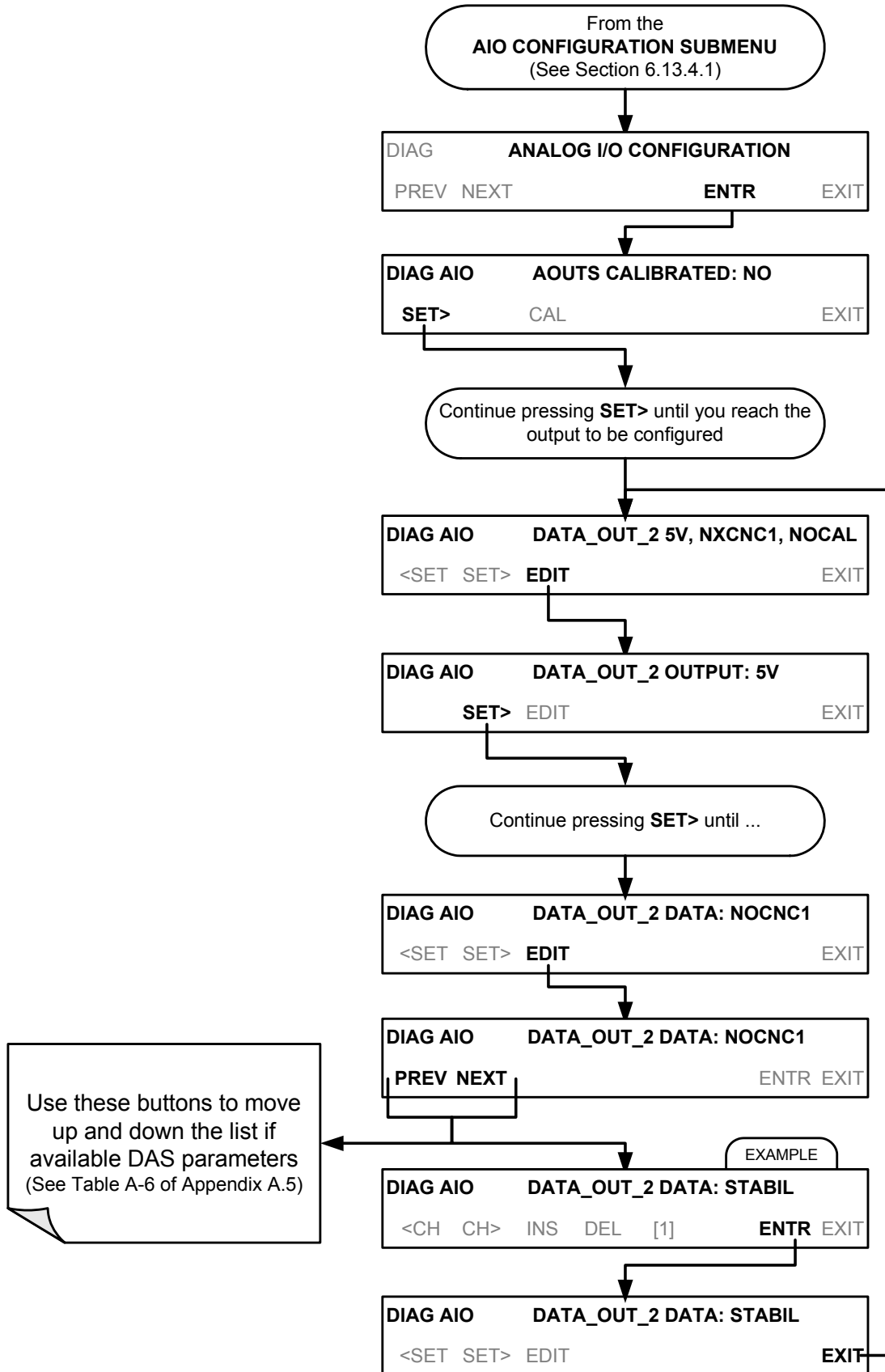
REPORTING RANGE	PARAMETER NAME ¹	DESCRIPTION
NO _x Range 1 (LOW)	NXCNC1	Concentration
	NXSLP1	Slope
	NXOFS1	Offset
	NXZSC1	Concentration during calibration, prior to computing new slope and offset
NO _x RANGE 2 (HIGH)	NXCNC2	Concentration
	NXSLP2	Slope
	NXOFS2	Offset
	NXZSC2	Concentration during calibration, prior to computing new slope and offset
NO Range 1 (LOW)	NOCNC1	Concentration
	NOSLP1	Slope
	NOOFS1	Offset
	NOZSC1	Concentration during calibration, prior to computing new slope and offset
NO RANGE 2 (HIGH)	NOCNC2	Concentration
	NOSLP2	Slope
	NOOFS2	Offset
	NOZSC2	Concentration during calibration, prior to computing new slope and offset
NO ₂ Range 1 ² (LOW)	N2CNC1	Concentration - Computed with data from NO _x Range 1 and NO Range 1
	N2ZSC1	Concentration during calibration, prior to computing new slope and offset
NO ₂ RANGE 2 ² (HIGH)	N2CNC2	Concentration - Computed with data from NO _x Range 2 and NO Range 2
	N2ZSC2	Concentration during calibration, prior to computing new slope and offset
O ₂ Range ³	O2CONC³	Concentration
	O2OFST³	Slope
	O2SLPE³	Offset
	O2ZSCN³	Concentration during calibration, prior to computing new slope and offset

¹ Parameters are not listed in the order they appear on the DAS list (see Table A-6 or Appendix A.5 for the proper order of the full list of parameters)

² Since NO₂ values are computed rather than measured directly, no separate slope or offset exist.

³ Only available on instruments with O₂ sensor options installed.

To assign a DAS parameter to a specific analog output channel, press,



4.13.5.8. Setting the Reporting Range Scale for an Analog Output

Once the DAS parameter has been set, the top end of the scale must be selected. For concentration values this should be equal to the expected maximum value for the application. The analog channel will scale its output accordingly.

EXAMPLE:

DAS parameter being output: NXCNC1

Maximum value expected: 800 ppm

Output range; 10 V

Output: ...0 ppm	0.000 V
100 ppm	1.250 V
200 ppm	2.500 V
400 ppm	5.000 V
750 ppm	9.375 V

Note

Regardless of how the reporting range for an analog output channel is set, the instrument will continue to measure NO, NO₂ and NO_x accurately for the entire physical range of the instrument (See Section 4.13.4.2 for information on Physical range versus reporting range).

Each output channel can be programmed for a separate gas with independent reporting range.

EXAMPLE:

A1 → NXCNC1 (NO_x Range 1) → 0-1000 ppm NO_x.

A1 → NXCNC2 (NO_x Range 2) → 0-1250 ppm NO_x.

A3 → NOCNC1 (NO_x Range 1) → 0-500 ppm NO.

A4 → N2CNC1 (NO₂ Range 1) → 0-750 ppm NO₂.

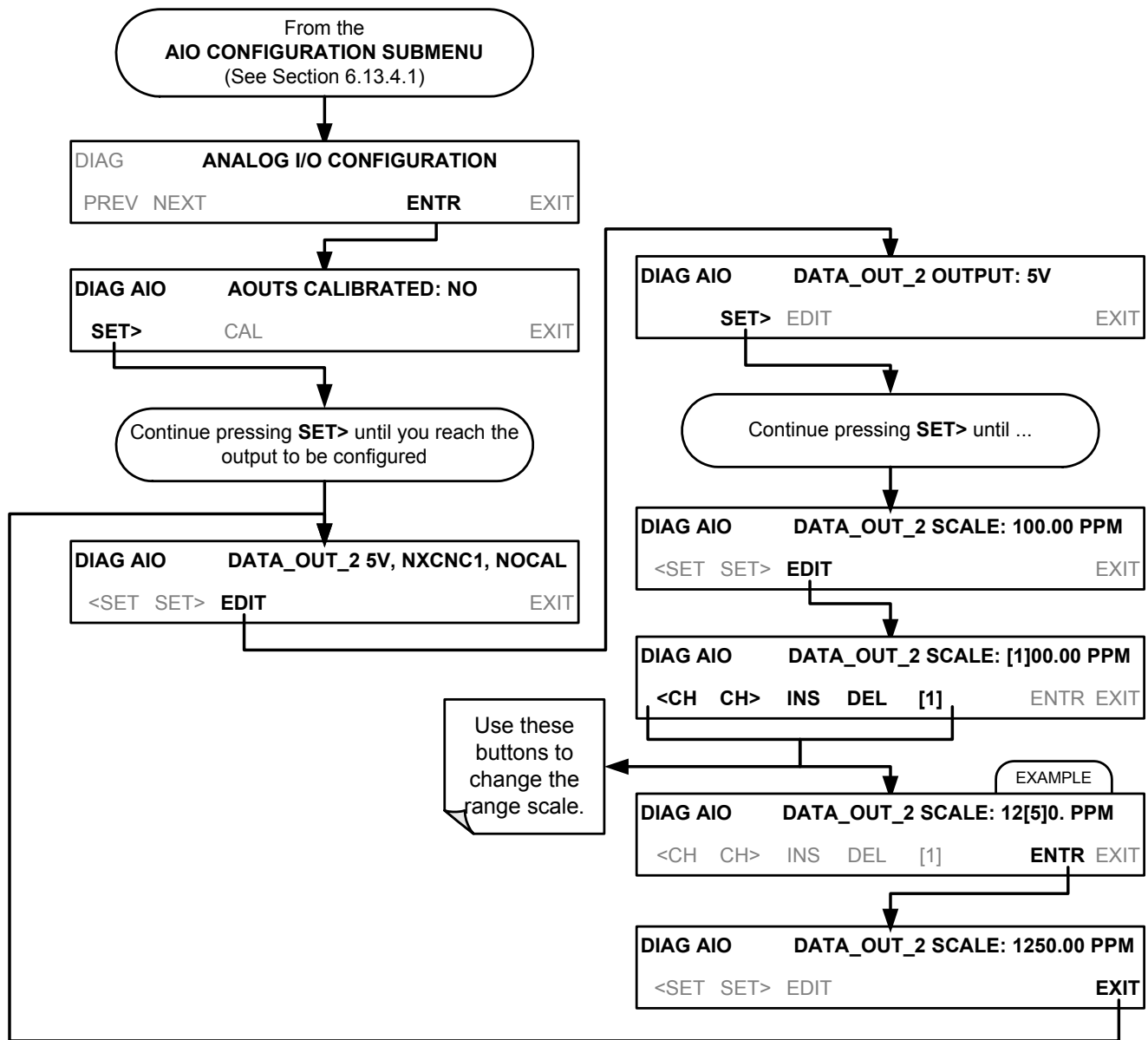
Note

While Range 1 for each gas type is often referred to as the LOW range and Range 2 as the HIGH range, this is simply a naming convention. The upper limit for each range can be set to any value.

EXAMPLE: A1 → NXCNC1 (NO_x Range 1) → 0-1500 ppm NO_x

A2 → NXCNC2 (NO_x Range 2) → 0-1000 ppm NO_x

To set the reporting range for an analog output, press:



RANGE SELECTION TOUCH SCREEN CONTROL BUTTON FUNCTIONS

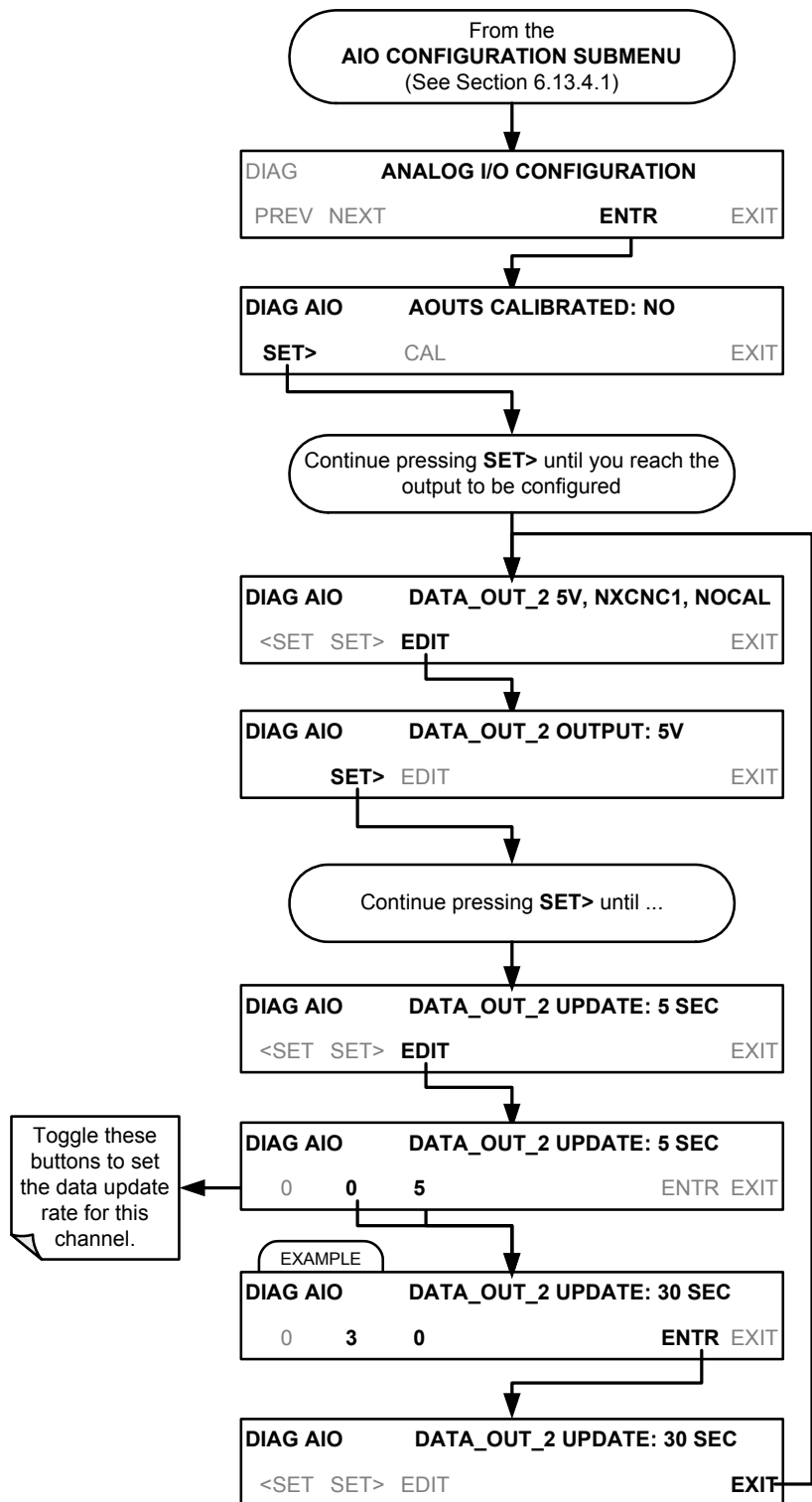
BUTTON	FUNCTION
<CH	Moves the cursor one character to the left.
CH>	Moves the cursor one character to the right.
INS	Inserts a character before the cursor location.
DEL	Deletes a character at the cursor location.
[?]	Press this key to cycle through the range of numerals and characters available for insertion: 0-9; as well as "+" & "-".
ENTR	Accepts the new setting and returns to the previous menu.
EXIT	Ignores the new setting and returns to the previous menu.

Some keys only appear as needed.

4.13.5.9. Setting Data Update Rate for an Analog Output

The data update rate for the 9110TH/M analog outputs can be adjusted to match the requirements of the specific DAS parameter chosen for each channel. For instance, if the parameter NXCNC1 (NO_x concentration; Range 1) is chosen for channel A1 on an instrument set for dual gas measurement mode, it would be meaningless to have an update rate of less than 30 seconds, since the NO_x-No measurement cycle takes that long to complete. On the other hand, if the channel were set to output the PMTDET voltage or the temperature of the moly converter, it might be useful to have output updated more frequently.

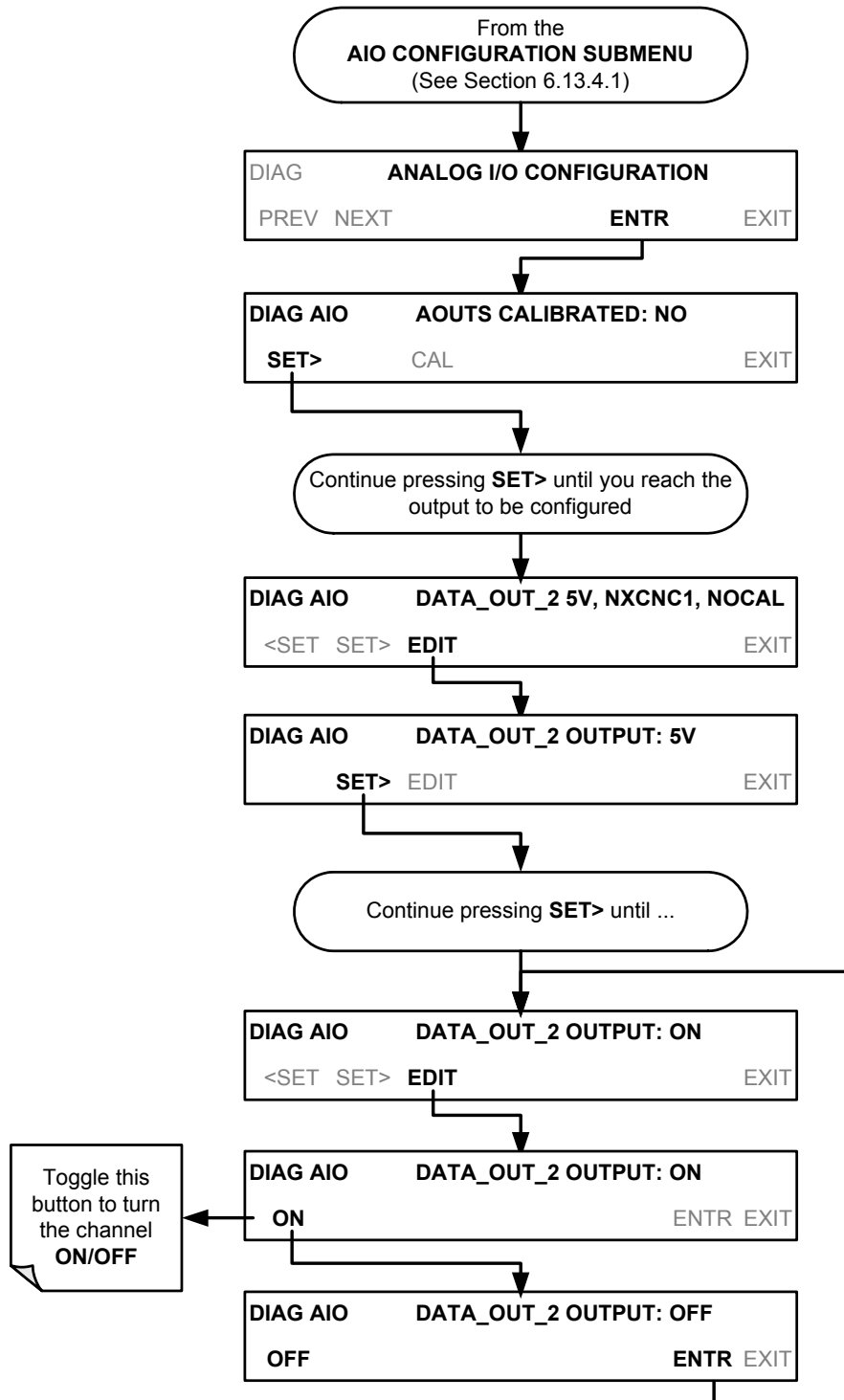
To change the update rate for an individual analog output channel, press:



4.13.5.10. Turning an Analog Output On or Off

Each output can be temporarily turned off. When off, no data is sent to the output. Electronically, it is still active, but there is simply no data being output, so the signal level at the rear of the instrument will fall to zero.

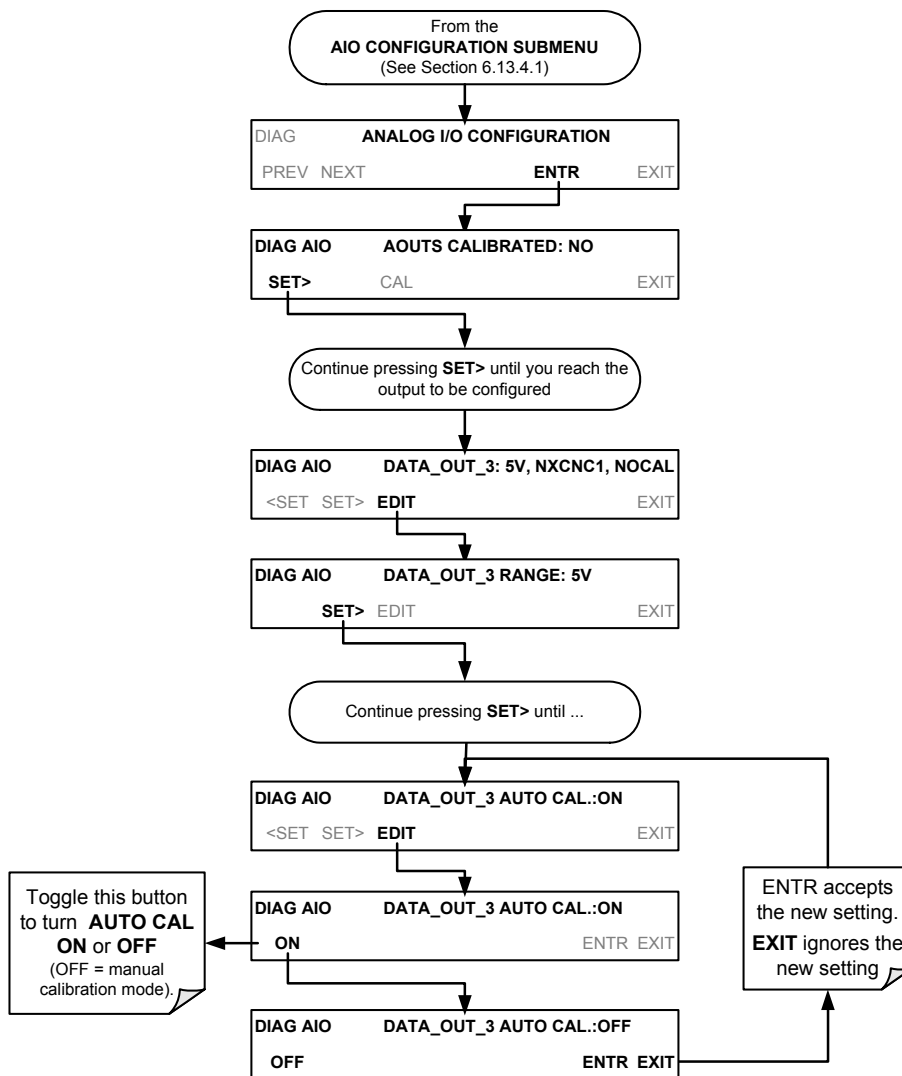
To turn an individual analog output channel ON/OFF, press:



4.13.6. ANALOG OUTPUT CALIBRATION

Analog calibration needs to be carried out on first startup of the analyzer (performed in the factory as part of the configuration process) or whenever recalibration is required. The analog outputs can be calibrated automatically, either as a group or individually (Section 4.13.6.1), or adjusted manually (see Section 4.13.6). (Manual calibration should be used for the 0.1V range or in cases where the outputs must be closely matched to the characteristics of the recording device. Manual calibration requires the AUTO CAL feature to be disabled). During automatic calibration the analyzer tells the output circuitry to generate a zero mV signal and high-scale point signal (usually about 90% of chosen analog signal scale) then measures actual signal of the output. Any error at zero or high-scale is corrected with a slope and offset.

To enable or disable the Auto-Cal feature for one output channel, press.

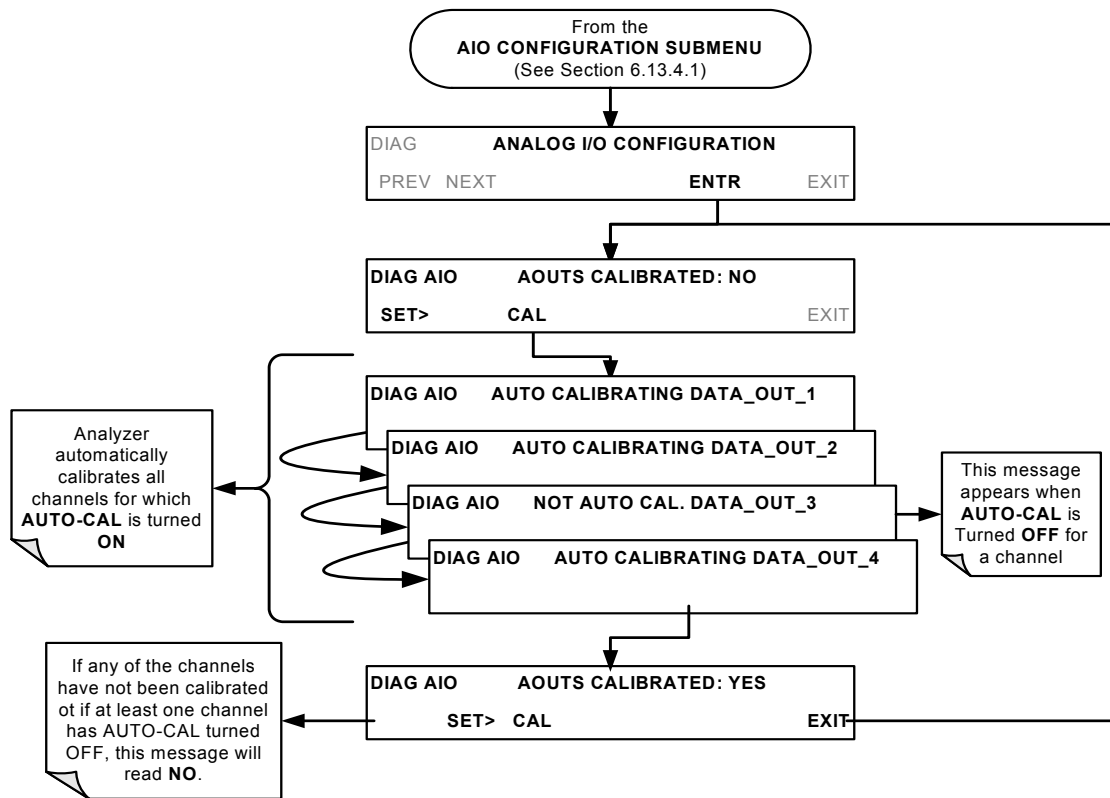


Note

Channels with current loop output options cannot be calibrated automatically. Outputs Configured for 0.1V full scale should always be calibrated manually.

4.13.6.1. Automatic Analog Output Calibration

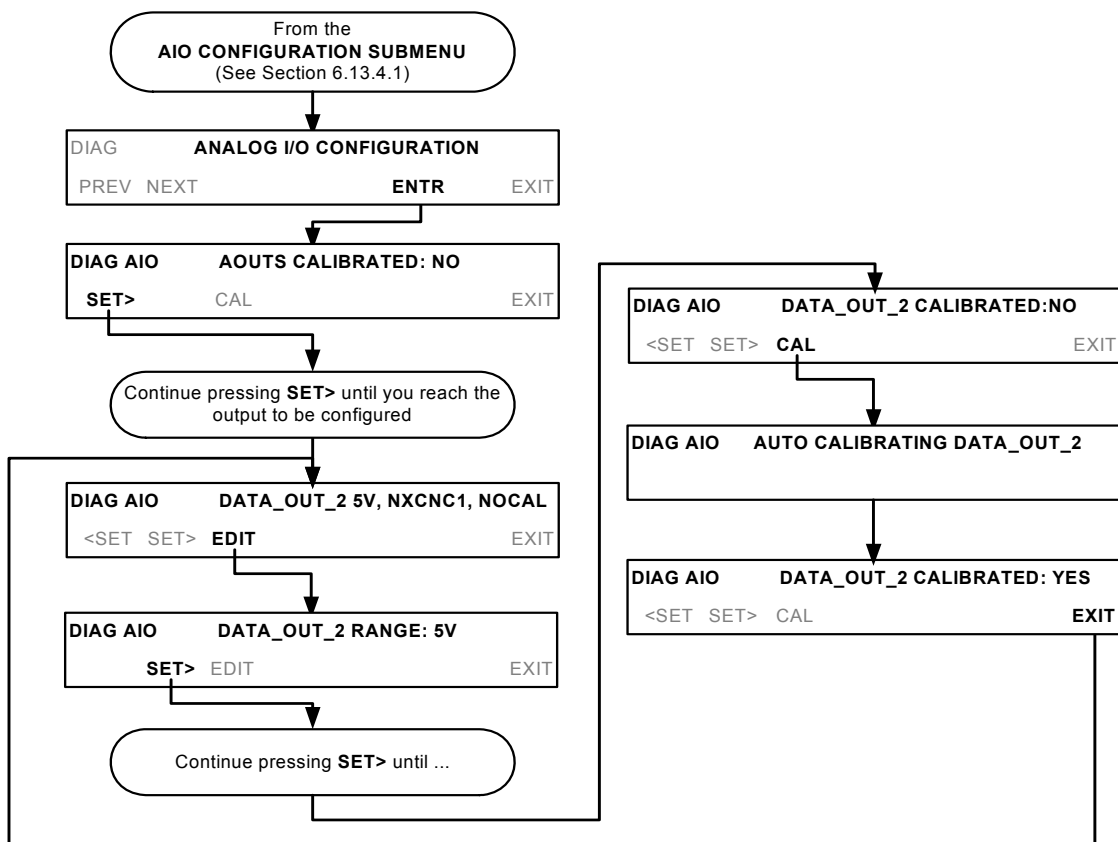
To calibrate the outputs as a group with the **AOUTS CALIBRATION** command, press:



Note

Manual calibration should be used for the 0.1V range or in cases where the outputs must be closely matched to the characteristics of the recording device.

To initiate an automatic calibration for an individual output channel, press:



4.13.6.2. Manual Calibration of Analog Output Configured for Voltage Ranges

For highest accuracy, the voltages of the analog outputs can be manually calibrated.

Note

The menu for manually adjusting the analog output signal level will only appear if the AUTO-CAL feature is turned off for the channel being adjusted.

Calibration is performed with a voltmeter connected across the output terminals (See Figure 6-14) and by changing the actual output signal level using the front panel keys in 100, 10 or 1 count increments.

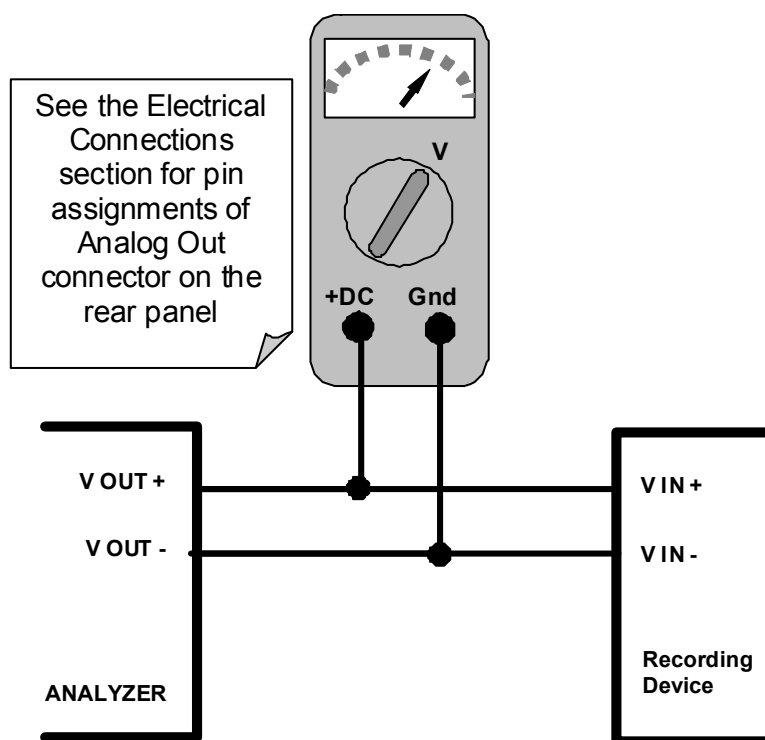
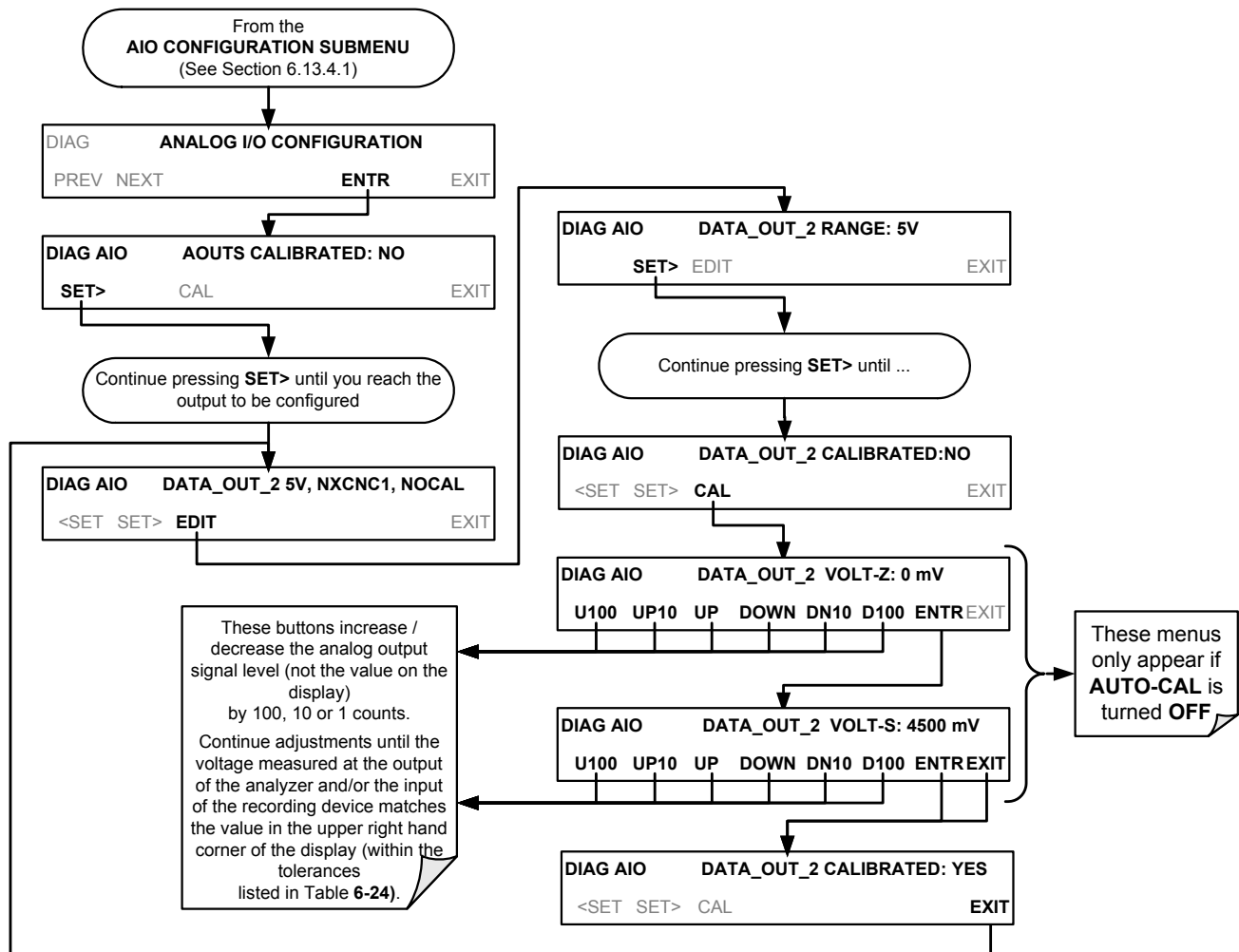


Figure 4-11: Setup for Calibrating Analog Outputs

Table 4-24: Voltage Tolerances for Analog Output Calibration

FULL SCALE	ZERO TOLERANCE	SPAN VOLTAGE	SPAN TOLERANCE	MINIMUM ADJUSTMENT (1 count)
0.1 VDC	±0.0005V	90 mV	±0.001V	0.02 mV
1 VDC	±0.001V	900 mV	±0.001V	0.24 mV
5 VDC	±0.002V	4500 mV	±0.003V	1.22 mV
10 VDC	±0.004V	4500 mV	±0.006V	2.44 mV

To manually adjust the signal levels of an analog output channel, press:



4.13.6.3. Manual Calibration of Analog Outputs Configured for Current Loop Ranges

The current loop output option (see Section 5.4) uses a small converter assembly to change the DC voltage output by the standard voltage output to a current signal ranging between 0-20 mA. Since the exact current increment per voltage count varies from converter to converter and from instrument to instrument, analog outputs with this option installed cannot be calibrated automatically and must be adjusted manually.

Adjusting the signal zero and full scale values of the current loop output is done in a similar manner as manually adjusting analog outputs configured for voltage output except that:

- In this case calibration is performed with a current meter connected in series with the output circuitry (See Figure 4-12).
- Adjustments to the output are made using the front panel touch screen, also in 100, 10 or 1 count increments, but the change in the voltage driving the converter assembly is displayed on the front panel.

- As before, adjustment of the output is performed until the current reading of the meter reaches the desired point (e.g. 2 mA, 4 mA, 20 mA, etc.)

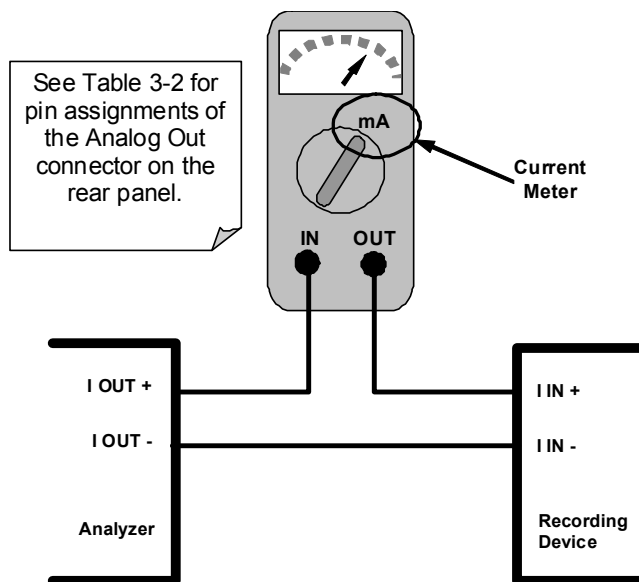


Figure 4-12: Setup for Calibrating Current Outputs

Note

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

If a current meter is not available, an alternative method for calibrating the current loop outputs is to connect a 250 Ω ±1% resistor across the current loop output. Using a voltmeter, connected across the resistor, follow the procedure above but adjust the output to the following values:

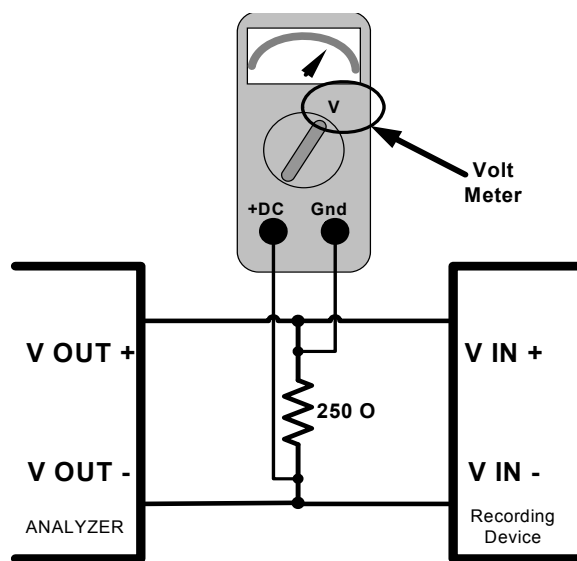
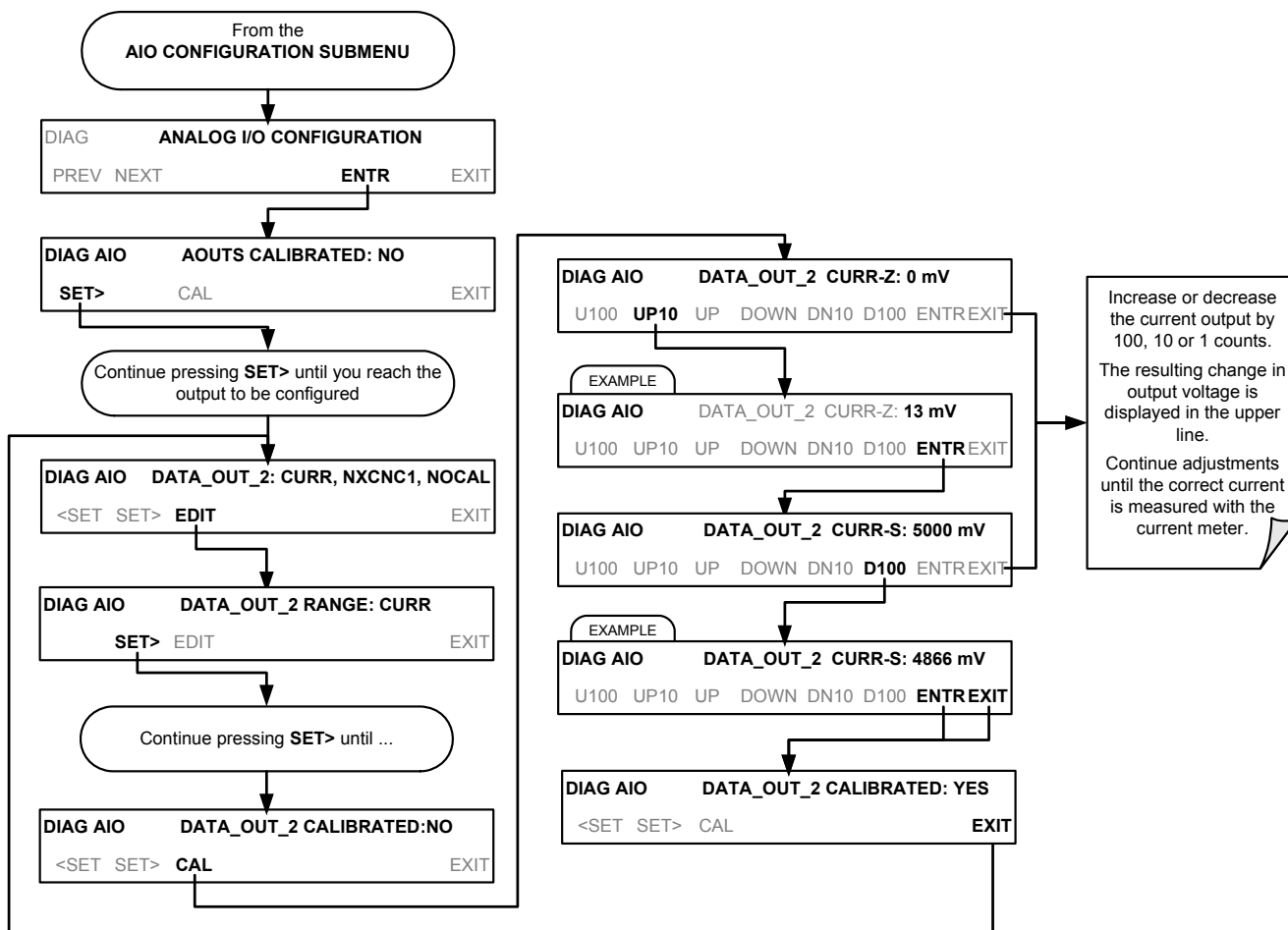


Figure 4-13: Alternative Setup for Calibrating Current Outputs

Table 4-25: Current Loop Output Calibration with Resistor

FULL SCALE	VOLTAGE FOR 2-20 MA (measured across 250Ω resistor)	VOLTAGE FOR 4-20 MA (measured across 250Ω resistor)
0%	0.5 V	1.0 V
100%	5.0 V	5.0 V

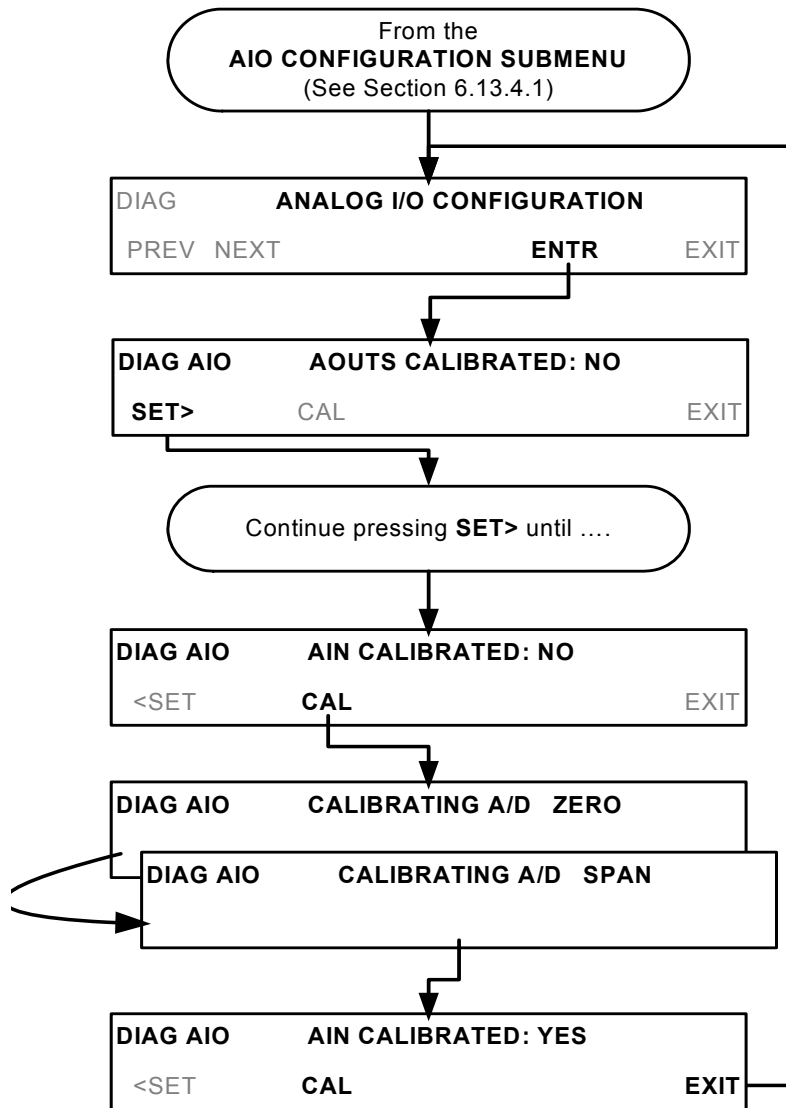
To adjust the zero and span values of the current outputs, press:



4.13.6.4. AIN Calibration

This is the sub-menu calibrates the analyzer’s A-to-D conversion circuitry. This calibration should only be necessary after major repair such as a replacement of CPU, motherboard or power supplies.

To perform a **AIN CALIBRATION**, press:



4.13.6.5. Configuring External Analog Inputs (Option) Channels

To configure the analyzer’s external analog inputs option, define for each channel:

- gain (number of units represented by 1 volt)

- offset (volts)
- engineering units to be represented in volts (each press of the touch screen button scrolls the list of alphanumeric characters from A-Z and 0-9)
- whether to display the channel in the Test functions

To access and adjust settings for the external Analog Inputs option channels press:

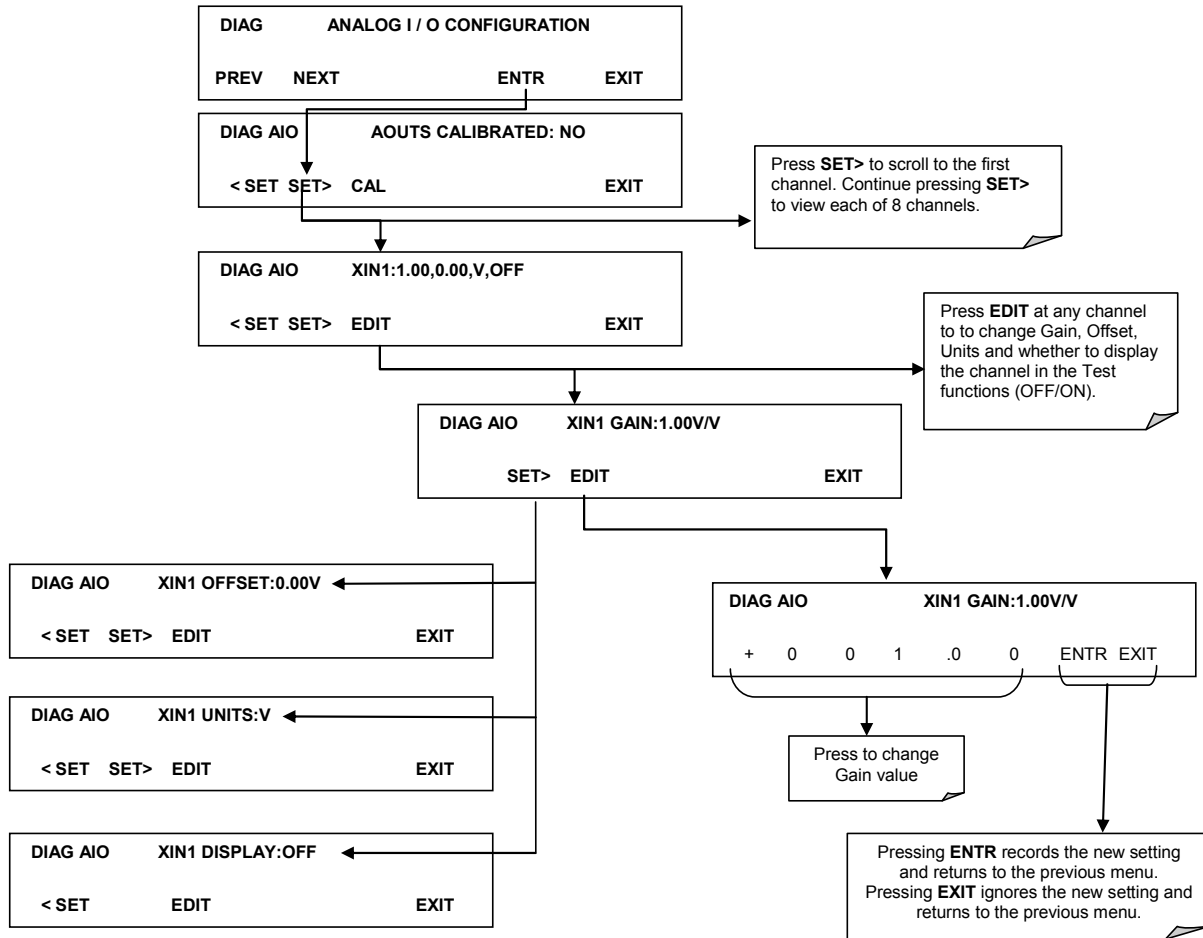


Figure 4-14. DIAG – Analog Inputs (Option) Configuration Menu

4.13.7. OTHER DIAG MENU FUNCTIONS

4.13.7.1. Display Sequence Configuration

The model 9110TH/M analyzer allows the user to choose which gas concentration measurement and reporting range is to be displayed in the concentration field on the instrument's front panel display as well as what order and how long each will appear before analyzer cycle to the next item on the display list.

Note

This 9110TH/M is constantly monitoring all of the gas measurements it is configured to make regardless of which range is being displayed. This feature merely changes how that display sequence occurs, not how the instrument makes measurements.

The software permits the user to choose from the following list of display values:

Table 4-26: 9110TH/M Available Concentration Display Values

DISPLAY VALUE	DESCRIPTION	ASSOCIATED DAS PARAMETER
NOX	NO _x value computed with the slope and offset values for the currently selected NO _x range. ¹	--
NXL	NO _x value computed with the slope and offset values for NO _x reporting range 1 (Low)	NXCNC1
NXH	NO _x value computed with the slope and offset values for NO _x reporting range 2 (High)	NXCNC2
NO	NO value of computed with the slope and offset values for the currently selected NO range ¹	--
NOL	NO value computed with the slope and offset values for NO reporting range 1 (Low)	NOCNC1
NOH	NO value computed with the slope and offset values for NO reporting range 2 (High)	NOCNC2
N2	NO ₂ value of computed with the slope and offset values for the currently selected NO ₂ range ¹	--
N2L	NO ₂ value computed for with the slope and offset values for NO _x reporting range 1 (Low) & NO reporting range 1 (Low)	N2CNC1
N2H	NO ₂ value computed for with the slope and offset values for NO _x reporting range 2 (High) & NO reporting range 2 (High)	N2CNC2
O2	O ₂ concentration value.	O2CONC ²

¹ With the following exceptions this will be reporting range 1 (Low) for the appropriate gas type:

- If the analyzer is in calibration mode, this will be the concentration value computed with the slope and offset for which ever range is being calibrated.
- If the instrument is in either E-Test or O-Test mode, this will be the value computed with the slope and offset values used by those tests.

² Only appears if O₂ sensor option is installed.

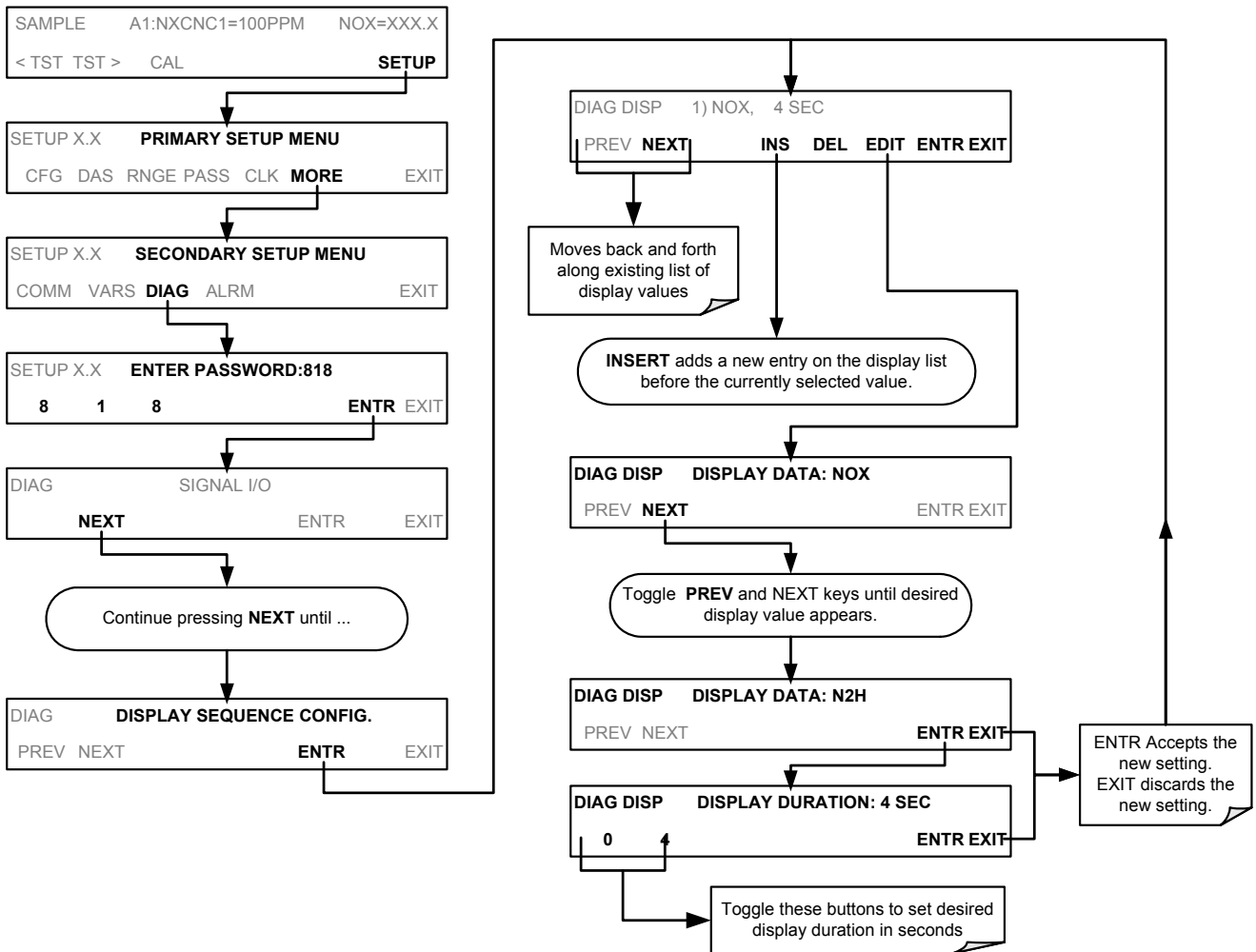
The default settings for this feature are:

Table 4-27: 9110TH/M Concentration Display Default Values

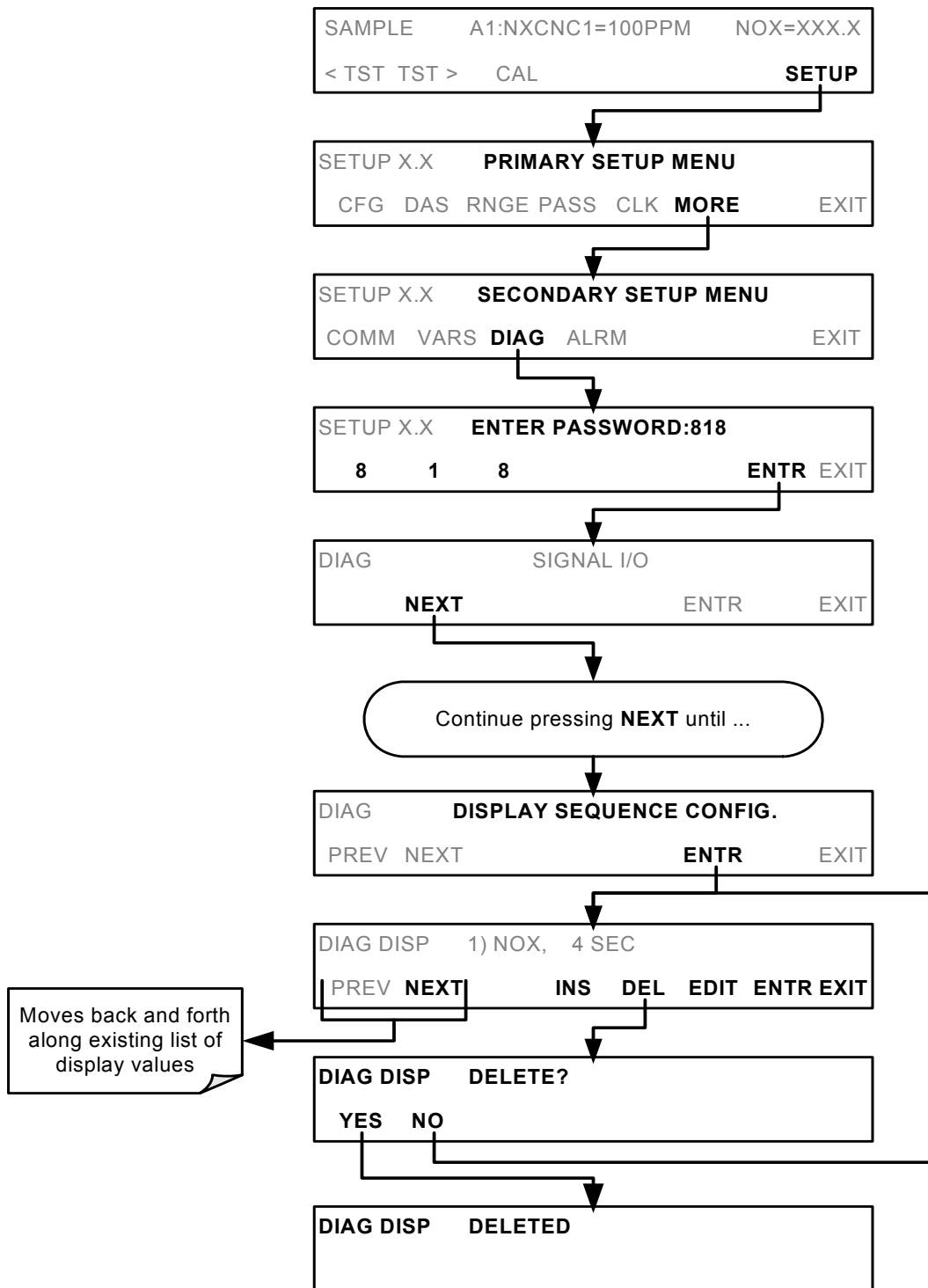
DISPLAY VALUE	DISPLAY DURATION
NOX	4 sec.
NO	4 sec.
NO2	4 sec.
O2	4 sec.

¹ Only appears if O₂ sensor option is installed.

To change these settings, press:

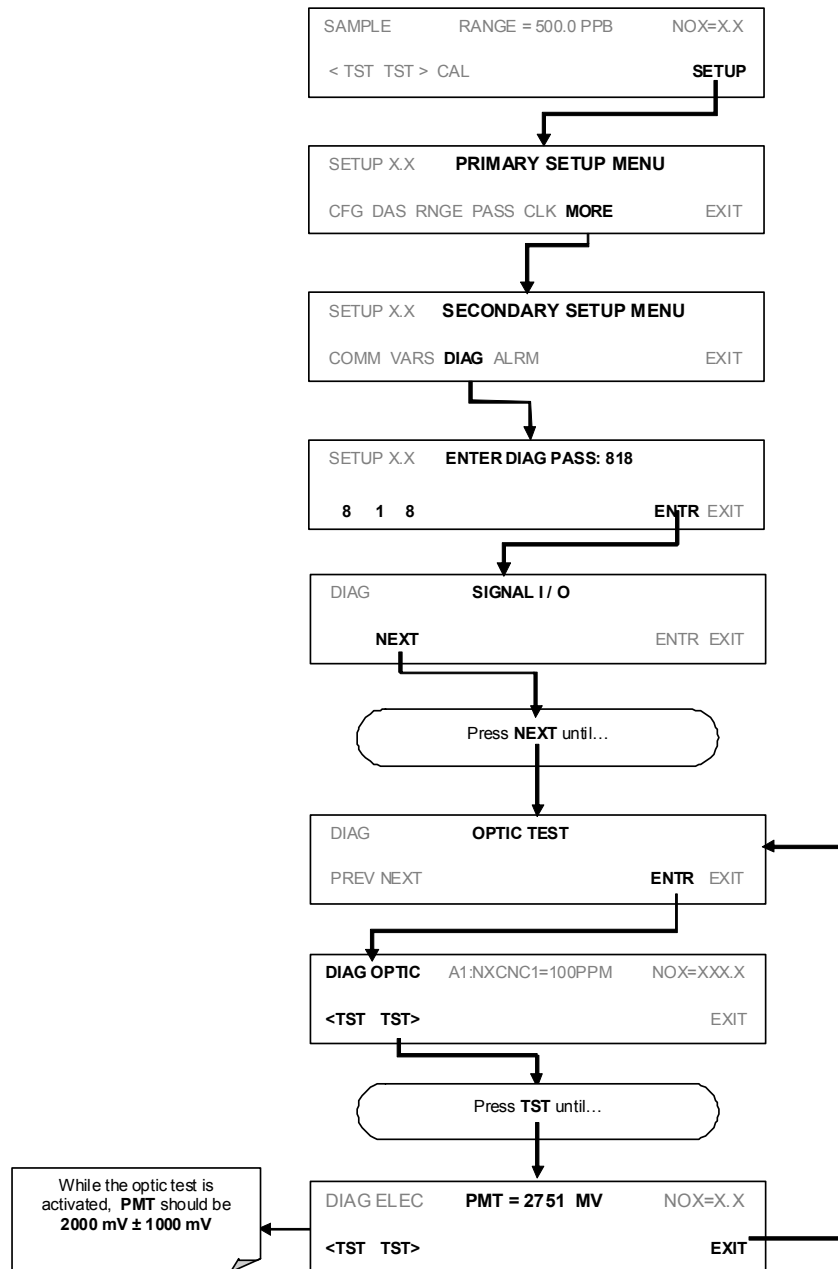


To delete an entry in the display value list, press:



4.13.7.2. Optic Test

The optic test function tests the response of the PMT sensor by turning on an LED located in the cooling block of the PMT (Fig. 10-15). The analyzer uses the light emitted from the LED to test its photo-electronic subsystem, including the PMT and the current to voltage converter on the pre-amplifier board. To make sure that the analyzer measures only the light coming from the LED, the analyzer should be supplied with zero air. The optic test should produce a PMT signal of about 2000±1000 mV. To activate the electrical test press the following touch screen button sequence.



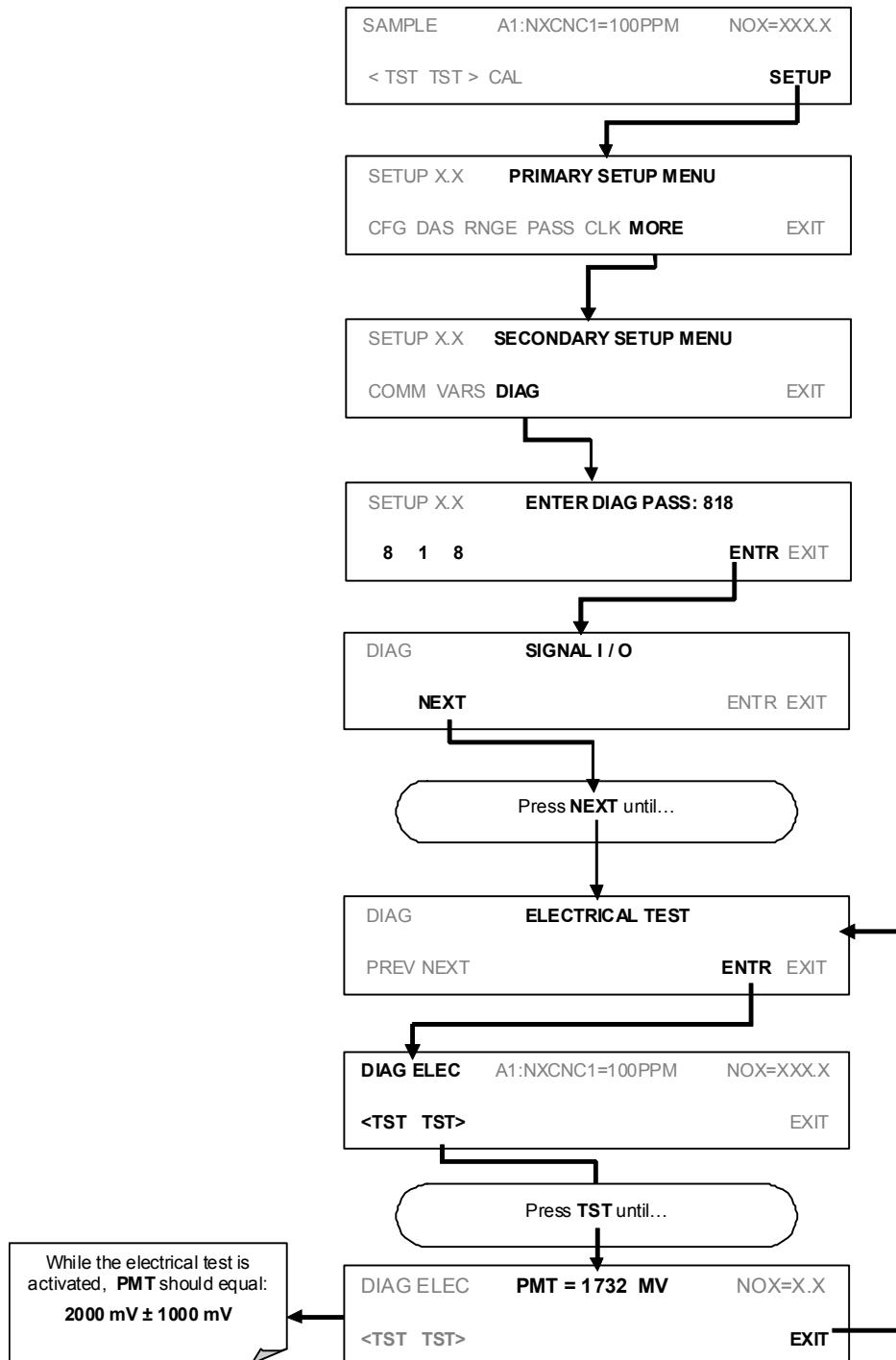
Note

This is a coarse test for functionality and not an accurate calibration tool. The resulting PMT signal can vary significantly over time and also changes with low-level calibration.

4.13.7.3. Electrical Test

The electrical test function creates a current, which substitutes the PMT signal, and feeds it into the preamplifier board. This signal is generated by circuitry on the preamplifier board itself and tests the filtering and amplification functions of that assembly along with the A/D converter on the motherboard. It does not test the PMT itself. The electrical test should produce a PMT signal of about 2000 ±1000 mV.

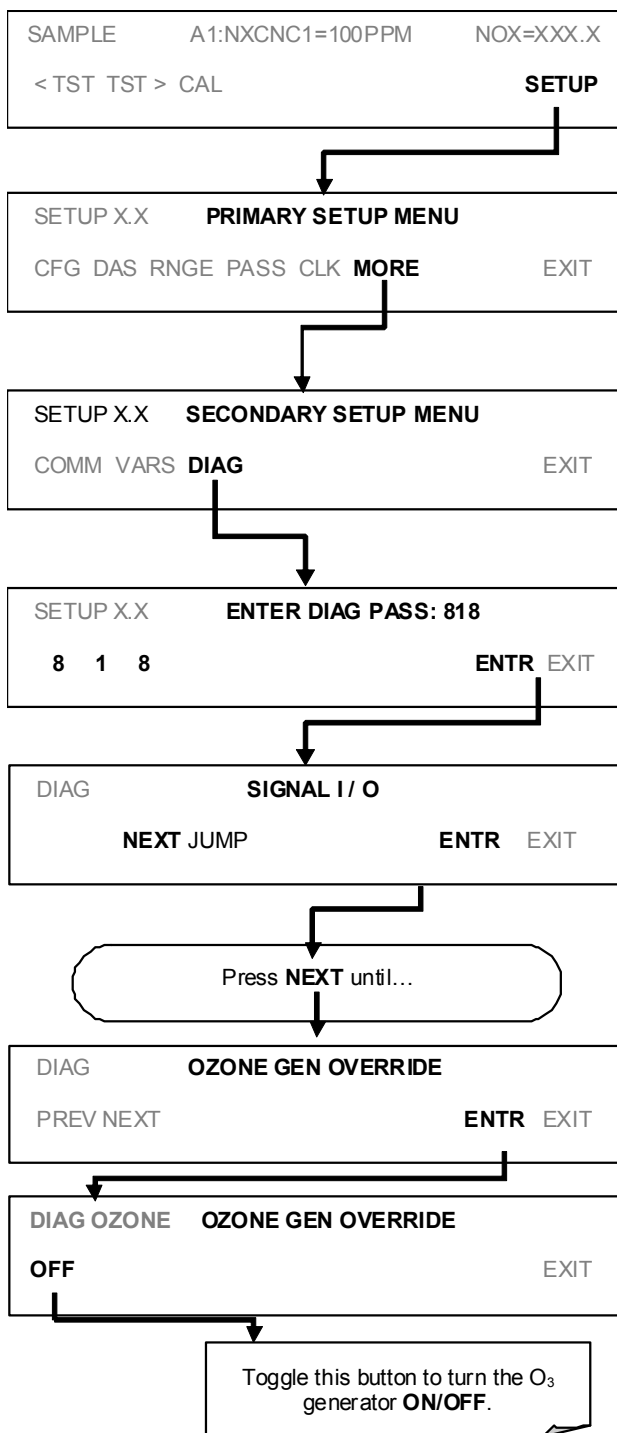
To activate the electrical test press the following buttons:



4.13.7.4. Ozone Generator Override

This feature allows the user to manually turn the ozone generator off and on. This can be done before disconnecting the generator, to prevent ozone from leaking out, or after a system restart if the user does not want to wait for 30 minutes during warm-up time. Note that this is one of the two settings in the **DIAG** menu that is retained after you exit the menu. (During initial power up TMR (timer) is displayed while the Ozone brick remains off for the first 30 minutes). Also note that the ozone generator does not turn on if the ozone flow conditions are out of specification (e.g., if there is no flow through the system or the pump is broken).

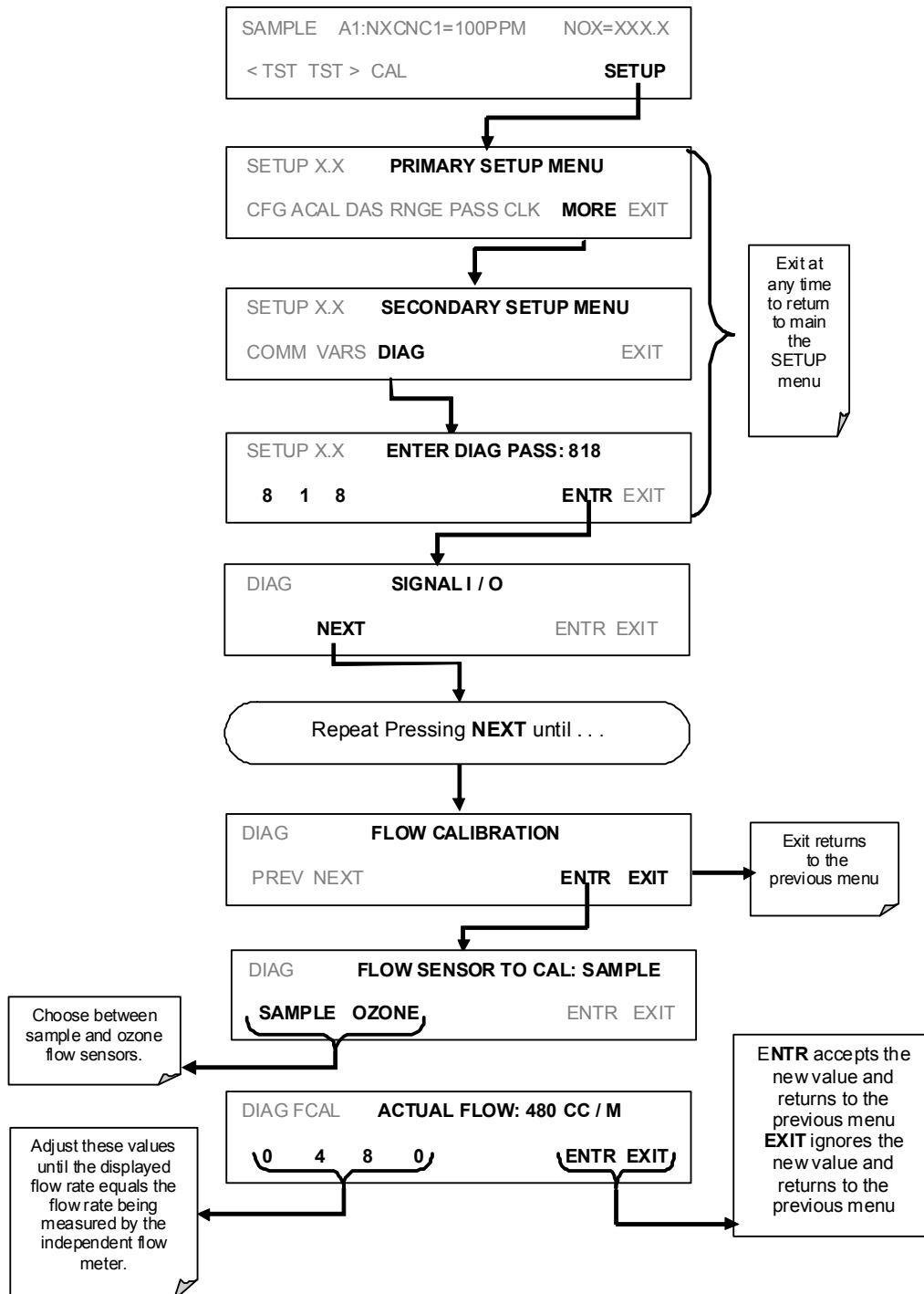
To access this feature press the following menu sequence:



4.13.7.5. Flow Calibration

The flow calibration allows the user to adjust the values of the sample flow rates as they are displayed on the front panel and reported through COM ports to match the actual flow rate measured at the sample inlet. This does not change the hardware measurement of the flow sensors, only the software-calculated values.

To carry out this adjustment, connect an external, sufficiently accurate flow meter to the sample inlet. Once the flow meter is attached and is measuring actual gas flow, press:



4.14. SETUP – ALARM: USING THE OPTIONAL GAS CONCENTRATION ALARMS (OPT 67)

The optional alarm relay outputs (Option 67) are installed includes two concentration alarms. Each alarm has a user settable limit, and is associated with an opto-isolated TTL relay accessible via the status output connector on the instrument’s back panel. If the concentration measured by the instrument rises above that limit, the alarm’s status output relay is closed NO₂.

The default settings for **ALM1** and **ALM2** are:

Table 4-28: Concentration Alarm Default Settings

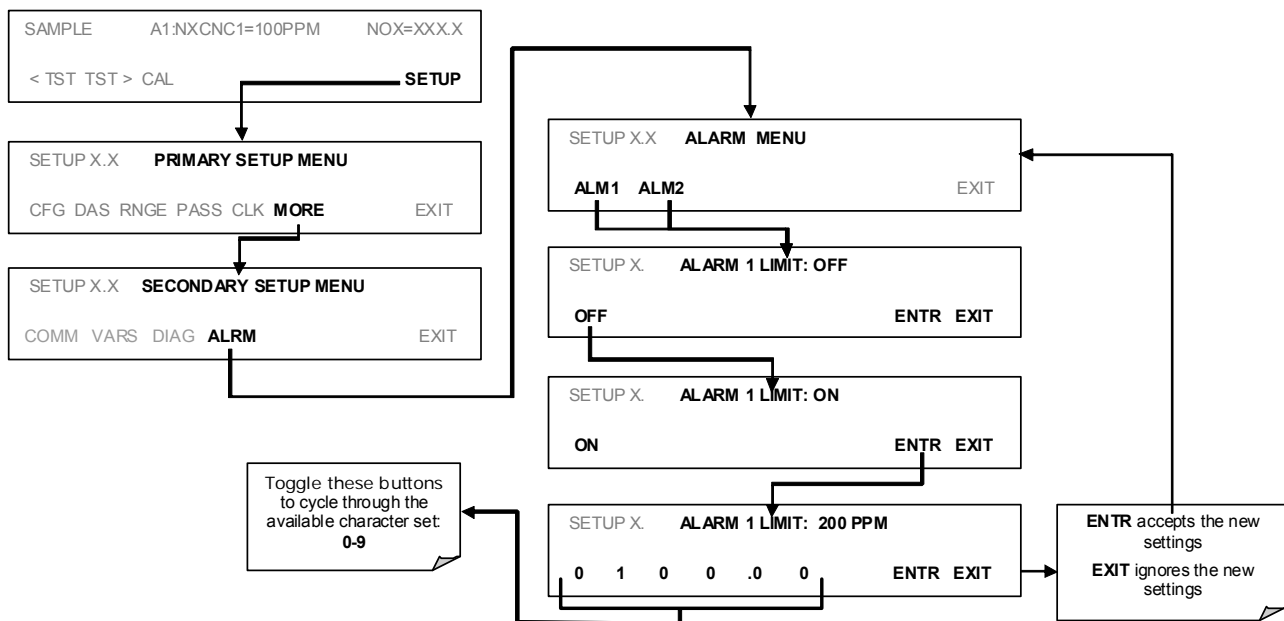
ALARM	STATUS	LIMIT SET POINT ¹		OUTPUT RELAY DESIGNATION
ALM1	Disabled	100 ppm	133.9 mg/m ³	AL2
ALM2	Disabled	300 ppm	401.6 mg/m ³	AL3

¹ Set points listed are for PPM. Should the reporting range units of measure be changed the analyzer will automatically scale the set points to match the new range unit setting.

Note

To prevent the concentration alarms from activating during span calibration operations make sure to press **CAL** or **CALS** button prior to introducing span gas into the analyzer.

To enable either of the concentration alarms and set the Limit points, press:



4.15. Remote Operation

4.15.1. REMOTE OPERATION USING THE EXTERNAL DIGITAL I/O

4.15.1.1. Status Outputs

The status outputs report analyzer conditions via optically isolated NPN transistors, which sink up to 50 mA of DC current. These outputs can be used interface with devices that accept logic-level digital inputs, such as programmable logic controllers (PLCs). Each Status bit is an open collector output that can withstand up to 40 VDC. All of the emitters of these transistors are tied together and available at D.

Note

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

The status outputs are accessed through a 12 pin connector on the analyzer’s rear panel labeled STATUS (see Figure 6-17). The function of each pin is defined in Table 6–29

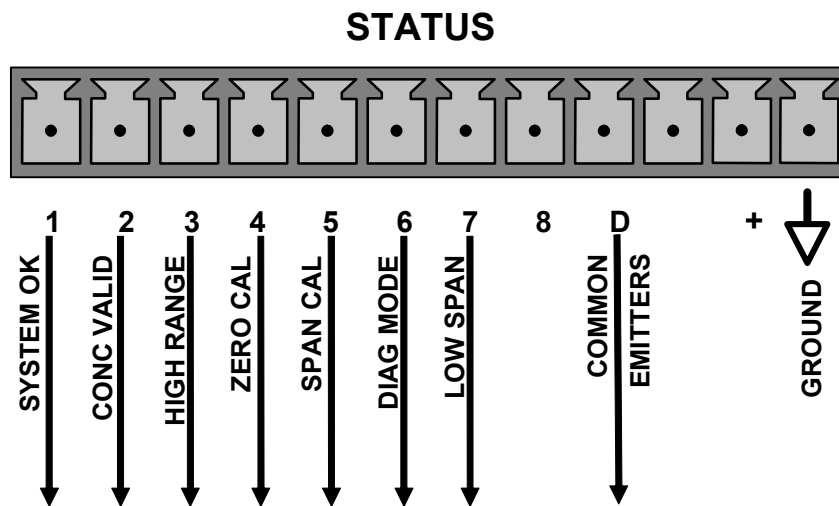



Figure 4-15: Status Output Connector


Table 4-29: Status Output Pin Assignments

CONNECTOR PIN	STATUS	CONDITION (ON=CONDUCTING)
1	SYSTEM OK	ON if no faults are present.
2	CONC VALID	ON if concentration measurement is valid, OFF when invalid.
3	HIGH RANGE	ON if unit is in high range of any AUTO range mode.
4	ZERO CAL	ON whenever the instrument is in ZERO calibration mode.
5	SPAN CAL	ON whenever the instrument is in SPAN calibration mode.
6	DIAG MODE	ON whenever the instrument is in DIAGNOSTIC mode.
7	LOW RANGE	ON if unit is in low range of any AUTO range mode.
8		Unused.
D	EMITTER BUS	The emitters of the transistors on pins 1-8 are bussed together. For most applications, this pin should be connected to the circuit ground of the receiving device.
+	DC POWER	+ 5 VDC, 30 mA maximum (combined rating with Control Inputs).
	DIGITAL GROUND	The ground from the analyzer's internal, 5 VDC power supply.

4.15.1.2. Control Inputs

Control inputs allow the user to remotely initiate ZERO and SPAN calibration modes are provided through a 10-pin connector labeled CONTROL IN on the analyzer's rear panel. These are opto-isolated, digital inputs that are activated when a 5 VDC signal from the "U" pin is connected to the respective input pin.

Table 4-30: Control Input Pin Assignments

INPUT	STATUS	CONDITION WHEN ENABLED
A	EXTERNAL ZERO CAL	Zero calibration mode is activated. The mode field of the display will read ZERO CAL R.
B	EXTERNAL SPAN CAL	Span calibration mode is activated. The mode field of the display will read SPAN CAL R.
C	EXTERNAL LOW SPAN CAL	Low span (mid-point) calibration mode is activated. The mode field of the display will read LO CAL R.
D, E & F		Unused
	DIGITAL GROUND	Provided to ground an external device (e.g., recorder).
U	DC power for Input pull ups	Input for +5 VDC required to activate inputs A - F. This voltage can be taken from an external source or from the "+" pin.
+	Internal +5V Supply	Internal source of +5V which can be used to activate inputs when connected to pin U.

There are two methods to activate control inputs. The internal +5V available from the “+” pin is the most convenient method (see Figure 6-18). However, to ensure that these inputs are truly isolated, a separate, external 5 VDC power supply should be used (see Figure 6-19).

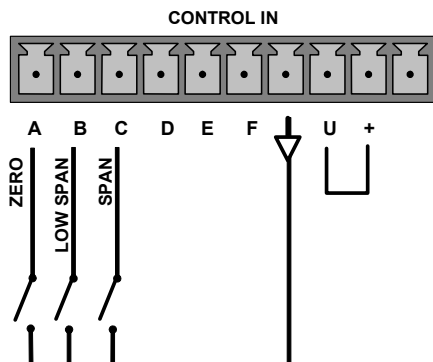


Figure 4-16: Control Inputs with Local 5 V Power Supply

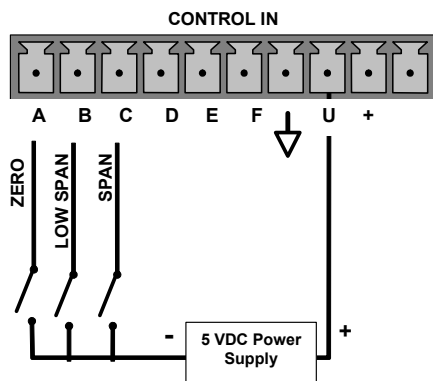


Figure 4-17: Control Inputs with External 5 V Power Supply

4.15.2. REMOTE OPERATION

4.15.2.1. Terminal Operating Modes

The Model 9110TH/M can be remotely configured, calibrated or queried for stored data through the serial ports. As terminals and computers use different communication schemes, the analyzer supports two communicate modes specifically designed to interface with these two types of devices.

- **Computer mode** is used when the analyzer is connected to a computer with a dedicated interface program such as APICOM. More information regarding APICOM can be found in later in this section or on the Teledyne API website at <http://www.teledyne-api.com/software/apicom/>.
- **Interactive mode** is used with a terminal emulation programs such as HyperTerminal or a “dumb” computer terminal. The commands that are used to operate the analyzer in this mode are listed in Table 6-31 and in Appendix A-6.

4.15.2.2. Help Commands in Terminal Mode

Table 4-31: Terminal Mode Software Commands

COMMAND	FUNCTION
Control-T	Switches the analyzer to terminal mode (echo, edit). If mode flags 1 & 2 are OFF, the interface can be used in interactive mode with a terminal emulation program.
Control-C	Switches the analyzer to computer mode (no echo, no edit).
CR (carriage return)	A carriage return is required after each command line is typed into the terminal/computer. The command will not be sent to the analyzer to be executed until this is done. On personal computers, this is achieved by pressing the ENTER key.
BS (backspace)	Erases one character to the left of the cursor location.
ESC (escape)	Erases the entire command line.
? [ID] CR	This command prints a complete list of available commands along with the definitions of their functionality to the display device of the terminal or computer being used. The ID number of the analyzer is only necessary if multiple analyzers are on the same communications line, such as the multi-drop setup.
Control-C	Pauses the listing of commands.
Control-P	Restarts the listing of commands.

4.15.2.3. Command Syntax

Commands are not case-sensitive and all arguments within one command (i.e. ID numbers, keywords, data values, etc.) must be separated with a space character.

All Commands follow the syntax:

X [ID] COMMAND <CR>

Where

X is the command type (one letter) that defines the type of command. Allowed designators are listed in Table 4-32 and Appendix A.

[ID] is the analyzer identification number (see Section 4.11.4.). Example: the Command “? 200” followed by a carriage return would print the list of available commands for the revision of software currently installed in the instrument assigned ID Number 200.

COMMAND is the command designator: This string is the name of the command being issued (LIST, ABORT, NAME, EXIT, etc.). Some commands may have additional arguments that define how the command is to be executed. Press ? <CR> or refer to Appendix A for a list of available command designators.

<CR> is a carriage return. All commands must be terminated by a carriage return (usually achieved by pressing the ENTER key on a computer).

Table 4-32: Command Types

COMMAND	COMMAND TYPE
C	Calibration
D	Diagnostic
L	Logon
T	Test measurement
V	Variable
W	Warning

4.15.2.4. Data Types

Data types consist of integers, hexadecimal integers, floating-point numbers, Boolean expressions and text strings.

- Integer data are used to indicate integral quantities such as a number of records, a filter length, etc. They consist of an optional plus or minus sign, followed by one or more digits. For example, *+1*, *-12*, *123* are all valid integers.
- Hexadecimal integer data are used for the same purposes as integers. They consist of the two characters “0x,” followed by one or more hexadecimal digits (0-9, A-F, a-f), which is the ‘C’ programming language convention. No plus or minus sign is permitted. For example, *0x1*, *0x12*, *0x1234abcd* are all valid hexadecimal integers.
- Floating-point numbers are used to specify continuously variable values such as temperature set points, time intervals, warning limits, voltages, etc. They consist of an optional plus or minus sign, followed by zero or more digits, an optional decimal point, and zero or more digits. (At least one digit must appear before or after the decimal point.) Scientific notation is not permitted. For example, *+1.0*, *1234.5678*, *-0.1*, *1* are all valid floating-point numbers.
- Boolean expressions are used to specify the value of variables or I/O signals that may assume only two values. They are denoted by the keywords *ON* and *OFF*.
- Text strings are used to represent data that cannot be easily represented by other data types, such as data channel names, which may contain letters and numbers. They consist of a quotation mark, followed by one or more printable characters, including spaces, letters, numbers, and symbols, and a final quotation mark. For example, *“a”*, *“1”*, *“123abc”*, and *“()[]<>”* are all valid text strings. It is not possible to include a quotation mark character within a text string.
- Some commands allow you to access variables, messages, and other items, such as DAS data channels, by name. When using these commands, you must type the entire name of the item; you cannot abbreviate any names.

4.15.2.5. Status Reporting

Reporting of status messages as an audit trail is one of the three principal uses for the RS-232 interface (the other two being the command line interface for controlling the instrument and the download of data in electronic format). You can effectively disable the reporting feature by setting the interface to quiet mode (see Communication Mode).

Status reports include DAS data (when reporting is enabled), warning messages, calibration and diagnostic status messages. Refer to Appendix A-3 for a list of the

possible messages, and this section for information on controlling the instrument through the RS-232 interface.

GENERAL MESSAGE FORMAT

All messages from the instrument (including those in response to a command line request) are in the format:

X DDD:HH:MM [Id] MESSAGE<CRLF>

Where

X is a command type designator, a single character indicating the message type, as shown in the Table 6-31.

DDD:HH:MM is the time stamp, the date and time when the message was issued. It consists of 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.

[ID] is the analyzer ID, a number with 1 to 4 digits.

MESSAGE is the message content that may contain warning messages, test measurements, DAS reports, variable values, etc.

<CRLF> is a carriage return / line feed pair, which terminates the message.

The uniform nature of the output messages makes it easy for a host computer to parse them into an easy structure. Keep in mind that the front panel display does not give any information on the time a message was issued, hence it is useful to log such messages for trouble-shooting and reference purposes. Terminal emulation programs such as HyperTerminal can capture these messages to text files for later review.

4.15.2.6. Remote Access by Modem

The 9110TH/M can be connected to a modem for remote access. This requires a cable between the analyzer's COM port and the modem, typically a DB-9F to DB-25M cable (available from TAI with part number WR0000024).

Once the cable has been connected, check to make sure the DTE-DCE is in the correct position. Also make sure the 9110TH/M COM port is set for a baud rate that is compatible with the modem, which needs to operate with an 8-bit word length with one stop bit.

The first step is to turn on the **MODEM ENABLE** communication mode (Mode 64). Once this is completed, the appropriate setup command line for your modem can be entered into the analyzer. The default setting for this feature is

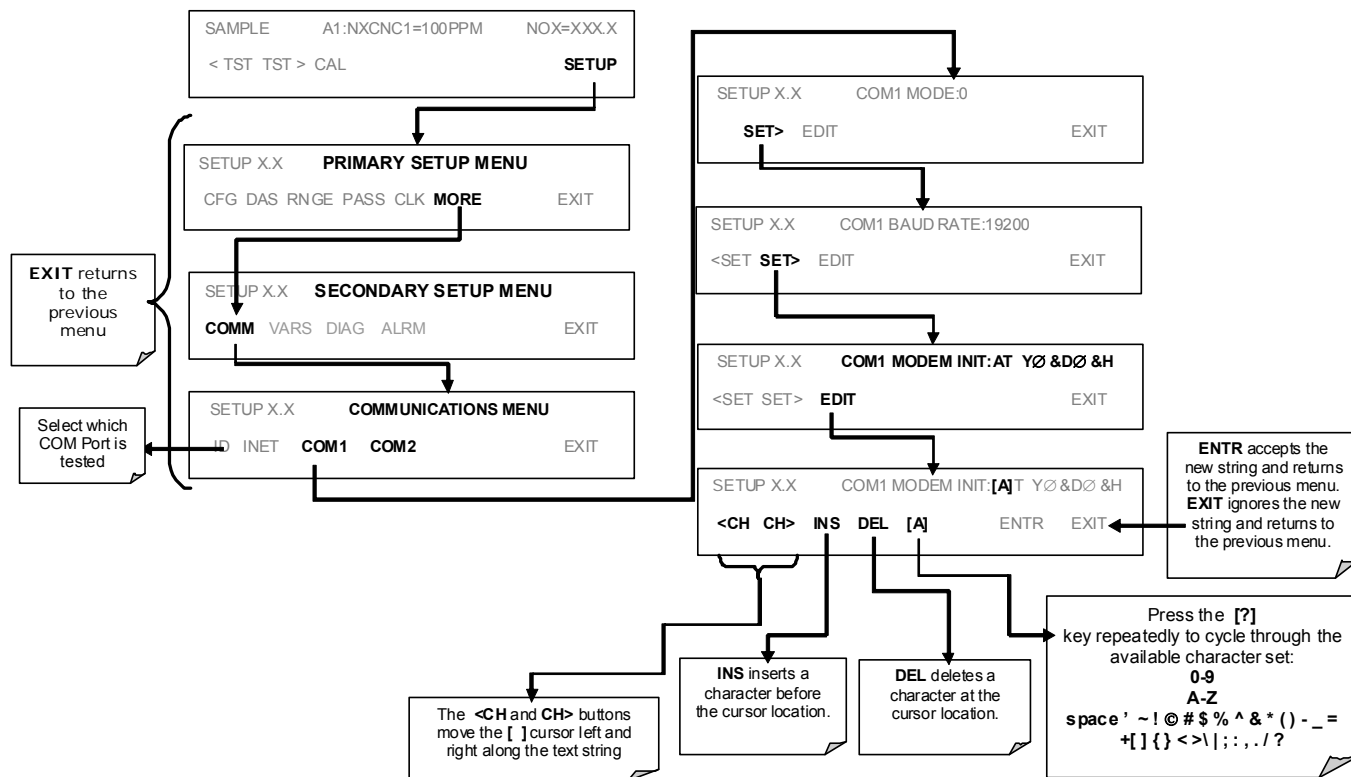
```
AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0
```

This string can be altered to match your modem's initialization and can be up to 100 characters long.

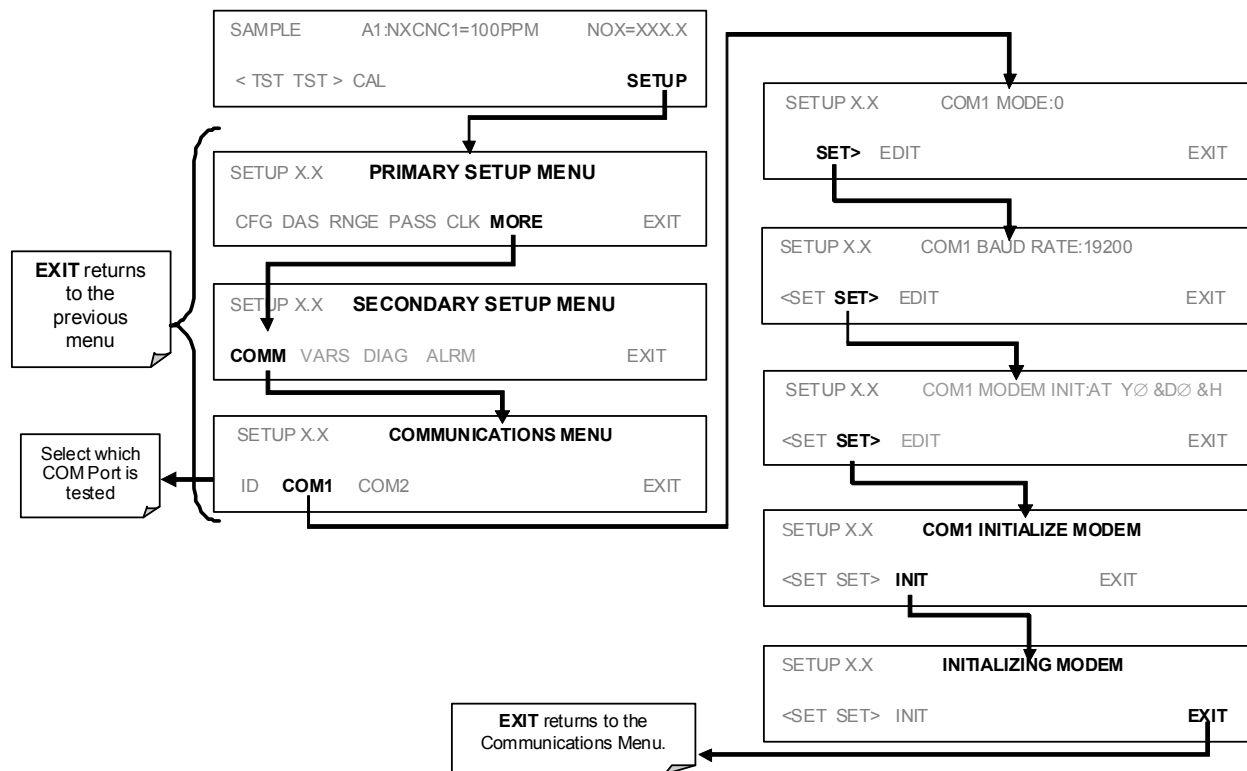
Note

If Hessen Protocol Mode is active for a com port, operation via a modem is not available on that port.

To change this setting press:



To initialize the modem press:



4.15.2.7. COM Port Password Security

In order to provide security for remote access of the 9110TH/M, a LOGON feature can be enabled to require a password before the instrument will accept commands. This is done by turning on the **SECURITY MODE** (see Section 4.9). Once the **SECURITY MODE** is enabled, the following items apply.

- A password is required before the port will respond or pass on commands.
- If the port is inactive for one hour, it will automatically logoff, which can also be achieved with the LOGOFF command.
- Three unsuccessful attempts to log on with an incorrect password will cause subsequent logins to be disabled for 1 hour, even if the correct password is used.
- If not logged on, the only active command is the '?' request for the help screen.
- The following messages will be returned at logon:
 - LOGON SUCCESSFUL - Correct password given
 - LOGON FAILED - Password not given or incorrect
 - LOGOFF SUCCESSFUL - Connection terminated successfully

To log on to the 9110TH/M analyzer with **SECURITY MODE** feature enabled, type:

LOGON 940331

940331 is the default password. To change the default password, use the variable RS232_PASS issued as follows:

V RS232_PASS=NNNNNN

Where N is any numeral between 0 and 9.

4.15.2.8. APICOM Remote Control Program

APICOM is an easy-to-use, yet powerful interface program that allows to access and control any of TAI main line of ambient and stack-gas instruments from a remote connection through direct cable, modem or Ethernet. Running APICOM, a user can:

- Establish a link from a remote location to the 9110TH/M through direct cable connection via RS-232 modem or Ethernet.
- View the instrument's front panel and remotely access all functions that could be accessed when standing in front of the instrument.
- Remotely edit system parameters and set points.
- Download, view, graph and save data for predictive diagnostics or data analysis.
- Retrieve, view, edit, save and upload DAS configurations.
- Check on system parameters for trouble-shooting and quality control.

APICOM is very helpful for initial setup, data analysis, maintenance and trouble-shooting. Figure 6-20 shows examples of APICOM's main interface, which emulates the look and functionality of the instruments actual front panel

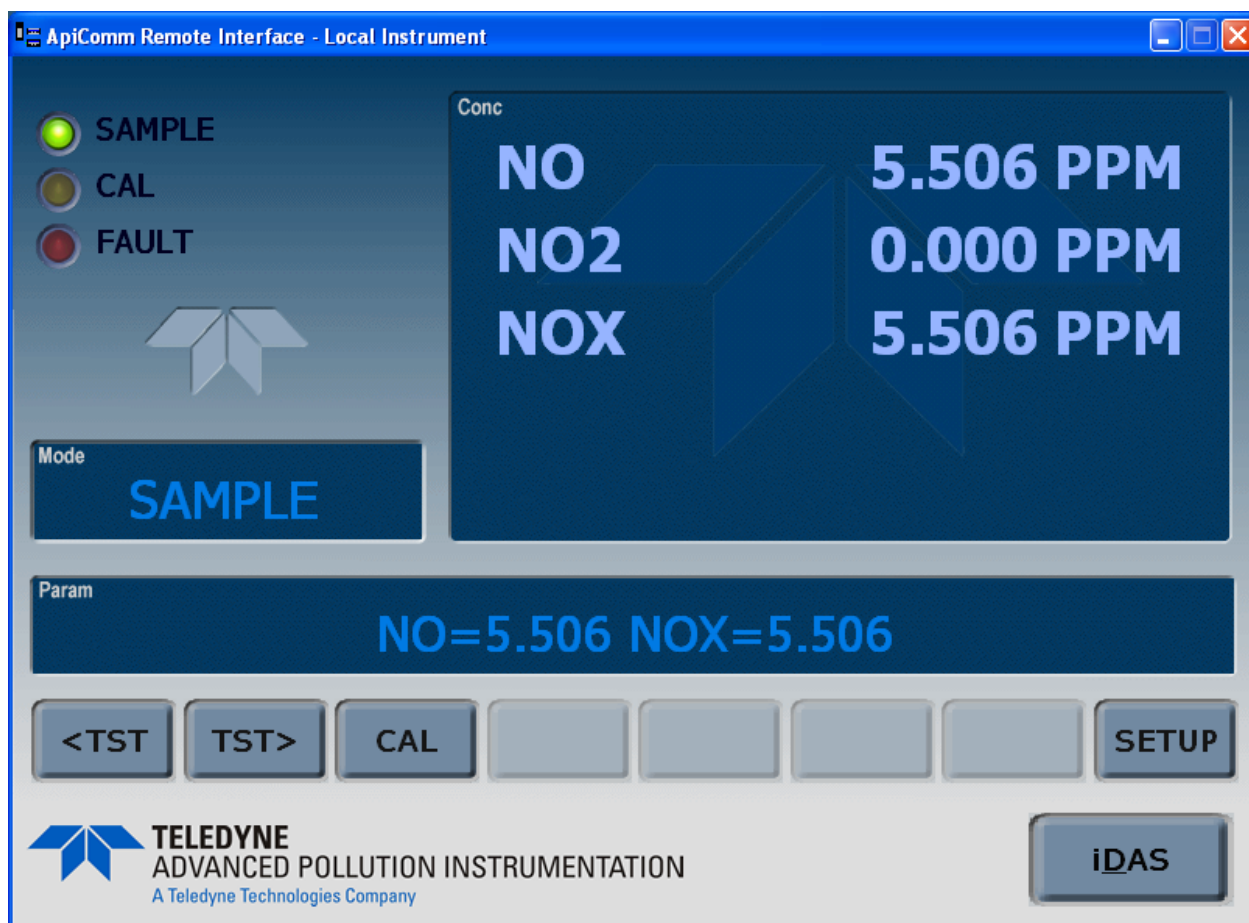


Figure 4-18: APICOM Remote Control Program Interface

APICOM is included free of cost with the analyzer and the latest versions can also be downloaded for free at <http://www.teledyne-api.com/software/apicom/>.

4.15.3. ADDITIONAL COMMUNICATIONS DOCUMENTATION

Table 4-33: Serial Interface Documents

Interface / Tool	Document Title	Part Number	Available Online*
APICOM	APICOM User Manual	039450000	YES
Multi-drop	RS-232 Multi-drop Documentation	021790000	YES
DAS Manual	Detailed description of the DAS.	028370000	YES

* These documents can be downloaded at <http://www.teledyne-api.com/manuals/>

4.15.4. USING THE 9110TH/M WITH A HESSEN PROTOCOL NETWORK

4.15.4.1. General Overview of Hessen Protocol

The Hessen protocol is a multidrop protocol, in which several remote instruments are connected via a common communications channel to a host computer. The remote instruments are regarded as slaves of the host computer. The remote instruments are unaware that they are connected to a multidrop bus and never initiate messages. They

only respond to commands from the host computer and only when they receive a command containing their own unique ID number.

The Hessen protocol is designed to accomplish two things: to obtain the status of remote instruments, including the concentrations of all the gases measured; and to place remote instruments into zero or span calibration or measure mode. API's implementation supports both of these principal features.

The Hessen protocol is not well defined, therefore while API's application is completely compatible with the protocol itself, it may be different from implementations by other companies.

The following subsections describe the basics for setting up your instrument to operate over a Hessen Protocol network. For more detailed information as well as a list of host computer commands and examples of command and response message syntax, download the *Manual Addendum for Hessen Protocol* from the Teledyne API web site: <http://www.teledyne-api.com/manuals/index.asp>.

4.15.4.2. Hessen Com Port Configuration

Hessen protocol requires the communication parameters of the 9110TH/M's com ports to be set differently than the standard configuration as shown in the table below.

Table 4-34: RS-232 Communication Parameters for Hessen Protocol

Parameter	Standard	Hessen
Data Bits	8	7
Stop Bits	1	2
Parity	None	Even
Duplex	Full	Half

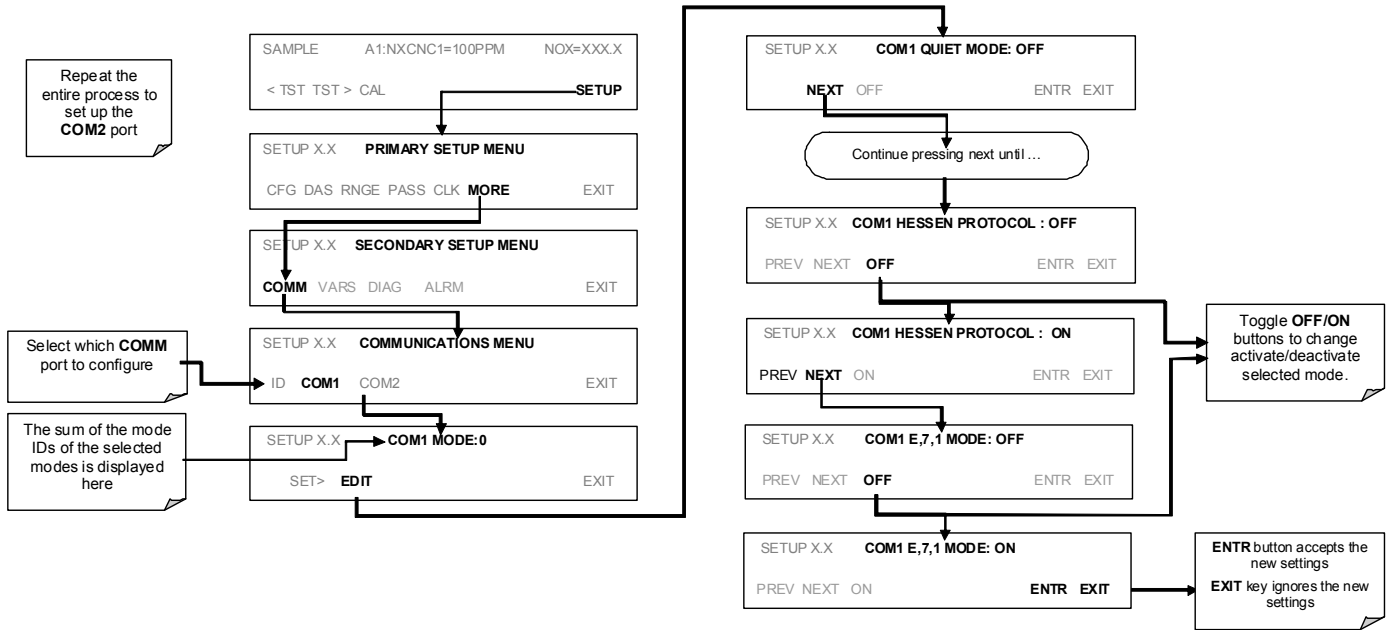
Note

Ensure that the communication parameters of the host computer are properly set

Be aware that the instrument software has a 200 ms latency response to commands issued by the host computer.

Operation via modem is not available over any com port on which HESSEN protocol is active.

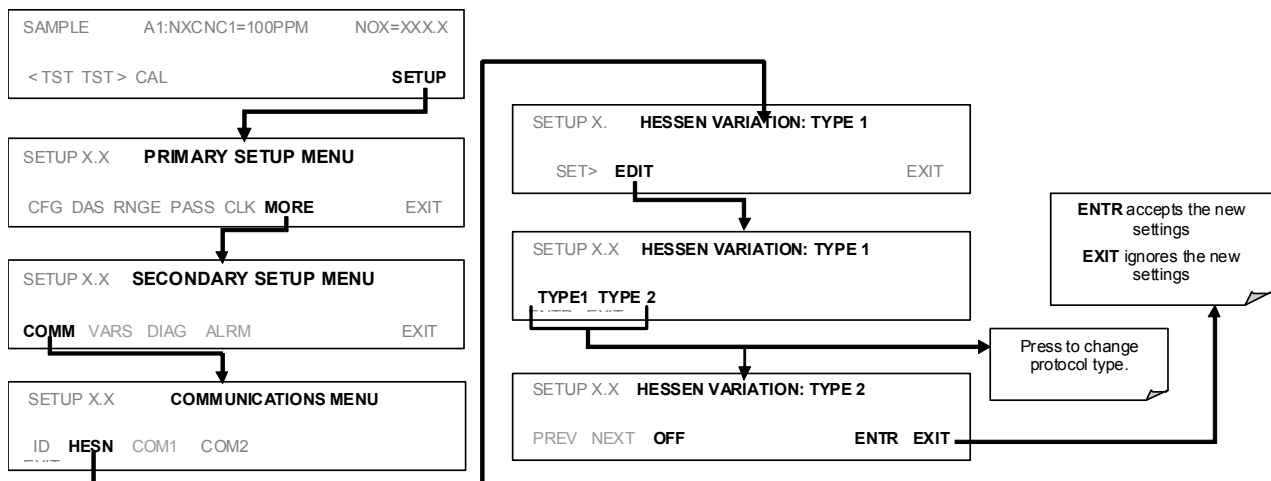
The first step in configuring the 9110TH/M to operate over a Hessen protocol network is to activate the Hessen mode for com ports and configure the communication parameters for the port(s) appropriately. Press:



4.15.4.3. Selecting a Hessen Protocol Type

Currently there are two version of Hessen Protocol in use. The original implementation, referred to as **TYPE 1**, and a more recently released version, **TYPE 2** that has more flexibility when operating with instruments that can measure more than one type of gas. For more specific information about the difference between **TYPE 1** and **TYPE 2** download the *Manual Addendum for Hessen Protocol* from the Teledyne API web site: <http://www.teledyne-api.com/manuals/index.asp>.

To select a Hessen Protocol Type press:



Note While Hessen Protocol Mode can be activated independently for COM1

and COM2, the TYPE selection affects both ports.

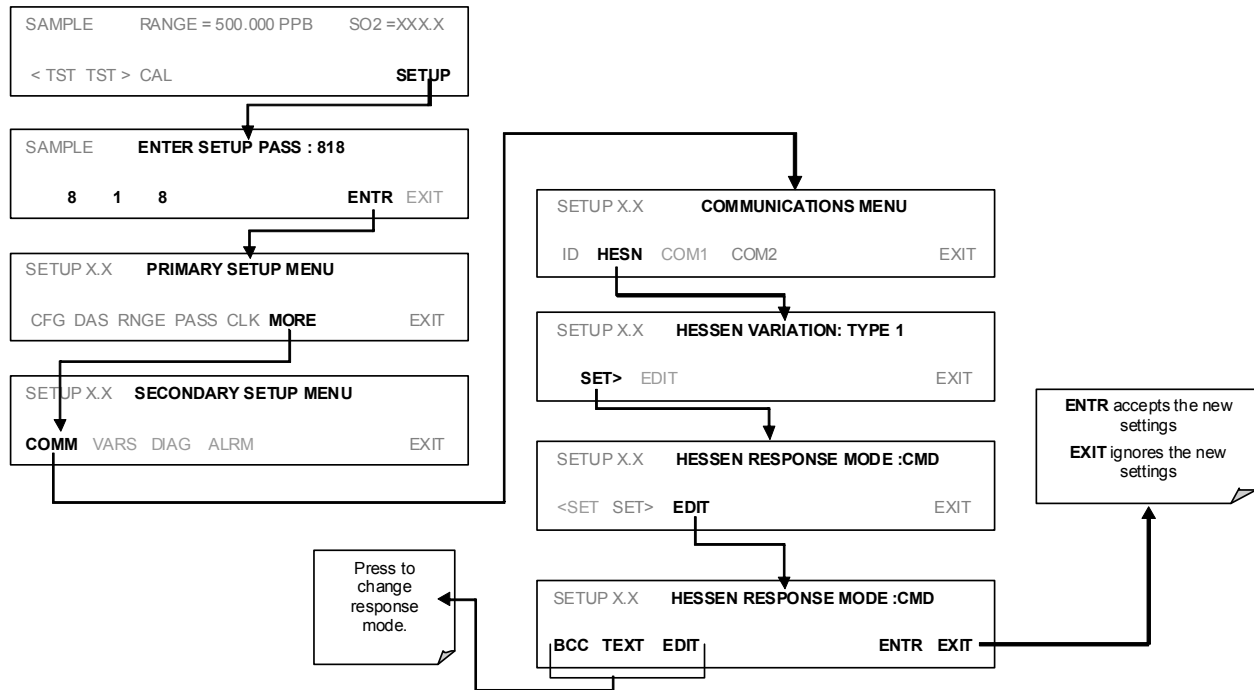
4.15.4.4. Setting The Hessen Protocol Response Mode

The Teledyne API implementation of Hessen Protocol allows the user to choose one of several different modes of response for the analyzer.

Table 6-28: 9110TH/M Hessen Protocol Response Modes

MODE ID	MODE DESCRIPTION
CMD	This is the Default Setting. Responses from the instrument are encoded as the traditional command format. Style and format of responses depend on exact coding of the initiating command.
BCC	Responses from the instrument are always delimited with <STX> (at the beginning of the response, <ETX> (at the end of the response followed by a 2 digit Block Check Code (checksum), regardless of the command encoding.
TEXT	Responses from the instrument are always delimited with <CR> at the beginning and the end of the string, regardless of the command encoding.

To Select a Hessen response mode, press:



4.15.4.5. Hessen Protocol Gas ID

Since the 9110TH/M measures NO_x, NO₂, NO and O₂ (if the optional sensor is installed), all of these gases are listed in the Hessen protocol gas list. In its default state the Hessen protocol firmware assigns each of these gases a Hessen ID number and actively reports all of them even if the instrument is only measuring one (see **MEASURE_MODE**, Section 4.12) .

To change or edit these settings press:

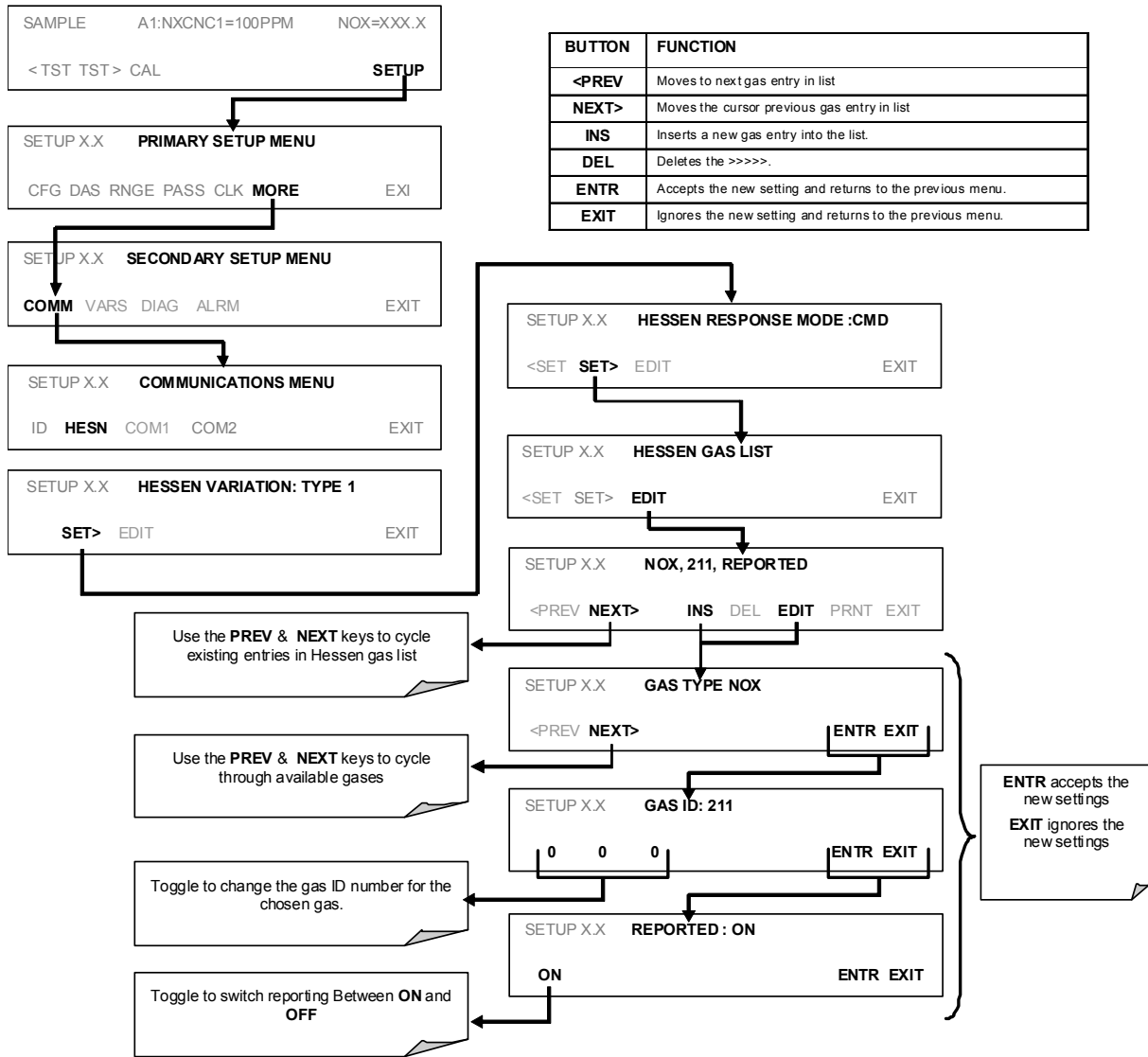


Table 4-35: 9110TH/M Hessen GAS ID List

GAS DEFAULT	HESSEN GAS ID
NO _x	211
NO	212
NO ₂	213
O ₂	214

4.15.4.6. Setting Hessen Protocol Status Flags

TAI implementation of Hessen protocols includes a set of status bits that are included in responses to inform the host computer of the 9110TH/M's condition. The default settings for these bit/flags are:

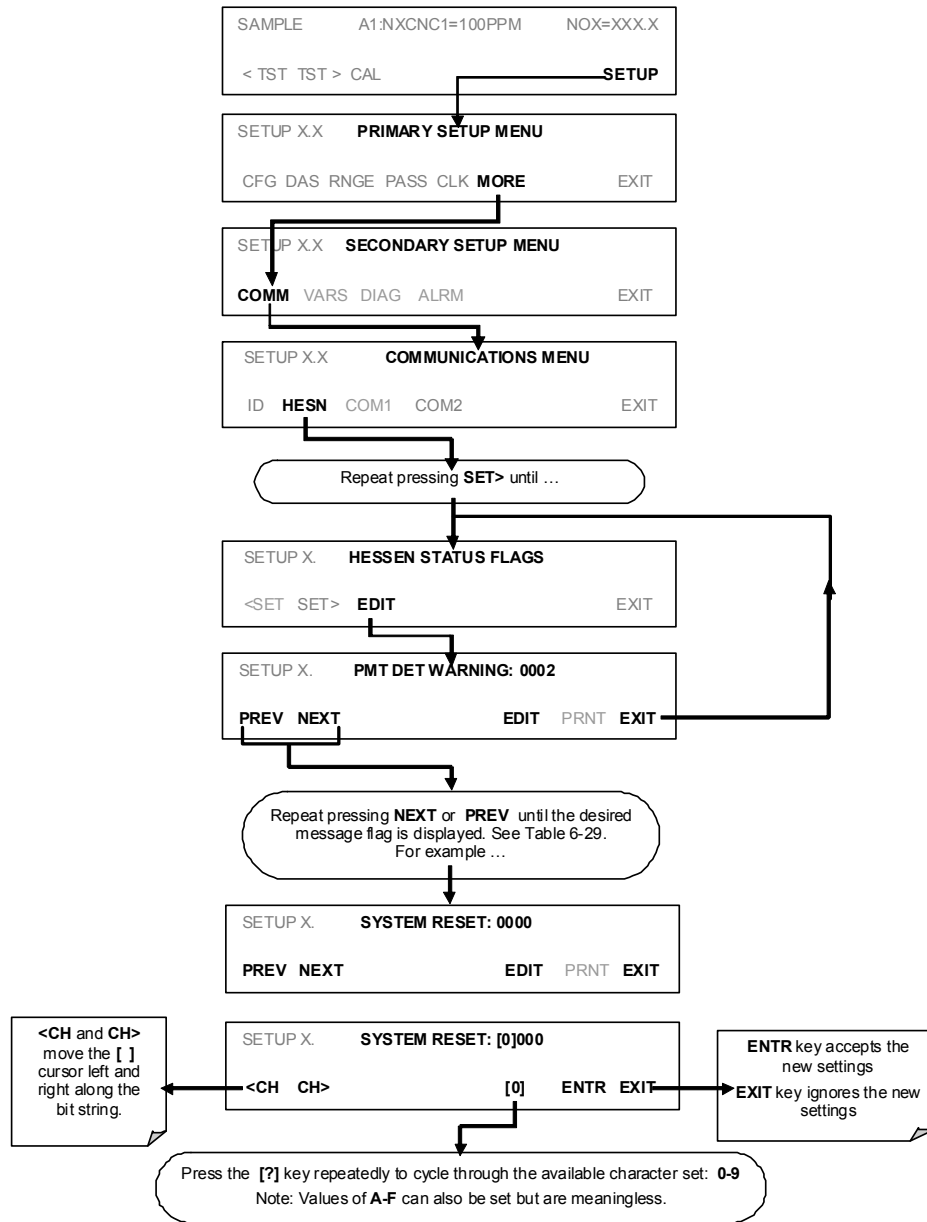
Table 4-36: Default Hessen Status Bit Assignments

STATUS FLAG NAME	DEFAULT BIT ASSIGNMENT
WARNING FLAGS	
SAMPLE FLOW WARNING	0001
OZONE FLOW WARNING	0002
RCELL PRESS WARN	0004
BOX TEMP WARNING	0008
RCELL TEMP WARNING	0010
PMT TEMP WARNING	0040
CONVERTER TEMP WARNING	0080
WARMUP MODE	1000
INVALID CONC	8000
OPERATIONAL FLAGS	
In Manual Calibration Mode	0200
In O ₂ Calibration Mode	0400
In Zero Calibration Mode	0400
In Low Span Calibration Mode	0800
In Span Calibration Mode	0800
UNITS OF MEASURE FLAGS	
MGM	2000
PPM	6000
SPARE/UNUSED BITS	0020, 0100
UNASSIGNED FLAGS	
Box Temp Warning	Analog Cal Warning
System Reset	Cannot Dyn Zero
Rear Board Not Detected	Cannot Dyn Span
Relay Board Warning	O ₂ Cell Temp Warn
Manifold Temp Warn	AutoZero Warning
Ozone Gen Off	Conc Alarm 2
Conc Alarm 1	In MP Calibration Mode
HVPS Warning	

Note

It is possible to assign more than one flag to the same Hessen status bit. This allows the grouping of similar flags, such as all temperature warnings, under the same status bit. Be careful not to assign conflicting flags to the same bit as each status bit will be triggered if any of the assigned flags is active.

To assign or reset the status flag bit assignments, press:



4.15.4.7. Instrument ID Code

Each instrument on a Hessen Protocol network must have a unique ID code. The 9110TH/M has a default ID of either **0** or **200**. To change this code see Section 4.11.1

5. CALIBRATION PROCEDURES

This section describes calibration procedures for the 9110TH/M. All of the methods described here can be initiated and controlled through the front panel or the COM ports. Interferents should be considered prior to calibration.

5.1.1. INTERFERENTS FOR NO_x MEASUREMENTS

The chemiluminescence method for detecting NO_x is subject to interference from a number of sources including water vapor (H₂O), ammonia (NH₃), sulfur dioxide (SO₂) and carbon dioxide (CO₂) but the Model 9110TH/M has been designed to reject most of these interferents. Section 8.2.4 contains more detailed information on interferents.

Ammonia is the most common interferent, which is converted to NO in the analyzer's NO₂ converter and creates a NO_x signal artifact. If the Model 9110TH/M is installed in an environment with high ammonia, steps should be taken to remove the interferent from the sample gas before it enters the reaction cell. TAI offers a sample gas conditioning option to remove ammonia and water vapor (contact Sales).

Carbon dioxide diminishes the NO_x signal when present in high concentrations. If the analyzer is used in an application with excess CO₂, contact TAI Technical Support for possible solutions. Excess water vapor can be removed with one of the dryer options described in Section 1.4. In ambient air applications, SO₂ interference is usually negligible.

5.1.1.1. Conditioners for High Moisture Sample Gas

Several permeation devices using Nafion[®] permeation gas exchange tubes are available for applications with high moisture and/or moderate levels of NH₃ in the sample gas. This type of sample conditioner is part of the standard 9110TH/M equipment to remove H₂O and NH₃ from the ozone generator supply gas stream but can be purchased for the sample gas stream as well. All gas conditioners remove water vapor to a dew point of about -20° C (~600 ppm H₂O) and effectively remove concentrations of ammonia up to about 1 ppm. More information about these dryers and their performance is available at <http://www.permapure.com/>.

It is MANDATORY that for calibrations and operation to be valid, the analyzer be calibrated using the same background gas (or diluent) for zero and span, as the background gas in the sample stream. Any other combinations will lead to calibration or operational errors since the efficiency of the analyzer's chemluminescent reaction varies with the background gas, since the background gas acts as a quencher.

Note

CALIBRATION vs. CALIBRATION CHECK:

DO NOT press the ENTR button during the following procedures if you are performing only a calibration check. ENTR recalculates the stored values for OFFSET and SLOPE, altering the instrument's calibration.

5.2. CALIBRATION PREPARATIONS

5.2.1. REQUIRED EQUIPMENT, SUPPLIES, AND EXPENDABLES

Calibration of the Model 9110TH/M analyzer requires a certain amount of equipment and supplies. These include, but are not limited to, the following:

- Zero-air source (defined in Section 3.5.1.1).
- Span gas source (defined in Section 3.5.1.2).
- Gas lines - all gas line materials should be stainless steel or Teflon-type (PTFE or FEP). High concentration NO gas transported over long distances may require stainless steel to avoid oxidation of NO with O₂ diffusing into the tubing.
- A recording device such as a strip-chart recorder and/or data logger (optional). For electronic documentation, the internal data acquisition system can be used.

5.2.2. ZERO AIR

Zero air is similar in chemical composition to the Earth's atmosphere but scrubbed of all components that might affect the analyzer's readings. For NO_x measuring devices, zero air should be devoid of NO_x and large amounts of CO₂, NH₃ and water vapor. Water vapor and moderate amounts of NH₃ can be removed using a sample gas conditioner (Section 5.10).

Devices such as the API Model 701 zero air generator that condition ambient air by drying and removal of pollutants are available. We recommend this type of device for generating zero air. Please contact our sales department for more information on this.

5.2.3. SPAN CALIBRATION GAS STANDARDS & TRACEABILITY

Note

We strongly recommend that span calibration is carried out with NO span gas, although it is possible to use NO₂. Quick span checks may be done with either NO, NO₂ or a mixture of NO and NO₂.

Span gas is specifically mixed to match the chemical composition of the gas being measured at about 80% of the desired full measurement range. For example, if the measurement range is 120 ppm, the span gas should have an NO concentration of about 96 ppm.

Span gases should be certified to a specific accuracy to ensure accurate calibration of the analyzer. Typical gas accuracy for NO_x gases is 1 or 2%. NO standards should be mixed in nitrogen (to prevent oxidation of NO to NO₂ over time).

For oxygen measurements, we recommend a reference gas of 21% O₂ in N₂. The user can either utilize the NO_x standards (if mixed in air). For quick checks, ambient air can be used at an assumed concentration of 20.8%. Generally, O₂ concentration in dry, ambient air varies by less than 1%.

5.2.3.1. Traceability

All equipment used to produce calibration gases should be verified against standards of the National Institute for Standards and Technology (NIST). To ensure NIST traceability, we recommend to acquire cylinders of working gas that are certified to be traceable to NIST standard reference materials (SRM). These are available from a variety of commercial sources.

Table 5-1: NIST-SRM's Available for Traceability of NO_x Calibration Gases

NIST-SRM ⁴	TYPE	NOMINAL CONCENTRATION
2627a	Nitric Oxide (NO) in N ₂	5 ppm
2628a	Nitric Oxide (NO) in N ₂	10 ppm
2629a	Nitric Oxide (NO) in N ₂	20 ppm
1683b	Nitric Oxide (NO) in N ₂	50 ppm
1684b	Nitric Oxide (NO) in N ₂	100 ppm
1685b	Nitric Oxide (NO) in N ₂	250 ppm
1686b	Nitric Oxide (NO) in N ₂	5000 ppm
1687b	Nitric Oxide (NO) in N ₂	1000 ppm
2630	Nitric Oxide (NO) in N ₂	1500 ppm
2631a	Nitric Oxide (NO) in N ₂	3000 ppm
2635	Nitric Oxide (NO) in N ₂	800 ppm
2636a	Nitric Oxide (NO) in N ₂	2000 ppm
2656	Oxides of Nitrogen (NO _x) in Air	2500 ppm
2660a	Oxides of Nitrogen (NO _x) in Air	100 ppm
2659a	Oxygen in Nitrogen (O ₂)	21 mol %

5.2.4. DATA RECORDING DEVICES

A strip chart recorder, data acquisition system or digital data acquisition system should be used to record data from the serial or analog outputs of the 9110TH/M. If analog readings are used, the response of the recording system should be checked against a NIST traceable voltage source or meter. Data recording devices should be capable of bipolar operation so that negative readings can be recorded. For electronic data recording, the 9110TH/M provides an internal data acquisition system (DAS), which is described in detail in Section 4.7. APICOM, a remote control program, is also provided as a convenient and powerful tool for data handling, download, storage, quick check and plotting.

5.2.5. NO₂ CONVERSION EFFICIENCY (CE)

To ensure accurate operation of the 9110TH/M, it is important to check the NO₂ conversion efficiency (CE) periodically and to update this value as necessary.

The default setting for the NO₂ converter efficiency is 1.0000. For the analyzer to function correctly, the converter efficiency must be between 0.9600 and 1.0200 (96-102% conversion efficiency) as per US-EPA requirements. If the converter's efficiency is outside these limits, the NO₂ converter should be replaced.

Note

The currently programmed CE is recorded along with the calibration data in the DAS for documentation and performance analysis.

5.2.5.1. Determining / Updating the NO₂ Converter Efficiency

The following procedure will cause the Model 9110TH/M to automatically calculate the current NO₂ conversion efficiency.

STEP ONE:

Connect a source of calibrated NO₂ span gas as shown below.

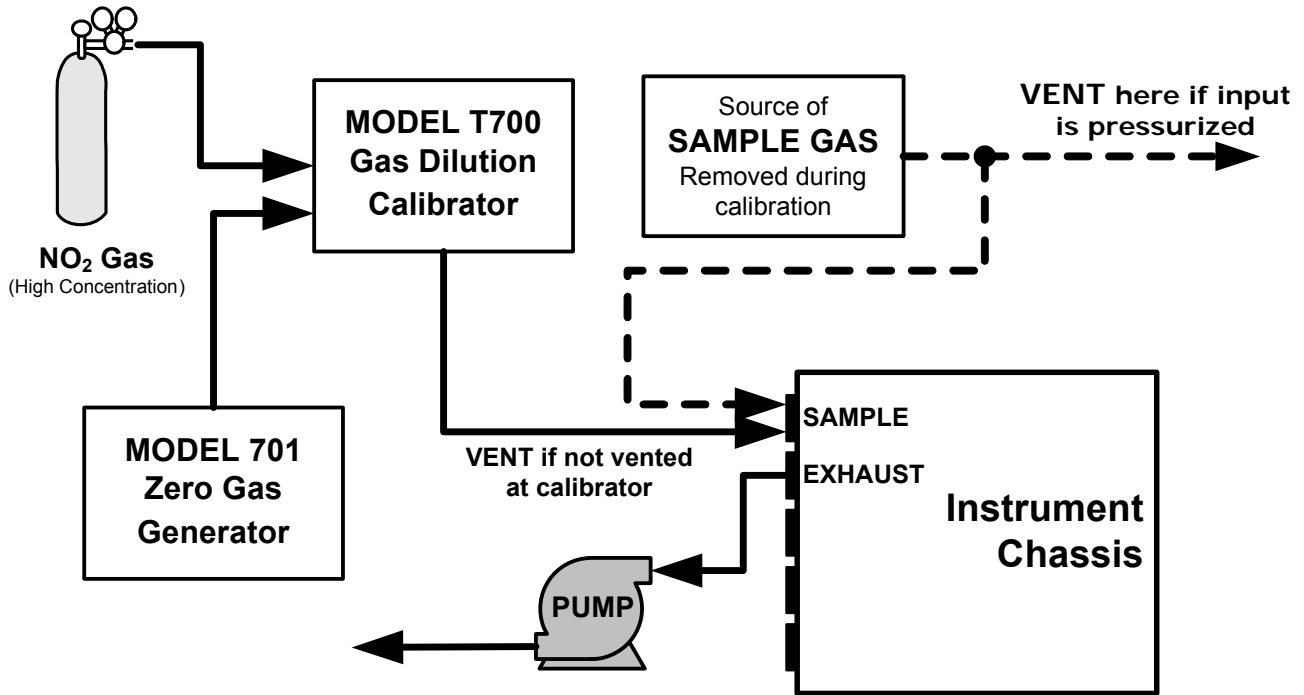
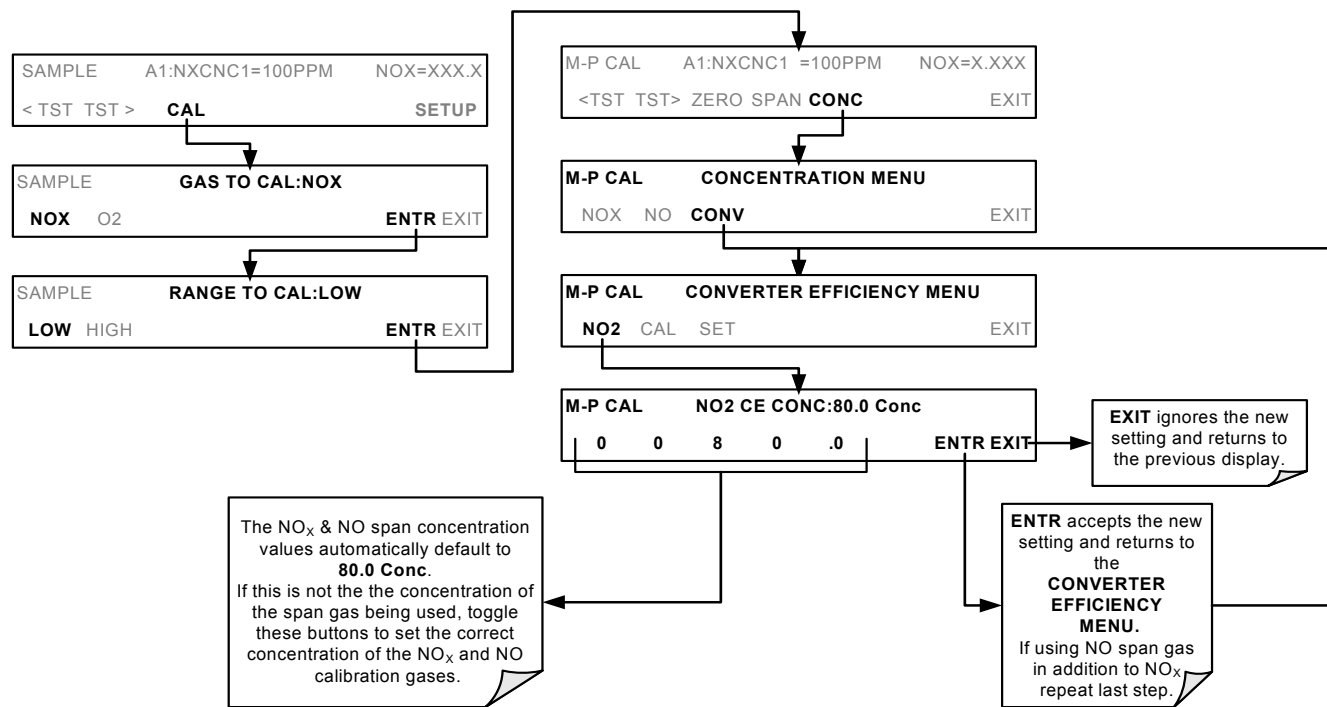


Figure 5-1: Gas Supply Setup for Determination of NO₂ Conversion Efficiency

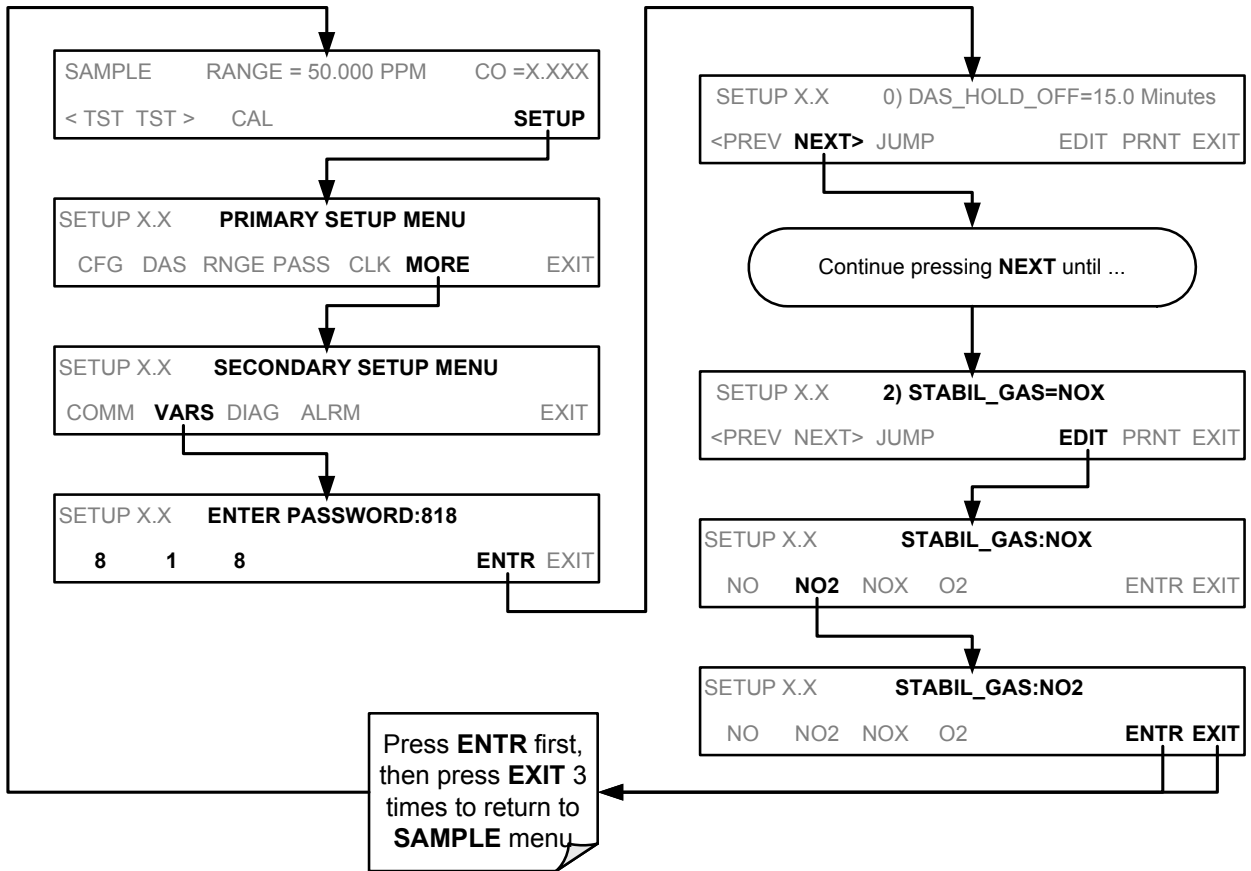
STEP TWO:

Set the expected NO₂ span gas concentration:



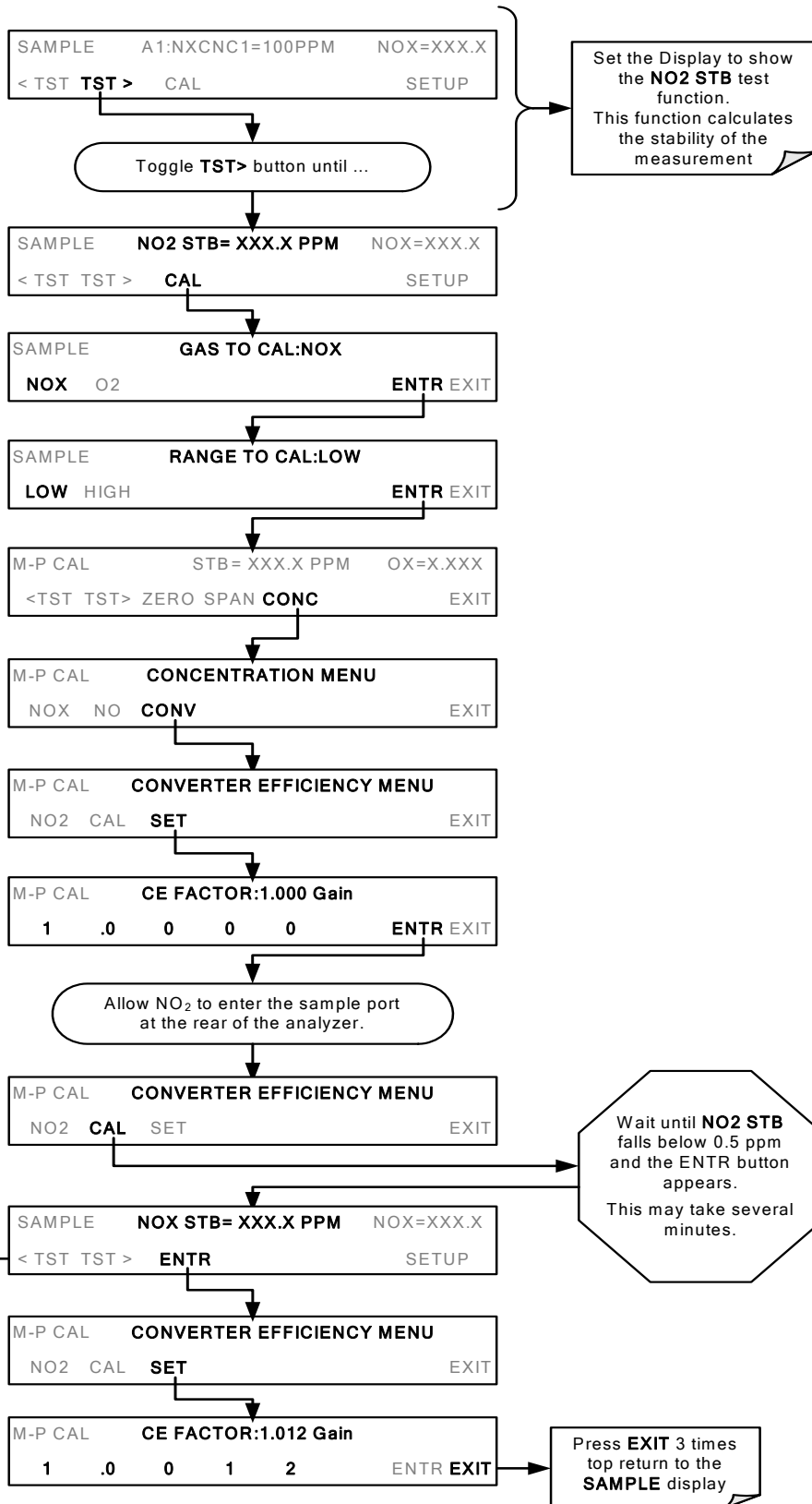
STEP THREE

Activate NO₂ measurement stability function.



STEP FOUR:

Perform the converter efficiency calculation procedure:



5.3. MANUAL CALIBRATION

The following section describes the basic method for manually calibrating the Model 9110TH/M NO_x analyzer.

If both available DAS parameters for a specific gas type are being reported via the instruments analog outputs e.g. NXCNC1 and NXCNC2, separate calibrations should be carried out for each parameter.

- Use the LOW button when calibrating for NXCNC1
- Use the HIGH button when calibrating for NXCNC2.

See Section 4.13.4 for more information on analog output reporting ranges

STEP ONE:

Connect the sources of zero air and span gas as shown below.

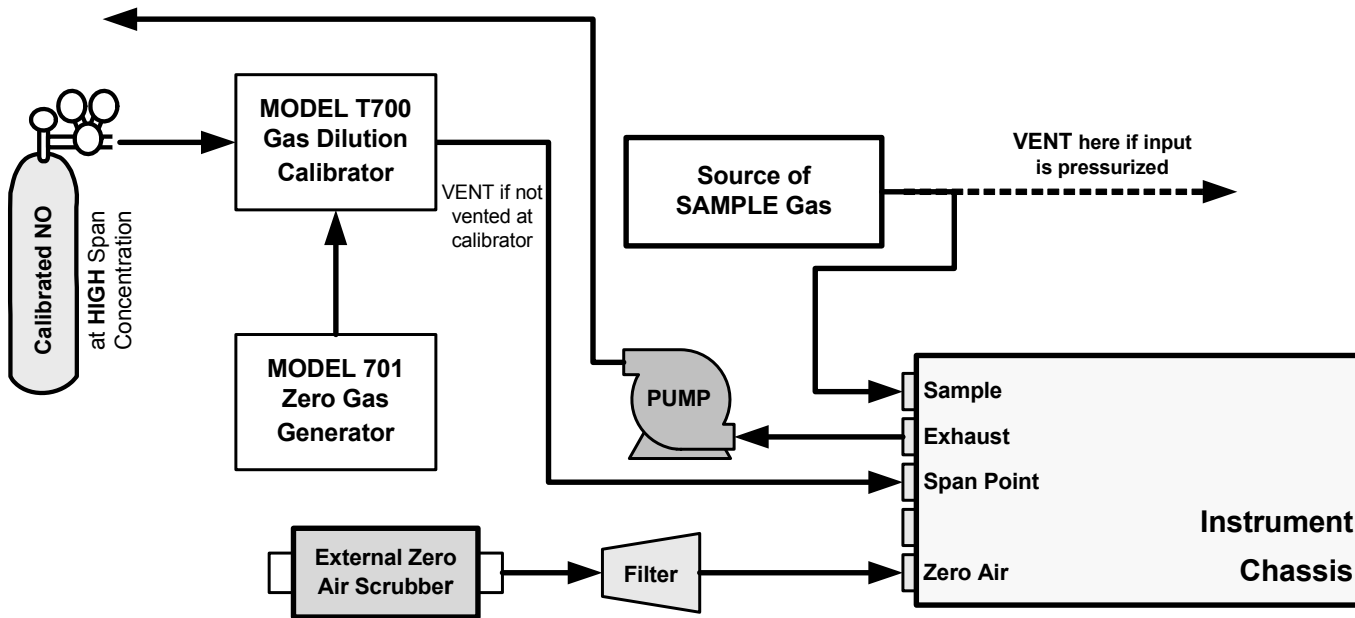


Figure 5-2: Pneumatic Connections–With Zero/Span Valve Option (50A)

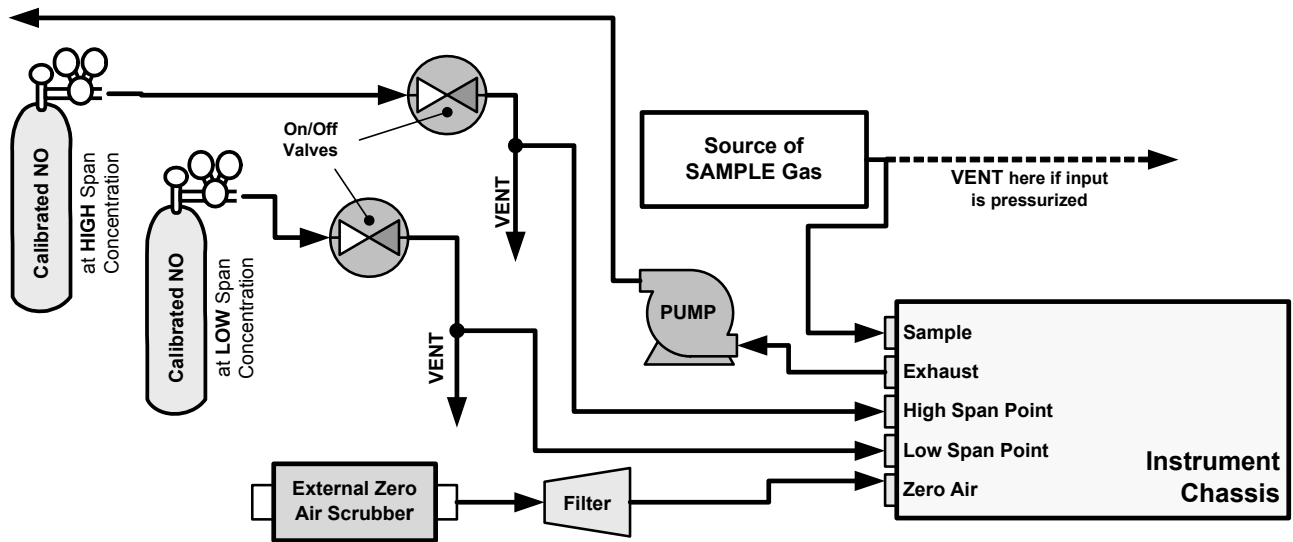
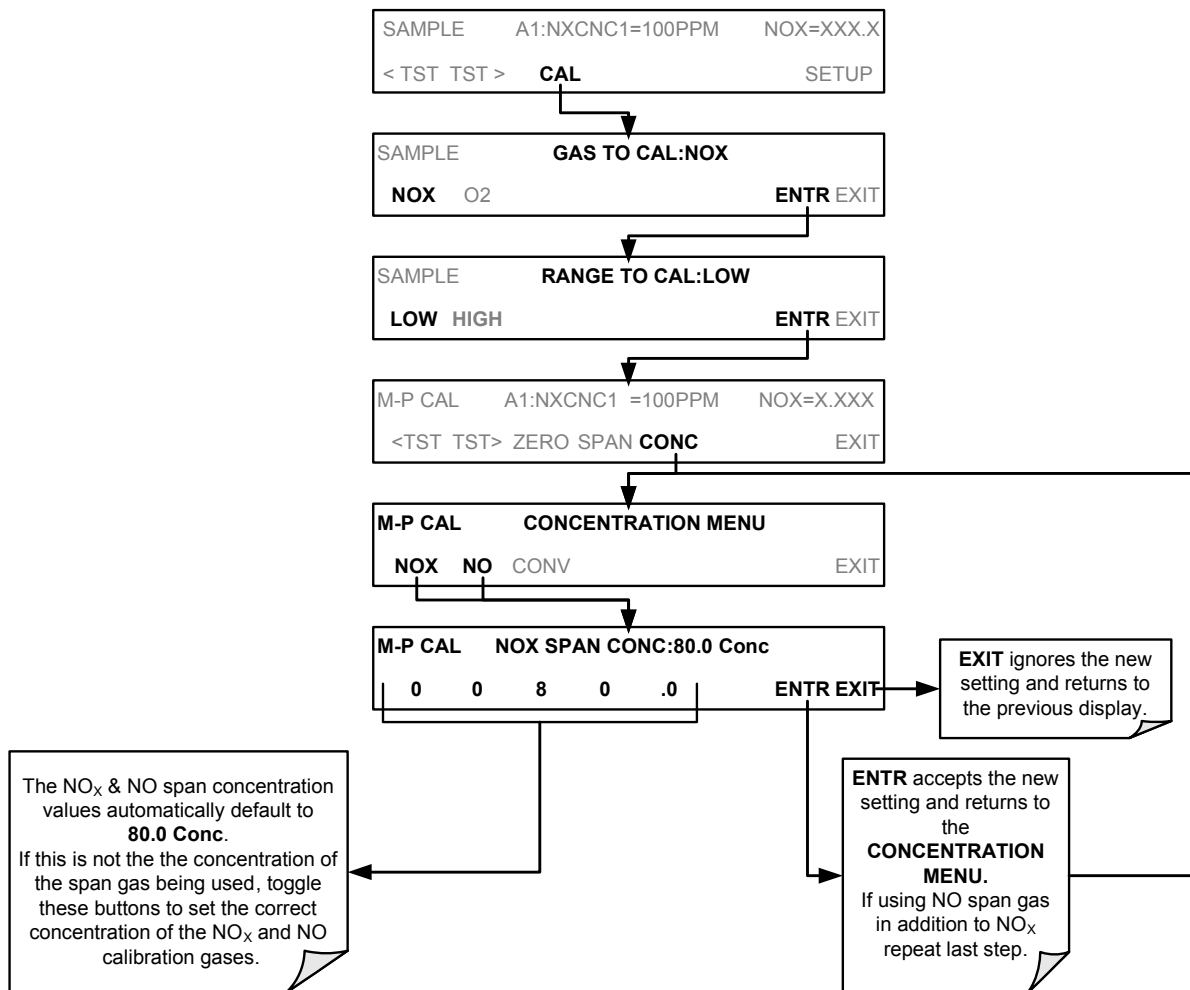


Figure 5-3: Pneumatic Connections—With 2-Span point Option (50D) —Using Bottled Span Gas

STEP TWO:

Set Expected NO and NO_x Span Gas Concentrations.

These should be 80% of range of concentration values likely to be encountered in this application. The default factory setting is 100 ppm. If one of the configurable analog outputs is to be set to transmit concentration values, use 80% of the reporting range set for that output (see Section 4.13.4)

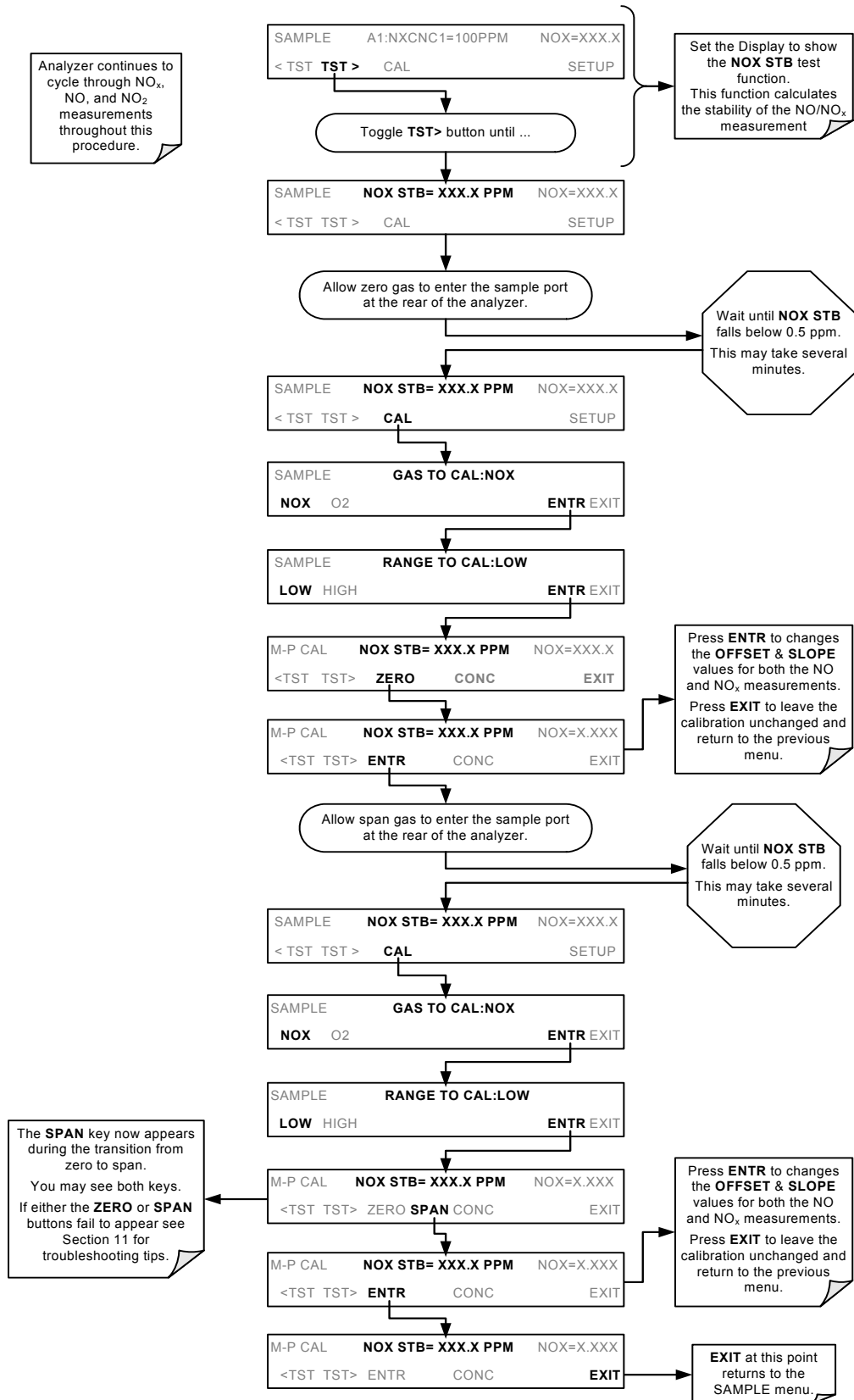


Note

The expected concentrations for both NO_x and NO are usually set to the same value unless the conversion efficiency is not equal to 1.000 or not entered properly in the conversion efficiency setting. When setting expected concentration values, consider impurities in your span gas source (NO often contains 1-3% NO₂ and vice versa).

STEP THREE:

Perform Zero/Span Calibration:



5.4. CALIBRATION CHECKS

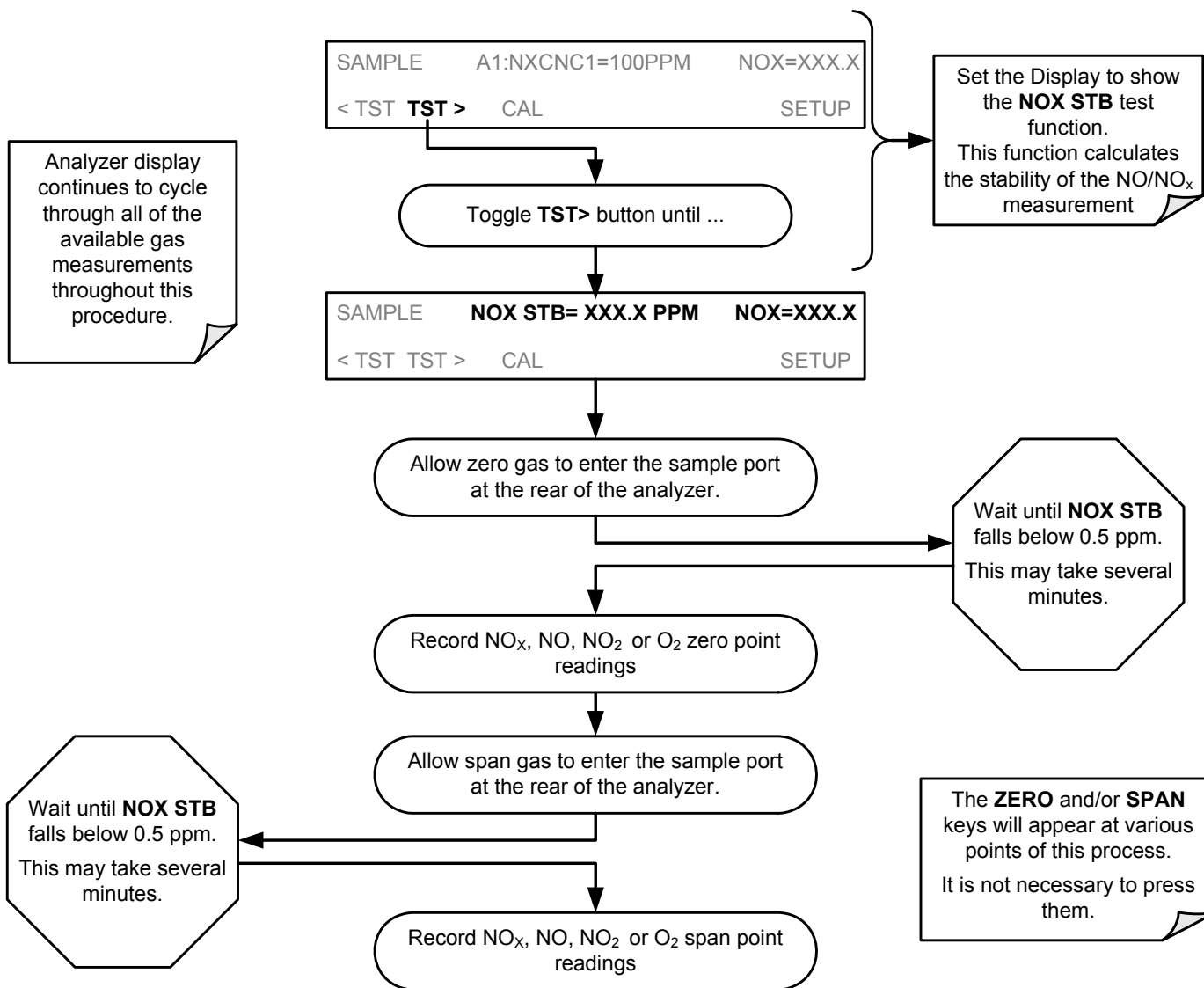
Informal calibration checks, which only evaluate but do not alter the analyzer's response curve, are recommended as a regular maintenance item and in order to monitor the analyzer's performance. To carry out a calibration check rather than a full calibration, follow these steps.

STEP ONE:

Connect the sources of zero air and span gas as shown in Figure 7.2 or 7.3.

STEP TWO:

Perform the zero/span calibration check procedure:



5.5. MANUAL CALIBRATION WITH ZERO/SPAN VALVES

Zero and Span calibrations using the Zero/Span Valve option are similar to that described in Section 7.2, except that:

- Zero air and span gas is supplied to the analyzer through the zero gas and span gas inlets rather than through the sample inlet.
- The zero and cal operations are initiated directly and independently with dedicated keys (**CALZ & CALS**)

If both available DAS parameters for a specific gas type are being reported via the instruments analog outputs e.g. NXCNC1 and NXCNC2, separate calibrations should be carried out for each parameter.

- Use the LOW button when calibrating for NXCNC1
- Use the HIGH button when calibrating for NXCNC2.

See Section 4.13.4 for more information on analog output reporting ranges

STEP ONE:

Connect the sources of zero air and span gas to the respective ports on the rear panel as shown below.

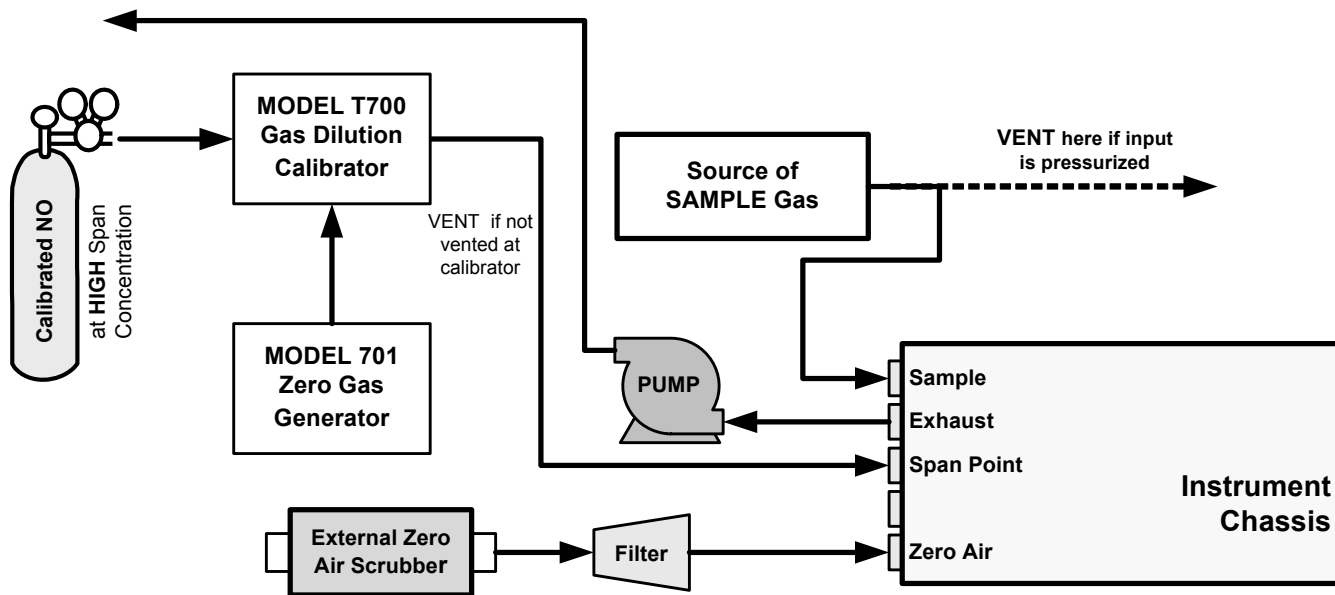
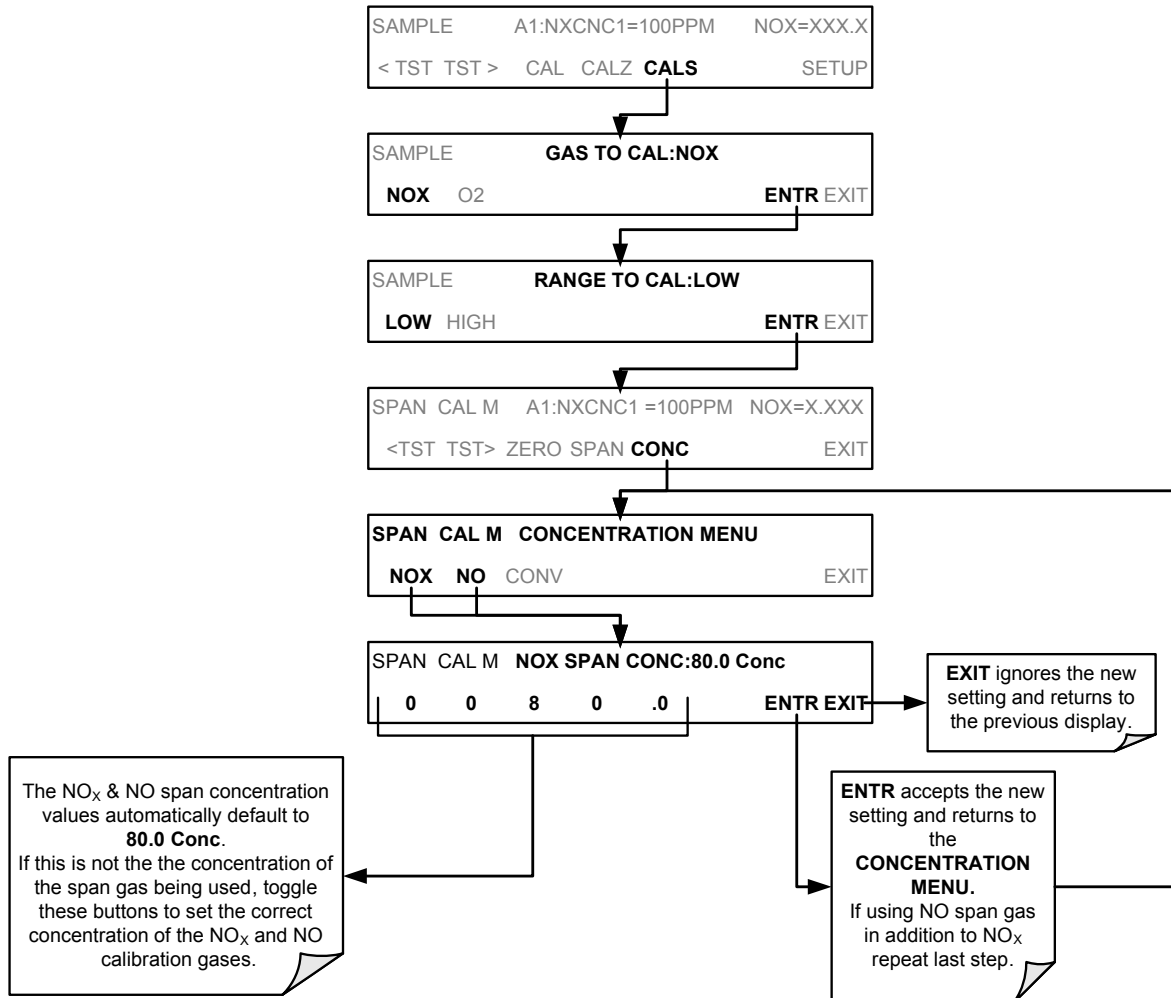


Figure 5-4: Pneumatic Connections—With Zero/Span Valve Option (50)

STEP TWO:

Set Expected NO and NO_x Span Gas Concentrations.

Set the expected NO and NO_x span gas concentration. These should be 80% of range of concentration values likely to be encountered in this application. The default factory setting is 100 ppm. If one of the configurable analog outputs is to be set to transmit concentration values, use 80% of the reporting range set for that output.

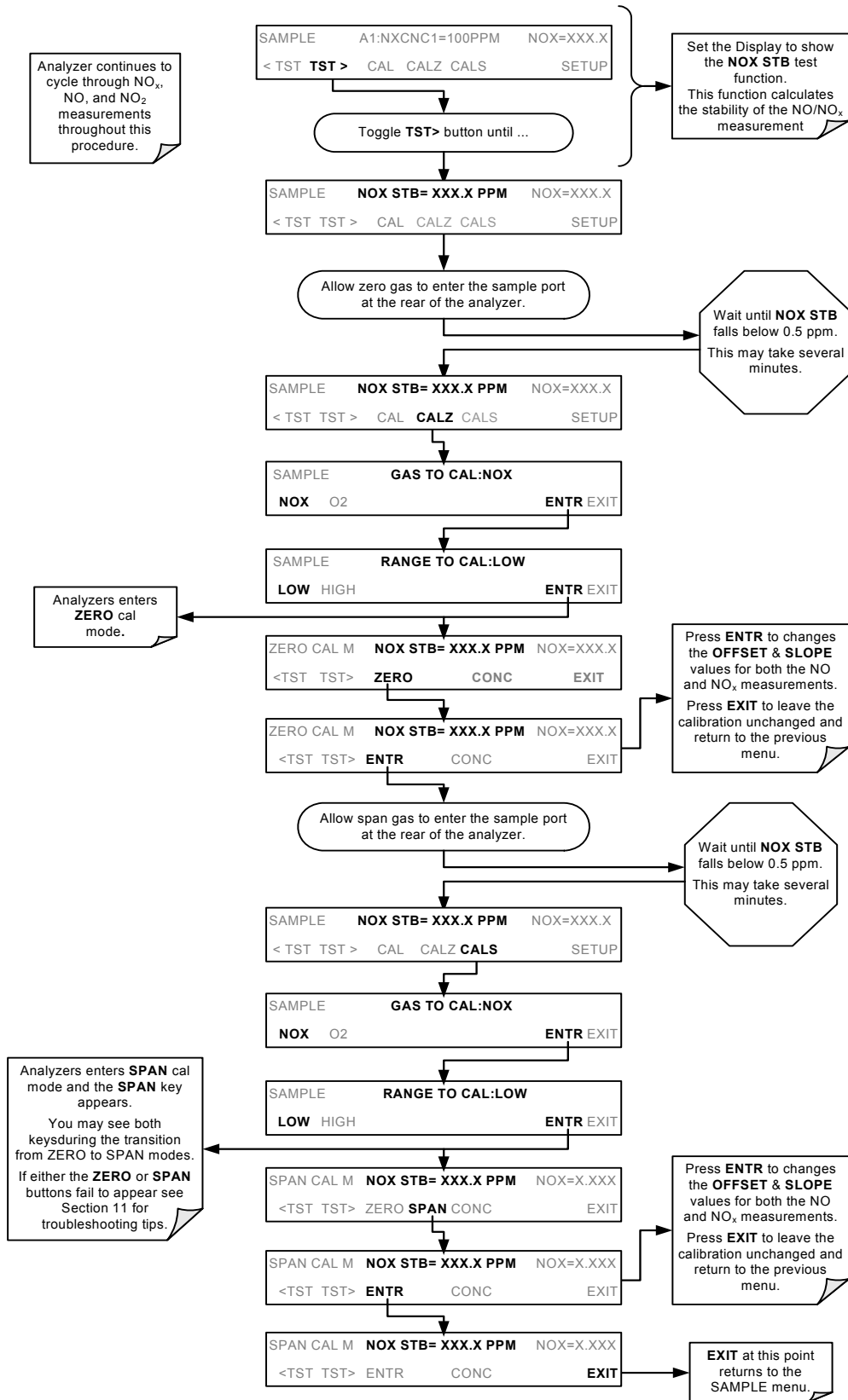


Note

The expected concentrations for both NO_x and NO are usually set to the same value unless the conversion efficiency is not equal to 1.000 or not entered properly in the conversion efficiency setting. When setting expected concentration values, consider impurities in your span gas source (NO often contains 1-3% NO₂ and vice versa).

STEP THREE:

Perform Zero/Span Calibration:



5.6. CALIBRATION CHECKS WITH ZERO/SPAN VALVES

Zero and span checks using the zero/span valve option are similar to that described in Section 7.4, except that zero air and span gas are supplied to the analyzer through the zero gas and span gas inlets from two different sources.

Informal calibration checks, which only evaluate but do not alter the analyzer's response curve, are recommended as a regular maintenance item and in order to monitor the analyzer's performance. To carry out a calibration check rather than a full calibration, follow these steps.

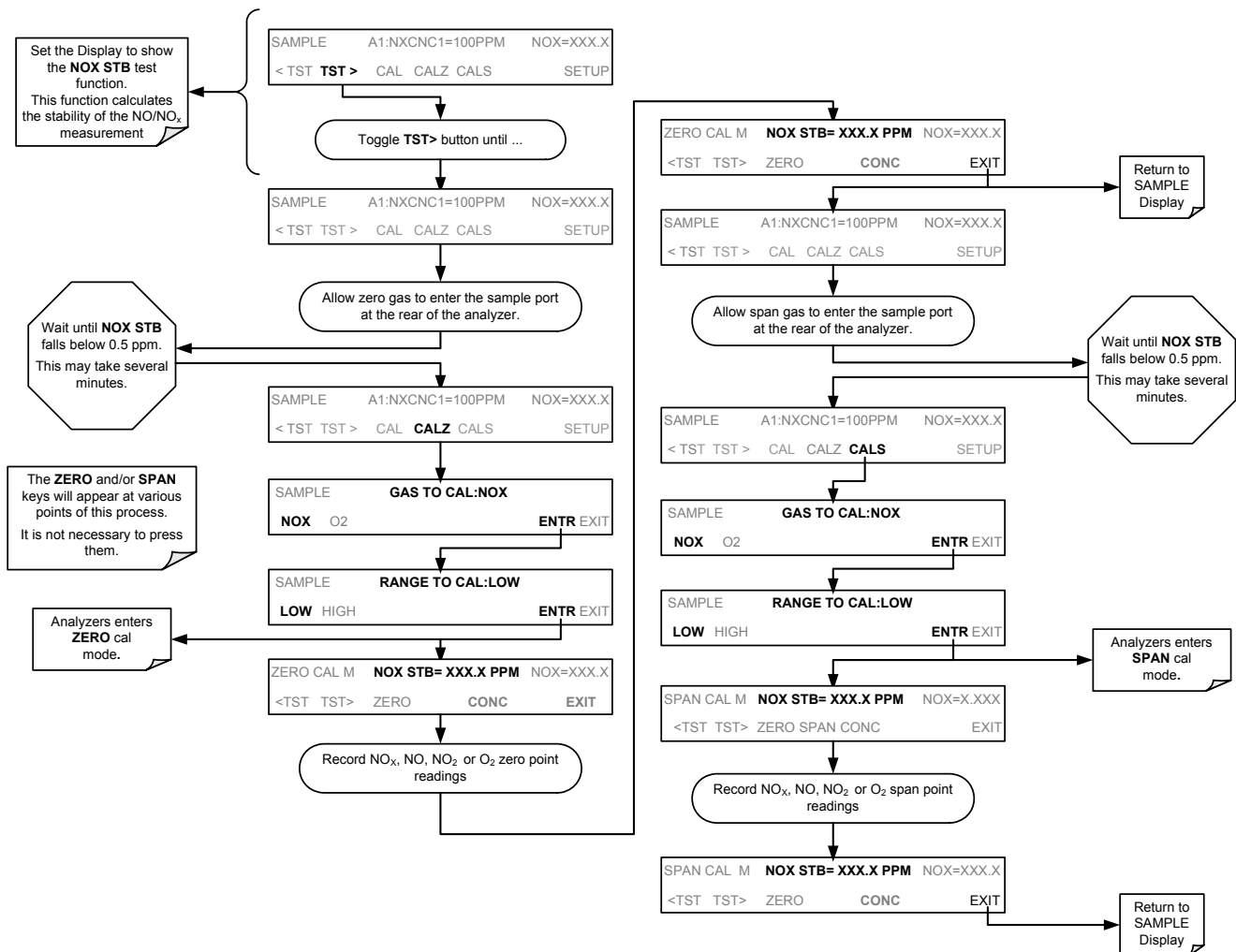
To perform a manual calibration check with zero/span valve:

STEP ONE:

Connect the sources of Zero Air and Span Gas as shown in section 7-4.

STEP TWO:

Perform the zero/span check.



5.7. CALIBRATION WITH REMOTE CONTACT CLOSURES

Contact closures for controlling calibration and calibration checks are located on the rear panel **CONTROL IN** connector. Instructions for setup and use of these contacts can be found in Section 4.15.1.2.

When the appropriate contacts are closed for at least 5 seconds, the instrument switches into zero, low span or high span mode and internal zero/span valves (if installed) will be automatically switched to the appropriate configuration. The remote calibration contact closures may be activated in any order. It is recommended that contact closures remain closed for at least 10 minutes to establish a reliable reading; the instrument will stay in the selected mode for as long as the contacts remain closed.

If contact closures are used in conjunction with the analyzer's AutoCal (Section 5.8) feature and the AutoCal attribute **CALIBRATE** is enabled, the 9110TH/M will not recalibrate the analyzer until the contact is opened. At this point, the new calibration values will be recorded before the instrument returns to SAMPLE mode. If the AutoCal attribute **CALIBRATE** is disabled, the instrument will return to SAMPLE mode, leaving the instrument's internal calibration variables unchanged.

5.8. AUTOMATIC CALIBRATION (AUTOCAL)

The AutoCal feature allows unattended, periodic operation of the zero/span valve options by using the analyzer's internal time of day clock. The AutoCal feature is only available on the front panel menu (ACAL) if either the zero/span valve or the IZS option is installed.

AutoCal operates by executing user-defined sequences to initiate the various calibration modes of the analyzer and to open and close valves appropriately. It is possible to program and run up to three separate sequences (SEQ1, SEQ2 and SEQ3). Each sequence can operate in one of three modes or be disabled:

Table 5-2: AutoCal Modes

MODE	BEHAVIOR
DISABLED	Disables the sequence
ZERO	Causes the sequence to perform a zero calibration or check
ZERO-LO¹	Causes the sequence to perform a zero calibration or check followed by a mid-span concentration calibration or check
ZERO-LO-HI¹	Causes the sequence to perform a zero calibration or check followed by a mid-span concentration calibration or check and finally a high-span point calibration or check.
ZERO-HI	Causes the sequence to perform a zero calibration or check followed by a high-span point calibration or check.
LO¹	Causes the sequence to perform a mid-span concentration calibration or check
LO-HI¹	Causes the sequence to perform a mid-span concentration calibration or check followed by a high-span point calibration or check
HI	Causes the sequence to perform a high-span point calibration or check.
O2 -ZERO²	Causes the sequence to do a zero-point calibration for the O ₂ sensor.
O2 ZERO-SP²	Causes the sequence to perform a zero calibration of the or check O ₂ sensor followed by a mid-span concentration calibration or check of the O ₂ sensor.
O2 SPAN²	Causes the sequence to perform a zero calibration or check of the O ₂ sensor.
¹ Only applicable if analyzer is equipped with the second span point valve option (52)	
² Only applicable if instrument is equipped with the O ₂ sensor option (65).	

Each mode has seven parameters to control operational details of the sequence:

Table 5-3: AutoCal Attribute Setup Parameters

PARAMETER	BEHAVIOR
TIMER ENABLED	Turns on the sequence timer
STARTING DATE	Sequence will operate on Starting Date
STARTING TIME	Sequence will operate at Starting Time
DELTA DAYS	Number of days between each sequence trigger. If set to 7, for example, the AutoCal feature will be enabled once every week on the same day.
DELTA TIME	Incremental delay on each delta day that the sequence starts. If set to 0, the sequence will start at the same time each day. Delta Time is added to Delta Days for the total time between cycles. This parameter prevents the analyzer from being calibrated at the same daytime of each calibration day and prevents a lack of data for one particular daytime on the days of calibration.
DURATION	Duration of the each sequence step in minutes. This parameter needs to be set such that there is enough time for the concentration signal to stabilize. The STABIL parameter shows if the analyzer response is stable at the end of the calibration. This parameter is logged with calibration values in the DAS.
CALIBRATE	Enable to do a true, dynamic zero or span calibration; disable to do a calibration <i>check</i> only.
RANGE TO CAL	LOW calibrates the low range, HIGH calibrates the high range. Applies only to auto and remote range modes; this property is not available in single and independent range modes.

The following example sets sequence #2 to carry out a zero-span calibration every other day starting at 14:00 on 01 January, 2003, lasting 30 minutes (15 for zero and 15 for span). This sequence will start 30 minutes later each day.

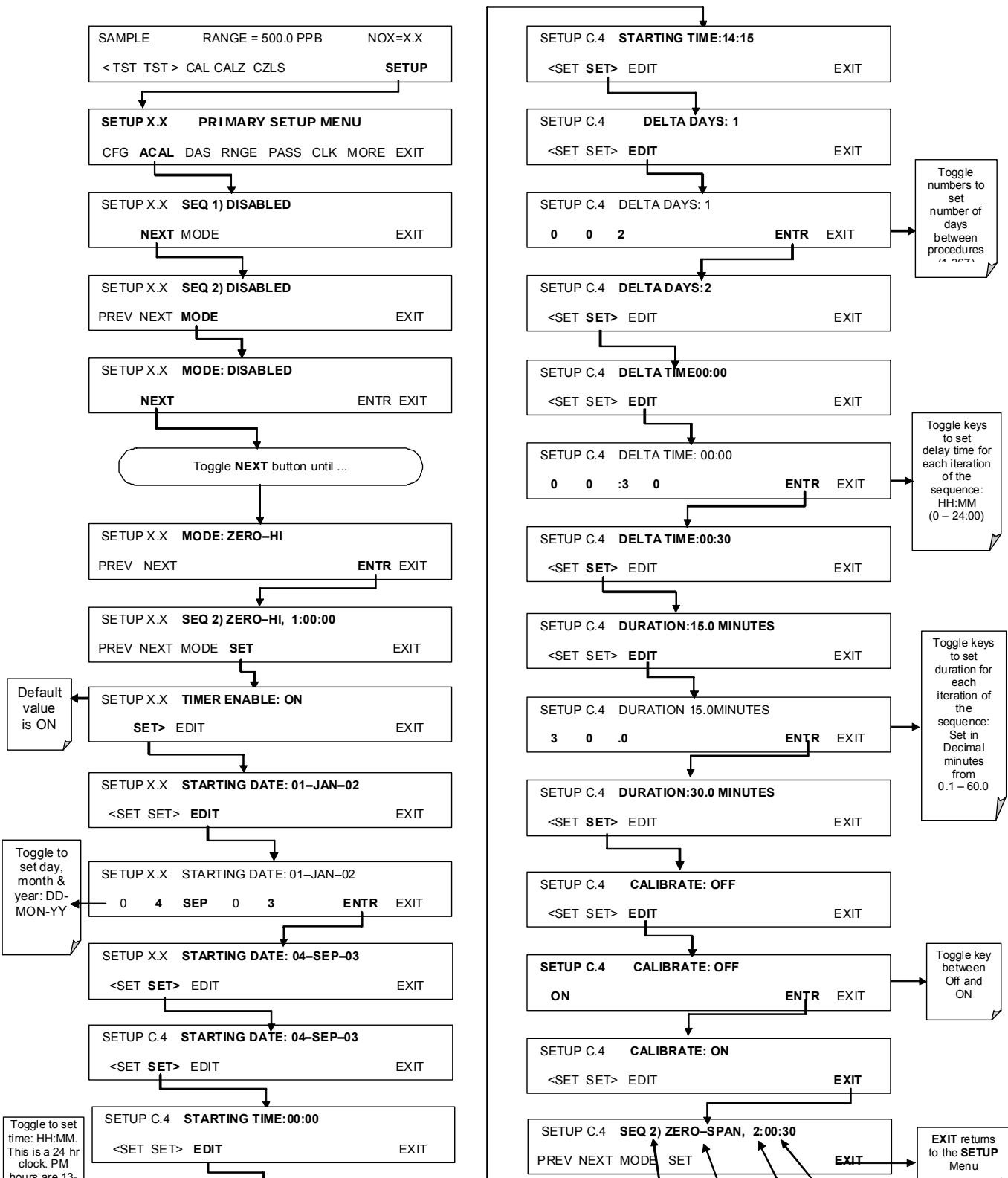
Table 5-4: Example Auto-Cal Sequence

MODE AND ATTRIBUTE	VALUE	COMMENT
SEQUENCE	2	Define sequence #2
MODE	ZERO-HI	Select zero and span mode
TIMER ENABLE	ON	Enable the timer
STARTING DATE	01-JAN-03	Start on or after 01 January 2003
STARTING TIME	14:00	First sequence starts at 14:00 (24-hour clock format)
DELTA DAYS	2	Repeat this sequence every 2 days
DELTA TIME	00:30	Repeat sequence 30 minutes later each time (every 2 days and 30 minutes)
DURATION	15.0	Each sequence step will last 15 minutes (total of 30 minutes when using zero-span mode)
CALIBRATE	ON	The instrument will recalculate the slope and offset values for the NO and NOx channel at the end of the AutoCal sequence.

Please the following suggestions for programming the AutoCal feature.

- The programmed **Starting Time** must be 5 minutes later than the real time clock.
- Avoid setting two or more sequences at the same time of the day. Any new sequence which is initiated from a timer, the COM ports, or the contact closures will override any sequence in progress. that two sequences with different daily increments may eventually overlap.
- If at any time an illegal entry is selected, (for example: Delta Days > 366) the ENTR button will disappear from the display.
- With **CALIBRATE** turned on, the state of the internal setup variables **DYN_SPAN** and **DYN_ZERO** is set to **ON** and the instrument will reset the slope and offset values for the NO and NO_x response each time the AutoCal program runs. This continuous re-adjustment of calibration parameters can often mask subtle fault conditions in the analyzer. It is recommended that, if **CALIBRATE** is enabled, the analyzer's test functions, slope and offset values be checked frequently to assure high quality and accurate data from the instrument.

To program the sample sequence shown above, follow this flow chart:



5.9. CALIBRATION QUALITY ANALYSIS

After completing one of the calibration procedures described above, it is important to evaluate the analyzer's calibration **SLOPE** and **OFFSET** parameters. These values describe the linear response curve of the analyzer, separately for NO and NO_x. The values for these terms, both individually and relative to each other, indicate the quality of the calibration. To perform this quality evaluation, you will need to record the values of the following test functions (Section 4.2.1 or Appendix A-3), all of which are automatically stored in the DAS channel **CALDAT** for data analysis, documentation and archival.

- NO OFFS
- NO SLOPE
- NOX OFFS
- NOX SLOPE

Make sure that these parameters are within the limits listed in Table 5-5 and frequently compare them to those values on the *Final Test and Checkout Sheet* that came attached to your manual, which should not be significantly different. If they are, refer to the troubleshooting Section 7.

Table 5-5: Calibration Data Quality Evaluation

FUNCTION	MINIMUM VALUE	OPTIMUM VALUE	MAXIMUM VALUE
NOX SLOPE	-0.700	1.000	1.300
NO SLOPE	-0.700	1.000	1.300
NOX OFFS	-20.0 mV	0.0 mV	150.0 mV
NO OFFS	-20.0 mV	0.0 mV	150.0 mV

The default DAS configuration records all calibration values in channel CALDAT as well as all calibration check (zero and span) values in its internal memory. Up to 200 data points are stored for up 4 years of data (on weekly calibration checks) and a lifetime history of monthly calibrations. Review these data to see if the zero and span responses change over time. These channels also store the STABIL value (standard deviation of NO_x concentration) to evaluate if the analyzer response has properly leveled off during the calibration procedure. Finally, the CALDAT channel also stores the converter efficiency for review and documentation.

6. INSTRUMENT MAINTENANCE

Predictive diagnostic functions, including data acquisition records, failure warnings and test functions built into the analyzer, allow the user to determine when repairs are necessary without performing unnecessary, preventative maintenance procedures. There is, however, a minimal number of simple procedures that, when performed regularly, will ensure that the analyzer continues to operate accurately and reliably over its lifetime. Repair and troubleshooting procedures are covered in Section 7 of this manual.

Pertinent information associated with the proper care, operation or maintenance of the analyzer or its parts.

A span and zero calibration check must be performed following some of the maintenance procedures listed below. Refer to Section 5.



WARNING

Risk of electrical shock. Disconnect power before performing any operations that require entry into the interior of the analyzer.



CAUTION

The operations outlined in this Section must be performed by qualified maintenance personnel only.

6.1. MAINTENANCE SCHEDULE

Table 9-1 shows the recommended maintenance schedule for the 9110TH/M. Please note that in certain environments with high levels of dust, humidity or pollutant levels some maintenance procedures may need to be performed more often than shown.

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Table 6-1: 9110TH/M Preventive Maintenance Schedule

ITEM	ACTION	FREQUENCY	CAL CHECK	MANUAL SECTION	DATE PERFORMED					
¹ Particulate Filter	Change filter	Weekly	No	9.3.1						
Verify Test Functions	Review and evaluate	Weekly	No	9.2; Appendix C						
Zero/Span Check	Evaluate offset and slope	Weekly	--	7.3, 7.5, 7.7						
¹ Zero/Span Calibration	Zero and span calibration	Every 3 months	--	7.2, 7.4, 7.6, 7.7, 7.8						
NO ₂ Converter	Replace converter & check efficiency	Every 3 years or if conversion efficiency < 96%	Yes if CE factor is used	--						
¹ External Zero Air Scrubber (Optional)	Exchange chemical	Every 3 months	No	3.5.3.2						
¹ Reaction Cell Window	Clean optics, Change O-rings	Annually or as necessary	Yes	6.4.5						
¹ Air Inlet Filter Of Perma Pure Dryer	Change particle filter	Annually	No	6.4.2						
Pneumatic Sub-System	Check for leaks in gas flow paths	Annually or after repairs involving pneumatics	Yes on leaks, else no	7.5.1, 7.5.2						
¹ All Critical Flow Orifice O-Rings & Sintered Filters	Replace	Annually	Yes	6.4.6						
^{1,2} Pump	Rebuild head	Annually	Yes	9.3.4						
Inline Exhaust Scrubber	Replace	Annually	No							
Pmt Sensor Hardware Calibration	Low-level hardware calibration	On PMT/ preamp changes & if $0.7 < \text{SLOPE} > 1.3$	Yes	11.6.5						

¹ These Items are required to maintain full warranty, all other items are strongly recommended.

² A pump rebuild kit is available from TAI Technical Support including all instructions and required parts (the pump part number is on the label of the pump itself).

6.2.

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6.3. PREDICTIVE DIAGNOSTICS

The analyzer's test functions can be used to predict failures by looking at trends in their values. Initially it may be useful to compare the state of these test functions to the values measured on your instrument at the factory and recorded on the *9110TH/M Final Test and Validation Data Form* (TAI part number 04490, attached to the manual). Table 6-2 can be used as a basis for taking action as these values change with time. The internal data acquisition system (DAS) is a convenient way to record and track these changes. APICOM control software can be used to download and review these data even from remote locations (Section 4.15.2.8 describes APICOM).

Table 6-2: Predictive Uses for Test Functions

FUNCTION	EXPECTED	ACTUAL	INTERPRETATION & ACTION
RCEL pressure	Constant to within ± 0.5	Fluctuating	Developing leak in pneumatic system. Check for leaks
		Slowly increasing	Pump performance is degrading. Replace pump head when pressure is above 10 in-Hg-A
SAMPLE pressure	Constant within atmospheric changes	Fluctuating	Developing leak in pneumatic system. Check for leaks
		Slowly decreasing	Flow path is clogging up. Replace orifice filters
		Slowly increasing	Developing leak in pneumatic system to vacuum (developing valve failure). Check for leaks
Ozone Flow	Constant to within ± 15	Slowly decreasing	Flow path is clogging up. Replace orifice filters
AZERO	Constant within ± 20 of check-out value	Significantly increasing	Developing AZERO valve failure. Replace valve
			PMT cooler failure. Check cooler, circuit, and power supplies
			Developing light leak. Leak check.
			O ₃ air filter cartridge is exhausted. Change chemical
NO ₂ CONC	Constant for constant concentrations	Slowly decreasing signal for same concentration	Converter efficiency may be degrading. Replace converter.
NO CONC	Constant for constant concentration	Decreasing over time	Drift of instrument response; clean RCEL window, change O ₃ air filter chemical.

6.4. MAINTENANCE PROCEDURES

The following procedures need to be performed regularly as part of the standard maintenance of the Model 9110TH/M.

6.4.1. CHANGING THE SAMPLE PARTICULATE FILTER

The particulate filter should be inspected often for signs of plugging or excess dirt. It should be replaced according to the service interval in Table 9-1 even without obvious signs of dirt. Filters with 1 μm pore size can clog up while retaining a clean look. We recommend to handle the filter and the wetted surfaces of the filter housing with gloves

and tweezers. We recommend not to touch any part of the housing, filter element, PTFE retaining ring, glass cover and the O-ring with bare hands as this may cause the pores to clog quicker and surfaces to become dirty due to possible oils from your hands.

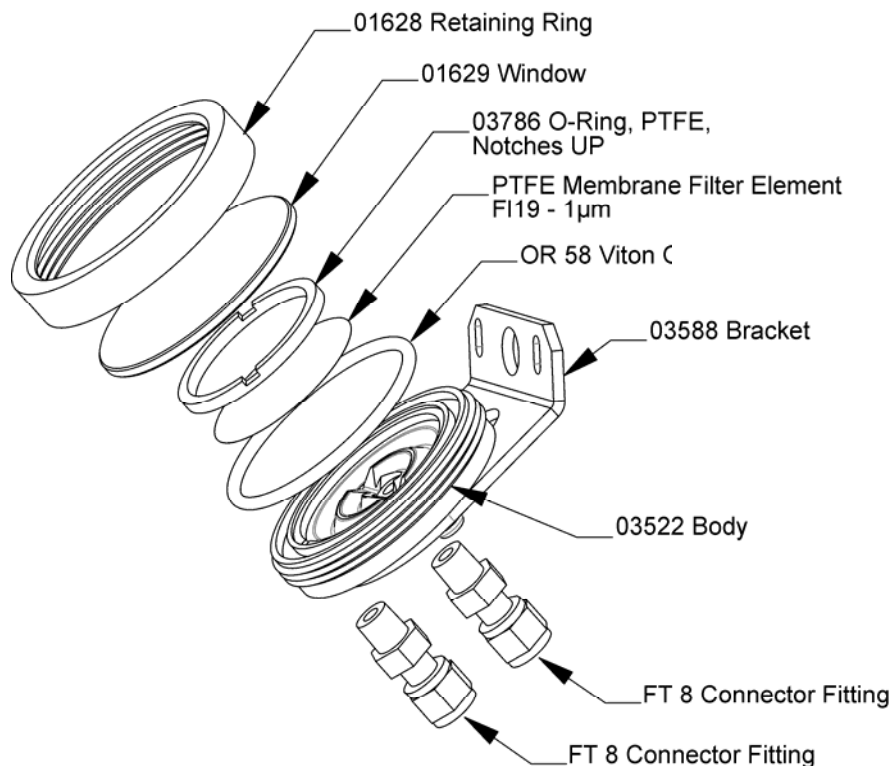


Figure 6-1: Sample Particulate Filter Assembly

To change the filter according to the service interval in Table 9-1, follow this procedure:

1. Turn OFF the pump to prevent drawing debris into the sample line.
2. Remove the CE Mark locking screw in the center of the front panel and open the hinged front panel and unscrew the knurled retaining ring of the filter assembly.
3. Carefully remove the retaining ring, glass window, PTFE O-ring and filter element. We recommend to clean the glass and O-rings at least once monthly, weekly in very polluted areas.
4. Install a new filter element, carefully centering it in the bottom of the holder.
5. Re-install the PTFE O-ring with the notches facing up (important!), the glass cover, then screw on the hold-down ring and hand-tighten the assembly. Inspect the (visible) seal between the edge of the glass window and the O-ring to assure proper gas tightness.
6. To fulfill CE Mark safety requirements, the front panel locking screw must be installed at all times during operation of the analyzer.
7. Re-start the analyzer.

6.4.2. CHANGING THE O₃ DRYER PARTICULATE FILTER

The air for the O₃ generator passes through a Perma Pure[®] dryer, which is equipped with a small particulate filter at its inlet. This filter prevents dust from entering the Perma Pure[®] dryer and degrading the dryer's performance over time. To change the filter according to the service interval in Table 6-1:

1. Check and write down the average RCEL pressure and the OZONE flow values.
2. Turn off the analyzer, unplug the power cord and remove the cover.
3. Unscrew the nut around the port of the filter using 5/8" and 9/16" wrenches and by holding the actual fitting body steady with a 7/16" wrench.

Note

RISK OF SIGNIFICANT LEAK

Make sure to use proper wrenches and to not turn the fitting against the Perma Pure[®] dryer. This may loosen the inner tubing and cause large leaks.

4. Take off the old filter element and replace it with a suitable equivalent (TAPI part# FL-3).

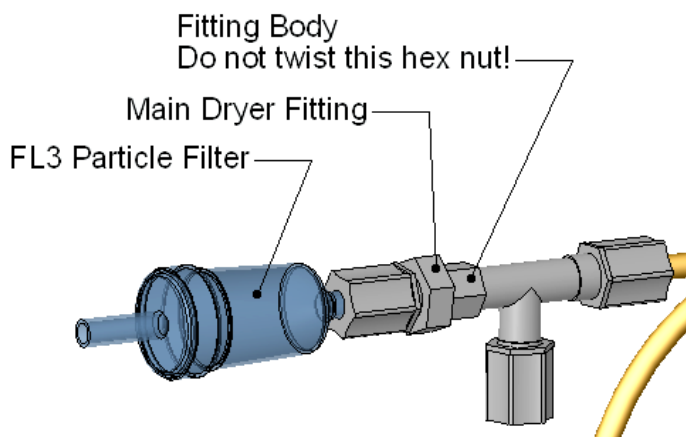


Figure 6-2: Particle Filter on O₃ Supply Air Dryer

5. Holding the fitting steady with a 5/8" wrench, tighten the nut with your hands. If necessary use a second wrench but do not over-tighten the nut.
6. Replace the cover, plug in the power cord and restart the analyzer.
7. Check the O₃ flow rate, it should be around 250 cm³/min ± 15. Check the RCEL pressure, it should be the same value as before.

6.4.3. MAINTAINING THE EXTERNAL SAMPLE PUMP

6.4.3.1. Rebuilding the Pump

The sample pump head periodically wears out and must be replaced when the RCEL pressure exceeds 10 in-Hg-A (at sea level, adjust this value accordingly for elevated locations). A pump rebuild kit is available from the factory. The part number of the pump rebuild kit is located on the label of the pump itself. Instructions and diagrams are included in the kit.

A flow and leak check after rebuilding the sample pump is recommended. A span check and re-calibration after this procedure is necessary as the response of the analyzer changes with the RCEL pressure.

6.4.3.2. Changing the Inline Exhaust Scrubber



CAUTION!

Do NOT attempt to change the contents of the inline exhaust scrubber cartridge; change the entire cartridge.

1. Through the SETUP>MORE>DIAG menu turn OFF the OZONE GEN OVERRIDE. Wait 10 minutes to allow pump to pull room air through scrubber before proceeding to step 2.
2. Disconnect exhaust line from analyzer.
3. Turn off (unplug) analyzer sample pump.
4. Disconnect tubing from (NOx or charcoal) scrubber cartridge.
5. Remove scrubber from system.
6. Dispose of according to local laws.
7. Install new scrubber into system.
8. Reconnect tubing to scrubber and analyzer.
9. Turn on pump.
10. Through the SETUP menu (per Step 1 above) turn ON the OZONE GEN OVERRIDE.

Note

The inline exhaust scrubber is strictly intended for Nitric Acid and NO₂ only.

6.4.4. CHANGING THE NO₂ CONVERTER

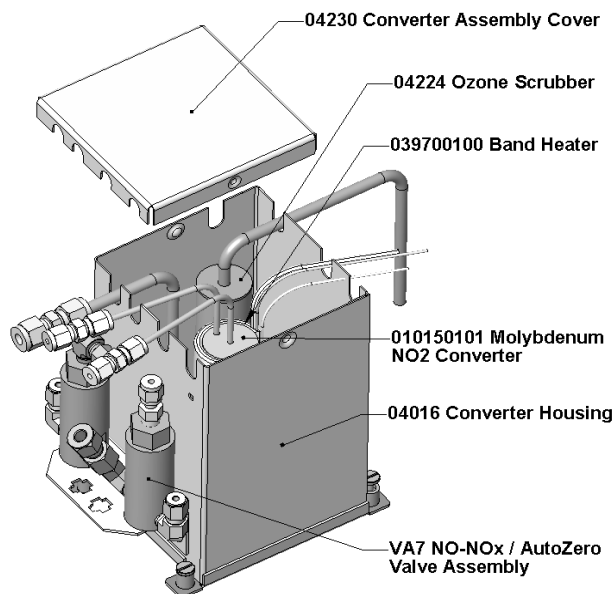
The NO₂ converter is located in the center of the instrument, see Figure 3-5 for location, and Figure 6-3 for the assembly. The converter is designed for replacement of the cartridge only, the heater with built-in thermocouple can be reused.

1. Turn off the analyzer power, remove the cover and allow the converter to cool.
2. Remove the top lid of the converter as well as the top layers of the insulation until the converter cartridge can be seen.



CAUTION
THE CONVERTER OPERATES AT 315° C. SEVERE BURNS CAN RESULT IF THE ASSEMBLY IS NOT ALLOWED TO COOL. DO NOT HANDLE THE ASSEMBLY UNTIL IT IS AT ROOM TEMPERATURE. THIS MAY TAKE SEVERAL HOURS.

3. Remove the tube fittings from the converter.
4. Disconnect the power and the thermocouple of the converter. Unscrew the grounding clamp of the power leads with a Phillips-head screw driver.
5. Remove the converter assembly (cartridge and band heater) from the can. Make a note of the orientation of the tubes relative to the heater cartridge.
6. Unscrew the band heater and loosen it, take out the old converter cartridge.



7. Wrap the band heater around the new replacement cartridge and tighten the screws using a high-temperature anti-seize agent such as copper paste. Make sure to use proper alignment of the heater with respect to the converter tubes.
8. Replace the converter assembly, route the cables through the holes in the can and reconnect them properly. Reconnect the grounding clamp around the heater leads for safe operation.

9. Re-attach the tube fittings to the converter and replace the insulation and cover.
10. Replace the instrument cover and power up the analyzer.
11. Allow the converter to burn-in for 24 hours, then re-calibrate the instrument.

6.4.5. CLEANING THE REACTION CELL

The reaction cell should be cleaned whenever troubleshooting suggests. A dirty reaction cell will cause excessive noise, drifting zero or span values, low response or a combination of all. To clean the reaction cell, remove it from the sensor housing: refer to Section 7.6.5. for an overview of the entire sensor assembly. Use the following guide to clean the reaction cell:

1. Turn off the instrument power and vacuum pump. Refer to Figure 6-4 for the following procedure.
2. Disconnect the black 1/4" exhaust tube and the 1/8" sample and ozone air tubes from the reaction cell. Disconnect the heater/thermistor cable.
3. Remove four screws holding the reaction cell to the PMT housing and lift the cell and manifold out as shown in the inset of Figure 6-4.

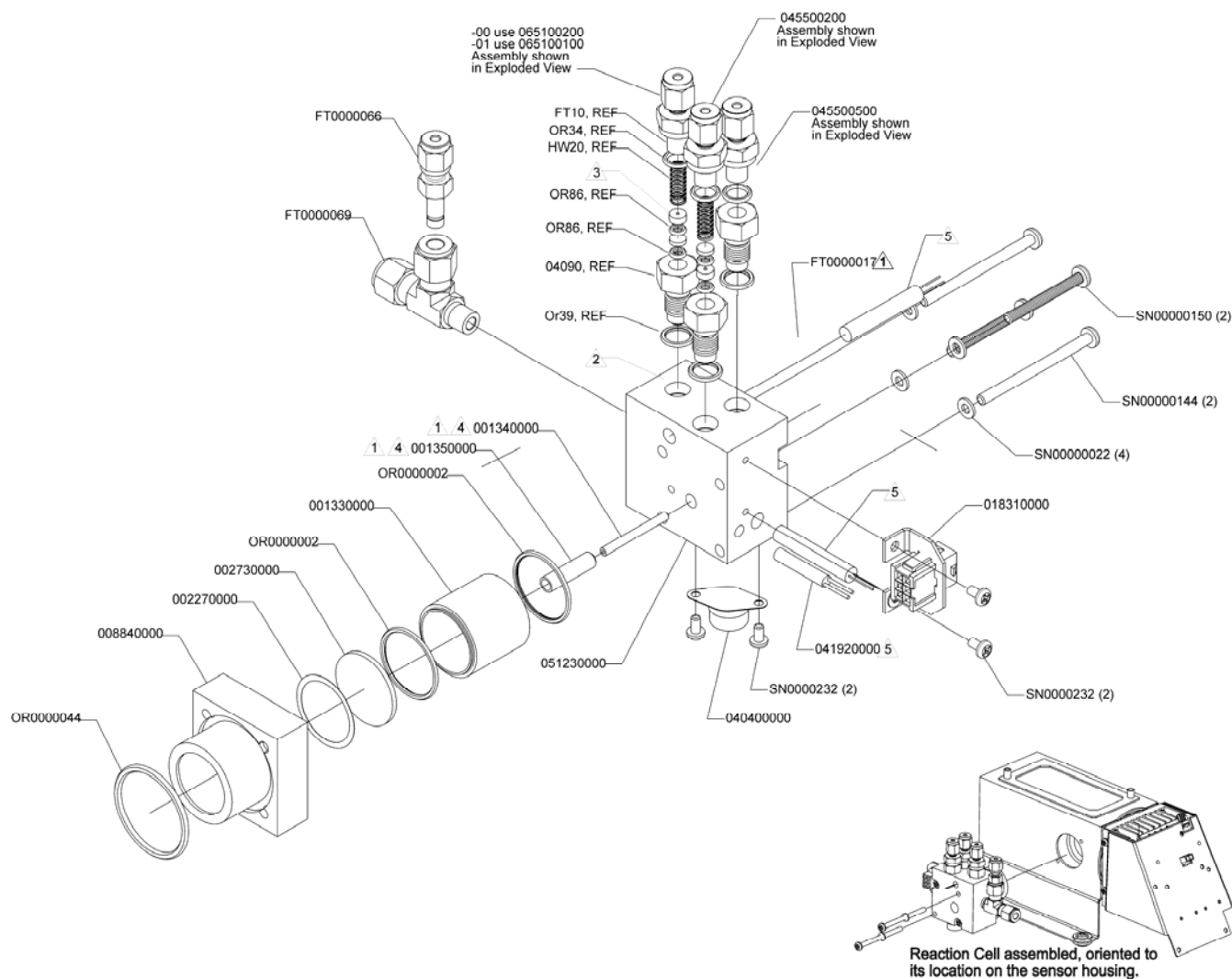


Figure 6-4: Reaction Cell Assembly

4. The reaction cell will separate into two halves, the stainless steel manifold assembly and the black plastic reaction cell with window, stainless steel cylinder and O-rings.
5. The reaction cell (both plastic part and stainless steel cylinder) and optical glass filter should be cleaned with methanol and a clean tissue and dried thereafter.
6. Usually it is not necessary to clean the ozone flow orifice since it is protected by a sintered filter. If tests show that cleaning is necessary, refer to Section 6.4.6 on how to perform maintenance on the critical flow orifice.
7. Do not remove the sample and ozone nozzles. They are Teflon threaded and require a special tool for reassembly. If necessary, the manifold with nozzles attached can be cleaned in an ultrasonic bath.
8. Reassemble in proper order and re-attach the reaction cell to the sensor housing. Reconnect pneumatics and heater connections, then re-attach the pneumatic sensor assembly and the cleaning procedure is complete.
9. After cleaning the reaction cell, it is also recommended to exchange the ozone supply air filter chemical.

- After cleaning, the analyzer span response may drop 10 - 15% in the first 10 days as the reaction cell window conditions. This is normal and does not require another cleaning.

6.4.6. CHANGING CRITICAL FLOW ORIFICES

There are several critical flow orifices installed in the 9110TH/M, Figure 6-4 shows one of the two most important orifice assemblies, located on the reaction cell. Refer to Section 8.3.3 for a detailed description on functionality and locations. Despite the fact that these flow restrictors are protected by sintered stainless steel filters, they can, on occasion, clog up, particularly if the instrument is operated without sample filter or in an environment with very fine, sub-micron particle-size dust.

The 9110TH/M introduces an orifice holder that makes changing the orifice very easy. In fact, it is recommended to keep spare orifice holder assemblies at hand to minimize downtime and swap orifices in a matter of a few minutes. Appendix B lists several complete spare part kits for this purpose.

To replace a critical flow orifice, do the following:

- Turn off power to the instrument and vacuum pump. Remove the analyzer cover and locate the reaction cell (Figure 3-7 for location in chassis, and Figure 6-4 for exploded view of assembly).
- Unscrew the 1/8" sample and ozone air tubes from the reaction cell
- For orifices on the reaction cell (Figure 6-4): Unscrew the orifice holder with a 9/16" wrench. This part holds all components of the critical flow assembly as shown in Figure 6-5. Appendix B contains a list of spare part numbers.
- For orifices in the vacuum manifold: the assembly is similar to the one shown in Figure 6-5, but without the orifice holder, part number 04090, and bottom O-ring OR34 and with an NPT fitting in place of the FT 10 fitting.

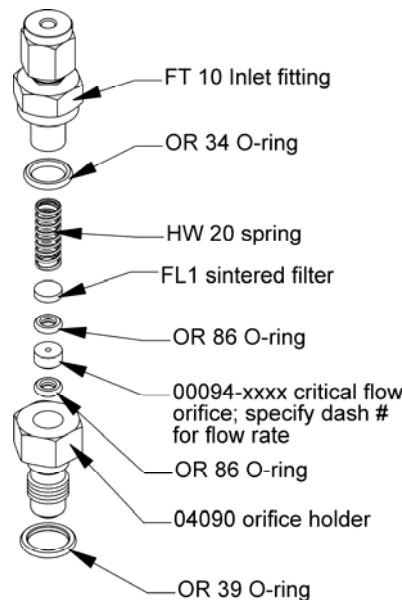


Figure 6-5: Critical Flow Orifice Assembly

5. Take out the components of the assembly: a spring, a sintered filter, two O-rings and the orifice. For the vacuum manifold only, you may need to use a scribe or pressure from the vacuum port to get the parts out of the manifold.
6. Discard the two O-rings and the sintered filter and the critical flow orifice.
7. Re-assemble the flow control assembly with new the parts (see Appendix B for part number or replacement kit) as shown in Figure 6-5 and re-connect them to the reaction cell manifold or the vacuum manifold.
8. Reconnect all tubing, power up the analyzer and pump and - after a warm-up period of 30 minutes, carry out a leak test as described in Section 7.5.

6.4.7. CHECKING FOR LIGHT LEAKS

When re-assembled or operated improperly, the 9110TH/M can develop small leaks around the PMT, which let stray light from the analyzer surrounding into the PMT housing. To find such light leaks, follow the below procedures. **CAUTION:** this procedure can only be carried out with the analyzer running and its cover removed. This procedure should only be carried out by qualified personnel.

1. Scroll the TEST functions to PMT.
2. Supply zero gas to the analyzer.
3. With the instrument still running, carefully remove the analyzer cover. Take extra care not to touch any of the inside wiring with the metal cover or your body. Do not drop screws or tools into a running analyzer!
4. Shine a powerful flashlight or portable incandescent light at the inlet and outlet fitting and at all of the joints of the reaction cell as well as around the PMT housing. The PMT value should not respond to the light, the PMT signal should remain steady within its usually noise.
5. If there is a PMT response to the external light, symmetrically tighten the reaction cell mounting screws or replace the 1/4" vacuum tubing with new, black PTFE tubing (this tubing will fade with time and become transparent). Often, light leaks are also caused by O-rings being left out of the assembly.
6. Carefully replace the analyzer cover.
7. If tubing was changed, carry out a leak check (Section 7.5).

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7. TROUBLESHOOTING & REPAIR

This section contains a variety of methods for identifying and solving performance problems with the analyzer.



CAUTION

The operations outlined in this Section must be performed by qualified maintenance personnel only.



WARNING

Risk of electrical shock. Some operations need to be carried out with the analyzer open and running. Exercise caution to avoid electrical shocks and electrostatic or mechanical damage to the analyzer. Do not drop tools into the analyzer or leave those after your procedures. Do not shorten or touch electric connections with metallic tools while operating inside the analyzer. Use common sense when operating inside a running analyzer.

7.1. GENERAL TROUBLESHOOTING

The analyzer has been designed so that problems can be rapidly detected, evaluated and repaired. During operation, the analyzer continuously performs diagnostic tests and provides the ability to evaluate its key operating parameters without disturbing monitoring operations.

A systematic approach to troubleshooting will generally consist of the following five steps:

- any warning messages and take corrective action as necessary.
- Examine the values of all TEST functions and compare them to factory values. any major deviations from the factory values and take corrective action.
- Use the internal electronic status LED's to determine whether the electronic communication channels are operating properly. Verify that the DC power supplies are operating properly by checking the voltage test points on the relay board. that the analyzer's DC power wiring is color-coded and these colors match the color of the corresponding test points on the relay board.

- Suspect a leak first! Technical Support data indicate that the majority of all problems are eventually traced to leaks in the pneumatic system of the analyzer (including the external pump), the source of zero air or span gases or the sample gas delivery system. Check for gas flow problems such as clogged or blocked internal/external gas lines, damaged seals, punctured gas lines, a damaged pump diaphragm, etc.
- Follow the procedures defined in Section 3.6.3. to confirm that the analyzer's vital functions are working (power supplies, CPU, relay board, PMT cooler, etc.). See Figure 3-5 for general layout of components and sub-assemblies in the analyzer. See the wiring interconnect diagram and interconnect list in Appendix D.

7.1.1. FAULT DIAGNOSIS WITH WARNING MESSAGES

The most common and/or serious instrument failures will result in a warning message being displayed on the front panel. Table 4-3 lists warning messages, along with their meaning and recommended corrective action.

It should be noted that if more than two or three warning messages occur at the same time, it is often an indication that some fundamental analyzer sub-system (power supply, relay board, motherboard) has failed rather than an indication of the specific failures referenced by the warnings. In this case, a combined-error analysis needs to be performed.

The analyzer will alert the user that a Warning message is active by flashing the red FAULT LED, displaying the Warning message in the Param field along with the **CLR** button (press to clear Warning message). The **MSG** button displays if there is more than one warning in queue or if you are in the TEST menu and have not yet cleared the message. The following display/touch screen examples provide an illustration of each:



The analyzer also issues an alert via the serial port(s).

To view or clear a warning messages press:

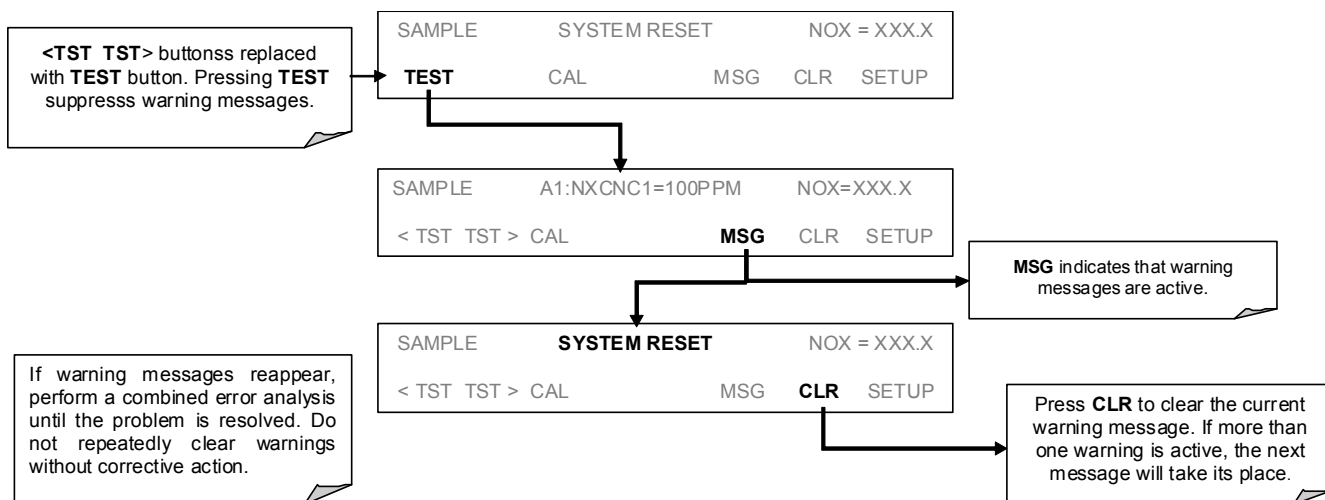


Figure 7-1: Viewing and Clearing Warning Messages

7.1.2. FAULT DIAGNOSIS WITH TEST FUNCTIONS

Besides being useful as predictive diagnostic tools, the TEST functions, viewable from the front panel, can be used to isolate and identify many operational problems when combined with a thorough understanding of the analyzer’s theory of operation (Section 8). We recommend using the APICOM remote control program to download, graph and archive TEST data for analysis and long-term monitoring of diagnostic data (Section 4.15.2.8).

The acceptable ranges for these test functions are listed in Appendix A-3. The actual values for these test functions on checkout at the factory were also listed in the *Final Test and Validation Data Sheet*, which was shipped with the instrument. Values outside the acceptable ranges indicate a failure of one or more of the analyzer’s subsystems. Functions with values that are within the acceptable range but have significantly changed from the measurements recorded on the factory data sheet may also indicate a failure or a maintenance item. A problem report worksheet has been provided in Appendix C (TAI part number 04503) to assist in recording the value of these test functions. The following table contains some of the more common causes for these values to be out of range.

Table 7-1: Test Functions - Possible Causes for Out-Of-Range Values

TEST FUNCTION	INDICATED FAILURE(S)
NOX STB	Unstable concentrations; leaks
SAMPLE FL	Leaks; clogged critical flow orifice
OZONE FL	Leaks; clogged critical flow orifice
PMT	Calibration off; HVPS problem; no flow (leaks)
NORM PMT	AutoZero too high
AZERO	Leaks; malfunctioning NO/NOx or AutoZero valve; O ₃ air filter cartridge exhausted
HVPS	HVPS broken; calibration off; preamp board circuit problems
RCELL TEMP	Malfunctioning heater; relay board communication (I ² C bus); relay burnt out
BOX TEMP	Environment out of temperature operating range; broken thermistor
PMT TEMP	TEC cooling circuit broken; relay board communication (I ² C bus); 12 V power supply
IZS TEMP (OPTION)	Malfunctioning heater; relay board communication (I ² C bus); relay burnt out
MOLY TEMP	Malfunctioning heater; disconnected or broken thermocouple; relay board communication (I ² C bus); relay burnt out; incorrect AC voltage configuration
RCEL (PRESSURE)	Leak; malfunctioning valve; malfunctioning pump; clogged flow orifices
SAMP (PRESSURE)	Leak; malfunctioning valve; malfunctioning pump; clogged flow orifices; sample inlet overpressure;
NOX SLOPE	HVPS out of range; low-level (hardware) calibration needs adjustment; span gas concentration incorrect; leaks
NOX OFF	Incorrect span gas concentration; low-level calibration off
NO SLOPE	HVPS out of range; low-level calibration off; span gas concentration incorrect; leaks
NO OFFS	Incorrect span gas concentration; low-level calibration off
TIME OF DAY	Internal clock drifting; move across time zones; daylight savings time?

7.1.3. USING THE DIAGNOSTIC SIGNAL I/O FUNCTION

The signal I/O parameters found under the diagnostics (DIAG) menu combined with a thorough understanding of the instrument’s theory of operation (Section 8) are useful for troubleshooting in three ways:

- The technician can view the raw, unprocessed signal level of the analyzer’s critical inputs and outputs.
- All of the components and functions that are normally under instrument control can be manually changed.
- Analog and digital output signals can be manually controlled.

This allows to systematically observe the effect of these functions on the operation of the analyzer. Figure 7-2 shows an example of how to use the signal I/O menu to view the raw voltage of an input signal or to control the state of an output voltage or control signal. The specific parameter will vary depending on the situation.

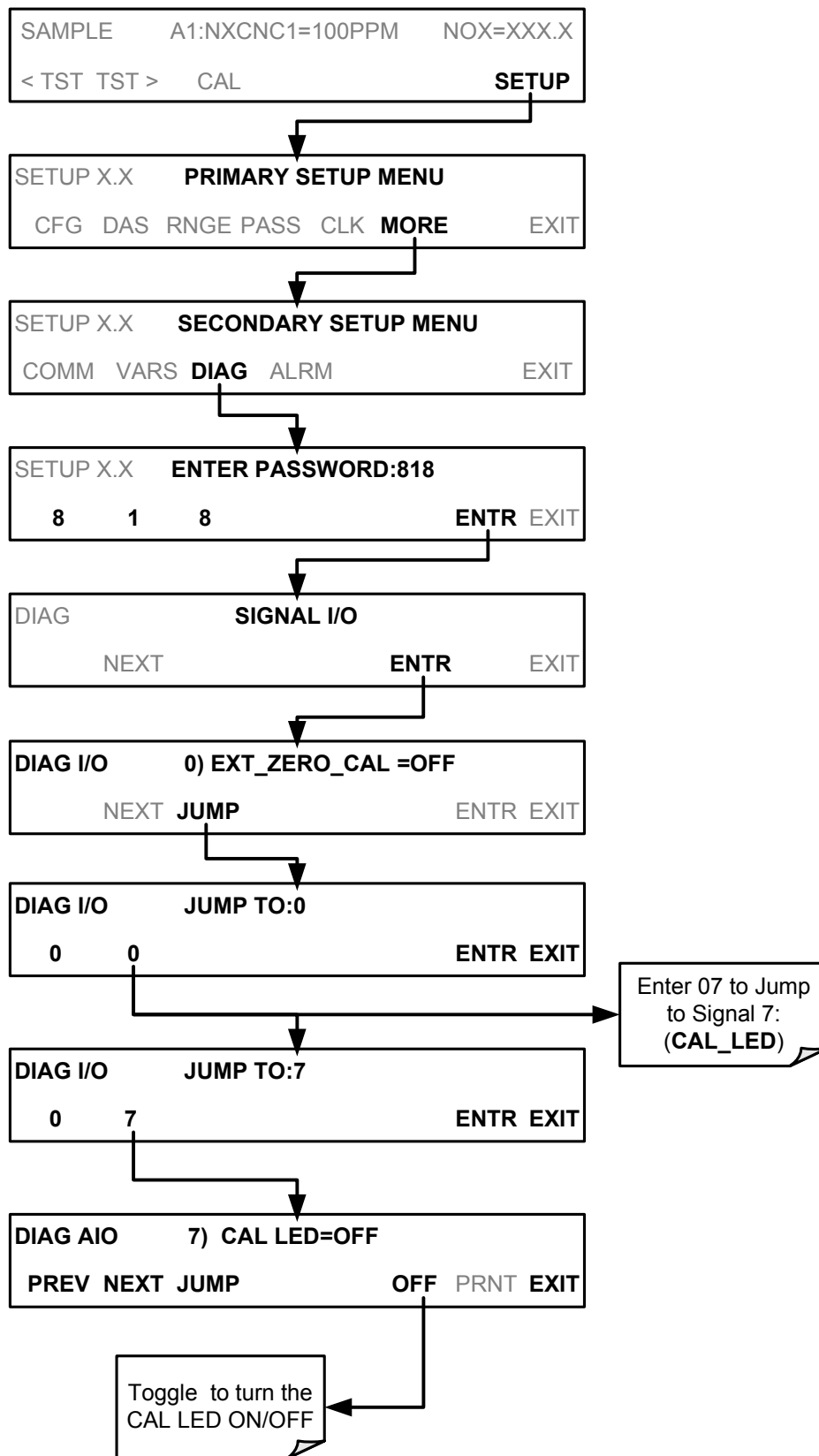


Figure 7-2: Switching Signal I/O Functions

7.1.4. STATUS LED'S

Several color-coded, light-emitting diodes (LED) are located inside the instrument to determine if the analyzer's CPU, I²C communications bus and the relay board are functioning properly.

7.1.4.1. Motherboard Status Indicator (Watchdog)

A red LED labeled DS5 in the upper portion of the motherboard (Figure 11-3), just to the right of the CPU board, flashes when the CPU is running the main program. After power-up, DS5 should flash on and off about once per second. If characters are visible on the front panel display but DS5 does not flash then the program files have become corrupted. Contact Technical Support because it may be possible to recover operation of the analyzer. If 30 - 60 seconds after a restart neither DS5 is flashing nor any characters are visible on the front panel display, the firmware may be corrupted or the CPU may be defective. If DS5 is permanently off or permanently on, the CPU board is likely locked up and the analyzer should not respond (either with locked-up or dark front panel).

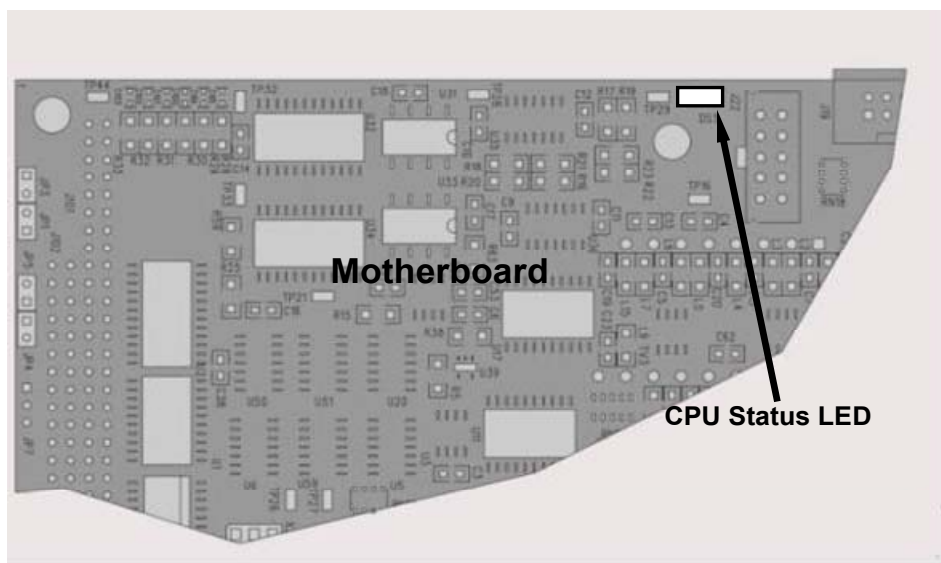


Figure 7-3: Motherboard Watchdog Status Indicator

7.1.4.2. CPU Status Indicator

The CPU board has two red LEDs, the lower of which is the watchdog timer (the device that pulses the motherboard watchdog). This LED is labeled **LED2** and blinks about twice per second (twice as fast as the motherboard LED) when operating normally. LED1 above LED2 should always be on. However, both CPU LEDs only indicate if the CPU is powered up properly and generally working. The lower LED can continue to blink even if the CPU or firmware are locked up.

7.1.4.3. Relay Board and Status LEDs

The most important status LED on the relay board is the red I²C Bus watch-dog LED, labeled **D1**, which indicates the health of the I²C communications bus. This LED is the left-most in LED row 1 in the center of the relay board when looking at the electronic components. If **D1** is blinking, then the other LEDs can be used in conjunction with the **DIAG** menu I/O functions to test hardware functionality by manually switching devices on and off and watching the corresponding LED go on or off.

Figure 7-4 illustrates the relay board layout including the two rows of LEDs,

Table 11-2 lists the individual LED functions and the menu tree below shows how to access the manual control of the I/O functions that only some or the LEDs may be functional in your analyzer model; the relay board layout is conceptualized for spare, future functionality and is also common to many of the E-series analyzers.

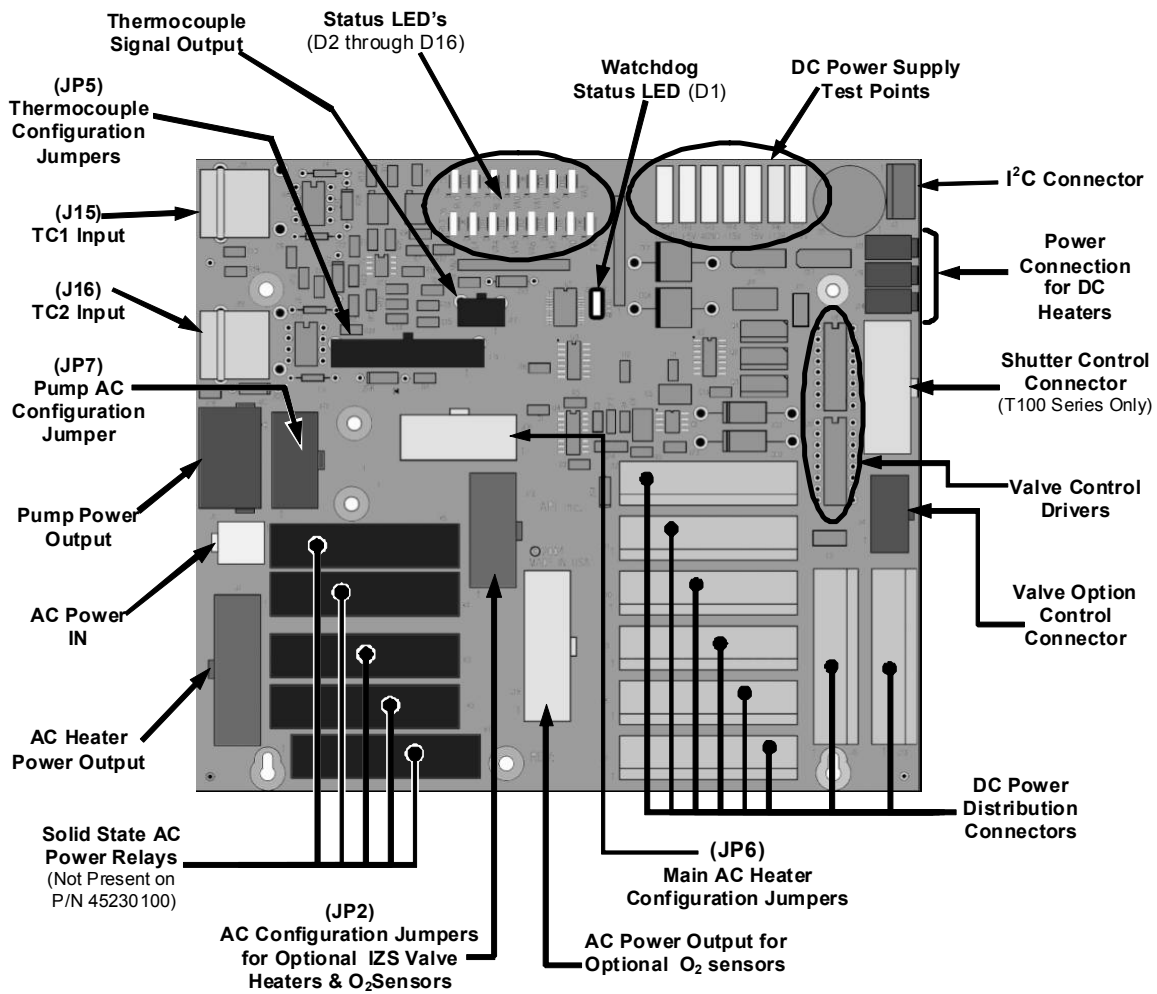
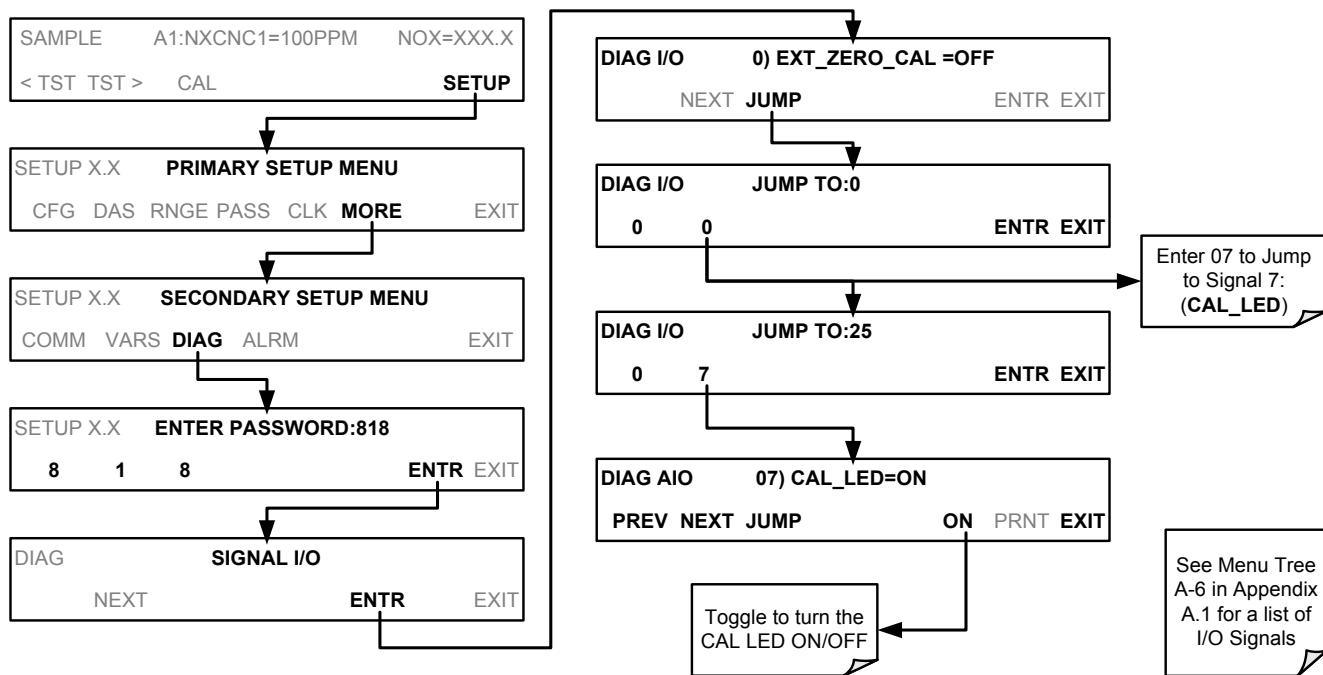


Figure 7-4: Relay Board PCA

Table 7-2: Relay Board Status LEDs

LED	COLOR	FUNCTION	FAULT STATUS	INDICATED FAILURE(S)
LED ROW 1				
D1	Red	Watchdog Circuit; I ² C bus operation.	Continuously ON or OFF	Failed or halted CPU; faulty motherboard, keyboard, relay board; wiring between motherboard, keyboard or relay board; +5 V power supply
D2	Yellow	Relay 0 - reaction cell heater	Continuously ON or OFF	Heater broken, thermistor broken
D3	Yellow	Relay 1 - NO ₂ converter heater	Continuously ON or OFF	Heater broken, thermocouple broken
D4	Yellow	Relay 2 - manifold heater	Continuously ON or OFF	Heater broken, thermistor broken
D7 ¹	Green	Valve 0 - zero/span valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D8 ¹	Green	Valve 1 - sample/cal valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D9	Green	Valve 2 - auto-zero valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D10	Green	Valve 3 - NO/NO _x valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
LED ROW 2				
D6	Yellow	Relay 4 – (O ₂ sensor heater 9110TH/M)	N/A	N/A
D11- 16	Green	Spare	N/A	N/A
¹ Only active for instruments with Z/S valve options installed				

To enter the signal I/O test mode to manually control I/O functions such as valves and heaters, press the following touch screen button sequence while observing the relay board LEDs:



7.2. GAS FLOW PROBLEMS

The 9110TH/M has two main flow paths, the sample flow and the flow of the ozone supply air. With zero/span valve option installed, there is a third (zero air) and a fourth (span gas) flow path, but either one of those is only controlled by critical flow orifices and not displayed on the front panel or stored to the DAS. The full flow diagrams of the standard configuration and with options installed (Appendix D, document 04574) help in troubleshooting flow problems. In general, flow problems can be divided into three categories:

- Flow is too high
- Flow is greater than zero, but is too low, and/or unstable
- Flow is zero (no flow)

When troubleshooting flow problems, it is essential to confirm the actual flow rate without relying on the analyzer’s flow display. The use of an independent, external flow meter to perform a flow check as described in Section 4.13.7.5 is essential.

The flow diagrams found in a variety locations within this manual depicting the 9110TH and 9110TM in their standard configuration and with options installed can help in troubleshooting flow problems. For your convenience they are collected here in Sections 11.2.1 (9110TH) and 11.2.2 (9110TM)

7.2.1. 9110TH INTERNAL GAS FLOW DIAGRAMS

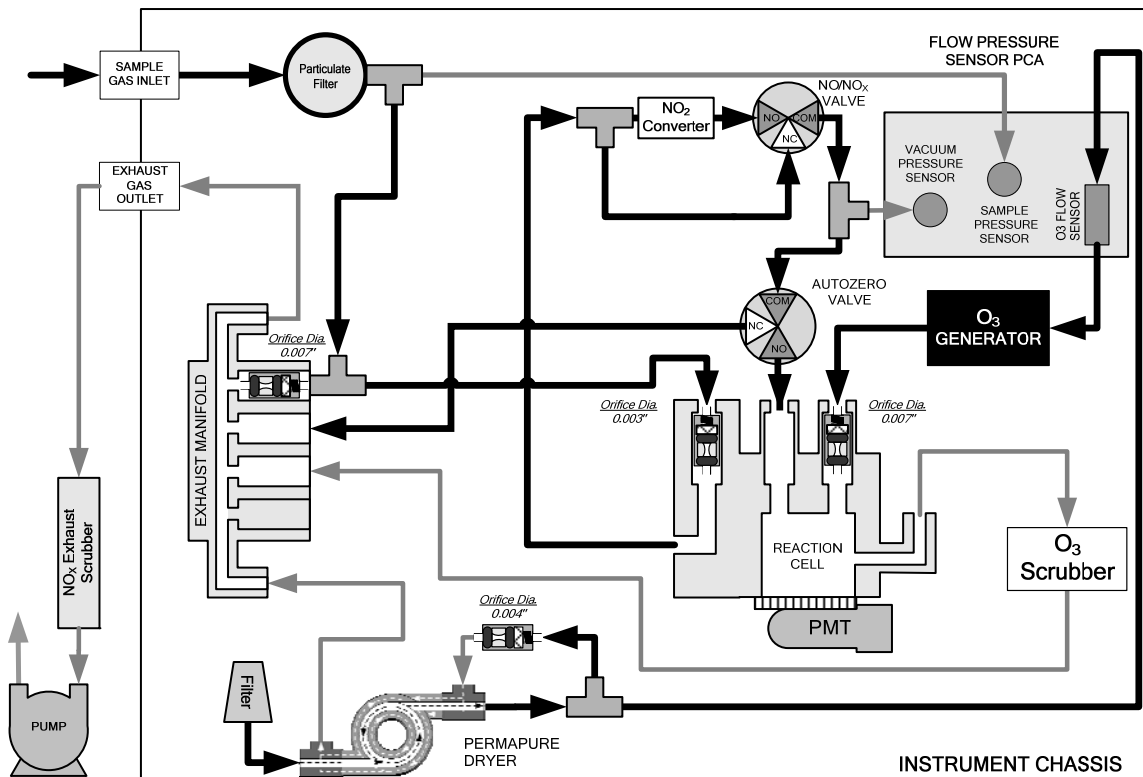


Figure 7-5: 9110TH – Basic Internal Gas Flow

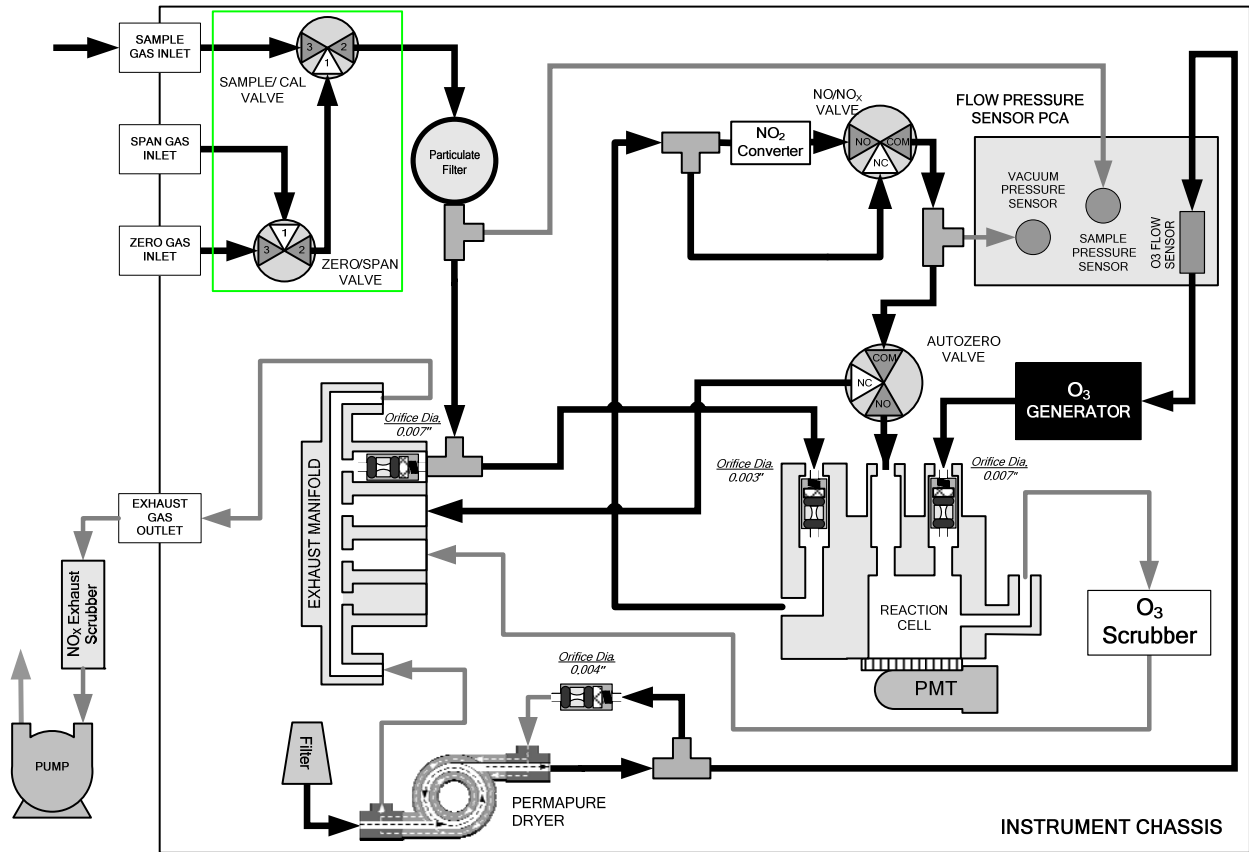


Figure 7-6: 9110TH – Internal Gas Flow with Ambient Zero Span, OPT 50A

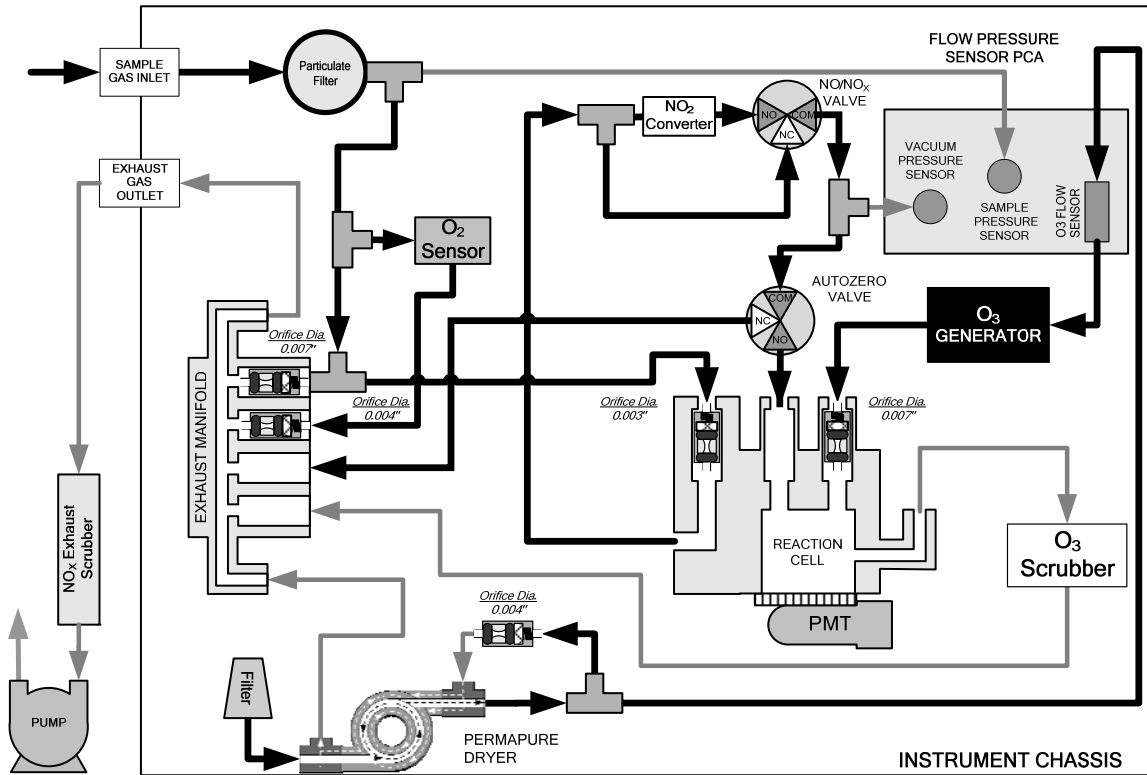


Figure 7-7: 9110TH – Internal Gas Flow with O₂ Sensor, OPT 65A

7.2.2. 9110TM INTERNAL GAS FLOW DIAGRAMS

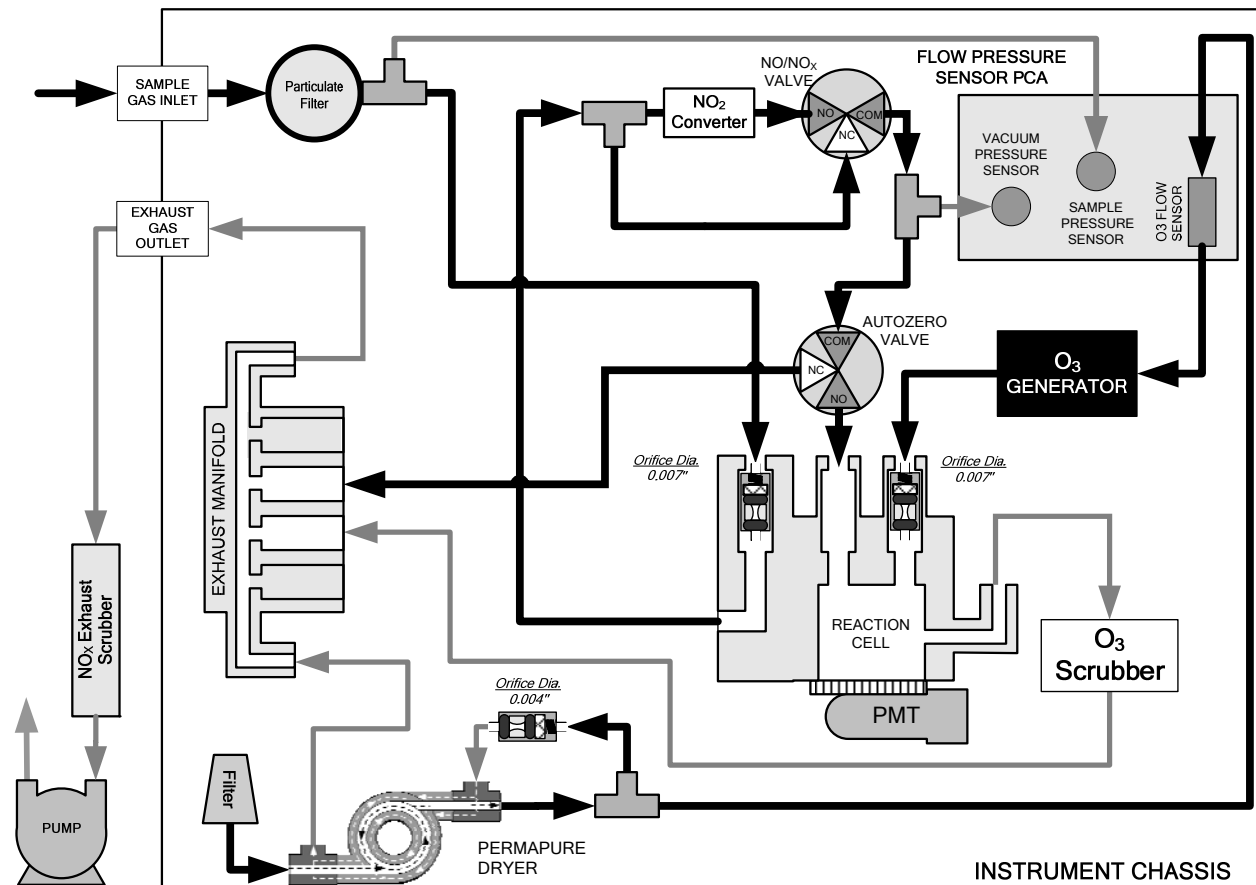


Figure 7-8: 9110TM – Basic Internal Gas Flow

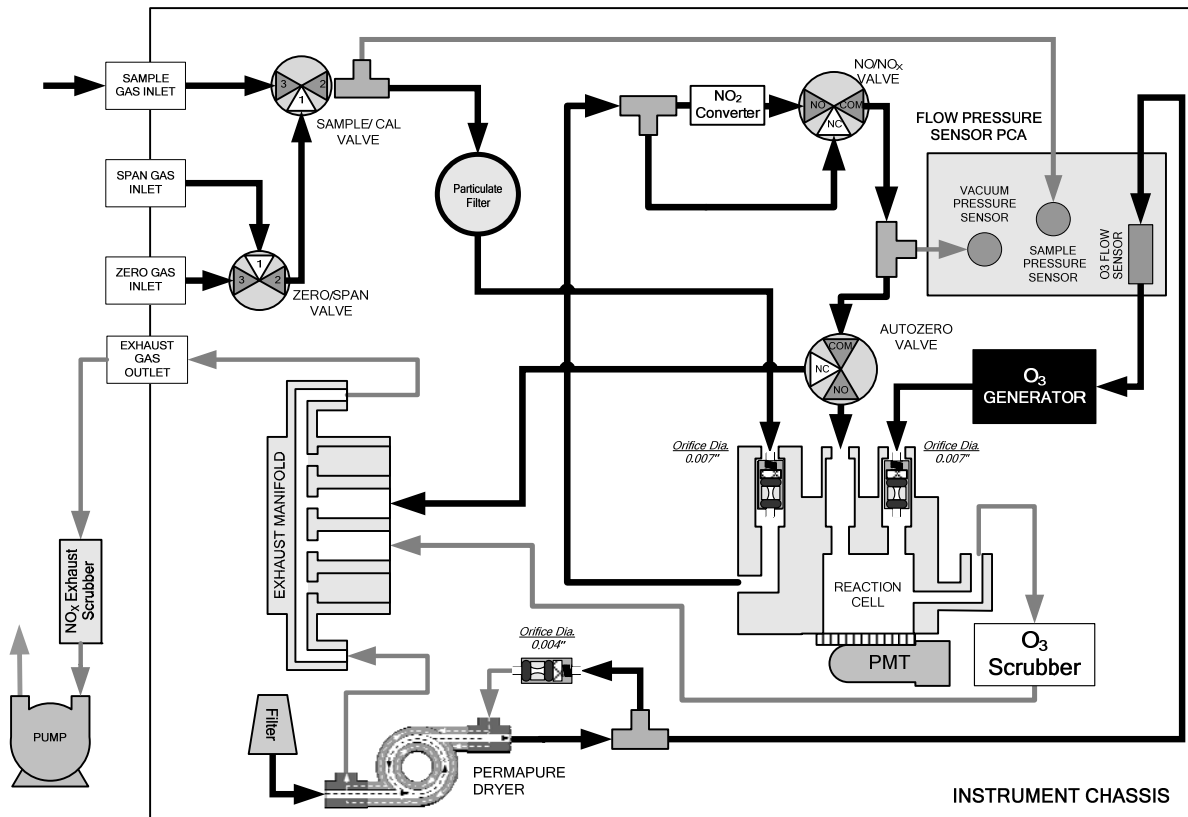


Figure 7-9: 9110TM – Internal Gas Flow with Ambient Zero Span, OPT 50A

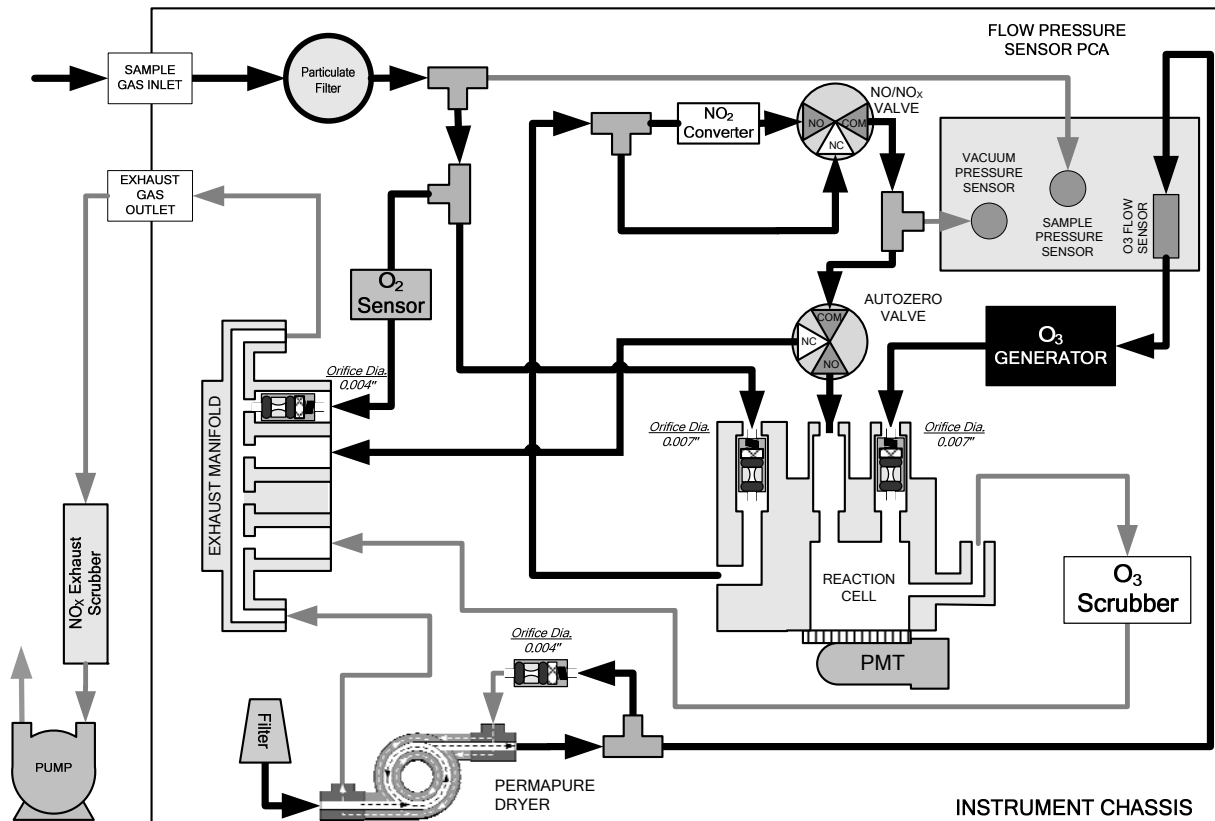


Figure 7-10: 9110TM – Internal Gas Flow with O₂ Sensor, OPT 65A

7.2.3. ZERO OR LOW FLOW PROBLEMS

7.2.3.1. Sample Flow is Zero or Low

The 9110TH/M does not actually measure the sample flow but rather calculates it from a differential pressure between sample and vacuum manifold. On flow failure, the unit will display a **SAMPLE FLOW WARNING** on the front panel display and the respective test function reports **XXXX** instead of a value “0”. This message applies to both a flow rate of zero as well as a flow that is outside the standard range (200-600 cm³/min; 300-700 cm³/min with O₂ option installed).

If the analyzer displays **XXXX** for the sample flow, confirm that the external sample pump is operating and configured for the proper AC voltage. Whereas the 9110TH/M can be internally configured for two different power regimes (100-120 V and 220-240 V, either 50 or 60 Hz), the external pump is physically different for each of three power regimes (100 V / 50 Hz, 115 V / 60 Hz and 230 V / 50 Hz). If the pump is not running, use an AC Voltmeter to make sure that the pump is supplied with the proper AC power. If AC power is supplied properly, but the pump is not running, replace the pump.

Note

Sample and vacuum pressures mentioned in this Section refer to operation of the analyzer at sea level. Pressure values need to be adjusted for elevated locations, as the ambient pressure decreases by about 1 in-Hg per 300 m / 1000 ft.

If the pump is operating but the unit reports a **XXXX** gas flow, do the following:

- Check for actual sample flow. To check the actual sample flow, disconnect the sample tube from the sample inlet on the rear panel of the instrument. Make sure that the unit is in basic SAMPLE mode. Place a finger over the inlet and see if it gets sucked in by the vacuum or, more properly, use a flow meter to measure the actual flow. If there is proper flow (see Table 10-3 for flow rates), contact Technical Support. If there is no flow or low flow, continue with the next step.
- Check pressures. Check that the sample pressure is at or around 28 in-Hg-A at sea level (adjust as necessary when in elevated location, the pressure should be about 1" below ambient atmospheric pressure) and that the RCEL pressure is below 10 in-Hg-A. The 9110TH/M will calculate a sample flow up to about 14 in-Hg-A RCEL pressure but a good pump should always provide less than 10 in.
- If both pressures are the same and around atmospheric pressure, the pump does not operate properly or is not connected properly. The instrument does not get any vacuum.
- If both pressures are about the same and low (probably under 10 in-Hg-A, or ~20" on sample and 15" on vacuum), there is a cross-leak between sample flow path and vacuum, most likely through the Perma Pure dryer flow paths. See troubleshooting the Perma Pure dryer later in this Section.
- If the sample and vacuum pressures are around their nominal values (28 and <10 in-Hg-A, respectively) and the flow still displays **XXXX**, carry out a leak check as described in Section 7.5.
- If gas flows through the instrument during the above tests but goes to zero or is low when it is connected to zero air or span gas, the flow problem is not internal to the analyzer but likely caused by the gas source such as calibrators/generators, empty gas tanks, clogged valves, regulators and gas lines.
- If an Zero/Span valve option is installed in the instrument, press **CALZ** and **CALS**. If the sample flow increases, suspect a bad Sample/Cal valve.
- If none of these suggestions help, carry out a detailed leak check of the analyzer as described in Section 7.5.2.

7.2.3.2. Ozone Flow is Zero or Low

If there is zero or a low (<200 cm³/min) ozone flow, the unit displays an **OZONE FLOW WARNING** message on the front panel and a value between 0.0 and 200 cm³/min for the actual ozone flow as measured by the internal mass flow meter. In this case, carry out the following steps:

- Check the actual flow rate through the ozone dryer by using an external flow meter to the inlet port of the dryer. This inlet port is inside the analyzer at the end of the plastic particle filter (Section 6.4.2 for illustration). If there is nominal flow (see Table 10-3 for flow rates), consult Technical Support as there is a problem with the firmware or electronics.
- If the actual flow is low or zero, check if the pump operates properly. The **RCEL** pressure should be below 10 in-Hg-A at sea level. If it is above 10", rebuild the pump (Section 6.4.3). Check the spare parts list in Appendix B on how to order pump rebuild kits.
- Check if the particle filter is clogged. **Briefly** remove the particle filter to see if this improves the flow. Be very cautious about handling the Perma Pure dryer fittings - refer to Section 6.4.2 on proper handling instructions. If the filter is clogged, replace it with a new unit. If taking off this filter does not solve the problem, continue to the next step. Do not leave the Perma Pure dryer without filter for more than a few seconds, as you may draw in dust, which will reduce the performance of the dryer.
- A leak between the flow meter and the reaction cell (where the flow-determining critical orifice is located) may cause a low flow (the system draws in ambient air through a leak after the flow meter). Check for leaks as described in Section 7.5. Repair the leaking fitting, line or valve and re-check.
- The most likely cause for zero or low ozone flow is a clogged critical flow orifice or sintered filter within the orifice assembly. The orifice that sets the ozone flow is located on the reaction cell. Check the actual ozone flow by disconnecting the tube from the reaction cell and measuring the flow going into the cell. If this flow is correct (see Table 10-3 for flow rates), the orifice works properly. If this flow is low, replace or clean the orifice. The orifice holder assembly allows a quick and easy replacement of the orifice, refer to Section 6.4.6 on how to do this. Appendix B lists a spare part kit with a complete orifice assembly that allows a quick replacement with minimum instrument down-time. The clogged orifice can then be cleaned while the instrument is running with the replacement.

7.2.4. HIGH FLOW

Flows that are significantly higher than the allowed operating range (typically $\pm 10\text{-}11\%$ of the nominal flow) should not occur in the 9110TH/M unless a pressurized sample, zero or span gas is supplied to the inlet ports. Ensure to vent excess pressure and flow just before the analyzer inlet ports.

When supplying sample, zero or span gas at ambient pressure, a high flow would indicate that one or more of the critical flow orifices are physically broken (very unlikely case), allowing more than nominal flow, or were replaced with an orifice of wrong specifications. If the flows are within 15% higher than normal, we recommend to

re-calibrate the flow electronically using the procedure in Section 4.13.7.5, followed by a regular review of these flows over time to see if the new setting is retained properly.

7.2.5. SAMPLE FLOW IS ZERO OR LOW BUT ANALYZER REPORTS CORRECT FLOW

that the 9110TH/M analyzer can report a correct flow rate even if there is no or a low actual sample flow through the reaction cell. The sample flow on the 9110TH/M is only calculated from the sample pressure and critical flow condition is verified from the difference between sample pressure and vacuum pressure. If the critical flow orifice is partially or completely clogged, both the sample and vacuum pressures are still within their nominal ranges (the pump keeps pumping, the sample port is open to the atmosphere), but there is no flow possible through the reaction cell.

Although measuring the actual flow is the best method, in most cases, this fault can also be diagnosed by evaluating the two pressure values. Since there is no longer any flow, the sample pressure should be equal to ambient pressure, which is about 1 in-Hg-A higher than the sample pressure under normal operation. The reaction cell pressure, on the other hand, is significantly lower than under normal operation, because the pump no longer has to remove the sample gas and evacuates the reaction cell much better. Those two indicators, taken together with a zero or low actual flow, indicate a clogged sample orifice.

The 9110TH/M features a orifice holder, which makes switching sample and ozone flow orifices very easy, refer to Section 6.4.6 on how to change the sample orifices and Appendix B for part numbers of these assemblies. Again, monitoring the pressures and flows regularly will reveal such problems, because the pressures would slowly or suddenly change from their nominal, mean values. TAI recommends to review all test data once per week and to do an exhaustive data analysis for test and concentration values once per month, paying particular attention to sudden or gradual changes in all parameters that are supposed to remain constant, such as the flow rates.

7.3. CALIBRATION PROBLEMS

7.3.1. NEGATIVE CONCENTRATIONS

Negative concentration values can be caused by any of several reasons:

- A slight, negative signal is normal when the analyzer is operating under zero gas and the signal is drifting around the zero calibration point. This is caused by the analyzer's zero noise and may cause reported concentrations to be negative for a few seconds at a time down to -0.2 ppm, but should randomly alternate with similarly high, positive values. The 9110TH/M has a built-in Auto-zero function, which should take care of most of these deviations from zero, but may yield a small, residual, negative value. If larger, negative values persist continuously, check if the Auto-zero function was accidentally turned off using the remote variables in Appendix A-2. In this case, the sensitivity of the analyzer may be drifting negative.

- A corruption of the Auto-zero filter may also cause negative concentrations. If a short, high noise value was detected during the AutoZero cycle, that higher reading will alter the Auto-zero filter value. As the value of the Auto-zero filter is subtracted from the current PMT response, it will produce a negative concentration reading. High AutoZero readings can be caused by:
 - a leaking or stuck AutoZero valve (replace the valve),
 - by an electronic fault in the preamplifier causing it to have a voltage on the PMT output pin during the AutoZero cycle (replace the preamplifier),
 - by a reaction cell contamination causing high background (>40 mV) PMT readings (clean the reaction cell),
 - by a broken PMT temperature control circuit, allowing high zero offset (repair the faulty PMT cooler). After fixing the cause of a high Auto-zero filter reading, the 9110TH/M will take 15 minutes for the filter to clear itself, or
 - by an exhausted chemical in the ozone scrubber cartridge (Section 6.4.4).
- Miscalibration is the most likely explanation for negative concentration values. If the zero air contained some NO or NO₂ gas (contaminated zero air or a worn-out zero air scrubber) and the analyzer was calibrated to that concentration as “zero”, the analyzer may report negative values when measuring air that contains little or no NO_x. The same problem occurs, if the analyzer was zero-calibrated using zero gas that is contaminated with ambient air or span gas (cross-port leaks or leaks in supply tubing or user not waiting long enough to flush pneumatic systems).
- If the response offset test functions for NO (**NO OFFS**) or NO_x (**NOX OFFS**) are greater than 150 mV, a reaction cell contamination is indicated. Clean the reaction cell according to Section 6.4.5.

7.3.2. NO RESPONSE

If the instrument shows no response (display value is near zero) even though sample gas is supplied properly and the instrument seems to perform correctly.

- Check if the ozone generator is turned on. Usually, the analyzer issues a warning whenever the ozone generator is turned off. Go to **SETUP-MORE-DIAG-ENTR**, then scroll to the **OZONE GEN OVERRIDE** and see if it shows **ON**. If it shows **OFF**, turn it **ON** and **EXIT** the **DIAG** menu. If this is done and the ozone flow is correct, the analyzer should be properly supplied with ozone unless the generator itself is broken. A more detailed description of the ozone generator subsystem checks are in Section 11.5.17.
- Confirm the lack of response by supplying NO or NO₂ span gas of about 80% of the range value to the analyzer.
- Check the sample flow and ozone flow rates for proper values.

- Check for disconnected cables to the sensor module.
- Carry out an electrical test with the **ELECTRICAL TEST** procedure in the diagnostics menu, see Section 4.13.7.3. If this test produces a concentration reading, the analyzer's electronic signal path is correct.
- Carry out an optical test using the **OPTIC TEST** procedure in the diagnostics menu, see Section 4.13.7.2. If this test results in a concentration signal, then the PMT sensor and the electronic signal path are operating properly. If the 9110TH/M passes both ETEST and OTEST, the instrument is capable of detecting light and processing the signal to produce a reading. Therefore, the problem must be in the pneumatics or the ozone generator.
- If NO₂ signal is zero while NO signal is correct, check the NO/NO_x valve and the NO₂ converter for proper operation.

7.3.3. UNSTABLE ZERO AND SPAN

Leaks in the 9110TH/M or in the external gas supply and vacuum systems are the most common source of unstable and non-repeatable concentration readings.

- Check for leaks in the pneumatic systems as described in Section 7.5. Consider pneumatic components in the gas delivery system outside the 9110TH/M such as a change in zero air source (ambient air leaking into zero air line or a worn-out zero air scrubber) or a change in the span gas concentration due to zero air or ambient air leaking into the span gas line.
- Once the instrument passes a leak check, do a flow check (this Section) to make sure that the instrument is supplied with adequate sample and ozone air.
- Confirm the sample pressure, sample temperature, and sample flow readings are correct and steady.
- Verify that the sample filter element is clean and does not need to be replaced.

7.3.4. INABILITY TO SPAN - NO SPAN BUTTON

In general, the 9110TH/M will not display certain keyboard choices whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a SPAN key when carrying out a span calibration, the actual concentration must be outside of the range of the expected span gas concentration, which can have several reasons.

- Verify that the expected concentration is set properly to the actual span gas concentration in the **CONC** sub-menu.
- Confirm that the NO_x span gas source is accurate. This can be done by comparing the source with another calibrated analyzer, or by having the NO_x source verified by an independent traceable photometer.
- Check for leaks in the pneumatic systems as described in Section 7.5. Leaks can dilute the span gas and, hence, the concentration that the analyzer measures may fall short of the expected concentration defined in the **CONC** sub-menu.
- If the low-level, hardware calibration has drifted (changed PMT response) or was accidentally altered by the user, a low-level calibration may be necessary to get the analyzer back into its proper range of expected values. One possible indicator of this scenario is a slope or offset value that is outside of its allowed range (0.7-1.3 for slope, -20 mV to 150 mV for offsets). See Section 13 on how to carry out a low-level hardware calibration.

7.3.5. INABILITY TO ZERO - NO ZERO BUTTON

In general, the 9110TH/M will not display certain touch screen buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a ZERO button when carrying out a zero calibration, the actual gas concentration must be significantly different from the actual zero point (as per last calibration), which can have several reasons.

- Confirm that there is a good source of zero air.
- Check to make sure that there is no ambient air leaking into zero air line. Check for leaks in the pneumatic systems as described in Section 7.5.

7.3.6. NON-LINEAR RESPONSE

The 9110TH/M was factory calibrated to a high level of NO and should be linear to within 1% of full scale. Common causes for non-linearity are:

- Leaks in the pneumatic system. Leaks can add a constant of ambient air, zero air or span gas to the current sample gas stream, which may be changing in concentrations as the linearity test is performed. Check for leaks as described in Section 7.5.
- The calibration device is in error. Check flow rates and concentrations, particularly when using low concentrations. If a mass flow calibrator is used and the flow is less than 10% of the full scale flow on either flow controller, you may need to purchase lower concentration standards.

- The standard gases may be mislabeled as to type or concentration. Labeled concentrations may be outside the certified tolerance.
- The sample delivery system may be contaminated. Check for dirt in the sample lines or reaction cell.
- Calibration gas source may be contaminated (NO₂ in NO gas is common).
- Dilution air contains sample or span gas.
- Ozone concentration too low because of wet air in the generator. Generator system needs to be cleaned and dried with dry supply air. Check the Perma Pure dryer for leaks. This mostly affects linearity at the low end.
- Sample inlet may be contaminated with NO_x exhaust from this or other analyzers. Verify proper venting of the pump exhaust.
- Span gas overflow is not properly vented and creates a back-pressure on the sample inlet port. Also, if the span gas is not vented at all and does not supply enough sample gas, the analyzer may be evacuating the sample line. Make sure to create and properly vent excess span gas.
- Diffusion of oxygen into Teflon-type tubing over long distances. PTFE or related materials can act as permeation devices. In fact, the permeable membrane of NO₂ permeation tubes is made of PTFE. When using very long supply lines (> 1 m) between high concentration span gases and the dilution system, oxygen from ambient air can diffuse into the line and react with NO to form NO₂. This reaction is dependent on NO concentration and accelerates with increasing NO concentration, hence, affects linearity only at high NO levels. Using stainless steel for long span gas supply lines avoids this problem.

7.3.7. DISCREPANCY BETWEEN ANALOG OUTPUT AND DISPLAY

If the concentration reported through the analog outputs does not agree with the value reported on the front panel, you may need to re-calibrate the analog outputs. This becomes more likely when using a low concentration or low analog output range. Analog outputs running at 0.1 V full scale should always be calibrated manually. See Section 4.13.6.2 for a detailed description of this procedure.

7.3.8. DISCREPANCY BETWEEN NO AND NO_x SLOPES

If the slopes for NO and NO_x are significantly different after software calibration (more than 1%), consider the following two problems

- NO₂ impurities in the NO calibration gas. NO gases often exhibit NO₂ on the order of 1-2% of the NO value. This will cause differences in the calibration slopes. If the NO₂ impurity in NO is known, it can easily be accounted for by setting the expected values for NO and NO₂ accordingly to different values, e.g., 0.448 ppm NO and 0.45 ppm NO_x. This problem is worse if NO gas is stored in a cylinder with balance air instead of balance gas nitrogen or large amounts of nitrous oxide (N₂O). The oxygen in the air slowly reacts with NO to yield NO₂, increasing over time.
- The expected concentrations for NO and NO_x in the calibration menu are set to different values. If a gas with 100% pure NO is used, this would cause a bias. See Section 7.2 on how to set expected concentration values.
- The converter efficiency parameter has been set to a value not equal to 1.000 even though the conversion efficiency is 1.0. The actual conversion efficiency needs to match the parameter set in the **CAL** menu. See Section 5.2.5 for more information on this feature.

7.4. OTHER PERFORMANCE PROBLEMS

Dynamic problems (i.e. problems which only manifest themselves when the analyzer is monitoring sample gas) can be the most difficult and time consuming to isolate and resolve. The following section provides an itemized list of the most common dynamic problems with recommended troubleshooting checks and corrective actions.

7.4.1. EXCESSIVE NOISE

Excessive noise levels under normal operation usually indicate leaks in the sample supply or the analyzer itself. Make sure that the sample or span gas supply is leak-free and carry out a detailed leak check as described earlier in this Section.

Another possibility of excessive signal noise may be the preamplifier board, the high voltage power supply and/or the PMT detector itself. Contact the factory on troubleshooting these components.

7.4.2. SLOW RESPONSE

If the analyzer starts responding too slow to any changes in sample, zero or span gas, check for the following:

- Dirty or plugged sample filter or sample lines.
- Sample inlet line is too long.
- Leaking NO/NO_x valve. Carry out a leak check.
- Dirty or plugged critical flow orifices. Check flows, pressures and, if necessary, change orifices (Section 6.4.6).

- Wrong materials in contact with sample - use glass, stainless steel or Teflon materials only. Porous materials, in particular, will cause memory effects and slow changes in response.
- Dirty reaction cell. Clean the reaction cell.
- Insufficient time allowed for purging of lines upstream of the analyzer. Wait until stability is low.
- Insufficient time allowed for NO or NO₂ calibration gas source to become stable. Wait until stability is low.
- NO₂ converter temperature is too low. Check for proper temperature.

7.4.3. AUTO ZERO WARNINGS

Auto-zero warnings occur if the signal measured during an auto-zero cycle is lower than -20 mV or higher than 200 mV. The Auto-Zero warning displays the value of the auto-zero reading when the warning occurs.

- If this value is higher than 150 mV, check that the auto-zero valve is operating properly. To do so, use the **SIGNAL I/O** functions in the **DIAG** menu to toggle the valve on and off. Listen if the valve is switching, see if the respective LED on the relay board is indicating functionality. Scroll the **TST** functions until **PMT** is displayed and observe the PMT value change between the two valve states.
- If the valve is operating properly, you should be able to hear it switch (once a minute under normal operation or when manually activated from the **SIGNAL I/O** menu), the PMT value should drop from its nominal reading for span gas level measurements to less than 150 mV and the LED on the relay board should light up when the valve is activated. If the PMT value drops significantly but not to less than 150 mV, the valve is probably leaking across its ports. In this case, replace the valve. If the PMT value does not change at all, the valve is probably not switching at all. Check the power supply to the valve (12 V to the valve should turn on and off when measured with a voltmeter).
- that it takes only a small leak across the ports of the valve to show excessive auto-zero values when supplying high concentrations of span gas.
- Another reason for high (although not necessarily out-of-range) values for AutoZero could be the ozone air filter cartridge, if its contents has been exhausted and needs to be replaced. This cartridge filters chemicals that can cause chemiluminescence and, if saturated, these chemicals can break through to the reaction cell, causing an erroneously high AutoZero value (background noise).

- A dirty reaction cell can cause high AutoZero values. Clean the reaction cell according to Section 6.4.5.
- Finally, a high **HVPS** voltage value may cause excess background noise and a high **AZERO** value. The HVPS value changes from analyzer to analyzer and could show nominal values between 450 and 800 V. Check the low-level hardware calibration of the preamplifier board and, if necessary, recalibrate exactly as described in Section 13 in order to minimize the **HVPS**.

7.5. SUBSYSTEM CHECKOUT

The preceding sections of this manual discussed a variety of methods for identifying possible sources of failures or performance problems within the analyzer. In most cases this included a list of possible causes and, in some cases, quick solutions or at least a pointer to the appropriate sections describing them. This section describes how to determine if a certain component or subsystem is actually the cause of the problem being investigated.

7.5.1. SIMPLE LEAK CHECK USING VACUUM AND PUMP

Leaks are the most common cause of analyzer malfunction; This section presents a simple leak check, whereas Section 7.5.2 details a more thorough procedure. The method described here is easy, fast and detects, but does not locate, most leaks. It also verifies the sample pump condition.

- Turn the analyzer ON, and allow at least 30 minutes for flows to stabilize.
- Cap the sample inlet port (cap must be wrench-tight).
- After several minutes, when the pressures have stabilized, the SAMP (sample pressure) and the RCEL (vacuum pressure) readings.
- If both readings are equal to within 10% and less than 10 in-Hg-A, the instrument is free of large leaks. It is still possible that the instrument has minor leaks.
- If both readings are < 10 in-Hg-A, the pump is in good condition. A new pump will create a pressure reading of about 4 in-Hg-A (at sea level).

7.5.2. DETAILED LEAK CHECK USING PRESSURE

If a leak cannot be located by the above procedure, obtain a leak checker similar to TAI part number 01960, which contains a small pump, shut-off valve, and pressure gauge to create both over-pressure and vacuum. Alternatively, a tank of pressurized gas, with the two stage regulator adjusted to ≤ 15 psi, a shutoff valve and pressure gauge may be used.

Note

Once tube fittings have been wetted with soap solution under a pressurized system, do not apply or re-apply vacuum as this will cause soap solution to be sucked into the instrument, contaminating inside

surfaces. Do not exceed 15 psi when pressurizing the system.

- Turn OFF power to the instrument and remove the instrument cover.
- Install a leak checker or a tank of gas (compressed, oil-free air or nitrogen) as described above on the sample inlet at the rear panel.
- Disconnect the pump tubing on the outside rear panel and cap the pump port. If zero/span valves are installed, disconnect the tubing from the zero and span gas ports and plug them (Figure 3-4). Cap the DFU particle filter on the Perma Pure dryer (Figure 6-2).
- Pressurize the instrument with the leak checker or tank gas, allowing enough time to fully pressurize the instrument through the critical flow orifice. Check each tube connection (fittings, hose clamps) with soap bubble solution, looking for fine bubbles. Once the fittings have been wetted with soap solution, do not re-apply vacuum as it will draw soap solution into the instrument and contaminate it. Do not exceed 15 psi pressure.
- If the instrument has the zero and span valve option, the normally closed ports on each valve should also be separately checked. Connect the leak checker to the normally closed ports and check with soap bubble solution.
- Once the leak has been located and repaired, the leak-down rate of the indicated pressure should be less than 1 in-Hg-A (0.4 psi) in 5 minutes after the pressure is turned off.
- Clean surfaces from soap solution, re-connect the sample and pump lines and replace the instrument cover. Restart the analyzer.

7.5.3. PERFORMING A SAMPLE FLOW CHECK

Note

Use a separate, calibrated flow meter capable of measuring flows between 0 and 1000 cm³/min to measure the gas flow rate through the analyzer. Do not use the built in flow measurement viewable from the front panel of the instrument. This value is only calculated, not measured

Sample flow checks are useful for monitoring the actual flow of the instrument, as the front panel display shows only a calculated value. A decreasing, actual sample flow may point to slowly clogging pneumatic paths, most likely critical flow orifices or sintered filters. To perform a sample flow check:

- Disconnect the sample inlet tubing from the rear panel SAMPLE port shown in Figure 3-4.

- Attach the outlet port of a flow meter to the sample inlet port on the rear panel. Ensure that the inlet to the flow meter is at atmospheric pressure.
- The sample flow measured with the external flow meter should be within $\pm 10\%$ of the nominal values shown in Table 10-3.
- Low flows indicate blockage somewhere in the pneumatic pathway.

7.5.4. AC POWER CONFIGURATION

The T-Series digital electronic systems will operate with any of the specified power regimes. As long as instrument is connected to 100-120 VAC or 220-240 VAC at either 50 or 60 Hz it will turn on and after about 30 seconds show a front panel display. Internally, the status LEDs located on the Relay PCA, Motherboard and CPU should turn on as soon as the power is supplied.

On the other hand, some of the analyzer's non-digital components, such as the pump and the various AC powered heaters must be properly configured for the type of power being supplied to the instrument. Figure 7-11 shows the location of the various sets of AC Configuration jumpers.

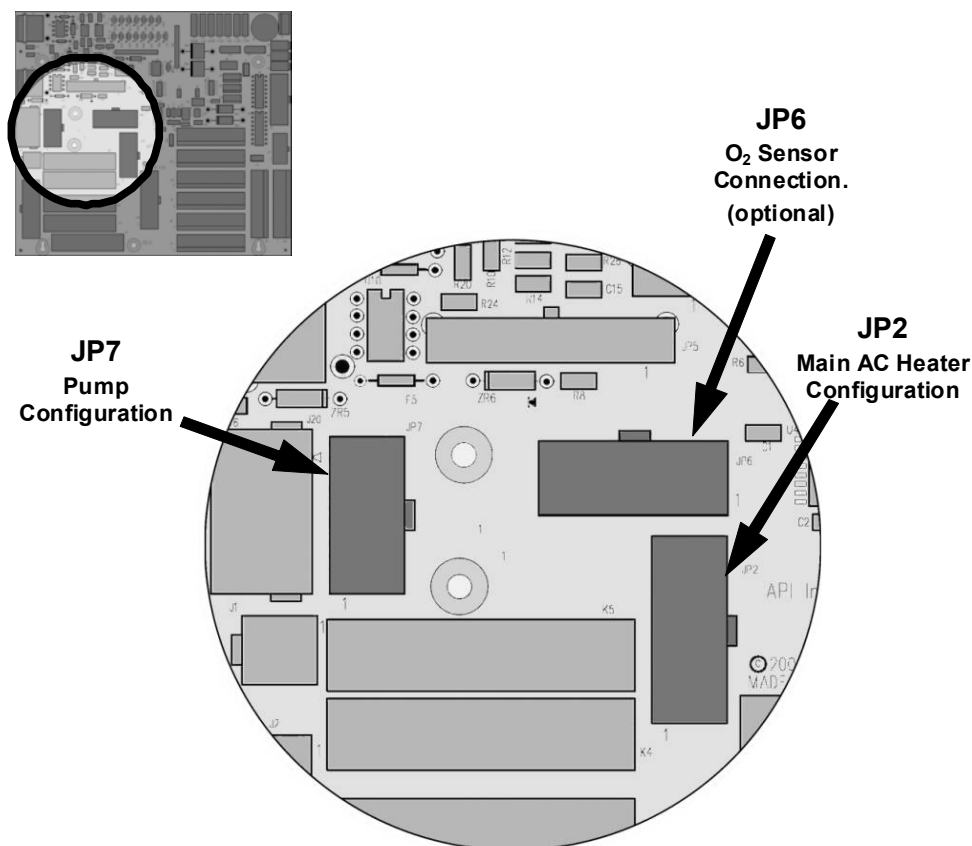


Figure 7-11: Location of AC power Configuration Jumpers

Functions of the Relay PCA include:

- handling all AC and DC power distribution including power to the pump.
- a set of jumpers that connect AC power to heaters included in several optional items, such as the zero/span valve options and the O₂ sensor option available on the 9110TH/M analyzers.

7.5.4.1. AC Configuration – Internal Pump (JP7)

AC power configuration for internal pumps is set using Jumper set JP7 (see Figure 7-4 for the location of JP7).

Table 7-3: AC Power Configuration for Internal Pumps (JP7)

LINE POWER	LINE FREQUENCY	JUMPER COLOR	FUNCTION	JUMPER BETWEEN PINS
110VAC 115 VAC	60 HZ	WHITE	Connects pump pin 3 to 110 / 115 VAC power line	2 to 7
			Connects pump pin 3 to 110 / 115 VAC power line	3 to 8
			Connects pump pins 2 & 4 to Neutral	4 to 9
	50 HZ ¹	BLACK	Connects pump pin 3 to 110 / 115 VAC power line	2 to 7
			Connects pump pin 3 to 110 / 115 VAC power line	3 to 8
			Connects pump pins 2 & 4 to Neutral	4 to 9
220VAC 240 VAC	60 HZ	BROWN	Connects pump pins 3 and 4 together	1 to 6
			Connects pump pin 1 to 220 / 240VAC power line	3 to 8
	50 HZ ¹	BLUE	Connects pump pins 3 and 4 together	1 to 6
			Connects pump pin 1 to 220 / 240VAC power line	3 to 8

¹ A jumper between pins 5 and 10 may be present on the jumper plug assembly, but has no function on the 9110TH/M analyzers.

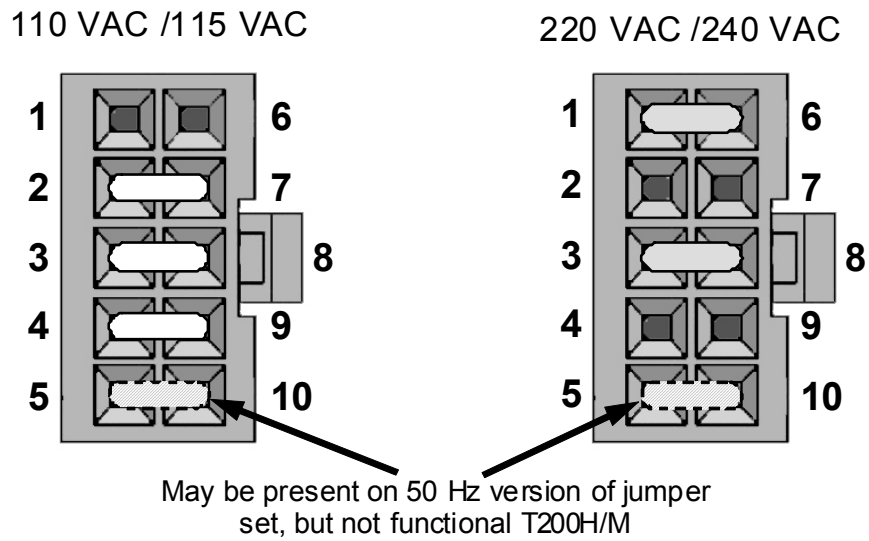


Figure 7-12: Pump AC Power Jumpers (JP7)

7.5.4.2. AC Configuration – Standard Heaters (JP2)

Power configuration for the AC the standard heaters is set using Jumper set JP2 (see Figure 7-4 for the location of JP2).

Table 7-4: Power Configuration for Standard AC Heaters (JP2)

LINE VOLTAGE	JUMPER COLOR	HEATER(S)	JUMPER BETWEEN PINS	FUNCTION
110 VAC / 115 VAC 50Hz & 60 Hz	WHITE	Reaction Cell / Sample Chamber Heaters	1 to 8	Common
			2 to 7	Neutral to Load
		Mini Hi-Con Converter	3 to 10	Common
			4 to 9	Neutral to Load
		Moly Converter	3 to 10	Common
			4 to 9	Neutral to Load
Bypass Manifold ¹	5 to 12	Common		
	6 to 11	Neutral to Load		
220 VAC / 240 VAC 50Hz & 60 Hz	BLUE	Reaction Cell / Sample Chamber Heaters	1 to 7	Load
		Hi Concentration Converter	3 to 9	Load
		Moly Converter	3 to 9	Load
		Bypass Manifold ¹	5 to 11	Load

¹ Bypass manifold is built into the reaction cell

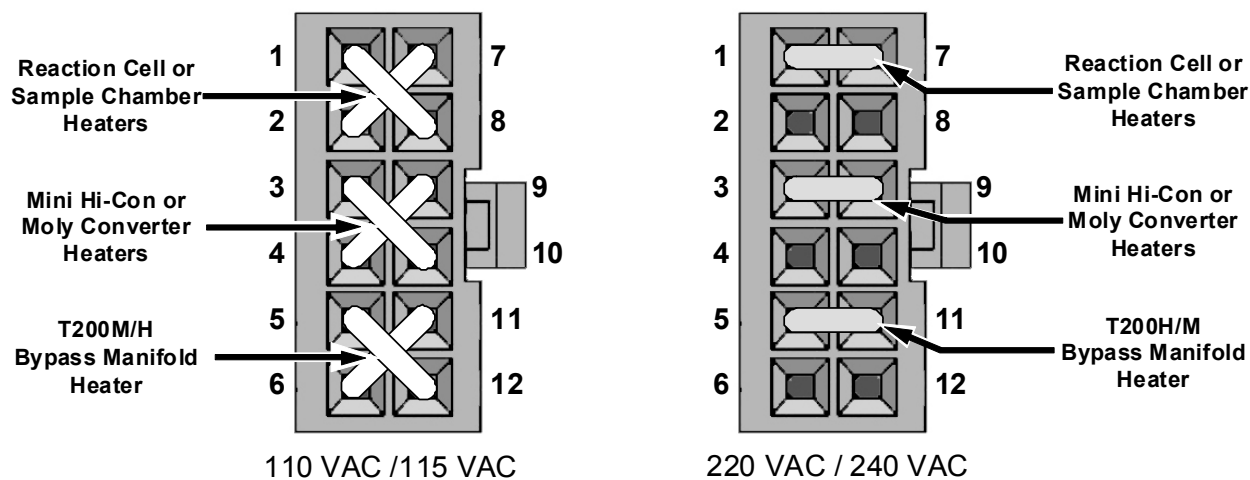


Figure 7-13: Typical Set Up of AC Heater Jumper Set (JP2)

7.5.4.3. AC Configuration –Heaters for Option Packages (JP6)

An O₂ sensor option includes AC heaters that maintain an optimum operating temperature for key components of those options. Jumper set JP6 is used to connect the heaters associated with those options to AC power. Since these heaters work with either 110/155 VAC or 220/240 VAC, there is only one jumper configuration.

Table 7-5: Power Configuration for Optional AC Heaters (JP6)

JUMPER COLOR	HEATER(S)	MODEL'S USED ON ¹	JUMPER BETWEEN PINS	FUNCTION
RED	IZS ¹ Permeation Tube Heater	100s, 200s ¹ & 400s	1 to 8	Common
			2 to 7	Neutral to Load
	O ₂ Sensor Heater	100s & 200s	3 to 10	Common
			4 to 9	Neutral to Load

¹ IZS option not available on the 9110TH/M

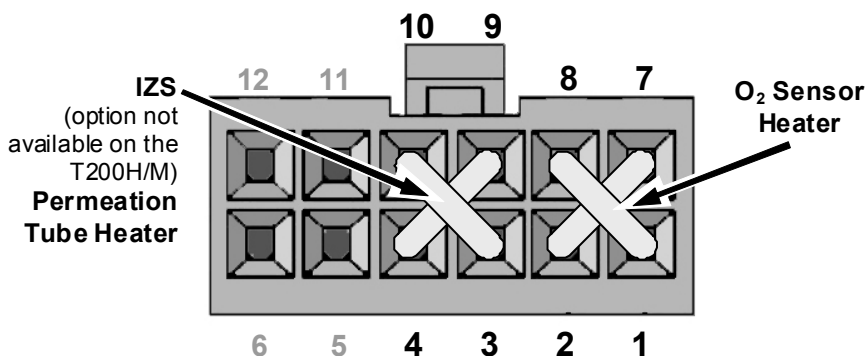


Figure 7-14: Typical Set Up of AC Heater Jumper Set (JP6)

7.5.5. DC POWER SUPPLY TEST POINTS

Table 7-6: DC Power Test Point and Wiring Color Code

NAME	TEST POINT#	COLOR	DEFINITION
DGND	1	Black	Digital ground
+5V	2	Red	
AGND	3	Green	Analog ground
+15V	4	Blue	
-15V	5	Yellow	
+12R	6	Purple	12 V return (ground) line
+12V	7	Orange	

Table 7-7: DC Power Supply Acceptable Levels

POWER SUPPLY	VOLTAGE	CHECK RELAY BOARD TEST POINTS				MIN V	MAX V
		FROM Test Point		TO Test Point			
		NAME	#	NAME	#		
PS1	+5	DGND	1	+5	2	+4.80	+5.25
PS1	+15	AGND	3	+15	4	+13.5	+16.0
PS1	-15	AGND	3	-15V	5	-14.0	-16.0
PS1	AGND	AGND	3	DGND	1	-0.05	+0.05
PS1	Chassis	DGND	1	Chassis	N/A	-0.05	+0.05
PS2	+12	+12V Ret	6	+12V	7	+11.8	+12.5
PS2	DGND	+12V Ret	6	DGND	1	-0.05	+0.05

The test points are located at the top, right-hand corner of the PCA (see Figure 7-4)

7.5.6. I²C BUS

Operation of the I²C bus can be verified by observing the behavior of D1 on the relay PCA & D2 on the Valve Driver PCA . Assuming that the DC power supplies are operating properly, the I²C bus is operating properly if: D1 on the relay PCA and D2 of the Valve Driver PCA are flashing

There is a problem with the I²C bus if both D1 on the relay PCA and D2 of the Valve Driver PCA are ON/OFF constantly.

7.5.7. TOUCH SCREEN INTERFACE

Verify the functioning of the touch screen by observing the display when pressing a touch-screen control button. Assuming that there are no wiring problems and that the DC power supplies are operating properly, but pressing a control button on the touch screen does not change the display, any of the following may be the problem:

- The touch-screen controller may be malfunctioning.
- The internal USB bus may be malfunctioning.

You can verify this failure by logging on to the instrument using APICOM or a terminal program. If the analyzer responds to remote commands and the display changes accordingly, the touch-screen interface may be faulty.

7.5.8. LCD DISPLAY MODULE

Verify the functioning of the front panel display by observing it when power is applied to the instrument. Assuming that there are no wiring problems and that the DC power supplies are operating properly, the display screen should light and show the splash screen and other indications of its state as the CPU goes through its initialization process.

7.5.9. GENERAL RELAY BOARD DIAGNOSTICS

The relay board circuit can most easily be checked by observing the condition of its status LEDs as described in Section 7.1.4.3, and the associated output when toggled on and off through the **SIGNAL I/O** function in the **DIAG** menu, see Section 4.13.2.

If the front panel display responds to key presses and D1 on the relay board is not flashing, then either the wiring between the keyboard and the relay board is bad, or the relay board itself is bad.

If D1 on the Relay board is flashing and the status indicator for the output in question (heater, valve, etc.) does not toggle properly using the **Signal I/O** function, then the associated device (valve or heater) or its control device (valve driver, heater relay) is malfunctioning. Several of the control devices are in sockets and can easily be replaced. The table below lists the control device associated with a particular function:

Table 7-8: Relay Board Control Devices

Function	Control Device	Socketed
All valves	U5	Yes
All heaters	K1-K5	Yes

7.5.10. MOTHERBOARD

7.5.10.1. A/D functions

A basic check of the analog to digital (A/D) converter operation on the motherboard is to use the **Signal I/O** function under the **DIAG** menu. Check the following two A/D reference voltages and input signals that can be easily measured with a voltmeter.

- Using the **Signal I/O** function (Section 4.13.2 Appendix D), view the value of **REF_4096_MV** and **REF_GND**. If both are within 3 mV of their nominal values (4096 and 0) and are stable to within ± 0.5 mV, the basic A/D converter is functioning properly. If these values fluctuate largely or are off by more than 3 mV, one or more of the analog circuits may be overloaded or the motherboard may be faulty.
- Choose one parameter in the Signal I/O function such as **SAMPLE_PRESSURE** (see previous section on how to measure it). Compare its actual voltage with the voltage displayed through the **SIGNAL I/O** function. If the wiring is intact but there is a difference of more than ± 10 mV between the measured and displayed voltage, the motherboard may be faulty.

7.5.10.2. Analog Output Voltages

To verify that the analog outputs are working properly, connect a voltmeter to the output in question and perform an analog output step test as described in Section 4.13.3.

For each of the steps, taking into account any offset that may have been programmed into the channel (Section 4.13.5.4), the output should be within 1% of the nominal value listed in the table below except for the 0% step, which should be within 2-3 mV. If one or more of the steps is outside of this range, a failure of one or both D/A converters and their associated circuitry on the motherboard is likely.

Table 7-9: Analog Output Test Function - Nominal Values

STEP	%	FULL SCALE OUTPUT VOLTAGE			
		100mV	1V	5V	10V
		NOMINAL OUTPUT VOLTAGE			
1	0	0 mV	0	0	0
2	20	20 mV	0.2	1	2
3	40	40 mV	0.4	2	4
4	60	60 mV	0.6	3	6
5	80	80 mV	0.8	4	8
6	100	100 mV	1.0	5	10

7.5.10.3. Status Outputs

The procedure below can be used to test the Status outputs.

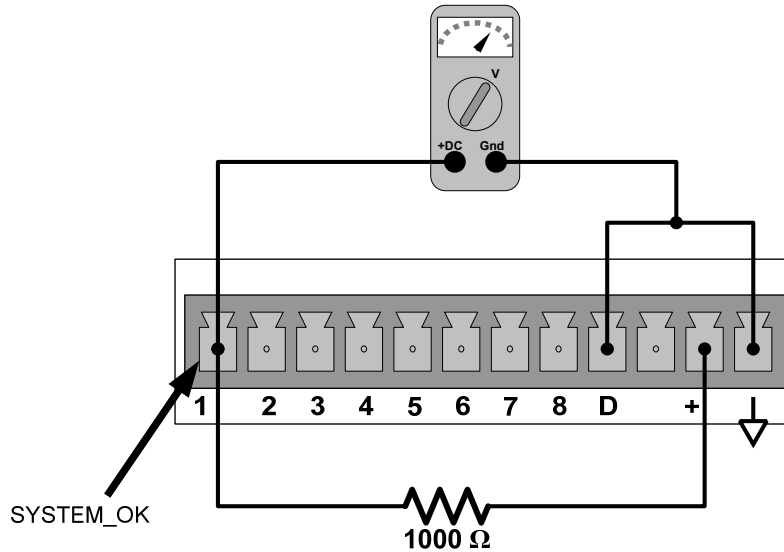


Figure 7-15: Typical Set Up of Status Output Test

1. Connect a cable between the “D” pin and the “∇” pin on the status output connector.
2. Connect a 1000 Ω resistor between the “+” pin and the pin for the status output that is being tested.
3. Connect a voltmeter between the “D” pin and the pin of the output being tested (Table 7-10).
4. Under the **DIAG / SIGNAL I/O** menu (Section 4.13.2), scroll through the inputs and outputs until you get to the output in question. Alternately turn the output on and off.
 - The Voltmeter will read approximately 5 VDC when the output is OFF.
 - The Voltmeter will read approximately 0 VDC when the output is ON.

Table 7-10: Status Outputs Pin Assignments

PIN #	STATUS
1	SYSTEM OK
2	CONC VALID
3	HIGH RANGE
4	ZERO CAL
5	SPAN CAL
6	DIAG MODE
7	LOW
8	SPARE

7.5.10.4. Control Inputs

The control input bits can be tested by the following procedure:

- Connect a jumper from the +5 V pin on the STATUS connector to the +5 V on the CONTROL IN connector.
- Connect a second jumper from the ‘-‘ pin on the STATUS connector to the A pin on the CONTROL IN connector. The instrument should switch from **SAMPLE** mode to **ZERO CAL R** mode.
- Connect a second jumper from the ‘-‘ pin on the STATUS connector to the B pin on the CONTROL IN connector. The instrument should switch from **SAMPLE** mode to **SPAN CAL R** mode.

In each case, the 9110TH/M should return to **SAMPLE** mode when the jumper is removed.

7.5.11. CPU

There are two major types of CPU board failures, a complete failure and a failure associated with the Disk-On-Module (DOM). If either of these failures occur, contact the factory.

For complete failures, assuming that the power supplies are operating properly and the wiring is intact, the CPU is faulty if on power-on:

- There is no activity from the primary RS-232 port (labeled **RS232**) on the rear panel even if “? <RETURN>” is pressed.
- In some rare circumstances, this failure may be caused by a bad IC on the motherboard, specifically U57, the large, 44 pin device on the lower right hand side of the board. If this is true, removing U57 from its socket will allow the instrument to start up but the measurements will be incorrect.

7.5.12. RS-232 COMMUNICATION

7.5.12.1. General RS-232 Troubleshooting

TAI analyzers use the RS-232 protocol as the standard, serial communications protocol. RS-232 is a versatile standard, which has been used for many years but, at times, is difficult to configure. TAI conforms to the standard pin assignments in the implementation of RS-232. Problems with RS-232 connections usually center around 4 general areas:

- Incorrect cabling and connectors. This is the most common problem. See Section 4.11.5 for connector and pin-out information.
- The communications (baud) rate and protocol parameters are incorrectly configured. See Section 4.11.3.2 on how to set the baud rate.
- The COM port communications mode is set incorrectly (Section 6.11.8).
- If a modem is used, additional configuration and wiring rules must be observed. See Section 6.15.2.6.
- Incorrect setting of the DTE - DCE switch. Typically, the red LED is on as soon as you power up the analyzer. If not, contact the factory, as this indicates a problem with the motherboard. As the analyzer is connected to the computer with a cable, the green LED should also illuminate. If not, set the DCE/DTE switch to the other position. See also Section 6.11.5.
- that some laptops do not enable their RS-232 port when in power-saving mode. In this case, connect the laptop and start either APICOM or a Hyperterminal window and start communicating with the analyzer. This will enable the serial port on the laptop and the green LED should illuminate. You may have to switch back and forth while communicating to get the right setting.

7.5.12.2. Modem or Terminal Operation

These are the general steps for troubleshooting problems with a modem connected to a Teledyne API analyzer.

- Check cables for proper connection to the modem, terminal or computer.
- Check the correct position of the DTE/DCE as described in Section 6.11.5.
- Check the correct setup command (Section 6.15.2.6).
- Verify that the Ready to Send (RTS) signal is at logic high. The 9110TH/M sets pin 7 (RTS) to greater than 3 volts to enable modem transmission.
- Make sure the baud rate, word length, and stop bit settings between modem and analyzer match, see Section 6.15.2.6 and 6.11.8.

- Use the RS-232 test function to send “w” characters to the modem, terminal or computer; See Section 6.11.10.
- Get your terminal, modem or computer to transmit data to the analyzer (holding down the space bar is one way). The green LED on the rear panel should flicker as the instrument is receiving data.
- Make sure that the communications software is functioning properly.

Further help with serial communications is available in a separate manual “RS-232 Manual”, TAI part number 013500000, available online at <http://www.Teledyne-api.com/manuals/>.

7.5.13. PMT SENSOR

The photo multiplier tube detects the light emitted by the reaction of NO with ozone. It has a gain of about 1: 500000 to 1:1000000. 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 properly is by using the optical test (**OTEST**), which is described in Section 6.13.6.2. The basic method to diagnose a PMT fault is to eliminate the other components using **ETEST**, **OTEST** and specific tests for other sub-assemblies.

7.5.14. PMT PREAMPLIFIER BOARD

To check the correct operation of the preamplifier board, we suggest to carry out the optical and electrical tests described in Sections 6.13.6.2 and 4.13.7.3. If the ETEST fails, the preamplifier board may be faulty. Refer to Section 13 on hardware calibration through the preamplifier board.

7.5.15. HIGH VOLTAGE POWER SUPPLY

The HVPS is located in the interior of the sensor module and is plugged into the PMT tube (Section 8.5.2). It requires 2 voltage inputs. The first is +15 V, which powers the supply. The second is the programming voltage which is generated on the preamplifier board. Adjustment of the HVPS is covered in the factory calibration procedure in Section 13. This power supply has 10 independent power supply steps, one to each pin of the PMT. The following test procedure below allows you to test each step.

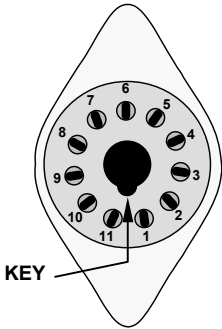
- Turn off the instrument.
- Remove the cover and disconnect the 2 connectors at the front of the NO_x sensor module.
- Remove the end cap from the sensor (4 screws).
- Remove the HVPS/PMT assembly from the cold block inside the sensor (2 plastic screws).
- Re-connect the 7 pin connector to the sensor end cap, and power-up the instrument. Scroll the front panel display to the **HVPS** test parameter.

Divide the displayed **HVPS** voltage by 10 and test the pairs of connector points as shown in Table 11-11.

- Check the overall voltage (should be equal to the **HVPS** value displayed on the front panel, for example 700 V) and the voltages between each pair of pins of the supply (should be 1/10th of the overall voltage, in this example 70 V):

Table 7-11: Example of HVPS Power Supply Outputs

If HVPS reading = 700 VDC	
PIN PAIR	NOMINAL READING
1 → 2	70 VDC
2 → 3	70 VDC
3 → 4	70 VDC
4 → 5	70 VDC
5 → 6	70 VDC
6 → 7	70 VDC
7 → 8	70 VDC



- Turn off the instrument power, and reconnect the PMT, then reassemble 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.

7.5.16. PNEUMATIC SENSOR ASSEMBLY

The pressure/flow sensor circuit board, located behind the sensor assembly, can be checked with a voltmeter using the following procedure, which assumes that the wiring is intact and that the motherboard and the power supplies are operating properly.

Measure the voltage across TP1 and TP2, it should be 10.0 ± 0.25 V. If not, the board is faulty. Measure the voltage across the leads of capacitor C2. It should be 5.0 ± 0.25 V, if not, the board may be faulty.

7.5.16.1. Reaction Cell Pressure

Measure the voltage across test points TP1 and TP5. With the sample pump disconnected or turned off, the voltage should be 4500 ± 250 mV. With the pump running, it should be 800-1700 mV depending on the performance of the vacuum pump.

The lower the reaction cell pressure, the lower the resulting voltage is. If this voltage is significantly different, the pressure transducer S1 or the board may be faulty. If this voltage is between 2 and 5 V, the pump may not be performing well, check that the reaction cell pressure is less than 10 in-Hg-A (at sea level). Ensure that the tubing is connected to the upper port, which is closer to the sensor's contacts; the lower port does not measure pressure.

7.5.16.2. Sample Pressure

Measure the voltage across test points TP1 and TP4. With the sample pump disconnected or turned off, this voltage should be 4500 ± 250 mV. With the pump running, it should be about 0.2 V less as the sample pressure drops by about 1 in-Hg-A below ambient pressure. If this voltage is significantly different, the pressure transducer S2 or the board may be faulty. A leak in the sample system to vacuum may also cause this voltage to be between about 0.6 and 4.5. Make sure that the front panel reading of the sample pressure is at about 1 in-Hg-A less than ambient pressure. Ensure that the tubing is connected to the upper port, which is closer to the sensor's contacts; the lower port does not measure pressure.

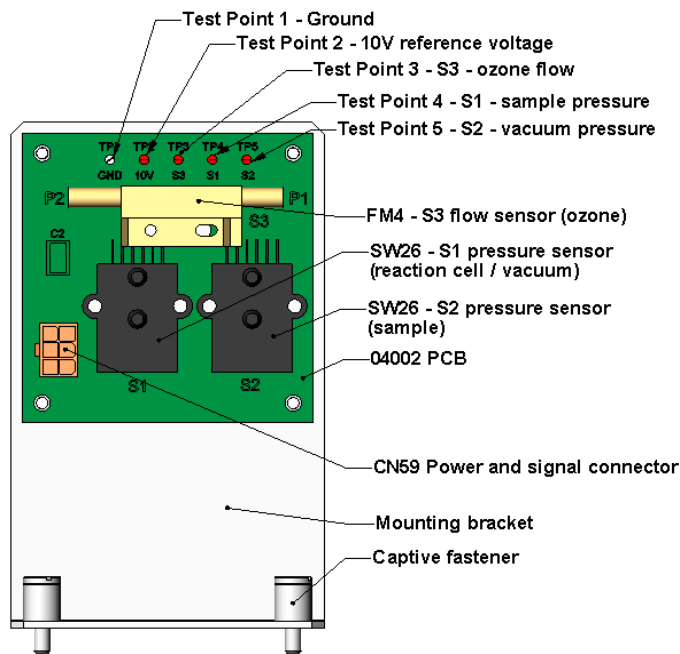


Figure 7-16: Pressure / Flow Sensor Assembly

7.5.16.3. Ozone Flow

Measure the voltage across TP1 and TP3. With proper ozone flow ($250 \text{ cm}^3/\text{min}$), this should be approximately 3.0 ± 0.3 V (this voltage will vary with altitude). With flow stopped (pump turned off), the voltage should be approximately 0 V. If the voltage is incorrect, the flow sensor or the board may be faulty. A cross-leak to vacuum inside the Perma Pure dryer may also cause this flow to increase significantly, and the voltage will increase accordingly. Also, make sure that the gas flows from P1 to P2 as labeled on the flow sensor (“high” pressure P1 to “low” pressure P2 or “Port” 1 to “Port” 2).

7.5.17. NO₂ CONVERTER

The NO₂ converter assembly can fail in two ways, an electrical failure of the band heater and/or the thermocouple control circuit and a performance failure of the converter itself.

NO₂ converter heater failures can be divided into two possible problems:

- Temperature is reported properly but heater does not heat to full temperature. In this case, the heater is either disconnected or broken or the power relay is broken.
 - Disconnect the heater cable coming from the relay board and measure the resistance between any two of the three heater leads with a multi-meter. The resistance between A and B should be about 1000 Ω and that between A and C should be the same as between B and C, about 500 Ω each. If any of these resistances is near zero or without continuity, the heater is broken.
- Temperature reports zero or overload (near 500° C). This indicates a disconnected or failing thermocouple or a failure of the thermocouple circuit.
 - First, check that the thermocouple is connected properly and the wire does not show signs of a broken or kinked pathway. If it appears to be properly connected, disconnect the yellow thermocouple plug (marked **K**) from the relay board and measure the voltage (not resistance) between the two leads with a multi-meter capable of measuring in the low mV range. The voltage should be about 12 mV (ignore the sign) at 315° C and about 0 mV at room temperature.
 - Measure the continuity with an Ohm-meter. It should read close to zero Ω . If the thermocouple does not have continuity, it is broken. If it reads zero voltage at elevated temperatures, it is broken. To test the thermocouple at room temperature, heat up the converter can (e.g., with a heat gun) and see if the voltage across the thermocouple leads changes. If the thermocouple is working properly, the electronic circuit is broken. In both cases, consult the factory.

If the converter appears to have performance problems (conversion efficiency is outside of allowed range of 96-102%), check the following:

- Conversion efficiency setting in the CAL menu. If this value is different from 1.000, this correction needs to be considered. Section 5.2.5 describes this parameter in detail.
- Accuracy of NO₂ source (gas tank standard). NO₂ gas standards are typically certified to only $\pm 2\%$ and often change in concentrations over time. You should get the standard re-certified every year. If you use GPT, check the accuracy of the ozone source.
- Age of the converter. The NO₂ converter has a limited operating life and may need to be replaced every ~3 years or when necessary (e.g., earlier if used with continuously high NO₂ concentrations). We estimate a lifetime of about 10000 ppm-hours (a cumulative product of the NO₂ concentration times the exposure time to that concentration). However, this lifetime heavily depends on many factors such as absolute concentration (temporary or permanent poisoning of the converter is possible), sample flow rate and pressure inside the converter, converter temperature, duty cycle etc. This lifetime is only an estimated reference and not a guaranteed lifetime.
- In some cases with excessive sample moisture, the oxidized molybdenum metal chips inside the converter cartridge may bake together over time and restrict air flow through the converter, in which case it needs to be replaced.

To avoid this problem, we recommend the use of a sample gas conditioner (Section 5.10). Section 6.4.4 describes how to replace the NO₂ converter cartridge.

- With no NO₂ in the sample gas and a properly calibrated analyzer, the NO reading is negative, while the NO₂ reading remains around zero. The converter destroys NO and needs to be replaced.
- With no NO₂ in the sample gas and a properly calibrated analyzer, the NOX reading is significantly higher than the actual (gas standard) NO concentration. The converter produces NO₂ and needs to be replaced.

7.5.18. O₃ GENERATOR

The ozone generator can fail in two ways, electronically (printed circuit board) and functionally (internal generator components). Assuming that air is supplied properly to the generator, the generator should automatically turn on 30 minutes after the instrument is powered up or if the instrument is still warm. See Section 10.3.6 for ozone generator functionality. Accurate performance of the generator can only be determined with an ozone analyzer connected to the outlet of the generator. However, if the generator appears to be working properly but the sensitivity or calibration of the instrument is reduced, suspect a leak in the ozone generator supply air.

A leak in the dryer or between the dryer and the generator can cause moist, ambient air to leak into the air stream, which significantly reduces the ozone output. The generator will produce only about half of the nominal O₃ concentration when run with moist, ambient air instead of dried air. In addition, moist supply air will produce large amounts of nitric acid in the generator, which can cause analyzer components downstream of the generator to deteriorate and/or causes significant deposit of nitrate deposits on the reaction cell window, reducing sensitivity and causing performance drift. Carry out a leak check as described earlier in this Section.

7.5.19. BOX TEMPERATURE

The box temperature sensor (thermistor) is mounted on the motherboard below the bottom edge of the CPU board when looking at it from the front. It cannot be disconnected to check its resistance. Box temperature will vary with, but will usually read about 5° C higher than, ambient (room) temperature because of the internal heating zones from the NO₂ converter, reaction cell and other devices.

- To check the box temperature functionality, we recommend to check the **BOX_TEMP** signal voltage using the **SIGNAL I/O** function under the **DIAG** Menu (Section 6.13.1). At about 30° C, the signal should be around 1500 mV.
- We recommend to use a certified or calibrated external thermometer / temperature sensor to verify the accuracy of the box temperature by placing it inside the chassis, next to the thermistor labeled **XT1** (above connector J108) on the motherboard.

7.5.20. PMT TEMPERATURE

PMT temperature should be low and constant. It is more important that this temperature is maintained constant than it is to maintain it low. The PMT cooler uses a Peltier thermo-electric cooler element supplied with 12 V DC power from the switching power supply PS2. The temperature is controlled by a proportional temperature controller located on the preamplifier board. Voltages applied to the cooler element vary from 0.1 to 12 VDC. The temperature set point (hard-wired into the preamplifier board) will vary by $\pm 1^{\circ}\text{C}$ due to component tolerances. The actual temperature will be maintained to within 0.1°C around that set point. On power-up of the analyzer, the front panel enables the user to watch that temperature drop from about ambient temperature down to its set point of $6\text{-}8^{\circ}\text{C}$. If the temperature fails to adjust after 30 minutes, there is a problem in the cooler circuit. If the control circuit on the preamplifier board is faulty, a temperature of -1°C is reported.

7.6. REPAIR PROCEDURES

This section contains some procedures that may need to be performed when a major component of the analyzer requires repair or replacement. Other maintenance procedures (e.g., replacement of regularly changed expendables) are discussed in Section 6 (Maintenance) and are not listed here. TAI Technical Support may have a more detailed service for some of the procedures listed here. Contact Technical Support.

7.6.1. DISK-ON-MODULE REPLACEMENT

Replacing the Disk-on-Module (DOM) will cause loss of all DAS data; it also may cause loss of some instrument configuration parameters unless the replacement DOM carries the exact same firmware version. Whenever changing the version of installed software, the memory must be reset. Failure to ensure that memory is reset can cause the analyzer to malfunction, and invalidate measurements.

After the memory is reset, the A/D converter must be re-calibrated, and all information collected in Step 1 below must be re-entered before the instrument will function correctly. Also, zero and span calibration should be performed.

1. Document all analyzer parameters that may have been changed, such as range, auto-cal, analog output, serial port and other settings before replacing the DOM
2. Turn off power to the instrument, fold down the rear panel by loosening the mounting screws.
3. When looking at the electronic circuits from the back of the analyzer, locate the Disk-on-Module in the right most socket of the CPU board.
4. The DOM should carry a label with firmware revision, date and initials of the programmer.
5. Remove the nylon fastener that mounts the DOM over the CPU board, and lift the DOM off the CPU. Do not bend the connector pins.
6. Install the new Disk-on-Module, making sure the notch at the end of the chip matches the notch in the socket.
7. It may be necessary to straighten the pins somewhat to fit them into the socket. Press the DOM all the way in and reinsert the offset clip.
8. Close the rear panel and turn on power to the machine.
9. If the replacement DOM carries a firmware revision, re-enter all of the setup information.

•

7.6.2. O₃ GENERATOR REPLACEMENT

The ozone generator is a black, brick-shaped device with printed circuit board attached to its rear and two tubes extending out the right side in the front of the analyzer. To replace the ozone generator:

1. Turn off the analyzer power, remove the power cord and the analyzer cover.
2. Disconnect the 1/8" black tube from the ozone scrubber cartridge and the 1/4" clear tube from the plastic extension tube at the brass fitting nearest to the ozone generator.
3. Unplug the electrical connection on the rear side of the brick.
4. Unscrew the two mounting screws that attach the ozone generator to the chassis and take out the entire assembly.
5. If you received a complete replacement generator with circuit board and mounting bracket attached, simply reverse the above steps to replace the current generator.
6. Make sure to carry out a leak check and a recalibration after the analyzer warmed up for about 30 minutes.

7.6.3. SAMPLE AND OZONE DRYER REPLACEMENT

The 9110TH/M standard configuration is equipped with a dryer for the ozone supply air. An optional dryer is available for the sample stream and a combined dryer for both gas streams can also be purchased. To change one or all of these options:

1. Turn off power to the analyzer and pump, remove the power cord and the analyzer cover.
2. Locate the dryers in the center of the instrument, between sensor and NO₂ converter.

They are mounted to a bracket, which can be taken out when unscrewing the two mounting screws (if necessary).

3. Disconnect all tubing that extends out of the dryer assembly,

These are usually the purge tube connecting to the vacuum manifold, the tube from the exit to the ozone flow meter (ozone dryer) or to the NO/NO_x valve (sample dryer) or two tubes to the ozone flow meter and the NO/NO_x valve (combo-dryer).

Take extra care not to twist any of the white plastic fittings on the dryer, which connect the inner drying tube to the outer purge tube.

4. Note the orientation of the dryer on the bracket.
5. Cut the tie wraps that hold the dryer to the mounting bracket and take out the old dryer.

If necessary, unscrew the two mounting screws on the bracket and take out the entire assembly.

6. Attach the replacement dryer to the mounting bracket in the same orientation as the old dryer.
7. Fix the dryer to the bracket using new tie wraps.
8. Cut off excess length of the wraps.
9. Put the assembly back into the chassis and tighten the mounting screws.
10. Re-attach the tubes to vacuum manifold, flow meter and/or NO/NO_x valve using at least two wrenches.

Take extra care not to twist the dryer's white plastic fittings, as this will result in large leaks that are difficult to trouble-shoot and fix.

11. Carry out a detailed leak check (Section 7.5.2),
12. Close the analyzer.
13. Power up pump and analyzer and re-calibrate the instrument after it stabilizes.

7.6.4. PMT SENSOR HARDWARE CALIBRATION

The sensor module hardware calibration is used in the factory to adjust the slope and offset of the PMT output and to optimize the signal output and HVPS. If the instrument's slope and offset values are outside of the acceptable range and all other more obvious causes for this problem have been eliminated, the hardware calibration can be used to adjust the sensor as has been done in the factory. This procedure is also recommended after replacing the PMT or the preamplifier board.

1. Perform a full zero calibration using zero air (Section 5.3, 7.4, or 7.6).
2. On the preamplifier board (located on the sensor housing, Figure 3-5) find the following components shown in Figure 7-17:
 - HVPS coarse adjustment switch (Range 0-9, then A-F).
 - HVPS fine adjustment switch (Range 0-9, then A-F).
 - Gain adjustment potentiometer (Full scale is 10 turns).
3. Turn the gain adjustment potentiometer 12 turns clockwise to its maximum setting.
4. Feed NO to the analyzer:
 - For the 9110TH use 450 ppm NO.
 - For the 9110TM use 18 ppm NO.
5. Wait until the **STABIL** value is below 0.5 ppm
6. Scroll to the **NORM PMT** value on the analyzer's front panel.
7. With the NO gas concentrations mentioned in step 5 above, the **NORM PMT** value should be 3600 mV.
8. Set the HVPS coarse adjustment to its minimum setting (0). Set the HVPS fine adjustment switch to its maximum setting (F).

- Set the HVPS coarse adjustment switch to the lowest setting that will give you just above 3600 mV **NORM PMT** signal. The coarse adjustment typically increments the **NORM PMT** signal in 100-300 mV steps.

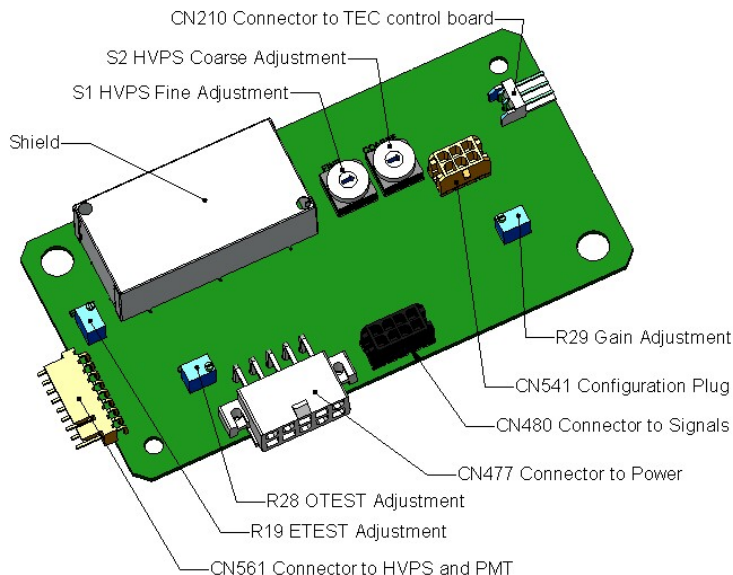


Figure 7-17: Pre-Amplifier Board Layout

- Adjust the HVPS fine adjustment such that the **NORM PMT** value is 3600-3700 mV.

The fine adjustment typically increments the **NORM PMT** value by about 30 mV.

It may be necessary to go back and forth between coarse and fine adjustments if the proper value is at the threshold of the min/max coarse setting.

Note

Do not overload the PMT by accidentally setting both adjustment switches to their maximum setting. Start at the lowest setting and increment slowly. Wait 10 seconds between adjustments..

- If the **NORM PMT** value set above is now between 3560-3640 mV, skip this step. Otherwise, adjust the **NORM PMT** value with the gain potentiometer down to 3600 ± 10 mV.
This is the final very-fine adjustment.
- that during adjustments, the **NORM PMT** value may be fluctuating, as the analyzer continues to switch between NO and NO_x streams as well as between measure and AutoZero modes.
You may have to mentally average the values of NO and NO_x response for this adjustment.
- Perform a software span calibration (Section 5.3, 7.4, or 7.6) to normalize the sensor response to its new PMT sensitivity.
- Review the slope and offset values, the slopes should be 1.000 ± 0.300 and the offset values should be 0.0 ± 20 mV (-20 to +150 mV is allowed).

7.6.5. REPLACING THE PMT, HVPS OR TEC

The photo multiplier tube (PMT) should last for the lifetime of the analyzer. However, in some cases, the high voltage power supply (HVPS) or the thermo-electric cooler (TEC) may fail. In case of PMT, HVPS or TEC failure, the sensor assembly needs to be opened in order to change one of these components. Refer to Figure 7-18 for the structure of the 9110TH/M sensor assembly and follow the steps below for replacement of one of its components. We recommend to ensure that the PMT, HVPS or TEC modules are, indeed, faulty to prevent unnecessary opening of the sensor.

CAUTION



Although it is possible for a skilled technician to change the PMT or HVPS through the front panel with the sensor assembly mounted to the analyzer, we recommend to remove the entire assembly and carry this procedure out on a clean, anti-static table with the user wearing an anti-static wrist strap to prevent static discharge damage to the assembly or its circuits.

1. Power down the analyzer, disconnect the power cord.
2. Remove the cover and disconnect all pneumatic and electrical connections from the sensor assembly.
3. If the TEC is to be replaced, remove the reaction cell assembly at this point by unscrewing two holding screws. This is necessary only if the PMT cold block is to be removed.

This step is not necessary if the HVPS or the PMT only are exchanged.

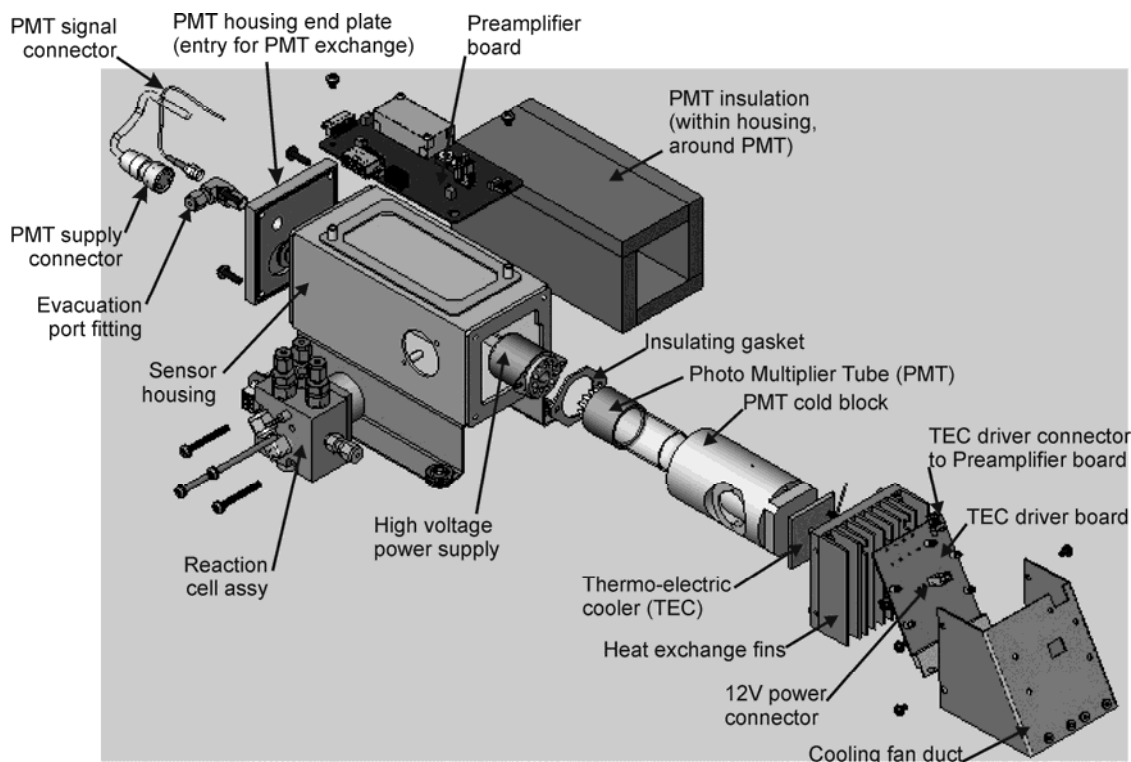


Figure 7-18: 9110TH/M Sensor Assembly

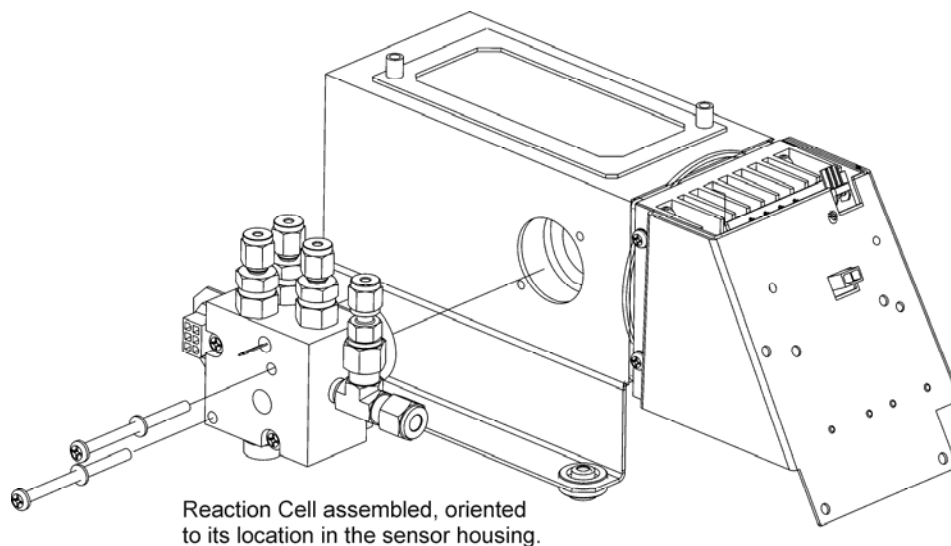


Figure 7-19. 3-Port Reaction Cell Oriented to the Sensor Housing

4. Remove the two connectors on the PMT housing end plate facing towards the front panel.
5. Remove the end plate itself (4 screws with plastic washers).
6. Remove the dryer packages inside the PMT housing.
7. Along with the plate, slide out the OPTIC TEST LED and the thermistor that measures the PMT temperature.
8. Unscrew the PMT assembly, which is held to the cold block by two plastic screws.

9. Discard the plastic screws and replace with new screws at the end of this procedure (the threads get stripped easily and it is recommended to use new screws).
 - a) Carefully remove the assembly consisting of the HVPS, the gasket and the PMT. Both may be coated with a white, thermal conducting paste.
 - b) Do not contaminate the inside of the housing with this grease, as it may contaminate the PMT glass tube on re-assembly.
10. Change the PMT or the HVPS or both, clean the PMT glass tube with a clean, anti-static wipe and do not touch it after cleaning.
11. If the cold block or TEC is to be changed:
 1. Disconnect the TEC driver board from the preamplifier board, remove the cooler fan duct (4 screws on its side) including the driver board.
 2. Disconnect the driver board from the TEC and set the sub-assembly aside.
12. Remove the end plate with the cooling fins (4 screws) and slide out the PMT cold block assembly, which contains the TEC.
13. Unscrew the TEC from the cooling fins and the cold block and replace it with a new unit.
14. Re-assemble this TEC subassembly in reverse order.

Make sure to use thermal grease between TEC and cooling fins as well as between TEC and cold block and that the side opening in the cold block will face the reaction cell when assembled.
15. Evenly tighten the long mounting screws for good thermal conductivity.

Note

The thermo-electric cooler needs to be mounted flat to the heat sink. If there is any significant gap, the TEC might burn out. Make sure to apply the thermal pads before mounting it and tighten the screws evenly and cross-wise..

16. Re-insert the TEC subassembly in reverse order.

Make sure that the O-ring is placed properly and the assembly is tightened evenly.
17. Re-insert the PMT/HVPS subassembly in reverse order and don't forget the gasket between HVPS and PMT.
 - a) Use new plastic screws to mount the PMT assembly on the PMT cold block.
 - b) Improperly placed O-rings will cause leaks, which – in turn – cause moisture to condense on the inside of the cooler and likely cause a short in the HVPS.
18. Reconnect the cables and the reaction cell (evenly tighten these screws).
19. Replace the sensor assembly into the chassis and fasten with four screws and washers.
20. Reconnect all electrical and pneumatic connections.
21. Leak check the system.
22. Power up the analyzer.
23. Verify the basic operation of the analyzer using the ETEST and OTEST features or zero and span gases, then carry out a hardware calibration of the analyzer (Section 13) followed by a software calibration.

7.7. REMOVING / REPLACING THE RELAY PCA FROM THE INSTRUMENT

This is the most commonly used version of the Relay PCA. It includes a bank of solid state AC relays. This version is installed in analyzers where components such as AC powered heaters must be turned ON & OFF. A retainer plate is installed over the relay to keep them securely seated in their sockets.

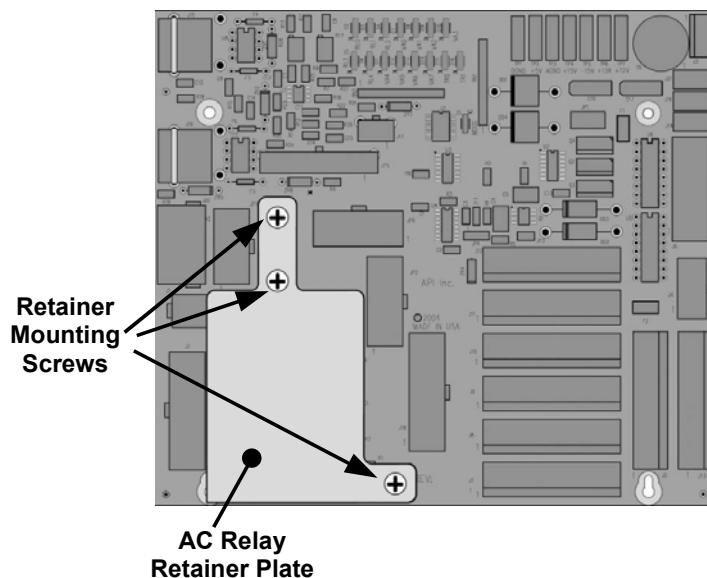


Figure 7-20: Relay PCA with AC Relay Retainer In Place

The Relay retainer plate installed on the relay PCA covers the lower right mounting screw of the relay PCA. Therefore, when removing the relay PCA, the retainer plate must be removed first.

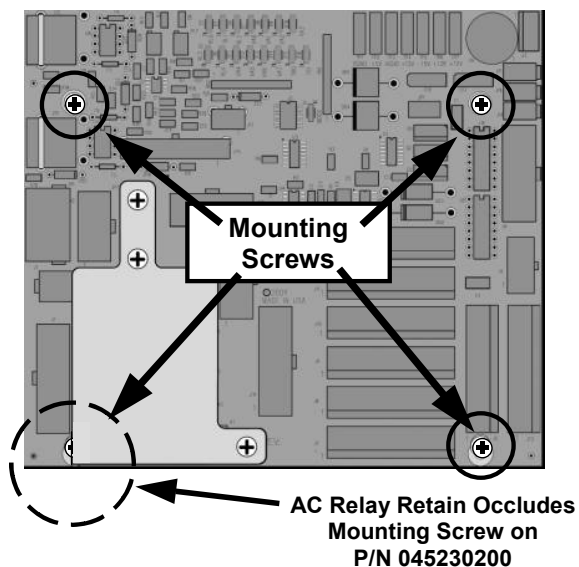


Figure 7-21: Relay PCA Mounting Screw Locations

7.8. FREQUENTLY ASKED QUESTIONS

The following list contains some of the most commonly asked questions relating to the Model 9110TH/M NO_x Analyzer.

QUESTION	ANSWER
<p>Why does the instrument not appear on the LAN or Internet?</p>	<p>Most problems related to Internet communications via the Ethernet card will be due to problems external to the instrument (e.g. bad network wiring or connections, failed routers, malfunctioning servers, etc.) However, there are several symptoms that indicate the problem may be with the Ethernet card itself. If neither of the Ethernet cable's two status LED's (located on the back of the cable connector) is lit while the instrument is connected to a network:</p> <ul style="list-style-type: none"> • Verify that the instrument is being connected to an active network jack. • Check the internal cable connection between the Ethernet card and the CPU board.
<p>Why does the ENTR button sometimes disappear on the front panel display?</p>	<p>Sometimes the ENTR button will disappear if you select a setting that is invalid or out of the allowable range for that parameter, such as trying to set the 24-hour clock to 25:00:00 or a reporting range outside the specified limits. Once you adjust the setting to an allowable value, the ENTR button will re-appear.</p>
<p>Why is the ZERO or SPAN button not displayed during calibration?</p>	<p>The 9110TH/M disables these buttons when the span or zero value entered by the user is too different from the gas concentration actual measured value at the time. This is to prevent the accidental recalibration of the analyzer to an out-of-range response curve.</p> <p>EXAMPLE: The span set point is 80 ppm and the measurement response is only 5 ppm. Section 7 describes this in detail.</p>
<p>Why does the analyzer not respond to span gas?</p>	<p>There are several reasons why this can happen. Section 10.3.2 has some possible answers to this question.</p>
<p>Can I automate the calibration of my analyzer?</p>	<p>Any analyzer with zero/span valve or IZS option can be automatically calibrated using the instrument's AutoCal feature.</p>
<p>What do I do if the concentration on the instrument's front panel display does not match the value recorded or displayed on my data logger even if both instruments are properly calibrated?</p>	<p>This most commonly occurs for one of the following reasons: (1) a difference in circuit ground between the analyzer and the data logger or a wiring problem; (2) a scale problem with the input to the data logger. The analog outputs of the analyzer can be manually calibrated to compensate for either or both of these effects, see Section 6.13.4; analog outputs are not calibrated, which can happen after a firmware upgrade (Section 6.13.5).</p>
<p>How do I measure the sample flow?</p>	<p>Sample flow is measured by attaching a calibrated flow meter to the sample inlet port when the instrument is operating.</p> <ul style="list-style-type: none"> • For the 9110TH in its basic configuration, the sample flow should be 290 cm³/min ±10%. • For the 9110TM in its basic configuration, the sample flow should be 250 cm³/min ±10%. <p>See Table 9-3 for more detailed information about gas flow rates. Section 7 includes detailed instructions on performing a check of the sample gas flow.</p>

QUESTION	ANSWER
Can I use the DAS system in place of a strip chart recorder or data logger?	Yes. Section 4.7 describes the setup and operation of the DAS system in detail.
How often do I need to change the particulate filter?	Once per week or as needed. Table 6-1 contains a maintenance schedule listing the most important, regular maintenance tasks. Highly polluted sample air may require more frequent changes.
How long does the sample pump last?	The sample pump should last one to two years and the pump head should be replaced when necessary. Use the RCEL pressure indicator on the front panel to see if the pump needs replacement. If this value goes above 10 in-Hg-A, on average, the pump head needs to be rebuilt.
Why does my RS-232 serial connection not work?	There are several possible reasons: <ul style="list-style-type: none"> • The wrong cable, please use the provided or a generic “straight-through” cable (do not use a “null-modem” type cable), • The DCE/DTE switch on the back of the analyzer is not set properly; make sure that both green and red lights are on, • The baud rate of the analyzer’s COM port does not match that of the serial port of your computer/data logger. See Section 11.5.11 more trouble-shooting information.

7.9. TECHNICAL ASSISTANCE

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

General Tech Support
(7:30 - 4:30 pm Pacific)
626-934-1673

Email: sda_techsupport@teledyne.com.

If none of our on-line guides provide a solution, please contact our Customer Service Department via email at TETCI_customerservice@teledyne.com Please include the following details in your email:

- Full name of the person placing the request
- Complete legal name of the company (No acronyms)
- Telephone and fax number with area code (country code for international numbers)
- Company street address, city, state and country
- Model number and serial number of the Teledyne product
- Brief explanation of technical support request
- Advise product application or end-use

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8. PRINCIPLES OF OPERATION

The 9110TH/M Nitrogen Oxides Analyzer is a microprocessor controlled instrument that determines the concentration of nitric oxide (NO), total nitrogen oxides (NO_x, the sum of NO and NO₂) and nitrogen dioxide (NO₂) in a sample gas drawn through the instrument. It requires that sample and calibration gases are supplied at ambient atmospheric pressure in order to establish a constant gas flow through the reaction cell where the sample gas is exposed to ozone (O₃), initiating a chemical reaction that gives off light (chemiluminescence). The instrument measures the amount of chemiluminescence to determine the amount of NO in the sample gas. A catalytic-reactive converter converts any NO₂ in the sample gas to NO, which is then – including the NO in the sample gas – is then reported as NO_x. NO₂ is calculated as the difference between NO_x and NO.

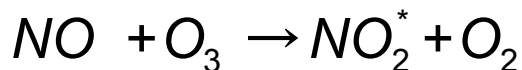
Calibration of the instrument is performed in software and usually does not require physical adjustments to the instrument. During calibration, the microprocessor measures the sensor output signal when gases with known amounts of NO or NO₂ are supplied and stores these results in memory. The microprocessor uses these calibration values along with the signal from the sample gas and data of the current temperature and pressure of the gas to calculate a final NO_x concentration.

The concentration values and the original information from which it was calculated are stored in the unit's internal data acquisition system (DAS Section 4.7.2) and are reported to the user through a vacuum fluorescence display or several output ports.

8.1. MEASUREMENT PRINCIPLE

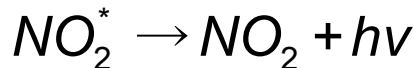
8.1.1. CHEMILUMINESCENCE

The principle of the 9110TH/M's measurement method is the detection of chemiluminescence, which occurs when nitrogen oxide (NO) reacts with ozone (O₃). This reaction is a two-step process. In the first step, one molecule of NO and one molecule of O₃ collide and chemically react to produce one molecule of oxygen (O₂) and one molecule of nitrogen dioxide (NO₂). Some of the NO₂ retains a certain amount of excess energy from the collision and, hence, remains in an excited state, which means that one of the electrons of the NO₂ molecule resides in a higher energy state than is normal (indicated by an asterisk in Equation 8-1).



Equation 8-1

Thermodynamics requires that systems seek the lowest stable energy state, hence, the NO₂ molecule quickly returns to its ground state in a subsequent step, releasing the excess energy in form of a quantum of light ($h\nu$) with wavelengths between 600 and 3000 nm, with a peak at about 1200 nm (Equation 9-2, Figure 8-1).



(Equation 9-2)

All things being constant, the relationship between the amount of NO present in the reaction cell and the amount of light emitted from the reaction is very linear. More NO produces more light, which can be measured with a light-sensitive sensor in the near-infrared spectrum (Figure 8-1). In order to maximize the yield of reaction (1), the 9110TH/M supplies the reaction cell with a large, constant excess of ozone (about 3000-5000 ppm) from the internal ozone generator.

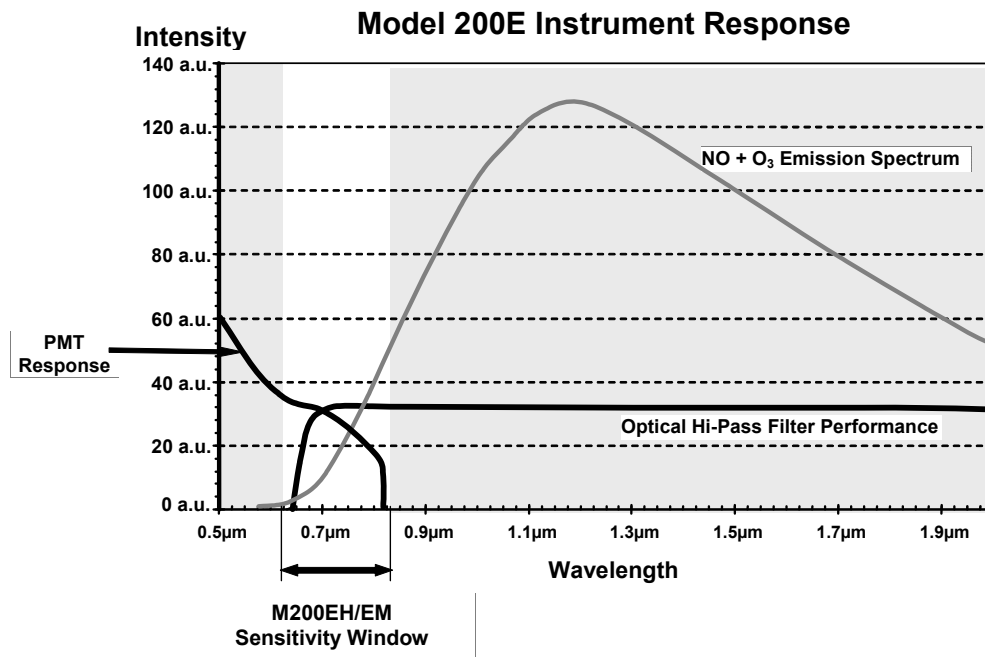
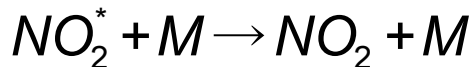


Figure 8-1: 9110TH/M Sensitivity Spectrum

However, only about 20% of the NO₂ that is formed through reaction 10-1 is in the excited state. In addition, the excited NO₂ can collide with another collision partner *M* in the reaction cell (mostly other molecules but also cell walls) and transfer its excess energy to its collision partner without emitting any light at all (Equation 9-3). In fact, by far the largest portion of the NO₂* returns to the ground state this way, leaving only a few percent yield of usable chemiluminescence.



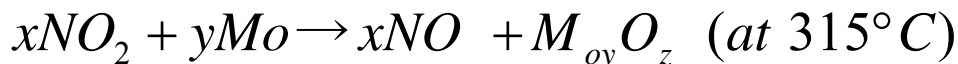
(Equation 9-3)

In order to enhance the light yield of the reaction, the reaction cell is maintained at reduced pressure. The probability of a collision between the NO₂* molecule and a collision partner *M* increases proportionally with the reaction cell pressure. This non-radiating collision with the NO₂* molecules is usually referred to as *quenching*, an unwanted process further described in Section 8.2.4.2.

8.1.2. NO_x AND NO₂ DETERMINATION

The only gas that is truly measured in the 9110TH/M is NO. Any NO₂ contained in the gas is not detected in the above process since NO₂ does not react with O₃ to undergo chemiluminescence.

In order to measure the concentration of NO or NO_x (which is defined here as the sum of NO and NO₂ in the sample gas), the 9110TH/M periodically switches the sample gas stream through a converter cartridge filled with molybdenum (Mo, “moly”) chips heated to a temperature of 315° C. The heated molybdenum reacts with NO₂ in the sample gas and produces a variety of molybdenum oxides and NO according to Equation 9-4.



(Equation 9-4)

Once the NO₂ in the sample gas has been converted to NO, it is routed to the reaction cell where it undergoes the chemiluminescence reaction described in Equations 9-1 and 9-2.

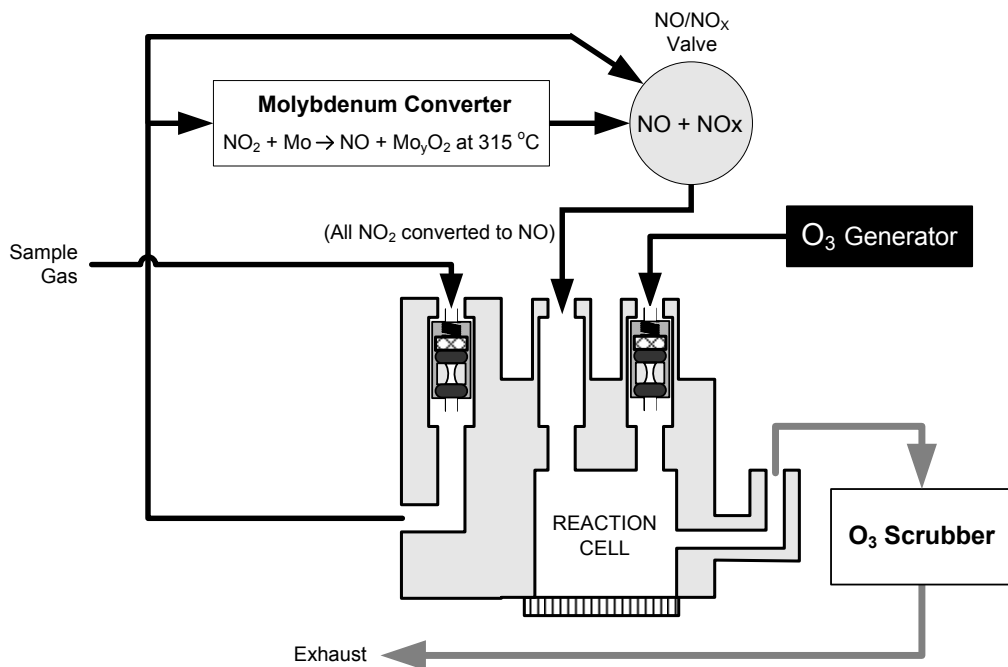


Figure 8-2: NO₂ Conversion Principle

By converting the NO₂ in the sample gas into NO, the analyzer can measure the total NO_x (NO+NO₂) content of the sample gas. By switching the NO₂ converter in and out of the sample gas stream every 6 - 10 seconds, the 9110TH/M analyzer is able to quasi-continuously measure both the NO and the total NO_x content.

The NO₂ concentration, finally, is not measured but calculated by simply subtracting the known NO content of the sample gas from the known NO_x content.

8.2. CHEMILUMINESCENCE DETECTION

8.2.1. THE PHOTO MULTIPLIER TUBE

The 9110TH/M uses a photo-multiplier tube (PMT) to detect the amount of light created by the NO and O₃ reaction in the reaction cell.

A PMT is typically a vacuum tube containing a variety of specially designed electrodes. Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by an applied high voltage and multiply through a sequence of such acceleration steps (dynodes) until a useable current signal is generated. This current increases or decreases with the amount of detected light (Section 10.4.3 for more details), is converted to a voltage and amplified by the preamplifier board and then reported to the motherboard's analog inputs.

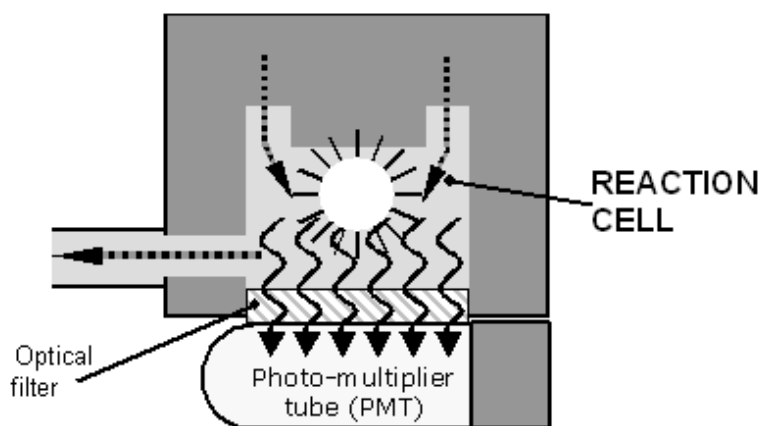


Figure 8-3: Reaction Cell with PMT Tube

8.2.2. OPTICAL FILTER

Another critical component in the method by which your 9110TH/M detects chemiluminescence is the optical filter that lies between the reaction cell and the PMT (Figure: 10-3). This filter is a high pass filter that is only transparent to wavelengths of light above 645 nm. In conjunction with the response characteristics of the PMT, this filter creates a very narrow window of wavelengths of light to which the 9110TH/M will respond (refer to Figure 8-1).

The narrow band of sensitivity allows the 9110TH/M to ignore extraneous light and radiation that might interfere with the 9110TH/M's measurement. For instance, some oxides of sulfur can also undergo chemiluminescence when in contact with O₃ but emit light at shorter wavelengths (~ 260 nm to 480 nm).

8.2.3. AUTO ZERO

Inherent in the operation of any PMT is a certain amount of noise. This is due to a variety of factors such as black body infrared radiation given off by the metal components of the reaction cell, unit to unit variations in the PMT units and even the constant universal background radiation that surrounds us at all times. In order to reduce this amount of noise and offset, the PMT is kept at a constant 7° C (45° F) by a thermo-electric cooler (TEC).

While this intrinsic noise and offset is significantly reduced by cooling the PMT, it is not eradicated. To determine how much noise remains, the 9110TH/M diverts the sample gas flow directly to the exhaust manifold without passing the reaction cell once every minute for about 5 seconds (Figure 8-4). During this time, only O₃ is present in the reaction cell, effectively turning off the chemiluminescence reaction. Once the chamber is completely dark, the 9110TH/M records the output of the PMT and keeps a running average of these **AZERO** values. This average offset value is subtracted from the raw PMT readings while the instrument is measuring NO and NO_x to arrive at a auto-zero corrected reading.

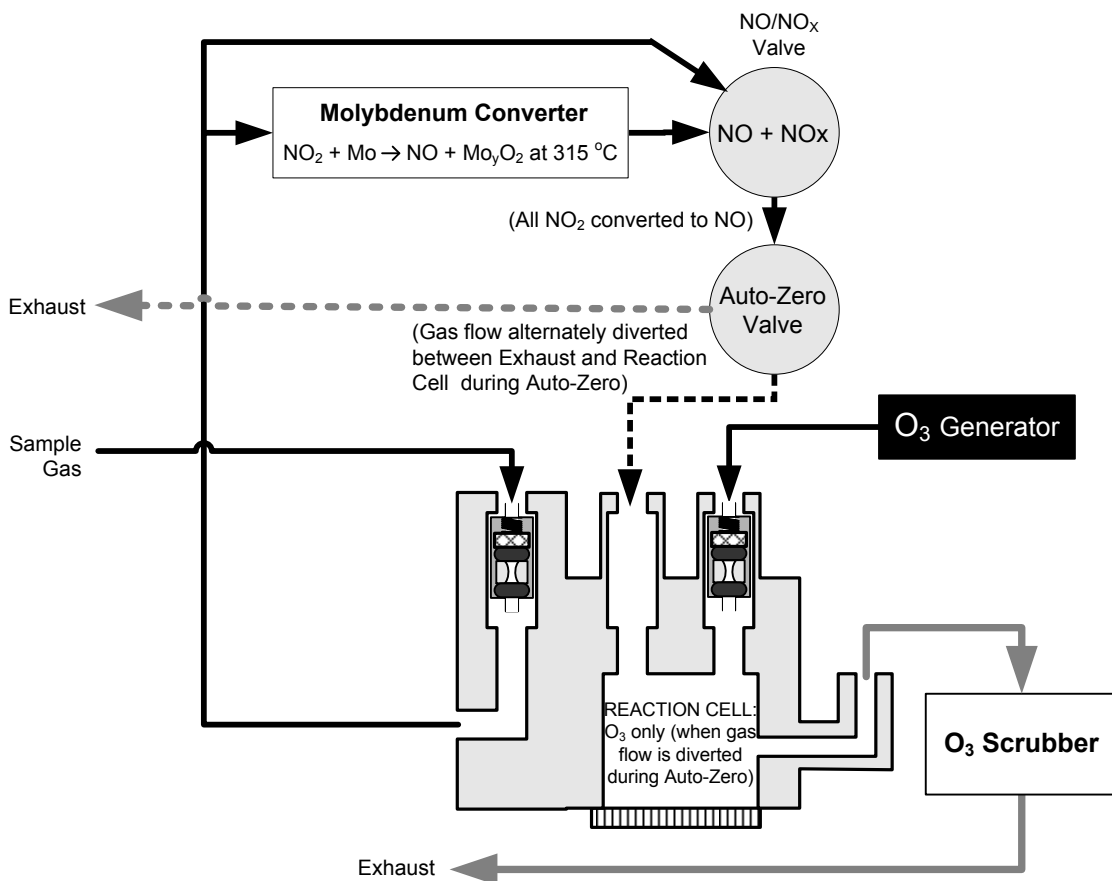


Figure 8-4: Reaction Cell During the AutoZero Cycle

8.2.4. MEASUREMENT INTERFERENCES

It should be noted that the chemiluminescence method is subject to interferences from a number of sources. The 9110TH/M has been successfully tested for its ability to reject interference from most of these sources. Table 8-1 lists the most important gases, which may interfere with the detection of NO in the 9110TH/M.

8.2.4.1. Direct Interference

Some gases can directly alter the amount of light detected by the PMT due to chemiluminescence in the reaction cell. This can either be a gas that undergoes chemiluminescence by reacting with O₃ in the reaction cell or a gas that reacts with other compounds and produces excess NO upstream of the reaction cell.

8.2.4.2. Third Body Quenching

As shown in Equation 9-3, other molecules in the reaction cell can collide with the excited NO₂^{*}, preventing the chemiluminescence of Equation 9-2, a process known as quenching. CO₂ and H₂O are the most common quenching interferences, but N₂ and O₂ also contribute to this interference type.

Quenching is an unwanted phenomenon and the extent to which it occurs depends on the properties of the collision partner. Larger, more polarized molecules such as H₂O and CO₂ quench NO chemiluminescence more effectively than smaller, less polar and electronically “harder” molecules such as N₂ and O₂.

The influence of water vapor on the 9110TH/M measurement can be eliminated with an optional, internal sample gas dryer. The concentrations of N₂ and O₂ are virtually constant in ambient air measurements, hence provide a constant amount of quenching and the interference of varying CO₂ amounts is negligible at low concentrations.

The 9110TH and 9110TM analyzers are typically used in high CO₂ concentration environments. The pneumatic setup of these two analyzer models minimizes the interference from CO₂ such that the analyzers conform to the standards set forth by the US-EPA in Method 20 - *NOx from Stationary Gas Turbines*, available at <http://www.epa.gov/ttn/emc/promgate.html>

Table 8-1: List of Interferents

GAS	INTERFERENCE TYPE	REJECTION METHOD
CO ₂	Dilution: Viscosity of CO ₂ molecules causes them to collect in aperture of Critical Flow Orifice altering flow rate of NO.	If high concentrations of CO ₂ are suspected, special calibration methods must be performed to account for the affects of the CO ₂ .
	3 rd Body Quenching: CO ₂ molecules collide with NO ₂ * molecules absorbing excess energy kinetically and preventing emission of photons.	Contact TAI Technical Support department for details.
SO _x	Some SO _x variants can also initiate a chemiluminescence reaction upon exposure to O ₃ producing excess light.	Wavelengths of light produced by chemiluminescence of SO _x are screened out by the Optical Filter.
	Chemically reacts with NH ₃ , O ₂ and H ₂ O in O ₃ generator to create (NH ₃) ₂ SO ₄ (ammonium sulfate) and NH ₃ NO ₂ (ammonium nitrate) which form opaque white deposits on optical filter window. Also forms highly corrosive HNO ₃ (Nitric Acid)	Most of the ammonium sulfate and ammonium nitrate produced is removed from the sample gas by an air purifier located between the O ₃ Generator and the reaction cell.
	3 rd Body quenching: SO _x molecules collide with NO ₂ * molecules absorbing excess energy kinetically and preventing emission of photons.	If high concentrations of SO _x are suspected, special calibration methods must be performed to account for the affects of the SO ₂ . Contact TAI Technical Support department for details.
H ₂ O	3 rd Body quenching: H ₂ O molecules collide with NO ₂ * molecules absorbing excess energy kinetically and preventing emission of photons.	Analyzer's operating in high humidity areas must have some method of drying applied to the sample gas supply (Section 5.10 for more details).
	Chemically reacts with NH ₃ and SO _x in O ₃ generator to create (NH ₃) ₂ SO ₄ (ammonium sulfate) and NH ₃ NO ₂ (ammonium nitrate) which form opaque white deposits on optical filter Window. Also forms highly corrosive HNO ₃ (nitric acid)	Removed from the O ₃ gas stream by the Perma Pure [®] Dryer (Section 8.3.7 for more details).
NH ₃	Direct Interference: NH ₃ is converted to H ₂ O and NO by the NO ₂ converter. Excess NO reacts with O ₃ in reaction cell creating excess chemiluminescence.	If a high concentration of NH ₃ is suspected, steps must be taken to remove the NH ₃ from the sample gas prior to its entry into the NO ₂ converter.
	Chemically reacts with H ₂ O, O ₂ and SO _x in O ₃ generator to create (NH ₃) ₂ SO ₄ (ammonium sulfate) and NH ₃ NO ₂ (ammonium nitrate) which form opaque white deposits on optical filter window. Also forms highly corrosive HNO ₃ (nitric acid).	The Perma Pure [®] dryer built into the 9110TH/M is sufficient for removing typical ambient concentration levels of NH ₃ .

In cases with excessively high CO₂ concentrations (larger than 0.5%), the effect can be calibrated out by using calibration gases with a CO₂ content equal to the measured air. Only very high and highly variable CO₂ concentrations will then be cause of measurable interference. For those applications, we recommend to use other analyzer models. Please consult sales or our website.

8.2.4.3. Light Leaks

The 9110TH/M sensitivity curve includes a small portion of the visible light spectrum (Figure 10-1), hence, it is important to make sure than the reaction cell is completely sealed with respect to light. To ensure this, all pneumatic tubing leading into the reaction cell is either opaque (vacuum exit tubing) in order to prevent light from entering the cell or light penetration is prevented by stainless steel filters and orifices (gas entries).

8.3. PNEUMATIC OPERATION

Note

It is important that the sample airflow system is leak-tight and not pressurized over ambient pressure. Regular leak checks should be performed on the analyzer as described in the maintenance schedule, Table 6-1. Procedures for correctly performing leak checks are provided in Section 7.5

8.3.1. PUMP AND EXHAUST MANIFOLD

Note

Relative Pressure versus absolute pressure. In this manual vacuum readings are given in inches of mercury absolute pressure (in-Hg-A), i.e. indicate an absolute pressure referenced against zero (a perfect vacuum).

The gas flow for the 9110TH/M is created by an external pump (Figure 8-5) that is pneumatically connected through a 6.4 mm / 0.25" tube to the analyzer's EXHAUST port located on the rear panel. This pump creates a vacuum of approximately 5 in-Hg-A at one standard liter/minute, which is provided to various pneumatic components by a vacuum manifold located just in front of the rear panel. Gas flow is created by keeping the analyzer's sample gas inlet near ambient pressure, usually by means of a small vent installed in the sample line at the inlet, in effect pulling the gas through the instrument's pneumatic systems.

There are several advantages to this external pump / pull-through configuration.

- By using an external pump, it is possible to remove a significant source of acoustic noise and vibration from the immediate vicinity of the sensor. The PMT can act as a "microphone", amplifying noise and vibration within the chassis. This is one of the main reasons, why the 9110TH/M has an external pump.
- Pumping heats and compresses the sample air, complicating the measurement process if the pump is upstream.
- Most importantly, however, certain physical parts of the pump itself are made of materials that might chemically react with the sample gas. Placing the pump downstream of the reaction cell avoids these problems.

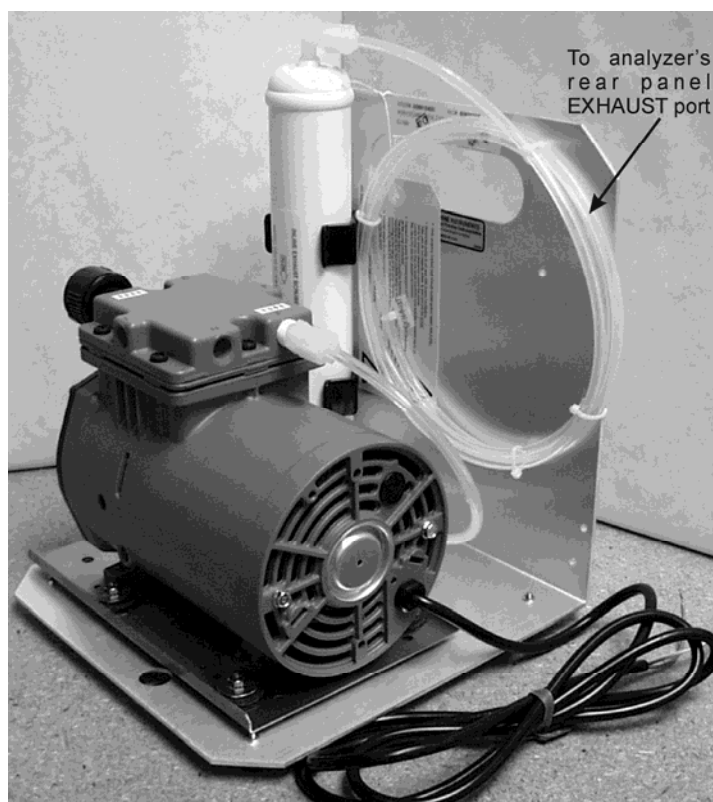


Figure 8-5: External Pump Pack

Finally, the 9110TH/M requires a steady, high under-pressure, which cannot be achieved reliably over extended periods of time with small vacuum pumps. The external pump used for the 9110TH/M has a very long lifetime and duty cycle and provides a very good vacuum for its entire lifetime. However, the pump is too large to fit into the chassis of the analyzer.

8.3.2. SAMPLE GAS FLOW

The sample gas is the most critical flow path in the analyzer, as the medium has to be routed through a variety of valves and tubes for the measurement of zero offset and concentrations of both NO and NO_x (and possibly the drying of the gas if the optional sample dryer is installed). At any point before and in the reaction cell, the integrity of the sample gas cannot be compromised.

Sample gas flow in the 9110TH/M analyzer is not a directly measured value, but is rather calculated from the sample pressure using the flow principle across a critical orifice. In general, the differential pressure ratio between sample pressure and reaction cell pressure needs to exceed 2:1 to allow critical flow. The actual flow rate is then only dependent on the size of the orifice and the upstream pressure. Refer to Section 8.3.3 for a detailed description of the instrument's method of gas flow rate control.

8.3.2.1. NO/NO_x and AutoZero cycles

For the routing of the sample gas flow, the analyzer uses a variety of valves. The NO/NO_x valve directs the sample gas either directly to the reaction cell or through the unit's NO₂ converter, alternating every ~4 s. The AutoZero valve directs the sample gas stream to completely bypass the reaction cell for dark noise measurement once every minute, which is then subtracted as a measurement offset from the raw concentration signal. The valve cycle phases are summarized in the following table.

Table 8-2: 9110TH/M Valve Cycle Phases

PHASE	NO/ NO _x VALVE STATUS	AUTOZERO VALVE STATUS	TIME INDEX	ACTIVITY	FIGURE
NO Measure	Open to AutoZero valve	Open to reaction cell	0 - 2 s	Wait period (NO dwell time). Ensures reaction cell has been flushed of previous gas.	Figure 8-2
			2 - 4 s	Analyzer measures chemiluminescence in reaction cell.	
NOX Measure	Open to NO ₂ converter	Open to reaction cell	4 - 6 s	Wait period (NOX dwell time). Ensures reaction cell has been flushed of previous gas.	Figure 8-2
			6 - 8 s	Analyzer measures NO + O ₃ chemiluminescence in reaction cell.	
Cycle repeats every ~8 seconds					
AutoZero	Open to AutoZero valve	Open to vacuum manifold	0 - 4 s	Wait period (AZERO dwell time). Ensures reaction cell has been flushed of sample gas and chemiluminescence reaction is stopped.	Figure 8-4
			4 - 6 s	Analyzer measures background noise without sample gas	
Cycle repeats every minute					

8.3.3. FLOW RATE CONTROL - CRITICAL FLOW ORIFICES

The Model 9110TH/M analyzers use special flow control assemblies (Figure 8-8) located at various locations within the instrument to maintain constant flow rates for both the O₃ supply air and the sample gas. These assemblies consists of:

- A critical flow orifice.
- Two o-rings: Located just before and after the critical flow orifice, the o-rings seal the gap between the walls of assembly housing and the critical flow orifice.
- A spring: Applies mechanical force needed to form the seal between the o-rings, the critical flow orifice and the assembly housing.

The figures that follow highlight the location of these flow control assemblies:

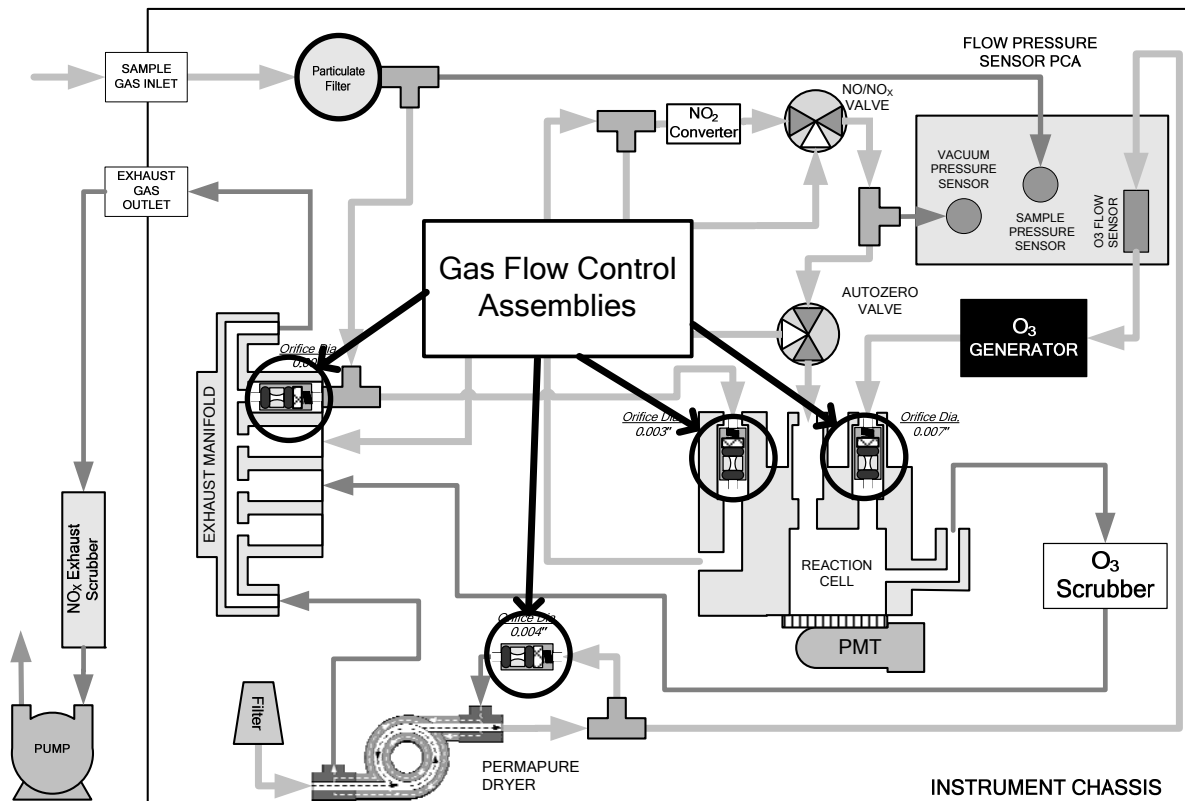


Figure 8-6: Location of Gas Flow Control Assemblies for 9110TH

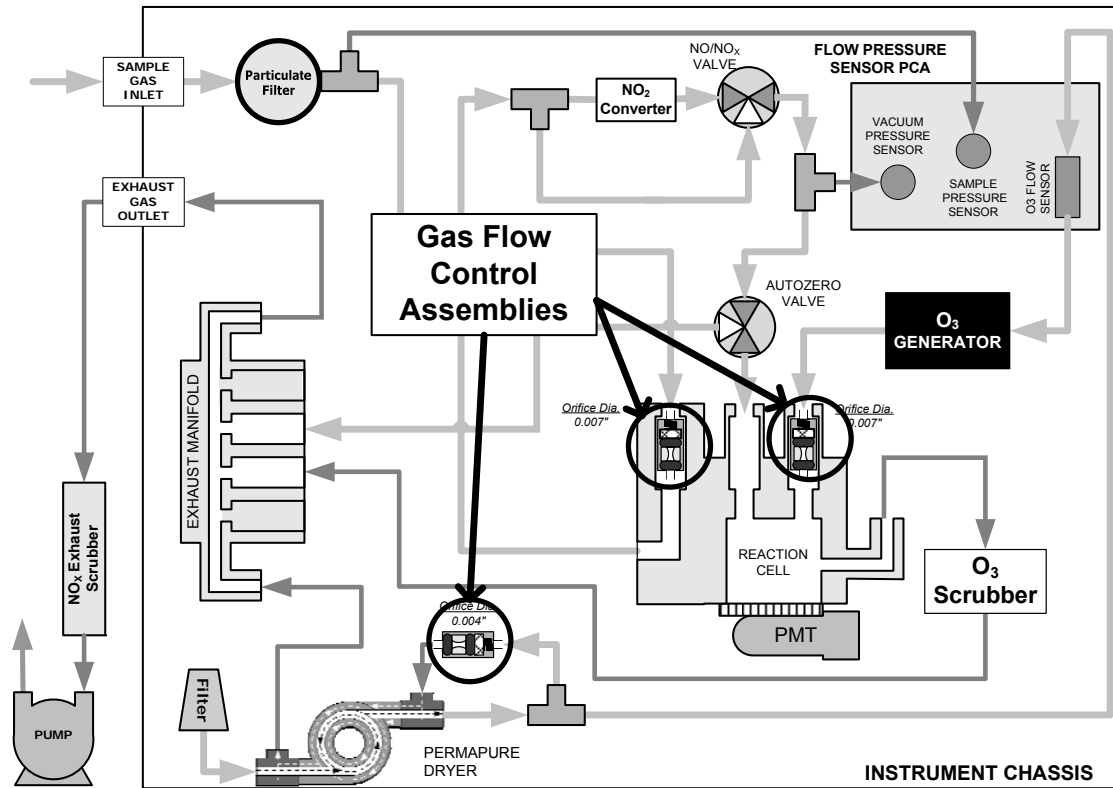


Figure 8-7: Location of Gas Flow Control Assemblies for 9110TM

Note

Location of flow control assemblies in the 9110TH/M with zero/span option 50 installed are the same as shown in Figure 8-6 and Figure 8-7.

8.3.3.1. Critical Flow Orifice

The most important component of the flow control assemblies is the critical flow orifice.

Critical flow orifices are a remarkably simple way to regulate stable gas flow rates. They operate without moving parts by taking advantage of the laws of fluid dynamics. By restricting the flow of gas through the orifice, a pressure differential is created. This pressure differential combined with the action of the analyzer's pump draws the gas through the orifice.

As the pressure on the downstream side of the orifice (the pump side) continues to drop, the speed that the gas flows through the orifice continues to rise. Once the ratio of upstream pressure to downstream pressure is greater than 2:1, the velocity of the gas through the orifice reaches the speed of sound. As long as that ratio stays at least 2:1 the gas flow rate is unaffected by any fluctuations, surges, or changes in downstream pressure because such variations only travel at the speed of sound themselves and are therefore cancelled out by the sonic shockwave at the downstream exit of the critical flow orifice.

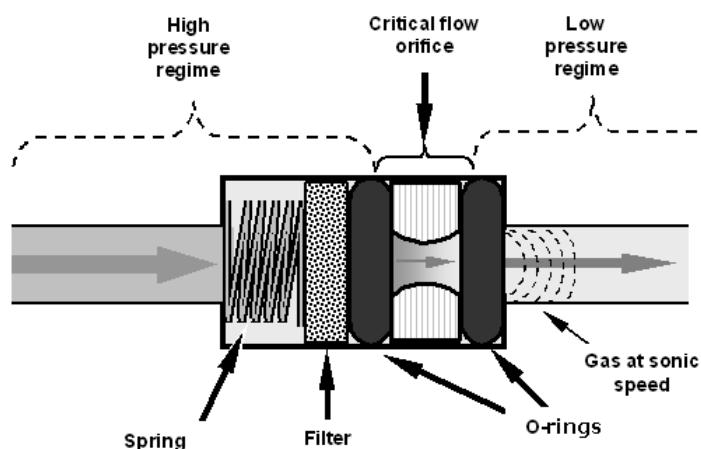


Figure 8-8: Flow Control Assembly & Critical Flow Orifice

The actual flow rate of gas through the orifice (volume of gas per unit of time), depends on the size and shape of the aperture in the orifice. The larger the hole, the more gas molecules, moving at the speed of sound, pass through the orifice.

With nominal pressures of 28 and 4 in-Hg-A for the sample and reaction cell pressures, respectively the necessary ratio of sample to reaction cell pressure of 2:1 is largely exceeded and accommodates a wide range of possible variability in atmospheric pressure and pump degradation extending the useful life of the pump. Once the pump degrades to the point where the vacuum pressure exceeds 14 in-Hg-A so that the ratio between sample and vacuum pressures is less than 2:1 a critical flow rate can no longer be maintained. At this point, the instrument will display "XXXX" indicating an invalid sample flow rate.

The following table lists the gas flow rates of the critical flow orifices in the standard 9110TH/M

Table 8-3: 9110TH/M Critical Flow Orifice Diameters and Gas Flow Rates

LOCATION	PURPOSE	ORIFICE DIAMETER		NOMINAL FLOWRATE (cm ³ /min)	
		9110TH	9110TM	9110TH	9110TM
Bypass manifold ¹ out to NO/NO _x valve and NO ₂ converter	Controls rate of flow of sample gas into the NO ₂ converter and reaction cell.	0.003"	0.007"	40	250
Vacuum manifold: Bypass manifold ¹ Port	Controls rate of sample gas flow that bypasses the analyzer when bypassing the reaction cell during the auto-zero cycle.	0.007"	N/A	250	N/A
TOTAL INLET GAS FLOW – Standard Configuration				290	250
Vacuum manifold: O ₂ sensor port	Controls rate of flow of zero purge gas through the O ₂ sensor (when installed and enabled) when inactive.	0.004"	0.004"	80	80
TOTAL INLET GAS FLOW – With O₂ Sensor Option				370	330
O ₃ supply inlet of reaction cell.	Controls rate of flow of ozone gas into the reaction cell.	0.007"	0.007"	250	250
Dry air return of Perma Pure [®] dryer	Controls flow rate of dry air return / purge air of the dryer.	0.004"	0.004"	80	80

¹ Bypass manifold is built into the 3-port reaction cell.

In addition to controlling the gas flows, the critical flow orifices at the inlets of the reaction cell also maintain an under-pressure inside the reaction cell, effectively reducing the number of molecules in the chamber and therefore increasing the chemiluminescence yield as the likelihood of third body quenching is reduced (Section 8.2.4.1). The 9110TH/M sensitivity reaches a peak at about 2 in-Hg-A, below which the sensitivity drops due to a low number of molecules and decreased yield in the chemiluminescence reaction.

EFFECT OF TEMPERATURE ON CRITICAL FLOW

Changes in temperature will cause the critical flow orifice materials to expand or contract. Even though these changes are extremely small, they can alter the diameter of the critical flow orifice enough to cause noticeable changes in the flow rate through the orifice. To alleviate this problem the two most important of the flow assemblies (those controlling the sample gas and O₃ gas flow) in the 9110TH/M are maintained at a constant temperature.

8.3.4. SAMPLE PARTICULATE FILTER

To remove particles in the sample gas, the analyzer is equipped with a PTFE membrane filter of 47 mm diameter (also referred to as the sample filter) with a 1 μm pore size. The filter is accessible through the front panel, which folds down (after removal of the

CE Mark safety screw), and should be changed according to the maintenance schedule in Table 9-1.

8.3.5. OZONE GAS AIR FLOW

The excess ozone needed for reaction with NO in the reaction cell is generated inside the analyzer because of the instability and toxicity of ozone. Besides the ozone generator itself, this requires a dry air supply and filtering of the gas before it is introduced into the reaction cell. Due to its toxicity and aggressive chemical behavior, O₃ must also be removed from the gas stream before it can be vented through the exhaust outlet.

In contrast to the sample flow, the ozone flow is measured with a mass flow sensor, which is mounted on the pneumatic sensor board, just behind the PMT sensor assembly.

This mass flow sensor has a full scale range of 0-1000 cm³/min and can be calibrated through software to its span point (Section 4.13.7.5). As the flow value displayed on the front panel is an actual measurement (and not a calculated value), the flow variability may be higher than that of the sample flow, which is based on a calculation from (more stable) differential pressures. On the other hand, the drift, i.e. long-term change, in the ozone flow rate may be higher and usually indicates a flow problem. As with all other test parameters, we recommend to monitor the ozone flow over time for predictive diagnostics and maintenance evaluation.



CAUTION

Ozone (O₃) is a toxic gas. Obtain a Material and Safety Data Sheet (MSDS) for this gas. Read and rigorously follow the safety guidelines described there. Always make sure that the plumbing of the O₃ generation and supply system is maintained and leak-free.

8.3.6. O₃ GENERATOR

The 9110TH/M uses a corona discharge (CD) tube for creating its O₃. Corona discharge generation is capable of producing high concentrations of ozone efficiently and with low excess heat. Although there are many cell designs, the fundamental principle remains the same (Figure 8-9).

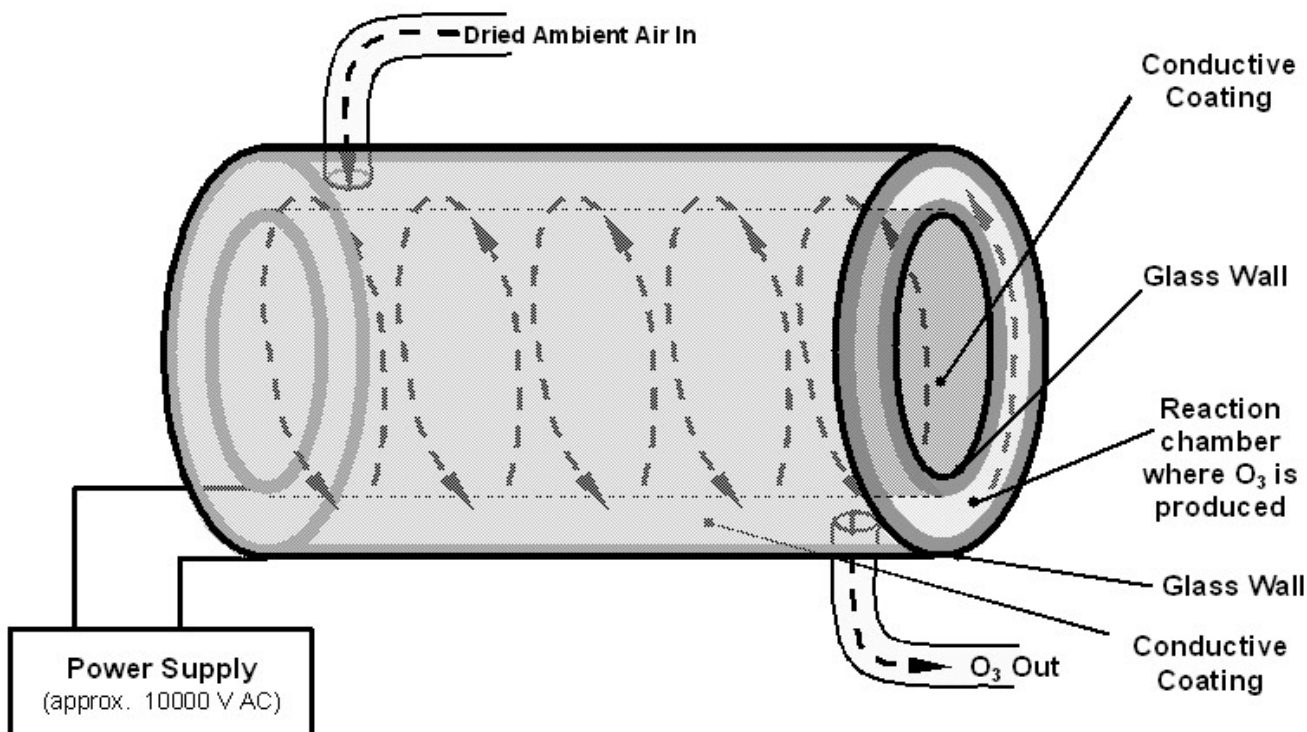


Figure 8-9: Ozone Generator Principle

The 9110TH/M utilizes a dual-dielectric design. This method utilizes a glass tube with hollow walls. The outermost and innermost surfaces are coated with electrically conductive material. The air flows through the glass tube, between the two conductive coatings, in effect creating a capacitor with the air and glass acting as the dielectric. The layers of glass also separate the conductive surfaces from the air stream to prevent reaction with the O₃. As the capacitor charges and discharges, electrons are created and accelerated across the air gap and collide with the O₂ molecules in the air stream splitting them into elemental oxygen. Some of these oxygen atoms recombine with O₂ to O₃.

The quantity of ozone produced is dependent on factors such as the voltage and frequency of the alternating current applied to the CD cells. When enough high-energy electrons are produced to ionize the O₂ molecules, a light emitting, gaseous plasma is formed, which is commonly referred to as a corona, hence the name corona discharge generator.

8.3.7. PERMA PURE[®] DRYER

The air supplied to the O₃ generation system needs to be as dry as possible. Normal room air contains a certain amount of water vapor, which greatly diminishes the yield of ozone produced by the ozone generator. Also, water can react with other chemicals inside the O₃ Generator to produce chemicals that damage the optical filter located in the reaction cell (Table 10-1) such as ammonium sulfate or highly corrosive nitric acid.

To accomplish this task the 9110TH/M uses a Perma Pure[®] single tube permeation dryer. The dryer consists of a single tube of Nafion[®], a co-polymer similar to Teflon[®] that absorbs water very well but not other chemicals. The Nafion[®] tube is mounted within an outer, flexible plastic tube. As gas flows through the inner Nafion[®] tube, water vapor is absorbed into the membrane walls. The absorbed water is transported through the membrane wall and evaporates into the dry, purge gas flowing through the outer tube, countercurrent to the gas in the inner tube (Figure 8-10).

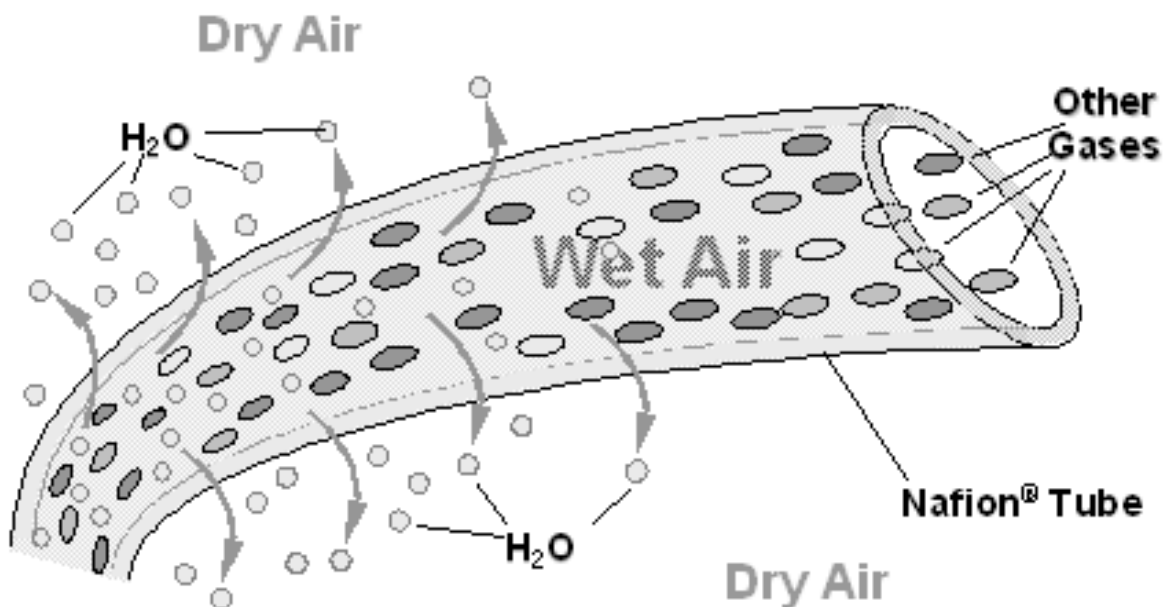


Figure 8-10: Semi-Permeable Membrane Drying Process

This process is called per-evaporation and is driven by the humidity gradient between the inner and outer tubes as well as the flow rates and pressure difference between inner and outer tubing. Unlike micro-porous membrane permeation, which transfers water through a relatively slow diffusion process, per-evaporation is a simple kinetic reaction.

Therefore, the drying process occurs quickly, typically within milliseconds. The first step in this process is a chemical reaction between the molecules of the Nafion[®] material and water, other chemical components of the gases to be dried are usually unaffected. The chemical reaction is based on hydrogen bonds between the water molecule and the Nafion material. Other small polar gases that are capable of hydrogen bonds can be absorbed this way, too, such as ammonia (NH₃) and some low molecular amines. The gases of interest, NO and NO₂, do not get absorbed and pass the dryer unaltered.

To provide a dry purge gas for the outer side of the Nafion tube, the 9110TH/M returns some of the dried air from the inner tube to the outer tube (Figure 8-11). When the analyzer is first started, the humidity gradient between the inner and outer tubes is not

very large and the dryer's efficiency is low at first but improves as this cycle reduces the moisture in the sample gas and settles at a minimum humidity.

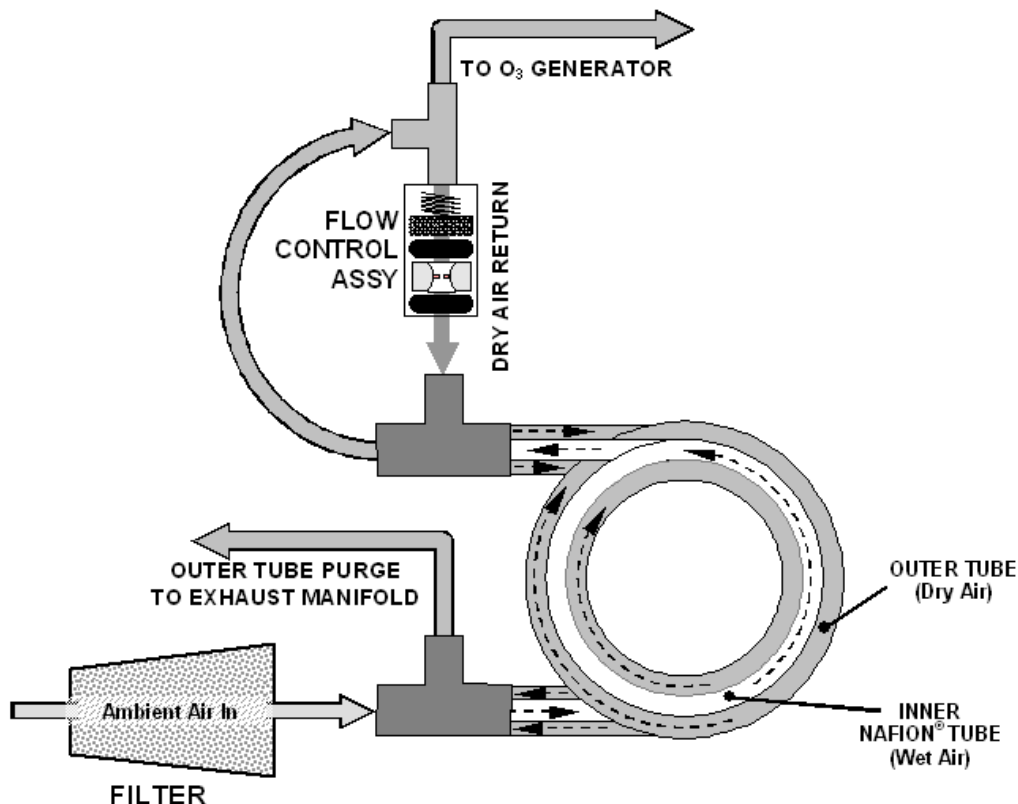


Figure 8-11: 9110TH/M Perma Pure® Dryer

Just like on startup, if the instrument is turned on after having been off for more than 30 minutes, it takes a certain amount of time for the humidity gradient to become large enough for the Perma Pure® Dryer to adequately dry the air. In this case, called a cold start, the O₃ Generator is not turned on for 30 minutes. When rebooting the instrument within less than 30 minutes of power-down, the generator is turned on immediately.

The Perma Pure® Dryer used in the 9110TH/M is capable of adequately drying ambient air to a dew point of $\leq -5^{\circ}\text{C}$ (~4000 ppm residual H₂O) at a flow rate of 1 standard liter per minute (slpm) or down to $\leq -15^{\circ}\text{C}$ (~1600 ppm residual H₂O) at 0.5 slpm. The Perma Pure® Dryer is also capable of removing ammonia from the sample gas up to concentrations of approximately 1 ppm.

8.3.8. OZONE SUPPLY AIR FILTER

The 9110TH/M uses ambient air as the supply gas for the O₃ generator and may produce a variety of byproducts. Small amounts of water, ammonia and various sulfur oxides can combine to create ammonium sulfate, ammonium nitrate, nitric acid and other compounds. Whereas sulfates and nitrates can create powdery residues inside the reaction cell causing sensitivity drift, nitric acid is a very aggressive compound, which can deteriorate the analyzer's components. In order to remove these chemical byproducts from the O₃ gas stream, the output of the O₃ generator flows through a special filter between the generator and the reaction cell.

Any NO_x that may be produced in the generator (from reaction of O₂ or O₃ and N₂ in the air) and may cause an artifact in the measurement, is calibrated out through the Auto-zero functionality, which checks the background signal of the O₃ stream only once per minute.

8.3.9. OZONE SCRUBBER

Even though ozone is unstable and typically reacts to form O₂, the break-down is not quite fast enough to ensure that it is completely removed from the exhaust gas stream of the 9110TH/M by the time the gas exits the analyzer. Due to the high toxicity and reactivity of O₃, a special catalytic ozone scrubber is used to remove all of the O₃ exiting the reaction cell. Besides its efficient destruction of O₃, this catalyst does not produce any toxic or hazardous gases as it only converts ozone to oxygen.

The O₃ scrubber is located inside the NO₂ converter housing next to the NO₂ converter in order to utilize residual heat given off by the converter heater. Even though the catalyst is 100% efficient at scrubbing ozone at room temperature, heating it significantly reduces the necessary residence time (the amount of time the gas must be in contact with the catalyst) for 100% efficiency and full efficiency can be maintained at higher gas flow rates. As this is a true catalytic converter, there are no maintenance requirements as would be required for charcoal-based scrubbers.

A certain amount of fine, black dust may exit the catalyst, particularly if the analyzer is subjected to sudden pressure drops (for example, when disconnecting the running pump without letting the analyzer properly and slowly equilibrate to ambient pressure). To avoid the dust from entering the reaction cell or the pump, the scrubber is equipped with sintered stainless steel filters of 20 µm pore size on either end and on some models, an additional dust filter may be attached to the exhaust port.

8.3.10. PNEUMATIC SENSORS

Note

The 9110TH/M displays all pressures in inches of mercury absolute (in-Hg-A), i.e. absolute pressure referenced against zero (a perfect vacuum).

The 9110TH/M uses three pneumatic sensors to verify gas streams. These sensors are located on a printed circuit assembly, called the pneumatic pressure/flow sensor board, located just behind the sensor assembly.

8.3.10.1. Vacuum Manifold

The vacuum manifold is the central exit port for all analyzer pneumatics. All gas streams of the analyzer exit through this assembly and connect to the instrument’s pump. Figure 8-12 shows the standard configuration. Configurations will vary depending on the optional equipment that is installed. An IZS option, for example, will add another FT8 connector and orifice assembly to the manifold, an optional sample dryer may add a Tee-fitting so that two ¼” tubes can be connected to the same port.

At this time, the vacuum manifold does not yet support the orifice holder shown in Figure 6-5. To exchange the critical orifice installed in the vacuum manifold, the user needs to either blow the orifice out with reversed pressure or remove the entire manifold for this task. However, orifices installed in the vacuum manifold should not have to be cleaned under normal circumstances.

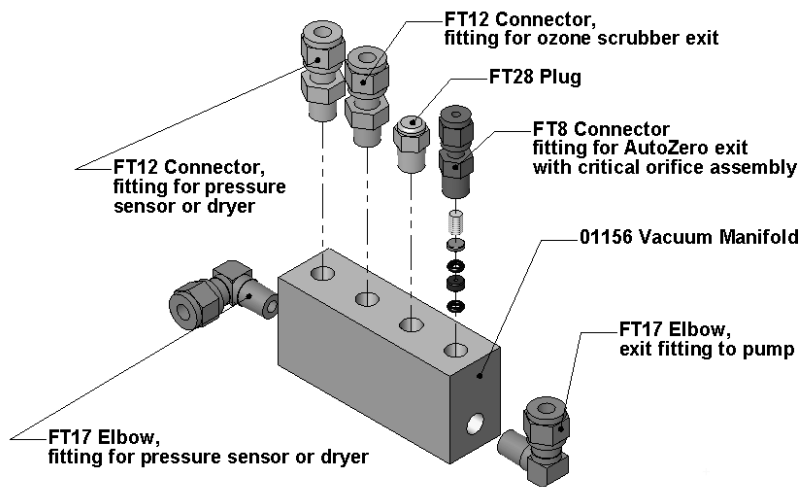


Figure 8-12: Vacuum Manifold

8.3.10.2. Sample Pressure Sensor

An absolute pressure transducer connected to the input of the NO/NO_x valve is used to measure the pressure of the sample gas before it enters the analyzer’s reaction cell. This is the “upstream” pressure mentioned above, which is used to compute sample flow rate. In conjunction with the vacuum pressure sensor, it is also used to validate the critical

flow condition (2:1 pressure ratio) through the sample gas critical flow orifice (Section 8.3.3). If the temperature/pressure compensation (TPC) feature is turned on (Section 8.8.3), the output of this sensor is also used to supply pressure data for that calculation.

The actual pressure value is viewable through the analyzer's front panel display as the test function **SAMP**. The flow rate of the sample gas is displayed as **SAMP FLW**.

8.3.10.3. Vacuum Pressure Sensor

An absolute pressure transducer connected to the exhaust manifold is used to measure the pressure downstream from and inside the instrument's reaction cell. The output of the sensor is used by the CPU to calculate the pressure differential between the gas upstream of the reaction cell and the gas downstream from it and is also used as the main diagnostic for proper pump operation. If the ratio between the upstream pressure and the downstream pressure falls below 2:1, a warning message (**SAMPLE FLOW WARN**) is displayed on the analyzer's front panel (Section 6.2.2) and the sample flow rate will display **XXXX** instead of an actual value. If this pressure exceeds 10 in-Hg-A, an **RCEL PRESSURE WARNING** is issued, even though the analyzer will continue to calculate a sample flow up to ~14 in Hg.

Also, if the temperature/pressure compensation (TPC) feature is turned on (Section 8.8.3), the output of this sensor is used to supply pressure data for that calculation. This measurement is viewable through the analyzer's front panel as the test function **RCEL**.

8.3.10.4. O₃ Supply Air Flow Sensor

A mass flow meter connected between the Perma Pure[®] dryer and the O₃ generator measures the flow rate of O₃ supply air through the analyzer. This information is used to validate the O₃ gas flow rate. If the flow rate exceeds $\pm 15\%$ of the nominal flow rate (250 cm³/min), a warning message **OZONE FLOW WARNING** is displayed on the analyzer's front panel (Section 6.2.2) and the O₃ generator is turned off. As second warning, **OZONE GEN OFF**, is displayed. This flow measurement is viewable through instrument's front panel display as the test function **OZONE FL**.

8.3.11. DILUTION MANIFOLD

Certain applications require to measure NO_x in sample gases that do not contain any oxygen. However, the molybdenum NO₂ converter requires a minimum amount of oxygen to operate properly and to ensure constant conversion efficiency. For these special applications, the analyzer may be equipped with a dilution manifold (Figure 8-13) to provide the instrument with an internal sample stream that contains about 2.5% O₂. This manifold is mounted between converter housing and vacuum manifold on a small mounting bracket. If the dilution manifold is to be mounted in the 9110TH/M analyzer.

The manifold is equipped with two orifice holders that control the flow of the O₂-free sample gas and the bleeds in a small amount of zero air before the combined sample stream goes to the NO/NO_x valve for measurement. The zero air is produced by an external zero air scrubber cartridge, mounted on the rear panel.

The dilution manifold is not temperature controlled, although the residual heat of the NO₂ converter housing provides some temperature stability. Tight temperature stability is not critical to the dilution application.

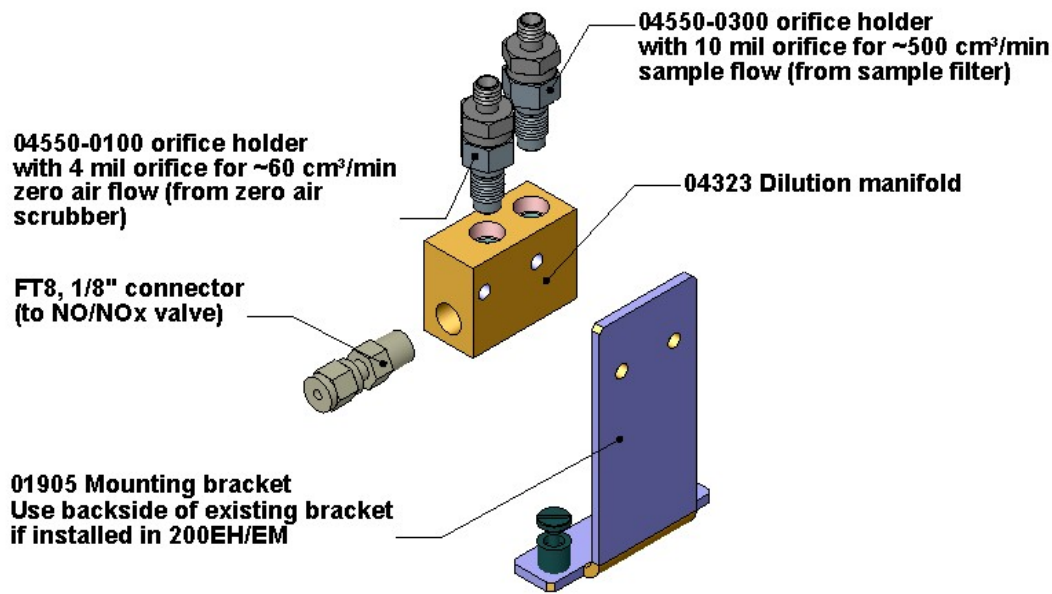


Figure 8-13: Dilution Manifold

Please inquire with Teledyne sales if the analyzer can be modified to fit your application.

8.4. OXYGEN SENSOR (OPT 65A) PRINCIPLES OF OPERATION

8.4.1. PARAMAGNETIC MEASUREMENT OF O₂

The oxygen sensor used in the 9110TH/M analyzer utilizes the fact that oxygen is attracted into strong magnetic field (in contrast with most other gases) to obtain fast, accurate oxygen measurements.

The sensor's core is made up of two nitrogen filled glass spheres, which are mounted on a rotating suspension within a magnetic field (Figure 8-14). A mirror is mounted centrally on the suspension and light is shone onto the mirror, which reflects the light onto a pair of photocells that then generate a signal. The signal generated by the photocells is passed to a feedback loop, which outputs a current to a wire winding (in effect, a small DC electric motor) mounted on the suspended mirror.

Oxygen from the sample stream is attracted into the magnetic field displacing the nitrogen filled spheres and causing the suspended mirror to rotate. This changes the amount of light reflected onto the photocells and therefore the output levels of the photocells. The feedback loop increases the amount of current fed into the wire winding in order to move the mirror back into its original position. The more O₂ present, the more the mirror moves and the more current is fed into the wire winding by the feedback control loop.

A sensor measures the amount of current generated by the feedback control loop which is directly proportional to the concentration of oxygen within the sample gas mixture (see Figure 8-14).

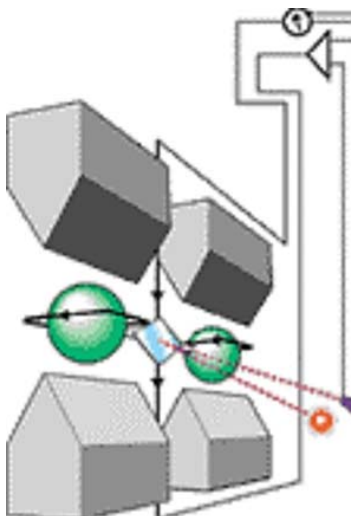


Figure 8-14: Oxygen Sensor - Principle of Operation

8.4.2. OPERATION WITHIN THE 9110TH/M ANALYZER

The oxygen sensor option is transparently integrated into the core analyzer operation. All functions can be viewed or accessed through the front panel, just like the functions for NO_x.

- The O₂ concentration is displayed in the upper right-hand corner, alternating with NO_x, NO and NO₂ concentrations.
- Test functions for O₂ slope and offset are viewable from the front panel along with the analyzer's other test functions.
- O₂ sensor calibration is performed via the front panel CAL function and is performed in a nearly identical manner as the standard NO_x/NO calibration. See Section 5 for more details.
- Stability of the O₂ sensor can be viewed (see 3.3.2.1)

The O₂ concentration range is 0-100% (user selectable) with 0.1% precision and accuracy and is available to be output via one of the instrument's four user selectable analog outputs (see Section 6.13.4).

The temperature of the O₂ sensor is maintained at a constant 50° C by means of a PID loop and can be viewed on the front panel as test function **O2 TEMP**.

The O₂ sensor assembly itself does not have any serviceable parts and is enclosed in an insulated canister.

8.4.3. PNEUMATIC OPERATION OF THE O₂ SENSOR

Pneumatically, the O₂ sensor is connected after the particulate filter and draws a flow of about 80 cm³/min in addition to the normal sample flow rate (See Table 10.-3 for nominal sample inlet gas flow rates) and is separately controlled with its own critical flow orifice located inside the vacuum manifold.

8.5. ELECTRONIC OPERATION

Figure 8-15 shows a block diagram of the major electronic components of the 9110TH/M.

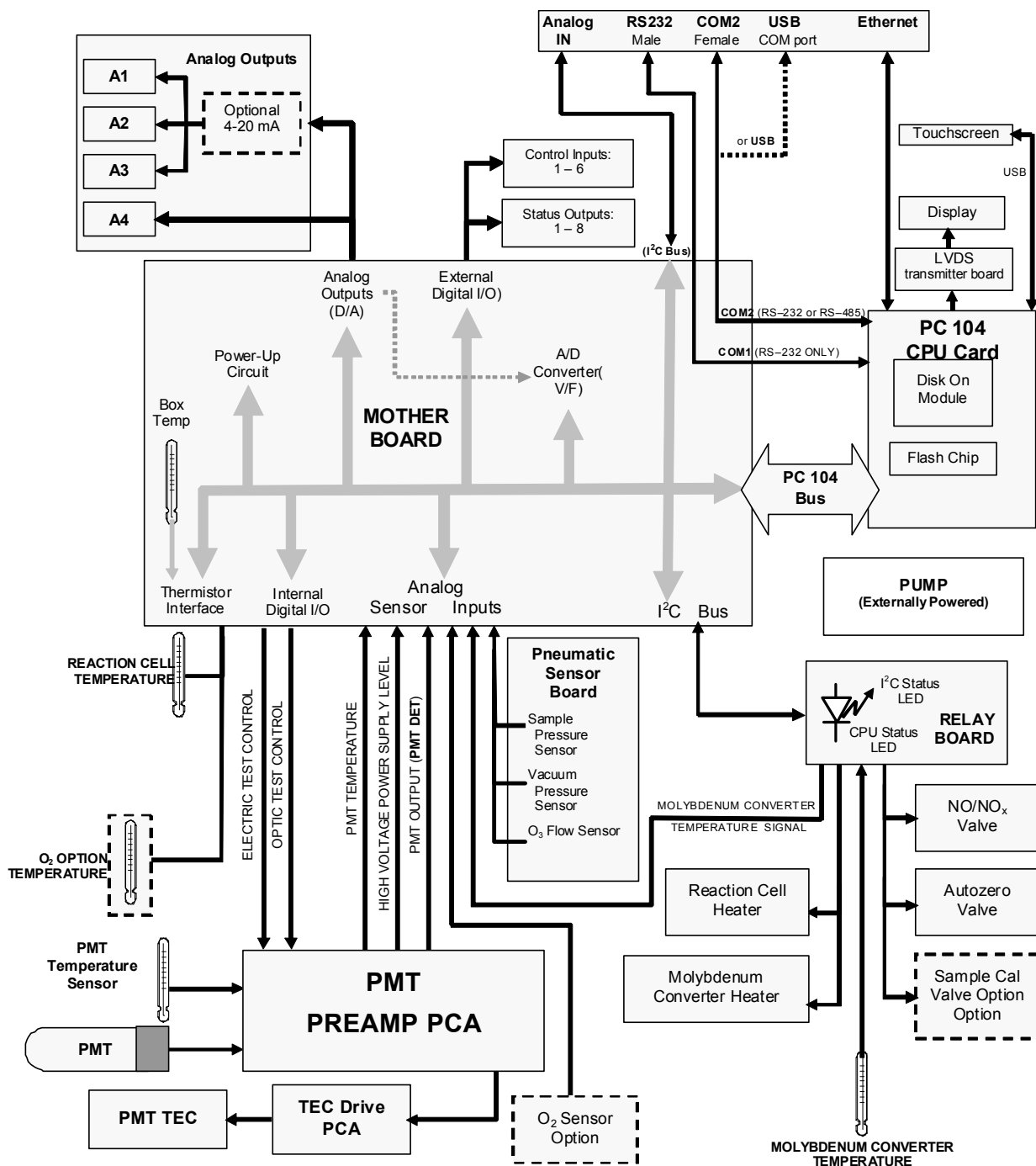


Figure 8-15: 9110TH/M Electronic Block Diagram

The core of the analyzer is a microcomputer (CPU) that controls various internal processes, interprets data, calculates data, and reports results using specialized firmware developed by Teledyne. It communicates with the user, receives data from and issues

commands to a variety of peripheral devices through the motherboard, the main printed circuit assembly on the rear panel.

8.5.1. CPU

The unit's CPU card, installed on the motherboard located inside the rear panel, is a low power (5 VDC, 720mA max), high performance, Vortex 86SX-based microcomputer running Windows CE. Its operation and assembly conform to the PC 104 specification.

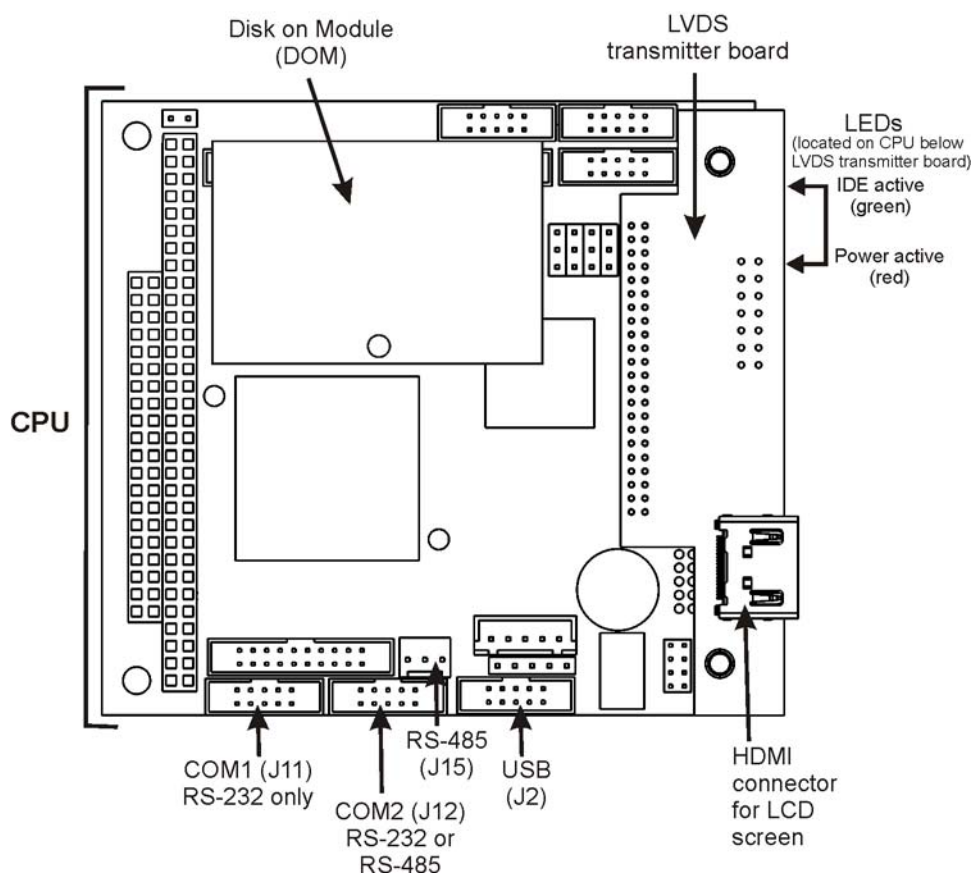


Figure 8-16: 9110TH/M CPU Board Annotated

The CPU includes two types of non-volatile data storage: a Disk on Module (DOM) with an embedded 2MB flash chip.

8.5.1.1. Disk On Module (DOM)

The DOM is a 44-pin IDE flash drive with storage capacity to 128 MB. It is used to store the computer's operating system files, the Teledyne firmware and peripheral files, and the operational data generated by the analyzer's internal data acquisition system (DAS).

8.5.1.2. Flash Chip

This non-volatile, embedded flash chip includes 2 MB of storage for calibration data as well as a backup of the analyzer configuration. Storing these key data on a less heavily accessed chip significantly decreases the chance of data corruption.

In the unlikely event that the flash chip should fail, the analyzer will continue to operate with just the DOM. However, all configuration information will be lost, requiring the unit to be recalibrated.

8.5.2. SENSOR MODULE, REACTION CELL

Electronically, the 9110TH/M sensor assembly (see Figure 9-6) consists of several subassemblies with different tasks: to detect the intensity of the light from the chemiluminescence reaction between NO and O₃ in the reaction cell, to produce a current signal proportional to the intensity of the chemiluminescence, to control the temperature of the PMT to ensure the accuracy and stability of the measurements and to drive the high voltage power supply that is needed for the PMT. The individual functions are described individually below, Section 7.6.5 shows the sensor assembly and its components.

8.5.2.1. Reaction Cell Heating Circuit

The stability of the chemiluminescence reaction between NO and O₃ can be affected by changes in the temperature and pressure of the O₃ and sample gases in the reaction cell. In order to reduce temperature effects, the reaction cell is maintained at a constant 50° C, just above the high end of the instrument's operation temperature range.

Two AC heaters, one embedded into the bottom of the reaction cell, the other embedded directly above the chamber's exhaust fitting, provide the heat source. These heaters operate off of the instrument's main AC power and are controlled by the CPU through a power relay on the relay board (Section 8.5.7). A thermistor, also embedded in the bottom of the reaction cell, reports the cell's temperature to the CPU through the thermistor interface circuitry of the motherboard (Section 8.5.9.3).

8.5.3. PHOTO MULTIPLIER TUBE (PMT)

The 9110TH/M uses a photo multiplier tube (PMT) to detect the amount of chemiluminescence created in the sample chamber.

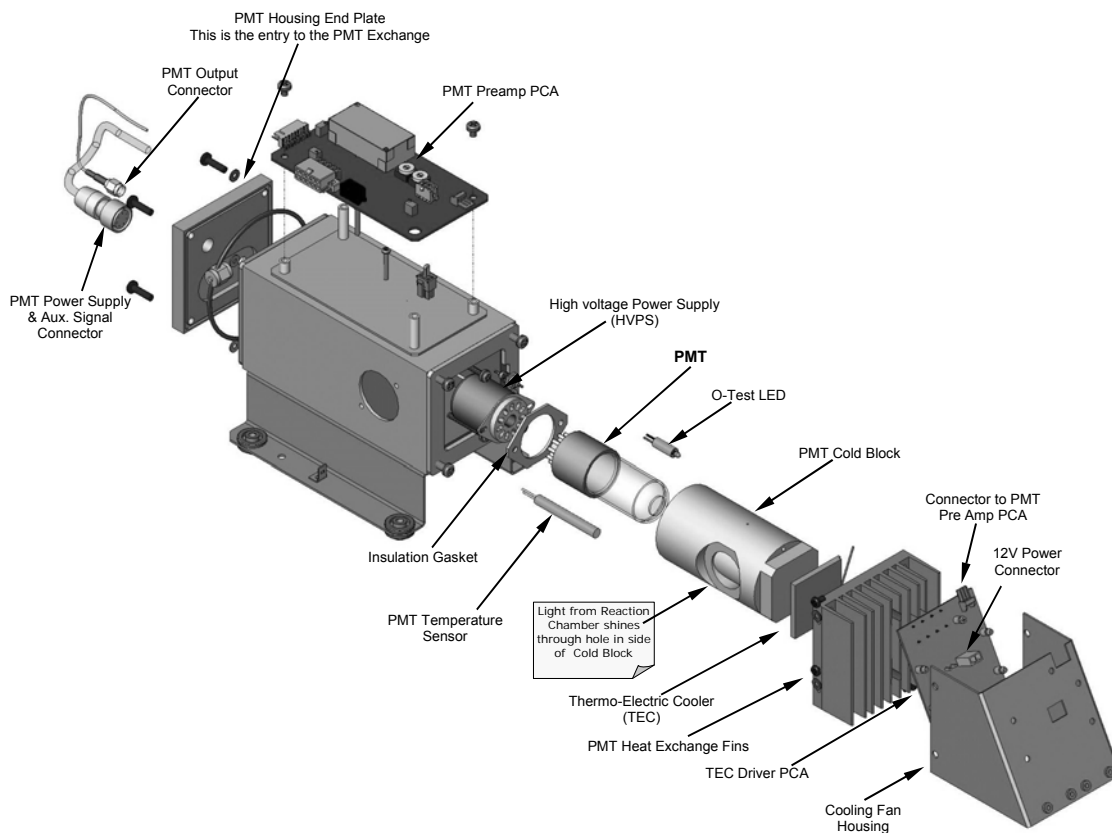


Figure 8-17: PMT Housing Assembly

A typical PMT is a vacuum tube containing a variety of specially designed electrodes. Photons from the reaction are filtered by an optical high-pass filter, enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. A high voltage potential across these focusing electrodes directs the electrons toward an array of high voltage dynodes. The dynodes in this electron multiplier array are designed so that each stage multiplies the number of emitted electrons by emitting multiple, new electrons. The greatly increased number of electrons emitted from one end of electron multiplier are collected by a positively charged anode at the other end, which creates a useable current signal. This current signal is amplified by the preamplifier board and then reported to the motherboard.

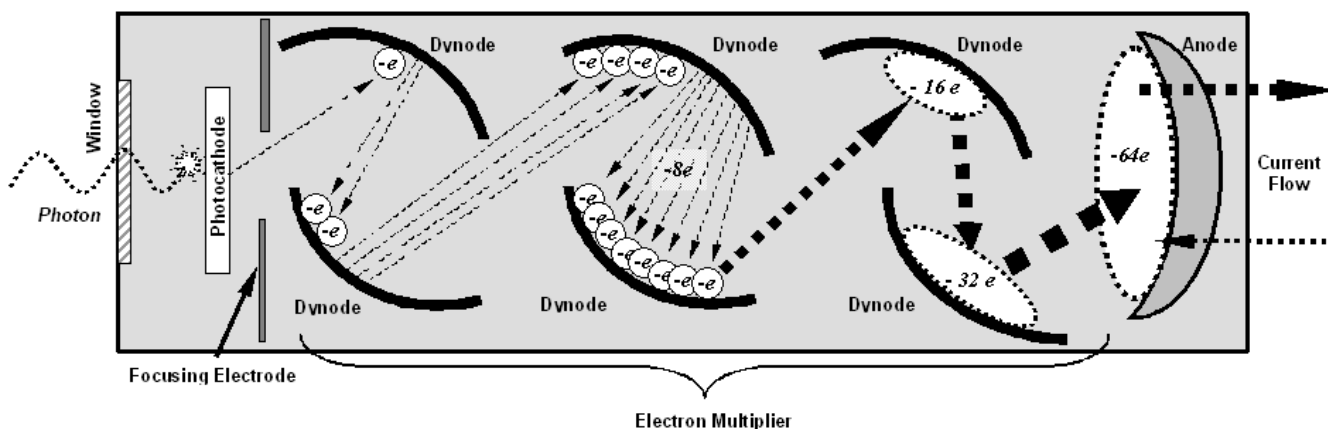


Figure 8-18: Basic PMT Design

A significant performance characteristic of the PMT is the voltage potential across the electron multiplier. The higher the voltage, the greater is the number of electrons emitted from each dynode of the electron multiplier, making the PMT more sensitive and responsive to small variations in light intensity but also more noisy (dark noise). The gain voltage of the PMT used in the 9110TH/M is usually set between 450 V and 800 V. This parameter is viewable through the front panel as test function **HVPS** (see Section 6.2.1). For information on when and how to set this voltage, see Section 11.6.3.8.

The PMT is housed inside the PMT module assembly (see Figure 10-18). This assembly also includes the high voltage power supply required to drive the PMT, an LED used by the instrument’s optical test function, a thermistor that measures the temperature of the PMT and various components of the PMT cooling system including the thermo-electric cooler (TEC).

8.5.4. PMT COOLING SYSTEM

The performance of the analyzer's PMT is significantly affected by temperature. Variations in PMT temperature are directly reflected in the signal output of the PMT. Also the signal to noise ratio of the PMT output is radically influenced by temperature as well. The warmer the PMT is, the noisier its signal becomes until the noise renders the concentration signal useless. To alleviate this problem a special cooling system exists that maintains the PMT temperature at a stable, low level.

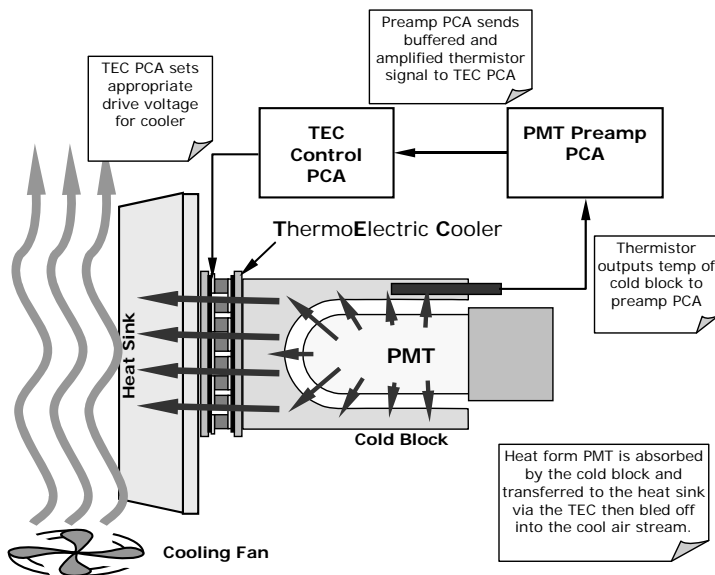


Figure 8-19: PMT Cooling System

8.5.4.1. TEC Control Board

The TEC control printed circuit assembly is located in the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan. Using the amplified PMT temperature signal from the PMT preamplifier board (see Section 10.4.5), it sets the drive voltage for the thermoelectric cooler. The warmer the PMT gets, the more current is passed through the TEC causing it to pump more heat to the heat sink.

A red LED located on the top edge of this circuit board indicates that the control circuit is receiving power. Four test points are also located at the top of this assembly. For the definitions and acceptable signal levels of these test points see Section 11.

8.5.5. PMT PREAMPLIFIER

The PMT preamplifier board amplifies the PMT signal into a useable analog voltage (PMT) that can be processed by the motherboard into a digital signal to be used by the CPU to calculate the NO, NO₂ and NO_x concentrations of the gas in the sample chamber.

The output signal of the PMT is controlled by two different adjustments. First, the voltage across the electron multiplier array of the PMT is adjusted with a set of two hexadecimal switches. Adjusting this voltage directly affects the HVPS voltage and, hence, the signal from the PMT. Secondly, the gain of the amplified signal can further

be adjusted through a potentiometer. These adjustments should only be performed when encountering problems with the software calibration that cannot be rectified otherwise. See Section 11.6.3.8 for this hardware calibration.

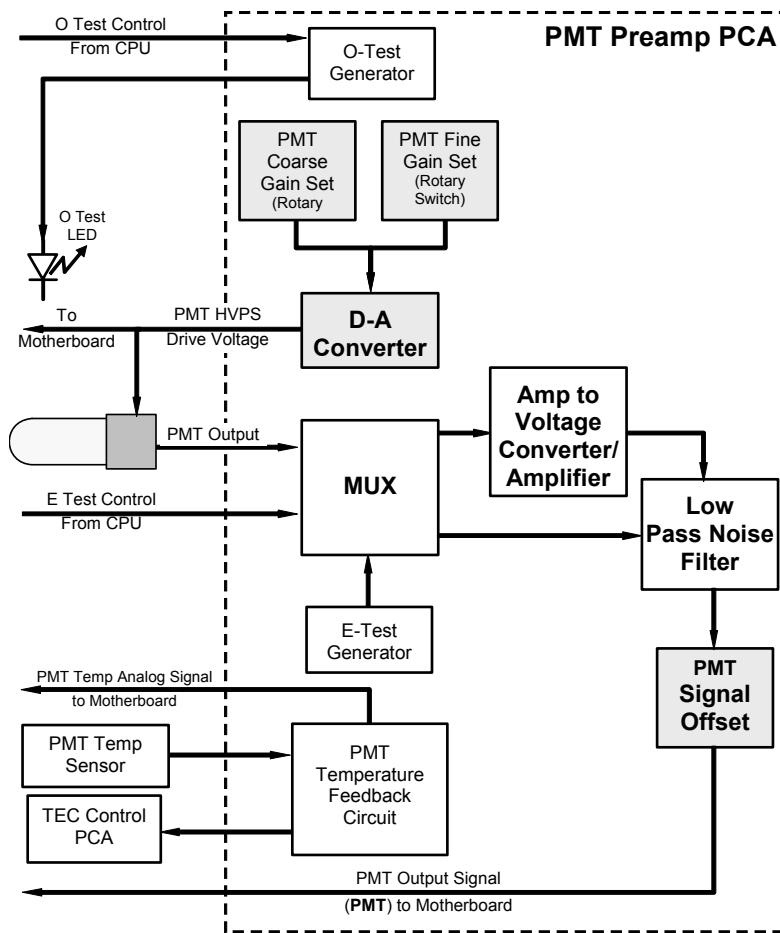


Figure 8-20: PMT Preamp Block Diagram

The PMT temperature control loop maintains the PMT temperature around 7° C and can be viewed as test function **PMT TEMP** on the front panel (see Section 6.2.1).

The electrical test (**ETEST**) circuit generates a constant, electronic signal intended to simulate the output of the PMT (after conversion from current to voltage). By bypassing the detector’s actual signal, it is possible to test most of the signal handling and conditioning circuitry on the PMT preamplifier board. See section 6.9.6 for instructions on performing this test.

The optical test (**OTEST**) feature causes an LED inside the PMT cold block to create a light signal that can be measured with the PMT. If zero air is supplied to the analyzer, the entire measurement capability of the sensor module can be tested including the PMT and the current to voltage conversion circuit on the PMT preamplifier board. See section 6.9.5 for instructions on performing this test.

8.5.6. PNEUMATIC SENSOR BOARD

The flow and pressure sensors of the 9110TH/M are located on a printed circuit assembly just behind the PMT sensor. Refer to Section 7.5.16 for information on how to test this assembly. The signals of this board are supplied to the motherboard for further signal processing. All sensors are linearized in the firmware and can be span calibrated from the front panel.

8.5.7. RELAY BOARD

The relay board is the central switching and power distribution unit of the analyzer. It contains power relays, valve drivers and status LEDs for all heated zones and valves, as well as thermocouple amplifiers, power distribution connectors and the two switching power supplies of the analyzer. The relay board communicates with the motherboard over the I²C bus and can be used for detailed trouble-shooting of power problems and valve or heater functionality. See Figure 7-4 for an annotated view of the relay board.

8.5.7.1. Relay PCA Location and Layout

Generally the relay PCA is located in the right-rear quadrant of the analyzer and is mounted vertically on the back side of the same bracket as the instrument's DC power supplies, however the exact location of the relay PCA may differ from model to model (see Figure 3-5)

8.5.7.2. Heater Control

The heater control loop is illustrated in Figure 8-21. Two thermocouples (T/C) inputs can be configured for either type-J or type-K thermocouples. Additionally:

- Both T/C's can be configured as either grounded or ungrounded thermocouples.
- Standard configuration of the both type of thermocouples is 10 mV/°C. In order to accommodate the 9110TH's Mini High-Con converter option, a type-K; 5mV/°C output configuration has been added.

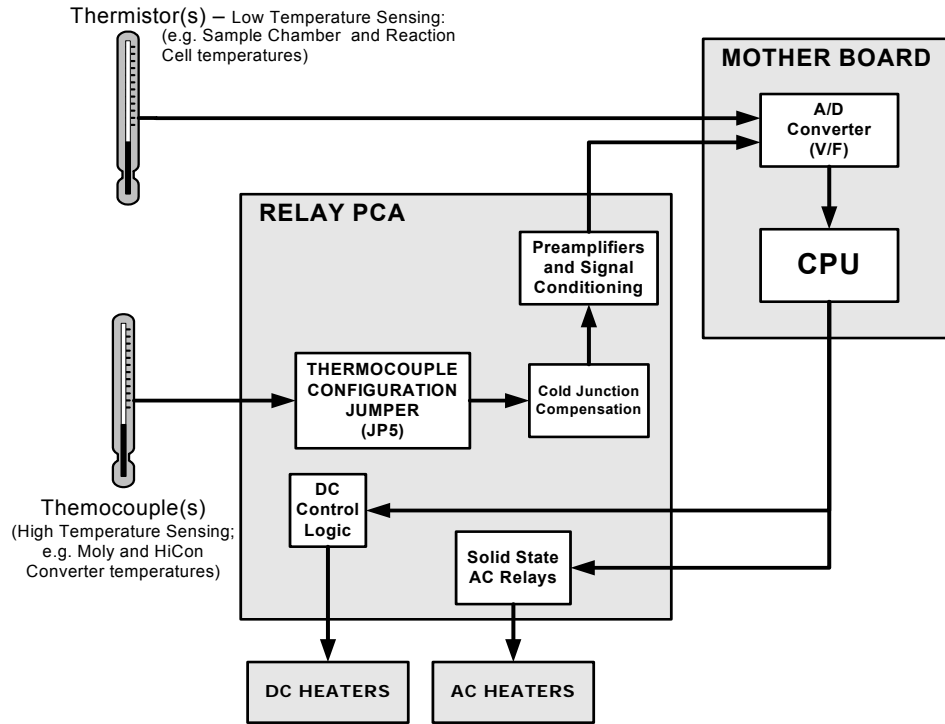


Figure 8-21: Heater Control Loop Block Diagram.

8.5.7.3. Thermocouple Inputs and Configuration Jumper (JP5)

Although the relay PCA supports two thermocouple inputs, the current 9110TH/M series analyzers only utilize one. By default, this single thermocouple input is plugged into the TC1 input (J15). TC2 (J16) is currently not used. See Figure 7-4 for location of J15 and J16

CAUTION
<div style="display: flex; align-items: center;"> <p style="margin: 0;">Avoid damage to the unit: use only the recommended thermocouple type and its specific settings. If in doubt, call T-API Technical Support for information about the correct part.</p> </div>

Table8-4: Thermocouple Configuration Jumper (JP5) Pin-Outs

TC INPUT	JUMPER PAIR	DESCRIPTION	FUNCTION
TC1	1 – 11	Gain Selector	Selects preamp gain factor for J or K TC - IN = J TC gain factor - OUT = K TC gain factor
	2 – 12	Output Scale Selector	Selects preamp gain factor for J or K TC - IN = 5 mV / °C - OUT = 10 mV / °C
	3 – 13	Type J Compensation	When present, sets Cold Junction Compensation for J type Thermocouple
	4 – 14	Type K Compensation	When present, sets Cold Junction Compensation for K type Thermocouple
	5 – 15	Termination Selector	Selects between Isolated and grounded TC - IN = Isolate TC - OUT = Grounded TC
TC2	6 – 16	Gain Selector	Same as Pins 1 – 11 above.
	7 – 17	Output Scale Selector	Same as Pins 2 – 12 above.
	8 – 18	Type J Compensation	Same as Pins 3 – 13 above.
	9 – 19	Type K Compensation	Same as Pins 4 – 14 above.
	10 – 20	Termination Selector	Same as Pins 5 – 15 above.

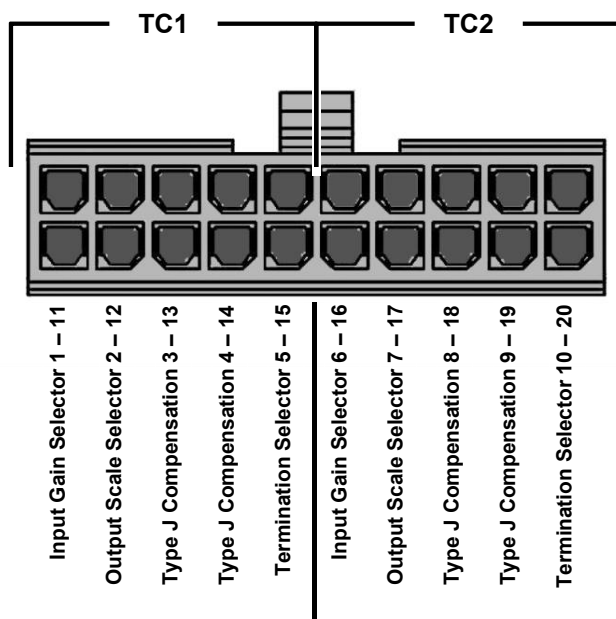


Figure 8-22: Thermocouple Configuration Jumper (JP5) Pin-Outs

Table 8-5: Typical Thermocouple Settings

TC TYPE	TERMINATION TYPE	OUTPUT SCALE TYPE	JUMPER BETWEEN PINS	USED ON	JUMPER COLOR
INPUT TC1 (J15)					
K	GROUNDED	5mV / °C	2 – 12 4 – 14	9110TH/M with Mini HiCon Converter	BROWN
K	ISOLATED	5mV / °C	2 – 12 4 – 14 5 – 15	9110TH/M with Mini HiCon Converter	GREY
K	ISOLATED	10mV / °C	4 – 14 5 – 15	9110TH/M models with Moly Converter	PURPLE
J	ISOLATED	10mV / °C	1 – 11 3 – 13 5 – 15	9110TH/M models with Moly Converter	RED
J	GROUNDED	10mV / °C	1 – 11 3 – 13	9110TH/M models with Moly Converter	GREEN

8.5.7.4. Valve Control

The relay board also hosts two valve driver chips, each of which can drive up four valves. The main valve assembly in the 9110TH/M is the NO/NO_x - Auto-zero solenoid valve assembly mounted right in front of the NO₂ converter housing. These two valves are actuated with 12 V supplied from the relay board and driven by the CPU through the I²C bus.

A second set of valves may be installed if the zero/span valve is enabled in the analyzer. Specialty manifold valves may be present in the analyzer.

8.5.8. STATUS LEDs & WATCH DOG CIRCUITRY

Thirteen LEDs are located on the analyzer’s relay board to indicate the status of the analyzer’s heating zones and valves as well as a general operating watchdog indicator. Table 11-2 shows the states of these LEDs and their respective functionality.

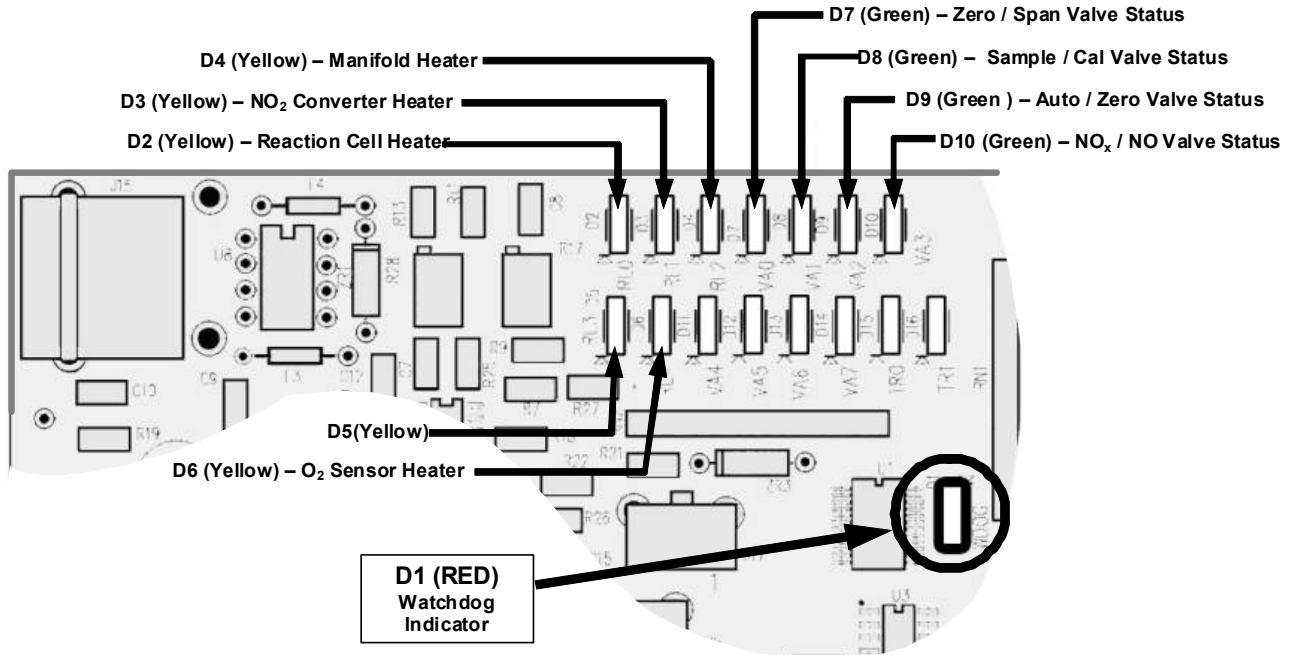


Figure 8-23: Status LED Locations – Relay PCA

8.5.8.1. Watchdog Indicator (D1)

The most important of the status LED’s on the relay board is the red I²C Bus watch-dog LED. It is controlled directly analyzer’s CPU over the I²C bus. Special circuitry on the relay PCA watches the status of D1. Should this LED ever stay ON or OFF for 30 seconds, indicating that the CPU or I²C bus has stopped functioning, this Watchdog Circuit automatically shuts all valves and turn off all heaters.

8.5.9. MOTHERBOARD

This is the largest electronic assembly in the analyzer and is mounted to the rear panel as the base for the CPU board and all I/O connectors. This printed circuit assembly provides a multitude of functions including A/D conversion, digital input/output, PC-104 to I²C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.

8.5.9.1. A to D Conversion

Analog signals, such as the voltages received from the analyzer's various sensors, are converted into digital signals that the CPU can understand and manipulate by the analog to digital converter (A/D). Under the control of the CPU, this functional block selects a particular signal input and then converts the selected voltage into a digital word.

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

The A/D can be configured for several different input modes and ranges but in the is used in uni-polar mode with a +5V full scale. The converter includes a 1% over and under-range. This allows signals from -0.05V to +5.05V to be fully converted.

For calibration purposes, two reference voltages are supplied to the A/D converter: Reference ground and +4.096 VDC. During calibration, the device measures these two voltages, outputs their digital equivalent to the CPU. The CPU uses these values to compute the converter's offset and slope and uses these factors for subsequent conversions. See Section 6.13.5.4 for instructions on performing this calibration.

8.5.9.2. Sensor Inputs

The key analog sensor signals are coupled to the A/D converter through the master multiplexer from two connectors on the motherboard. Terminating resistors (100 k Ω) on each of the inputs prevent cross-talk between the sensor signals.

PMT DETECTOR OUTPUT: This signal, output by the PMT preamp PCA, is used in the computation of the NO, NO₂ and NO_x concentrations displayed at the top right hand corner of the front panel display and output through the instruments analog outputs and com ports.

PMT HIGH VOLTAGE POWER SUPPLY LEVEL: This input is based on the drive voltage output by the PMT pram board to the PMT's high voltage power supply (HVPS). It is digitized and sent to the CPU where it is used to calculate the voltage setting of the HVPS and stored in the instruments memory as the test function **HVPS**. **HVPS** is viewable as a test function (see Section 6.2.1) through the analyzer's front panel.

PMT TEMPERATURE: This signal is the output of the thermistor attached to the PMT cold block amplified by the PMT temperature feedback circuit on the PMT preamp board. It is digitized and sent to the CPU where it is used to calculate the current temperature of the PMT.

This measurement is stored in the analyzer. Memory as the test function **PMT TEMP** and is viewable as a test function (see Section 6.2.1) through the analyzer's front panel.

NO₂ CONVERTER TEMPERATURE: This parameter is measured with a Type-K thermocouple attached to the NO₂ converter heater and its analog signal is amplified by the circuitry on the relay board. It is sent to the CPU and then digitized and is used to calculate the current temperature of the NO₂ converter. It is also stored in the DAS and reported as test function **MOLY TEMP**.

SAMPLE GAS PRESSURE: This is measured upstream of the reaction cell, stored in the DAS and reported as **SAMPLE**. The vacuum gas pressure is measured downstream of the reaction cell and is stored in the DAS and reported as **RCEL**. For more information on these sensor's functions see Section 8.3.10.

O₃ GAS FLOW This sensor measures the gas flow upstream of the ozone generator, stored in the DAS and reported as test function **OZONE FL**. For more information on this sensor's function see Section 8.3.10.

8.5.9.3. Thermistor Interface

This circuit provides excitation, termination and signal selection for several negative-coefficient, thermistor temperature sensors located inside the analyzer. They are:

REACTION CELL TEMPERATURE SENSOR: A thermistor embedded in the reaction cell manifold. This temperature is used by the CPU to control the reaction cell heating circuit and as a parameter in the temperature/pressure compensation algorithm. This measurement is stored in the analyzer's DAS and reported as test function **RCEL TEMP**.

BOX TEMPERATURE SENSOR: A thermistor is attached to the motherboard. It measures the analyzer's inside temperature. This information is stored by the CPU and can be viewed by the user for troubleshooting purposes through the front panel display. It is also used as part of the NO, NO_x and NO₂ calculations when the instrument's Temperature/Pressure Compensation feature is enabled. This measurement is stored in the analyzer. Memory as the test function **BOX TEMP** and is viewable as a test function (Section 4.2.1) through the analyzer's front panel.

The thermistor inside the PMT cold block as well as the thermistor located on the preamplifier board are both converted to analog signals on the preamplifier board before being sent to the motherboard's A/D converter.

O₂ SENSOR TEMPERATURE: For instruments with the oxygen sensor option installed, the thermistor measuring the temperature of the heating block mounted to the sensor is reported as test function **O2 TEMP** on the front panel. This temperature is maintained at 50° C.

8.5.10. ANALOG OUTPUTS

The analyzer comes equipped with four Analog Outputs: **A1**, **A2**, **A3** and a fourth that is a spare.

A1 and **A2** Outputs: The first two, **A1** and **A2** are normally set up to operate in parallel so that the same data can be sent to two different recording devices. While the names imply that one should be used for sending data to a chart recorder and the other for interfacing with a data logger, either can be used for both applications.

Output Loop-back: All of the functioning analog outputs are connected back to the A/D converter through a Loop-back circuit. This permits the voltage outputs to be calibrated by the CPU without need for any additional tools or fixtures (see Section 6.13.5.4)

8.5.11. EXTERNAL DIGITAL I/O

The external digital I/O performs two functions.

The **STATUS** outputs carry logic-level (5V) signals through an optically isolated 8-pin connector on the rear panel of the analyzer. These outputs convey on/off information about certain analyzer conditions such as **CONC VALID**. They can be used to interface with certain types of programmable devices (Section 6.15.1.1).

The **CONTROL** inputs can be initiated by applying 5V DC power from an external source such as a PLC or data logger (Section 6.15.1.2). Zero and span calibrations can be initiated by contact closures on the rear panel.

8.5.12. I²C DATA BUS


I²C is a two-wire, clocked, bi-directional, digital serial I/O bus that is used widely in commercial and consumer electronic systems. A transceiver on the motherboard converts data and control signals from the PC-104 bus to I²C. The data are then fed to the relay board and optional analog input circuitry.

8.5.13. POWER-UP CIRCUIT

This circuit monitors the +5V power supply during analyzer start-up and sets the analog outputs, external digital I/O ports, and I²C circuitry to specific values until the CPU boots and the instrument software can establish control.

8.6. POWER DISTRIBUTION & CIRCUIT BREAKER

The analyzer operates in two main AC power ranges: 100-120 VAC and 220-240 VAC (both $\pm 10\%$) between 47 and 63 Hz. A 5 ampere circuit breaker is built into the ON/OFF switch. In case of a wiring fault or incorrect supply power, the circuit breaker will automatically turn off the analyzer.



CAUTION

Should the power circuit breaker trip correct the condition causing this situation before turning the analyzer back on.

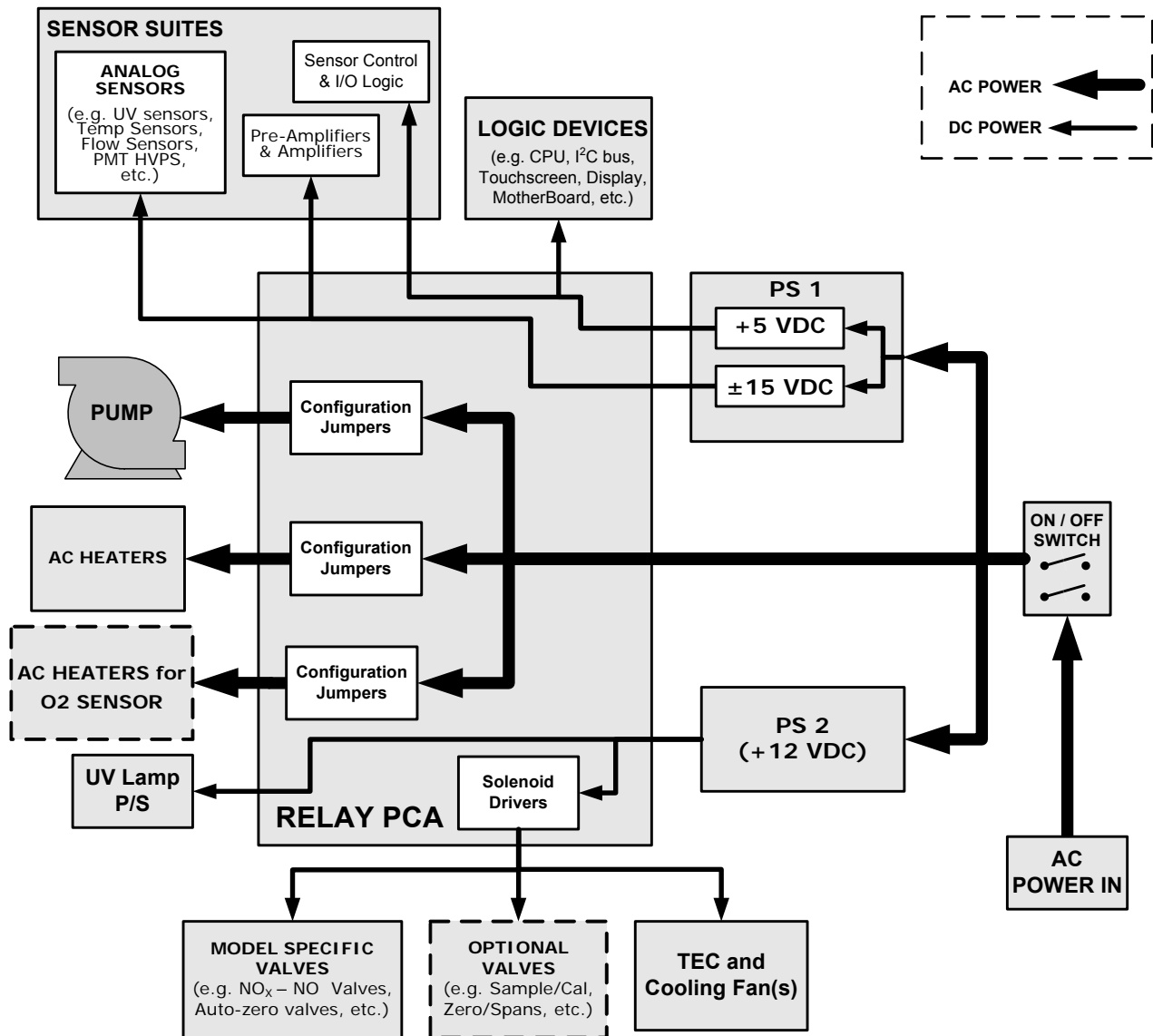


Figure 8-24: Power Distribution Block Diagram

Under normal operation, the 9110TH/M draws about 1.5 A at 115 V and 2.0 A during start-up.

8.7. FRONT PANEL/DISPLAY INTERFACE ELECTRONICS

Users can input data and receive information directly through the front panel touch-screen display. The LCD display is controlled directly by the CPU board. The touch screen is interfaced to the CPU by means of a touch screen controller that connects to the CPU via the internal USB bus and emulates a computer mouse.

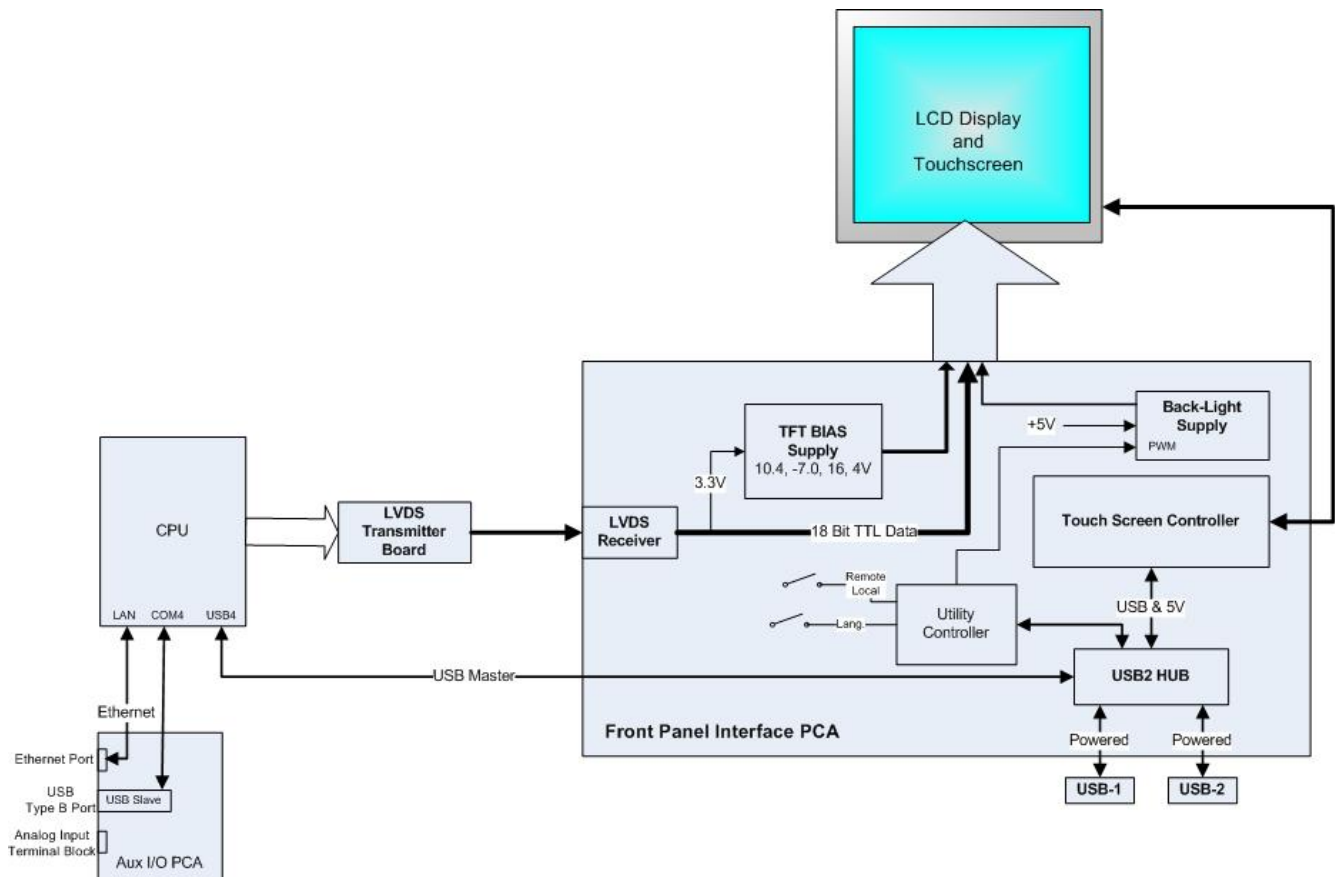


Figure 8-25: Front Panel and Display Interface Block Diagram

8.7.1. FRONT PANEL INTERFACE PCA

The front panel interface PCA controls the various functions of the display and touch screen. For driving the display it provides connection between the CPU video controller and the LCD display module. This PCA also contains:

- power supply circuitry for the LCD display module
- a USB hub that is used for communications with the touch screen controller and the two front panel USB peripheral device ports
- the circuitry for powering the display backlight

8.8. SOFTWARE OPERATION

The instrument's core module is a high performance, X86-based microcomputer running Windows CE. Inside Windows CE, special software developed by Teledyne interprets user commands from the various interfaces, performs procedures and tasks, stores data in the CPU's various memory devices and calculates the concentration of the gas being sampled.

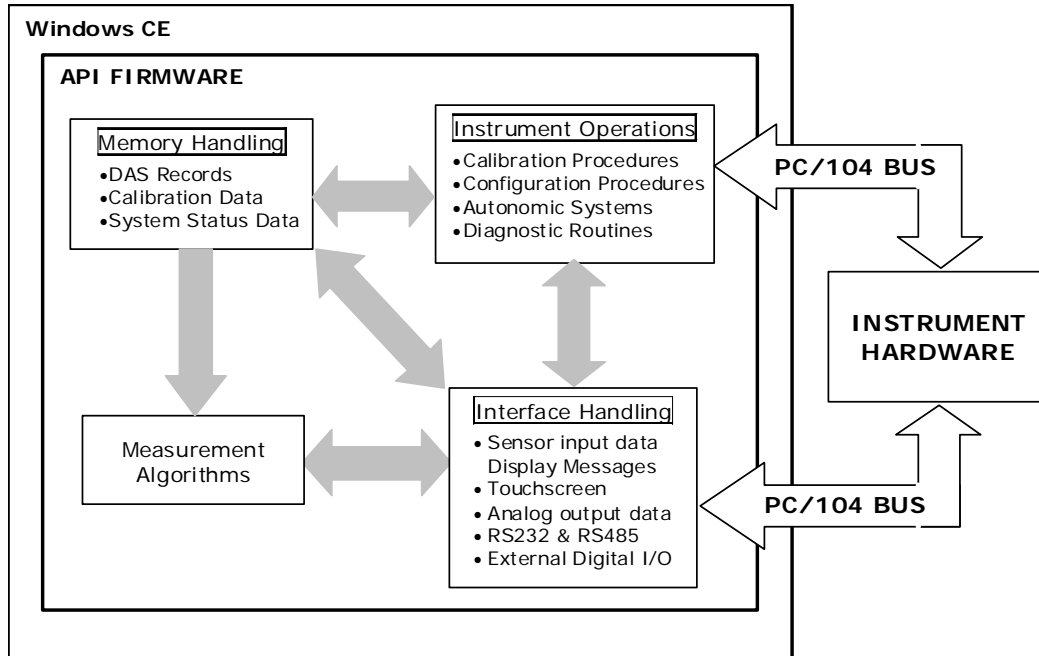


Figure 8-26: Basic Software Operation

8.8.1. ADAPTIVE FILTER

The 9110TH/M NO_x analyzer software processes sample gas concentration data through a built-in adaptive filter. Unlike other analyzers that average the output signal over a fixed time period, the 9110TH/M averages over a defined number of samples, with samples being about 8 seconds apart (reflecting the switching time of 4 s each for NO and NO_x). This technique is known as boxcar filtering. During operation, the software may automatically switch between two different filter lengths based on the conditions at hand.

During constant or nearly constant concentrations, the software, by default, computes an average of the last 42 samples, or approximately 5.6 minutes. This provides smooth and stable readings and averages out a considerable amount of random noise for an overall less noisy concentration reading.

If the filter detects rapid changes in concentration the filter reduces the averaging to only 6 samples or about 48 seconds to allow the analyzer to respond more quickly. Two conditions must be simultaneously met to switch to the short filter. First, the instantaneous concentration must differ from the average in the long filter by at least 50 ppb. Second, the instantaneous concentration must differ from the average in the long filter by at least 10% of the average in the long filter.

If necessary, these boxcar filter lengths can be changed between 1 (no averaging) and 1000 samples but with corresponding tradeoffs in rise time and signal-to-noise ratio. Signal noise increases accordingly when in adaptive filter mode, but remains within the official 9110TH/M specifications as long as the filter size remains at or above 3 samples.

In order to avoid frequent switching between the two filter sizes, the analyzer has a delay of 120 s before switching out of adaptive filter mode, even if the two threshold conditions are no longer met.

that the filter settings in NO_x only or NO only

8.8.2. CALIBRATION - SLOPE AND OFFSET

Aside from the hardware calibration of the preamplifier board (Section 13) upon factory checkout, calibration of the analyzer is usually performed in software. During instrument calibration (Section 7) the user enters expected values for span gas concentration through the front panel keypad and supplies the instrument with sample gas of known NO and NO_x concentrations. The readings are then compared to the expected values and the software computes values for the new instrument slope and offset for both NO and NO_x response. These values are stored in memory for use in calculating the NO, NO_x and NO₂ concentration of the sample gas. By default, the DAS stores 200 software calibration settings for documentation, review and data analysis.

Instrument slope and offset values recorded during the last calibration can be viewed on the front panel. **NO SLOPE**, **NOX SLOPE**, **NO OFFS** and **NOX OFFS** are four of the test parameters accessible through the <TST TST> buttons.

8.8.3. TEMPERATURE/PRESSURE COMPENSATION (TPC)

The software features a compensation of some temperature and pressure changes critical in the measurement of NO and NO_x concentration. When the TPC feature is enabled (default setting), the analyzer divides the value of the PMT output signal (**PMTDET**) by a value called **TP_FACTOR**. **TP_FACTOR** is calculated according to the following equation.

$$TP_FACTOR = A \left[\frac{RCELLTEMP(K)}{323(K)} \right] \times B \left[\frac{7(inHg)}{RCEL(inHg)} \right] \times C \left[\frac{SAMP(inHg)}{29.92(inHg)} \right] \times D \left[\frac{BOXTEMP(K)}{298(K)} \right]$$

(Equation 9-5)

Where A, B, C, D are gain functions. The four parameters used to compute TP_FACTOR are:

- **RCELL TEMP**: The temperature of the reaction cell, measured in K.
- **RCEL**: The pressure of the gas in the vacuum manifold, measured in in-Hg-A.
- **SAMP**: The pressure of the sample gas before it reaches the reaction cell, measured in in-Hg-A. This measurement is ~1 in-Hg-A lower than atmospheric pressure.
- **BOX TEMP**: The temperature inside the analyzer's case measured in K. This is typically about 5 K higher than room temperature.

The current value of all four of these measurements are viewable as **TEST FUNCTIONS** through the instrument's front panel display.

that, as **RCEL TEMP**, **BOX TEMP** and **SAMP** pressure increase, the value of **TP_FACTOR** increases and, hence, the **PMTDET** value decreases. Conversely, increases in the reaction cell pressure (**RCEL**) decrease **TP_FACTOR** and, hence increase the **PMTDET** value. These adjustments are meant to counter-act changes in the concentrations caused by these parameters.

Each of the terms in the above equation is attenuated by a gain function with a numerical value based on a preset gain parameter (shown below in *CAPITALIZED ITALICS*) normalized to the current value of the parameter being attenuated. The gain functions A, B, C and D are defined as:

$$A = 1 + \left[\left(\frac{rcell_temp(K)}{323(K)} - 1 \right) \times RCTEMP_TPC_GAIN \right]$$

(Equation 9-6)

$$B = 1 + \left[\left(\frac{5("Hg)}{rcell_pressure("Hg)} - 1 \right) \times RCPRESS_TPC_GAIN \right]$$

(Equation 9-7)

$$C = 1 + \left[\left(\frac{rcell_temp(K)}{323(K)} - 1 \right) \times SPRESS_TPC_GAIN \right]$$

(Equation 9-8)

$$D = 1 + \left[\left(\frac{box_temp(K)}{298(K)} - 1 \right) \times BXTEMP_TPC_GAIN \right]$$

(Equation 9-9)

The preset gain parameters are set at the factory and may vary from analyzer to analyzer. Section 6.12 describes the method for enabling/disabling the TPC feature.

8.8.4. NO₂ CONVERTER EFFICIENCY COMPENSATION

Over time, the molybdenum in the NO₂ converter oxidizes and loses its original capacity of converting NO₂ into NO, eventually resulting in a decreased converter efficiency (CE). Even though we recommend to replace the converter if CE drops below 96%, the analyzer's firmware allows adjusting minor deviations of the CE from 1.000 and enables reporting the true concentrations of NO₂ and NO_x. Converter efficiency is stored in the instrument's memory as a decimal fraction that is multiplied with the NO₂ and NO_x measurements to calculate the final concentrations for each. Periodically, this efficiency factor must be measured and - if it has changed from previous measurements - entered into the analyzer's memory (Section 5.2.5).

8.8.5. INTERNAL DATA ACQUISITION SYSTEM (DAS)

The DAS is designed to implement predictive diagnostics that stores trending data for users to anticipate when an instrument will require service. Large amounts of data can be stored in non-volatile memory and retrieved in plain text format for further processing with common data analysis programs. The DAS has a consistent user interface among all Teledyne A-Series, E-Series, and T-Series instruments. New data parameters and triggering events can be added to the instrument as needed. Section 6.7 describes the DAS and its default configuration in detail, Section 6.3 shows the parameters that can be used for predictive diagnostics.

Depending on the sampling frequency and the number of data parameters, the DAS can store several months of data, which are retained even when the instrument is powered off. However, if new firmware or a new DAS configuration are uploaded to the analyzer, we recommend retrieving data before doing so to avoid data loss. The DAS permits users to access the data through the instrument's front panel or the remote interface. The latter can automatically report stored data for further processing. APICOM, a user-friendly remote control program is the most convenient way to view, retrieve and store DAS data (Section 6.15.2.8)

9. A PRIMER ON ELECTRO-STATIC DISCHARGE

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

9.1. HOW STATIC CHARGES ARE CREATED

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

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

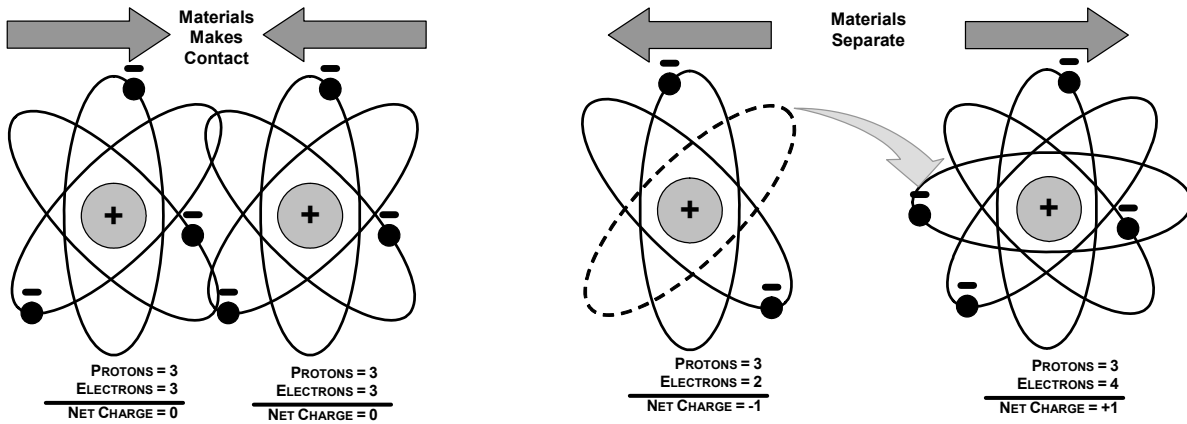


Figure 9-1: Triboelectric Charging

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

Table 9-1: Static Generation Voltages for Typical Activities

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

9.2. HOW ELECTRO-STATIC CHARGES CAUSE DAMAGE

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

A quick comparison of the values in Table 9-1 with the those shown in the Table 9-2, listing device susceptibility levels, shows why *Semiconductor Reliability News* estimates that approximately 60% of device failures are the result of damage due to electro-static discharge.

Table 9-2: Sensitivity of Electronic Devices to Damage by ESD

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

Potentially damaging electro-static discharges can occur:

- Any time a charged surface (including the human body) discharges to a device. Even simple contact of a finger to the leads of a sensitive device or assembly can allow enough discharge to cause damage. A similar discharge

can occur from a charged conductive object, such as a metallic tool or fixture.

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

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

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

9.3. COMMON MYTHS ABOUT ESD DAMAGE

- **I didn't feel a shock so there was no electro-static discharge:** The human nervous system isn't able to feel a static discharge of less than 3500 volts. Most devices are damaged by discharge levels much lower than that.
- **I didn't touch it so there was no electro-static discharge:** Electro-static charges are fields whose lines of force can extend several inches or sometimes even feet away from the surface bearing the charge.
- **It still works so there was no damage:** Sometimes the damage caused by electro-static discharge can completely sever a circuit trace causing the device to fail immediately. More likely, the trace will be only partially occluded by the damage causing degraded performance of the device or worse, weakening the trace. This weakened circuit may seem to function fine for a short time, but even the very low voltage and current levels of the device's normal operating levels will eat away at the defect over time causing the device to fail well before its designed lifetime is reached.

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

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

Conductive devices can build static charges if they are not grounded. The charge will be equalized across the entire device, but without access to earth ground, they are

still trapped and can still build to high enough levels to cause damage when they are discharged.

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

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

9.4. BASIC PRINCIPLES OF STATIC CONTROL

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

9.4.1. GENERAL RULES

Only handle or work on all electronic assemblies at a properly set up ESD station. Setting up an ESD safe workstation need not be complicated. A protective mat properly tied to ground and a wrist strap are all that is needed to create a basic anti-ESD workstation (see figure 9-2).

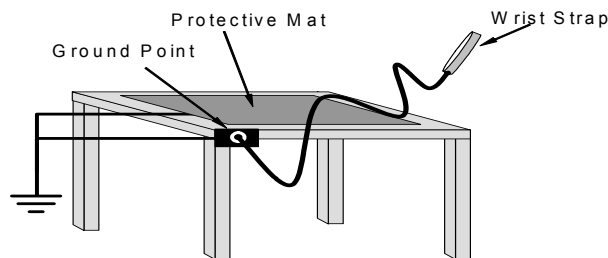


Figure 9-2: Basic anti-ESD Work Station

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

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

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

- **Simply touching a grounded piece of metal is insufficient.** While this may temporarily bleed off static charges present at the time, once you stop touching the grounded metal new static charges will immediately begin to rebuild. In some conditions, a charge large enough to damage a component can rebuild in just a few seconds.
- **Always store sensitive components and assemblies in anti-ESD storage bags or bins:** Even when you are not working on them, store all devices and assemblies in a closed anti-Static bag or bin. This will prevent induced charges from building up on the device or assembly and nearby static fields from discharging through it.
- **Use metallic anti-ESD bags for storing and shipping ESD sensitive components and assemblies rather than pink-poly bags.** The famous, “pink-poly” bags are made of a plastic that is impregnated with a liquid (similar to liquid laundry detergent) which very slowly sweats onto the surface of the plastic creating a slightly conductive layer over the surface of the bag.

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

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

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

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

9.4.2. BASIC ANTI-ESD PROCEDURES FOR ANALYZER REPAIR AND MAINTENANCE

9.4.2.1. Working at the Instrument Rack

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

1. Attach your anti-ESD wrist strap to ground before doing anything else.
 - Use a wrist strap terminated with an alligator clip and attach it to a bare metal portion of the instrument chassis. This will safely connect you to the same ground level to which the instrument and all of its components are connected.
2. Pause for a second or two to allow any static charges to bleed away.
3. Open the casing of the analyzer and begin work. Up to this point, the closed metal casing of your analyzer has isolated the components and assemblies inside from any conducted or induced static charges.
4. If you must remove a component from the instrument, do not lay it down on a non-ESD preventative surface where static charges may lie in wait.
5. Only disconnect your wrist strap after you have finished work and closed the case of the analyzer.

9.4.2.2. Working at an Anti-ESD Work Bench.

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

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

9.4.2.3. Transferring Components from Rack to Bench and Back

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

1. Follow the instructions listed above for working at the instrument rack and workstation.
2. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
3. Before using the bag or container allow any surface charges on it to dissipate:
 - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
 - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
 - In either case wait several seconds.
4. Place the item in the container.
5. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
 - Folding the open end over isolates the component(s) inside from the effects of static fields.
 - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.
6. Once you have arrived at your destination, allow any surface charges that may have built up on the bag or bin during travel to dissipate:
 - Connect your wrist strap to ground.
 - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
 - If you are at a anti-ESD work bench, lay the container down on the conductive work surface
 - In either case wait several seconds
7. Open the container.

9.4.2.4. Opening Shipments from Teledyne


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

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

1. Opening the outer shipping box away from the anti-ESD work area.
2. Carry the still sealed anti-ESD bag, tube or bin to the anti-ESD work area.
3. Follow steps 6 and 7 of Section 9.4.2.3 above when opening the anti-ESD container at the work station.
4. Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to TAI.

9.4.2.5. Packing Components for Return to TAI

Always pack electronic components and assemblies to be sent to TAI in anti-ESD bins, tubes or bags.

	<p>WARNING</p> <p>DO NOT use pink-poly bags.</p> <p>NEVER allow any standard plastic packaging materials to touch the electronic component/assembly directly</p> <ul style="list-style-type: none"> • This includes, but is not limited to, plastic bubble-pack, Styrofoam peanuts, open cell foam, closed cell foam, and adhesive tape <p>DO NOT use standard adhesive tape as a sealer. Use ONLY anti-ESD tape</p>
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1. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
2. Before using the bag or container allow any surface charges on it to dissipate:
 - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
 - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
 - In either case wait several seconds.

3. Place the item in the container.
4. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
 - Folding the open end over isolates the component(s) inside from the effects of static fields.
 - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.

Note

If you do not already have an adequate supply of anti-ESD bags or containers available, TAI Technical Support department will supply them. Follow the instructions listed above for working at the instrument rack and workstation.

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10. GLOSSARY

Note: Some terms in this glossary may not occur elsewhere in this manual.

Term	Description/Definition
10BaseT	an Ethernet standard that uses twisted ("T") pairs of copper wires to transmit at 10 megabits per second (Mbps)
100BaseT	same as 10BaseT except ten times faster (100 Mbps)
APICOM	name of a remote control program offered by Teledyne-API to its customers
ASSY	<i>Assembly</i>
CAS	<i>Code-Activated Switch</i>
CD	<i>Corona Discharge</i> , a frequently luminous discharge, at the surface of a conductor or between two conductors of the same transmission line, accompanied by ionization of the surrounding atmosphere and often by a power loss
CE	<i>Converter Efficiency</i> , the percentage of light energy that is actually converted into electricity
CEM	<i>Continuous Emission Monitoring</i>
	Chemical formulas that may be included in this document:
• CO ₂	• carbon dioxide
• C ₃ H ₈	• propane
• CH ₄	• methane
• H ₂ O	• water vapor
• HC	• general abbreviation for hydrocarbon
• HNO ₃	• nitric acid
• H ₂ S	• hydrogen sulfide
• NO	• nitric oxide
• NO ₂	• nitrogen dioxide
• NO _x	• nitrogen oxides, here defined as the sum of NO and NO ₂
• NO _y	• nitrogen oxides, often called odd nitrogen: the sum of NO _x plus other compounds such as HNO ₃ (definitions vary widely and may

Term	Description/Definition
	include nitrate (NO ₃), PAN, N ₂ O and other compounds as well)
• NH ₃	• ammonia
• O ₂	• molecular oxygen
• O ₃	• ozone
• SO ₂	• sulfur dioxide
cm ³	metric abbreviation for <i>cubic centimeter</i> (replaces the obsolete abbreviation "cc")
CPU	<i>Central Processing Unit</i>
DAC	<i>Digital-to-Analog Converter</i>
DAS	<i>Data Acquisition System</i>
DCE	<i>Data Communication Equipment</i>
DFU	<i>Dry Filter Unit</i>
DHCP	<i>Dynamic Host Configuration Protocol</i> . A protocol used by LAN or Internet servers to automatically set up the interface protocols between themselves and any other addressable device connected to the network
DIAG	<i>Diagnostics</i> , the diagnostic settings of the analyzer.
DOM	<i>Disk On Module</i> , a 44-pin IDE flash drive with up to 128MB storage capacity for instrument's firmware, configuration settings and data
DOS	<i>Disk Operating System</i>
DRAM	<i>Dynamic Random Access Memory</i>
DR-DOS	<i>Digital Research DOS</i>
DTE	<i>Data Terminal Equipment</i>
EEPROM	<i>Electrically Erasable Programmable Read-Only Memory</i> also referred to as a FLASH chip or drive
ESD	<i>Electro-Static Discharge</i>
ETEST	<i>Electrical Test</i>
Ethernet	a standardized (IEEE 802.3) computer networking technology for local area networks (LANs), facilitating communication and sharing resources
FEP	<i>Fluorinated Ethylene Propylene</i> polymer, one of the polymers that Du Pont markets as <i>Teflon</i> [®]
Flash	non-volatile, solid-state memory
FPI	<i>Fabry-Perot Interface</i> : a special light filter typically made of a transparent plate with two reflecting surfaces or two parallel, highly reflective mirrors

Term	Description/Definition
GFC	<i>Gas Filter Correlation</i>
I ² C bus	a clocked, bi-directional, serial bus for communication between individual analyzer components
IC	<i>Integrated Circuit</i> , a modern, semi-conductor circuit that can contain many basic components such as resistors, transistors, capacitors etc in a miniaturized package used in electronic assemblies
IP	<i>Internet Protocol</i>
IZS	<i>Internal Zero Span</i>
LAN	<i>Local Area Network</i>
LCD	<i>Liquid Crystal Display</i>
LED	<i>Light Emitting Diode</i>
LPM	<i>Liters Per Minute</i>
MFC	<i>Mass Flow Controller</i>
M/R	<i>Measure/Reference</i>
MOLAR MASS	<p>the mass, expressed in grams, of 1 mole of a specific substance. Conversely, one mole is the amount of the substance needed for the molar mass to be the same number in grams as the atomic mass of that substance.</p> <p>EXAMPLE: The atomic weight of Carbon is 12 therefore the molar mass of Carbon is 12 grams. Conversely, one mole of carbon equals the amount of carbon atoms that weighs 12 grams.</p> <p>Atomic weights can be found on any Periodic Table of Elements.</p>
NDIR	<i>Non-Dispersive Infrared</i>
NIST-SRM	<i>National Institute of Standards and Technology - Standard Reference Material</i>
PC	<i>Personal Computer</i>
PCA	<i>Printed Circuit Assembly</i> , the PCB with electronic components, ready to use
PC/AT	<i>Personal Computer / Advanced Technology</i>
PCB	<i>Printed Circuit Board</i> , the bare board without electronic component
PFA	<i>Per-Fluoro-Alkoxy</i> , an inert polymer; one of the polymers that Du Pont markets as <i>Teflon</i> [®]
PLC	<i>Programmable Logic Controller</i> , a device that is used to control instruments based on a logic level signal coming from the analyzer
PLD	<i>Programmable Logic Device</i>
PLL	<i>Phase Lock Loop</i>
PMT	<i>Photo Multiplier Tube</i> , a vacuum tube of electrodes that multiply electrons collected and charged to create a detectable current signal
P/N (or PN)	<i>Part Number</i>
PSD	<i>Prevention of Significant Deterioration</i>
PTFE	<i>Poly-Tetra-Fluoro-Ethylene</i> , a very inert polymer material used to

Term	Description/Definition
	handle gases that may react on other surfaces; one of the polymers that <i>Du Pont</i> markets as <i>Teflon</i> [®]
PVC	<i>Poly Vinyl Chloride</i> , a polymer used for downstream tubing
Rdg	Reading
RS-232	specification and standard describing a serial communication method between DTE (Data Terminal Equipment) and DCE (Data Circuit-terminating Equipment) devices, using a maximum cable-length of 50 feet
RS-485	specification and standard describing a binary serial communication method among multiple devices at a data rate faster than RS-232 with a much longer distance between the host and the furthest device
SAROAD	<i>Storage and Retrieval of Aerometric Data</i>
SLAMS	<i>State and Local Air Monitoring Network Plan</i>
SLPM	<i>Standard Liters Per Minute</i> of a gas at standard temperature and pressure
STP	<i>Standard Temperature and Pressure</i>
TCP/IP	<i>Transfer Control Protocol / Internet Protocol</i> , the standard communications protocol for Ethernet devices
TEC	<i>Thermal Electric Cooler</i>
TPC	<i>Temperature/Pressure Compensation</i>
USB	<i>Universal Serial Bus</i> : a standard connection method to establish communication between peripheral devices and a host controller, such as a mouse and/or keyboard and a personal computer or laptop
VARS	<i>Variables</i> , the variable settings of the instrument
V-F	<i>Voltage-to-Frequency</i>
Z/S	<i>Zero / Span</i>